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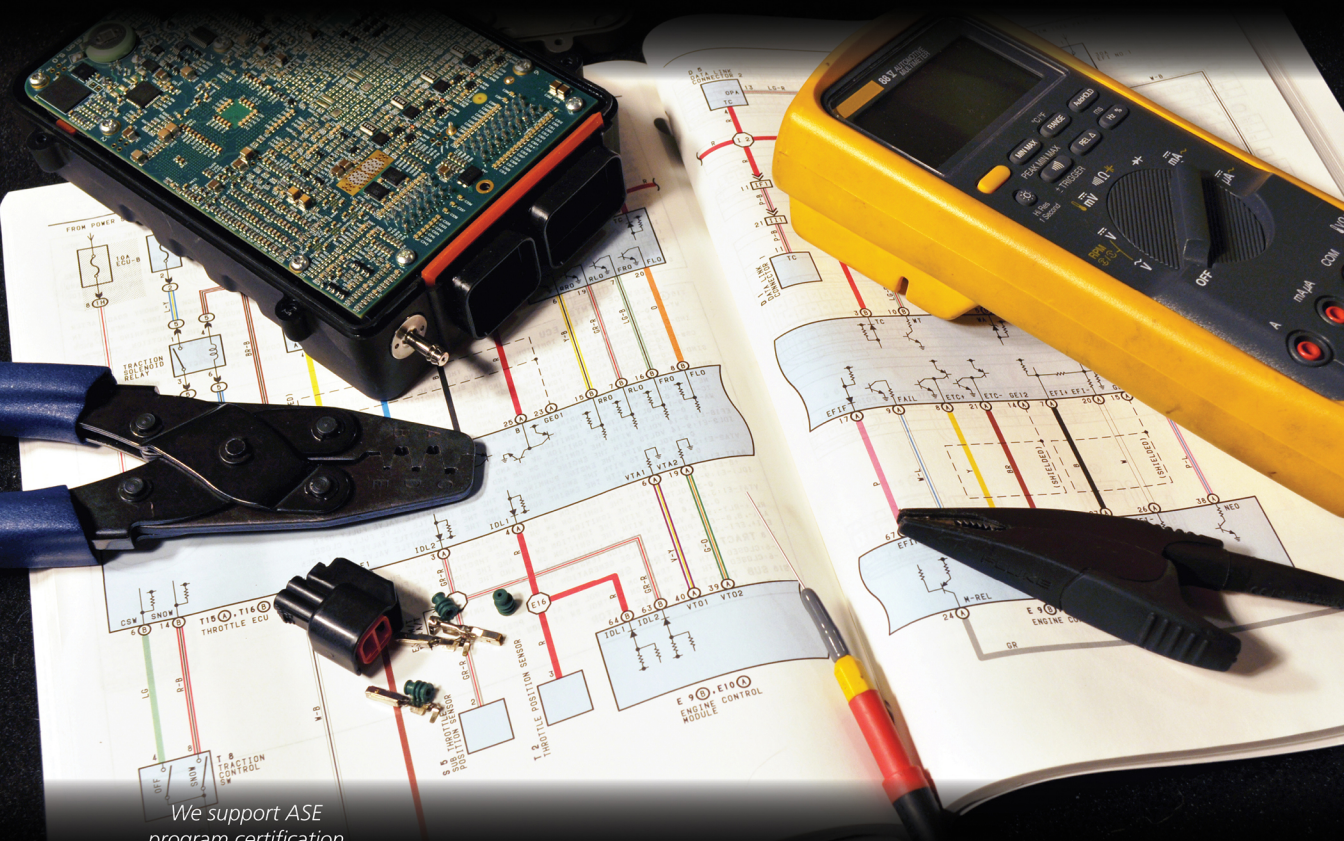

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Michael Klyde
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Cover Design: Scott Moden
Rights & Media Specialist: Robert Boder
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Cover Image (Title Page): © ratmaner/Shutterstock
Printing and Binding: LSC Communications
Cover Printing: LSC Communications

Library of Congress Cataloging-in-Publication Data unavailable at time of printing.

6048

Printed in the United States of America
21 20 19 18 17 10 9 8 7 6 5 4 3 2 1

Source: NATEF Program Accreditation Standards, 2013, National Automotive Technicians Education Foundation (NATEF).

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NOTE TO STUDENTS

This book was created to help you on your path to a career in the transportation industry. Employability basics covered early in the text will help you get and keep a job in the field. Essential technical skills are built in cover to cover and are the core building blocks of an advanced technician's skill set. This book also introduces "strategy-based diagnostics," a method used to solve technical problems correctly on the first attempt. The text covers every task the industry standard recommends for technicians, and will help you on your path to a successful career.

As you navigate this textbook, ask yourself, "What does a technician need to know and be able to do at work?"

This book is set up to answer that question. Each chapter starts by listing the technicians' tasks that are covered within the chapter. These are your objectives. Each chapter ends by reviewing those things a technician needs to know. The content of each chapter is written to explain each objective. As you study, continue to ask yourself that question. Gauge your progress by imagining yourself as the technician. Do you have the knowledge, and can you perform the tasks required at the beginning of each chapter? Combining your knowledge with hands-on experience is essential to becoming a Master Technician.

During your training, remember that the best thing you can do as a technician is learn to learn. This will serve you well because vehicles keep advancing, and good technicians never stop learning.

Stay curious. Ask questions. Practice your skills, and always remember that one of the best resources you have for learning is right there in your classroom… your instructor.

Best wishes and enjoy!
The CDX Automotive Team

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CHAPTER 1
Strategy-Based Diagnostics

NATEF Tasks

- **N01001** Review vehicle service history.
- **N01002** Demonstrate use of the three C's (concern, cause, and correction).
- **N01003** Identify information needed and the service requested on a repair order.
- **N01004** Research vehicle service information including fluid type, vehicle service history, service precautions, and technical service bulletins.

Knowledge Objectives

After reading this chapter, you will be able to:

- **K01001** Describe the purpose and use of vehicle service history.
- **K01002** Demonstrate an understanding of the active listening process.
- **K01003** Demonstrate an understanding of the strategy-based diagnosis process.
- **K01004** Describe step one of the strategy-based diagnosis.
- **K01005** Describe step two of the strategy-based diagnosis.
- **K01006** Describe step three of the strategy-based diagnosis.
- **K01007** Describe step four of the strategy-based diagnosis.
- **K01008** Describe step five of the strategy-based diagnosis.
- **K01009** Explain how the three Cs are applied in repairing and servicing vehicles.
- **K01010** Describe the information and its use within a repair order.

Skills Objectives

After reading this chapter, you will be able to:

- **S01001** Use service history in the repair and service of vehicles.
- **S01002** Complete a repair order.

You Are the Automotive Technician

A regular customer brings his 2014 Toyota Sienna into your shop, complaining of a "clicking" noise when he turns the steering wheel. You ask the customer further questions and learn that the clicking happens whenever he turns the wheel, especially when accelerating. He tells you he has just returned from vacation with his family and has probably put 300 miles (482 kms) on the car during their trip.

1. What additional questions should you ask the customer about his concern, the clicking noise he hears when turning?
2. How would you verify this customer's concern?
3. What sources would you use to begin gathering information to address this customer's concern?
4. Based on what you know this far about the customer's concern, what systems might be possibly related to this customer's concern?

▶ Introduction

The overall vehicle service involves three major components. Those pieces are gathering information from the customer, the strategy-based diagnostic process, and documenting the repair. The flow of the overall service can be seen below.

1. Initial information gathering is often completed by a service advisor (consultant) and should contain details about the customer concern and pertinent history.
2. Verifying the customer concern begins the strategy-based diagnostic process. Technicians will complete this step to ensure that a problem exists and that their repair eliminated it.
3. Researching the possible cause will provide a list of possible faults. The technician will expand this list as testing continues.
4. Testing will focus on the list of possibilities. Technicians will start with broad, simple tests that look at an entire system or group of components. Testing will progressively become more narrowly focused as it pinpoints an exact cause.
5. Repairs will be made using suggested tools and recommended procedures. This is done to ensure a reliable repair and that manufacturer requirements are met.
6. Repairs must always be verified. This confirms that the technician has completed the diagnosis accurately and completely.

The repair must be documented. The technician has been doing this all along. When the customer concern is recorded, the tests are recorded, and the final repair procedure recorded, the repair has been documented.

▶ Vehicle Service History

K01001 Describe the purpose and use of vehicle service history.

N01001 Review vehicle service history.

S01001 Use service history in the repair and service of vehicles.

Service history is a complete list of all the servicing and repairs that have been performed on a vehicle (**FIGURE 1-1**). The scheduled service history can be recorded in a service booklet or owner's manual that is kept in the glove compartment. The service history can provide valuable information to technicians conducting repairs. It also can provide potential new owners of used vehicles an indication of how well the vehicle was maintained. A vehicle with a regular service history is a good indication that all of the vehicle's systems have been well maintained, and the vehicle will often be worth more during resale. Most manufacturers store all service history performed in their dealerships (based on the VIN) on a corporate server that is accessible from any of their dealerships. They also use this vehicle service history when it comes to evaluating warranty claims. A vehicle that does not have a complete service history may not be eligible for warranty claims. Independent shops generally keep records of the repairs they perform. However, if a vehicle is repaired at multiple shops, repair history is much more difficult to track and, again, may result in a denial of warranty claims.

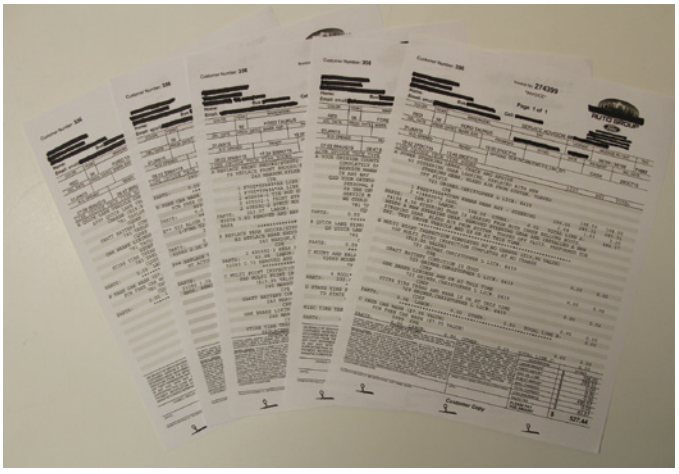


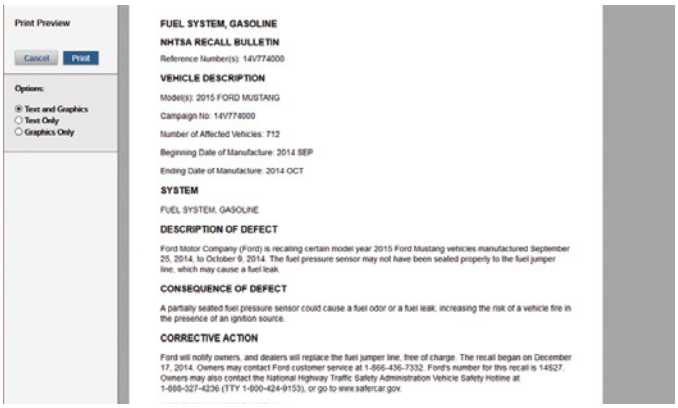
FIGURE 1-1 Print outs of completed repair order as saved in the online repair order system.

Vehicle service history can be very valuable to the technician. This history is typically retrieved from service records kept by the shop, dealer network, **original equipment manufacturer (OEM)**, or **aftermarket** service center. This information often contains a list of services performed on a vehicle and the date and mileage at which they were completed. Not all service history contains the same information. Some histories may only contain repair information, while others include every customer concern and maintenance task performed. This information can be very helpful when diagnosing a concern. Service history may help technicians diagnose a vehicle and can also be used to prevent costly duplicated repairs.

Service history can also be used to guide repairs. Records of vehicle service history may indicate that the customer has recently been in for service and now has returned with a new concern. This all-too-common situation is usually found to be caused by error during the previous service. When working on a vehicle that has returned after a recent repair, the previous technician's work (whoever that may be) should be inspected meticulously.

The service history may also show that the customer is returning for the same issue due to a component failure. The history might indicate when the component was installed, help the customer get their vehicle repaired, and help the shop to get paid under the component warranty. A vehicle that returns more than once for the same repair could be an indicator that an undiagnosed problem is causing these failures. The service history allows technicians to determine if the vehicle has been well maintained. This can be extremely useful when a technician suspects that lack of maintenance may be the cause of the problem.

The vehicle's service history helps technicians determine what maintenance needs to be performed, and therefore helps customers save money over time by preventing future costly repairs. Routine maintenance is essential on today's modern automobile and prevents premature failures due to contamination and component wear.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FUEL SYSTEM, GASOLINE

NHTSA RECALL BULLETIN

Reference Number(s): 14V774000

VEHICLE DESCRIPTION

Model(s): 2015 FORD MUSTANG

Campaign No: 14V774000

Number of Affected Vehicles: 712

Beginning Date of Manufacture: 2014 SEP

Ending Date of Manufacture: 2014 OCT

SYSTEM

FUEL SYSTEM, GASOLINE

DESCRIPTION OF DEFECT

Ford Motor Company (Ford) is recalling certain model year 2015 Ford Mustang vehicles manufactured September 25, 2014, to October 9, 2014. The fuel pressure sensor may not have been sealed properly to the fuel jumper line, which may cause a fuel leak.

CONSEQUENCE OF DEFECT

A partially seated fuel pressure sensor could cause a fuel odor or a fuel leak, increasing the risk of a vehicle fire in the presence of an ignition source.

CORRECTIVE ACTION

Ford will notify owners, and dealers will replace the fuel jumper line, free of charge. The recall began on December 17, 2014. Owners may contact Ford customer service at 1-866-436-7332. Ford's number for this recall is 14S27. Owners may also contact the National Highway Traffic Safety Administration Vehicle Safety Hotline at 1-888-327-4236 (TTY 1-800-424-9153), or go to www.safercar.gov.

FIGURE 1-2 Recall notice example.

Today's vehicles also require regular software updates. There are many advanced computer systems on modern vehicles. From time to time, updates will be available to fix a bug or glitch in the computer programming. These updates are often designed to eliminate a customer concern, improve owner satisfaction, or increase vehicle life. This is very similar to an update for your PC or mobile device. Service history will indicate to the technician that the vehicle may need an update. The technician will inspect the vehicle's computer system and perform any needed updates as necessary.

Service history can also be used to keep customers safe. Occasionally, manufacturers may need to recall a vehicle for service due to a safety concern that has been identified for a vehicle (**FIGURE 1-2**). This means that the manufacturer has found that the potential exists for a dangerous situation to occur, and the vehicle must be serviced to eliminate it. Depending on the nature of the problem, recalls can be mandatory and required by law, or manufacturers may voluntarily choose to conduct a recall to ensure the safe operation of the vehicle or minimize damage to their business or product image. The service history would be used to verify that the vehicle is subject to the recall and has or has not had the recall service completed. The technician would perform the service, update the service history, and return the vehicle to the customer.

▶ TECHNICIAN TIP

Technicians and service advisors should check the vehicle service history against the manufacturer's service maintenance schedule to determine if the vehicle is due for scheduled maintenance. The maintenance schedule is a guide that indicates what service is due when; it can be found in the manufacturer's service information and often in the owner's manual. Keeping the vehicle well maintained can avoid a failure that strands the customer on the roadside.

Applied Science

AS-11 Information Processing: The technician can use computer databases to input and retrieve customer information for billing, warranty work, and other record-keeping purposes.

Dealership service departments have access to databases run by manufacturers for the purposes of accessing warranty information, tracking vehicle servicing and warranty repair history, and logging warranty repair jobs for payment by the manufacturer. When a customer presents their vehicle for a warranty repair, the customer service department staff begin by consulting the database to confirm that the vehicle is within its warranty period and that the warranty has not been invalidated for any reason. Once it is confirmed that the vehicle is still under a valid warranty, the repair order will be passed to the workshop for diagnosis and repair. Any parts required for the warranty repair must be labeled by the technician and stored for possible recall by the manufacturer.

For example, a young man comes in complaining that his vehicle is "running rough." The customer service staff confirms that the vehicle is nine months old and only has 14,500 miles (approx. 23,000 km), so it is within the manufacturer's 3-year/100,000 mile (160,000 km) warranty period. They check the manufacturer's database to confirm that the vehicle's warranty has not been invalidated before handing the repair order onto the workshop. Then a technician diagnoses the fault as a defective ignition coil and fills out a warranty parts form.

Once the repair has been completed and the parts labeled, the warranty parts form and any repair order paperwork is passed back to administrative staff for processing. Processing will include billing the manufacturer for the correct, pre-approved amount of time, logging the repair on the database for payment, and ensuring that all documentation is correct for auditing purposes.

Warranty Parts Form	
Customer concern: Vehicle running rough	Vehicle Information
Cause: #6 ignition coil open circuit on primary winding	VIN: IG112345678910111
Correction: Replaced #6 ignition coil	RO Number: 123456
Parts description: #6 ignition coil	Date of repair: 10/04/2016

SKILL DRILL 1-1 Reviewing Service History

1. Locate the service history for the vehicle. This may be in shop records or in the service history booklet within the vehicle glove compartment. Some shops may keep the vehicle's service history on a computer.
2. Familiarize yourself with the service history of the vehicle.
   a. On what date was the vehicle first serviced?
   b. On what date was the vehicle last serviced?
   c. What was the most major service performed?
   d. Was the vehicle ever serviced for the same problem more than once?
3. Compare the vehicle service history to the manufacturer's scheduled maintenance requirements, and list any discrepancies.
   a. Have all the services been performed?
   b. Have all the items been checked?
   c. Are there any outstanding items?

To review the vehicle service history, follow the steps in **SKILL DRILL 1-1**.

Active Listening Skills

K01002 Demonstrate an understanding of the active listening process.

Depending on the size of a shop, the first point of contact for the customer is the **service advisor** or consultant. This person answers the phone, books customer work into the shop, fills out repair orders, prices repairs, invoices, keeps track of work being performed, and builds customer relations with the goal of providing a high level of customer support. The service advisor also serves as a liaison between the customer and the technician who is working on the vehicle. A service advisor or consultant may advance to become a service manager. In smaller shops, a technician may perform these duties.

When the customer brings his or her vehicle in for service, the service advisor or technician should ask for more information than just the customer concern. It is important to let the customer speak while you use active listening skills to gather as many pertinent details as possible. Active listening means paying close attention to not only the customer's words, but also to their tone of voice and body language. Maintain eye contact with the customer throughout your conversation and nod to show you understand and are paying attention. Do not interrupt. Wait for the customer to finish speaking before responding, then ask open-ended questions to verify that you have heard the complaint clearly and understand the problem. An open-ended question is one that cannot be answered with a yes or no, but instead requires the customer to provide you with more information about the problem (**FIGURE 1-3**). If the shop is noisy, try to find a quieter location in which to speak with the customer. Excellent communication helps ensure that all relevant information is collected. It also makes a good first impression with customers; they are likely to feel that they were listened to and cared for.

Politely use open-ended questions to ask about any symptoms the customer may have noticed, such as:

- Under what circumstances does the concern occur or not occur?
- What unusual noises do you hear (e.g., squeaks, rattles, clunks, and other noises)?
- What odd smells or fluid leaks have you noticed?
- What recent work, service, or accessories have been added to the vehicle?
- What other recent changes or experiences have you had with the vehicle?
- What other systems seem to be operating improperly?

▶ TECHNICIAN TIP

A vehicle's service history is valuable for several reasons:

- It can provide helpful information to the technician when performing repairs.
- It allows potential new owners of the vehicle to know how well the vehicle and its systems were maintained.
- Manufacturers use the history to evaluate warranty claims.

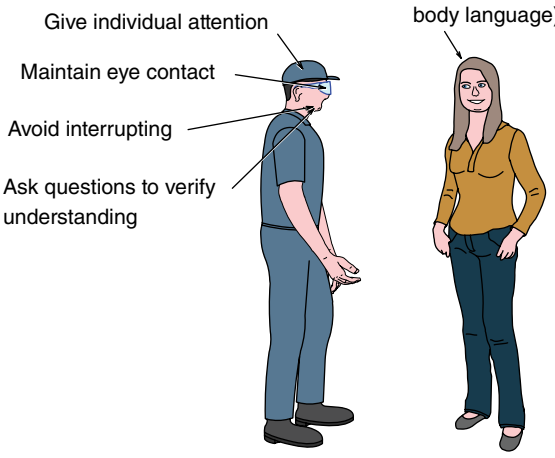


FIGURE 1-3 The active listening process.

Although problems may seem unrelated initially, when multiple systems fail at the same time, the issues are frequently related. Open-ended questions can provide valuable information to the technician who is performing the diagnosis.

▶ Strategy-Based Diagnostic Process

K01003 Demonstrate an understanding of the strategy-based diagnosis process.

Diagnostic problems can be very challenging to identify and correct in a timely and efficient manner. Technicians will find that having a plan in place ahead of time will vastly simplify the process of logically and systematically (strategically) solving problems. The plan should be simple to remember and consistent in its approach; yet it must work for the entire range of diagnostic problems that technicians will encounter. In this way, technicians will have one single plan to approach any diagnostic situation they may encounter, and will be confident in their ability to resolve it. This problem solving plan is called the **Strategy-Based Diagnostic Process**.

The strategy-based diagnostic process is focused on fixing problems correctly the first time. It is a scientific process of elimination, which is much the same process as a medical doctor uses for their diagnosis. It begins with identifying the customer's concern and ends with confirming that the problem has been resolved. The purpose of the problem-solving process is twofold: to provide a consistent road map for technicians as they address customer concerns that require diagnosis, and to ensure that customer concerns are resolved with certainty.

This process simplifies the problem-solving portion of the repair, making the job easier for the technician; it prevents technicians from having to work on the same job more than once; and it all but eliminates customer comebacks. While repeat customers are good for business, a customer coming back with the same problem is not. The customer is likely to be upset and the technician is likely to be working for free. In order to avoid this scenario, it is imperative to address customer concerns correctly the first time.

Proper diagnosis is important to consumers and to the federal government. Federal and state law protects consumers against the purchase of vehicles with significant persistent defects. Technicians are held to a standard of reasonable repair times and limited visits for the same concern. Although the law varies from state to state, this means technicians must not return a vehicle to a customer without addressing the customer's original concern. Also, technicians cannot make the vehicle unavailable to the customer for a long period while the vehicle is being repaired. The purpose of the state and federal laws is to protect consumers buying new vehicles.

Failure to comply with the state and federal law can be very expensive for the dealership and manufacturer. Although most state laws hold the manufacturer directly responsible, dealerships are also hurt by a loss in sales revenue, a loss in repair revenue, and irreparable damage to their customer and sometimes manufacturer relationships. Many state laws hold the manufacturer responsible for full purchase price, incurred loan fees, installed accessories, and registration and similar government charges. This can be a heavy cost on top of the value of the vehicle itself.

▶ TECHNICIAN TIP

Technicians need to do their best to find the issue and resolve it; otherwise, the vehicle may be required to be bought back from the customer, costing the dealership and manufacturer significant money.

Need for the Strategy-Based Diagnostic Process

Finding the source of every customer concern can prove to be a challenge. Novice technicians frequently struggle with diagnostics situations. Even some veteran technicians have difficulty tackling diagnosis on some new technologies. However, if the strategy for solving a problem is generally the same every time, this greatly simplifies the process. Hopefully, by applying a strategy-based diagnostic process, technicians will resolve challenging customer concerns 100% of the time in an efficient manner.

Customer comebacks occur when the customer picks up the vehicle after service, only to bring it back shortly thereafter with the same concern. This situation is understandably upsetting to the customer. Typically, the end result is wasted labor time and a loss in shop productivity. The customer is left with one of the following impressions:

- The work was not performed;
- The shop is incompetent;
- Or, worse yet, the shop was trying to scam the customer.

▶ TECHNICIAN TIP

The diagnostic process makes the technician's job easier by providing a step-by-step strategy to solving the problem. It also answers the question: "Now what do I do?" As even the toughest job becomes easier, technicians will find their rate of diagnostic success increasing.

Customer comebacks are usually caused by one of two avoidable reasons:

1. The customer concern is misinterpreted or misunderstood. This results in the technician "fixing" a problem that does not exist or missing a problem altogether.
2. The technician failed to verify that the original concern was resolved. Technicians are often hurried; some will forget to ensure that the repair they had performed actually fixed the original customer concern.

Use of the strategy-based diagnostic process enables the technician and shop to make more money and satisfy more customers. This is a win-win situation for all involved. Using the strategy-based diagnostic process requires starting at the beginning and following it through to the end every time (**FIGURE 1-4**). This systematic approach will ensure the best results for each diagnostic situation.

Step 1: Verify the Customer's Concern

K01004 Describe step one of the strategy-based diagnosis.

The first step in the diagnostic process is to verify the customer's concern. This step is completed for two main purposes:

- To verify that the vehicle is not operating as designed
- To guarantee that the customer's concern is addressed

Failure to complete this step may result in wasted time, wasted money, and, worst of all, an unhappy customer. The customer is probably not an experienced automotive technician. For this reason, the customer does not always accurately verbalize the problem that may be occurring. Therefore, it is very important that you have a complete understanding of the customer's concern before beginning the diagnosis. This will enable you to know with certainty that you have actually resolved the original concern after repairing the vehicle and before returning it to the customer. During this step, you may perform several of the following tasks, depending on the customer concern.

First, ask the customer to demonstrate the concern, if possible. This may necessitate a test drive (**FIGURE 1-5**). The customer should be encouraged to drive the vehicle while you ride along as a passenger and gather symptoms and details about the concern. Seeing the customer recreate the concern in real time will often provide some much needed context to the problem. Having the customer demonstrate the concern is ideal in most situations, though not always possible. In the event that the customer is not present, you must do your best to recreate the concern on your own based on the information obtained from the customer. With or without the customer present, be sure to document in writing any details about the scenario in which the concern arises.

Next, make sure that the customer concern doesn't fall outside the range of normal operation of the component or system. The manufacturer's service information provides

SAFETY TIP

There should be limits to recreating the customer concern. Technicians need to be careful when riding as a passenger with the customer or driving an unfamiliar customer vehicle. Technicians have died during test drives due to customers' driving or their own driving of unfamiliar vehicles. The purpose of the test drive is to verify the concern or its repair. It is not an opportunity for a thrill ride. Customers and their vehicles should be treated with respect. Additionally, customers should respect the technician. If a customer asks a technician to verify a concern in an unsafe situation, such as a high rate of speed, the technician should decline. This is for both safety and liability reasons.

FIGURE 1-4 The strategy-based diagnostic process.

FIGURE 1-5 Ask the customer to describe the concern.

system descriptions and expected operations; technicians can use these details, provided in the owner's manual or in the vehicle service manual, to become familiar with the system and then explain its operation to the customer. Especially on new cars with many amenities, customers may not be familiar with the controls and subsequent operation. This can cause a customer to bring a vehicle in for service unnecessarily, due to unfamiliarity with the system controls. Many shops use online service (shop) manuals where you can quickly access any information related to the customer's concern (**FIGURE 1-6**). Checking to make sure that the concern is really a fault, and not a normal operation, will avoid unnecessary diagnosis time. This is also an opportunity to provide excellent customer service by demonstrating the features and their controls to the customer.

Conducting a quick visual inspection to look for obvious faults can be very helpful (**FIGURE 1-7**). However, it does not replace the need for testing and is absolutely not intended as a shortcut to the diagnostic process. With that said, the visual inspection can provide valuable information that may speed up the testing processes. The visual inspection provides an opportunity for a quick safety check by the technician and may help to avoid some potentially dangerous situations during service.

While visual inspections can be very valuable, technicians must be careful not to jump to conclusions based on what they see. For example, a customer comes in with an illuminated and flashing overdrive light on the control panel. The technician has seen this problem before and it was caused by a bad solenoid pack in the transmission. If the technician decides that this problem is also caused by a bad solenoid pack, this determination is one that was reached solely on conjecture; no actual test was performed. Although the flashing light might indicate a fault with the solenoid pack, steps in the diagnostic process should never be skipped. This guess can lead to a very costly mistake when it is discovered that the new solenoid pack does not, in fact, fix the problem. In reality, the wiring harness to the transmission is frayed and shorting out. Had the technician performed a test, the cause of the customer concern could have been confirmed or denied before a solenoid pack was put in unnecessarily. While the visual inspection is very valuable, tests must always be performed to compare suspected faults against the expectations and specifications defined in the service information.

When recreating the customer concern, the technician should operate the system in question in all practically available modes. System operation should be checked to see if there are other symptoms that may have gone unnoticed by the customer. These other symptoms can be very valuable when determining which tests to perform; they could save the technician significant time during the diagnosis. When recreating the customer concern, it is important to check the entire system for symptoms and related faults.

Recreating **intermittent faults** can be a challenge. Intermittent symptoms often stem from a component or system that is failing or one where the nature of the fault is not yet clear. In these situations, the aforementioned check of system operation can prove to be highly valuable, as it may uncover previously unnoticed but consistent symptoms. Attempting to repair

FIGURE 1-6 A technician researching service information.

FIGURE 1-7 Performing a visual inspection.

an intermittent fault without consistent symptoms, data, or diagnostic trouble codes (DTCs) is a gamble, because a technician cannot be certain that the actual problem is isolated. This means that there would be no way to confirm with certainty that a repair was effective. The fault could appear again as soon as the vehicle is returned to the customer. To avoid such a situation, look for symptoms, data, or DTCs that are repeatable or consistent. Intermittent diagnosis may require the use of an oscilloscope (a specialized tool for looking at electrical waveforms), or a "wiggle" test (as the name implies, a test instrument is monitored as the electrical or vacuum harness is manipulated by hand). This can verify the customer concern and remove some of the challenge from the diagnosis of an intermittent fault.

Lastly, but notably, save DTCs and freeze frame data. **Freeze frame data** refers to snapshots that are automatically stored in a vehicle's power train control module (PCM) when a fault occurs; this is only available on vehicles model year 1996 and newer. Intermittent faults may be found by reviewing data stored just before, during, and after the fault occurred, similar to an instant replay. When working with computer controlled systems, it is very important to save the recorded data. It may become necessary to erase this information from the computer, though that should generally be avoided. This information is absolutely critical when the technician is trying to answer the questions, "When did this happen?" and "What was going on at the time?"

What will step one look like? When information is gathered and recorded for step one, it should contain the customer concern, any symptoms, and any retrieved DTCs. View the following example from a vehicle that has no reverse. The technician verified the customer concern and recorded:

1. Vehicle will not move when shifted into reverse
2. Vehicle operates normally in all forward gears in OD, D, L2, and L1
3. Current code P0868

Notice that the technician in this example verified and recorded the customer concern. The technician also tried other functions in the system. Specifically, the technician drove the vehicle and tested the other gears in each of the gear ranges and then recorded the results. The DTC data was also retrieved from the control module and recorded. Although it was short and concise, the information will be very useful in the next step.

▶ TECHNICIAN TIP

All too often, the customer does not have symptoms to share and their only concern is that the malfunction indicator is illuminated. In this situation, the data stored in the computer is invaluable. Record it and do not clear it out unless directed to do so in the manufacturer's service procedure. Even then, you should capture the information before clearing the memory.

Step 2: Researching Possible Faults and Gathering Information

K01005 Describe step two of the strategy-based diagnosis.

The second step in the diagnostic process is to research possible faults that may be related to the customer's concern. The goal of this step is to create a list of possible faults. The list is created based on the information gathered in step one. The list will later be narrowed down by the tests performed in step three until the cause of the concern has been confirmed.

N01004 Research vehicle service information including fluid type, vehicle service history, service precautions, and technical service bulletins.

Before testing can begin, a technician must know what possible faults need to be tested. Researching possible faults should begin broadly. Especially when diagnosing electrical and electronic systems, this step should begin at the system level and work down to individual components. For example, if a vehicle engine cranks, but will not start, a technician would list these familiar possible faults: Air, Fuel, Ignition, Compression, and Security. These possible faults are not single components, but rather they are systems. This is where a diagnosis should begin. Starting a diagnosis by listing the dozens of components for each system will make the job unreasonably time intensive. However, once a test determines that there is a fault within a specific system, the list should be expanded to encompass that particular system's subsystems and components. This systematic elimination starts broadly and narrows, allowing technicians to work more efficiently.

In the second step of the diagnostic process, the technician creates a list to help focus their tests. The list may aid in a simple process of elimination by testing one possibility after the next. The list can also start broadly and narrow as testing continues. When starting a list, it may look similar to the following:

1. Air
2. Fuel

3. Ignition
4. Compression
5. Security

This list is broad and starts at the system level. As you'll soon see in the next step, the technician would eliminate possible faults with a test that is focused on analyzing the whole system. When a system is located with a fault, in the ignition system for example, the list would become more specific:

1. Spark Plug
2. Coil on Plug
3. CKP
4. CMP
5. Sensor Triggers
6. Harness
7. Control Module

The technician would again focus his or her testing on the list, seeking to eliminate possible faults until one is confirmed, repaired, and verified.

Several great sources of information are available for researching possible faults, although the best source of information is usually the manufacturer's service information system. These systems are typically found online; however, some manufactures still publish paper service manuals. The manufacturer's service information contains definitions for diagnostic trouble codes, system description and operation, electrical wiring diagrams, diagnostic steps, repair procedures, and much more. Fault diagnosis should almost always begin with the factory service information.

Other resources for identifying faults can be used in conjunction with the factory service information. As previously discussed, the vehicle service history can provide valuable insight into the past maintenance or lack thereof. It can also provide information about recent or repeated repairs. **Technical service bulletins (TSBs)** are service notifications and procedures sent out by the manufacturers to dealer groups alerting technicians about common issues with a particular vehicle or group of vehicles (**FIGURE 1-8**). Some aftermarket sources also exist for the pattern failures addressed by TSBs (**FIGURE 1-9**). Additionally, both original equipment manufacturers (OEM) and aftermarket technician support services offer hotlines, or call-in support, that specifically provide technical support to professional technicians. Some of these hotlines offer subscriptions to searchable web-based components. These resources do not guarantee a repair; that is still the responsibility of the technician. However, all of the sources mentioned here can be a huge help as technicians research possible faults.

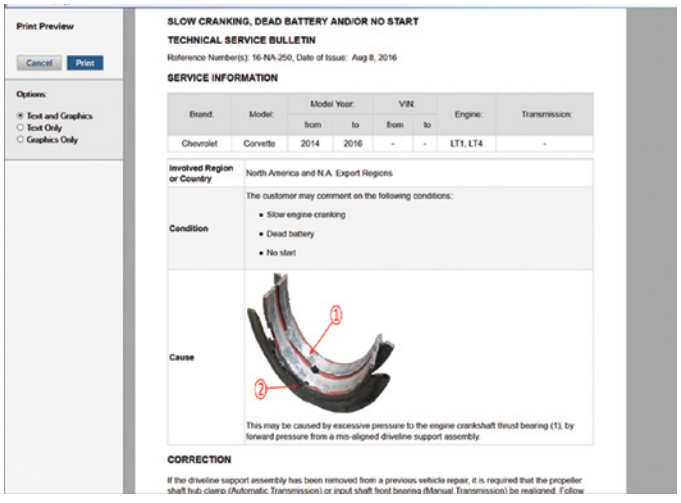

Print Preview
Cancel Print
Options:
Text and Graphics
Text Only
Graphics Only
SLOW CRANKING, DEAD BATTERY AND/OR NO START
TECHNICAL SERVICE BULLETIN
Reference Number(s): 16-NA-250, Date of Issue: Aug 8, 2016
SERVICE INFORMATION
Brand | Model | Model Year: from | to | VIN: from | to | Engine | Transmission
Chevrolet | Corvette | 2014 | 2016 | - | - | LT1, LT4 | -
Involved Region or Country: North America and N.A. Export Regions
Condition: The customer may comment on the following conditions:
• Slow engine cranking
• Dead battery
• No start
Cause
This may be caused by excessive pressure to the engine crankshaft thrust bearing (1), by forward pressure from a mis-aligned driveline support assembly.
CORRECTION

FIGURE 1-8 Technical service bulletin.

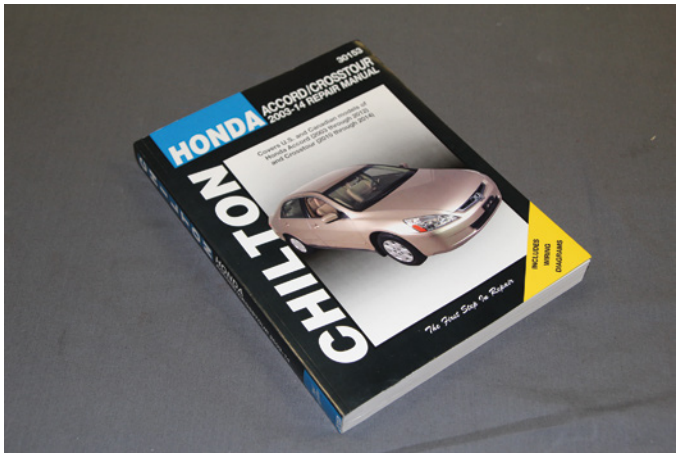


FIGURE 1-9 Aftermarket source.

While these resources are essential, the list of possible faults is just that: a list of possible faults. A technician must always be aware that steps in the diagnostic process cannot be skipped.

Step 3: Focused Testing

K01006 Describe step three of the strategy-based diagnosis.

Step three of the diagnostic process involves focused testing. In this step technicians use their testing skills to eliminate possible faults from the list they created in step two. Steps two and three work together; testing will start at a system level and work down to subsystems, then finally to individual components. The idea of focused testing should be to eliminate as many potential faults as possible with each test.

Focused testing is intended to eliminate possible causes with certainty. Each time a test is performed, the following three pieces of information must be recorded:

- a test description
- an expectation
- a result

These can be recorded on the repair order, electronic service record, or on an extra sheet of paper. Test records must be kept handy because they will become part of the documented record for this repair.

The three pieces of test information are recorded carefully for several reasons. Having an expectation before a test is performed makes each test objective and effective. The expectation is what the result is compared against, in order to determine if the vehicle passed or failed.

Many manufacturers, both original equipment and aftermarket, require that documented test results be submitted with each warranty claim. If the technician fails to document his or her work, the manufacturer will not pay the claim. The result is that the shop is out money for the parts and service, and the technician will not be paid for their work. Be sure to document the work properly (**FIGURE 1-10**).

▶ TECHNICIAN TIP

A repair should never be performed unless the possible fault has been verified through testing. Do not let a possible fault become a possible mistake. In some cases, the list of possible faults can be found in the service information, but many times the technician will need to produce the list based on the concern, the information gathered, and the results of the research.

▶ TECHNICIAN TIP

The test description must provide enough information that someone could repeat the test with the same result. This is very important!

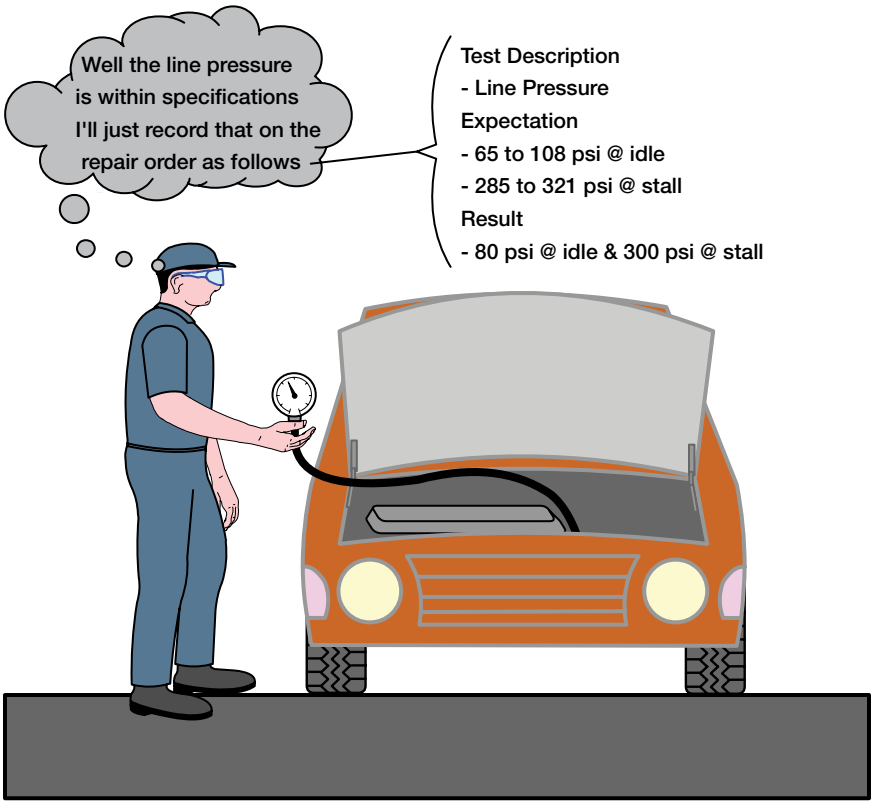


FIGURE 1-10 The test record should include the test description, expectation or specification, and the result of measurement.

1. The test description is not long, or even a complete sentence; it is simply a brief description. It allows the reader to know what test was performed and on what component or system. The test description should be accurate enough that the reader could repeat the test with the same result.
2. The expectation should describe the expected result as if the system is operating normally. The expectation could come directly from the system specifications listed in the manufacturer's service information or from system description and operation.
3. The result is the third part that must be recorded for each test. This information should accurately reflect what happened when the test was performed.

In summary, the testing is focused on isolating a fault or faults from the list of potential faults, and the results are compared to the expectation.

Testing should begin broadly and simply. Consider the following example: A light bulb circuit is suspected of having a fault. If the light bulb is easily accessible, the first test might be to check the voltage drop (i.e., voltage used to push current through the bulb). If the result of the voltage drop measurement is as expected (i.e., within specification), then the problem is in the bulb or socket. In this test, the technician is able to check the integrity of the entire electrical circuit with one test. If the result of the measurement is outside of the expectation (i.e., out of specification), the technician would know that the bulb is not the source of the problem. Further testing would isolate the problem to the ground or power side of the circuit.

The technician in the example performed a simple test with an easy expectation. The test allowed the technician to quickly determine the state of operation for the entire system/circuit and move on. If a fault had been found, then the technician would have isolated the cause of the customer's concern to that particular system/circuit and would need to perform further testing to isolate the cause to a particular component. To do that, the technician would use the service information to determine what components comprise the system and adjust the list from step two to take into account the new information. Then testing would continue.

The next test might measure voltage supply at the bulb (i.e., available voltage). In this way, the technician would be testing the power supply, the conductors, and the switch (assuming a power-side switched circuit). The technician would have an expectation for the circuit voltage and compare his or her result to this expected voltage. As we saw earlier, the technician is testing more than one component with a single test, thereby operating in an efficient manner.

This strategy—starting with broad, simple tests and moving to more complicated, pinpoint tests—makes efficient use of the technician's time while still effectively testing the possible faults.

1. A technician is investigating a customer concern of "no heat from the dash." The technician's investigation might begin with a simple list.
    a. Engine cooling system
    b. HVAC duct and controls
2. The technician would then eliminate one or the other and expand the list. The technician might verify coolant level and temperature at the inlet and outlet of the heater core. The HVAC components controlling and delivering warm air could then be used to expand the list for the next round of testing.
    a. Doors and ducts
    b. Cables
    c. Servos
    d. HVAC control head
    e. Blower motor
    f. Harness
    g. In-cabin filter or debris
3. Notice that the technician has moved from broad system tests to individual components or component groups. The technician's test continues to become more specific as the possibilities are narrowed down.

FIGURE 1-11 Select tests that have simple expectations and are easy to perform.

Technicians commonly encounter vehicles with more than one customer concern. When these concerns both originate from the same or companion systems, technicians are inclined to search for one cause to both problems. Unfortunately, trying to diagnose two faults at once can quickly become problematic and confusing. Instead, select the easier customer concern and follow it through to the end. If both problems were caused by the same faults, then both were fixed. If they were caused by two separate faults, the technician is no worse off for having fixed one concern.

When selecting tests to perform, remember that they should be simple and easy (**FIGURE 1-11**). Except when following service procedures, you should select tests that have simple expectations, are easy to perform, and provide you with the maximum amount of information. This means simple tests that inspect an entire system or circuit are ideal ways to begin testing. Simple tests have expectations and results that are quickly understood and interpreted. They are short and involve basic tools and access to areas that are comfortable to reach.

▶ TECHNICIAN TIP

When selecting tests, it is not a bad idea to choose those tests that might look at components of both systems (e.g., voltage drop on a shared electrical ground), but DO NOT attempt to test for both faults at once. While multiple faults within a companion or the same system often turn out to be related, they should be isolated and tested separately.

When selecting tests, prioritize your testing. First choose tests that can be performed quickly and simply, even if they do not test an entire circuit. If a preferred test is in a difficult place to access, move to another test and come back to it, if needed. The answer may be found in the meantime and the time-consuming test can be avoided. Simple and easy tests are ideal, but they must be measurable or objective.

Yes, a visual inspection is a simple and valuable test, but a technician must determine what the issue is in an objective manner, with help from the service information. A guess based only on appearance is insufficient. If the service information says, "cracks in the serpentine belt indicate that it needs replaced," the belt can be visually and objectively (yes or no) tested. The belt will either have the indicated wear or it will not. If the service information states, "Chain deflection cannot exceed 0.75," then the deflection can be measured and compared to the specification. As testing continues, it may become necessary to use advanced tests, sophisticated equipment, additional time, or tests in areas difficult to access. Keeping initial testing simple and easy will produce the quickest, most reliable, and effective results.

▶ TECHNICIAN TIP

When performing tests for an inspection under warranty, it is absolutely necessary to follow the manufacturers' guidelines.

When testing, use the recommended procedures and equipment. Manufacturers frequently recommend a particular procedure when testing one of their systems.

Failure to follow the specified service procedure can result in the warranty claim being denied by the manufacturer. In that case, both the shop and the technician lose money. Manufacturers may recommend a certain procedure because of the way their system is designed or monitored. Technicians must also be very careful to perform tests safely (**FIGURE 1-12**).

Beyond the mechanical dangers posed by automobiles, many of today's vehicles have dangerously high fluid pressures and deadly high voltage. It is of the utmost importance for the safety of the technician, and those working in the area, that safety procedures are always followed.

Proper test equipment and procedures are intended to test a particular component or system without causing any damage. Improper equipment or test procedures can create a second fault in the system being tested; making the technician's job even more difficult. For example, front probing an electrical terminal with the lead of a DMM can cause the terminal to spread or deform. This can create an intermittent high resistance or open within the circuit that was not there prior to the technician's test. Using the recommended equipment and procedures will help to ensure warranty claims are approved, people are safe, and testing goes smoothly.

When performing repairs, look beyond the obvious for the root cause. This simple suggestion can avoid customer comebacks. Novice technicians frequently have problems with misdiagnosing fuse-related issues. For example, a technician diagnoses a blown fuse as the cause of the customer concern. While replacing the fuse may have fixed the immediate fault, the technician did not look beyond the obvious. What causes a fuse to blow? Low

FIGURE 1-12 Always perform all tests safely.

resistance and increased amperage cause a fuse to blow. However, the technician did not test for one of these faults and the vehicle is likely to return with the same customer concern and the same blown fuse.

In another example of incomplete reasoning, a technician diagnoses a leaky transmission cooler line. The line is chaffed and leaking. This cooler line runs along the frame rail; the inner and outer tie rods are immediately below. The technician diagnoses the vehicle while it is on a lift and the suspension is unloaded (increasing the distance between the hose and steering linkage). The technician should have looked for the root cause of the chaffing, but instead the vehicle and customer come back some time later for the same concern. The technician notices several broken clips that held the flexible line into place on the frame rail. In both cases, the technician will work for free to repair the same vehicle, because time was not taken to ask the question: "Did something else cause this failure?" Testing must be focused beyond the obvious to identify the root cause of the problem and consequently avoid customer comebacks.

In summary, focused testing has several key elements. It picks up the possible faults identified in step two and begins testing each one broadly, narrowing down to more specific tests. Focused testing requires accurately documenting the tests performed, including a test description, expectation, and result, each and every time a test is performed. It should also be performed in a safe and proper manner, following manufacturers' guidelines and safety protocols. Focused testing is a safe, accurate, and repeatable method for isolating possible faults.

Step 4: Performing the Repair

K01007 Describe step four of the strategy-based diagnosis.

The fourth step of the diagnostic process is to perform the repair. Although performing the repair is often the most straightforward step in the process, technicians must still avoid making several common mistakes. The following tips will help you to perform an effective and reliable repair.

Use Proper Service Procedures

Manufacturers will often indicate what procedures are appropriate for their vehicles and components. Many design features and component materials require certain procedures be used and others avoided. Following the manufacturer's service information can prevent premature failure of the repair (**FIGURE 1-13**). For example, repair methods that are safe around the home may be unacceptable in the automotive industry. The use of twist-on wire connectors can create an unreliable and potentially dangerous electrical situation when used in a vehicle. Additionally, warranties, both original equipment and aftermarket, rely on the technicians' adherence to the manufacturer's service information. If technicians fail to do so, the warranty claim can go unpaid and the shop will lose money. Therefore, it is important for reliable repairs and warranty reimbursements that technicians follow the service information when performing repairs.

Use the Correct Tool for the Job

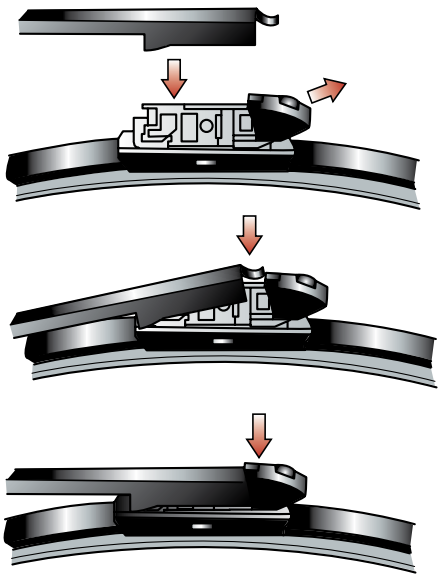
Failure to use the correct tool can lead to a customer comeback and injury to the technician. Proper tool selection is essential. If you are ever in doubt, refer to the manufacturer's service information. Improper tool use or selection can damage the component being installed or other components around it. For example, a technician may choose to install a pump busing with a hammer instead of using the recommended press and bushing driver. This incorrect tool selection can easily lead to misalignment, or damage to the bushing, pump, or torque converter. Using the wrong tool (or the right tool in the wrong manner) can also damage the tool and potentially injure those in the area. For example, if a technician is using a hardened chrome socket on an impact wrench, the socket may shatter, sending shrapnel flying. Using the correct tool for the job will produce better work and ensure the safety of the technician.

MAINTENANCE/SPECIFICATIONS

CHANGING YOUR WIPERS

The wiper arms can be manually moved when the ignition is disabled. This allows for ease of blade replacement and cleaning under the blades.

1. Disable the ignition before removing the blade.
2. Pull the arm away from the glass.
3. Left leading edge retaining block to release the blade. Swing the blade, away from with the arm, to remove it.
4. Swing the new blade toward the arm and snap it into place. Replace the retaining block at the leading edge of the wiper arm. Lower the wiper arm back to the windshield. The wiper arms will automatically return to their normal position the next time the ignition is enabled.



Refresh wiper blades at least twice a year for premium performance.

Poor preforming wipers quality can be improved by cleaning the blades and the windshield. See *Windows and wiper blades* in the *Cleaning* chapter.

To extend the life of wiper blades, scrape off the ice on the windshield BEFORE turning on the wipers. The ice has many sharp edges and will damage and shred the cleaning edge of your wiper blade.

FIGURE 1-13 A typical shop manual page has a task description broken into steps and diagrams or pictures to aid the technician.

Take Time to Perform the Repair Properly

Because technicians are frequently paid by the job, or a flat rate, rather than paid hourly, it is possible for technicians to feel a rush to complete their current job. Rushing increases the likelihood of a mistake. If a mistake occurs, the customer will come back with the vehicle and the technician will work for free to repair the mistake. For example, if a technician replaces a water pump and fills the coolant without bleeding the system, a potentially damaging situation can occur. The trapped gas can affect the flow of coolant and create a hot spot in the cylinder head. This can lead to warning lights, poor performance, and possible engine damage. Take a little extra time to ensure that the work is performed correctly, with the right tools and the proper service procedures. Taking time to perform the repair will ensure fewer "comebacks" and more satisfied customers.

Make Sure the Customer Approves of the Repair

This may seem trivial, but it is extremely important. Most states' laws protect consumers by preventing unauthorized services from being charged or performed. This means that technicians cannot just repair a vehicle and charge the customer for the cost incurred. If the customer is paying, shops must receive a customer's approval prior to performing repairs.

▶ TECHNICIAN TIP

It is very important to quote accurately and wait for approval before performing repairs on a customer's vehicle.

Check for Updates Prior to the Repair

It is also good practice to check for updated parts and software/firmware before performing a repair. It is possible that manufacturers have become aware of a problem with a particular component or software version and issued a software update or produced an updated component. When performing repairs it is a good idea to check for these sorts of updates (often found in TSBs), because it may prevent a customer comeback. Software updates are often downloaded from the manufacturer's website. For hard parts, the best resource is frequently the respective dealership's parts department.

Technical service bulletins also provide information related to unexpected problems, updated parts, or changes to a repair procedure on a particular vehicle system, part, or component. The typical TSB contains step-by-step procedures and diagrams on how to identify if there is a fault and perform an effective repair. Shops typically keep TSBs in a central location, or you may look them up online. Compare the information contained in the TSB with that of the shop manual. Note the differences and, if necessary, copy the TSB to take with you to perform the repair.

Pay Attention to Details

Performing the repair is straightforward but requires attention to detail. There are several things to keep in mind. Proper service procedures can be located in the manufacturer's service information. The correct tool for the job will lessen injury and ensure reliability. Use the necessary time to make sure that the repair was completed correctly. Document your work. These tips can greatly improve the likelihood of a successful repair, but the process does not stop with the repair.

Step 5: Verify the Repair

K01008 Describe step five of the strategy-based diagnosis.

The most important step of the strategy-based diagnostic process is verifying the repair. The reason that this is the most important step is straightforward. The vehicle would never have been in the shop if the customer did not have a concern. If the technician fails to address the original concern, the customer may view the trip as ineffective, a waste of their time and money. Even when a valid repair that makes the vehicle safer and more reliable was performed, the customer will still be unsatisfied if his or her original concern was not addressed. For example, a customer brings the vehicle into the shop for a sticky glove box latch. The technician identifies and repairs a dangerous brake line leak, but fails to fix the glove box. Some customers may view this trip to the shop as unsuccessful because it failed to fix their original issue. When verifying the repair, technicians must always double check their work. This is a valuable confirmation that the repair performed did fix the identified problem.

There are several ways to verify a repair, but generally, the simplest method is the best method. For example, a customer is concerned that the wipers stop moving when the switch is moved into the high position. In step one, the technician will verify that the customer concern and fault exist by turning the wiper switch to all positions. Then the technician uses the wiring diagram (step 2) to diagnose a fault (step 3) within the wiring harness and repairs it (step 4). The technician could then verify the repair by performing the last diagnostic test (from step 3) again. In most cases, the repair would be confirmed if the results had changed and were within expectation/specification.

But what if there was a second problem affecting the wipers such as worn brushes in the motor, or the wiper linkage fell off of the pivot on one side? The customer would still have issues with the wipers and would likely to be unhappy with the repair. So while performing the last diagnostic test (step 3) is a valid verification method, it is not foolproof. An easier method exists: simply return to the process used in step one to verify the customer concern. If the repair has eliminated the problem, the technician should now be able to turn the wiper switch to all positions (step 1) and confirm normal operation. Be certain to perform the same inspections used to verify the customer concern in step one after the repair is performed. This may include checking the entire system operation, not just a single function. This method of verifying that the customer concern is resolved is usually best in most scenarios because it is simple and it is exactly what the customer will do to check your work.

However, sometimes verifying the repair requires a more complicated means of verification. A common concern that falls into this scenario is as follows: The customer brings their vehicle in with a concern that the MIL (malfunction indicator lamp) or "check engine" light is illuminated. In this scenario, *NEVER* verify the repair by simply checking to see that the light is off. While this is what the customer will do to check your work, the failure of the MIL to light can often be misleading and result in a comeback for the exact same problem. This can occur because the MIL is illuminated when tests run by the computers in the vehicle fail. The computers are constantly running tests, but some tests require very specific conditions before they can be run and, hence, fail. Due to the requirements for the conditions to be right, simply checking to see if the light is illuminated is an inadequate method of verification.

For more complicated computer-controlled systems, the best method of verification is checking the test results stored on the vehicle's computer. This option will require an electronic scan tool that communicates with the vehicle's computer, along with a high level of diagnostic experience and service information to verify that the concern has been fully resolved. If the communication option is not available, the second best method of verification is repeating the last diagnostic test performed (in step 3) and confirming that the result has changed to now match the expectation/specification. Complicated computer-controlled systems require that the technician do more than verify the customer concern is eliminated. The technician will have to repeat a diagnostic test (step 3) or view test results stored on the vehicle's computer (this is the preferred method) in order to verify that the repair was effective.

Step five of the strategy-based diagnostic process is the most important. A vehicle should never be returned to a customer without this step completed.

▶ TECHNICIAN TIP

The job is not complete until you have verified that the repair resolved the customer's concern.

▶ Documenting the Repair

The first two components, gathering information from the customer and the strategy-based diagnostic process, have already been described; this section discusses documentation. The repair is documented for several reasons: accurate vehicle history, returns or comebacks, and OEM or aftermarket warranties. Keeping accurate service records will help technicians to know what services and repairs have been performed on a vehicle when it needs any future services. This can be invaluable during the diagnostic process and can also help service advisors and technicians identify what maintenance or recall work still needs to be completed. Documenting the repair also helps technicians in the event that a vehicle returns, now or in the future, with the same customer concern or fault. This can help to identify defective parts or common problems.

Warranty work is another reason that all repairs must be documented. Whether the repair is submitted to an original equipment manufacturer or to an aftermarket warranty

company for reimbursement, the repair must be well documented. Warranty clerks will review the repair order to ensure that proper testing and repair procedures have been followed. Technicians must document their work to ensure that the shop, and in turn the technician, get paid for the work performed.

Finally, documenting the work provides the shop with a record that the work was initiated and completed. This is important in case the vehicle is later involved in an accident or other mishap and the shop is involved in a lawsuit. It is important to have the customer sign or initial, depending on shop policy, the repair order, to verify that the customer accepted the repair.

The Three Cs of Documentation

When documenting a repair, technicians need to remember the **3 Cs**: **concern**, **cause**, and **correction** (**FIGURE 1-14**).

K01009 Explain how the three Cs are applied in repairing and servicing vehicles.

N01002 Demonstrate use of the three C's (concern, cause, and correction).

Concern

The main focus of the 3 Cs is the customer *concern*, which is also the focus of step one of the diagnostic process. Often the concern is documented on the repair order prior to the technician receiving the vehicle. If this is the case, the technician who works on the vehicle should take time to fully understand the concern, read the repair order, and possibly talk further with the customer to understand the nature of the problem. Think through the problem and develop a strategy to attack it. Other symptoms and diagnostic troubles codes are some examples of other information that should be included in the "concern."

Cause

The second C in the 3 Cs is *cause,* which details the cause of the customer concern. This correlates to the documentation done in step three of the diagnostic process. The technician should document any tests that they perform with enough detail that they can be repeated, as well as specifications/expectations, and results. This goes for all tests, even the simple ones.

Correction

The technician should then document the last C, the correction. This must include the procedure used as well as a brief description of the correction. This information comes from the fourth step of the diagnostic process. When documenting the repair order, technicians should include the customer concern and symptoms (DTCs are symptoms); brief descriptions of tests; expectations; and results, along with the procedure and repair that were performed. The technician should also include all parts that were replaced as well, and noted if they were new or used, OEM, or aftermarket.

Other Parts of Documentation

Additional service recommendations should also be documented on the repair order. While working on the vehicle, technicians should also be mindful of other work that may need to be performed. Technicians are obligated to make the customer aware of safety concerns that require attention. Customers may be unaware of a potential hazard or lack of maintenance. Bringing this to the attention of the customer right away can help the technician, as well as the customer. For example, if the technician is already working on the vehicle, they would not have to remove the vehicle from the service bay, bring in a new vehicle, and start all over. Repairing multiple issues in one trip to the service bay makes good use of the technician's time. It also improves customer relations by bringing the customer's attention to problems and thereby preventing possible failures.

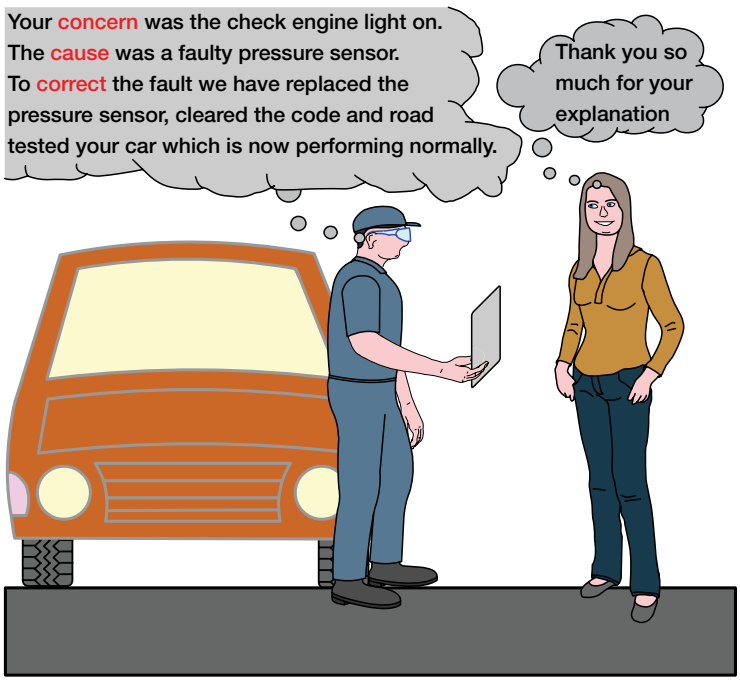


FIGURE 1-14 The 3Cs of documenting the repair.

For example, a technician may be changing the fluid in a transmission and notice that the brake friction pads are extremely low. Bringing this to the attention of the customer can result in additional work for the technician and save the customer from a potentially more costly repair. For this reason, technicians should also note safety issues and maintenance items on the repair order.

Repair Order

K01010 Describe the information and its use within a repair order.

N01003 Identify information needed and the service requested on a repair order.

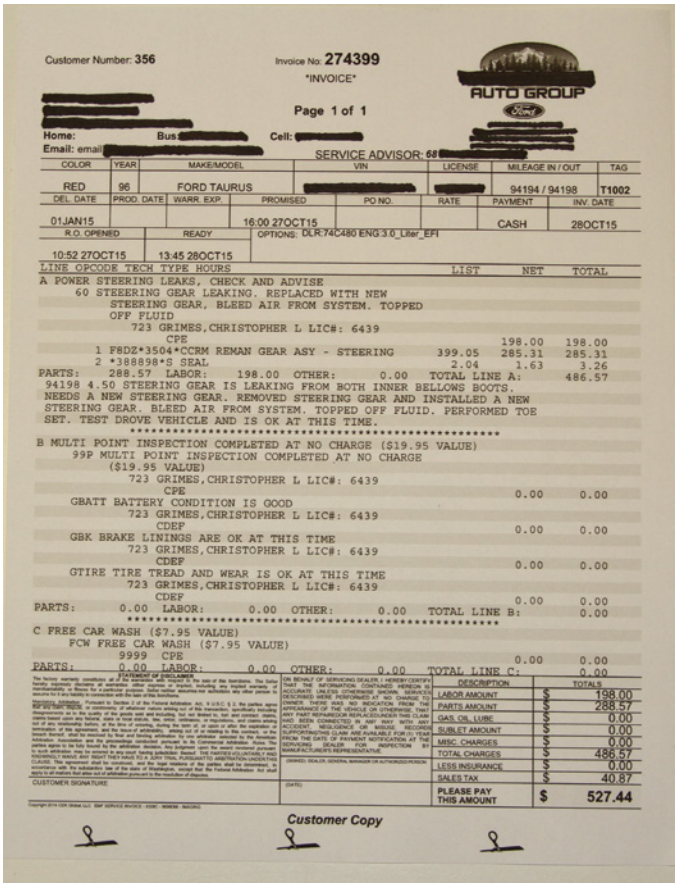
S01002 Complete a repair order.

A **repair order** is a key document used to communicate with both your customers and coworkers. Thoroughly document the information provided by the customer on the repair order; every bit of it may be helpful during the diagnosis (**FIGURE 1-15**). If you are not typing this information, make sure your handwriting is clear and easy for others to read. Unfortunately, if documentation of a complaint is not done well, the technician could be led on a much longer diagnostic path, wasting everyone's time. It can also be a time-consuming process for the diagnosing technician to make contact with the customer in order to get more information that was missed the first time. From time to time, it may be inevitable that the customer will need to be contacted for further inquiry after the initial visit. However, carefully gathering information from the customer on their initial visit will save time, prevent inconveniencing the customer, and aid in the diagnostic process.

To complete a repair order using the 3 Cs, follow the steps in **SKILL DRILL 1-2**.

▶ TECHNICIAN TIP

A repair order is a legal document that can be used as evidence in the event of a lawsuit. Always make sure the information you enter on a repair order is complete and accurate. The information required on a repair order includes: date; customer's name, address, and phone number; vehicle's year, make, model, color, odometer reading, and VIN; and description of the customer's concern. Store repair orders in a safe place, such as in a fireproof filing cabinet or electronically on a secure computer network. Finally, to prevent future complications, it is a good idea to have the customer sign or initial the repair order, indicating that they understand and agree to the needed repair. Having the customer's signature will help prevent the shop from being held liable in an accident involving the vehicle later.



Customer Number: 356 Invoice No: 274399 "INVOICE" Page 1 of 1

AUTO GROUP

Home: Bus Cell: Email: email SERVICE ADVISOR: 68

COLOR	YEAR	MAKE/MODEL	VIN	LICENSE	MILEAGE IN / OUT	TAG
RED	96	FORD TAURUS			94194 / 94198	T1002

DEL. DATE	PROD. DATE	WARR. EXP.	PROMISED	PO NO.	RATE	PAYMENT	INV. DATE
01JAN15			16:00 27OCT15			CASH	28OCT15

R.O. OPENED	READY	OPTIONS: DLR:74C480 ENG:3.0_Liter_EFI
10:52 27OCT15	13:45 28OCT15	

LINE OPCODE TECH TYPE HOURS	LIST	NET	TOTAL
A POWER STEERING LEAKS, CHECK AND ADVISE			
60 STEEERING GEAR LEAKING. REPLACED WITH NEW STEERING GEAR, BLEED AIR FROM SYSTEM. TOPPED OFF FLUID			
723 GRIMES,CHRISTOPHER L LIC#: 6439			
CPE		198.00	198.00
1 F8DZ*3504*CCRM REMAN GEAR ASY - STEERING	399.05	285.31	285.31
2 *388898*S SEAL	2.04	1.63	3.26
PARTS: 288.57 LABOR: 198.00 OTHER: 0.00 TOTAL LINE A:			486.57
94198 4.50 STEERING GEAR IS LEAKING FROM BOTH INNER BELLOWS BOOTS. NEEDS A NEW STEERING GEAR. REMOVED STEERING GEAR AND INSTALLED A NEW STEERING GEAR. BLEED AIR FROM SYSTEM. TOPPED OFF FLUID. PERFORMED TOE SET. TEST DROVE VEHICLE AND IS OK AT THIS TIME.			
B MULTI POINT INSPECTION COMPLETED AT NO CHARGE ($19.95 VALUE)			
99P MULTI POINT INSPECTION COMPLETED AT NO CHARGE ($19.95 VALUE)			
723 GRIMES,CHRISTOPHER L LIC#: 6439			
CPE		0.00	0.00
GBATT BATTERY CONDITION IS GOOD			
723 GRIMES,CHRISTOPHER L LIC#: 6439			
CDEF		0.00	0.00
GBK BRAKE LININGS ARE OK AT THIS TIME			
723 GRIMES,CHRISTOPHER L LIC#: 6439			
CDEF		0.00	0.00
GTIRE TIRE TREAD AND WEAR IS OK AT THIS TIME			
723 GRIMES,CHRISTOPHER L LIC#: 6439			
CDEF		0.00	0.00
PARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE B:			0.00
C FREE CAR WASH ($7.95 VALUE)			
FCW FREE CAR WASH ($7.95 VALUE)			
9999 CPE		0.00	0.00
PARTS: 0.00 LABOR: 0.00 OTHER: 0.00 TOTAL LINE C:			0.00

DESCRIPTION	TOTALS
LABOR AMOUNT	$ 198.00
PARTS AMOUNT	$ 288.57
GAS, OIL, LUBE	$ 0.00
SUBLET AMOUNT	$ 0.00
MISC. CHARGES	$ 0.00
TOTAL CHARGES	$ 486.57
LESS INSURANCE	$ 0.00
SALES TAX	$ 40.87
PLEASE PAY THIS AMOUNT	$ 527.44

Customer Copy

FIGURE 1-15 A repair order.

Applied Communications

AC-23: Repair Orders: The technician writes a repair order containing customer vehicle information, customer complaints, parts and materials used (including prices), services performed, labor hours, and suggested repairs/maintenance.

A repair order is a legal contract between the service provider and the customer. It contains details of the services to be provided by you and the authorization from the customer. To make sure everyone understands clearly what is involved, a repair order should contain information about the following aspects of the repair.

- Your company or service providers: The service provider section contains the company name, address, and contact details; the name of a service advisor who is overseeing the job; and the amount of time the service technician will have to service the vehicle.
- The customer: The customer section contains the customer's name, address, and contact phone numbers.
- The customer's vehicle: The vehicle section includes details about the vehicle to be serviced. Check the vehicle's license plate before starting work. The license plate numbers are usually unique within a country. You should also record information about the vehicle's make, model, and color. This information will make it easier for you to locate the vehicle on the parking lot. You may also need to know the manufacture date of the vehicle to be able to order the right parts. The odometer reading and the date will help keep track of how much distance the vehicle travels and the time period between each visit to the shop. The VIN is designed to be unique worldwide and contains specific information about the vehicle. Many shops do a "walk-around" with the customer to note any previous damage to the vehicle and to look for any obvious faults such as worn tires, rusted-out exhaust pipes, or torn wiper blades.
- The service operations: This section contains the details of the service operations and parts.
  - The first part is the service operation details. For example, the vehicle is in for a 150,000 mile (240,000-km) service, which can be done in 3 hours and results in approximately $300 of labor costs. The information about the chargeable labor time to complete a specific task can be found in a labor guide manual. In some workplaces, this information is built into the computer system and will be automatically displayed.
  - The second part of this section is the details of parts used in the service, including the descriptions, quantities, codes, and prices. The codes for each service and part are normally abbreviations that are used for easy reference in the shop. Some shops may have their own reference code system.
  - As you do the vehicle inspection, you may discover other things that need replaced or repaired. These additional services can be recorded in another section. It is essential that you check with the customer and obtain their approval before carrying out any additional services.
  - The parts requirements: This section lists the parts required to perform the repair.

Some repair orders also contain accounting information so they can be used as invoices.

SKILL DRILL 1-2 Completing a Repair Order

1. Greet the customer.
2. Locate a repair order used in your shop and obtain or verify the customer's name, address, and phone number.
3. Obtain details about the vehicle, including the year, make, model, color, odometer reading, and VIN.
4. Ask the customer to tell you more about the *concern* by using open-ended questions, such as "When does problem occur?" "At what speed(s)?" "How do you experience the problem?" "How long has this been occurring?" "How many passengers do you typically carry?" Type or clearly write the customer's responses on the repair order.
5. Ask the customer about other changes with the vehicle, such as recent work, or recent travel. Type or clearly write the customer's responses on the repair order.
6. Remembering the lessons learned regarding the proper diagnostic process, begin to verify the customer's *concern* by first performing a visual inspection.
7. If you see nothing unusual during your visual inspection, continue to verify the customer's concern by conducting a road test of the vehicle. The customer may ride along, if possible, to help identify the issue as it occurs, or you may conduct the test by yourself. Following the test drive, after verifying the customer's concern, record it on the repair order.
8. The second step of the diagnostic process is to research the possible faults, and gather information. Access the vehicle service history to determine if the vehicle has experienced a similar problem in the past, requires a routine service maintenance, or has been serviced recently. Document this information, if applicable, on the repair order.
9. Conduct research by accessing various sources of information related to the vehicle, such as the vehicle service manual or the owner's manual. Check to see if a TSB related to the issue exists. As part of the process, rule out the possibility that the customer's concern is a normal operation of the vehicle.
10. Now that you have your broad list of possible faults related to the concern, begin step three, focused testing. Choose one of the possible broad faults you identified in step two. Now refer to the service manual to locate information that matches the concern. Service manuals usually contain diagnostic charts to aid in the focused testing process.
11. Conduct a test and record its description, your expectation, and the result on the repair order or another piece of paper. Continue to check each possible fault until you identify the *cause* of the concern.
12. Once you have identified the fault, you're ready for step four, performing the repair. You would inform the customer of your finding and obtain his or her approval to make the repair. Pending customer approval, you would then follow proper safety procedures and use the manufacturer's guidelines to correct the problem, being sure to use the correct tools and taking the time to complete the job properly.
13. Once you've made the repair, you are ready for step five, verifying the repair. The simplest way to verify that you have addressed and corrected the customer's concern is to repeat the test drive. Take the vehicle for a test drive and repeat the tests you initially performed. Is the issue gone? If so, you have verified the repair and can return the vehicle to the customer.
14. Document the correction on the repair order. If the issue is not resolved, you must return to your list of possible faults and continue testing after first alerting the customer that additional work and time will be necessary.

Wrap-Up

Ready for Review

- Service history is typically retrieved from service records kept by the shop, dealer network, original equipment manufacturer (OEM), or aftermarket service center and contains a list of services performed on a vehicle and the date and mileage at which they were completed.
- The service history allows technicians to determine if the vehicle has been well maintained. This can be extremely useful when a technician suspects that lack of maintenance may be the cause of the problem.
- Failure to comply with the state and federal law can be very expensive for the dealership and manufacturer.
- Today's vehicles also require regular software updates made available to fix a bug or glitch in the computer programming. These updates are often designed to eliminate a customer concern, improve owner satisfaction, or increase vehicle life.
- The strategy-based diagnostic process is focused on fixing problems correctly the first time. It begins with identifying the customer's concern and ends with confirming that the problem has been resolved.
- The problem-solving process provides a consistent road map for technicians as they address customer concerns that require diagnosis and to make sure that customer concerns are resolved with certainty.
- Strategy-based diagnosis simplifies the problem-solving portion of the repair, making the job easier for the technician; it prevents technicians from having to work on the same job more than once; and it all but eliminates customer comebacks.
- Customer comebacks are usually caused by the customer concern being misinterpreted or misunderstood or failing to verify that the original concern was resolved.
- The strategy-based diagnostic process begins by gathering preliminary information from the customer and by reviewing the vehicle's service history.
- The first step in the diagnostic process is to verify the customer concern. This step is completed for two main purposes: verify that there is an actual problem present, and guarantee that the customer's concern is addressed.
- Visual inspections can be very valuable, but technicians need to be careful not to jump to conclusions.
- DTC's (Diagnostic Trouble Codes) and freeze frame data should always be saved and recorded on the repair order. Freeze-frame data provide a snapshot of the entire engine data when the DTC occurs, which allows for duplication of the condition so that the DTC can be replicated.
- The second step in the diagnostic process is to research possible faults. The goal of this step is to create a list of possible faults. The list will be created based on the information gathered in step 1 and narrowed down by the tests performed in step 3 until the cause of the concern has been confirmed.
- The best source of information is usually the manufacturer's service information system.
- Technical service bulletins (TSBs) are service notifications and procedures sent out by the manufacturers to dealer groups, alerting technicians to common issues with a particular vehicle or group of vehicles. Some aftermarket sources also exist for the pattern failures addressed by TSBs
- A technician must always be aware that steps in the diagnostic process cannot be skipped. A repair should never be performed unless the possible fault has been verified through testing.
- Step 3 of the diagnostic process involves focused testing, where technicians use their testing skills to eliminate possible faults from the list they created in step two. Steps 2 and 3 work together, because testing starts at a system level and works down to subsystems, then finally to individual components.
- When selecting tests prioritize your testing. First choose tests that can be performed quickly and simply, even if they do not test an entire circuit. If a preferred test is in a very difficult place to access, move to another test and come back to it, if needed.
- Following manufacturers' guidelines and safety protocols keeps technicians safe. Focused testing is a safe, accurate, and repeatable method for isolating possible faults. Once the fault has been isolated, it is time to perform the repair.
- The fourth step of the diagnostic process is to perform the repair. Performing the repair is often the most straightforward step in the process.
- Use proper service procedures when performing a repair. Manufacturers often indicate what procedures are appropriate for their vehicles and components.
- Use the correct tool for the job when performing a repair. Failure to use the correct tool for the job can lead to a customer comeback and injury to the technician.
- Take time to perform the repair properly. Technicians are frequently paid by the job, or flat rate, rather than paid hourly, it is possible for technicians to feel a rush to complete their current job. Rushing increases the likelihood of a mistake and the next time you may pay for it.
- The most important step of the strategy-based diagnostic process is verifying the repair. The reason that this is the most important step is straightforward. The vehicle would never have been in the shop if the customer did not have a concern.
- Verifying the original concern is the best method of double-checking your work and meeting your customers' expectations. The job is not complete until you have verified that the repair resolved the customer's concern.

- Documentation is key to effective and efficient repairs. Keeping all the information available to the service advisor, technician, and the customer allows for a more open dialogue which can limit the confusion of the repair process.
- The repair is documented for several reasons: accurate vehicle history, returns or comebacks, and warranties. Keeping accurate service records will help technicians to know what services and repairs have been performed on a vehicle when it needs any future services.
- When documenting a repair, technicians need to remember the three Cs: concern, cause, and correction.
- When documenting the repair order, technicians should include the customer concern and symptoms (Diagnostic Trouble Codes are symptoms) and a brief description of tests, expectations, and results, along with the procedure and repair that were processed.

Key Terms

Strategy-Based Diagnostic Process A systematic process used to diagnose faults in a vehicle.

service advisor The person at a repair facility that is in charge of communicating with the customer.

service history A complete listing of all the servicing and repairs that have been performed on that vehicle.

repair order The document that is given to the repair technician that details the customer concern and any needed information.

freeze frame data Refers to snapshots that are automatically stored in a vehicle's power train control module (PCM) when a fault occurs (only available on model year 1996 and newer).

technical service bulletin (TSB) Service notifications and procedures sent out by the manufacturers to dealer groups alerting technicians about common issues with a particular vehicle or group of vehicles.

original equipment manufacturer (OEM) The company that manufactured the vehicle.

aftermarket A company other than the original manufacturer that produces equipment or provides services.

intermittent faults A fault or customer concern that you can not detect all of the time and only occurs sometimes.

3 Cs A term used to describe the repair documentation process of 1st documenting the customer concern, 2nd documenting the cause of the problem, and 3rd documenting the correction.

concern Part of the 3Cs, documenting the original concern that the customer came into the shop with. This documentation will go on the repair order, invoice, and service history.

cause Part of the 3Cs, documenting the cause of the problem. This documentation will go on the repair order, invoice, and service history.

correction Part of the 3Cs, documenting the repair that solved the vehicle fault. This documentation will go on the repair order, invoice, and service history.

Review Questions

1. When a vehicle comes in for repair, detailed information regarding the vehicle should be recorded in the:
   a. service booklet.
   b. repair order.
   c. vehicle information label.
   d. shop manual.
2. The service history of the vehicle gives information on whether:
   a. the vehicle was serviced for the same problem more than once.
   b. an odometer rollback has occurred.
   c. the vehicle meets federal standards.
   d. the vehicle has Vehicle Safety Certification.
3. Which of the following steps is the last step in a strategy-based diagnostic process?
   a. Verifying the customer's concern
   b. Researching possible faults
   c. Performing the repair
   d. Verifying the repair
4. When possible, which of the following is the best way to understand the customer's concern?
   a. Asking the customer to guess the cause of the problem.
   b. Asking the customer to suggest a solution to the problem.
   c. Encouraging the customer to demonstrate the problem.
   d. Encouraging the customer to help you fix the problem.
5. The best way to address intermittent faults is to:
   a. look for symptoms, data, or DTCs that are repeatable or consistent.
   b. reverse the steps in the diagnostic process.
   c. ask the customer to bring back the vehicle when the fault occurs.
   d. take it up only when it is covered by warranty.
6. When the technician encounters a vehicle with more than one customer concern, and both originate from companion systems, the technician:
   a. should attempt to test for both faults at once.
   b. need not attempt to fix the second fault.
   c. should never choose those tests that might look at components of both systems.
   d. should isolate the faults and test them separately.
7. Choose the correct statement.
   a. When performing tests for an inspection under warranty, follow your intuition rather than the manufacturers' guidelines.
   b. Researching possible faults should begin with a specific cause in mind.
   c. For hard parts, the best resource is frequently the respective dealership's parts department.
   d. DTCs and freeze frame data need not be captured before clearing the memory.
8. All of the following will happen if the technician fails to document test results *except*:
   a. The manufacturer will not pay the claim.
   b. The shop is out money for the parts and service.

c. The technician will be unable to diagnose the fault.
d. The technician will not be paid for his or her work.

9. All of the following statements with respect to the 3 Cs are true *except*:
   a. Customer concern is documented on the repair order prior to the technician receiving the vehicle.
   b. The second C in the 3 Cs refers to the cause of the customer's concern.
   c. Technicians should note safety issues and maintenance items on the repair order.
   d. Additional service recommendations should never be documented on the repair order.
10. Which of the following is not one of the 3 Cs of vehicle repair?
   a. Cause
   b. Cost
   c. Concern
   d. Correction

ASE Technician A/Technician B Style Questions

1. Tech A says that when diagnosing a transmission problem, it is important to first verify the customer concern by taking the vehicle on a road test if possible. Tech B says that you should check for TSBs during the diagnostic process. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B
2. Tech A says that additional service recommendations should be documented on the repair order. Tech B says technicians are obligated to make the customer aware of safety concerns that require attention. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B
3. Tech A says the strategy-based diagnostic process is a scientific process of elimination. Tech B says the strategy-based diagnostic process begins with scanning the vehicle for DTCs. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B
4. Tech A says that manufacturers will often indicate what procedures are appropriate for their vehicles and components. Tech B says that the manufacturer's service information can avoid premature failure of the repair. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B
5. Tech A says that technicians are frequently paid by the job, or flat rate, rather than paid hourly. Tech B says rushing the repair is best for the customer, so they get their vehicle back quickly. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B
6. Tech A says that it is only necessary for dealerships to check for updated parts and software/firmware before performing a repair. Tech B says that it is possible that manufacturers have become aware of a problem with a particular component or software version and have issued a software update. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B
7. Tech A says that the customer concern is the focus of step 1 of the diagnostic process. Often the concern is documented on the repair order prior to the technician receiving the vehicle. Tech B says the technician who works on the vehicle should take time to fully understand the concern, read the repair order, and possibly talk further with the customer to understand the nature of the problem. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B
8. Tech A says that a repair order is only used in the shop and will be discarded when the vehicle is complete. Tech B says that the repair order is a legal document and could be used in a court. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B
9. Two technicians are discussing a transmission problem. Tech A says that it is important to test drive the vehicle because there may actually be no issue with the vehicle and the customer complaint is actually a normal operational characteristic of the transmission. Tech B says you should always check TSBs before performing any service of the transmission because the manufacturer may have updated a component. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B
10. Tech A says that experience will allow you to skip many of the steps of the diagnostic process because you will be familiar with the transmission. Tech B says that skipping steps of the diagnostic process can cause issues to be missed, or misdiagnosis of the problem. Who is correct?
   a. Tech A only
   b. Tech B only
   c. Both A and B
   d. Neither A nor B

CHAPTER 2
Safety

NATEF Tasks

- **N02001** Comply with the required use of safety glasses, ear protection, gloves, and shoes during lab/shop activities.
- **N02002** Identify and wear appropriate clothing for lab/shop activities.
- **N02003** Identify general shop safety rules and procedures.
- **N02004** Utilize proper ventilation procedures for working within the lab/shop area.
- **N02005** Identify the location and the types of fire extinguishers and other fire safety equipment; demonstrate knowledge of the procedures for using fire extinguishers and other fire safety equipment.
- **N02006** Identify the location of the posted evacuation routes.
- **N02007** Locate and demonstrate knowledge of safety data sheets (SDS).

Knowledge Objectives

After reading this chapter, you will be able to:

- **K02001** Describe the personal safety equipment and precautions for the workplace.
- **K02002** Describe the different kinds of hand protection.
- **K02003** Understand why it is important to wear headgear.
- **K02004** Describe the types of ear protection.
- **K02005** Describe the types of breathing devices.
- **K02006** Describe the types of eye protection.
- **K02007** Describe proper lifting techniques.
- **K02008** Comply with safety precautions in the workplace.
- **K02009** Describe how OSHA rules and the EPA impact the automotive workplace.
- **K02010** Explain how shop policies, procedures, and safety inspections make the workplace safer.
- **K02011** Describe the importance of demonstrating a safe attitude in the workplace.
- **K02012** Identify workplace safety signs and their meanings.
- **K02013** Describe the standard safety equipment.
- **K02014** Maintain a safe air quality in the workplace.
- **K02015** Describe appropriate workplace electrical safety practices.
- **K02016** Prevent fires in the workplace.
- **K02017** Identify hazardous environments and the safety precautions that should be applied.
- **K02018** Identify the proper method to clean hazardous dust safely.
- **K02019** Explain the basic first aid procedures when approaching an emergency.

Skills Objectives

After reading this chapter, you will be able to:

- **S02001** Maintain a clean and orderly workplace.
- **S02002** Use information in an SDS.
- **S02003** Properly dispose of used engine oil and other petroleum products.

You Are the Automotive Technician

It's your first day on the job, and you are asked to report to the main office, where your new supervisor gives you your PPE. Before you can begin working on the shop floor, you are given training on the proper use of PPE. Here are some of the questions you must be able to answer.

1. Which type of gloves should be worn when handling solvents and cleaners?
2. Why must safety glasses be worn at all times in the shop?
3. Why should rings, watches, and jewelry never be worn in the shop?
4. When should hearing protection be worn?
5. For what types of tasks should a face shield be worn?
6. Why must hair be tied up or restrained in the shop?
7. Which type of eye protection should be worn when using or assisting a person using an oxyacetylene welder?

Introduction

Motor vehicle servicing is one of the most common vocations worldwide. Hundreds of thousands of shops service millions of vehicles every day. That means at any given time, many people are conducting automotive servicing, and there is great potential for things to go wrong. It is up to you and your workplace to make sure all work activities are conducted safely. Accidents are not caused by properly maintained tools; accidents are generally caused by people.

Personal Safety

K02001 Describe the personal safety equipment and precautions for the workplace.

N02001 Comply with the required use of safety glasses, ear protection, gloves, and shoes during lab/shop activities.

Personal safety is not something to take lightly. Accidents cause injury and death every day in workplaces across the world (**FIGURE 2-1**). Even if accidents don't result in death, they can be very costly in lost productivity, disability, rehabilitation, and litigation costs. Because workplace safety affects people and society so heavily, government has an interest in minimizing workplace accidents and promoting safe working environments. The primary federal agency for workplace safety is the Occupational Safety and Health Administration (OSHA). States have their own agencies that administer the federal guidelines as well as create additional regulations that apply to their state.

Personal protective equipment (PPE) is equipment used to block the entry of hazardous materials into the body or to protect the body from injury. PPE includes clothing, shoes, eye protection, face protection, head protection, hearing protection, gloves, masks, and respirators (**FIGURE 2-2**). Before you undertake any activity, consider all potential hazards and select the correct PPE based on the risk associated with the activity. For example, if you are going to change hydraulic brake fluid, put on some impervious gloves to protect your skin from chemicals.

Protective Clothing

N02002 Identify and wear appropriate clothing for lab/shop activities.

Protective clothing includes items like shirts, vests, pants, shoes, and gloves. These items are your first line of defense against injuries and accidents, and clothing appropriate for the task must be worn when performing any work. Always make sure protective clothing is kept clean and in good condition. You should replace any clothing that is not in good condition, as it is no longer able to fully protect you. Types of protective clothing materials and their uses are as follows:

- Paper-like fiber: Disposable suits made of this material provide protection against dust and splashes.
- Treated wool and cotton: Adapts well to changing workplace temperatures. Comfortable and fire resistant. Protects against dust, abrasion, and rough and irritating surfaces.

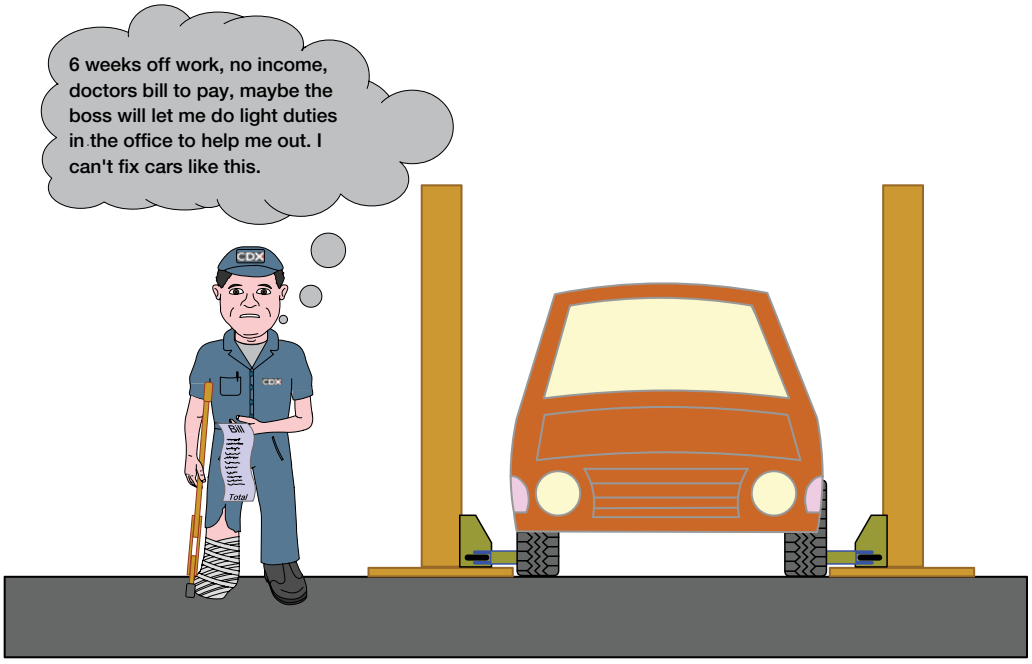


FIGURE 2-1 Accidents are costly.

- Duck: Protects employees against cuts and bruises while they handle heavy, sharp, or rough materials.
- Leather: Often used against dry heat and flame.
- Rubber, rubberized fabrics, neoprene, and plastics: Provides protection against certain acids and other chemicals.

Source: PPE Assessment, Occupational Safety & Health Administration, U.S. Department of Labor.

FIGURE 2-2 Personal protective equipment (PPE) includes clothing, shoes, safety glasses, hearing protection, masks, and respirators.

Always wear appropriate work clothing. Whether this is a one-piece coverall/overall or a separate shirt and pants, the clothes you work in should be comfortable enough to allow you to move, without being loose enough to catch on machinery (**FIGURE 2-3**). The material must be flame retardant and strong enough that it cannot be easily torn. A flap must cover buttons or snaps. If you wear a long-sleeve shirt, the cuffs must be close fitting, without being tight. Pants should not have cuffs so that hot debris cannot become trapped in the fabric.

Always wash your work clothes separately from your other clothes to prevent contaminating your regular clothes. Start a new working day with clean work clothes, and change out of contaminated clothing as soon as possible. It is a good idea to keep a spare set of work clothes in the shop in case the ones you are wearing become overly dirty or a toxic or corrosive fluid is spilled on them.

The proper footwear provides protection against items falling on your feet, chemicals, cuts, abrasions, punctures, and slips. They also provide good support for your feet, especially when working on hard surfaces like concrete. The soles of your shoes must be acid and slip resistant, and the uppers must be made from a puncture-proof material such as leather.

Some shops and technicians prefer safety shoes with a steel toe cap to protect the toes. Always wear shoes that comply with your local shop standards.

▶ TECHNICIAN TIP

Each shop activity requires specific clothing, depending on its nature. Research and identify what specific type of clothing is required for every activity you undertake. Wear appropriate clothing for the activity you will be involved in, according to the shop's policies and procedures.

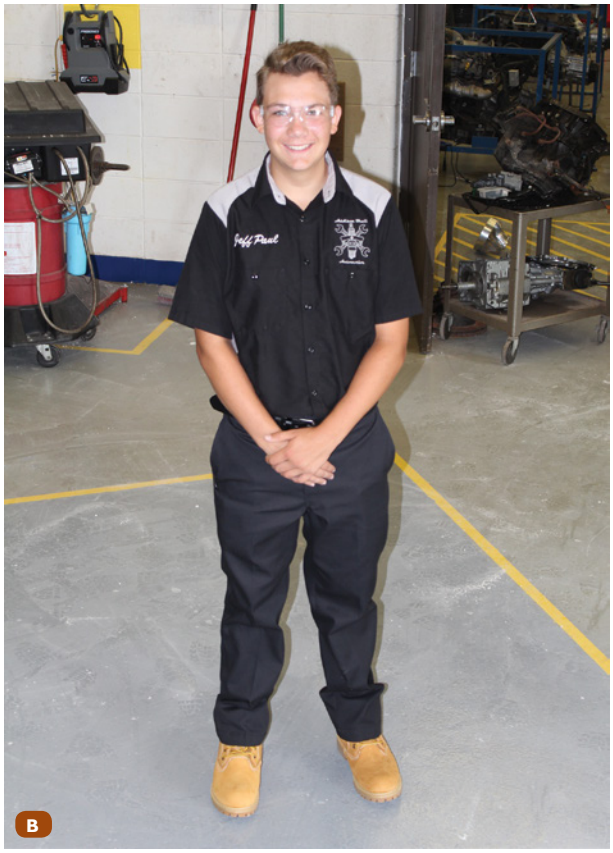


FIGURE 2-3 **A.** One-piece coverall. **B.** Shirt and pants.

Hand Protection

K02002 Describe the different kinds of hand protection.

Hands are a very complex and sensitive part of the body, with many nerves, tendons, and blood vessels. They are susceptible to injury and damage. Nearly every activity performed on vehicles requires the use of your hands, which provides many opportunities for injury. Whenever required, wear gloves to protect your hands. There are many types of gloves available, and their applications vary greatly as you will see below. It is important to wear the correct type of glove for the various activities you perform. In fact, when working on rotating equipment, it may be necessary for you to remove your gloves so that they don't get caught in the machinery and pull you into it.

Heavy-duty and impenetrable chemical gloves should always be worn when using solvents and cleaners. They should also be worn when working on batteries. Chemical gloves should extend to the middle of your forearm to reduce the risk of chemicals splashing onto your skin (**FIGURE 2-4**). Always inspect chemical gloves for holes or cracks before using them, and replace them when they become worn. Some chemical gloves are also slightly heat resistant. This type of chemical glove is suitable for use when removing radiator caps and mixing coolant.

Leather gloves protect your hands from burns when welding or handling hot components (**FIGURE 2-5**). You should also use them when removing steel from a storage rack and when handling sharp objects. When using leather gloves for handling hot components, be aware of the potential for **heat buildup**. Heat buildup occurs when the leather glove can no longer absorb or reflect heat, and heat is transferred to the inside of the leather glove. At this point, the leather gloves' ability to protect you from the heat is reduced, and you need to stop work, remove the leather gloves, and allow them to cool down before continuing to work. Also avoid picking up very hot metal with leather gloves, because it causes the leather to harden, making it less flexible during use. If very hot metal must be moved, it would be better to use an appropriate pair of pliers.

FIGURE 2-4 Chemical gloves should extend to the middle of your forearm to reduce the risk of chemical burns.

Light-duty gloves should be used to protect your hands from exposure to greases and oils (**FIGURE 2-6**). Light-duty gloves are typically disposable and can be made from a few different materials, such as nitrile, latex, and even plastic. Some people have allergies to these materials. If you have an allergic reaction when wearing these gloves, try using a glove made from a different material.

Cloth gloves are designed to be worn in cold temperatures, particularly during winter, so that cold tools do not stick to your

FIGURE 2-5 Leather gloves protect your hands from burns when welding or handling hot components.

FIGURE 2-6 Light-duty gloves should be used to protect your hands from exposure to greases and oils.

FIGURE 2-7 Cloth gloves work well in cold temperatures, particularly during winter, so that cold tools do not stick to your skin.

FIGURE 2-8 Barrier cream helps prevent chemicals from being absorbed into your skin and should be applied to your hands before you begin work.

skin (**FIGURE 2-7**). Over time, cloth gloves accumulate dirt and grime, so you need to wash them regularly. Regularly inspect cloth gloves for damage and wear, and replace them when required. Cloth gloves are not an effective barrier against chemicals or oils, so never use them for that purpose.

Barrier cream looks and feels like a moisturizing cream, but it has a specific formula to provide extra protection from chemicals and oils. Barrier cream prevents chemicals from being absorbed into your skin and should be applied to your hands before you begin work (**FIGURE 2-8**). Even the slightest exposure to certain chemicals can lead to dermatitis, a painful skin irritation. Never use a standard moisturizer as a replacement for proper barrier cream. Barrier cream also makes it easier to clean your hands because it can prevent fine particles from adhering to your skin.

When cleaning your hands, use only specialized hand cleaners, which protect your skin. Your hands are porous and easily absorb liquids on contact. Never use solvents such as gasoline or kerosene to clean your hands, because they can be absorbed into the bloodstream and remove the skin's natural protective oils.

Headgear

K02003 Understand why it is important to wear headgear.

Headgear includes items like hairnets, caps, and hard hats. These help protect you from getting your hair caught in rotating machinery and protect your head from knocks or bumps. For example, a hard hat can protect you from bumping your head on vehicle parts when working under a vehicle that is raised on a hoist. Head wounds tend to bleed a lot, so hard hats can prevent the need for visiting an emergency room for stitches.

Some technicians wear a cap to keep their hair clean when working under vehicles, or to contain hair that reaches a shirt collar. Some caps are designed specifically with additional padding on the top to provide extra protection against bumps. If hair is longer than can be contained in a cap, then technicians can either use a ponytail holder or hairnet (**FIGURE 2-9**).

When in a workshop environment, watches, rings, necklaces, and dangling earrings and other jewelry present a number of hazards. They can get caught in rotating machinery, and because they are mainly constructed from metal, they can conduct electricity. Imagine leaning over a running engine with a dangling necklace; it could get caught in the fan belt and pull you into the rotating parts if it doesn't break; not only will it get destroyed but it could seriously injure you. A ring or watch could inadvertently short out an electrical circuit, heat up quickly and severely burn you, or cause a spark that might make the battery explode. A ring can also get caught on moving parts, breaking the finger bone or even ripping the finger out of the hand (**FIGURE 2-10**). To be safe, always remove watches, rings, and jewelry before starting work. Not only is it safer to remove these items but your valuables will not get damaged or lost.

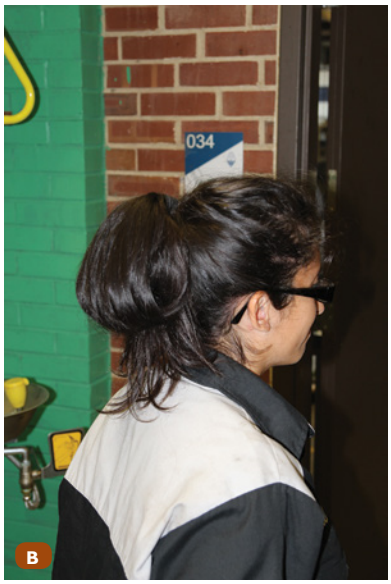


FIGURE 2-9 Containing hair. **A.** Ball cap. **B.** Pony tail.

FIGURE 2-10 Finger missing because the wedding ring caught on rotating machinery.

Ear Protection

K02004 Describe the types of ear protection.

Ear protection should be worn when sound levels exceed 85 decibels, when you are working around operating machinery for any period of time, or when the equipment you are using produces loud noise. If you have to raise your voice to be heard by a person who is 2' (50 mm) away from you, then the sound level is about 85 decibels or more. Ear protection comes in two forms: One type covers the entire outer ear, and the other is fitted into the ear canal (**FIGURE 2-11**). Generally speaking, the in-the-ear style has higher noise-reduction ratings. If the noise is not excessively loud, either type of protection will work. If you are in an extremely loud environment, you will want to verify that the option you choose is rated high enough.

Breathing Devices

K02005 Describe the types of breathing devices.

Dust and chemicals from your workspace can be absorbed into the body when you breathe. When working in an environment where dust is present or where the task you are performing will produce dust, you should always wear an appropriate form of breathing device. When working in an environment where chemical vapors are present, you should always wear the proper respirator. There are two types of breathing devices: disposable dust masks and respirators.

FIGURE 2-11 Ear protection comes in two forms: **A.** One type covers the entire outer ear. **B.** The other type is fitted into the ear canal.

A disposable dust mask is made from paper with a wire-reinforced edge that is held to your face with an elastic strip. It covers your mouth and nose and is disposed of at the completion of the task. This type of mask should only be used as a dust mask and should not be used if chemicals, such as paint solvents, are present in the atmosphere. It should also not be used when working around asbestos dust as the asbestos particles are too small for the filter to remove them, allowing then to be inhaled deeply into the lungs where their sharp tips pierce the lung's lining and become trapped. Over time, these create scar tissue in the lungs and can potentially cause cancer or other life-threatening diseases. Dust masks and respirators should fit securely on your face to minimize leaks around the edges. This can be especially difficult to prevent if you have a beard.

FIGURE 2-12 To be completely effective, the respirator mask must make a good seal onto your face.

The **respirator** has removable cartridges that can be changed according to the type of contaminant being filtered. Always make sure the cartridge is the correct type for the contaminant in the atmosphere. For example, when chemicals are present, use the appropriate chemical filter in your respirator. The cartridges should be replaced according to the manufacturer's recommended replacement schedule to ensure their effectiveness. To be completely effective, the respirator mask must make a good seal onto your face (**FIGURE 2-12**).

In some situations where the environment either contains too high a concentration of hazardous chemicals or a lack of oxygen, a fresh air respirator must be used. This device pumps a supply of fresh air to the mask from an outside location (**FIGURE 2-13**). Being aware of the environment you are working in allows you to determine the proper respirator or fresh air supply system.

Eye Protection

K02006 Describe the types of eye protection.

Eyes are very sensitive organs, and they need to be protected against damage and injury. There are many things in the workshop environment that can damage or injure eyes, such as high-velocity particles coming from a grinder or high-intensity light coming from a welder. In fact, the American National Standards Institute (ANSI) reports that 2000 workers per day suffer on-the-job eye injuries. Always select the appropriate eye protection for the work you are undertaking. Sometimes this may mean that more than one type of protection is required. For example, when grinding, you should wear a pair of safety glasses underneath your face shield for added protection.

The most common type of eye protection is a pair of **safety glasses**, which must be clearly marked with "Z87.1." Safety glasses have built-in side shields to help protect your eyes from the side. Approved safety glasses should be worn whenever you are in a workshop. They are designed to help protect your eyes from direct impact or debris damage (**FIGURE 2-14**).

FIGURE 2-13 Fresh air respirator.

FIGURE 2-14 Safety glasses are designed to protect your eyes from direct impact or debris damage.

SAFETY TIP

You might be tempted to take your safety glasses off while you are doing a nonhazardous task in the shop like a former student of mine. He was doing paperwork in his stall while his best friend was driving pins out of the tracks of a bulldozer. Unfortunately, the head of the punch his friend was using was mushroomed. And on one hit, a fragment broke off, flew across the stall, and hit the student in the eye, blinding him permanently. So always wear safety glasses while in a work area, even if you aren't working.

▶ TECHNICIAN TIP

Each lab/shop activity requires at least the safe use of safety glasses, clothing, and shoes, depending on its nature. Research and identify whether any additional safety devices are required for every activity you undertake.

SAFETY TIP

Be aware that the ultraviolet radiation can burn your skin like a sunburn, so wear the appropriate welding apparel to protect yourself from this hazard.

The only time they should be removed is when you are using other eye protection equipment. Prescription and tinted safety glasses are also available. Tinted safety glasses are designed to be worn outside in bright sunlight conditions. Never wear them indoors or in low-light conditions because they reduce your ability to see clearly. For people who wear prescription glasses, there are three acceptable options that OSHA makes available:

- Prescription spectacles, with side shields and protective lenses meeting requirements of ANSI Z87.1
- Goggles that can fit comfortably over corrective eyeglasses without disturbing their alignment
- Goggles that incorporate corrective lenses mounted behind protective lenses

Safety goggles don't provide as much eye protection as safety glasses, but they do have added protection against harmful chemicals that may splash up behind the lenses of safety glasses (**FIGURE 2-15**). Goggles also provide additional protection from foreign particles. Safety goggles must be worn when servicing air-conditioning systems or any other system that contains pressurized gas. Goggles can sometimes fog up when in use; if this occurs, use one of the special antifog cleaning fluids or cloths to clean them.

A full face shield gives you added protection from sparks or chemicals over safety glasses alone (**FIGURE 2-16**). The clear mask of the face shield allows you to see all that you are doing and helps protect your eyes and face from chemical burns should there be any splashes or battery explosions. It is also recommended that you use a full face shield combined with safety goggles when using a bench or angle grinder.

The light from a welding arc is very bright and contains high levels of ultraviolet radiation. So wear a **welding helmet** when using, or assisting a person using, an electric welder. The lens on a welding helmet has heavily shaded glass to reduce the intensity of the light from the welding arc, allowing you to see the task you are performing more clearly (**FIGURE 2-17**).

Lenses come in a variety of ratings depending on the type of welding you are doing; always make sure you are using a properly rated lens for the welder you are using. The remainder of the helmet is made from a durable material that blocks any other light, which can burn your skin similar to a sunburn, from reaching your face. It also protects you from welding sparks. Photosensitive welding helmets that darken automatically when an arc is struck are also available. Their big advantage is that you do not have to lift and lower the helmet by hand while welding.

Gas welding goggles can be worn instead of a welding mask when using or assisting a person using an oxyacetylene welder (**FIGURE 2-18**). The eyepieces are available in heavily shaded versions, but not as shaded as those used in an electric welding helmet. There is much less ultraviolet radiation from an oxyacetylene flame, so a welding helmet is not required. However, the flame is bright enough to damage your eyes, so always use goggles of the correct shade rating.

FIGURE 2-15 Safety goggles provide much the same eye protection as safety glasses, but with added protection against any harmful fluid that may find its way behind the lenses.

FIGURE 2-16 Full face shield.

FIGURE 2-17 The lens on a welding helmet has heavily tinted glass to reduce the intensity of the light from the welding tip, allowing you to see what you are doing.

FIGURE 2-18 Gas welding goggles can be worn instead of a welding helmet when using or assisting a person using an oxyacetylene welder.

Lifting

K02007 Describe proper lifting techniques.

Whenever you lift something, there is always the possibility of injury; however, by lifting correctly, you reduce the chance of injuring yourself or others. Before lifting anything, you can reduce the risk of injury by breaking down the load into smaller quantities, asking for assistance if required, or possibly using a mechanical device to assist the lift. If you have to bend down to lift something, you should bend your knees to lower your body; do not bend over with straight legs because this can damage your back (**FIGURE 2-19**). Place your feet about shoulder width apart, and lift the item by straightening your legs while keeping your back as straight as possible.

SAFETY TIP

Never lift anything that is too heavy for you to comfortably lift, and always seek assistance if lifting the object could injure you. Always err on the side of caution.

▶ Shop Safety

K02008 Comply with safety precautions in the workplace.

N02003 Identify general shop safety rules and procedures.

The work environment can be described as anywhere you work. The condition of the work environment plays an important role in making the workplace safer. A safe work environment goes a long way toward preventing accidents, injuries, and illnesses. There are many ways to describe a safe work environment, but generally it would contain a well-organized shop layout, use of shop policies and procedures, safe equipment, safety equipment, safety training, employees who work safely, good supervision, and a workplace culture that supports safe work practices. Conversely, a shop that is cluttered with junk, poorly lit, and full of safety hazards is unsafe (**FIGURE 2-20**).

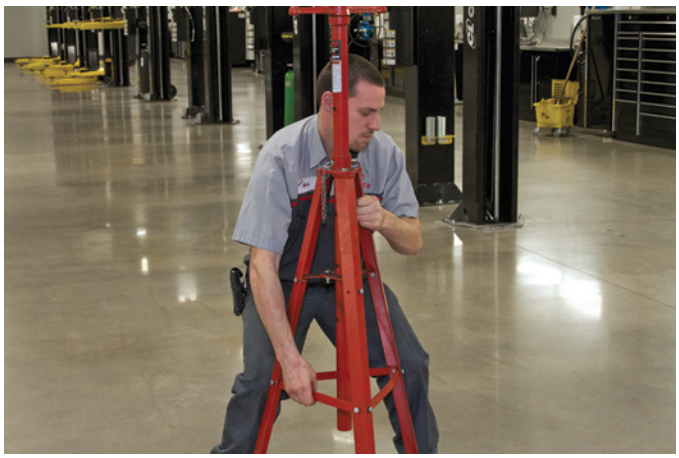


FIGURE 2-19 Prevent back injuries when lifting heavy objects by crouching with your legs slightly apart, standing close to the object, positioning yourself so that the center of gravity is between your feet.

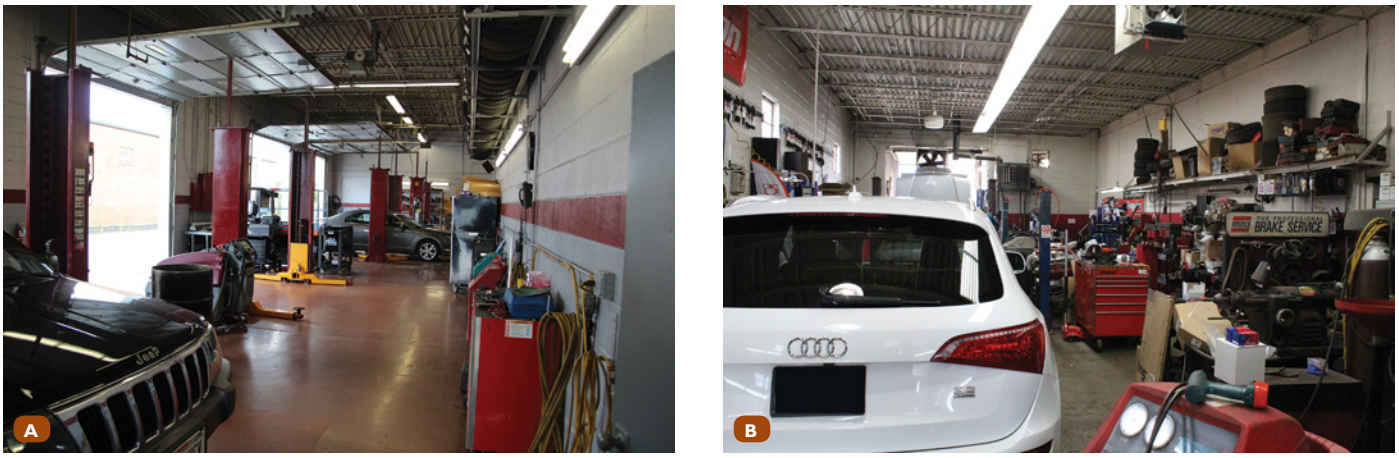


FIGURE 2-20 **A.** Relatively safe shop. **B.** Relatively unsafe shop.

Applied Science

AS-1: Safety: The technician follows all safety regulations and applicable procedures while performing the task.

Using a bench grinder to grind down a steel component is a simple everyday activity in shops. In terms of its potential safety implications, it carries significant risk of injury. Before beginning the task, you must ensure that the machinery is safe and ready to use. Inspect and/or adjust the guards/shields, grinding wheels, electrical cord, etc. From a personal perspective, you must make sure your clothing is suitable and safe for the task. Clothing cannot be loose, as it may get caught in the grinder; it must be made of flame-retardant material because of the risk of ignition from sparks. Long hair must be tied back or contained within a hairnet or cap because of the risk of it getting caught in rotating machinery. Various items of PPE are required to safely carry out this task: safety goggles to protect against foreign objects entering the eyes, ear protection to guard against hearing damage due to excessive noise, steel-capped boots to prevent injury from falling heavy objects, and heavy-duty gloves to protect against skin contact with sharp or hot components.

K02009 Describe how OSHA rules and the EPA impact the automotive workplace.

OSHA and EPA

OSHA stands for the **Occupational Safety and Health Administration (OSHA)**. It is a U.S. government agency that was created to provide national leadership in occupational safety and health, and it works toward finding the most effective ways to help prevent worker fatalities and workplace injuries and illnesses. OSHA has the authority to conduct workplace inspections and, if required, fine employers and workplaces if they violate its regulations and procedures. For example, a fine may be imposed on the employer or workplace if a worker is electrocuted by a piece of faulty machinery that has not been regularly tested and maintained.

OSHA standard 29 CFR 1910.132 requires employers to assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of PPE. In addition, OSHA regulations require employers to protect their employees from workplace hazards such as machines, work procedures, and hazardous substances that can cause injury. To do that, employers must institute all feasible **engineering and work practice controls** to eliminate and reduce hazards before using PPE to protect against hazards. This means that the employers have a responsibility not only to assess safety issues but to eliminate or reduce those that can be mitigated, and then provide PPE and training for those hazards that cannot be mitigated. At the same time, if you are injured, you are the one suffering the consequences, such as being out of work for a period of time, permanent disability, or death. So it is in your best interest to take responsibility for your own safety while on the job. Engineering controls means the employer has physically changed the machine or work environment to prevent employee exposure to the potential hazard. An example might be adding a ventilation system to an area where solvent tanks are used. Work practice controls means the employer changes the way employees do their jobs in order to reduce exposure to the hazard. An example of this might be requiring employees to use a brake wash station when working on brake systems.

EPA stands for the **Environmental Protection Agency**. This federal government agency deals with issues related to environmental safety. The EPA conducts research and monitoring, sets standards, conducts workplace inspections, and holds employees and companies legally accountable in order to keep the environment protected. Shop activities need to comply with EPA laws and regulations by ensuring that waste products are disposed of in an environmentally responsible way, chemicals and fluids are correctly stored, and work practices do not contribute to damaging the environment.

Applied Science

AS-2: Environmental Issues: The technician develops and maintains an understanding of all federal, state, and local rules and regulations regarding environmental issues related to the work of the automobile technician.

You need to keep up to date with local laws and regulations regarding environmental issues. There are large fines associated with disregarded environmental regulations. To remain informed, you can log on to local state websites to check the latest laws and regulations. The U.S. Environmental Protection Agency (EPA) website also has up-to-date information on environmental regulations (www.epa.gov/lawsregs/). More information can be found on the specific regulations for the automotive industry at www.epa.gov/lawsregs/sectors/automotive.html. This site has a full listing of laws and regulations, compliance measures, and enforcement tactics. For additional laws that are enforced by your local state environmental agencies, go to www.epa.gov/epahome/state.htm.

AS-3: Environmental Issues: The technician uses such things as government impact statements, media information, and general knowledge of pollution and waste management to correctly use and dispose of products that result from the performance of a repair task.

When you complete a job, you must be able to identify what to do with any waste products created from the repair task. This could be as simple as knowing where and how to recycle cardboard boxes or as complex as knowing what to do with brake components that may contain asbestos. Normally, there is a table posted in the garage that details the correct measures for disposing of and storing waste material. A sample table follows:

Component	Material/Parts	Removal and Safety Information	Recommended Storage
Air-conditioning gases (refrigerant)	R12, R134a	Use approved evacuation and collection equipment required. *Note:* Requires AC license.	Use approved storage containers—reused or recycled.
Batteries	Plastic, rubber, lead, sulfuric acid	Avoid contact between sulfuric acid and your skin, clothing, or eyes.	Store off the ground in a covered area for collection by recycler.
Brake fluid	Diethylene and polyethylene glycol-monoalkyl ethers	These are corrosive and highly toxic to the environment. Drain into pan or tray.	Store in a drum in a covered area for collection by a licensed operator.
Brake shoes and pads pre-2004	Asbestos	Fibers are dangerous if inhaled.	Put in a plastic bag in a sealed container for collection by contractor.
Coolant	Phosphoric acid, hydrazine ethylene glycol, alcohols	Radiator coolant can be toxic to the environment.	Store in sealed drums in a covered area for recycling or collection by a licensed operator.
Coverings for plastic parts, and plastic bags and containers for parts shipping	Plastic-made components	Plastic components that can be recycled bear a recycling symbol: this symbol has a number inside telling the recycling company what the product is made of.	If the plastic container has a recycle code, then put it in the recycle bin. If it does not, then put in general waste. Plastic oil containers cannot be recycled.
Fuel	Unleaded, diesel	Avoid fumes. Fire hazard; keep well away from ignition sources. Siphon from tank to avoid spillage.	Store in a drum in a covered area.
Metal	Brake discs, housings made of metal (gearbox/engine case and components), metal cuttings	Some metal products can be heavy, so lift with care.	All metal components can be recycled; keep waste metal in a separate recycle bin for sale or disposal.
Oil	Engine, transmission, and differential oils	Fire hazard; keep well away from ignition sources.	Store in a drum/container in a covered area for collection by a licensed operator.

(*Continues*)

Applied Science (Continued)

Component	Material/Parts	Removal and Safety Information	Recommended Storage
Oil filters	Steel paper fiber	—	Drain filter, then crush and store in a leakproof drum for collection.
Parts boxes and paperwork	Paper, cardboard	—	Store in a recycling bin to be taken away for recycling.
Tires	Rubber, steel, fabric	Keep away from ignition sources.	Store in a fenced area for collection by recycler.
Trim, plastic fittings, and seats	Plastic, metal, cloth	—	Store racked or binned for reuse, sale, or recycling.
Tubes and rubber components	Rubber hoses, mounts, etc.	Keep away from ignition sources.	Store in a collection bin, to be collected and recycled.
Undeployed airbags	Plastics, metals, igniters, explosives	Recommended specific training on airbags before attempting removal. Handle with care; accidental deployment can cause serious harm. If unit is to be scrapped, ensure that it is safely deployed first.	Store face up in a secure area.

Shop Policies, Procedures, and Safety Inspections

K02010 Explain how shop policies, procedures, and safety inspections make the workplace safer.

Shop policies and procedures are a set of documents that outline how tasks and activities in the shop are to be conducted and managed. They also ensure that the shop operates according to OSHA and EPA laws and regulations. A **policy** is a guiding principle that sets the shop direction, and a **procedure** is a list of the steps required to get the same result each time a task or activity is performed (**FIGURE 2-21**). An example of a policy is an OSHA document for the shop that describes how the shop complies with legislation, such as a sign simply saying, "Safety glasses must be worn at all times in the shop." An example of a procedure is a document that describes the steps required to safely use the vehicle hoist.

FIGURE 2-21 **A.** Policy. **B.** Procedure.

Each shop has its own set of policies and procedures and a system in place to make sure the policies and procedures are regularly reviewed and updated. Regular reviews ensure that new policies and procedures are developed and old ones are modified in case something has changed. For example, if the shop moves to a new building, then a review of policies and procedures will ensure that they relate to the new shop, its layout, and equipment. In general, the policies and procedures are written to guide shop practice; help ensure compliance with laws, statutes, and regulations; and reduce the risk of injury. Always follow your shop policies and procedures to reduce the risk of injury to your coworkers and yourself and to prevent damage to property.

FIGURE 2-22 Shop safety inspection using a checklist.

It is everyone's responsibility to know and follow the rules. Locate the general shop rules and procedures for your workplace. Look through the contents or index pages to familiarize yourself with the contents. Discuss the policy and the shop rules and procedures with your supervisor. Ask questions to ensure that you understand how the rules and procedures should be applied and your role in making sure they are followed.

Shop safety inspections are valuable ways of identifying unsafe equipment, materials, or activities so they can be corrected to reduce the risk of accidents or injuries. The inspection can be formalized by using inspection sheets to check specific items, or they can be general walk-arounds where you consciously look for and document problems that can be corrected (**FIGURE 2-22**).

Here are some of the common things to look for:

Items blocking emergency exits or walkways

- Poor safety signage
- Unsafe storage of flammable goods
- Tripping or slipping hazards
- Faulty or unsafe equipment or tools
- Missing equipment guards
- Misadjusted bench grinder tool rests
- Missing or expired fire extinguishers
- Clutter, spills, unsafe shop practices
- People not wearing the correct PPE

Formal and informal safety inspections should be held regularly. For example, an inspection sheet might be used weekly or monthly to formally evaluate the shop, and informal inspections might be held daily to catch issues that are of a more immediate nature. Never ignore or put off a safety issue.

Housekeeping and Orderliness

S02001 Maintain a clean and orderly workplace.

Good housekeeping is about always making sure the shop and your work surroundings are neat and kept in good order. This habit pays off in a couple of ways. It makes the shop a safer place to work by not allowing clutter or spills to accumulate. It also makes the shop more efficient if everything is kept neat and orderly, by making it easier to find needed tools and equipment. Trash and liquid spills should be quickly cleaned up; tools need to be cleaned and put away after use; spare or removed parts need to be stored or disposed of correctly; and generally everything needs to have a safe place to be kept.

You should carry out good housekeeping practices while working, not just after a job is completed. For example, throw trash in the garbage can as it accumulates, clean up spills when they happen, and put tools away when you are finished working with them. It is also good practice to periodically perform a deep clean of the shop so that any neglected areas are taken care of.

Safe Attitude

K02011 Describe the importance of demonstrating a safe attitude in the workplace.

Develop a safe attitude toward your work. You should always think "safety first" and then act safely (**FIGURE 2-23**). Think ahead about what you are doing, and put in place specific measures to protect yourself and those around you. For example, you could ask yourself the following questions:

- What could go wrong?
- What measures can I take to ensure that nothing goes wrong?
- What PPE should I use?
- Have I been trained to use this piece of equipment?
- Is the equipment I'm using safe?

Answering these questions and taking appropriate action before you begin will help you work safely. If you don't know the answers to those questions, don't work! Stop and ask someone with more experience than yourself, or your supervisor. Also, don't count on others for your safety. You alone are primarily responsible for your own safety.

Also remember that the time to make a good decision is before an accident happens. Once the accident occurs, you will likely have very little to no control over the outcome. In fact, there are very few true accidents that happen all by themselves. Accidents are almost always caused by poor decisions or poor actions. Almost all accidents can be prevented with a little more thought, training, and practice.

Don't Underestimate the Dangers

Because vehicle servicing and repair are so commonplace, it is easy to overlook the many potential risks related to this field. Think carefully about what you are doing and how you are doing it. Think through the steps, trying to anticipate things that may go wrong and

FIGURE 2-23 Always think "safety first."

taking steps to prevent them. Also be wary of taking shortcuts. In most cases, the time saved by taking a shortcut is nothing compared to the time spent recovering from an accident.

Accidents and Injuries Can Happen at Any Time

There is the possibility of an accident occurring whenever work is undertaken. For example, fires and explosions are a constant hazard wherever there are flammable fuels. Electricity can kill quickly as well as cause painful shocks and burns. Heavy equipment and machinery can easily cause broken bones or crush fingers and toes. Hazardous solvents and other chemicals can burn or blind as well as contribute to many kinds of illness. Oil spills and tools left lying around can cause slips, trips, and falls. Poor lifting and handling techniques can cause chronic strain injuries, particularly to your back.

FIGURE 2-24 Clean up spills immediately.

Slip, Trip, and Fall Hazards

Slip, trip, and fall hazards are ever present in the shop, and they can be caused by trash, tools and equipment, or liquid spills being left lying around. Always be on the lookout for hazards that can cause slips, trips, or falls. Floors and steps can become slippery, so they should be kept clean and have antislip coatings applied to them. High-visibility strips with antislip coatings can be applied to the edge of step treads to reduce the hazard. Clean up liquid spills immediately, and mark the area with wet floor signs until the floor is dry (**FIGURE 2-24**). Make sure the workshop has good lighting, so hazards are easy to spot, and keep walkways clear from obstruction. Think about what you are doing and make sure the work area is free of slip, trip, and fall hazards as you work.

Accidents and Injuries Are Avoidable

Almost all accidents are avoidable or preventable by taking a few precautions. Think of nearly every accident you have witnessed or heard about. In most cases someone made a mistake. Whether caused by horseplay, neglecting maintenance on tools or equipment, or using tools improperly, these instances lead to injury. Most of these accidents can be prevented if people follow policies and develop a "safety first" attitude. By following regulations and safety procedures, you can make your workplace much safer. Learn and follow all of the correct safety procedures for your workplace. Always wear the right PPE, and stay alert and aware of what is happening around you.

Think about what you are doing, how you are doing it, and its effect on others. You also need to know what to do in case of an emergency. Document and report all accidents and injuries whenever they happen, and take the proper steps to make sure they never happen again.

Signs

K02012 Identify workplace safety signs and their meanings.

Always remember that a shop is a hazardous environment. To make people more aware of specific shop hazards, legislative bodies have developed a series of safety signs. These signs are designed to give adequate warning of an unsafe situation. Each sign has four components:

- Signal word: There are three signal words—danger, warning, and caution. Danger indicates an immediately hazardous situation, which, if not avoided, will result in death or serious injury. Danger is usually indicated by white text with a red background. Warning indicates a potentially hazardous situation, which, if not avoided, could result in death or serious injury. The sign is usually in black text with an orange or yellow background. Caution indicates a potentially hazardous situation, which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices. This sign is usually in black text with a yellow background (**FIGURE 2-25**).

FIGURE 2-25 Signs. **A.** Danger is usually indicated by white text on a red background. **B.** Warning is usually in black text with an orange background. **C.** Caution is usually in black text with a yellow background.

- Background color: The choice of background color also draws attention to potential hazards and is used to provide contrast so the letters or images stand out. For example, a red background is used to identify a definite hazard; yellow indicates caution for a potential hazard. A green background is used for emergency-type signs, such as for first aid, fire protection, and emergency equipment. A blue background is used for general information signs.
- Text: The sign will sometimes include explanatory text intended to provide additional safety information. Some signs are designed to convey a personal safety message.
- Pictorial message: In symbol signs, a pictorial message appears alone or is combined with explanatory text. This type of sign allows the safety message to be conveyed to people who are illiterate or who do not speak the local language.

Safety Equipment

K02013 Describe the standard safety equipment.

Shop safety equipment includes items such as:

- Handrails: Handrails are used to separate walkways and pedestrian traffic from work areas. They provide a physical barrier that directs pedestrian traffic and also offer protection from vehicle movements.
- Machinery guards: Machinery guards and yellow lines prevent people from accidentally walking into the operating equipment or indicate that a safe distance should be kept from the equipment.

- Painted lines: Large, fixed machinery such as lathes and milling machines present a hazard to the operator and others working in the area. To prevent accidents, a machinery guard or a painted yellow line on the floor usually borders this equipment.
- Sound-insulated rooms: Sound-insulated rooms are usually used when operating equipment makes a lot of noise, for example a chassis dynamometer. A vehicle operating on a dynamometer produces a lot of noise from its tires, exhaust, and engine. To protect other shop users from the noise, the dynamometer is usually placed in a sound-insulated room, keeping shop noise to a minimum.
- Adequate ventilation: Exhaust gases and chemical vapors are serious health hazards in the shop. Whenever a vehicle's engine is running, toxic gases are emitted from its exhaust. To prevent an excess of toxic gas buildup, a well-ventilated work area is needed, as well as a method of directly venting the vehicle's exhaust to the outside. It may only take a minute or two for a poorly running vehicle to fill the shop with enough carbon monoxide to affect people's health. Chemical vapors are also a hazard and need to be vented outside.
- Doors and gates: Doors and gates are used for the same reason as machinery guards and painted lines. A doorway is a physical barrier that can be locked and sealed to separate a hazardous environment from the rest of the shop or a general work area from an office or specialist work area.
- Temporary barriers: In the day-to-day operation of a shop, there is often a reason to temporarily separate one work bay from others. If a welding machine or an oxyacetylene cutting torch is in use, it may be necessary to place a temporary screen or barrier around the work area to protect other shop users from welding flash or injury.

Air Quality

K02014 Maintain a safe air quality in the workplace.

Managing air quality in shops helps protect you from potential harm and also protects the environment. There are many shop activities, stored liquids, and other hazards that can reduce the quality of air in shops. Some of these are listed here:

- Dangerous fumes from running engines
- Welding (gas and electric)
- Painting
- Liquid storage areas
- Air conditioning servicing
- Dust particles from brake servicing

Running engines produce dangerous exhaust gases including carbon monoxide (CO) and carbon dioxide (CO_2). Carbon monoxide in small concentrations can kill or cause serious injuries. Carbon dioxide is a greenhouse gas, and vehicles are a major source of carbon dioxide in the atmosphere. Exhaust gases also contain hydrocarbons (HC) and oxides of nitrogen (NOx). These gases can form smog and also cause breathing problems for some people.

Carbon monoxide in particular is extremely dangerous, as it is odorless and colorless and can build up to toxic levels very quickly in confined spaces. In fact, it doesn't take very much carbon monoxide to pose a danger. The maximum exposure limit is regulated by the following agencies:

- OSHA permissible exposure limit (PEL) is 50 parts per million (ppm) of air for an eight-hour period.
- National Institute for Occupational Safety and Health has established a recommended exposure limit of 35 ppm for an eight-hour period.

The reason the PEL is so low is because carbon monoxide attaches itself to red blood cells much more easily than oxygen does, and it never leaves the blood cell. This prevents the blood cells from carrying as much oxygen, and if enough carbon monoxide has been inhaled, it effectively asphyxiates the person. Always follow the correct safety precautions when running engines indoors or in a confined space, including over service pits,

FIGURE 2-26 Exhaust hoses should be vented to where the fumes will not be drawn back indoors.

as gases can accumulate there. The best solution when running engines in an enclosed space (shop) is to directly connect the vehicle's exhaust pipe to an exhaust extraction system hose that ventilates the fumes to the outside air. The extraction system should be vented to where the fumes will not be drawn back indoors, to a place well away from other people and other premises (**FIGURE 2-26**).

Do not assume that an engine fitted with a catalytic converter can be run safely indoors; it cannot. Catalytic converters are fitted into the exhaust system to help control exhaust emissions through chemical reaction. They require high temperatures to operate efficiently and are less effective when the exhaust gases are relatively cool, such as when the engine is only idling or being run intermittently. A catalytic converter can never substitute for adequate ventilation or exhaust extraction equipment. In fact, even if the catalytic converter were working at 100% efficiency, the exhaust would contain large amounts of carbon dioxide and very low amounts of oxygen, neither of which conditions can sustain life.

Proper Ventilation

N02004 Utilize proper ventilation procedures for working within the lab/shop area.

Proper ventilation is required for working in the shop area. The key to proper ventilation is to ensure that any task or procedure that may produce dangerous or toxic fumes is recognized, so measures can be put in place to provide adequate ventilation. Ventilation can be provided by natural means, such as by opening doors and windows to provide air flow for low-exposure situations. However, in high-exposure situations, such as vehicles running in the shop, a mechanical means of ventilation is required; an example is an exhaust extraction system. Parts cleaning areas or areas where solvents and chemicals are used should also have good general ventilation, and if required, additional exhaust hoods or fans should be installed to remove dangerous fumes. In some cases, such as when spraying paint, it may be necessary to use a personal respirator in addition to proper ventilation.

▶ TECHNICIAN TIP

Before starting a vehicle in the shop, make sure the correct ventilation equipment is connected properly and turned on. Also, if the system uses rubber hoses, make sure they aren't kinked.

Electrical Safety

K02015 Describe appropriate workplace electrical safety practices.

Many people are injured by electricity in shops. Poor electrical safety practices can cause shocks and burns as well as fires and explosions. Make sure you know where the electrical shutoffs, or panels for your shop, are located. All circuit breakers and fuses should be clearly labeled so that you know which circuits and functions they control (**FIGURE 2-27**).

In the case of an emergency, you may need to know how to shut off the electricity supply to a work area or to your entire shop. Keep the circuit breaker and/or electrical panel covers closed to keep them in good condition, prevent unauthorized access, and prevent accidental contact with the electricity supply. It is important that you do not block or obstruct access to this electrical panel; keep equipment and tools well away so emergency access is not hindered. In some localities, 3' (0.91 m) of unobstructed space must be maintained around the panel at all times.

There should be a sufficient number of electrical receptacles in your work area for all your needs. Do not connect multiple appliances to a single receptacle with a simple double adapter. If necessary, use a multi-outlet safety strip that has a built-in overload cutout feature. Electric receptacles should be at least 3' (0.91 m) above floor level to reduce the risk of igniting spilled fuel vapors or other flammable liquids.

If you need to use an extension cord, make sure it is made of flexible wiring—not the stiffer type of house wiring—and that it is fitted with a ground wire. The cord should be neoprene-covered, as this material resists oil damage.

Always check it for cuts, abrasions, or other damage. Be careful how you place the extension cord, so it does not cause a tripping hazard. Also avoid rolling equipment or vehicles over it, as doing so can damage the cord. Never use an extension cord in wet conditions or around flammable liquids. Portable electric tools that operate at 240 volts are

often sources of serious shock and burn accidents. Be particularly careful when using these items. Always inspect the cord for damage and check the security of the attached plug before connecting the item to the power supply. Use 110-volt or lower voltage tools if they are available. All electric tools must be equipped with a ground prong or be **double insulated**.

If electrical cords don't have the ground prong or aren't double insulated, do not use them. Never use any high-voltage tool in a wet environment. In contrast, air-operated tools cannot give you an electric shock, because they operate on air pressure instead of electricity, and therefore, they are safer to use in a wet environment.

Portable shop lights/droplights have been the cause of many accidents over the years. Incandescent bulbs get extremely hot and can cause burns. They are also prone to shatter, which can cut skin and damage eyes or cause fires and electric shock. In fact, in some places incandescent portable shop lights cannot be used in automotive shops and must be replaced with less hazardous lights.

One such light is the fluorescent droplight. Although this type of light stays much cooler than incandescent lights, it still can shatter, causing cuts or damage to eyes. Because of this, droplights should be fully enclosed in a clear, insulating case. They may also contain mercury, which becomes dispersed when the bulb is shattered, creating a hazardous-materials situation.

The safest portable shop light to come on the market is the LED (light-emitting diode) shop light. It uses much lower voltage, and the LED is much less prone to shattering, so it is much safer to use. It also uses a small amount of electricity to produce a large amount of light, so many of them are cordless. They may also include a magnetic base, so the light can be attached to any steel surface and then adjusted to shine where needed.

FIGURE 2-27 All electrical switches and fuses should be clearly labeled so that you know which circuits and functions they control.

Preventing Fires

K02016 Prevent fires in the workplace.

The danger of a gasoline fire is always present in an automotive shop. Most automobiles carry a fuel tank, often with large quantities of fuel on board, which is more than sufficient to cause a large, very destructive, and potentially explosive fire.

In fact, 1 gallon of gasoline has the same amount of energy as 20 sticks of dynamite. So take precautions to make sure you have the correct type and size of extinguishers on hand for a potential fuel fire. Make sure you clean up spills immediately and avoid ignition sources, like sparks, near flammable liquids or gases. Being aware of the following topics will help you know how to minimize the risk of fires in the shop.

▶ TECHNICIAN TIP

Try out the new LED flashlights or cordless LED shop lights. Good ones provide a lot of light, and the batteries last a long time. It is not unusual to hear about an LED flashlight that got dropped behind a toolbox while it was on, and was still illuminated days later.

Extinguishing Fires

N02005 Identify the location and the types of fire extinguishers and other fire safety equipment; demonstrate knowledge of the procedures for using fire extinguishers and other fire safety equipment.

Three elements must be present at the same time for a fire to occur: fuel, oxygen, and heat (**FIGURE 2-28**). The secret of firefighting involves the removal of at least one of these elements. If a fire occurs in the shop, it is usually the oxygen or the heat that is removed to extinguish the fire. For example, a fire blanket when applied correctly removes the oxygen, and a water extinguisher removes heat from the fire. Fire extinguishers are used to extinguish the majority of small fires in a shop. Never hesitate to call the fire department if you cannot extinguish a fire quickly and safely.

In the United States, there are five classes of fire:

- Class A fires involve ordinary combustibles such as wood, paper, or cloth.
- Class B fires involve flammable liquids or gaseous fuels.

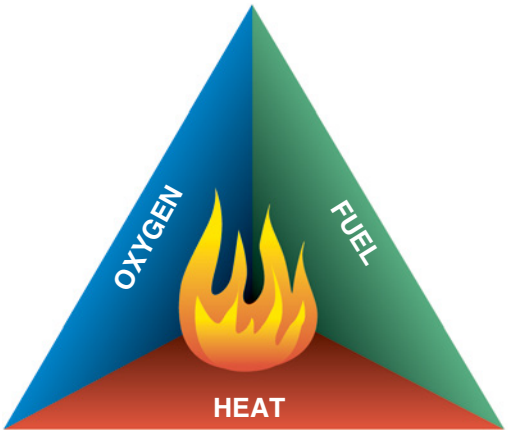


FIGURE 2-28 Fire triangle.

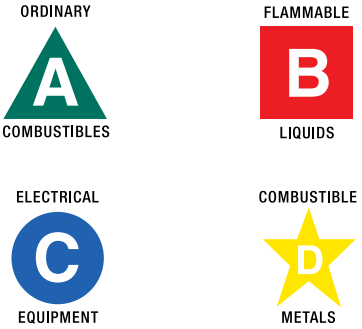


FIGURE 2-29 Traditional labels on fire extinguishers often incorporate a shape as well as a letter.

▶ TECHNICIAN TIP

It's not a matter of "if" but "when" a shop is going to have a fire. When shops do catch on fire, the fire can grow quickly out of control. So preventing a fire is the best action you can take. If a fire starts, react appropriately. In some cases, you just need to get out safely. In other cases, it may be safe to try to fight the fire quickly before it spreads too far. Always be aware of the potential for a fire, and plan ahead by thinking through the task you are about to undertake. Know where firefighting equipment is kept and how it works.

- Class C fires involve electrical equipment.
- Class D fires involve combustible metals such as sodium, titanium, and magnesium.
- Class K fires involve cooking oil or fat.

Fire extinguishers are marked with pictograms depicting the types of fires that the extinguisher is approved to fight (**FIGURE 2-29**):

- Class A: Green triangle
- Class B: Red square
- Class C: Blue circle
- Class D: Yellow pentagram
- Class K: Black hexagon

Unless the fire is very small, always sound the alarm before attempting to fight a fire. If you cannot fight the fire safely, leave the area while you wait for backup. You need to size up the fire before you make the decision to fight it with a fire extinguisher, by identifying what sort of material is burning, the extent of the fire, and the likelihood of it spreading. Also, if the fire is in electrical wires or equipment, make sure you won't be electrocuted while trying to extinguish it. To operate a fire extinguisher, follow the acronym for fire extinguisher use: PASS (pull, aim, squeeze, sweep).

- Pull out the pin that locks the handle at the top of the fire extinguisher to prevent accidental use. Carry the fire extinguisher in one hand, and use your other hand to:
- Aim the nozzle at the base of the fire. Stand about 8–12 feet (2.4–3.7 m) away from the fire, and
- Squeeze the handle to discharge the fire extinguisher. Remember that if you release the handle on the fire extinguisher, it will stop discharging.
- Sweep the nozzle from side to side at the base of the fire.

Continue to watch the fire. Although it may appear to be extinguished, it may suddenly reignite. Portable fire extinguishers only operate for about 10–25 seconds before they are empty. So use them effectively (**FIGURE 2-30**).

If the fire is indoors, you should be standing between the fire and the nearest safe exit. If the fire is outside, you should stand facing the fire, with the wind on your back, so that the smoke and heat are being blown away from you. If possible, get an assistant to guide you and inform you of the fire's progress. Again, make sure you have a means of escape, should the fire get out of control. When you are certain that the fire is out, report it to your supervisor. Also report what actions you took to put out the fire. Once the circumstances of the fire have been investigated and your supervisor or the fire department has given you the all clear, clean up the debris and submit the used fire extinguisher for inspection and service.

Fire blankets are designed to smother a small fire. They are ideal for use in situations where a fire extinguisher could cause damage. For example, if there is a small fire under the hood of a vehicle, a fire blanket might be able to smother the fire without running the risk of getting powder from the fire extinguisher down the intake system. They are also very useful in putting out a fire on a person. The fire blanket can be thrown around the person, smothering any fire.

Obtain a fire blanket and study the use instructions on the packaging. If instructions are not provided, research how to use a fire blanket, or ask your supervisor. You may require instruction from an authorized person in using the fire blanket. If you do use a fire blanket, make sure you return the blanket for use or, if necessary, replace it with a new one.

Evacuation Routes

N02006 Identify the location of the posted evacuation routes.

Evacuation routes are a safe way of escaping danger and gathering in a prearranged safe place where everyone can be accounted for in the event of an emergency. It is important to have more than one evacuation route in case any single route is blocked during the

FIGURE 2-30 To operate a fire extinguisher, follow PASS. **A.** Pull. **B.** Aim. **C.** Squeeze. **D.** Sweep.

emergency. Your shop may have an evacuation procedure that clearly identifies the evacuation routes (**FIGURE 2-31**).

Often the evacuation routes are marked with colored lines painted or taped on the floors. Exits should be highlighted with signs that may be illuminated, and should never be chained closed or obstructed (**FIGURE 2-32**).

Always make sure you are familiar with the evacuation routes for the shop. Before conducting any task, identify which route you will take if an emergency occurs.

▶ TECHNICIAN TIP

Never place anything in the way of evacuation routes, including equipment, tools, parts, cleaning supplies, or vehicles.

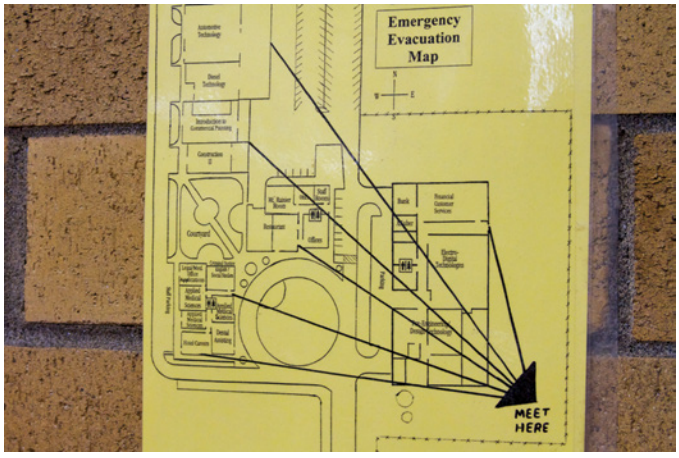


FIGURE 2-31 Your shop may have an evacuation procedure that clearly identifies the evacuation routes.

FIGURE 2-32 Exits should be marked, clear of obstructions, and not chained closed.

K02017 Identify hazardous environments and the safety precautions that should be applied.

N02007 Locate and demonstrate knowledge of safety data sheets (SDS).

S02002 Use information in an SDS.

▶ Hazardous Materials Safety

A **hazardous material** is any material that poses an unreasonable risk of damage or injury to persons, property, or the environment if it is not properly controlled during handling, storage, manufacture, processing, packaging, use and disposal, or transportation. These materials can be solids, liquids, or gases. Most technicians use hazardous materials daily, such as cleaning solvents, gasket cement, brake fluid, and coolant. In fact, there are likely to be hundreds of hazardous materials in a typical shop. Hazardous materials must be properly handled, labeled, and stored in the shop.

Safety Data Sheets

Hazardous materials are used daily and may make you very sick if they are not used properly. **Safety data sheets (SDS)** contain detailed information about hazardous materials to help you understand how they should be safely used, any health effects relating to them, how to treat a person who has been exposed to them, and how to deal with them in a fire situation. SDS can be obtained from the manufacturer of the material. The shop should have an SDS for each hazardous substance or dangerous product. In the United States, it is required that workplaces have an SDS for every chemical that is on site.

Safety data sheets (SDS) were formerly called material safety data sheets (MSDS). In 2012, OSHA changed the requirements for the hazard communication system (HCS) to conform to the United Nations Globally Harmonized System of Classification and Labeling of Chemicals (GHS). The MSDS needed to change its name and its format to fit the new standards. Whereas the original MSDS had 8 sections, safety data sheets are required to have 16 sections that provide additional details and make it easier to find specific data when needed. In addition, GHS requires all employers to train their employees in the new chemical labeling requirements and the new format for the safety data sheets.

Whenever you deal with a potentially hazardous product, you should consult the SDS to learn how to use that product safely. If you are using more than one product, make sure you consult all the SDS for those products. Be aware that certain combinations of products can be more dangerous than any of them separately.

SDS are usually kept in a clearly marked binder and should be regularly updated as chemicals come into the workplace. As of June 1, 2015, the HCS requires new SDS to be in a uniform format, and include the section numbers, the headings, and associated information under the headings below:

Section 1, Identification, includes product identifier; manufacturer or distributor name, address, and phone number; emergency phone number; recommended use; restrictions on use.

Section 2, Hazard(s) identification, includes all hazards regarding the chemical; required label elements.

Section 3, Composition/information on ingredients, includes information on chemical ingredients; trade secret claims.

Section 4, First-aid measures, includes important symptoms/effects, acute, delayed; required treatment.

Section 5, Firefighting measures, lists suitable extinguishing techniques, equipment; chemical hazards from fire.

Section 6, Accidental release measures, lists emergency procedures; protective equipment; proper methods of containment and cleanup.

Section 7, Handling and storage, lists precautions for safe handling and storage, including incompatibilities.

Section 8, Exposure controls/personal protection, lists OSHA's permissible exposure limits (PELs); threshold limit values (TLVs); appropriate engineering controls; personal protective equipment (PPE).

Section 9, Physical and chemical properties, lists the chemical's characteristics.

Section 10, Stability and reactivity, lists chemical stability and possibility of hazardous reactions.

Section 11, Toxicological information, includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.

Section 12, Ecological information*

Section 13, Disposal considerations*

Section 14, Transport information*

Section 15, Regulatory information*

Section 16, Other information, includes the date of preparation or last revision.

*Note: Since other Agencies regulate this information, OSHA will not be enforcing Sections 12 through 15 (29 CFR 1910.1200(g)(2)).

Source: https://www.osha.gov/Publications/HazComm_QuickCard_SafetyData.html.

To identify information found on an SDS, follow the steps in **SKILL DRILL 2-1**.

Cleaning Hazardous Dust Safely

K02018 Identify the proper method to clean hazardous dust safely.

Toxic dust is any dust that may contain fine particles that could be harmful to humans or the environment. If you are unsure as to the toxicity of any particular dust, then you should always treat it as toxic and take the precautions identified in the SDS or shop procedures. Brake and clutch dust are potential toxic dusts that automotive shops must manage. The dust is made up of very fine particles that can easily spread and contaminate an area. One of the more common sources of toxic dust is inside drum brakes and manual transmission bell housings. It is a good idea to avoid all dust if possible, whether it is classified as toxic or not. If you do have to work with dust, never use compressed air to blow it from components or parts, and always use PPE such as face masks, eye protection, and gloves.

After completing a service or repair task on a vehicle, there is often dirt and dust left behind. The chemicals present in this dirt usually contain toxic chemicals that can build up and cause health problems. To keep the levels of dirt and dust to a minimum, clean it up immediately after the task is complete. The vigorous action of sweeping causes the dirt and dust to rise; therefore, when sweeping the floor, use a soft broom that pushes, rather than flicks, the dirt and dust forward. Create smaller piles and dispose of them frequently. Another successful way of cleaning shop dirt and dust is to use a water hose. The

SKILL DRILL 2-1 Identifying Information in an SDS

1. Once you have studied the information on the container label, find the SDS for that particular material. Always check the revision date to ensure that you are reading the most recent update.
2. Note the chemical and trade names for the material, its manufacturer, and the emergency telephone number to call.
3. Find out why this material is potentially hazardous. It may be flammable, it may explode, or it may be poisonous if inhaled or touched with your bare skin. Check the **threshold limit values (TLVs)**. The concentration of this material in the air you breathe in your shop must not exceed these figures. There could be physical symptoms associated with breathing harmful chemicals. Find out what will happen to you if you suffer overexposure to the material, either through breathing it or by coming into physical contact with it. This helps you to take safety precautions, such as wearing eye, face, or skin protection, or a mask or respirator, while using the material, or like washing your skin afterward.
4. Note the flash point for this material so that you know at what temperature it may catch fire. Also note what kind of fire extinguisher you would use to fight a fire involving this material. The wrong fire extinguisher could make the emergency even worse.
5. Study the reactivity for this material to identify the physical conditions or other materials that you should avoid when using this material. It could be heat, moisture, or some other chemical.
6. Find out what special precautions you should take when working with this material. These include personal protection for your skin, eyes, and lungs, and proper storage and use of the material.
7. Be sure to refresh your knowledge of your SDS from time to time. Be confident that you know how to handle and use the material and what action to take in an emergency, should one occur.

FIGURE 2-33 Used oil and fluids often contain dangerous chemicals and need to be safely recycled or disposed of in an environmentally friendly way.

wastewater must be caught in a settling pit and not run into a storm water drain. Many shops also have floor scrubbers that use a water/soap solution to clean the floor. These shops usually vacuum up the dirty water and store it in a tank until it can be disposed of properly.

Various tools have been developed to clean toxic dust from vehicle components. The most common one is the brake wash station. It uses an aqueous solution to wet down and wash the dust into a collection basin. The basin needs periodic maintenance to properly dispose of the accumulated sludge. This tool is probably the simplest way to effectively deal with hazardous dust because it is easy to set up, use, and store. One system that used to be approved for cleanup of hazardous dust is no longer approved for that purpose. It is called a high-efficiency particulate air (HEPA) dust collection system and used a HEPA filter to trap very small particles. But these types of hazardous dust collection systems are no longer approved.

Used Engine Oil and Fluids

S02003 Properly dispose of used engine oil and other petroleum products.

Used engine oil and fluids are liquids that have been drained from the vehicle, usually during servicing operations. Used oil and fluids often contain dangerous chemicals and impurities such as heavy metals that need to be safely recycled or disposed of in an environmentally friendly way (**FIGURE 2-33**).

There are laws and regulations that control the way in which they are to be handled and disposed. The shop will have policies and procedures that describe how you should handle and dispose of used engine oil and fluids. Be careful not to mix incompatible fluids such as used engine oil and used coolant. Doing so makes the hazardous materials very much more expensive to dispose of.

Generally speaking, petroleum products can be mixed together. Follow your local, state, and federal regulations when disposing of waste fluids. Used engine oil is a hazardous material containing many impurities that can damage your skin. Coming into frequent or prolonged contact with used engine oil can cause dermatitis and other skin disorders, including some forms of cancer. Avoid direct contact as much as possible by always using impervious gloves and other protective clothing, which should be cleaned or replaced regularly. Using a barrier-type hand lotion also helps protect your hands and makes cleaning them much easier. Always follow safe work practices, which minimize the possibility of accidental spills. Keeping a high standard of personal hygiene and cleanliness is important so that you get into the habit of washing off harmful materials as soon as possible after contact. If you have been in periodic contact with used engine oil, you should regularly inspect your skin for signs of damage or deterioration. If you have any concerns, consult your doctor.

▶ First Aid Principles

K02019 Explain the basic first aid procedures when approaching an emergency.

The following information is designed to provide you with an awareness of basic first aid principles and the importance of first aid training courses. You will find general information about how to take care of someone who is injured. However, this information is only a guide. It is not a substitute for training or professional medical assistance. Always seek professional advice when tending to an injured person. One of the best things you can do is take a first aid class and periodic refresher courses. These courses help you stay current on first aid practices as they change. They also help remind you of the importance of preventing accidents so that first aid is less likely to be needed.

First aid is the immediate care given to an injured or suddenly ill person. Learning first aid skills is valuable in the workplace in case an accident or medical emergency arises. First aid courses are available through many organizations, such as the Emergency Care and Safety Institute (ECSI). It is strongly advised that you seek out a certified first aid course and become certified in first aid. The following information highlights some of the principles of first aid.

In the event of an accident, the possibility of injury to the rescuer or further injury to the victim must be evaluated. This means the first step in first aid is to survey the scene. While doing this, try to determine what happened, what dangers may still be present, and the best actions to take. Only remove the injured person from a dangerous area if it is safe for you to do so. When dealing with electrocution or electrical burns, make sure the electrical supply is switched off before attempting any assistance. Always perform first aid techniques as quickly as is safely possible after an injury. When breathing or the heart has stopped, brain damage can occur within four to six minutes. The degree of brain damage increases with each passing minute, so make sure you know what to do, and do it as quickly as is safe to do so.

Prompt care and treatment before the arrival of emergency medical assistance can sometimes mean the difference between life and death. The goals of first aid are to make the immediate environment as safe as possible, preserve the life of the patient, prevent the injury from worsening, prevent additional injuries from occurring, protect the unconscious, promote recovery, comfort the injured, prevent unnecessary delays in treatment, and provide the best possible immediate care for the injured person. When attending to an injured victim, always send for assistance. Make sure the person who stays with the injured victim is more experienced in first aid than the messenger. If you are the only person available, request medical assistance as soon as reasonably possible.

When you approach the scene of an accident or emergency, do the following:

1. Danger: Survey the scene to make sure there are no other dangers, and assist only if it is safe to do so.
2. Response: Check to see if the victim is responsive and breathing. If responsive, ask the victim if he or she needs help. If the victim does not respond, he or she is unresponsive.
3. Send for help: Have a bystander call 9-1-1. Always have the person with the most first aid experience stay with the victim. If alone, call 9-1-1 yourself.
4. Airway: Open the airway by tilting the victim's head back and lifting the chin.
5. Breathing: Check for normal breathing by placing one of your hands on the victim's chest, and lean down so your ear is near the person's mouth. Listen and watch for breathing. If the victim is breathing, monitor the victim for further issues. If the victim is not breathing normally, start CPR.
6. Circulation/CPR (cardiopulmonary resuscitation): If no pulse is present, start chest compressions at the rate of approximately 100 per minute. You can either give sequences of 30 compressions to two breaths, or just compressions if you are reluctant to give mouth to mouth resuscitation. Repeat the compression and breath cycles, or compression only cycles, until an automated external defibrillator (AED) is available or emergency medical system (EMS) personnel arrive.
7. Defibrillation: If a pulse is still not present once an AED arrives, expose the victim's chest and turn on the AED. Attach the AED pads. Ensure that no one touches the victim. Follow the audio and visual prompts from the AED. If no shock is advised, resume CPR immediately (five sets of 30 compressions and two breaths, or compressions by themselves). If a shock is advised, do not touch the victim and give one shock. Or shock as advised by AED. Follow the directions given by the AED.

▶ TECHNICIAN TIP

- Some vehicle components, including brake and clutch linings, contain asbestos, which, despite having very good heat properties, is toxic. Asbestos dust causes lung cancer. Complications from breathing the dust may not show until decades after exposure.
- Airborne dust in the shop can also cause breathing problems such as asthma and throat infections.
- Never cause dust from vehicle components to be blown into the air. It can stay floating for many hours, meaning that other people will breathe the dust unknowingly.
- Wear protective gloves whenever using solvents.
- If you are unfamiliar with a solvent or a cleaner, refer to the SDS for information about its correct use and applicable hazards.
- Always wash your hands thoroughly with soap and water after performing repair tasks on brake and clutch components.
- Always wash work clothes separately from other clothes so that toxic dust does not transfer from one garment to another.
- Always wear protective clothing and the appropriate safety equipment.

▶ TECHNICIAN TIP

Three important rules of first aid:

1. Know what you must not do.
2. Know what you must do.
3. If you are not sure what procedures to follow, send for trained medical assistance.

▶ Wrap-Up

Ready for Review

- Your employer is responsible for maintaining a safe work environment; you are responsible for working safely.
- Always wear the correct personal protective equipment, such as gloves or hearing protection.
- Personal protective equipment (PPE) protects the body from injury but must fit correctly and be task appropriate.
- Work clothing should be clean, loose enough for movement, but not baggy, and should also be flame-retardant.
- Footwear should be acid- and slip-resistant and made of puncture-proof material.
- Headgear can protect your head from bumps and should hold long hair in place.

- Hand protection includes chemical gloves, leather gloves, light-duty gloves, general-purpose cloth gloves, and barrier cream.
- Hazardous chemicals and oils can be absorbed into your skin.
- Wear ear protection if the sound level is 85 decibels or above.
- Breathing devices include disposable dust masks and respirators.
- Forms of eye protection are safety glasses, welding helmet, gas welding goggles, full face shield, and safety goggles.
- You may need two types of eye protection for some tasks.
- Before starting work, remove all jewelry and watches, and make sure your hair is contained.
- Lifting correctly or seeking assistance helps prevent back injuries.
- Thinking "safety first" will lead to acting safely.
- Accidents and injuries can be avoided by safe work practices.
- OSHA is a federal agency that oversees safe workplace environments and practices.
- The EPA monitors and enforces issues related to environmental safety.
- Shop policies and procedures are designed to ensure compliance with laws and regulations, create a safe working environment, and guide shop practice.
- Shop safety inspections ensure that safety policies and procedures are being followed.
- Safety includes keeping a clean shop with everything put where it belongs and all spills cleaned up.
- Safety signs include a signal word, background color, text, and a pictorial message.
- Shop safety equipment includes handrails, machinery guards, painted lines, soundproof rooms, adequate ventilation, gas extraction hoses, doors and gates, and temporary barriers.
- Air quality is an important safety concern.
- All shops require proper ventilation.
- Carbon monoxide and carbon dioxide from running engines can create a hazardous work environment.
- Electrical safety in a shop is important to prevent shocks, burns, fires, and explosions.
- Portable electrical equipment should be the proper voltage and should always be inspected for damage.
- Use caution when plugging in or using a portable shop light.
- Fuels and fuel vapors are potential fire hazards.
- Use fuel retrievers when draining fuel, and have a spill response kit nearby.
- Fuel, oxygen, and heat must all be present for fire to occur.
- Types of fires are classified as A, B, C, D, or K, and fire extinguishers match them accordingly.
- Do not fight a fire unless you can do so safely.
- Operating a fire extinguisher involves the PASS method: pull, aim, squeeze, and sweep.
- Every shop should mark evacuation routes; always know the evacuation route for your shop.
- Identify hazards and hazardous materials in your work environment.
- Safety data sheets contain important information on each hazardous material in the shop.
- Using a soap and water solution is the safest method of cleaning dust or dirt that may be toxic.
- Used engine oil and fluids must be handled and disposed of properly.
- First aid involves providing immediate care to an ill or injured person.
- Do not perform first aid if it is unsafe to do so.

Key Terms

barrier cream A cream that looks and feels like a moisturizing cream but has a specific formula to provide extra protection from chemicals and oils.

double insulated Tools or appliances that are designed in such a way that no single failure can result in a dangerous voltage coming into contact with the outer casing of the device.

ear protection Protective gear worn when the sound levels exceed 85 decibels, when working around operating machinery for any period of time, or when the equipment you are using produces loud noise.

engineering and work practice controls Systems and procedures required by OSHA and put in place by employers to protect their employees from hazards.

Environmental Protection Agency (EPA) Federal government agency that deals with issues related to environmental safety.

first aid The immediate care given to an injured or suddenly ill person.

gas welding goggles Protective gear designed for gas welding; they provide protection against foreign particles entering the eye and are tinted to reduce the glare of the welding flame.

hazardous material Any material that poses an unreasonable risk of damage or injury to persons, property, or the environment if it is not properly controlled during handling, storage, manufacture, processing, packaging, use and disposal, or transportation.

headgear Protective gear that includes items like hairnets, caps, or hard hats.

heat buildup A dangerous condition that occurs when the glove can no longer absorb or reflect heat, and heat is transferred to the inside of the glove.

Occupational Safety and Health Administration (OSHA) Government agency created to provide national leadership in occupational safety and health.

personal protective equipment (PPE) Safety equipment designed to protect the technician, such as safety boots, gloves, clothing, protective eyewear, and hearing protection.

policy A guiding principle that sets the shop direction.

procedure A list of the steps required to get the same result each time a task or activity is performed.

respirator Protective gear used to protect the wearer from inhaling harmful dusts or gases. Respirators range from single-use disposable masks to types that have replaceable cartridges. The correct types of cartridge must be used for the type of contaminant encountered.

safety data sheet (SDS) A sheet that provides information about handling, use, and storage of a material that may be hazardous.

safety glasses Safety glasses are protective eye glasses with built-in side shields to help protect your eyes from the front and side. Approved safety glasses should be worn whenever you are in a workshop. They are designed to help protect your eyes from direct impact or debris damage.

threshold limit value (TLV) The maximum allowable concentration of a given material in the surrounding air.

toxic dust Any dust that may contain fine particles that could be harmful to humans or the environment.

welding helmet Protective gear designed for arc welding; it provides protection against foreign particles entering the eye, and the lens is tinted to reduce the glare of the welding arc.

Review Questions

1. Neoprene gloves are ideal for protection from:
   a. dust.
   b. heavy materials.
   c. changing workplace temperatures.
   d. certain acids and other chemicals.
2. You can use a disposable dust mask to protect yourself against:
   a. asbestos dust.
   b. brake dust.
   c. brake fluid vapors.
   d. paint solvents.
3. When bending down to lift something, you should:
   a. bend over with straight legs.
   b. put your feet together.
   c. bend your knees.
   d. bend your back.
4. Which of the following works toward finding the most effective ways to help prevent worker fatalities and workplace injuries and illnesses?
   a. EPA
   b. FDA
   c. OSHA
   d. ASA
5. The list of steps required to get the same result each time a task or activity is performed is known as the:
   a. shop policy.
   b. shop regulations.
   c. shop procedure.
   d. shop system.
6. The signal word that indicates a potentially hazardous situation, which, if not avoided, could result in death or serious injury is:
   a. danger.
   b. caution.
   c. warning.
   d. hazardous.
7. Which of these should not be used in a shop?
   a. Incandescent bulbs
   b. Extension cords
   c. Low-voltage tools
   d. Air-operated tools
8. To operate a fire extinguisher, follow the acronym for fire extinguisher use: PASS, which stands for:
   a. Press, aim, squeeze, sweep.
   b. Pull, aim, shake, sweep.
   c. Press, aim, shake, sweep.
   d. Pull, aim, squeeze, sweep.
9. Which of these should never be used to remove dust?
   a. Floor scrubbers
   b. Water hoses
   c. Compressed air
   d. Brake wash stations
10. When disposing of used liquids:
    a. federal regulations need not be followed.
    b. incompatible liquids can be mixed together.
    c. impervious gloves are not needed.
    d. petroleum products can be mixed together.

ASE Technician A/Technician B Style Questions

1. Tech A says that personal protective equipment (PPE) does not include clothing. Tech B says that the PPE used should be based on the task you are performing. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says that rings, watches, and other jewelry should be removed prior to working. Tech B says that you should always wear cuffed pants when working in a shop. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says that one use of barrier creams is to make cleaning your hands easier. Tech B says that hearing protection only needs to be worn by people operating loud equipment. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

4. Tech A says that tinted safety glasses can be worn when working outside. Tech B says that welding can cause a sunburn. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. Tech A says that exposure to solvents may have long-term effects. Tech B says that accidents are almost always avoidable. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says that after an accident you should take measures to avoid it in the future. Tech B says that it is okay to block an exit for a shop if you are actively working. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. Tech A says that both OSHA and the EPA can inspect facilities for violations. Tech B says that a shop safety rule does not have to be reviewed once put in place. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. Tech A says that a safety data sheet (SDS) contains information on procedures to repair a vehicle. Tech B says that you only need an SDS after an accident occurs. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. Tech A says that one approved way to clean dust off brakes is with compressed air. Tech B says that some auto parts may contain asbestos. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Tech A says that if you are unsure of what personal protective equipment (PPE) to use to perform a job, you should just use what is nearby. Tech B says that air tools are less likely to shock you than electrically powered tools. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B

CHAPTER 3
Basic Tools and Precision Measuring

NATEF Tasks

- **N03001** Demonstrate safe handling and use of appropriate tools.
- **N03002** Utilize safe procedures for handling of tools and equipment.
- **N03003** Identify standard and metric designation.
- **N03004** Demonstrate proper use of precision measuring tools (i.e., micrometer, dial-indicator, dial-caliper).
- **N03005** Demonstrate proper cleaning, storage, and maintenance of tools and equipment.

Knowledge Objectives

After reading this chapter, you will be able to:

- **K03001** Describe the safety procedures to take when handling and using tools.
- **K03002** Describe how to properly lockout and tag-out faulty equipment and tools.
- **K03003** Describe typical tool storage methods.
- **K03004** Identify tools and their usage in automotive applications.
- **K03005** Describe the type and use of wrenches.
- **K03006** Describe the type and use of sockets.
- **K03007** Describe the type and use of torque wrenches.
- **K03008** Describe the type and use of pliers.
- **K03009** Describe the type and use of cutting tools.
- **K03010** Describe the type and use of Allen wrenches.
- **K03011** Describe the type and use of screwdrivers.
- **K03012** Describe type and use of magnetic pickup tools and mechanical fingers.
- **K03013** Describe the type and use of hammers.
- **K03014** Describe the type and use of chisels.
- **K03015** Describe the type and use of punches.
- **K03016** Describe the type and use of pry bars.
- **K03017** Describe the type and use of gasket scrapers.
- **K03018** Describe the type and use of files.
- **K03019** Describe the type and use of clamps.
- **K03020** Describe the type and use of taps and dies.
- **K03021** Describe the type and use of screw extractors.
- **K03022** Describe the type and use of pullers.
- **K03023** Describe the type and use of flaring tools.
- **K03024** Describe the type and use of riveting tools.
- **K03025** Describe the type and use of measuring tapes.
- **K03026** Describe the type and use of steel rulers.
- **K03027** Describe the type and use of outside, inside, and depth micrometers.
- **K03028** Describe the type and use of telescoping gauges.
- **K03029** Describe the type and use of split ball gauges.
- **K03030** Describe the type and use of dial bore gauges.
- **K03031** Describe the type and use of vernier calipers.
- **K03032** Describe the type and use of dial indicators.
- **K03033** Describe the type and use of straight edges.
- **K03034** Describe the type and use of feeler gauges.
- **K03035** Describe the importance of proper cleaning and storage of tools.

Skills Objectives

There are no Skills Objectives for this chapter.

You Are the Automotive Technician

After finishing work on the last vehicle of the day, you are required to return your workstation back to order. You clean, inspect, and return tools and equipment to their designated place. You wipe up any spills, according to the shop procedure, and clear the floor of any debris, to avoid slips and falls. During your workspace inspection, you determine that the insulation on the droplight cord is frayed, and there are some tools that need to be cleaned and put away.

1. What needs to happen with the droplight?
2. What should you do to with a micrometer before storing it?
3. How do you check a micrometer for accuracy?
4. Describe a double flare and how it is different from a single flare.

▶ Introduction

In this chapter, we explore a variety of tool and basic shop equipment topics that are fundamental to your success as an automotive technician. They provide the means for work to be undertaken on vehicles, from lifting to diagnosing, removing, installing, cleaning, and inspecting. Nearly all shop tasks involve the use of some sort of tool or piece of equipment (**FIGURE 3-1**). This makes their purchase, use, and maintenance very important to the overall performance of the shop. In fact, most tool purchases are considered an investment because they generate income when they are used. For example, if you can buy a tool for $100 that saves you two hours of working time every time you use it, you only need to use it a couple of times in order to pay for it. Then, every time after that, it pays you a bonus. This means that you need to treat tools like your own personal moneymakers. One way to do that is to always use tools and equipment in the way they are designed to be used. Don't abuse them. Think about the task at hand, identify the most effective tools to do the task, inspect the tool before using it, use it correctly, clean and inspect it after you use it, and store it in the correct location. Doing all of these things ensures that your tools will be available the next time you use them and that they will last a long time.

▶ TECHNICIAN TIP

A sticker on the dash of a work truck I once used read: "Treat me well—your paycheck depends on it. If I can't work, neither can you!" That goes for all tools and equipment. Your ability to do work as a technician will either be enhanced or reduced by the condition of the tools and equipment you use.

▶ General Safety Guidelines

N03001 Demonstrate safe handling and use of appropriate tools.

N03002 Utilize safe procedures for handling of tools and equipment.

K03001 Describe the safety procedures to take when handling and using tools.

Although it is important to be trained on the safe use of tools and equipment, it is even more critical to have a safe attitude. A safe attitude will help you avoid being involved in an accident. Students who think they will never be involved in an accident will not be as aware of unsafe situations as they should be. And that can lead to accidents. So while we are covering the various tools and equipment you will encounter in the shop, pay close attention to the safety and operation procedures. Tools are a technician's best friend, but if used improperly, they can injure or kill (**FIGURE 3-2**).

FIGURE 3-1 Technicians rely on tools to perform work.

Work Safe and Stay Safe

Whenever using tools, always think safety first. There is nothing more important than your personal safety. If tools (both hand and power) are used incorrectly, you can potentially injure yourself and others. Always follow equipment and shop instructions, including the use of recommended personal protective equipment (PPE). Accidents only take a second or two to happen but can take a lifetime to recover from. You are ultimately responsible for your safety, so remember to work safe and stay safe.

Safe Handling and Use of Tools

Tools must be safely handled and used to prevent injury and damage. Always inspect tools prior to use, and never use damaged tools. Check the manufacturer and the shop procedures, or ask your supervisor if you are uncertain about how to use tools. Inspect and clean tools when you are finished using them. Always return tools to their correct storage location.

To safely handle and use appropriate tools, follow **SKILL DRILL 3-1**.

▶ TECHNICIAN TIP

Using tools can make you much more efficient and effective in performing your job. Without tools, it would be very difficult to carry out vehicle repairs and servicing. It is also the reason that many technicians invest well over $20,000 in their personal tools. If purchased wisely, tools can help you perform more work in a shorter amount of time, thereby making you more money. So think of your tools as an investment that pays for themselves over time.

Safe Procedures for Handling Tools and Equipment

Some tools are heavy or awkward to use, so seek assistance if required, and use correct manual handling techniques when using tools. To utilize safe procedures for handling tools and equipment, follow the steps in **SKILL DRILL 3-2**.

Tool Usage

Tools extend our abilities to perform many tasks; for example, jacks, stands, and hoists extend our ability to lift and hold heavy objects. Hand tools extend our ability to perform

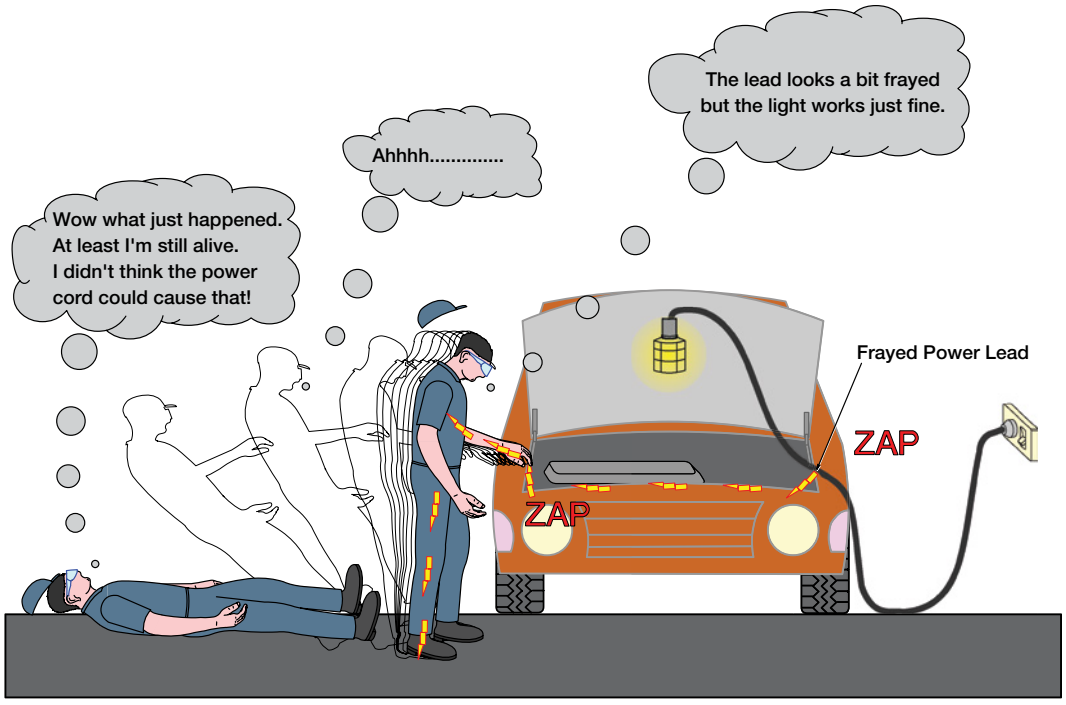
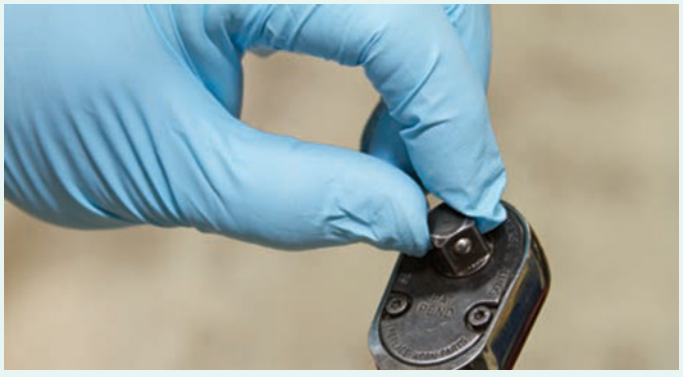


FIGURE 3-2 Tools used improperly can injure or kill.

SKILL DRILL 3-1 Safe Handling and Use of Tools

1. Select the correct tool(s) to undertake tasks.



2. Inspect tools prior to use to ensure they are in good working order. If tools are faulty, remove them from service according to shop procedures.

3. Clean tools prior to use if necessary.

4. Use tools to complete the task while ensuring manufacturer and shop procedures are followed. Always use tools safely to prevent injury and damage.

5. Ensure tools are clean and in good working order after use. Report and tag damaged tools, and remove them from service, following shop procedures.

6. Return tools to correct storage locations.

SKILL DRILL 3-2 Safe Procedures for Handling Tools and Equipment

1. Seek assistance if tools and equipment are too heavy or too awkward to be managed by a single person.

2. Inspect tools and equipment for possible defects before starting work. Report and/or tag faulty tools and equipment according to shop procedures.

Continued

3. Select and wear appropriate PPE for the tools and equipment being used.

4. Use tools and equipment safely.

5. Check tools for faults after using them and report and/or tag faulty tools and equipment according to shop procedures.

6. Clean and return tools and equipment to correct storage locations when tasks are completed.

fundamental tasks like gripping, turning, tightening, measuring, and cutting (**FIGURE 3-3**). Electrical meters enable us to measure things we cannot see, feel, or hear; and power and air tools multiply our strength by performing tasks quickly and efficiently. As you are working, always think about what tool can make the job easier, safer, or more efficient. As you become familiar with more tools, your productivity, quality of work, and effectiveness will improve.

FIGURE 3-3 Tools extend our abilities.

Every tool is designed to be used in a certain way to do the job safely. It is critical to use a tool in the way it was designed to be used and to do so safely. For example, a screwdriver is designed to tighten and loosen screws, not to be used as a chisel. Ratchets are designed to turn sockets, not to be used as a hammer. Think about the task you are undertaking, select the correct tools for the task, and use each tool as it was designed.

Lockout/Tag-Out

K03002 Describe how to properly lockout and tag-out faulty equipment and tools.

Lockout/tag-out is an umbrella term that describes a set of safety practices and procedures that are intended to reduce the risk of technicians inadvertently using tools, equipment, or materials that have been determined to be unsafe or potentially unsafe, or that are in the process of being serviced. An example of lockout would be physically securing a broken, unsafe, or out-of-service tool so that it cannot be used by a technician. In many cases, the item is also tagged out so it is not inadvertently placed back into service or operated. An example of tag-out would be affixing a clear and obvious label to a piece of equipment that describes the fault found, the name of the person who found the fault, and the date that the fault was found, and that warns not to use the equipment (**FIGURE 3-4**).

SAFETY TIP

Standardized lockout/tag-out procedures are a mandatory part of workplace safety regulations in most countries. Familiarize yourself with your local legislation and with the specific lockout/tag-out practices that apply in your workplace.

Tool Storage

K03003 Describe typical tool storage methods.

Typically, technicians have a selection of their own tools, which include various hand tools, air tools, measuring tools, and electrical meters (**FIGURE 3-5**). Often they add to their toolbox over time. These tools are kept in a toolbox that can be rolled around as needed but is typically kept in the technician's work stall. The shop usually has a selection of specialty tools and equipment that is available for technicians to use on a shared basis. These tools are located in specific areas around the shop, typically in a centralized location so they are relatively easy to access (**FIGURE 3-6**). They include specialized manufacturer tools, such as pullers or installation tools; high-cost tools such as factory scan tools; and tools that are not portable, such as hoists and tire machines. But because they are shared by everyone in the shop, it is critical that they are inspected for damage and put in their proper storage space after each use so they will be available to the other technicians.

FIGURE 3-4 **A.** An example of lockout would be physically locking out a tool or piece of equipment so that it cannot be accessed and used by someone who may be unaware of the potential danger of doing so. **B.** An example of tag-out would be affixing a clear and obvious label to a piece of equipment that describes the fault found and that warns not to use the equipment.

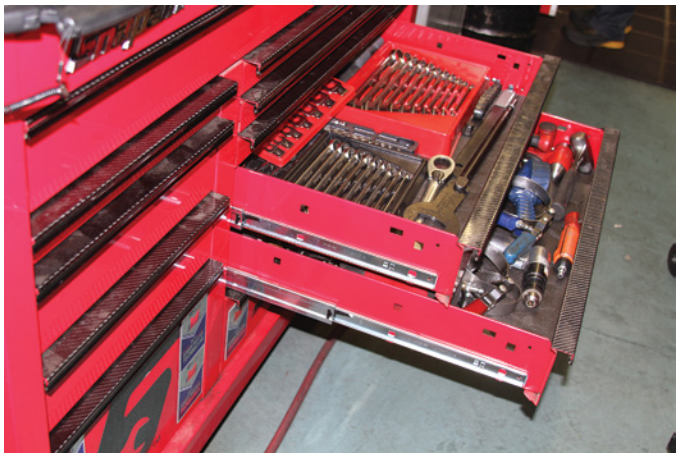


FIGURE 3-5 Typical technician's toolbox.

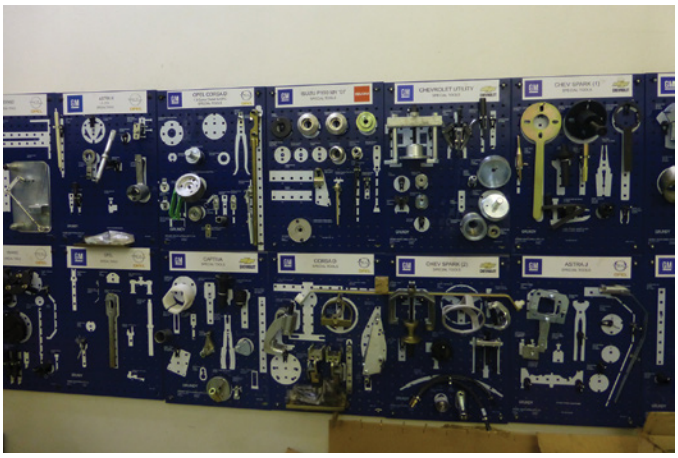


FIGURE 3-6 Manufacturer's special tools.

To identify tools and their usage in automotive applications, follow these steps:

1. Create a list of tools in your toolbox and identify their application for automotive repair and service.
2. Look through the shop's tool storage areas, and create a list of the tools found in each storage area; identify their application for automotive repair and service.

Standard and Metric Designations

N03003 Identify standard and metric designation.

Many tools, measuring instruments, and fasteners come in United States customary system (USCS) sizes, more commonly referred to as "standard," or in metric sizes. Tools and measuring instruments can be identified as standard or metric by markings identifying their size on tools or the increments on a measuring tool. **Fasteners** bought new have their designation identified on the packaging. Other fasteners may have to be measured by a ruler or **vernier caliper** to identify their designation. Manufacturer's charts showing thread and fastener sizing assist in identifying standard or metric sizing.

To identify standard and metric designation, follow these steps:

1. Examine the component, tool, or fastener to see if any marking identifies it as standard or metric. Manufacturer specifications and shop manuals can be referred to and may identify components as standard or metric (**FIGURE 3-7**).
2. If no markings are available, use measuring devices to gauge the size of the item and compare thread and fastener charts to identify the sizing. Inch-to-metric conversion charts assist in identifying component designation (**FIGURE 3-8**).

FIGURE 3-7 Manufacturer specifications and shop manuals can be referred to and may identify components as standard or metric.

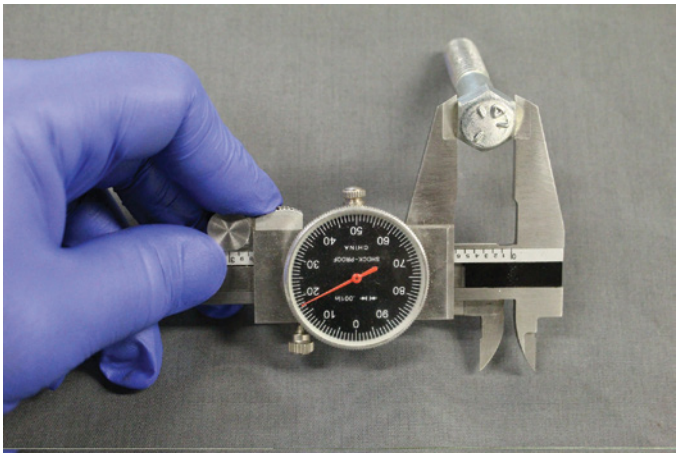


FIGURE 3-8 If no markings are available, use measuring devices to gauge the size of the item and compare thread and fastener charts to identify the sizing.

Basic Hand Tools

K03004 Identify tools and their usage in automotive applications.

TECHNICIAN TIP

Invest in quality tools. Because tools extend your abilities, poor-quality tools affect the quality and quantity of your work. Price is not always the best indicator of quality, but it plays a role. As you learn the purpose and function of the tools in this chapter, you should be able to identify high-quality tools versus poor-quality tools by looking at them, handling them, and putting them to work.

Like all tools, hand tools extend our ability to do work. Hand tools come in a variety of shapes, sizes, and functions (**FIGURE 3-9**). A large percentage of your personal tools will be hand tools. Over the years, manufacturers have introduced new fasteners, wire harness terminals, quick-connect fittings for fuel and other lines, and additional technologies that require their own different types of hand tools. This means that technicians need to continually add updated tools to their toolbox.

Speaking of toolboxes, technicians need to invest in a quality toolbox to keep their tools secure, so toolboxes should have enough capacity to hold all current and future tools. They should be built to last because a toolbox is in continuous use throughout the workday. A toolbox should have drawers that can handle the weight of the tools in it. Plus it should open and close easily; drawer slides that use bearings make them much easier to open and close (**FIGURE 3-10**). The toolbox should also be equipped with an easy-to-use locking system to secure the tools when they aren't being used.

Wrenches

K03005 Describe the type and use of wrenches.

Wrenches are used to tighten and loosen nuts and **bolts**, which are two types of fasteners. There are three commonly used wrenches: the **box-end wrench**, the **open-end wrench**, and the **combination wrench** (**FIGURE 3-11**). The box-end wrench fits fully around the head of the bolt or nut and grips each of the six points at the corners, just like a socket. This is exactly the sort of grip needed if a nut or bolt is very tight, and makes the box-end wrench less likely to round off the points on the head of the bolt than the open-end wrench. The ends of box-end wrenches are bent or offset, so they are easier to grip and have different-sized heads at each end (**FIGURE 3-12**). One disadvantage of the box-end wrench is that it can be awkward to use once the nut or bolt has been loosened a bit, because you have to lift it off the head of the fastener and move it to each new position.

The open-end wrench is open on the end, and the two parallel flats only grip two points of the fastener. Open-end wrenches usually either have different-sized heads on each end of the wrench, or they have the same size, but with different angles (**FIGURE 3-13**). The head is at an angle to the handle and is not bent or offset, so it can be flipped over and used on both sides. This is a good wrench to use in very tight spaces as you can flip it over and get a new angle so the head can catch new points on the fastener. Although an open-end wrench often gives the best access to a fastener, if the fastener is extremely

FIGURE 3-9 Hand tools.

FIGURE 3-10 Toolbox drawers need to open and close easily.

FIGURE 3-11 **A.** Box-end wrench. **B.** Open-end wrench. **C.** Combination wrench. **D.** Flare nut wrench. **E.** Ratcheting box-end wrench.

FIGURE 3-12 Box-end wrenches.

FIGURE 3-13 Types of open-end wrenches.

tight, the open-end wrench should not be used, as this type of wrench only grips two points. If the jaws flex slightly, the wrench can suddenly slip when force is applied. This slippage can round off the points of the fastener. The best way to approach a tight fastener is to use a box-end wrench to break the bolt or nut free, then use the open-end wrench to finish the job. The open-end wrench should only be used on fasteners that are no more than firmly tightened.

The combination wrench has an open-end head on one end and a box-end head on the other end (**FIGURE 3-14**). Both ends are usually of the same size. That way the box-end wrench can be used to break the bolt loose, and the open end can be used for turning the bolt. Because of its versatility, this is probably the most popular wrench for technicians.

A variation on the open-end wrench is the **flare nut wrench**, also called a flare tubing wrench, or line wrench. It gives a better grip than the open-end wrench because it grabs all six points of the fastener, not two (**FIGURE 3-15**). However, because it is open on the end, it is not as strong as a box-end wrench. The partially open sixth side lets the wrench be placed over the tubing or pipe so the wrench can be used to turn the tube fittings. Do not use the flare nut wrench on extremely tight fasteners as the jaws may spread, damaging the nut.

FIGURE 3-14 Combination wrenches.

One other open-end wrench is the open-end adjustable wrench or crescent wrench. This wrench has a movable jaw that can be adjusted by turning an adjusting screw to fit any fastener within its range (**FIGURE 3-16**). It should only be used if other wrenches are not available because it is not as strong as a fixed wrench, so it can slip off and damage the head of tight bolts or nuts. Still, it is a handy tool to have because it can be adjusted to fit most any fastener size.

A **ratcheting box-end wrench** is a useful tool in some applications because it does not require removal of the tool to reposition it. It has an inner piece that fits over and grabs the points on the fastener and is able to rotate within the outer housing. A ratcheting mechanism lets it rotate in one direction and lock in the other direction. In some cases, the wrench just needs to be flipped over to be used in the opposite direction. In other cases, it has a lever that changes the direction from clockwise to counterclockwise (**FIGURE 3-17**). Just be careful to not overstress this tool by using it to tighten or loosen very

FIGURE 3-15 Flare nut wrenches.

FIGURE 3-16 Open-end adjustable wrench.

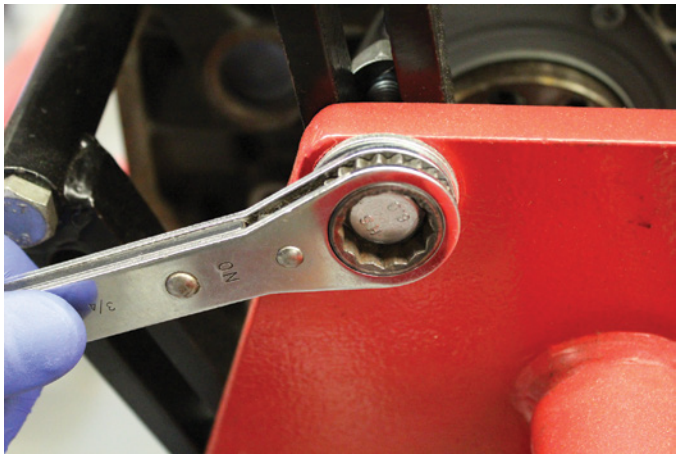


FIGURE 3-17 Ratcheting box-end wrench.

tight fasteners, as the outer housing is not very strong. There is also a ratcheting open-end wrench, but it uses no moving parts. One of the sides is partially removed so that only the bottom one-third remains to catch a point on the bolt (**FIGURE 3-18**). When it is used, the normal side works just like a standard open-end wrench. The shorter side of the open-end wrench catches the point on the fastener so it can be turned. When moving the wrench to get a new bite, the wrench is pulled slightly outward, disengaging the short side while leaving the long side to slide along the faces of the bolt. The wrench is then rotated to the new position and pushed back in so the short side engages the next point. This wrench, like other open-end wrenches, is not designed to tighten or loosen tight fasteners, but it does work well in blind places where a socket or ratcheting box-end wrench cannot be used.

Specialized wrenches such as the **pipe wrench** grip pipes and can exert a lot of force to turn them (**FIGURE 3-19**). Because the handle pivots slightly, the more pressure put on the handle to turn the wrench, the more the grip tightens. The jaws are hardened and serrated, and increasing the pressure also increases the risk of marking or even gouging metal from the pipe. The jaw is adjustable, so it can be threaded in or out to fit different pipe sizes. Also, they come in different lengths, allowing you to increase the leverage applied to the pipe.

A specialized wrench called an **oil filter wrench** grabs the filter and gives you extra leverage to remove an oil filter when it is tight. These wrenches are available in various designs and sizes (**FIGURE 3-20**), and some are adjustable to fit many filter sizes. Also note that an oil filter wrench should be used *only* to remove an oil filter, never to install it. Almost all oil filters should be installed and tightened by hand.

▶ TECHNICIAN TIP

Wrenches (which are also known as spanners in some countries) will only do a job properly if they are the right size for the given nut or bolt head. The size used to describe a wrench is the distance across the flats of the nut or bolt. There are two systems in common use—standard (in inches) and metric (in millimeters). Each system provides a range of sizes, which are identified by either a fraction, which indicates fractions of an inch for the standard system, or a number, which indicates millimeters for the metric system. In most cases, standard and metric tools cannot be used interchangeably on a particular fastener. Even though a metric tool fits a standard sized fastener, it may not grip as tight, which could cause it to round the head of the fastener off.

FIGURE 3-18 Ratcheting open-end wrench.

FIGURE 3-19 Pipe wrench.

FIGURE 3-20 Oil filter wrenches.

Using Wrenches Correctly

Choosing the correct wrench for a job usually depends on two things: how tight the fastener is and how much room there is to get the wrench onto the fastener, and then to turn it. When being used, it is always possible that a wrench could slip. Before putting a lot of tension on the wrench, try to anticipate what will happen if it does slip. If possible, it is usually better to pull a wrench toward you than to push it away (**FIGURE 3-21**). If you have to push, use an open palm to push, so your knuckles won't get crushed if the wrench slips. If pulling toward yourself, make sure your face is not close to your hand or in line with your pulling motion. Many technicians have punched themselves in the face when the wrench slipped.

Sockets

K03006 Describe the type and use of sockets.

Sockets are very popular because of their adaptability and ease of use (**FIGURE 3-22**). Sockets are a good choice where the top of the fastener is reasonably accessible. The **socket** fits onto the fastener snugly and grips it on all six corners, providing the type of grip needed on any nut or bolt that is extremely tight. Sockets come in a variety of configurations, and technicians usually have a lot of sockets so they can get in a multitude of tight places. Individual sockets fit a particular size nut or bolt, so they are usually purchased in sets.

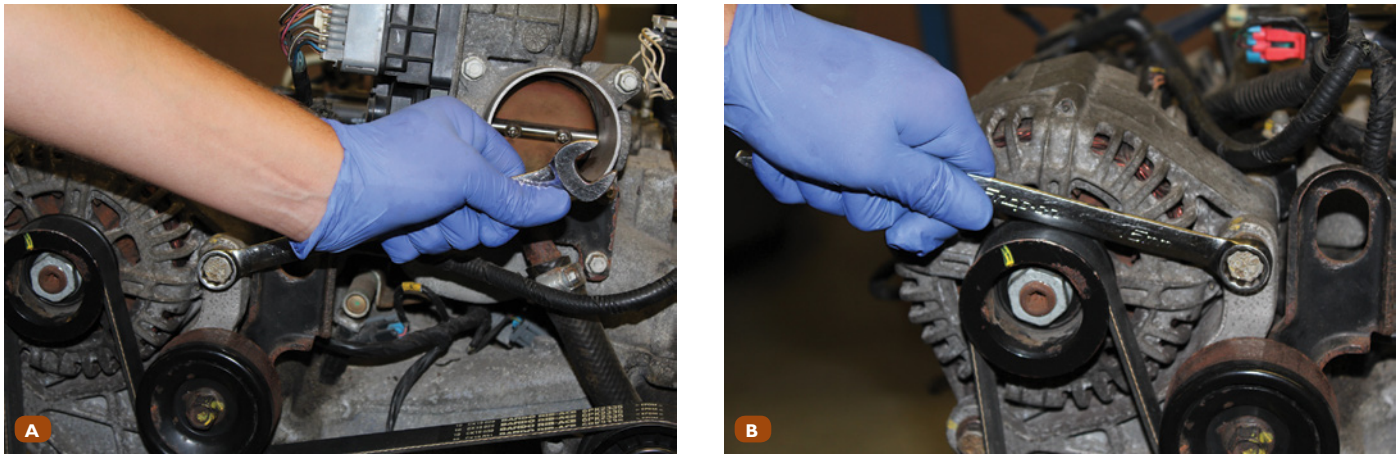


FIGURE 3-21 **A.** Pulling on a wrench is generally better than pushing on a wrench. **B.** Pushing regularly results in bruised or broken knuckles.

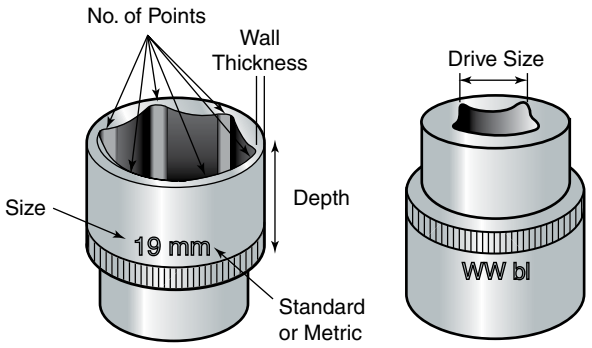


FIGURE 3-22 The anatomy of a socket.

FIGURE 3-23 Sockets are designed to fit a matching drive on a ratchet.

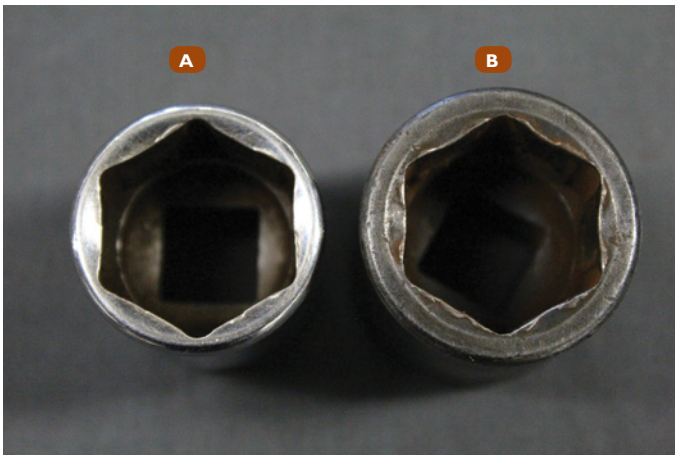


FIGURE 3-24 **A.** Standard wall socket. **B.** Impact socket.

Sockets are classified by the following characteristics:

- Standard or metric
- Size of drive used to turn them: 1/2" (12.7 mm), 3/8" (9.525 mm), and 1/4" (6.35 mm) are most common; 1" (25.4 mm) and 3/4" (19.05 mm) are less common.
- Number of points: 6 and 12 are most common; 4 and 8 are less common.
- Depth of socket: Standard and deep are most common; shallow is less common.
- Thickness of wall: Standard and impact are most common; thin wall is less common.

Sockets are built with a recessed square drive that fits over the square drive of the ratchet or other driver (**FIGURE 3-23**). The size of the drive determines how much twisting force can be applied to the socket. The larger the drive, the larger the twisting force. Small fasteners usually only need a small torque, so having too large of a drive may make it so the socket cannot gain access to the bolt. For fasteners that are really tight, an impact wrench exerts a lot more torque on a socket than turning it by hand does. Impact sockets are usually thicker walled than standard wall sockets and have six points so they can withstand the forces generated by the impact wrench as well as grip the fastener securely (**FIGURE 3-24**).

Six- and 12-point sockets fit the heads of hexagonal-shaped fasteners. Four- and 8-point sockets fit the heads of square-shaped fasteners (**FIGURE 3-25**). Because 6-point and 4-point sockets fit the exact shape of the fastener, they have the strongest grip on the fastener, but they only can fit on the fastener in half as many positions as a 12- or 8-point socket, making them harder to fit onto the fastener in places where the ratchet handle is restricted.

Another factor in accessing a fastener is the depth of the socket. If a nut is threaded quite a way down a stud or bolt, then a standard length socket will not fit far enough over the stud to reach the nut (**FIGURE 3-26**). In this case, a deep socket will usually reach the nut.

The most common socket handle, the **ratchet**, makes easy work of tightening or loosening a nut where not a lot of pressure is involved. It can be set to turn in either direction and does not need much room to swing. It is built to be convenient, not super strong, so too much pressure could strip the ratchet mechanism. For heavier tightening or loosening, a breaker bar gives the most leverage. When that is not available, a **sliding T-handle** may be more useful. With this tool, both hands can be used, and the position of the T-piece is adjustable to clear any obstructions when turning it. The connection between the socket and the accessory is made by a square drive. The larger the drive, the heavier and bulkier the socket will be. The 1/4" (6.35 mm) drive is for small work in

▶ TECHNICIAN TIP

Because sockets are usually purchased in sets, with each set providing a slightly different capability, you can see why technicians could easily have several hundred sockets in their toolbox. Having a variety of sockets allows the technician to do jobs easier and quicker, which makes them an investment. Turning a socket requires a handle (**FIGURE 3-27**).

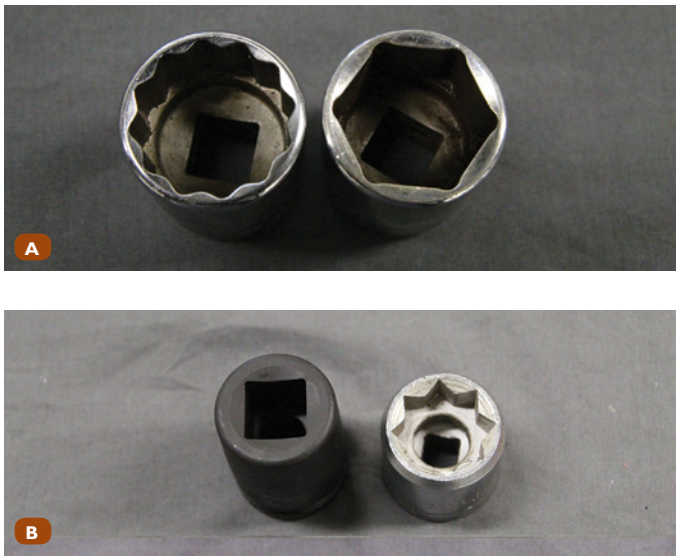


FIGURE 3-25 **A.** Six- and 12-point sockets. **B.** Four- and 8-point sockets.

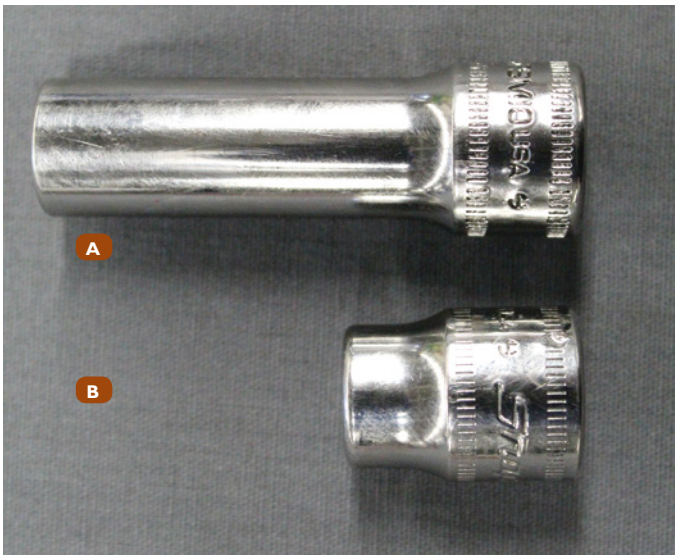


FIGURE 3-26 **A.** Deep socket. **B.** Standard length socket.

difficult areas. The 3/8" (9.525 mm) drive accessories handle a lot of general work where torque requirements are not too high. The 1/2" (12.7 mm) drive is required for all-around service. The 3/4" (19.05 mm) and 1" (25.4 mm) drives are required for large work with high torque settings.

Many fasteners are located in positions where access can be difficult. There are many different lengths of extensions available to allow the socket to be on the fastener while extending the drive point out to where a handle can be attached. Because extensions come in various lengths, they can be connected together to get just the right length needed for a particular situation.

If an object is in the way of getting a socket on a fastener, a flexible joint is used to apply the turning force to the socket through an angle. This can allow you to still turn the socket even though you are no longer directly in line with the fastener. There are four common types of flexible joints: U-joint style, wobble extension, cable extension, and flex socket (**FIGURE 3-28**). The flex

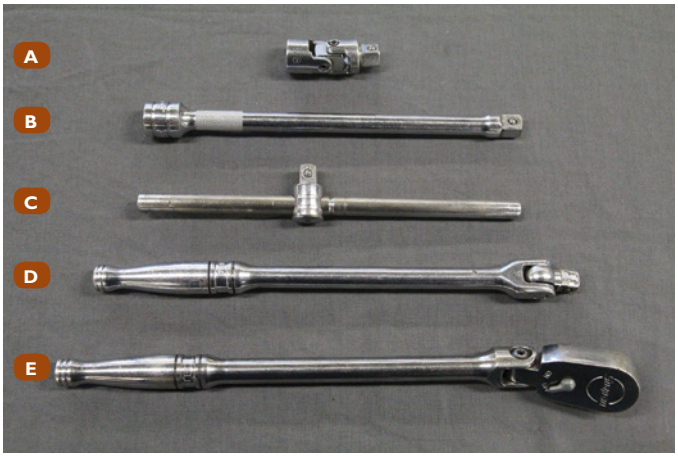


FIGURE 3-27 Tools to turn sockets. **A.** Universal joint. **B.** Extension. **C.** T-handle. **D.** Breaker bar. **E.** Ratchet.

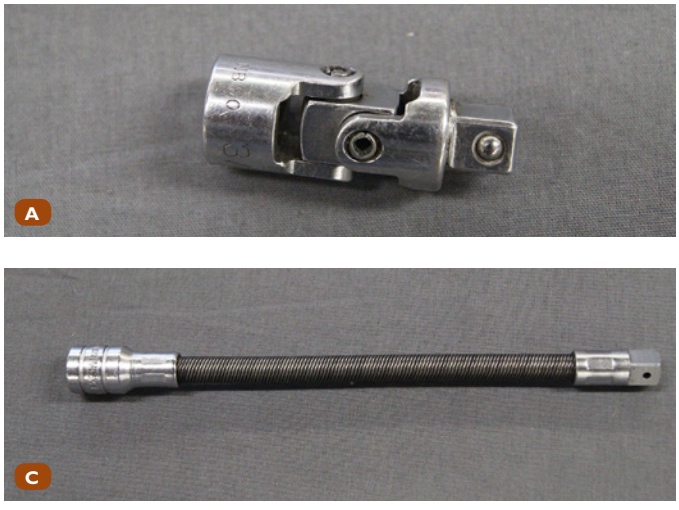


FIGURE 3-28 Flexible extensions. **A.** U-joint style. **B.** Wobble extension style. **C.** Cable extension style. **D.** Flex socket style.

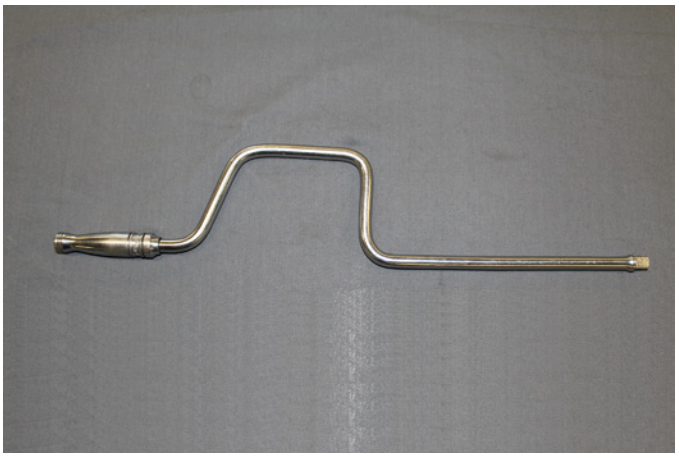


FIGURE 3-29 Speed brace.

FIGURE 3-30 Lug wrench.

socket has the universal built into it, so it's overall length is shorter, making it able to get into tighter spaces. In some situations, you may need to use more than one flexible joint to get around objects that are in the way. This is especially true when removing some bell housing bolts on some transmissions.

A **speed brace** or speeder handle is the fastest way to spin a fastener on or off a thread by hand, but it cannot apply much torque to the fastener; therefore, it is mainly used to remove a fastener that has already been loosened or to run the fastener onto the thread until it begins to tighten (**FIGURE 3-29**).

A **lug wrench** has special-sized lug nut sockets permanently attached to it. One common model has four different-sized sockets, one on each arm (**FIGURE 3-30**). Never hit or jump on a lug wrench when loosening lug nuts. If the lug wrench will not remove them, you should use an impact wrench. The impact wrench provides a hammering effect in conjunction with rotation to help loosen tight fasteners. *Never* use an impact wrench to tighten lug fasteners. Torque all lug fasteners to the proper torque with a properly calibrated torque wrench. And do it in the proper sequence.

Torque and Torque Wrenches

K03007 Describe the type and use of torque wrenches.

Bolt tension is what keeps a bolt from loosening and what causes it to hold parts together with the proper clamping force. **Torque** is the twisting force used to create bolt tension so that surfaces are clamped together with the proper force. The torque value is the amount of twisting force applied to a fastener by the torque wrench. A foot-pound is described as the amount of twisting force applied to a shaft by a perpendicular lever 1 ft (0.30m) long with a weight of 1 lb (0.45 kg) placed on the outer end (**FIGURE 3-31**). A torque value of 100 ft-lb (13.83 m-kg) is the same as a 100 lb (45.36 kg) weight placed at the end of a 1' (0.30m) long lever. A torque value of an inch-pound is 1 lb (0.45 kg) placed at the end of a 1" (25.40 mm) long lever. This means that 12 in-lb equals 1 ft-lb (0.14 m-kg) and vice versa. A newton meter (Nm) is described as the amount of twisting force applied to a shaft by a perpendicular lever 1 meter long with a force of 1 newton applied to the outer end. A torque value of 100 Nm is the same as applying a 100-newton force to the end of a 1 m long lever. One ft-lb is equal to 1.35 Nm. So torque is the measurement of twisting force.

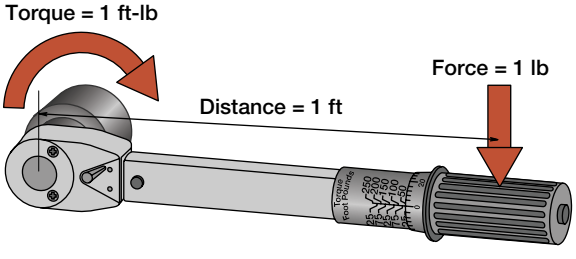


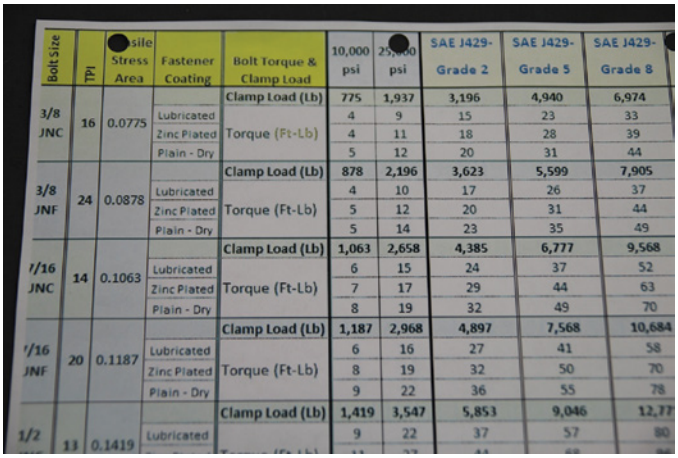
FIGURE 3-31 Torque is the measurement of twisting force. 1 ft-lb of torque.

Torque Charts

Torque specifications for bolts and nuts in vehicles are usually contained within service information. Bolt, nut, and stud manufacturers also produce torque charts, which contain the information you need to determine the maximum torque of bolts or nuts. For example, most charts include the bolt diameter, threads per inch, grade, and maximum torque setting for both dry and lubricated bolts and nuts (**FIGURE 3-32**).

A lubricated bolt and nut reach their maximum clamping force at a lower torque setting than if they are dry. In practice, most torque

specifications call for the nuts and bolts to have dry threads prior to tightening. There are some exceptions, so close examination of the torque specification is critical. Also remember that the bolt manufacturer's torque chart is a maximum recommended torque, not necessarily the torque required by the vehicle manufacturer for the specific application that the bolt is used for.



Bolt Size	TPI	Tensile Stress Area	Fastener Coating	Bolt Torque & Clamp Load	10,000 psi	25,000 psi	SAE J429-Grade 2	SAE J429-Grade 5	SAE J429-Grade 8
3/8 UNC	16	0.0775		Clamp Load (Lb)	775	1,937	3,196	4,940	6,974
			Lubricated	Torque (Ft-Lb)	4	9	15	23	33
			Zinc Plated		4	11	18	28	39
			Plain - Dry		5	12	20	31	44
3/8 UNF	24	0.0878		Clamp Load (Lb)	878	2,196	3,623	5,599	7,905
			Lubricated	Torque (Ft-Lb)	4	10	17	26	37
			Zinc Plated		5	12	20	31	44
			Plain - Dry		5	14	23	35	49
7/16 UNC	14	0.1063		Clamp Load (Lb)	1,063	2,658	4,385	6,777	9,568
			Lubricated	Torque (Ft-Lb)	6	15	24	37	52
			Zinc Plated		7	17	29	44	63
			Plain - Dry		8	19	32	49	70
7/16 UNF	20	0.1187		Clamp Load (Lb)	1,187	2,968	4,897	7,568	10,684
			Lubricated	Torque (Ft-Lb)	6	16	27	41	58
			Zinc Plated		8	19	32	50	70
			Plain - Dry		9	22	36	55	78
1/2	13	0.1419		Clamp Load (Lb)	1,419	3,547	5,853	9,046	12,77
			Lubricated		9	22	37	57	80

FIGURE 3-32 Bolt torque chart.

Torque Wrenches

A **torque wrench** is also known as a tension wrench (**FIGURE 3-33**) and is used to tighten fasteners to a predetermined torque. The drive on the end fits any socket and accessory of the same drive size found in ordinary socket sets. Although manufacturers do not specify torque settings for every nut and bolt, when they do, it is important to follow the specifications. For example, manufacturers specify a torque for head bolts.

FIGURE 3-33 A torque wrench.

The torque specified ensures that the bolt provides the proper clamping pressure and will not come loose, but will not be so tight as to risk breaking the bolt or stripping the threads. The torque value is specified in foot-pounds (ft-lb), inch-pounds (in-lb), or newton meters (N m).

Torque wrenches come in various types: beam style, clicker, dial, and electronic (**FIGURE 3-34**). The simplest and least expensive is the beam-style torque wrench, which uses a spring steel beam that flexes under tension. A smaller fixed rod then indicates the amount of torque on a scale mounted to the bar. The amount of deflection of the bar coincides with the amount of torque on the scale. One drawback of this design is that you have to be positioned directly above the scale so you can read it accurately. That can be a problem when working under the hood of a vehicle.

The clicker-style torque wrench uses an adjustable clutch inside that slips (clicks) when the preset torque is reached. You can set it for a particular torque on the handle

FIGURE 3-34 Torque wrenches. **A.** Beam style. **B.** Clicker style. **C.** Dial. **D.** Electronic.

(**FIGURE 3-35**). As the bolt is tightened, once the preset torque is reached, the torque wrench clicks. The higher the torque, the louder the click; the lower the torque, the quieter the click. Be careful when using this style of torque wrench, especially at lower torque settings. It is easy to miss the click and over-tighten, break, or strip the bolt. Once the torque wrench clicks, stop turning it, as it will continue to tighten the fastener if you turn it past the click point.

FIGURE 3-35 Torque setting scale on the handle.

FIGURE 3-36 Dial torque wrench reading torque.

The dial torque wrench turns a dial that indicates the torque based on the torque being applied. Like the beam-style torque wrench, you have to be able to see the dial to know how much torque is being applied (**FIGURE 3-36**). Many dial torque wrenches have a movable indicator that is moved by the dial and stays at the highest reading. That way you can double-check the torque achieved once the torque wrench is released. Once the proper torque is reached, the indicator can be moved back to zero for the next fastener being torqued.

The digital torque wrench usually uses a spring steel bar with an electronic strain gauge to measure the amount of torque being applied. The torque wrench can be preset to the desired torque. It will then display the torque as the fastener is being tightened (**FIGURE 3-37**). When it reaches the preset torque, it usually gives an audible signal, such as a beep. This makes it useful in situations where a scale or dial cannot be read.

Torque wrenches fall out of calibration over time or if they are not used properly, so they should be checked and calibrated on a periodic basis (**FIGURE 3-38**). This can be performed in the shop if the proper calibration equipment is available, or the torque wrench can be sent to a qualified service center. Most quality torque wrench manufacturers provide a recalibration service for their customers.

Using Torque Wrenches

The torque wrench is used to apply a specified amount of torque to a fastener. There are various methods used by torque wrenches to indicate that the correct torque has been reached. Some give an audible signal, such as a click or a beep, whereas others give a visual signal such as a light or a pin moving or clicking out. Some provide a scale and needle that must be observed while you are torquing the fastener. To help ensure that the proper amount of torque gets from the torque wrench to the bolt, support the head

FIGURE 3-37 Digital torque wrench displaying torque.

FIGURE 3-38 Checking torque wrench calibration.

of the torque wrench with one hand (**FIGURE 3-39**). When using a torque wrench, it is best not to use extensions. Extensions make it harder to support the head, which can end up absorbing some of the torque. If possible, use a deep socket instead.

Pliers

K03008 Describe the type and use of pliers.

Pliers are a hand tool designed to hold, cut, or compress materials (**FIGURE 3-40**). They are usually made out of two pieces of strong steel joined at a fulcrum point, with jaws and cutting surfaces at one end and handles designed to provide leverage at the other. There are many types of pliers, including slip-joint, combination, arc joint, needle-nose, and flat-nose (**FIGURE 3-41**).

Quality **combination pliers** are one of the most commonly used pliers in a shop. They pivot together so that any force applied to the handles is multiplied in the strong jaws. Most combination pliers are designed so they have surfaces to both grip and cut. Combination pliers offer two gripping surfaces, one for gripping flat objects and one for gripping rounded objects, and one or two pairs of cutters. The cutters in the jaws should be used for softer materials that will not damage the blades. The cutters next to the pivot can shear through hard, thin materials, like steel wire or pins.

Most pliers are limited by their size in what they can grip. Beyond a certain point, the handles are spread too wide, or the jaws cannot open wide enough, but **arc joint pliers** overcome that limitation with a moveable pivot. Often, these are called Channellocks™ after the company that first made them. These pliers have parallel jaws that allow you to increase or decrease the size of the jaws by selecting a different set of channels (**FIGURE 3-42**). They are useful for a wider grip and a tighter squeeze on parts too big for conventional pliers.

Another type of pliers is **needle-nose pliers**, which have long, pointed jaws and can reach into tight spots or hold small items that other pliers cannot (**FIGURE 3-43**). For example, they can pick up a small bolt that has fallen into a tight spot. **Flat-nose pliers** have an end or nose that is flat and square; in contrast, combination pliers have a rounded end. A flat nose makes it possible to bend wire or even a thin piece of sheet steel accurately along a straight edge. **Diagonal cutting pliers** are used for cutting wire or cotter pins (**FIGURE 3-44**). Diagonal cutters are the most common cutters in the toolbox, but they should not be used on hard or heavy-gauge materials because the cutting surfaces will be damaged. End cutting pliers, also called **nippers**, have a cutting edge at right angles to their length (**FIGURE 3-45**). They are designed to cut through soft metal objects sticking out from a surface.

Snap ring pliers have metal pins that fit in the holes of a snap ring (**FIGURE 3-46**). Snap rings can be of the internal or external type. If internal, then internal snap ring pliers compress the snap ring so it can be removed from and installed in its internal groove. If external, then external snap ring pliers are used to expand the snap ring so it can

SAFETY TIP

When applying pressure to pliers, make sure your hands are not greasy, or they might slip. Select the right type and size of pliers for the job. As with most tools, if you have to exert almost all your strength to get something done, then you are using either the wrong tool or the wrong technique. If the pliers slip, you will get hurt. At the very least, you will damage the tool and what you are working on. Pliers get a lot of hard use in the shop, so they do get worn and damaged. If they are worn or damaged, they will be inefficient and can be dangerous. Always check the condition of all shop tools on a regular basis, and replace any that are worn or damaged.

FIGURE 3-39 It may be necessary to support the torque wrench when using extensions.

FIGURE 3-40 Pliers are used for grasping and cutting. These are slip-joint pliers.

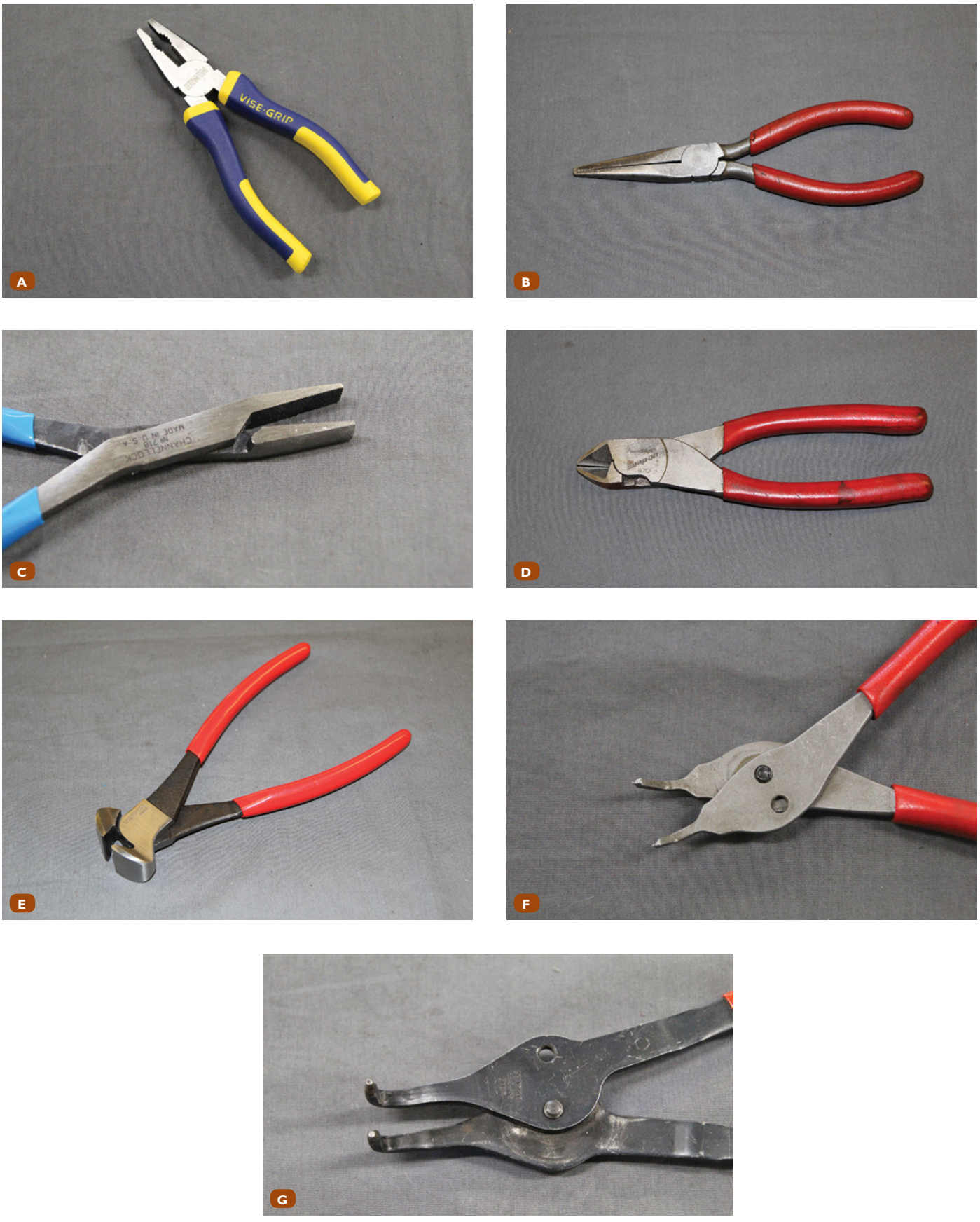


FIGURE 3-41 **A.** Combination pliers. **B.** Needle-nose pliers. **C.** Flat-nose pliers. **D.** Diagonal cutting pliers. **E.** Nippers. **F.** Internal snap ring pliers. **G.** External snap ring pliers.

FIGURE 3-42 Arc joint pliers.

FIGURE 3-43 Needle-nose pliers.

FIGURE 3-44 Diagonal side cutters.

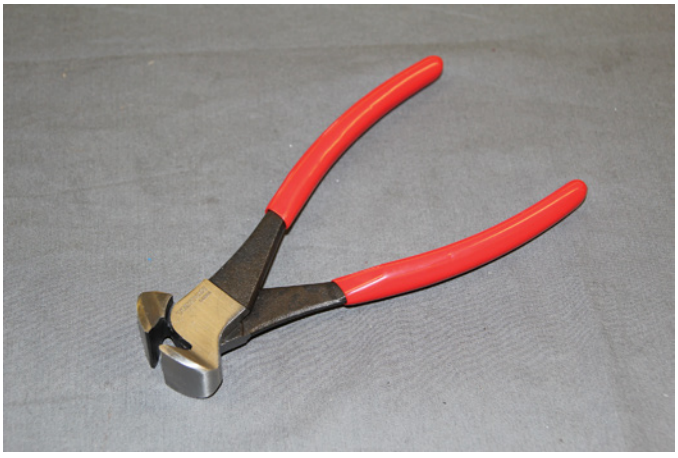


FIGURE 3-45 Nippers, or end cutting, pliers.

FIGURE 3-46 Snap ring pliers and snap ring.

FIGURE 3-47 Locking pliers.

remove and install the snap ring in its external groove. Always wear safety glasses when working with snap rings, as the snap rings can easily slip off the snap ring pliers and fly off at tremendous speeds, possibly causing severe eye injuries.

Locking pliers, also called vice grips, are general-purpose pliers used to clamp and hold one or more objects (**FIGURE 3-47**). Locking pliers are helpful by freeing up one or

more of your hands when you are working, because they can clamp something and lock themselves in place to hold it. They are also adjustable, so they can be used for a variety of tasks. To clamp an object with locking pliers, put the object between the jaws, turn the screw until the handles are almost closed, then squeeze them together to lock them shut. You can increase or decrease the gripping force with the adjustment screw. To release them, squeeze the release lever, and they should open right up.

Cutting Tools

K03009 Describe the type and use of cutting tools.

Bolt cutters cut heavy wire, non-hardened rods, and bolts (FIGURE 3-48). Their compound joints and long handles give the leverage and cutting pressure that is needed for heavy gauge materials. **Tin snips** are the nearest thing in the toolbox to a pair of scissors. They can cut thin sheet metal, and lighter versions make it easy to follow the outline of gaskets. Most snips come with straight blades, but if there is an unusual shape to cut, there is a pair with left- or right-handed curved blades. **Aviation snips** are designed to cut soft metals. They are easy to use because the handles are spring-loaded in the open position and double pivoted for extra leverage.

Allen Wrenches

K03010 Describe the type and use of Allen wrenches.

Allen wrenches, sometimes called Allen or hex keys, are tools designed to tighten and loosen fasteners with Allen heads (FIGURE 3-49). The Allen head fastener has an internal hexagonal recess that the Allen wrench fits in snugly. Allen wrenches come in sets, and there is a correct wrench size for every Allen head. They give the best grip on a screw or bolt of all the drivers, and their shape makes them good at getting into tight spots. Care must be taken to make sure the correct size of Allen wrench is used, or else the wrench and/or socket head will be rounded off. The traditional Allen wrench is a hexagonal bar with a right-angle bend at one end. They are made in various metric and standard sizes. As their popularity has increased, so too has the number of tool variations. Now Allen sockets are available, as are T-handle Allen keys (FIGURE 3-50).

K03011 Describe the type and use of screwdrivers.

Screwdrivers

The correct screwdriver to use depends on the type of slot or recess in the head of the screw or bolt, and how accessible it is (FIGURE 3-51). Most screwdrivers cannot grip as securely as wrenches, so it is very important to match the tip of the screwdriver exactly with the slot or recess in the head of a fastener. Otherwise, the tool might slip, damaging the fastener or the tool and possibly injuring you. When using a screwdriver, always check where the screwdriver blade can end up if it slips off the head of the screw. Many technicians who have not taken

FIGURE 3-48 **A.** Bolt cutters. **B.** Tin snips. **C.** Aviation snips.

FIGURE 3-49 Typical Allen wrench head.

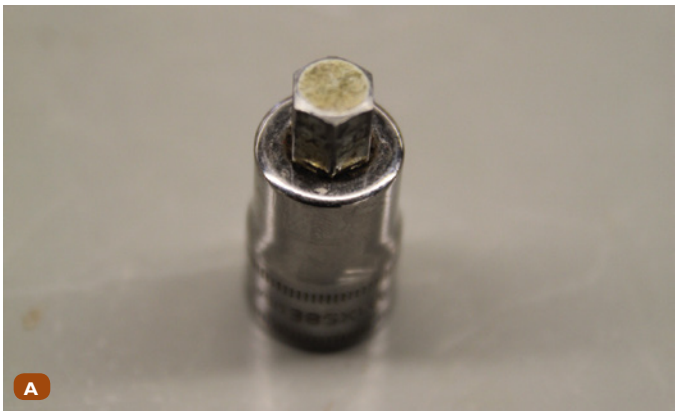
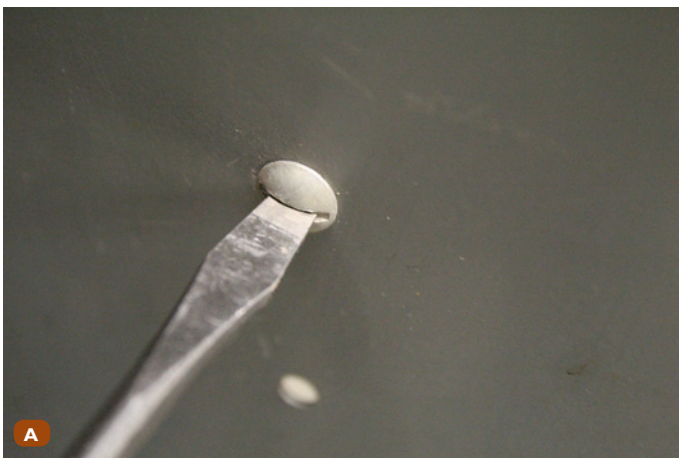


FIGURE 3-50 **A.** Allen socket. **B.** T-handle Allen wrench.

this precaution have stabbed a screwdriver into or through their hand, which can be painful as well as become infected or damage nerves.

The most common screwdriver has a flat tip, or blade, which gives it the name **flat blade screwdriver**. The blade should be almost as wide and thick as the slot in the fastener so that twisting force applied to the screwdriver is transferred right out to the edges of the head, where it has most effect. The blade should be a snug fit in the slot of the screw head. Then the twisting force is applied evenly along the sides of the slot. This guards against the screwdriver suddenly chewing a piece out of the slot and slipping just when the most force is being exerted. Flat blade screwdrivers come in a variety of sizes and lengths, so find the right one for the job. If viewed from the side, the blade should taper slightly to the very end where the flat tip fits into the slot. If the tip of the blade is not clean and square, it should be reshaped or replaced.

When you use a flat blade screwdriver, support the shaft with your free hand as you turn it (but keep it behind the tip). This helps keep the blade square in the slot and centered. Screwdrivers that slip are a common source of damage and injury in shops. A screw or bolt with a cross-shaped recess requires a **Phillips head screwdriver** or a Pozidriv screwdriver (**FIGURE 3-52**). The cross-shaped slot holds the tip of the screwdriver securely on the head. The Phillips tip fits a tapered recess, whereas the Pozidriv fits into slots with parallel sides in the head of the screw. Both a Phillips and a Pozidriv screwdriver are less likely to slip sideways, because the point is centered in the screw, but again the screwdriver must be the



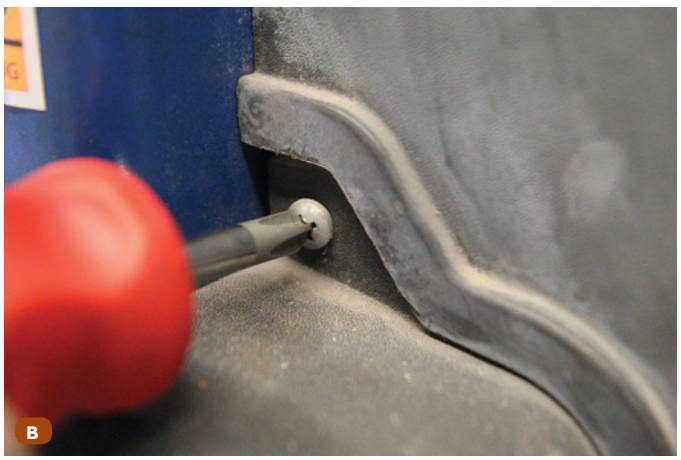


FIGURE 3-51 **A.** Slotted screw and screw driver. **B.** Phillips screw and screw driver.

FIGURE 3-52 **A.** Flat blade screwdrivers. **B.** Phillips screwdriver. **C.** Pozidriv screwdriver.

FIGURE 3-53 Four sizes of Phillips screwdrivers.

right size. The fitting process is simplified with these two types of screwdrivers because four sizes are enough to fit almost all fasteners with this sort of screw head (**FIGURE 3-53**).

The **offset screwdriver** fits into spaces where a straight screwdriver cannot and is useful where there is not much room to turn it (**FIGURE 3-54**). The two tips look identical, but one is set at 90 degrees to the other. This is because sometimes there is only room to make a quarter turn of the driver. Thus the driver has two blades on opposite ends so that offset ends of the screwdriver can be used alternately.

The **ratcheting screwdriver** is a popular screwdriver handle that usually comes with a selection of removable flat and Phillips tips. It has a ratchet inside the handle that turns the blade in only one direction, depending on how the slider is set. When set for loosening, a screw can be undone without removing the tip of the blade from the head of the screw. When set for tightening, a screw can be inserted just as easily.

An **impact driver** is used when a screw or a bolt is rusted/corroded in place or over-tightened, and needs a tool that can apply more force than the other members of this family. Screw slots can easily be stripped with the use of a standard screwdriver. The force of the hammer forcing the bit into the screw while turning it makes it more likely the screw

FIGURE 3-54 **A.** Offset screwdriver. **B.** Ratcheting screwdriver. **C.** Impact driver.

will break loose. The impact driver accepts a variety of special impact tips. Choose the right one for the screw head, fit the tip in place, and then tension it in the direction it has to turn. A sharp blow with the hammer breaks the screw free, and then it can usually be unscrewed normally.

Magnetic Pickup Tools and Mechanical Fingers

Magnetic pickup tools and **mechanical fingers** are very useful for grabbing items in tight spaces (**FIGURE 3-55**). A magnetic pickup tool typically is a telescoping stick that has a magnet attached to the end on a swivel joint. The magnet is strong enough to pick up screws, bolts, sockets, and other ferrous (containing iron, making it magnetic) metals. For example, if a screw is dropped into a tight crevice where your fingers cannot reach, a magnetic pickup tool can be used to extract it.

Mechanical fingers are also designed to extract or insert objects in tight spaces. Because they actually grab the object, they can pick up nonmagnetic objects, which makes them handy for picking up rubber or plastic parts. They use a flexible body and come in different lengths, but typically are about 12–18" (305–457 mm) long. They have expanding grappling fingers on one end to grab items, and the other end has a push mechanism to expand the fingers and a retracting spring to contract the fingers.

K03012 Describe type and use of magnetic pickup tools and mechanical fingers.

SAFETY TIP

The hammer you use depends on the part you are striking. Hammers with a metal face should almost always be harder than the part you are hammering. Never strike two hardened tools together, as this can cause the hardened parts to shatter.

Hammers

Hammers are a vital part of the shop tool collection, and a variety are commonly used (**FIGURE 3-56**). The most common hammer in an automotive shop is the **ball-peen (engineer's) hammer**. Like most hammers, its head is hardened steel. A punch or a chisel can be driven with the flat face. Its name comes from the ball peen or rounded face. This end is usually used for flattening or **peening** a rivet. The hammer should always match the size of the job, and it is usually better to use one that is too big than too small.

Hitting chisels with a **steel hammer** is fine, but sometimes you only need to tap a component to position it. A steel hammer might mark or damage the part, especially if it is made of a softer metal, such as aluminum. In such cases, a soft-faced hammer should normally be used for the job. Soft-faced hammers range from very soft with rubber or plastic heads to slightly harder with brass or copper.

When a large chisel needs a really strong blow, it is time to use a **sledgehammer**. The sledgehammer is like a small mallet, with two square faces made of high carbon steel. It is the heaviest type of hammer that can be used one-handed. The sledgehammer is used in conjunction with a chisel to cut off a bolt where corrosion has made it impossible to remove the nut.

A **dead blow hammer** is designed not to bounce back when it hits something. A rebounding hammer can be dangerous or destructive. A dead blow hammer can be made

K03013 Describe the type and use of hammers.

▶ TECHNICIAN TIP

It may be challenging getting the magnet down inside some areas because the magnet wants to keep sticking to other objects. One trick in this situation is to roll up a piece of paper so that a tube is created. Stick that down into the area of the dropped part, then slide the magnet down the tube, which helps it get past magnetic objects. Once the magnet is down, you may want to remove the roll of paper. Just remember two things: First, patience is important when using this tool, and second, don't drop anything in the first place!

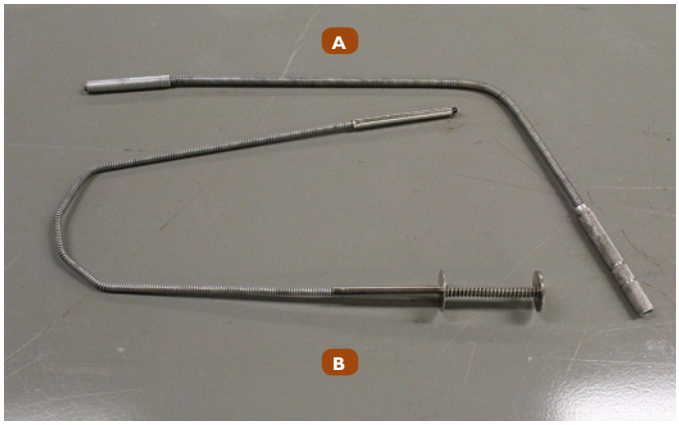


FIGURE 3-55 **A.** Magnetic pickup tools. **B.** Mechanical fingers.

FIGURE 3-56 **A.** Ball peen hammer. **B.** Sledge hammer. **C.** Soft-faced hammer. **D.** Dead blow hammer.

with a lead head or, more commonly, a hollow polyurethane head filled with lead shot or sand. The head absorbs the blow when the hammer makes contact, reducing any bounce-back or rebounding. This hammer can be used when working on the vehicle chassis or when dislodging stuck parts.

A **hard rubber mallet** is a special-purpose tool and has a head made of hard rubber. It is often used for moving things into place where it is important not to damage the item being moved. For example, it can be used to install a hubcap or to break a gasket seal on an aluminum housing.

SAFETY TIP

When using hammers and chisels, always wear safety glasses. Also be aware that safety glasses by themselves need to be form fitting and must not be allowed to slide down your nose, for them to be effective. It may be prudent to wear either a face shield or safety goggles for extra protection.

K03014 Describe the type and use of chisels.

Chisels

The most common kind of chisel is a **cold chisel** (**FIGURE 3-57**). It gets its name from the fact it is used to cut cold metals rather than heated metals. It has a flat blade made of high-quality steel and a cutting angle of approximately 70 degrees. The cutting end is tempered and hardened because it has to be harder than the metals it is cutting. The head of the chisel needs to be softer so it will not chip when it is hit with a hammer. Technicians sometimes use a cold chisel to remove bolts whose heads have rounded off.

A variation of the cold chisel is a spring-loaded cold chisel (**FIGURE 3-58**). This chisel works really well in tight spaces where a hammer can't be swung. The chisel is made up of three parts: the chisel, the weighted hammerhead, and a spring in tension, holding the other two components together. It is operated by holding the chisel end against the part you are working on, pulling back on the hammerhead, and allowing the spring to rapidly slam the hammerhead into the end of the chisel. The force of the hammerhead hitting the end of the chisel transfers a lot of energy to the chisel. This type of arrangement is also used on some spring-loaded center punches.

A **cross-cut chisel** is so named because the sharpened edge is across the blade width. This chisel narrows down along the stock, so it is good for getting in grooves. It is used for cleaning out or even making key ways. The flying chips of metal should always be directed away from the user.

SAFETY TIP

Chisels and punches are designed with a softer striking end than hammers. Over time, this softer metal "mushrooms," and small fragments are prone to breaking off when hammered. These fragments can cause eye or other penetrative injuries to people in the area. Always inspect chisels and punches for mushrooming, and dress them on a grinder when necessary (**FIGURE 3-59**).

K03015 Describe the type and use of punches.

Punches

Punches are used when the head of the hammer is too large to strike the object being hit without causing damage to adjacent parts. A punch transmits the hammer's striking power from the soft upper end down to the tip that is made of hardened high-carbon steel. A punch transmits an accurate blow from the hammer at exactly one point, something that cannot be guaranteed using a hammer on its own.

Four of the most common punches are the prick punch, center punch, drift punch, and pin punch (**FIGURE 3-60**). When marks need to be drawn on an object like a steel plate, to help locate a hole to be drilled, a **prick punch** can be used to mark the points so they will not rub off. They can also be used to scribe intersecting lines between given points. The

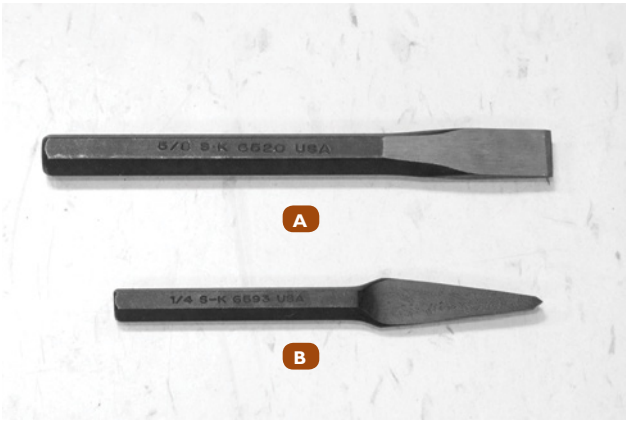


FIGURE 3-57 **A.** Cold chisel. **B.** Cross-cut chisel.

FIGURE 3-58 Spring-loaded chisels.

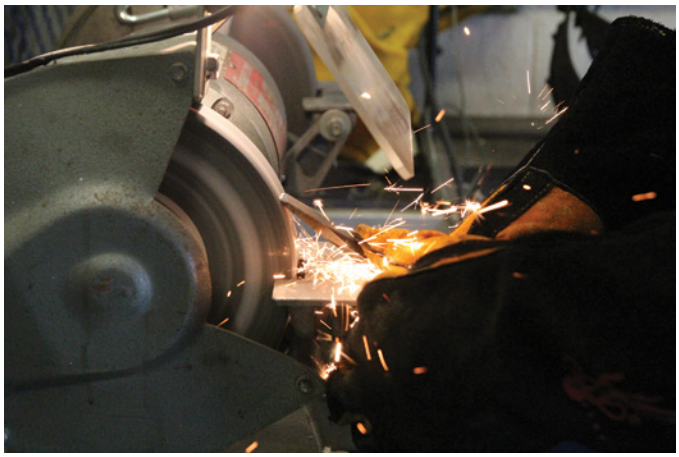


FIGURE 3-59 Dressing a chisel.

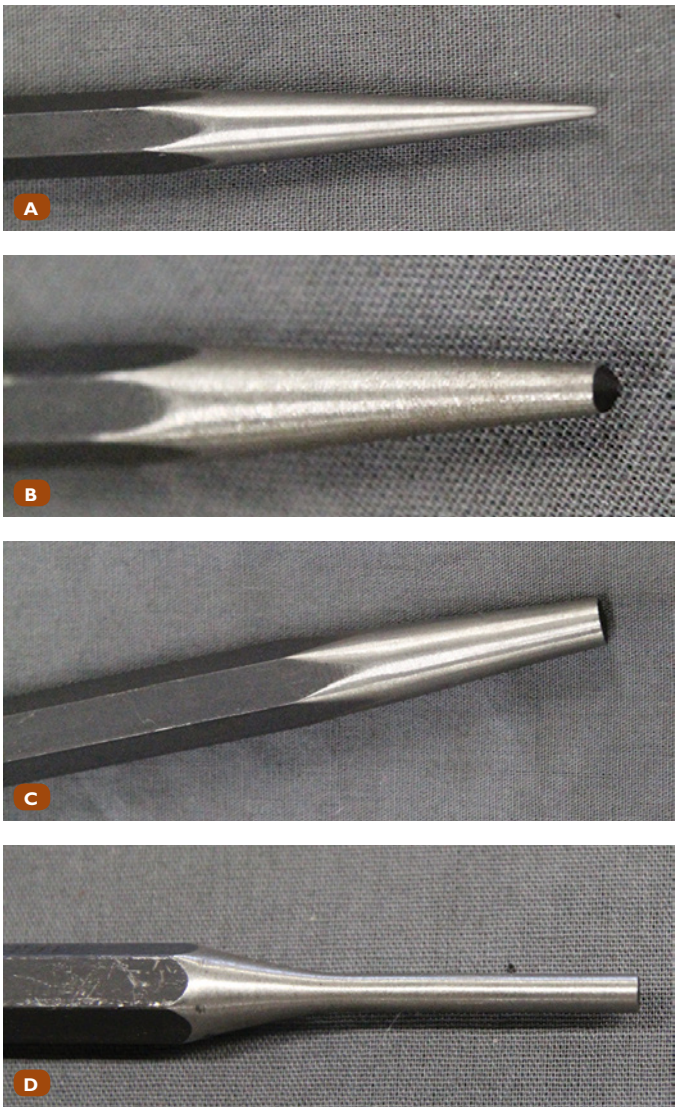


FIGURE 3-60 **A.** Prick punch. **B.** Center punch. **C.** Drift punch. **D.** Pin punch.

prick punch's point is very sharp, so a gentle tap leaves a clear indentation. The **center punch** is not as sharp as a prick punch and is usually bigger. It makes a bigger indentation that centers a drill bit at the point where a hole is required to be drilled.

Although most center punches are used with a hammer, some center punches operate automatically when the punch is pressed tightly up against the part you are punching. This type of punch has a spring and weighted hammer inside of the back end of the center punch. It is machined in such a way that pushing the center punch against a surface compresses a spring behind a movable weight (**FIGURE 3-61**). When pushed far enough, the weight is released, and the spring forces it against the center rod in the punch, causing it to indent the work surface.

A **drift punch** is also named a starter punch because you should always use it first to get a pin moving. It has a tapered shank, and the tip is slightly hollow so it does not spread the end of a pin and make it an even tighter fit. Once the starter drift has gotten the pin moving, a suitable pin punch will drive the pin out or in. A drift punch also works well for aligning holes on two mating objects, such as a valve cover and cylinder head. Forcing the drift punch in the hole aligns both components for easier installation of the remaining bolts. **Pin punches** are available in various diameters. A pin punch has a long slender shaft that has straight sides. It is used to drive out pins or rivets (**FIGURE 3-62**). A lot of components are either held together or accurately located by pins. Pins can be pretty tight, and a group of pin punches is specially designed to deal with them.

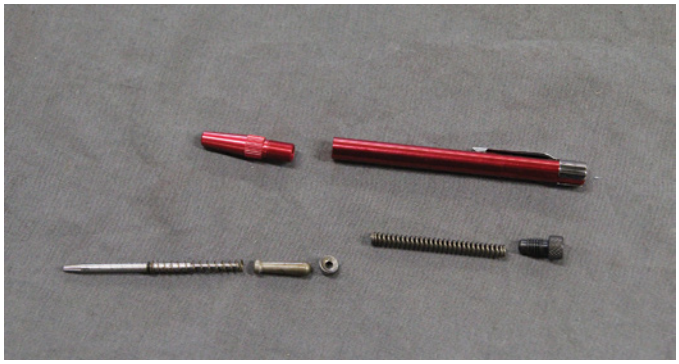


FIGURE 3-61 Internal workings of an automatic center punch.

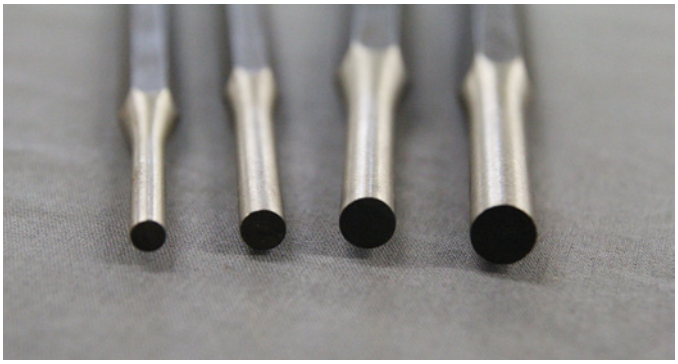


FIGURE 3-62 Various pin punches.

FIGURE 3-63 Wad punch.

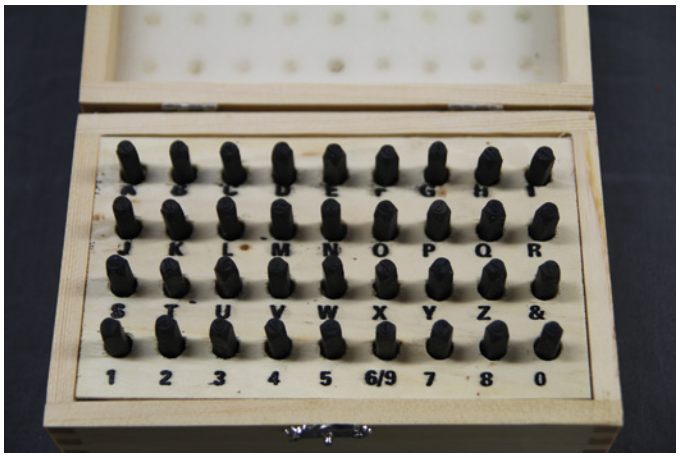


FIGURE 3-64 Number and letter punches.

▶ TECHNICIAN TIP

Many engine components are made of aluminum. Because aluminum is quite soft, it is critical that you use the gasket scraper very carefully so as not to damage the surface. This can be accomplished by keeping the gasket scraper at a fairly flat angle to the surface. Also, the gasket scraper should only be used by hand, not with a hammer. Some manufacturers specify using plastic gasket scrapers only on certain aluminum components such as cylinder heads and blocks.

Special punches with hollow ends are called **wad punches** or **hollow punches** (**FIGURE 3-63**). They are the most efficient tool to make a hole in soft sheet material like shim steel, plastic, and leather, or, most commonly, in a gasket. When being used, there should always be a soft surface under the work, ideally the end grain of a wooden block. If a hollow punch loses its sharpness or has nicks around its edge, it will make a mess instead of a hole.

Numbers and letters, like the engine numbers on some cylinder blocks, are usually made with number and letter punches that come in boxed sets (**FIGURE 3-64**). The rules for using a number or letter punch set are the same as for all punches. The punch must be square with the surface being worked on, not on an angle, and the hammer must hit the top squarely.

Pry Bars

K03016 Describe the type and use of pry bars.

Pry bars are tools constructed of strong metal that are used as a lever to move, adjust, or pry (**FIGURE 3-65**). Pry bars come in a variety of shapes and sizes. Many have a tapered end that is slightly bent, with a plastic handle on the other end. This design works well for applying force to tension belts or for moving parts into alignment. Another type of pry bar is the **roll bar**. One end is sharply curved and tapered, which is used for prying. The other end is tapered to a dull point and is used to align larger holes such as transmission bell housings or engine motor mounts. Because pry bars are made of hardened steel, care should be taken when using them on softer materials, to avoid any damage.

Gasket Scrapers

K03017 Describe the type and use of gasket scrapers.

A **gasket scraper** has a hardened, sharpened blade. It is designed to remove a gasket without damaging the sealing face of the component when used properly (**FIGURE 3-66**). On

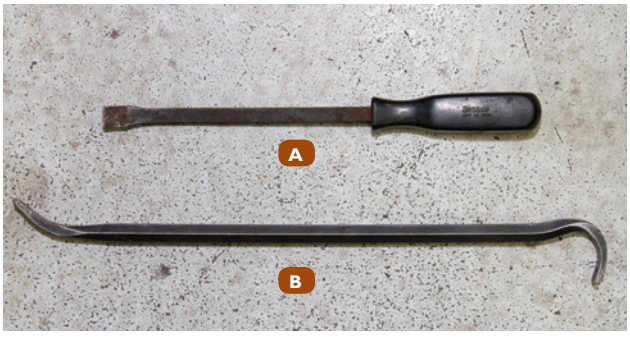


FIGURE 3-65 **A.** Pry bar. **B.** Roll bar.

FIGURE 3-66 A gasket scraper.

one end, it has a comfortable handle like a screwdriver handle; on the other end, a blade is fitted with a sharp edge to assist in the removal of gaskets. The gasket scraper should be kept sharp and straight to make it easy to remove all traces of the old gasket and sealing compound. The blades come in different sizes, with a typical size being 1" (25 mm) wide. Whenever you use a gasket scraper, be very careful not to nick or damage the surface being cleaned.

Files

K03018 Describe the type and use of files.

Files are hand tools designed to remove small amounts of material from the surface of a workpiece. Files come in a variety of shapes, sizes, and coarseness depending on the material being worked and the size of the job. Files have a pointed tang on one end that is fitted to a handle. Files are often sold without handles, but they should not be used until a handle of the right size has been fitted. A correctly sized handle fits snugly without working loose when the file is being used. Always check the handle before using the file. If the handle is loose, give it a sharp rap to tighten it up, or if it is the threaded type, screw it on tighter. If it fails to fit snugly, you must use a different-size handle.

What makes one file different from another is not just the shape but how much material it is designed to remove with each stroke. The teeth on the file determine how much material will be removed (**FIGURE 3-67**). Because the teeth face one direction only, the file cuts in one direction only. Dragging the file backward over the surface of the metal only dulls the teeth and wears them out quickly. Teeth on a coarse-grade file are larger, with a greater space between them. A coarse-grade file working on a piece of mild steel removes a lot of material with each stroke, but it leaves a rough finish. A smooth-grade file has smaller teeth cut more closely together. It removes much less material on each stroke, but the finish is much smoother. On many jobs, the coarse file is used first to remove material quickly, and then a smoother file gently removes the remaining material and leaves a smoother finish to the work. The full list of grades in flat files, from rough to smooth, follows:

- **Rough files** have the coarsest teeth, with approximately 20 teeth per inch (25 mm). They are used when a lot of material must be removed quickly. They leave a very rough finish and have to be followed by the use of finer files to produce a smooth final finish.
- **Coarse bastard files** are still a coarse file, with approximately 30 teeth per inch (25 mm), but they are not as course as the rough file. They are also used to rough out or remove material quickly from the job.
- **Second-cut files** have approximately 40 teeth per inch (25 mm) and provide a smoother finish than the rough or coarse bastard file. They are good all-round intermediary files and leave a reasonably smooth finish.
- **Smooth files** have approximately 60 teeth per inch (25 mm) and are a finishing file used to provide a smooth final finish.
- **Dead smooth files** have 100 teeth per inch (25mm) or more and are used where a very fine finish is required.

SAFETY TIP

Hands should always be kept away from the surface of the file and the metal that is being worked on. It is easy for skin to get caught between the edge of the file and the piece you are working. This creates a scissor-like condition that can result in severe cuts. Also, filing can produce small slivers of metal that penetrate your skin and can be difficult to remove from a finger or hand.

Some flat files are available with one smooth edge (no teeth), called safe edge files. They allow filing up to an edge without damaging it. Flat files work well on straightforward jobs, but some jobs require special files. A **warding file** is thinner than other files and comes to a point; it is used for working in narrow slots (**FIGURE 3-68**). A **square file** has teeth on all four sides, so you can use it in a square or rectangular hole. A square file can make the right shape for a squared metal key to fit in a slot.

A **triangular file** has three sides. It is triangular, so it can get into internal corners easily. It is able to cut right into a corner without removing material from the sides. **Curved files** are typically either half-round or round. A half-round file has a shallow convex surface that can file in a concave hollow or in

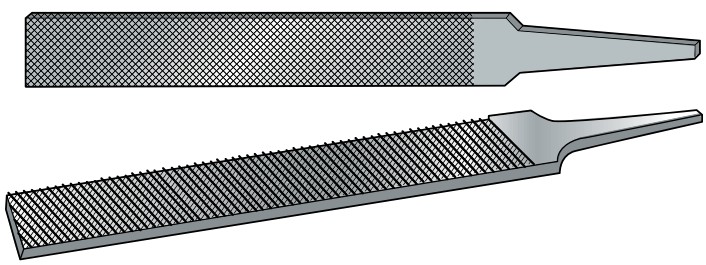


FIGURE 3-67 The teeth on a file determine how much material will be removed from the object being filed.

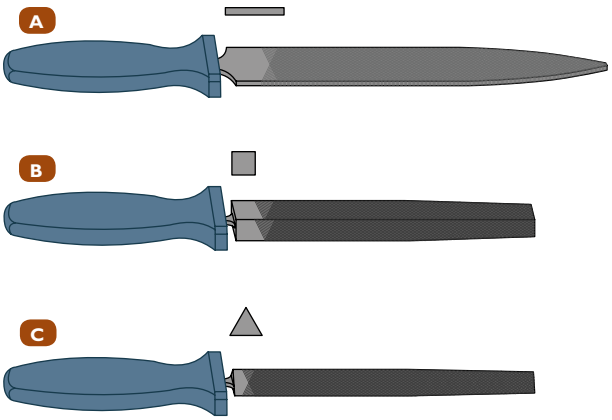


FIGURE 3-68 **A.** Warding file. **B.** Square file. **C.** Triangular file.

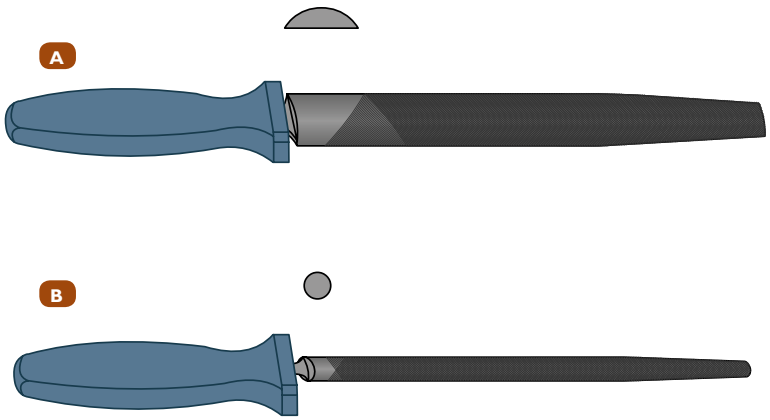


FIGURE 3-69 **A.** Half-round file. **B.** Round, or rat-tail, file.

an acute internal corner (**FIGURE 3-69**). The fully round file, sometimes called a rat-tail file, can make holes bigger. It can also file inside a concave surface with a tight radius.

The **thread file** cleans clogged or distorted threads on bolts and studs. Thread files come in either standard or metric configurations, so make sure you use the correct file. Each file has eight different surfaces that match different thread dimensions, so the correct face must be used (**FIGURE 3-70**).

Files should be cleaned after each use. If they are clogged, they can be cleaned by using a file card, or file brush (**FIGURE 3-71**). This tool has short steel bristles that clean out the small particles that clog the teeth of the file. Rubbing a piece of chalk over the surface of the file prior to filing makes it easier to clean.

Clamps

K03019 Describe the type and use of clamps.

There are many types of vices or clamps available (**FIGURE 3-72**). The **bench vice** is a useful tool for holding anything that can fit into its jaws. Some common uses include sawing, filing, or chiseling. The jaws are serrated to give extra grip. They are also very hard, which means that when the vice is tightened, the jaws can mar whatever they are gripping. To prevent this, a pair of soft jaws can be fitted whenever the danger of damage arises. They are usually made of aluminum or some other soft metal or can have a rubber-type surface applied to them.

When materials are too awkward to grip vertically in a plain vice, it may be easier to use an **offset vice**. The offset vice has its jaws set to one side to allow long components to be held vertically (**FIGURE 3-73**). For example, a long threaded bar can be held vertically in an offset vice to cut a thread with a die.

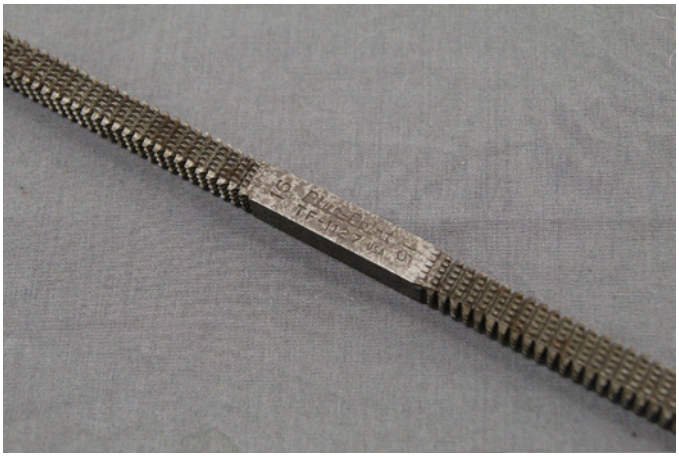


FIGURE 3-70 Thread file.

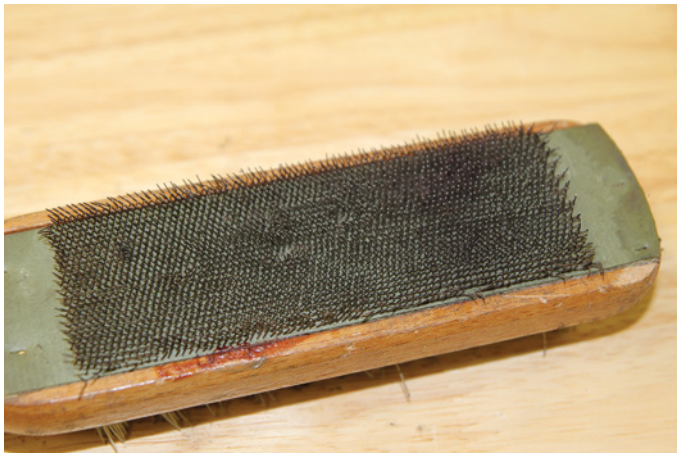


FIGURE 3-71 File card.

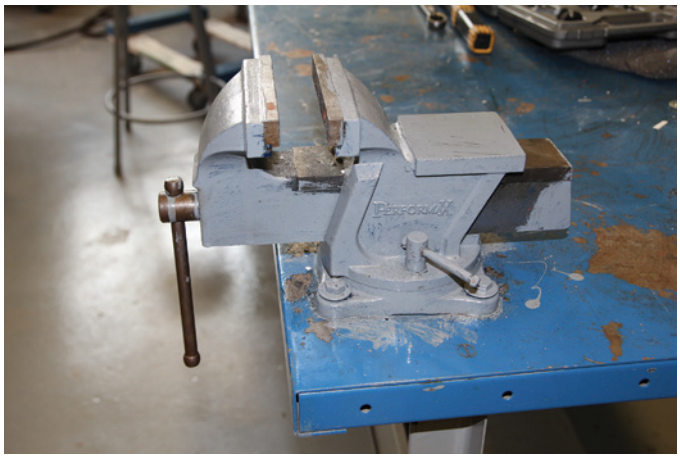


FIGURE 3-72 Bench vice.

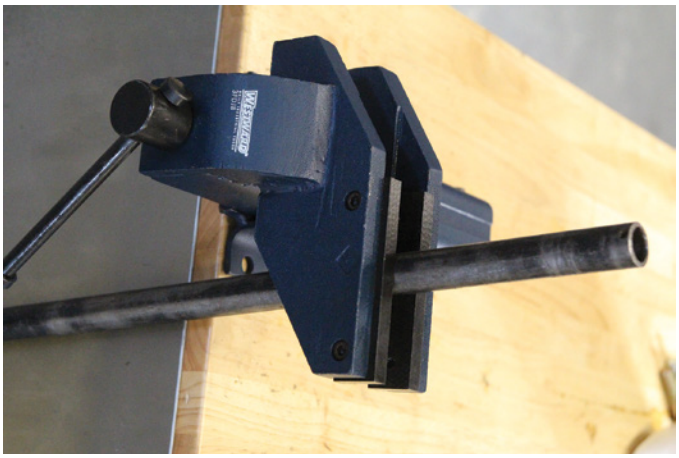


FIGURE 3-73 Offset vice being used to hold a pipe.

A **drill vice** is designed to hold material on a drill worktable (**FIGURE 3-74**). The drill worktable has slots cut into it to allow the vice to be bolted down on the table, to hold material securely. To hold something firmly and drill it accurately, the object must be secured in the jaws of the vice. The vice can be moved on the bed until the precise drilling point is located and then tightened down by bolts to hold the drill vice in place during drilling.

The name for the **C-clamp** comes from its shape (**FIGURE 3-75**). It can hold parts together while they are being assembled, drilled, or welded. It can reach around awkwardly shaped pieces that do not fit in a vice. It is also commonly used to retract disc brake caliper pistons. This clamp is portable, so it can be taken to the work.

Taps and Dies

K03020 Describe the type and use of taps and dies.

Taps and dies are used to form threads in metal so that they can be fastened together (**FIGURE 3-76**). The tap cuts female threads in a component so a fastener can be screwed into it. The die is used to cut male threads on a bolt so that it can be screwed into the female threads created by the tap. The tap and die are companion tools that create matching threads so that they can both be used to fasten things together.

Taps

Various types of taps are designed to be used based on what you want to do and the material you are working with. The most common taps are the taper tap, intermediate tap (also called a plug tap), bottoming tap (also called a flat-bottomed tap), and the thread chaser (**FIGURE 3-77**). These are explored in more depth below.

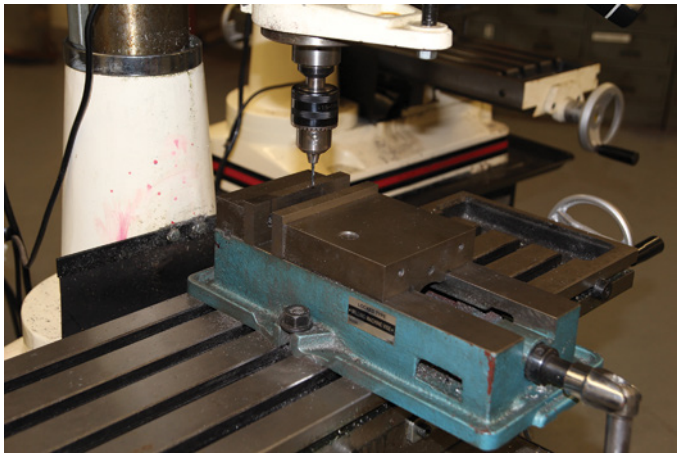


FIGURE 3-74 Drill vice on a drill worktable.

FIGURE 3-75 C-Clamp.

FIGURE 3-76 **A.** Tap. **B.** Die.

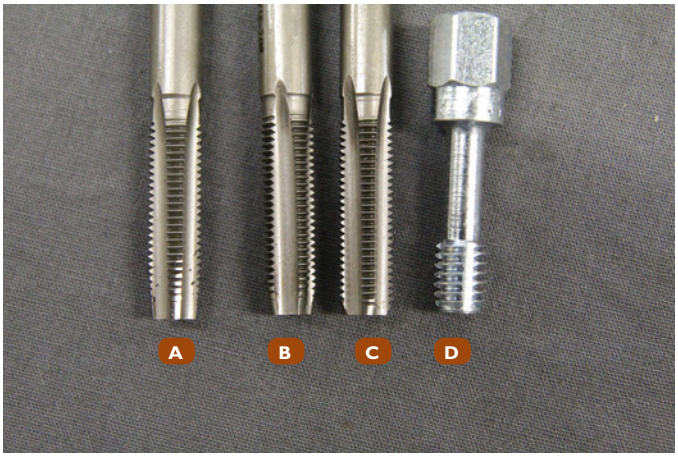


FIGURE 3-77 **A.** Taper tap. **B.** Intermediate tap. **C.** Bottoming tap. **D.** Thread chaser.

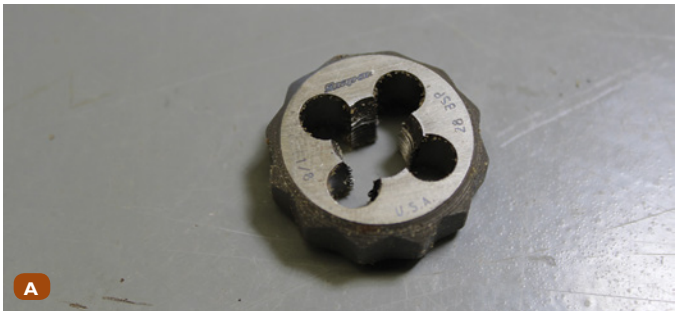


FIGURE 3-78 **A.** Die nut. **B.** Split die.

Taper Tap

A **taper tap** narrows at the tip, which makes it easier to start straight when cutting threads in a new hole. It also makes it less likely to break the tip off the tap because it removes metal in a less aggressive manner. Taps are very hard, which gives them good wear resistance but also makes them very brittle; they can break off easily. If a tap breaks in the hole, it can be very hard to remove. This makes taper taps good taps to use when starting a hole. Plus, they are easier to get started straight in the hole.

Intermediate Tap

The second type of tap is an **intermediate tap**, also known as a plug tap. It is more aggressive than a taper tap, but not as aggressive as a bottoming tap. This is the most common tap used by technicians. Although it is a bit more aggressive than the taper tap, it can be used as a starter tap for a new hole.

Bottoming Tap

The **bottoming tap** is used when you need to cut threads to the very bottom of a blind hole and in holes that already have threads started that just need to be extended slightly. It has a flat bottom. and the threads are the same all the way to the end. This type of tap is virtually impossible to use in a new, unthreaded hole.

Thread Chaser

Thread chasers are used to clean up the threads of a hole to make sure they are free from debris and dirt. They do not cut threads, but just clean up the existing threads so that the bolt doesn't encounter any excessive resistance.

Dies

A **die** is used to cut external threads on a metal shank or bolt. The threads in a die create the male companion to the female threads that have been cut into the material by a tap. Usually the dies come with a setscrew that allows the user to slightly adjust the size of the die so the threads can be cut to the right fit that matches the threaded hole. Loose-fitting threads strip more easily than they should and are not as secure. Tight-fitting threads increase the torque required to turn the bolt, thereby reducing the clamping force relative to bolt torque. So adjusting thread fit is typically accomplished by adjusting the die. Dies are hardened, which makes them very wear resistant, but very brittle. Die nuts do not have the split like the threading die does because they are used to clean up threads like the thread chasers (**FIGURE 3-78**).

Proper Use of Taps and Dies

The proper use of taps and dies is a major issue often overlooked in repairing a thread on a bolt or threads in a hole. Improper use of these two items causes the bolt not to thread into the hole properly, or it could even break the tool, which is something to avoid. Both of these tools are made of hardened steel, which makes them very wear resistant but also makes them very brittle. If they are used improperly they have a tendency to facture and break.

Because taps and dies both need to be rotated, special tools are used to turn them. A **tap handle** is used to turn taps. It has a right-angled jaw that matches the squared end of all the taps (**FIGURE 3-79**). The jaws are designed to hold the tap securely, and the handles provide the leverage for the operator to comfortably rotate the tap to cut the thread. To cut a thread in an awkward space, a T-shaped tap handle is very convenient (**FIGURE 3-80**). Its handle is not as long, so it fits into tighter spaces; however, it is harder to turn and to guide accurately.

To cut a brand new thread on a blank rod or shaft, a die held in a **die stock** is used (**FIGURE 3-81**). The die fits into the octagonal recess in the die stock and is usually held in place by a thumb screw. The die may be split so that it can be adjusted more tightly onto the work with each pass of the die as the thread is cut deeper and deeper, until the external thread fits the threaded hole properly.

When tapping a hole, the diameter of the hole is determined by a tap drill chart, which can be obtained from engineering suppliers. This chart shows what hole size has to be drilled and what tap size is needed to cut the right thread for any given bolt size (**FIGURE 3-82**).

Just remember that if you are drilling a 1/4" (6 mm) or larger hole, use a smaller pilot drill first. Once the properly sized hole has been drilled, the taper tap or intermediate tap can be started in the hole. Make sure to use the proper lubricant for the metal you are tapping. Also be sure to start the tap straight. The best way to do that is to start the tap about one turn, stop, and then use a square to check the position of the tap in two places 90 degrees apart. If it isn't perfectly straight, you can usually straighten it while turning it another half turn. Again stop and verify that it is straight in two positions, 90 degrees apart. If the tap is straight, turn the tap about one full turn, and then back it off about a quarter turn. Continue cutting and backing off the tap until either the tap turns easily or you are at the bottom of the hole. Remove the tap. If you are cutting threads in a blind hole, you need to use a bottoming tap to finish the threads off. If not, clean the threaded hole and test-fit a bolt in the hole to check the threads. The bolt should turn smoothly by hand.

FIGURE 3-79 Tap handle.

FIGURE 3-80 T-shaped tap handle.

FIGURE 3-81 Die stock.

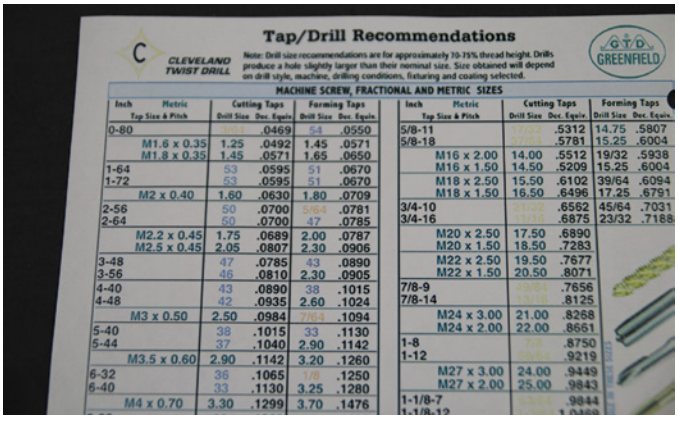


FIGURE 3-82 Tap drill chart.

Screw Extractors

Screw extractors are devices designed to remove screws, studs, or bolts that have broken off in threaded holes. A common type of extractor uses a coarse left-hand tapered thread formed on its hardened body (**FIGURE 3-83**). Normally, a hole is drilled in the center of the broken screw, and then the extractor is screwed into the hole. The left-hand thread grips the broken part of the bolt and unscrews it. The extractor is marked with two sizes: one showing the size range of screws it is designed to remove, and the other, the size of the hole that needs to be drilled. It is important to carefully drill the hole in the center of the bolt or

K03021 Describe the type and use of screw extractors.

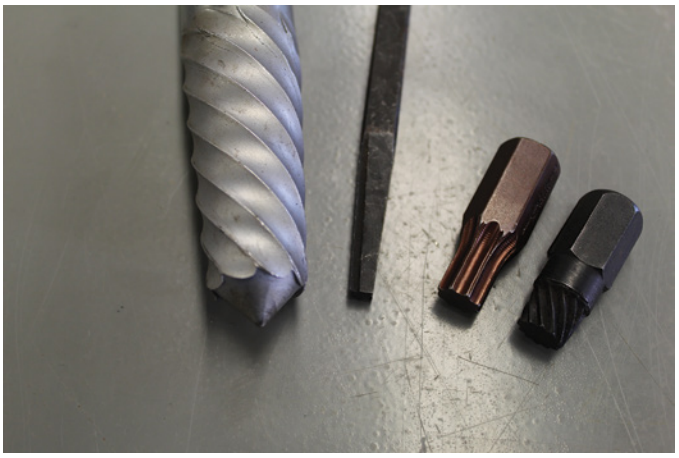


FIGURE 3-83 Screw extractors.

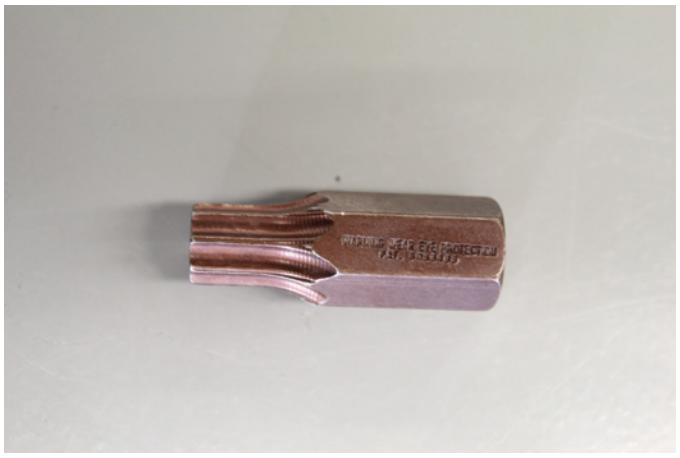


FIGURE 3-84 Straight-sided screw extractor.

stud in case you end up having to drill the bolt out. If you drill the hole off center, you will not be able to drill it out all the way to the inside diameter of the threads, as the hole is offset from center. This makes removal of the bolt much harder.

Some screw extractors use a hardened, tapered square shank that is hammered into a hole drilled into the center of the broken off bolt. The square edges of the screw extractor cut into the bolt and are used to grip it so it can be removed. Another type of screw extractor is the straight-sided, vertically splined, round shaft. The sides of the shaft have straight splines running the length of the extractor (**FIGURE 3-84**). It doesn't taper, so it is strong up and down its length. A straight hole of the correct diameter is drilled into the broken-off bolt. Then the extractor is driven into the newly drilled hole. The vertical splines, being larger than the hole, grab onto the bolt, allowing it to be unthreaded.

Pullers

K03022 Describe the type and use of pullers.

Pullers are a very common universal tool that can be used for removing bearings, bushings, pulleys, and gears (**FIGURE 3-85**). Specialized pullers are also available for specific tasks where a standard puller is not as effective. The most common pullers have two or three legs that grip the part to be removed. A center bolt, called a forcing screw or jacking bolt, is then screwed in, producing a jacking or pulling action, which extracts the part. **Gear pullers** come in a range of sizes and shapes, all designed for particular applications. They consist of three main parts: jaws, a cross-arm, and a forcing screw. There are normally two or three jaws on a puller. They are designed to connect to the component either externally or internally.

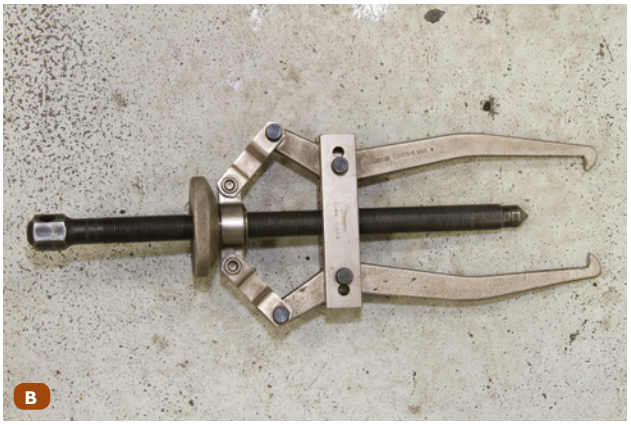


FIGURE 3-85 **A.** Puller. **B.** Gear puller.

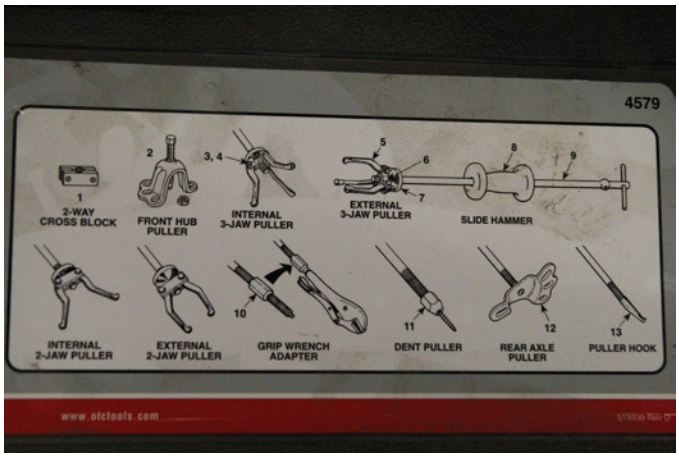


FIGURE 3-86 Interchangeable feet for the gear puller.

FIGURE 3-87 Four-arm puller.

The **forcing screw** is a long, fine-threaded bolt that is applied to the center of the cross-arm. When the forcing screw is turned, it applies a very large force to the component you are removing. The forcing screw typically has interchangeable feet (**FIGURE 3-86**). A tapered cone style of foot does a good job of centering the puller, but it also creates a very large wedging effect, which can distort the end of the shaft. A flat-style foot is very good for pushing against the end of a shaft, but doesn't center itself. In either situation, the wrong foot size can push on the internal threads of the shaft, damaging them. The cross-arm attaches the jaws to the forcing screw. If the **cross-arm** has four arms, three of the arms are spaced 120 degrees apart. The fourth arm is positioned 180 degrees apart from one arm (**FIGURE 3-87**). This allows the cross-arm to be used as either a two- or a three-arm puller.

Using Gear Pullers

Gear and bearing pullers are designed for hundreds of applications. Their main purpose is to remove a component such as a gear, pulley, or bearing from a shaft; or to remove a shaft from inside a hole. Normally these components have been pressed onto that shaft or into the hole, so removing them requires considerable force. To select, install, and use a gear puller to remove a pulley, follow the steps in **SKILL DRILL 3-3**.

SAFETY TIP

- Always wear eye protection when using a gear puller.
- Make sure the puller is located correctly on the workpiece. If the jaws cannot be fitted correctly on the part, then select a more appropriate puller. Do not use a puller that does not fit the job.

Flaring Tools

A **tube flaring tool** is used to flare the end of a tube so it can be connected to another tube or component. One example of this is where the brake line screws into a wheel cylinder. The flared end is compressed between two threaded parts so that it seals the joint and withstands high pressures. The three most common shapes of flares are the **single flare**, for tubing carrying low pressures like a fuel line; the **double flare**, for higher pressures such as in a brake system; and the ISO flare (sometimes called a bubble flare), which is the metric version used in brake systems (**FIGURE 3-88**).

K03023 Describe the type and use of flaring tools.

Flaring tools have two main parts: a set of bars with holes that match the diameter of the tube end that is being shaped, and a yoke that drives a cone into the mouth of the tube (**FIGURE 3-89**). To make a single flare, the end of the tube is placed level with the surface of the top of the flaring bars. With the clamp screw firmly tightened, the feed screw flares the end of the tube. Making a double flare is similar, but an extra step is added before flaring the tube, and more of the tube is exposed to allow for folding the flare over into a double flare. A double flaring button is placed into the end of the tube, and when it is removed after tightening, the pipe looks like a bubble. Placing the cone and yoke over the bubble allows you to force the bubble to fold in on itself, forming the double flare.

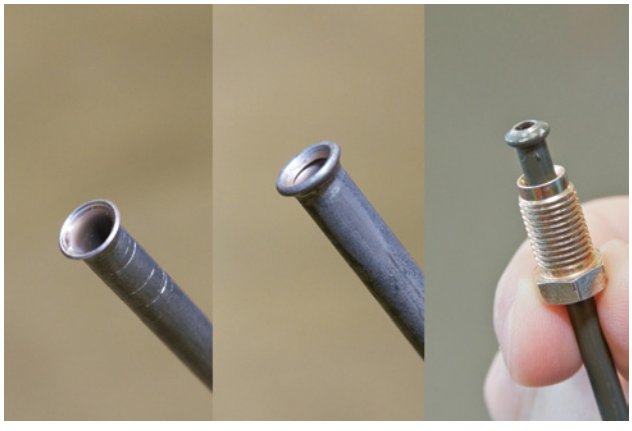
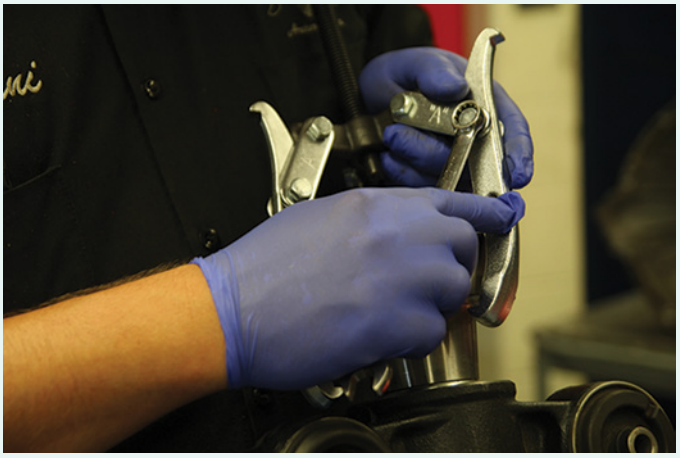
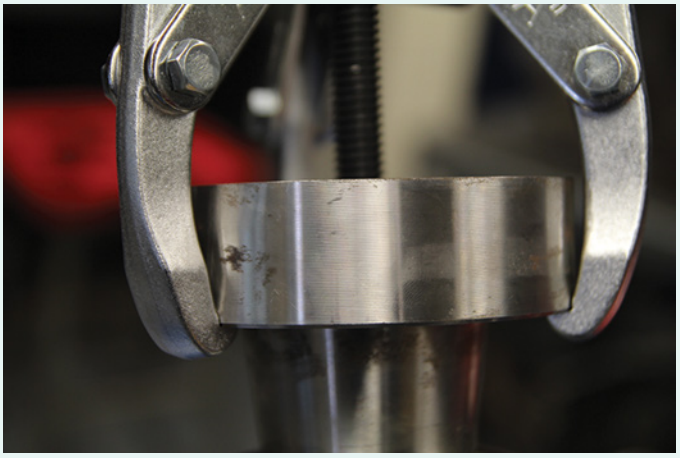


FIGURE 3-88 Single flare, double flare, and ISO flare.

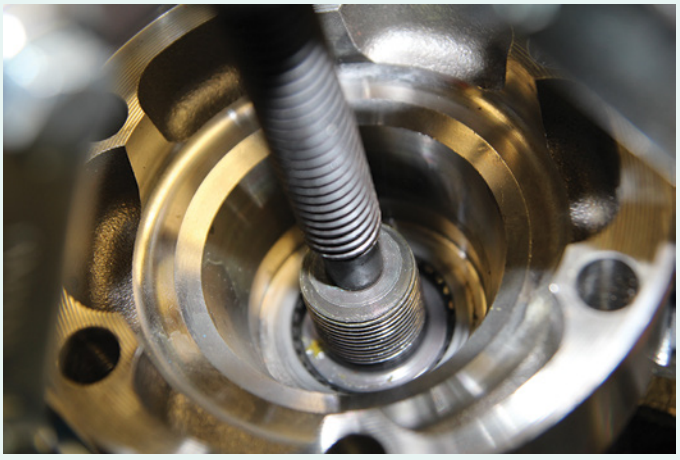
SKILL DRILL 3-3 Using Gear Pullers



1. Examine the gear puller you have selected for the job. Identify the jaws; there may be two or three of them, and they must fit the part you want to remove. The cross-arm enables you to adjust the diameter of the jaws. The forcing screw should fit snugly onto the part you are removing. Finally, select the right wrench or socket size to fit the nut on the end of the forcing screw.



2. Adjust and fit the puller. Adjust the jaws and cross-arms of the puller so that it fits tightly around the part to be removed. The arms of the jaws should be pulling against the component at close to right angles.



3. Position the forcing screw. Use the appropriate wrench to run the forcing screw down to touch the shaft. Check that the point of the forcing screw is centered on the shaft. If not, adjust the jaws and cross-arms until the point is in the center of the shaft. Also be careful to use the correct foot on the end of the puller.

4. Tighten the forcing screw slowly and carefully onto the shaft. Check that the puller is not going to slip off center or off the pulley. Readjust the puller if necessary.

Continued

5. If the forcing screw and puller jaws remain in the correct position, tighten the forcing screw, and pull the part off the shaft.

6. You may sometimes have to use a hammer to hit directly on the end of the forcing screw to help break the part loose.

An ISO flare uses a flaring tool made specifically for that type of flare. The process is similar to that of the double-flare but differs in the use of the button, because an ISO flare does not get doubled back on itself. It should resemble a bubble shape when you are finished.

A **tubing cutter** is more convenient and neater than a saw when cutting pipes and metal tubing (**FIGURE 3-90**). The sharpened wheel does the cutting. As the tool turns

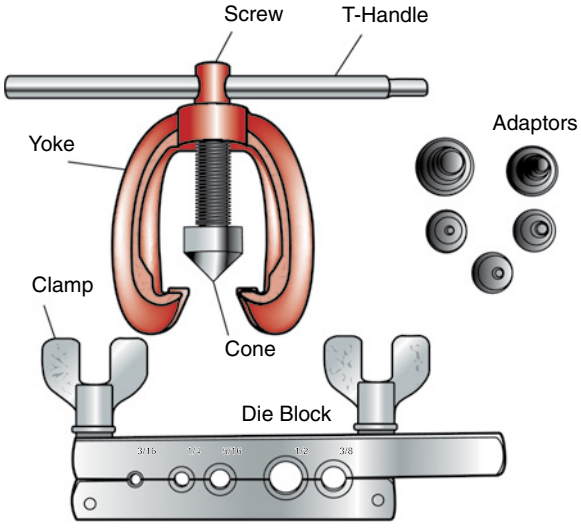


FIGURE 3-89 Components of a flare tool.

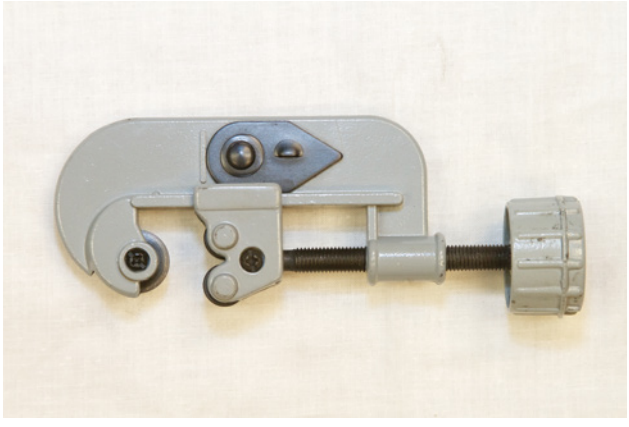


FIGURE 3-90 Tubing cutter.

SAFETY TIP

A flaring tool is used to produce a pressure seal for sealing brake lines and fuel system tubing. Make sure you test the flared joint for leaks before completing the repair; otherwise, the brakes could fail or leaking fuel could catch on fire.

SAFETY TIP

Always wear eye protection when using a flaring tool. Make sure the tool is clean, in good condition, and suitable for the type of material you are going to flare.

around the pipe, the screw increases the pressure, driving the wheel deeper and deeper through the pipe until it finally cuts through. There is a larger version that is used for cutting exhaust pipes.

Using Flaring Tools

To make a successful flare, it is important to have the correct amount of tube protruding through the tool before clamping. Otherwise, too much of the end will fold over and leave too small of a hole for fluid to pass through. Too little and there won't be enough tube to fold over properly, and the joint won't have full surface contact.

If you are making a double flare or ISO flare, make sure you use the correctly sized button for the tubing size. The button is also used to measure the amount of tube required to protrude from the tool prior to forming it. To prevent the tool from slipping on the tube and ruining the flare, make sure the tool is sufficiently tight around the tube before starting to create the flare.

To use a flaring tool to make a flare in a piece of tubing, follow the steps in **SKILL DRILL 3-4**.

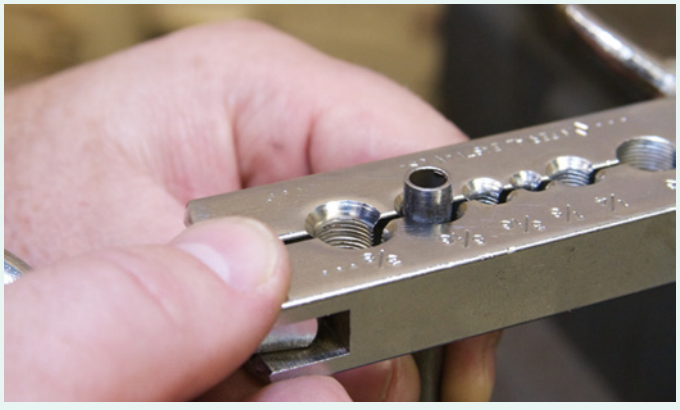
Riveting Tools

K03024 Describe the type and use of riveting tools.

There are many applications for blind rivets, and various rivet types and tools may be used to do the riveting. Rivets are used in many places in automotive applications where there is a need for a fastener that doesn't have to be easily removed. Some older window regulators,

SKILL DRILL 3-4 Using Flaring Tools

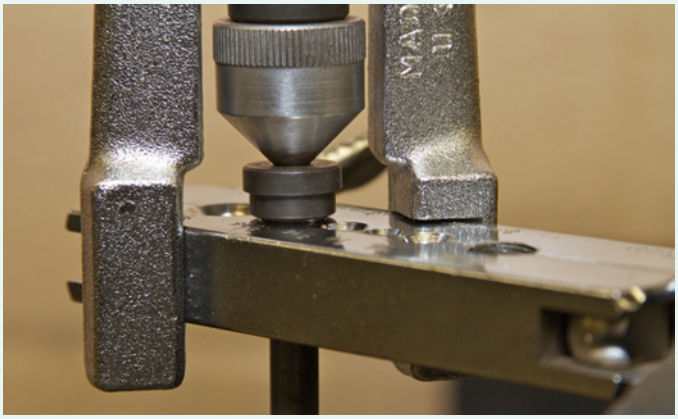
1. Choose the tube you will use to make the flare, and put the flare nut on the tube before creating the flare.



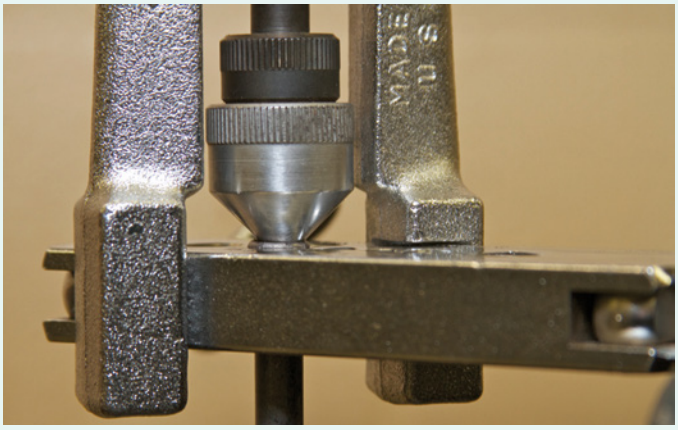
2. Match the size of the tube to the correct hole in the tubing clamp.

Continued

3. Holding the flaring tool, put the tube into the clamp. Position the tube so the correct amount is showing through the tool. If you are conducting a double flare, use the correctly sized button to ensure the proper amount of the tube is sticking up above the top of the clamp. Tighten the two halves of the clamp together using the wing nuts. Make sure the tool is tight enough to clamp the tube so it will not slip.

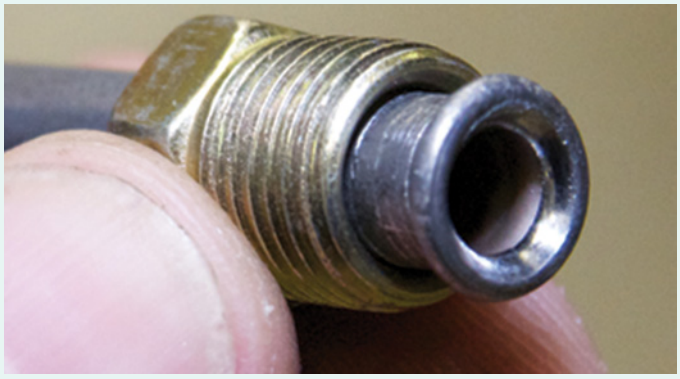


4. Put the cone and forming tool over the clamp, and turn the handle to make the flare. If you are doing a double flare or ISO flare, place the button in the end of the tube, install the cone and forming tool, and turn the handle to make the bubble. Remove the button from the tube.



5. If this is an ISO flare, inspect it to see if it is properly formed. If it is a double flare, put the cone and forming tool back on the clamp, and tighten the forming tool handle to create the double flare.

6. Remove the forming tool.



7. Remove the tube from the clamp, and check the flare to ensure it is free of burrs and is correctly formed.

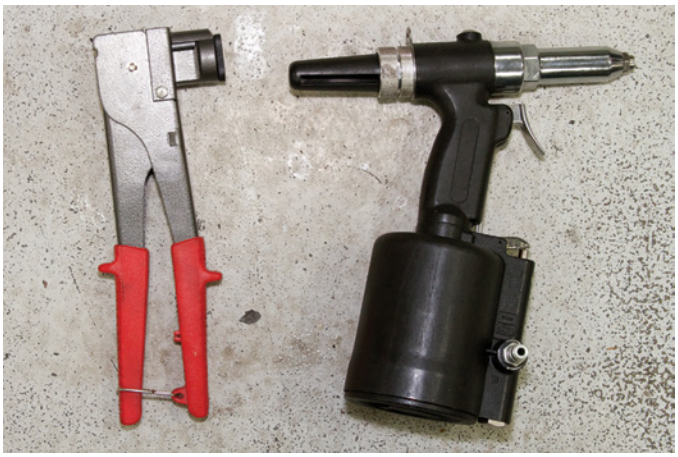


FIGURE 3-91 Pop rivet guns.

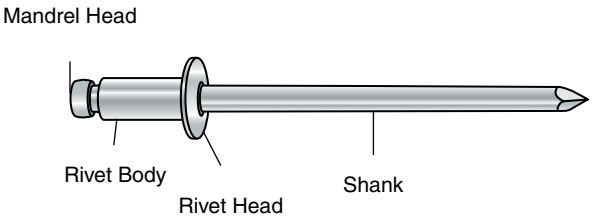


FIGURE 3-92 Anatomy of a rivet.

body panels, trim pieces, and even some suspension members use rivets to keep them attached without vibrating loose. **Pop rivet guns** are convenient for occasional riveting of light materials (**FIGURE 3-91**).

A typical pop, or **blind rivet**, has a body that forms the **finished rivet** and a mandrel, which is discarded when the riveting is completed (**FIGURE 3-92**). It is called a blind rivet because there is no need to see or reach the other side of the hole in which the rivet goes to do the work. In some types, the rivet is plugged shut so that it is waterproof or pressure proof.

The rivet is inserted into the riveting tool, which, when squeezed, pulls the end of the **mandrel** back through the body of the rivet. Because the **mandrel head** is bigger than the hole through the body, the body swells tightly against the hole. Finally, the mandrel head will snap off under the pressure and fall out, leaving the rivet body gripping the two pieces of material together.

Using Riveting Tools

Rivet tools are used to join two pieces of metal or other material together—for example, sheet metal that needs to be attached to a stiffening frame. To perform a riveting operation, you need a rivet gun, rivets, a drill, a properly sized drill bit, and the materials to be riveted.

Rivets come in various diameters and lengths for different sizes of jobs and are made of various types of metals to suit the job at hand. When selecting rivets to suit the job, consider the diameter, length, and rivet material. Larger diameter rivets should be used for jobs that require more strength. The rivet length should be sufficient to protrude past the thickness of the materials being riveted by about 1.6 times the diameter of the rivet stem. Typically, you should select rivets that are made from the same material as that being riveted. For example, stainless steel rivets should be used for riveting stainless steel, and aluminum rivets should be used to rivet aluminum.

Pilot holes must be drilled through the metal to be riveted. Ensure that the hole is just large enough for the rivet to comfortably pass through it, but do not make it too large. If the hole is too large, the rivet will be loose and will not hold the materials securely together. When drilling holes for rivets, stay back from the material's edge to ensure that the rivets do not break through the edge of the materials being riveted. A good rule of thumb is to allow at least twice the diameter of the rivet stem as clearance from any edge.

Most rivet tools are capable of riveting various sizes of rivets and have a number of nosepiece sizes to work with different sizes of rivets. Make sure you select the properly sized nosepiece for the rivet you are using.

To use a riveting tool to rivet two pieces of material together, follow the steps in **SKILL DRILL 3-5**.

▶ TECHNICIAN TIP

A rivet is a single-use fastener. Unlike a nut and bolt, which can normally be disassembled and reused, a rivet cannot. The metal shell that makes up a pop rivet is crushed into place so that it holds the parts firmly together. If it ever needs to be removed, it must be drilled out or cut off.

SAFETY TIP

When compressing the rivet handles, be careful not to place your fingers between the handles as they could end up pinching your fingers when the mandrel on the rivet breaks.

N03004 Demonstrate proper use of precision measuring tools (i.e., micrometer, dial-indicator, dial-caliper).

▶ Precision Measuring Tools

Technicians are required to perform a variety of measurements while carrying out their job. This requires knowledge of what tools are available and how to use them. Measuring tools can generally be classified according to what type of measurements they can make. A measuring tape is useful for measuring longer distances and is accurate to a millimeter or fraction of an inch (**FIGURE 3-93**). A steel rule is capable of accurate measurements on shorter lengths, down to a millimeter or a fraction of an inch. Precision measuring tools are accurate to much smaller dimensions, such as a micrometer, which in some cases can accurately measure down to 1/10,000 of an inch (0.0001") or 1/1000 of a millimeter (0.001 mm).

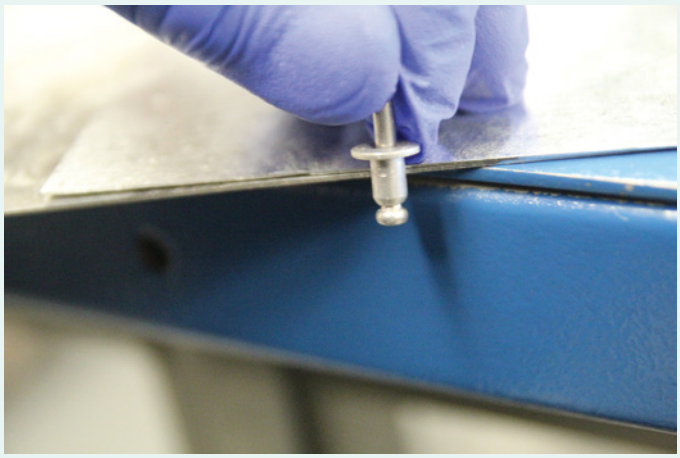
FIGURE 3-93 **A.** Measuring tape. **B.** Steel rule.

Measuring Tapes

Measuring tapes are a flexible type of ruler and are a common measuring tool. The most common type found in shops is a thin metal strip about 0.5" to 1" (13 to 25 mm) wide that is rolled up inside a housing with a spring return mechanism. Measuring tapes can be of various lengths, with 16' or 25' (5 or 8 m) being very common. The measuring tape

K03025 Describe the type and use of measuring tapes.

SKILL DRILL 3-5 Using Riveting Tools



1. Select the correct rivet for the material you are riveting. Make sure the rivet is the correct length.

2. Drill pilot holes in the material to be riveted. Remove any burrs. Ensure that the pilot hole is the correct size—not too large or too small.

Continued

3. Make sure the correctly sized nosepiece for the rivet size is fitted to the rivet tool.

4. Insert the rivet into the gun, and push the rivet through the materials to be riveted. Hold firm pressure while pushing the rivet into the work.

5. Squeeze and release the rivet tool handle to compress the rivet. Continue this process until the rivet stem or shank breaks away from the rivet head.

6. Check the rivet joint to ensure the pieces are firmly held together.

is pulled from the housing to measure items, and a spring return winds it back into the housing. The housing usually has a built-in locking mechanism to hold the extended measuring tape against the spring return mechanism. The hooked end can be placed over the edge of the object you are measuring and pulled against spring tension to take the measurement (**FIGURE 3-94**).

Steel Rulers

K03026 Describe the type and use of steel rulers.

As the name suggests, a **steel rule** is a ruler that is made from steel. Steel rules commonly come in 12" (0.030 m), 24" (0.60 m), and 36" (0.91 m) lengths. They are used like any ruler to measure and mark out items. A steel rule is a very strong ruler, has precise markings, and resists damage. When using a steel rule, you can rest it on its edge so the markings are closer to the material being measured, which helps to mark the work more precisely

FIGURE 3-94 The hook makes it easy to take a measurement with one hand.

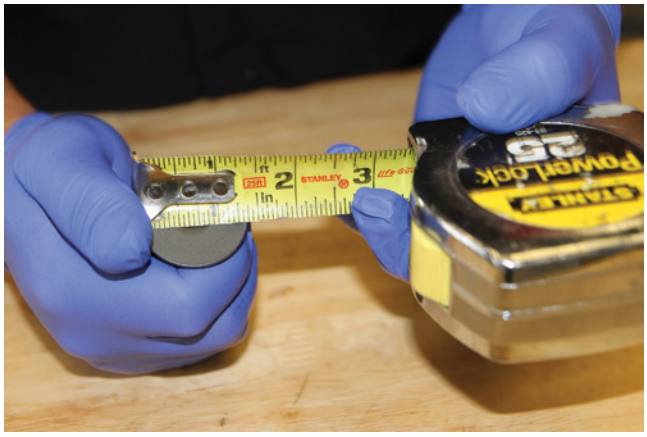


FIGURE 3-95 Tipping a steel rule on its side to get a more accurate reading.

(**FIGURE 3-95**). Always protect the steel rule from damage by storing it carefully; a damaged ruler will not give an accurate measurement. Never take measurements from the very end of a damaged steel rule, as damaged ends may affect the accuracy of your measurements.

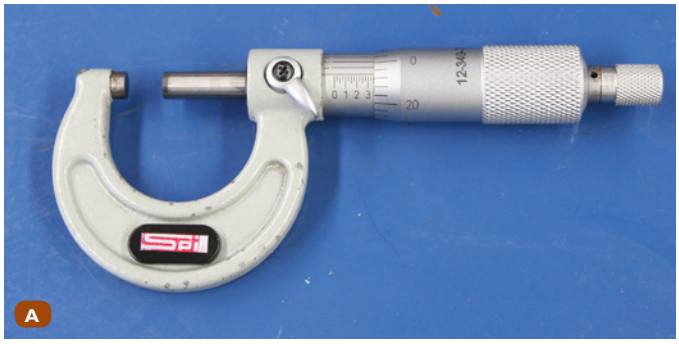
Outside, Inside, and Depth Micrometers

K03027 Describe the type and use of outside, inside, and depth micrometers.

Micrometers are precise measuring tools designed to measure small distances and are available in both inch and millimeter (mm) calibrations. Typically they can measure down to a resolution of 1/1000 of an inch (0.001") for a standard micrometer or 1/100 of a millimeter (0.01 mm) for a metric micrometer. Vernier micrometers equipped with the addition of a vernier scale can measure down to 1/10,000 of an inch (0.0001") or 1/1000 of a millimeter (0.001 mm).

The most common types of micrometers are the outside, inside, and depth micrometers (**FIGURE 3-96**). As the name suggests, an **outside micrometer** measures the outside dimensions of an item. For example, it could measure the diameter of a valve stem. The **inside micrometer** measures inside dimensions. For example, the inside micrometer could measure an engine cylinder bore. **Depth micrometers** measure the depth of an item such as how much clearance a piston has below the surface of the block.

The most common micrometer is an outside micrometer and is made up of several parts (**FIGURE 3-97**). The horseshoe-shaped part is the frame. It is built to make sure the micrometer holds its shape. Some frames have plastic finger pads so that body heat is not



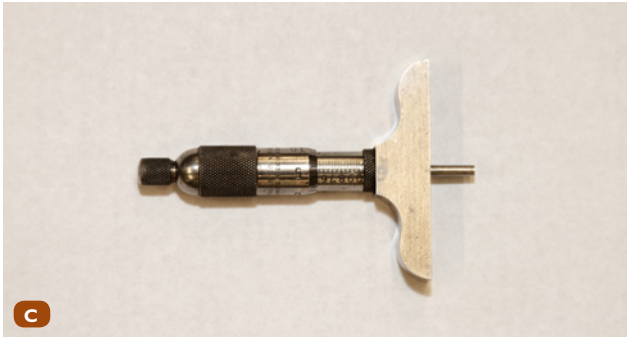


FIGURE 3-96 **A.** Outside micrometer. **B.** Inside micrometer. **C.** Depth micrometer.

▶ TECHNICIAN TIP

The United States customary system (USCS), also called the standard system, and the metric system are two sets of standards for quantifying weights and measurements. Each system has defined units. For example, the standard system uses inches, feet, and yards, whereas the metric system uses millimeters, centimeters, and meters. Conversions can be undertaken from one system to the other. For example, 1 inch is equal to 25.4 millimeters, and 1 foot is equal to 304.8 millimeters. Tools that make use of a measuring system, such as wrenches, sockets, drill bits, micrometers, rulers, and many others, come in both standard and metric measurements. To work on modern vehicles, an understanding of both systems and their conversion is required. Conversion tables can be used to convert from one system to the other. The more you work with both systems, the easier it will be to understand how they relate to each other.

▶ TECHNICIAN TIP

If the end of a rule is damaged, you may be able to measure from the 1" mark and subtract an inch from the measurement.

transferred to the metal frame as easily, as heat can cause the metal to expand slightly and affect the reading. On one end of the frame is the anvil, which contacts one side of the part being measured. The other contact point is the spindle. The micrometer measures the distance between the anvil and spindle, so that is where the part being measured fits.

The measurement is read on the sleeve/barrel and thimble. The sleeve/barrel is stationary and has the linear markings on it. The thimble fits over the sleeve and has the graduated marking on it. The thimble is connected directly to the spindle, and both turn as a unit. Because the spindle and sleeve/barrel have matching threads, the thimble rotates the spindle inside of the sleeve/barrel, and the thread moves the spindle inward and outward. The thimble usually incorporates either a ratchet or a clutch mechanism, which is turned lightly by finger, thus preventing over-tightening of the micrometer thimble when taking a reading.

A lock nut, lock ring, or lock screw is used on most micrometers to lock the thimble in place while you read the micrometer. Standard micrometers use a specific thread of 40 TPI (threads per inch) on the spindle and sleeve. This means that the thimble rotates exactly 40 turns in 1' of travel. Every complete rotation moves the spindle one 40th of an inch, or 0.025" (1 ÷ 40 = 0.025). In four rotations, the spindle moves 0.100" (0.025 × 4 = 0.100). The linear markings on the sleeve show each of the 0.100" marks between 0 and 1 inch as well as each of the 0.025" marks (**FIGURE 3-98**). Because the thimble has graduated marks from 0 to 24 (each mark representing 0.001"), every complete turn of the thimble uncovers another one of the 0.025" marks on the sleeve. If the thimble stops short of any complete turn, it will indicate the number of 0.001" marks past the zero line on the sleeve (**FIGURE 3-99**). So reading a micrometer is as simple as adding up the numbers as shown below.

To read a standard micrometer, perform the following steps (**FIGURE 3-100**):

1. Verify that the micrometer is properly calibrated.
2. Verify what size of micrometer you are using. If it is a 0–1" micrometer, start with 0.000. If it is a 1–2" micrometer, start with 1.000". A 2–3" micrometer would start with 2.000", etc. (To give an example, let's say it is 2.000".)
3. Read how many 0.100" marks the thimble has uncovered (example: 0.300").
4. Read how many 0.025" marks the thimble has uncovered past the 0.100" mark in step 3 (example: 2 × 0.025 = 0.050").
5. Read the number on the thimble that lines up with the zero line on the sleeve (example: 13 × 0.001 = 0.013").
6. Lastly, total all of the individual readings (example: 2.000 + 0.300 + 0.050 + 0.013 = 2.363").

A metric micrometer uses the same components as the standard micrometer. However, it uses a different **thread pitch** on the spindle and sleeve. It uses a 0.5 mm thread pitch (2.0 threads per millimeter) and opens up approximately 25 mm. Each rotation of the thimble moves the spindle 0.5 mm, and it therefore takes 50 rotations of the thimble to move

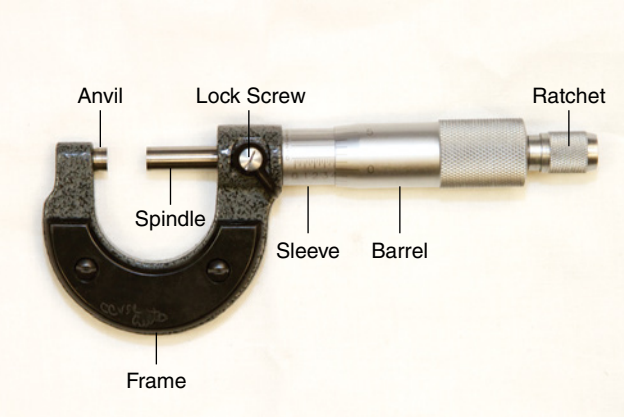


FIGURE 3-97 Parts of an outside micrometer.

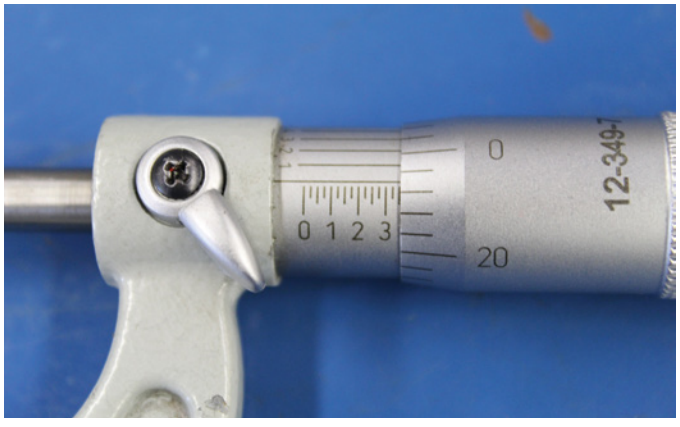


FIGURE 3-98 0.100" and 0.025" markings on the sleeve.

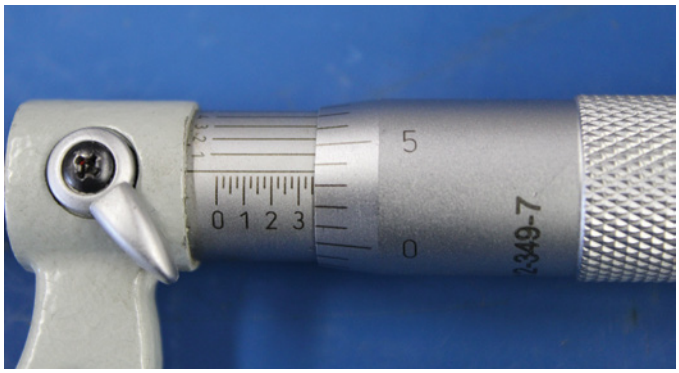


FIGURE 3-99 Markings on the thimble.

the full 25 mm distance. The sleeve/barrel is labeled with individual millimeter marks and half-millimeter marks from the starting millimeter to the ending millimeter, 25 mm away (**FIGURE 3-101**). The thimble has graduated marks from 0 to 49 (**FIGURE 3-102**).

Reading a metric micrometer involves the following steps:

1. Read the number of full millimeters the thimble has passed (To give an example, let's say it is 23.00 mm).
2. Check to see if it passed the 0.5 mm mark (example: 0.50 mm).
3. Check to see which mark on the thimble lines up with or is just passed (example: 37 × 0.01 mm = 0.37 mm).
4. Total all of the numbers (example: 23.00 mm + 0.50 mm + 0.37 mm = 23.87 mm).

If the micrometer is equipped with a vernier gauge, meaning it can read down to 1/10,000 of an inch (0.0001") or 1/1000 of a millimeter (0.001 mm), you need to complete one more step. Identify which of the vernier lines is closest to one of the lines on the thimble (**FIGURE 3-103**). Sometimes it is hard to determine which is the closest, so decide which three are the closest, and then use the center line. At the frame side of the sleeve will be a number that corresponds to the vernier line, numbered 1–0. Add the vernier to the end of your reading. For example: 2.363 + 0.0007 = 2.3637", and 23.77 + 0.007 = 23.777 mm.

For inside measurements, the inside micrometer works on the same principles as the outside micrometer and so does the depth micrometer. The only difference is that the scale on the sleeve of the depth micrometer is backward, so be careful when reading it.

Using Micrometers

To maintain accuracy of measurements, it is important that both the micrometer and the items to be measured are clean and free of any dirt or debris. Also make sure the micrometer is zeroed before taking any measurements. Never over-tighten a micrometer or store it with its measuring surfaces touching, as this may damage the tool and affect its accuracy. When measuring, make sure the item can pass through the micrometer surfaces snugly

▶ TECHNICIAN TIP

Micrometers are precision measuring instruments and must be handled and stored with care. They should always be stored with a gap between the spindle and anvil so metal contraction and expansion do not interfere with their calibration.

▶ TECHNICIAN TIP

All micrometers need to be checked for calibration (also called "zeroing") before each use. A 0–1" or 0–25 mm outside micrometer can be lightly closed all of the way. If the anvil and spindle are clean, the micrometer should read 0.000, indicating the micrometer is calibrated correctly. If the micrometer is bigger than 1", or 25 mm, then a "standard" is used to verify the calibration. A standard is a hardened, machined rod of a precise length, such as 2", or 50 mm. When inserted in the same-sized micrometer, the reading should be exactly the same as listed on the standard. If a micrometer is not properly calibrated, it should not be used until it is recalibrated. See the tool's instruction manual for the calibration procedure.

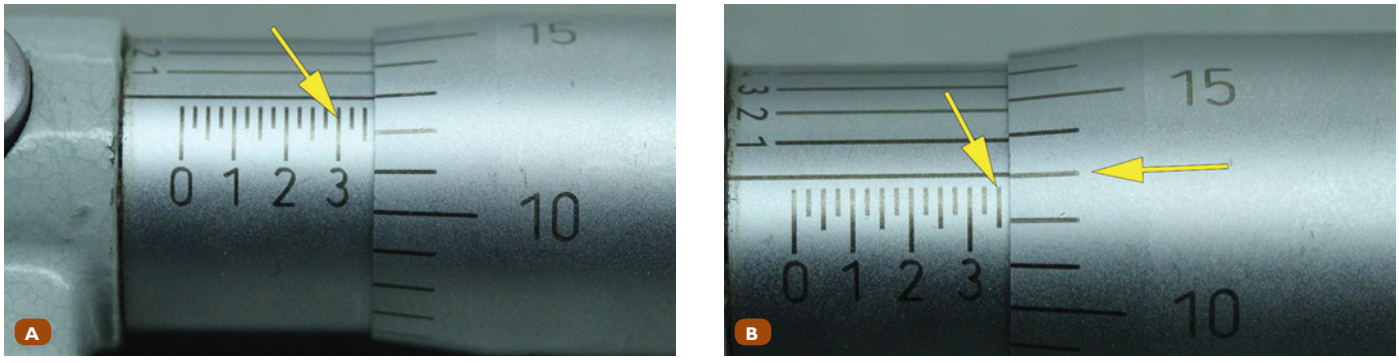


FIGURE 3-100 **A.** Read how many 0.100" marks the thimble has uncovered. **B.** Read the number on the thimble that lines up with the zero line on the sleeve.

FIGURE 3-101 Metric markings on the sleeve.

FIGURE 3-102 Markings on the thimble.

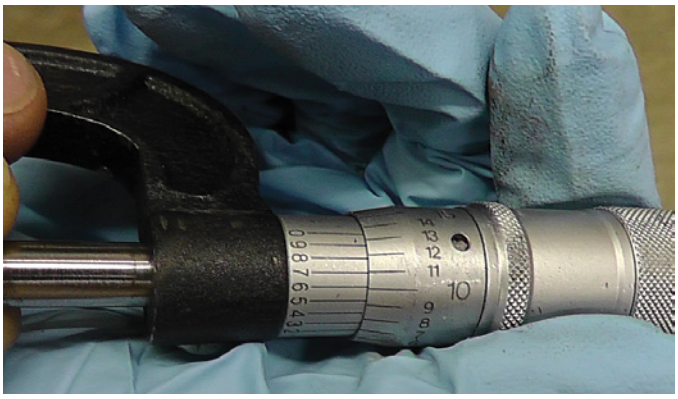


FIGURE 3-103 Vernier scale on a micrometer showing 7 on the sleeve lined up the best with a line on the thimble.

and squarely. This is best accomplished by using the ratchet to tighten the micrometer. Always take the measurement a number of times and compare results to ensure you have measured accurately.

To correctly measure using an outside micrometer, follow the steps in **SKILL DRILL 3-6**.

Telescoping Gauges

K03028 Describe the type and use of telescoping gauges.

For measuring distances in awkward spots like the bottom of a deep cylinder, the **telescoping gauge** has spring-loaded plungers that can be unlocked with a screw on the handle so they slide out and touch the walls of the cylinder (**FIGURE 3-104**). The screw then locks them in that position, the gauge can be withdrawn, and the distance across the plungers can be measured with an outside micrometer or calipers to convey the diameter of the cylinder at that point. Telescoping gauges come in a variety of sizes to fit various sizes of holes and bores.

Split Ball Gauges

K03029 Describe the type and use of split ball gauges.

A **split ball gauge** or small hole gauge is good for measuring small holes where telescoping gauges cannot fit (**FIGURE 3-105**). They use a similar principle to the telescoping gauge, but the measuring head uses a split ball mechanism that allows it to fit into very small holes. Split ball gauges are ideal for measuring valve guides on a cylinder head for wear. A split ball gauge can be fitted in the bore and expanded until there is a slight drag. Then it can be retracted and measured with an outside micrometer.

Dial Bore Gauges

K03030 Describe the type and use of dial bore gauges.

A **dial bore gauge** is used to measure the inside diameter of bores with a high degree of accuracy and speed (**FIGURE 3-106**). The dial bore gauge can measure a bore directly by using telescoping pistons on a T-handle with a dial mounted on the handle. The dial bore gauge combines a telescoping gauge and dial indicator in one instrument. A dial bore gauge determines if the diameter is worn, tapered, or out-of-round according to the manufacturer's specifications. The resolution of a dial bore gauge is typically accurate to 5/10,000 of an inch (0.0005") or 1/100 of a millimeter (0.01 mm).

Using Dial Bore Gauges

To use a dial bore gauge, select an appropriate-sized adapter to fit the internal diameter of the bore, and install it to the measuring head. Many dial bore gauges also have a fixture to calibrate the tool to the size you desire (**FIGURE 3-107**). The fixture is set to the size desired,

SKILL DRILL 3-6 Using Micrometers

1. Select the correct size of micrometer. Verify that the anvil and spindle are clean and that it is calibrated properly. Clean the surface of the part you are measuring.

2. In your right hand, hold the frame of the micrometer between your pinky, ring finger, and the palm of your hand, with the thimble between your thumb and forefinger.

3. With your left hand, hold the part you are measuring, and place the micrometer over it.

4. Using your thumb and forefinger, lightly tighten the ratchet. It is important that the correct amount of force is applied to the spindle when taking a measurement. The spindle and anvil should just touch the component with a slight amount of drag when the micrometer is removed from the measured piece. Be careful that the part is square in the micrometer so the reading is correct. Try rocking the micrometer in all directions to make sure it is square.

Continued

5. Once the micrometer is properly snug, tighten the lock mechanism so the spindle will not turn. Read the micrometer and record your reading.

6. When all readings are finished, clean the micrometer, position the spindle so it is backed off from the anvil, and return it to its protective case.

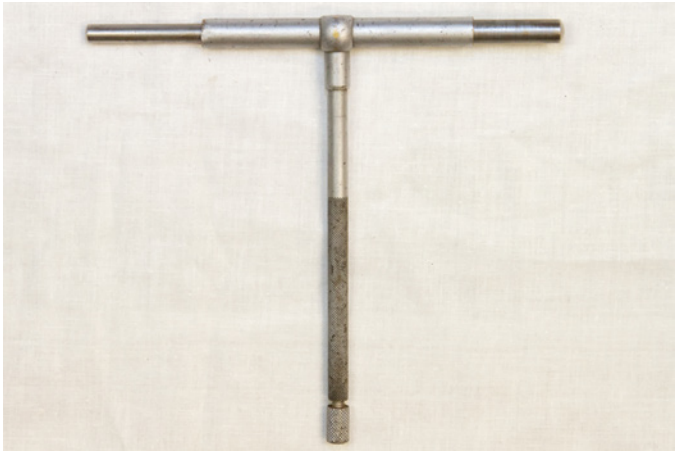


FIGURE 3-104 Telescoping gauge.

FIGURE 3-105 Split ball gauges.

FIGURE 3-106 A dial bore gauge set.

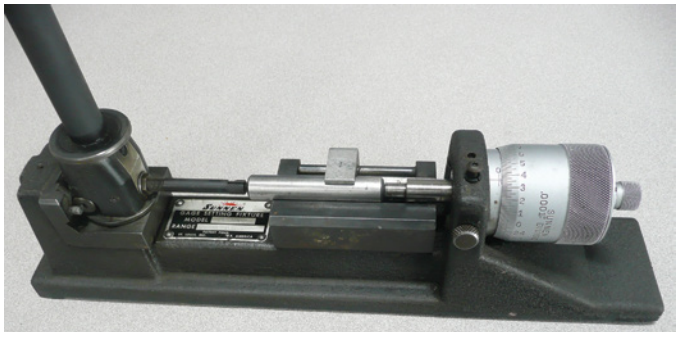


FIGURE 3-107 Dial bore gauge being calibrated to a predetermined size.

and the dial bore gauge is placed in it. The dial bore gauge is then adjusted to the proper reading. Once it is calibrated, the dial bore gauge can be inserted inside the bore to be measured. Hold the gauge in line with the bore, and slightly rock it to ensure it is centered. Read the dial when it is fully centered and square to the bore, to determine the correct measurement. It takes a bit of practice to get accurate readings.

Store a bore gauge carefully in its storage box and ensure the locking mechanism is released while in storage. Bore gauges are available in different ranges of size. It is important to select a gauge with the correct range for the bore you are measuring. When measuring, make sure the gauge is at a 90-degree angle to the bore and read the dial. Always take the measurement a number of times and compare results to ensure you have measured accurately.

To correctly measure using a dial bore gauge, follow the steps in **SKILL DRILL 3-7**.

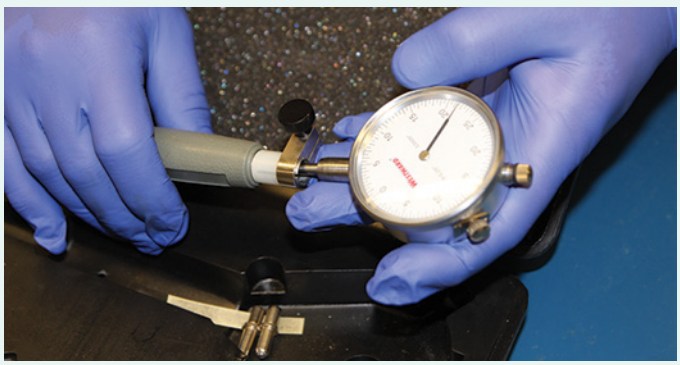
Vernier Calipers

K03031 Describe the type and use of vernier calipers.

Vernier calipers are a precision instrument used for measuring outside dimensions, inside dimensions, and depth measurements, all in one tool (**FIGURE 3-108**). They have a graduated bar with markings like a ruler. On the bar, a sliding sleeve with jaws is mounted for taking inside or outside measurements. Measurements on older versions of vernier calipers are taken by reading the graduated bar scales, and fractional measurements are read by comparing the scales between the sliding sleeve and the graduated bar. Technicians often use vernier calipers to measure length and diameters of bolts and pins or the depth of blind holes in housings.

Newer versions of vernier calipers have dial and digital scales (**FIGURE 3-109**). The dial caliper has the main scale on the graduated bar, and fractional measurements are taken from a dial with a rotating needle. These tend to be easier to read than the older versions.

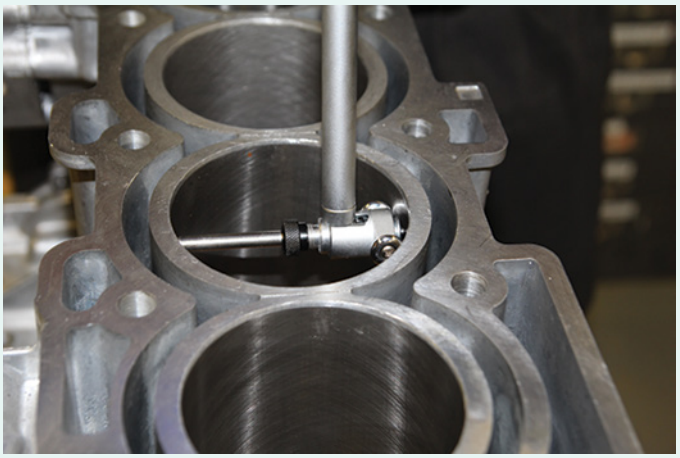
SKILL DRILL 3-7 Using Dial Bore Gauges



1. Select the correct size of the dial bore gauge you will use, and fit any adapters to it. Check the calibration and adjust it as necessary. Insert the dial bore gauge into the bore. The accurate measurement will be at exactly 90 degrees to the bore. To find the accurate measurement, rock the dial bore gauge handle slightly back and forth until you find the centered position.

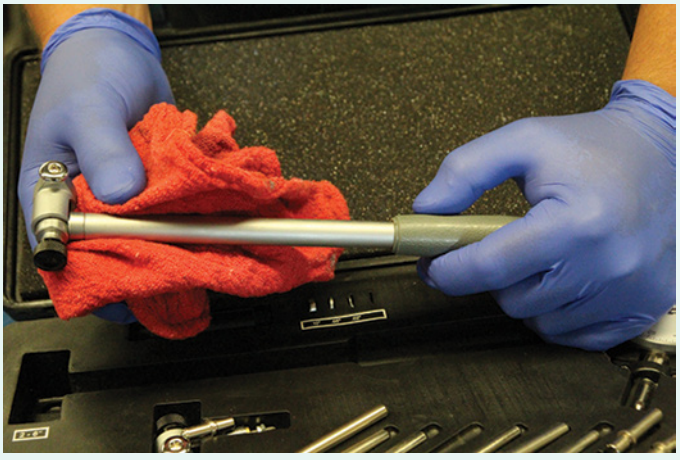
2. Check the calibration and adjust it as necessary.

Continued



3. Insert the dial bore gauge into the bore. The accurate measurement will be at exactly 90 degrees to the bore. To find the accurate measurement, rock the dial bore gauge handle slightly back and forth until you find the centered position.

4. Read the dial to determine the bore measurement.



5. Always clean the dial bore gauge, and return it to its protective case when you have finished using it.

More recently, digital scales on vernier calipers have become commonplace (**FIGURE 3-110**). The principle of their use is the same as any vernier caliper; however, they have a digital scale that reads the measurement directly.

Using Vernier Calipers

Always store vernier calipers in a storage box to protect them and ensure the measuring surfaces are kept clean for accurate measurement. If making an internal or external measurement, make sure the caliper is at right angles to the surfaces to be measured. You should always repeat the measurement a number of times and compare results to ensure you have

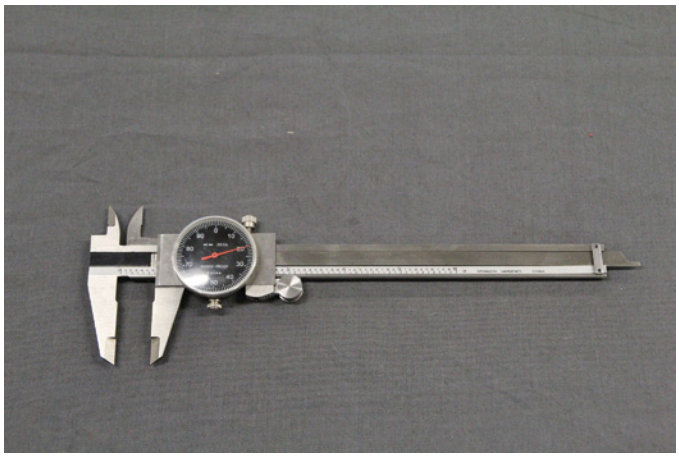


FIGURE 3-108 Vernier calipers can take three types of readings.

FIGURE 3-109 Dial vernier caliper.

measured accurately. To correctly measure using digital vernier calipers, follow the steps in **SKILL DRILL 3-8**.

Dial Indicators

Dial indicators can also be known as dial gauges, and as the name suggests, they have a dial and needle where measurements are read. They have a measuring plunger with a pointed or rounded contact end that is spring loaded and connected via the housing to the dial needle (**FIGURE 3-111**). The dial accurately displays movement of the plunger in and out as it rests against an object. For example, they can be used to measure the trueness of a rotating disc brake rotor. A dial indicator can also measure how round something is, such as a **crankshaft**, which can be rotated in a set of **V blocks** (**FIGURE 3-112**). If the crankshaft is bent, it will show as movement on the dial indicator as the crankshaft is rotated. The dial indicator senses slight movement at its tip and magnifies it into a measurable swing on the dial. Dial indicators normally have either one or two indicator needles. The large needle indicates the fine reading of thousandths of an inch. If it has a second needle, it will be smaller and indicates the coarse

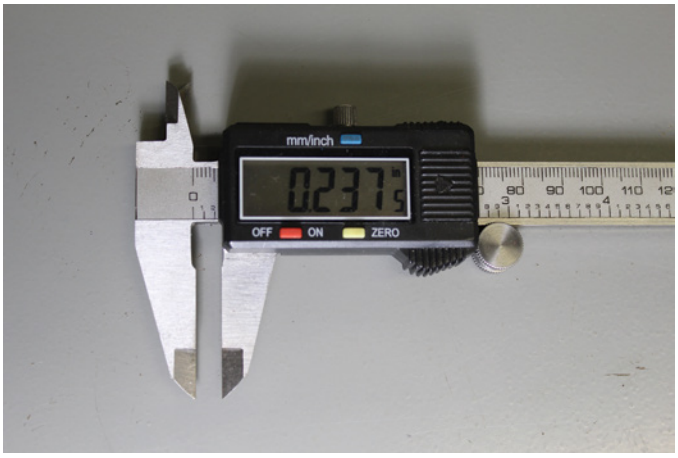


FIGURE 3-110 Digital caliper.

K03032 Describe the type and use of dial indicators.

SKILL DRILL 3-8 Using Vernier Calipers

1. Verify that the vernier caliper is calibrated (zeroed) before using it.

Continued

2. Position the caliper correctly for the measurement you are making. Internal and external readings are normally made with the vernier caliper positioned at 90 degrees to the face of the component to be measured. Length and depth measurements are usually made parallel to or in line with the object being measured. Use your thumb to press or withdraw the sliding jaw to measure the outside or inside of the part.

3. Read the scale of the vernier caliper, being careful not to change the position of the moveable jaw. If using a non-digital caliper, always read the dial or face straight on. A view from the side can give a considerable **parallax error**. Parallax error is a visual error caused by viewing measurement markers at an incorrect angle.

reading of tenths of an inch. The large needle is able to move numerous times around the outer scale. One full turn may represent 0.100" or 1 mm. The small inner scale indicates how many times the outer needle has moved around its scale. In this way, the dial indicator is able to read movement of up to 1" or 2 cm. Dial indicators can typically measure with an accuracy of 0.001" or 0.01 mm.

The type of dial indicator you use is determined by the amount of movement you expect from the component you are measuring. The indicator must be set up so that there

FIGURE 3-111 Dial indicator.

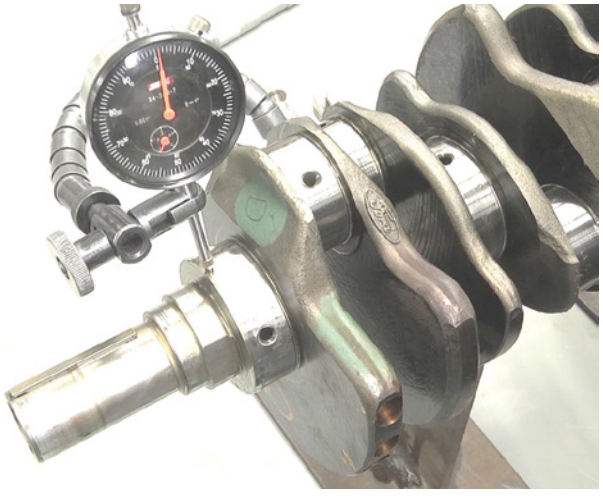


FIGURE 3-112 A dial indicator being used to measure crankshaft runout.

is no gap between the dial indicator and the component to be measured. It also must be set perpendicular and centered to the part being measured. Most dial indicator sets contain various attachments and support arms, so they can be configured specifically for the measuring task.

Using Dial Indicators

Dial indicators are used in many types of service jobs. They are particularly useful in determining runout on rotating shafts and surfaces. Runout is the side-to-side variation of movement when a component is turned. When attaching a dial indicator:

- Keep support arms as short as possible.
- Make sure all attachments are tightened to prevent unnecessary movement between the indicator and the component.
- Make sure the dial indicator plunger is positioned at 90 degrees to the face of the component to be measured.
- Always read the dial face straight on, as a view from the side can give a considerable parallax error.

The outer face of the dial indicator is designed so it can be rotated so that the zero mark can be positioned directly under the pointer. This is how a dial indicator is zeroed. To correctly measure using a dial indicator, follow the steps in **SKILL DRILL 3-9**.

SKILL DRILL 3-9 Using Dial Indicators

1. Select the gauge type, size, attachment, and bracket that fit the part you are measuring. Mount the dial indicator firmly to keep it stationary.

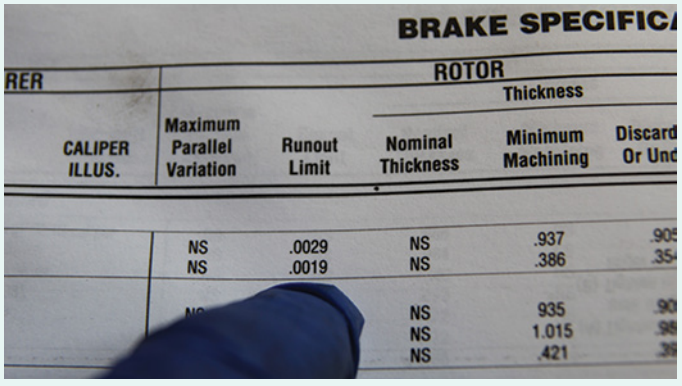
2. Adjust the indicator so that the plunger is at 90 degrees to the part you are measuring, and lock it in place.

Continued

3. Rotate the part one complete turn, and locate the low spot. Zero the indicator.

4. Find the point of maximum height and note the reading. This indicates the runout value.

5. Continue the rotation, making sure the needle does not go below zero. If it does, re-zero the indicator and remeasure the point of maximum variation.



6. Check your readings against the manufacturer's specifications. If the deviation is greater than the specifications allow, consult your supervisor.

Straight Edges

Straight edges are usually made from hardened steel and are machined so that the edge is perfectly straight. A straight edge is used to check the flatness of a surface. It is placed on its edge against the surface to be checked (**FIGURE 3-113**). The gap between the straight edge and the surface can be measured by using feeler gauges. Sometimes the gap can be seen easily if light is shone from behind the surface being checked. Straight edges are often used to measure the amount of warpage the surface of a cylinder head has.

K03033 Describe the type and use of straight edges.

Feeler Gauges

Feeler gauges (also called feeler blades) are used to measure the width of gaps, such as the clearance between valves and rocker arms. Feeler gauges are flat metal strips of varying thicknesses (**FIGURE 3-114**). The thickness of each feeler gauge is clearly marked on each one. They are sized from fractions of an inch or fractions of a millimeter. They usually come in sets with different sizes and are available in standard and metric measurements. Some sets contain feeler gauges made of brass. These are used to take measurements between components that are magnetic. If steel gauges are used, the drag caused by the magnetism would mimic the drag of a proper clearance. Brass gauges are not subject to magnetism, so they work well in that situation. Some feeler gauges come in a bent arrangement to be more easily inserted in cramped spaces. Others come in a stepped version. For example, the end of the gauge might be 0.010" thick, while the rest of the gauge is 0.012" thick. This works well for adjusting valve clearance. If the specification is 0.010", then the 0.010 section can be placed in the gap. If the 0.012 section slides into the gap, then the valve needs to be readjusted. If it stops at the lip of the 0.012" section, then the gap is correct (**FIGURE 3-115**).

K03034 Describe the type and use of feeler gauges.

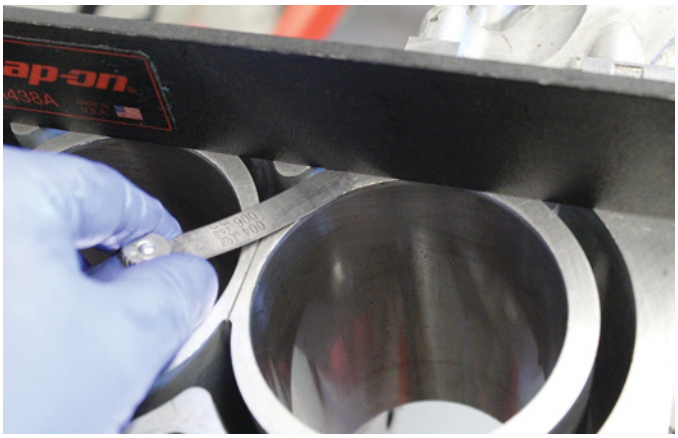


FIGURE 3-113 Straight edge being used to measure the flatness of a surface.

FIGURE 3-114 Feeler blade set. **A.** Straight. **B.** Bent. **C.** Stepped. **D.** Wire gauge.

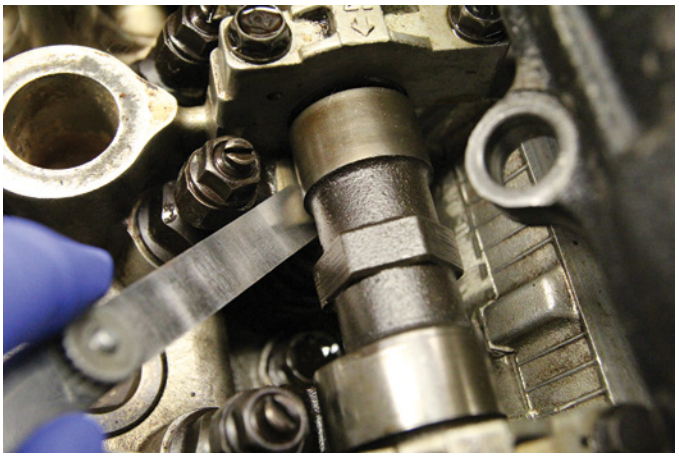


FIGURE 3-115 Stepped feeler blade being used during a valve adjustment.

FIGURE 3-116 Wire feeler gauge used to check a spark plug gap.

SAFETY TIP

Never use feeler gauges on operating machinery.

SAFETY TIP

Feeler gauges are strips of hardened metal that have been ground or rolled to a precise thickness. They can be very thin and will cut through skin if not handled correctly.

Two or more non-stepped feeler gauges can be stacked together to make up a desired thickness. For example, to measure a thickness of 0.029 of an inch, a 0.017 and a 0.012 feeler gauge could be used together to make up the size. Alternatively, if you want to measure an unknown gap, you can interchange feeler gauges until you find the one or more that fits snugly into the gap and total their thickness to determine the measurement of the gap. In conjunction with a straight edge, they can be used to measure surface irregularities on a cylinder head.

Using Feeler Gauges

If the feeler gauge feels too loose when measuring a gap, select the next size larger, and measure the gap again. Repeat this procedure until the feeler gauge has a slight drag between both parts. If the feeler gauge is too tight, select a smaller size until the feeler gauge fits properly. When measuring a spark plug gap, feeler gauges should not be used because the surfaces of the spark plug electrodes are not perfectly parallel, so it is preferable to use wire feeler gauges (**FIGURE 3-116**).

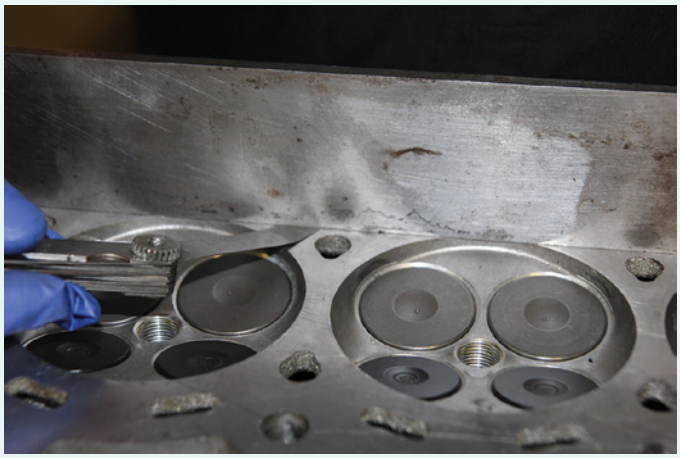
Wire feeler gauges use accurately machined pieces of wire instead of flat metal strips. To select and use feeler gauge sets, follow the steps in **SKILL DRILL 3-10**.

SKILL DRILL 3-10 Using Feeler Gauges

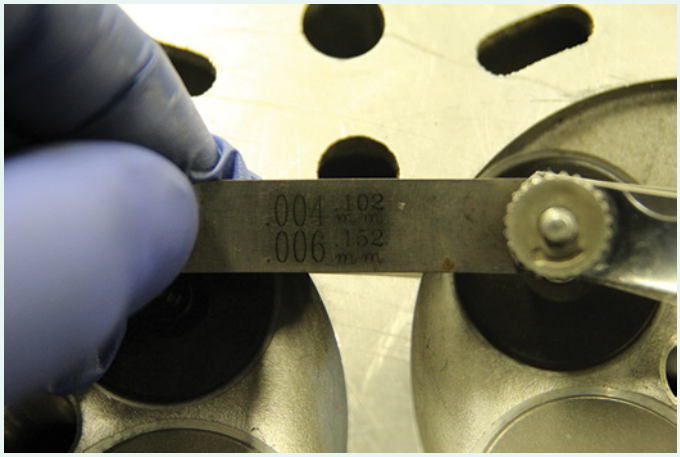
1. Select the appropriate type and size feeler gauge set for the job you are working on.

2. Inspect the feeler gauges to make sure they are clean, rust-free, and undamaged, but slightly oiled for ease of movement.

Continued



3. Choose one of the smaller wires or blades, and try to insert it in the gap on the part. If it slips in and out easily, choose the next size up. When you find one that touches both sides of the gap and slides with only gentle pressure, then you have found the exact width of that gap.



4. Read the markings on the wire or blade, and check these against the manufacturer's specifications for this component. If gap width is outside the tolerances specified, inform your supervisor.

5. Clean the feeler gauge set with an oily cloth before storage to prevent rust.

▶ Cleaning Tools and Equipment

Clean tools and equipment work more safely and efficiently. At the end of each working day, clean the tools and equipment you used and check them for any damage. If you note any damage, tag the tool as faulty and organize a repair or replacement. Electrical current can travel over oily or greasy surfaces. Be sure to keep electrical power tools clean. All shop equipment should have a maintenance schedule. Always complete the tasks described on the schedule at the required time. This helps to keep the equipment in safe working order.

N03005 Demonstrate proper cleaning, storage, and maintenance of tools and equipment.

K03035 Describe the importance of proper cleaning and storage of tools.

Store commonly used tools in an easy-to-reach location. If a tool or piece of equipment is too difficult to return, then it will likely be left on a workbench or on the floor, where it will become a safety hazard. Keep your work area tidy. This will help you work more efficiently and safely. Keep a trash can close to your work area, and place any waste in it as soon as possible. Dispose of liquid and solid waste, such as oils, coolant, and worn components, in the correct manner. Local authorities provide guidelines for waste disposal with fines for noncompliance. When cleaning products lose their effectiveness, they need to be replaced. Refer to the supplier's recommendations for collection or disposal. Do not pour solvents or other chemicals into the sewage system. This is both environmentally damaging and illegal.

Always use chemical gloves when using any cleaning material, because excessive exposure to cleaning materials can damage skin. Also, absorbing some chemicals through the skin over time can cause permanent harm to your body. Some solvents are flammable; never use cleaning materials near an open flame or cigarette. The fumes from cleaning chemicals can be toxic, so wear appropriate respirator and eye protection wherever you are using these products.

SAFETY TIP

Do not use flammable cleaners or water on electrical equipment.

To keep work areas and equipment clean and operational, follow the steps in **SKILL DRILL 3-11**.

SKILL DRILL 3-11 Tool and Equipment Cleaning

1. Clean hand tools. Keep your hand tools in good, clean condition with two types of rags. One rag should be lint-free to clean or handle precision instruments or components. The other should be oily to prevent rust and corrosion.

2. Clean floor jacks. Wipe off any oil or grease on the floor jack, and check for fluid leaks. If you find any, remove the jack from use, and have it repaired or replaced. Occasionally, apply a few drops of lubricating oil to the wheels and a few drops to the posts of threaded jack stands.

Continued

3. Clean electrical power tools. Keep power tools clean by brushing off any dust and wiping off excess oil or grease with a clean rag. Inspect any electrical cables for dirt, oil, or grease, and for any chafing or exposed wires. With drills, inspect the chuck and lubricate it occasionally with machine oil.

4. Clean air-powered tools. Apply a few drops of oil into the inlet of your air tools every day. Although these tools have no electrical motor, they do need regular lubrication of the internal parts to prevent wear.

5. Clean hoists and heavy machinery. Locate the checklist or maintenance record for each hoist or other major piece of equipment before carrying out cleaning activities.

6. You should clean equipment operating mechanisms and attachments of excess oil or grease.

Wrap-Up

Ready for Review

- Tools and equipment should be used only for the task they were designed to do.
- Always have a safe attitude when using tools and equipment.
- Do not use damaged tools; inspect before using, then clean and inspect again before putting them away.
- Lockouts and tag-outs are meant to prevent technicians from using tools and equipment that are potentially unsafe.
- Many tools and measuring instruments have USCS or metric system markings to identify their size.
- Torque defines how much a fastener should be tightened.
- Torque specification indicates the level of tightness each bolt or nut should be tightened to; torque charts list torque specifications for nuts and bolts.
- Torque (or tension) wrenches tighten fasteners to the correct torque specification.
- Torque value—the amount of twisting force applied to a fastener by the torque wrench—is specified in foot-pounds (ft-lb), inch-pounds (in-lb), or newton meters (Nm).
- Torque wrench styles are beam (simplest and least expensive), clicker, dial, and electronic. Each gives an indication of when proper torque is achieved.
- Bolts that are tightened beyond their yield point do not return to their original length when loosened.
- Common wrenches include box end, open end, combination (most popular), flare nut (or flare tubing), open-end adjustable, and ratcheting box end.
- Box-end wrenches can loosen very tight fasteners, but open-end wrenches usually work better once the fastener has been broken loose.
- Use the correct wrench for the situation, so as not to damage the bolt or nut.
- Sockets grip fasteners tightly on all six corners and are purchased in sets.
- Sockets are classified as follows: standard or metric, size of drive used to turn them, number of points, depth of socket, and thickness of wall.
- The most common socket handle is a ratchet; a breaker bar gives more leverage, or a sliding T-handle may be used.
- Fasteners can be spun off or on (but not tightened) by a speed brace or speeder handle.
- Pliers hold, cut, or compress materials; types include slip-joint, combination, arc joint, needle-nose, flat, diagonal cutting, snap ring, and locking.
- Always use the correct type of pliers for the job.
- Cutting tools include bolt cutters, tin snips, and aviation snips.
- Allen wrenches are designed to fit into fasteners with recessed hexagonal heads.
- Screwdriver types include flat blade (most common), Phillips, Pozidriv, offset, ratcheting, and impact.
- The tip of the screwdriver must be matched exactly to the slot or recess on the head of a fastener.
- Magnetic pickup tools and mechanical fingers allow for the extraction and insertion of objects in tight places.
- Types of hammers include ball peen (most common), sledge, mallet, and dead blow.
- Chisels are used to cut metals when hit with a hammer.
- Punches are used to mark metals when hit with a hammer and come in different diameters and different points for different tasks; types of punches include prick, center, drift, pin, ward, and hollow.
- Pry bars can be used to move, adjust, or pry parts.
- Gasket scrapers are designed to remove gaskets without damaging surrounding materials.
- Files are used to remove material from the surface of an automotive part.
- Flat files come in different grades to indicate how rough they are; grades are rough, coarse bastard, second cut, smooth, and dead smooth.
- Types of files include flat, warding, square, triangular, curved, and thread.
- Bench vices, offset vices, drill vices, and C-clamps all hold materials in place while they are worked on.
- Taps are designed to cut threads in holes or nuts; types include taper, intermediate, and bottoming.
- A die is used to cut a new thread on a blank rod or shaft.
- Gear and bearing pullers are designed to remove components from a shaft when considerable force is needed.
- Flaring tools create flares at the end of tubes to connect them to other components; types include single, double, and ISO.
- Rivet tools join together two pieces of metal; each rivet can be used only once.
- Measuring tapes and steel rules are commonly used measuring tools; more precise measuring tools include micrometers, gauges, calipers, dial indicators, and straight edges.
- Micrometers can be outside, inside, or depth.
- Learn to read micrometer measurements on the sleeve/barrel and thimble; always verify the micrometer is properly calibrated before use.
- Gauges are used to measure distances and diameters; types include telescoping, split ball, and dial bore.
- Vernier calipers measure outside, inside, and depth dimensions; newer versions have dial and digital scales.
- Dial indicators are used to measure movement.
- A straight edge is designed to assess the flatness of a surface.
- Feeler blades are flat metal strips that are used to measure the width of gaps.
- Keep work area, tools, and equipment clean and organized.

Key Terms

Allen wrench A type of hexagonal drive mechanism for fasteners.

arc joint pliers Pliers with parallel slip jaws that can increase in size. Also called Channellocks.

aviation snips A scissor-like tool for cutting sheet metal.

ball-peen (engineer's) hammer A hammer that has a head that is rounded on one end and flat on the other; designed to work with metal items.

bench vice A device that securely holds material in jaws while it is being worked on.

blind rivet A rivet that can be installed from its insertion side.

bolt A type of threaded fastener with a thread on one end and a hexagonal head on the other.

bolt cutters Strong cutters available in different sizes, designed to cut through non-hardened bolts and other small-stock material.

bottoming tap A thread-cutting tap designed to cut threads to the bottom of a blind hole.

box-end wrench A wrench or spanner with a closed or ring end to grip bolts and nuts.

C-clamp A clamp shaped like the letter C; it comes in various sizes and can clamp various items.

center punch Less sharp than a prick punch, the center punch makes a bigger indentation that centers a drill bit at the point where a hole is required to be drilled.

cold chisel The most common type of chisel, used to cut cold metals. The cutting end is tempered and hardened so that it is harder than the metals that need to be cut.

combination pliers A type of pliers for cutting, gripping, and bending.

combination wrench A type of wrench that has a box-end wrench on one side and an open end on the other.

crankshaft A vehicle engine component that transfers the reciprocating movement of pistons into rotary motion.

cross-arm A description for an arm that is set at right angles or 90 degrees to another component.

cross-cut chisel A type of chisel for metal work that cleans out or cuts key ways.

curved file A type of file that has a curved surface for filing holes.

dead blow hammer A type of hammer that has a cushioned head to reduce the amount of head bounce.

depth micrometer A measuring device that accurately measures the depth of a hole.

diagonal cutting pliers Cutting pliers for small wire or cable.

dial bore gauge An accurate measuring device for inside bores, usually made with a dial indicator attached to it.

dial indicator An accurate measuring device where measurements are read from a dial and needle.

die Used to cut external threads on a metal shank or bolt.

die stock A handle for securely holding dies to cut threads.

double flare A seal that is made at the end of metal tubing or pipe.

drift punch A type of punch used to start pushing roll pins to prevent them from spreading.

drill vice A tool with jaws that can be attached to a drill press table for holding material that is to be drilled.

fasteners Devices that securely hold items together, such as screws, cotter pins, rivets, and bolts.

feeler gauge A thin blade device for measuring space between two objects.

finished rivet A rivet after the completion of the riveting process.

flare nut wrench A type of box-end wrench that has a slot in the box section to allow the wrench to slip through a tube or pipe. Also called a flare tubing wrench.

flat blade screwdriver A type of screwdriver that fits a straight slot in screws.

flat-nose pliers Pliers that are flat and square at the end of the nose.

forcing screw The center screw on a gear, bearing, or pulley puller. Also called a jacking screw.

gasket scraper A broad sharp flat blade to assist in removing gaskets and glue.

gear pullers A tool with two or more legs and a cross bar with a center forcing screw to remove gears.

hard rubber mallet A special-purpose tool with a head made of hard rubber; often used for moving things into place where it is important not to damage the item being moved.

hollow punch A punch with a center hollow for cutting circles in thin materials such as gaskets.

impact driver A tool that is struck with a hammer to provide an impact turning force to remove tight fasteners.

inside micrometer A micrometer designed to measure internal diameters.

intermediate tap One of a series of taps designed to cut an internal thread. Also called a plug tap.

locking pliers A type of pliers where the jaws can be set and locked into position.

lockout/tag-out A safety tag system to ensure that faulty equipment or equipment in the middle of repair is not used.

lug wrench A tool designed to remove wheel lugs nuts and commonly shaped like a cross.

magnetic pickup tools An extending shaft, often flexible, with a magnet fitted to the end for picking up metal objects.

magnetic pickup tools Useful for grabbing items in tight spaces, it typically is a telescoping stick that has a magnet attached to the end on a swivel joint.

mandrel The shaft of a pop rivet.

mandrel head The head of the pop rivet that connects to the shaft and causes the rivet body to flare.

measuring tape A thin measuring blade that rolls up and is contained in a spring-loaded dispenser.

mechanical fingers Spring-loaded fingers at the end of a flexible shaft that pick up items in tight spaces.

micrometer An accurate measuring device for internal and external dimensions. Commonly abbreviated as "mic."

needle-nose pliers Pliers with long tapered jaws for gripping small items and getting into tight spaces.

nippers (pincer pliers) Pliers designed to cut protruding items level with the surface.

nut A fastener with a hexagonal head and internal threads for screwing on bolts.

offset screwdriver A screwdriver with a 90-degree bend in the shaft for working in tight spaces.

offset vice A vice that allows long objects to be gripped vertically.

oil filter wrench A specialized wrench that allows extra leverage to remove an oil filter when it is tight.

open-end wrench A wrench with open jaws to allow side entry to a nut or bolt.

outside micrometer A micrometer designed to measure the external dimensions of items.

parallax error A visual error caused by viewing measurement markers at an incorrect angle.

peening A term used to describe the action of flattening a rivet through a hammering action.

phillips head screwdriver A type of screwdriver that fits a head shaped like a cross in screws.

pin punch A type of punch in various sizes with a straight or parallel shaft.

pipe wrench A wrench that grips pipes and can exert a lot of force to turn them. Because the handle pivots slightly, the more pressure put on the handle to turn the wrench, the more the grip tightens.

pliers A hand tool with gripping jaws.

pop rivet gun A hand tool for installing pop rivets.

prick punch A pinch with a sharp point for accurately marking a point on metal.

pry bar A high-strength carbon steel rod with offsets for levering and prying.

pullers A generic term to describe hand tools that mechanically assist the removal of bearings, gears, pulleys, and other parts.

punches A generic term to describe a high-strength carbon steel shaft with a blunt point for driving. Center and prick punches are exceptions and have a sharp point for marking or making an indentation.

ratchet A generic term to describe a handle for sockets that allows the user to select direction of rotation. It can turn sockets in restricted areas without the user having to remove the socket from the fastener.

ratcheting box-end wrench A wrench with an inner piece that is able to rotate within the outer housing, allowing it to be repositioned without being removed.

ratcheting screwdriver A screwdriver with a selectable ratchet mechanism built into the handle that allows the screwdriver tip to ratchet as it is being used.

roll bar Another type of pry bar, with one end used for prying and the other end for aligning larger holes, such as engine motor mounts.

screw extractor A tool for removing broken screws or bolts.

single flare A sealing system made on the end of metal tubing.

sledgehammer A heavy hammer, usually with two flat faces, that provides a strong blow.

sliding T-handle A handle fitted at 90 degrees to the main body that can be slid from side to side.

snap ring pliers A pair of pliers for installing and removing snap rings or circlips.

socket An enclosed metal tube commonly with 6 or 12 points to remove and install bolts and nuts.

speed brace A U-shaped socket wrench that allows high-speed operation. Also called a speeder handle.

split ball gauge A measuring device used to accurately measure small holes.

square file A type of file with a square cross section.

steel hammer A hammer with a head made of hardened steel.

steel rule An accurate measuring ruler made of steel.

straight edge A measuring device generally made of steel to check how flat a surface is.

tap A term used to generically describe an internal thread-cutting tool.

taper tap A tap with a tapper; it is usually the first of three taps used when cutting internal threads.

tap handle A tool designed to securely hold taps for cutting internal threads.

telescoping gauge A gauge that expands and locks to the internal diameter of bores; a caliper or outside micrometer is used to measure its size.

thread file A type of file that cleans clogged or distorted threads on bolts and studs.

thread pitch The coarseness or fineness of a thread as measured by either the threads per inch or the distance from the peak of one thread to the next. Metric fasteners are measured in millimeters.

tin snips Cutting device for sheet metal, works in a similar fashion to scissors.

torque Twisting force applied to a shaft that may or may not result in motion.

torque specifications Supplied by manufacturers and describes the amount of twisting force allowable for a fastener or a specification showing the twisting force from an engine crankshaft.

torque wrench A tool used to measure the rotational or twisting force applied to fasteners.

triangular file A type of file with three sides so it can get into internal corners.

tube flaring tool A tool that makes a sealing flare on the end of metal tubing.

tubing cutter A hand tool for cutting pipe or tubing squarely.

V blocks Metal blocks with a V-shaped cutout for holding shafts while working on them. Also referred to as vee blocks.

vernier calipers An accurate measuring device for internal, external, and depth measurements that incorporates fixed and adjustable jaws.

wad punch A type of punch that is hollow for cutting circular shapes in soft materials such as gaskets.

warding file A type of thin, flat file with a tapered end.

wrenches A generic term to describe tools that tighten and loosen fasteners with hexagonal heads.

Review Questions

1. Specialty tools:
   a. should not be shared among technicians.
   b. should have tag-out practices for regular storage.
   c. should be put in the proper storage space after each use.
   d. can be used for purposes they were not designed for.
2. A set of safety practices and procedures that are intended to reduce the risk of technicians inadvertently using tools that have been determined to be unsafe is known as:
   a. lockout.
   b. shop policy.
   c. equipment storage procedure.
   d. PPE maintenance.
3. Which of these wrenches can be awkward to use once the nut or bolt has been loosened a bit?
   a. Open-end
   b. Flare nut
   c. Combination
   d. Box-end
4. Oil filters should be installed using:
   a. an oil filter wrench.
   b. a flare nut wrench.
   c. your hand.
   d. arc joint pliers.
5. When tightening lug fasteners, an impact wrench should:
   a. always be used.
   b. never be used.
   c. be used in difficult-to-access positions.
   d. never be used in high-torque settings.
6. Which of these would you use for a wider grip and a tighter squeeze on parts too big for conventional pliers?
   a. Diagonal cutting pliers
   b. External snap ring pliers
   c. Arc joint pliers
   d. Combination pliers
7. When a large chisel needs a really strong blow, use a:
   a. sledgehammer.
   b. hard rubber mallet.
   c. dead blow hammer.
   d. ball-peen hammer.
8. Which style of torque wrench is the simplest and least expensive?
   a. Clicker
   b. Dial
   c. Beam
   d. Electronic
9. The depth of blind holes in housings can best be measured using a:
   a. measuring tape.
   b. steel rule.
   c. dial bore gauge.
   d. vernier caliper.
10. All of the following are good practices *except*:
    a. replacing cleaning products when they lose their effectiveness.
    b. discarding solvents into the sewage system immediately after use.
    c. using chemical gloves when using any cleaning material.
    d. wearing a respirator when using toxic cleaning chemicals.

ASE Technician A/Technician B Style Questions

1. Tech A says that knowing how to use tools correctly creates a safe working environment. Tech B says that a flare nut wrench is used to loosen very tight bolts and nuts. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says that lockout is designed to secure a vehicle after all work on it has been completed. Tech B says that tag-out is used when a tool is no longer fit for use and identifies what is wrong with it. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says that torque wrenches need to be calibrated periodically to ensure proper torque values. Tech B says that when using a clicker-style torque wrench, keep turning the torque wrench ⅛–¼ turn to make sure the bolt is properly tightened. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
4. Tech A says that when using a micrometer, a "standard" is used to hold the part you are measuring. Tech B says that the micrometer spindle should be firmly closed against the anvil prior to storage. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

5. Tech A says that a box-end wrench is more likely to round the head of a bolt than an open-end wrench. Tech B says that 6-point sockets and wrenches will hold more firmly when removing and tightening bolts. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says that it is usually better to pull a wrench to tighten or loosen a bolt. Tech B says that pushing a wrench will protect your knuckles if the wrench slips. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. Tech A says that a feeler gauge is used to measure the diameter of small holes. Tech B says that a feeler gauge and straight edge are used to check surfaces for warpage. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. Tech A says that a dead blow hammer reduces rebound of the hammer. Tech B says that a dead blow hammer should be used with a chisel to cut the head of a bolt off. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. Tech A says that gaskets can be removed quickly and safely with a hammer and sharp chisel. Tech B says that extreme care must be used when removing a gasket on an aluminum surface. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Tech A says that when using a file, apply pressure to file in the direction of the cut and no pressure when pulling the file back. Tech B says that file cards are used to file uneven surfaces. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B

CHAPTER 4
Fasteners and Thread Repair

NATEF Tasks

- **N04001** Perform common fastener and thread repair, to include: remove broken bolt, restore internal and external threads, and repair internal threads with thread insert.

Knowledge Objectives

After reading this chapter, you will be able to:

- **K04001** Identify threaded fasteners and describe their use.
- **K04002** Identify standard and metric fasteners.
- **K04003** Describe how bolts are sized.
- **K04004** Describe thread pitch and how it is measured.
- **K04005** Describe bolt grade.
- **K04006** Describe the types of bolt strength required.
- **K04007** Describe nuts and their application.
- **K04008** Describe washers and their applications.
- **K04009** Describe the purpose and application of thread-locking compounds.
- **K04010** Describe screws and their applications.
- **K04011** Describe the torque-to-yield and torque angle.
- **K04012** Describe how to avoid broken fasteners.
- **K04013** Identify situations where thread repair is necessary.
- **K04014** Describe trim panel fastener removal procedures.

Skills Objectives

- **S04001** Perform common fastener and thread repair.
- **S04002** Perform trim panel fastener removal procedures.

You Are the Automotive Technician

The new intern was helping you disassemble a leaking water pump. All was going well until one of the bolts broke off while removing it. It is evident that the shank of the bolt had been narrowed considerably due to rust and corrosion over time. You know that removing this bolt could turn the job into a real nightmare if not performed properly and carefully. It is also an opportunity to teach the intern how to perform this important task. As you are thinking about this task, several questions come to mind.

1. If part of the bolt extends past the surface it is threaded into, what can be done to try to remove it without using a bolt extractor?
2. What processes can be tried on bolts that are stuck, before they are broken off?
3. Is it okay to use a replacement bolt of a different grade from the original bolt? Why or why not?
4. What is the purpose of a thread-locking compound? Give an example of when should it be used?
5. What is the purpose of antiseize? Give examples of when it should and shouldn't be used?

▶ Introduction

Fasteners come in two common types: threaded fasteners and non-threaded fasteners (**FIGURE 4-1**). Both types of **fasteners** are designed to secure parts. **Threaded fasteners** are primarily designed to clamp objects together. Non-threaded fasteners are designed to hold parts together, such as preventing a component from falling off a shaft by using C-clips, cotter pins, roll pins, or other retainers. They can also be used to clamp components together, for example, with rivets. Each type of fastener has a different purpose or application, so getting to know the various kinds will help you know how to disassemble and reassemble component assemblies. We cover the major types of threaded and non-threaded fasteners below.

▶ Threaded Fasteners and Torque

K04001 Identify threaded fasteners and describe their use.

Threaded fasteners are designed to secure parts that are under various tension and sheer stresses. The nature of the stresses placed on parts and threaded fasteners depends on their use and location. For example, head bolts withstand tension stresses by clamping the head gasket between the cylinder head and block so that combustion pressures can be contained in the cylinder (**FIGURE 4-2**). The bolts must withstand the very high combustion pressures trying to push the head off the top of the engine block in order to prevent leaks past the head gasket. In this situation, the pressure is trying to stretch the head bolts, which means they are under tension.

Some fasteners must withstand sheer stresses, which are sideways forces trying to shear the bolt in two (**FIGURE 4-3**). An example of fasteners withstanding sheer stresses is wheel lug studs and lug nuts. They clamp the wheel assembly to the suspension system, and the weight of the vehicle tries to sheer the lug studs. If this were to happen, the wheel would fall off the vehicle, likely leading to an accident.

FIGURE 4-1 **A.** Threaded fasteners. **B.** Non-threaded fasteners.

To accomplish their job, fasteners come in a variety of diameters for different sized loads, and hardnesses, which are defined in grades. Threaded fasteners are designed to be tightened to a specified amount depending on several factors such as the job at hand, the grade or hardness of the material they are made from, their size, and the thread type. If a fastener is over-tightened, it could become damaged or could break. If it is under-tightened, it could work loose over time. Torque is a measure of twisting force around an axis, so it is a way of defining how much a fastener should be, or is, tightened to. Manufacturers print **torque specifications** in torque charts for virtually every fastener on a vehicle.

The idea of threaded fasteners has been around since approximately 240 B.C., when Archimedes invented the screw conveyor. The screw design was adapted to a straight pin to attach different materials together. As time progressed, the materials that the screw was made from became stronger, and the sizing became more precise. Whitworth created a thread profile that had a rounded crest and rounded root in England in 1841 (**FIGURE 4-4**). Then in 1864, in the United States, Sellers created a thread profile that had a flat crest and flat root (**FIGURE 4-5**).

In order to create the threaded fasteners we use today, the flat crest and rounded root is used along with a 60-degree pitch angle (**FIGURE 4-6**). Metric and standard size bolts use the same shape of threads, excluding specialty-use bolts, which are made for a particular purpose, such as the lead screw for a vice or gear puller. The square edges of this specialty thread (**square thread**) tend to exert force more in line with the screw, where a V-thread tends to push at a 90-degree angle to the thread, not the screw (**FIGURE 4-7**).

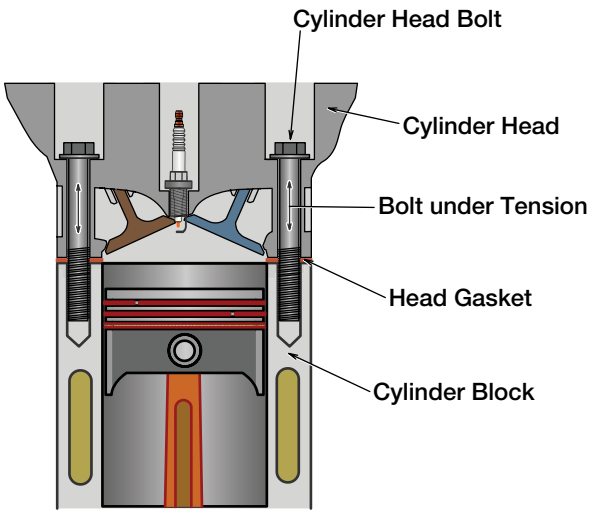


FIGURE 4-2 Bolts clamp parts together.

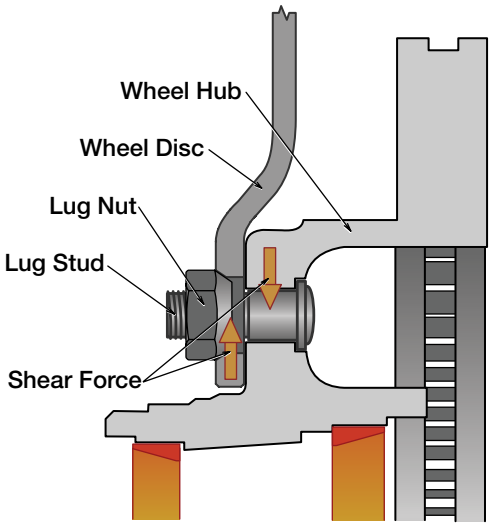


FIGURE 4-3 Bolt under sheer stresses.

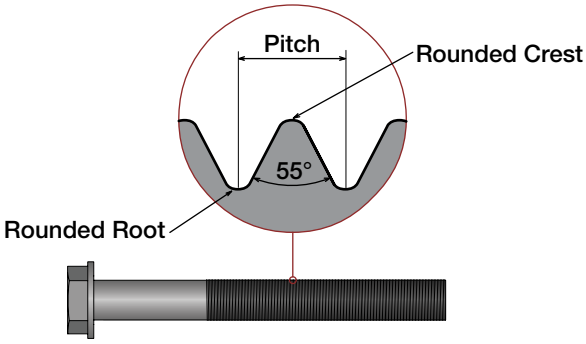


FIGURE 4-4 Whitworth thread.

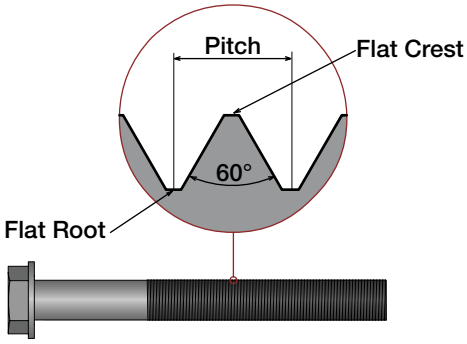


FIGURE 4-5 Sellers thread.

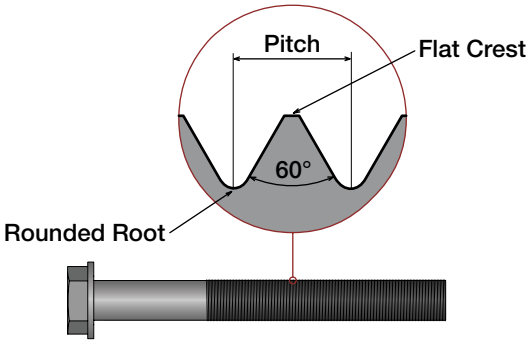


FIGURE 4-6 Current thread.

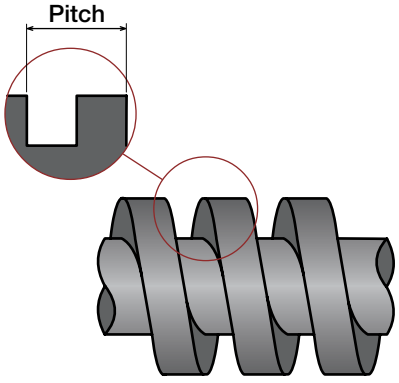


FIGURE 4-7 Square thread as used in a vice.

▶ Fastener Standardization

There are many different groups that monitor and set the standards that make the automotive industry conform to one universally recognized specification set. There are three main groups to know about. The American Society for Testing and Materials (ASTM) is a nongovernmental controlled group that tests and sets standards in all areas of industry. The International Organization for Standardization (ISO) is an independent developer of standards that are created to ensure a reliable, safe, and quality product. The Society of

K04002 Identify standard and metric fasteners.

Automotive Engineers (SAE) was initially started to standardize automotive production and has since grown to encompass a lot of engineering disciplines creating standards and best practices literature.

Metric Bolts

The metric bolt came about from the ISO standard 898, which defines mechanical and physical properties of metric fasteners. The ISO is an independent developer of voluntary international standards. In other words, any one government or group does not control them. The ISO develops standards that apply to many different industries in many different countries, using an unbiased logical approach. The metric decimal system has been around since the late 1600s and is sequential, so people can quickly see which number is larger. Many countries have adopted this standard for their weights and measure systems, but have also retained their own customary standards. Certain industries have required more precision in measurement, so they have adopted the metric system exclusively.

FIGURE 4-8 Metric bolts can be identified by the grade number on the top of the bolt head.

The automotive industry is one that deals in precise measurement and exact specifications in every aspect of automobile design. For this reason and because most automotive companies are worldwide, the automotive industry has embraced the metric measuring system. Uniformity is very important in the production environment, as it leads to efficiencies and conformity. Because of this, most vehicle manufacturers use metric fasteners almost exclusively, but not entirely. So you need to be able to distinguish between metric and standard fasteners. Most metric fasteners can be identified by the grade number cast into the head of the bolt (**FIGURE 4-8**).

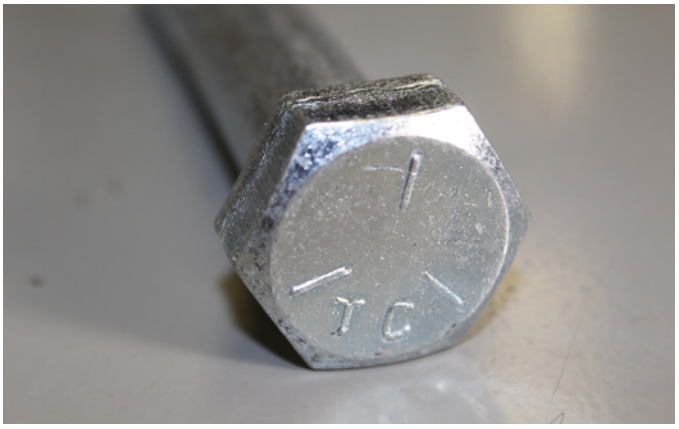


FIGURE 4-9 Standard bolts can be identified by the hash marks on top of the bolt head.

Standard Bolts

The standard measurement of bolts is a combination of the Imperial and U.S. customary measurement systems. SAE standard J429 covers the Mechanical and Material Requirements that govern this standard for externally threaded fasteners. It combines the British measuring units and the U.S. measuring units created after the Revolutionary War. Based on the British units of measure, units have been developed over the past millennia to arrive at today's standards. Instead of using a decimal number–based system like the Metric units, they are fractional based. Because the measurement system is based on a fractional scale, people unfamiliar with fractions can find using it difficult. This system is falling out of favor with many industries. As technology becomes more demanding, more precision and standardization is required for both effectiveness and efficiency. Standard bolts can generally be identified by hash marks cast into the head of the bolt, indicating the bolt's grade (**FIGURE 4-9**).

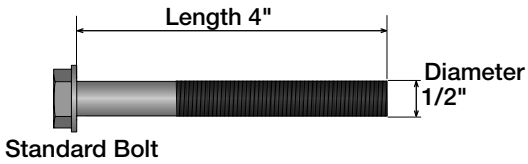
FIGURE 4-10 Bolts, studs, and nuts.

▶ Bolts, Studs, and Nuts

Bolts, studs, and nuts are threaded fasteners designed for jobs requiring a fastener heavier than a screw and tend to be made of metal alloys, making them stronger (**FIGURE 4-10**). Typical **bolts** are cylindrical pieces of metal with a hexagonal head on one end and a thread cut into the shaft at the other end. The thread acts as an inclined plane; as the bolt is turned, it is drawn into or out of the mating thread. Hexagonal **nuts** thread onto the bolt thread. The hexagonal heads for the bolt and nut are designed

to be turned by tools such as wrenches and sockets. Note that other bolt head designs are used as well. These require special shaped tools as covered in the Hand Tools chapter.

A **stud** does not have a fixed hexagonal head; rather, it has a thread cut on each end. It is threaded into one part where it stays. The mating part is then slipped over it, and a nut is threaded onto the other end of the stud to secure the part. Studs are commonly used to attach one component to another, such as a throttle body to the intake manifold. Studs can have different threads on each end, to work best with the material they are threaded into. Coarse threads work well in aluminum; in such cases, one end of the stud may use a coarse thread to grip the threads in an aluminum intake manifold and to position the throttle body. On the other end, there may be a fine thread for pulling everything together tightly with a steel nut. Bolts, nuts, and studs have either standard or metric threads. They are designated by their thread diameter, thread pitch, length, and grade. The diameter is measured across the outside of the threads, in fractions of an inch for standard-type fasteners, and millimeters for metric-type fasteners. So a 3/8" (9.5 mm) bolt has a thread diameter of 3/8" (9.5 mm). It is important to note that a 3/8" (9.5 mm) bolt does not have a 3/8" (9.5 mm) bolt head.



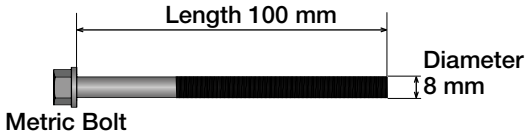


FIGURE 4-11 Bolt diameter and length.

Sizing Bolts

K04003 Describe how bolts are sized.

Bolts are sized either by metric or standard measuring systems. A ½" (12.7 mm) bolt does not mean that the bolt has a head that fits into a ½" (12.7 mm) socket. It means that the distance across the outside diameter of the bolt's threads measures ½" (12.7 mm) in diameter. The same goes for the metric equivalent; an 8 mm bolt is the diameter of the outside diameter of the bolt's threads. The length of a bolt is fairly straightforward. It is measured from the end of the bolt to the bottom of the head and is listed in inches or millimeters (**FIGURE 4-11**).

Thread Pitch

K04004 Describe thread pitch and how it is measured.

The coarseness of any thread is called its **thread pitch** (**FIGURE 4-12**). In the standard system, bolts, studs, and nuts are measured in threads per inch (TPI). To determine the TPI, simply count the number of threads there are in 1" (25.4 mm). Each bolt diameter in the standard system can typically have one of two thread pitches, **Unified National Coarse Thread (UNC)** or **Unified National Fine Thread (UNF)**. For example, a 3/8–16 is coarse, and a 3/8–24 is fine. In the metric system, the thread pitch is measured in millimeters by the distance between the peaks of the threads. So course threads have larger distances, and fine threads have smaller distances. Each bolt diameter in the metric system can have up to four thread pitches (**FIGURE 4-13**). Consult a metric thread pitch chart, because there is no clear pattern of thread pitches for metric fasteners. These charts can be found in tap and die sets or on the Internet.

FIGURE 4-12 UNC and UNF standard bolt thread pitch.

FIGURE 4-13 Metric thread pitches.

Thread Pitch Gauge

Thread pitch gauges make identifying the thread pitch on any bolt quick and easy. Without a thread pitch gauge, technicians are stuck measuring the number of threads per inch, or the distance from peak to peak in millimeters, with a ruler. Each thread pitch gauge matches a particular thread pitch that is stamped or engraved on the gauge. To use a thread pitch gauge, find the gauge that fits perfectly into the threads on the bolt you are measuring. Just make sure you keep the gauge parallel to the shaft of the bolt; otherwise, you will get a wrong match (**FIGURE 4-14**).

Grading of Bolts

K04005 Describe bolt grade.

What is bolt grading? Bolt grade or class means that the fastener meets the strength requirements of that grade or classification. There are a variety of grades, so it is important to use the specified grade of bolt for each component. When bolts are tested for grade, the bolt is put in a testing tool and abused to the point of breakage so that the maximum readings can be determined to properly grade the fastener. We need to know a bolt's grade so that we are able to use the correct fastener for the application and avoid bolt failures down the road. Standard bolts are typically grade 1 to grade 8, with grade 8 being the strongest. The grade can be identified by counting the hash marks on the head of the bolt and adding two to that number. For example, there are three hash marks on the head of a grade 5 bolt and six on the head of a grade 8 bolt (**FIGURE 4-15**).

Metric bolt grades are typically grade 4.6 to grade 12.9, with grade 12.9 being the strongest. In metric bolts, the grade number is cast into the top of the bolt head. These numbers on metric bolts have specific meanings. The number before the decimal indicates its tensile strength in megapascals (MPa), which is found by multiplying the number by 100. For example a metric 12.9-grade bolt would have a tensile strength of 1200 MPa. The number to the right of the decimal, when multiplied by 10 indicates the yield point as a percentage of the tensile strength (**FIGURE 4-16**).

Just because the higher grades are stronger doesn't mean you should use those in all applications. There are times when lower-graded bolts are more appropriate for particular applications, such as with some head bolts that need to have a little bit of give in them to allow for expansion and contraction of the cylinder head when the head gasket is clamped in place. Otherwise, the head gasket seal could fail. In other situations, using the wrong grade of bolt could cause either the bolt to fail or the threads in the threaded hole to fail. So you should always use the specified grade bolt when replacing bolts with new ones.

FIGURE 4-14 Thread pitch gauge being used. **A.** Standard. **B.** Metric.

FIGURE 4-15 **A.** Grade 5 standard bolt. **B.** Grade 8 standard bolt.

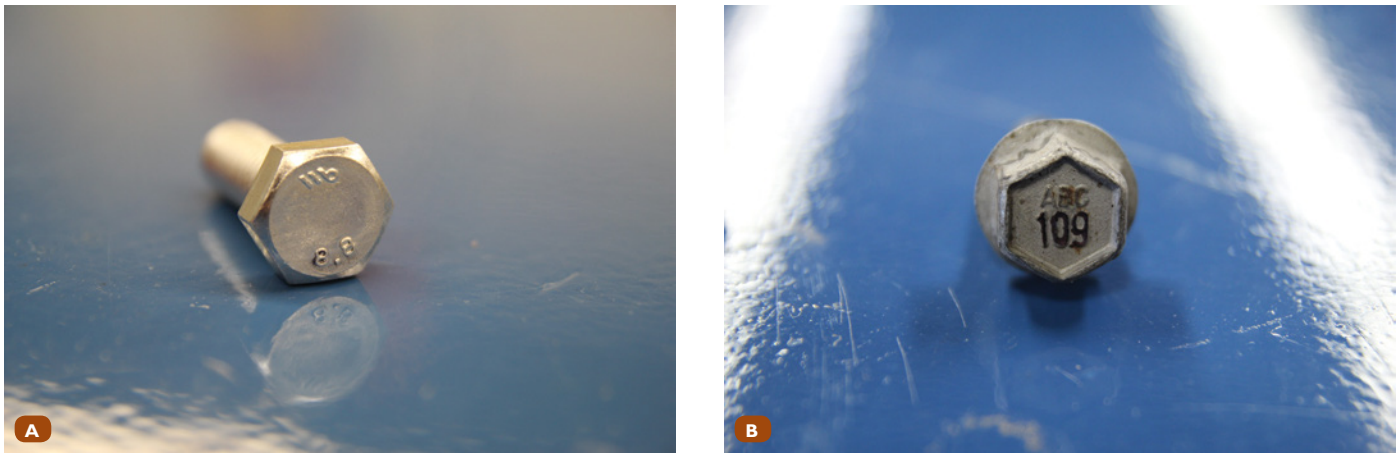


FIGURE 4-16 **A.** Grade 8.8 metric bolt **B.** Grade 10.9 metric bolt.

Strength of Bolts

Tensile Strength

Tensile strength is the maximum tension (applied load) the fastener can withstand without being torn apart or the maximum stress used under tension (lengthwise force) without causing failure. Tensile strength is determined by the strength of the material and the size of the stress area. When a typical threaded fastener fails in pure tension, it usually fractures through the threaded portion, as that is the weakest area because it is also the smallest area of the bolt (**FIGURE 4-17**). Generally speaking, the higher the grade of bolt, the higher the tensile strength.

K04006 Describe the types of bolt strength required.

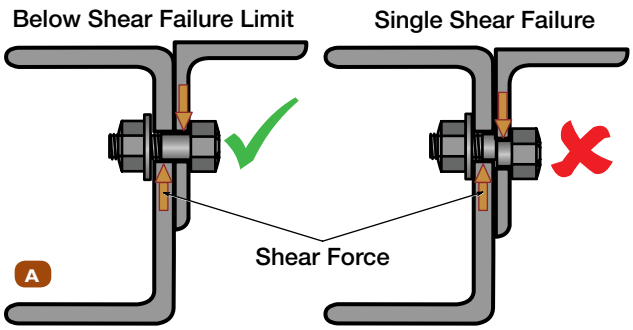
FIGURE 4-17 Bolt failure (tension).

Shear Strength

Shear strength is defined as the maximum load that can be supported prior to fracture, when applied at a right angle to the fastener's axis. A load occurring in one transverse plane is known as single shear (**FIGURE 4-18**). Double shear is a load applied in two planes, where the fastener could be cut into three pieces. For most standard threaded fasteners, shear strength is not specified, even though the fastener may be commonly used in shear applications. Generally speaking, the higher the grade of bolt, the higher the shear strength.

Proof Load

The proof load represents the usable strength range for certain standard fasteners. By definition, the proof load is an applied



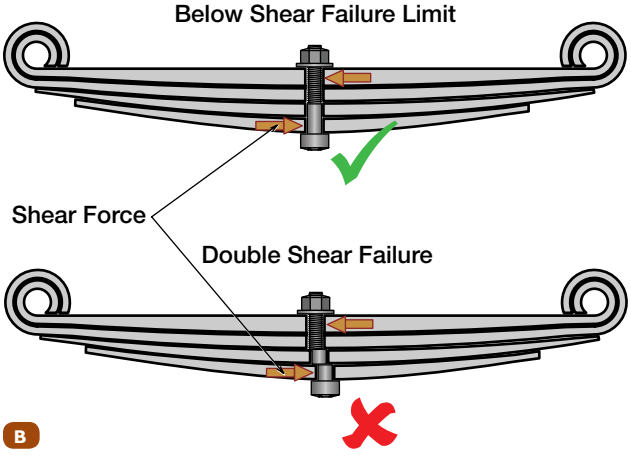


FIGURE 4-18 **A.** Single shear. **B.** Double shear.

tensile load that the fastener must support without exceeding the elastic phase, which is the point up to which the bolt returns to its original point when tension is removed.

Fatigue Strength

A fastener subjected to repeated cyclic loads can suddenly and unexpectedly break, even if the loads are well below the strength of the material. The repeated cyclic loading weakens the fastener over time, and it fails from fatigue. The fatigue strength is the maximum stress a fastener can withstand for a specified number of repeated cycles before failing. Connecting rod bolts are an example of a situation where fatigue strength would need to withstand millions of cyclic loads.

Torsional Strength

Torsional strength is a measure of a material's ability to withstand a twisting load, usually expressed in terms of torque, in which the fastener fails by being twisted off about its axis. A fastener that fails due to low torsional strength typically fails during installation or removal. Generally speaking, the higher the grade, the higher the torsional strength of the fastener.

Ductility

Ductility is the ability of a material to deform before it fractures. A material that experiences very little or no plastic deformation before fracturing is considered brittle. Think of a piece of flat glass: If you try to bend it, it breaks easily. This is an example of a material with low ductility material. Most automotive fasteners need to have some measure of ductility to avoid catastrophic failure. A reasonable indication of a fastener's ductility is the ratio of its specified minimum yield strength to the minimum tensile strength. The lower this ratio, the more ductile the fastener, meaning that the more ductile the bolt, the more it can flex or stretch without breaking. Generally speaking, the higher the grade, the lower the ductility of the fastener. So a balance between tensile strength and ductility is needed that depends on the requirements of the application.

Toughness

Toughness is defined as a material's ability to absorb impact or shock loading. Impact strength toughness is rarely a specified requirement for automotive applications. In addition to its specification for various aerospace industry fasteners, ASTM A320 specification for alloy steel bolting materials for low-temperature service is one of the few specifications that requires impact testing on certain grades.

Nuts

K04007 Describe nuts and their application.

Nuts are screwed onto the threads of a bolt to hold something together. They have internal threads that match the threads on the same size bolt. The many different kinds of nuts are mostly application specific. We cover some of the more popular ones below. When you replace a nut with a new nut on a vehicle, you need to match the nut to the grade of bolt or stud that it is going to be screwed onto. For example, if the bolt is a grade 8, you need a grade 8 nut. By matching the grade of fasteners, you are keeping the integrity of the manufacturer's intended fastening system. If you mix different grades of bolts and nuts, one could prematurely fail, causing catastrophic failure of the component.

Locking Nuts

Locking nuts are used when there is a chance of the nut vibrating loose. Two common types of locking nuts are used in automotive applications: the nylon insert lock nut and the deformed lock nut (**FIGURE 4-19**). The nylon lock nut has a nylon insert with a smaller diameter hole than the threads in the nut. As the nut is threaded onto the bolt, the nylon insert is deformed by the bolt threads, which tends to lock the nut onto the thread of the bolt or stud so that it can't vibrate loose. In a deformed lock nut, the top thread of the nut is deformed, thus pinching the bolt threads so the nut can't vibrate loose. Both of these types of lock nuts are considered single use, meaning they should be replaced with new ones once they have been removed.

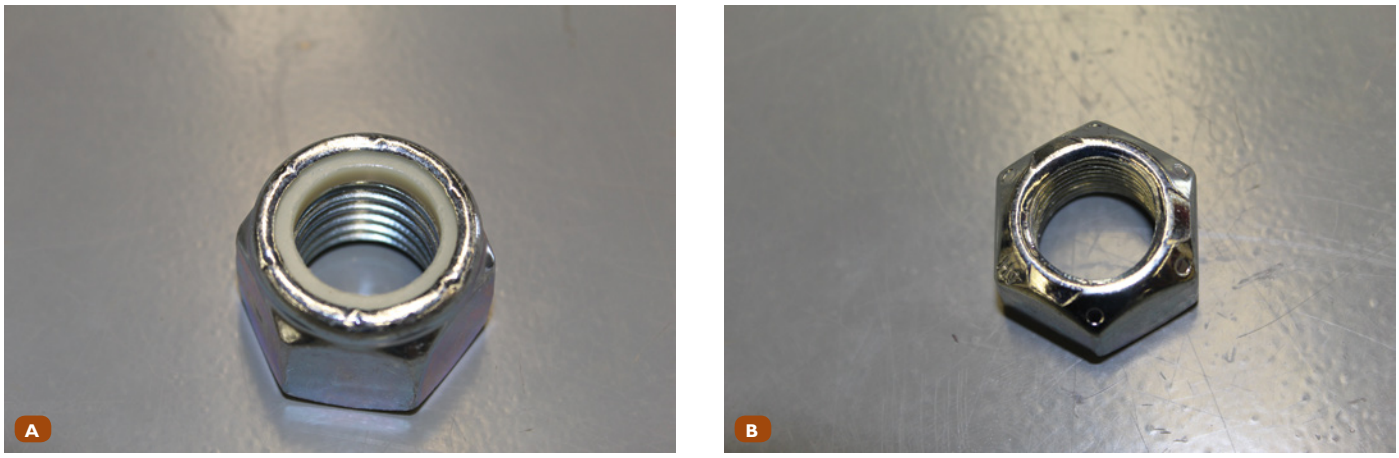


FIGURE 4-19 **A.** Nylon lock nut. **B.** Deformed lock nut.

Castle Nuts

Castle nuts, sometimes called castellated nuts, are used with a cotter pin to keep them from moving once they are installed. Protrusions and notches are machined into the top of the nut. The notches then can be lined up with a hole in the threaded bolt or stud (**FIGURE 4-20**). A cotter pin passes through the notch on one side of the nut, then through the hole in the stud and out the notch in the other side of the nut. The cotter pin physically prevents the castle nut from backing off the stud. These nuts are usually used on suspension components or other critical components so that they can't loosen up. It is good practice to always use new cotter pins and visually check to verify if they are installed in the castle nuts before finishing up a job (**FIGURE 4-21**).

FIGURE 4-20 Castle nut used on a ball joint.

Specialty Nuts

In the automotive industry. there are lot of specialty nuts with special characteristics—for example, an extended shoulder, a special head size, or a special material—required for a particular application. You must use the correct nut for the correct application (**FIGURE 4-22**). Sheet metal nuts are a cheap alternative to a regular nut that manufactures are using on different components. Sometimes called J nuts, these nuts are folded

FIGURE 4-21 New cotter pins installed in the castle nuts.

FIGURE 4-22 A variety of specialty nuts.

piece of sheet metal that fits over a hole in a piece of sheet metal; they are threaded to accept a fastener, and they usually do not need to be held as they are clipped to the component. Failure to use the proper fasteners for the proper uses usually results in failure of the component.

Washers

K04008 Describe washers and their applications.

Why are washers used underneath bolt heads and nuts? There are three main purposes of a washer:

- To distribute the force exerted on the component that it is pressing against evenly
- To prevent the surface around the hole from being worn down due to tightening of the head of the bolt or nut against a surface
- To provide a measure of locking force to keep the bolt or nut from loosening due to vibration

Not all applications require washers that provide all three functions, so make sure you know what the application requires. When selecting a washer for a bolt or nut, make sure you use the correct type, size, and grade.

Grades of Washers

Just as with nuts, you want to match the grade of washer to the nut and bolt so that you can maximize the clamping force on the component (**FIGURE 4-23**). Using dissimilar metals that have different hardness characteristics can cause the surface of the softer metal to wear away. This reduces the clamping force over time, which can cause the bolt or component to fail. Not all washers have grade ratings on them, so be careful to select the proper one when replacing a damaged or missing washer with a new one.

Flat Washers

A flat washer is a piece of steel that has been cut in a circular shape with a hole in the middle for the bolt or stud to fit through. Washers are sized and paired with a metric or standard bolt so that the pressure created by torquing the bolt down is spread out on the component that it is being used on (**FIGURE 4-24**). They prevent marring of the surface of the component around the bolt hole. They also act as a bearing surface so that the bolt achieves the expected clamping force at the specified torque. Flat washers are graded just like bolts, which means you need to match the grade on the washer with the fasteners that you are using them on.

Lock Washers

Lock washers are made from spring steel and have a slit cut in them to allow for the spring action to hold tension against the nut so that the nut will not loosen. Also, the slit is cut at an angle, with sharp edges on the top and bottom to cut into the bottom of the bolt head and the surface of the component being clamped (**FIGURE 4-25**). The sharp edges bite into the bolt and component if the bolt tries to loosen. These are used with conventional nuts and are usually used in applications that create a lot of vibration. Lock washers are usually considered to be single use and should be replaced rather than reused.

FIGURE 4-23 Washer with its grade rating marked on it.

Star Washers

Star washers, also called toothed lock washers, are used sometimes to stop the rotation of the nut above. They work in a similar way to lock washers in that the teeth are at angles so that they bite into the bottom of the bolt head and the surface being clamped (**FIGURE 4-26**). If these washers are required for your application, they need to be reinstalled before the nut is installed. They also should be replaced with new ones rather than reused.

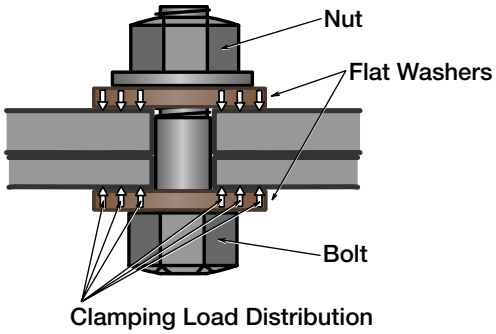


FIGURE 4-24 Flat washer spreading out the clamping force.

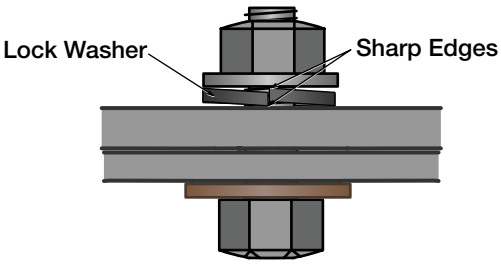


FIGURE 4-25 Lock washers prevent bolts and nuts from loosening. (Note: this nut and bolt is not fully tightened to show the action of the lock washer.)

FIGURE 4-26 Star washers prevent nuts and bolts from loosening.

▶ Threadlocker and Antiseize

K04009 Describe the purpose and application of thread-locking compounds.

Thread-locking compound is a liquid that is put on the threads of a bolt or stud to hold the nut that is threaded over it. The thread-locking compound acts like very strong glue. Once the compound between the nut and bolt cures, it bonds the two together so that they do not move. A popular thread-locking compound (threadlocker) that most automotive technicians prefer is Loctite®. The two main strengths of locking compound that are used in the automotive industry are blue and red (**FIGURE 4-27**). The blue allows for relatively easy removal of the nut or bolt with a socket and ratchet, whereas the red is much stronger. The red version usually requires a fair amount of heat to soften the compound so the nut or bolt can be removed. Thread-locking compound is a good safety item that technicians use on critical parts they do not want to come loose. In fact, the manufacturer may specify its use on certain fasteners, so be aware of situations that require thread-locking compound, and use the strength required.

Antiseize compound is the opposite of thread-locking compound as it keeps threaded fasteners from becoming corroded together or seized due to galling. One common use of antiseize compound is on black steel spark plug threads when the spark plug is installed into an aluminum cylinder head. Antiseize compound is a coating that prevents rust and provides lubrication so that the fastener can be removed in the future. Because of that, it should *not* be used on most fasteners in a vehicle; otherwise, they

FIGURE 4-27 Thread-locking compound.

could vibrate loose, causing damage or an accident. When you do use antiseize compound on specified fasteners, use a very light coating, as a little bit goes a very long way. In fact, a small can of antiseize lasts the average technician several years.

▶ Screws

K04010 Describe screws and their applications.

Many different types of screws are found in automotive applications (**FIGURE 4-28**). A screw is very similar to a bolt except for a couple of differences: They are not hardened and they tend to be used in light-duty applications where they need to hold together components that have a low shear or tensile strength.

Machine Screws

Similar to a bolt, a machine screw is used to fasten components together, but these are usually driven by a screwdriver with a Philips or slotted head. Machine screws are usually driven into a nut or threaded hole that has been tapped to the thread pitch of the screw. As vehicles become more complex, manufacturers have started to introduce new types of driving tools for these screws. Torx, square, and Allen head screws are becoming prevalent in this fastener group (**FIGURE 4-29**).

Self-Tapping Screws

Self-tapping screws are designed to create their own holes in the material they are being driven into. They have a fluted tip so you can drill a hole into the base material, without needing a pilot hole (**FIGURE 4-30**). The threads on a self-tapping screw are very similar to those on a sheet metal screw as they grip onto the metal as you drill through it. Usually they have a cap screw–type head so they can be driven with a screw gun, but they can have Phillips, square, Allen, or Torx heads as well.

FIGURE 4-28 Variety of screws.

Trim Screws

Trim screws are used in applications where there is a need to hold plastic and metal ornamentation to the vehicle. They are also used to hold door panels, trim pieces, and other small components to the vehicle. They are basic screws that are usually painted either the trim color or black so that they blend in with the material that they are used with (**FIGURE 4-31**).

Sheet Metal Screws

Sheet metal screws are used to attach things to sheet metal. They have a chip on the tip of the screw to push away material as it

FIGURE 4-29 Machine screw heads.

FIGURE 4-30 Self-tapping screws.

FIGURE 4-31 Trim screws.

FIGURE 4-32 Sheet metal screws.

comes off (**FIGURE 4-32**). These screws are usually threaded all the way up to the head so that they can be run down all the way, clamping the pieces together.

▶ Torque-to-Yield and Torque Angle

K04011 Describe the torque-to-yield and torque angle.

Torque is not always the best method of ensuring that a bolt is tightened enough as to give the proper amount of clamping force. If the threads are rusty, rough, or damaged in any way, the amount of twisting force required to tighten the fastener increases. Tightening the rusty fastener to a particular torque does not provide as much clamping force as a smooth fastener torqued the same amount. This also brings up the question of whether threads should be lubricated. In most automotive cases, the torque values specified are for dry, non-lubricated threads. But always check the manufacturer's specifications.

When bolts are tightened, they are also stretched. As long as they are not tightened too much, they will return to their original length when loosened. This is called **elasticity**. If they continue to be tightened and stretch beyond their point of elasticity, they will not return to their original length when loosened. This is called the **yield point**. As threaded fasteners are torqued, they go through the following phases:

- **Rundown Phase:** Free running fastener (may or may not have prevailing torque).
- **Alignment Phase:** Fastener and joint mating surfaces are drawn into alignment.
- **Elastic Phase:** *This is the third and final stage for normal bolts!* The slope of the torque/angle curve is constant. The fastener is elongated but will return to original length upon loosening.
- **Plastic or Yield Phase:** *Over-torqued condition for normal bolts. TTY bolts are tightened just into the beginning points of this phase.* Permanent deformation and elongation of the fastener and/or joint occur. Necking of the fastener occurs.

Torque-to-yield means that a fastener is torqued to, or just beyond, its yield point. With the changes in engine metallurgy that manufacturers are using in today's vehicles, bolt technology had to change also. To help prevent bolts from loosening over time and to maintain an adequate clamping force when the engine is both cold and hot, manufacturers have adopted **torque-to-yield (TTY) bolts**. TTY bolts are designed to provide a consistent clamping force when torqued to their yield point or just beyond. The challenge is that the torque does not increase very much, or at all, once yield is reached. So using a torque wrench by itself will not indicate the point at which the manufacturer wants the bolt tightened. TTY bolts generally require a new torquing procedure called torque angle. Also, it is important to note that in virtually all cases, TTY bolts cannot be reused because they have been stretched into their yield zone and would very likely fail if retorqued (**FIGURE 4-33**).

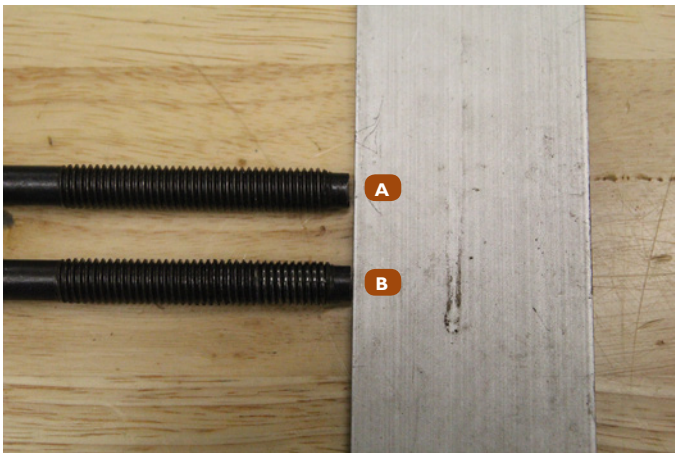
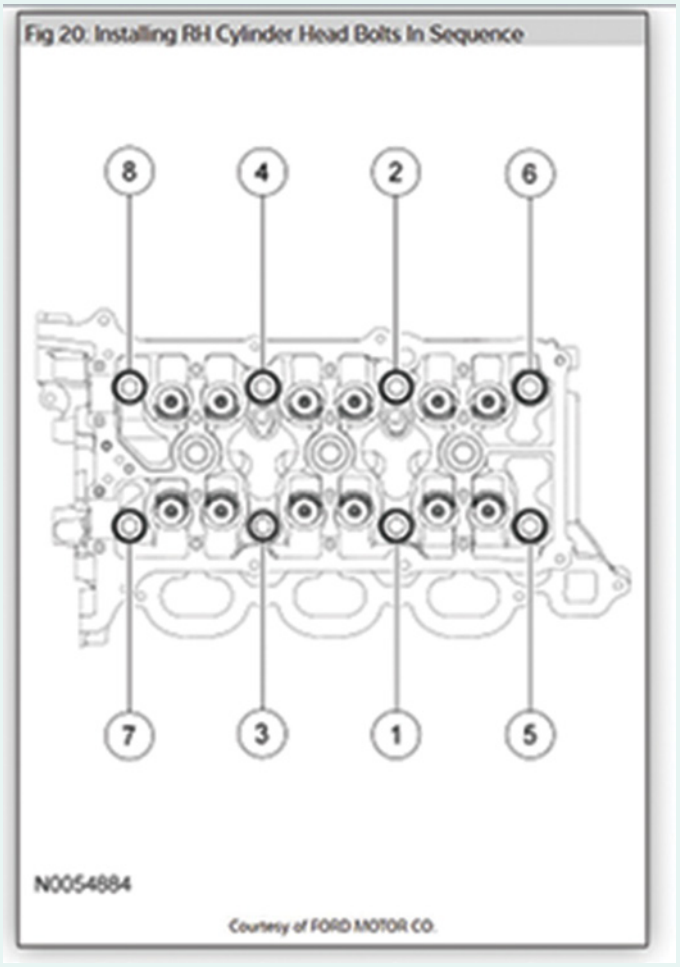


FIGURE 4-33 **A.** New TTY bolt. **B.** Used TTY bolt.

Torque angle is considered a more precise method to tighten TTY bolts and is essentially a multistep process. Bolts are first torqued in the required pattern, using a standard torque wrench to a required moderate torque setting. They are then further tightened one or more additional specified angles (torque angle) using an angle gauge, thus providing further tightening, which tightens the bolt to, or just beyond, their yield point. In some cases, after the initial torquing, the manufacturer first wants all of the bolts to be turned to an initial angle and then turned an additional angle. And in other cases, the manufacturer wants all of the bolts torqued in a particular sequence, then detorqued in a particular sequence, then retorqued once again in a particular sequence, and finally tightened an additional specified angle. So always check the manufacturer's specifications and procedure before torquing TTY bolts.

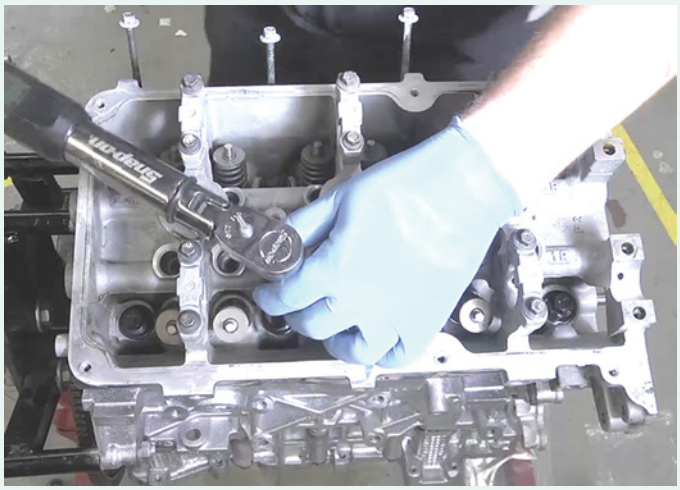
To use a torque angle gauge in conjunction with a torque wrench, follow the steps in **SKILL DRILL 4-1**.

SKILL DRILL 4-1 Using a Torque Angle Gauge with a Torque Wrench

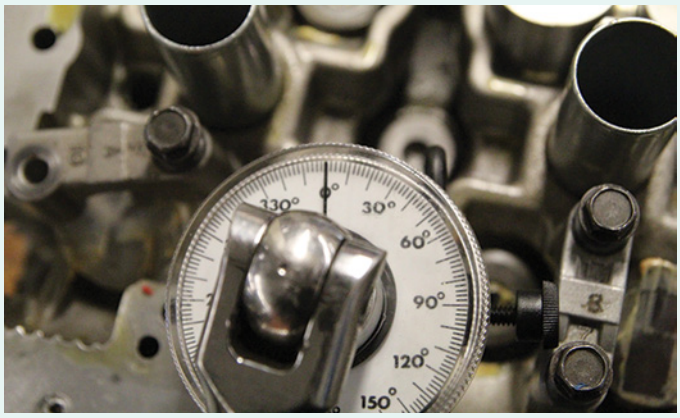


1. Check the specifications. Determine the correct torque value (ft-lb or N·m) and sequence for the bolts or fasteners you are using. Also, check the torque angle specifications for the bolt or fastener, and whether it involves one step or more than one step.

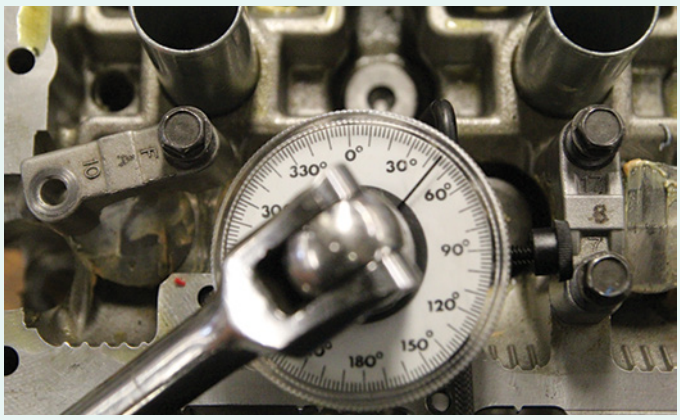
Continued



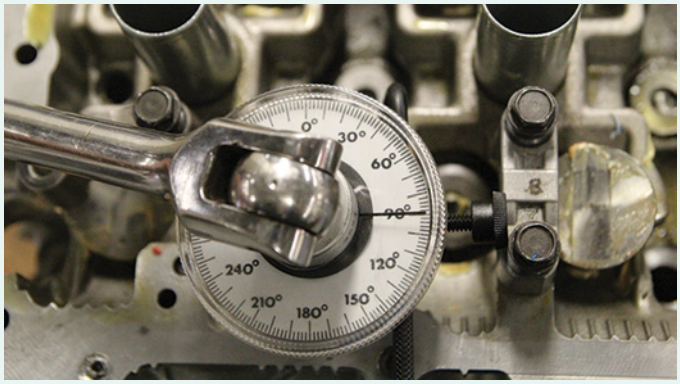
2. Tighten the bolt to the specified torque. If the component requires multiple bolts or fasteners, make sure to tighten them all to the same torque value in the sequence and steps that are specified by the manufacturer.



3. Install the torque angle gauge over the head of the bolt, and then put the torque wrench on top of the gauge and zero it, if necessary.



4. Turn the torque wrench the specified number of degrees indicated on the angle gauge.



5. If the component requires multiple bolts or fasteners, make sure to tighten them all to the same torque angle in the sequence that is specified by the manufacturer. Some torquing procedures could call for four or more steps to complete the torquing process properly.

How to Avoid Broken Fasteners

K04012 Describe how to avoid broken fasteners.

Broken bolts can turn a routine job into a nightmare job by adding hours dealing with the broken bolt. In most cases, it is worth taking a bit of extra time doing whatever is needed to avoid breaking a bolt. One of the first things to do is to make sure that you are not dealing with a left-handed bolt (**FIGURE 4-34**). Left-hand bolts loosen by turning them clockwise. So trying to loosen them by turning them counterclockwise will actually tighten them, making it likely you will break them off.

Another cause of broken bolts is fasteners that are rusted or corroded in place. Although it is impossible to prevent all broken bolts in this case, there are several things you can do to minimize the percentage of bolts you break. One of the first things to do is use a good penetrating oil. Penetrating oil actually penetrates the rust between the nut and bolt and breaks it down, making it easier to break the nut or bolt loose. Once the penetrating oil has been given time to soak into the threads of the fastener, you may attempt, with the proper tool, to try to loosen the fastener. Note that you may want to try both loosening and tightening the bolt to help break it loose. It may be good to try using an impact wrench as well, because the hammering effect might assist in breaking it loose. Just try it a little at a time in each direction, and not with too much force.

If the fastener is still not loosening, you may need to heat up the component to help break up the rust or corrosion. The heat not only expands the metal components, it also expands the space between the nut and bolt. This also helps break the nut or bolt loose. The bolt or nut can be heated up in two primary ways. The first is with an oxyacetylene torch, but be careful because the flame from the torch also burns everything in its path. When heating up a bolt on a vehicle, there are almost always other things in the way that could be affected by the heat. The second is with an inductive heater, which uses electrical induction to heat up any ferrous metal that is placed in the inductive coil (**FIGURE 4-35**). The induction heater is preferred by many technicians for many applications, as it doesn't have a flame and it only heats up what is in the induction coil. Most induction heaters come with several sizes of induction coils that make them handy for most applications.

When heating a fastener to remove it, you usually heat it up to a dull orange color and then let it cool a bit before attempting to remove it. Once a heated fastener is removed, it must be replaced with a new bolt because the heat alters the strength of the fastener.

Thread Repair

N04001 Perform common fastener and thread repair, to include: remove broken bolt, restore internal and external threads, and repaire internal threads with thread insert.

K04013 Identify situations where thread repair is necessary.

S04001 Perform common fastener and thread repair.

Thread repair is used in situations where it is not feasible to replace a damaged thread. This may be because the damaged thread is located in a large expensive component, such as the engine block or cylinder head of a vehicle, or because replacement parts are expensive or not available. The aim of thread repair is to restore the thread to a condition that restores

FIGURE 4-34 Left-hand lug nuts are installed on some vehicles.

FIGURE 4-35 Heating a stuck nut with an induction heater.

the fastening integrity (**FIGURE 4-36**). It can be performed on internal threads, such as in a housing, engine block, or cylinder head, or on external threads, such as on a bolt. However, it is usually easier to replace a bolt if the threads become damaged than repairing it.

FIGURE 4-36 Repaired thread.

Types of Thread Repair

Many different tools and methods can be used to repair a thread. The least invasive method is to reshape the threads. If the threads are not too badly damaged, such as when the end thread is slightly damaged from the bolt being started crooked (cross-threaded), then a thread file can be used to clean them up, or a restoring tool can be used to reshape them (**FIGURE 4-37**). Each thread file has eight different sets of file teeth that match various thread pitches. Select the set that matches the bolt you are working on, and file the bolt in line with the threads. The file removes any distorted metal from the threads. Only file until the bad spot is reshaped.

The thread-restoring tool looks like an ordinary tap and die set, but instead of cutting the threads, it reshapes the damaged portion of the thread (**FIGURE 4-38**). Threads that have substantial damage require other methods of repair.

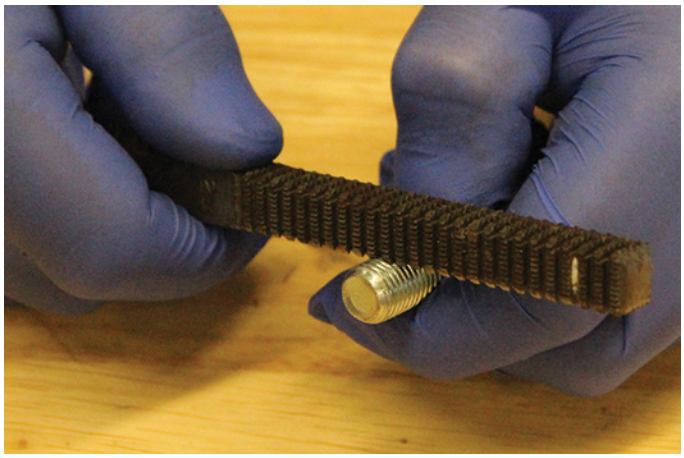


FIGURE 4-37 Threads being cleaned up with a thread file.

A common method for repairing damaged internal threads is a thread insert. A number of manufacturers make thread inserts, and they all work in a similar fashion. There are two main types of thread inserts: helical thread inserts and sleeve-type thread inserts (**FIGURE 4-39**). A helical thread insert of the same internal thread pitch is used when the threads need to be replaced with the same size thread. The damaged threaded hole is drilled out bigger, tapped with a special tap to a larger size that matches the outside size of the helical insert, and then the threaded coil insert is screwed into place. The insert provides a brand new internal thread that matches the original size. A common name for this type is a HeliCoil®.

The solid sleeve type of insert also replaces the damaged thread with the same size thread as the original. The difference between this type of insert compared to the helical insert is that this one is a slightly thicker insert that resembles a sleeve or bushing, but with threads on both the inside and outside. It may also have a small flange at the top of the insert that prevents it from being installed too deeply in the hole. Like the previous insert, the damaged hole needs to be drilled out to the proper oversize. Then a special tap is used to cut new threads in the hole that match the external thread on the insert. The insert is then installed in the hole and locked into place with either thread-locking compound or keys that get driven down into the base metal. A common name for this type is a Time-Sert.

FIGURE 4-38 Thread-restoring tool being used.

Self-tapping inserts are a type of insert that is driven in a similar way to a self-tapping screw, making its own threads and at the same time locking the insert into the base material. Bushing inserts are a type of threaded insert that is pressed into a blind hole with an arbor press. These types of inserts can be inserted in any material, so you must be aware of material that is soft as it may break if too much force is put to it. It has internal threads, so bolts and screws can be threaded into them.

The process of repairing a thread should first start with attempting to remove the broken bolt without damaging the threads. If this can be accomplished, then you will likely save time as well as avoid the possibility of making the problem worse, such as breaking off an

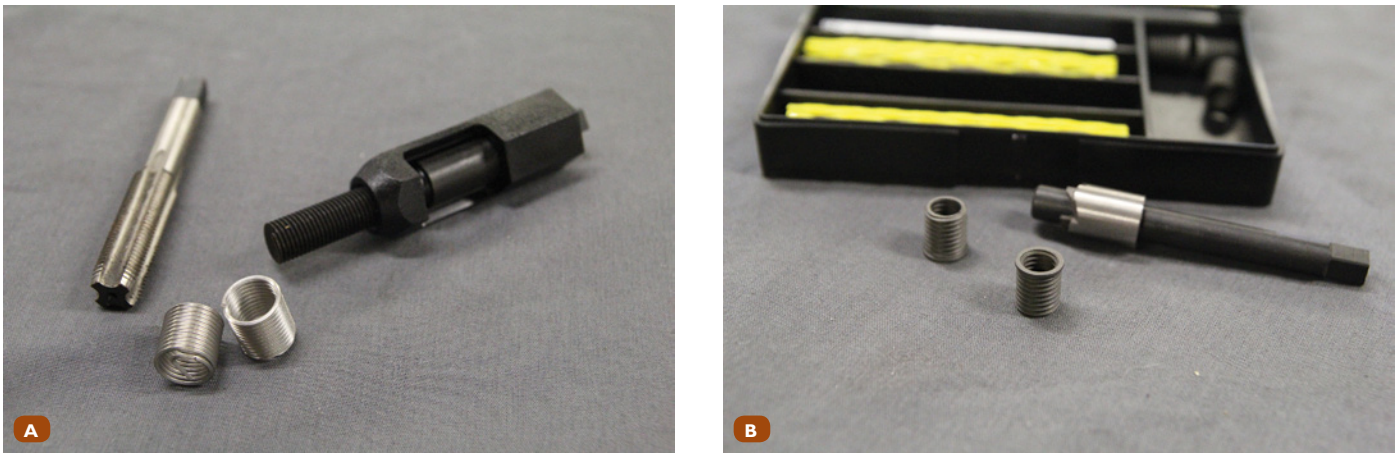


FIGURE 4-39 Thread inserts. **A.** Heli-Coil. **B.** Time-Sert.

easy out in the broken bolt. If the bolt can't be removed without damaging the threads, then the use of a thread insert to repair an internal thread is probably needed.

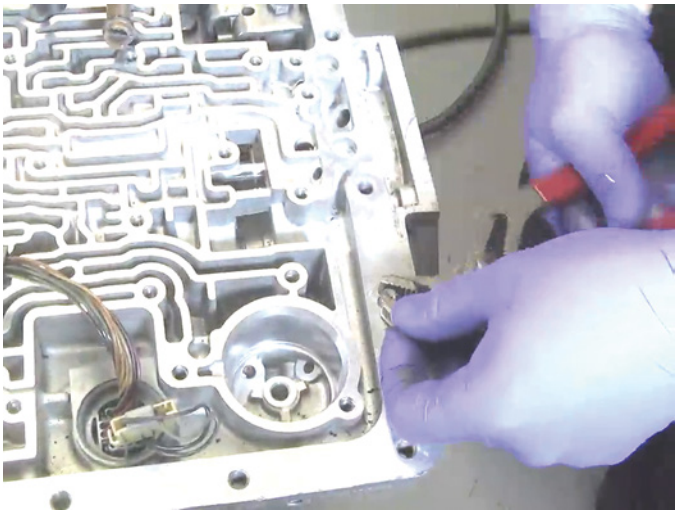


FIGURE 4-40 Using pliers to remove a broken bolt.

To remove a broken bolt, inspect the site. If enough of the bolt is sticking out of the surface, then a pair of pliers or locking pliers may be enough to turn and remove the bolt. The author has had quite a bit of luck using a pair of special curved jaw Channellock pliers. The curved jaw tends to get a better grip on the broken-off bolt than regular straight jaw Channellock pliers (**FIGURE 4-40**). Using penetrant or heat may help coax the bolt out. If the bolt is broken off flush with the surface, and the bolt is large enough in diameter, then you may be able to use a small center punch to turn the bolt by tapping on the outside diameter of the bolt, but in the reverse direction (**FIGURE 4-41**). If that doesn't work, or the bolt is too small in diameter, then a screw or bolt extraction tool can be tried.

Use a center punch to mark the center of the bolt to assist in centering the hole to drill. Select the correctly sized **screw extractor**, and drill the designated hole size in the center of the broken bolt to accommodate the extractor. Once the hole is drilled, insert the extractor and turn it counterclockwise (**FIGURE 4-42**).

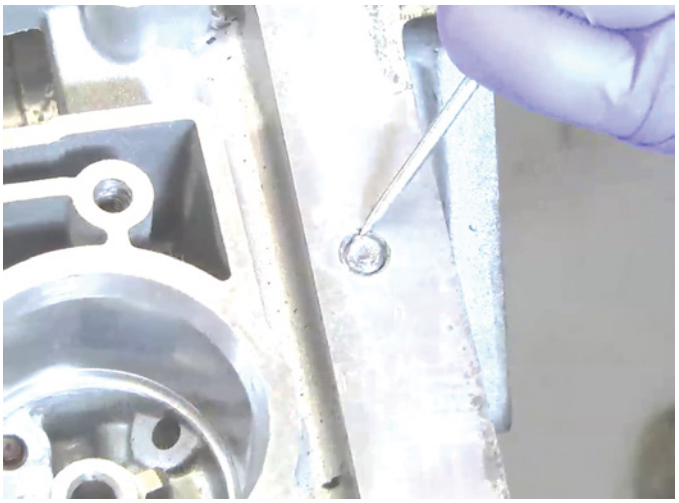


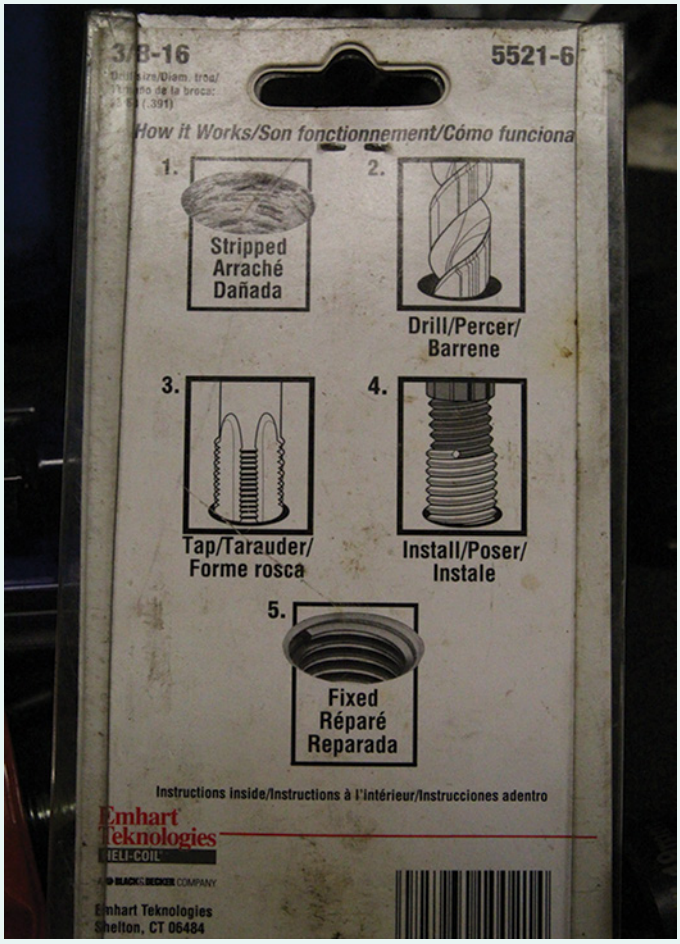
FIGURE 4-41 Removing a broken bolt with a center punch or cold chisel.

FIGURE 4-42 Removing a bolt with a screw extractor.

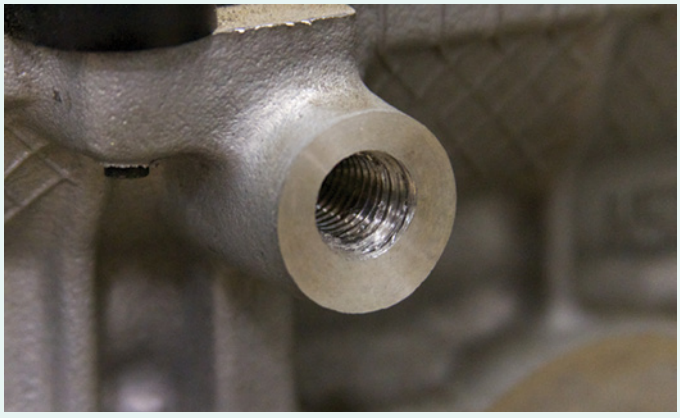
The flutes on the extractor should grab the inside of the bolt and hopefully enable you to back it out. Be careful not to exert too much force on the extractor if the bolt is extremely stuck in place. If the extractor breaks, it is almost impossible to remove it, as it is made of hardened steel that cannot be cut by most drill bits. Once the broken bolt is removed, run a lubricated tap or thread-restoring tool of the correct size and thread pitch through the hole, to clean up any rust or damage. If the screw extractor can't remove the broken bolt, then it will need to be drilled out. If the internal treads are damaged during the removal process, then the thread will have to be repaired with a thread insert, as described earlier.

To conduct thread repair, follow the steps in **SKILL DRILL 4-2**.

SKILL DRILL 4-2 Conducting Thread Repair



1. Always refer to the manufacturer's manual for specific operating instructions.



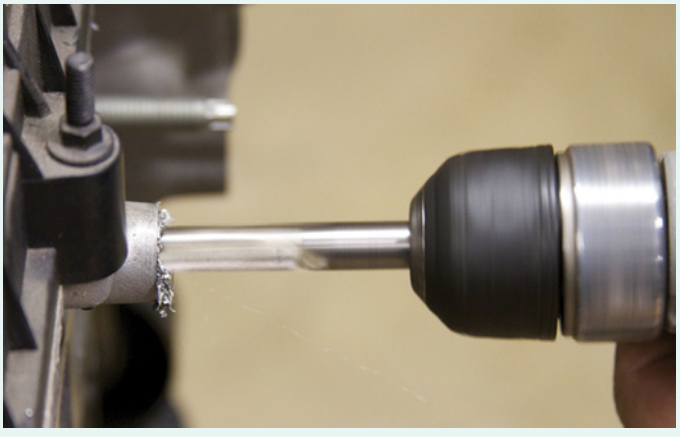
2. Inspect the condition of the threads, and determine the repair method.

Continued

3. Determine the type and size of the thread to be repaired. Thread pitch gauges and vernier calipers may be used to measure the thread.

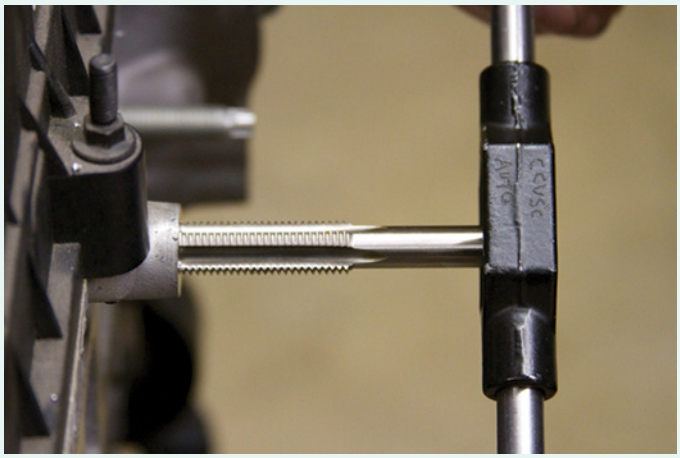
4. Prepare materials for conducting the repair: dies and taps or a drill bit and drill; cutting oil, if required; and inserts.

5. Select the correctly sized tap or die if conducting a minor repair. Run the die or tap through or over the thread; be sure to use cutting lubricant.



6. If using inserts, select the correctly sized insert, based on the original bolt size. Drill the damaged hole, ensuring the drill is in perfect alignment with the hole.

Continued



7. Cut the new thread, using the proper size tap. Make sure you use cutting lubricant if required.

8. Using the insert-installing tool, install the insert by screwing it into the newly cut threads. Make sure the insert is secure or locked into the hole using the method specified by the manufacturer. Some inserts use a locking tab, whereas others use a liquid thread locker that hardens and holds the insert in place.

9. Test the insert to ensure it is secure and that the bolt will screw all the way in.

▶ Trim Panel Fastener Removal Procedures

Overview

Interior trim panels must often be removed to access electrical harness wiring and components as part of electrical system diagnosis and repair. Trim panels are installed with a variety of fasteners, including familiar hardware like sheet metal and machine screws, hex head bolts and speed nuts. Trim is also installed and held in place by specialized fasteners

K04014 Describe trim panel fastener removal procedures.

S04002 Perform trim panel fastener removal procedures.

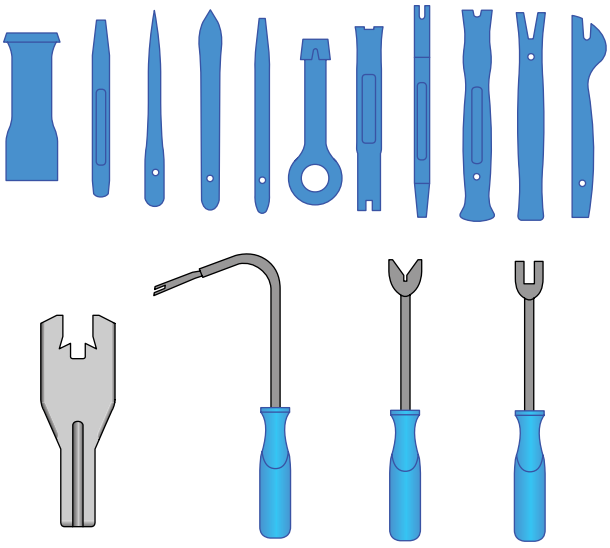


FIGURE 4-43 A variety of trim panel removal tools are required when performing electrical system diagnosis and repair.

usually referred to as trim clips. These trim clips come in a variety of types depending on application. Technicians are most familiar with door panel clips that pop into place and trunk lining clips that are pushed into place to keep the trunk lining material in place.

Trim panel clips are just as essential as the other fasteners used in the vehicle. These fasteners hold the various components in their correct location to provide proper fit and eliminate any squeaks and rattles. Damaged, missing or using an incorrect fastener may result in improper panel fit and could lead to a squeak, rattle, or worse, the panel comes loose during customer use.

Removing Trim Panel Fasteners

Trim fasteners must be removed using the appropriate tools (**FIGURE 4-43**). These tools are designed to facilitate removing trim panels without doing any damage to them or the surrounding area. For example, it is unfortunately common for technicians to remove door panels by pulling and tugging on the panel or using a flat blade screwdriver or gasket scraper to pry out the fasteners from their mounting location. This leads to broken fasteners or worse, damage to the door panel in the form of visible stress lines and damage to the trim clip retainer that is part of the panel (**FIGURE 4-44**). Many luxury vehicles use real wood trim that often comes as a matched set, meaning that the wood grain matches from piece to piece. Damaging this trim requires that all new trim be installed at great expense to your shop, as it is usually sold only as a matched set. The same applies for machine turned or brushed metal types of interior trim.

Access the related service information for trim panel removal. This information includes what type of trim clips are used, where they are located, and what tool is recommended for removal of the component.

To remove and install a door panel, follow the steps in **SKILL DRILL 4-3**. Follow the procedures carefully as you release the trim fasteners from their installed position. When working around painted surfaces you can apply painters tape to the tool and to the painted surface to avoid scratching the paint during your work.

▶ TECHNICIAN TIP

Some service information may not have a direct link to trim panel removal. For example, if you are working on the door lock, you may need to remove components on the door panel or the entire panel for component access. Searching for door panel removal may not yield any results. If it does not, then refer to the component you are diagnosing, in this case the door lock. Usually you can find trim panel removal as part of the door lock service procedures.

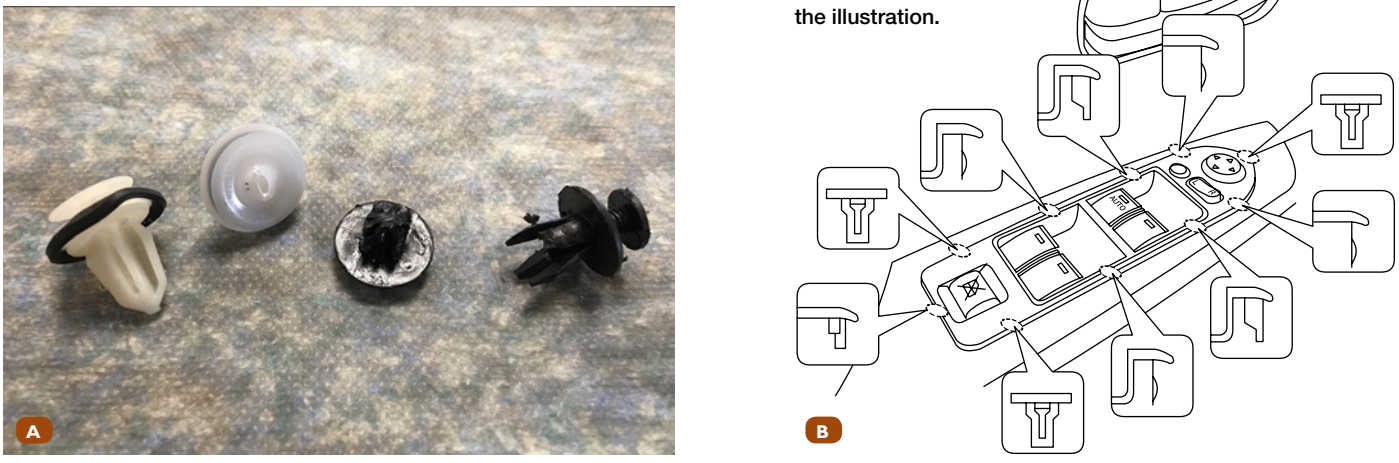


FIGURE 4-44 **A.** Improper trim removal results in damaged fasteners and trim panel components. **B.** Trim panel removal is referenced using the service information to note clip location and type along with any specific procedures required.

▶ TECHNICIAN TIP

As stated, trim fasteners are designed to perform a specific job. If a fastener is damaged it must be replaced. You should be aware that these fasteners range from under $1 to an average of about $3 for each clip. Some specific clips cost over $15 each. Your awareness of their cost and importance is demonstrated when you follow procedures and use the correct tools to do the job right.

SKILL DRILL 4-3 Removing and Installing a Door Panel

Your instructor will assign you a vehicle to remove the door panel.

1. Obtain the related service information for panel removal.
2. Obtain the required tools to remove the door panel.
3. Use painters tape as required to prevent damage to painted surfaces.
4. Follow the service procedure to remove the door panel.
5. Review your door panel removal with your instructor before re-installing.
6. Install the door panel following the service procedure. Ensure that all fasteners are in their proper place and align with the mating surface on the door or related trim before applying pressure during installation.
7. Review your door panel installation with your instructor.

▶ Wrap-Up

Ready for Review

- Threaded fasteners include bolts, studs, and nuts, and are designed to secure vehicle parts under stress.
- Torque defines how much a fastener should be tightened.
- Bolts, nuts, and studs use threads to secure each part; these threads can be in standard or metric measures.
- Thread pitch refers to the coarseness of the thread; bolts, nuts, and studs are measured in threads per inch (TPI), classified as Unified National Coarse Thread (UNC) or Unified National Fine Thread (UNF).
- Fasteners are graded by tensile strength (how much tension can be withstood before breakage).
- The SAE rates fasteners from grade 1 to grade 8; always replace a nut or bolt with one of the same grade.
- Torque specification indicates the level of tightness each bolt or nut should be tightened to; torque charts list torque specifications for nuts and bolts.
- Torque (or tension) wrenches tighten fasteners to the correct torque specification.
- Torque value—the amount of twisting force applied to a fastener by the torque wrench—is specified in foot-pounds (ft-lb), inch-pounds (in-lb), or newton meters (N·m).
- Bolts that are tightened beyond their yield point do not return to their original length when loosened.
- Torque-to-yield (TTY) bolts can be torqued just beyond their yield point, but should not be reused.
- Torque angle can be used to tighten TTY bolts and requires both a torque wrench and an angle gauge.
- Thread repair is performed to restore fastening integrity to a damaged fastener.
- Threads can be reshaped with a file, or a thread insert may be used.

Key Terms

bolt A type of threaded fastener with a thread on one end and a hexagonal head on the other.

coarse (UNC) Used to describe thread pitch; stands for Unified National Coarse.

elasticity The amount of stretch or give a material has.

fasteners Devices that securely hold items together, such as screws, cotter pins, rivets, and bolts.

fine (UNF) Used to describe thread pitch; it stands for Unified National Fine.

nut A fastener with a hexagonal head and internal threads for screwing on bolts.

screw extractor A tool for removing broken screws or bolts.

square thread A thread type with square shoulders used to translate rotational to lateral movement.

stud A type of threaded fastener with a thread cut on each end rather than having a bolt head on one end.

tensile strength In reference to fasteners, the amount of force it takes before a fastener breaks.

threaded fasteners Bolts, studs, and nuts designed to secure parts that are under various tension and sheer stresses. These include bolts, studs, and nuts, and are designed to secure vehicle parts under stress.

thread pitch The coarseness or fineness of a thread as measured by either the threads per inch or the distance from the peak of one thread to the next. Metric fasteners are measured in millimeters.

thread repair A generic term to describe a number of processes that can be used to repair threads.

torque Twisting force applied to a shaft, which may or may not result in motion.

torque angle A method of tightening bolts or nuts based on angles of rotation.

torque specifications Supplied by manufacturers and describes the amount of twisting force allowable for a fastener or a specification showing the twisting force from an engine crankshaft.

torque-to-yield A method of tightening bolts close to their yield point or the point at which they will not return to their original length.

torque-to-yield (TTY) bolts Bolts that are tightened using the torque-to-yield method.

torque wrench A tool used to measure the rotational or twisting force applied to fasteners.

yield point The point at which a bolt is stretched so hard that it will not return to its original length when loosened; it is measured in pounds per square inch of bolt cross section.

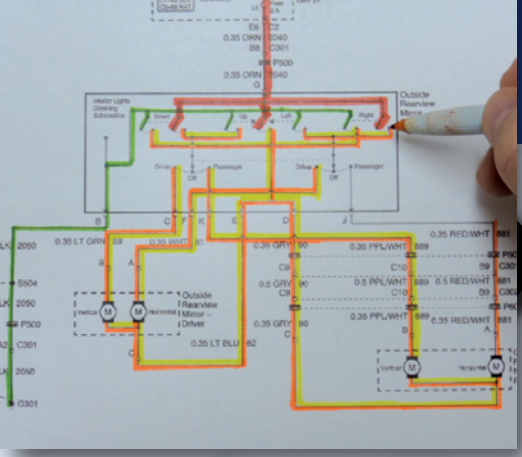
Review Questions

1. Which of these are threaded fasteners?
   a. C-clips
   b. Trim screws
   c. Cotter pins
   d. Solid rivets
2. All of the following statements are true *except*:
   a. Metric bolts can be identified by the grade number on the top of the bolt heads.
   b. Measuring units of standard bolts use a fractional number–based system.
   c. Standard bolts can be identified by the hash marks on the top of the bolt heads.
   d. Measuring units of metric bolts use a roman number–based system.
3. In an 8 mm bolt, 8 mm refers to the:
   a. length of the bolt.
   b. size of the bolt head.
   c. threads' outer diameter.
   d. number of threads per inch.
4. The easiest way to identify the TPI is to:
   a. use a vernier caliper.
   b. count the number of threads.
   c. measure distance from peak to peak.
   d. use a thread pitch gauge.
5. A bolt has 3 hash marks on its head. What is its grade?
   a. 2
   b. 5
   c. 6
   d. 8
6. Which nut is made with a deformed top thread?
   a. Lock nut
   b. J nut
   c. Castle nut
   d. Specialty nut
7. When you want a nut or bolt to hold tight such that it needs heat to be removed with a socket and ratchet, you should use a(n):
   a. lubricant.
   b. blue thread-locking compound.
   c. antiseize compound.
   d. red thread-locking compound.
8. Which of these has a fluted tip to drill a hole into the base material so that there is no need for a pilot hole?
   a. Machine screw
   b. Self-tapping screw
   c. Trim screw
   d. Sheet metal screw
9. Torque-to-yield bolts:
   a. should be tightened using torque angle.
   b. can be reused multiple times.
   c. cannot be torqued beyond the elastic phase.
   d. do not get stretched.
10. All of the following are ways to avoid breaking a bolt when removing it *except*:
    a. using penetrating oil with bolts that are rusted or corroded in place.
    b. applying maximum force in both directions.
    c. first checking whether it is a left-hand bolt.
    d. as a last resort, you may heat up the bolt that is rusted or corroded in place.

ASE Technician A/Technician B Style Questions

1. Tech A says that most metric fasteners can be identified by the grade number cast into the head of the bolt. Tech B says that standard bolts can generally be identified by hash marks cast into the head of the bolt indicating the bolt's grade. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Two technicians are discussing bolt sizes. Tech A says that the diameter of a bolt is measured across the flats on the head. Tech B says that the length of a bolt is measured from the top of the head to the bottom of the bolt. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says that a standard grade 5 bolt is stronger than a standard grade 8 bolt. Tech B says that a metric grade 12.9 bolt is stronger than a metric grade 4.6 bolt. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

4. Tech A says that torque-to-yield head bolts are tightened to, or just past, their yield point. Tech B says torque to yield bolts stretch as part of the tightening process. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. Tech A says that some locking nuts have a nylon insert that has a smaller diameter hole than the threads in the nut. Tech B says that castle nuts are used with cotter pins to prevent the nut from loosening. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says that antiseize compound is a type of thread-locking compound. Tech B says that thread-locking compounds acts like very strong glue. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. Tech A says that flat washers act as a bearing surface, making it so that the bolt achieves the expected clamping force at the specified torque. Tech B says that lock washers are usually considered single use and should be replaced rather than reused. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. Tech A says that a common method for repairing damaged internal threads is a thread insert. Tech B says that a thread file is used to repair the threads on the inside of a bolt hole. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. Tech A says that if a bolt breaks off above the surface, you might be able to remove it using locking pliers or curved jaw Channellock pliers. Tech B says that a hammer and punch can sometimes be used to remove a broken bolt. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Tech A says that when using a Heli-Coil to repair a damaged thread, the Heli-Coil is welded into the bolt hole. Tech B says that when using a solid sleeve type of insert, the damaged threads need to be drilled out with the correct size drill bit. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B



CHAPTER 5

Electrical Wiring Diagrams

NATEF Tasks

- **N05001** Research vehicle service information including vehicle service history, service precautions, and technical service bulletins. (MLR/AST/MAST)
- **N05002** Use wiring diagrams during the diagnosis (troubleshooting) of electrical/electronic circuit problems. (AST/MAST)
- **N05003** Identify electrical/electronic system components and configurations. (MLR)
- **N05004** Use wiring diagrams to trace electrical/electronic circuits. (MLR)

Knowledge Objectives

After reading this chapter, you will be able to:

- **K05001** Use the service information to obtain applicable wiring diagrams and technical service bulletins.
- **K05002** Explain common wiring diagram layouts.
- **K05003** Identify and locate wiring harness connectors using the wiring diagram.
- **K05004** Use the service information to identify the location of electrical components on the vehicle.
- **K05005** Describe the process of tracing circuit current paths using the wiring diagram.
- **K05006** Use the wiring diagram to predict circuit voltages.

Skills Objectives

After reading this chapter, you will be able to:

- **S05001** Print out a wiring diagram and any related repair manual information for your assigned vehicle and circuit using your assigned service information resource.
- **S05002** Trace circuit current paths and identify the source and ground portions of the circuit.
- **S05003** Predict circuit voltages when the circuit is off and on, and note them on your assigned wiring diagram.

You Are the Automotive Technician

The repair order states that the customer's rear window defogger stopped working. The vehicle is only a few months old, and a quick visual inspection shows that the rear window defogger grid connectors are connected to the rear window assembly. You start the vehicle and push the rear window defogger switch on the HVAC control panel, but the indicator light does not illuminate. To ensure that it is not just an indicator light concern, you place your hand on the rear window and it is cool to the touch; there is no heating element action. These are all logical actions and are actually part of the diagnostic process—verify the concern and eliminate any obvious cause of the concern. This concern, like many on modern vehicles, is most likely electrical in nature.

1. What do you need next to continue your diagnosis?
2. Describe the tools you may use as part of your diagnosis.
3. How will you document your diagnostic work?

Introduction

This chapter provides the knowledge and hands-on practice that enables you to make full use of body electrical wiring diagrams. You may have seen a circuit wiring diagram in the past so some of this may be review, however the techniques for using the wiring diagram as part of the diagnosis process as presented here may be new to you. Tracing current paths, predicting circuit voltages, and locating where specific connectors and pins in those connectors is probably new to you. Also, you will be introduced and begin using power distribution and ground distribution diagrams, as well as component location information. Mastering use of the wiring diagram information leads to efficient and accurate body electrical system diagnosis so you get more vehicles in and out of your service bay and take home more pay at the end of the week.

Wiring Diagram Use

N05001 Research vehicle service information including vehicle service history, service precautions, and technical service bulletins. (MLR/AST/MAST)

K05001 Use the service information to obtain applicable wiring diagrams and technical service bulletins.

Use of **wiring diagrams** and technical service bulletins, also known as **electrical schematics** or **electrical diagrams**, use abstract graphical **symbols** to represent electrical circuits and their connection or relationship to other components in the system. They are essentially a map of all of the electrical components and their connections (**FIGURE 5-1**).

The wiring on modern vehicles is very complex, with many interconnected wires and components. A single wiring diagram of the whole vehicle would be very difficult to read. Most manufacturers provide a wiring diagram for each system. For example, there is a wiring diagram for the lighting system, another for the power window system, and others for the engine control, transmission control, vehicle stability control, and HVAC systems.

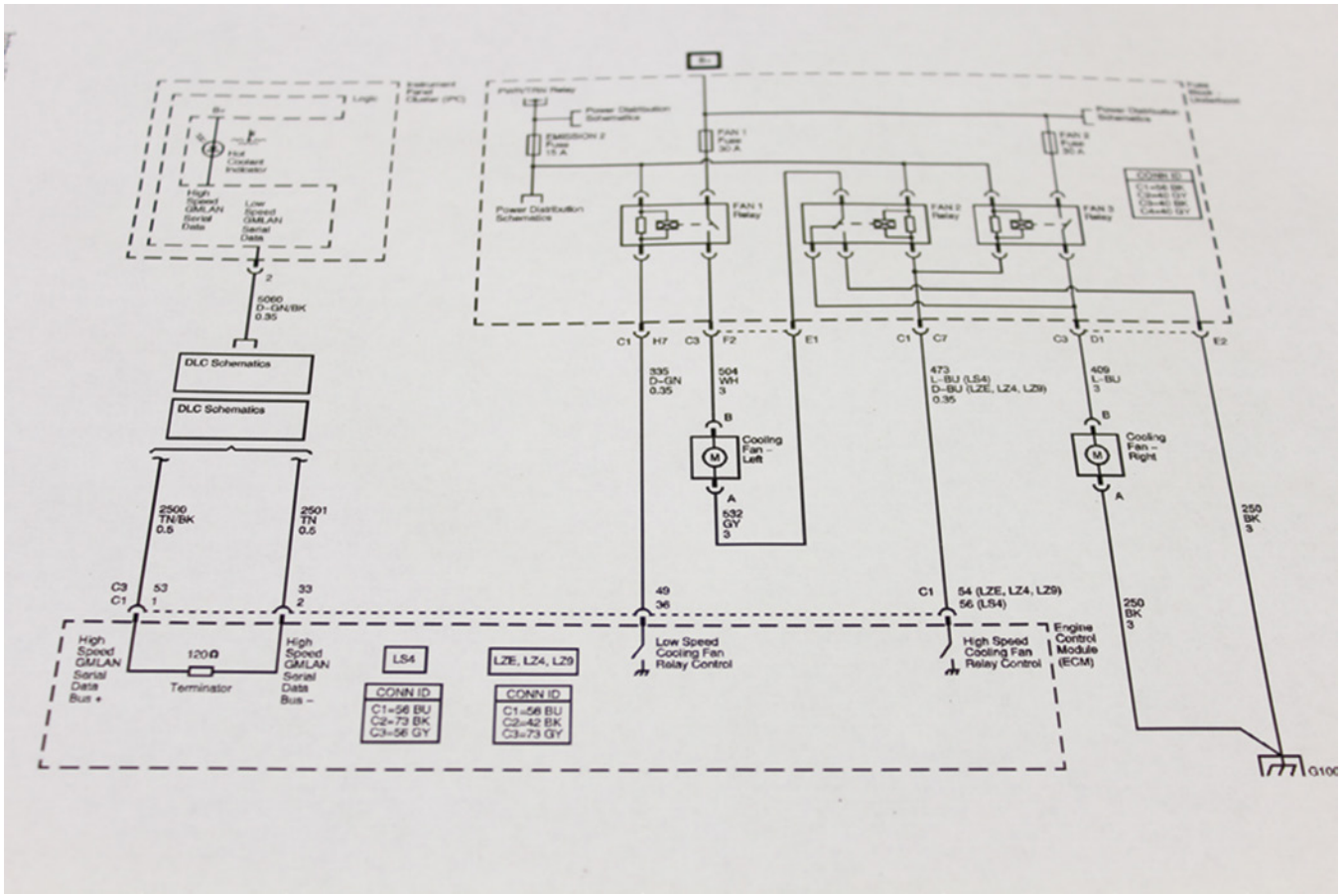


FIGURE 5-1 Typical wiring diagram.

▶ TECHNICIAN TIP

Modern vehicles have many electrical components, wiring connectors, and wires. Working on vehicles requires an understanding of how all the components are assembled together and arranged in circuits. Electrical symbols and circuit diagrams provide this information in a logical way that represents the physical wiring harness and components attached to vehicles (**FIGURE 5-2**). Every electrical device and component has a corresponding electrical symbol. Many of the symbols are standardized and used universally by manufacturers, although variations may exist in some cases. Manufacturers' diagrams and manuals often include a "How to Use the Wiring Diagram" section which includes how to identify the various symbols and their meaning.

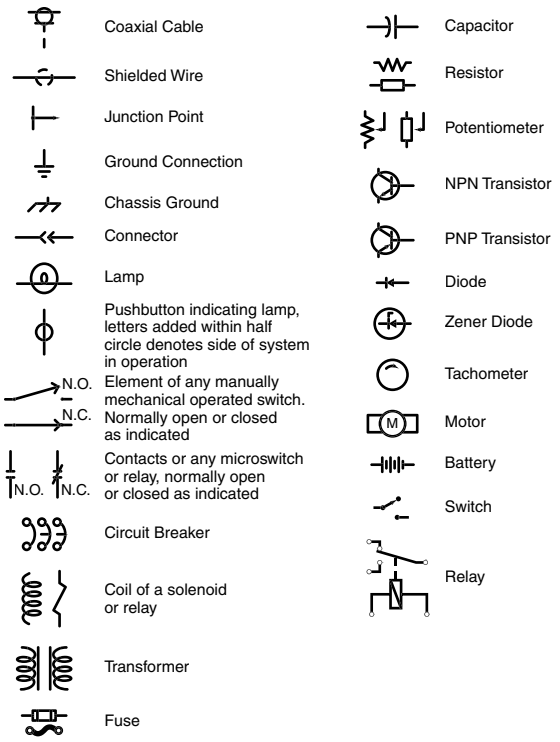


FIGURE 5-2 Every electrical device and component has a corresponding electrical symbol.

Wiring diagrams contain large amounts of information in the form of lines and symbols. The technician will need to interpret this information, which is presented as symbols and connections that represent the actual components on the vehicle. The wiring diagram section of the service information provides definitions of the symbols and terminology used.

Wiring diagrams are part of the manufacturer's or independent service information provider's (e.g., ALLDATA, Mitchell ProDemand) computer-based repair information. Many manufacturer websites offer interactive wiring diagrams that allow you to select an item on the diagram and view its details. For example, you could view a connector to determine its location and the number of pins it has (**FIGURE 5-3**). You could also navigate through the diagram by scrolling up/down or left/right (**FIGURE 5-4**). Many offer a search function to quickly locate a component.

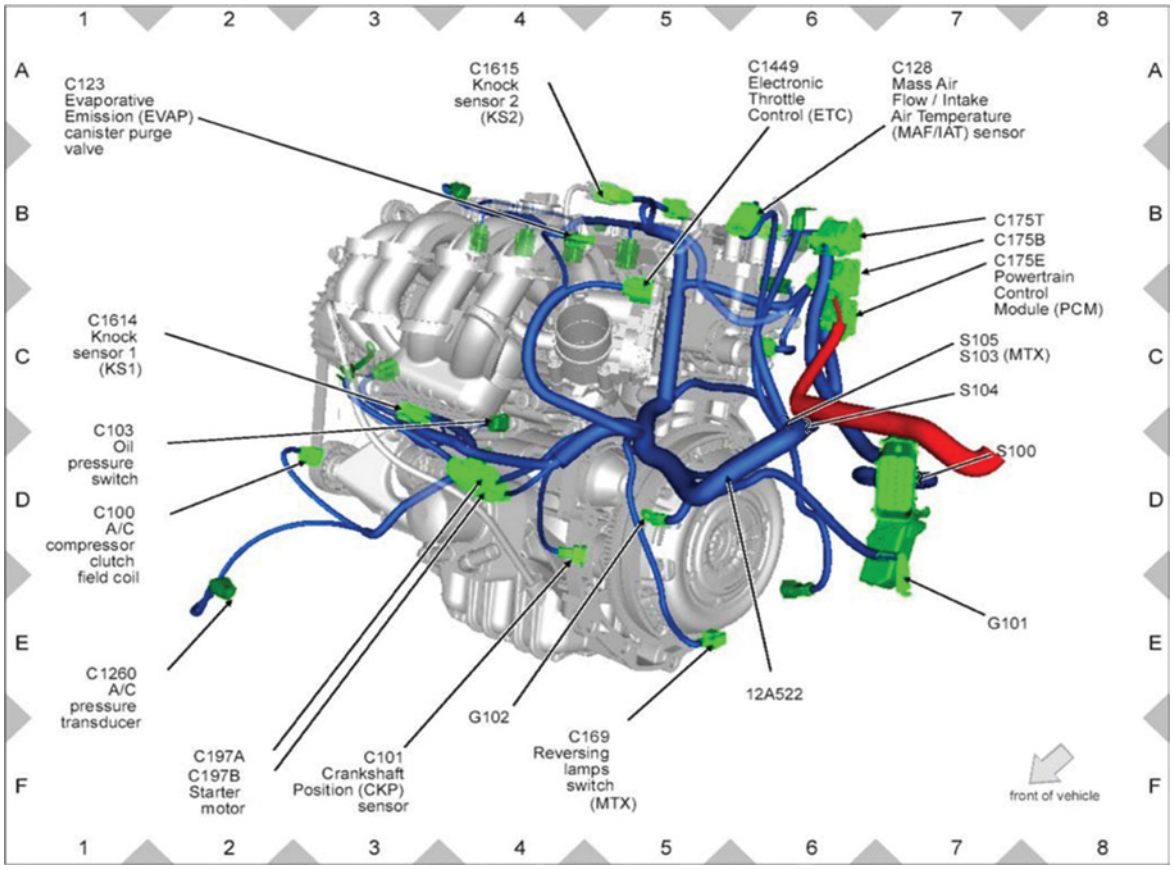


FIGURE 5-3 Connector locations on the vehicle and connector views are found in the service information.

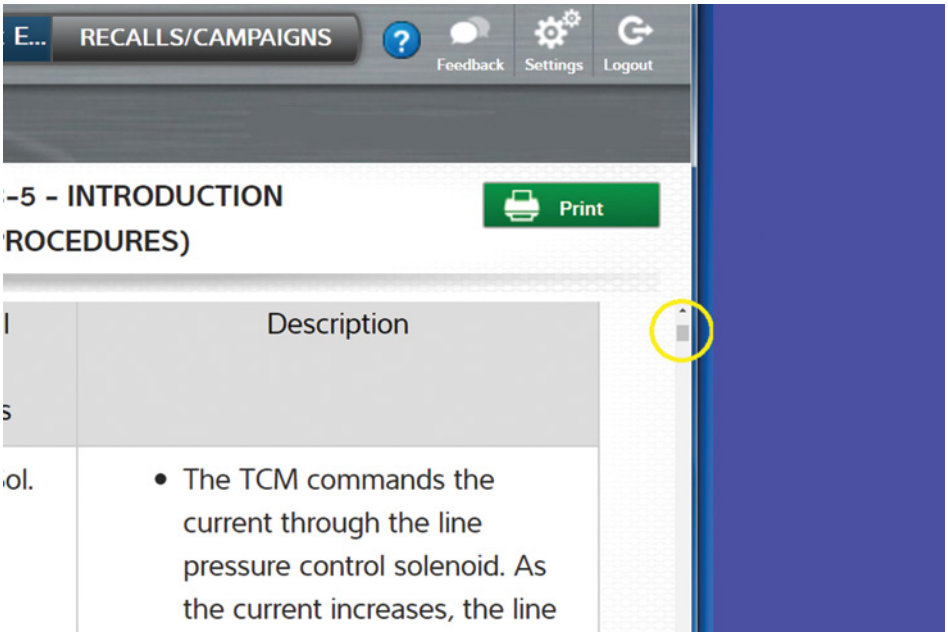


FIGURE 5-4 Scroll bars are provided when the data on the screen require moving up/down or left/right to view all of the information.

Some manufacturers and the independent service information systems (ALLDATA, Mitchell ProDemand, and others) essentially offer an electronic version of the wiring diagram manual in a page-by-page format. There is little or no interactivity and diagrams are not continuous; large diagrams require scrolling to the next page (**FIGURE 5-5**). Whichever type you have access to, mastering the use of wiring diagrams and related repair manual information is vital to develop electrical diagnostic skills.

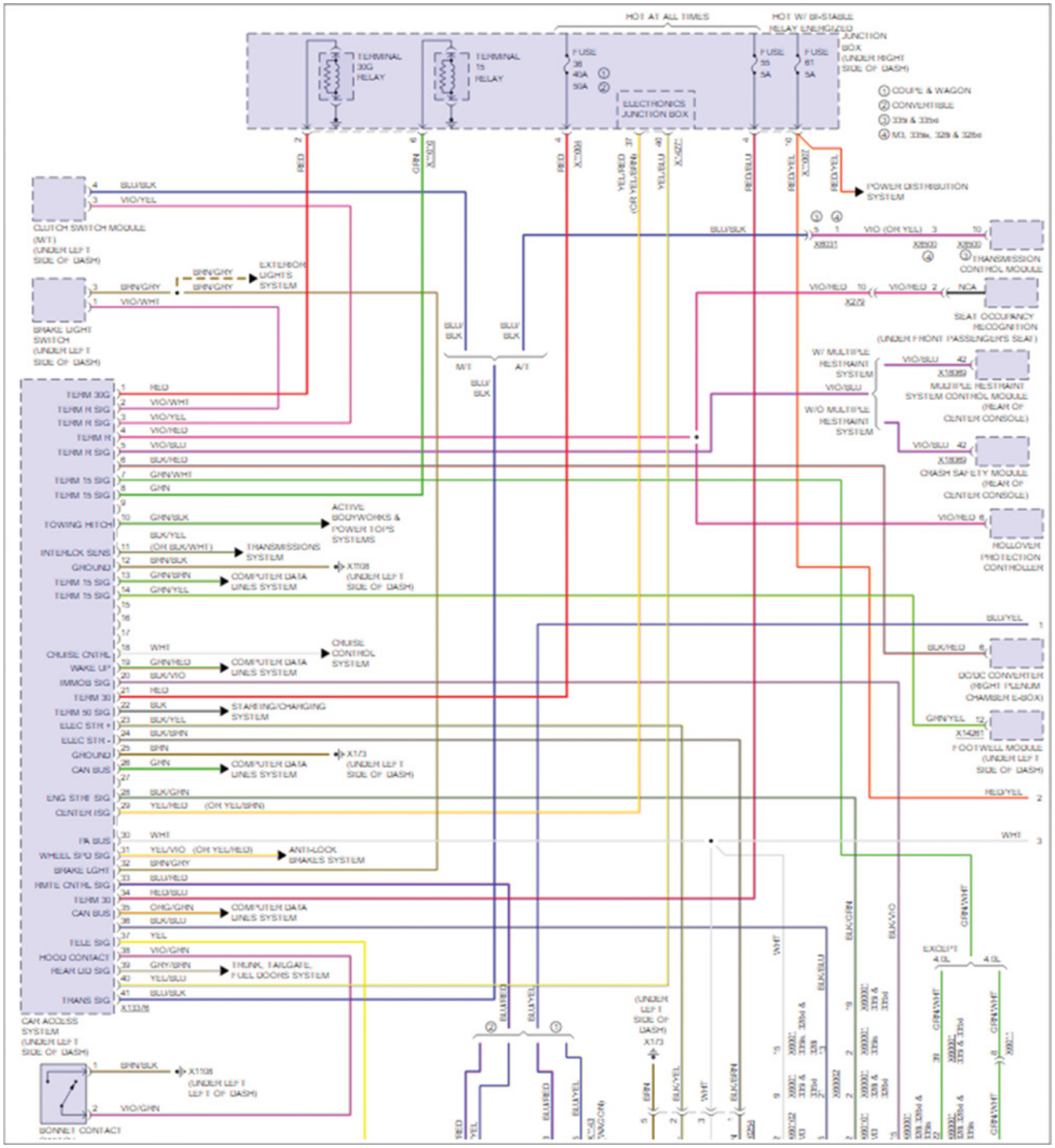


FIGURE 5-5 Non-manufacturer service information sites usually offer screenshot images of the wiring diagrams and other information but usually do not offer hot spot links or other types of interactivity.

Wiring Diagram Layout

K05002 Explain common wiring diagram layouts.

N05002 Use wiring diagrams during the diagnosis (troubleshooting) of electrical/electronic circuit problems. (AST/MAST)

Automotive manufacturers must create the wiring diagrams that are referenced for each vehicle's circuits. The layout of the diagrams is often very similar for most automotive companies based in the United States and Asia (**FIGURE 5-6**). The top portion of the wiring diagram usually has the source-related components, including wiring from the power source and related circuit protection, fuses, fusible links, or circuit breakers used in the circuit. The center portion shows components that form the circuit including switches, relays, and the load (like the fog lights). The lower portion of the circuit shows the circuit path to ground.

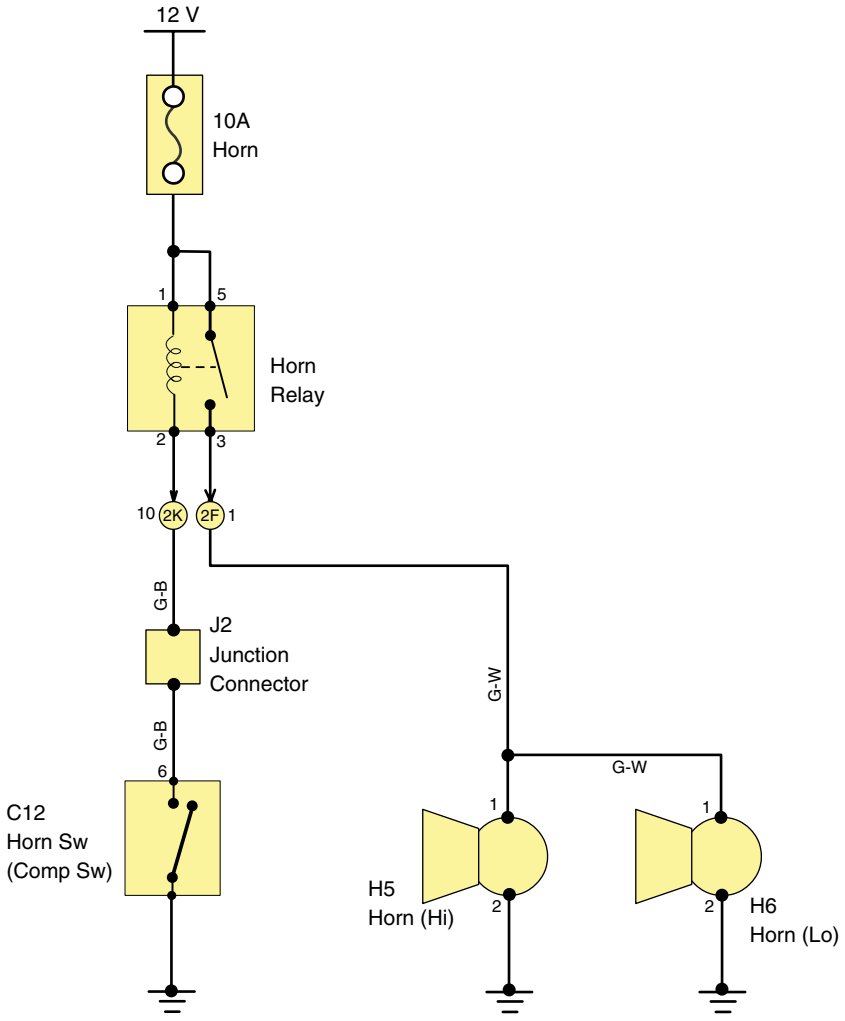


FIGURE 5-6 Most domestic and Asian manufacturer wiring diagrams place the source at the top and ground at the bottom of the wiring diagram.

Some manufacturers produce diagrams that use a left-to-right format rather than a top-to-bottom format (**FIGURE 5-7**). Others may integrate several related systems on one diagram. Technicians who work for a new vehicle dealer usually have a consistent format for the vehicles they diagnose, and the technician is provided access by using a password to the manufacturer's service website. Independent repair technicians must become familiar with the variety of wiring diagram layouts that apply to each vehicle type they work on. Independent repair facilities often access vehicle service information through a repair service like ALLDATA, Identifix, or Mitchell ProDemand.

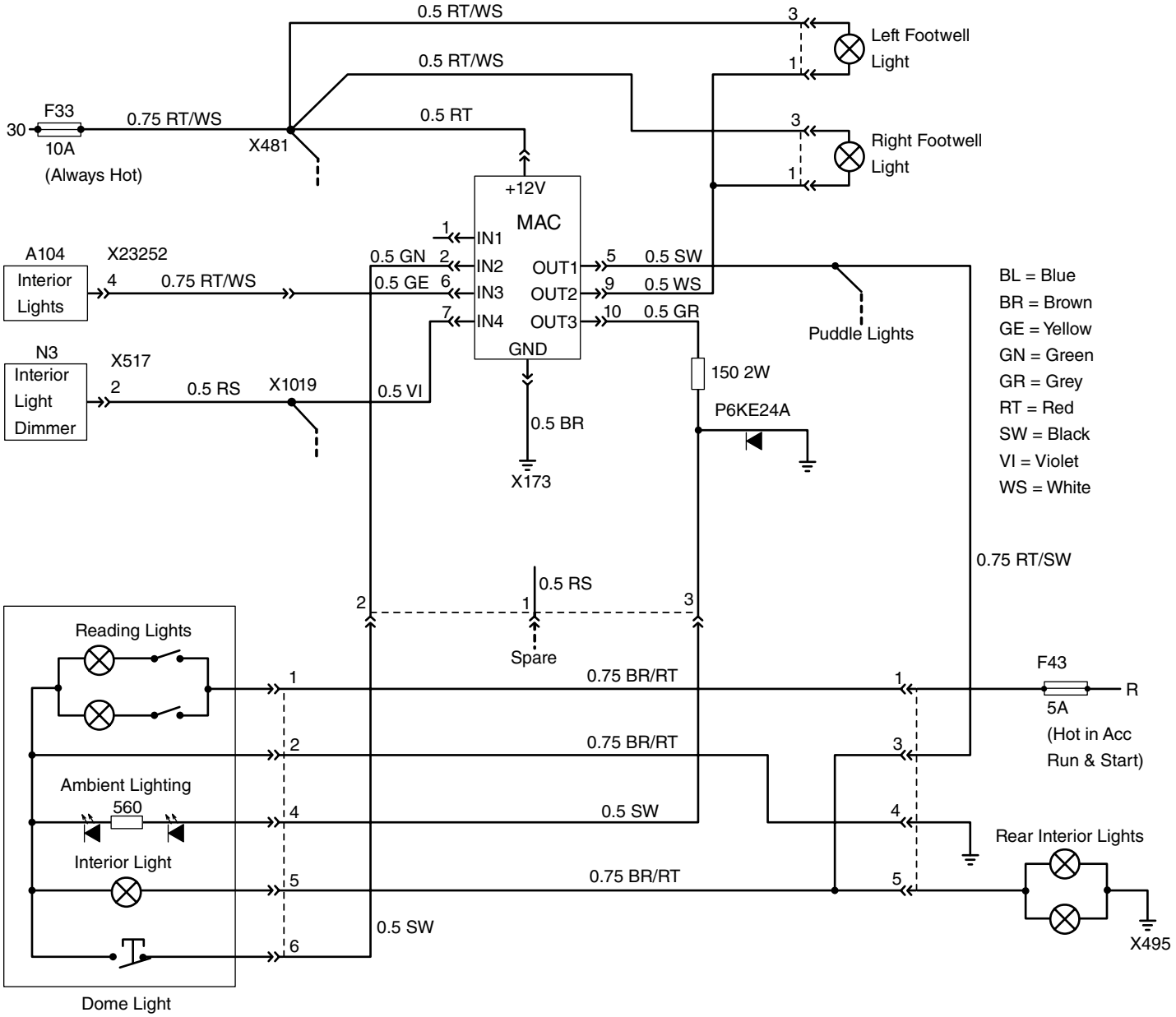


FIGURE 5-7 Some wiring diagrams are laid out with the source on the left and the ground on the right.

Power source diagrams illustrate the connections from battery positive (+) to all the system circuits in the vehicle (**FIGURE 5-8**). Refer to the power source diagram when you or the customer identify two or more circuits that are not functioning. For example, the customer states that the power outlets in the vehicle are not working and in heavy traffic the engine temperature gauge gets very close to the HOT position.

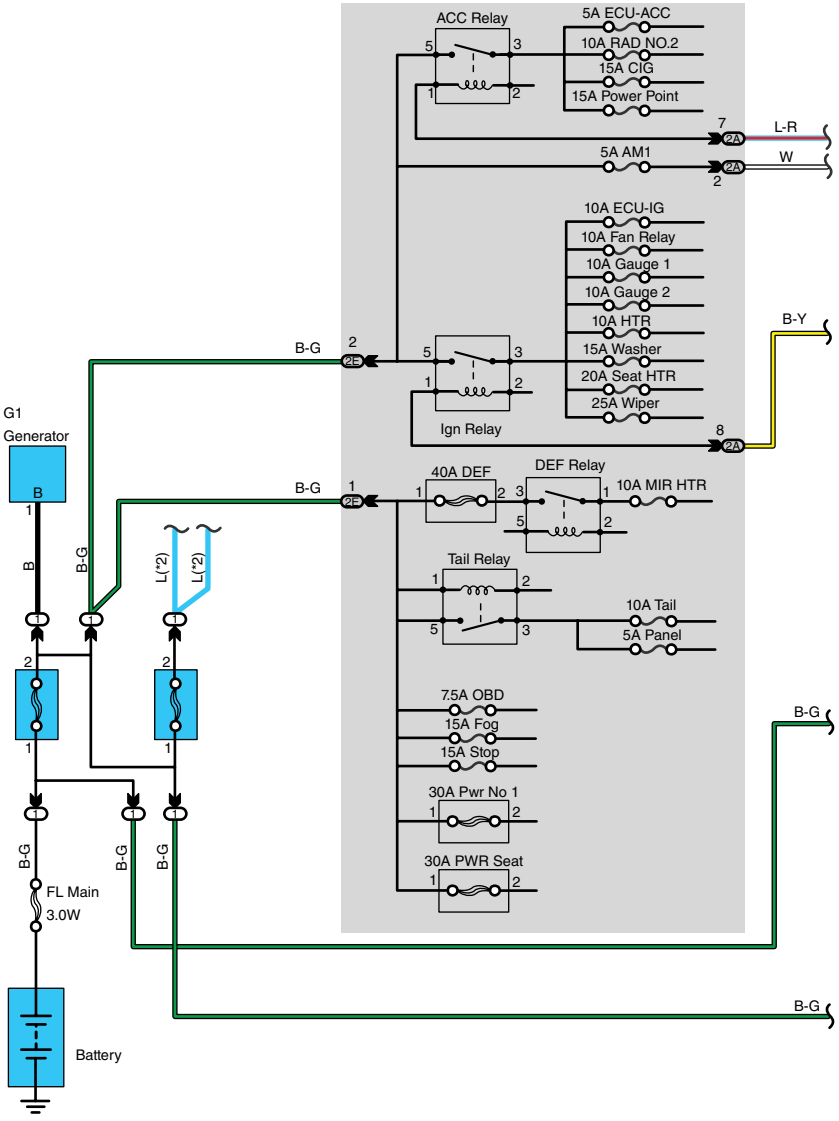


FIGURE 5-8 The power source diagram provides source voltage paths from the battery to the various vehicle circuits.

After verifying the power outlets do not have source voltage, refer to the related power source diagram (**FIGURE 5-9**). Note that the ACC (accessory) relay supplies battery voltage to the power outlets and one of the radiator fan circuits in this vehicle. The power source diagram gets you focused on where to begin your circuit testing.

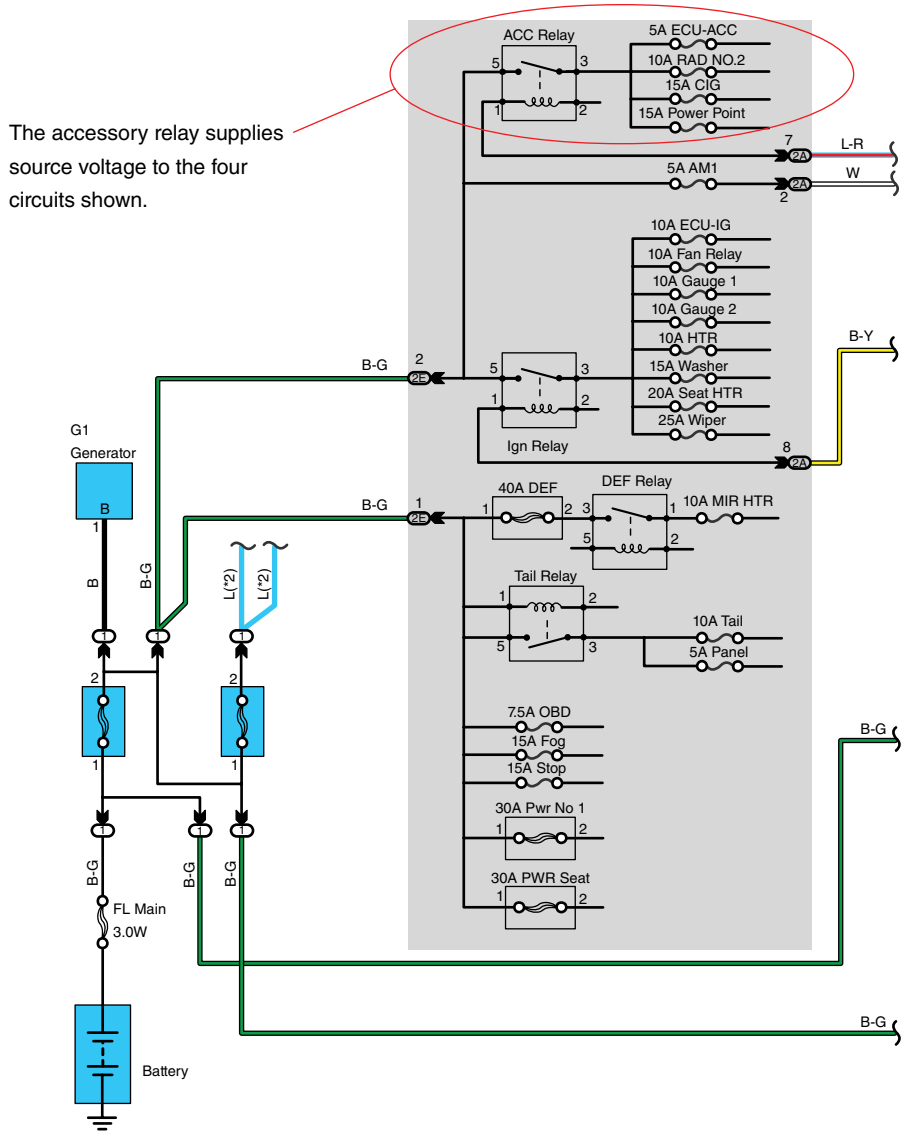


FIGURE 5-9 The accessory relay supplies source voltage to the four circuits shown.

Check the related circuit fuses. There should be source voltage at the power point, cigar, radiator no. 2, and ECU-ACC fuses (**FIGURE 5-10**). If two or more fuses do not have source voltage, you will need to verify ACC relay operation. Check if the ACC relay coil (pin 1) and switch (pin 5) have source voltage (**FIGURE 5-11**). If they do, verify that the relay operates properly by checking that there is very close to 0V at pin 2 and source voltage at pin 3 when the relay is energized (turned on with the ignition switch in the ACC or on position). Source voltage at pin 2 indicates there is an open circuit in the relay coil ground control circuit. No voltage at pin 3 may indicate faulty relay operation. This example demonstrates the importance the power source diagram plays in diagnosing a circuit that has no source voltage present.

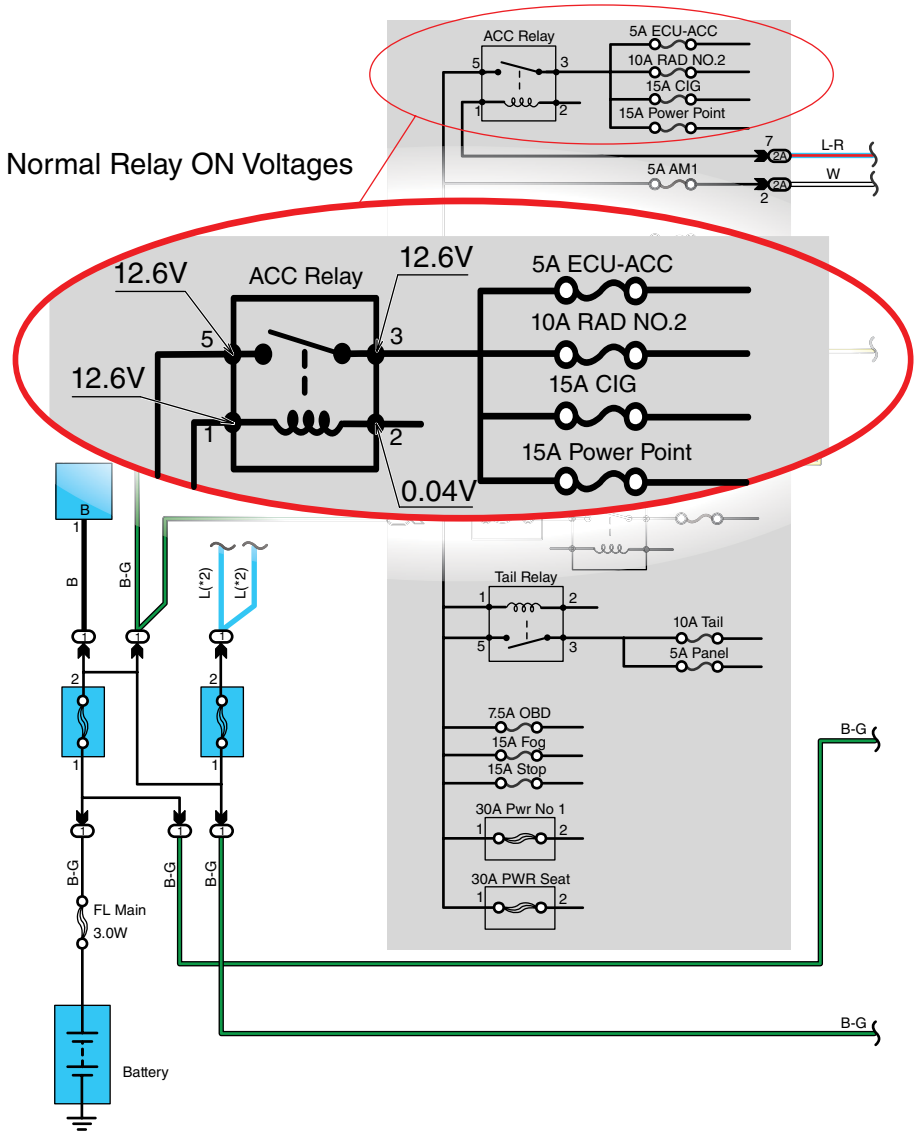


FIGURE 5-10 The power source diagram identifies which circuits share source voltage controlled by a common source. This helps you determine where to begin your circuit testing when two or more circuits are not operating correctly.

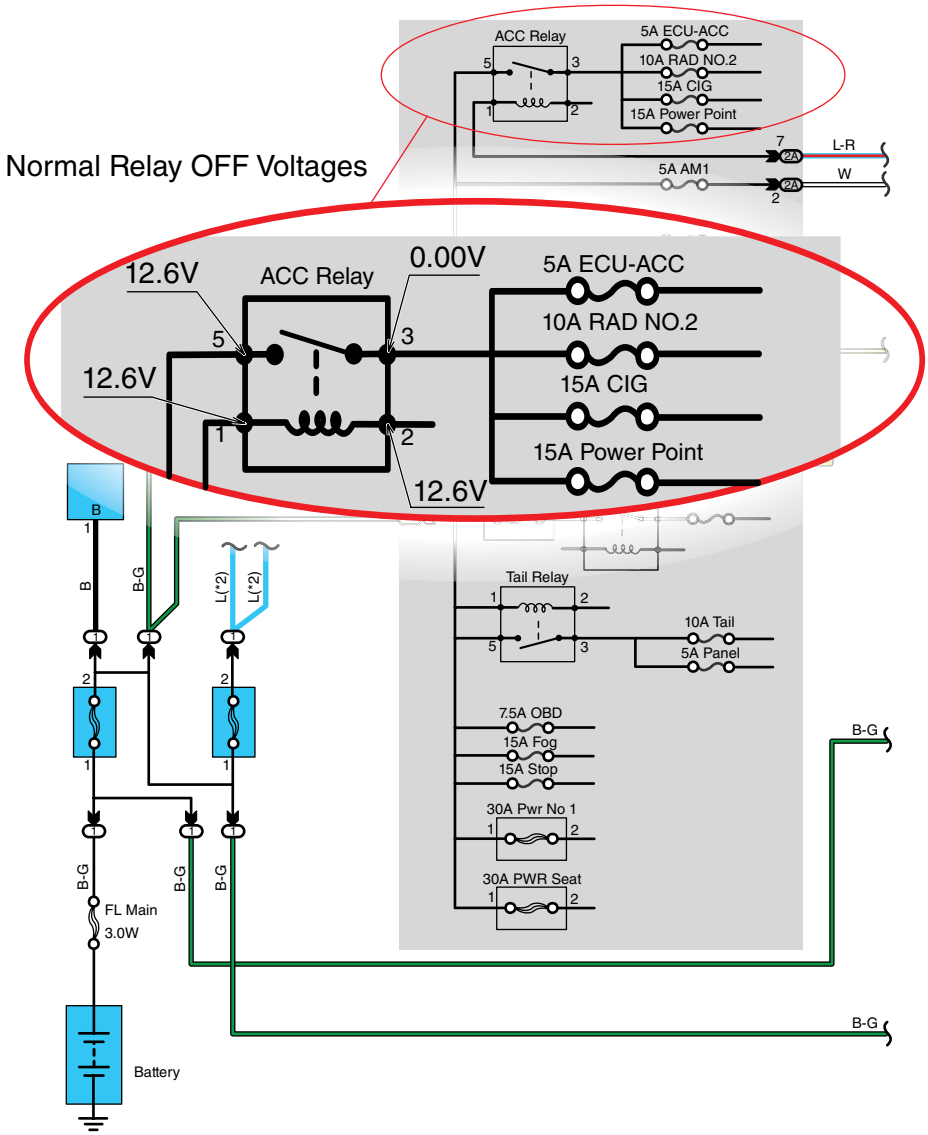


FIGURE 5-11 No source voltage at the four fuses shown may indicate that the relay is not functioning. Voltage tests along with a functional test of the relay may be required to verify if the relay is the cause of the concern or if the problem is further back toward the battery.

▶ TECHNICIAN TIP

Create a 3-ring binder with tab section separators and clear sheet protectors. When you print out a circuit, power source, or ground points diagram, save it for future reference by placing it in a sheet protector. Organize the binder based on the vehicle model and model year (**FIGURE 5-13**). This will save time because you will not have to access and print the information when you need it in the future, and any notes you made from your previous work may help to diagnose the concern on this vehicle, saving additional time.

The **ground points (or ground location) diagram** shows the ground location for each circuit on the vehicle (**FIGURE 5-12**). In this figure, you can see that several circuits ground at location BQ. Note that there are two BQ ground points shown. One has a *8 and the other a *9. By looking at the circled portion of the diagram, a note references whether this vehicle is made at Toyota Motor Manufacturing in Kentucky (TMMK) or at Toyota Motor Company (TMC) in Japan. You can determine this by examining the vehicle data plate on the driver side B pillar or referencing the vehicle identification number (VIN). Note that ground point BQ connects to ground point BO and to ground point BS. This would indicate that an open at ground point BQ may not have any effect on the circuits because there are two other ground points. The use of more than one ground point is often referred to as redundant grounds (or ground points). Redundant grounds allow circuits to continue functioning if the primary ground point fails. However, do not ignore a damaged or open ground. The other ground point(s) must now carry additional current, which can create a voltage drop situation. Voltage drop at ground points or in the ground portion of the circuit may cause erratic circuit behavior.

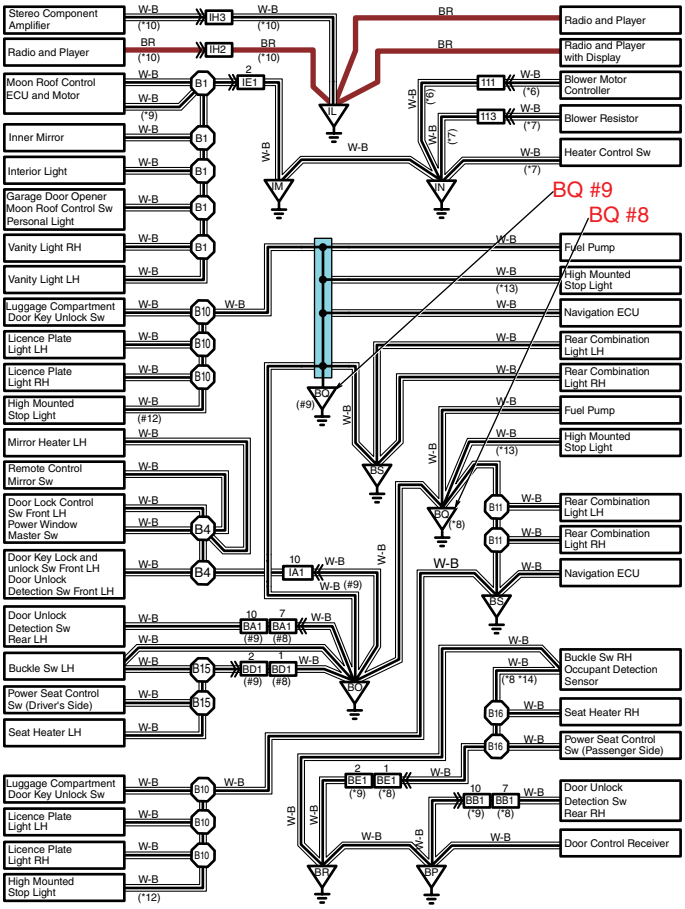


FIGURE 5-12 The ground location diagram illustrates the circuit ground points and which circuits share one or more ground points.

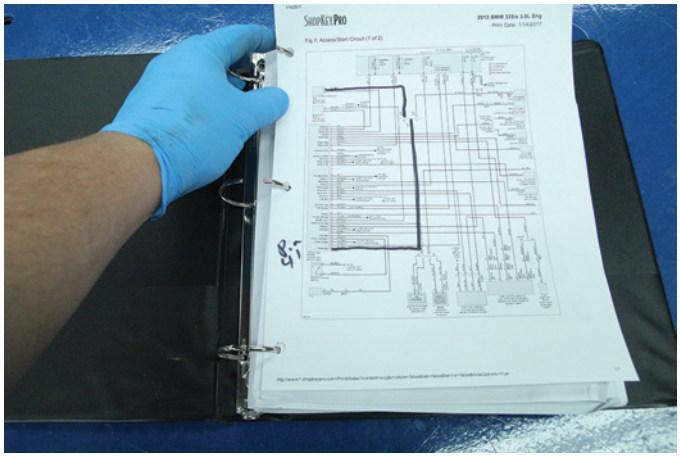


FIGURE 5-13 Create a binder to store your diagrams. This creates a reference for future diagnosis of similar circuits that can save you time and improve your efficiency.

Wiring Diagram Symbols and Text

Wiring diagrams use symbols and text to represent the circuit components. Lines represent wires, and various shapes represent switches, relays, connectors, motors, and lighting components. Some symbols are usually the same on every diagram (e.g., the ground symbol). Other wiring diagram symbols may be unique to that particular vehicle manufacturer (**FIGURE 5-14**).

Wiring diagrams may include text to identify connectors, wire insulation color, and wire size, as well as specific components on the diagram (**FIGURE 5-15**). Wire color may be spelled out as a whole word or may be an abbreviation. Connectors may be identified using numeric or alpha-numeric callouts. Splice and ground points are also identified in this manner. Switches, relays, and motorized components are often identified with a callout. Other symbols may be used to indicate that the diagram continues in another section of the service information.

The wiring diagram section of the service information often provides a "How to Use" section. It is here that wiring diagram symbols, abbreviations, and wire colors are referenced for the vehicle. Reference this section to familiarize yourself with the symbols and terminology used on the wiring diagram and as a resource to identify a symbol or text that is unfamiliar to you.

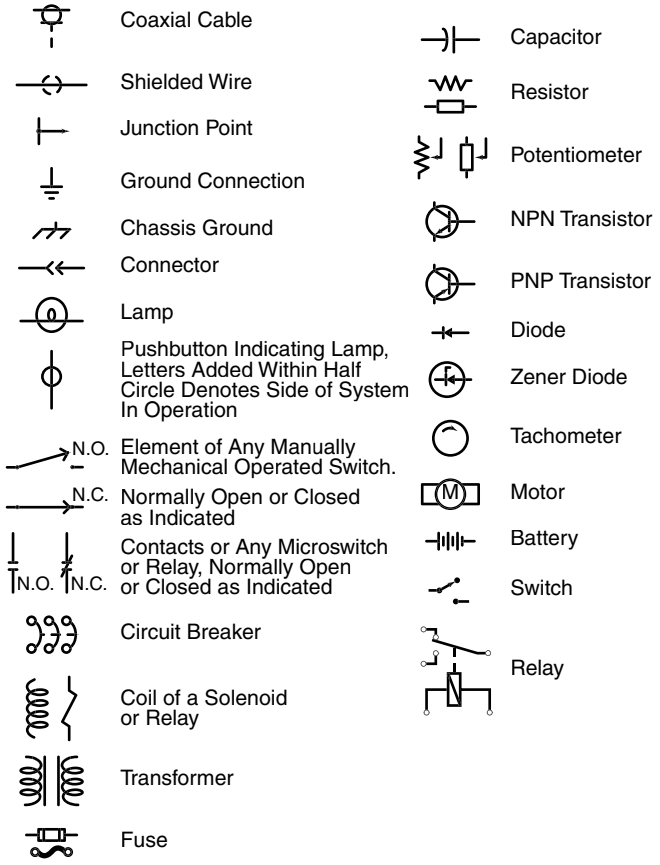
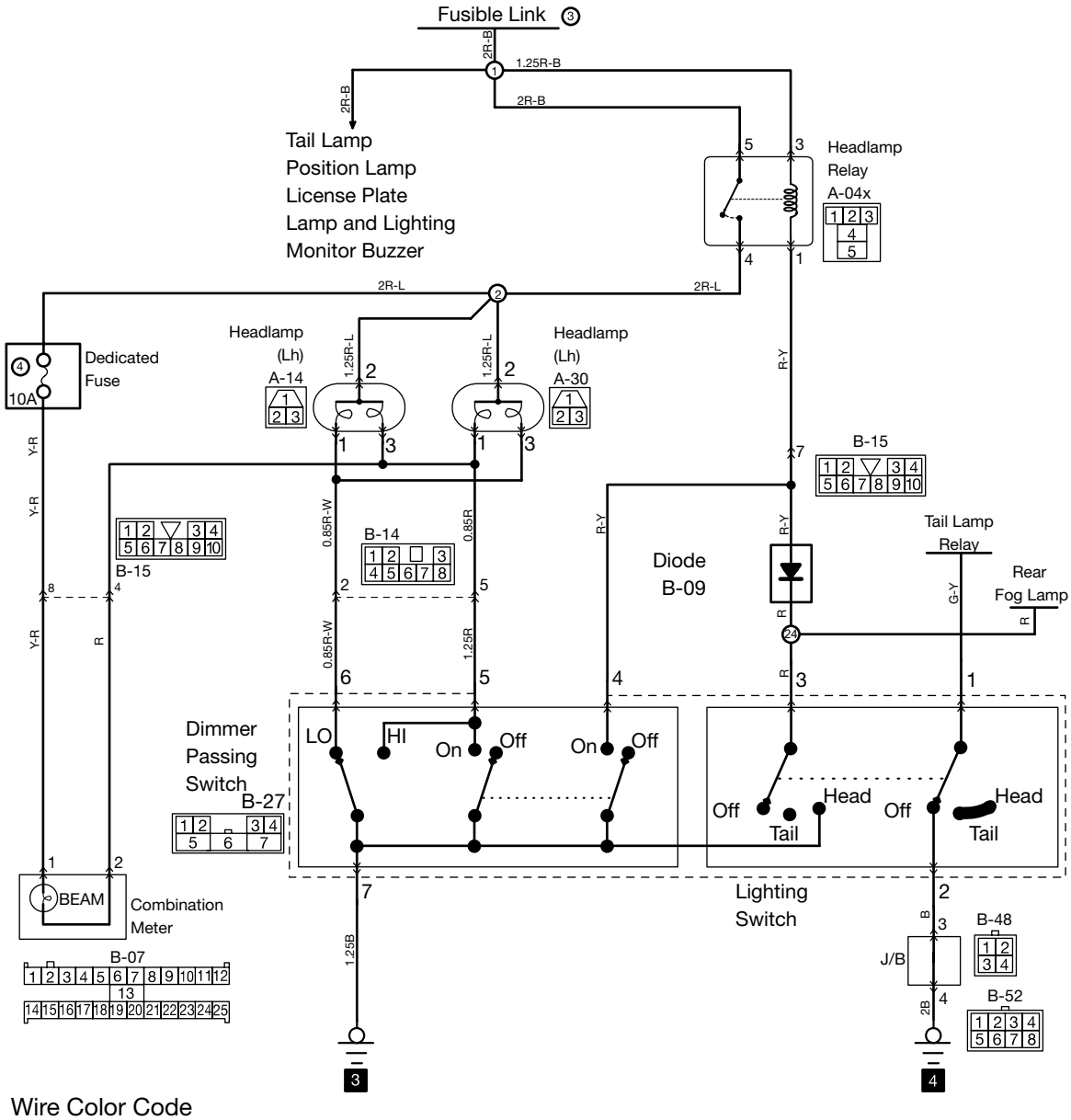


FIGURE 5-14 A variety of symbols and graphics form the representative circuit elements on the wiring diagram.



Wire Color Code

B: Black LG: Light Green G: Green L: Blue W: White Y: Yellow SB: Sky Blue
BR: Brown O: Orange GR: Gray R: Red P: Pink V: Violet

FIGURE 5-15 Wire color abbreviations are usually defined as part of the "How to Use the Wiring Diagram" section of the service information.

▶ Wiring Harness Connectors

K05003 Identify and locate wiring harness connectors using the wiring diagram.

Vehicle wiring is created in sections using multiple wires and connectors to create a wiring harness. This allows the vehicle to be assembled with sections of wiring harness rather than one very large bundle of wires. The typical vehicle wiring harness can weigh 80 pounds or more (**FIGURE 5-16**). The same type of vehicle may use varying wiring harness configurations to match the engine type, transmission/transaxle, and various power accessories. An engine room harness for a four-cylinder engine with manual transmission would differ from that required for a V6 engine with an automatic transmission in the same vehicle model (**FIGURE 5-17**). The applicable harnesses join together using connectors to form the vehicle's wiring system (**FIGURE 5-18**).

FIGURE 5-16 Vehicle wiring is bundled together to form a wiring harness. Several harness sections connect together to form the overall vehicle wiring system.

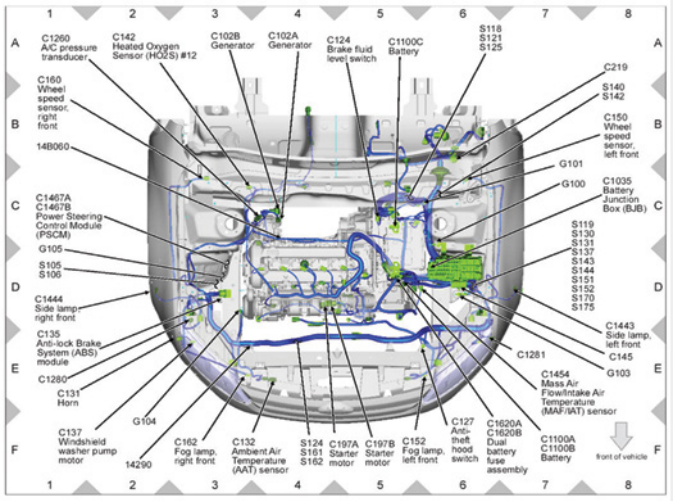


FIGURE 5-18 Connectors join sections of the harness together and to join circuit components to the harness.

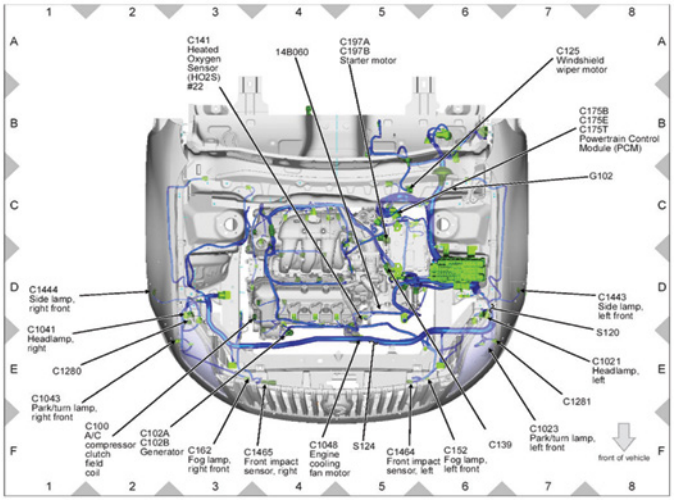


FIGURE 5-17 Harness configurations vary depending on the applicable engine, transmission, and accessories.

Connectors may have one or more pins, and the connector housing may use colored plastic so it can be identified during assembly and service. Some connectors and the related harness are color coded to indicate caution. Supplemental restraint system harness coverings and connectors are usually yellow, and hybrid high voltage (HV) wires use orange wire insulation and connectors (**FIGURE 5-19**).

Connectors join together using pins. Generally, one side of the connector will have male pins and the other has female pins (**FIGURE 5-20**). The connector housing keeps the pins spaced correctly so the male and female sides mate together to provide a continuous path for current. Some connectors use a pin lock to keep the pins in their correct position. This lock must be disengaged if you ever need to remove a connector pin.

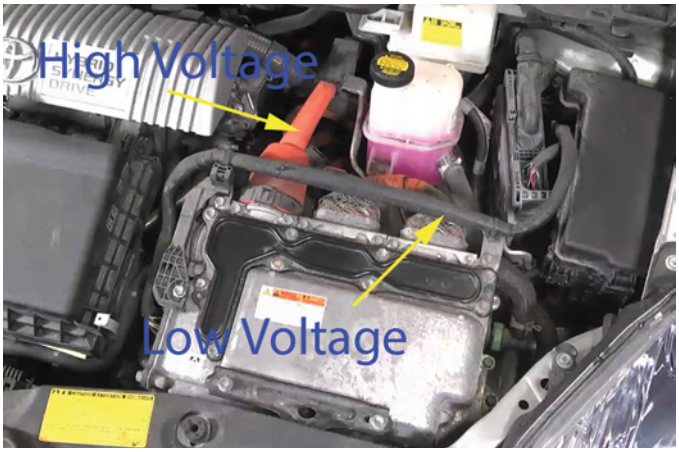


FIGURE 5-19 Wiring caution is indicated by conduit, wire insulation, and/or connector color.

FIGURE 5-20 Wiring harness connectors.

The connector pin slots are usually designated by numbers starting at the left side of the top row (**FIGURE 5-21**). The wiring diagram indicates the pin number location in the applicable connector. Interpreting this information allows you to locate the wire in the harness. You can then use a digital multimeter (DMM) to perform applicable circuit tests (**FIGURE 5-22**).

FIGURE 5-21 SRS wiring is usually indicated by yellow connectors and conduit.

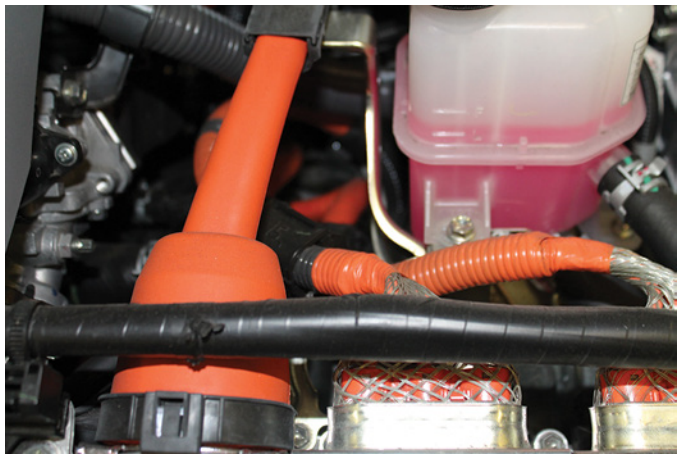


FIGURE 5-22 High voltage automotive wiring is usually indicated by orange connectors, wiring insulation, and conduit.

K05004 Use the service information to identify the location of electrical components on the vehicle.

S05001 Print out a wiring diagram and any related repair manual information for your assigned vehicle and circuit using your assigned service information resource.

▶ Wiring Harness Components

The wiring diagram is where you begin to map out your diagnostic strategy. When ready, you will begin to perform tests on various circuit components; in order to do so, you must know where the component is located on the vehicle. The interactive wiring diagrams often allow you to select a component with the mouse cursor (**FIGURE 5-23**).

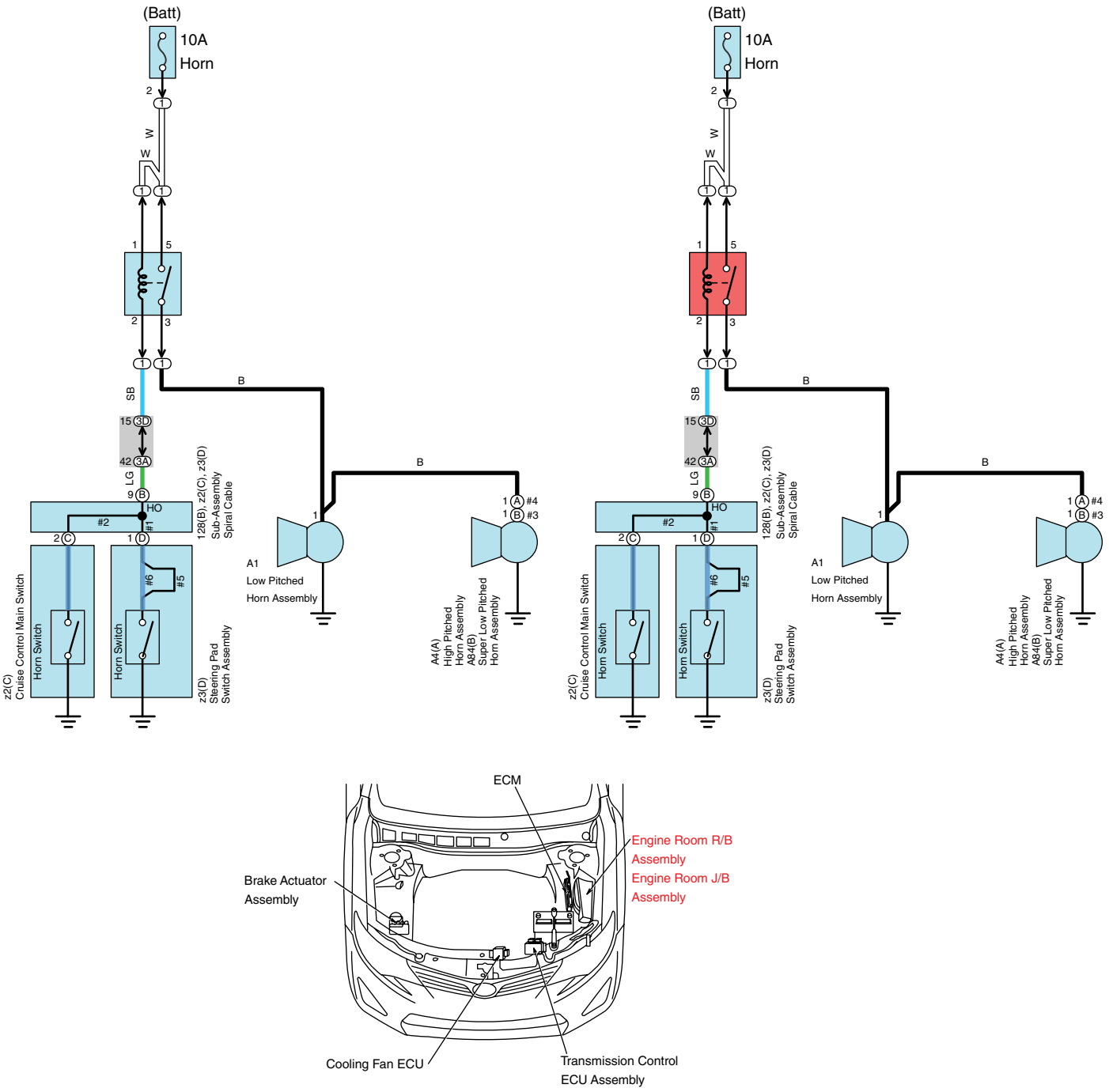


FIGURE 5-23 Interactive diagrams allow the user to select items to obtain additional information including component location.

N05003 Identify electrical/electronic system components and configurations. (MLR)

This may open a drop-down menu where you can select a location or the related location information may open right away, usually showing a cutaway image of the vehicle and a highlight that identifies the component (**FIGURE 5-24**). The non-interactive diagrams require you to use a menu to navigate their site to locate specific components. The location content for this diagram type is usually non-interactive and contains a graphic identifying multiple components and their locations (**FIGURE 5-25**).

Locating the components allows you to review the wiring diagram and fine-tune your diagnostic strategy. Determine the accessibility of each component that may require testing, then plan your testing by beginning with the components that are easiest to access and are the most likely cause of the concern.

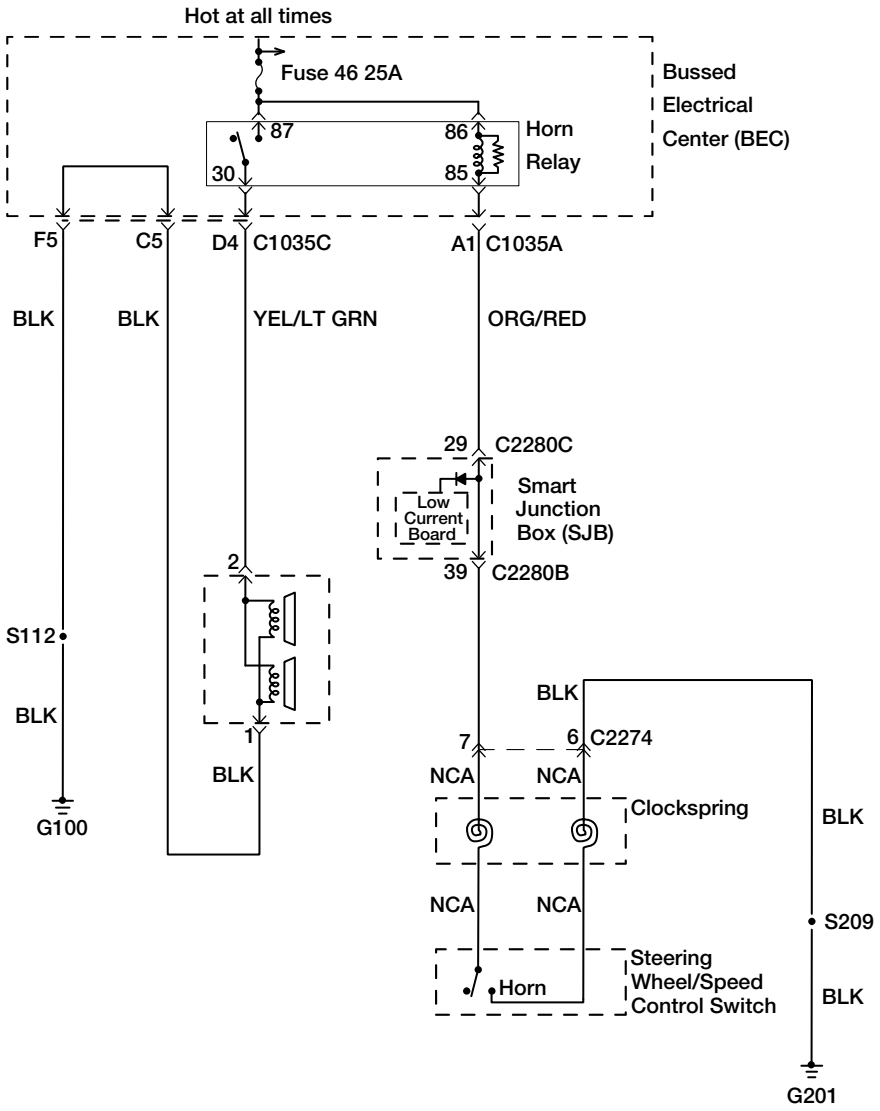


FIGURE 5-24 Non-interactive diagrams do not have any hot spots that link to related information. For example, viewing the location of ground 201 requires the user to access the ground location diagram from the system menu or in the applicable section of the printed electrical manual.

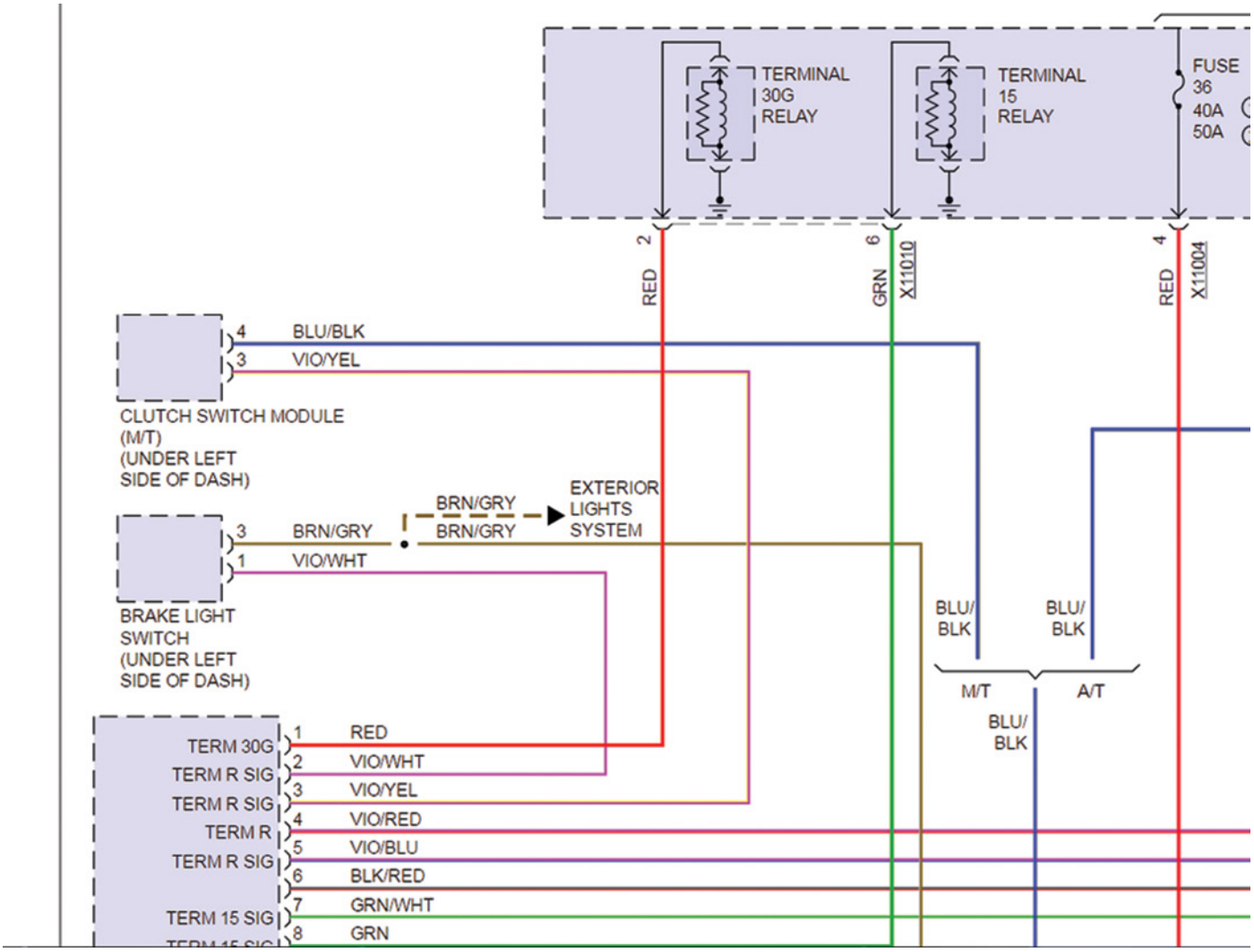


FIGURE 5-25 Non-interactive diagrams require that you access other areas of the service information site to obtain component locations and connector information.

▶ Tracing Circuit Current Paths

Circuit tracing is done using highlighting pens to trace the current paths in a circuit on the wiring diagram printout. Locate the applicable circuit wiring diagram in the service information website, then use the print function to create a paper copy for circuit tracing and other related diagnostic activities (**FIGURE 5-26**).

K05005 Describe the process of tracing circuit current paths using the wiring diagram.

S05002 Trace circuit current paths and identify the source and ground portions of the circuit.

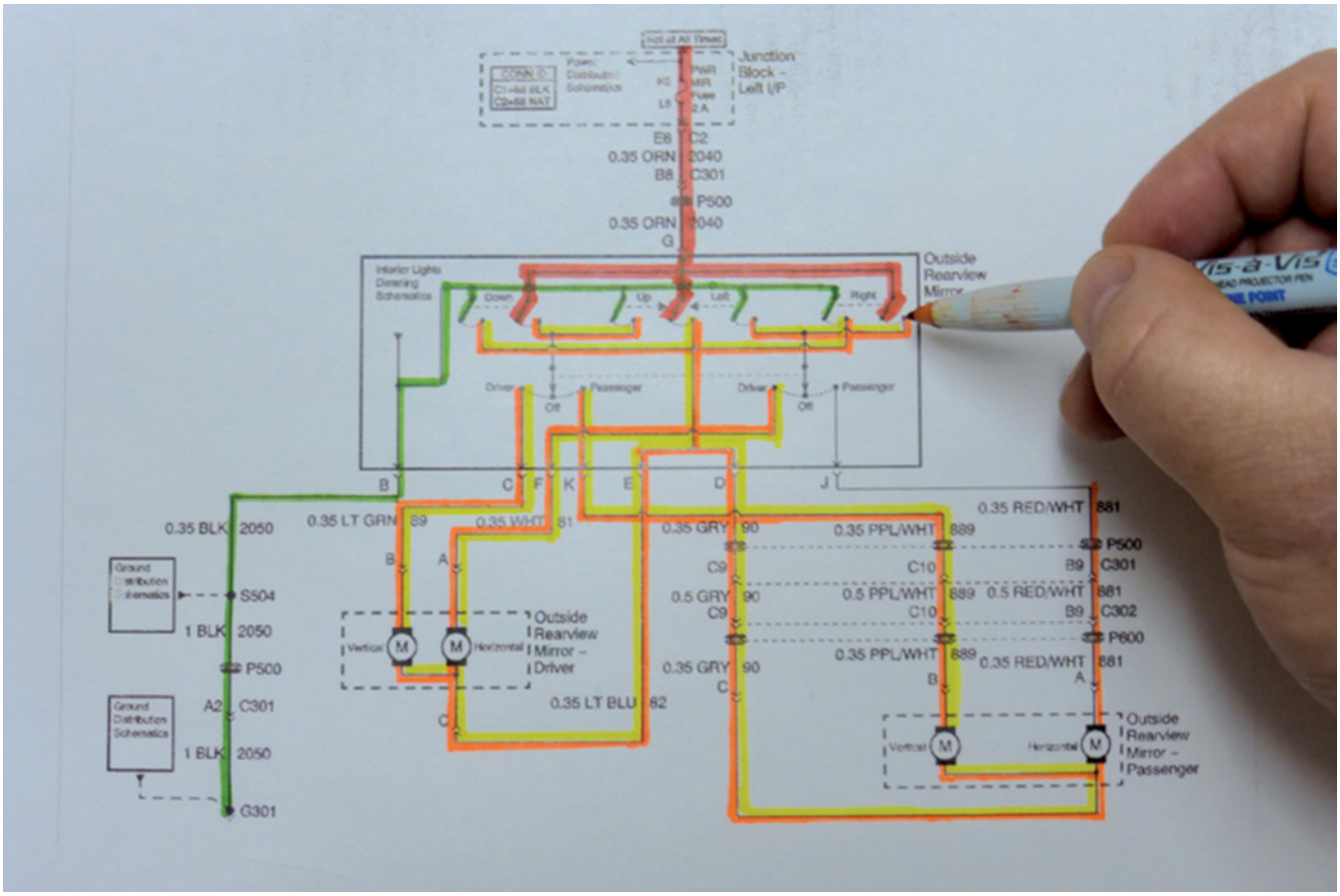


FIGURE 5-26 Circuit tracing begins with a printout of the wiring diagram of the applicable circuit.

N05004 Use wiring diagrams to trace electrical/electronic circuits. (MLR)

Circuit tracing requires the use of several highlighter colors. Begin by using one color to trace the current path from the voltage source to the load in the circuit (**FIGURE 5-27**). Use a designated color for circuits that have power at all times and a different color for circuits that have power when the ignition is on. The load in the circuit is the component that does some form of work, like a light bulb or motor. Use a designated color highlighter for the load, since this is usually where the voltage is used, or drops, in the circuit (**FIGURE 5-28**).

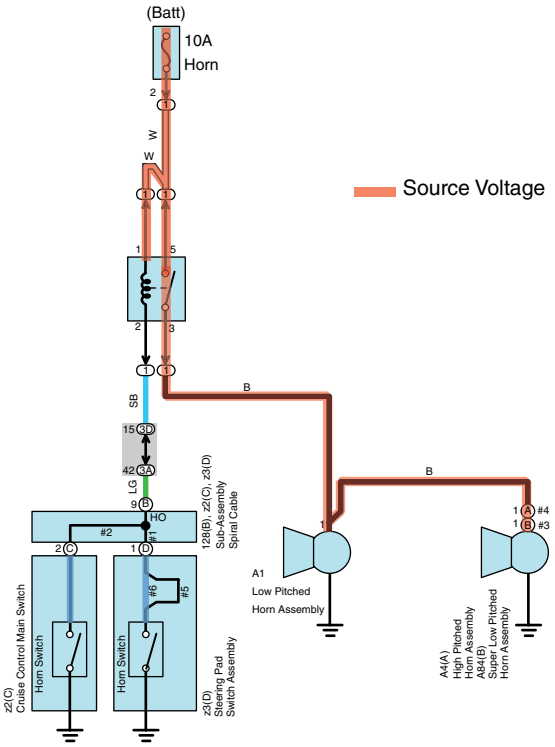


FIGURE 5-27 Use one color to designate the source voltage portion of the circuit.

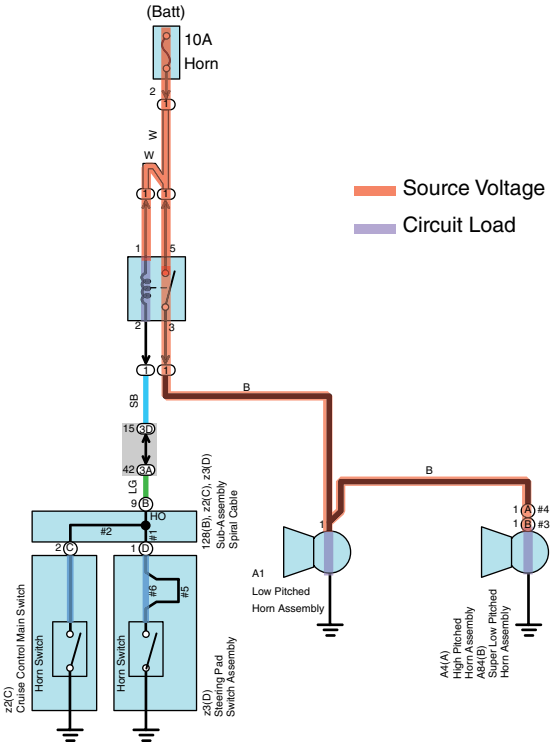


FIGURE 5-28 Use a highlighter of a different color to identify the circuit load(s).

Use another highlighter color to trace the current path to ground (**FIGURE 5-29**). This horn circuit is actually made up of two circuit paths, one for the relay coil and one for the horns. It can be helpful to use a color to identify circuits that have source voltage at all times and another color for circuits that only have power when the vehicle ignition is in the on or Accessory (ACC) position.

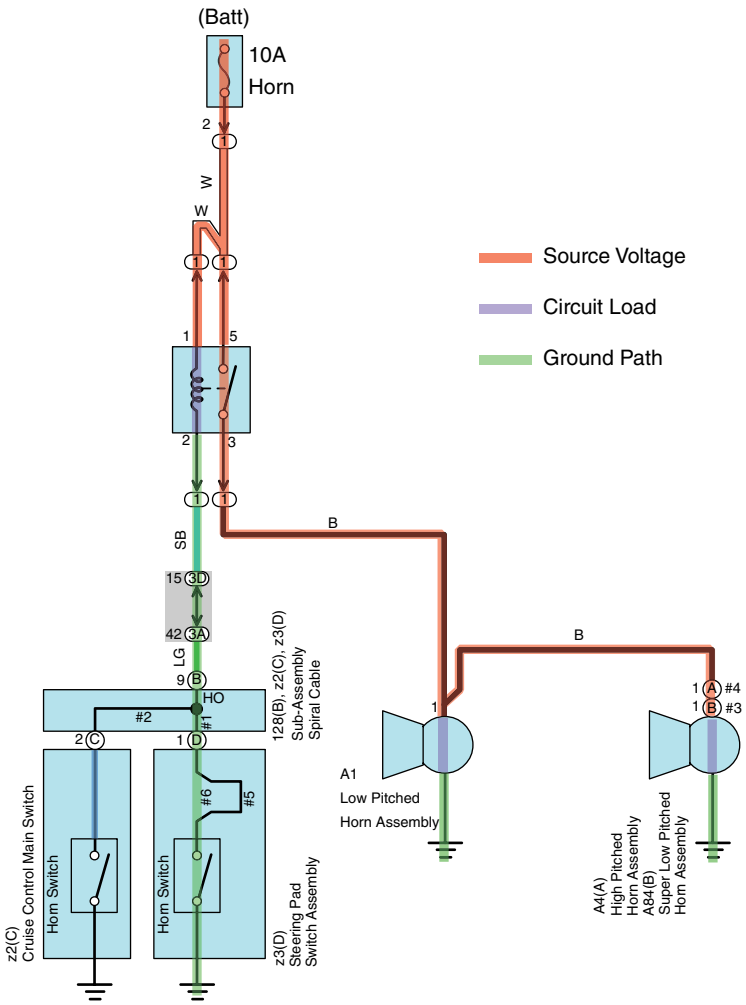


FIGURE 5-29 Use a third color to identify the ground path to ground in the circuit.

The use of highlighters helps clarify the source, load, and ground portions of a circuit. It also focuses your attention to the elements on the wiring diagram specifically related to the circuit that you are diagnosing. Many diagrams contain more than one circuit on the page or there may be components that are unrelated to the circuit or portion of the circuit you are working on. Highlighting the circuit with the concern, the left rear taillight in this example, also keeps you focused on the areas related to the circuit with the concern and not other components or circuits on the wiring diagram (**FIGURE 5-30**).

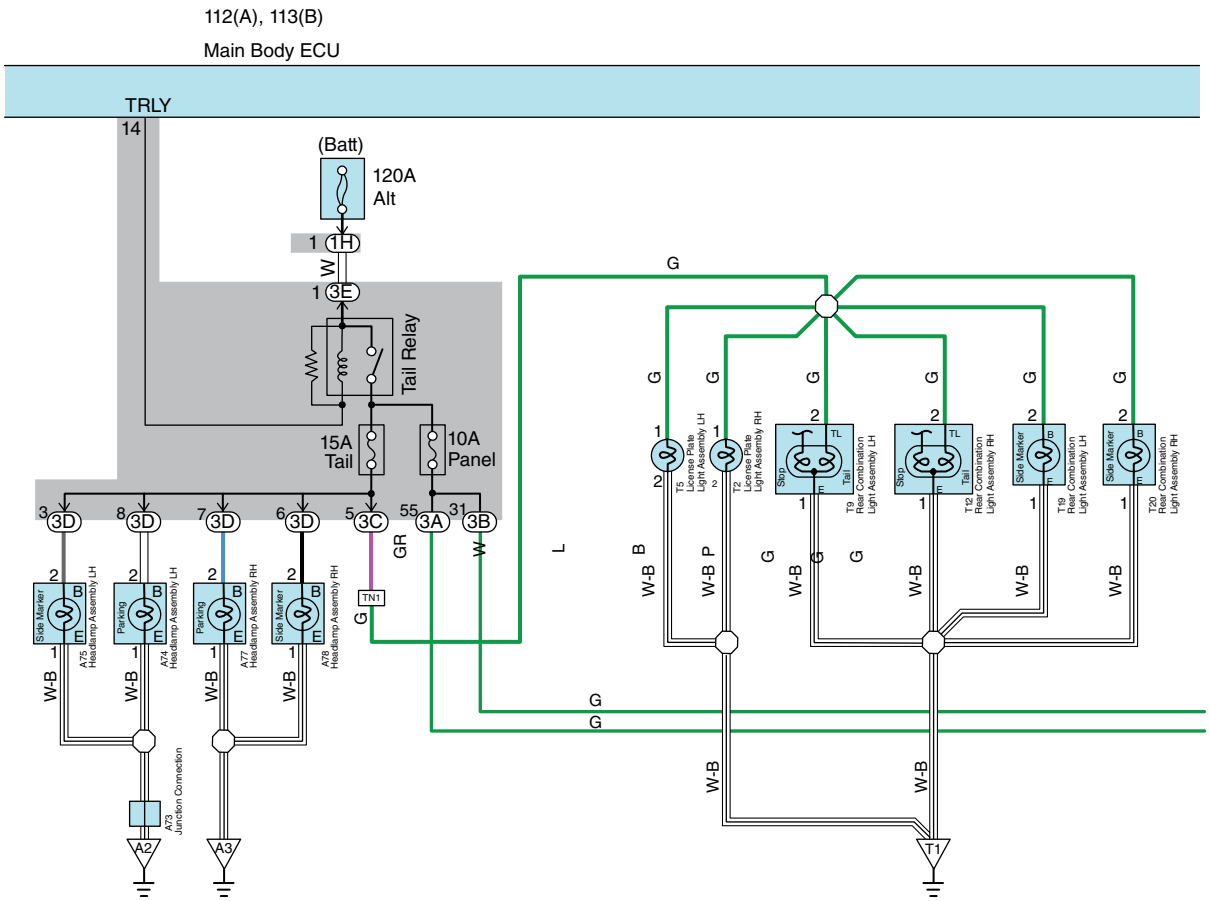


FIGURE 5-30 Highlighting also focuses your diagnosis to the affected area of the circuit, the left taillight in this example.

▶ Predicting Circuit Voltages

K05006 Use the wiring diagram to predict circuit voltages.

S05003 Predict circuit voltages when the circuit is off and on, and note them on your assigned wiring diagram.

Predicting circuit voltages on the wiring diagram ensures you can interpret the reading you obtain with your DMM when performing a circuit test. This may seem at first overly obvious; however, taking the time to write down the predicted circuit voltages at available test locations helps ensure a quick and accurate diagnosis.

Begin at the voltage source on the diagram. It may be a visual representation of the battery or a fuse. Write 12V (12 volts) at this location on the diagram. Note that we are using round numbers for the voltage predictions rather than the fully charged battery voltage of 12.6V. Continue to note the source voltage at those points in the circuit that should have source voltage at all times or with the ignition in ACC (Accessory) or on position (**FIGURE 5-31**).

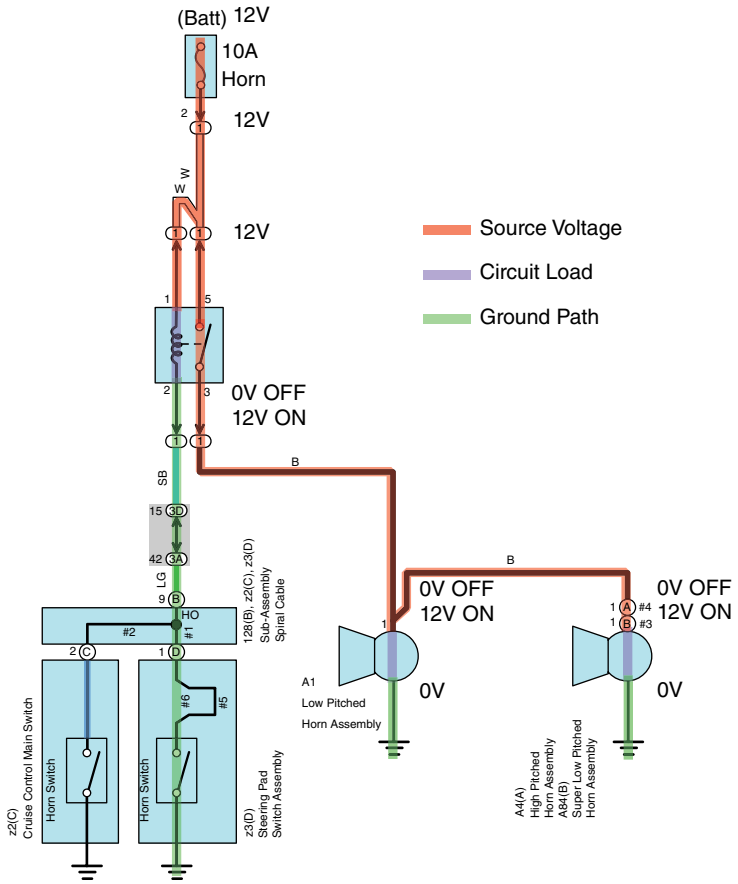


FIGURE 5-31 Predict available voltage at logical test locations in the circuit.

Source-controlled circuits have the circuit control on the source side of the circuit before the load. The control is most often a switch of some type. Here, note the voltage reading for the switch in the relay when the switch is off and when on, as follows: 12V on, 0V off.

Ground-controlled circuits have the circuit control on the ground side of the circuit after the load. The horn switch in this circuit is on the ground side of the circuit, after the relay coil, which is the circuit load. In this case, source voltage will be present at each test point up to the switch (or other control device) when the circuit is off. When the circuit is on for either source or ground control, the voltage will be 12V before the load and 0V after the load at each applicable test point (**FIGURE 5-32**).

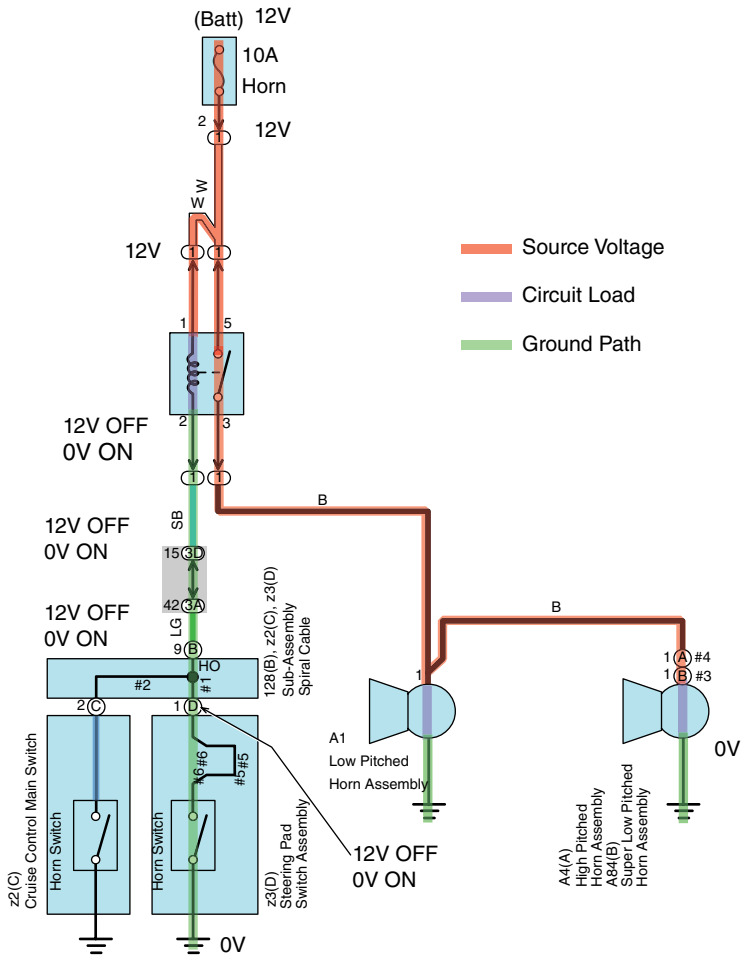


FIGURE 5-32 This is the switch side of the horn circuit so show the ground control portion from the relay to the horn switch.

After predicting the circuit voltages, you are now prepared to use your meter to obtain circuit voltage readings. Isolating where the voltage is different than what you predicted directs you to the cause of the circuit fault. In the example shown, a check of the fuse shows 12V at both fuse test points. The DMM displays 0V available at relay pin 1 (**FIGURE 5-33**). The predicted voltage is 12V. The circuit concern is now isolated to somewhere between the fuse and relay pin 1. Your diagnosis would continue by inspecting the wiring between the fuse and relay for an open circuit (**FIGURE 5-34**). To trace circuits and voltage prediction, follow the steps in **SKILL DRILL 5-1**.

FIGURE 5-33 The fuse has source voltage at both test points. This indicates the fuse has the proper voltage and is OK.

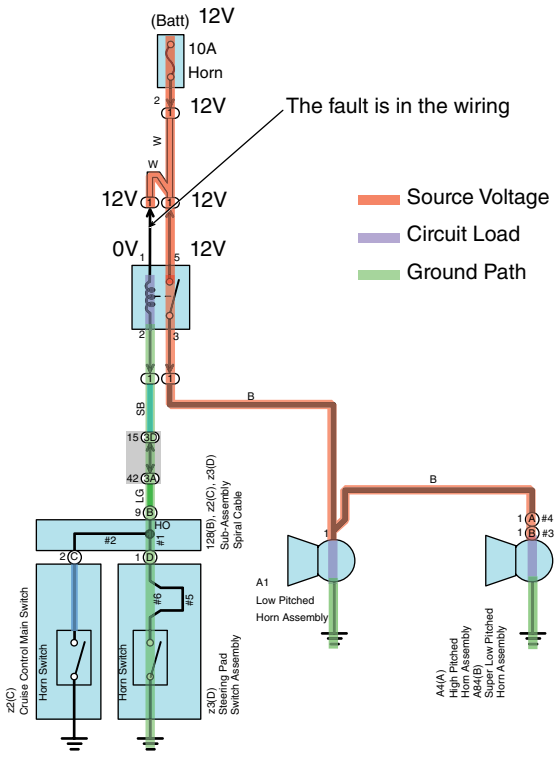


FIGURE 5-34 Relay pin 1 has 0 volts present. The fuse is OK and has source voltage present so the fault is in the wiring between the fuse and relay pin 1.

SKILL DRILL 5-1 Tracing Circuits and Voltage Prediction

This Skill Drill offers a chance to identify the circuit source, load, and ground and then predict available voltage at circuit test points. These skills are critical to the electrical diagnostic process and prepare you for the on-vehicle testing with your DMM or other required test equipment. Several wiring diagrams are presented for you to practice with. Your instructor may also offer several other wiring diagrams for you to practice. Note that if you really want to master these skills you can practice by doing two or three diagrams on different vehicle systems every day. When you look at a diagram and you begin to see the highlighted current paths and available voltage values even before you begin to use your highlighters, then you are on your way to mastering this critical part of the electrical diagnostic process.

Wrap-Up

Ready for Review

- The wiring diagram, is a map of the circuit.
- The wiring diagram may be laid out with source at the top and ground at the bottom or from left to right.
- Besides circuit diagrams, there are diagrams for power source and ground points.
- Most manufacturer service information sites offer interactive diagrams which allow you to select components on the diagram to follow the path of a wire or to find where a connector is located on the vehicle.
- Various abbreviations are used on wiring diagrams to denote wire color, wire size, and connector numbers. There may be notes that relate to parts of the diagram when a certain feature is present, like daytime running lights, or where the vehicle was assembled.
- Circuit tracing is the process a technician performs using colored highlighters to denote the current path in the circuit. One color is used to indicate source voltage, one to denote the circuit load, and another to show the circuit path on the ground portion of the circuit. Other colors may be used for more complex circuits to denote input or output signals to an ECU.
- Available voltage is noted on the wiring diagram at available circuit test points, such as at the fuse, load, and connectors. This is a critical part of the electrical diagnosis. Before the DMM is used during circuit testing, you need to know what the voltage should be at each test location.
- Ground-controlled circuits use a control device to open or close the path from battery negative and this device, like a switch, is located after the circuit load.

Key Terms

electrical schematic (electrical diagram) Another name for the wiring diagram.

ground points (ground location) diagram A wiring diagram that shows the current path to ground for each circuit. Ground points are identified and this information can be used with the ground location diagram to locate the applicable ground point of a circuit.

power source diagram A wiring diagram that provides the current paths from the battery positive post (+) and related circuit protection for all vehicle circuits. Use this diagram when several circuits are not operating or when diagnosing a parasitic (ignition off) draw concern.

symbols Wiring diagrams primarily use automotive and electronic industry standard symbols for circuit components. Most manufacturers provide a "How to Use the Wiring Diagram" section in their service information that provides a definition for the various symbols used.

wiring diagram A schematic drawing and symbol representation of the wiring and components; also called electrical schematic.

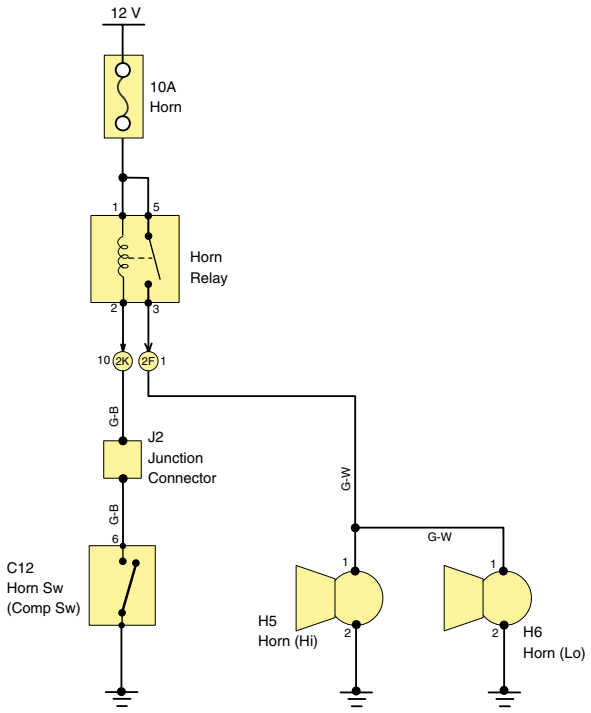
Review Questions

1. All of the following statements are true *except*:
   a. Wiring diagrams are essentially a map of all of the electrical components and their connections.
   b. Wiring diagrams play an important role in diagnostic strategy.
   c. Wiring diagrams help you know where the component is located on the vehicle.
   d. A single wiring diagram of the whole vehicle would be very helpful and easy to read.
2. Technicians interpret the actual components on the vehicle with the help of wiring diagrams. They contain large amounts of information in the form of:
   a. numbers and alphabets.
   b. lines and numbers.
   c. lines and symbols.
   d. alphabets and lines.
3. The top portion of the wiring diagram layout usually has information on:
   a. components that form the circuit, including switches, relays, and the load.
   b. the circuit path to ground.
   c. the source-related components.
   d. the key for wiring diagram symbols, abbreviations, and wire colors.
4. What does the lower portion of the circuit show?
   a. Wiring from the power source
   b. Circuit path to ground
   c. Fog lights
   d. Circuit breakers

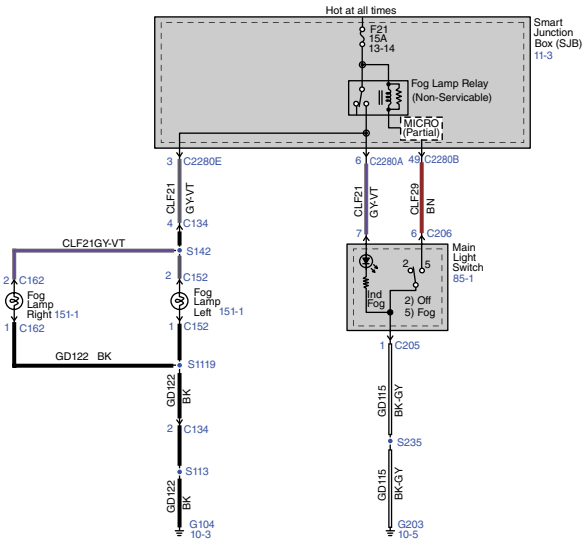
5. Lines in a wiring diagram represent:
   a. connectors.
   b. wires.
   c. relays.
   d. switches.
6. Which of the following components in wiring diagrams are identified using alphanumeric callouts?
   a. Motorized components
   b. Relays
   c. Connectors
   d. Switches
7. All of the following statements are true *except*:
   a. Connector housing uses colored plastic so it can be identified during assembly and service.
   b. Hybrid high voltage wires use yellow wire insulation.
   c. Connector pin slots are usually designated by numbers starting at the left side of the top row.
   d. The wiring diagram indicates the pin number location in the applicable connector.
8. Some connectors and the related harness are color coded to indicate caution. Supplemental restraint system harness covering and connectors are usually:
   a. yellow.
   b. green.
   c. orange.
   d. black.
9. All of the following statements with respect to identifying the location of electrical components using service information resources are true, *except*:
   a. Service information resources help in planning the proper diagnostic strategy and testing plan.
   b. Interactive wiring diagrams show a cutaway image of the vehicle and highlight the selected component.
   c. In non-interactive diagrams a graphic with multiple components and their location is shown.
   d. Non-interactive diagrams are not of use to the technician.
10. Choose the correct statement.
    a. Circuit tracing is the use of highlighting pens to trace the current paths in a circuit.
    b. Circuit tracing should be done using only one highlighter color.
    c. The load in the circuit is the component that does not perform any form of work.
    d. The horn circuit is actually made up of a single circuit path.

ASE Technician A/Technician B Style Questions

1. Tech A says the wording "Hot in Run" means the circuit is powered at all times. Tech B says most wiring diagrams show the expected voltage before and after the load device. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says a junction block may be identified by a shaded area on some wiring diagrams. Tech B says the position of the components on the wiring diagram helps identify where they are located on the vehicle. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says the horn switch is normally open. Tech B says the horn switch controls source voltage to the relay coil. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

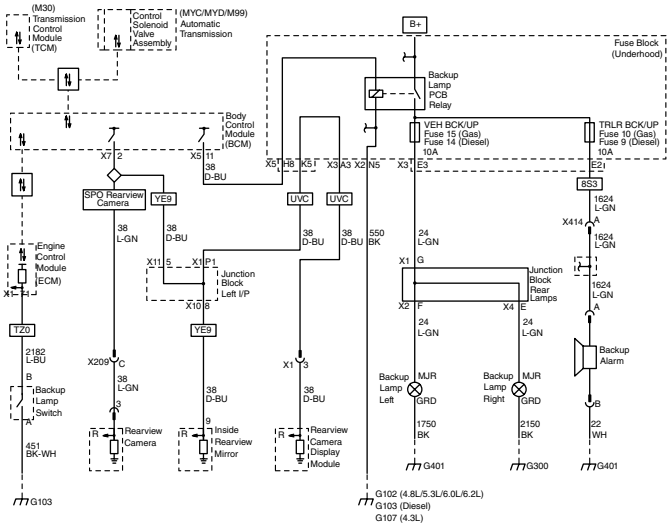


4. This question refers to the fog light wiring diagram shown. Technician A says the fog lamp relay in the diagram shown can be replaced if it fails. Technician B says there will be very close to zero volts at C205 pin 1 when the fog lights are on. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. This question refers to the fog light wiring diagram below: Tech A says the fog light relay is source controlled. Tech B predicts each fog light pin 2 receives 6 volts. Who is correct?
   a. Tech A
   b. Tech B

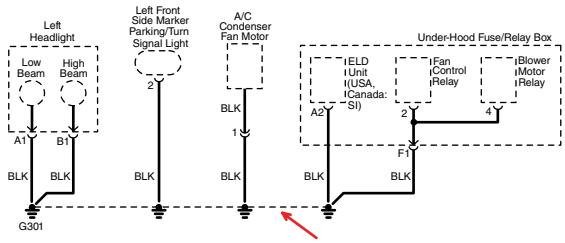


c. Both A and B
d. Neither A nor B

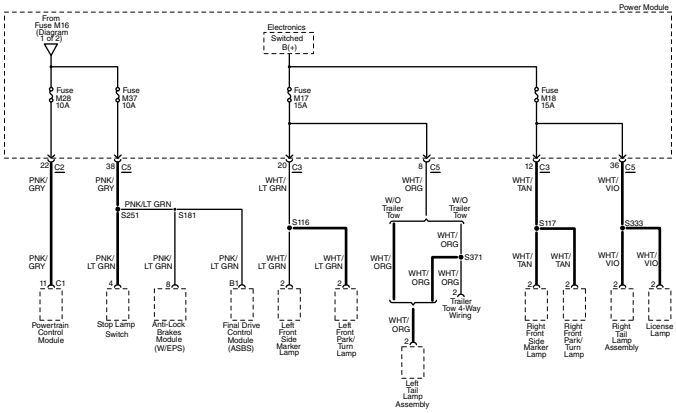
6. This question refers to the fog light wiring diagram above: Tech A says the predicted voltage at pin 49 when the fog light switch is OFF should be 12V. Tech B says predicted voltage at main switch pin 7 when the fog lights are ON should be 12V. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. This question refers to the back-up lamp circuit shown below: Tech A says the left back-up lamp has a path to ground at G401. Tech B says the back-up light relay is source controlled. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

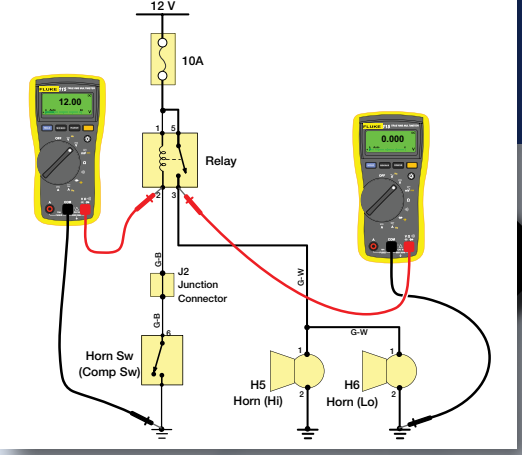


8. This question refers to the back-up lamp circuit shown above: Tech A says the back-up lamp relay always grounds at G107. Tech B says the predicted voltage at pin A of the back-up lamp switch is 12 V when the switch is open. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. This question refers to the ground distribution diagram below: Tech A says the dotted line (refer to the red arrow) indicates a wire that connects each circuit ground-to-ground point G301. Tech B says an open circuit at G301 would affect all circuits shown. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



10. This question refers to the power distribution diagram shown: Tech A says the left and right front marker lamps share the Fuse M17. Tech B says a short-to-ground on the pink/light green wire on the stop lamp switch could affect three circuits. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B





CHAPTER 6
Circuit Diagnosis

NATEF Tasks

- **N06001** Demonstrate proper use of a digital multimeter (DMM) when measuring source voltage, voltage drop (including grounds), current flow and resistance. (MLR/AST/MAST)
- **N06002** Use fused jumper wires to check operation of electrical circuits. (MLR/AST/MAST)
- **N06003** Demonstrate knowledge of the causes and effects from shorts, grounds, opens, and resistance problems in electrical/electronic circuits. (MLR/AST/MAST)
- **N06004** Measure key-off battery drain (parasitic draw). (MLR) Diagnose the cause(s) of excessive key-off battery drain (parasitic draw); determine needed action. (AST/MAST)
- **N06005** Inspect and test switches, connectors, and wires of starter control circuits; determine needed action. (MLR/AST/MAST)

Knowledge Objectives

After reading this chapter, you will be able to:

- **K06001** Describe how to measure voltage.
- **K06002** Outline the process of measuring amperage.
- **K06003** Describe the various types of circuit faults that you will diagnose as a technician.
- **K06004** Explain the diagnostic importance of testing switches, connectors, and wiring.

Skills Objectives

After reading this chapter, you will be able to:

- **S06001** Create a repair order for your assigned vehicle(s) to document your diagnosis of automotive circuits that have one of the following faults:
  - **a.** Open circuit
  - **b.** High resistance
  - **c.** Short circuit
  - **d.** Shared voltage fault
  - **e.** Parasitic draw fault

You Are the Automotive Technician

The customer states the driver's door window operates slower than it used to and sometimes gets stuck in the down position. The technician verifies the driver's window is much slower going down or up than the other windows, which operate at normal speed. From the verification of the concern answer the following:

1. Can any circuit components be eliminated as the cause of the fault?
2. What components may be causing this fault?
3. What type of circuit tests would you use to isolate the cause of this fault?

Introduction

A source, protection device, control device, load (component that does the work) and ground path are found in every automotive circuit. Customers do not bring in their vehicles for circuit checkups or maintenance; they come to the shop or, even worse, are towed in when an electrical system fault has occurred. The technician must be up for the task. Unlike a fluid leak or an abnormal noise, electrons flowing in a circuit cannot be seen or heard. Technicians must be proficient at using service information, circuit wiring diagrams, and the digital multimeter (DMM) for electrical system diagnosis. Like any task, repetition and practice allow technicians to identify the cause of electrical faults—just like a good baseball pitcher can, with practice, place the ball where desired over home plate.

K06001 Describe how to measure voltage.

N06001 Demonstrate proper use of a digital multimeter (DMM) when measuring source voltage, voltage drop (including grounds), current flow and resistance. (MLR/AST/MAST)

Measuring Voltage

Measuring voltage is the most frequently performed electrical system diagnostic test. Measuring source voltage should be one of the first inspection points of any electrical system concern (**FIGURE 6-1**). Measure source voltage at the battery with the vehicle off and all electrical loads off. A fully charged battery should indicate very close to 12.6 volts on the **digital multimeter (DMM)**. Perform a battery test if source voltage is 12.4 volts or less before continuing diagnosis. The concern may be due to a faulty battery or a problem with the charging system.

The DMM on the volt setting is measuring the difference in voltage (potential or pressure) between the positive test lead and the negative test lead. Using the battery as an example, the positive post of the battery has a potential of 12.6 volts and the negative post of the battery has a potential of 0 volts when fully charged. In simple terms, the DMM takes the voltage measured on the positive lead and subtracts it from the negative lead: 12.6V – 0.0V = 12.6V. Looking at the voltage predicted in the circuit in **FIGURE 6-3**, the technician has predicted source voltage before the load and after the load when the circuit is off: 12.6V – 12.6V = 0.0V. There is no potential difference between these two test points when the circuit is off so the DMM displays 0.00V.

Measuring available voltage and voltage drop in the circuit is part of the diagnostic process. Perform these tests once you have reviewed the service information, traced circuit current paths, and predicted circuit voltages at applicable test points. It is usually best to start with available voltage tests as the results are shown on the DMM display even if no current is present in the circuit. Available voltage tests are made by placing the DMM negative test lead on a known good ground location. Place the DMM positive test lead at the desired test point in the circuit. Compare the test result to your predicted voltage on

▶ TECHNICIAN TIP

A source voltage reading of 12.8 volts or more indicates the battery has a surface charge (**FIGURE 6-2**). Turn the headlights on for approximately one minute with the engine off, and then turn the lights off. Wait approximately two minutes and then measure source voltage again. A source voltage of 12.4 volts or less indicates the battery is discharged as follows: 12.4V = 75% charged, 12.2V = 50% charged, 12.0V = 25% charged, and 11.9V or less the battery is discharged. Modern batteries should be charged using a "**smart charger**" that monitors battery voltage and current, controlling how fast the battery is charged to prevent damage. Be sure to select the correct battery construction type on the smart charger control panel to prevent battery damage.

FIGURE 6-1 Source voltage is measured at the battery and should be very close to 12.6 volts.

FIGURE 6-2 A battery with 12.4V or less should be tested and, if OK, charged to 100% using a "Smart" charging system.

the wiring diagram. A circuit fault is noted when the voltage is not close to what should be present. The available voltage test can quickly narrow your search for the cause of a circuit fault, like an open circuit concern (**FIGURE 6-4**).

Voltage drop tests require that current is present in the circuit. Remember, voltage only drops in the presence of current. The voltage drop test is the best test for isolating high resistance faults in a circuit (**FIGURE 6-5**). A voltage drop test is performed by placing the positive lead of the DMM on the most positive portion of the circuit and the negative lead on the most negative portion of the circuit with the test circuit energized (on). A voltage drop can be performed on any portion of the circuit—across the load where most of the voltage should be used to perform work, a connector, a switch, a section of wiring, or the ground (**TABLE 6-1**). You can apply one of Kirchhoff's laws to verify your voltage drop testing was done correctly. Kirchhoff stated that the sum of the voltage drops in a circuit must equal source voltage. After you note your voltage drops, add them up to verify they equal source voltage. This ensures that you did not misinterpret a voltage reading or have one or both of the test leads in the wrong location.

Resistance Testing

A resistance test is best used when testing a circuit component as part of the service information's diagnostic procedure. You may need to measure a relay coil, thermistor, solenoid, or a fuel injector for resistance and then compare your DMM reading with the service information specification (**FIGURE 6-6**).

Resistance tests are made with the circuit off and isolating the component or portion of the circuit you will be testing. Isolate the component by disconnecting the harness

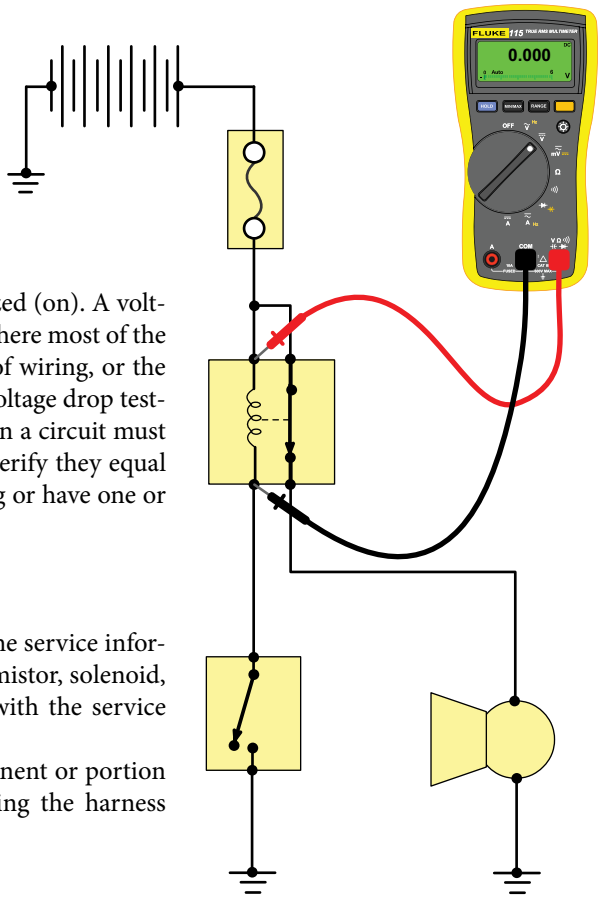


FIGURE 6-3 The DMM test leads are measuring the voltage before and after the relay coil with the circuit off. Source voltage is present at the positive and negative test lead so the DMM displays a difference between the two test points as 0.00V.

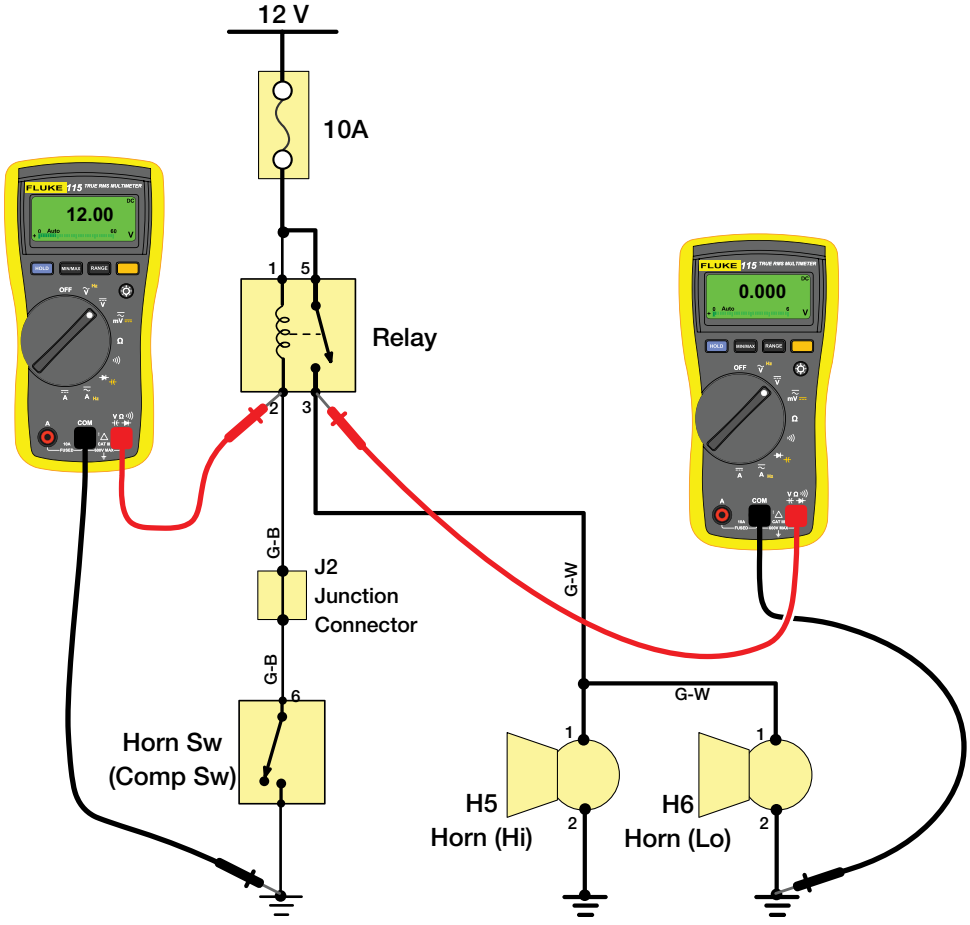


FIGURE 6-4 Available voltage tests do not require current to be present in the circuit and can quickly pinpoint that there is an open circuit fault.

▶ TECHNICIAN TIP

Why not use the resistance function of the DMM test to find an unwanted circuit resistance? DMM resistance tests require the circuit is off and the portion of the circuit or component you are testing is isolated from other parts of the circuit by disconnecting them. The DMM places a low voltage at each lead and monitors current to then calculate and display the resistance. The problem with this method is that the current is so low that it is very easy for faulty components to show normal resistance during the test. An example is a damaged wire where only one or two strands of copper are connected through the whole section of the wire. The resistance test will show the wire is OK; however, when the circuit is turned on, the normal current levels cause a high voltage drop at the point where the wire is damaged since only a small amount of current can pass through the remaining strands of wiring. The voltage drop test is able to detect the damaged wire because the circuit is on when being tested.

▶ TECHNICIAN TIP

It is important to note that the resistance of a component can change when it is energized (turned on). The resistance may increase or decrease and cause erratic operation. A component that is turned on by an electronic control unit (ECU), like a fuel injector, can damage the internal ECU circuits if the resistance drops to near zero or completely shorts to 0 ohms. This increases current to levels that damage electronic circuits. Many manufacturers require that both the component, like a fuel injector in this example, be replaced if it is also determined that the ECU is not functioning to operate it.

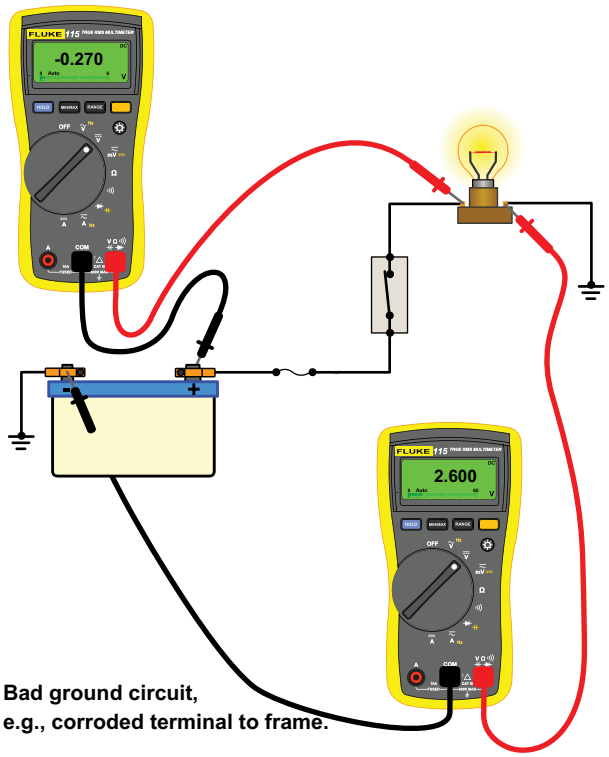


FIGURE 6-5 Voltage drops in the presence of current and can be measured with the DMM when the circuit is on.

TABLE 6-1 Non-ECU Circuit Voltage Drop Limits

Component	Maximum voltage drop
Circuit load	Very close to source voltage
Connector	0.0 – 0.1 volt (<100 mV)
Section of wire	0.0 – 0.1 volt (<100 mV)
Current carrying switch	0.0 – 0.1 volt (<100 mV)
Relay contacts	0.0 – 0.1 volt (<100 mV)
Ground	0.0 – 0.05 volt (<50 mV)

connector. You may need to use a pin test toolkit to connect the DMM leads to the component (**FIGURE 6-7**). Compare your reading to the specification in the service information and note that if the temperature is warmer or colder than noted, your reading will vary. Warmer conditions increase resistance; cooler temperatures will lower the resistance. To measure resistance in a portion of the wiring harness, isolate it by disconnecting it at two locations (see Figure 6-7); you can then connect the DMM to the related pin in each connector and note the resistance reading. Wiring should have almost no resistance so the reading should be very close to 0 ohms.

▶ TECHNICIAN TIP

Most DMMs offer a "**zero**" feature when measuring resistance. This feature compensates for any resistance in the DMM test leads. Use the feature by touching the test leads together with the DMM set to the resistance function and then press the "zero" button. The DMM will reset the display to "zero." If your DMM does not have this feature, you can touch the test leads together and note the resistance, for example 1.3 ohms. Subtract 1.3 ohms from your resistance measurement to obtain the correct reading.

1. Inspect Fuel Injector Assembly

(a) Measure the resistance according to the value(s) in the table below.

Standard resistance:

TESTER CONNECTION	CONDITION	SPECIFICATION
1-2	20°C (68°F)	11.6 Ω to 12.4 Ω

If the result is not as specified replace the fuel injector assembly.

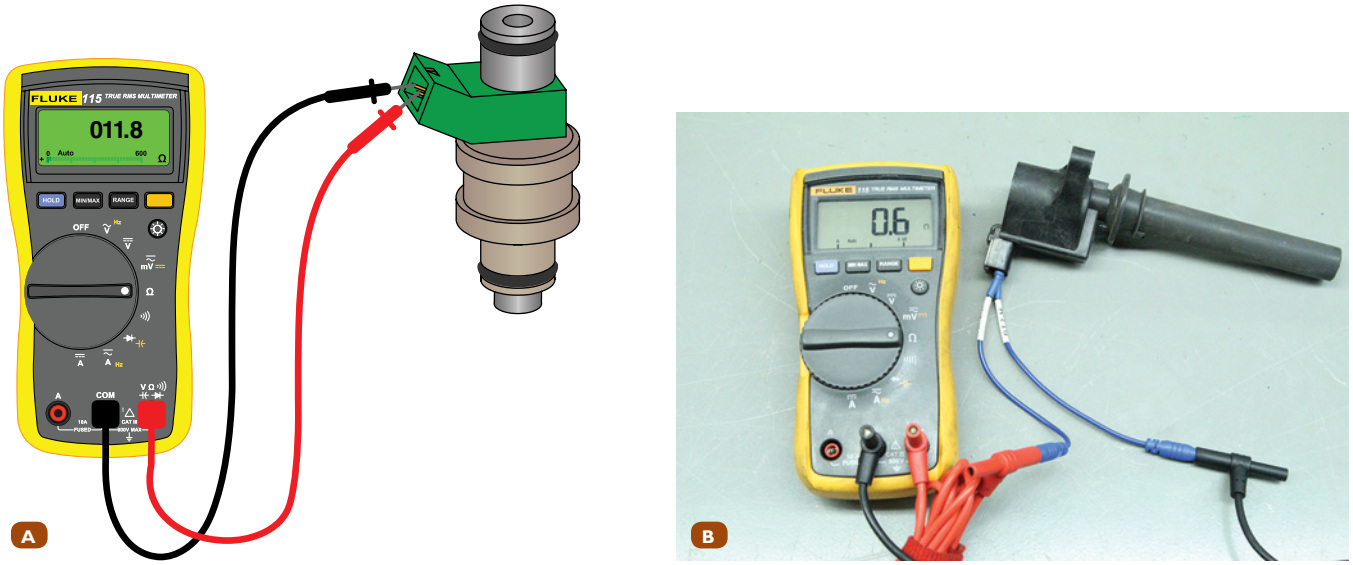


FIGURE 6-6 A resistance test can determine if a component is within service information specifications.

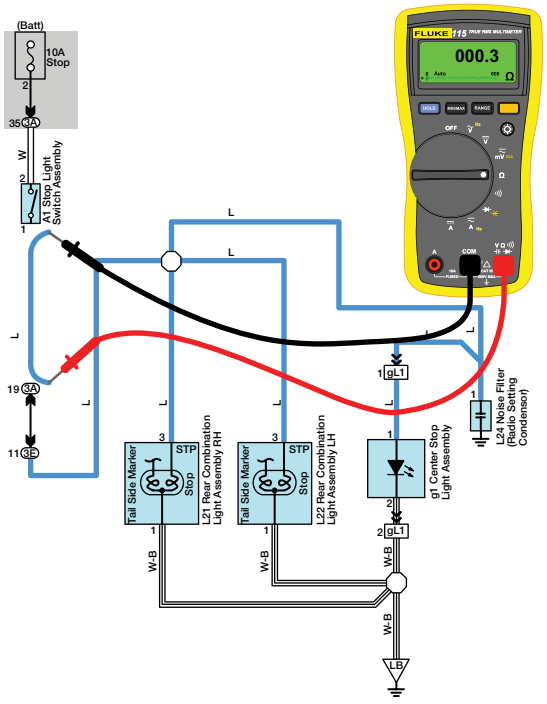


FIGURE 6-7 Measure resistance of the harness by disconnecting the wiring and then measuring with the DMM. Wiring resistance should be very close to 0 ohms. Disconnect the section of the circuit that you are testing. Connect the DMM leads and note the resistance reading on the display.

▶ Measuring Amperage

Using the DMM to measure circuit amperage is not often performed in automotive circuits. Most DMMs can only measure up to 10 amps of current, and most automotive body electrical circuits require more amperage than this to operate (note the fuse rating for the circuit you are diagnosing). The most common use for the ammeter function of the DMM

K06002 Outline the process of measuring amperage.

N06002 Use fused jumper wires to check operation of electrical circuits. (MLR/AST/MAST)

▶ TECHNICIAN TIP

It can be tempting to remove the circuit fuse and use this location to obtain the amperage reading. Only do this using fused jumper leads. Failure to do so can result in damage to the vehicle and to the DMM.

▶ TECHNICIAN TIP

An **inductive amperage pickup** is often used for circuit diagnosis where the amperage reading is required. The inductive pickup measures the magnetic field created in the wiring when the circuit is on and converts it into a voltage that is displayed on the DMM or a digital storage oscilloscope (DSO). The reading is usually in millivolts, and most low amperage inductive pickups use a conversion setting of 10mV or 100mV = 1 amp. A reading of 45mV when set to the 10mV scale would calculate to 4.5 amps (45 ÷ 10 = 4.5). Using the 100mV setting, the same measurement would display as 450mV on the DMM but the result would be the same, 4.5 amps (450 ÷ 100 = 4.5). High amperage inductive pickups are used for high current circuits like the charging or starting system and can display readings that convert to between 100 and 1000 amps.

FIGURE 6-8 An inductive clamp can be used to measure amperage values that exceed the limit of the DMM or if you want to view the signal on a DSO.

is measuring parasitic draw, which if excessive can cause the battery to discharge. Also the service information rarely provides current specifications.

It is recommended that you use **fused jumper leads** to prevent a short circuit that damages the DMM, the test leads, or vehicle circuits for amperage testing. The negative lead remains in the common jack of the DMM. Move the positive lead to the appropriate amperage jack, usually to measure either up to 200 milliamps or more than 200 milliamps to the DMM's limit (usually 10 amps). The DMM test leads become part of the circuit to measure amperage, as the current must go through the DMM so it can be measured. Open the circuit at a connector if possible and connect the positive lead to the most positive side of the circuit and the negative lead to the most negative side of the circuit. Turn the circuit on and note the reading on the DMM.

Warning: The DMM becomes part of the circuit when the amperage function is selected. Incorrect procedures or forgetting to place the positive lead back into the volt-ohm jack of the DMM can result in a short circuit if you then use the DMM to measure voltage. Some DMMs produce a warning beep when the positive lead is in the amperage jack with the function selector set to measure voltage. Failure to follow these procedures can blow circuit fuses, main body fusible links, or, if testing source voltage at the battery, create a spark that can cause the battery to explode (**FIGURE 6-8**).

▶ Circuit Faults

Circuit faults result in a customer concern. These faults can be categorized as an open circuit, high resistance in a circuit, a short circuit, a shared voltage fault, or parasitic draw. It is important to determine the type of circuit fault you are dealing with during your diagnosis as it will affect the strategy and test methods used to isolate the cause of the fault.

K06003 Describe the various types of circuit faults that you will diagnose as a technician.

N06003 Demonstrate knowledge of the causes and effects from shorts, grounds, opens, and resistance problems in electrical/electronic circuits. (MLR/AST/MAST)

S06001 Create a repair order for your assigned vehicle(s) to document your diagnosis of automotive circuits that have one of the following faults.

- **a.** Open circuit
- **b.** High resistance
- **c.** Short circuit
- **d.** Shared voltage fault
- **e.** Parasitic draw fault

Open Circuit

An open circuit no longer has a continuous path for current in the circuit and is the most common electrical system fault. Causes of an open circuit include disconnected connectors, a bad switch, damaged terminal connectors, cut wires, or a defective or blown fuse. When there is no observable sign of circuit operation, there may be an open circuit (**FIGURE 6-9**).

Begin by testing the available voltage in the circuit that is the easiest to reach of those that are the most likely cause of the concern. For the stop light circuit shown, you can test at left stop light connector pin 3. If source voltage is present, then the circuit open is after this point. If no voltage is present, the open is before this point in the circuit. With continued circuit testing, you find that there is source voltage at left stop light connector pin 1. This indicates the bulb should be OK. The next test location is the circuit ground point, L3—the DMM indicates 0 volts. Since there is source voltage at the ground side of the stop light bulb connector (L31 pin 1) and no voltage at the circuit ground point, the open is between these two points. Further testing should be performed by visually inspecting this section of the harness to determine the where the open is located.

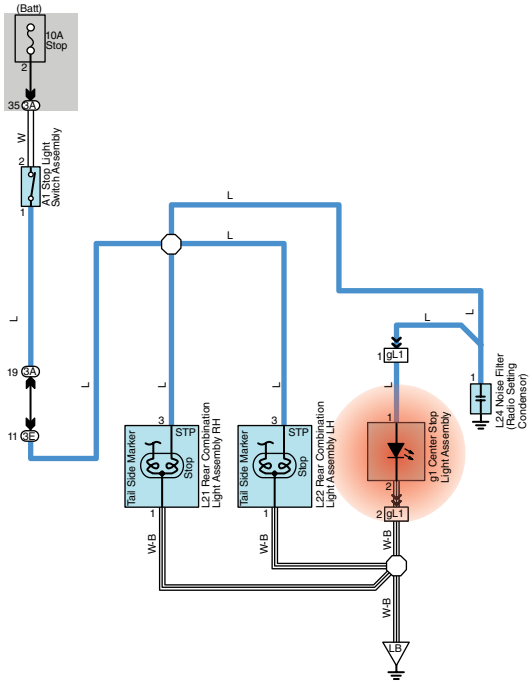


FIGURE 6-9 An open circuit may be indicated when there is no observable operation of the stop lights.

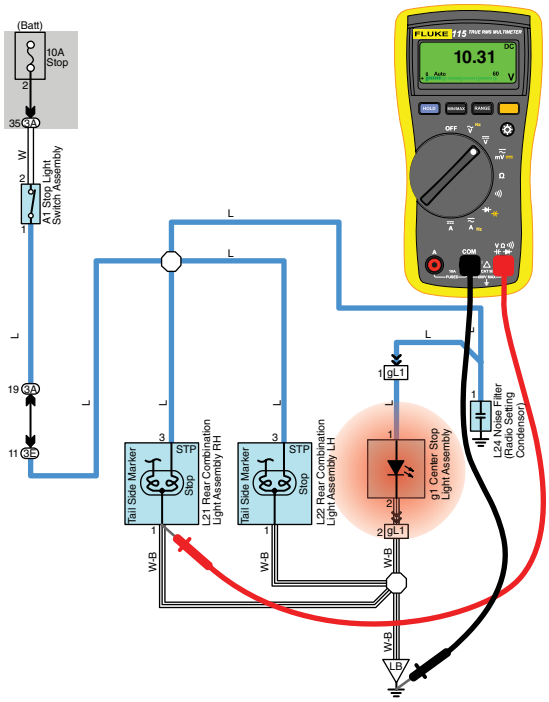


FIGURE 6-10 A very high voltage drop after the circuit load indicates excessive resistance in the ground side of this stop light circuit.

High Resistance in a Circuit

In some cases high resistance faults may appear to be open circuit faults. The difference is that current is present in the circuit with a high resistance fault. Additionally, instead of infinite resistance like an open circuit, there is a resistance that is causing an excessive voltage drop at some point before or after the circuit load (**FIGURE 6-10**).

The strategy for isolating the location of the high resistance fault is very similar to open circuit voltage testing. If the circuit load functions, but does not function correctly, you know that current is present. Therefore you can perform available voltage tests and voltage drop tests throughout the circuit to isolate the high resistance. If you are unable to determine whether current is present because the load does not appear to operate, begin with available voltage testing at the load at both the positive and ground pins of the connector. Source voltage at the load indicates the resistance is after the load, which should be confirmed when you obtain a reading that exceeds 100mV or greater on the ground side of the load (with the circuit on) (**FIGURE 6-11**).

Voltage that is much less than source voltage indicates the high resistance is before the load. Once you have isolated which part of the circuit has excess resistance, you can continue to use available voltage tests or voltage drop tests to isolate where the high resistance is.

Short Circuit

A short circuit occurs when current bypasses the load and goes directly to ground or when there is some fault in a circuit component (usually the load) that reduces resistance and increases current beyond normal levels. A relay coil that has failing wire insulation increases current, for example. Fuses, fusible links, and circuit breakers serve as circuit protection devices in case of a short circuit. Fuses and fusible links are designed to have their conductor melt from the excess current of a short circuit. When the conductor melts away, it opens the circuit and prevents overheating wiring, switches, and the load device which could lead to a vehicle fire.

Diagnosing a short circuit can seem like a daunting task since you cannot power the circuit on and then use your DMM to find the cause. There are a couple of methods that you can use to locate the fault. The first method involves using an incandescent light as a short-finding tool. Create the short-finding tool by using a 12-volt 1156 light socket, a fuse

▶ TECHNICIAN TIP

Never replace a blown fuse or fusible link with one of a higher amperage rating. Doing this can lead to a great deal of damage, an accident, injury, or death. The owner of a vehicle became frustrated by a fuse that kept blowing so one of a higher rating was installed. The circuit worked for two days and all seemed OK until he and his family came back to the vehicle in a large shopping center parking lot to find it surrounded by fire trucks. It had caught fire and was destroyed. The most likely cause was replacing the blown fuse with one of a higher amperage rating.

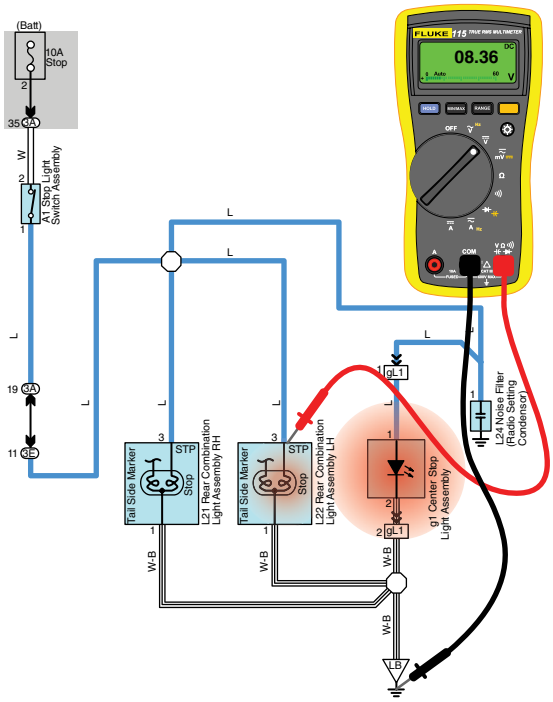


FIGURE 6-11 Measure voltage at the load. Less than source voltage on the source side indicates resistance before the load. Voltage that is greater than 100–300mV after the load indicates excess resistance after the load.

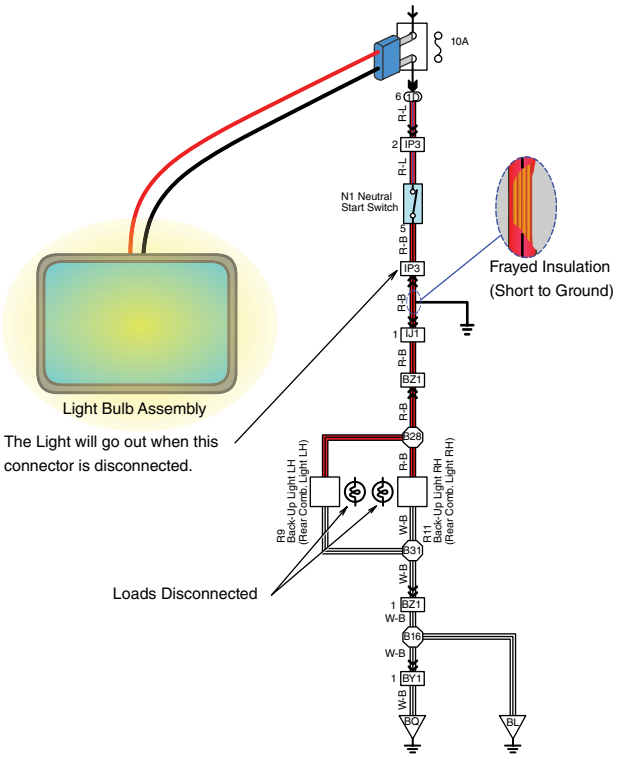


FIGURE 6-12 Locate the short using an 1156 lamp and socket with a fuse. Disconnect connectors in the circuit before the load until the light turns off to isolate the short location. Using an incandescent lamp with fused leads connected to the fuse holder is one method for locating a short circuit.

holder, and 16 gauge wire. Assemble as shown in **FIGURE 6-12**. Remove the circuit fuse and install the short-finding tool. Turn the affected circuit on and the 1156 bulb will illuminate. Begin disconnecting circuit connectors in the affected circuit one at a time. When the 1156 bulb goes out, you know the short is in that section of the circuit. You can then inspect the harness or component further to determine what repair is required.

Another option is to use a short-detecting tool. There are two basic types. The first uses a circuit breaker to power up the circuit for very short intervals. While it is energized, you use a hand-held tool that detects the magnetic field in the wiring harness. If the needle on the tool moves, there is current present. When the needle stops moving, you have found where the short to ground is. The second type of short detector uses a signal generating device connected to the affected circuit. Once it is connected, you leave the circuit off and then use the signal detector along the harness. As long as there is a signal, the wiring is OK. The signal stops where the short is. The difficulty with both of these methods is in the amount of the harness you must expose to find the short location, especially where the harness is difficult to reach behind the instrument panel.

Whichever method you use to find the cause of the short circuit, once found, perform the recommended repair and then thoroughly retest the circuit to ensure all is OK.

▶ TECHNICIAN TIP

Many vehicle manufacturers no longer allow wiring harness repairs under warranty. Instead, the whole harness must be replaced to repair an open, high resistance, short to ground, or other fault in the harness and related connectors. Customer pay repairs will often require repairing the harness due the potentially high cost of harness replacement.

Shared Voltage

A shared voltage fault is one of the most confusing faults to diagnose. A shared voltage fault occurs when one circuit shares its voltage with another causing it to operate at the same time. A shared voltage fault can occur when one circuit joins with another circuit causing the two circuits to operate when one or the other is energized. This may be caused when two wires chafe through the insulation and the bare wire touches, when damage to a connector causes adjacent pins to touch, when a fault or damage inside a junction block allows two distinct circuit paths to intersect and connect, or when a damaged dual filament light

bulb allows voltage in one filament to touch the other filament and turn that part of the circuit on. An open ground in one circuit can also allow current to seek a path to ground through another related component like a light bulb or shared fuse (**FIGURE 6-13**).

Isolate the cause of a shared voltage fault by first checking for a blown fuse. The blown fuse may cause the lack of voltage in one circuit to seek a path through another circuit where they intersect in a junction block or junction connector. Shared voltage concerns in incandescent lighting circuits can be diagnosed by removing each bulb one at a time. Inspect the bulb to be sure it is the correct type and there is no damage to the bulb base or socket in the vehicle harness. If the other circuit turns off when you remove the bulb, you have isolated the cause to either the bulb or that part of the harness and bulb socket. Do this for each bulb in the circuit until you locate the cause of the fault. It is possible that a damaged harness or connector is allowing one circuit to power another due to exposed wires touching each other or two or more connector pins touching. Isolating where the short to voltage is should begin with where the two (or more) circuits have wiring in the same connector(s). Check for continuity between the two suspected wires. It should be an open circuit, but a resistance reading near 0 ohms indicates the two wires have made contact. Carefully inspect connectors for damage. If OK, move on to the harness sections and carefully inspect the individual wires for damage to insulation that would allow the circuits to share voltage from one to the other. Lastly, some circuits use diodes to isolate one part of the circuit from another. Refer to the wiring diagram; if there is an isolation diode present, locate the diode and check its operation with your DMM. Replace the diode if it fails the forward or reverse bias tests.

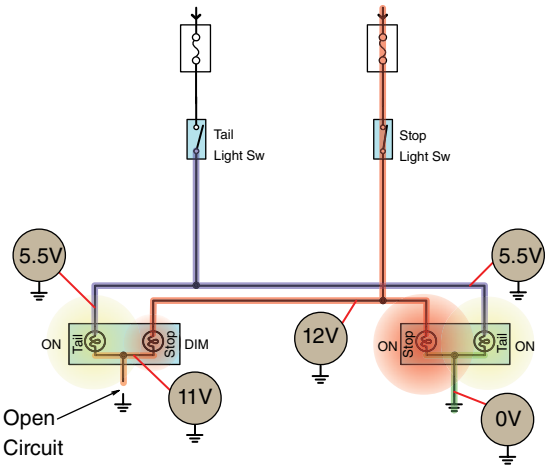


FIGURE 6-13 Shared voltage faults can be caused by two wires or two filaments in an incandescent bulb shorting together or by an open ground as shown.

Parasitic Draw

N06004 Measure key-off battery drain (parasitic draw). (MLR) Diagnose the cause(s) of excessive key-off battery drain (parasitic draw); determine needed action. (AST/MAST)

A parasitic draw is always present in the modern vehicle. ECUs have keep alive memory functions, and ECUs related to alarm and keyless entry systems remain active while the vehicle is locked and off. The typical vehicle should have less than 50mA (milliamps) of parasitic or ignition-off draw and should have little effect on battery voltage over a vehicle storage period of two to four weeks. Excessive parasitic draw usually presents as a customer concern that the battery has low or no charge to start the vehicle after it has been parked for a period of a few hours to a day or so.

Your diagnosis should begin with a thorough battery and charging system test. A failing battery or charging system that does not fully charge the battery can cause symptoms that may seem like a parasitic draw concern but are not. If the battery and charging system are OK, check for parasitic draw (**FIGURE 6-14**).

Parasitic current draw can be measured in several ways, the most common being the process of using an ammeter capable of measuring milliamps and inserting it in series

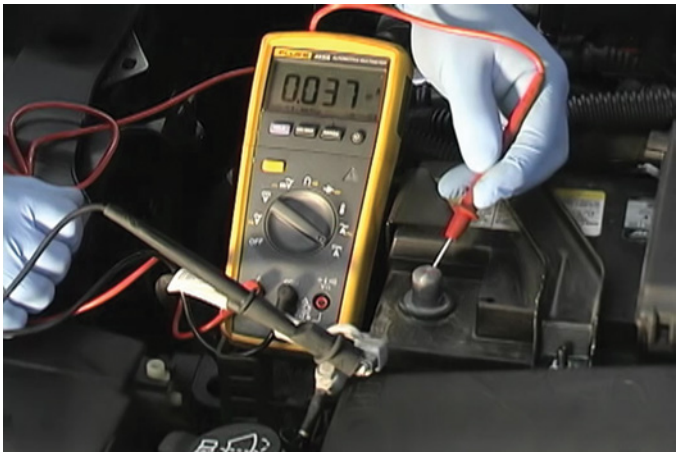


FIGURE 6-14 The parasitic draw test determines the amount of current used by systems when the vehicle is off.

FIGURE 6-15 DMM hooked up to measure parasitic draw.

FIGURE 6-16 Low-amps probe hooked up to battery cable.

between the battery post and the battery terminal. The ammeter is usually put in series with the negative battery lead (**FIGURE 6-15**). If the vehicle is equipped with systems or modules that require electronic memory to be maintained, follow the procedure listed in previous paragraphs for identifying modules that lose their initialization during battery removal and maintain or restore electronic memory functions. Note that the timers may reset during the process of disconnecting the battery terminal and connecting the ammeter in series, so you may have to wait for the timers to go back to sleep. If excessive parasitic draw is measured, disconnect fuses or systems one at a time while monitoring parasitic current draw to determine the systems causing excessive draw. Also, in most cases, opening a door or trunk will cause the timers to reset.

Disconnecting the battery can be avoided if a sensitive, low-current (i.e., milliamps) clamp is available (**FIGURE 6-16**). The low-amps **current clamp** measures the magnetic field generated by a very small current flow through a wire or cable. Placing the low-amp current clamp around the negative battery cable will allow you to measure the parasitic draw. If excessive parasitic draw is measured, disconnect fuses or systems one at a time while monitoring parasitic current draw to determine the systems causing the excessive draw.

The last way to measure a parasitic draw is a bit controversial, but it is well worth trying out since it can save a lot of time and requires no special tools other than a DMM. It is named the Chesney parasitic load test after its creator, Sean Chesney. Instead of using an ammeter to measure the draw, an ohmmeter is used. Before doing anything, set the ohmmeter to ohms (the lowest scale), touch the meter leads together, and read the screen. The reading is the resistance of the meter leads and is called the "delta" value, which is the meter's true zero when used with those leads. Typically an ohmmeter will read about 0.1 ohms when the leads are touched together. Remember this number for later. Some meters have a delta feature that recalibrates the ohmmeter to zero when the leads are placed together and the delta button is pushed. If your meter has this delta feature, you can use it so that you will not have to remember the delta reading.

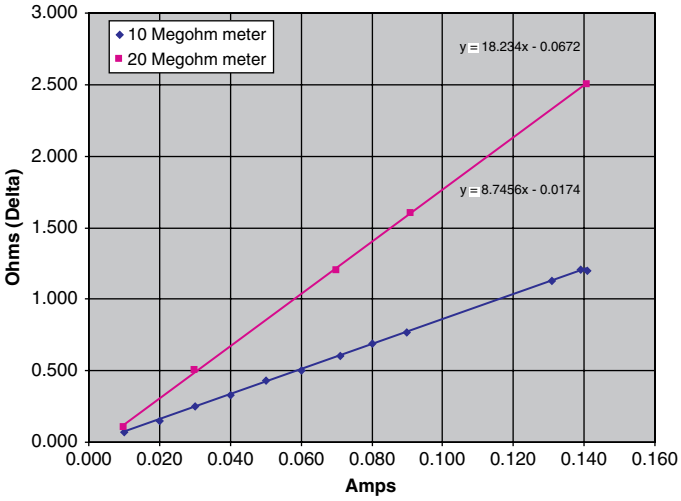


FIGURE 6-17 Chesney parasitic load test-ratio graph.

Next, with the battery terminals still connected to the battery, place the black lead on the negative post of the battery and the red lead on an unpainted surface of the alternator housing. Read the ohmmeter and subtract the delta value from the reading. This reading corresponds to the relative parasitic draw on the system.

Through testing, Chesney found that a draw of about 35 milliamps equaled an ohm reading of about 0.3 ohms delta (above the delta value) on a DMM with 10 megohms of impedance, and about 0.6 ohms delta on a DMM with 20 megohms of impedance (**FIGURE 6-17**). Anything above those readings

indicates an excessive parasitic draw. You may be skeptical of this method, so go out and try it on any vehicle. Simulate a parasitic draw by opening the driver's door, which illuminates the dome light, and watch the ohmmeter. It went up, right? Close the door. As soon as the light went off, the ohmmeter reading went back down, right? If you use this test and find an excessive draw, you can pull fuses one at a time, watching for the ohmmeter reading to decrease. If it does not decrease after removing all of the fuses, suspect an unfused circuit such as the alternator diodes or the ignition circuit on some vehicles.

▶ Testing Switches, Connectors, and Wiring

K06004 Explain the diagnostic importance of testing switches, connectors, and wiring.

N06005 Inspect and test switches, connectors, and wires of starter control circuits; determine needed action. (MLR/AST/MAST)

Switches, connector pins, and wiring from one part of a circuit to the next are often tested as part of the electrical system diagnosis. Service information often provides resistance specifications to check these components; however, the best test for component resistance is the voltage drop test, as discussed earlier in this chapter. Switch contacts should have infinite resistance when off and very close to 0 ohms when in the on position. Wiring and connector pins should have very close to 0 ohms of resistance. Also, wiring that delivers voltage to the load should have no continuity to ground (OL on the DMM).

Voltage drop testing is a dynamic test. The component is tested when current is present in the circuit. A switch, wire, or harness connector pins may have very little resistance when tested by the DMM and its very small current present during the resistance test. Applying full circuit current will cause resistance to show in the form of a voltage drop. Perform a voltage drop across a switch by measuring at the connector pins. The voltage drop should be less than 100mV for most circuits. Circuits with high current may have a higher voltage drop. For example, an incandescent stop light circuit may have 200–300mV drop across the brake light switch. Switch contacts can corrode or be damaged from repeated on to off cycling. A voltage drop of more than 500mV usually indicates the switch is faulty and should be replaced.

Connectors join sections of the harness together and allow for easier assembly or disassembly of the vehicle and related repairs that may be required. Connector pins are really only designed to be connected and disconnected three or four times in their vehicle life. Every time a connector is disconnected and reconnected, its pins may be damaged or there may be wear and damage to the housing and the retaining lock mechanism. Use caution when disconnecting the connectors and avoid repeated removing and installing. Tools are available to test for connector pin fit (**FIGURE 6-18**). An excessive voltage drop across a connector may be caused by a damaged pin. The use of this tool can help identify whether pin fit is the cause. A damaged connector or damaged pin usually requires a harness replacement if the vehicle is under warranty. Customer pay may require you repair or replace the connector pin or entire connector if the components are available. Some vehicle manufacturers provide terminal repair kits and a catalog of replacement connectors that are a direct replacement or can be adapted to fit, like using a 6 pin connector in place of a 4 pin.

Wiring can be damaged due many factors including high heat environments, flexing as the powertrain moves, chafing from road vibration and heat expansion and contraction, rubbing and flexing when doors and the deck lid or hatch open/close, and physical damage due to an accident or improperly installed accessories. The service information usually provides harness testing specifications in the related circuit diagnosis where required. Usually the information relates to resistance tests from connector to connector and to chassis ground. Unfortunately, a resistance test can miss diagnosing a damaged wire that can handle the full circuit current. For this reason a voltage drop test is recommended. The wiring should have very little resistance and a voltage drop that is less than 100mV for most body electrical circuits. Wiring that exceeds voltage drop limits or has a short to ground must be repaired by harness replacement or repair.

FIGURE 6-18 Terminal pin test tools can be used to verify the correct pin fit tension is present.

Wrap-Up

Ready for Review

- Circuit tests are most often made using a DMM to measure voltage, amperage, or resistance.
- Voltage tests include the following: source voltage measured at the battery, available voltage at circuit test points measured by placing the negative lead on a known "good" ground and then testing at various circuit test points with the positive lead, and measuring voltage drop by placing the positive and negative lead across the load or any other portion of the circuit to measure how much voltage is used in that portion.
- Amperage testing requires that the circuit be opened at some point so the DMM can become part of the circuit. The most common amperage test made with a DMM is for measuring parasitic draw.
- Resistance tests are most often made for the following: to measure the resistance of a component when specifications are provided in the service information, to determine if a circuit is open or if a section of wiring is shorted to chassis ground. Resistance testing requires that the circuit is off (deenergized) and that sections of the circuit are isolated for accurate test results.
- Open circuit faults occur when there is an incomplete path for current in the circuit. Causes include damaged wiring, a disconnected or damaged connector, or a faulty circuit component. Testing is usually done with available voltage testing and can be verified using a continuity test in the circuit section where the fault is suspected.
- High resistance faults occur when the path for current is restricted. This may be caused by a faulty load, damaged wiring, poor harness connections, and a poor ground. Available voltage and voltage drop testing are the best test methods to isolate a high resistance fault.
- A short circuit occurs when a path to ground exists that bypasses the circuit load. Current increases to very high levels and the fuse or related circuit protection opens the circuit to prevent major damage to the vehicle. Circuit diagnosis can be made using a load inserted into the circuit at the fuse and disconnecting sections of the circuit until the load turns off. This indicates the area where the short is located. It is also possible to isolate a short using a short detector provided there is adequate access to the vehicle harness so you can isolate where the short is located.
- A short to voltage concern is one of the most difficult electrical issues to diagnose. Diagnose by determining the possible locations the two (or more) circuits could intersect and then isolate those sections and use continuity testing to determine where the circuits have connected to each other.
- Parasitic draw faults are often indicated by repeated need to jump start a good battery and the charging system is operating to specification. Parasitic, or dark current as it is sometimes called, is excess current present when the vehicle is off. This drains the battery over several hours to a day or so. Isolate the circuit where the excess current is being used by monitoring parasitic draw with your DMM ammeter connected to the negative battery post and battery cable. Remove each circuit fuse, one at a time. When the draw returns to normal you have isolated which circuit(s) are at fault. Continue diagnosis to isolate which component is using excess current in the off condition and repair as required.
- Component tests may be made using voltage drop or resistance tests. Voltage tests are preferred as this is a dynamic test made with the circuit energized and is best for isolating faults that might appear OK when performing a resistance test.

Key Terms

DMM Digital multimeter, used to measure voltage amperage and resistance along with several other electrical measurement functions.

DMM "zero" function Used during resistance testing. Touch the DMM test leads together and select the zero function. The meter will "learn" the resistance of the test leads and then display 0 ohms on the display. This provides a more accurate test result when measuring resistance of a component or isolated sections in the circuit.

fused jumper leads Incorporate a replaceable fuse. This allows for safe circuit testing in case the test lead creates an excessive current condition during a circuit test.

inductive amperage pickup Used to measure amperage in a circuit. Most DMMs are limited to direct amperage measurements of less than 10 amps max. Many automotive circuits operate at higher amperage levels and an inductive pickup can be used to do this. The tool is placed around the circuit conductor anywhere in the applicable circuit. The DMM will display a reading in mV and this is multiplied by the factor selected on the tool. The result indicates the amount of amperage present in the circuit.

smart charger A battery charger with microprocessor control that manages voltage and amperage during charging that is matched to the type of battery being charged. This prevents over charging and any resulting damage that it could cause.

Review Questions

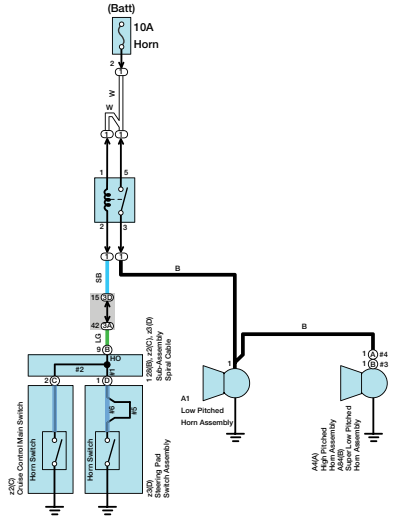
1. When there is a resistance that is causing an excessive voltage drop at some point before or after the circuit load, what type of circuit fault is it?
   a. High resistance circuit fault
   b. Shared voltage fault
   c. Parasitic draw
   d. Short circuit
2. What is a short circuit?
   a. A circuit that no longer has a continuous path for current.
   b. A circuit that shares its voltage with another, causing it to operate at the same time.

c. Current bypasses the load and goes directly to ground.
d. The battery has low or no charge to start the vehicle.

3. All of the following statements with respect to the use of DMM in circuit diagnosis are true *except*:
   a. Measuring source voltage is the first inspection point of any electrical system concern.
   b. The DMM on the volt setting is measuring the difference in voltage between the positive test lead and the negative test lead.
   c. Measuring available voltage and voltage drop in the circuit are performed as part of the diagnostic process.
   d. The DMM voltage circuit in simple terms takes the voltage measured on the negative lead and subtracts it from the positive lead.
4. The voltage drop test is the best test for isolating:
   a. high resistance faults.
   b. open circuit.
   c. short circuit.
   d. parasitic draw.
5. Choose the correct statement with respect to performing the resistance test.
   a. It is performed by placing the positive lead of the DMM on the most positive portion of the circuit and the negative lead on the most negative portion of the circuit, with the circuit that you are testing energized (on).
   b. It is performed with the circuit off and by isolating the component or portion of the circuit you will be testing.
   c. It is performed by measuring source voltage at the battery with the vehicle off and all electrical loads off.
   d. It is performed with the circuit on and by isolating the component or portion of the circuit you will be testing.
6. The most common use for the ammeter function of the DMM is measuring:
   a. parasitic draw.
   b. open circuit.
   c. short circuit.
   d. shared voltage fault.
7. All of the following statements with respect to diagnosing parasite draw are true *except*:
   a. The typical vehicle should have less than 50mA (milliamps) of parasitic or ignition off draw.
   b. Diagnosis should begin with a thorough battery and charging system test.
   c. The parasitic draw test determines the amount of current used by systems when the vehicle is on.
   d. ECUs related to alarm and keyless entry systems remain active while the vehicle is locked and off.
8. All of the following statements with respect to wiring and connector repairs are true *except*:
   a. Use caution when disconnecting the connectors and avoid repeated removing and installing.
   b. Every time a connector is disconnected, its pins get damaged so the connector has to be replaced.
   c. An excessive voltage drop across a connector may be caused by a damaged pin.
   d. If direct replacement is not available, a 6-pin connector can be used in place of a 4 pin.
9. Choose the correct statement.
   a. The best test for component resistance is the DMM resistance test.
   b. Switch contacts should have very close to 0 ohms when off.
   c. Switch contacts should have infinite resistance when on.
   d. Wiring and connector pins should have very close to 0 ohms of resistance.
10. A resistance test can miss diagnosing a damaged wire that can handle the full circuit current. For this reason, it is recommended that:
    a. voltage drop test is performed.
    b. source voltage test is performed.
    c. an inductive amperage pickup is used.
    d. the parasitic draw is measured first.

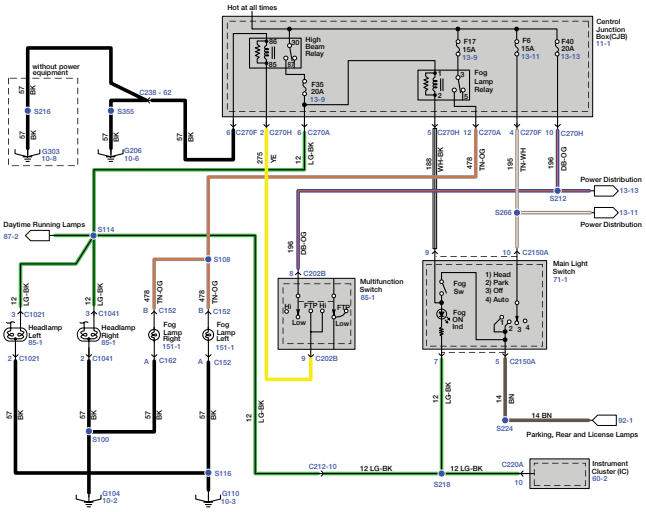
ASE Technician A/Technician B Style Questions

1. Tech A says a short circuit may be indicated by a blown fuse. Tech B says a short to power fault may cause a blown fuse. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says an open circuit may be indicated when the circuit load does not operate. Tech B says an open circuit may be similar to a high resistance fault. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Refer to the horn circuit shown. The horns do not operate and the 10A fuse is blown. Tech A says a short to ground at the horn switch could be the cause. Tech B says an open circuit on the black wire from pin 1 of the low pitched horn to the high pitched horn could be the cause. Who is correct?



   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

4. Refer to the fog light circuit shown where the left fog light does not work and 8.3V is present at C270H pin 5. Tech A says the fog light switch may be at fault. Tech B says the fog lamp relay may be at fault. Who is correct?



a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

5. Refer to the fog light circuit shown. Tech A says the path to ground for the left fog light connects to ground point S116. Tech B says one of the components inside the fog lamp relay is a resistor. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

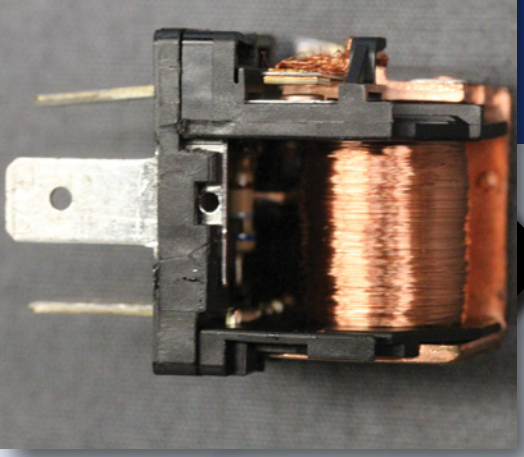
6. Tech A says the cause of a short circuit may be isolated by using a short detection tool. Tech B says the cause of a short to voltage fault may be located in or near a connector that is shared between both affected circuits. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

7. Tech A says excessive resistance in a circuit can be isolated with an available voltage test at various circuit test points. Tech B says the cause of an open circuit can be isolated by measuring voltage drop throughout the circuit. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

8. Tech A says when diagnosing a high resistance fault, you can measure available voltage at the load to determine if the fault is on the source or ground side of the circuit. Tech B says voltage drop tests can isolate the location of a high resistance fault in a circuit. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

9. Tech A says parasitic draw diagnosis uses the DMM amperage function. Tech B says removing fuses one at a time and monitoring parasitic amperage usually isolates the circuit that is causing the concern. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

10. Tech A says isolating the cause of high resistance in a circuit is most accurate when using the voltage drop test. Tech B says a switch that has 0.8 ohms of resistance when OFF will function normally when current is present. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B



CHAPTER 7
Relays

NATEF Tasks

There are no NATEF tasks in this chapter.

Knowledge Objectives

After reading this chapter, you will be able to:

- **K07001** Describe the function of a relay in an automotive circuit.
- **K07002** Explain the operation of a relay in an automotive circuit.
- **K07003** Describe electronic relays.
- **K07004** Describe relay diagnosis and testing.

Skills Objectives

After reading this chapter, you will be able to:

- **S07001** Perform technician-related diagnostic testing on automotive relays.
- **S07002** Provided with a repair order that details a relay related circuit concern, apply the diagnostic process for isolating the cause of the concern and document your testing and recommended repair on the RO for the following:
  - **a.** Horn circuit
  - **b.** Rear window defogger circuit

You Are the Automotive Technician

The customer states the rear window defogger does not work. You verify the concern; the rear window defogger button light turns on, but the rear window heating grid does not get warm. You print out the related wiring diagram to trace the circuit and predict voltages. Since the rear window defogger light turns on, you know the concern may be with the relay, wiring to the rear window grid, the rear window defogger itself, or the rear window defogger grid ground. The rear window defogger connectors are very easy to reach and checking the source side shows 0 volts when the switch is on. This isolates the concern to either the relay or the wiring to and from the relay. Further testing confirms an open in the relay wiring.

1. How does a relay operate?
2. What types of tests are used to verify correct or incorrect relay operation?
3. What precautions should be observed when testing relay circuits?

▶ Introduction

A relay is an electrical component that uses a small current to control a larger current. You know that many automotive circuits require more than 5 amperes (amps) to operate. For example, note how many fuses located in the average vehicle are rated from 10–30 amps, with several fusible links higher than that. The high current required for many circuits, like the headlights, fuel pump, and rear window defogger, would require switches and wiring capable of carrying the necessary current. This would increase wire and switch size, increasing the cost and weight of the components. Vehicle engineers often use relays in circuits that require high current (**FIGURE 7-1**). The name relay comes from its function, to relay the power required to operate the load.

▶ Automotive Relay Function

K07001 Describe the function of a relay in an automotive circuit.

A relay is often used in automotive circuits where the load requires high current to operate. The relay uses an inductive coil to create a magnetic field when it is energized. The current required to create the magnetic field is very low, often less than 200 milliamps. The magnetic field created by the energized relay coil acts upon switch contacts which can handle

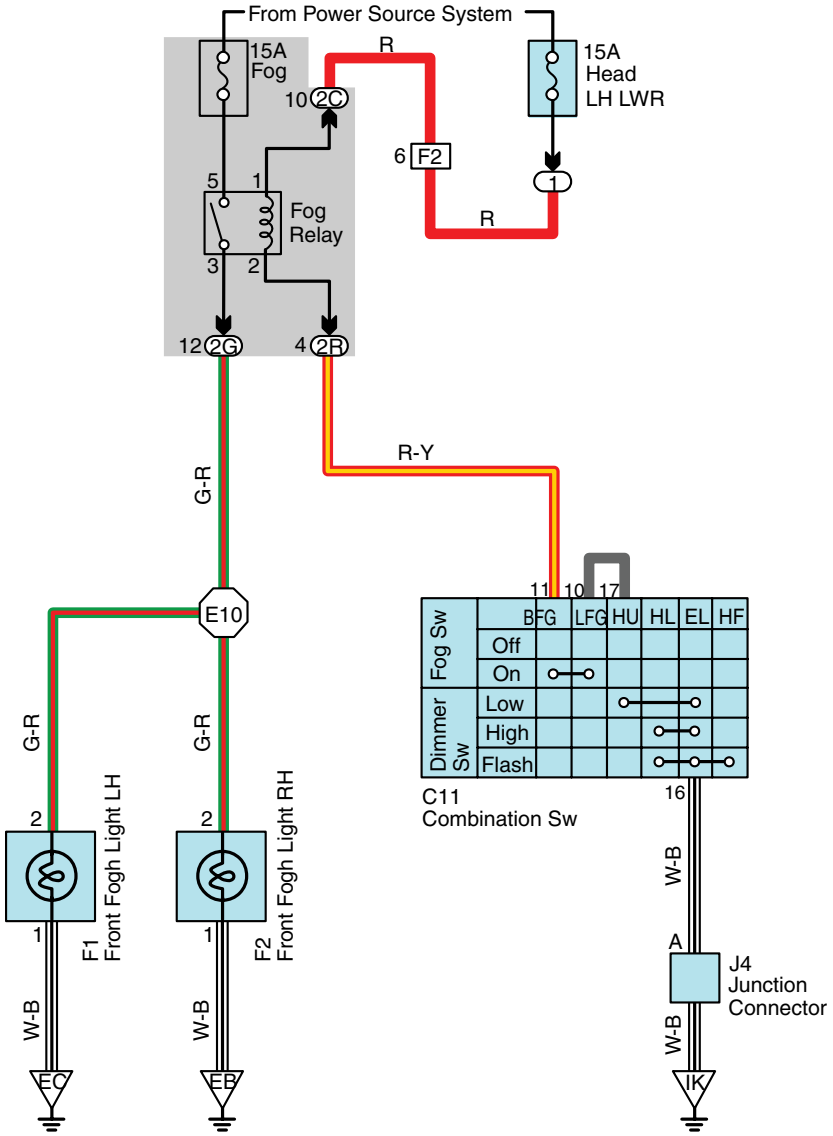


FIGURE 7-1 Fog light circuit.

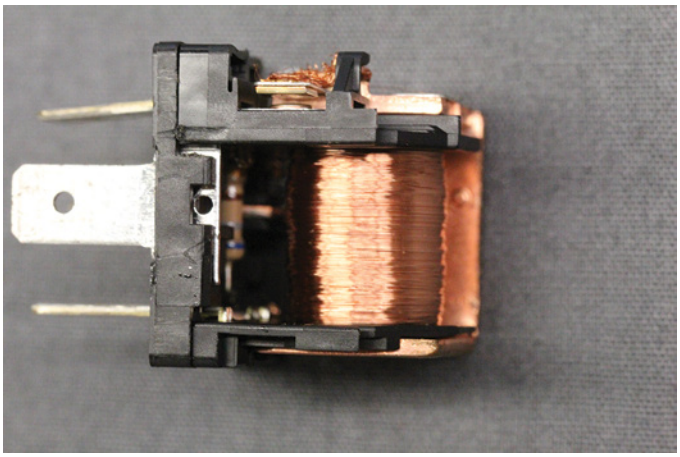


FIGURE 7-2 Electro-mechanical relays use an inductive coil which creates a magnetic field to operate the switch contact.

the high current for the circuit load. For example, the customer turns on the headlight switch. The headlight switch completes a current path for the relay at pins 85 and 86. The relay switch contacts close to send current from terminal 30 to 87 and then to the headlights (**FIGURE 7-2**). Automotive relays are most often the **electro-mechanical** type (using a coil and mechanical switch contacts) and are often located in junction blocks. Relays may also be mounted inside electronic control units on the printed circuit board. These relays may be miniature versions of the electro-mechanical type or fully electronic with no moving parts.

Automotive Relay Construction

Electro-mechanical relays use an inductive coil and mechanical switch contacts that are usually mounted in a plastic housing. There are usually four or five contact pins on the bottom of the relay housing, depending on switch contact design, that connect the relay to the circuit. For review, an inductor relies on the relationship between electricity and magnetism. Current in a conductor creates a magnetic field around the conductor. This magnetic field is very weak when the conductor is laid out in a straight line. Creating a coil of wire concentrates the magnetic field. The magnetic field becomes very concentrated if the wire is wrapped around an iron core. The coil in a mechanical relay is made in this way (**FIGURE 7-3**). A metal switch arm is placed in close proximity to the coil. When the coil is turned on, the magnetic field pulls the switch arm to operate the switch portion of the relay. The relay switch is usually one of three types: normally open, normally closed, or a type that moves the switch arm from one contact point to another (**FIGURE 7-4**).

The relay coil is made of very fine copper wire wrapped around a metal core, usually made of iron. The relay wire may look non-insulated; however, it has a very fine insulation around the copper. Using bare copper wire would create a very large conductor and result in a short circuit rather than creating a magnetic field to operate the relay when turned on. The fine copper wire makes many hundreds of turns around the metal core to form the relay coil. The very small conductor path along with its length creates resistance of about 70–120 ohms in most automotive relays (**FIGURE 7-5**).

The relay coil is energized when the control device, like the fog light switch, is turned on. Current moving through the relay coil creates a magnetic field which acts upon the relay switch contacts to turn on the fog lights in this circuit.

The relay coil magnetic field does the work inside the relay to move the relay contacts. Turning the circuit off deenergizes the relay and the switch contacts return to their at-rest position. The magnetic field in the relay coil creates a **voltage spike** when

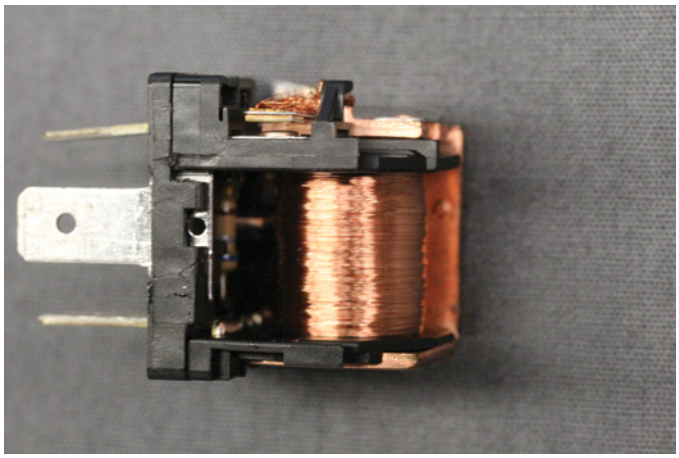


FIGURE 7-3 The relay coil is made from very fine insulated wire wrapped around an iron core.

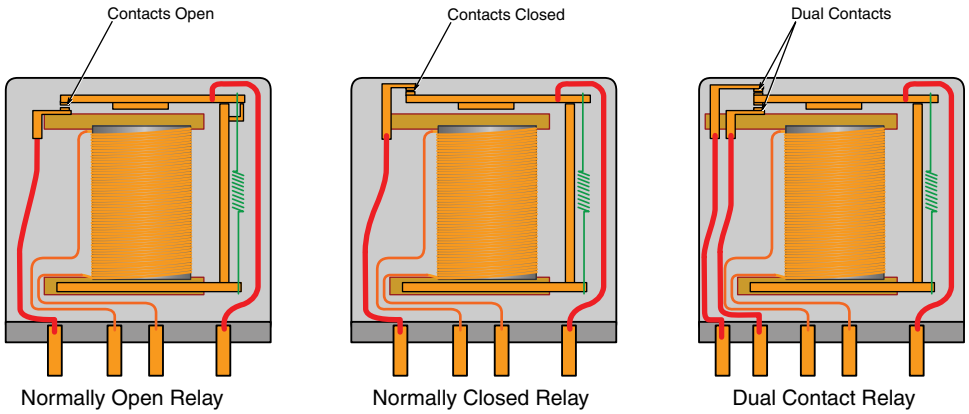


FIGURE 7-4 Relays are configured in normally open, normally closed, and dual contact switch designs.

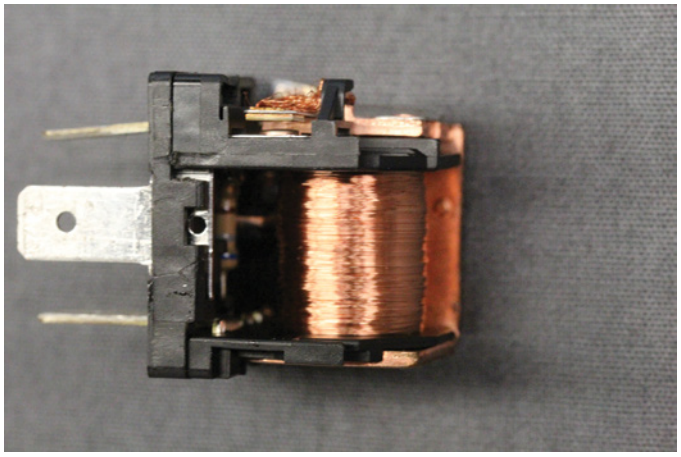


FIGURE 7-5 The very small gauge wire used to create the relay coil usually has a resistance of 75 to 100 ohms when measured with a DMM.

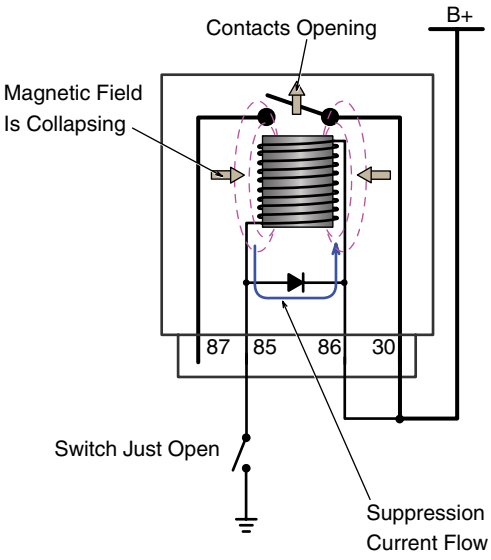


FIGURE 7-6 The relay coil magnetic field collapses when the relay is deenergized which creates a very high voltage spike.

the relay is turned off. This voltage spike occurs as the magnetic field quickly collapses when the current through the coil stops (**FIGURE 7-6**). This voltage spike is opposite in polarity to the voltage when the circuit was energized and can be several hundred volts. The voltage spike could damage the electronic control unit transistors used to provide a ground or source path for the relay coil. The voltage spike is controlled using a diode or a resistor. Relays using a spike-suppression diode place the diode in parallel with the relay coil (**FIGURE 7-7**). The diode is in reverse bias so it blocks current from going through it when the relay is on. When the relay turns off, the collapsing magnetic field is opposite in polarity to the supplied voltage. The diode is forward biased and allows the current to flow through the coil until it dissipates. Note that a relay with a spike-suppression **diode** must be installed in a circuit so that the coil circuit polarity allows for the diode to forward bias only when the relay is turned off. Installing it with the diode forward biased when the relay coil is energized will create a short circuit and most likely blow a fuse and destroy the diode.

The other spike-suppression relay type uses a resistor that is about 10 times greater in resistance than the resistor coil (**FIGURE 7-8**). The resistor is in parallel with the relay coil. Its high resistance allows most of the current to go through the relay coil and create the magnetic field. Turning the relay off causes the magnetic field to collapse and the resistor blocks

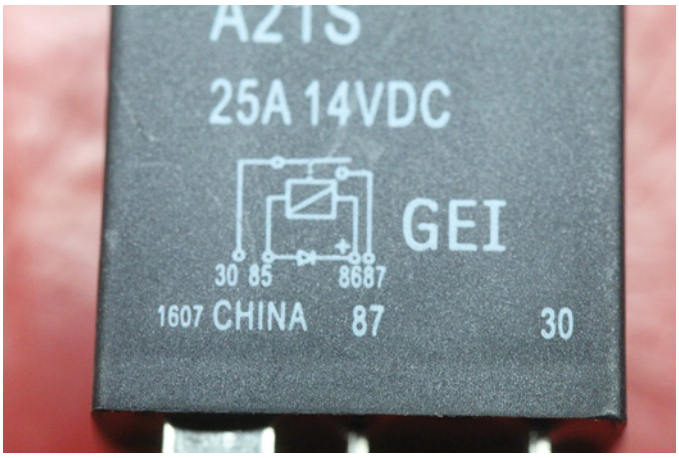


FIGURE 7-7 Some relays use a diode, called a clamping diode, to suppress the high voltage spike created in the relay coil when the relay is turned off.

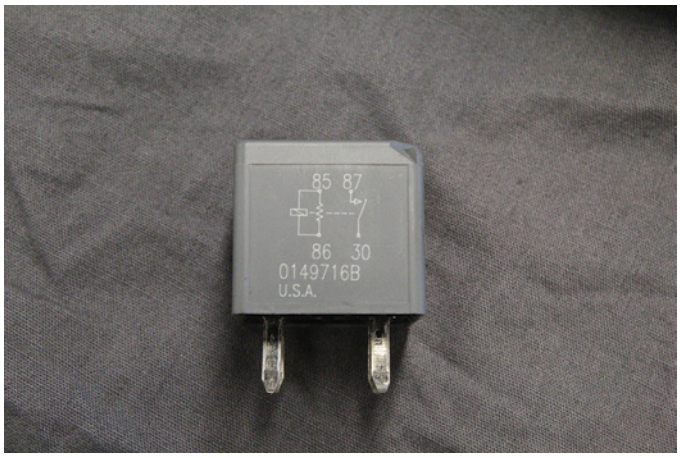


FIGURE 7-8 Some relays use a resistor to suppress the high voltage spike created in the relay coil when the relay is turned off.

the voltage spike forcing it to dissipate in the relay coil. This type of spike suppression is not as effective as the diode type; however, it is less expensive and it allows the relay to be installed without regard to relay coil polarity since the resistor provides protection regardless of the location of battery positive or negative for the relay coil terminals.

▶ Automotive Relay Operation

K07002 Explain the operation of a relay in an automotive circuit.

Following is an example of relay operation in an automotive fog light circuit (**FIGURE 7-9**). The fog light circuit shown uses the fog light switch to provide the ground path for the relay coil. Turning the fog light switch on energizes the relay coil. The energized relay coil creates a magnetic field that acts upon the relay switch contacts. The relay switch contacts close and the fog lights turn on. The purpose of the relay is to use a small current to control a larger current. The fog light relay coil for this circuit has 70 ohms of resistance. The 12.6 voltage source to the relay coil is referenced when using Ohm's law to calculate the amperage in the relay coil—12.6V divided by 70 ohms equals 0.18 amperes (180mA).

Each fog light is 55 watts, so 110 watts of power are used in the fog light portion of the circuit. You can calculate circuit amperage using Watt's law, Watts = Voltage × Amperage, 110 watts divided by 12.6 volts equals 4.87 amperes. This relay circuit uses 180 milliamperes of current to control 4.87 amperes of current.

A relay may also be controlled by an **ECU**. In this example (**FIGURE 7-10**), the body ECU receives an input from the headlight switch. The ECU turns on an output transistor to supply the ground path to the relay coil and the relay turns on.

Inductor type relays have several switch configurations. Relays are shown in circuit diagrams with their switch contacts in the at-rest position (**FIGURE 7-11**). Relays with switch contacts that close when the relay is energized are referred to as **normally open**. Relays with switch contacts that open when the relay is energized are referred to as a normally closed. Another relay type uses two switch contacts, one is normally open and the other is **normally closed**. This type of relay, sometimes called a crossover relay, allows current to part of the circuit when off as shown and to another part of the circuit when on as shown.

Relay pins may be identified by the manufacturer's nomenclature on the wiring diagram. Many relays use DIN relay pin number identification to denote relay pins as shown (**FIGURE 7-12**). Pins 85 and 86 are for the relay coil. Pins 30 and 87 are for the relay switch. Pin 30 is usually closest to the source side of the circuit and pin 87 is usually closest to the ground side of the circuit. Five-pin crossover relays that have two switch positions have the second position labeled 87a. Pin 87a is the normally closed contact and pin 87 is the normally open contact.

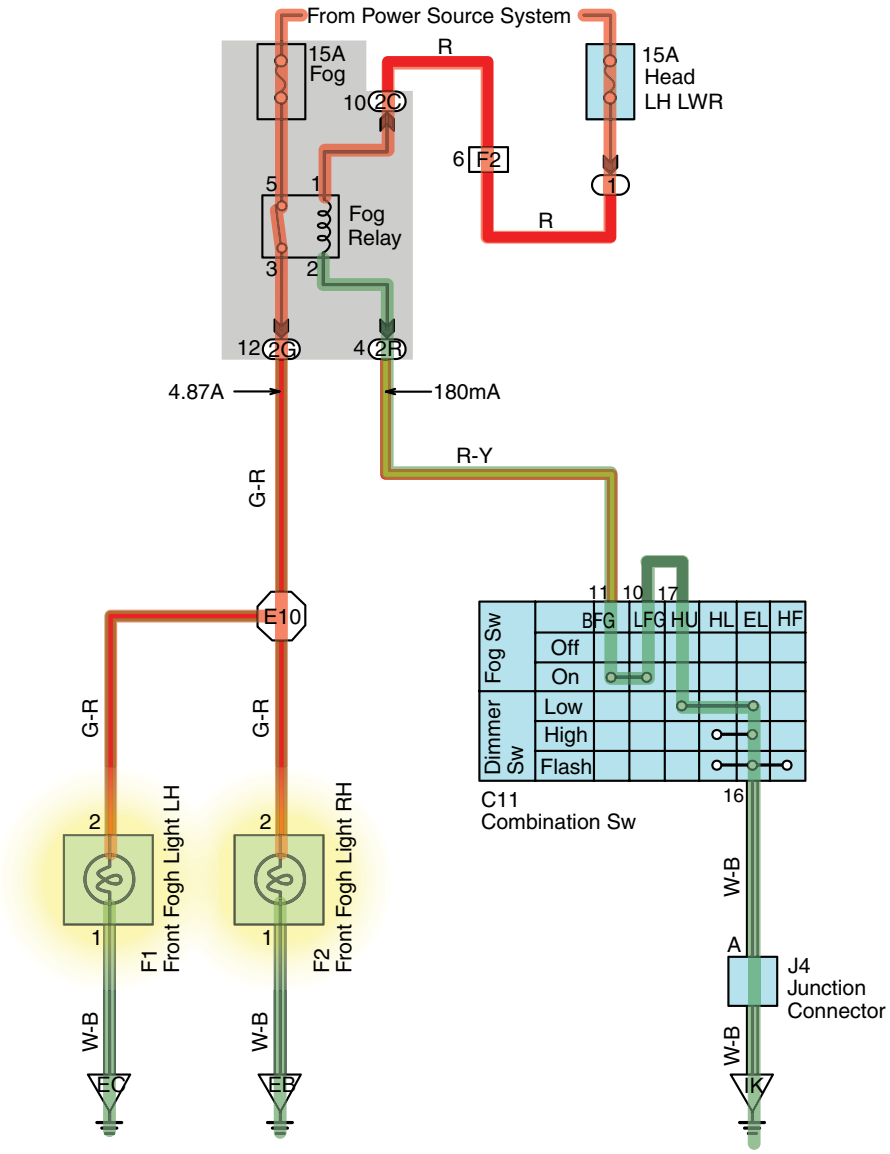


FIGURE 7-9 Relays allow the use of a small amount of current to operate the relay coil and turn on the much higher current portion of the circuit.

Relays are often designed so they fasten into the junction block connector socket correctly. This may be done by having relay pins of different sizes or arranging some of the pins in a north–south direction and the others in an east–west direction. Some manufacturers use 4-pin relays that have pins 85 and 86, and 30 and 87 diagonal from each other. The pins are the same size and oriented in the same direction eliminating the need to check the pin orientation when installing the relay. Note that these relays cannot use a diode for spike suppression. The diode must be reverse biased when the relay is energized; therefore, the polarity of the relay pins that connect to the coil cannot be reversed. This type of relay must use a resistor for spike suppression.

Relay pin size often indicates what those pins are connected to inside the relay. The coil contacts are the low current portion of the relay. These contacts are often a smaller size and may even be made of a cheaper conductor material, like aluminum instead of copper, than the switch related relay contacts (**FIGURE 7-13**). The switch contacts may be larger than the coil contacts and may be made of copper instead of aluminum as they carry the high current to the circuit load(s) (**FIGURE 7-14**).

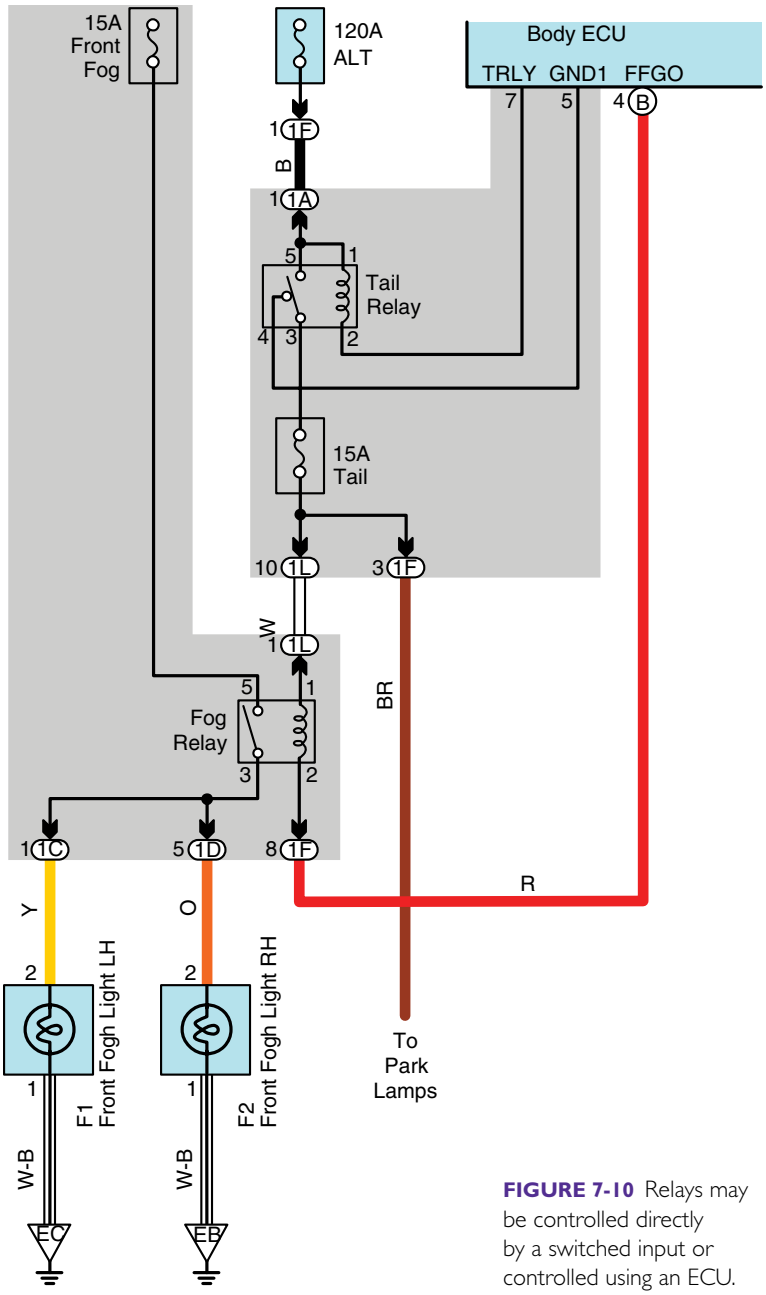


FIGURE 7-10 Relays may be controlled directly by a switched input or controlled using an ECU.

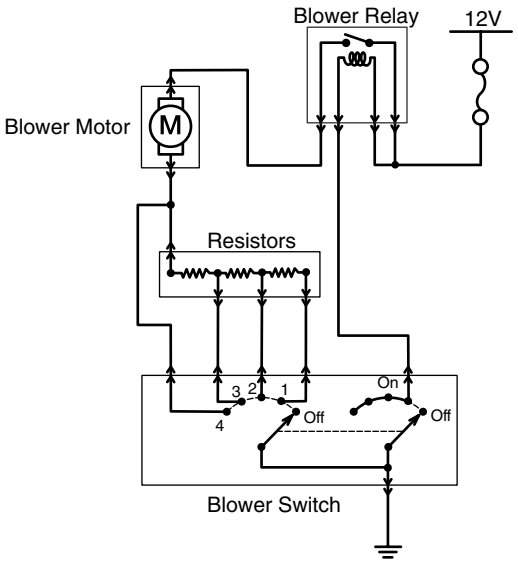


FIGURE 7-11 The relay in this circuit is a normally open type. Relays are shown in their deenergized position in most wiring diagrams.

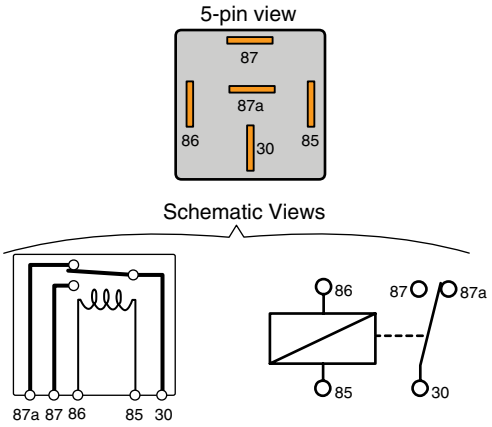


FIGURE 7-12 Relay pins are usually numbered. They may be numbered using ISO DIN standards or by a numbering method selected by the manufacturer.

▶ Electronic Relays

K07003 Describe electronic relays.

The relays discussed so far are electro-mechanical in nature. It is becoming more common for relays to be installed inside junction blocks and ECUs (**FIGURE 7-15**). These relays may be smaller versions of electro-mechanical relays or fully electronic (without any moving parts). These types of relays are usually diagnosed using the scan tool to determine operation. These relays are not serviceable and the junction block or ECU must be replaced if it is determined that they are not functioning correctly.

▶ Relay Diagnosis and Testing

K07004 Describe relay diagnosis and testing.

S07001 Perform technician-related diagnostic testing on automotive relays.

Relay circuit diagnosis builds upon circuit diagnostic skills where a switch direction controls the circuit load. The technician verifies the relay coil has source voltage, a path to ground, and that the relay coil functions correctly. The relay switch contacts are checked for operation when the relay is energized. The technician also confirms that the voltage drop across the switch contacts are within limits.

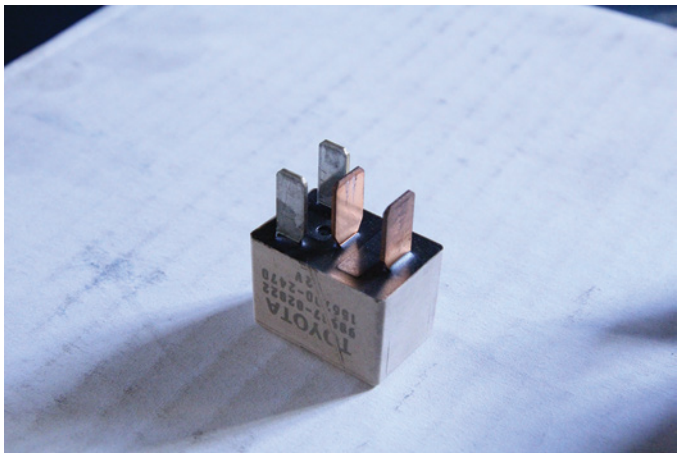


FIGURE 7-13 Some relays use different conductor types for the relay coil pins and the switch contact pins. The low current contacts for the relay coil may be aluminum while the high current switch contacts are copper.

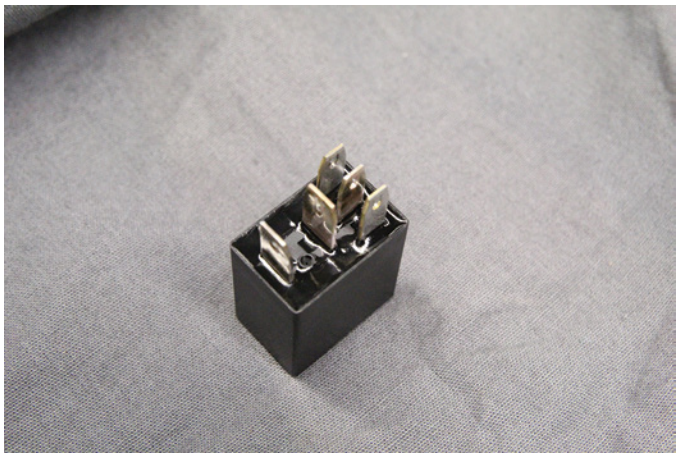


FIGURE 7-14 Some relays use different sized pins for the relay coil and relay switch contacts. The relay coil uses a small amount of current and uses the smaller contact pins.

The relay coil can fail either shorted or open. The relay coil wire has a very thin insulating layer. Vibration, heat expansion, and cooling contraction can cause the insulation to fail over time. This can cause a short circuit and result in a blown fuse for the relay coil portion of the circuit. The relay coil wiring can also break creating an open circuit. Most manufacturers provide a resistance specification in ohms for the relay coil. Remove the relay from the junction block or connector and use the ohmmeter function of your DMM to measure the resistance across the relay coil (pins 85 and 86) (**FIGURE 7-16**). A coil that has resistance very close to specification passes this part of the test. Resistance that is higher than specification indicates the relay coil is failing open and the relay should be replaced. A relay coil circuit that has resistance below specifications indicates the relay coil is failing shorted and the relay should be replaced.

The relay switch contacts must be tested for function and continuity with the DMM ohmmeter function. The switch contacts should have very close to 0 ohms when they are in the closed (on) position. Resistance on the switch contacts can create a voltage drop across them affecting overall circuit operation. A normally open relay should have no continuity across the switch contacts (pins 30 and 87) when the relay is off (**FIGURE 7-17**). There should be continuity across the switch contacts (very close to 0 ohms) when the relay is energized. Energize the relay by using fused jumper leads to connect the relay coil to source voltage. Connect pin

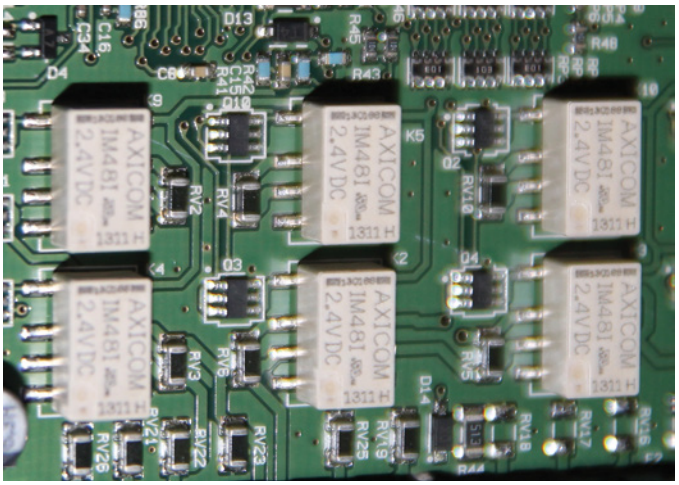


FIGURE 7-15 Fully electronic relays may be found in smart junction blocks and ECUs and are usually mounted on a printed circuit board.

FIGURE 7-16 Measure the relay coil for resistance and compare your reading to the service specification.

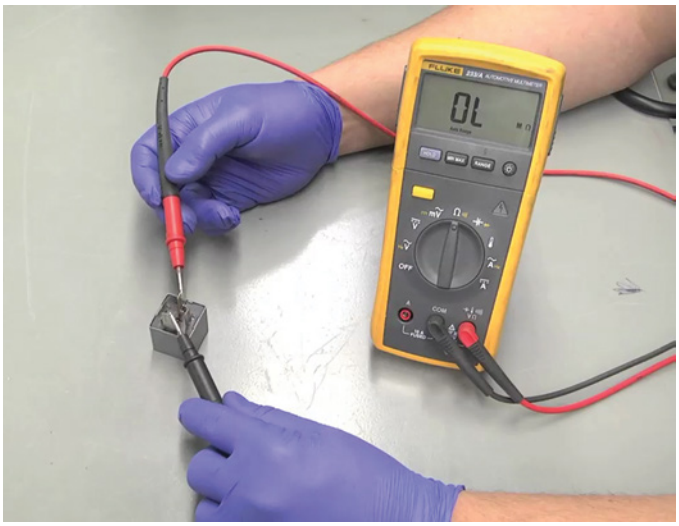


FIGURE 7-17 A normally open relay should show an OL (out of limits) ohms reading for the switch contacts when it is off.

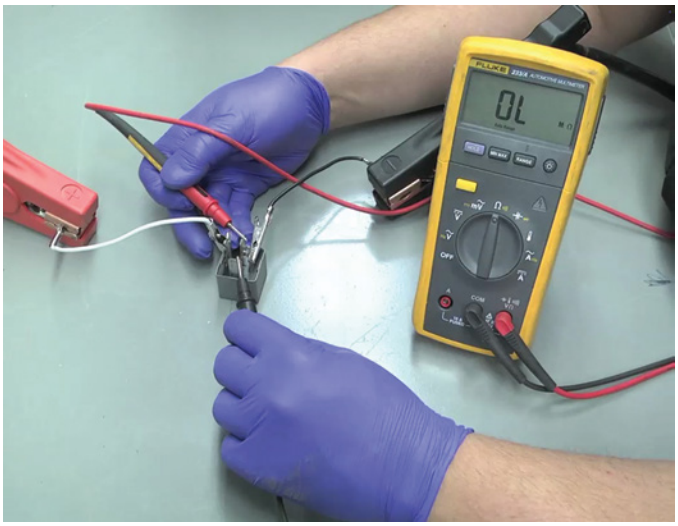


FIGURE 7-18 The relay coil may be powered on using fused jumper leads to operate the switch contacts.

85 to battery positive and pin 86 to a known good body ground (do not use the battery negative post, since a spark near the battery can cause the battery to explode) or you can use test leads as shown to connect the relay to the circuit (**FIGURE 7-18**). Listen for the relay to "click" and note your resistance reading on the DMM. For a normally closed relay, there should be continuity when it is off and no continuity when it is on. Relays with pins 30, 87, and 87a should have continuity from pin 30 to pin 87a when off and from pin 30 to 87 when energized. A relay with excess resistance on the switch contacts should be replaced.

Relay resistance tests are made with the relay removed from the circuit. This type of testing does not always identify faulty switch contacts, as the DMM continuity test uses a very small amount of current to determine resistance. It is good practice to measure the voltage drop across the switch contacts. Do this by locating the connector pin before the relay contact and the closest accessible pin after the relay contact (**FIGURE 7-19**). The voltage drop across the relay contacts should be less than 100 millivolts (0.1V).

FIGURE 7-19 Measure the voltage drop across the relay contacts with current present at the contacts using a relay test kit or locating the closest test point before and after the relay switch contacts.

The spike-suppression diode or resistor can fail and affect relay or circuit operation. A diode or resistor that fails shorted will lower resistance in the relay coil circuit to the point that the circuit fuse will blow. The blown fuse indicates that too much current was present. Measure the resistance of the relay coil (**FIGURE 7-20**). Resistance that is below specifications, including near 0 ohms, may indicate the coil, diode, or resistor is shorted and the relay must be replaced.

The spike-suppression diode or resistor can also fail open. In this case the relay will still function but it will no longer offer voltage spike protection. Non-ECU-controlled relays may exhibit a "pop" heard through the audio system when the relay related circuit is turned off. ECUs that control a relay with damaged spike protection can be damaged from this condition. The voltage spike can damage the control circuit in the ECU so that it no longer functions to energize the relay. The relay may test OK, but the ECU has failed because of it. For this reason, most manufacturers specify that both the ECU and the relay must be replaced.

There are special test relay tools that feature some of the most common relay types. These "test relays" offer test tabs so you can measure voltage with the relay installed in the relay block (**FIGURE 7-21**).

▶ TECHNICIAN TIP

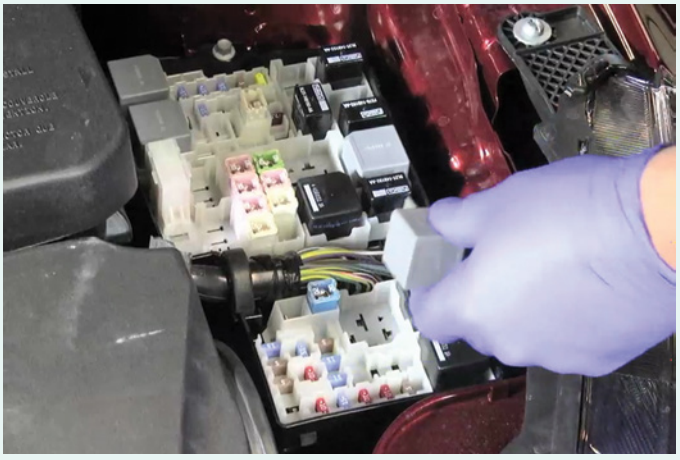
Some vehicles may use more than one relay of the same type. A quick circuit operation check can be made by swapping the known good relay in place of the possibly faulty relay. If the circuit now works normally, the relay, or relay connection, was faulty.

FIGURE 7-20 A relay coil with little or no resistance may indicate a shorted relay coil, or the diode or resistor used for spike suppression has failed or shorted.

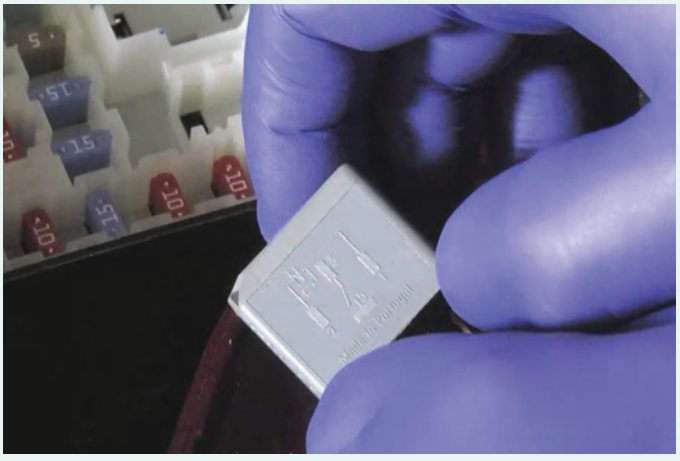
FIGURE 7-21 Several tool companies offer relay test kits that allow the relay to be plugged into a test stand that mounts in between the relay and the relay pins in the junction block.

To test a relay coil, follow the steps in **SKILL DRILL 7-1.**
To test relay switch contacts, follow the steps in **SKILL DRILL 7-2.**

SKILL DRILL 7-1 Testing a Relay Coil



1. Remove the relay from its mounting location.

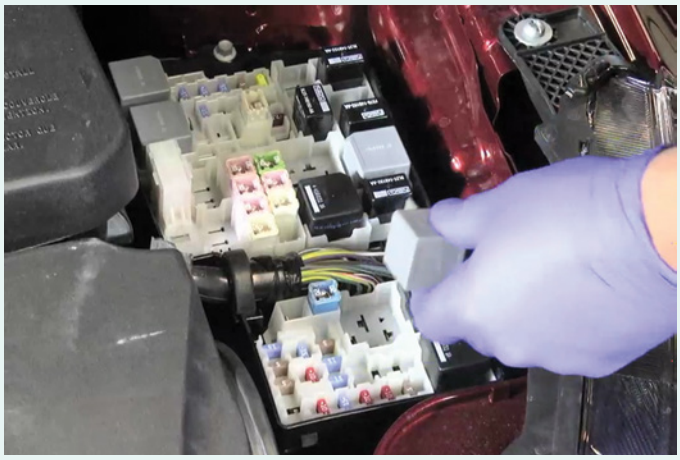


2. Identify the relay coil contacts, pins 85 and 86. There may be a diagram on the side of the relay for this. If there is no diagram, the coil contacts may be smaller in size than the switch contacts. Some relays use aluminum instead of copper for the coil contacts so the coil contacts will be silver in color.

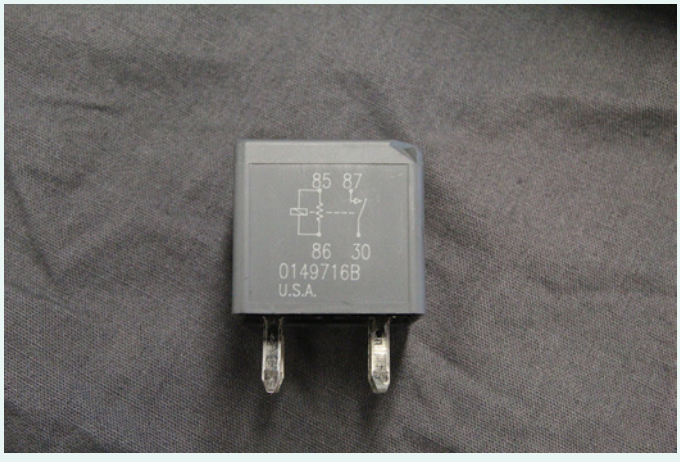
Continued

3. Use the DMM ohmmeter function. Connect each DMM lead to a coil contact and then note the ohm reading on the DMM. Compare the reading to service specifications. Most automotive relays use coils with between 70 and 120 ohms of resistance. A reading that is very low in resistance indicates a shorted coil winding. A reading that is very high or the DMM shows OL (out of limits) indicates an open coil winding. Replace the relay if the resistance reading is not near specification.

SKILL DRILL 7-2 Testing Relay Switch Contacts

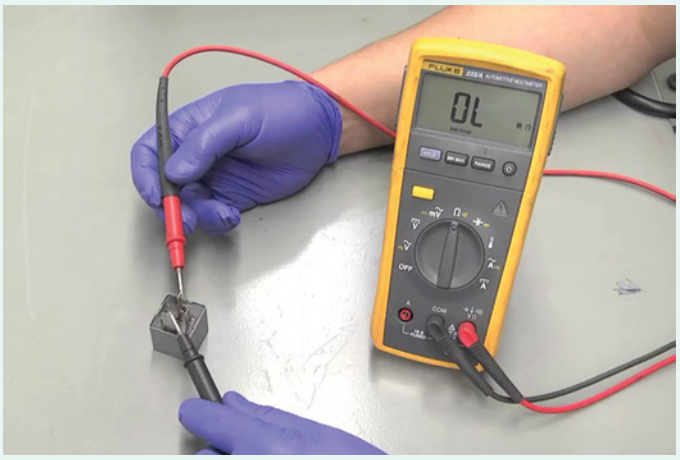


1. Remove the relay from its mounting location.



2. Identify the relay switch contacts, pins 30 and 87. There may be a diagram on the side of the relay for this. If there is no diagram, the switch contacts may be larger in size than the coil contacts. Some relays use aluminum instead of copper for the coil contacts so the switch contacts will be copper in color.

Continued



3. Use the DMM ohmmeter function. Connect each DMM lead to a switch contact and then note the ohm reading on the DMM. Compare the reading to service specifications. Normally open relays should have an OL reading when the relay is off.

4. Use fused jumper leads to power the relay coil. Carefully connect one jumper lead to battery positive. Connect the other jumper lead to a ground point away from the battery. The relay should make an audible click and the DMM reading should change from OL to very close to 0 ohms. This indicates the switch is now in the closed position.

5. Normally closed relays are tested the same way; however, the DMM reading will be very close to 0 ohms when the relay is off and OL when the relay is on indicating the switch is now open.

S07002 Provided with a repair order that details a relay related circuit concern, apply the diagnostic process for isolating the cause of the concern and document your testing and recommended repair on the RO for the following:

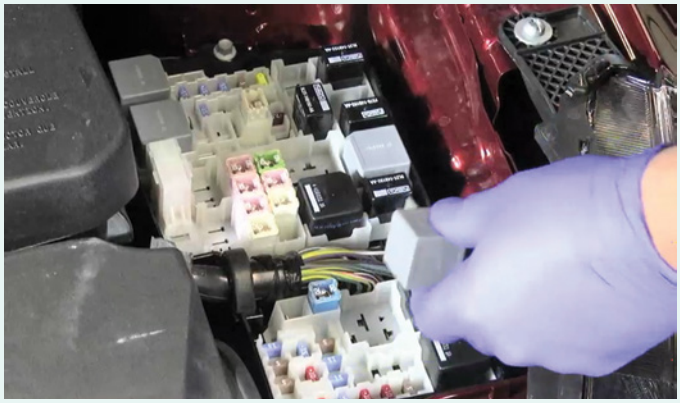
- **a.** Horn circuit
- **b.** Rear window defogger circuit

To measure relay switch contact voltage drop, follow the steps in **SKILL DRILL 7-3**.

Automotive Horn Circuit Operation

The horn circuit shown is an example of the most common use of a relay—controlling a high current load with a low current control circuit (**FIGURE 7-22**). This allows the use of small gauge wiring to the horn switch and relay coil. The relay can be placed underhood near the horns with larger gauge wire to operate the horns when the relay is energized (**FIGURE 7-23**).

SKILL DRILL 7-3 Measuring Relay Switch Contact Voltage Drop



1. Remove the relay from its mounting location.

2. Identify the relay coil contacts, pins 85 and 86. There may be a diagram on the side of the relay for this. If there is no diagram, the coil contacts may be smaller in size than the switch contacts. Some relays use aluminum instead of copper for the coil contacts so the coil contacts will be silver in color.

3. Use test leads to connect the relay coil contacts to the applicable relay pins where the relay mounts (usually in the junction–relay block). Connect the switch contact relay pins 86 and 87 to the applicable pins where the relay mounts.

4. Connect the DMM leads to the switch contact pin test points, 30 and 87. With the DMM set to the 20-volt scale, turn the circuit on and measure the drop across the relay switch contacts. A reading of less than 300mV indicates the switch contacts are OK. A higher reading indicates there may be corrosion or pitting of the switch contacts and the relay should be replaced.

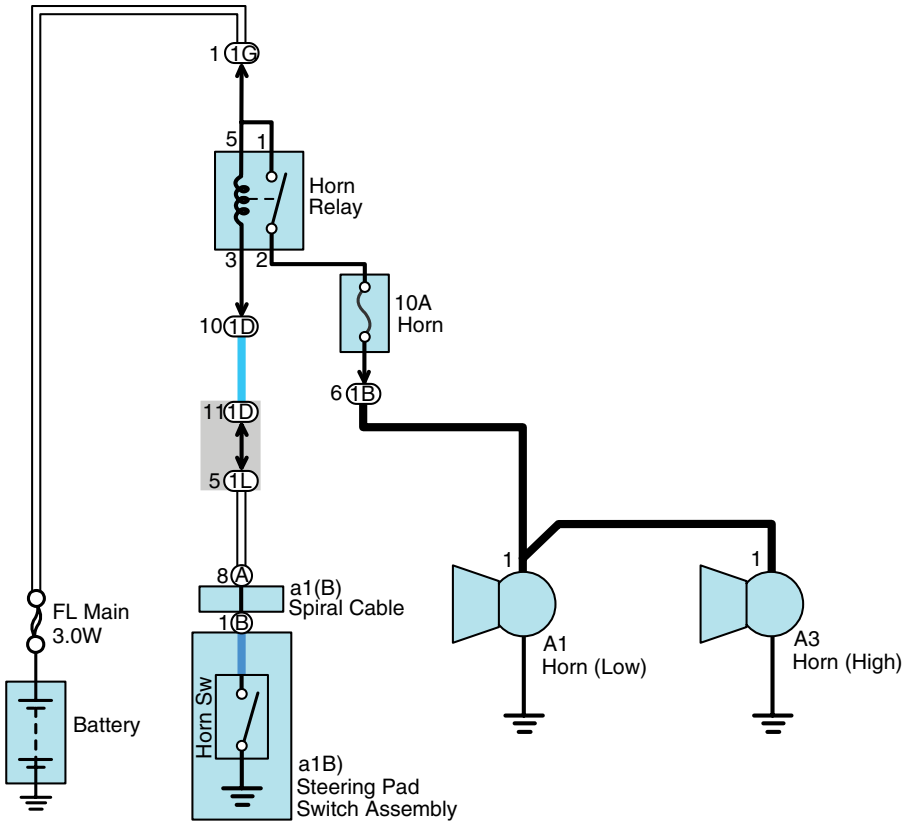


FIGURE 7-22 Sample horn circuit.

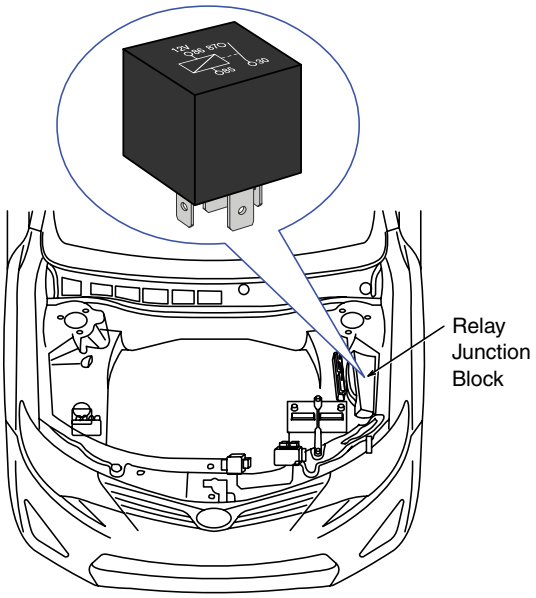


FIGURE 7-23 Relays are often located in junction blocks. The junction blocks may be located under the hood and inside the vehicle at various locations to help locate relays near the components they control.

Rear Window Defogger Circuit Operation

The rear window defogger circuit is an example of a relay circuit where an ECU controls the relay operation (**FIGURE 7-24**). The customer turns on the rear window defogger. This signals the body ECU to turn on the rear window defogger relay by supplying a path to

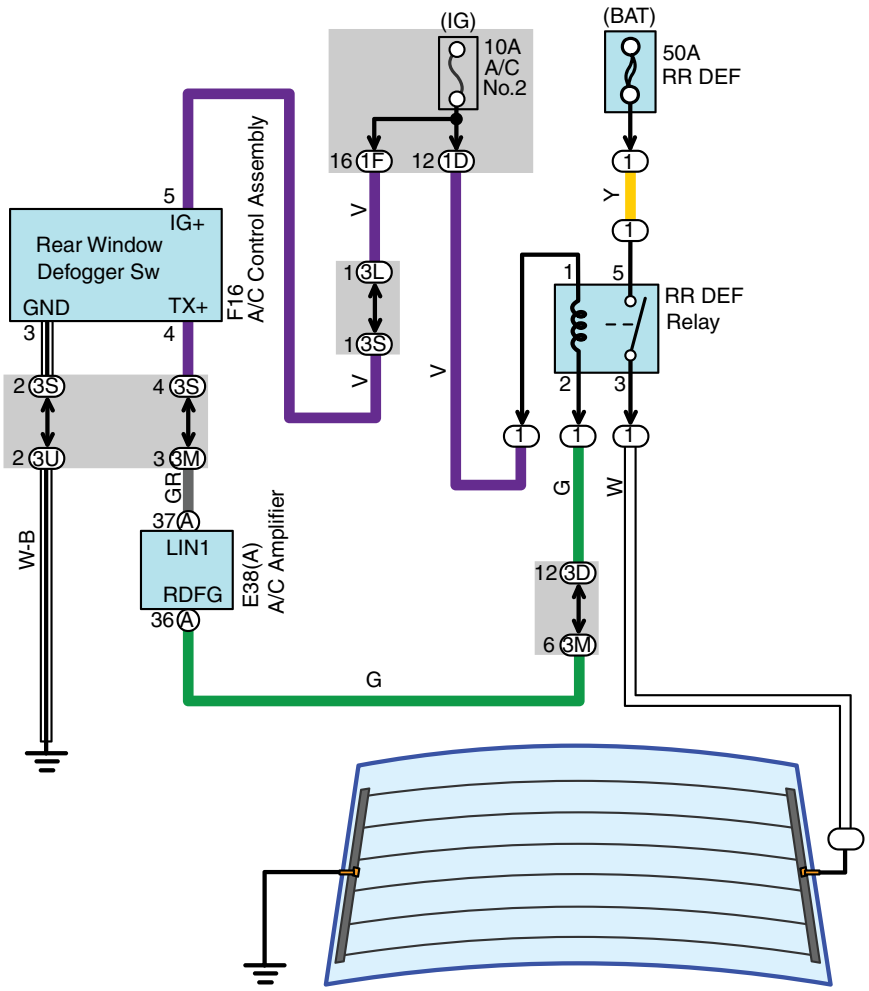


FIGURE 7-24 The rear window defogger circuit often uses a switch as an input to an ECU, the A/C amplifier in this example. The ECU then provides a ground path for the relay coil to turn the relay ON.

ground for the relay coil. Most vehicles use a timer circuit to automatically turn off the rear window defogger circuit. The timer on some vehicles is a fixed setting, often 10 to 15 minutes, while other vehicles may vary the timer function based on ambient temperature to better ensure the rear window is clear.

Wrap-Up

Ready for Review

- Relays use a coil of wire that creates a magnetic field when energized to operate a switch to control current to the desired load device.
- Relays are often used to control a larger current with a smaller current. This reduces the current load on the switch and can save cost and reduce vehicle weight by limiting the amount of larger sized wire required for the high current portion of a relay circuit.
- Relay switch contacts may be normally open, normally closed, or use two switch contacts sometimes referred to as a crossover relay.
- Relay coils create an inductive kickback or voltage spike when turned off. Many relays use a resistor or diode to suppress this voltage spike to prevent damage to other electronic components in the vehicle.
- Relay pins are often identified with pin numbers that are based on the DIN standards, with pins 85 and 86 for the relay coil, and pins 30, 87, and 87a related to the switch contact(s).
- Relays coils may be tested for resistance using your DMM and the test result compared to service specifications. Low resistance indicates a breakdown in wire insulation of the coil that could lead to a short circuit. Very high or an open circuit indicates the coil wiring most likely has a broken current path in the winding or at the junction with the related relay terminals.
- The relay can be tested with fused jumper leads to operate the coil and using a DMM to monitor switch contact

operation. A normally open relay would have a resistance of OL across the contacts when off and very close to 0 ohms when the relay is on.

- Smart junction boxes and ECUs are now incorporating very small electro-mechanical and fully electronic relays inside. These relays are not serviceable and the related junction box or ECU must be replaced if these relays fail.

Key Terms

diode The most basic of semiconductor components which acts like one valve to control current in a circuit. A diode may be used in a relay to control the voltage spike that occurs when the relay coil is turned off.

DIN The country of Germany's standards organization. DIN standards are often used for terminal pin designations on relays.

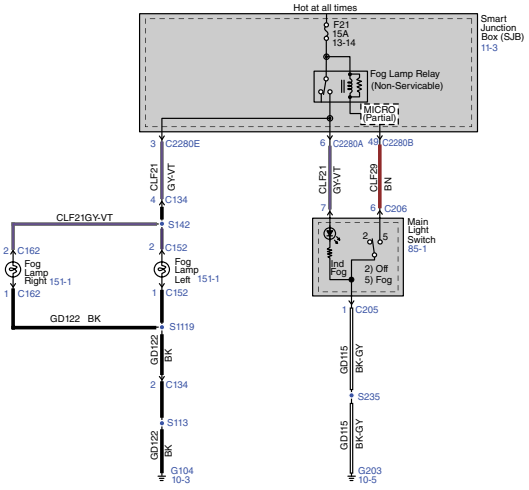
ECU Common abbreviation for an electronic control unit. ECUs are used to control various vehicle systems including body control systems, internal combustion engine functions, vehicle stability control, and many others. The average vehicle has 15 to 30 ECUs and some luxury vehicles may use more than 80 ECUs for various system controls.

electro-mechanical A device which makes use of electrical and mechanical properties. A relay uses electricity to create a magnetic field that acts upon a mechanical switch to open or close the switch contacts.

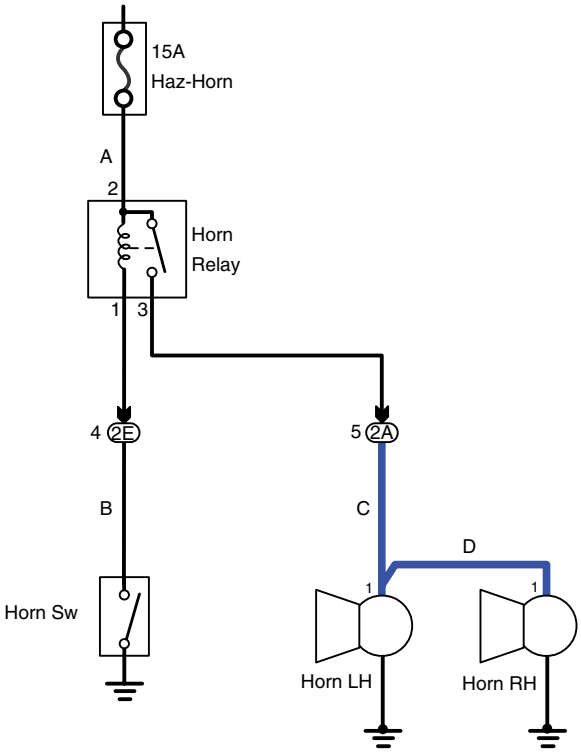
voltage spike A rapid increase in circuit voltage. Relay coils and other inductive devices create a very high voltage spike when they are turned off and the related magnetic field collapses. The collapsing magnetic creates a very high voltage spike, opposite in polarity to source voltage, which can damage electronic components if not controlled with a suppression device like a diode or resistor in parallel with the relay coil

Review Questions

1. The fog lights do not illuminate. Which of the following can cause this condition?
   a. A short to ground at S236
   b. A Short to ground between C134 pin 4 and C2280E pin 3
   c. A short to ground between C2280B Pin 49 and C206 pin 6
   d. An open at C152 pin 1



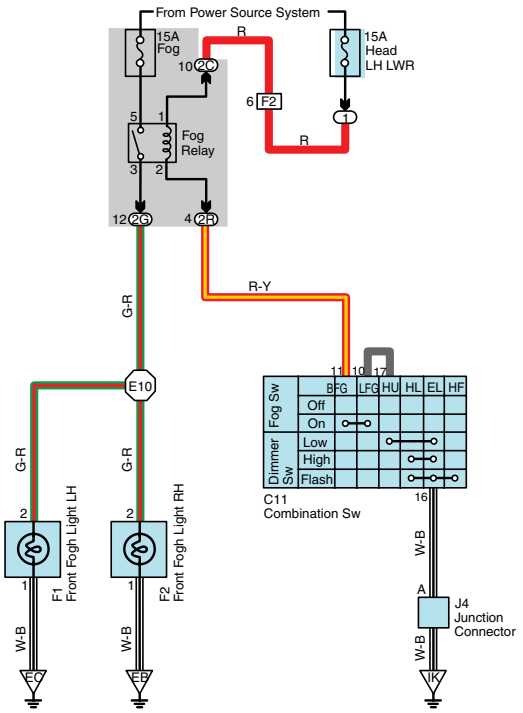
2. All of the following can cause a relay to fail *except*:
   a. coil has more than 10K ohms of resistance.
   b. coil has less than 3 ohms of resistance.
   c. switch contacts have 80 ohms of resistance.
   d. switch contacts have continuity.
3. A five-pin relay features all of the following *except*:
   a. uses two relay coils to create a stronger magnetic field.
   b. uses DIN pin numbers 87 and 87a for switch contacts.
   c. functions to direct current to one of two different paths.
   d. one of the switch contacts is always connected to pin 30.
4. The horns do not operate. This could be caused by which of the following?
   a. An open at point D
   b. A short to ground at point B
   c. Source voltage at point A
   d. A short to ground at point C



5. Choose the correct statement with respect to the automotive relay function.
   a. A relay is often used in automotive circuits when the load requires less current to operate.
   b. The relay uses an inductive coil to create a magnetic field when it is energized.
   c. Relays are always placed outside the printed circuit board.
   d. The relay uses magnets to create an electric field.
6. Which of the following is an advantage of using a resistor rather than a diode for spike suppression?
   a. It can be installed without regard to relay coil polarity.
   b. It can handle higher voltage spikes.
   c. It works efficiently in higher temperatures.
   d. It reduces the number of components used in the circuit.

7. All of the following statements with respect to automotive relay construction are true *except*:
   a. Electro-mechanical relays use an inductive coil and mechanical switch contacts that are usually mounted in a plastic housing.
   b. The relay coil is made of very fine copper wire wrapped around a metal core, usually made of iron.
   c. A diode that is forward biased when the relay coil is energized will create a short circuit.
   d. The magnetic field in the relay coil creates a voltage spike when the relay is turned on.
8. Relays with switch contacts that close when the relay is energized are referred to as:
   a. normally open.
   b. two-switch contacts.
   c. crossover relays.
   d. normally closed.
9. Choose the correct statement with respect to DIN relay pin identification.
   a. Pin 30 is usually closest to the ground side of the circuit.
   b. Pin 87 is usually closest to the source side of the circuit.
   c. Pins 30 and 87 are for the relay switch.
   d. Pin 87a is the normally open contact and pin 87 is the normally closed contact.
10. Electronic relays:
   a. cannot be installed inside junction blocks and ECUs.
   b. have moving parts and are smaller.
   c. are usually diagnosed using the scan tool to determine operation.
   d. are serviceable.

ASE Technician A/Technician B Style Questions



Refer to the diagram above for questions 1–3.

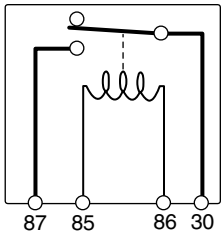
1. Tech A says the relay in the circuit shown is source controlled. Tech B says the relay uses normally open contacts. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. The customer states the fog lights do not operate. There is source voltage at C11-11, the red/yellow wire at the combination switch when the fog lights switch is in the on position and dimmer switch is in the low position. Tech A says the fog light switch may be faulty. Tech B says the relay coil may have failed open. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says you can use a fused jumper lead at connector pin C11-11 connected to a known good ground and the fog lights should turn on. Tech B says the fog lights work in low beam and in high beam headlight operation. Who is correct?
   a. A only
   b. B only
   c. Both A and B
   d. Neither A nor B
4. Tech A says you can remove the relay and use a jumper lead across the switch contact pins of the relay connector to verify the load operates normally. Tech B says a 5 pin relay usually has one normally open and one normally closed switch contact. Who is correct?
   a. A only
   b. B only
   c. Both A and B
   d. Neither A nor B
5. Tech A says some relay pins are identified by DIN numbering and pins 85 and 86 are for the relay coil. Tech B says a relay that is shown on the wiring diagram with the switch contacts closed indicates that the relay switch contacts open when the relay is energized. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says a relay may test okay during a resistance test but fail shorted or open when energized. Tech B says a voltage drop test across the relay coil contacts can help identify high resistance on the source or ground side of the relay coil circuit. Who is correct?
   a. A only
   b. B only
   c. Both A and B
   d. Neither A nor B
7. Tech A says when testing the relay coil, the resistance should be very close to the service information specifications, usually around 10,000 ohms. Tech B says the relay

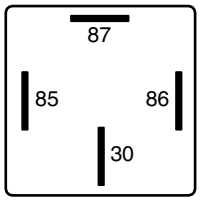
coil resistance may be below specifications if the voltage spike diode has failed open. Who is correct?

a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

8. Tech A says energizing a normally open relay will close the relay contacts. Tech B says a normally closed relay should have continuity across the relay contacts when it is off. Who is correct?

a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B





9. Refer to the relay diagram above. Tech A says a source-controlled relay will have source voltage at either pin 85 or 86 at all times. Tech B says this relay is normally open. Who is correct?

a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

10. A cooling fan circuit that is controlled by a relay is not operating. Tech A says you can install a known good relay to quickly determine if the relay is at fault. Tech B says the relay may be okay and that there may be a fault in the coolant temperature circuit. Who is correct?

a. A only
b. B only
c. Both A and B
d. Neither A nor B

CHAPTER 8

Lighting System Diagnosis (Non-ECU-Controlled)

NATEF Tasks

- **N08001** Identify system voltage and safety precautions associated with high-intensity discharge headlights. (MLR/AST/MAST)
- **N08002** Inspect interior and exterior lamps and sockets including headlights and auxiliary lights (fog lights/driving lights); replace as needed. (MLR/AST/MAST)
- **N08003** Aim headlights. (MLR/AST/MAST)

Knowledge Objectives

After reading this chapter, you will be able to:

- **K08001** Describe lighting systems.
- **K08002** Explain the operation of different lighting systems.
- **K08003** Describe the lighting system circuit operation.
- **K08004** Explain the diagnostic process for lighting system circuit faults.

Skills Objectives

After reading this chapter, you will be able to:

- **S08001** Use the applicable lighting circuit wiring diagram to trace circuit current and predict test point voltages.
- **S08002** Apply the diagnostic process to isolate the cause of lighting system concerns based on circuit and component test results.

You Are the Automotive Technician

The customer states the left headlight does not illuminate. The technician verifies the right headlight turns on but the left headlight is off. From the verification of the concern answer the following:

1. Can any circuit components be eliminated as the cause of the fault?
2. What components may be causing this fault?
3. What type of circuit tests would you use to isolate the cause of this fault?

▶ Introduction

This chapter offers the opportunity to bring together your electrical system knowledge and skills and apply them in diagnosing automotive lighting circuits. The lighting circuits covered in this chapter offer the opportunity to practice use of the wiring diagram, apply the diagnostic process, perform circuit tests, and isolate the cause of lighting system circuit faults. Ask any diagnostic technician what allows them to know what is causing a system circuit fault and they will tell you doing it all day every day. In other words, practice, practice, and more practice. Electrical diagnosis is not a skill you obtain by finding the fault in one circuit. The skills develop through repeating the electrical system diagnostic process and learning from every vehicle you repair. Someone who excels in a sport cannot just show up on game day and perform as a champion—and a diagnostic technician cannot excel without practice. The effort you put into practicing the electrical diagnostic process advances your skills, helping you achieve master diagnostic technician status.

▶ Lighting Systems

K08001 Describe lighting systems.

Lighting systems improve visibility at night and make a vehicle visible to other road users. A lighting switch activates taillights, park lights, and headlights to allow the driver to see ahead and be seen from the side and rear. A beam selector switch allows the driver to change the beams from high to low, or vice versa, as required. Brake lights operate when the brake pedal is pressed or when a vehicle control module is automatically applying the brakes. Red or amber turn signals alert other drivers of a change in direction and are mounted so they can be seen from the front, the rear, and sometimes the sides of the automobile. The emergency flasher system operates both front and rear turn signals at the same time as a warning to others. Other circuits operate courtesy (convenience) lights, back-up (reverse) lights, fog lights, and fault indicators.

Types of Lamps

N08001 Identify system voltage and safety precautions associated with high-intensity discharge headlights. (MLR/AST/MAST)

Modern vehicles use many different kinds and sizes of lamps, also known in some places as light bulbs or light globes. There are several lamp types available, including standard incandescent lamps, halogen lamps, vacuum tube fluorescent (VTF) lighting, high-intensity discharge (HID) xenon gas systems, LEDs, and more. Conventional incandescent lamps are being replaced in many applications by these other more efficient types of lights.

Incandescent and Halogen Lamp Operation

Incandescent lamps consist of one or more filaments that heat up to approximately 5000°F (2760°C) and glow white hot (**FIGURE 8-1**). The filament material does not burn because most of the oxygen in the bulb has been replaced by inert gases that stop combustion from

FIGURE 8-1 Incandescent bulb with single filament.

FIGURE 8-2 Halogen bulb.

occurring. The power in watts consumed is often marked on the lamp; wattage (work performed) is found by multiplying the voltage used by the lamp by the current flowing through it. The higher the wattage, the more light that can be created when compared to a similar type of bulb. Incandescent bulbs are inefficient, converting only about 10% of the electricity to visible light.

Halogen lamps are another type of incandescent lamp, but they are filled with a halogen gas such as bromine or iodine (**FIGURE 8-2**). These lamps have a much longer life and are generally brighter and produce more light per unit of power consumed. However, they become very hot in use. They are manufactured from highly heat-resistant materials, and the bulbs must be handled carefully because they are sensitive and can be damaged even by finger oil residue left by fingerprints.

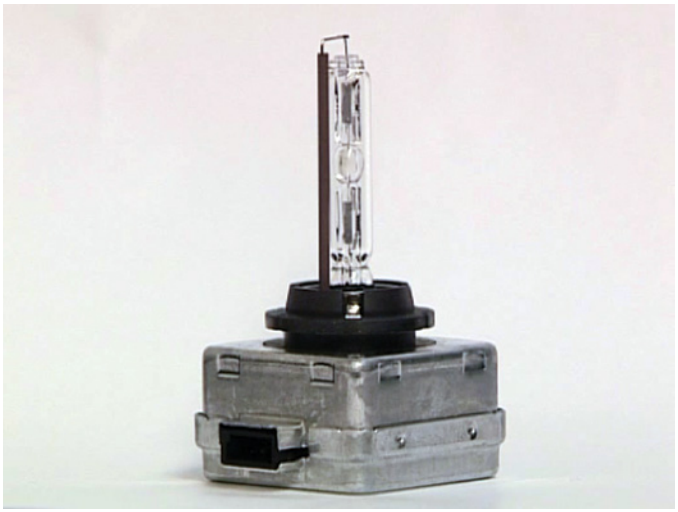


FIGURE 8-3 HID headlamp assembly.

High-Intensity Discharge Lamp Operation

High-intensity discharge (HID) headlamps produce light with an electric arc rather than a glowing filament (**FIGURE 8-3**). The high intensity of the arc comes from metallic salts that are vaporized within an arc chamber. HIDs produce more light for a given level of power consumption than ordinary tungsten or halogen bulbs. Automotive HID lamps are commonly called "xenon headlamps," though they are actually metal halide lamps that contain xenon gas. The light from HID headlamps exhibits a distinct bluish tint as compared with the yellow-white color of tungsten filament headlamps.

HID headlamp bulbs do not run on low voltage direct current; they require a **ballast** with an internal or an external igniter that is either integrated into the bulb or included as a separate unit or part of the ballast. The ballast increases the voltage substantially and controls the current to the bulb.

HID headlamps produce between 2800 and 3500 lumens from between 35 and 38 watts, while halogen filament headlamp bulbs produce between 700 and 2100 lumens from between 40 and 72 watts at 12.8 volts. The advantage of using HID headlight systems is that they offer substantially greater luminance than halogen bulbs (about 3000 lumens versus 1400 lumens for comparable halogen bulbs). If the higher output HID light source is used in a well-engineered headlamp optic, the driver gets more usable light. Studies indicate that drivers react faster and more accurately to roadway obstacles when using good HID headlamps than when using halogen headlamps; therefore, good HID headlamps contribute to driving safety.

The contrary argument is that HID headlamps can impact negatively the vision of oncoming traffic due to their high intensity and the "flashing" effect caused by the rapid transition between low and high illumination in the field of illumination. This potential distraction increases the risk of a head-on collision between a vehicle using HID headlamps and a blinded oncoming driver. Scientific studies of headlamp glare from HID systems has shown that for any given intensity level, the light from HID headlamps is 40% more glaring than the light from tungsten halogen headlamps.

Some countries mandate that HID headlamps may only be installed on vehicles (except motorcycles) with lens-cleaning systems (to reduce glare) and automatic self-leveling systems (which prevent dazzling oncoming traffic). These systems are usually absent on vehicles not originally equipped with HID lamps, so if a halogen headlamp is retrofitted with an HID bulb, light distribution with illegal levels of glare will be produced.

Another disadvantage of HID headlamps is that they are significantly more costly to produce, install, purchase, and repair. However, some of this cost is offset by the longer lifespan of the HID burner relative to halogen bulbs.

Light-Emitting Diode Operation

Light-emitting diodes (LEDs) have been used for some time in various automotive applications, such as warning indicators and alphanumeric displays. More recent developments in LED technology have seen the production of a wider range of colors and LEDs that are

FIGURE 8-4 LED lights.

brighter than previous types. It is now possible to get LEDs that emit bright red, green, blue, yellow, and clear or white light. This has made it possible to use LEDs for many new applications, such as more general lighting applications. For example, LEDs are now often used for stop lights, turn signals, and interior lighting on vehicles (**FIGURE 8-4**).

One of the advantages of LEDs is that they turn on instantly. This is particularly useful in brake lights, as they can reduce the braking light response time by two-tenths of a second. This translates to an extra 16' (4.9 meters) of stopping distance for vehicles traveling at highway speeds. LEDs also have better visibility in inclement weather, operate at cooler temperatures, consume less energy, are much smaller, and can last up to 100 times longer, reducing the cost of servicing. LEDs can be specifically designed for LED lighting and also as LED replacement bulbs for more traditional bulb holders.

For automotive applications, a number of LEDs are grouped together to provide the amount of light required for the application. Additionally, LED light lenses are specifically designed with light-focusing prisms and lenses to focus the light generated by the LEDs. A typical LED has a voltage drop of 1.2 to 3.5 volts across it, depending upon the color, when it is forward biased and emitting light.

When used in automotive lighting, many LEDs are required to give off a specified amount of light. To do so they are usually connected in groups called series strings. A number of series strings are then connected in parallel until enough LEDs are connected to give off the required amount of light.

LEDs work best when the voltage to them and the current flow through them remains constant at a preset level. There are two main ways to achieve this; the first is via a resistor. The second and more preferred way is through the use of a voltage regulation circuit.

Some LED lights are multivoltage, which means they can work on both 12- and 24-volt systems. These lights are normally used in aftermarket products, which can be installed in a wide range of vehicles. Note that most LED lighting systems use several LEDs as part of the light assembly. If one LED fails, it usually requires replacing the whole unit as the LEDs are often soldered to a circuit board and are not usually designed to be replaced individually.

Lamp/Light Bulb Information

All lamps or light bulbs have letters and numbers stamped on them that typically indicate their part number and often the operating voltage and power consumed. For instance, in a bulb marked 12V/21W, the filament will consume 21 watts of power when 12 volts is applied across the filament. While the wattage is not necessarily an indication of light output, it can be generally assumed that the higher the wattage, the greater the light output.

FIGURE 8-5 Dual-filament bulb.

Lamps and light bulbs come in a variety of configurations to fit the various applications within a vehicle. One designation is how many filaments the bulb has (**FIGURE 8-5**). Single-filament bulbs are common for use as courtesy lights, dash lights, and warning lights. Dual-filament bulbs have two filaments of different wattage; one filament emits a small amount of light, and the second filament emits more light. These bulbs work well as a combination taillight and brake light. Headlights can also be dual-filament bulbs. In some cases, the low-beam filament is lower wattage than the high-beam filament. In a headlight, the filaments are positioned to give a different profile of light. Low beams emit light closer to the vehicle and angled slightly toward the side of the road, while high beams tend to focus farther down the road and straight ahead.

FIGURE 8-6 Bayonet-style bulbs.

FIGURE 8-7 Wedge-style bulbs.

Another feature that differs among lights is the type of base on the lamp—in other words, what type of socket it is retained in. Bayonet-style bulbs have been around for a long time. They get their name from the two retaining pins on the side of the base (**FIGURE 8-6**). The pins follow slots in the side socket and at the bottom, and the slots turn sideways into a small pocket. The pins are retained in the pocket by the spring-loaded base in the bottom of the socket, which pushes the bulb upward. This design resists vibration very well. Removal of the bulb requires carefully pushing in on the bulb and rotating the bulb slightly counterclockwise and pulling it out. One or two electrical contacts are built into the bottom of the bulb's base. If the bulb is a dual-filament bulb with two contacts on the base, then the pins will be unequal height so that the contacts will be registered properly with the contacts in the socket.

FIGURE 8-8 Festoon-style bulbs.

Many newer bulbs use a wedge base either made from the glass bulb itself or with a built-in plastic base (**FIGURE 8-7**). The bulbs are pushed straight into the socket, and tension from the socket retains the bulb. The electrical contact on the glass-based bulbs is made by wires extending from the base of the bulb and bent over opposite sides of the wedge.

Dome lights use festoon lights, which have a base on each end of a cylindrical light bulb (**FIGURE 8-8**). Each end of the filament is connected to one of the bases. Generally, the bases fit in spring steel contacts, which hold the light bulb securely in place.

▶ Types and Styles of Lighting Systems

K08002 Explain the operation of different lighting systems.

N08002 Inspect interior and exterior lamps and sockets including headlights and auxiliary lights (fog lights/driving lights); replace as needed. (MLR/AST/MAST)

There are many different styles and types of lights. Each style and type is designed to perform specific roles. For example, warning lamps, turn indicators, stop lights, taillights, courtesy lamps, and headlamps all perform different roles. Lamp locations, color, and brightness are governed by regulations to ensure consistency and safety in the application of lighting on vehicles. Lighting regulations should always be consulted before modifying or adding to any of the vehicle lighting systems. Well-maintained lighting systems improve road safety for all drivers.

Courtesy Lights Operation

Courtesy lights or lamps are used to provide ambient lighting in the cabin (**FIGURE 8-9**). They are usually low-intensity or low-wattage bulbs and can be overhead, in the doors,

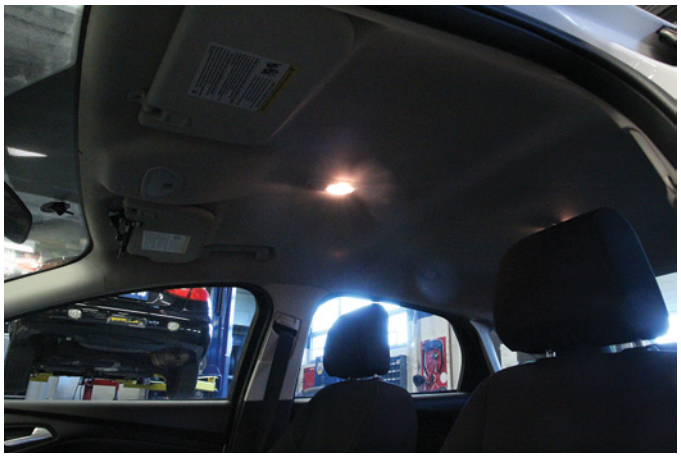


FIGURE 8-9 Courtesy lights.

FIGURE 8-10 Warning lamp.

glove compartment, and the trunk. Door and latch switches control the various lamps for the trunk and glove compartment. Courtesy lights are usually controlled by the vehicle body computer with inputs from the ignition and door switches either in the handle, latch, or door pillar. Courtesy lights may be designed with timing circuits that allow for the cabin lamps to stay on for a short period after all the doors are shut or the vehicle is locked.

Warning Lights Operation

Warning lamps are usually part of the instrument cluster and are controlled by electronic control units in the vehicle on a modern vehicle. Warning lamps provide the vehicle operator with information regarding the operation of the main vehicle systems, such as the vehicle battery charge level, oil pressure level, and airbag system status (**FIGURE 8-10**). When the ignition initially comes on, the warning lamps usually light up as part of a self-test to show that they are in working order. Once the engine starts, the warning lamps should extinguish and not come on again while the engine is running, unless there is a system fault. Some vehicles have warning lights that self-test while the vehicle is being cranked. This function is performed by the "proofing circuit" in the ignition switch, which grounds certain warning lights when turned to the "crank" position.

Park/Tail/Marker/License Lights Operation

Park, tail, and marker lights are all low-intensity or low-wattage bulbs used to mark the outline or width of the vehicle. Park and tail lamps tend to be installed close to the corners of the vehicle. Park lamps are placed to the front of the vehicle, or in some cases they are incorporated in the headlight assembly and are white or yellow in color. Tail lamps are red and usually installed in a cluster assembly with the stop lamps at the rear of the vehicle.

License plate lamps produce a white light and are designed to illuminate the lettering on the license plate at night without the white light itself being seen from the rear. The bulbs are connected in parallel to each other so that the failure of one filament will not cause a total circuit failure. A license plate illumination lamp or lamps are usually connected in parallel to the taillights and operate whenever the taillights are on.

Taillights are usually incorporated in a cluster assembly at the rear of the vehicle. Government regulations control the height of the lamps and their brightness.

Park lights are located at the front of the vehicle and are used at night when the vehicle is parked on the side of the road; they are also on anytime the headlights are on. They use low-wattage bulbs and may have a lens or diffuser that makes the emitted light widespread. In some cases, park lights are incorporated in the headlight assembly. Park lights operate when the light switch is moved to the park light position. For safety reasons, park lights and taillights continue to operate when the light switch is moved to the headlight position. The bulbs are connected in parallel with each other.

On computer-controlled lighting systems, the park lights and taillights are BCM controlled. The lights are supplied with power and ground through a networked light controller. The controller is connected to a network/bus system (discussed later in this chapter) by the twisted pair of communication wires. The park light switch is hardwired to a module. When the park light switch is activated, the module sends a park light request out on the network where the appropriate controllers pick up the message and supply power or ground to the appropriate light bulb filaments to illuminate the park lights.

Marker lights are used to mark the sides of some vehicles; they are often located down the sides of the vehicle or trailer. They can be located on the front and rear fenders. On newer vehicles, they are sometimes placed on side-view mirrors or between the front and the rear doors on large SUVs or pickups (**FIGURE 8-11**). Red marker lamps face toward the rear, and yellow lamps face toward the front of the vehicle. These lights are designed to work when the park lights or headlights are selected, and they sometimes operate as turn signals so a driver can warn others of his or her intent to switch lanes or turn a corner.

FIGURE 8-11 Marker lights on an SUV.

Government regulations control the positioning of lights, including the height of the lamps' beam and their brightness. The park, tail, marker, and license plate lamps operate when the headlight switch is in both the park and the headlight-on positions. The bulbs are connected in parallel to each other so that the failure of one filament will not cause a total circuit failure. Tail and park lamps may use separate fuses, so if one circuit fails the other will continue to operate.

Brake Lights and CHMSL Operation

Brake lights, which may also be called stop lights, are red lights mounted to the rear of the vehicle. They are usually incorporated in the taillight cluster. Many vehicles by law now have a higher additional third brake light mounted on top of the trunk lid or on the rear window. This light is called a center high mount stop light (CHMSL), or "chimsul" (**FIGURE 8-12**). The brake lights are activated whenever the driver operates the foot brake to slow or stop the vehicle or when a control module automatically applies the brakes. The lighting circuit consists of the battery, fusible links and fuses, a brake light switch, brake light bulbs, wiring to connect the components, and the ground circuit to return current from the light to the battery. It may also include a BCM to command the lights on when the proper inputs are present.

On older vehicle models, when the operator of the vehicle presses the brake pedal, a switch mounted on the pedal support closes. This allows the electrical current to flow from the battery through the fuse, through the switch, to the brake lamp, and to return to the battery by the ground circuit. When the driver releases the pedal, it returns to the rest position and opens the brake switch. The flow of electrical current stops and the brake lamps are extinguished. Today, computer-controlled brake lights are activated by the body control module (BCM) when the computer sees an input from the brake pedal switch.

FIGURE 8-12 Center high mount stop light.

Back-Up Lights Operation

The back-up lights, also called reverse lights, are white lights mounted at the rear of a vehicle (**FIGURE 8-13**). They provide the driver with vision behind the vehicle at night and alert other drivers to the fact that the vehicle is in reverse. The lighting circuit consists of the battery, fuses and fusible links, the ignition switch, the back-up light (reverse) switch or a combined transmission back-up light/neutral-safety switch on the transmission,

FIGURE 8-13 Back-up lights.

back-up lamps, wiring to connect the components, and the ground circuit to allow current to return to the battery through the vehicle chassis.

When the ignition is on, and the vehicle is placed in reverse gear, the current flows from the battery, through the ignition switch, and through the closed reverse lamp or transmission position switch on the transmission. Electrical current then flows out of the closed switch to the back-up lamps and returns to the battery by the vehicle chassis ground circuit. Modern vehicles use network/bus systems and the BCM to command the back-up lights to come on.

Back-up lights are the only white lights on the rear of the vehicle. Since they operate only in reverse, other drivers can tell that the driver is backing up. This is why it is illegal to have broken tail/brake/turn signal lenses in the rear of the vehicle since white light would be visible, confusing other drivers.

FIGURE 8-14 Turn signal indicators.

Turn Signal Lights Operation

Turn signal indicators are located on the extreme corners of the vehicle. They are usually amber in the front and can be either red or amber in the rear (**FIGURE 8-14**). A column-mounted switch, operated by the driver, commands a pulsing current to the indicator lights on one side of the vehicle or the other. These pulsing lights warn other road users of the driver's intended change of direction.

Once activated, they continue until the switch is cancelled either by the operator or by a cancelling mechanism in the switch. The cancelling mechanism operates to return the switch to its central or "off" position after a turn has been completed and the steering wheel is returned to the straight-ahead position. The circuit consists of the battery, fusible links and fuses, the ignition switch, the flasher unit, a three-position switch used as the direction indicator switch, the lights at the front and rear of the vehicle, indicator lights mounted in the instrument cluster to indicate to the driver which way the switch has been operated, wiring to connect all of the components, and the ground circuit to return the electrical current to the battery.

If the indicator switch is turned to indicate a right-hand turn, current from the battery typically flows through the fusible link to the ignition switch, where it is directed through a fuse to the flasher unit. The flasher unit uses a timing circuit to pulse the current flowing out of the flasher unit 60 to 120 times per minute. This pulsing current is directed through the indicator switch to the right-hand indicator lights at the front and rear of the vehicle, causing the lamps to flash on and off. An indicator light on the instrument cluster also blinks in sync with the turn signals. The operation of the flasher unit also produces a clicking sound to audibly inform the driver that the indicators are in operation.

When the turn signal switch is returned to the off position, no current flows through the flasher unit, so the timer circuit is switched off. When the turn signal switch is turned in the opposite direction, it directs the pulsing current to the left-hand lights at the front and rear of the vehicle as well as the left-hand indicator light on the instrument cluster. Older vehicles used a thermo-mechanical flasher unit that relied on heat from the current flow to cause the flasher unit to work. It is very important to use bulbs of the proper wattage on all types of flasher units, as the speed of the flash may be incorrect if incorrect bulbs are used.

These indicators can also be computer controlled. The BCM commands the appropriate turn indicators to come on as it sees an input from the turn signal switch, and it flashes the light at the proper rate. The computer turns off the turn signals when a steering angle sensor signals the steering wheel is being centered. It can also cancel the turn indicators

if the vehicle is driven for a programmed amount of time or distance without the steering wheel being turned. Often a chime will alert the driver if the turn indicator has been left on for too long. On many computer-controlled turn signals, the turn signals will not work at all when the computer senses the wrong amperage flow.

Turn Signal Lights—Domestic and Import Systems

All turn signal lamps flash, but there are variations in layout and design. This is most noticeable when comparing some domestic and imported vehicles. Imported vehicles tend to have separate amber-colored turn signal lamps on both the front and the rear of the vehicle. Some domestic vehicles use the rear brake lamps as turn signals by flashing the brake lamp on one side to indicate the turn. Wiring schematics should always be checked because the dual function of the brake lamps means the wiring for brake lamps on vehicles with this feature is different than those where the brake lamps perform only during braking (**FIGURE 8-15**). In such cases, current for the brake lights must flow first from the brake switch, then through the turn signal switch, and on to the individual brake lights. This design tends to make the study of the current path more complicated, since there are two inputs—one for the turn signals and one for the brake lights. So the turn signal switch is much more complicated on a domestic-style turn signal switch than an import-style switch.

Hazard Warning Lights Operation

All modern vehicles are equipped with hazard warning lights. This circuit is similar to the turn indicator lights except that it simultaneously causes a pulsing in all exterior indicator lights and both indicator lights on the instrument panel. Hazard lights can warn other road users that a hazardous condition exists or that the vehicle is standing or parked in a dangerous position on the side of the road. The hazards also use a flasher unit that can be a separate unit or the same as that used for the turn signals. The BCM may control the hazard lights when it sees an input from the hazard switch or an input from the restraints control module indicating a vehicle crash.

Daytime Running Lights Operation

Daytime running lights (DRLs) are an additional safety feature designed on vehicles to improve the vehicle's visibility to other drivers in all weather conditions. They are existing lights that turn on when the vehicle is running and turn off when the engine stops. The lamps on the front are the headlights, which are typically operated at about a 60% power level, providing light without excessively decreasing bulb life or using full electrical power. The lamps used on the rear in DRL systems are the taillights.

DRLs are mandatory on modern vehicles licensed in Canada and some other countries. In the United States, DRLs are permitted but not required. Their use is somewhat controversial. First, if they are too bright, they can cause daytime glare. Second, they tend to mask the visibility of turn signals, making it harder for other drivers to determine a vehicle's intent. Overall, they have not been proved to reduce accidents or increase safety. They also require energy to operate, which reduces fuel economy and increases carbon dioxide emissions.

Headlights Operation

N08003 Aim headlights. (MLR/AST/MAST)

Headlights are built into the front of a vehicle to illuminate the road ahead of the vehicle when driving at night or in other conditions of reduced visibility. In headlights, most vehicles require two beams to provide for a high-beam and low-beam operation. The beams are created by separate filaments, included either in one light bulb or in separate bulbs. These filaments must be positioned correctly in relation to the highly polished reflector. This is called focusing, and it is carried out when designing the light assembly and lens for the vehicle. The high-beam filament is positioned at the focal point of the reflector to project the maximum amount of light forward and parallel to the reflector axis (**FIGURE 8-16**). This light is then shaped by the lens, which is made up of many small glass or plastic prisms fused together. These prisms bend the light horizontally and vertically to achieve the desired light pattern for road illumination.

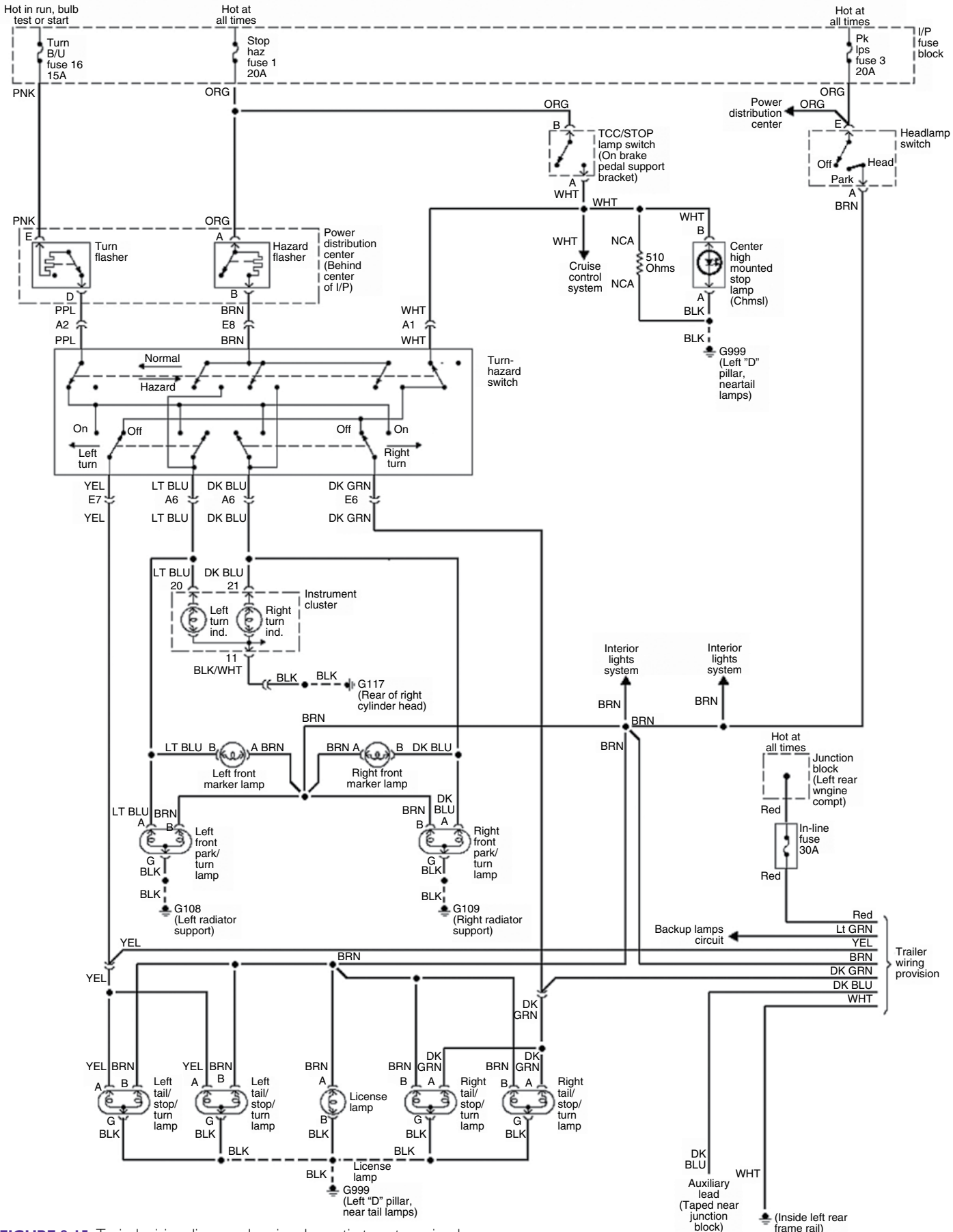


FIGURE 8-15 Typical wiring diagram showing domestic-type turn signals.

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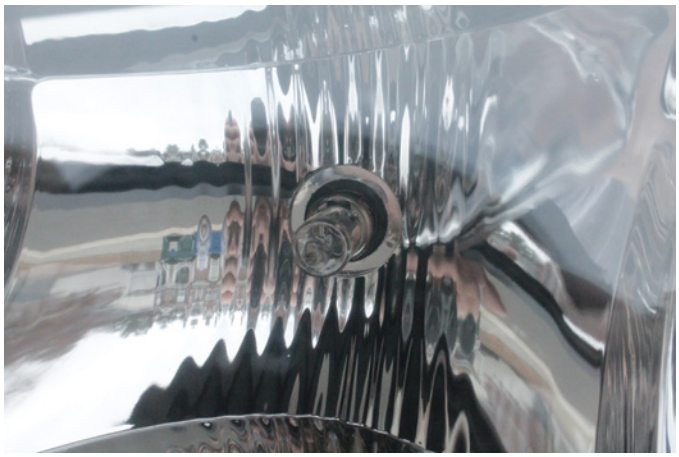


FIGURE 8-16 High- and low-beam filament position in relation to the reflector.

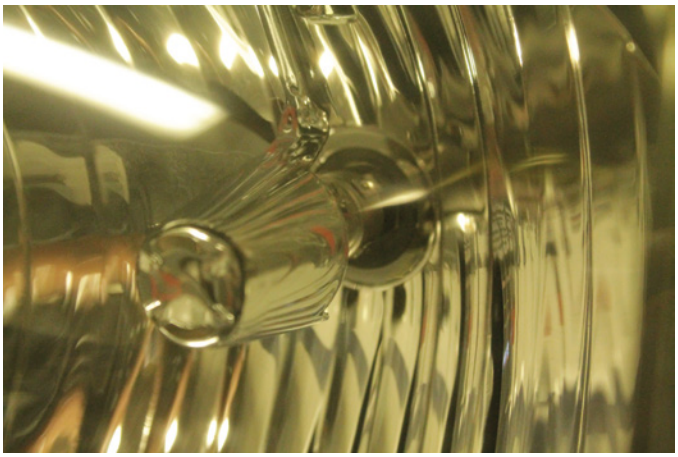


FIGURE 8-17 Low-beam filament position in relation to the reflector.

The low-beam filament is often placed above and slightly to one side of the high-beam filament. Mounting the low-beam filament in this position produces a beam of light that is projected downward and toward the curb side (**FIGURE 8-17**). With this arrangement, the high-beam filament produces the most concentrated light output, while the low-beam filament gives a downward and dispersed beam that is less likely to blind oncoming drivers.

Generally speaking, the headlight circuit consists of the battery, the fusible link or Maxi-Fuse, headlight fuses, the headlight switch, the headlight relay(s), the beam selector switch, headlights, the high-beam indicator light, wiring of a suitable size to carry the electrical current through the circuit, and the ground circuit. Modern vehicles use the BCM to manage headlight functions.

On older, noncomputer-controlled systems, when the headlights are switched on, current is supplied from the battery and proceeds through the fusible link or maxi-fuse, headlight fuse(s), headlight switch, and dimmer switch, reaching either the low or the high beams. In more recent noncomputer-controlled systems, some vehicles use relays to control the current through the low- or high-beam circuits. In this configuration, the beam selector switch either powers or grounds the relay windings in each of the relays, depending on the position of the beam selector switch. Activating the beam selector switch in the low-beam position creates a magnetic field inside the low-beam relay that closes the relay contacts, which allows electrical current to flow to the low beams. Activating the beam selector switch in the high-beam position creates a magnetic field inside the high-beam relay that closes the relay contacts, turning on the high beams.

The beam selector switch is a single-pole, double-throw switch, meaning it has one movable pole but makes contact in two positions. In the high-beam position, the current is switched to the high-beam circuit. In the low-beam position, the current is switched to the low-beam circuit. The beam selector switch can be set to switch a common power input to two outputs, or it can switch a common ground input to two outputs.

As with other advanced-technology on-board systems, modern vehicles use a network/bus system to manage these and other headlight and dimmer functions. On many vehicles, the headlight switch and dimmer switch are just inputs to a control module that sends a headlight "on" or "off" request over the network. The appropriate light controller processes the request and actually commands the lights on or off, sometimes with the help of relays—especially for high beams.

A sealed-beam headlight has a highly polished aluminized glass reflector that is fused to the optically designed lens. It is a completely sealed unit that has the filaments accurately positioned in relation to the reflector. Most older vehicles used two dual-filament 7" (178 mm) round lamps; for a time, four single-filament 5.25" (133 mm) round lamps were used. Other older vehicles used two large dual-filament 7.875" (200 mm) rectangular lamps or four smaller rectangular single-filament lamps. Regardless of size, when a filament fails in a sealed-beam light, the whole sealed unit must be replaced.

FIGURE 8-18 Replaceable halogen bulb.

A semisealed-beam headlight uses a replaceable bulb with a prefocus collar. The collar locates the bulb in the headlight and also controls the correct positioning of the filaments to the reflector and lens (**FIGURE 8-18**). Some replaceable headlight bulbs have a partial shield below the low-beam filament. This shield prevents light from the filament from striking the lower part of the reflector, which would be reflected higher than the midpoint of the lamp. The shield provides the primary shape of the low beam. The final shaping of the beam is carried out by small cylindrical prisms in the headlight lens. This provides a low beam that is asymmetrical. The asymmetrical lens pattern causes light to be thrown upward at a 15-degree angle on the curb side to better illuminate objects, persons, or animals close to the road.

Identify Headlight Type

Headlight systems have traditionally used reflector-type lighting systems. In a reflector headlight, the light from the bulb is reflected forward by a specially shaped reflector. An alternative is a projection-type headlight system. This type of headlight often has a smaller front lens; however, it produces a high-intensity forward beam. It uses a lens system to project the light forward, rather than the traditional reflector system (**FIGURE 8-19**). A projector-style light can use a standard incandescent bulb or, more commonly, an HID light.

HID lights use light from an electric arc rather than heating up a filament until it glows (**FIGURE 8-20**). High voltage is applied to tungsten electrodes. Xenon gas inside the bulb is then ionized and creates an electrical path between the electrodes, which lowers the resistance of the gap. As the temperature rises, metallic salts are vaporized and provide a stable arc, emitting much light. To initially jump the gap, a ballast and igniter raise the vehicle's low voltage direct current (DC) to as much as 25,000 volts alternating current (AC). Once the light reaches full operation, voltage is maintained between approximately 40 and 85 volts AC, depending on the system. HID lights use less electrical energy and give off a brighter and bluer light than halogen bulbs, so they help fuel efficiency slightly. They last two to four times as long as a halogen bulb but are quite a bit more expensive. Also, they take up more room in the engine compartment.

Some vehicles use LED lights as headlights. They are not currently as bright as HID lights but are at least as bright as halogen lights. LED lights are known for low power consumption, but for LEDs to create enough light to function as headlights, they must consume almost as much energy as HID lights. Still, LED technology continues to improve. One

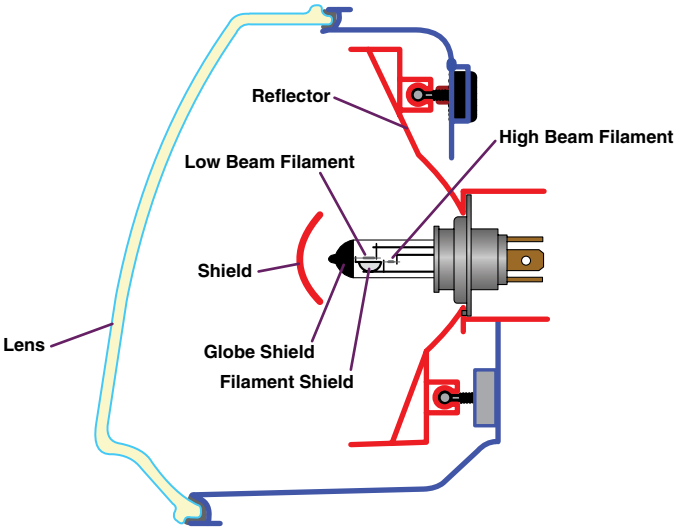


FIGURE 8-19 Projector bulb assembly.

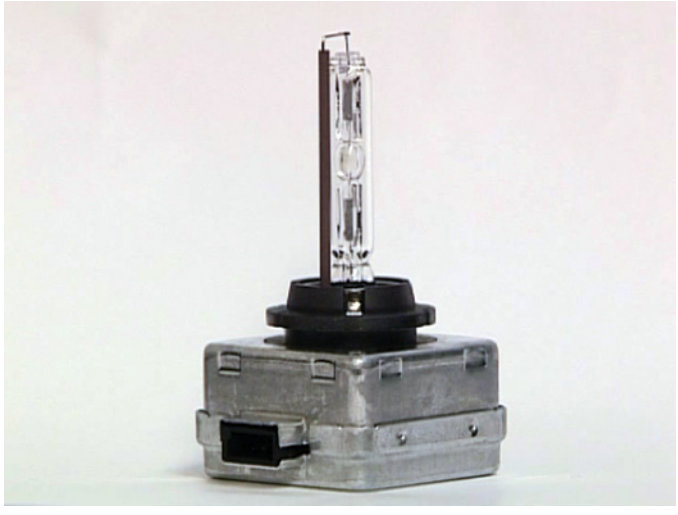


FIGURE 8-20 HID headlight assembly.

drawback of current LED headlights is that high temperatures degrade or damage them. Thus, heat sinks and cooling measures are needed, which add complexity, cost, and size.

Night vision is another relatively new technology that enhances a driver's visual perception in dark or poor weather conditions. There are two types of night vision systems: active and passive. Active systems use an infrared light generator that projects infrared light in front of and to the side of the roadway ahead. A special camera picks up the reflected infrared radiation. The image is then displayed either on the windshield using a heads-up display or on an LCD screen on the dash or navigation system.

Passive night vision systems use a heat-sensing camera (thermal imaging) to pick up thermal radiation emitted by objects. This system does not have an infrared light source on the vehicle. The captured thermal image is then displayed either on a heads-up display or on an LCD screen. One benefit of the thermal system is that it can be programmed to recognize pedestrians and animals and can then either place an outline around them on the display or flash a warning symbol.

Driving Lights Operation

Driving lights are used to supplement vehicle headlight systems. The driving lights are installed on the front of the vehicle and provide higher intensity illumination over longer distances than standard headlight systems (**FIGURE 8-21**). Vehicle design rules and regulations specify the limitations in relation to the positioning and lens configuration of driving lights. It is essential that the local regulations are adhered to when mounting or adjusting driving lights.

There are many types of driving lights available. They come in different sizes, shapes, lens patterns, and bulb wattage. In some instances, a single driving light can be installed to suit particular applications, but lights are normally installed in pairs.

Most driving lights use quartz halogen bulbs in the 55- to 120-watt range. The quality of the reflector is extremely important in driving lights to get optimum performance. Driving lights are wired so that they operate only when the high beam is operating. This safety feature ensures that driving lights turn off when the headlights are switched from high to low beam, thus ensuring that oncoming traffic is not blinded by excessive light. While many performance vehicles come equipped with driving lights, they can be added to almost any vehicle. If they are added, a relay and circuit breaker should always be used for circuit protection reasons.

FIGURE 8-21 Vehicle with factory driving lights.

Fog Lights Operation

Fog lights are used with other vehicle lighting in poor weather such as thick fog, driving rain, or blowing snow. Because fog is made up of water droplets suspended in the air, it can reflect headlights back into the driver's eyes at night. In such conditions, fog lights can help drivers see farther ahead and illuminate the road's edges at reasonable speeds. They are used with park lights and low-beam headlights but not with high beams.

Most older fog lights have yellow reflectors; more recently, however, white fog lights have become more widely used because they are 30% brighter than yellow lenses. Fog lights typically use quartz halogen bulbs and are available in different shapes and sizes. Fog lights are usually mounted lower than headlights and tend to be aimed straight forward and low (**FIGURE 8-22**). Fog light lenses have a sharp cutoff pattern so that most of the light projected remains below the driver's eye level. Fog lights are typically wired with a relay and circuit breaker. The method of connection of fog lights will depend on local regulations. They may be wired to work only with park lights and to turn off when headlights are used or to work when high beams are used.

FIGURE 8-22 Vehicle with factory fog lights.

K08003 Describe the lighting system circuit operation.

S08001 Use the applicable lighting circuit wiring diagram to trace circuit current and predict test point voltages.

▶ Lighting System Circuit Operation

The headlight switch controls the headlights and parking lights. The switch may control source voltage or the path to ground for the circuit. The sample circuit shown controls the path to ground for the headlight relay, and the headlight relay controls source voltage to the headlights (**FIGURE 8-23**).

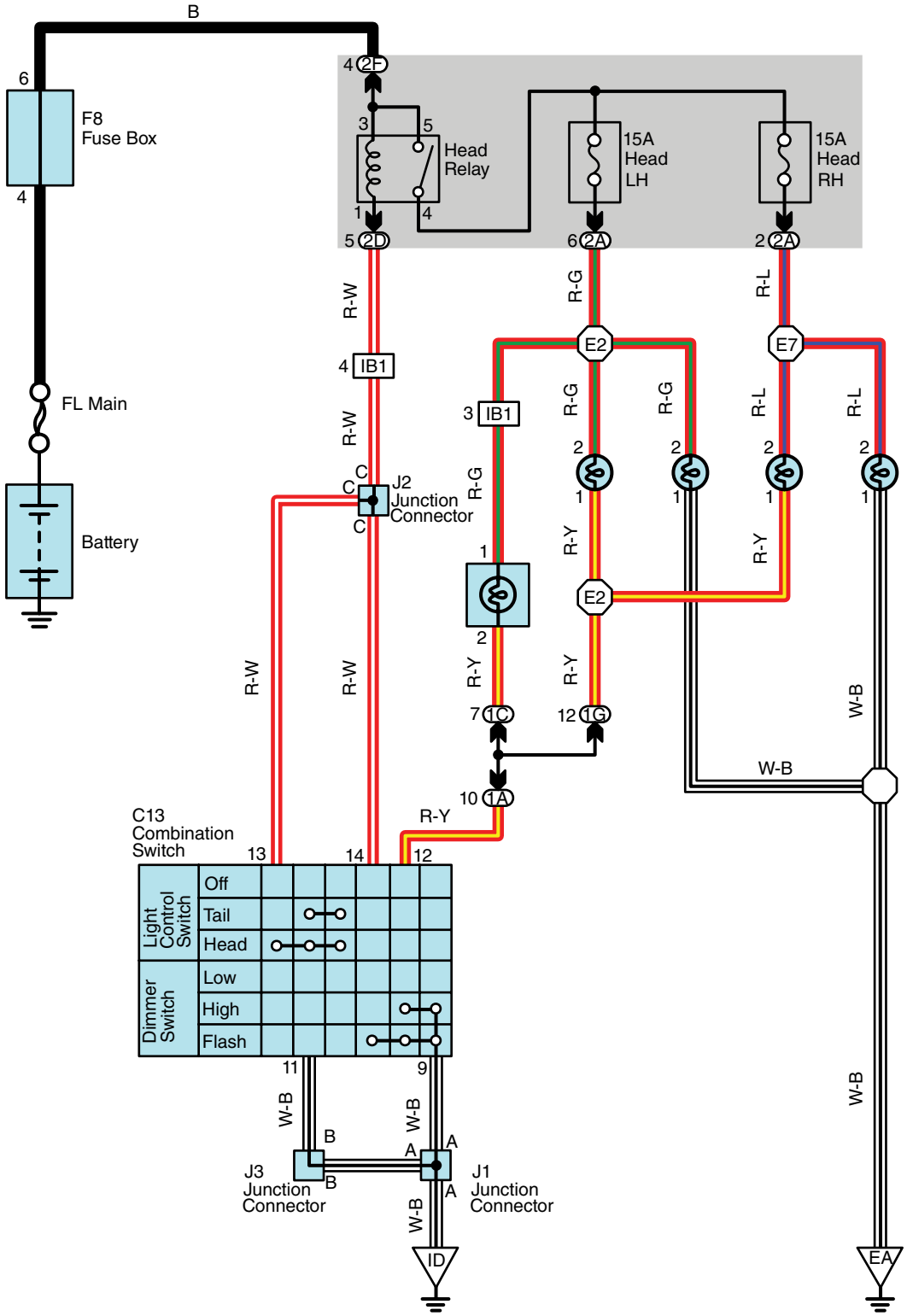


FIGURE 8-23 The headlight switch is located on the ground side of this circuit to control the headlight relay.

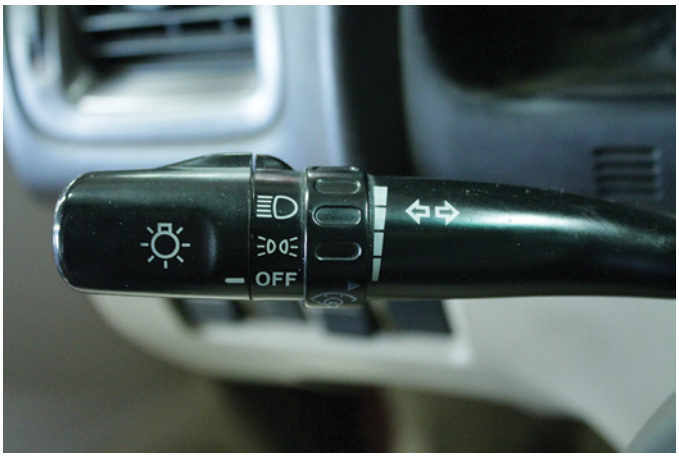


FIGURE 8-24 Headlight switch mounted on the steering column.

FIGURE 8-25 Headlight switch mounted on the instrument panel.

Headlight Switch

The headlight switch may be mounted on the steering column (**FIGURE 8-24**) or in the instrument panel (**FIGURE 8-25**). Most vehicles you will encounter use a headlight switch that controls a relay or the switch is an input to an ECU. Use of a relay or ECU eliminates the need for the headlight switch to handle the high current load of the headlights and running lights. The switch contacts can be smaller and the related wiring size can be reduced. This saves space, weight, and cost.

Vintage vehicles use headlight switches that directly control the headlights and running lights. These switches have very large contacts and often incorporate a circuit breaker in case of a current overload. A rheostat is used to control instrument panel light brightness and operates by rotating the control left or right (**FIGURE 8-26**).

The current paths through the switch are shown by the dotted lines (**FIGURE 8-27**). The current connects switch pin 13 to pin 11 to turn on the headlight relay. The headlight switch in this circuit controls a relay that provides source voltage to the headlights. This switch in the sample circuit shown combines the headlights off and on control with the low- or high-beam switch and the flash-to-pass switch.

FIGURE 8-26 Older vehicles use headlight switches with large contacts and larger wires to handle full circuit current.

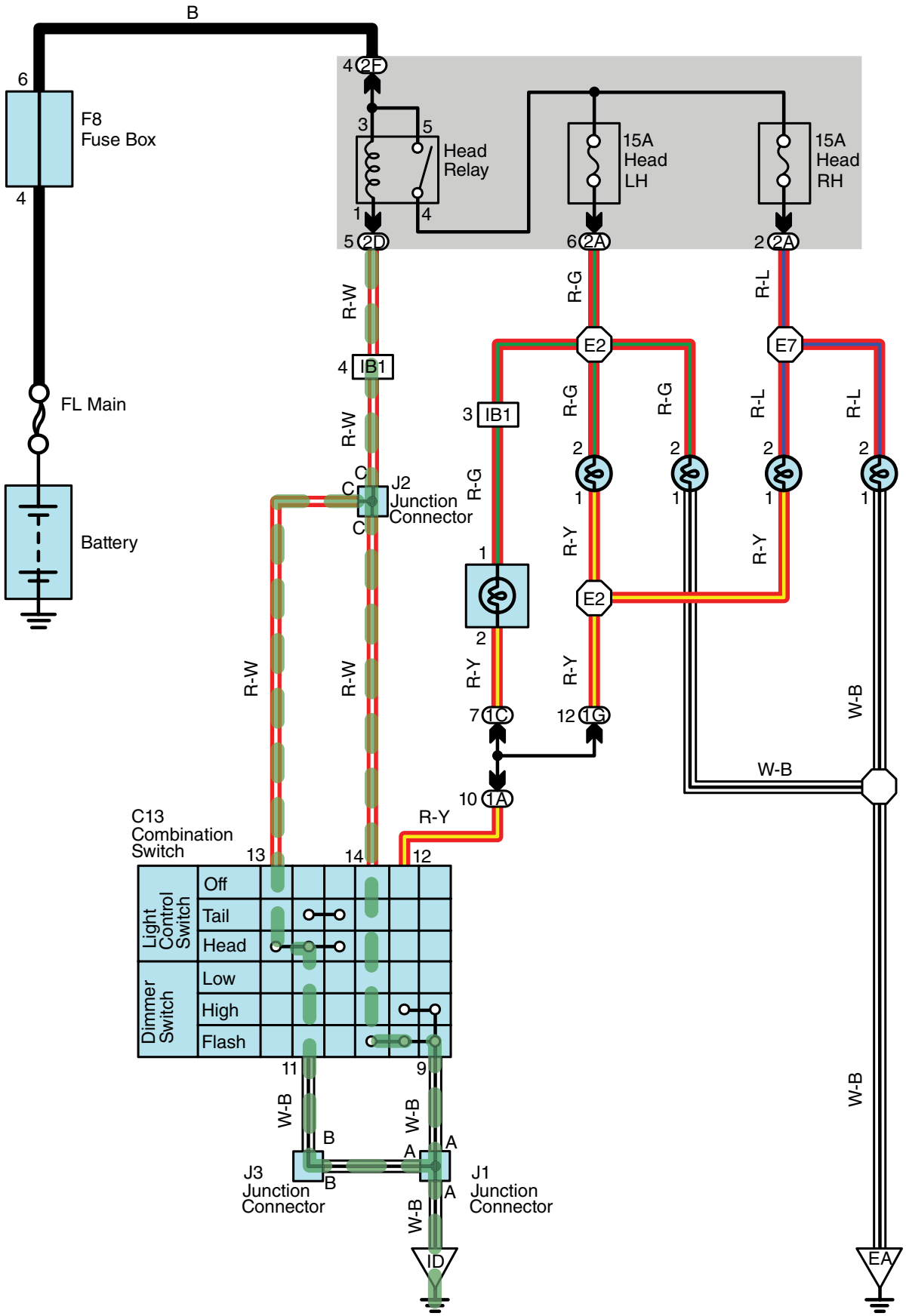


FIGURE 8-27 The dotted lines in the switch indicate the current path through the internal contacts.

Headlight Circuit

The headlights receive source voltage from the headlight relay through a dedicated fuse for left and right lights. The low beams have a path to ground at EA (**FIGURE 8-28**).

The high beams ground through the headlight switch assembly at ground point ID (**FIGURE 8-29**) when the dimmer switch is in the high position. Both the low- and high-beam filaments are on when the high beams are selected.

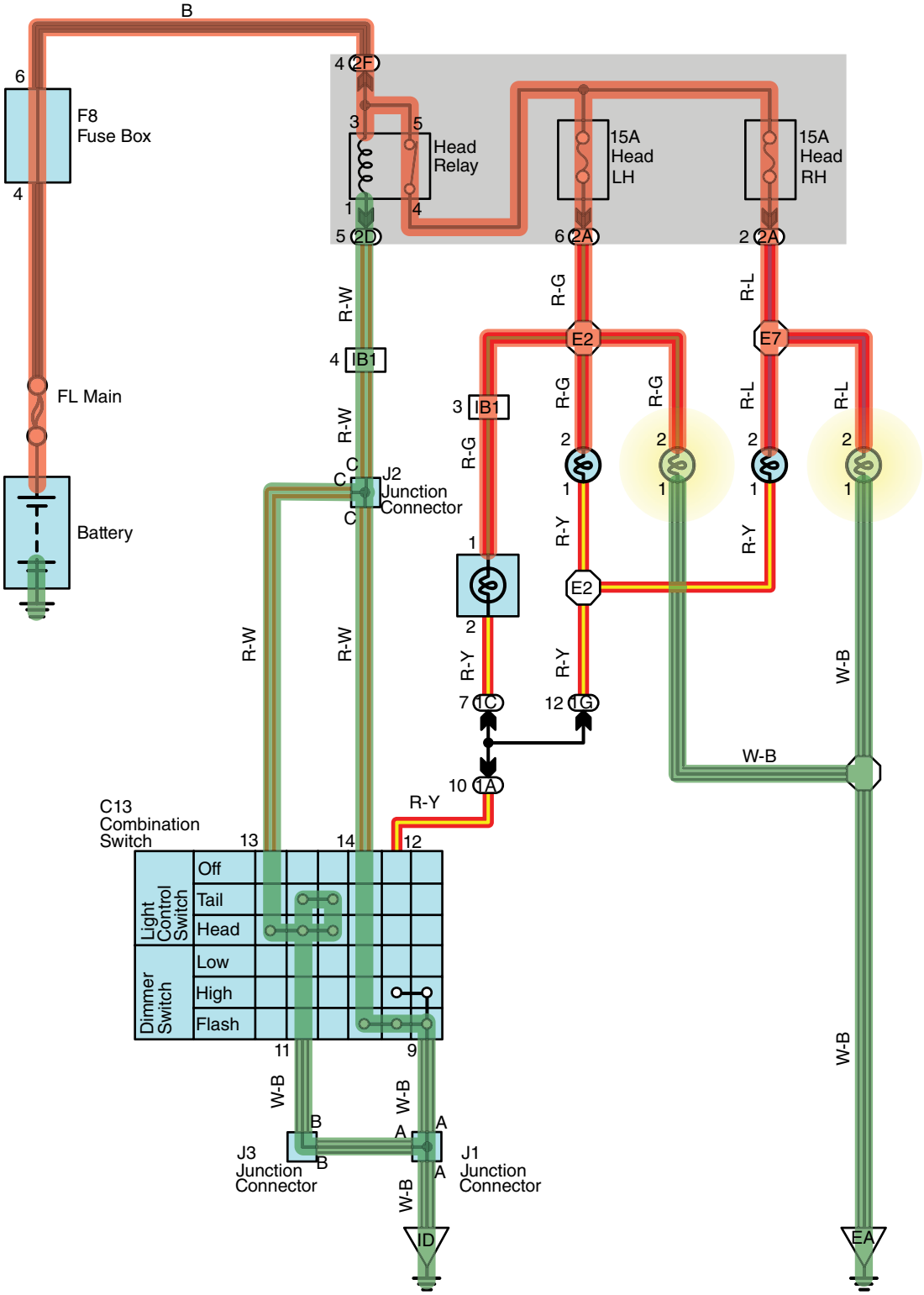


FIGURE 8-28 The low-beam circuit grounds at point EA.

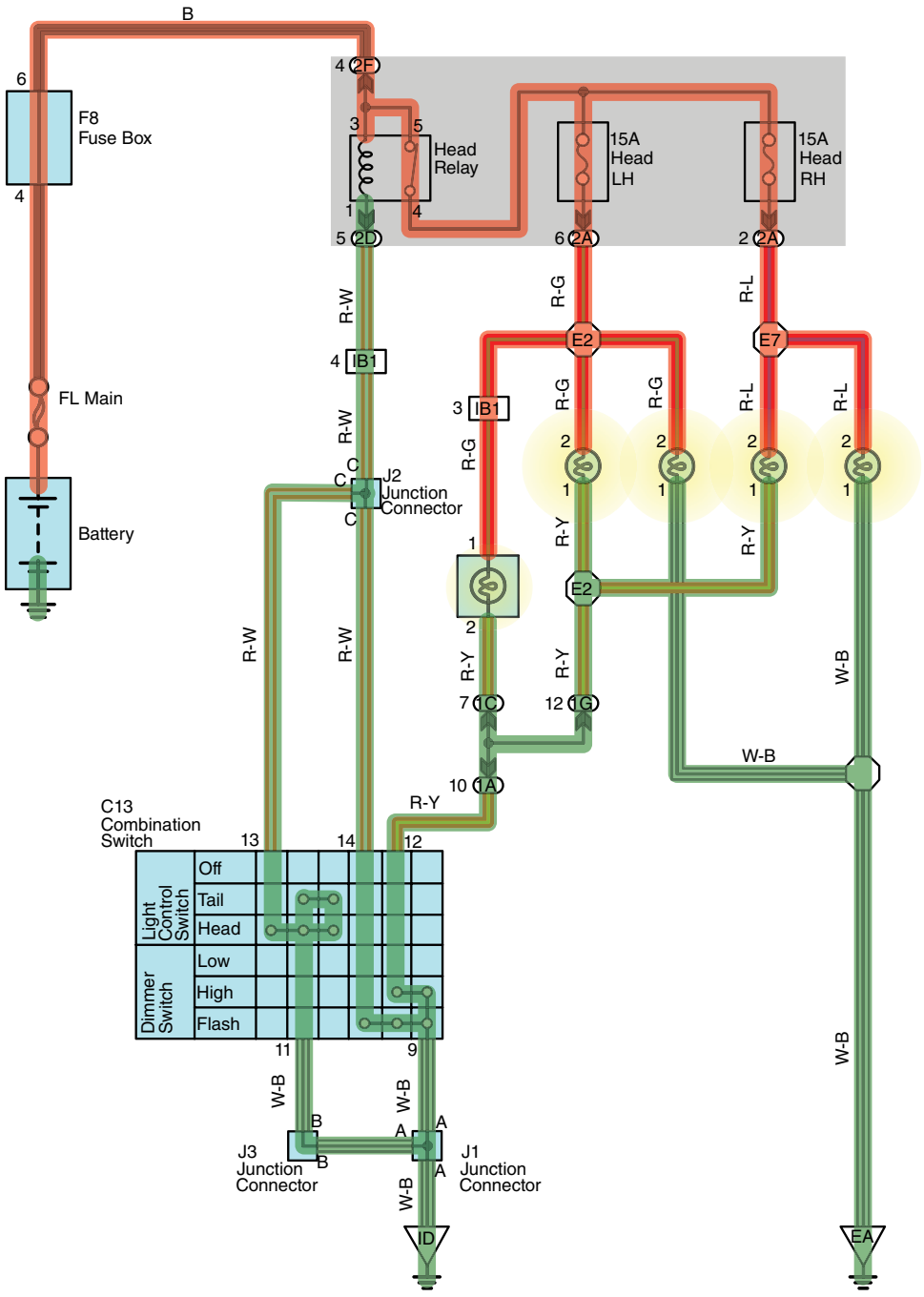


FIGURE 8-29 The high-beam circuit grounds at point ID.

To predict headlight circuit current path and voltage, follow the steps in **SKILL DRILL 8-1**.

SKILL DRILL 8-1 Predicting Headlight Circuit Current Path and Voltage

1. Obtain the headlight wiring diagram for the vehicle assigned by your instructor.
2. Trace the current paths for low beam and high beam using different colored highlighters to indicate source voltage, the load, and ground voltage.
3. Predict the available voltage at critical test points in the circuit. For example, the voltage at the headlights, the relay, and the switch.
4. Review your work with your instructor.

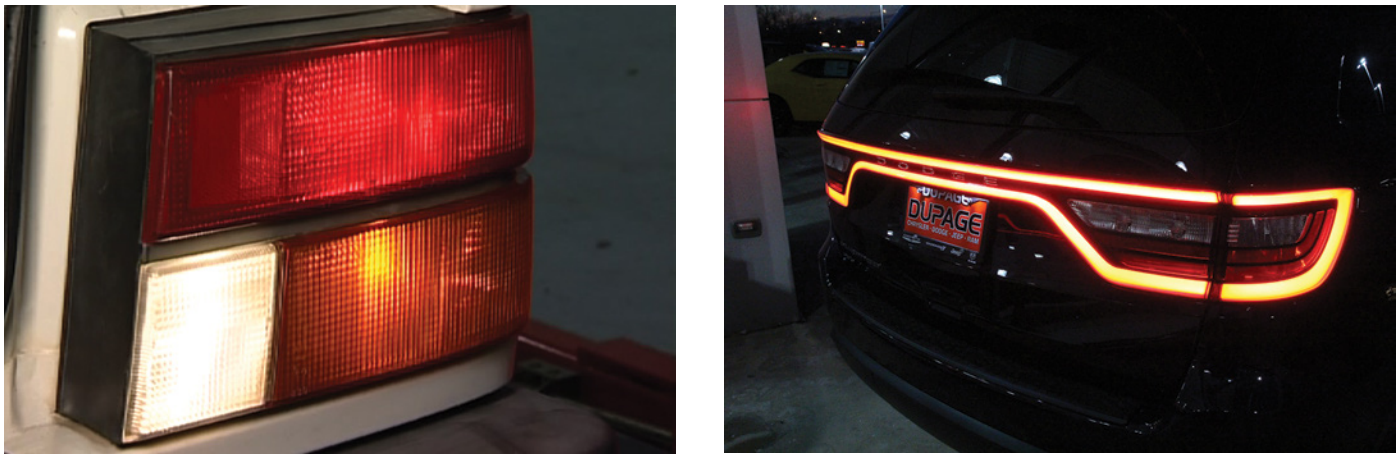


FIGURE 8-30 Taillights may be very simple or an integral part of the vehicle design.

Taillights and Running Lights

The taillights are located at the back of the vehicle, and running lights (sometimes called side marker lights) are located on the side of the vehicle. The taillights may be as simple as one bulb per vehicle side inside a red lens or they may be much more elaborate with multiple bulbs or LEDs which become a design element for the vehicle (**FIGURE 8-30**).

Running lights are located on the side of the vehicle. They may be a separate lens or integral to the headlight and taillight assemblies. Many vehicles now incorporate running lights on the front fender or in the rearview mirrors. Lights or LEDs are used to illuminate the rear license plate when the running lights are on (**FIGURE 8-31**).

The taillight and running light circuit is usually separate from the headlight circuit, though some older vehicles only use one master wiring diagram for the lighting circuit. Notice in the sample diagram shown that it appears there are two headlight switches. This is not the case; there is a notation that refers to the applicable vehicle trim level (DX/LX or EX in this case). This is very common on wiring diagrams, so be sure read any footnotes or callouts for this type of information before doing your circuit tracing and voltage predicting. We will focus on the DX/LX portion of the diagram. The headlight switch controls the taillights and running lights. These lights are turned on in the Park and Head switch positions. The headlight switch provides source voltage to the all the lights in the circuit (**FIGURE 8-32**).

The headlight switch for this taillight and running light circuit controls source voltage to the lights (**FIGURE 8-33**). Source voltage is supplied to all the bulbs and the grounds

FIGURE 8-31 Running lights.

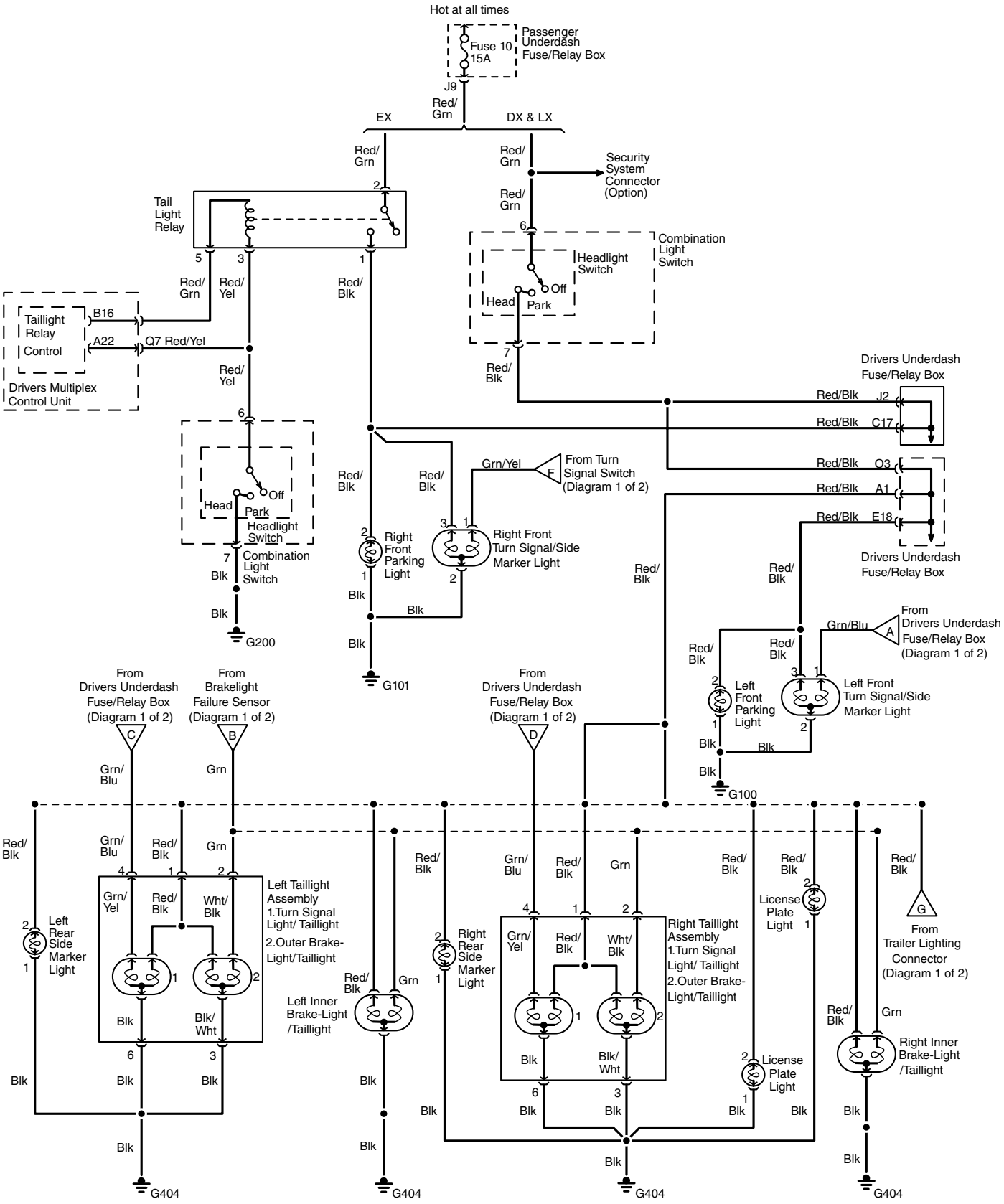


FIGURE 8-32 The taillights, running lights, and license plate lights are controlled with the headlight switch.

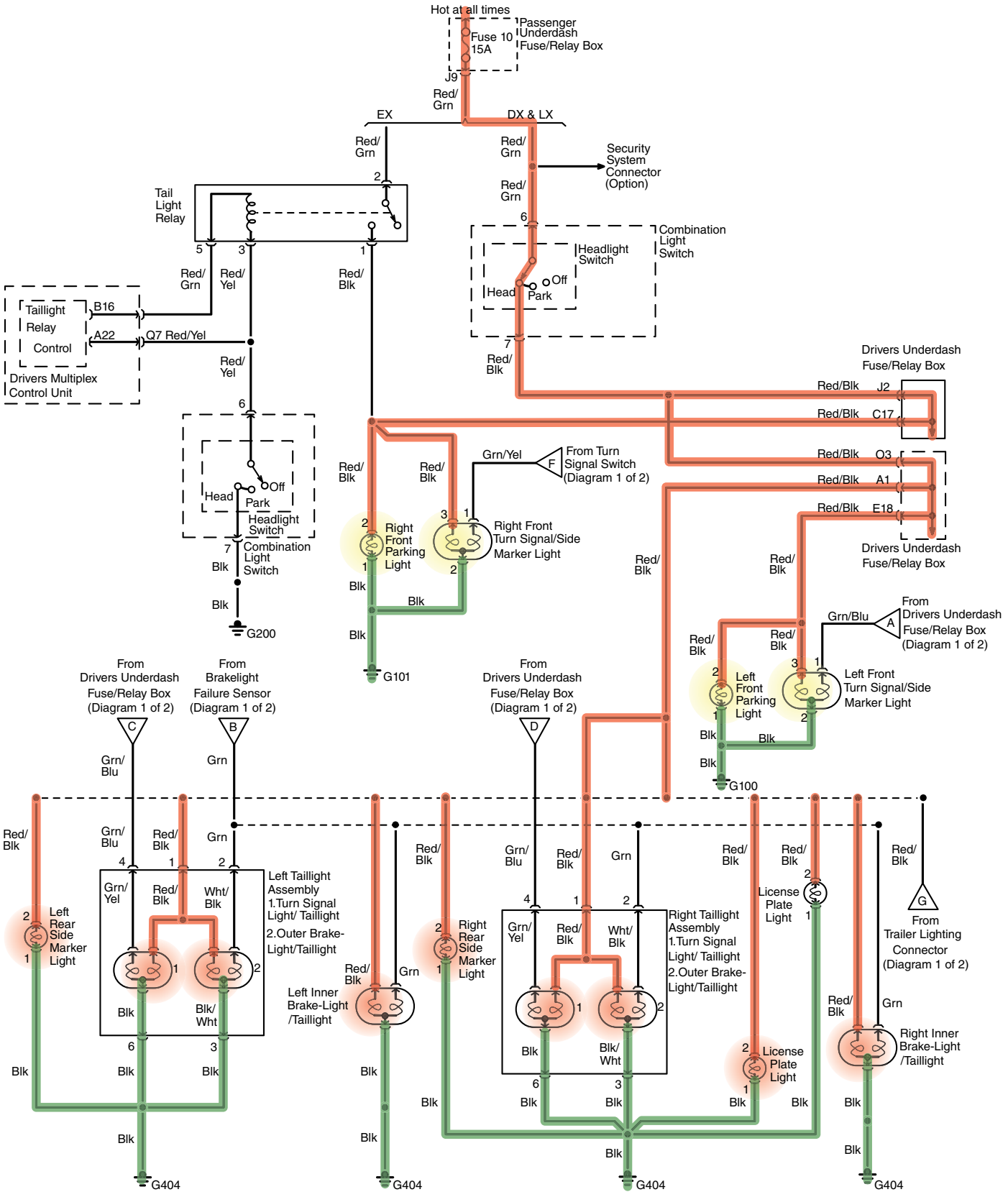


FIGURE 8-33 The headlight switch in this circuit controls source voltage to the taillights and running lights.

FIGURE 8-34 Stop lights and back-up lights may use incandescent or LED lamps.

as noted by their numerical identifier. Several lamps connect to the same ground point (G404). Note that several bulbs have dual filaments. One filament is for the taillight, and the other may be for the stop light or the turn signal as noted on the wiring diagram.

Stop Lights and Back-Up Lights

The stop or brake lights illuminate when the brake pedal is pressed to apply the brakes (**FIGURE 8-34**). Since 1986, all passenger vehicles must have a center high mounted stop lamp (CHMSL)—all vehicles now use them, including pickup trucks and vans. The back-up lights illuminate when the transmission is in reverse. These lights serve a dual purpose: they let others know the vehicle is going to back up and they help light up the area behind the vehicle to assist the driver's vision as the vehicle moves in reverse when it is dark out. Both of these lighting systems use a stop light back-up light switch that usually controls source voltage to the lamps. Most recent vehicles use a switch that is an input to a body ECU (those systems are covered in greater detail in the Electronic Components and ECU-Controlled Body Electrical Circuit Diagnosis chapters).

The back-up light circuit in our sample wiring diagram is a source-controlled circuit, with the back-up light (lamp) switch on the source side of the circuit loads. Note that this particular vehicle may be equipped with a manual or automatic transmission so each switch type is shown on the diagram (**FIGURE 8-35**). Also, remember that switches are shown in their "at rest" position on the wiring diagram. The technician has traced the current paths as if the transmission is in reverse.

The back-up light switch is usually integrated with the neutral-safety switch and mounted on the transmission or transaxle as part of the shift lever assembly for automatic transmissions (**FIGURE 8-36**). The switch assembly usually incorporates an adjustment to ensure the back-up lights turn on only when in reverse and that the Park/Neutral switch functions for the starter circuit.

Manual transmissions usually use a switch that a plunger pushes on when the transmission is shifted into reverse (**FIGURE 8-37**). The plunger moves the switch contact into the on position to turn on the back-up lights. On some transmissions the switch may be adjustable.

The stop light circuit is also a source-controlled circuit (**FIGURE 8-38**). The stop light switch provides source voltage to the brake lamps when the brake pedal is pressed.

The stop light switch for most vehicles uses normally open switch contacts. The stop light switch is mounted above the brake pedal pad and on some older vehicles may have an adjustment so the brake lights only turn on when the brake pedal is pressed during braking and the switch contacts close (**FIGURE 8-39**). The adjustment is usually made by moving the switch closer or farther away from the switch activating pad. This switch uses a threaded shaft that allows it to move closer or farther from the pad. Once it is adjusted, the locknuts are tightened so the adjustment does not change.

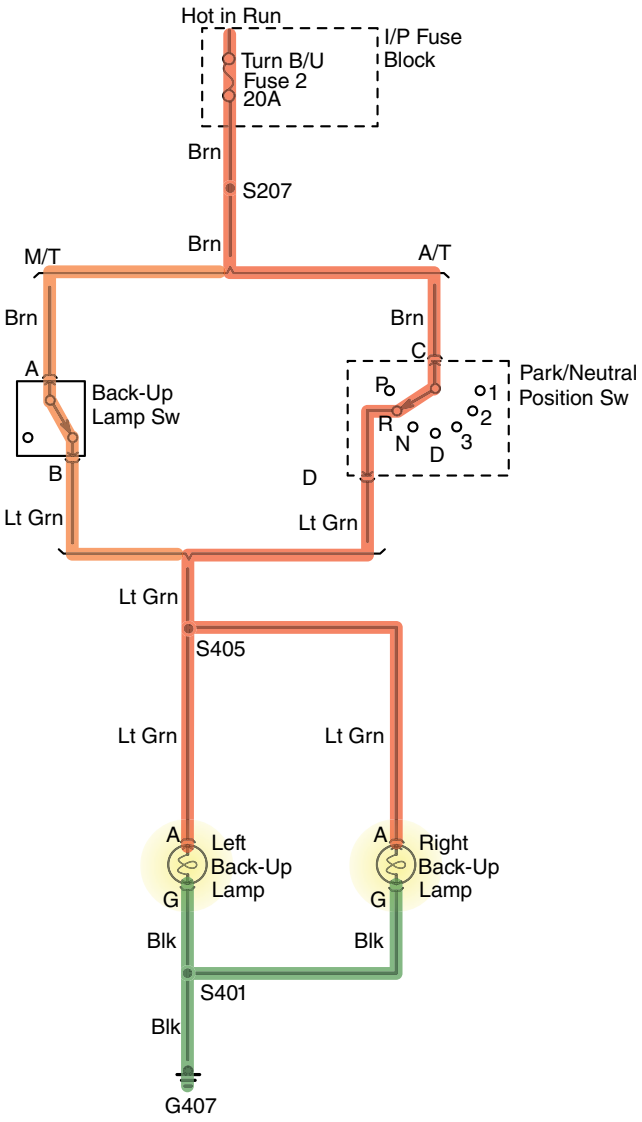


FIGURE 8-35 The back-up light circuit may show two switches, one is for an automatic transmission (A/T) and the other is for a manual transmission (M/T) equipped vehicle.

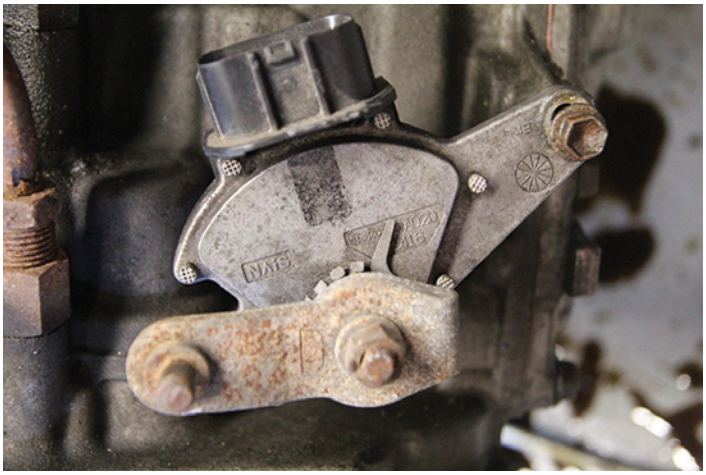


FIGURE 8-36 Most back-up light switch contacts are part of the transmission neutral-safety switch assembly and mount on the transmission or transaxle.

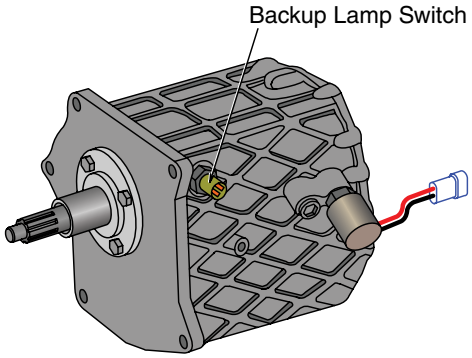


FIGURE 8-37 Manual transmissions often use a mechanical switch that is operated when the shift mechanism is moved to the reverse position.

Turn Signals

Turn signals alert traffic of a driver's intention to turn left or right or change lanes. The turn signal lights may use incandescent bulbs or LEDs. The turn signal lights are located at the front and rear of the vehicle and on some vehicles flash the side marker lights.

A switch on the steering column activates the turn signal left or right circuit. The turn signal switch in the sample circuit shown controls the current path to the left or the right lights (**FIGURE 8-40**). Source voltage comes from the turn signal fuse to the hazard switch; in the off position, source voltage is present at the flasher relay. The flasher relay is what turns the lights on and off repeatedly. Source voltage is present from the flasher relay pin 1 to turn signal switch pin 2. Moving the turn signal switch to the left-hand position connects source voltage to pin 1 of the turn signal switch, and the green wire with the black trace (G-B) provides the path through the junction connector to all the related left-hand turn signal lights. Moving the turn signal switch to the right-hand position connects pin 2 to pin 3 of the turn signal switch, and it provides source voltage through the green wire with the yellow trace (G-Y) to the junction connector for the right-hand turn signal lights. The flasher relay uses an electronic switch circuit that incorporates a transistor to flash the turn

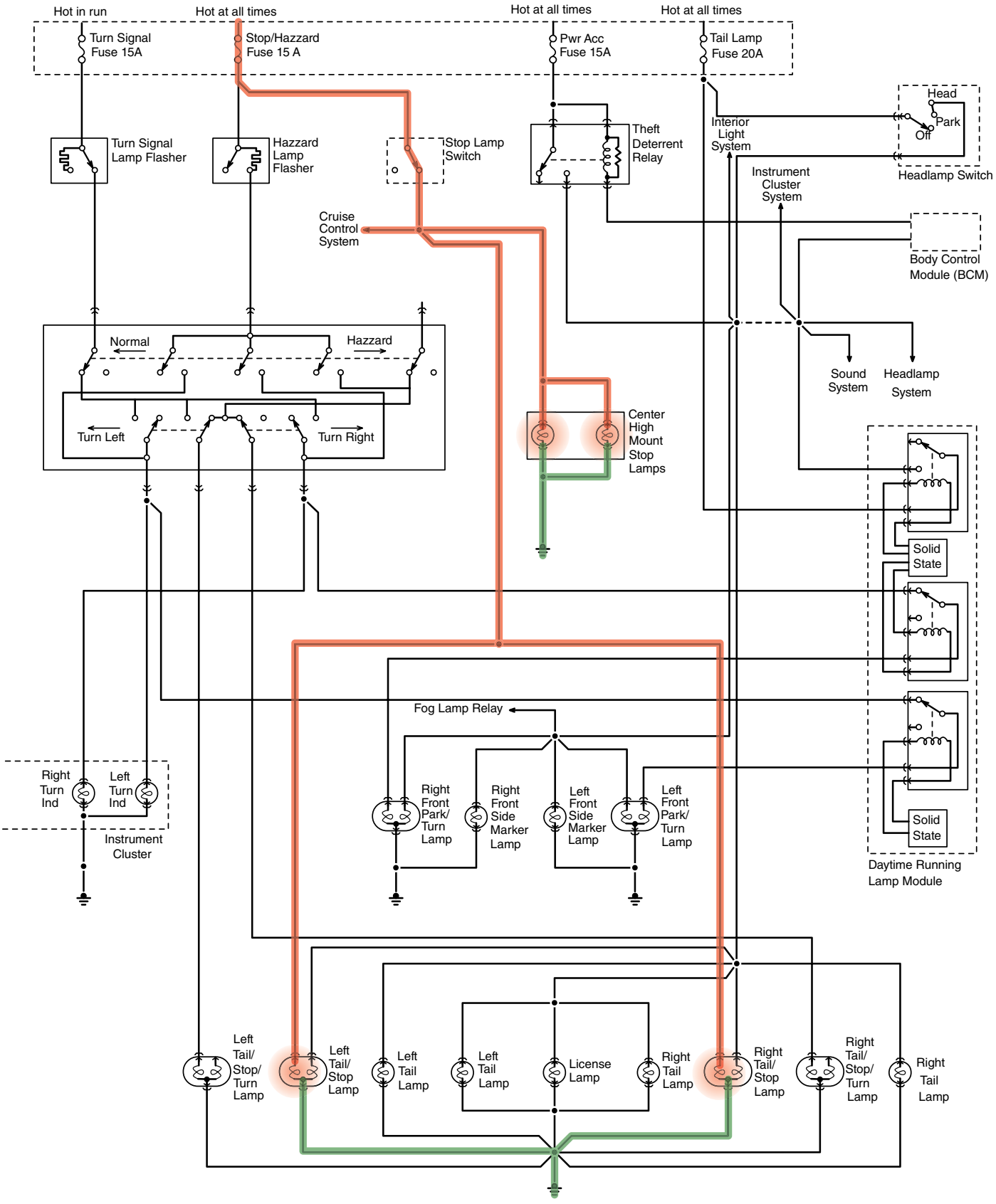


FIGURE 8-38 The stop light circuit supplies source voltage to the stop lamps in this circuit.

FIGURE 8-39 The brake light switch mounts near the top of the brake pedal.

signal lights on and off. The flasher relay circuit can also detect a change in current draw if one or more bulbs are not working. It then flashes the lights at a much faster rate to alert the driver that the turn signal lights should be checked. Some vehicles may also alert the driver with a warning indicator or an alert that displays in the instrument cluster message center. The hazard switch connects pin 4 of its connector to pins 1 and 2 to flash the left and right turn signal lights at the same time when it is turned on.

Other Light Circuits

Other lighting circuits include the interior lights, the trunk light, and puddle lights located on the outside mirrors. These lighting circuits on older vehicles use a door switch or trunk/hatch switch, located in the latch mechanism, to turn the lights on and off. Most new vehicles use the body ECU for light operation, with the switch being an input to the ECU (these circuits are covered in the ECU-Controlled Body Electrical Circuit Diagnosis chapter), and many of the interior lights are now LEDs rather than incandescent lamps.

The instrument cluster and many of the interior control switches are illuminated for viewing when it is dark outside. The instrument cluster and control switch lamps in most modern vehicles use LED lights, and on some vehicles the color of the LEDs can be selected by the driver. The instrument panel dimmer control may be integral to the headlight switch assembly or a separate unit. The brightness control may be a variable resistor called a potentiometer or, for most new vehicles, a control that modulates the voltage to the instrument cluster and other related control lamps or LEDs (**FIGURE 8-41**).

Puddle lights on the mirrors may be incandescent or LED. Many new vehicles project an image on the ground, like a logo or the vehicle name or brand (**FIGURE 8-42**). These are also available as an aftermarket accessory.

▶ Diagnosing Lighting System Faults

K08004 Explain the diagnostic process for lighting system circuit faults.

S08002 Apply the diagnostic process to isolate the cause of lighting system concerns based on circuit and component test results.

Lighting system diagnosis relies on you using the diagnostic process, related service information, and your system knowledge. Non-ECU-controlled lighting circuits use a very direct diagnostic approach. Your visual observation of which lights, if any, function and which ones do not, in conjunction with the wiring diagram, allows you to focus on the area of the circuit that is not working. For example, if no lights turn on, then you will focus on wiring and components that are common to all the lights in the circuit, like a fuse, ground, or control switch. If some of the lights work, you know the fuse and switch are OK and you can focus on a wire, junction connector, or the light itself in that part of the circuit. LED and HID lighting components often require you follow a diagnostic flowchart to determine why they are not working. Note that HIDs and some LED lights use voltage step-up transformers and other components that require you to follow the service procedures exactly to avoid damaging components or

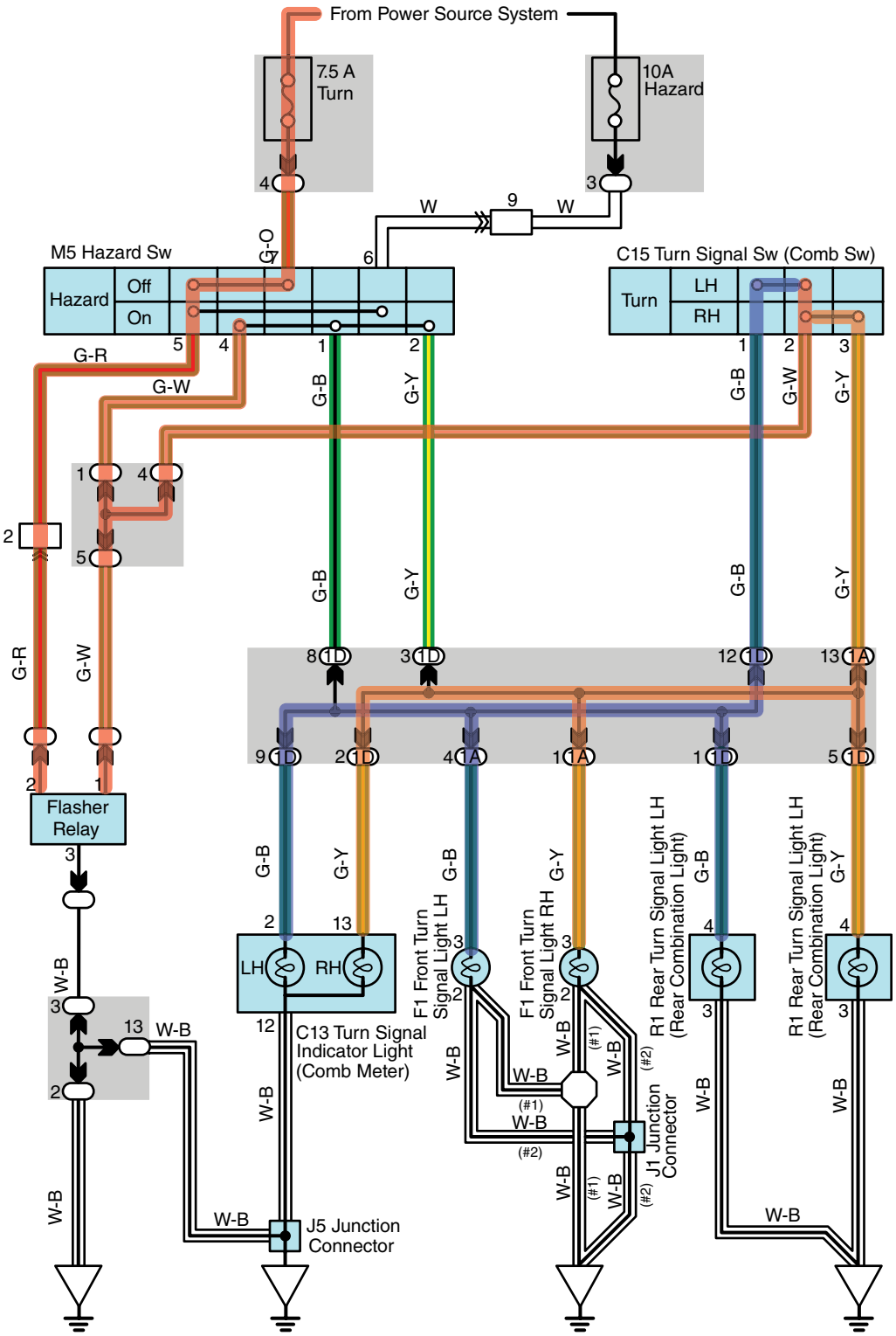


FIGURE 8-40 The turn signal circuit uses a switch to activate the left or right turn signals.

being injured by the higher voltage. An incandescent bulb with two filaments that touch and create a shared voltage fault can present a challenging lighting system diagnosis. This situation may present itself as a concern about the brake lights coming on when the running lights are on and vice versa. Carefully check each dual-filament bulb and, if they are all OK, check

FIGURE 8-41 Instrument panel dimmer switch.

FIGURE 8-42 Puddle lights on many vehicles project an image on the ground.

the bulb sockets and related wiring. This condition can also occur if the wrong lamp type is forced into the socket and the contacts short together through the contacts on the bulb.

Dual filament bulbs can also create a voltage feedback situation (as discussed in the Relays chapter). An open on the ground circuit for one of the bulbs allows current to feedback through the other filament in the bulb and turn on other related lighting, though often at lower-than-normal levels. The key symptom of this fault is that when the stop light, turn signal, or parking lights are turned on, the other related lights also illuminate. After preparing the related wiring diagram(s), part of circuit testing where feedback voltage is suspected includes verifying that all paths to ground are OK using a voltage drop test. It may help to isolate which area of the circuit is causing the concern by removing the lights that have dual filaments one at a time. The area of the circuit fault will be indicated when the feedback voltage is gone and the lights that should be off are no longer illuminated. You can then look for the open ground that is related to that light bulb.

Parasitic draw concerns can occur when a compartment light does not turn off, such as the glove compartment, trunk, or underhood light. When diagnosing a parasitic draw concern related to lighting circuits, disconnect components one at a time to isolate the cause of the draw. Following the diagnostic process along with your knowledge ensures you correct the concern the first time every time.

Wrap-Up

Ready for Review

- Incandescent lamps consist of one or more filaments which heat up until they glow and emit light.
- Halogen lamps are much brighter than incandescent types and use about the same amount of energy but they operate at much higher temperatures.
- High-intensity discharge (HID) lights use an arc rather than a filament.
- Light-emitting diodes have been used for several years and are quickly becoming as common as incandescent lights were just a few years ago. LEDs have the advantage of illuminating the instant they are turned on.
- Different lighting technologies are often packaged together in the same housing to form smart lighting systems.
- Lighting system diagnosis relies on the diagnostic process and use of the related wiring diagram. Trace current paths and predict lighting system voltages before you begin your circuit testing.
- Replace lighting components with the correct part. Use of the wrong bulb or other component can cause erratic or no operation.

Key Terms

ballast A device that increase lighting voltage substantially and controls the current to the bulb.

halogen lamp A type of bulb that produces a bright white light.

high-intensity discharge (HID) A type of lighting that produces light with an electric arc rather than a glowing filament.

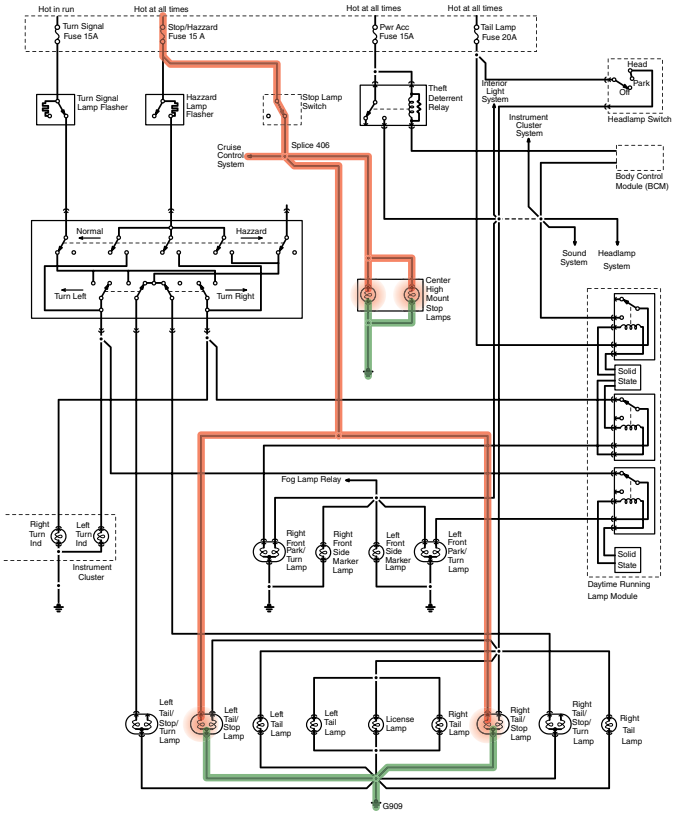
incandescent lamp The traditional bulb that uses a heated filament to produce light.

light-emitting diode (LED) A type of lighting used in various automotive applications, such as warning indicators and alphanumeric displays.

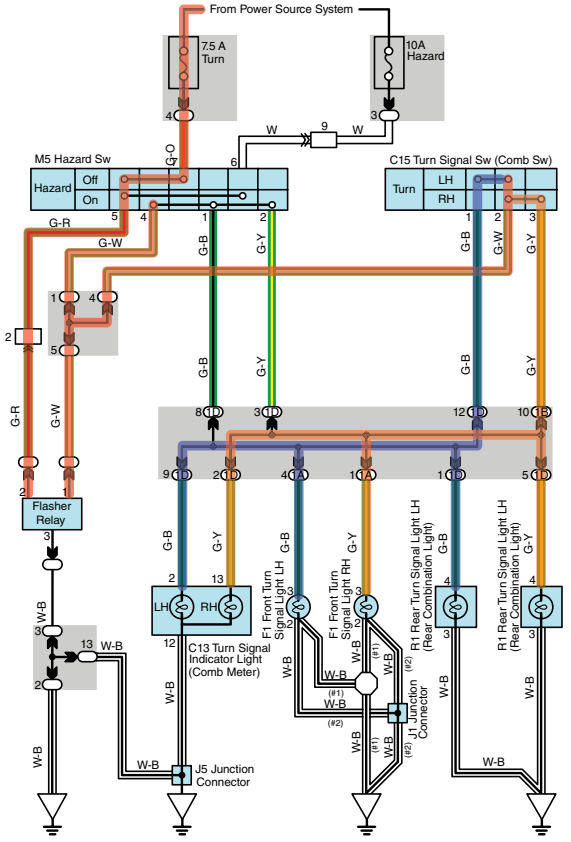
puddle lights Used to illuminate the area around the entry doors to make entry safer from objects or pooled water on the ground. The light usually comes from the outside rearview mirror assembly and may be in the form of an image or logo.

Review Questions

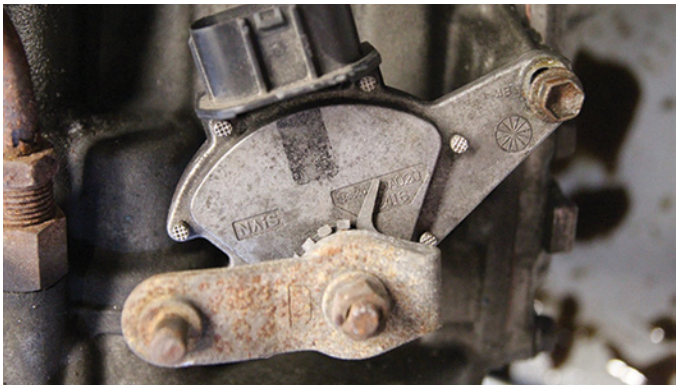
1. Stop light circuits usually have use a switch that features which of the following:
   - **a.** No adjustment
   - **b.** Located on the source side of the load
   - **c.** Controls the path to ground in the circuit
   - **d.** Features normally closed contacts
2. The center high mounted stop light functions but the left and right stop lights do not. Which of the following would most likely cause this concern:
   - **a.** Open brake light switch
   - **b.** Open at ground G909
   - **c.** Open at splice 406
   - **d.** Both stop light filaments have failed



3. The right turn signal bulbs do not operate when using the turn signal switch but do operate when the hazard switch is used. The left-hand turn signals work normally. Which of the following could cause this concern?
   - **a.** Open at ground BJ
   - **b.** High resistance in the wire between turn signal switch pin 3 and the junction connector (pin 10 of 1B)
   - **c.** Right front turn signal bulb is burned out
   - **d.** Blown 7.5A turn signal fuse



4. The component shown controls which of the following?
   - **a.** Transmission gear selection
   - **b.** Back-up light ground circuit
   - **c.** Back-up light switch
   - **d.** Allows the starter to function only when in a selected gear range of Reverse or Drive

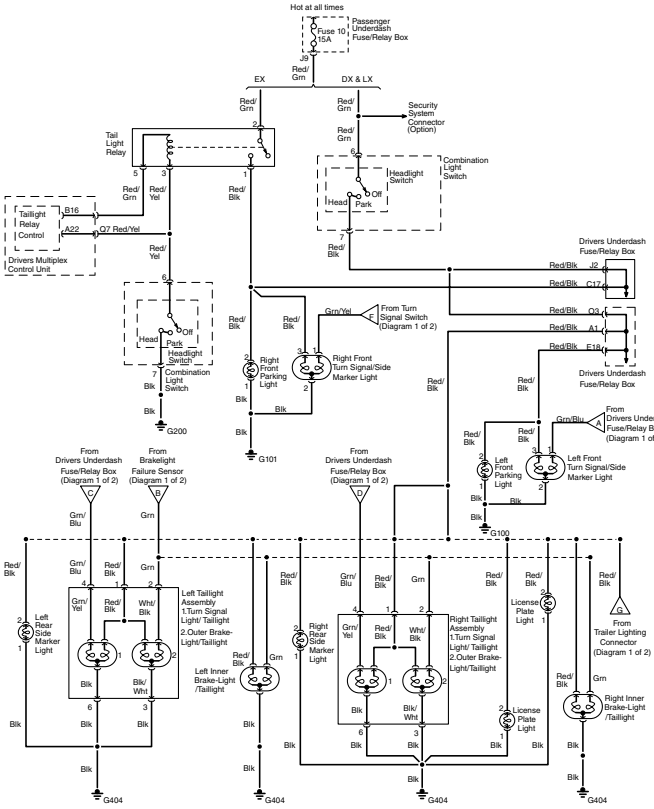


5. Choose the correct statement with respect to high-intensity discharge lamps.
   a. The ballast reduces the voltage to the bulb.
   b. The ballast increases the voltage and regulates the current.
   c. HID headlamp bulbs run on low voltage direct current.
   d. They produce lesser glare when compared to halogen lamps.
6. All of the following statements with respect to LEDs are true *except*:
   a. LEDs have good visibility in inclement weather.
   b. They have a voltage drop of 1.2 to 3.5 volts.
   c. They are usually connected in parallel strings.
   d. They consume less energy.
7. Dual-filament bulbs have two filaments of different wattage. They work well as a combination:
   a. warning lamp and headlamp.
   b. turn indicator and stop light.
   c. warning light and taillight.
   d. taillight and brake light.
8. Which of the following lights are usually controlled by the vehicle body computer with inputs from ignition and door switches?
   a. Headlights
   b. Warning lights
   c. Courtesy lights
   d. Brake lights
9. All of the following statements with respect to back-up lights are true *except*:
   a. They are controlled using network/bus systems.
   b. They operate when the vehicle is in reverse gear.
   c. They provide the driver with vision behind the vehicle.
   d. They work even when the ignition is not on.
10. It is very important to use bulbs of the proper wattage on all types of flasher units. If incorrect bulbs are used, the:
    a. flash may not appear.
    b. speed of the flash may be incorrect.
    c. bulbs will burn out quickly.
    d. bulbs will consume too much energy.

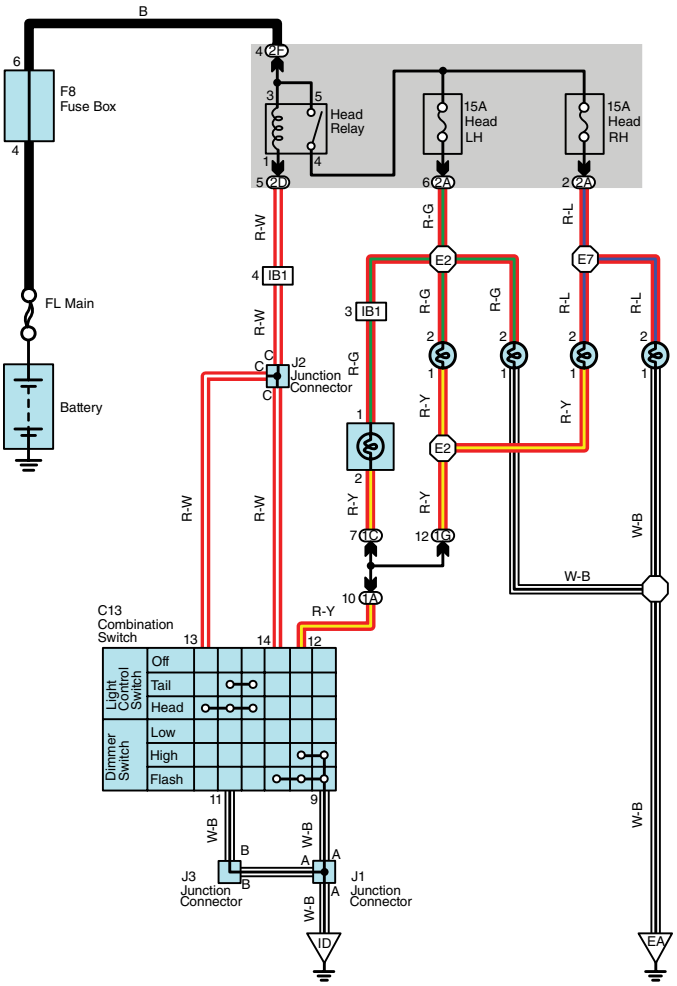
ASE Technician A/Technician B Style Questions

1. Tech A says individual LEDs can be replaced in an LED taillight array. Tech B says HID headlights require a ballast to step up the voltage to create an arc inside the lamp assembly. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says the turn signal switch usually mounts to the steering column. Tech B says a dual-filament bulb can cause a short to voltage concern if the filaments short together. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says you can test if the EX combination light switch may be at fault by using a fused jumper lead to ground at combination light switch pin 7. Tech B says the LX combination light switch controls source voltage in the circuit. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

This diagram is for questions 3–4.



4. The LX left and right rear taillights do not illuminate. All other taillights and running lights are OK. Tech A says this could be caused by an open at ground 404. Tech B says this may be caused by an open at pin 6 of the left rear taillight. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. The customer states the right-hand headlight is very dim (low light output). Tech A says the 10 amp right headlight fuse may have failed. Tech B says there may be high resistance at ground EA. Who is correct?
   a. Tech A
   b. Tech B



c. Both A and B
d. Neither A nor B

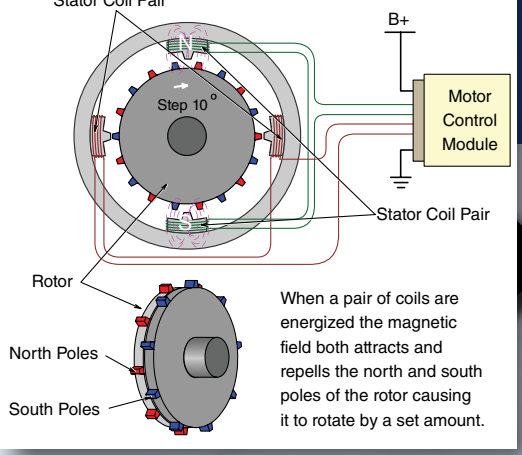
6. The stop lights on a vehicle do not operate. Tech A says there should be source voltage at one pin of the stop light switch at all times. Tech B uses a pedal depressor to apply and hold the brake pedal so the stop light switch is in the ON position. There should now be a very low voltage drop across the stop light switch contacts, usually less than 0.5V. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

7. Tech A says most HID headlights use a replaceable bulb, similar to a halogen type headlight. Tech B says it is ok to measure voltage at an HID headlight assembly as they operate at source voltage. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

8. An older vehicle with non-ECU-controlled lighting has operating low beam headlights but the high beams do not operate. Tech A says the headlight dimmer switch may be at fault. Tech B says one high beam headlight may be at fault since the high beams are connected in a series circuit. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

9. Tech A says the back-up lights use a switch that is often integrated with the neutral-safety switch on an automatic transmission. Tech B says this switch usually has provisions for adjustment. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

10. An LED is not illuminating in the left taillight array of a vehicle. Tech A says the LED can be replaced just like an incandescent bulb. Tech B says LED light diagnosis often requires use of high voltage gloves during circuit testing. Who is correct?
a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B



CHAPTER 9

Diagnosing Motor Circuits

NATEF Tasks

- **N09001** 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, back-up camera, park assist, cruise control, and auto dimming headlamps); determine needed repairs. (AST/MAST)

Knowledge Objectives

After reading this chapter, you will be able to:

- **K09001** Identify motor types used in vehicle circuits.
- **K09002** Describe the various types of body electrical motor circuits.

Skills Objectives

After reading this chapter, you will be able to:

- **S09001** Test electromagnetic DC motor circuits.
- **S09002** Test DC stepper motor circuits.

You Are the Automotive Technician

The customer states the right mirror does not move up/down but does move left and right. The technician verifies the concern and checks the left mirror and it moves up/down and left/right. From the verification of the concern answer the following:

1. Can any circuit components be eliminated as the cause of the fault?
2. What components may be causing this fault?
3. What type of circuit tests would you use to isolate the cause of this fault?

▶ Introduction

Motor circuits are found in several body electrical circuits including the HVAC blower motor, vent/blend air/intake air door motors, power windows, power door locks, power seats, power mirrors, and wiper system. Automotive circuits most often use DC electro-magnet motors. Stepper motors are also used in some circuits. The motor circuits covered in this chapter offer an opportunity to identify the type of motor in the circuit, practice use of the motor circuit wiring diagram, apply the diagnostic process, perform circuit tests, and isolate the cause of motor system circuit faults.

▶ Direct Current Automotive Electric Motors

K09001 Identify motor types used in vehicle circuits.

Electric motors are used for many body electrical system functions (**FIGURE 9-1**). Some are in systems that have been on vehicles for many years including windshield wipers, blower motors, power windows, and power seat adjusters. Motors are also being used in systems that were once mechanical in nature (e.g., electric power steering) or to perform functions the customer often did for themselves (e.g., opening and closing the sliding doors or opening and closing the deck lid (trunk) or rear hatch). Motors are found in the engine control system to pump fuel from the tank to the engine and in the brake system to increase brake fluid pressure inside the vehicle stability control hydraulic unit. This text will focus on motors used in vehicle body electrical systems.

Rotating DC Electromagnetic Motor Operation

Most of the motors in body electrical circuits are DC motors. The motor functions using opposing magnetic fields between the rotor and the **stator**. These terms should be familiar to you from your understanding of automotive alternator and starter operation. The **rotor** is the part of the motor that rotates and ultimately does the work in the system, rotating the fan to move air through the ventilation system for example. The rotor, like a relay coil, has segments wound with copper wire. The many segments of the rotor are divided so that one end of the wire winding is connected to positive and one is connected to negative. Remember that current through a coil of wire creates a strong magnetic field with a north pole and a south pole. Current also passes through the stator **field windings**, and these windings surround an iron pole shoe so it can become magnetized. The field windings also form north and south poles. The rotor is segmented so that the polarity in each rotor segment creates a magnetic field that will be opposite in polarity to one set of field windings and the same polarity as the other set.

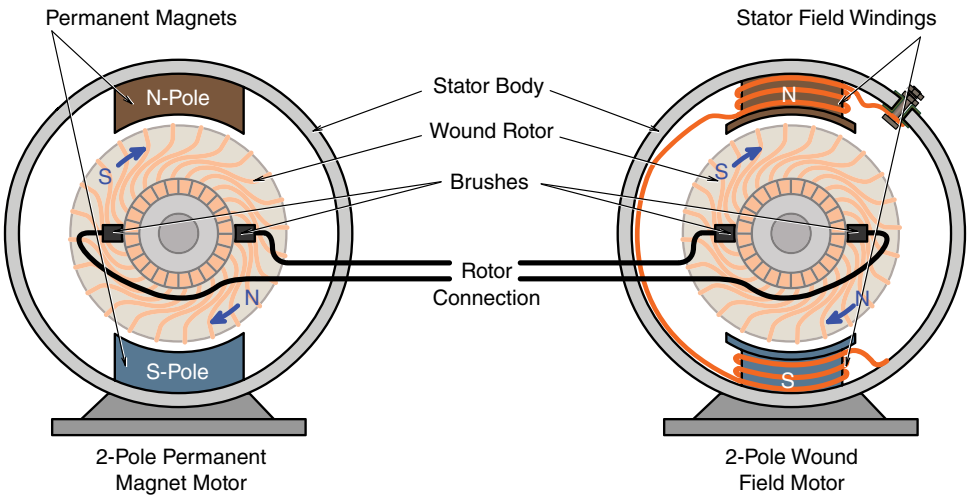


FIGURE 9-1 Electromagnetic motors are used to perform many automotive body electrical functions, from door locks and power window operation to proving air circulation through the air conditioning system.

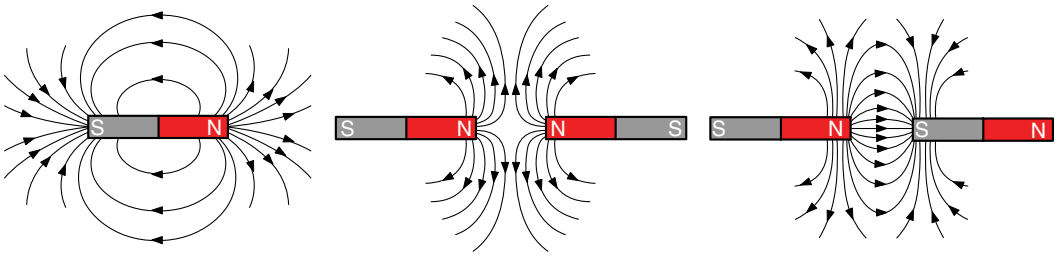


FIGURE 9-2 DC electromagnetic motors use attracting and repelling forces to create movement of the rotor. The rotor is often called an **armature**.

Remember, the opposite poles of two magnets attract and the same poles repel (**FIGURE 9-2**). This attraction and repelling creates the forces required to spin the rotor. The rotor segments keep the orientation of the magnetic fields maximized so the rotor keeps spinning as long as the circuit is on. The armature contacts brushes that are connected to the positive and negative sides of the circuit. The armature segments are energized as they contact the brushes in sequence. This is what creates the rotational forces necessary to move the armature. The size of the rotor and related armature windings, and the size of the field windings and pole shoes, affect the speed and torque of the motor. DC motors have very little measurable resistance when at rest and measured with a DMM (**FIGURE 9-3**). Motor resistance is created by magnetic forces that are created in the armature and field windings. These forces are opposite in polarity to the current present in the circuit and oppose current through the armature and field windings. Circuit current is stronger than the opposing magnetic forces. Also, these opposing magnetic fields are weak when the motor is stationary or at very low speeds and grow stronger as the motor reaches operating speed. This is why a stalled (nonrotating motor) can cause circuit breakers to open or blow a circuit fuse.

DC motors may also use **permanent magnets** instead of field windings (**FIGURE 9-4**). This simplifies design since there is no need for field windings, so it allows for a smaller and lighter motor design that is now commonly used to operate power accessories in vehicles.

DC Stepper Motor Operation

Stepper motors differ from constantly rotating DC motors in design and operation (**FIGURE 9-5**). A stepper motor is used to precisely control position. The rotor in a stepper motor is made up of many teeth. Several field windings are used around the rotor. An

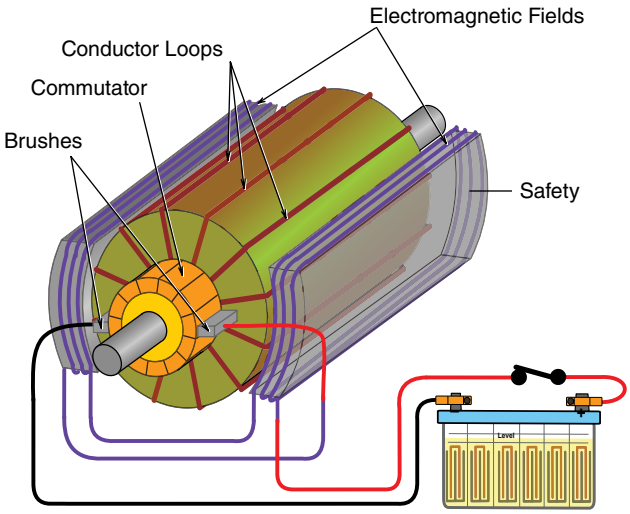


FIGURE 9-3 A field winding type motor.

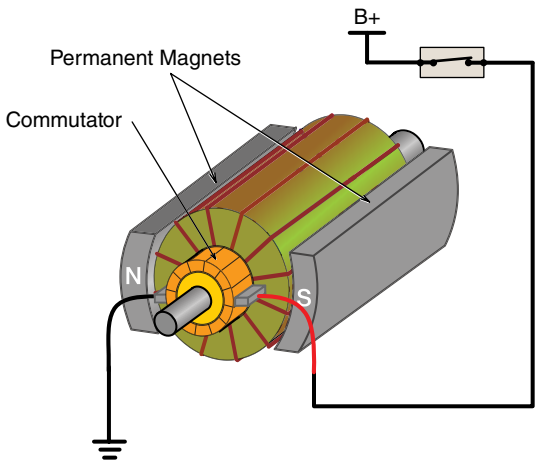


FIGURE 9-4 A permanent magnet type motor.

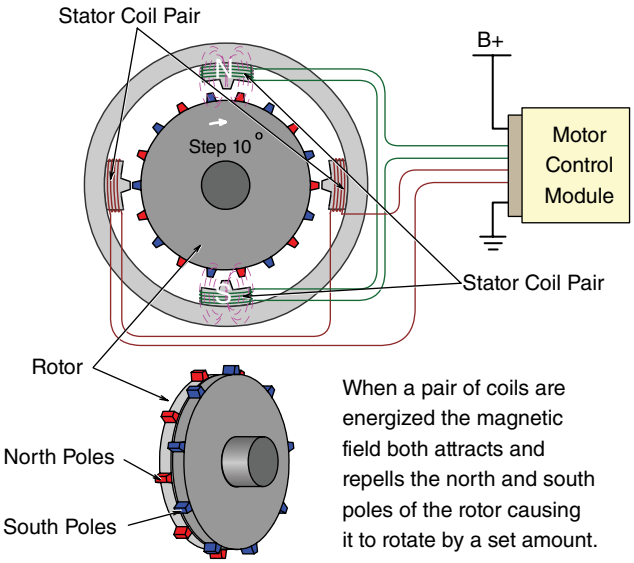


FIGURE 9-5 A stepper motor uses multiple coils operated in sequence to move the motor in steps.

electronic control unit (ECU) controls the field windings using DC voltage pulses in sequence to each field coil to step the rotor around them. Once the desired position is reached, the ECU continues to supply a small amount of current to hold the motor in position. The ECU circuit can reverse the polarity of the field coils so it can move the rotor in the opposite direction. Some stepper motor circuits must do a reset to learn the position of the rotor if ECU memory is lost. This may be part of an **initialization** procedure the technician must perform or the system may do it automatically when the system powers up after a memory loss event such as disconnecting the vehicle battery. Vehicles began using stepper motors to control engine idle speed in the early 1980s, but electronic throttle control has eliminated their use for this function. Some HVAC systems use stepper motors to control doors in the duct system that control outlet air temperature and air distribution through the various outlets (defrost, vent, or floor).

DC Servomotor Operation

A **servomotor** is used when there are very specific location requirements for a component, like a temperature blend air door, and the system ECU needs to monitor the exact motor position (**FIGURE 9-6**). The motor rotor uses an encoder to monitor rotor position and provides this data to the ECU that is controlling it. A stepper motor does not send its position data to the ECU, the ECU initializes stepper motor position to a minimum or maximum position to essentially "learn" the min or max position; the ECU can then count up or down to move the motor to the desired position. The encoder in a servomotor allows the ECU to determine where it is even after power shutdown. Very few body electrical circuits use servomotors, though some HVAC systems use them to control the air distribution and temperature doors. Servomotors may be used in electric power steering systems. The electric motors used in hybrid vehicles use servomotor encoders to ensure the motor and the internal combustion engine's power output synchronizes as it is transitioned from the AC motor only to being supplied by both power units. It is also used to create the correct alternating current output when the AC motor generates current for the batteries during regenerative braking.

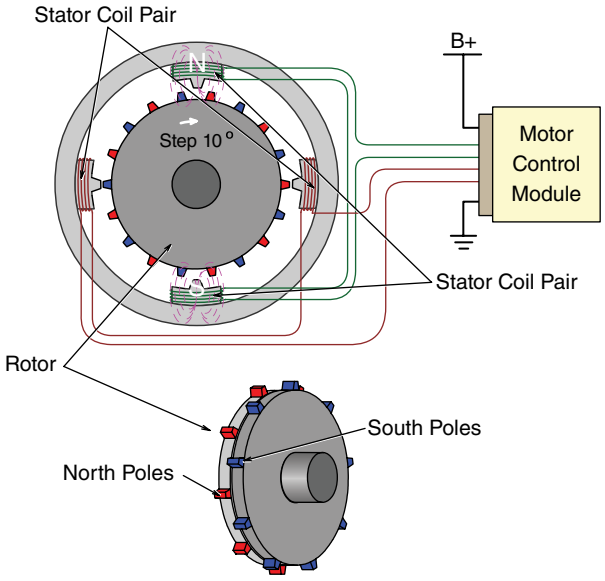


FIGURE 9-6 A servomotor uses an encoder to monitor motor position.

DC Electro-Magnet Motor Test Procedures

S09001 Test electromagnetic DC motor circuits.

DC motor circuit testing relies on application of the diagnostic process as detailed in the Electrical Wiring Diagrams chapter. The following procedure is often used when your diagnostic testing has narrowed focus to the motor used in the circuit. The following test procedure is for motors that operate by having source voltage and ground applied to the motor. DC electro-magnet motors that are operated using an electronic control unit to control the voltage at the motor should not be tested with this method (see the Blower Motor Circuit Diagnosis section for testing an ECU-controlled motor).

DC electro-magnet motor testing requires the use of fused jumper leads. After verifying other circuit components are operating normally, disconnect the wiring harness connector from the motor. Many motors have a dedicated connector, but it is good practice to refer to the wiring diagram to determine motor polarity (which wire has source voltage and which has ground) and if there are any other wires in the connector not related to the motor. Note that some motors have their circuit polarity reversed depending on switch position, to lower or raise the window, for example. When testing, be sure to connect the test leads in the appropriate polarity so the motor can operate. For example, when testing a power lock motor when the door lock is in the unlocked position, connect the jumper leads so the motor polarity will operate the motor to move the lock to the locked position.

Connect one test lead to a power source. You can connect to the battery, a fuse terminal in the junction block, or by accessing power from the related motor source voltage wire in the harness connector.

Verify that the fuse size in the test lead has the same amperage rating as the fuse used for the motor circuit. Do not use a fuse with a higher rating as this could damage other components during testing. Using a fuse with a lower rating may cause the fuse to fail (blow) during your testing. Connect the test lead to the positive side of the motor. Be sure that no conductive part of your test lead touches body ground as this will cause a short circuit and blow the test lead fuse. Connect the other fused test lead to the ground side of the motor. Touch the other end of the test lead to a known good ground. If the motor operates normally, then it is OK. If there is no motor movement, a light tap on the motor housing may allow it to move again. If the motor does move, this may indicate the motor is failing or the related mechanism the motor operates is binding. Verify the mechanism is OK, like the window regulator or door lock components, before condemning the motor. Refer to the service information to ensure that the related mechanism is properly assembled and lubricated and that there are no damaged components. If all is OK, remove the motor and you can bench test it using the same procedure. A motor that still does not work on the bench, is making abnormal noises, or draws too much current (the fuse blows during the bench test) must be replaced.

▶ TECHNICIAN TIP

Some manufacturers do not allow for back probing at harness connectors. Follow the test procedures that are recommended for the vehicle you are diagnosing.

▶ TECHNICIAN TIP

A DC electromagnetic motor can be current tested using an inductive pick up and viewing the signal on a digital storage oscilloscope (DSO). The current signal should be steady and within the range of a known good motor, as there usually are no service specifications for this type of testing. Current that is much higher or lower indicates a failing motor. Current that is very unsteady may indicate a failed open or shorted segment in the armature, worn motor brushes, lubricant has been exhausted, or bushing or motor bearing failure. These faults usually require replacing the motor or having it rebuilt by a specialist if a replacement cannot be obtained. Use of these tools are covered in the Advanced Diagnostic Tools chapter.

DC Stepper Motor Test Procedures

S09002 Test DC stepper motor circuits.

DC stepper motor circuit testing relies on application of the diagnostic process as detailed in the Electrical Wiring Diagrams chapter. The following procedure is often used when your diagnostic testing has narrowed focus to the motor used in the circuit. The following test procedure is for motors that operate by having the source voltage or ground path pulsed on and off by an electronic control unit to move the motor step by step to a specific position.

Stepper motors are usually tested using a scan tool. Follow the service procedures to access the applicable scan tool active test. The active test is used to command the ECU to operate the stepper motor. While testing the motor, you can verify if the motor is receiving a pulsed source voltage (or ground) signal using a DMM to monitor circuit voltage at the motor connector. Verifying there is the correct pulsed signal at the stepper motor indicates that the ECU is OK. Verify circuit connections; if they are OK, the stepper motor could be faulty. If possible, you may be able to remove the motor from its mounting location and perform the active test again. If the motor now operates and moves in commanded steps, the related mechanism the stepper motor operates may be jammed or damaged in some manner. Continue your diagnosis if required to verify the mechanism is OK or needs repair. If all is OK with the mechanism and the stepper motors still does not work, it should be replaced.

▶ Body Electrical Motor Circuits

K09002 Describe the various types of body electrical motor circuits.

N09001 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, back-up camera, park assist, cruise control, and auto dimming headlamps); determine needed repairs. (AST/MAST)

Wiper System Operation

The most common vehicle wiper system consists of a single motor driving a set of wiper links which move the wipers (**FIGURE 9-7**). The motor rotates in the same direction when the wiper circuit is turned on (**FIGURE 9-8**). The motor turns a gear drive that connects to an output arm (**FIGURE 9-9**). The output arm connects to the wiper arm linkage to move the wipers up and down across the windshield.

Some wiper systems use an articulated arm to help the wiper blade reach a greater portion of the windshield (**FIGURE 9-10**). The auxiliary arm is attached to a pivot point near the main arm mounting point.

Single-motor wiper motor systems usually incorporate a mechanical switch to park the wipers at the bottom of the windshield when the driver turns them off. Most circuits just stop working when turned off, but if the wipers did that, they would most likely stop in the middle of the windshield partially blocking the view of the road ahead. A wiper **park switch** is located on the wiper output shaft and operated by a cam to close the switch contacts when the wipers are not in the park position. This switch connects the wiper motor to power at low speed after the wiper switch is turned off. The wiper motor continues to operate at low speed to park the wiper arms and blades at the bottom of the windshield. At this point the cam opens the switch to power for the motor and it stops (**FIGURE 9-11**).

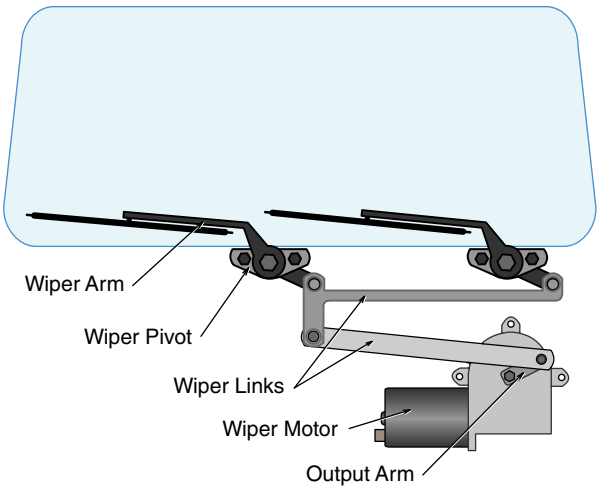


FIGURE 9-7 The wiper motor rotates an arm that connects to the wiper linkage. The linkage connects to the wiper pivots to move the wipers up and across the windshield and then back down in an arc motion.

Mercedes has developed a system for some of its vehicles that uses one wiper blade to clear the windshield (**FIGURE 9-12**). This system uses a motor and a wiper connected to a series of linked arms and a wiper arm on a track to move the wiper arm in an almost 180 degree arc across the windshield (**FIGURE 9-13**).

Recently vehicles have been moving away from the one-motor wiper system and using a two-motor system (**FIGURE 9-14**). This requires synchronizing the motors so the wipers do not interfere with each other as they move across the windshield. The synchronization is accomplished by using a position sensing system on each wiper drive gear (not a servomotor with an encoder) as inputs to the body ECU. This type of system requires initialization after the wiper motor, body ECU, or battery is serviced. The initialization is usually accomplished by using the scan tool to put the wiper system in a learn mode and then moving the wipers to specific positions on the windshield. Follow the procedures for the specific vehicle you are working on as procedures will vary.

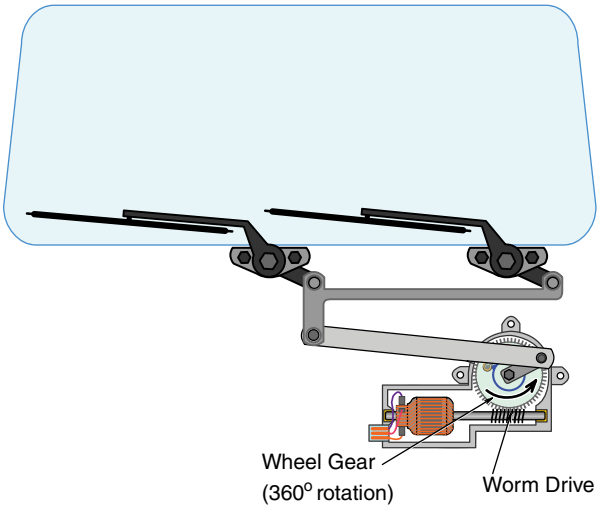


FIGURE 9-8 The motor rotates in continuous 360 degree circular motion when it is operating.

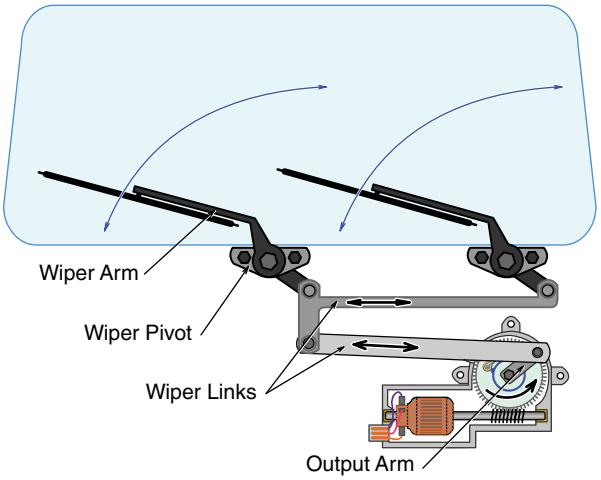


FIGURE 9-9 The output arm connects to the wiper linkage to move it back and forth. This motion then operates the wiper arm pivots to move the wipers up and down across the windshield.

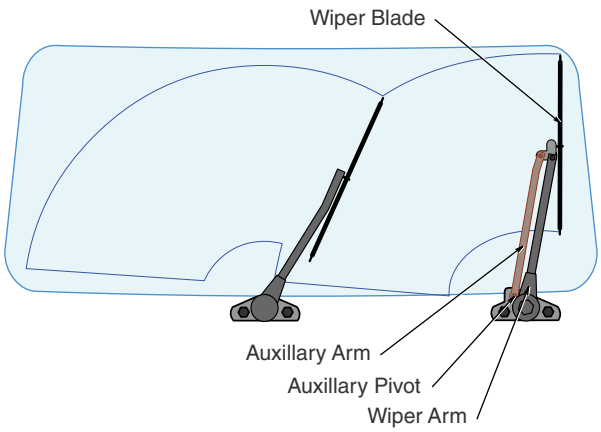


FIGURE 9-10 Some wiper systems use an auxiliary arm to articulate the wiper in a greater arc area across the windshield.

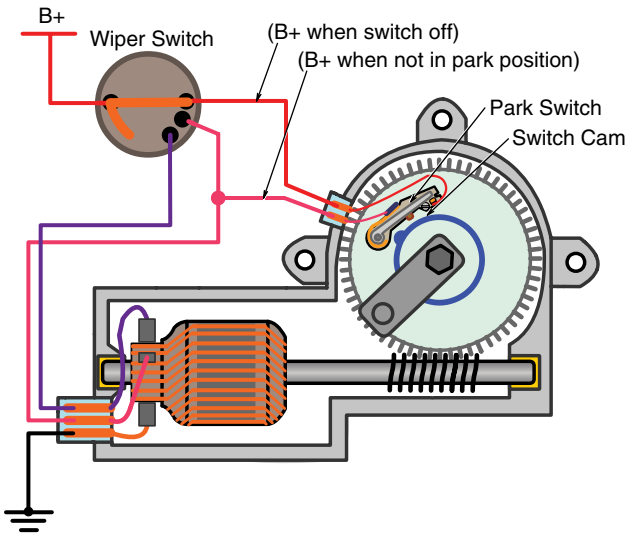


FIGURE 9-11 A park switch operated by a cam inside the wiper motor connects the motor to source voltage after the wiper switch is turned off. This allows the wiper motor to operate until the wipers have reached the bottom of the windshield in their parked position.

FIGURE 9-12 Some wiper systems only use one wiper blade to articulate across the entire windshield.

FIGURE 9-13 The wiper motor connects to an auxiliary arm like other systems but this arm moves the blade that has a pinion gear riding on a ring gear to create an arc across the windshield. The arm also extends and retracts to clear the greatest amount of windshield area possible for the one wiper.

FIGURE 9-14 Many vehicles are now using a wiper motor for each wiper. These motors incorporate position sensors and use the body ECU to control wiper operation.

FIGURE 9-15 Wiper blades should be inspected for every vehicle you work on. Recommend replacement when you see signs of excess stiffness, cracking, or tearing of the blade material.

FIGURE 9-16 Follow service information procedures to release the wiper arm from the pivot shaft.

▶ TECHNICIAN TIP

Wiper washer fluid contains an additive to prevent freezing of the liquid at low temperatures. Water or household window cleaner may freeze in the reservoir at low temperatures causing damage to the reservoir, pump motor, fluid lines, or nozzles. Refill the reservoir with automotive washer fluid to prevent system damage and ensure operation at below freezing temperatures.

Wiper system service includes inspecting the wiper blades for visible damage such as cuts and tears of the wiping surface (**FIGURE 9-15**). Replace damaged blades or blades that do not clear the windshield properly.

Accessing the wiper mechanism components usually requires removing the windshield wiper arms so you can remove the cowl trim (**FIGURE 9-16**). The wiper arms have a release tab, and a special puller tool may be used to remove the wiper arm. The wiper arms must be clocked on the mechanism shaft for proper operation. Clocking the wiper arms can be accomplished by first placing blue painter's tape on the windshield under the wiper blade when in the "park" position at the base of the windshield. Trace an outline of the blade on the blue tape using a medium-point marker. The marks on the tape ensure you install the wiper arm in the correct position. After your service work is complete, make sure the wiper motor and mechanism is in the "park" position. Install the wiper arm so that the wiper blade lines up with your outline marks on the blue tape. Failure to properly clock the wiper arms can result in damage to the wiper arms, wiper mechanism, paint, cowl trim, or windshield.

To remove and install wiper arms, follow the steps in **SKILL DRILL 9-1.**

Rear Wiper Operation

Many hatchback style vehicles use a wiper on the rear window (**FIGURE 9-17**). The rear wiper is usually a single wiper design and uses a motor and small mechanism to move the wiper in an arc across the rear window.

Windshield Washer System Operation

The windshield washer system, and on some vehicles a system for the rear wiper system, uses a small electric pump and a reservoir to hold the washer fluid (**FIGURE 9-18**). The pump sends the washer fluid through small hoses that connect to washer nozzles which shape the spray onto the windshield surface. Activating the washer system usually cycles the wipers for several sweeps to clear the windshield. Rear wiper washer systems may use the same reservoir as the front wipers or may have a separate reservoir at the rear of the vehicle. Refer to the service information and wiring diagram to determine the component layout for the vehicle you are servicing. Special fluids with very low freezing temperatures are also available.

Wiper Circuit Wiring Diagram

A sample wiper circuit is shown in (**FIGURE 9-19**). The wiper circuit consists of a control switch for low and high speed (some systems may have a medium speed), intermittent operation, and washer function.

Fuses protect the washer and wiper motor circuit, and most wiper motors incorporate a circuit breaker (**FIGURE 9-20**). The circuit breaker is designed to open the circuit before the fuse would blow and open the circuit. The reason for this is that ice and snow or an obstruction can cause the wipers to be difficult or impossible to move. The circuit breaker opens to cool the motor and prevent a blown fuse if at all possible. The driver can clean the ice and snow from the windshield and the wipers can then function once the circuit breaker closes as the motor cools off. If there were only a fuse, the fuse would blow and it would have to be replaced to restore wiper operation.

The wiper motor in this example achieves two different speeds by placing the brushes at different positions for each speed (**FIGURE 9-21**). Low speed puts one brush at 3 o'clock

SKILL DRILL 9-1 Removing and Installing Wiper Arms

1. Obtain the service information for windshield wiper arm removal and installation for your assigned vehicle.
2. Use painter's tape to create a position template of the wiper on the windshield under each wiper arm to be removed. The wipers should be off and in the park position. Use a medium-tip marking pen to trace the position of the wiper blade on the painter's tape for each wiper arm you are removing.
3. Remove the wiper arm(s) by releasing the lock tab and using a puller tool or pry tool to lift it off of the wiper mechanism shaft.
4. Install the wiper arm by matching up your wiper blade template with the wiper arm and then gently push the wiper arm onto the wiper mechanism shaft until the locking tab seats in place.
5. Cycle the wipers on and off and verify they park in the correct position. Remove the painter's tape and clean the windshield after verifying the wipers have been installed correctly.

FIGURE 9-17 The rear wiper may use a wiper motor, output arm and linkage to operate the motor. Some vehicles may use a motor that is directly connected to the arm and operation is controlled by an ECU.

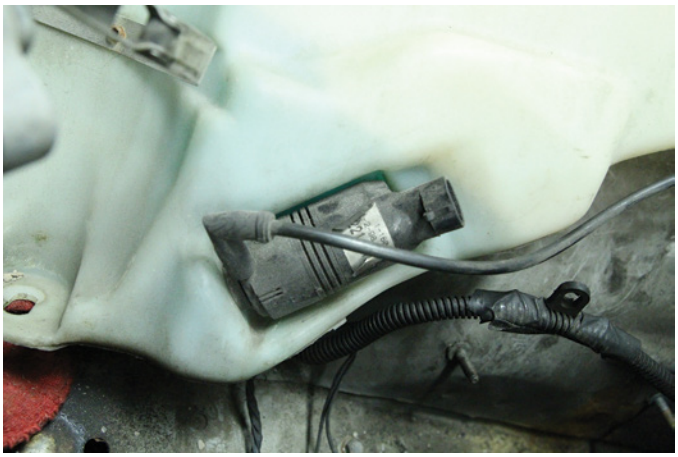


FIGURE 9-18 The windshield washer pump uses a small electromagnetic motor to pump fluid from the reservoir and through the washer nozzle jets.

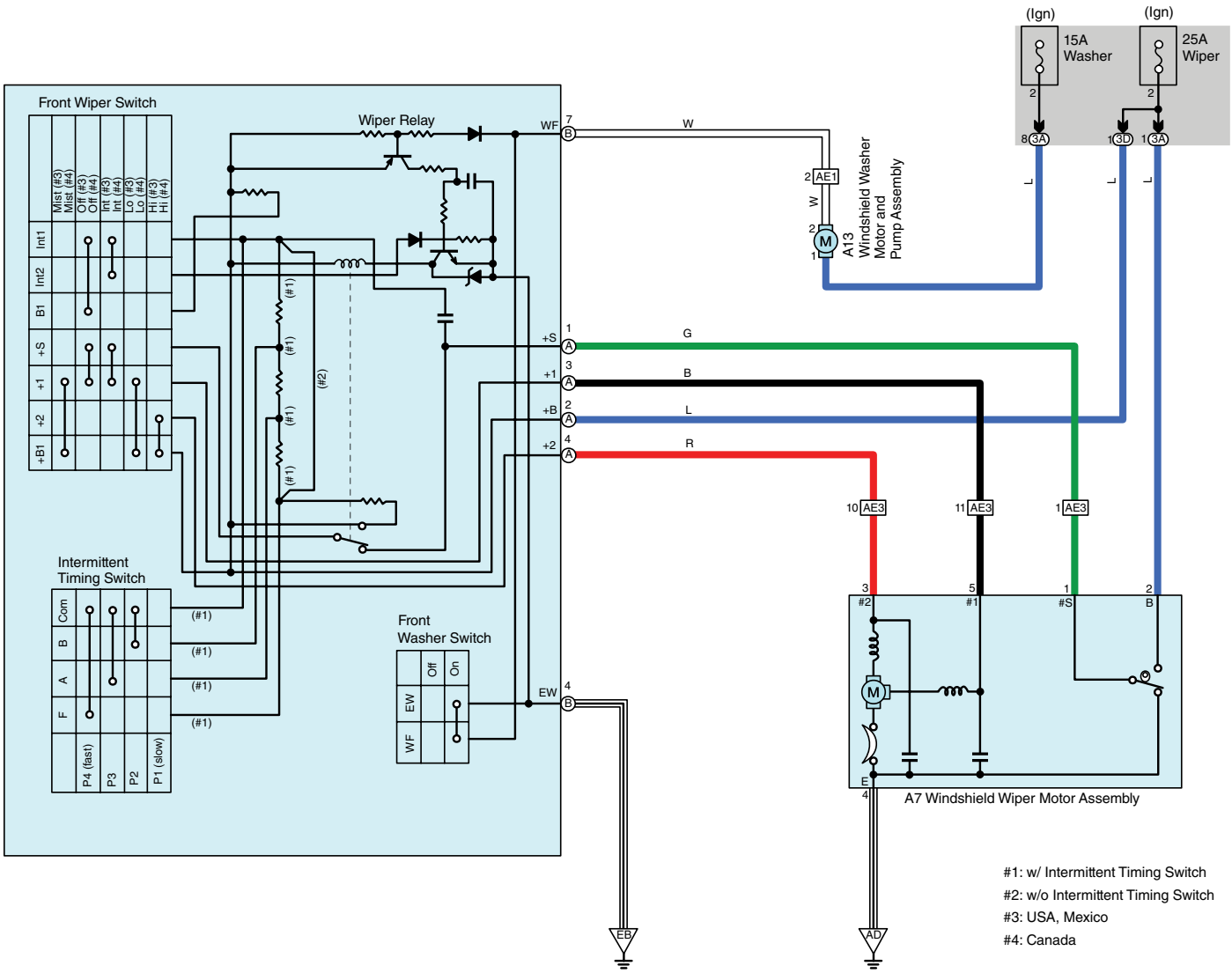


FIGURE 9-19 A wiper motor wiring diagram for a two-speed wiper system with intermittent wiper sweep operation built into the switch assembly.

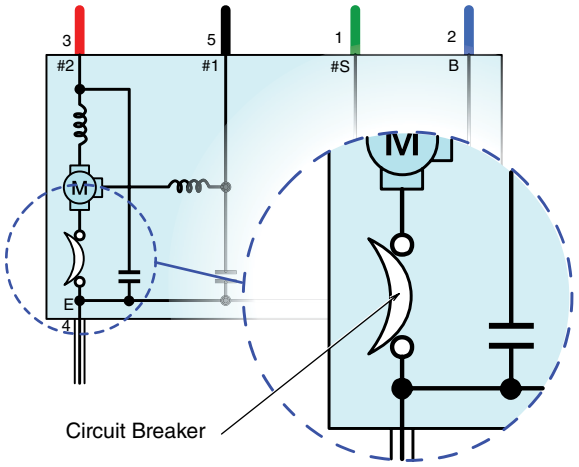


FIGURE 9-20 The circuit breaker protects the motor from overheating.

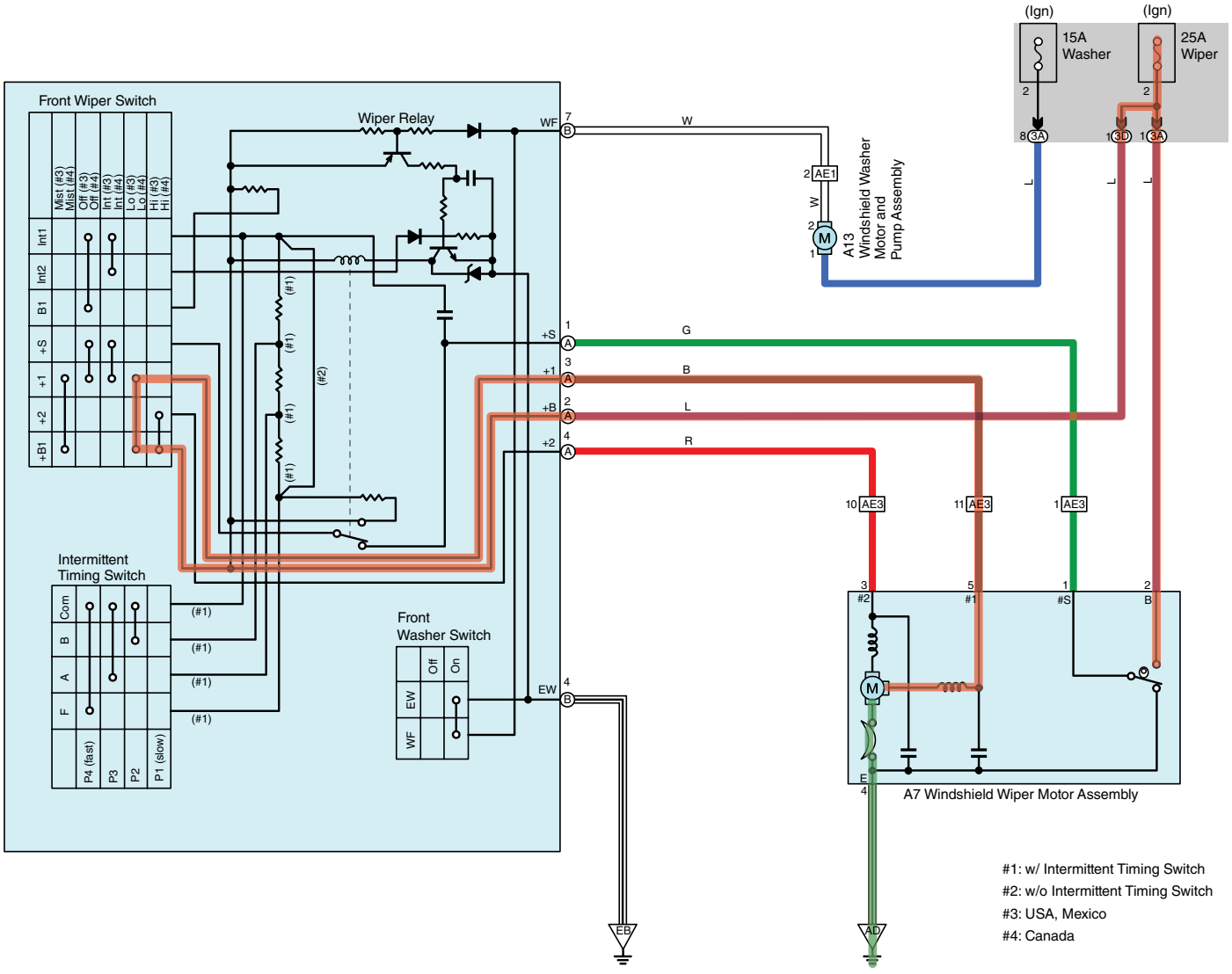


FIGURE 9-21 Low-speed wiper current paths: orange is source voltage, pink is ground.

and the other at 6 o'clock. This brush positioning reduces the size of the magnetic field created in the motor armature (rotor) so the motor runs at a slower speed. At high speed the brushes are opposite each other to create the maximum magnetic field in the armature resulting in high-speed wiper operation. Some wiper systems may use a resistor to control wiper speed but this is not very common due to the high heat generated by the current in the wiper circuit.

The park switch provides current to the motor at low speed after the wiper switch is turned off (**FIGURE 9-22**). The current remains until the wiper arms are at the park position and the switch opens and the wiper motor stops.

Intermittent Wiper Circuit Wiring Diagram

Intermittent wipers use a **timer circuit** to intermittently switch current on to the motor, and then the park switch keeps the motor on for one wiper sweep cycle (**FIGURE 9-23**). The timer circuit is controlled using the settings on the wiper intermittent switch. The intermittent settings provide current paths through resistors of varying size to control the current in the timer circuit. The timer circuit uses capacitors along with the resistors to create the time delay between wiper sweeps. A higher resistance is used to increase the delay time. This reduces current in the circuit and it takes longer for the capacitors to fully charge with electrons. Once the capacitor charges, it then allows current through to the transistors which

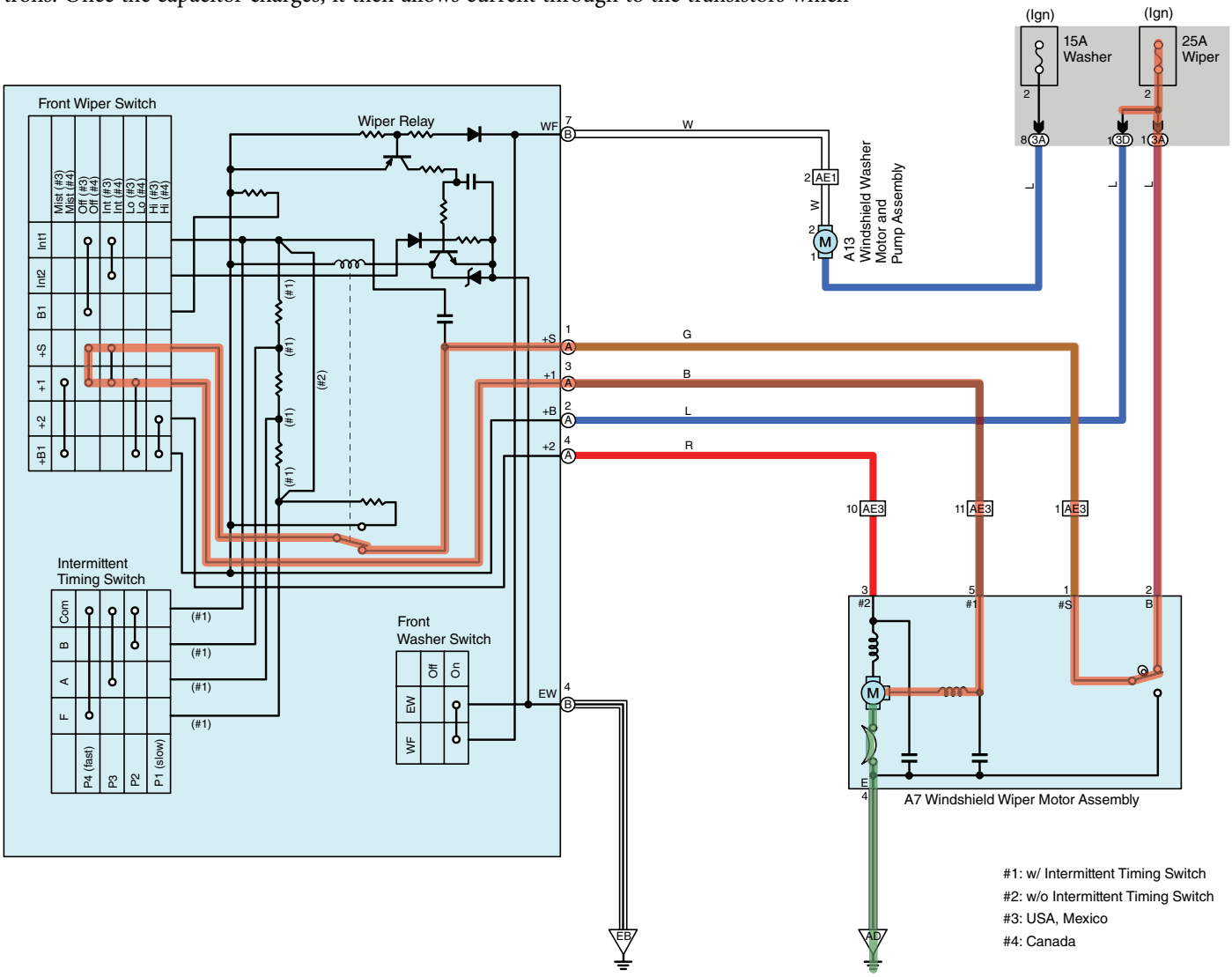


FIGURE 9-22 The park switch provides a current path to park the wipers.

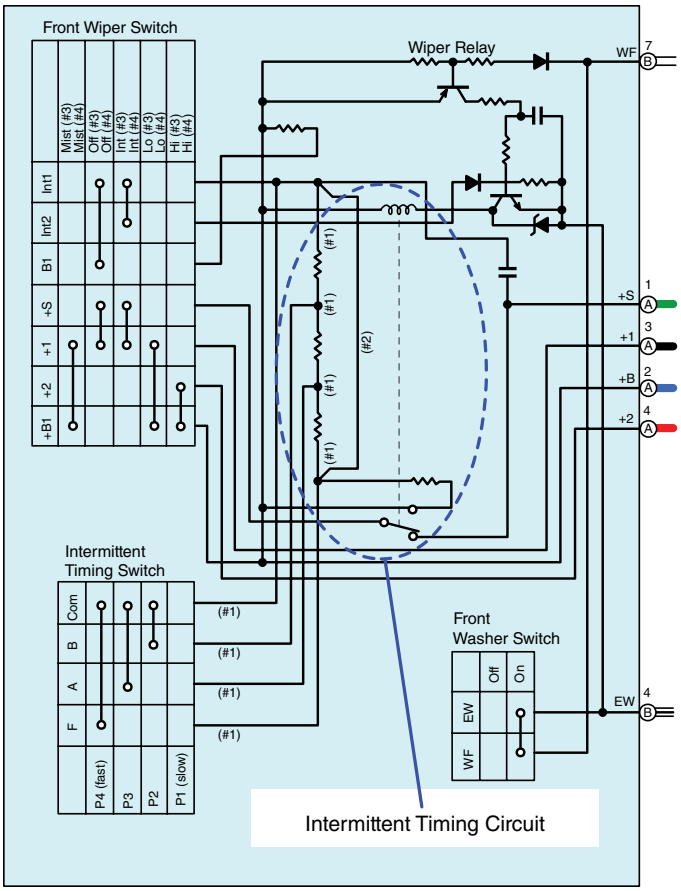


FIGURE 9-23 The intermittent function allows the wipers to operate for one cycle then pause.

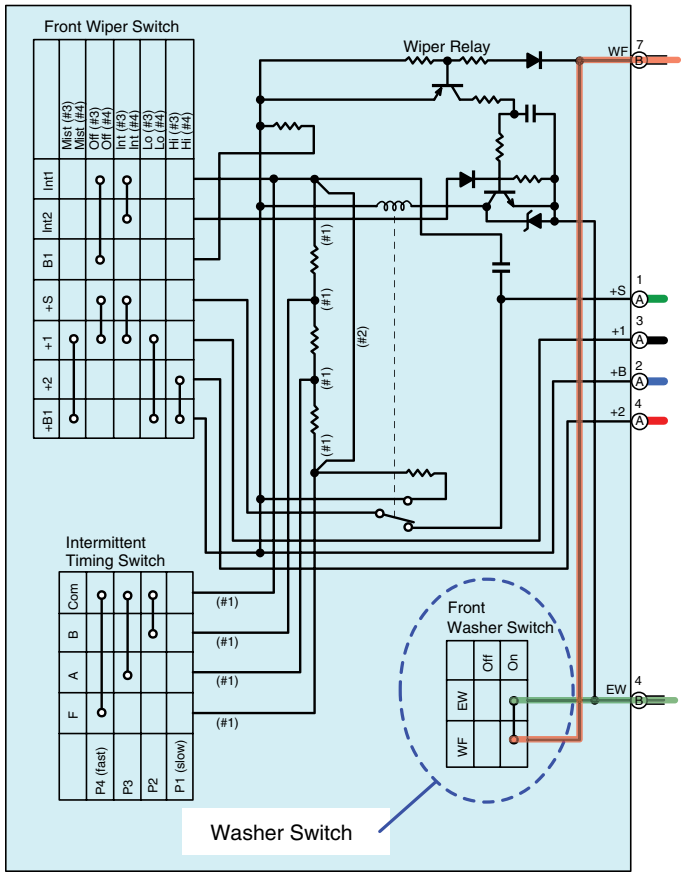


FIGURE 9-24 The washer switch controls the washer motor operation.

▶ TECHNICIAN TIP

It is possible to monitor current in motor circuits using an inductive current pickup and digital storage oscilloscope (DSO). This type of testing is usually not required on body electrical type motor circuits; however, if you are having difficulty diagnosing the cause of the concern based on your voltage tests, this is an option to consider. DSO use is covered in the Advanced Diagnostic Tools chapter.

▶ TECHNICIAN TIP

Blower motors that are controlled by an ECU may use a different test procedure than those that use resistors to vary the blower speed. These blower motor circuits and related test procedures are covered in the ECU-Controlled Body Electrical Circuit Diagnosis chapter.

operate the wiper relay to start the wiper cycle. Once the circuit turns on, the capacitors quickly discharge and the cycle starts again. The wipers complete the sweep cycle from the current path through the park switch.

Washer Circuit Wiring Diagram

The washer circuit is turned on using the washer switch (**FIGURE 9-24**). The washer switch supplies a path to ground for the washer motor and the wiper relay circuit (**FIGURE 9-25**). The washer pump motor operates to draw washer fluid from the reservoir and send it through the hoses to the discharge nozzles. The wiper relay cycles the wipers on while the washer switch is in the on position.

Wiper System Diagnosis

Wiper diagnosis requires you obtain the applicable wiring diagram and service information on system operation. Trace the circuit and predict system voltages as part of the diagnostic process. The wiper motor is usually located under the cowl trim and it can take time to access it. For this reason, most diagnosis begins by verifying system voltages at the switch; if those are OK, then move on to inspecting at the wiper motor. Measuring (or calculating from available voltage readings) voltage drop across the switch contacts through the wiring harness to the motor and from the circuit ground to a known good chassis ground is critical to accurate diagnosis of motor circuits.

Blower Motor Circuit Wiring Diagram

The HVAC **blower motor** functions to circulate air inside the vehicle. The blower motor operates at several speed settings to provide rapid air movement to quickly

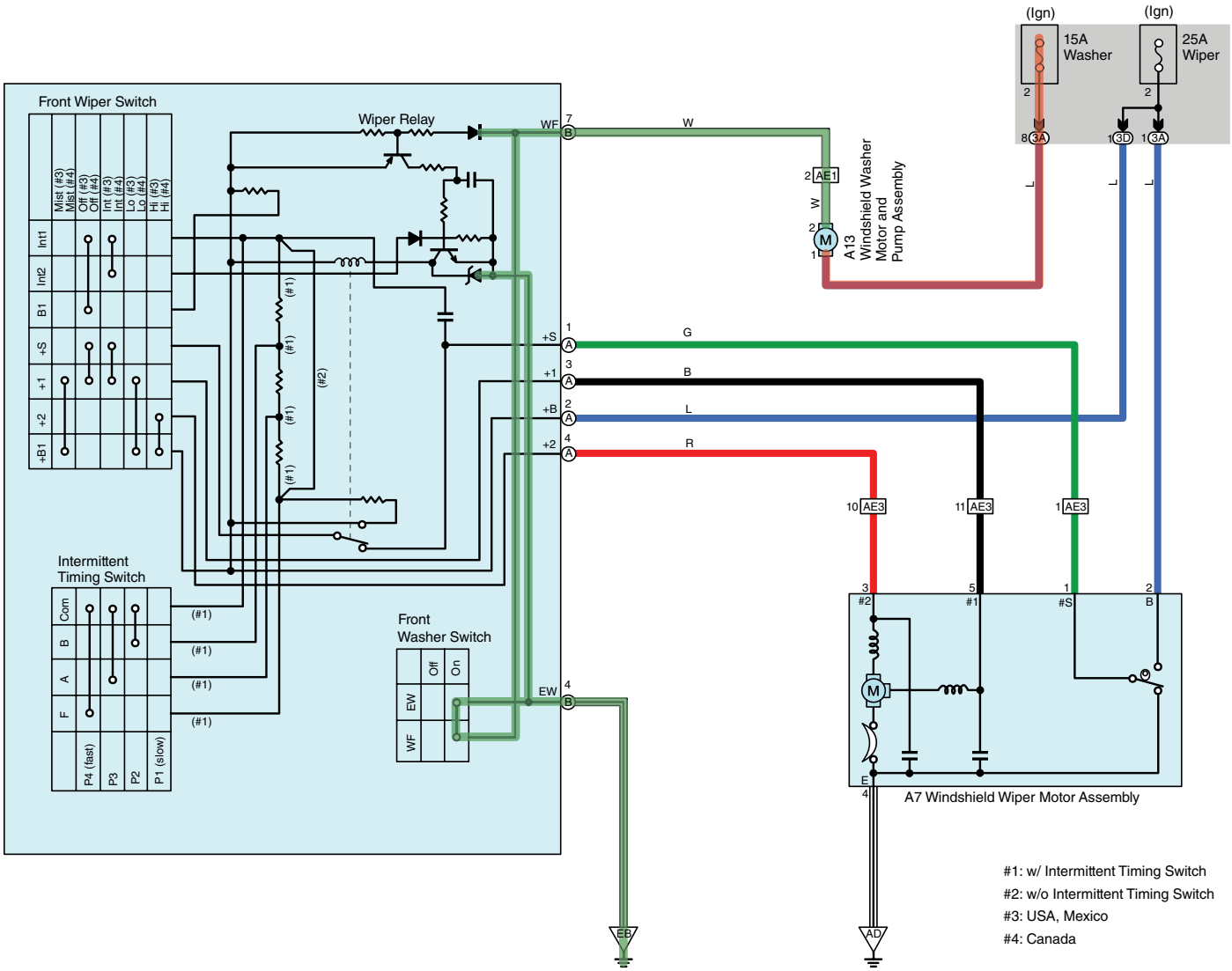


FIGURE 9-25 The washer switch controls the washer motor.

heat or cool the vehicle and then more moderate speed settings to maintain a comfort level. Non-ECU-controlled systems use a resistor block to create the blower speeds (**FIGURE 9-26**).

The blower motor operates on high speed when the switch is in the high position (**FIGURE 9-27**). This switch position supplies source voltage for the high blower relay. The relay supplies source voltage to the motor so it operates at maximum speed. The other speeds are created by putting one or more resistors in series with the motor. For medium high speed, the blower switch provides a current path through one resistor. The resistor shares the voltage with the motor so the motor operates at approximately 10 volts, causing it to run at a slower speed. Medium low speed has two resistors in series, and low speed has all three resistors in series with the motor. The resistors are often mounted on an insulated material to form the resistor block, and it is located inside the HVAC air distribution system near the evaporator. It is important that the resistor block has sufficient airflow to keep the resistors from overheating and failing.

Blower Motor Circuit Diagnosis

Blower motor diagnosis is straightforward. It is usually fairly easy to access the blower motor, so you can begin your circuit testing at this point to determine if the blower motor has source voltage to it. Refer to the applicable wiring diagram to determine

▶ TECHNICIAN TIP

Use caution when investigating noise concerns, especially if the noise does not sound like a bearing or something rubbing. It is possible a small animal has sought shelter in the air box and has built a nest in the fan area. It is not uncommon in vehicles that are stored for a few days or weeks, especially as the weather changes during the fall from warm to cool, for animals to seek shelter where it is warmer. Wear thick protective gloves if you suspect there may be an animal in the air box so that you are not scratched or bitten as you investigate.

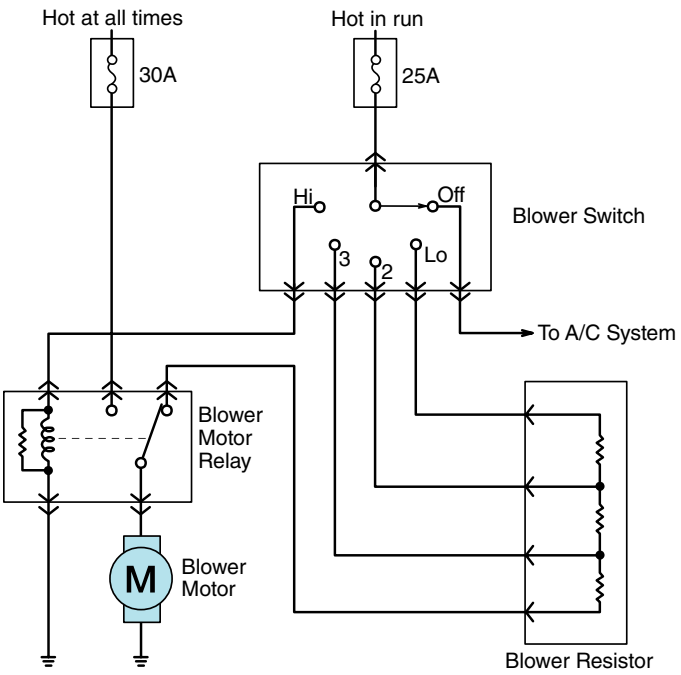


FIGURE 9-26 The blower motor circuit uses resistors in series with the motor to offer slower speeds from the high setting.

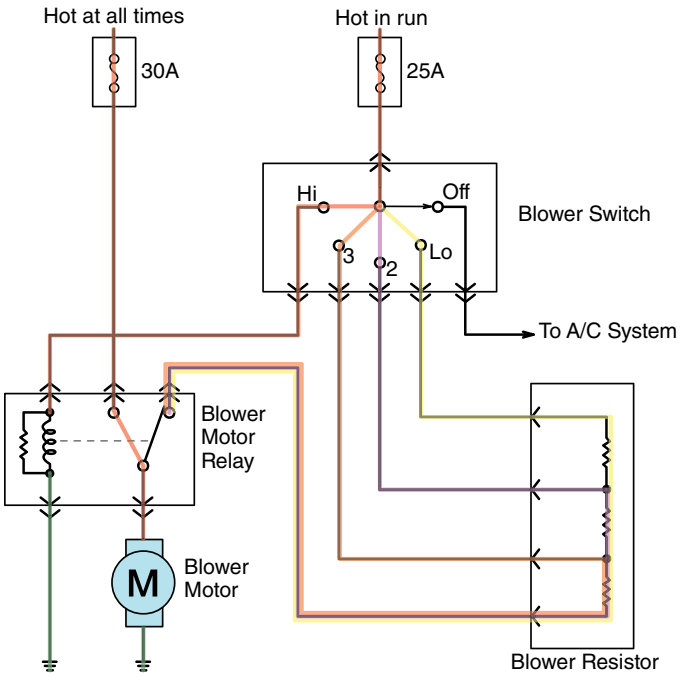


FIGURE 9-27 The blower motor resistor provides three blower speeds that are slower than high speed.

whether the blower motor has voltage only when the blower switch is set to a fan speed or if it has voltage at all times when the ignition is on. If there is voltage at the motor, there may be a ground fault or fault in the motor. If there is no voltage at the motor, you will have to isolate the fault by testing at the fuses, relay, switch, and resistor block. A blower motor that works on high speed only or high speed and one or two other speeds may indicate a fault with the resistor block. The resistor block can be tested with your DMM to measure resistance of each resistor on the block to determine if one or more have failed open. Resistor blocks are usually replaced as a unit if there is a fault. A noisy blower motor may indicate worn motor bearings or there may be debris in the fan or air box.

To inspect the blower motor voltage, follow the steps in **SKILL DRILL 9-2.**

To inspect the resistor block, follow the steps in **SKILL DRILL 9-3.**

SKILL DRILL 9-2 Inspecting the Blower Motor Voltage

1. Obtain the wiring diagram and service information for your assigned vehicle.
2. Trace the current paths for the motor circuit using multicolored highlighters and predict available voltage where possible.
3. Use your DMM to measure available voltage to the source side of the blower motor at each blower speed. Note your readings on the wiring diagram and review your findings with your instructor.

SKILL DRILL 9-3 Inspecting the Resistor Block

1. Obtain the service information to locate the resistor block in the HVAC system for your assigned vehicle.
2. Remove the resistor block from its mounting location and carefully disconnect the connector.
3. Use the DMM to measure the resistance of each resistor, and refer to the wiring diagram to determine which resistors are used for each blower speed. Note your findings on the wiring diagram. Review your results with your instructor.

Power Window System Operation

Electric windows use permanent magnet motors located in each of the passenger doors, and sometimes in a rear door, to control the up-and-down movement of vehicle windows. Voltage polarity to the motor is controlled by the window switch to provide the movement in either direction. The control circuit turns the motors on and off, controls the direction of rotation, and provides dynamic braking. A switch on each door controls the direction of travel, and a master switch panel to control all windows is usually located on the driver side front door. If equipped, a lockout switch in the master switch panel disables the switches for the other window switches.

The mechanical arrangements for connecting the motors to the windows will vary by manufacturer and vehicle model. They will usually comprise a window regulator made up of gears and scissor-acting levers or a cable and lever system (**FIGURE 9-28**).

Modern vehicles will often have more sophisticated electric window control systems to improve safety and usability. They include one-touch up and down, where a single full push on the control switch in either direction enables the window to go all the way up or down without the need to hold the switch. The control system monitors current flow and can reverse the window winding if it senses excessive resistance, such as would occur if an arm were caught or trapped in the window. The electric window system includes the battery supply, fuses or circuit breakers, switches at each door and the master panel in the driver side door, relays, and the DC motor (**FIGURE 9-29**).

A (non-ECU) power window circuit uses a master switch for driver control of all windows and then a switch at the right front and rear quarter or door windows for passenger control at their window (**FIGURE 9-30**). Most master switches offer a lockout feature to disable the passenger door switches, usually so children cannot play with the windows. At first glance, the power window circuit looks very confusing, but as soon as you begin to trace the current paths the operation of the system is straightforward. A **bus bar** for source voltage and ground is located in the master switch assembly. The switch contacts provide a path for source or ground depending on whether the window will be lowered or raised. The sample diagram shows the current path for the left rear window being raised. Source voltage is connected to the up switch contact when the window switch is activated at the master switch (or the left rear door switch if the passenger were to activate the switch). Source voltage is present to the motor, and the motor has a ground path back through the down switch contact that remains on the ground bus bar. The sample diagram also shows the current path for the driver's door window using the auto or express down feature. Note that the dotted line indicates that the switch contacts for express and down move together. When the down switch is pressed past the first contact, it then contacts the express down contact to activate the module which will then keep the motor energized until the window is all the way down (open).

Note that the polarity of the window going down is the opposite of the window going up. The window switch design controls the polarity to the motor so it can reverse direction for raising or lowering the window.

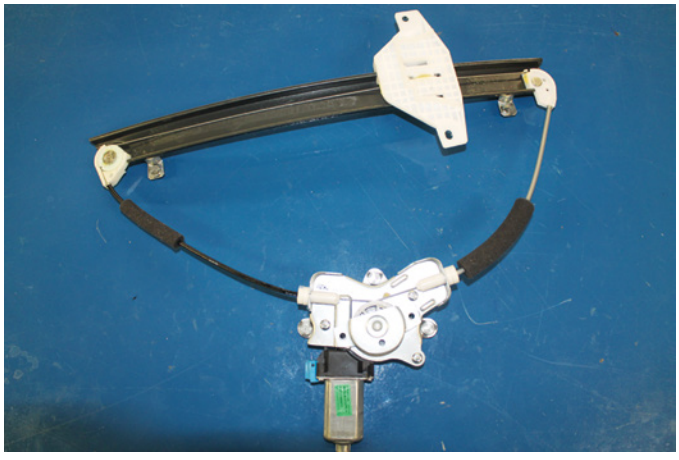


FIGURE 9-28 The mechanical components for a window regulator system.

▶ TECHNICIAN TIP

The module may require an **initialization** to learn the amount of time or current level used during the down action of the motor. The auto/express down feature may not function until the window is initialized. The module learns how much time or, in some types of vehicles, monitors current of the motor circuit to know when to open the circuit and stop the motor. Refer to the applicable service information to determine if any initialization procedures are required.

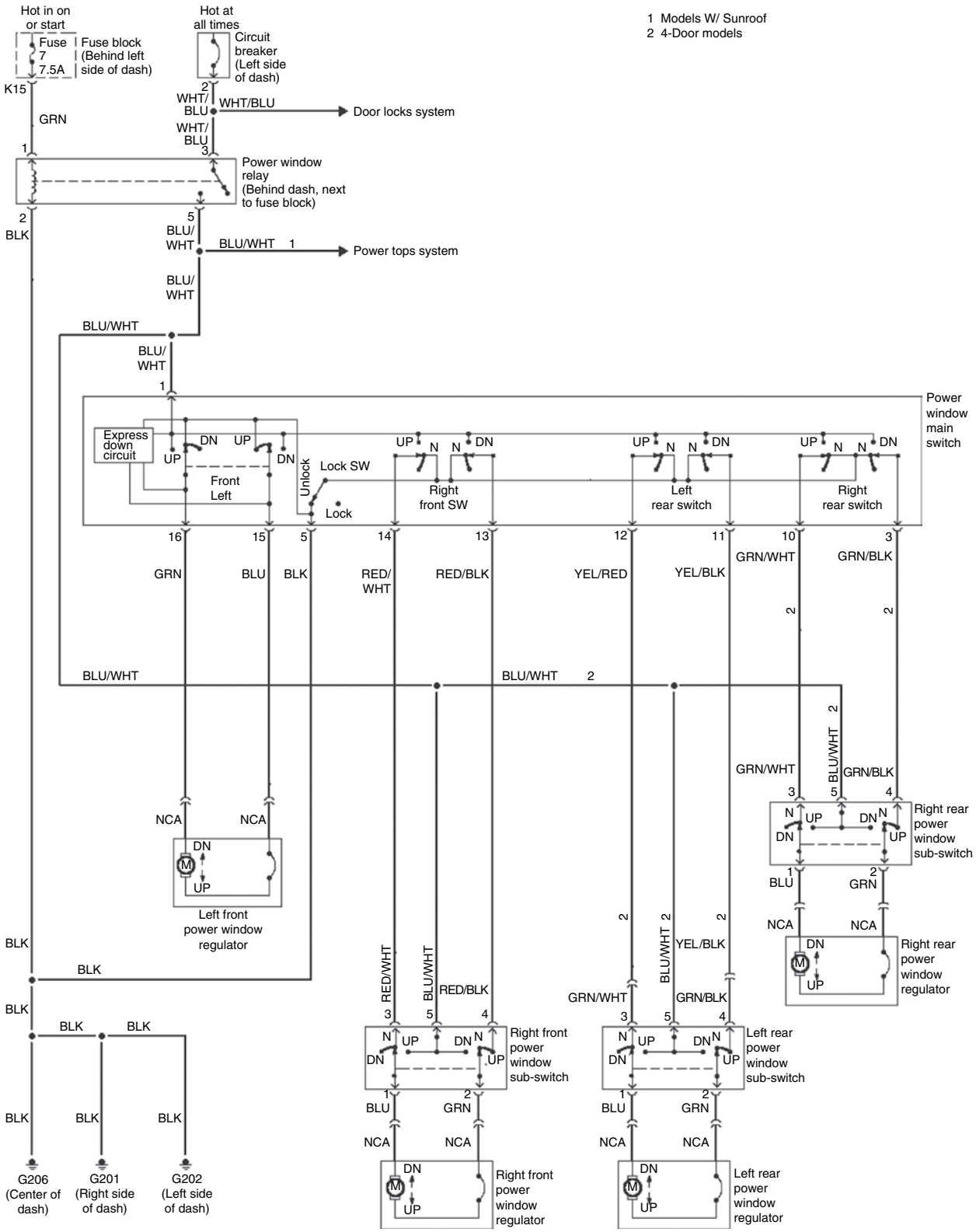


FIGURE 9-29 A circuit diagram for electric windows.

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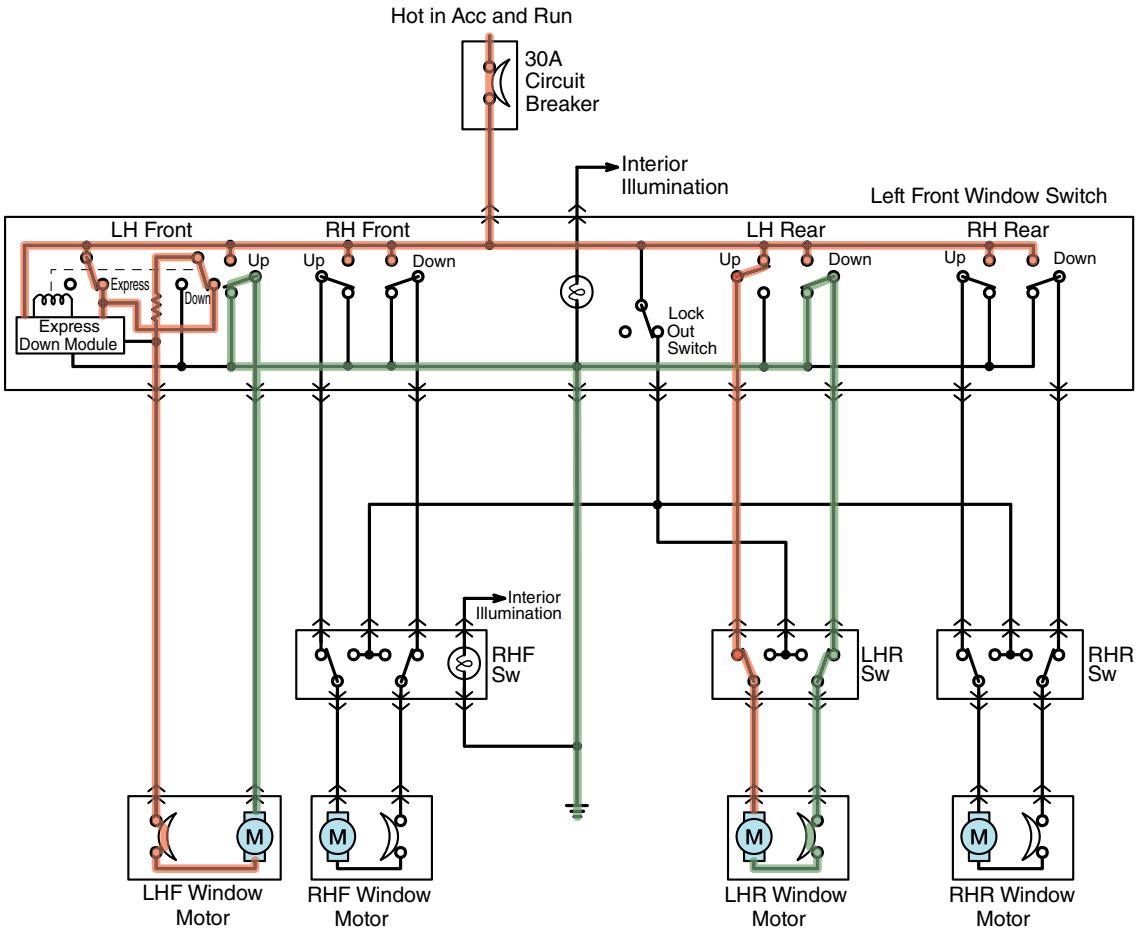


FIGURE 9-30 The power window circuit may look confusing, but highlighting the current path quickly simplifies it for your diagnosis.

Power Window System Diagnosis

Power window concerns may be caused by electrical or mechanical faults. Also, a mechanical fault like a sticking window guide track or damaged regulator can cause additional stress on the motor causing it to fail over time. Your observations during diagnosis are very important to determine if the fault may be electrical. If none of the windows work, for example, there may be an electrical issue. If the window goes up and down but much slower than the other windows, the issue may be a mechanical issue. The service information usually provides a diagnostic chart that can help with diagnosis and, of course, your knowledge of system circuit testing and measurement of available voltage and voltage drops will further help to isolate the cause of the concern (**TABLE 9-1**). Motor circuits require sufficient current to operate the motor against the mechanical load in the system, in this case lowering and raising the window. Dirty or worn switch contacts can cause an abnormal voltage drop.

To test the voltage on power windows, follow the steps in **SKILL DRILL 9-4.**

Power Door Lock System Operation

The power lock system uses permanent magnet motors to operate a lever that operates the door lock mechanism (**FIGURE 9-31**). The motors operate in one direction for locking and are reversed for unlocking. The motor direction is controlled by the door lock switch, which controls the polarity of the voltage to the motor.

The lock/unlock switch controls which wire to the motor is supplied source voltage (**FIGURE 9-32**). The example shown supplies source voltage in the unlock position

TABLE 9-1 The power window problem symptoms table helps isolate the possible causes for your window system diagnosis.

PROBLEM SYMPTOMS TABLE		
Symptom	**Suspected Area**	**See Page**
Power window does not operate (ALL) (Power door lock does not operate)	1. P/W fuse 2. IG1 relay 3. Gauge fuse 4. Write harness	– 68–1 – –
Power window does not operate (ALL) (Power door lock is normal)	1. Ignition Switch 2. Power window master switch 3. Write harness 4. Power window motor	80–2 70–4 – 70–4
"One-Touch Power Window System" does not operate	1. Power window master switch 2. Power window motor	70–4 70–4
Only one window glass does not move	1. Power window master switch 2. Power window regulator switch 3. Power window motor 4. Wire harness	70–4 70–4 70–4 –
"Window Lock System" does not operate	1. Power window master switch	70–4

Data from 2005 Toyota Corolla.

SKILL DRILL 9-4 Testing Voltage on Power Windows

1. Obtain the power window circuit diagram and related service information for your assigned vehicle.
2. Trace the current path and predict circuit voltages for the right front door window motor for both up and down operation on the wiring diagram.
3. Follow service manual procedures to remove the right front door panel so you can access the power window motor. Use trim tools to prevent damage to the panel and the panel clips.
4. Use your DMM to measure voltage at the motor for down and up operation. NOTE: Operate the window up and down so you can observe if the glass or mechanism will contact or interfere with your DMM leads before you test at the window motor. A tight clearance may require only operating the window part way or finding a way to ensure the DMM test leads do not interfere with the window glass or regulator.
5. Measure for available voltage up and down and calculate the voltage drop across the motor. Review your test results with your instructor.
6. Reinstall the door panel and be sure all clips and retaining screws are installed properly.

through the pink wire with the orange trace. Ground is supplied through the pink wire with the black trace that connects to each switch and then to the black wire connected to ground 200.

Locking the doors in this example (**FIGURE 9-33**) shows the lock switch supplying source voltage in the lock position through the pink wire with the yellow trace to the passenger switch, then to the pink wire with the black trace to the door lock motors. Ground is supplied through the pink wire with the orange trace that connects from the door lock motors to the passenger door switch and then to the pink wire with the light green trace to the driver's door switch. The black wire connects to ground 200 to complete the circuit path.

Power Door Lock System Diagnosis

Door lock diagnosis relies on determining if any part of the circuit operates and then referring to your wiring diagram with current paths traced and predicted voltages. No lock motor operation requires you begin at the fuse and then continue to the switches to check for available voltages. A system that locks the doors but does not unlock them requires you review the wiring diagram to determine which switch pins to test (you do not need to test the motors since you know that they work because they operate to lock the doors). A system

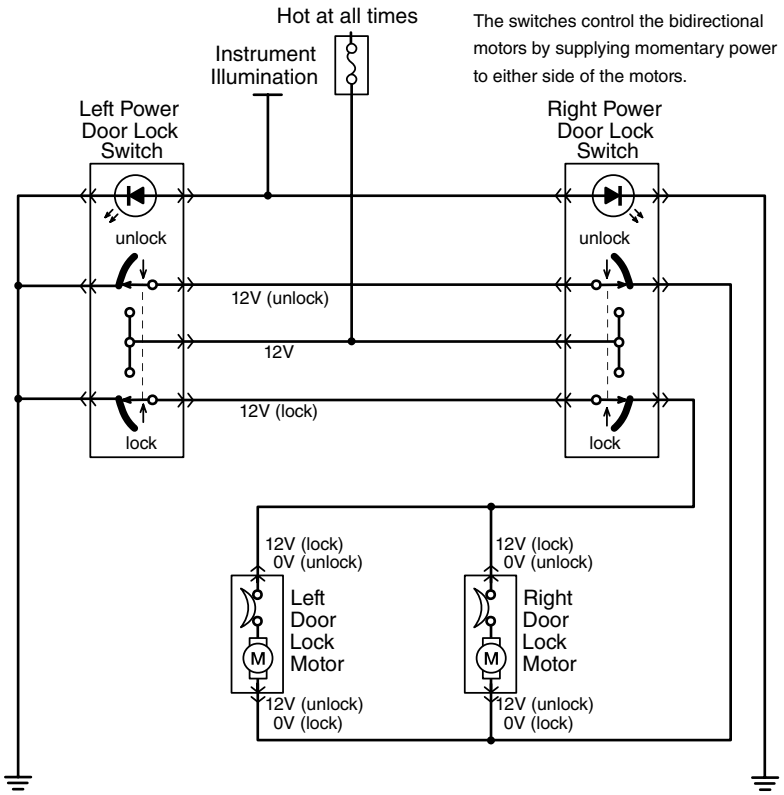


FIGURE 9-31 Power door locks use a motor to move a lever to lock or unlock the door latch mechanism.

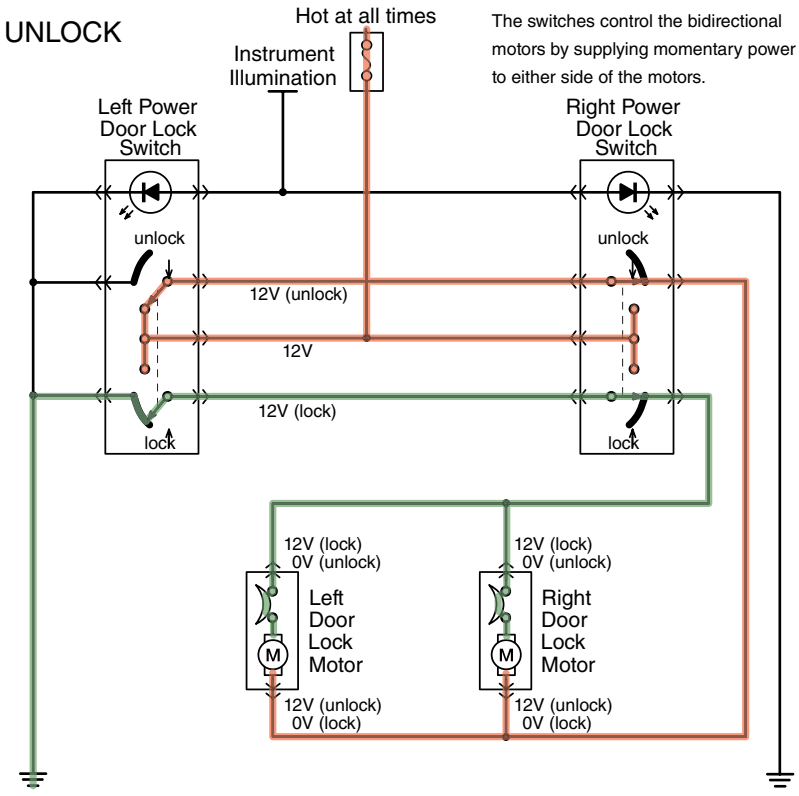


FIGURE 9-32 The unlock switch position supplies source voltage to the door lock motors through the pink wire with the orange trace as shown in this example.

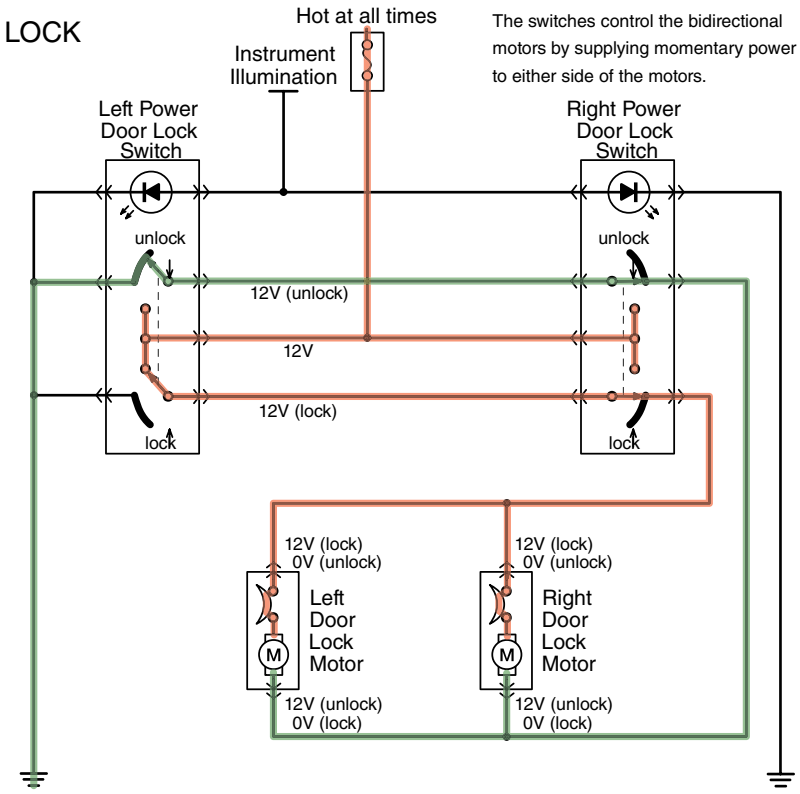


FIGURE 9-33 The lock switch position supplies source voltage to the door lock motors through the pink wire with the yellow trace as shown in this example.

fault where one door locks and unlocks but the other door does not, may indicate a motor fault. If you are noting a pattern here, you are correct. For any circuit where switches control motor direction and operation, you must have the wiring diagram and trace the current paths for lock and unlock. Skipping this diagnostic activity only leads to frustration and possibly replacing switches and motors that are not causing the fault.

To test the power lock system, follow the steps in **SKILL DRILL 9-5.**

Power Mirror System Operation

Power mirrors use permanent magnet electric motors to control the up-and-down and in-and-out movement of the passenger and driver side mirrors. Most mechanisms use two motors for each mirror: one for the up-and-down movement and one for the in-and-out movement (**FIGURE 9-34**). The motors are reversible so that they can provide the movements in either direction. The control circuit turns the motors on and off, controls direction of rotation, and provides dynamic braking. Reversal of the motors is achieved by reversing

SKILL DRILL 9-5 Testing the Power Lock System

1. Obtain the power door lock wiring diagram for your assigned vehicle. Trace the current paths and predict the circuit voltages at applicable test points for lock and unlock (you may need to use two diagram printouts for this).
2. Obtain the service information to remove the door panels or other trim components to reach the power door lock system components.
3. Use trim tools and any applicable hand tools to remove the door trim panel on the left front door to access the door lock system components.
4. Use your DMM to test for available voltage at the applicable test points for lock and unlock and note your findings on the applicable wiring diagram. Review your findings with your instructor.
5. Reassemble the vehicle taking care not to damage trim or trim clips and install any fasteners.

current flow through the armature. The mechanical arrangements for connection of the motors to the mirrors will vary by manufacturer and vehicle model. Dynamic braking is critical in this application because it ensures that the motor stops quickly without overrun, thus ensuring that the mirror stops quickly when the power is removed by the driver operating the switch. Dynamic braking is achieved by ensuring that the same potential is applied to both brushes at the time the switch is turned off. The circuit shows a basic control circuit that reverses the motor and provides dynamic braking. The typical power mirror circuit includes the battery supply, fuse or circuit breaker, control switches, relays, and motors. The control switches usually incorporate a switch to select between passenger and driver side mirrors and a joystick-type switch with east, west, north, and south positions to control the up-and-down movement and the in-and-out movement.

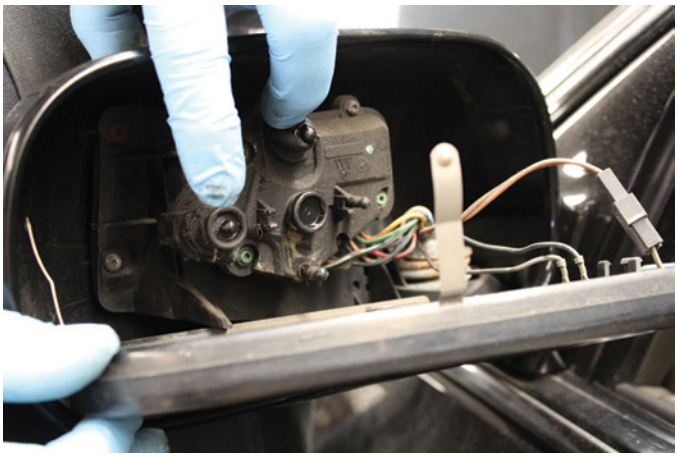


FIGURE 9-34 A basic power mirror showing the position of both motors.

The power mirror system uses a switch that has a bus bar for source voltage and ground. A gang type selector switch is used to select the left or right mirror (**FIGURE 9-35**). A spring-loaded momentary contact switch is used for each mirror movement, up/down and outward/inward. The current path is shown for adjusting the right side mirror upward. The folding mirror function incorporates a control circuit for operation. The fold/unfold switch provides a current path to the left and right control circuit which then operates the motor in each mirror to fold or unfold. It then turns off the motors once the movement to either position is complete.

Power Mirror System Diagnosis

Power mirror diagnosis time can be reduced by verifying if any mirror operation functions. For example, if the left mirror functions normally but the right mirror has no movement in any direction, the fault may be in the mirror select switch or the ground wire, as these are common for operation of both the up/down and left/right motor circuits. It is unlikely that

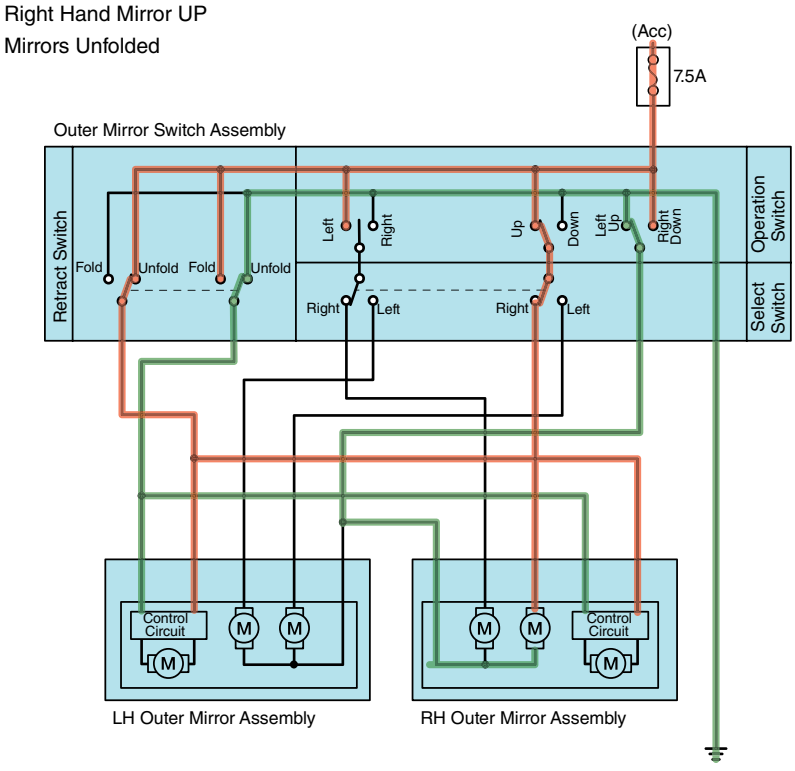


FIGURE 9-35 The remote control mirror uses a switch to control left and right mirror position and, on some vehicles, to fold the mirrors inward after parking.

SKILL DRILL 9-6 Testing Remote Control Mirrors

1. Obtain the remote control mirror wiring diagram for your assigned vehicle. Trace the current paths for each mirror movement (up, down, left, and right). It is recommended you use a separate diagram for each mirror movement and also note the predicted voltages at appropriate circuit test points.
2. Review the service manual information to access the mirror switch and the outside mirror harness connectors. Use appropriate trim panel tools to access the mirror switch harness and the left and right mirror connectors.
3. Operate the applicable mirror for each movement position while measuring available voltage at the switch connector and at the mirror connector. Note your voltage readings on the wiring diagram.
4. Review your findings with your instructor. Reassemble the vehicle using care not to damage any trim clips.

both the right mirror motors or all the wiring to the right mirror have failed under normal operation, but it could happen if there is evidence of collision-related damage. Another example, if both mirrors move left/right but not up/down, it is most likely a switch concern. Verifying which system functions work and which ones do not helps you determine where to begin your circuit testing. The power mirror circuit wiring diagram appears confusing, so tracing the current paths for each mirror operation that is not functioning will provide a clear understanding of which switch components and wires in the harness are used for those functions.

To test remote control mirrors, follow the steps in **SKILL DRILL 9-6.**

Power Seat System Operation

The power seat system uses permanent magnet motors to move the seat forward and backward on the simplest type of system (**FIGURE 9-36**). Most power seats offer motors that adjust the reclining angle of the seat back and the height and angle of the seat bottom. Some seats also offer a lumbar, lower back, support that consists of an air bladder and small electric air pump motor to inflate the air bladder. Adjusting the amount of air in the bladder can provide support and proper positioning of the lower back. This section covers the seat position motors. The system uses a switch with a bus bar for source voltage and ground. The

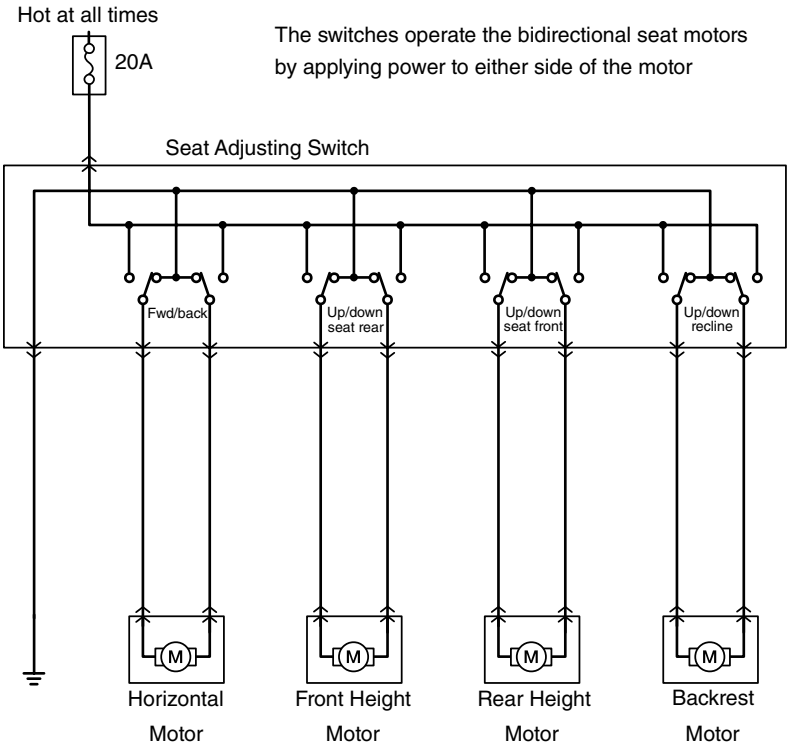


FIGURE 9-36 The power seat system uses motors to move the seat forward and back, and on some vehicles there may be motors for seat back position and seat bottom height adjustment.

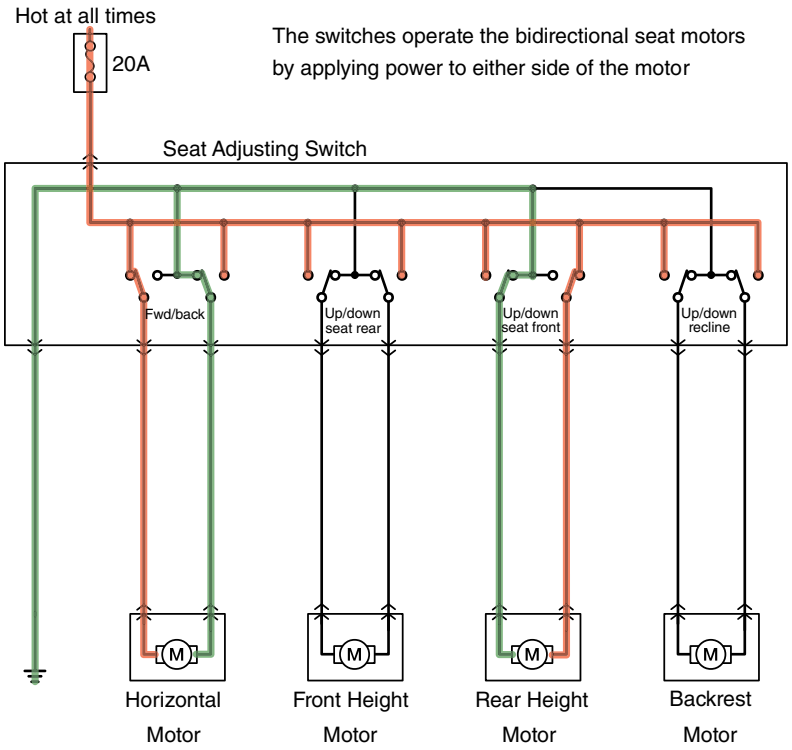


FIGURE 9-37 The power seat motor voltage polarity controls the motor rotation direction.

position of the seat switch controls which motor operates and which direction the motor rotates. The switch position controls voltage polarity to operate the motor in one direction or to reverse the direction, moving the seat component, like the seat back recline function, forward or backward (**FIGURE 9-37**).

Power Seat System Diagnosis

Power seat motor diagnosis is similar to the other motor control circuits using a bus bar type switch control. If there is no seat movement no matter which switch position is selected, a source voltage, ground path open, or very high resistance concern may be the cause. If one of the seat motors does not function, it may be the switch assembly or the motor. A mechanical issue with the seat gear drive (sometimes called a seat transmission) may also be the cause of a concern. Some power seat systems use cables to connect the motor to the gear drive and these can break. This may be indicated if you can hear the motor operate in both directions but the seat or seat component does not move. While most modern systems use gear drive systems, some may use a drive belt. The belts area prone to stretching over time and can slip. Follow the five-step diagnostic process, including a thorough visual inspection and reviewing applicable service information and TSBs before doing any system tests.

To inspect power seat systems, follow the steps in **SKILL DRILL 9-7.**

SKILL DRILL 9-7 Inspecting Power Seat Systems

1. Obtain the power seat system wiring diagram for your assigned vehicle. Trace the current paths for each motor movement. Predict the expected available voltage at the applicable test points.
2. Review the service manual information to access the power seat switch and the outside mirror harness connectors. Use appropriate trim panel tools to access the power seat switch harness and motor connectors.
3. Operate the applicable power seat switch for each movement position while measuring available voltage at the switch connector and at the related seat motor connector. Note your voltage readings on the wiring diagram.
4. Review your findings with your instructor. Reassemble the vehicle using care not to damage any trim clips.

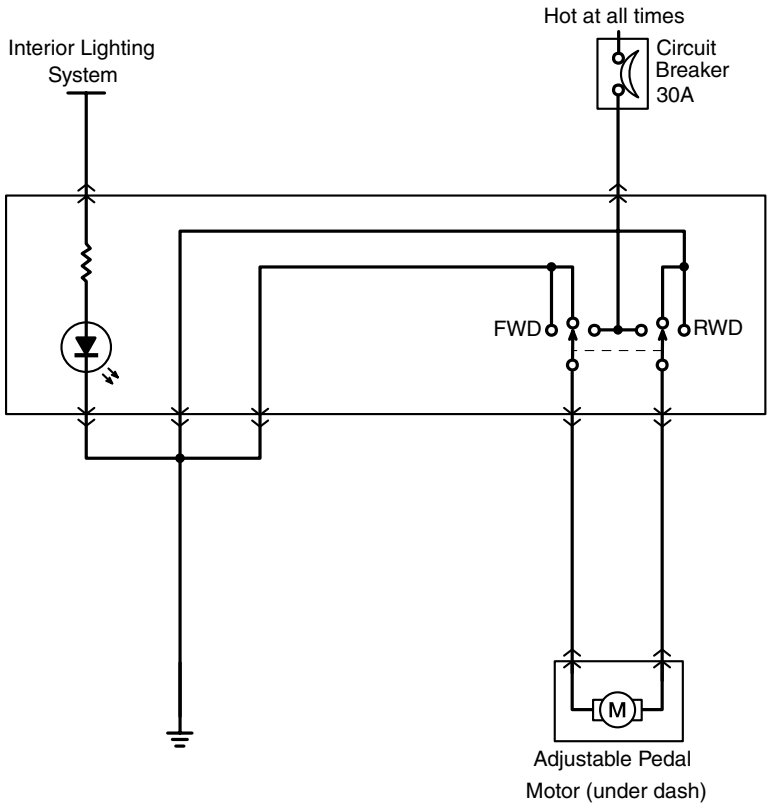


FIGURE 9-38 Power adjustable pedals afford drivers the ability to position the seat and the pedals for comfortable and safe positioning without causing the distance from the steering wheel to be too close or too far.

Power Adjustable Pedals

Electric pedal height adjustment allows the repositioning of the brake and accelerator pedals in and out from the firewall (**FIGURE 9-38**). This provides the driver with additional ergonomic comfort by allowing him or her to more effectively position the driving controls in relation to seat and steering position. The movement of the pedals is achieved by a reversible motor-driven screw (**FIGURE 9-39**). Operating the switch activates the drive motor, which in turn rotates an adjustment screw, moving the pedals in toward the firewall or out toward the driver. The accelerator pedal and brake pedal move together at the same distance so the pedal relationship to each other is maintained. The circuit consists of the fuse or circuit breaker, an adjustment switch, and the reversible motor. Additionally, the system is likely to be controlled by an electronic control unit and may incorporate memory functions and additional safety features, such as inhibitor circuits, that prevent it from operating when the vehicle is in reverse or cruise control is enabled.

FIGURE 9-39 Adjustable pedal assembly.

Adjustable pedal systems use a gang type switch that moves both switch contacts to control the voltage polarity to the motor (**FIGURE 9-40**). The motor direction is controlled by changing the voltage polarity to the motor so the pedals can be moved inward or outward. System diagnosis is straightforward: Verify source voltage is present at the switch and then perform voltage tests to verify if the switch, motor, or related wiring is the cause of the concern.

Motor circuits may seem complex when first reviewing the wiring diagram. Current paths through the switch assembly must be interpreted, and related service information must be reviewed. Completing the Skill Drills in this chapter should help you feel comfortable with what is required to prepare wiring diagrams, access the circuit components, and perform diagnostic voltage tests on these circuits.

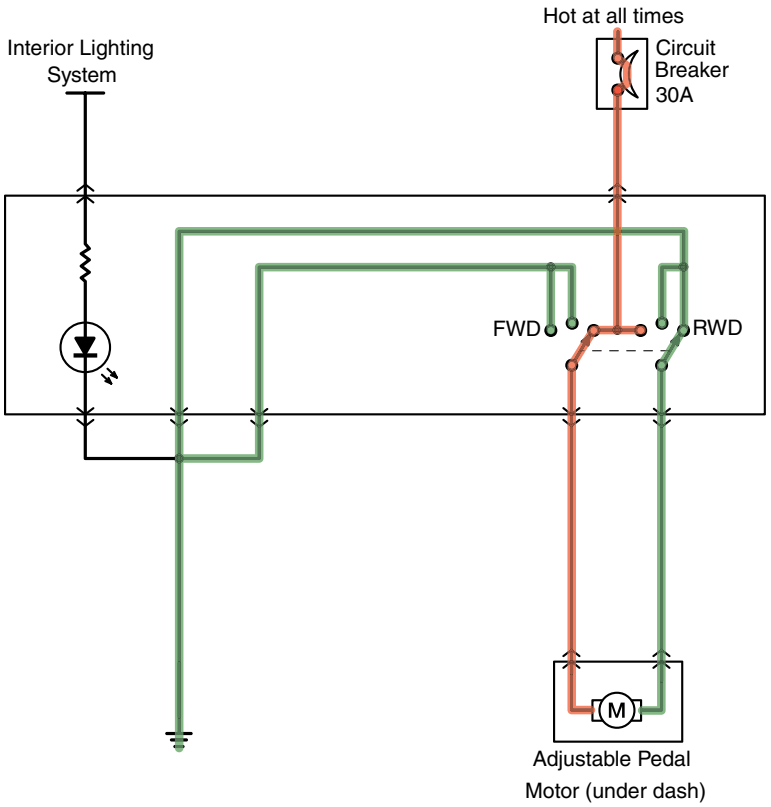


FIGURE 9-40 This adjustable pedal system uses a gang type switch to control motor rotation direction to move the pedals forward or backward.

Wrap-Up

Ready for Review

- Motors may be electromagnetic, stepper, or DC servo controlled.
- Electromagnetic motors have been the most common type used in automobiles but stepper and DC servo types are being used in more applications with each new model year.
- DC electromagnetic motors use magnetism to create the rotating motion and necessary torque to operate accessories.
- DC motors have very little measurable resistance when off. Operation of the motor creates counter-electromotive forces that create resistance to current in the motor when it is on.
- DC electromagnetic motors may use field coils that surround an iron core to create a magnetic field. Many newer motors use permanent magnets, which allow the motor to be smaller in size and lower in weight.
- The rotating part of an electromagnetic motor is usually referred to as an armature with segmented coils of wire that retain correct polarity through the windings as it rotates on the brushes.
- Vehicle DC motors use permanent type lubrication in their construction. Under normal use the motor should not require maintenance and many are permanently sealed. Motors with very high use eventually exceed the life of the lubricant, which can lead to motor noise, slow or erratic operation, or a stuck motor. Some motors can be disassembled and repaired, while those that are permanently sealed usually require replacement.
- Stepper motors use staged coils that are operated by an ECU or small electronic controller to control movement. Stepper motors are often used where specific movement is required rather than continuous movement at high speed.
- DC servomotors are similar to electromagnetic motors but incorporate electronic components that monitor their speed and position so an ECU or logic control unit can operate them with precise control. These may be used for windshield wipers, sunroofs, power tailgates, and sliding doors where position of the component and obstacle detection is required.
- Electromagnetic motor circuit diagnosis may require use of an inductive current pickup to determine if excess current is present or if there are problems within the motor. Use of a digital storage oscilloscope can determine current and if there are faults inside the motor like a partially shorted or open armature, worn brushes, or worn bearings.
- DC stepper and servomotors may be diagnosed using a scan tool communicating with the related system ECU.

Some systems store DTCs for these motor circuits. The scan tool may also offer test functions to control motor operation and verify that the motor and related circuit components are functioning.

- Motor circuit diagnosis relies on use of the circuit diagram and related service information on circuit operation and any applicable symptom tables or diagnostic flowcharts. Circuit tracing and available voltage prediction on the wiring diagram ensure that your testing is focused and you can efficiently isolate where the fault may be.

Key Terms

armature The motor rotor is divided into segments that contain loops of copper wire. Segments 180 degrees apart are energized by a positive and negative brush that is attached to the source voltage (positive) or ground (negative) in the circuit. This energizes that segment of the rotor to create a magnetic field that interacts with the magnetic field created by the field winding around the pole shoe. The armature has several segments which allow the magnetic field to be essentially continuous. As one set of armature segments rotate away from brush contact, another set takes their place to provide smooth motor speed and torque output.

blower motor A motor used to circulate air through the heating, ventilation, and air conditioning system in the vehicle. The blower motor speed may be controlled by adding resistors in series with the motor depending on the blower motor switch position. Most newer vehicles use electronic circuits to control current or voltage to a transistor that is in series with the blower motor and can provide eight or more different fan speeds.

bus bar A bus bar may be used in switch panels that have two or more switches in them. The bus bars provide a path to source or ground to control the circuit. Motor circuits that reverse direction often use bus bars to control circuit polarity depending on switch position. The power window switch connects to the bus bar in two ways, one to control the motor to lower the window and in reverse polarity to raise the window.

field windings Loops of wire wound around metal that is curved in shape to be as close as possible to the motor armature/rotor. The field windings create a magnetic field that is focused around the metal they wrap around. This metal, usually iron, is called a pole shoe. This magnetic field interacts with the magnetic field in the armature to create the rotating motion and torque output of the motor.

initialize Some body electrical systems require initializing for proper operation. This is usually required after the battery is disconnected during battery replacement or as part of a service procedure like diagnosing an SRS (airbag) fault. Auto up/down power windows may require initialization for this feature to function. Follow the procedures outlined in the service information under "Initialization." Failure to do this can lead to vehicle comebacks because the customer believes the windows or other system is no longer working as it did before your vehicle service.

park switch A switch that is integral to the rotating gear in the wiper motor. This switch allows the motor to operate after the wiper switch is turned off. The switch opens when the wipers reach their parked position at the lower edge of the windshield and the motor then stops.

permanent magnet Permanent magnets do not require a field winding to create a magnetic field. These are essentially permanently magnetized pole shoes that surround the armature. Permanent magnets are created using rare earth metals blended together to form a magnetized metal. Permanent magnet motors can be smaller and lighter since field coils are not required.

rotor The rotating portion of the motor may be referred to as a rotor (or armature in electromagnetic type motors).

servomotor A motor with built-in electronic circuitry and components to monitor motor position and speed.

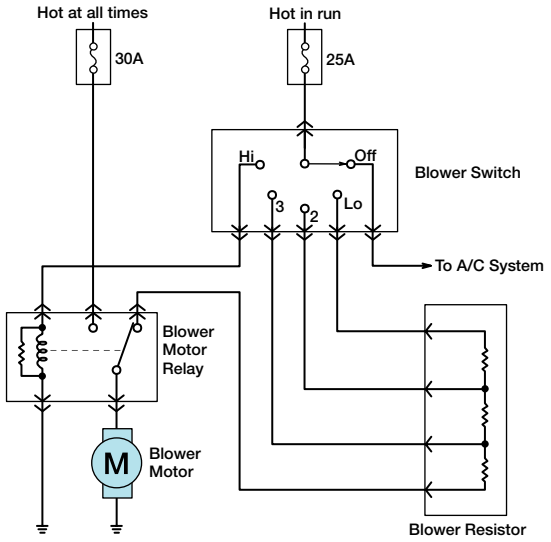
stator The stationary part of the motor that contains the field windings and pole shoes. These components usually mount to the inside of the motor case or housing.

stepper motor A specialized DC motor that has a rotor that is operated by a series of coils that surround the rotor. The rotor is stepped, or moved incrementally, by pulsing the coils in sequence causing the rotor to move in a specific direction and amount of rotation. The coils can be pulsed in either direction so the rotor can move clockwise or counterclockwise. These motors are often used to move a component a very specific amount for precise control of the related output system, like the heating and air conditioning duct work. A stepper motor may be used to operate the outlet doors to control where the air is directed inside the passenger compartment.

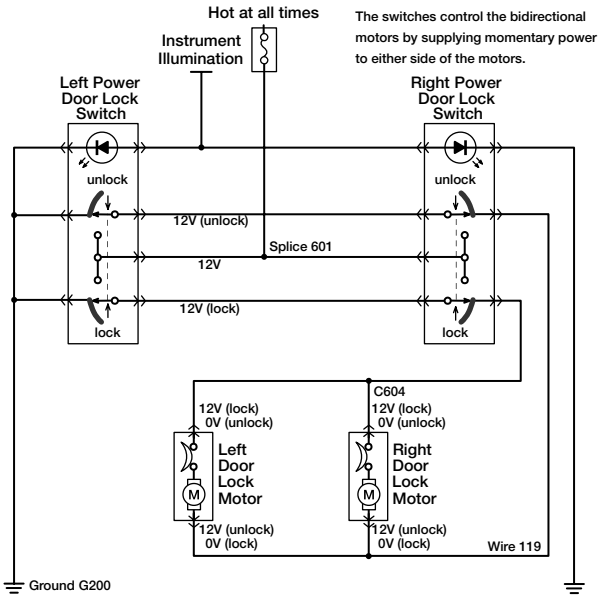
timer circuit Timer circuits are used in many body electrical circuits. The example in this chapter refers to the timer that operates the windshield wiper intermittent function. The timer circuit uses resistors to control the charge rate of capacitors. When the capacitors reach full charge, they trigger a transistor to provide voltage to the wiper motor. The resistance is varied by the customer selecting the rate of intermittent wiper action from short to longer interval selections on the wiper control switch.

Review Questions

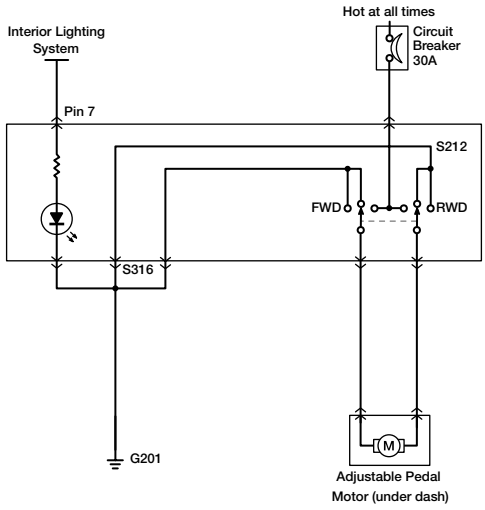
1. Power window switches usually feature all of the following *except*:
   - **a.** auto up/down operation.
   - **b.** mechanical master gang type switch connection to the related door switch.
   - **c.** a lockout feature to disable the function of the passenger door switch(es).
   - **d.** features normally open contacts.
2. The blower motor functions on Hi and M3 only. Which of the following would most likely cause this concern?
   - **a.** Open motor ground
   - **b.** Damaged blower motor brushes
   - **c.** Open in resistor block middle resistor
   - **d.** Open in blower motor relay coil



3. The right door lock motor does not function. The left door motor functions correctly for lock and unlock. Which of the following could cause this concern?
   - **a.** Open at ground G200
   - **b.** Open at splice 601
   - **c.** High resistance on PK/Y wire (119)
   - **d.** High resistance at connector C604



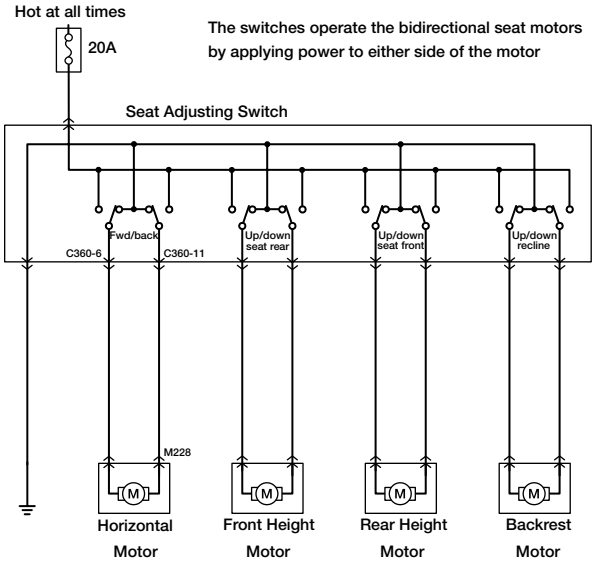
4. The pedals do not adjust. This could be caused by all of the following *except*:
   - **a.** open at S316.
   - **b.** open at G201.
   - **c.** high resistance at S212.
   - **d.** high resistance at pedal switch pin 7.



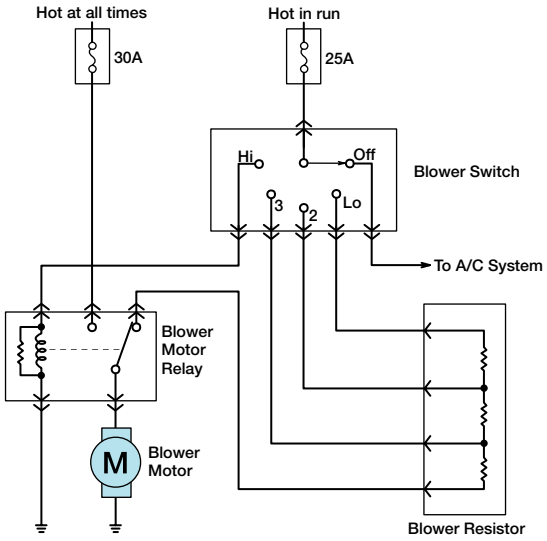
5. Which of the following motors uses an encoder to determine the exact position of the rotor and provide the input to ECU?
   - **a.** DC stepper motor
   - **b.** AC stepper motor
   - **c.** DC servomotor
   - **d.** Electromagnetic DC motor
6. Which component is connected to the wiper park switch to help park the wiper blades in the parking position such that it does not block the driver's view?
   - **a.** Gear teeth
   - **b.** Articulated arm
   - **c.** Pivot point
   - **d.** Output shaft connected to cam
7. Which mechanism is used in the two-motor wiper system so that the blades do not interfere with each other?
   - **a.** Wiper motor connected to a series of linked arms
   - **b.** Wiper motor connected to the articulated pivot point
   - **c.** Motor connected to a gear drive
   - **d.** Position sensing system
8. Which of the following is to be isolated and fault tested if there is no voltage at the blower motor?
   - **a.** Stator
   - **b.** Ground fault in the motor
   - **c.** Brushes
   - **d.** Fuses
9. Which of the following motors is used in power window systems?
   - **a.** An induction motor
   - **b.** A permanent magnet motor
   - **c.** An induced magnet motor
   - **d.** An AC induction electric motor
10. Which component controls voltage polarity in electric windows?
    - **a.** Window switch
    - **b.** Gear
    - **c.** Scissor-acting lever
    - **d.** Cable and lever system

ASE Technician A/Technician B Style Questions

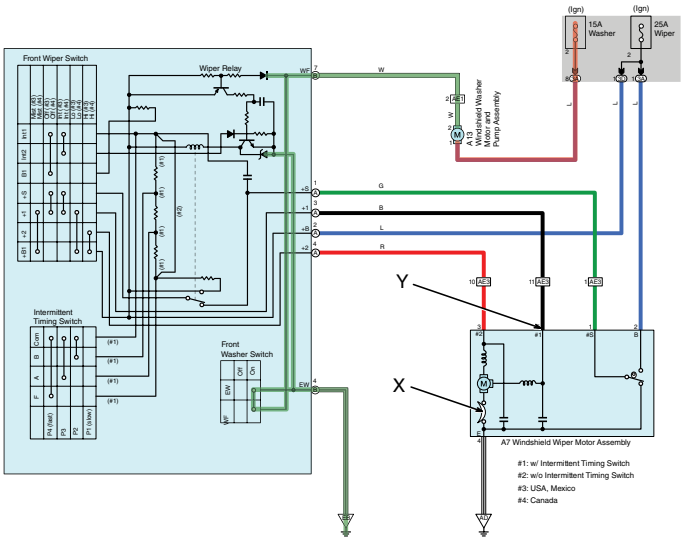
1. Tech A says most wiper motors use resistors to control low and high speed. Tech B says the intermittent wiper function timer is controlled by using resistors to control capacitor charge time in some wiper systems. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says blower motor high-speed position may use a relay for this speed only. Tech B says the lowest blower speed is created by resistors in series with the blower motor. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says the voltage drop between C360 pin 6 and pin 11 should be more than 500mV during seat operation. Tech B says M228 should have a voltage drop close to source voltage. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



4. The left power mirror does not operate for any adjustment function. The right mirror operates normally. Tech A says this could be caused by a faulty position switch. Tech B says this may be caused by an open in the wiring harness to the right mirror. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. The customer states the auto down feature does not work on the driver's window. It goes up and down normally. Tech A says the window system may require initialization. Tech B says the motor is failing and using too much current. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says the power window circuit usually uses switches that can reverse current polarity to operate the motor in two directions for lowering and raising the window. Tech B says most power window switches use a bus bar to supply source and ground to the window motor. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. Refer to the blower motor circuit shown. The blower motor does not operate on low speed. Tech A says the blower motor may have a bad armature winding. Tech B says there may be an open in the resistor block. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



8. Refer to the wiper motor circuit shown. The blower motor only operates on low speed. Tech A says there may be an open at point X. Tech B says there may be an open at point Y. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



9. Tech A says most DC electro-magnet motors can be tested using fused jumper leads connected to source and ground. Tech B says stepper motors may require a re-learn procedure during service. Who is correct?

a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

10. Tech A says most electro-magnet type motors have about 50 Ω of resistance when off. Tech B says a stalled motor can cause a fuse to blow due to high current. Who is correct?

a. Tech A
b. Tech B
c. Both A and B
d. Neither A nor B

CHAPTER 10

Instrument Cluster, Non-ECU-Controlled

NATEF Tasks

- **N10001** Inspect and test gauges and gauge sending units for causes of abnormal gauge readings; determine needed action. (AST/MAST)
- **N10002** Diagnose (troubleshoot) the causes of incorrect operation of warning devices and other driver information systems; determine needed action. (AST/MAST)

Knowledge Objectives

After reading this chapter, you will be able to:

- **K10001** Describe the operation of the instrument cluster gauges.
- **K10002** Describe the operation of the warning lights.

Skills Objectives

After reading this chapter, you will be able to:

- **S10001** Perform diagnostic tests on the fuel gauge circuit.
- **S10002** Perform diagnostic tests on the coolant temperature gauge or warning light circuit.
- **S10003** Perform diagnostic tests on the oil pressure gauge or warning light circuit.

You Are the Automotive Technician

The customer states they have run out of fuel several times even though the fuel gauge did not go below the ¼ tank remaining level. The technician removes the fuel sending unit from the fuel tank and verifies that at the Empty position the gauge displays ¼.

1. How is does the fuel gauge sending unit operate?
2. How does the fuel gauge use the voltage signal from the fuel sending unit?
3. What precautions should be observed when testing these circuits?

Introduction

Instrument clusters provide the driver with information on coolant temperature, oil pressure, engine rpm, battery rate of charge, fuel level, transmission range indication, vehicle speed, and vehicle mileage (**FIGURE 10-1**). There may be additional gauges, system indicators, and warning lights depending on the applicable systems that are found on a particular vehicle.

FIGURE 10-1 The instrument cluster house gauges and warning indicators to keep the driver informed of engine operating information, fuel level, battery charge, and many other systems.

Instrument clusters can be separated into four generations. The first-generation instrument clusters used in automobiles of the early twentieth century were primarily mechanical in their operation. The Model A Ford used a cable-operated speedometer/odometer, a mechanical fuel level gauge, and an electro-mechanical ammeter to monitor charging system operation (**FIGURE 10-2**).

Second-generation instrument clusters continued to use mechanical gauges for speed, mileage, engine temperature, and even oil pressure, but the fuel gauge used a sending unit in the fuel tank that varied voltage to the fuel gauge to indicate fuel level. Within a few years, more of the instruments used sending units to send engine coolant temperature and oil pressure readings using voltage rather than by mechanical means.

The third generation of instrument clusters used fully electronic instrumentation and continue to primarily use dedicated sending units to provide voltage signals to operate the gauges and warning indicators (**FIGURE 10-3**). This chapter will focus on the technology used for these instrument clusters, as there are still many vehicles in use that require your knowledge of how they operate in the event a customer concern requires diagnosis.

The fourth generation of instrument clusters will be covered in the Vehicle Network Systems chapter. These instrument clusters are ECU based and the instruments obtain data primarily from the vehicle **network**, as the sending unit or input sensor signals are sent to specific ECUs and then shared over the vehicle network.

FIGURE 10-2 Early instrument clusters used mechanical instruments to display vehicle speed and fuel level. The Model A fuel gauge read directly from the fuel tank mounted in the cowl area below the windshield.

FIGURE 10-3 Vehicles in the late 1980s and through the 1990s used fully electronic instrumentation.

▶ Instrument Cluster Gauge Operation

K10001 Describe the operation of the instrument cluster gauges.

N10001 Inspect and test gauges and gauge sending units for causes of abnormal gauge readings; determine needed action. (AST/MAST)

Gauge operation in non-ECU type instrument clusters is primarily electro-mechanical. Electro-mechanical reflects that the operation of the gauge has electrical and mechanical elements for it to function. There were some instrument clusters in the 1980s and early 1990s that used digital readouts with LEDs or vacuum fluorescent displays rather than electro-mechanical gauges. The content in this chapter will focus on the instrumentation systems that still rely on **analog** gauges. Although, like the **digital** instrument clusters, this technology now dates back to the 1990s, there are still many vehicles in use with these instrument clusters and they may require service. Also, the ASE A6 test still covers some of these systems, so this chapter ensures you are familiar with them. Two gauge designs have been used for most vehicles. One uses coils that create magnetic fields to move the needle. The other uses a bi-metallic arm that reacts to temperature to move the needle.

Fuel Gauge

S10001 Perform diagnostic tests on the fuel gauge circuit.

The fuel gauge was one of the first electro-mechanical gauges used in motor vehicles, and the technology of the gauge continues to this day (**FIGURE 10-4**). The **sending unit** portion of the gauge is located in the fuel tank. It uses a float usually made out of brass or plastic that moves a lever depending on the amount of fuel in the tank. The float lever has a wiper that contacts the wire wound resistor and completes the circuit to ground.

There are two common analog gauge designs used in instrument clusters. The first type uses two coils with one connected in series with the sending unit. The coils create a magnetic field that acts upon the gauge needle to move it toward the left or right depending upon fuel level. The coil connected to the sending unit balances the coil on the left that connects to ground (**FIGURE 10-5**). The sending unit is at its lowest resistance when the fuel

FIGURE 10-4 The fuel gauge is the second most looked at instrument in front of the driver, the speedometer being first.

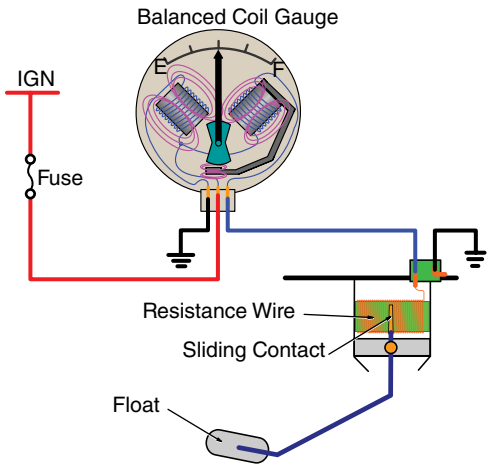


FIGURE 10-5 One type of fuel gauge uses coils and magnetic fields to operate the gauge needle.

level is near empty and at its highest resistance when the fuel tank is full. When the tank is full, the left coil is more dominant and its magnetic field causes the needle base to rotate the needle to the Full mark. As fuel is consumed from the fuel tank, the coil connected to the sending unit starts to act upon the needle and the needle is pushed back against the left coil's magnetic field. When the tank is very close to empty, the fuel sending unit resistance is very low. This creates a strong magnetic field in the right coil that is stronger than the coil on the left and the gauge needle is moved to the Empty mark. Gauges that use the balanced coil system may not move after the ignition is turned off or they may move to a resting position that could be anywhere in the gauge range of travel. This is normal. An open circuit on the sending unit ground or sending unit wire will cause the gauge to always read Full, and a shorted sending unit or sending unit wire will cause the gauge to always read Empty. Diagnosis usually includes testing the sending unit for proper resistance, ensuring that voltage is present to the sending unit, and ensuring there is a good sending unit ground. If all is OK, the gauge may be faulty. Refer to the related service information for the test procedures required for the fuel gauge circuit you are diagnosing.

Most fuel sending units are calibrated to read Empty when approximately two gallons of fuel are remaining in the tank. Assembly variations of sending units and gauges cannot provide a 100% accurate reading, so the engineers built in a two-gallon cushion to allow for these variables and to allow the customer to locate a fuel station without running out of fuel.

The bi-metallic arm gauge system also uses a sending unit mounted in the fuel tank (**FIGURE 10-6**). The sending unit in this system has high resistance when the tank is near empty and low resistance when the tank is full. The resistance of the sending unit is in a series circuit, sharing voltage with the heating coil located on the bi-metallic arm in the gauge. When the tank is full, the low sending unit resistance causes the heating coil to heat up enough to move the gauge needle to the Full mark. The sending unit moves downward in the fuel tank as fuel is consumed. This increases the resistance across the sending unit which increases the voltage drop across the sending unit resistor. This reduces the voltage at the heating coil and the gauge needle moves toward Empty as the bi-metallic arm temperature lowers due to the lower voltage drop across it.

These gauges may require the use of a voltage regulator in the circuit. The voltage regulator allows the circuit to operate on a lower voltage that will not be affected by changes in voltage due to electrical load on the charging system. Also, these gauges typically return to the minimum indicator position when the ignition is turned off. An open circuit, open ground, or open in the sending unit resistance wire will cause this gauge to remain at the minimum position. Diagnosis focuses on the correct voltage at the gauge, the correct

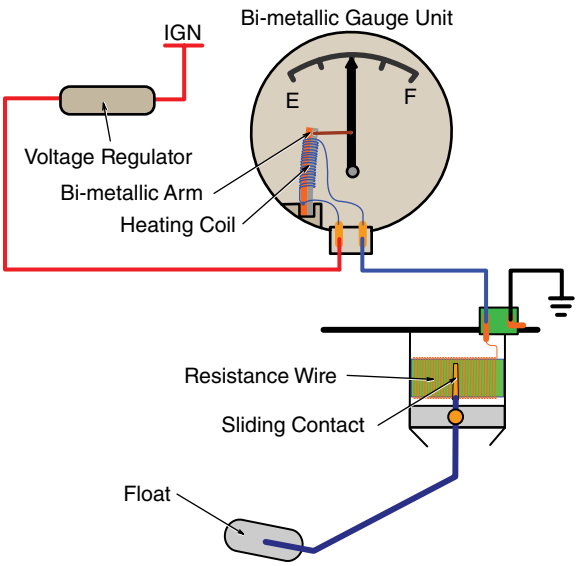


FIGURE 10-6 Another type of gauge uses a heating element wrapped around a bi-metallic arm to move the needle.

SKILL DRILL 10-1 Testing Fuel Gauge Circuits

1. Refer to the service information to verify the type of fuel gauge used (bi-metallic heater or balanced coil).
2. Locate the wiring diagram and note the color of the fuel gauge sending unit wire and its location in the tank unit harness connector.
3. Locate the fuel sending unit wiring harness connector at the fuel tank. For balanced coil types, disconnect the harness connector and note the fuel gauge reading. It should go to the Full position.
4. For bi-metallic types, use a fused jumper lead to connect the fuel sending unit signal wire to a known good ground. The fuel gauge should now read at the Full position.
5. Reconnect any disconnected harness connectors or remove the jumper lead. Verify that the fuel gauge now functions normally and verify your work with your instructor.

resistance range of the sending unit, and confirmation that there is a good ground. If all is OK, the gauge is most likely at fault. Refer to the service information for the vehicle you are diagnosing for specific tests and specifications.

To test fuel gauge circuits, follow the steps in **SKILL DRILL 10-1**.

Temperature Gauge

S10002 Perform diagnostic tests on the coolant temperature gauge or warning light circuit.

Engine coolant and other temperature gauges, like oil or transmission fluid, indicate the temperature of the system fluid. Some gauge face displays only use hash marks to indicate that the temperature is in the normal zone. They often use a zone in red to indicate the fluid is too hot and that damage may occur if the vehicle continues to be operated (**FIGURE 10-7**). Other gauge faces may use temperature values which indicate the temperature of the fluid.

Temperature gauge circuits are essentially identical to the fuel gauge type except that a sending unit that reacts to temperature is used. The sending unit uses a temperature sensitive resistance. Some units use a thermistor while others use a temperature conducting spring connected to a sensing element (**FIGURE 10-8**). Both sender unit types have high resistance when the fluid is cold and low resistance when the fluid is hot. Diagnosis focuses on the sending unit. When you ground the sending unit wire, the gauge should go to the Hot position. This quickly verifies whether the gauge is OK. If the gauge is OK, follow the service information procedures to inspect the sending unit. If the gauge does not react to a grounded sending unit wire, there may be an open circuit in the harness or the gauge may be at fault. The sending unit wire should have voltage when disconnected from the sending unit. If it does, verify that the voltage matches service information specifications. If the voltage is 0, check the wiring and related harness connections for continuity and voltage to the gauge.

FIGURE 10-7 The engine coolant temperature gauge indicates the temperature of the cooling system.

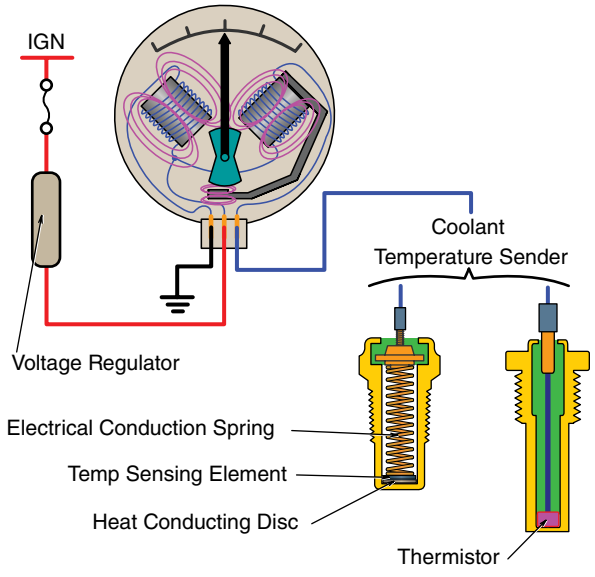


FIGURE 10-8 Temperature gauges use temperature senders to operate the gauge.

SKILL DRILL 10-2 Testing Temperature Gauge Circuits

1. Refer to the service information to verify the type of temperature gauge used (bi-metallic heater or balanced coil).
2. Locate the wiring diagram and note the color of the temperature gauge sending unit wire and its location in the engine compartment.
3. Disconnect the sending unit wire and measure the available voltage with the key on, engine off. Compare your reading with the service information specification to ensure the circuit is operating normally.
4. Use a fused jumper lead to connect the fuel sending unit signal wire to a known good ground. The temperature gauge should now read at the Hot position.
5. Reconnect any disconnected harness connectors or remove the jumper lead. Verify the temperature gauge now functions normally and verify your work with your instructor.

To test the temperature gauge circuits, follow the steps in **SKILL DRILL 10-2**.

Oil Pressure Gauge

S10003 Perform diagnostic tests on the oil pressure gauge or warning light circuit.

The oil pressure gauge circuit is similar to the fuel gauge circuit. The oil pressure sending unit is mounted in the oil galley of the engine and it has an open path to the oil pressure. The oil enters the sending unit and pushes against a diaphragm that is sealed to the housing of the sending unit (**FIGURE 10-9**). The diaphragm moves a wiper arm across a resistance, similar to the fuel sending unit, which is in a series circuit with the gauge. The change in voltage drop across the gauge and the sending unit moves the gauge pointer to indicate the amount of engine oil pressure.

To test oil pressure gauge circuits, follow the steps in **SKILL DRILL 10-3**.

Speedometer and Odometer

The speedometer and odometer for many years were mechanically connected to a drive wheel or output shaft of the transmission using a cable housed inside a protective sheath. Electronic speed sensors saw use in the 1970s, and by the 1980s, the **vehicle speed sensor (VSS)** replaced the speedometer/odometer cable in most vehicles (**FIGURE 10-10**). The vehicle speed sensor was usually mounted on the output shaft of the transmission or transaxle in the same location that the speedometer cable drive gear assembly had been previously. The VSS is rotated by a gear on the transmission output shaft. The operation of most VSS uses magnetism to create an alternating current (AC) output voltage in the form of a sine wave (see the Electronic Components chapter for complete operating details of speed sensors). The speedometer and odometer assembly in the instrument cluster of most vehicles uses an electronic circuit that converts the AC output VSS signal into a direct current digital output signal. The digital output signal is

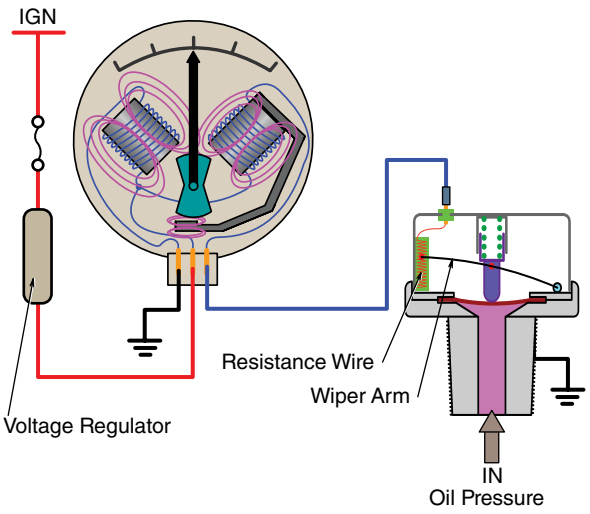


FIGURE 10-9 The oil pressure sending unit in many vehicles uses a wiper that changes the resistance in the circuit based on the amount of engine oil pressure.

SKILL DRILL 10-3 Testing Oil Pressure Gauge Circuits

1. Refer to the service information to verify the type of oil pressure gauge used (bi-metallic heater or balanced coil).
2. Locate the wiring diagram and note the color of the oil pressure gauge sending unit wire and its location in the engine compartment.
3. Disconnect the sending unit wire and measure the available voltage with the key on, engine off. Compare your reading with the service information specification to ensure the circuit is operating normally.
4. Use a fused jumper lead to connect the fuel sending unit signal wire to a known good ground. The oil pressure gauge should now read at the maximum position.
5. Reconnect any disconnected harness connectors or remove the jumper lead. Verify the oil pressure gauge now functions normally and verify your work with your instructor.

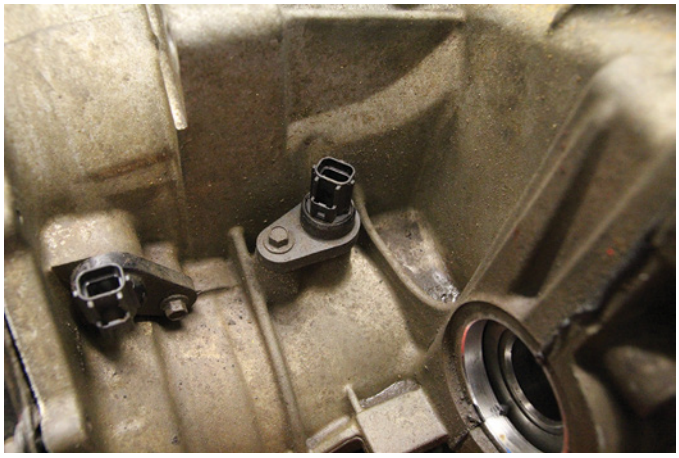


FIGURE 10-10 The speedometer and odometer receive signals from the vehicle speed sensor usually located on the transmission output shaft.

FIGURE 10-11 Digital instrumentation was popular in the 1980s and 1990s. Most current vehicles use both analog and digital instruments.

a varying voltage that can be used to operate a motor that operates the speedometer and odometer, similar to the way the mechanical cable type speedometer/odometer operated. Other vehicles may use the VSS signal to create a magnetic pulse output to drive the speedometer and odometer.

Digital Instrumentation Displays

Vehicles that use a digital display rather than an analog needle type gauge and mechanical odometer use the VSS input to an electronic circuit that converts the signal into a numeric value on the display (**FIGURE 10-11**). The digital odometer uses a circuit that counts the pulses to determine mileage. The mileage is "saved" by using a memory circuit that permanently stores the mileage as it accumulates. This prevents the mileage from being reset if the battery is disconnected or the instrument cluster is disconnected from its harness connector.

Electronic speedometer and odometer diagnosis focuses on correct VSS operation and the related wiring and harness connections. VSS testing is covered in the Electronic Components chapter. If the sensor or wiring harness is OK, the fault is in the speedometer/odometer assembly. A faulty assembly usually requires replacement. Ensure the current vehicle mileage is noted following federal and state laws; they often require that an "Odometer Replacement" tag is located on the B pillar near the manufacturing data plate. Some of these components are now obsolete; new parts are scarce or no longer available on vehicles from the 1990s, so they may require the use of a repair service or replacement with a used part to restore speedometer/odometer function. Whether using a new or used speedometer/odometer cluster unit, you must follow the law to document the vehicle mileage at replacement and the mileage of the new or used unit.

▶ TECHNICIAN TIP

Odometer tampering is a federal crime. Altering mileage or replacing an instrument cluster with one that has less mileage than what is actually on the vehicle is a fraud. Someone may purchase the vehicle believing that the mileage displayed on the odometer is accurate for the vehicle. If a failed odometer must be replaced, the current mileage of the vehicle must be noted on an approved "Odometer Replacement" decal that is then placed on the left side "B" pillar. Review the law to ensure your repair and any required notice of odometer change is performed according to federal and state laws.

K10002 Describe the operation of the warning lights.

N10002 Diagnose (troubleshoot) the causes of incorrect operation of warning devices and other driver information systems; determine needed action. (AST/MAST)

▶ Warning Lights

Vehicles contain an array of **warning lights** (**FIGURE 10-12**). Some of these lights may be used in conjunction with an analog or digital gauge or they may be a substitute for a gauge. Lights that replace a gauge for engine coolant temperature and oil pressure have received unkind nicknames because they can leave the driver with the sense that everything is OK until it is too late and engine damage is done.

A warning light uses a sending unit that provides a path to source voltage or ground and is basically a switch. The warning lights usually illuminate when the vehicle is started, sometimes called a prove-out, to let the driver know that the lights operate. The lights go out as the engine starts on most vehicles (if everything is within normal parameters).

Coolant Temperature Warning Light

A coolant temperature warning light sending unit contains a switch that is operated by an expanding spring or wax that closes the switch contact when the coolant temperature approaches the overheat limit (**FIGURE 10-13**). The closed switch provides a path to ground and the warning light turns on. Some vehicles use a dual temperature switch with two switches, one that illuminates an "engine cold" light and the other to warn of an overheat condition. These dual temperature switches can be identified by having two contact pins rather than one.

▶ TECHNICIAN TIP

Some vehicles use the oil pressure switch as part of a fuel pump shutoff safety circuit. Should the vehicle be involved in a serious collision, the engine will most likely stop with the ignition on. The stopped engine no longer has oil pressure so this opens the current path to the fuel pump to shut it off, preventing it from continuing to pump fuel should there be a fuel leak that could result in a fire. Vehicles with CAN OBD II (covered in the Vehicle Network Systems chapter) use shared data to determine if the fuel pump should be turned off in a collision event.

Oil Pressure Warning Light

The oil pressure switch is used to turn on the low oil pressure warning indicator when oil pressure falls below minimum levels, usually 5 to 10 psi (**FIGURE 10-14**). The oil pressure switch uses normally closed contacts that provide a path to ground for the warning indicator light. The light turns on when the ignition is turned on, and it remains on until the engine starts and oil pressure rises to normal levels. The oil pressure pushes on a diaphragm that opens the switch contacts and the light turns off.

Fluid Level Warning Light

Fluid level switches may be used to indicate low fluid level for the brake master cylinder, coolant reservoir, washer fluid, and engine oil (**FIGURE 10-15**). Fluid level switches usually use a moveable float that raises or lowers depending on fluid level. The float usually has a small magnet in it that reacts with a reed switch inside the main body of the switch.

A **reed switch** reacts to magnetism (**FIGURE 10-16**). Most fluid level sensors use a normally closed reed switch. When the float with the magnet is at normal fluid level, the circuit is off (open) and the warning light remains off. When fluid level drops below normal levels, the reed switch contacts close and turn on the related fluid level warning light.

FIGURE 10-12 Warning lights may be used with or in place of some gauges.

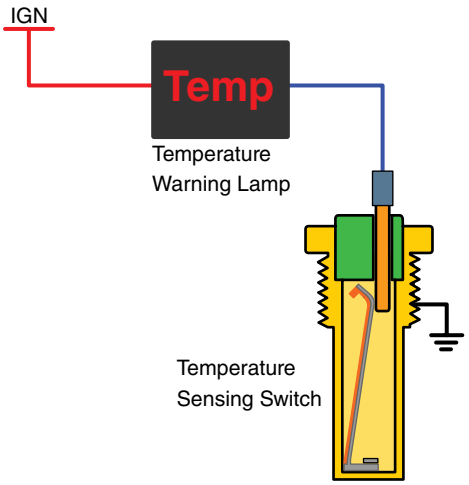


FIGURE 10-13 A coolant temperature switch is used to turn the warning light on.

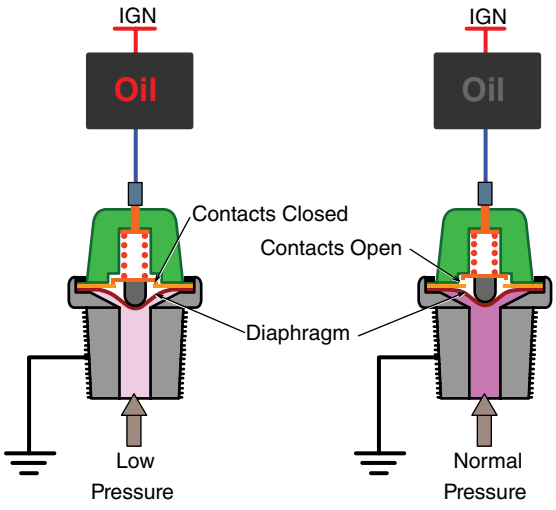


FIGURE 10-14 Oil pressure switches usually have normally closed switch contacts. Oil pressure opens the switch contacts to turn off the warning indicator.

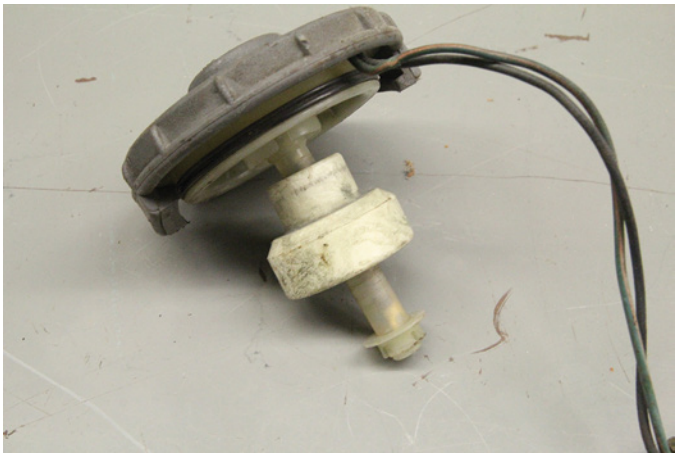


FIGURE 10-15 Fluid level switches use a float to open or close a switch to indicate low fluid level.

Fuel Level Warning Light

The low fuel warning indicator usually turns on when there are about two gallons of fuel remaining in the fuel tank (**FIGURE 10-17**). The fuel level sensor for the fuel gauge usually incorporates a switch that controls the ground path for the warning light. The warning light turns on when the fuel level float reaches the point that the swing arm touches the low fuel circuit contact, which turns the warning indicator on.

Some older vehicles used a **thermistor** to determine low fuel level. The fuel is typically cooler than the fuel vapor in the tank. The thermistor is in a series circuit with the warning light. The thermistor has high resistance when cool, so most of the warning light circuit voltage drops across the thermistor and the light remains off. As the fuel level drops in the tank, more of the thermistor housing is no longer immersed in the fuel, to the point that when about two gallons are remaining, the thermistor is completely exposed. The thermistor resistance decreases in the warmer vapor allowing most of the voltage to drop across the warning light and it turns on.

To test the warning light circuits, follow the steps in **SKILL DRILL 10-4**.

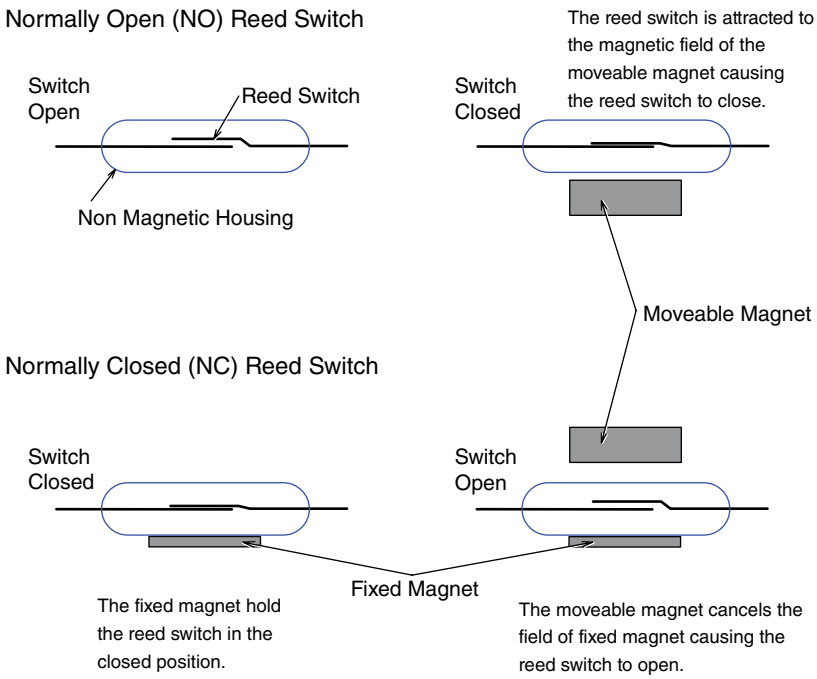


FIGURE 10-16 Fluid level switch assemblies often use reed switches to control warning light operation.

FIGURE 10-17 The low fuel level warning light indicates the fuel level is approximately two gallons from empty for most vehicles.

SKILL DRILL 10-4 Testing Warning Light Circuits

1. Refer to the service information for the warning light circuit assigned by your instructor.
2. Locate the wiring diagram and note the color of the warning light sending unit wire or wires and their location in the engine compartment.
3. Disconnect the sending unit wire and measure the available voltage with the key on, engine off. Compare your reading with the service information specification to ensure the circuit is operating normally.
4. For warning lights that use the fluid level switch to control the circuit ground, use a fused jumper lead to connect the warning light fluid level sensor wire to a known good ground. The warning light should now turn on.
5. Reconnect any disconnected harness connectors or remove the jumper lead. Verify the fluid warning light now functions normally and verify your work with your instructor.

The instrument cluster gauge and warning light systems in this chapter form the basis for those to be discussed in the Vehicle Network Systems chapter. The systems in this chapter are now approaching 20 years old. Some of the gauge designs carry over to the new ECU-based instrument cluster systems. The systems in this chapter may still be covered in the ASE A6 test, and there are still many of these vehicles in service so you are very likely to encounter one needing repair.

Wrap-Up

Ready for Review

- The instrument cluster houses various gauges to inform the driver of vehicle speed, accumulated mileage, fuel level, and engine temperature.
- Some vehicles use analog gauges to convey information while others may use warning indicators that illuminate when a system is operating outside of its normal range.
- The analog fuel gauge uses a sending unit with a float that operates a lever. The lever contacts a resistance wire that is in series with the fuel gauge. This creates a varying voltage drop based on fuel level that controls the position of the fuel gauge indicator.
- The temperature gauge uses a sending unit that changes resistance based on temperature. The sending unit is in series with the temperature gauge, and the varying voltage drop created by the varying resistance in the sending unit controls the temperature gauge indicator.
- The oil pressure gauge uses a sending unit that alters resistance based on the amount of oil pressure present. The sending unit is sometimes referred to as a transducer. The varying resistance controls the position of the gauge indicator just like the fuel and temperature gauges.
- The speedometer and odometer were operated using a rotating cable in a housing. The cable connected to a gear that was driven by the transmission output shaft, or on some vehicles connected to a gear on one of the front wheel hubs. These mechanical units were used until the early 1980s.
- Cable operated speedometer/odometers were replaced with electronic units using a vehicle speed sensor that was gear driven off the transmission output shaft. The vehicle speed sensor created a voltage signal that operated the speedometer and odometer through the use of a small motor.
- Digital gauges were popular in the 1980s though the technology was not as robust and they had a high failure rate. Many new vehicles use analog readouts with some information provided in digital or text-based readouts.
- Warning lights are used to indicate that a system is not operating correctly. The light may illuminate to indicate the system has experienced a failure and remains on. Others turn on or off to indicate whether a particular system is operating or turned off. Warning indicators often only indicate an engine temperature or oil pressure problem at the same time that components may be damaged. This is why many customers interested in their vehicle's performance prefer gauges rather than warning lights.
- Warning lights are usually operated by a switch that controls a path to ground to turn on the indicator light. The switch may be inside a sending unit or may be mechanically operated like the float in the windshield washer fluid reservoir.
- Gauge diagnosis usually is made by verifying whether the gauge reacts to being grounded at the sending unit. The gauge should respond by moving fully in one direction or the other based on design. No response usually indicates a gauge or wiring fault. If the gauge responds correctly, then the sending unit is usually at fault.

Key Terms

analog For gauges, refers to the type that use a needle or pointer that varies position to indicate the related reading (e.g., fuel level). Analog can also refer to the type of signal used in a circuit. Analog signals are based on a varying voltage.

digital For gauges, refers to numeric readouts or electronic bar graph indicators for vehicle speed or fuel level. Digital can also refer to signals created using pulsed voltage signals that are either low or high. The signal is sometimes referred to as on/off pulses, duty cycle, pulse width, or a binary signal.

instrument cluster The unit that houses the gauges and warning lights.

network A system that connects vehicle ECUs so data and commands can be shared between them.

reed switch A reed switch uses metal contacts housed inside a glass housing. The switch is opened and closed when a magnetic field passes by the contacts. Reed switches were used in some instrument clusters to create a vehicle speed sensor signal from the rotating speedometer drive wheel.

sending unit A sending unit is the device that changes a temperature, fluid level, or pressure into a varying resistance. This varying resistance is in series with the related instrument cluster gauge, and the resulting voltage drop across the sending unit is what causes the needle on the gauge to indicate the related temperature, fluid level, or pressure.

thermistor A variable resistor that changes its resistance based on temperature. Most thermistors used in automotive applications have a negative temperature coefficient, meaning that their resistance decreases as temperature increases.

vehicle speed sensor (VSS) A vehicle speed sensor creates a voltage signal when the sensor gear drive is rotated by the transmission/transaxle output shaft. The output signal may be analog or digital, and the signal is used to operate the speedometer/odometer in the instrument cluster.

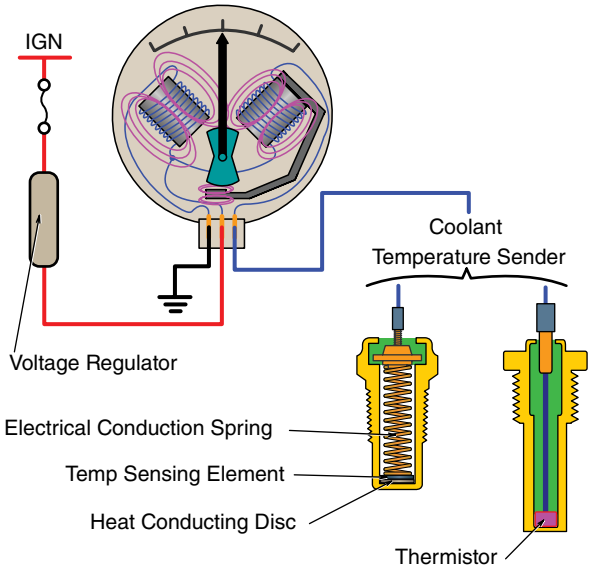
warning light An icon in the instrument cluster is illuminated to indicate there is a problem with a system or the status of a system (e.g., being on or off). A temperature warning light turns on to indicate the engine coolant temperature is exceeding normal range. A low fuel level light turns on when the fuel in the tank is very low and alerts the driver that refueling is required very soon.

Review Questions

1. A reed switch is used for which of the following warning indicator types?
   a. Low brake fluid
   b. Oil pressure
   c. Engine coolant temperature
   d. Low fuel
2. A balanced coil type fuel gauge will usually read at what fuel level if there is an open circuit ground?
   a. Low fuel
   b. Full fuel level
   c. Half fuel level
   d. Empty fuel level
3. All of the following may affect gauge operation *except*:
   a. open circuit from source voltage.
   b. high resistance at the sensor ground.
   c. open circuit in the gauge balance or heating coil.
   d. gauge illumination bulb or LED has failed.
4. Which type of operation do the gauges in non-ECU type rely on?
   a. Purely electrical operation
   b. Purely mechanical operation
   c. Electro-mechanical operation
   d. Electromagnetic operation
5. Choose the correct statement with respect to bi-metallic arm fuel gauge.
   a. The sending unit is at its highest resistance when the tank is near Empty.
   b. It will not return to the min. position after the ignition is turned off.
   c. A voltage regulator is not required in the circuit.
   d. The sending unit is at its lowest resistance when the tank is near Empty.
6. Which of the following can lead the fuel gauge to read minimum even when the ignition is on?
   a. When the fuel level is more than two gallons
   b. When the float does not have a brass valve
   c. When the bi-metallic arm system has low resistance
   d. When there is an open in the sending unit resistance wire
7. The sending unit of which of the following gauges contains a diaphragm?
   a. Fuel gauge
   b. Oil pressure gauge
   c. Temperature gauge
   d. Speedometer
8. Which of the following warning lights switches on when ignition is turned on and turns off once the normal levels are reached?
   a. Oil pressure warning light
   b. Fluid level warning light
   c. Coolant temperature warning light
   d. High speed warning light
9. Dual temperature switches can be identified by:
   a. the presence of two contact pins.
   b. their maximum heat limit.
   c. the position in which they are placed in a vehicle.
   d. the presence of a diaphragm.
10. Fluid level warning lights can be used to indicate the low fluid level in all of the following components of an automobile *except*:
    a. the brake master cylinder.
    b. the fuel tank.
    c. the engine oil.
    d. the coolant reservoir.

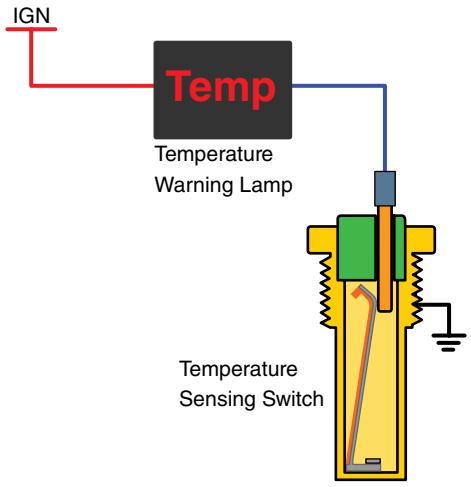
ASE Technician A/Technician B Style Questions

1. Refer to the coolant temperature circuit shown. Tech A says the coolant temperature sending unit controls the path to ground for the gauge. Tech B says an open circuit in the wire from the gauge to the sending unit will cause the gauge needle to move to the H position. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

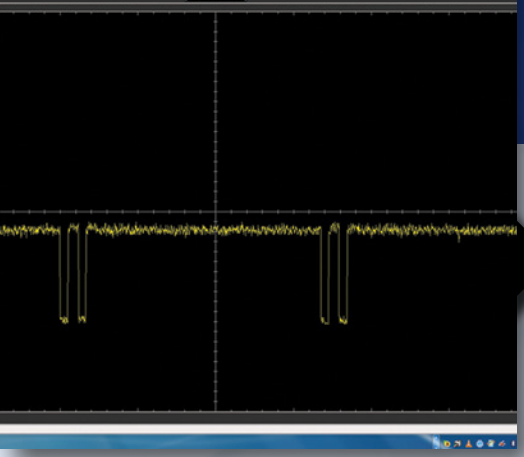


2. Tech A says the fuel level sensor uses a wiper arm connected to a reed switch. Tech B says the oil pressure gauge sending unit uses a switch to operate the gauge. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says some gauges use coils to vary a magnetic field that acts upon the gauge needle. Tech B says some gauges use a coil to heat up a bi-metallic arm to move the gauge needle. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

4. Tech A says the engine coolant temperature switch shown uses a varying resistance to operate the warning light. Tech B says the temperature switch is normally open when the coolant is within operating range. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



5. Tech A says you can usually test a warning indicator by removing the wire or connector at the sending unit and use a fused jumper lead to connect to ground. Tech B says most warning indicator lights turn on during engine start (called a prove-out). Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says the VSS usually outputs a digital signal. Tech B says the VSS is usually driven by the transmission input shaft. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. Tech A says some gauge circuits use a voltage regulator. Tech B says most warning light circuits are source controlled. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. The oil pressure warning lamp remains on after the engine is running. Tech A says the oil pressure switch contacts may be stuck open. Tech B says you can remove the oil pressure switch and connect a mechanical oil pressure gauge to determine the actual oil pressure. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. The fuel gauge of a vehicle reads erratically. Tech A says there may be a fault with the sending unit. Tech B says the gauge voltage regulator may be at fault. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Tech A says most modern vehicles use a vehicle speed sensor for speedometer and odometer operation. Tech B says the low fuel level sensor usually turns on when about 0.5 gallons of fuel remain in the tank. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B



CHAPTER 11
Advanced Diagnostic Tools

NATEF Tasks

- **N11001** Check electrical/electronic circuit waveforms; interpret readings and determine needed repairs. (MAST)

Knowledge Objectives

After reading this chapter, you will be able to:

- **K11001** Explain the use of DMM frequency, duty cycle, and Min/Max functions.
- **K11002** Explain the use of digital storage oscilloscopes (DSO).
- **K11003** Explain the use of graphing digital multimeters.

Skills Objectives

After reading this chapter, you will be able to:

- **S11001** Demonstrate use of advanced DMM functions in diagnosing on the job.
- **S11002** Demonstrate use of a DSO for signal waveform diagnosis on the job.
- **S11003** Demonstrate use of a graphing DMM in diagnosing on the job.

You Are the Automotive Technician

The customer states several warning indicators are on in the instrument cluster. You verify that the check engine (MIL) light is on, the VSC warning light is on, and the electric power steering warning light is on. There are network communication DTCs stored for each system. From the verification of the concern answer the following:

1. How can a DMM be used for diagnosis on this vehicle?
2. How can a digital storage oscilloscope (DSO) be used for diagnosis on this vehicle?
3. How can a graphing multimeter (GMM) be used for diagnosis on this vehicle?
4. What are the advantages of the DMM, the DSO, or the GMM for various vehicle electronic system diagnosis situations?

▶ Introduction

The digital multimeter (DMM) is the primary automotive electrical and electronic circuit test tool. Digital graphing multimeters and digital storage oscilloscopes are able to display voltage readings not just as a number but as a waveform on a graph. This chapter offers the opportunity to learn how to use these tools so you are prepared when the applicable diagnostic situation occurs.

▶ Advanced DMM Features

K11001 Explain the use of DMM frequency, duty cycle, and Min/Max functions.

S11001 Demonstrate use of advanced DMM functions in diagnosing on the job.

The DMM is primarily used to measure voltage when diagnosing circuit concerns (**FIGURE 11-1**). You will also use the DMM to measure resistance and on occasion to measure current, usually when diagnosing a parasitic draw concern. DMMs designed for use by automotive technicians have additional features that are required when working with ECU-controlled circuits. These features allow the technician to measure frequency, duty cycle, and record minimum and maximum voltage readings.

Measuring Frequency

Frequency related to electrical and electronic circuits is defined as the number of cycles per second and is measured in Hertz (Hz). Frequency measurements are most often used to monitor varying voltage signals in automotive circuits.

Examples of these include wheel speed sensors and crankshaft and camshaft position sensors. The sensor output signal may be an alternating current (**FIGURE 11-2**) or a digital pulse signal depending on sensor design (**FIGURE 11-3**). Speed and position sensors generate an increasing frequency as the speed of the component increases. The service information often provides a frequency value at a given speed or engine rpm so you can compare your readings and determine if the output signal is within specification.

Measuring frequency is very similar to measuring voltage. Set the DMM to AC or DC voltage, depending on the type of signal. Connect the positive lead to the signal wire of the sensor and the negative lead to a known good ground or battery negative post. Select the frequency function, usually identified by "Hz". Follow the applicable service information procedure, measure the frequency, and compare your readings with the specification provided (**FIGURE 11-4**). The DMM will usually auto range to display the most applicable reading. Review your DMM user's manual for the specific frequency ranges it provides.

FIGURE 11-1 Advanced DMM features include frequency (Hz), duty cycle percent, and Min/Max functions.

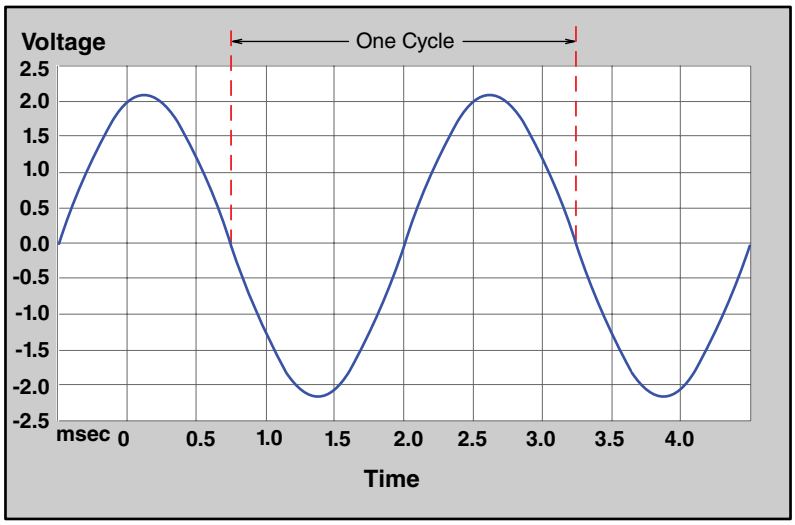


FIGURE 11-2 Signal frequency is how many times the signal completes one cycle every second. The arrows show the start and end of one cycle. This sample alternating current (AC) pattern occurs every 1/10th of a second creating 10 cycles per second.

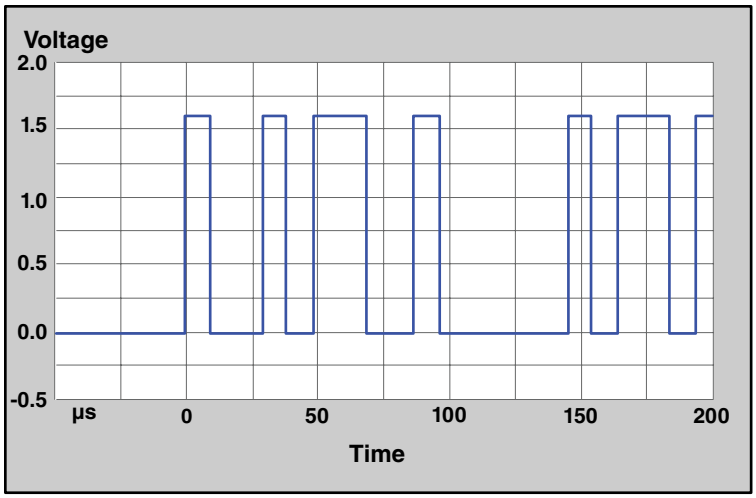


FIGURE 11-3 An example of a digital signal with distinct on and off pulses.

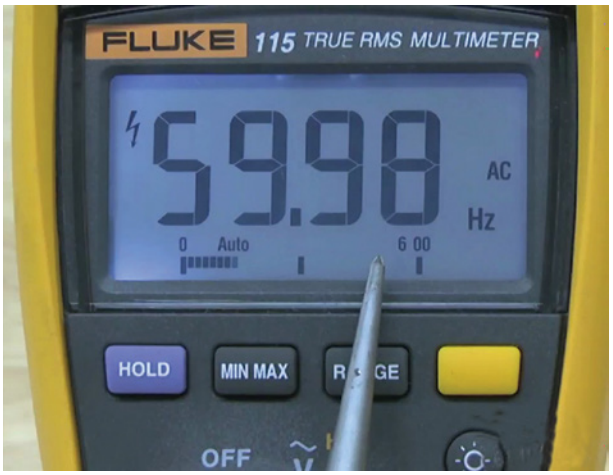


FIGURE 11-4 DMM measuring AC signal frequency.

SKILL DRILL 11-1 Measuring Frequency

1. Refer to the signal generator board schematic and connect the negative test lead to connector the sine wave output and the positive test lead to connector ground.
2. Set the DMM to AC volts and then select the frequency function.
3. Turn on the signal generator board. A frequency is generated and displayed on the signal board.

To measure frequency, follow the steps in **SKILL DRILL 11-1**.

Measuring Duty Cycle

Duty cycle is a method to operate an output device at a desired voltage that is less than source voltage. Some vehicles control the blower motor speed using a duty cycle ECU output signal. Duty cycle is measured in percent which represents the amount of time the ECU pulses the signal on or off. For example, a 12-volt signal at 50% duty cycle of on time would provide 6 volts to the circuit load (**FIGURE 11-5**). Measuring duty cycle is very similar to measuring voltage. Set the DMM to DC voltage. Place the negative lead on a known good ground. Connect the positive lead to the voltage (output signal) wire at the circuit load. Select the Duty Cycle function on the DMM to display the on (or off) time. During diagnosis, you would compare your measured readings with the service information to help determine the cause of the concern.

To measure duty cycle, follow the steps in **SKILL DRILL 11-2**.

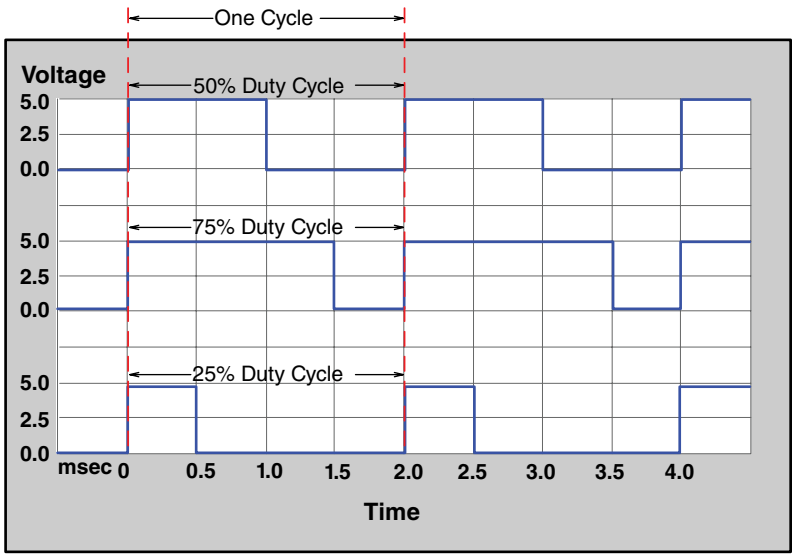


FIGURE 11-5 Duty cycle is measured as a percentage of on or off time.

DMM Min/Max Function

Some DMMs offer a minimum and maximum voltage recording function. This feature is useful when you only need to verify that there is a minimum or maximum voltage present. It can also be used to capture an intermittent fault where the voltage goes too low, to 0V for example, or goes too high, to 12V for example. The DMM also uses a bar graph that varies in size to indicate that the voltage value is changing.

SKILL DRILL 11-2 Measuring Duty Cycle

1. Refer to the signal generator board schematic and connect the positive test lead to the duty cycle connector and the negative test lead to connector ground.
2. Set the DMM to DC volts and then select the Duty Cycle function.
3. Turn on the signal generator board. The DMM displays the duty cycle in the circuit.

SKILL DRILL 11-3 Using DMM Min/Max Function

1. Refer to the signal generator board schematic and connect the positive test lead to the frequency position and the negative test lead to ground on the simulator board. Turn all the control knobs on the simulator board fully counterclockwise.
2. Set the DMM to DC volts and turn the circuit board on.
3. Press the Min/Max button on the DMM. Some DMMs may "beep" when a new minimum or maximum voltage is recorded.

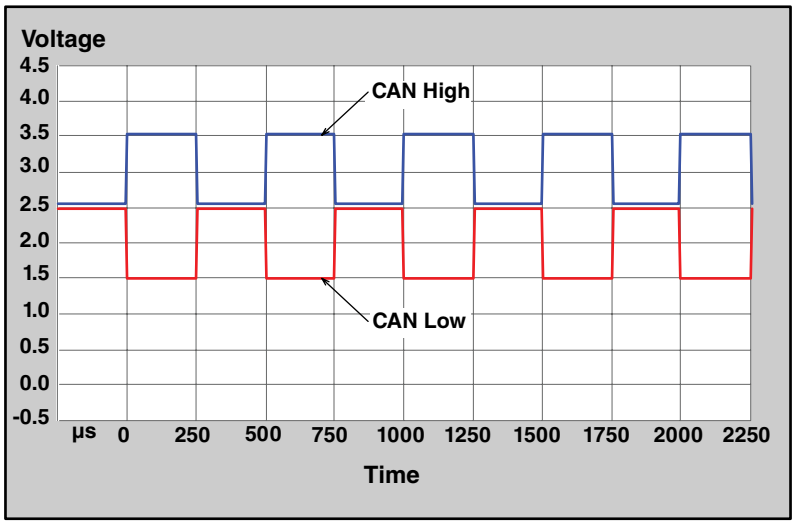


FIGURE 11-6 A controller area network signal may be monitored for voltage dropouts or spikes using the DMM Min/Max function.

▶ TECHNICIAN TIP

The Min/Max function is a powerful tool for a DMM; however, it can prove difficult to capture data or to be sure that you are actually recording a problem or an intermittent connection to the circuit at your DMM lead. If a digital storage oscilloscope or graphing multimeter is available, they are probably a better choice for use in diagnosis since you can actually see the voltage signal waveform and look for abnormalities.

▶ NOTE:

Review the applicable DMM manual on how to review the recorded minimum and maximum readings, how to change the voltage range of the Min/Max function, and how to erase stored data.

K11002 Explain the use of digital storage oscilloscopes (DSO).

N11001 Check electrical/electronic circuit waveforms; interpret readings and determine needed repairs. (MAST)

You may already have some knowledge that many vehicle systems must communicate with each other using an industry standardized controller area network, or CAN (sometimes referred to as CAN OBD II). The CAN communicates by sending pulse signal messages that drop to 1.5 volts on the CAN LO wire and rise to 3.5 volts on the CAN HI wire from a base line of 2.5 volts (**FIGURE 11-6**). If the signal voltage drops to 0 or spikes to 12 volts, this can cause data transmission errors between control units. The DMM Min/Max function can be used to detect these conditions.

▶ Digital Storage Oscilloscope

The **digital storage oscilloscope** (DSO) can be described as a DMM that displays voltage or current as a line trace, or pattern, on the screen of the DSO or on a computer (**FIGURE 11-7**). A DSO was a very expensive tool only a few years ago; however, there are now many types of DSO tools designed for automotive applications that are very affordable. The DSO displays voltage data as a trace on a graph-based display and is also able to record and store the data for playback.

The DSO test leads are designed to minimize signal interference and usually use a BNC type connector where the lead connects to the DSO (**FIGURE 11-8**). The other end of the lead has a provision for connecting an alligator clamp or probe test tool and a pigtail to connect the test lead to a known good ground. Laptop-based DSOs can be set up so that

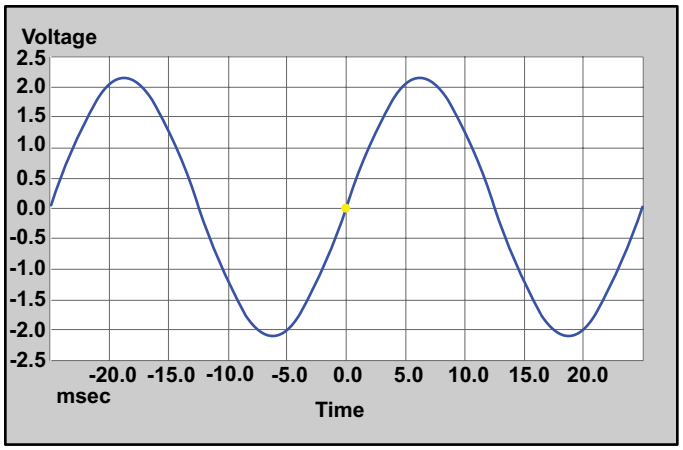


FIGURE 11-7 A digital storage oscilloscope displays voltage or current signals on a time-based graph.

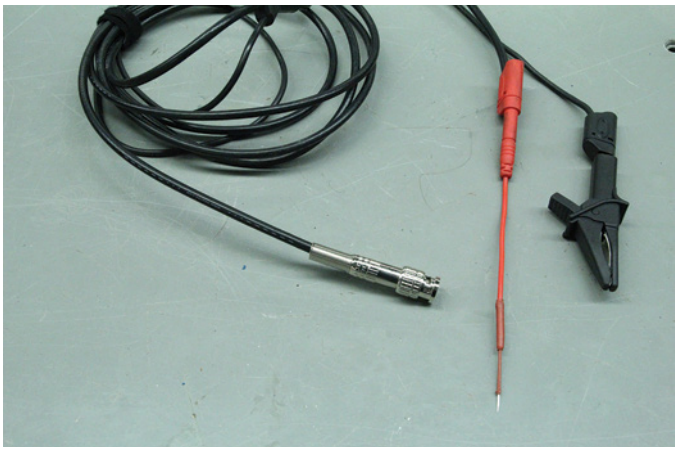


FIGURE 11-8 DSO test leads include a BNC type connector and provisions for connecting to the voltage source and ground.

once connected to the desired signal wires, some offering up to 4 inputs, you can test drive the vehicle and record the data, then play it back when you return to your shop stall. This is the type of tool that a master diagnostic technician will have in their toolbox.

A DMM only offers a numerical display of voltage or current values. The DSO displays the voltage or current signal on a time-based graph called a waveform, allowing the technician to "see" the signal and look for abnormalities that may be affecting system operation. DSOs feature a very fast data sample rate. This means that the DSO can display essentially the complete voltage signal, with time divisions on some DSOs that are less than 1/1000th of a second (1mS). There are essentially no gaps in the data, so if there is a fault in the voltage being observed, you are very likely to capture it. Most DSOs record the data as it is captured for a specific time increment. This allows playback of the waveform data so it can be analyzed to determine if there is a fault. The vehicle service information often provides sample signal waveforms for components that may be diagnosed using a DSO. This gives the technician a "good" waveform to compare with during diagnosis. Many technicians share their stored waveforms on various technician forums to assist each other with electrical related diagnosis.

Interpreting and Adjusting for Signal Diagnostics

The DSO displays the waveform on a graph with the voltage scale on the vertical axis and time scale on the horizontal axis. In the sample shown, we see a voltage signal displayed over a time period on the laptop screen. The sample signal uses a voltage scale in increments of 2 volts (**FIGURE 11-9**). Each grid segment is called a division, so this is a

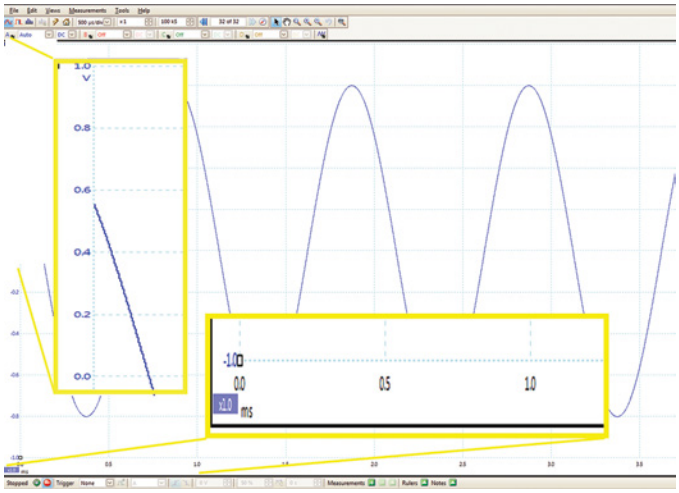


FIGURE 11-9 The DSO displays the waveform on a graph with time across the horizontal axis and voltage on the vertical axis.

2-volts-per-division scale. The time scale is set at 5 milliseconds (5/1000th of a second) per division on the sample graph. The scales must be set for the voltage being measured and for how quickly the voltage changes over time. The waveform may appear as a blob of activity if the time per division is too large; if the time per division is too small, only a portion of the waveform may be displayed. Selecting a voltage per division scale that is too low will cause the waveform to go "offscreen" and appear cut off. If the voltage scale is too large, the waveform will appear very small on the display making it difficult to view the nuances of the waveform for analysis. Some DSOs offer an auto feature to set the voltage and time scales.

Interpreting Voltage Signals

The DSO is used primarily to measure voltage signals. The DSO leads are similar to the DMM and are connected to the circuit in the same manner. Connect the positive lead to the signal wire and the negative lead to a known good ground. The DSO can measure AC or DC signals by selecting the signal type on the tool menu (**FIGURE 11-10**). Once the signal waveform is displayed, it may appear to be moving across the display screen.

Using the DSO Trigger Function

The "**Trigger**" function can be used to start the DSO data recording and to steady the waveform on the screen. Some DSOs allow you to adjust the position of the waveform on the display to line it up with the voltage and/or time graph grid lines (**FIGURE 11-11**).

The DSO may be able to display duty cycle and frequency data, along with several other parameters (**FIGURE 11-12**). Use the applicable menu to view measurements that may be useful for your circuit diagnosis.

DSO Waveform Analysis

Waveform analysis is the process of observing the voltage signals on the DSO display and looking for portions of the signal that fall outside the normal range (**FIGURE 11-13**). The most obvious example would be no signal present. This may indicate a component failure or a wiring or harness fault. Intermittent faults may have a voltage signal that at first appears normal and then goes to 0 or signal source voltage indicating there may be an intermittent open circuit, a short to ground or source, or a fault in the component.

Some signal waveforms have abnormal shapes at intermittent intervals (**FIGURE 11-14**). This could indicate some form of outside interference like a cell phone signal, a fault in the component that is beginning to fail, or, if on the output side from an ECU, a fault in the ECU.

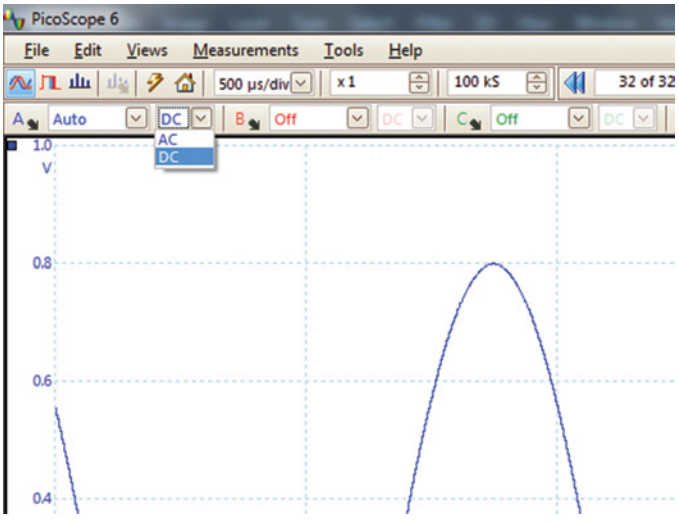


FIGURE 11-10 The DSO can measure alternating or direct current signals.

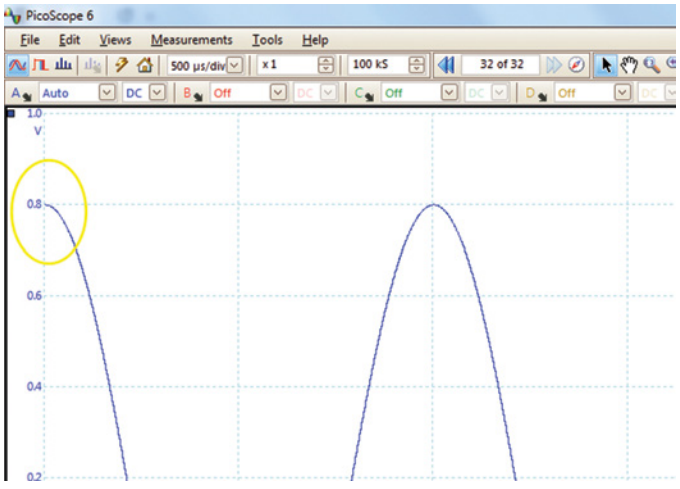


FIGURE 11-11 The waveform can often be moved on the display to align with the time and/or voltage graph grid lines.

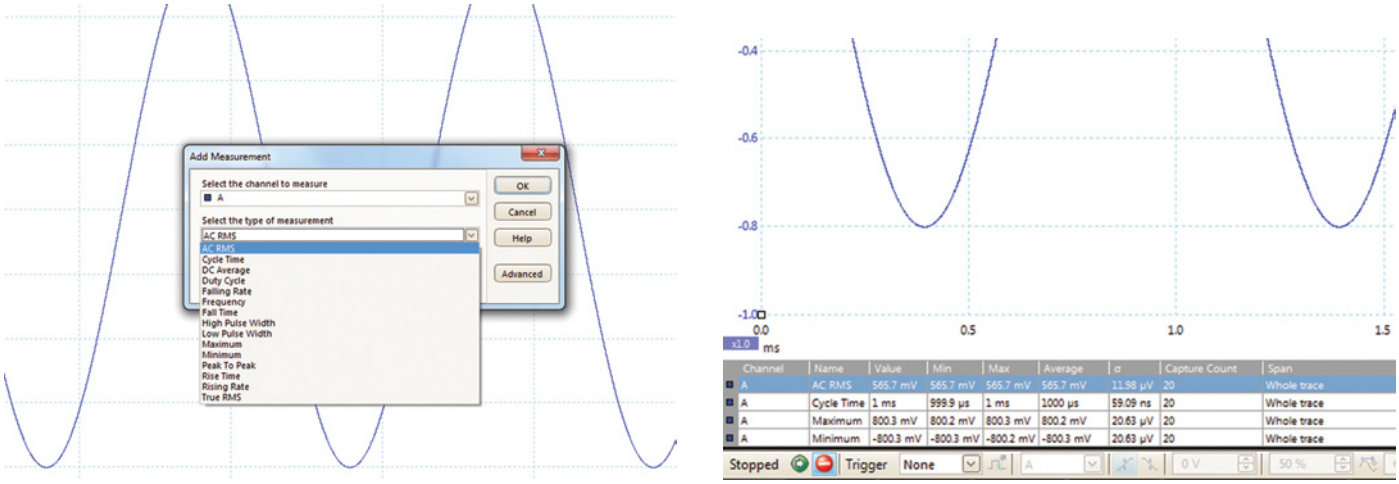


FIGURE 11-12 Many DSOs offer several waveform data measurement display options.

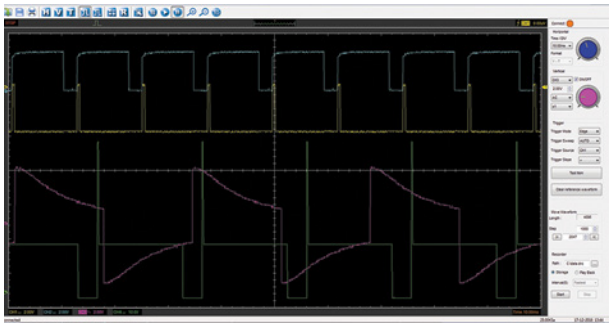
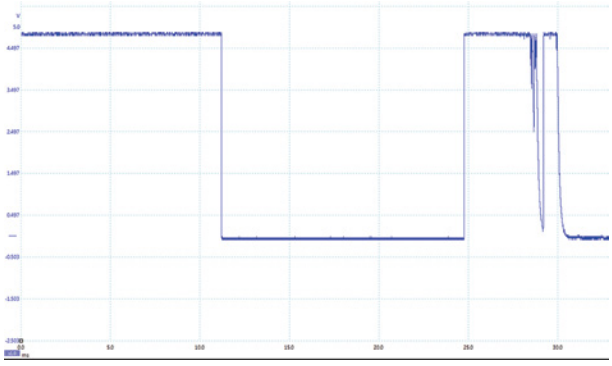


FIGURE 11-13 DSO signals are reviewed and analyzed looking for data that are out of the normal range.



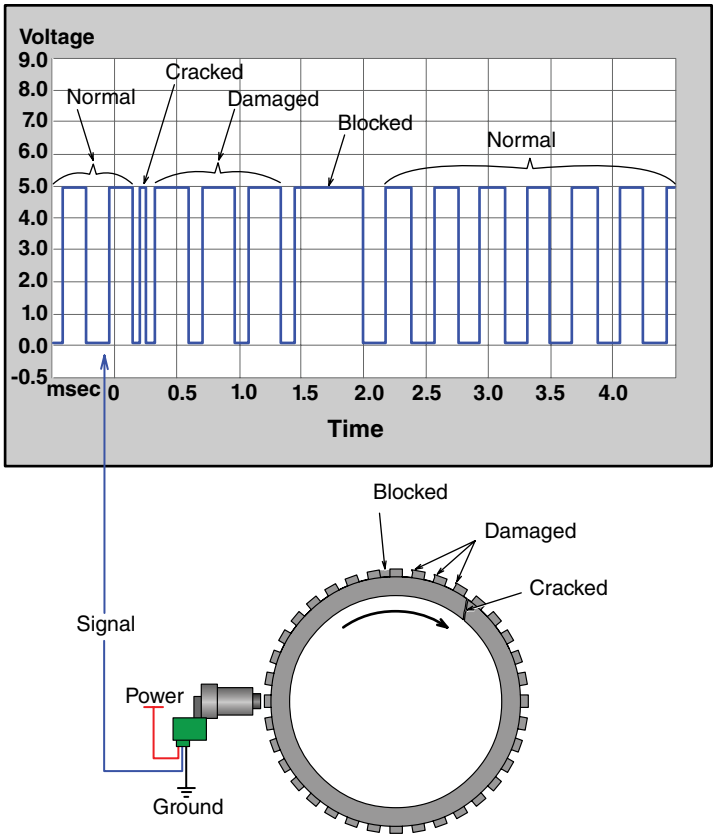


FIGURE 11-14 A signal waveform with an abnormal pattern indicates a fault and requires additional tests to isolate the cause.

Additional DSO Functions

Some DSOs can measure current directly but most require the use of an inductive pickup, similar to those used to measure starter circuit current draw (**FIGURE 11-15**). A magnetic pickup actually measures the amount of magnetic field created by the current that is present in the circuit. The magnetic pickup uses an internal circuit to send a voltage signal based on the current level present. Current signals are monitored to view transient or intermittent issues that can cause the current to be outside of normal operating parameters. Diagnosing the motor of a fuel pump may require using the DSO to view pump motor current under

S11002 Demonstrate use of a DSO for signal waveform diagnosis on the job.

FIGURE 11-15 An inductive pickup is used to measure the magnetic field around the wire that is created by current in the circuit.

a variety of engine loads and driving conditions. Since the pump cannot be directly be accessed or, at best, may be difficult to access, a thorough diagnosis is required before condemning the component and spending time to access it for replacement.

The DSO is a very powerful tool. It is not difficult to use but, like any tool or system that is new to you, it requires practice to master its full potential as a diagnostic tool.

To use the DSO to measure a waveform, follow the steps in **SKILL DRILL 11-4**.

To use the magnetic pickup for current measurement, follow the steps in **SKILL DRILL 11-5**.

▶ Graphing Multimeter

K11003 Explain the use of graphing digital multimeters.

S11003 Demonstrate use of a graphing DMM in diagnosing on the job.

A DMM displays a numeric value when measuring voltage and current. A DSO uses special test leads to minimize outside signal interference and displays the data on a graph with many display options. The DSO is also able to display signal data that changes very quickly, like engine rpm and CAN-bus signals, with very accurate detail. It also can display other data parameters, such as frequency and duty cycle, while also displaying the waveform.

SKILL DRILL 11-4 Using the DSO to Measure a Waveform

1. Set up the DSO in your shop according to the tool instructions or ask your instructor for assistance. Some DSOs are a self-contained unit while others connect to a PC or tablet, and some may use adapters for your smart phone along with an installed app.
2. Refer to the signal generator board schematic and connect the positive test lead to the duty cycle connector and the negative test lead to connector ground. Turn on the signal generator and adjust all the control knobs to their center position.
3. Set the DSO to DC volts. Adjust the DSO voltage and time scales if necessary to view the signal properly.
4. Set the trigger as required to steady the waveform on the DSO screen. Use the adjustment function to line up the waveform with the time graph bar near the center of the display.
5. Turn on the frequency and duty cycle measurement functions if available. Review your waveform and related signal data with your instructor.

SKILL DRILL 11-5 Using the Magnetic Pickup for Current Measurement

1. Connect the magnetic pickup to the DSO.
2. Set the sensitivity to 10mV on the tool.
3. Place the inductive pickup around the source voltage wire to the blower motor (refer to the applicable wiring diagram for your assigned vehicle).
4. Set the DSO to measure DC voltage and use the auto voltage and time base settings if applicable.
5. Turn the blower motor on low speed.
6. The DSO will display a fairly steady signal waveform that represents the current in the circuit. Each 10mV on the voltage scale equals 1 amp of current in the circuit. Increase the blower speed and note how the current in the circuit increases. Review your findings with your instructor.

The **graphing multimeter** (GMM) bridges the gap between a DSO and a DMM (**FIGURE 11-16**). The GMM uses DMM type test leads to connect to the circuit. The GMM display is much simpler in design than a DSO and does not offer as many display options. The display screens are often "preset" for what you are going to measure. For example, when testing a fuel injector or analog wheel speed sensor, the GMM (being designed for use in automotive system diagnosis) may have a menu item for the various components most likely to be tested. This makes it very quick to get set up and use compared to the DSO. Also, being specific to the automotive industry, most tool manufacturers include a database of known good sample waveform graphs along with waveform samples of the most common types of failures.

Several years ago, a DSO was very expensive and the GMM was a very cost-effective alternative. Today, the price gap has narrowed so it is up to you to decide which tool is most effective for the type of work you encounter. Most Master Diagnostic Technicians will have a full feature DMM, GMM, and a DSO so they can handle any job required. A DSO may not always be the fastest choice due to setup time, and the DMM cannot display voltage on a graph, so the GMM may become the tool of choice for most ECU-related circuit diagnosis. However, the GMM is just not capable of looking at very fast signals, like those used in vehicle network data transmission, since it has a much slower sample rate and fewer display options. There is a purpose for each diagnostic tool, which is why many diagnostic technicians have all three in their toolbox.

GMMs connect to a circuit just like a DMM. Use the tool menu or function selector to set up the GMM to measure and display the desired voltage signal. Selecting from the menu, you can use a generic setup or select preset modes that have the screen ready to display a specific signal, like an air/fuel ratio sensor or throttle position sensor. Once the data are displayed, you can often use a reference library of good and bad waveforms in the GMM to compare.

Tech Note: Some scan tools offer GMM functions and the ability to display scan tool data list items in a graphic format. This is a useful option for diagnosis, but the technician must recognize that the data coming through the OBD II connector to the scan tool is filtered data from the ECU. It is not the same as live data obtained by connecting a DMM, GMM, or DSO to the circuit(s) being tested. It is often difficult to use scan tool Data List data in graph format to capture signal waveform errors since the data refresh rate is relatively slow compared to a GMM or DSO.

To use the GMM to view voltage data, follow the steps in **SKILL DRILL 11-6**.

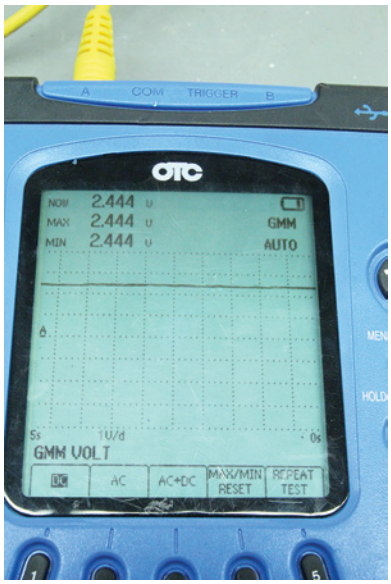


FIGURE 11-16 Graphing multimeters bridge the gap between a DMM and a DSO.

SKILL DRILL 11-6 Using the GMM to View Voltage Data

1. Set up the GMM in your shop according to the tool instructions or ask your instructor for assistance.
2. Refer to the signal generator board schematic and connect the positive test lead to the duty cycle connector and the negative test lead to connector ground. Turn on the signal generator and adjust all the control knobs to their center position.
3. Set the GMM to DC volts. Adjust the GMM voltage and time scales if necessary to view the signal properly. Review your signal display with your instructor.

Wrap-Up

Ready for Review

- DMMs designed for automotive use often have advanced features that allow the measurement of frequency and duty cycle and can record a minimum and maximum voltage.
- Electronic sensors may output a varying frequency signal. During diagnosis you may need to directly verify the signal using the frequency function of your DMM. Frequency is measured in hertz (Hz).
- Electronic control units often control output devices using duty cycle. Duty cycle is the amount of on or off time the output device receives. This allows for precise control of the component. An example is the air conditioning blower motor. Duty cycle control of the blower motor allows for a wide range of fan speeds rather than three or four of the resistor-controlled type. Diagnosis may require verification of the duty cycle percentage to determine whether the output device, the ECU, or the wiring is at fault in the circuit.

- The DMM Min/Max function is used to capture a reading that exceeds normal values but happens so quickly that it could be missed by someone simply viewing the display. The capture rate is usually around 250mS, or about ¼ of a second. You can see that a momentary glitch in a position sensor or a voltage spike in a circuit could easily be missed. The Min/Max capture function allows you to view the minimum and/or maximum voltage (and amperage on some DMMs) captured during your testing.
- A digital storage oscilloscope (DSO) is used when you need to view a voltage signal in great detail. A DSO is basically a voltmeter, and it connects to the circuit in the same manner as DMM leads used to measure available voltage. The DSO then displays the voltage as a waveform, showing how the voltage signal changes over time. The DSO display features voltage and time scales that can be adjusted to provide the best detail for the type of signal being monitored. Electrical interference, poor connections, and faulty sensor input or ECU output signals may seem OK when measured with a DMM, but actually viewing the signal on a DSO can reveal a problem with the signal.
- A graphing multimeter (GMM) is essentially a DMM with a graphic display that is similar to an oscilloscope. The GMM displays the signal being measured on a graph with voltage (or amperage) displayed over time. It can be helpful to view a signal over time, but since this is still basically a DMM, the refresh rate is usually much slower than a DSO and it may be possible for a signal glitch to happen so fast that it is not displayed. Also, some signals are too fast for some GMMs and may not display in a format that could be used for diagnosis. The GMM offers many functions in one tool, and many technicians use a GMM for a great deal of their diagnosis.

Key Terms

digital storage oscilloscope Displays voltage over a time allowing the technician to see the signal. The DSO has a very fast refresh rate and is able to catch even the smallest signal error or fault. A DSO connects to a circuit in the same manner as using a DMM to measure available voltage. Technicians become skittish around the DSO because it requires setting the voltage and time scales to display the signal correctly. There are many other features including data recording and setting a trigger to start or stop recording.

duty cycle A method for an ECU to control an output device. Rather than turning the device on or off, the ECU can modulate the voltage by using duty cycle. A device that is always on would have a duty cycle of 100% on, 0% off. If we wanted to operate the device at a lower rate, the ECU could turn it on 50% of the time and the other 50% it is off. Doing this allows the body ECU to slowly dim the interior lights from full on to off, for example.

frequency Frequency is the measure of cycles per second, measured in hertz (Hz). An alternating current (AC) cycle is based on one cycle of AC current, starting at 0 volts, increasing to a peak positive voltage, going back to 0, going to a peak negative voltage, and then ending back at 0. Frequency of DC signals is based on a cycle that has low voltage (usually 0 volts) and a high voltage (can be 5 volts or 12 volts, but other values are also used). The most common DC-based frequency signal is duty cycle which has a fixed frequency. Some automotive systems may use a varying DC voltage frequency.

graphing multimeter A DMM with a graphic display similar to a DSO. The voltage (or amperage) signal is displayed as a waveform on the display. GMMs usually cannot capture data as quickly as a DSO so they may not be able to display very fast waveforms that are used in vehicle networks. They do offer a great deal of features and some are based around a scan tool architecture which makes them very popular with diagnostic technicians.

trigger A setting on a DMM, GMM, or DSO that starts or stops a recording or signal display event. The trigger usually has several options that allow one time or repeat functions.

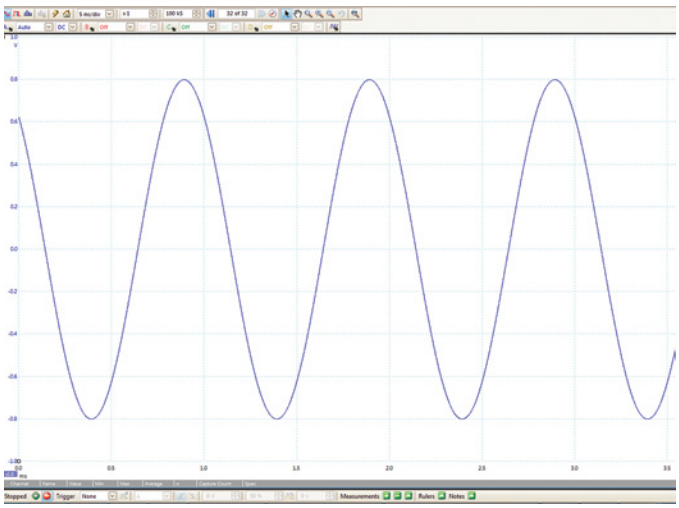
waveform The voltage or amperage reading displayed on a DSO, and to a lesser extent on a GMM, is called a waveform. A waveform is created by connecting each signal data point together on a graphic-based display so the signal can be viewed for analysis. Most GMMs and DSOs allow you to alter the voltage and time scales to view the waveform with the best detail for your diagnosis.

Review Questions

1. When measuring duty cycle, the negative lead of the DMM should be placed at what point in the circuit?
   a. Known good ground.
   b. The signal wire
   c. At the voltage source of the battery
   d. On the wire that supplies source voltage to the sensor circuit
2. The DMM shown is displaying which of the following?
   a. 50.0V
   b. 50 cycles per second
   c. 50% duty cycle
   d. 50.0mV

3. The DSO uses which type of test lead?
   a. Only a positive lead, similar to a DMM lead
   b. Only a negative lead, similar to a DMM lead
   c. Color-coded DMM type leads so they are not confused with negative or positive when used
   d. A lead with a BNC type connector
4. The meter function selector is set to which of the following?
   a. DC Hz
   b. DC cycles per second
   c. AC Hz
   d. Varying DC voltage cycles

5. The horizontal axis of the DSO display is for which of the following?
   a. Time per division
   b. Voltage per division
   c. Frequency
   d. Duty cycle
6. The DSO display features which of the following?
   a. A 2 volt/division scale
   b. A DC voltage signal
   c. A digital signal
   d. Has a 5mS/division time base

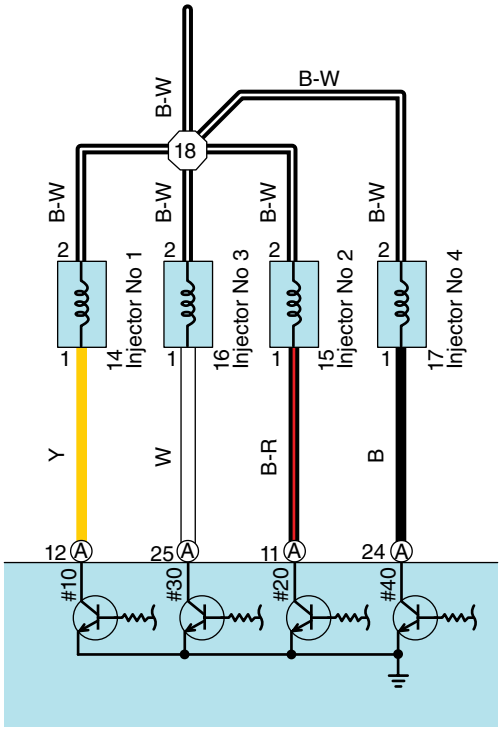


7. A DMM is used to monitor varying voltage signals in all of the following components *except*:
   a. wheel speed sensors.
   b. crankshaft position sensors.
   c. camshaft position sensors.
   d. HVAC fan speed sensors.
8. Choose the correct statement regarding the DMM Min/Max function.
   a. The Min/Max function is used to capture an intermittent fault where the voltage goes too low or too high.
   b. The Min/Max function is used to measure current.
   c. The Min/Max function is used to measure resistance.
   d. The Min/Max function uses a wave graph to indicate changing voltage value.
9. Which of the following can be accurately done using graphing multimeters (GMMs) but cannot be achieved using DMMs?
   a. Measuring resistance in the connectors
   b. Diagnosing issues in the electronic communication system in the vehicle
   c. Determining the position of a sensor using live data
   d. Checking the battery life in the vehicle
10. A graphing multimeter (GMM) differs from a digital multimeter (DMM) in which of these aspects?
    a. GMM contains the vehicle and component database in itself.
    b. GMM can measure amps, volts, and ohms precisely.
    c. GMM can diagnose harness problems.
    d. GMM can measure the electricity output of a battery.

ASE Technician A/Technician B Style Questions

1. Tech A says frequency is displayed as cycles per second, CPS on the DMM display. Tech B says duty cycle is measured as a percentage of on or off time. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says a graphing multimeter has the capability to display circuit voltage as a line trace on a graph. Tech B says the DSO can display voltage signals that change at very high speed. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says a DSO waveform that is not steady on the screen indicates the test leads are not connected to the circuit correctly. Tech B says a DSO waveform that is cut at the top or bottom of the screen, or both, does not have the voltage per division set correctly. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

4. Tech A says a GMM connects to a circuit in the same manner as a DMM when measuring voltage. Tech B says the GMM usually has a database in the tool memory to view good and bad waveforms. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. Tech A says a GMM provides a waveform that is as accurate as a DSO. Tech B says the Min/Max function of the DMM can be used to determine the minimum voltage of a rapidly changing signal. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Refer to the fuel injector circuit shown. Tech A says the signal lead of the DSO should be connected to pin 1 of the injector that is being tested. Tech B says the fuel injectors have a path to ground through their related transistor. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



7. A vehicle has a DTC stored for a wheel speed sensor signal. Tech A says you can use the DMM to view the sensor signal voltage and if voltage is present the sensor is okay. Tech B says a DSO can help you determine if the sensor signal is normal or if there is a fault in the sensor. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. Tech A says the GMM provides a visual of a voltage signal like a DSO. Tech B says that signals which have very fast voltage changes may require a DSO to view accurately. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. Tech A says a duty cycle of 0% usually refers to a circuit that is OFF. Tech B says even if the circuit has a duty cycle of 0% it will have a steady frequency up to 100% duty cycle. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Two technicians are discussing advanced DMM functions. Tech A says the position of the DMM test leads for a digital signal are the same as if you were measuring voltage. Tech B says alternating current low voltage signals require use of fused jumper leads. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B

CHAPTER 12
Electronic Components

NATEF Tasks

There are no NATEF tasks in this chapter.

Knowledge Objectives

After reading this chapter, you will be able to:

- **K12001** Describe the use of semiconductors.
- **K12002** Explain the operation of transistors.
- **K12003** Explain the operation of thyristors.
- **K12004** Describe the function of ECUs.

Skills Objectives

After reading this chapter, you will be able to:

- **S12001** Perform diagnostic tests on a diode.
- **S12002** Use the appropriate diagnostic tool to check the operation of electronically controlled components.

You Are the Automotive Technician

The customer states the air conditioning and heater blower motor does not work. You verify the concern; the blower motor does not operate at all. You print out the related wiring diagram to trace the circuit and predict voltages (**FIGURE 12-4**). The blower motor circuit uses a speed control unit. The blower motor speed control unit is connected to the HVAC module (ECU).

1. How is the blower motor speed controlled?
2. What types of tests are used to verify correct or incorrect HVAC ECU and blower motor speed control unit operation?
3. What precautions should be observed when testing these circuits?

▶ Introduction

Electrical and electronic are words which denote the basic way a device operates. Electrical components are used in circuits where the voltage and current directly produce a desired operation like creating light, heat, or motion (**FIGURE 12-1**). Electrical automotive circuit examples include incandescent lighting circuits, the rear window defroster, and the wiper motor.

Electronic components are categorized as those which manipulate electrical energy to produce very specific outcomes (**FIGURE 12-2**). Electronic components may be used individually in a circuit or may include many components assembled together to form a computing circuit that can determine what action is required. For example, a diode can be used to block current or allow it to pass in the automotive generator (alternator); a transistor can be used to control the HVAC blower speed or diodes; transistors and other electronic components can be assembled in a processor circuit to sense current conditions and calculate how to control a device, like rain-sensing wipers, and operate the wiper motor when needed to keep the windshield clear.

Most electronic components have no moving parts, and when first introduced were called solid state devices. For example, a relay has a moving switch and is an electrical component that can switch the fuel pump on or off. A transistor has no moving parts and is considered an electronic component that can also turn the fuel pump on or off. The advantage of the transistor is it can be turned on and off many times per second. Engineers can use a transistor to control fuel pressure by turning a transistor on and off to control the voltage to the fuel pump, using duty cycle to control the voltage on time. A 12-volt signal at 75% on time would operate the fuel pump at 9 volts (**FIGURE 12-3**).

▶ Semiconductors

K12001 Describe the use of semiconductors.

Semiconductors are materials that can switch between being a conductor or insulator just by temporarily removing or adding electrons to the material. This means that current flowing through the material can be controlled by adding or removing a small number of electrons in the material. Notice that the ability to control the current flow requires no mechanical movement or separation of the material, only the addition or removal of electrons. So there is no appreciable wear in the material when it is turned on and off over thousands or even millions of cycles. Because of this, semiconductor materials are ideal for use in control devices such as transistors and microchips.

Remember that conductors have less than four valance ring electrons and resistors have more than four valance ring electrons. Atoms that have four valance ring electrons are considered semiconductors (**FIGURE 12-5**) meaning they are not good conductors or resistors. Note that because the semiconductor material has precisely four electrons, it

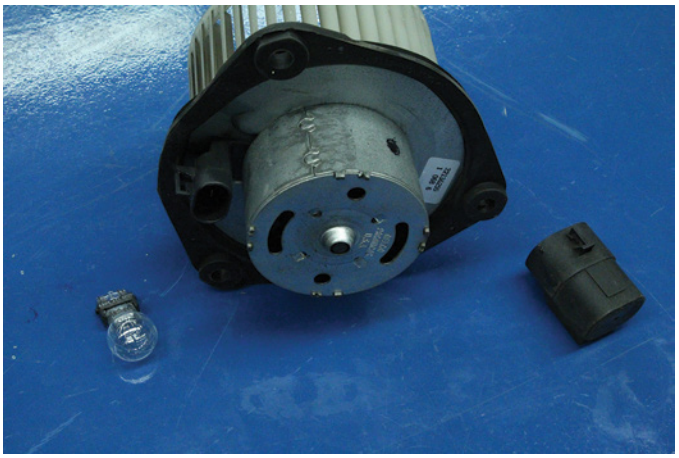


FIGURE 12-1 Incandescent lights, mechanical relays, and motors are designated automotive electrical components.

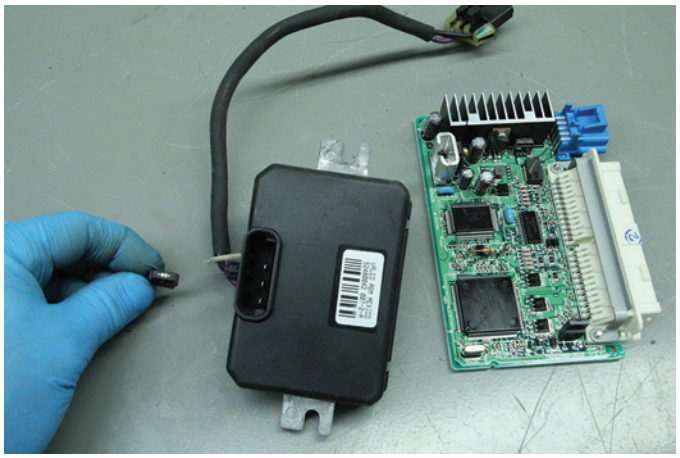


FIGURE 12-2 Diodes, transistors, and electronic control units (ECUs) are designated automotive electronic components.

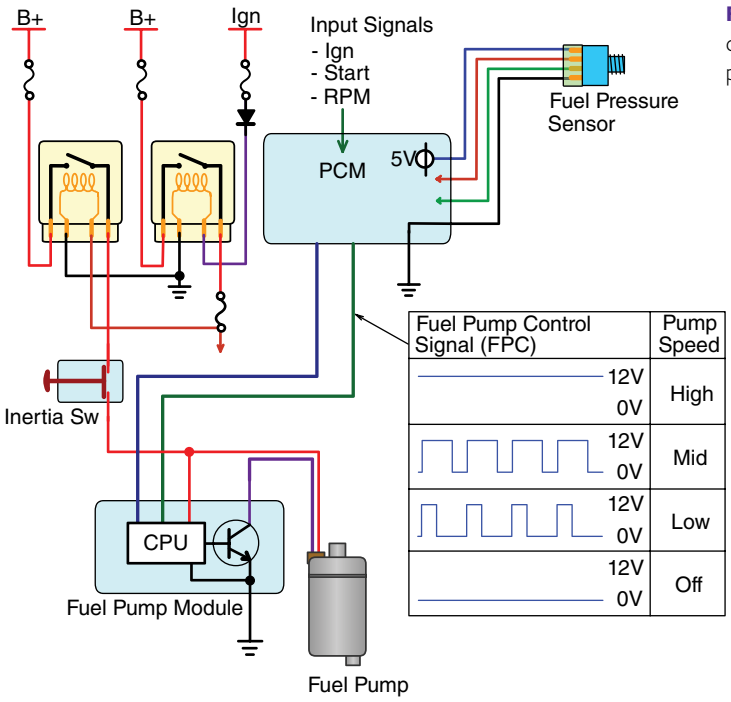


FIGURE 12-3 An electronic fuel pump control can regulate voltage to the fuel pump for precise fuel pressure.

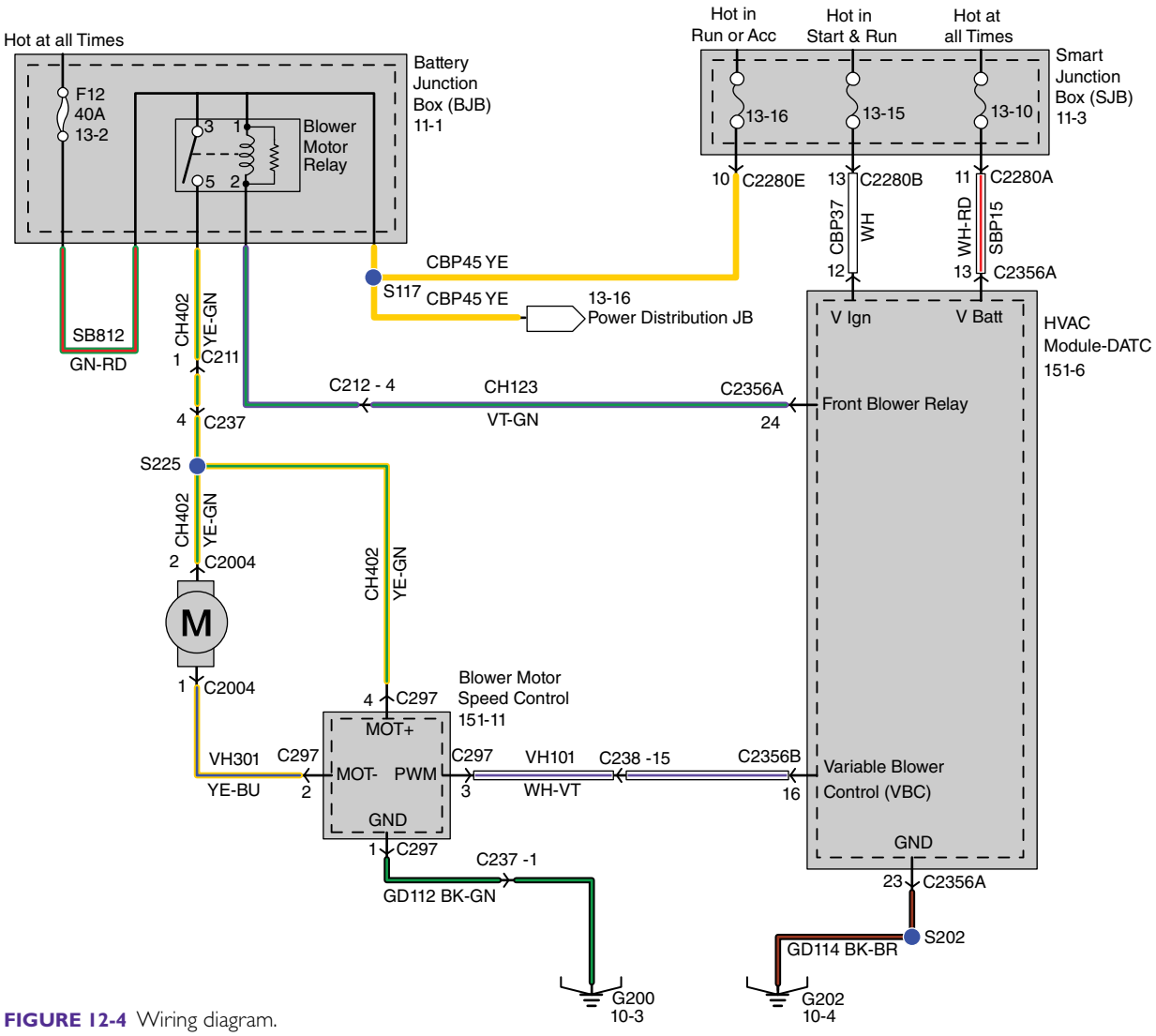


FIGURE 12-4 Wiring diagram.

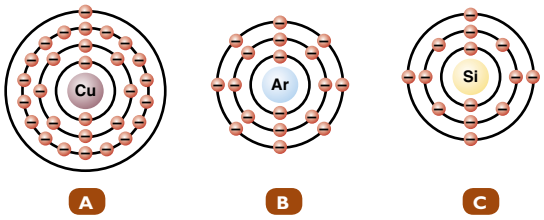


FIGURE 12-5 **A.** Conductor. **B.** Insulator. **C.** Semiconductor.

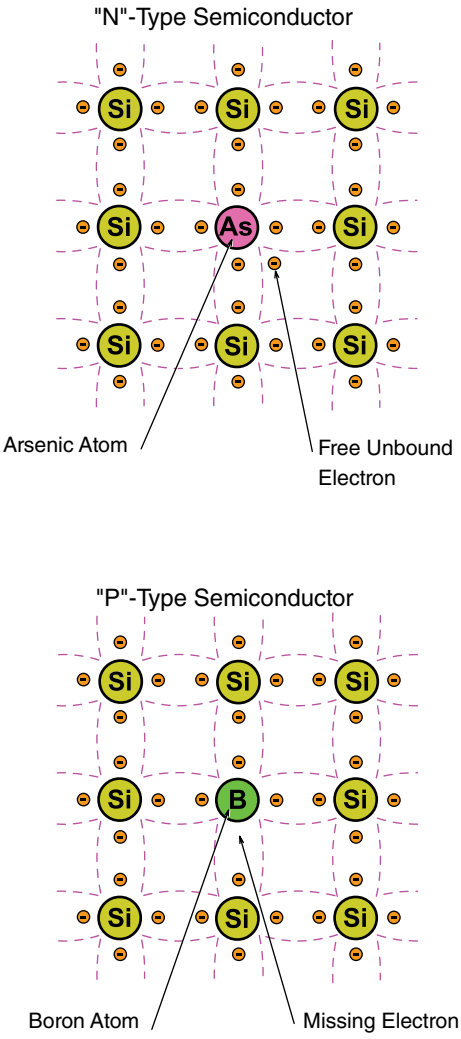


FIGURE 12-6 P-type semiconductor material has an excess of positive charge carriers called holes. N-type has an excess of negative charge carriers, which are the electrons in an atom.

S12001 Perform diagnostic tests on a diode.

is only one electron away from becoming either an insulator or a conductor. If an electron is added, it becomes an insulator; if an electron is removed, it becomes a conductor. This is why the semiconductor material can be used as a switch to control whether electrons flow though the semiconductor material or are stopped by it.

A semiconductor's conducting ability depends on two kinds of charge carriers: The first type of charge carrier is the negative electron. This kind of semiconductor contains an excess of free electrons. They can be made to flow and carry charge. The second type of charge carrier is the hole. Holes occur when an electron moves from its existing place to a new place, leaving a void where it was. Because the holes are positive, a voltage can make them move toward the negative pole. When connected in a circuit, both the electrons and the holes move, but in opposite directions. The number of charge carriers, either an excess of electrons or deficiency of electrons (causing holes in a material), can be altered by doping, or adding very small quantities of impurities to a semiconductor material. A doped semiconductor always has an excess of one type of charge carrier. For example, electrons in excess make it an N-type semiconductor (**FIGURE 12-6**). N stands for negative. N-type semiconductor material can be created by doping silicon with phosphorus to create a material with an abundance of negative charge carriers. Holes in excess make it a P-type semiconductor. P-type semiconductors can be created by doping silicon with boron to create a material with an excess of positive charge carriers. Each of these materials responds to positive or negative current flow oppositely.

Most electronic components combine P-type and N-type semiconductors. The point where they join is called the P-N junction. In this area, the **depletion layer** occurs, and some electrons and holes cancel each other out and few charge carriers are present. The depletion layer is very thin and acts like an insulator. A diode is one P-type semiconductor material joined to one N-type semiconductor material with a single P-N junction. If it is connected to a voltage source so that the P region is connected to a negative pole and the N region to a positive pole, then the negative pole attracts the holes and the positive pole attracts the electrons. This enlarges the depletion layer and the insulated space, making it a stronger insulator.

Diodes

A **diode** is a semiconductor. It functions to block current or allow current to pass through it depending on the polarity of the applied voltage (**FIGURE 12-7**). A diode is sometimes referred to as a one-way electrical check valve in a circuit because it blocks current in one direction but allows it to pass through it in the opposite direction.

A diode is made up of P and N semiconductor material. The area between the P and N material is called the P-N junction or depletion layer (**FIGURE 12-8**). The positive side of the diode is called the anode and denoted by the triangle shape. The negative side of a diode is called the cathode and denoted by the vertical line in wiring diagrams. You can determine which end is which on a diode by noting the stripe on one end. The end with the stripe is the cathode. Diodes must always be in series with a load in a circuit. This is because when the diode allows current to pass through, a load must be present otherwise a short circuit will occur and the diode will be destroyed from the very high current.

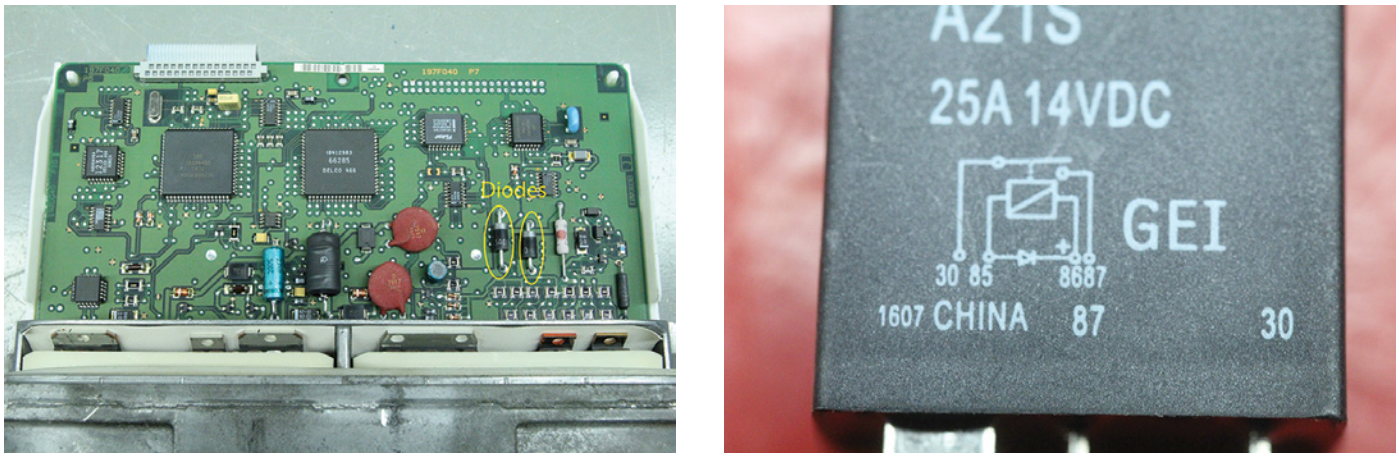


FIGURE 12-7 Diodes are used in ECUs, relays, generators, and may be part of an automotive circuit.

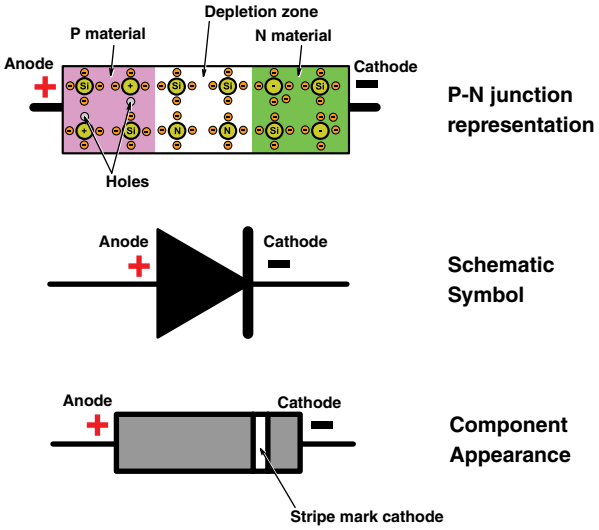


FIGURE 12-8 A diode has positive and negative semiconductive materials separated by a junction.

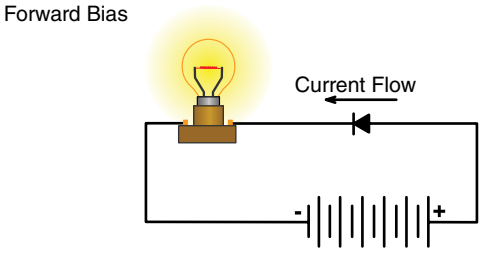


FIGURE 12-9 A diode in forward bias.

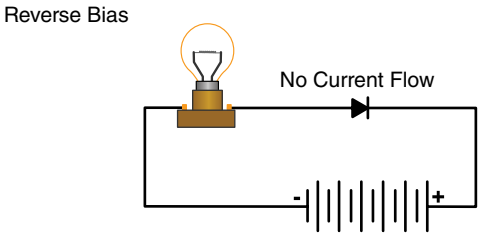


FIGURE 12-10 A diode in reverse bias.

A diode that allows current to pass through it is in forward bias (**FIGURE 12-9**). A diode in forward bias has the positive and negative charge carriers moving toward each other reducing the size of the depletion layer allowing current to pass through the diode.

A diode that blocks current from passing through it is in reverse bias (**FIGURE 12-10**). A diode in reverse bias has the positive and negative charge carriers moving away from each other which increases the size of the depletion layer. The diode acts as an insulator and blocks current from passing through it in this direction. Diodes are rated by how much voltage they can block and how much current they can handle.

A silicon diode requires about 0.7V (700mV) to forward bias. Therefore, a small amount of voltage will drop across the diode when the circuit is operating, reducing available voltage to the load by about 0.7V (**FIGURE 12-11**).

Clamping Diodes

Diodes may be part of an automotive electrical circuit. The diode is sometimes referred to as a clamping diode (**FIGURE 12-12**). Conventional current theory has the electrons flowing from battery positive through the relay switch contacts, the compressor clutch coil, and then to ground. The current enters the clutch at connector pin A and continues to

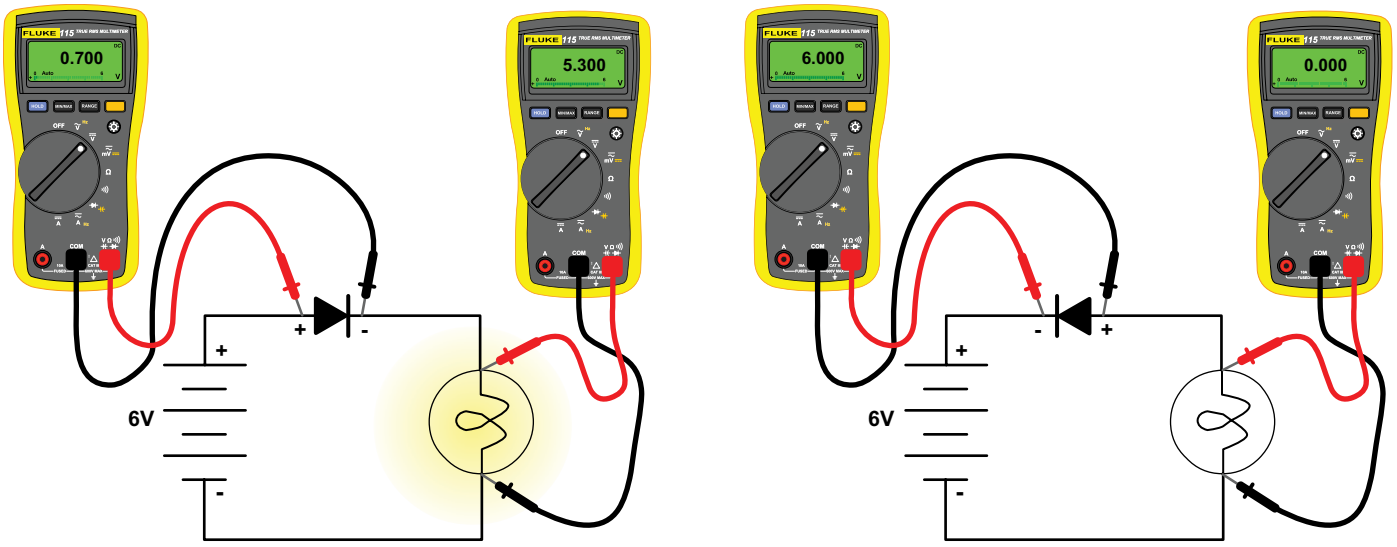


FIGURE 12-11 A diode requires about 0.7V when the circuit is on.

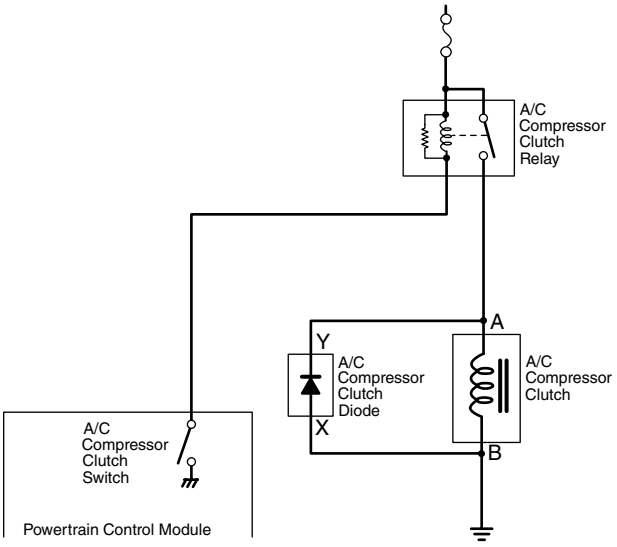


FIGURE 12-12 Diode in an automotive compressor clutch circuit.

ground through connector pin B. The diode is in a parallel path to the compressor clutch and blocks current from passing through it when the circuit is on, as the diode is in **reverse bias**. The magnetic field in the clutch coil creates a very high voltage spike when the clutch coil is turned off as the magnetic field attempts to sustain itself. The current created as the magnetic field collapses is opposite in polarity to the current when the circuit is on. Positive voltage is now present at connector terminal B and the current forward biases the diode so it can then go through it. The relay switch contacts are open so the current path forces the current to enter the clutch coil. This voltage spike and associated current only happens for a fraction of a second with the diode allowing this current to circle back through the compressor clutch coil until it dissipates. The diode in Figure 12-12 is used to prevent noise in the audio system when the compressor clutch is turned off. Clamping diodes are also used in inductive components, like relays, to protect the electronic control units that directly control them from voltage spikes when inductive components that use coils are turned off.

Rectifying Diodes

Diodes are used in the generator to convert the alternating current (AC) to direct current (DC) so it can be used to charge the battery and provide current for the vehicle's electrical system. The diodes are placed in pairs, two for each stator winding. Each diode pair is to battery positive and negative (ground).

Specialty Diodes

Zener Diodes A **Zener diode** functions like a standard diode but it can also allow current to flow when reverse biased when voltage is at or above a predesigned level. This level is called the avalanche point (**FIGURE 12-13**). Voltage below the avalanche point allows the diode to block current. Once the voltage reaches the avalanche point, the diode allows current to flow through it.

Zener diodes are used to regulate voltage in a circuit to protect other electronic components from an overvoltage condition (**FIGURE 12-14**). The Zener diode blocks current until the avalanche point is reached, in this case 12 volts. The Zener diode allows current to pass through it if the source voltage reaches 12 volts or more. The excess voltage and current pass through the Zener diode and the resistor to regulate the voltage for the load.

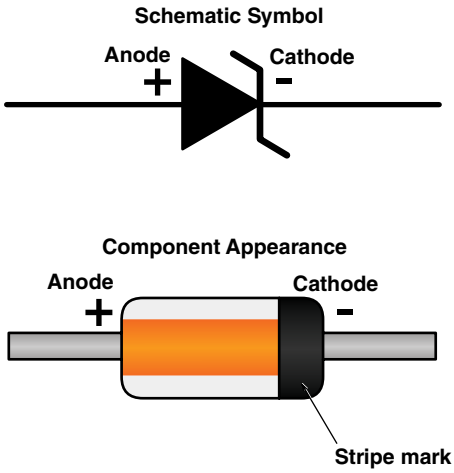


FIGURE 12-13 Zener diode and related schematic symbol.

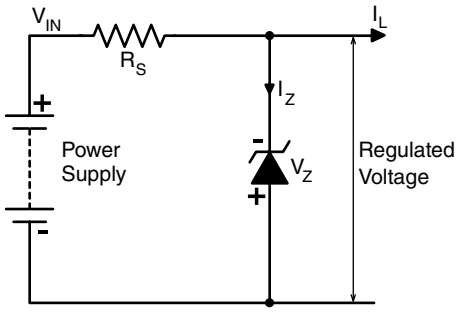


FIGURE 12-14 Zener diode in a voltage regulating circuit.

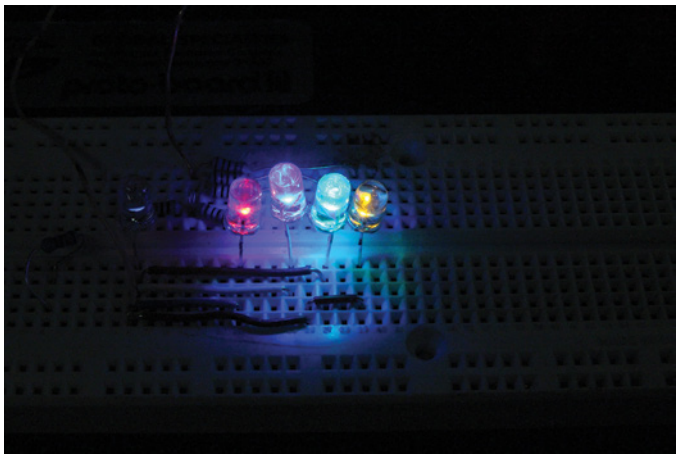


FIGURE 12-15 Light-emitting diodes can produce a variety of output color and brightness depending on their design.

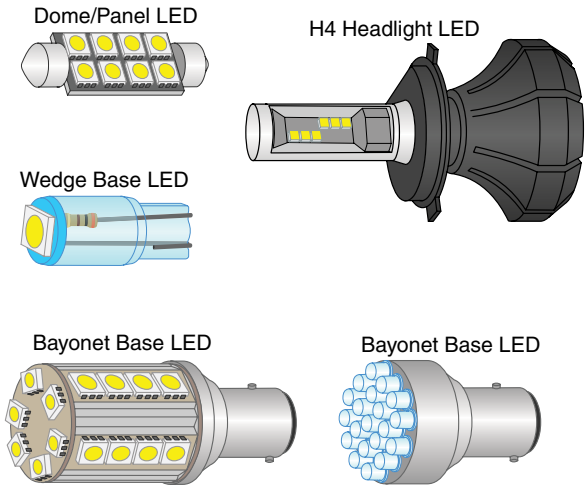


FIGURE 12-16 Various LED lighting applications.

Light-Emitting Diodes **Light-emitting diodes** output light when energized (**FIGURE 12-15**). They are more efficient than incandescent lights because they do not require heat to generate light.

LED color can be created by doping with certain elements or by using a lens of the desired color. LED lighting was initially limited to indicators in instrument panel displays many years ago but is now powerful enough to use in exterior vehicle lighting applications (**FIGURE 12-16**).

Photo Diodes **Photo diodes** take advantage of the P-N junction's reaction to a light source (**FIGURE 12-17**). When light is present, the photo diode conducts current. A photo diode can be used in auto headlight on/off circuits as a sensor and in other circuits where light can be used to provide a trigger signal. Some early electronic ignition systems used LEDs and photo diodes as rpm and crankshaft position signals. Rain-sensing wipers may use photo diodes to detect water droplets on the windshield.

To test a diode with a DMM, follow the steps in **SKILL DRILL 12-1**.

▶ Transistors

A **transistor** usually functions as a switch, a relay, or a signal amplifier in automotive circuits. The transistor gets its name from how it behaves electrically. The engineers who invented the solid state transistor merged the words "transfer" and "varistor" (variable resistor) to create its name. The transistor can transfer current, like a switch or relay, or it can amplify a small current into a larger current (**FIGURE 12-18**).

K12002 Explain the operation of transistors.

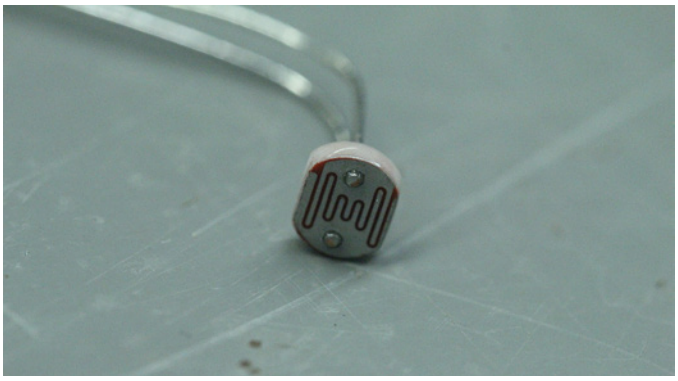
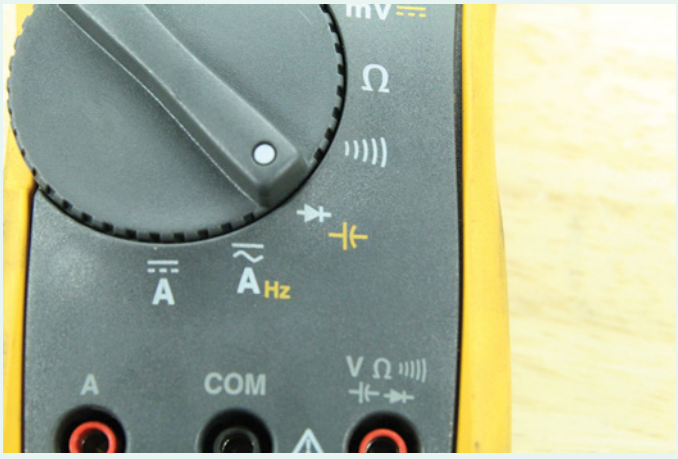


FIGURE 12-17 A photo diode uses a P-N junction that reacts to light.

SKILL DRILL 12-1 Testing a Diode with a DMM

1. A diode can be tested with a digital multimeter that has a diode test function.



2. Look for the diode symbol on the DMM function selector. Select this function to begin the diode test.

Continued

3. The diode requires about 0.11 volts to forward bias. The DMM provides higher voltage than that to enable the diode to **forward bias** and then displays the voltage drop across it.

4. Forward Bias: Place the DMM positive lead on the anode of the diode and DMM negative lead on the cathode of the diode. The DMM should display the voltage drop across the diode and be very close to 0.7 volts.

5. Reverse Bias: Place the DMM negative lead on the anode of the diode and the DMM positive lead on the cathode of the diode. The DMM should display OL for out of limits. This indicates the diode is blocking current and there is no voltage drop across the diode.

6. A diode with a voltage drop that is too low or too high when forward biased or allows current to flow when reverse biased has failed and must be replaced.

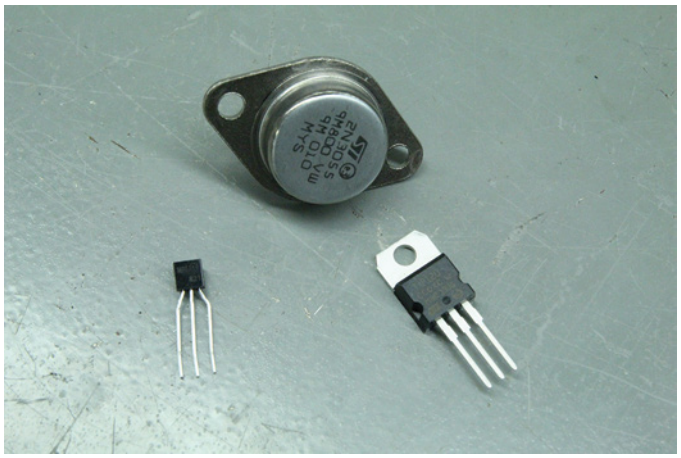


FIGURE 12-18 Transistors come in a variety of designs.

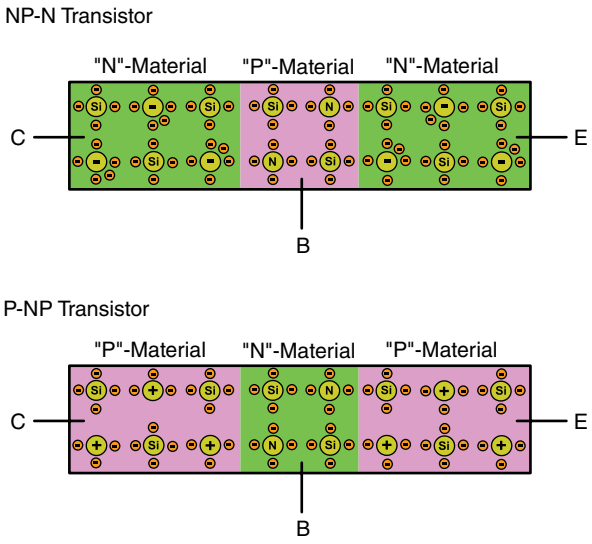


FIGURE 12-19 Bipolar junction transistors are designated by the use of P- and N-type material to make the transistor.

▶ TECHNICIAN TIP

These simple phrases may help you to remember the transistor arrow placement: NPN— the arrow Never Points iN. PNP—the arrow Points iN Permanently.

Bipolar Transistors

A bipolar junction transistor is created using three semiconductor materials. The transistors can be made in a PNP or NPN placement of the semiconductor materials, and each one has a base, collector, and emitter. The emitter can be identified in the transistor diagram by the arrow (**FIGURE 12-19**). The arrow always designates the emitter and always points toward the ground point in a circuit. The placement of the arrow can be used to identify a PNP or an NPN transistor. PNP transistors have an arrow that points toward the base of the transistor. NPN transistors have an arrow that points toward the outside of the transistor.

Bipolar Transistor Operation

A transistor blocks current when it is off. The base is connected to a control current and acts like a switch inside the transistor. Current applied to the base allows current to flow through the collector and emitter. A transistor is turned fully on when base current is at the level that allows the maximum current to pass through the collector and emitter. Current through the collector and emitter can also be modulated by controlling current to the base. The transistor earned its name based on this function as a transitional resistor. A transistor that is used as a switching device in a fuel injector circuit turns fully on then off to operate the fuel injector. You could also say this transistor is like a relay in that a small current is used to turn on a larger current for the injector circuit. It is important to note that the current applied to the base merges with the current flowing through the collector and emitter. For example, a PNP transistor with 0.05 amps at the base controlling a 7 amp load connected to the collector will result in a total current at the emitter of 7.05 amps (0.05 + 7.00) (**FIGURE 12-20**).

A transistor can function to amplify a signal. The low current signal from a crankshaft position sensor signal is converted to a digital signal that is then sent to the base of the transistor. The signal transistor amplifies the input to the base to operate the related ignition coil and create a spark at the spark plug (**FIGURE 12-21**).

Power transistors are used in audio systems to amplify the low current input signals into a higher strength signal to operate the speakers. They are also used in other circuits which require high current levels (**FIGURE 12-22**).

Junction Field Effect Transistors

A **junction field effect transistor (J-FET)** is similar to a bipolar transistor. A bipolar transistor uses a small current to control a larger current (**FIGURE 12-23**). A J-FET uses voltage to control the current passing through the transistor. A J-FET uses semiconductor

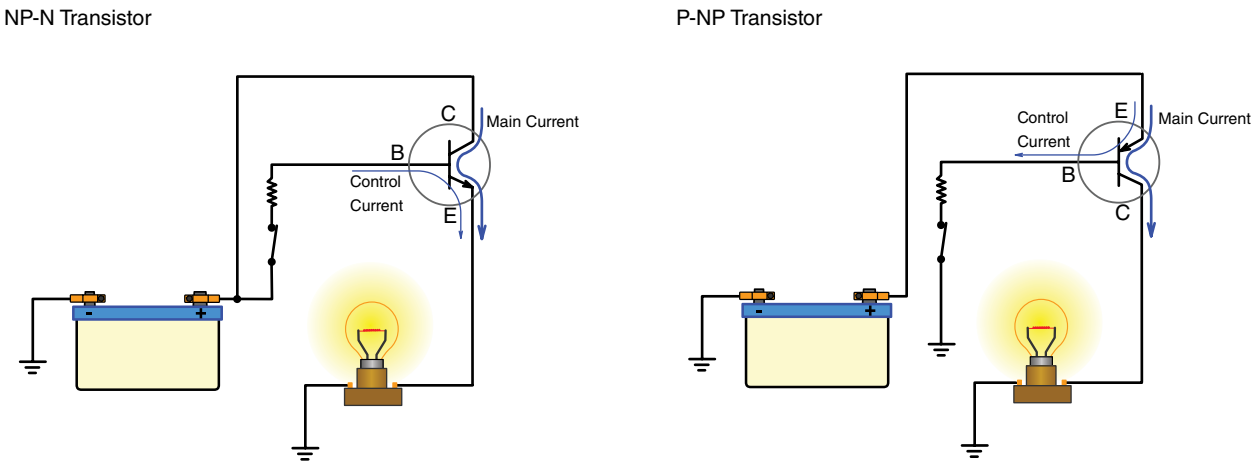


FIGURE 12-20 A transistor is off until a small current is applied to the transistor base.

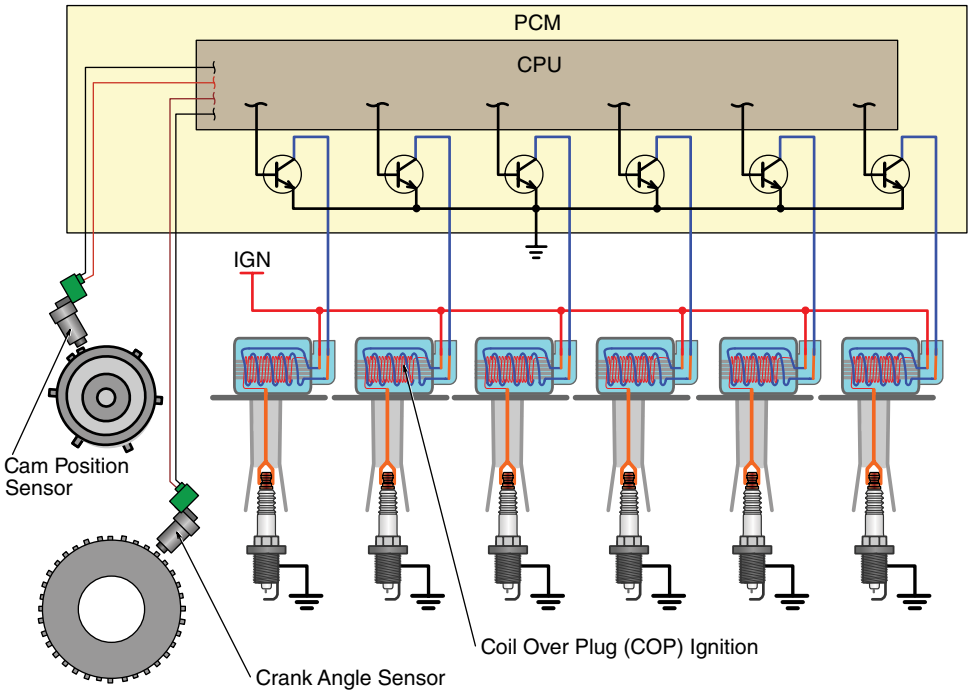


FIGURE 12-21 The ignition system uses transistors to amplify and condition the crankshaft position signal.

material similar to a bipolar transistor, but it has a slightly different symbol and uses a gate, source, and drain rather than a base collector and emitter. The arrow in a J-FET schematic symbol is always on the gate and points inward on an N-channel type and outward on an P-channel type.

The J-FET operates by applying a voltage at the gate to control current through the source and drain. When there is no voltage at the gate, the J-FET is on and current flows through the transistor. Applying a voltage to the gate begins to close the current path. Varying the amount of voltage controls the current through the transistor. J-FETs are popular with components that are duty cycle controlled, like the HVAC blower motor. Use of a J-FET allows the blower motor to operate at several speed settings (**FIGURE 12-24**).

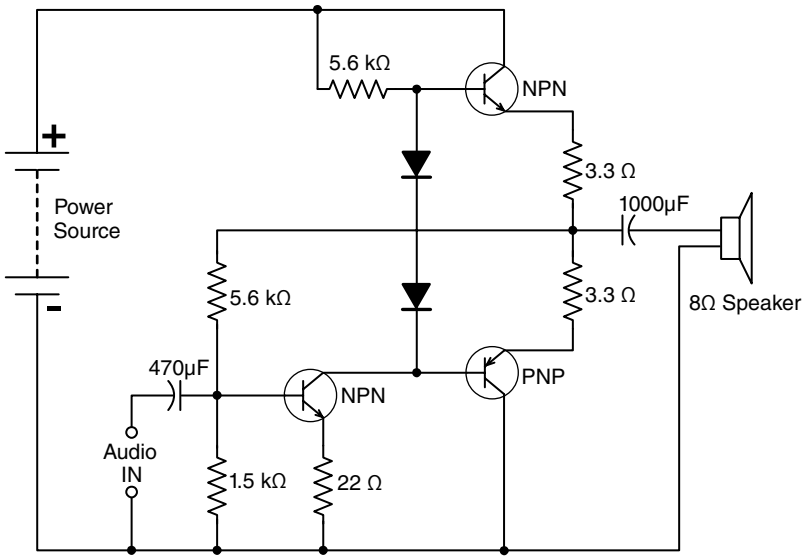


FIGURE 12-22 Transistors are used to amplify audio signals.

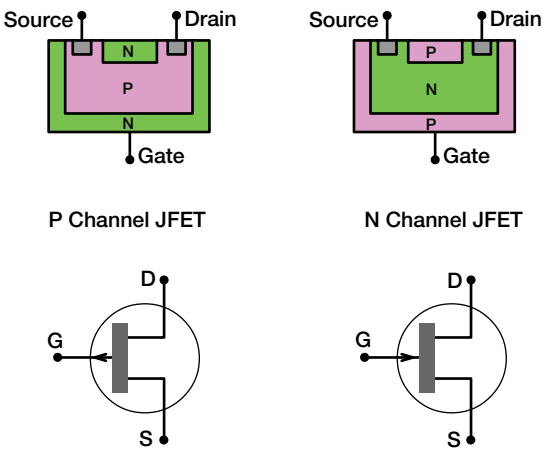


FIGURE 12-23 A J-FET is similar to a bipolar transistor in design but operates using voltage instead of current.

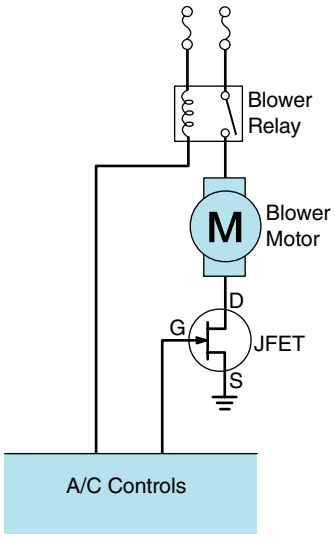


FIGURE 12-24 A J-FET transistor in series with the blower motor provides several fan speeds based on the voltage applied to the gate of the J-FET.

Metal Oxide Semiconductor Field Effect Transistors (MOSFETS)

The **metal oxide semiconductor field effect transistor (MOSFET)** is similar to a J-FET except, rather than using semiconductor material, it uses a metal oxide electrode along with a micro thin layer of glass (silicon dioxide) as an insulating material to join with the P or N junction of the transistor (**FIGURE 12-25**). The advantage is that a MOSFET has much better controlling gate function than a J-FET. For this reason, MOSFETs can be used in logic circuits or where extremely precise control of a component, like an electronic throttle control, is required.

Insulated Gate Bipolar Transistors

Insulated gate bipolar transistors (IGBTs) offer the precise control of a MOSFET with the low voltage requirements of a bipolar transistor (**FIGURE 12-26**). The advantage of the IGBT is it allows for very fast switching like a MOSFET while offering greater power gain. IGBT transistors also offer greater power gains than bipolar transistors and create less heat. IGBTs require very little power to control so they are an efficient option compared to bipolar transistors.

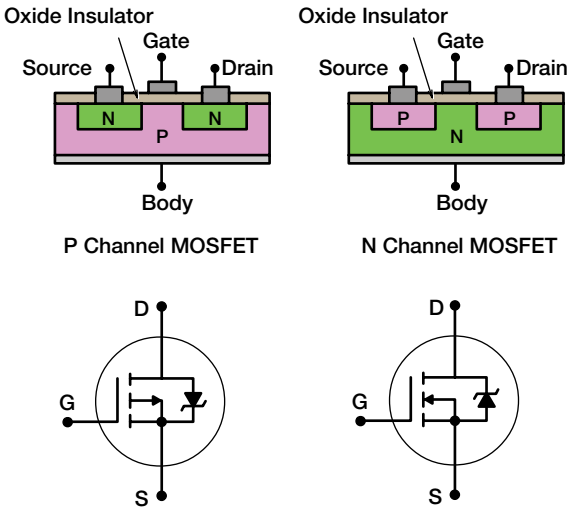


FIGURE 12-25 A metal oxide semiconductor field effect transistor or MOSFET.

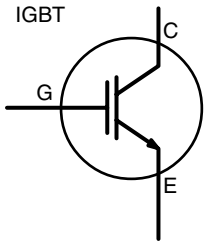


FIGURE 12-26 Insulated gate bipolar transistors look similar to J-FETs.

▶ Thyristors

K12003 Explain the operation of thyristors.

Thyristors function in a similar manner to transistors. A transistor can act as a switch as long as there is sufficient current at the base. Take away the base current and the transistor turns off. A thyristor uses an anode, a cathode, and a gate. This allows the thyristor to turn a circuit on or off, but it is more like a trip switch. Once the thyristor is turned on it stays on even if the gate voltage is turned off (**FIGURE 12-27**).

Thyristors must be turned off by opening the current path to the anode or from the cathode. Electrical engineers use thyristors when a circuit must remain on after being switched on. Thyristors with specific purposes include silicon-controlled rectifiers and A/C circuits (which use diacs and triacs and are often used for motor controls in hybrid vehicles).

▶ Electronic Control Units

K12004 Describe the function of ECUs.

Electronic control units (ECUs) first appeared in automobiles in the mid-1970s. Their purpose was to provide more precise control of spark timing and fuel delivery than the purely mechanical methods used at that time. By the mid-1980s electronic fuel injection was quickly being adapted to most vehicles and the related ECUs gained faster processing speed, adaptive control, and on-board diagnostics. Vehicles now have many ECUs to control the powertrain, brake, safety, lighting, and infotainment systems (**FIGURE 12-28**).

Thyrister

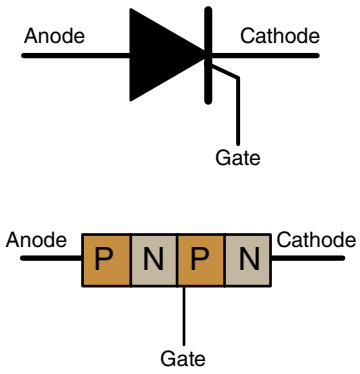


FIGURE 12-27 Gate voltage turns the thyristor on and then by design it is able to stay on even when the gate voltage is turned off.

FIGURE 12-28 Today's vehicles may have over 115 ECUs communicating with each other over various vehicle networks and from vehicle to vehicle.

S12002 Use the appropriate diagnostic tool to check the operation of electronically controlled components.

ECU Operation

ECUs function on the premise of "sense – decide – act" (also called input – process – output) in order to provide system control (**FIGURE 12-29**). Sensors are used as inputs to the ECU and can be as simple as a door switch or as complex as an air/fuel ratio sensor. The sensor data are monitored and evaluated by the processor programming in the ECU. The processor then "decides" what action is necessary and then controls the related device to complete the cycle. A simple example of this is the interior lighting system. Opening the door operates a switch input to the body ECU. The body ECU processes the door switch input signal into an action to control a transistor that turns on the interior lights. When the door is closed, the switch signal to the ECU changes and the body ECU processes then slowly dims the interior lights until they turn off. More specific examples of ECU control are covered in the related system chapters of this text.

Understanding ECU Processor Operation

The brain power of the ECU comes from the computer **processor** (**FIGURE 12-30**). Early automotive ECUs used **integrated circuit** (IC) chips to form the processor. An integrated circuit takes electrical and electronic components and miniaturizes them into a component called an IC chip (**FIGURE 12-31**).

The processor operates at very high speed measured in megahertz (MHz). One MHz equals 1,000,000 cycles per second. Most modern automotive ECUs operate at 32 or 64 MHz. The data processing must be synchronized by an internal clock in the ECU. This is required so that the data are interpreted correctly. For example, as you read this, you can tell when one word ends and another begins by the space between each. The ECU clock generates pulses which synchronize the data transmission so the processor can determine when one data message ends and the next begins.

Most vehicle ECUs communicate with other computers, including the diagnostic scan tool. Data process or speed and the speed of data sent from one ECU to another is usually at a fixed speed called **baud rate**. The baud rate varies depending upon the function of the ECU. A powertrain ECU has a very fast baud rate to ensure correct engine and transmission operation for conditions that are always changing, while an ECU that controls the HVAC system has a slower baud rate since changes required to

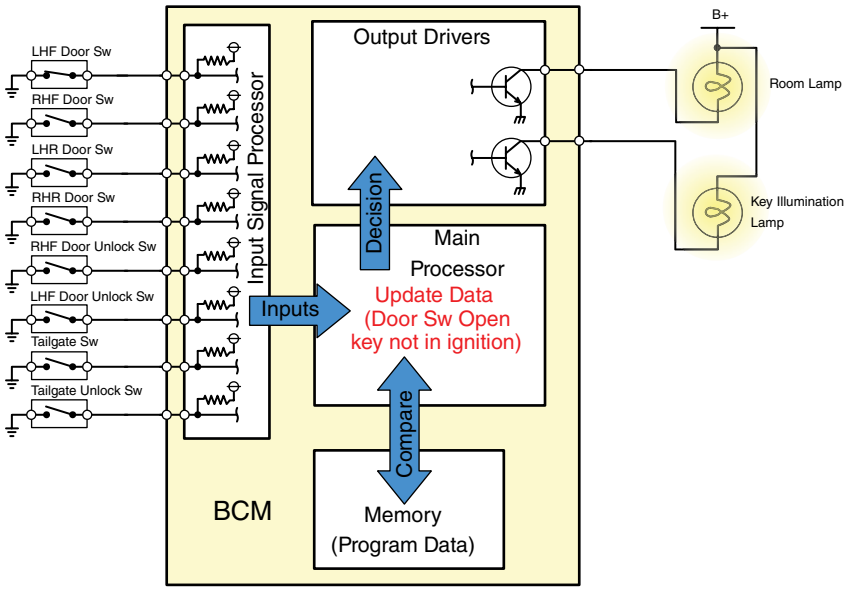


FIGURE 12-29 ECUs function on input-process-output in order to provide system control.

FIGURE 12-30 The large square components are the ECU processors.

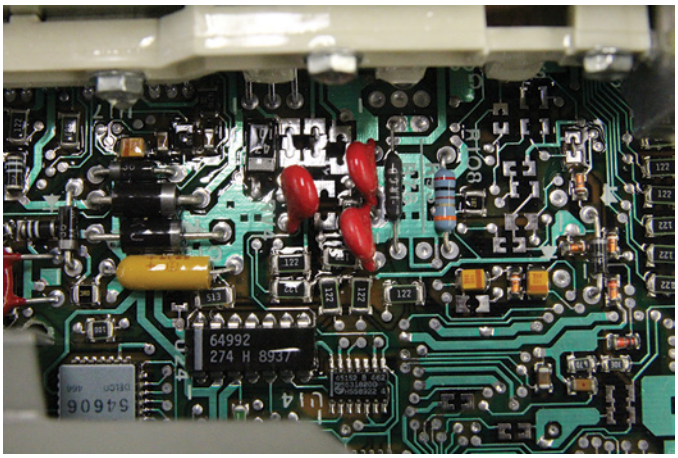


FIGURE 12-31 Resistors, capacitors, transistors, diodes, and other components are still used in the IC chip circuit.

reach and maintain interior temperature require output actions at reduced update intervals (**FIGURE 12-32**).

ECUs now use processor chips as the core of the unit. IC chips may still be used to provide specific functions that support the overall system control. The increase in processor speed and reduction in processor chip size has allowed control units to become smaller, lighter, and less expensive. Functions that once required driver-controlled switches, relays, and other mechanical components are often now handled by ECU-controlled systems. Only a few years ago, most drivers had to use a key placed in a mechanical lock cylinder to unlock the door and only when the door opened did the interior lights turn on. Vehicles today use "smart" keys; the driver rarely has to do anything but carry them. When the driver is close enough to the vehicle, the vehicle unlocks with just a touch of the door handle. The doors unlock, the interior and several exterior lights turn on, and the driver information panel comes to life.

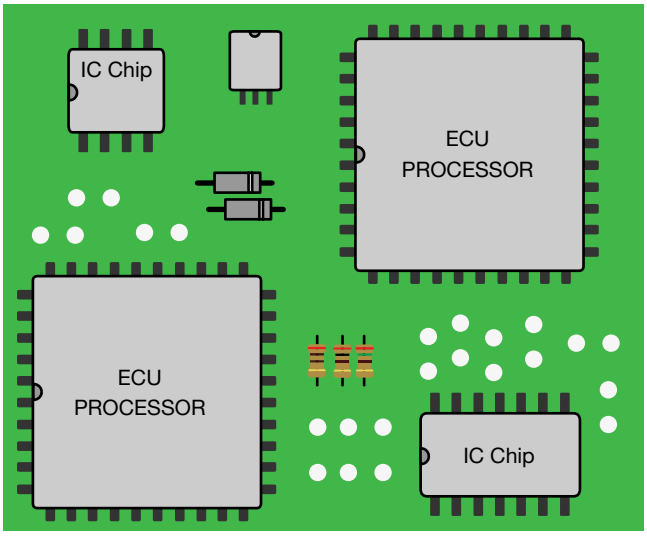


FIGURE 12-32 The ECU uses a processor and supports integrated circuit (IC) chips.

ECUs on the modern vehicle are also connected using networks (**FIGURE 12-33**). This allows data to be shared between various systems and simplifies wiring, since the input data required by different systems does not have to be wired to each ECU. ECU networks are covered in the Vehicle Network Systems chapter.

ECU capabilities are also being added to components like junction blocks and the components themselves. **Smart junction blocks (SJBs)** add ECU processing power to what was previously a fuse, relay, and circuit junction location (**FIGURE 12-34**). Other components that may have ECU-type control include master power window switch assemblies, power window motor assemblies, and electric power steering units. These components are sometimes referred to as microcontrollers.

Input Sensor Operation

Sensor inputs provide data to the ECU so the processor can then output appropriate commands to actuate an output component correctly. This section provides detail on the type of inputs that may be used in various body electrical circuits and systems. The testing and diagnostic procedures for these sensor components will be covered when the applicable circuits they apply to are covered in the text (**FIGURE 12-35**).

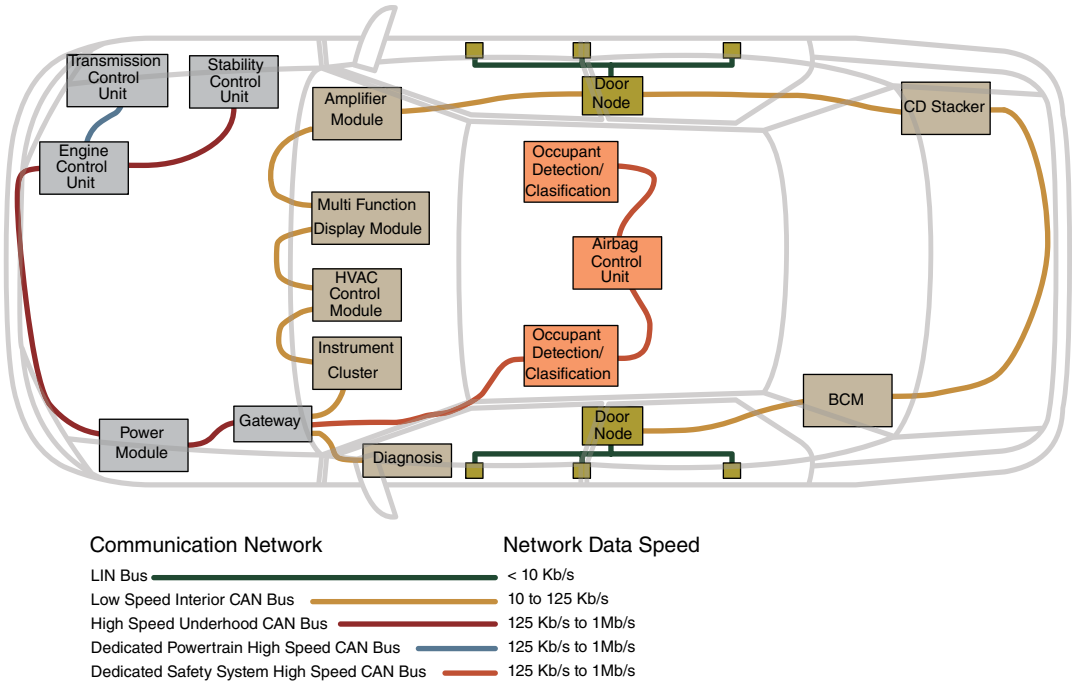


FIGURE 12-33 ECUs share data over vehicle networks.

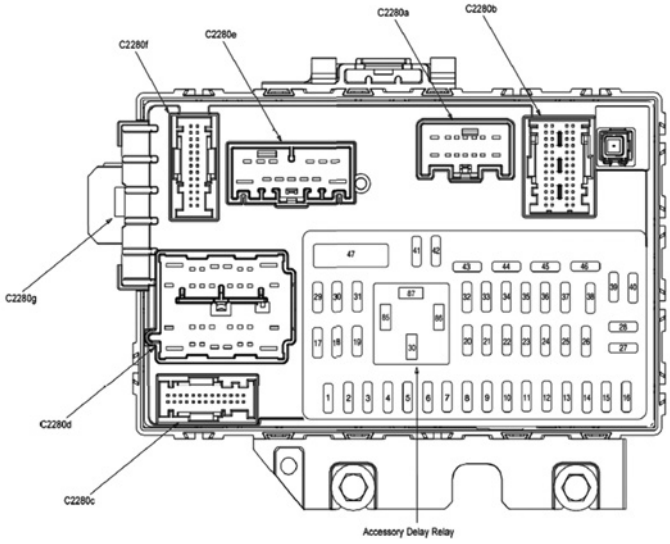


FIGURE 12-34 A smart junction block (SJB) includes the usual junction block components and an ECU.

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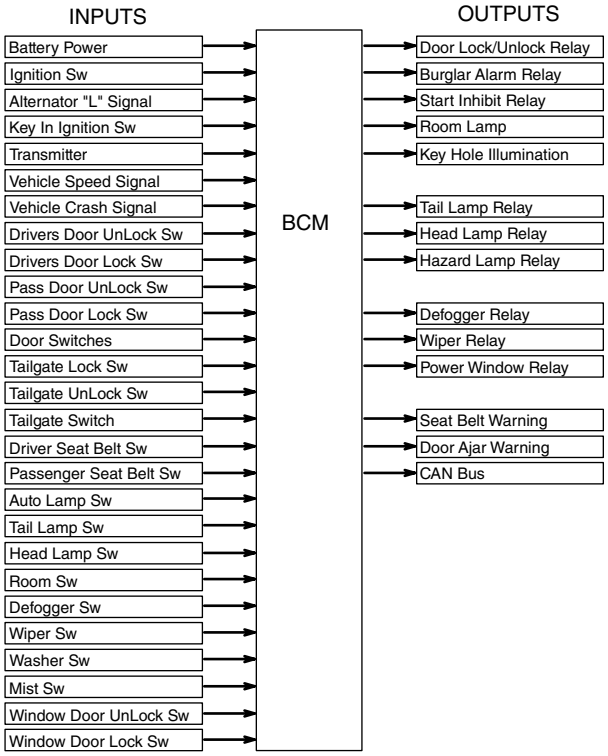


FIGURE 12-35 Sensor inputs often include switches, thermistors, and position and speed sensors.

Determining Whether an Input Signal Is Analog or Digital

Input signals are usually classified as analog or digital (**FIGURE 12-36**). Analog signals provide a varying voltage signal. Digital signals are usually pulsed voltage signals with a defined low voltage (usually 0 volts) and a high voltage (usually source voltage, though some operate at a 5-volt reference level and others may vary). The service information provides this information for you to reference when you begin your diagnostics of ECU-controlled systems.

ECUs function on a **binary code** language of zeros and ones (**TABLE 12-1**). A voltage near 0 volts equals a zero and a high voltage, most often either 5 or 12 volts, equals a one. A digital input provides either a near 0 or near 5-or 12-volt signal and the ECU can directly use this voltage in the processor. Analog signals require the use of an analog-to-digital converter circuit for the signal to be used by the processor. The conversion process varies depending on the type of analog signal, and specific details are provided in the input operation sections that follow.

ECU Logic Gates Enable Data Processing

ECU processors incorporate **logic gates**. A logic gate is an electronic component that reacts to the zeros and ones. Logic gates are an essential part of the building blocks of integrated processing circuits. There are seven basic types of logic gates and these can be combined, much like you combine letters to form words, to create additional functions (**FIGURE 12-37**). Each logic gate is based on a truth table. The truth table shows the input on the left and, if there is

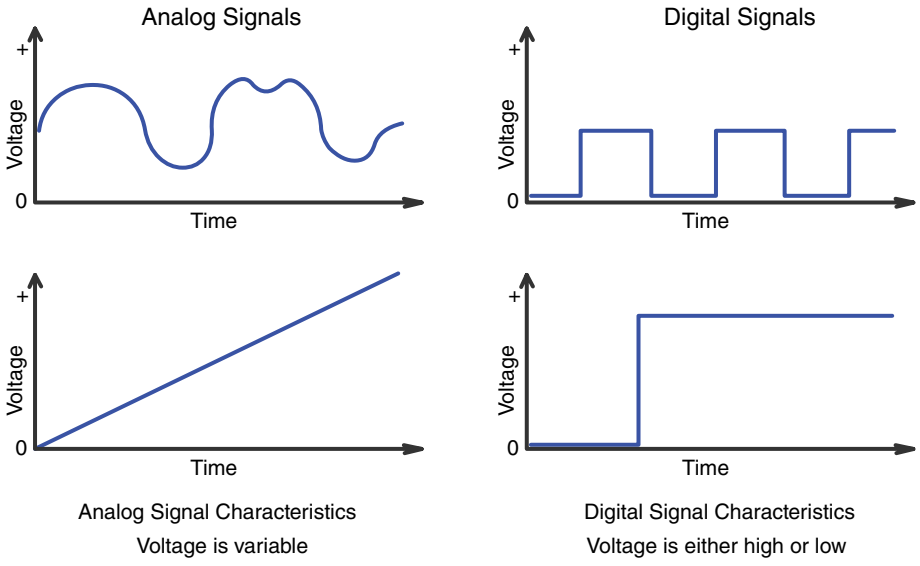


FIGURE 12-36 Analog signal voltages vary over time while digital signal voltages are on or off.

TABLE 12-1 Binary code is a language based on 0s and 1s to represent letters, numbers, or specifically designated items.

Binary Numbers and Their Bits (0–20)			
0 = 0	6 = 110	12 = 1100	18 = 10010
1 = 1	7 = 111	13 = 1101	19 = 10011
2 = 10	8 = 1000	14 = 1110	20 = 10100
3 = 11	9 = 1001	15 = 1111	
4 = 100	10 = 1010	16 = 10000	
5 = 101	11 = 1011	17 = 10001	

▶ TECHNICIAN TIP

While technicians do not repair components inside ECUs, it is helpful to understand what is going on inside. Your ability to diagnose ECU-controlled circuit concerns is enhanced by knowing how the ECU processes input data and what type of ECU output drivers may be used to provide a correct response—whether it is operating the HVAC blower motor at the desired speed, controlling vehicle acceleration via an internal combustion engine throttle control, or the electric motor of an EV or hybrid vehicle. If this subject matter entices you to learn more, the automotive industry is always searching for qualified electrical engineers and computer programmers. A technician who furthers their career to achieve a degree in these fields is a valuable resource to a manufacturer's research and development staff. Technicians know how systems work, how they can fail, and what it takes to repair them. That knowledge combined with a four-year degree in engineering can lead to many opportunities to advance your career.

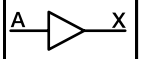
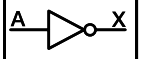
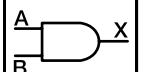
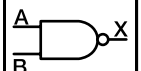
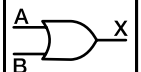
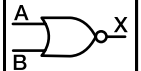
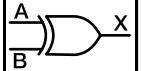
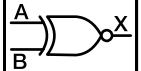
Symbol	Name	Alg. Expr.	Truth Table
	Buffer	A	A | X 0 | 0 1 | 1
	NOT	$\overline{A}$	A | X 0 | 1 1 | 0
	AND	AB	B A | X 0 0 | 0 0 1 | 0 1 0 | 0 1 1 | 1
	NAND	$\overline{AB}$	B A | X 0 0 | 1 0 1 | 1 1 0 | 1 1 1 | 0
	OR	$A+B$	B A | X 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 1
	NOR	$\overline{A+B}$	B A | X 0 0 | 1 0 1 | 0 1 0 | 0 1 1 | 0
	XOR	$A \oplus B$	B A | X 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 0
	XNOR	$\overline{A \oplus B}$	B A | X 0 0 | 1 0 1 | 0 1 0 | 0 1 1 | 1

FIGURE 12-37 Logic gates are the basis for digital programming.

more than one column, each column represents the possible input. For our examples, a 0 is a low input or output (usually an off signal) and the 1 is a high signal (usually an on signal). The most basic logic gate is the NOT logic gate. This gate produces the opposite outcome of the input. If the input is on, the output is off for example. The AND gate requires that both inputs are the same to produce the related output. For example if A and B are both 1, then the output will be 1; the logic gate requires a high signal at A and B to output a high signal. The NAND gate functions in the opposite fashion of the AND gate. The output signal is always high unless both inputs are high. The OR gate outputs a high signal if any input signal is high; if A is high or B is high, it will output a high signal. NOR gate is the opposite of the OR gate. The NOR gate outputs a high signal only when both signals are low. Anytime there is a high input signal there is a low output signal. The XOR gate will output a high signal only if one input signal is high. If both are low or both are high, it outputs a low signal. The XNOR gate is the opposite of the XOR gate. It outputs a high signal if both inputs are same and a low signal if only one input is high.

Understanding Switch Input Operation

A switch in non-ECU-controlled circuits directly provides circuit operation control. ECU-controlled circuits use a switch to provide an input signal to the processor (**FIGURE 12-38**). The processor then uses this data to control the desired output action. Let's review two fog light circuits. A non-ECU-controlled fog light circuit uses the fog light switch to provide a ground for the fog light relay. Turning the fog light switch on turns the relay on and the fog lights illuminate. An ECU-controlled fog light circuit uses the fog light switch as an input to the ECU. When the fog light switch is turned on, the ECU detects a voltage change and the processor provides an output command to turn on a transistor which provides a ground path for the internal body-ECU-mounted electronic fog light relay.

You may wonder why an ECU is used for something this basic. ECUs are used because input data are needed by various ECUs in the vehicle. In this example, turning on the fog lights places an increased electrical load on the charging system. Precise control of the charging system allows the engine to idle at the most efficient speed which increases fuel economy and reduces exhaust emissions.

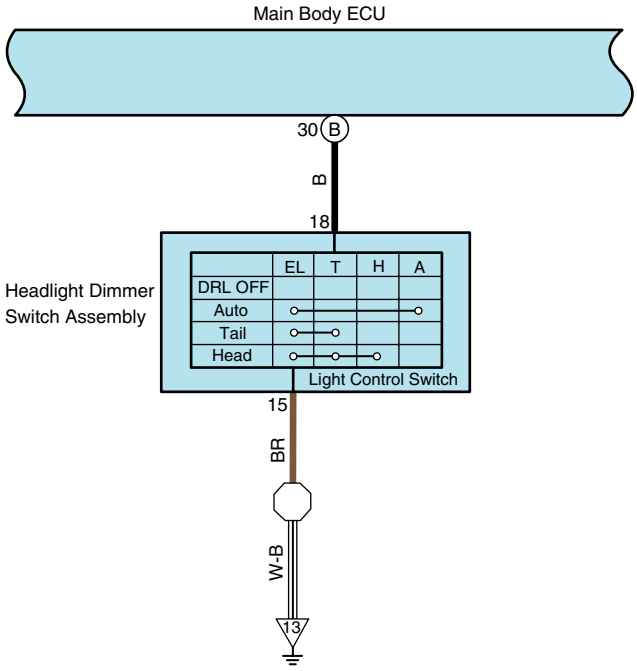


FIGURE 12-38 An ECU switch input circuit uses a source, load, switch, and path to ground.

The body ECU can share circuit load information with the charging system ECU in this example. The use of ECUs and sharing input data over vehicle networks reduces the need to run wiring to each separate ECU that requires the data. This reduces wiring cost and vehicle weight, and it simplifies the vehicle wiring harness.

A switch input may at first seem like a mystery in its operation as an input for the ECU. It is actually very basic and is the simplest of digital signal inputs to an ECU. Remember that every input is by itself a circuit, and every circuit requires a source, load, and ground. A switch input circuit may use source voltage or a regulated voltage that is less than source voltage. The load in the circuit is usually a resistor, often called a dropping resistor, since the voltage drops to almost 0 volts after the resistor when the switch contacts close turning the circuit on. The voltage does not drop when the input switch is in the open contact position, since current is not flowing through the resistor. This circuit creates either a full voltage or no voltage signal as the switch is turned off and on. Since this is a digital signal, the processor can use it without any conversion (**FIGURE 12-39**). A switch input uses a dropping resistor inside the ECU. The ECU circuit uses a logic gate to monitor the voltage after the resistor. Voltage present indicates the switch is open. When the switch closes, the voltage drops to 0 and the logic gate operates in the processor to provide the correct ECU output command.

For the interior light circuit shown (**FIGURE 12-40**), when the door is closed, the door switch contacts are open. The ECU detects source voltage after the dropping resistor. A logic gate is used for this circuit and is connected to the circuit after the dropping resistor. When the doors are closed, all the door switches are in the open contact position. Source voltage is present after the dropping resistor since the circuit is open (off). The logic gate interprets this voltage as a high voltage signal, or a 1 in binary code. Essentially, the doors are closed so the logic gate detects a 1 which requires no action (i.e., do not turn on the interior lights).

When a door is opened, the related door switch contacts close. The switch input circuit turns on and the source voltage drops to 0 volts after the dropping resistor. The logic gate detects the low voltage now present as a 0. The processor interprets this data as a command to turn on the interior lights. The processor commands an output signal to the output driver transistor that controls the interior light relay. The transistor provides a ground path for the interior light relay coil and the interior lights turn on. All of this happens in less than 100mS (a tenth of a second).

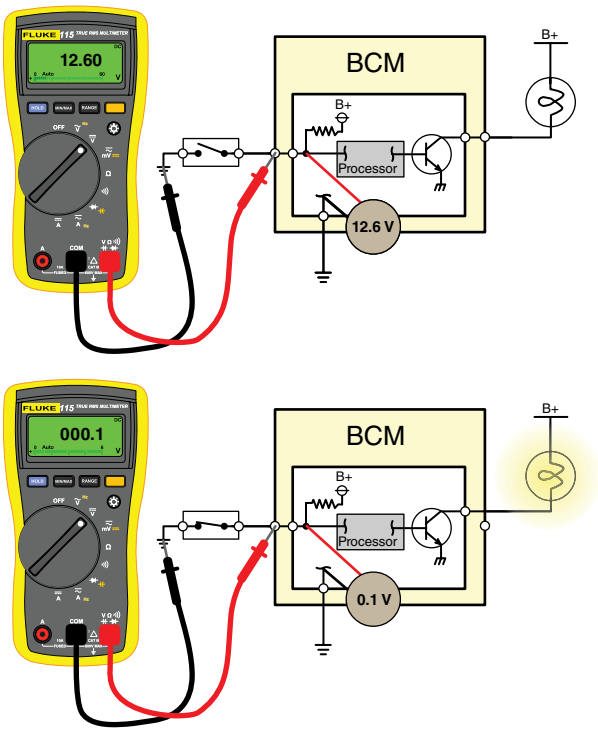


FIGURE 12-39 Since this is a digital signal, the processor can use it without any conversion.

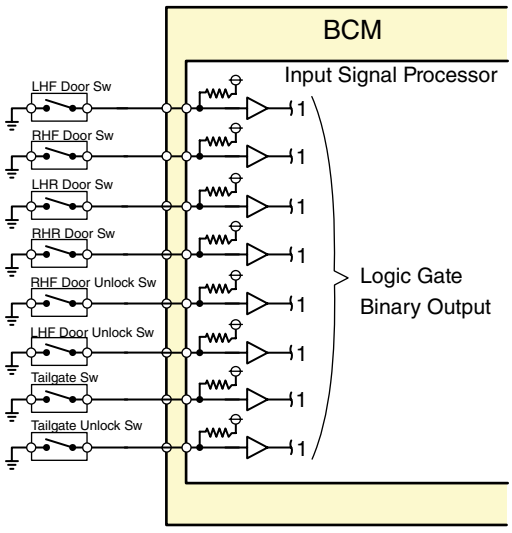


FIGURE 12-40 Interior light circuit that uses a switch at each door as an input to the ECU.

SKILL DRILL 12-2 Testing a Switch Input Circuit

1. Obtain the interior light circuit wiring diagram and service information for your assigned vehicle.
2. Trace the current path for the driver's door light switch input to the ECU, and refer to the service information to determine the expected voltage at the circuit side of the switch contact (not the ground side) when the switch is in the open (off position).
3. Use the DMM to verify voltage at the door switch when the switch is open and when it is in the closed position. Note your voltage readings on the wiring diagram. Review your test results with your instructor.

To test a switch input circuit, follow the steps in **SKILL DRILL 12-2**.

Understanding Position Sensor Input Operation

Position sensors provide input data to the ECU about the position of a component (**FIGURE 12-41**). Examples include throttle, accelerator pedal, HVAC system door controls, and power sliding and tailgate door mechanisms. The sensors may be analog or digital.

The analog **position sensor** is most often a three-wire sensor (**FIGURE 12-42**). The blend air door position sensor sample shown uses a 5V reference that drops across a fixed resistance inside the sensor. This fixed resistor has a conducting contact surface so that a moveable wiper in contact with the resistor picks up the voltage. Measuring available voltage at pin 6 of our sample circuit should show the reference voltage value on the DMM and very close to 0 volts measuring at pin 5. The moveable wiper picks up the voltage based on where it contacts the fixed resistor. For example, the midpoint of the fixed resistor has 2.5V (half of the 5V reference has dropped at this point). So if the blend air door was in its middle position, the wiper would be touching the middle of the fixed resistor and sending the 2.5V signal to the ECU. The ECU processor uses a look-up table that equates the signal voltage to the position of the blend air door in this example, with 2.5V being mid-position, 0.5V being the full cool position, and 4.5V being the full hot position. Sometimes the service information and scan tool display a percentage that equates to the position of the component, with 0% being the closed position and 100% being the open position.

To test resistor-type position sensors, follow the steps in **SKILL DRILL 12-3**.

Position Sensors in Body ECU-Controlled Systems

Some sliding doors, power-operated trunks and tailgates, and power window motors may use position sensors (**FIGURE 12-43**). These position sensors often use a type of counting system that determines the position of the component. The example shown is for a minivan

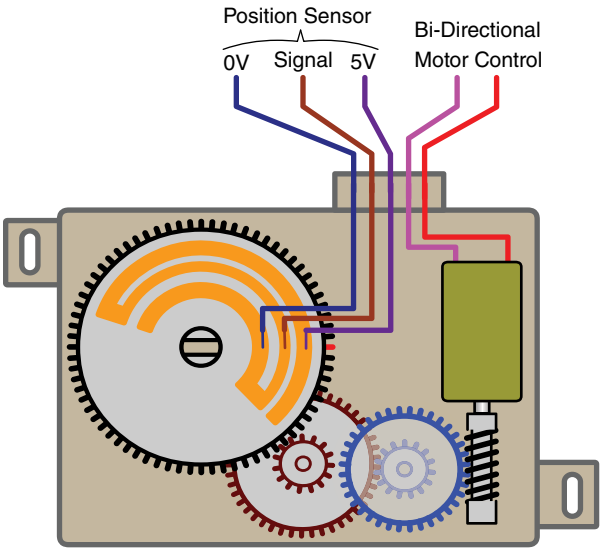


FIGURE 12-41 Position sensors are used in many ECU input circuits.

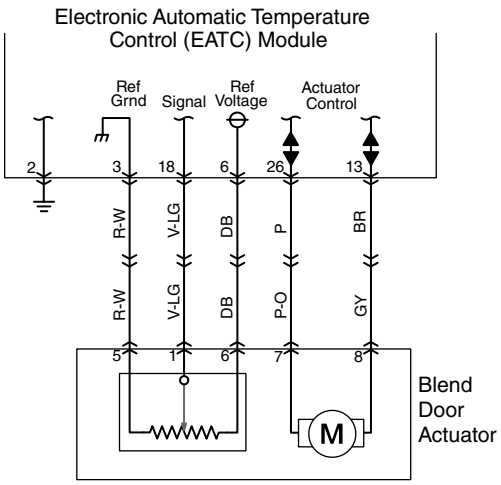


FIGURE 12-42 An analog position sensor is used to monitor the HVAC blend air door position.

SKILL DRILL 12-3 Testing Resistor-Type Position Sensors

1. Obtain the HVAC blend air door motor wiring diagram for your assigned vehicle.
2. Trace the current path for the blend air door position sensor circuit. Refer to the service information to determine the expected voltages at the reference pin, ground pin, and position input pin of the sensor.
3. Use the DMM to verify voltages at the position sensor. Note your voltage readings on the wiring diagram. Review your test results with your instructor. (Depending on the vehicle, it may be easier to take your readings at the HVAC ECU/control unit rather than at the blend air door position sensor due to access behind the instrument panel.)

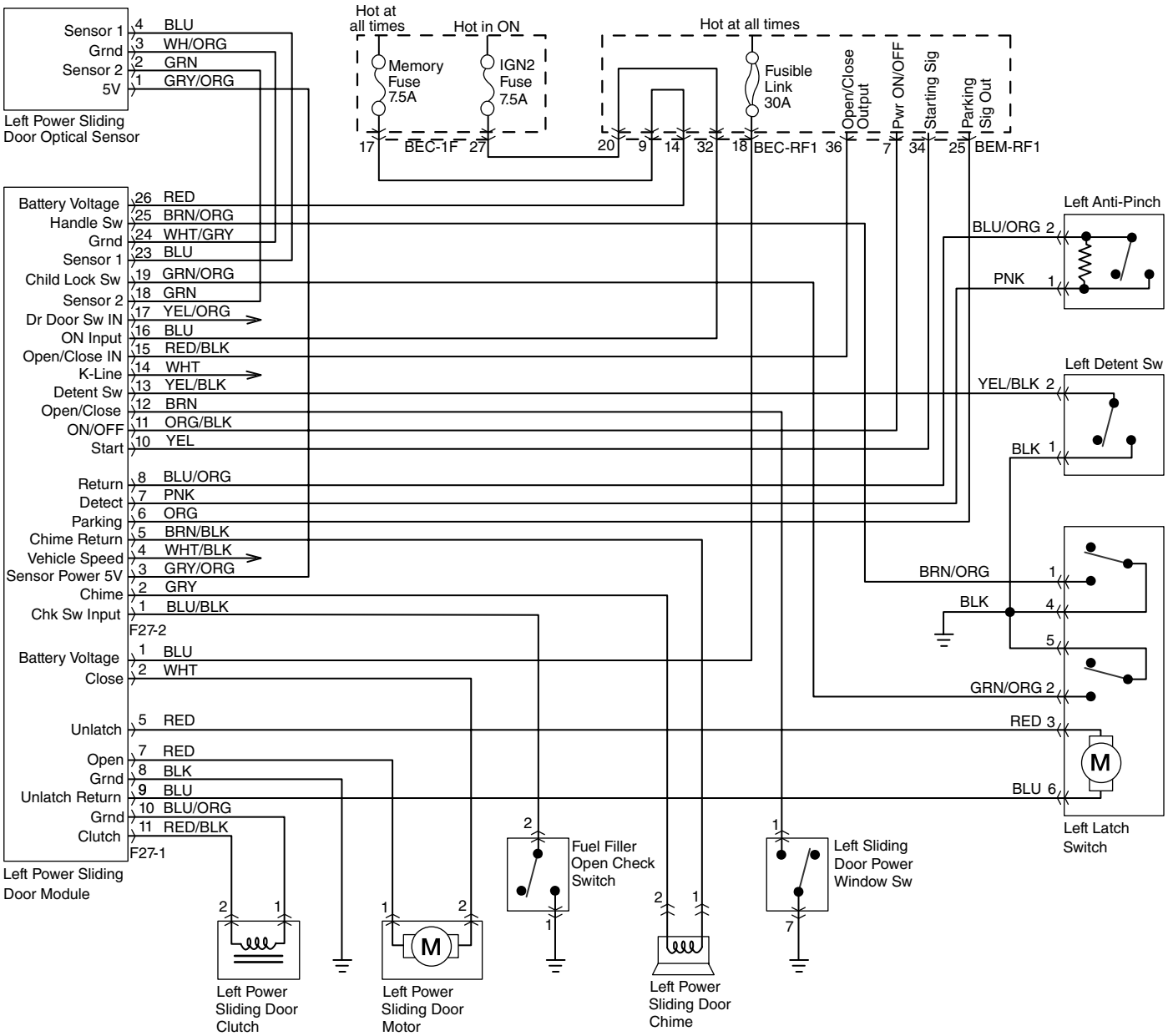


FIGURE 12-43 Digital position sensor is used in this vehicle's power sliding door control assembly.

▶ TECHNICIAN TIP

Position and thermistor circuits can provide inaccurate data if there is resistance in the circuit. There should be less than a 0.05 volt drop through the sensor wiring and the sensor ground. Always check circuit voltage drop through the wiring, connectors, and ground before replacing what seems like a bad sensor; it could be a circuit resistance issue.

power sliding door. The door motor uses an optical sensor that outputs a digital pulse signal to the door ECU. The ECU learns the number of pulses and the time interval between pulses required for the door to open; it then stores this data. This data helps control the speed of the door opening and how much motor torque to provide while the door is in motion. For example, when the vehicle is parked on an incline, this will affect the motor torque required to open and close the door. The weight of the door helps it open and if the torque remained the same, the door would open too fast and could damage components or cause an injury to a passenger. When the door closes, the torque required is much greater since the door is being pushed upward against gravity. The ECU detects this by counting the pulses and the speed of the pulses and then adjusts the current to the sliding door motor and clutch assembly.

Understanding Temperature Sensor Operation in System Input Circuits: Thermistors

Various vehicle systems require temperature data to operate correctly. It may be as simple as displaying the outside (ambient) temperature in the instrument cluster or as complex as the powertrain control module monitoring coolant, oil, transmission, fluid, cylinder head, and intake air temperatures. Temperature sensor data comes from the use of a thermistor (**FIGURE 12-44**). A thermistor is a temperature-sensitive resistor. The resistance of the thermistor changes as the temperature changes. Most automotive thermistors have very high resistance when the temperature is cold and low resistance as the temperature increases. These thermistors are labeled NTC for negative temperature coefficient. This means that, unlike most electrical systems and electronic components where resistance increases as temperature increases, the resistance decreases as temperature increases in an NTC-type thermistor.

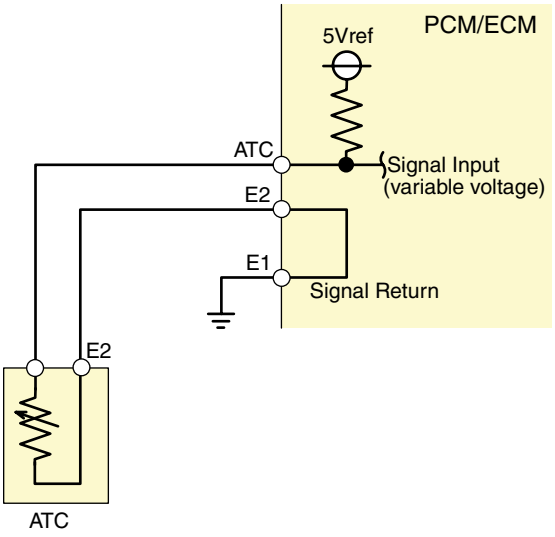


FIGURE 12-44 A temperature sensor circuit uses a thermistor and a dropping resistor.

Thermistor Operation

The thermistor circuit uses a reference voltage and a dropping resistor, similar to the switch input circuit. The circuit has two loads that share the reference voltage. This is often called a voltage dividing circuit. The dropping resistor is usually 1000 ohms. The ECU monitors the voltage drop between the 1000 ohm resistor and the thermistor. When the temperature is cold, the thermistor has very high resistance so most of the voltage drops across it and the ECU senses approximately 0.5 volts. When it is very hot, the thermistor has very low resistance, about 100–200 ohms and the ECU senses about 4.5 volts. The thermistor input is an analog signal since the voltage varies as the temperature changes. The ECU processor uses look-up table data that equates the sensed voltage to a temperature. The temperature data are then used by another portion of the processor to determine what action may be required for system operation.

To test thermistors, follow the steps in **SKILL DRILL 12-4**.

SKILL DRILL 12-4 Testing Thermistors

1. Obtain the ambient temperature diagram and service information for your assigned vehicle.
2. Trace the current path for the temperature sensor and refer to the service information to predict the voltages available in the circuit.
3. Use the DMM to measure the voltage at the temperature sensor when it is connected and when it is disconnected. Note your voltage readings on the wiring diagram.
4. Why is there full reference voltage when the connector is disconnected from the sensor but a different voltage when it is connected? Be prepared to answer this question and review your test results with your instructor.

Understanding Speed Sensor Operation in ECU-Controlled Circuits

Speed sensor data provides vehicle and component speed to various ECUs. Examples include wheel speed, engine crankshaft speed and position, A/C compressor clutch speed, and transmission input and output shaft speed. Speed sensors may output an analog or digital signal, depending on their design (**FIGURE 12-45**). Speed sensors use magnetism to induce a current in a conductive material. Remember that magnetism and electricity are related. Current in a wire creates a magnetic field around the wire, and a magnet can be used to induce current in a conductor when the magnetic field passes through it.

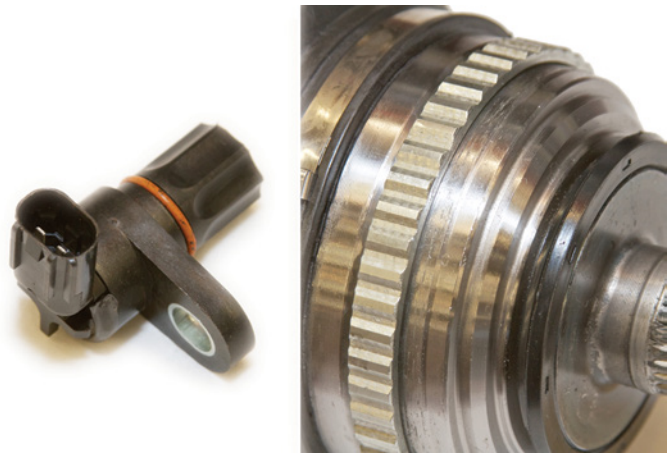


FIGURE 12-45 A wheel speed sensor provides a wheel speed signal input for many vehicle ECUs.

Analog Speed Sensor Operation

Analog speed sensors output an alternating current sine wave signal and are usually referred to as magneto-reluctance sensors. The sensor is made up of a **reluctor ring**, sometimes called a **tone ring**, and a magnetic pickup (**FIGURE 12-46**). The reluctor has teeth and gaps. As the reluctor rotates it interacts with the magnetic field of the magnetic pickup. The reaction with the magnetic field creates a sine wave in the positive direction as the reluctor tooth approaches the magnetic field, and then the voltage falls off and creates a sine wave in the negative direction as the reluctor tooth moves away from the magnetic field. The analog sine wave must pass through an analog-to-digital converter inside the ECU so the data can be used by the processor. Some engine speed sensor reluctors place a larger gap between two of the teeth that is timed with top dead center of cylinder number 1. In this case, the sensor is a speed sensor and a position sensor. Most magneto-reluctance sensors are two-wire sensors (**FIGURE 12-47**).

To test magneto-reluctance sensors, follow the steps in **SKILL DRILL 12-5**.

Digital Speed Sensor Operation

Digital speed sensors use a trigger device to create a pulse signal. The faster the component moves, the faster the pulse signal is generated. There are three main types of digital speed sensors: magnetoresistive, Hall effect, and optical.

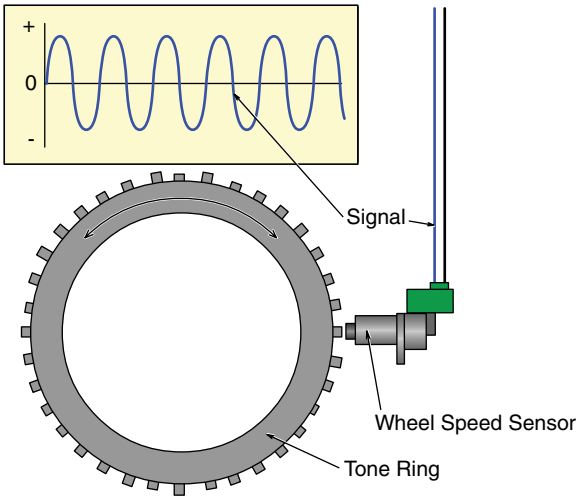


FIGURE 12-46 An analog wheel speed sensor outputs a sine wave voltage signal.

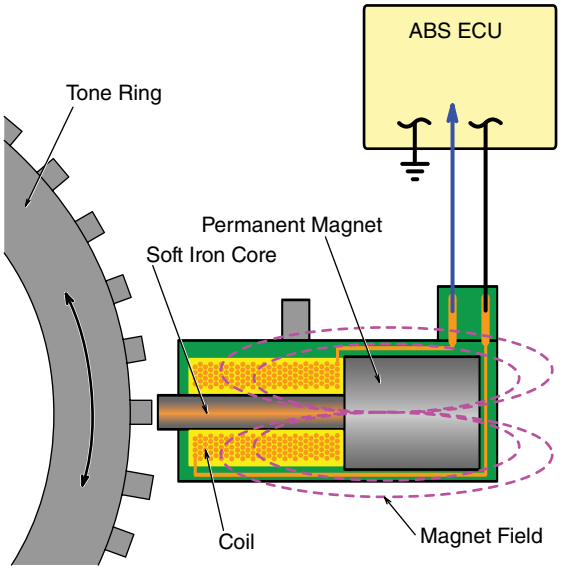


FIGURE 12-47 Wheel speed sensors use a tone ring on the rotating component and signal generating unit that locates the magnetic pickup very close to the tone ring teeth.

SKILL DRILL 12-5 Testing Magneto-Reluctance Sensors

1. Obtain the wheel speed circuit wiring diagram and service information for your assigned vehicle.
2. Trace the current path for the speed sensor input to the ECU and refer to the service information to determine the expected voltage at the sensor.
3. Use the DMM to verify sensor voltage at the sensor by rotating the hub assembly. Remember this is an alternating current (AC) voltage so use the correct DMM setting. Note your voltage readings on the wiring diagram. Review your test results with your instructor.
4. Use the DMM to measure frequency when rotating the hub. Many manufacturers provide a frequency reading at a certain wheel speed to verify proper sensor operation. Compare your reading to the service information if the data are available.

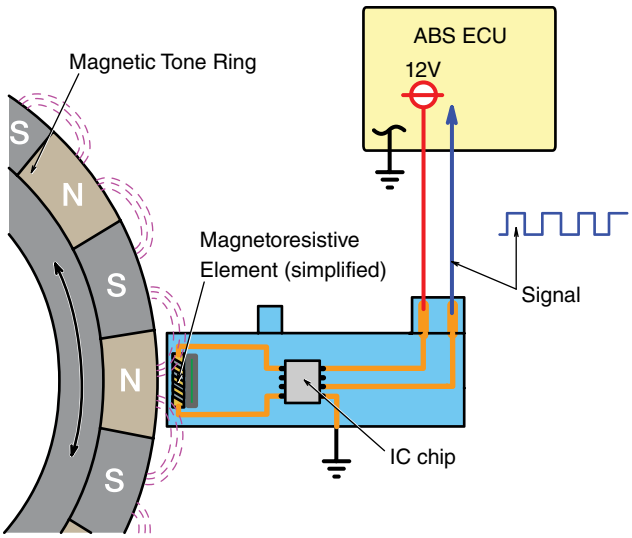


FIGURE 12-48 Magnetoresistive sensors output a digital signal.

Magnetoresistive sensors use a magnetic pickup and a tone ring similar to magneto-reluctance sensors. The tone ring is made up of magnetic north and south pole segments rather than teeth and gaps. A magnetic field is created between each north and south pole (**FIGURE 12-48**). The rotating tone ring induces current in the sensor that is amplified and output as a digital pulse signal. The frequency of the pulses varies as the rotating speed of the tone ring changes. Magnetoresistive sensors may be two- or three-wire sensors. Refer to the service information to determine the type of sensor that is used before performing any circuit testing.

To test magnetoresistive speed sensors, follow the steps in **SKILL DRILL 12-6**.

Hall Effect Position and Speed Sensor Operation

A Hall-effect sensor most often uses P-type semiconductor material to detect a magnetic field (**FIGURE 12-49**). The semiconductor has current passing through it at all times. The current passes directly through the material until it interacts with a magnetic field. Most Hall-effect sensors react only with the south pole of the magnetic field. When the south pole is at a right angle to the semiconductor, it causes the charge carriers (negative ions) and the holes (positive ions) to opposite sides of the semiconductive material where the Hall voltage terminals connect. Remember, voltage is potential difference, so the positive and negative charges on opposite sides of the semiconductor material create a voltage and very small current between the terminals. This small voltage is called the Hall-effect voltage, named after Edwin Hall who discovered it in the 1800s.

The early style Hall-effect sensors used a shutter wheel to block the magnetic field. The semiconductor creates a pulse signal as the shutter wheel unblocks the magnetic field causing the movement of charge carriers in the semiconductor to create the Hall voltage. The Hall voltage is then amplified (**FIGURE 12-50**). The signal output is a digital square wave signal.

More recent examples of Hall-effect sensors no longer use a shutter wheel (**FIGURE 12-51**). A magnetic sensor disc is used to carry the south pole magnetic fields past the Hall circuit semiconductor and create the Hall-effect voltage. The output is a digital square wave signal.

SKILL DRILL 12-6 Testing Magnetoresistive Speed Sensors

1. Obtain the wheel speed circuit wiring diagram and service information for your assigned vehicle.
2. Trace the current path for the speed sensor input to the ECU and refer to the service information to determine the expected voltage at the sensor.
3. Use the DMM to verify sensor voltage at the sensor by rotating the hub assembly. Remember this is pulsing direct current (DC) voltage so use the correct DMM setting. Note your voltage readings on the wiring diagram. Review your test results with your instructor.
4. Use the DMM to measure frequency when rotating the hub. Many manufacturers provide a frequency reading at a certain wheel speed to verify proper sensor operation. Compare your reading to the service information if the data are available.

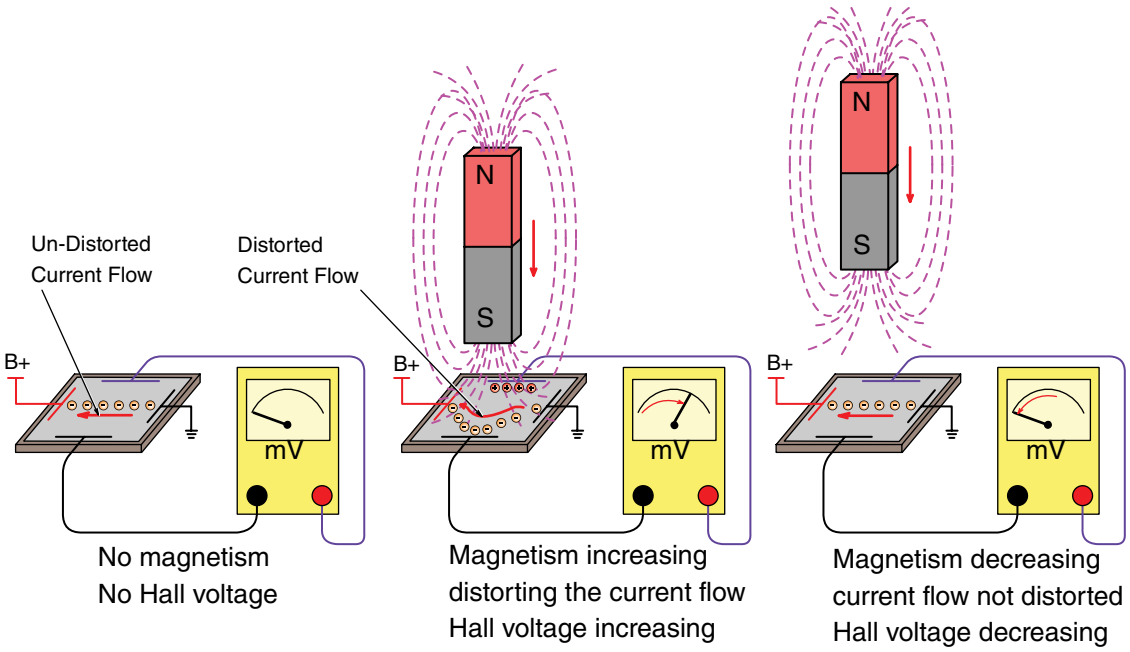


FIGURE 12-49 A Hall-effect sensor uses a semiconductor to detect rotational speed and output a digital signal.

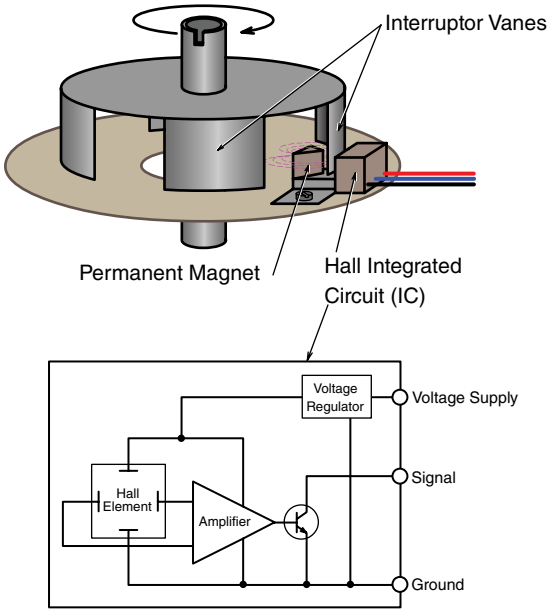


FIGURE 12-50 The Hall voltage is then amplified.

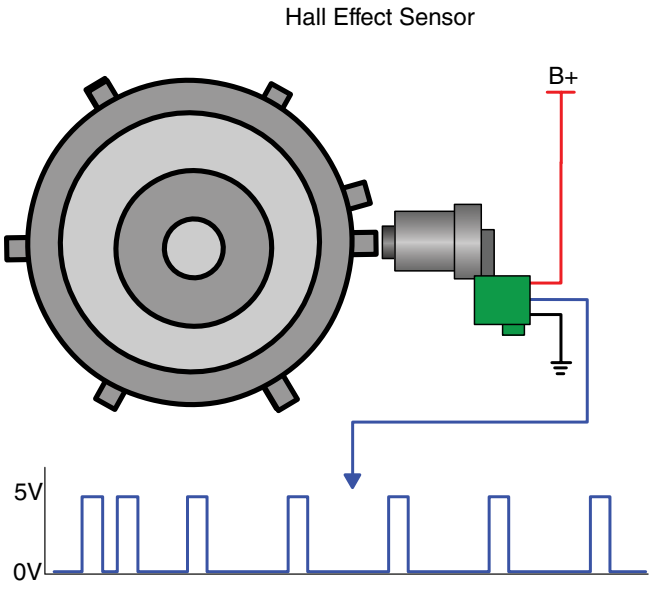


FIGURE 12-51 Most modern Hall-effect sensors use tone rings rather than shutter wheels.

This signal can offer synchronization by placing gaps in the magnetic field that correspond to component position (e.g., which cylinder is at top dead center or the position of a sunroof mechanism gear). Hall-effect sensors are almost always three-wire sensors: one wire for source or reference voltage, one for sensor ground, and one for sensor output signal.

To test a Hall-effect sensor, follow the steps in **SKILL DRILL 12-7**.

Optical Sensor Speed and Position Sensor Operation

Optical sensors use LEDs and photo diodes separated by a shutter wheel (**FIGURE 12-52**). As the wheel rotates, the light from the LEDs is picked up when it passes through the shutter wheel slots and strikes the photo diode. The photo diode then outputs a voltage which

SKILL DRILL 12-7 Testing a Hall-Effect Sensor

1. Obtain the Hall-effect circuit wiring diagram and service information for your assigned vehicle.
2. Trace the current path for the Hall-effect sensor voltage, ground, and input signal to the ECU. Refer to the service information to determine the expected voltage at the sensor.
3. Use the DMM to verify sensor voltage at the sensor when the component is operating. Remember this is pulsing direct current (DC) voltage so use the correct DMM setting. Note your voltage readings on the wiring diagram. Review your test results with your instructor.
4. Use the DMM to measure the frequency of the signal. Many manufacturers provide a frequency reading at a certain speed to verify proper sensor operation. Compare your reading to the service information if the data are available.

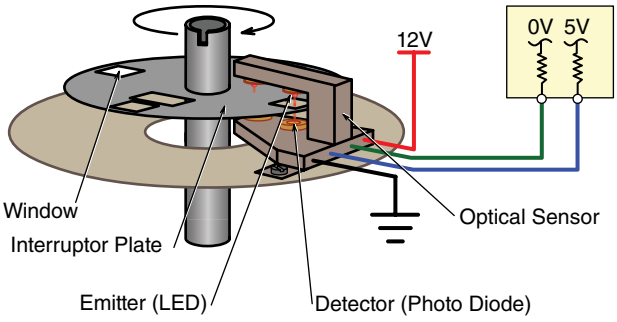


FIGURE 12-52 Optical sensors use LEDs and photo diodes to detect open slots in a shutter wheel to determine speed and position.

triggers an amplifier circuit to output a digital square wave signal. Optical speed sensors are very accurate; however, they cost more to assemble and the optical sections must be shielded from light and any possible contamination in order to operate correctly. This limits their use inside an engine, transmission, or as a wheel speed sensor. Optical sensors may be used inside power window, sunroof, and power sliding door motor units to monitor motor speed and position.

Understanding ECU Output Control for Accurate Diagnosis

The ECU uses **output drivers** to control either source voltage or ground path for the output circuits (**FIGURE 12-53**). The output drivers are usually electronic switching devices in the form of the transistor types described earlier in this chapter.

The electronic switching by the ECU may be done one of two ways: duty cycle or pulse width modulation.

Understanding Duty Cycle Output Control

Duty cycle control is based on a fixed frequency, usually 500 cycles per second or 500 hertz (Hz). Duty cycle control of an output is then based on turning the load on (or in

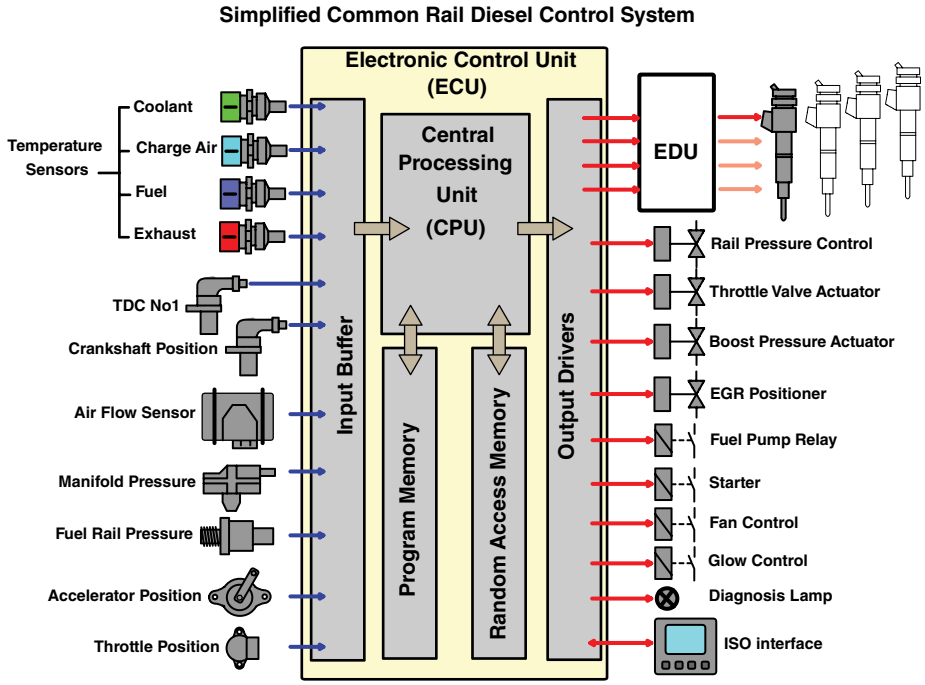


FIGURE 12-53 ECU outputs are controlled by output drivers.

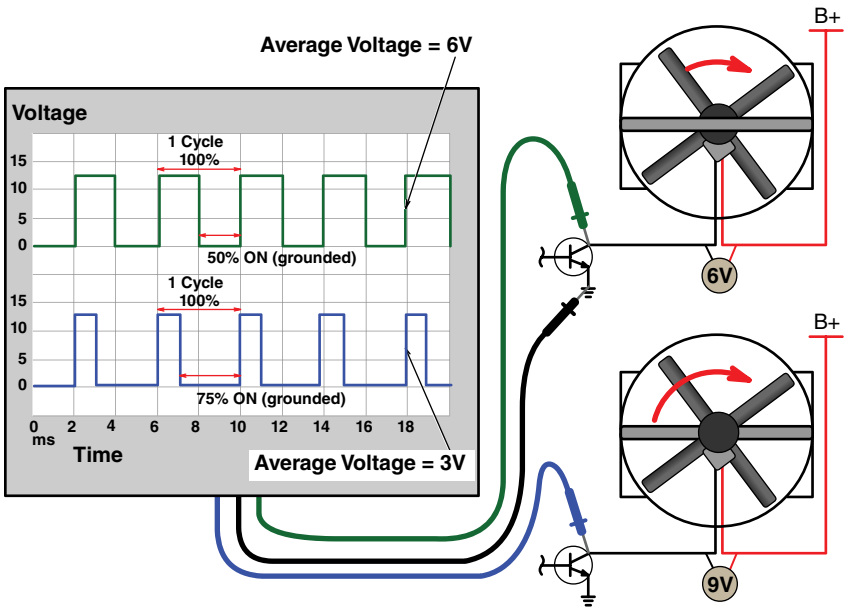


FIGURE 12-54 Duty cycle controls the "on" time which also controls the voltage to the output device.

some cases off) for a percentage of the duty cycle time (**FIGURE 12-54**). The strategy of duty cycle is to allow a varying voltage to a component to control its action. For example, the cooling fans turn on when the air conditioning compressor turns on, but the heat load of the radiator may be at normal temperature. The cooling fans do not need to operate at their highest speed, so the ECU turns the cooling fan driver on and off at a 50% duty cycle. This provides an average of around 6V to the cooling fan motors and they operate at low speed. When required (e.g., sitting in heavy traffic causing the heat load on the radiator to increase), the ECU can duty cycle the output driver at 100% providing an average of 12V to the cooling fan and operating it at high speed. A load that is turned on by the ECU driver at full voltage would be operating at 100% duty cycle. A load that is fully off is operating at 0% duty cycle. The ability to vary the average voltage to the output device offers more precise control of lighting, motors, and solenoid actuators. Loads that operate only in an on/off mode use a simple output control circuit to switch the output driver on or off.

To measure duty cycle, follow the steps in **SKILL DRILL 12-8**.

Understanding Pulse Width Modulation Output Control

Some output devices require full voltage to operate properly but they only operate for very short bursts of time. Fuel injectors are an example of a device that requires very

SKILL DRILL 12-8 Measuring Duty Cycle

1. Obtain the circuit wiring diagram and service information for your assigned vehicle.
2. Trace the current path for the component output from the ECU and refer to the service information to determine the expected voltage at the output.
3. Use the DMM to verify output voltage at the sensor. Remember this is pulsing direct current (DC) voltage so use the correct DMM setting. Note your voltage readings on the wiring diagram. Review your test results with your instructor.
4. Use the DMM to measure the duty cycle. Place the positive lead on the ECU output (signal) wire at the component and the negative lead on a known good ground. Set the DMM to display duty cycle (refer to your DMM user's guide if necessary). Compare your reading to the service information if the data are available.
5. Use the DMM to measure frequency. Change the duty cycle if possible (change blower motor speed or use a scan tool to control the purge solenoid duty cycle). Compare your reading to the service information if the data are available.
6. Use the DSO to view the duty cycle signal. Connect the positive lead to the signal wire (the wire from the ECU) and the negative lead to a known good ground. Set the DSO to display DC volts with a scale of 0–20 volts and a time setting of 100mS per division. Review your results with your instructor.

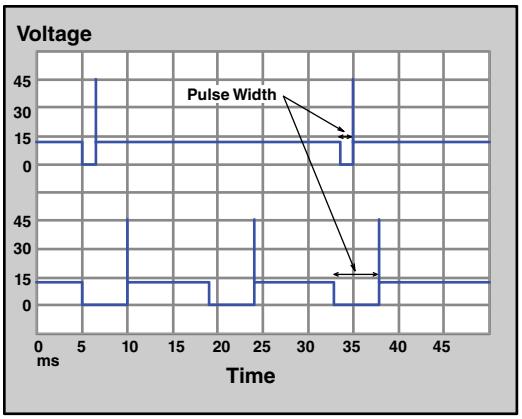


FIGURE 12-55 Pulse width can be varied to change the "on" time of an output at full circuit voltage.

precise control, in this case to deliver the correct amount of fuel into the cylinder (**FIGURE 12-55**). For this reason, the ECU processor uses complex programming to directly control the fuel injector operation time. This is called **pulse width modulation**. The ECU turns on the injector circuit for very small time increments. These increments can vary to adjust the amount of fuel delivered. For example, with the engine at idle speed and the vehicle waiting at a stop sign, very little fuel is required. The processor pulses the injectors for approximately 2 milliseconds (mS) each. Each injector turns on for 1/500th of a second but receives the full 12V to operate. As the vehicle accelerates away from the stop, the engine requires more fuel. The processor increases the pulse width from 2mS to 5mS and then continues to vary it based on engine data to continuously ensure that the fuel delivery is correct.

Diagnosing ECU-Controlled Circuits

Diagnosing ECU-controlled circuits is similar to diagnosing the circuits you have been working with so far; the five-step diagnostic process continues to apply. There are some additional steps required and you have the added use of a scan tool for most ECU systems.

Always refer to the wiring diagram. It is recommended you print it out so you can trace the current paths and predict voltages at your prioritized test points. Unlike non-ECU circuits where the voltage is at source level before the load and close to 0 volts after the load, ECU input circuits and output circuits may not operate at source or ground voltage. Refer to the service information for the ECU terminal pin check voltage values (**TABLE 12-2**).

The ECU terminal pin voltage values assist you in verifying whether the voltage you measure at the ECU or related component is correct. Note that some ECU terminals in the example shown generate a pulse voltage signal. You can use a DMM to measure this; however, the use of a digital storage oscilloscope (DSO) would provide more detail on the input signal if required for diagnosis.

ECU-controlled systems may store diagnostic trouble codes (DTCs) if there is a fault present. Use the scan tool to obtain any DTCs and then follow the service information procedure to diagnose the cause of the concern.

The scan tool can offer other functions that can assist your diagnosis. For example, the headlight switch is an input to the body ECU. If the headlights do not turn on with the switch, the scan tool output/active test (if available) can allow the scan tool to command the body ECU to turn on the headlights. If the headlights turn on when commanded, you know the body ECU output driver and the headlight output portion of

▶ TECHNICIAN TIP

OBD II level vehicles (since 1996) use a standardized set of DTC descriptors among most manufacturers. The first character in the DTC relates to the area of the vehicle as follows: P = powertrain, B = body, C = chassis, and U = network-related DTCs.

▶ TECHNICIAN TIP

Many ECUs require initialization of some systems after they are serviced or the battery is disconnected. Refer to the service information on system initialization procedures and complete them before returning the vehicle to the customer (e.g., initializing window auto down/up).

TABLE 12-2 ECU Terminal Pin Check Voltage Values

3C-5 – Body ground	P – Body ground	Taillight relay drive signal output	Light control switch in tail or head position Light control switch off	11 to 14 V Below 1 V
113-5 (HU) – Body ground	LG – Body ground	Dimmer switch high position signal input	Dimmer switch in high position Dimmer switch not in high position	Below 1V Below 1V
113-8 (HF) – Body ground	R – Body ground	Dimmer switch high flash position signal input	Dimmer switch in high flash position Dimmer switch not in high flash position	Below 1 V Pulse generation
113-20 (CLTB) – 113-22 (CLTE)	B - P	Automatic light control sensor power supply output	Ignition switch off Ignition switch ON, light control switch in AUTO position	Below 1 V 11 to 14 V
113-21 (CLTS) – Body ground	G – Body ground	Automatic light control sensor signal input	Ignition switch off Automatic light control system operates	Below 1 V Pulse generation (See waveform 1)

Data from Toyota/Lexus Technical Information System.

the circuit is OK. You can then focus on the input side of the circuit. Also, the data list allows you to observe ECU input data. The data shows if the headlight switch data are being received by the ECU. Check whether the switch position matches the data listed on the scan tool. If yes, the input is OK; if not, you now know where your diagnosis needs to focus.

ECU-controlled circuits require you to build upon your fundamental circuit operation knowledge. The same basic rules apply: all circuits have a source, control device, circuit protection, load, and ground return path. The use of an ECU with inputs and outputs requires focus on additional service information resources and use of the scan tool, advanced DMM features, and at times the DSO. Using these resources along with your knowledge of circuit operation will ensure you diagnose the customer concern quickly and accurately every time.

Wrap-Up

Ready for Review

- Electrical components are those that use electrical and mechanical elements in their construction and operation. Relays, motors, and incandescent bulbs are examples of electrical components.
- Electronic components are those that are primarily electrical in construction and operation. They generally have no moving parts and function to control and/or manipulate current and voltage in a circuit. These components can be designed to perform some of the same functions as electrical components. A transistor can function as a switch or a relay, for example.
- Most modern semiconductors are silicon based. The silicon is doped with phosphorus or boron to create P-type and N-type silicon. P-type silicon has an abundance of positive charge carriers called holes. N-type silicon has an abundance of negative charge carriers that are electrons, just like those in an atom. The two types of silicon can be joined to form components like diodes and transistors.
- A diode is one of the simplest types of semiconductors. N- and P-type silicon are joined. The area where they meet is called the P-N junction and forms a depletion layer. A diode can let current pass through or it can block current depending on the polarity of the voltage applied. The positive side of a diode is noted by a triangle shape on a wiring diagram and is called the anode. The negative side of a diode is noted by a vertical line and is called the cathode. A stripe closest to the cathode indicates to the user which side of the diode is negative. Diodes are used to control current in a circuit that has more than one possible path and to suppress high voltage spikes when inductors, like the compressor clutch coil, are turned off.
- A transistor is created by joining P- and N-type silicon with three junctions. They can be NPN or PNP in arrangement. A bipolar transistor has a base, collector, and emitter. The base controls current through the collector and emitter. The emitter is noted by an arrow in the wiring diagram. Transistors can function as a very fast switch, a relay, or a signal amplifier. Transistors come in a variety of designs including bipolar, J-FET, MOSFET, and thyristors.
- Logic gates form the basics of electronic processor functions. A logic gate functions to control current based on the current present, or not present, at its input points. There are several types of logic gates. The various types can be arranged to form an electronic-based brain-like thought process to determine actions based on the input data.
- Electronic control units (ECUs) house the electronic components that monitor input data, process the data, and control output actuators that operate the components in various vehicle systems. Electronic control units may be a stand-alone "box" or may be integrated into a component or a junction block. Components with built in ECU capabilities are often referred to as micro control units. Junction blocks with an integrated ECU are often called smart junction blocks (SJBs).
- ECU inputs include switches, temperature sensors, position sensors, and specialized diodes, like a photo (light) sensitive diode. Sensor input may be an analog or digital signal. Analog signals are a continuously varying voltage while digital signals are made up of on/off voltage pulses. Some ECU inputs operate on a reference voltage that is lower than battery voltage, often 5 volts.
- ECU memory contains the programming software to operate the processor. The processor monitors input data and, based on the programming instructions, operates various types of transistors to control output devices. The output transistors may be referred to as "drivers."
- Output drivers may operate an output by turning it on and off for a specific amount of time based on the software programming and the input data. The processor can vary the amount of time the driver is operated, offering very precise control of the output device. This type of operation is called pulse width modulation (PWM). Most components are operated using duty cycle control.

The output operation can still be modulated but not to the degree that PWM can offer. This is just fine for many components including interior lighting and the HVAC blower motor.

- Diagnosis of electronic circuits includes use of the wiring diagram and service information but additionally requires use of a scan tool if the system stores diagnostic trouble codes. The scan tool may be able to run various system tests, and the technician may also monitor the data from various inputs and whether specific outputs are turned on or off. DTC-based diagnostics usually follows a trouble tree or flowchart path to guide circuit and system testing.

Key Terms

baud rate The speed at which input data is reviewed by the ECUs processor.

binary code A computer language based on zeros and ones. Zeros represent low or zero voltage and ones represent a high voltage, which can vary depending on the system, from 2 volts to 12 volts. Each zero or one is called a bit, and eight bits form a byte.

depletion layer The depletion layer is very thin and acts like an insulator.

diode The most basic semiconductor device is a diode. A diode is made by joining P-type silicon and N-type silicon at a junction called the depletion zone. The positive end of a diode is the anode and the negative end is the cathode. The cathode is identified by a stripe on the body of the diode near the related lead. A diode can block current in one direction and allow it to pass when current is reversed. A diode is often referred to as a one-way valve for current.

forward bias The term used when a diode has current moving through it.

insulated gate bipolar transistor (IGBT) IGBTs offer the precise control of a MOSFET with very little heat generated in their operation. This offers greater packaging options in ECU design and can increase the service life of the ECU.

integrated circuit A complete circuit that is formed at a micro level. Processor chips include thousands of integrated circuits.

junction field effect transistor (J-FET) A J-FET is similar to a bipolar transistor but has a gate instead of base, a source instead of a collector, and a drain instead of an emitter. The core difference is that a J-FET uses voltage to control the depletion layer that forms the gate. No voltage allows current to flow through the J-FET. Applying very small amounts of voltage creates a depletion layer to control current.

light-emitting diode (LED) LEDs are made of materials that illuminate when forward biased. LED technology has quickly progressed from use as small indicator lights to their current high tech use in exterior lighting circuits, including headlights.

logic gates Logic gates form the internal connections that allow a processor to use input data and, along with programming software, determine the desired output for system operation.

metal oxide semiconductor field effect transistor (MOSFET) A MOSFET is similar to a J-FET but is made of different materials. Using metal oxide rather than silicon offers very precise control in ECU driver circuits.

output driver A device, usually a type of transistor, that controls an output device like the blower motor, interior light, or a fuel injector.

photo diode Photo diodes react to light. They block current when no light is present but allow current when light of sufficient brightness is present.

position sensor A sensor that monitors the position of a component. The sensor may be analog or digital. Some sensors monitor the movement of a component, like an HVAC blend air door or the engine throttle blade, as it moves from one position to another. Other position sensors monitor the location of rotating components like the crankshaft.

processor A solid state device that incorporates electronic components like resistors, diodes, and transistors on a mega miniature level. The processor circuits integrate logic gates that are used, along with software programming, to process the input data and then control the system outputs. The processor action is often referred to as sense – decide – act.

pulse width modulation (PWM) PWM is a very precise control method for an output device on a varying frequency. Usually only fuel injectors are operated in this format as the software programming and related circuits are very complex. Most other components are duty cycled on a fixed frequency.

reluctor or tone ring A reluctor or tone ring is used in many rotating position sensor applications. The ring is made up of teeth that are usually evenly spaced. Some reluctors have a missing tooth which is used to identify a specific location, like top dead center of cylinder 1 on the crankshaft.

reverse bias The term used when a diode is blocking current.

semiconductor A device usually made from silicon that has been doped with boron and phosphorus to create two or more distinct layers. The layers can be laid out to create components like diodes and transistors. A semiconductor has four valence electrons, and the doping creates a layer that has more positive charge carriers and a layer with more negative charge carriers. Current and voltage are used to manipulate the charge to provide various functions in a semiconductor.

smart junction block (SJB) A junction block with an integrated ECU.

thyristor A thyristor is similar to a transistor; however, once current turns it on, it remains on even after base current is turned off.

transistor A transistor is usually made with three layers of doped silicon material. Bipolar transistors can be constructed as PNP or NPN types. A transistor has a base, collector, and emitter. Current at the base controls current through the collector and emitter. The emitter is denoted by an arrow. The arrow usually points toward the ground portion of the circuit.

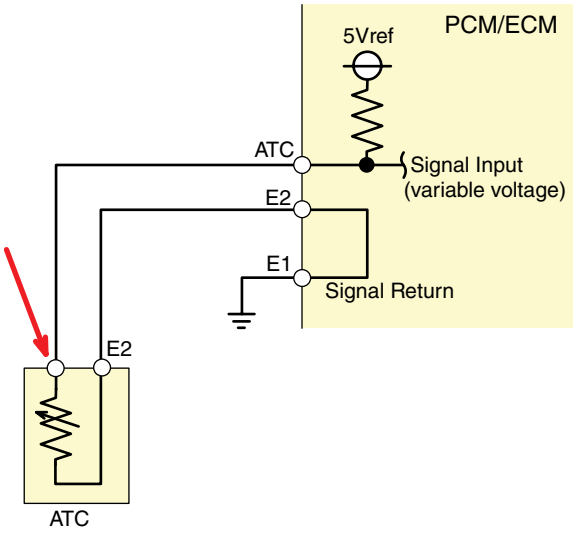
Zener diode A Zener diode operates like a normal diode when it blocks current but will conduct current when a designated voltage threshold is met.

Review Questions

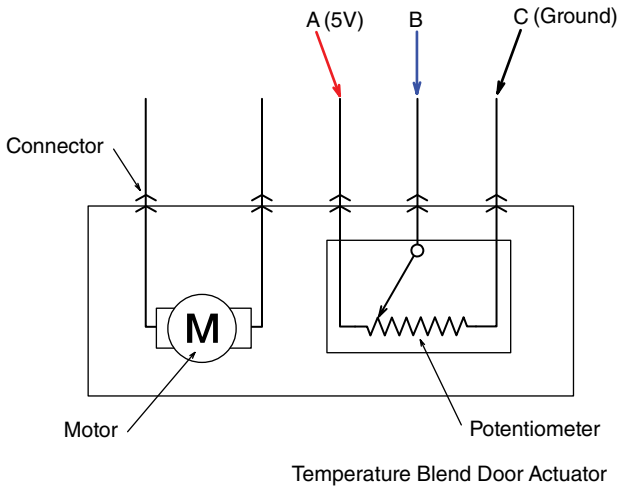
1. All of the following are inputs to an ECU *except*:
   a. ambient temperature sensor.
   b. switch.
   c. blower motor.
   d. wheel speed sensor.
2. Which of the following may be used as an output driver?
   a. Resistor
   b. IGBT
   c. Thermistor
   d. Hall-effect device
3. A Zener diode is often used for which of the following?
   a. To regulate voltage
   b. To block current at all voltage levels
   c. To function as a variable resistor
   d. To determine if it is dark enough to turn on the headlights
4. All of the following can determine component speed *except*:
   a. MOSFET.
   b. Hall-effect sensor.
   c. magnetoresistive sensor.
   d. optical sensor.
5. Choose the correct statement with respect to electronic components.
   a. They have moving parts.
   b. They manipulate electrical energy to produce very specific outcomes.
   c. They are only used individually in the circuits.
   d. They cannot function as electrical components in a circuit.
6. Which of the following statements is true with respect to a common diode in an electrical circuit?
   a. It allows current to pass rapidly through the circuit.
   b. It allows current in one direction and essentially blocks it in the opposite direction.
   c. It functions as an electronic version of a two-way check valve.
   d. If current is flowing through it, then it is reverse biased.
7. A diode is positioned in such a way that current is allowed to pass through it, causing a small voltage drop across it. The diode is:
   a. forward biased.
   b. reverse biased.
   c. a Zener diode.
   d. faulty.
8. All of the following statements are true with respect to transistors *except*:
   a. It can be used as a switch.
   b. It can be used to amplify currents.
   c. The central region is called the base.
   d. When current is applied to the base of the transistor, the transistor is said to be turned off.
9. Which type of transistor is capable of switching very high current loads and voltages at high frequencies?
   a. IGBT
   b. MOSFET
   c. FET
   d. BPT
10. All of the following statements are true regarding the logic gates used in the ECU *except*:
    a. each logic gate is based on a truth table.
    b. AND gate requires that both inputs be the same to produce the related output.
    c. OR gate outputs a high signal when both inputs are high.
    d. XOR gate will output a high signal only if one input signal is high.

ASE Technician A/Technician B Style Questions

1. Tech A says the voltage at E2 should be no more than 0.05 volts. Tech B says that testing for voltage at point X (red arrow) with the temperature sensor connected should be very close to 5 volts when the temperature is very warm. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

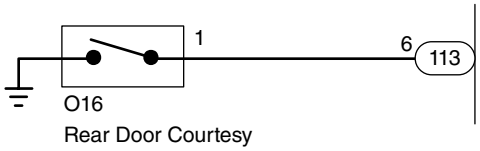


2. Tech A says the advantage of pulse width modulation is you can vary the voltage to the output device. Tech B says duty cycle operates on a fixed frequency even when the on time percentage is at 0%. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says the sensor signal with the blend air door in the position shown by the signal wiper pickup will be close to 4.5 volts. Tech B says an open between connector C and ground will result in a signal of 5 volts to the ECU. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

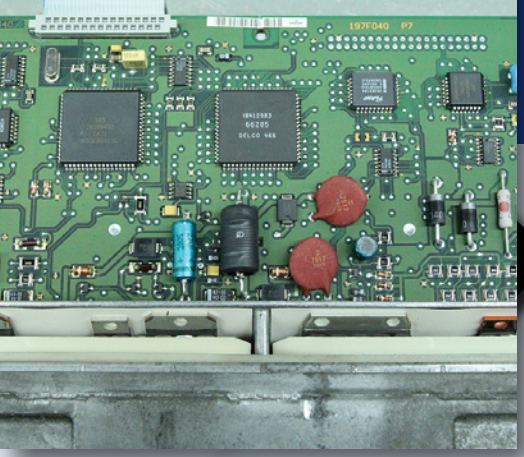


Temperature Blend Door Actuator

4. Tech A says thermistor circuit voltages are compared to look-up table data by the ECU processor to determine the temperature. Tech B says switch inputs usually do not use a dropping resistor inside the ECU. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. Tech A says sensor data are often shared by several ECUs using vehicle networks. Tech B says J-FETs use current at the gate to control voltage from the source to the drain that is supplied to the load in the circuit. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says the tone ring located on the axle shaft uses north and south poles for a magneto-reluctance type wheel speed sensor. Tech B says magnetoresistive speed sensors provide an analog sine wave output signal. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. Refer to the door courtesy switch shown. Tech A says pin 1 at the switch should have reference voltage when the door is open. Tech B says pin 6 of connector I13 should have 0 volts when the door is closed. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



8. Tech A says ECUs process using strings of transistors connected together to form darlington pairs. Tech B says that an AND logic gate requires both input signals to be the same to produce an output action. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. Tech A says a digital signal is produced with high and low DC voltage pulses. Tech B says a switch produces a digital signal. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Tech A says many junction blocks now incorporate ECU processing power to handle various body electrical system functions. Tech B says many ECU outputs are duty cycle controlled. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B



CHAPTER 13

ECU-Controlled Body Electrical Circuit Diagnosis

NATEF Tasks

There are no NATEF tasks in this chapter.

Knowledge Objectives

After reading this chapter, you will be able to:

- **K13001** Describe the function of the ECU.
- **K13002** Explain the diagnostic process for ECU-controlled body electrical circuit faults.

Skills Objectives

After reading this chapter, you will be able to:

- **S13001** Perform diagnostic tests on ECU body electrical circuit inputs and outputs using the DMM, DSO, and scan tool.
- **S13002** Diagnose ECU-controlled body electrical circuits that may have an input, output, or ECU-related fault.

You Are the Automotive Technician

The customer states the windshield wipers do not operate on high speed. The technician verifies the condition and that the wipers work on low speed. The technician obtains the wiring diagram and service information and notes that the wipers are controlled by an ECU. From the verification of the concern answer the following:

1. Can any circuit components be eliminated as the cause of the fault?
2. What components may be causing this fault?
3. What type of circuit tests would you use to isolate the cause of this fault?
4. What diagnostic tools may be required to diagnose this concern?

▶ Introduction

A non-ECU circuit uses a control device, like the headlight switch, to turn on the headlights. The switch contacts close and current has a path through the circuit to illuminate the headlights, taillights, and marker lights. A computer-controlled circuit uses an ECU to monitor input data and control the related output. An ECU-controlled lighting system circuit uses a headlight switch that provides an input signal to the ECU. The headlight switch input signal is used by the ECU processor which then commands an ECU output circuit to turn on the exterior lights. Using an ECU to control system circuits may at first seem overly complex. However, using an ECU affords many advantages. For example, using an ECU to control the exterior lights allows the lights to be turned on when the wipers are turned on, when the keyless entry is activated, or when a sensor detects it is dark enough at dusk or in a tunnel to turn them on. Using ECUs can also simplify wiring harness layout reducing cost, complexity, and vehicle weight. ECU-controlled circuits require similar diagnostic steps as circuits without an ECU, but there are additional tools and strategies required. This chapter prepares you to diagnose and repair ECU-controlled system circuits by covering their operation, outlining use of the diagnostic tools, and providing practice time. The circuits covered in this chapter represent a small sample of the type you will encounter on the job. The operation and diagnostic strategies presented here will prepare you to apply your knowledge on almost any type of ECU-controlled body electrical circuit.

▶ ECU Control

K13001 Describe the function of the ECU.

Computerized circuit control integrates an electronic control unit (ECU) in the system. Input data sent to the ECU are processed and output controls supply voltage or ground (e.g., to turn on lights or control blower motor speed). ECU input operation, including switch, temperature, speed, position, and other types of sensors, is covered in the Electronic Components chapter. This chapter will focus on ECU data processing, output control strategies, use of the scan tool, and other appropriate tools as part of the five-step diagnostic process for ECU-controlled circuits.

The service information usually provides a system diagram for most ECU-controlled circuits. The sample shown in (**FIGURE 13-1**) uses arrows that point toward the ECU to indicate the component is an input and arrows from the ECU that point to an output component. Refer to this diagram as part of the diagnostic process so you have an understanding of the inputs and outputs in the system.

Body Electrical ECU-Controlled Circuit Inputs

ECU-controlled system circuits use a variety of input types, depending on the requirements of the system (**FIGURE 13-2**). The lighting system uses a multifunction switch to provide input on which lights the driver wants to turn on; it may also use input from a photo diode to detect exterior light conditions to automatically turn the lights on as it gets close to sunset and turn them off at sunrise.

Body ECU Operation

ECUs can be described as operating on the principle of sense – decide – act. The ECU monitors sensor inputs, processes the data, and then decides on the correct action for the related output device. The ECU uses one or more processor chips to perform data interpretation and execute desired output commands (**FIGURE 13-3**). The programming information is stored using integrated circuit (IC) chip memory. There are different types of memory used in the ECU. **Read-only memory (ROM)** is where the vehicle specific system programming is stored. **Random-access memory (RAM)** is a partition of memory that stores current vehicle data while the system is in use and usually self-erases at vehicle shutoff. Another RAM partition is the **keep alive memory (KAM)**. KAM stores data related to system settings and other data that are learned from use. Body system examples of KAM include power seat position memory settings, automatic climate control temperature settings, and how long the driver desires the headlights to remain on after the engine is turned off.

▶ TECHNICIAN TIP

Many new vehicles with ECU-controlled circuits also incorporate network communication into these circuits. Vehicle ECU networks allow system ECUs to share data with each other. Controller area network (CAN) communication was required in 2008 for powertrain controls, and most manufacturers began using CAN many years earlier. This chapter covers body ECU-related system operation and diagnostic strategies for circuits that do not rely on network communication for their operation. Refer to the Vehicle Network Systems chapter for vehicle network systems including CAN.

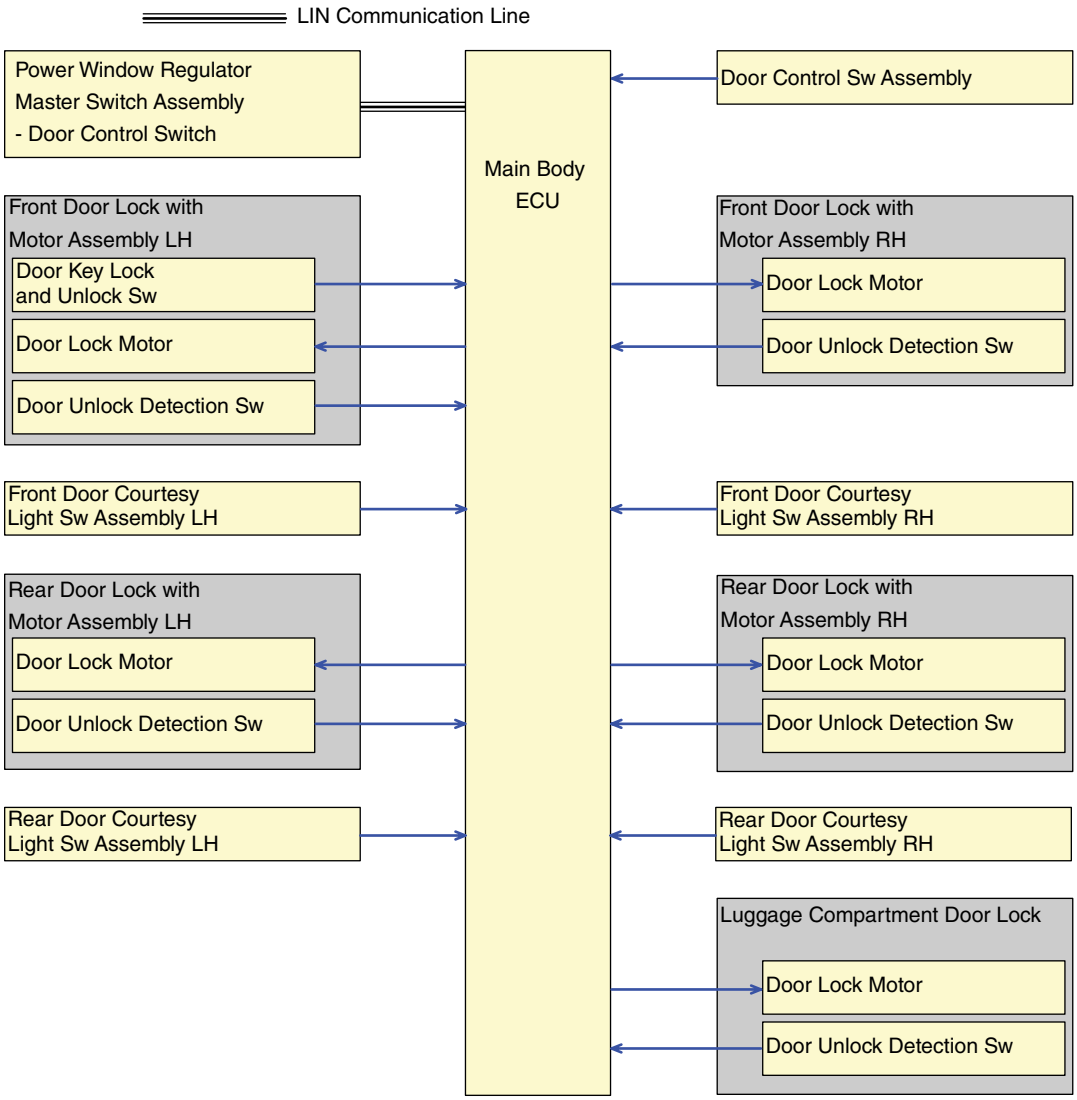


FIGURE 13-1 ECU-controlled circuits use inputs and outputs, as shown in this door lock system diagram.

ECU Memory Operation

Most vehicles now use **electronically erasable programmable read-only memory (EEPROM)** IC chips in the ECUs. This allows the programming to be updated to improve functionality or to correct a programming instruction that may lead to improper system operation under some conditions. ECU updating is done using the scan tool which communicates with the appropriate ECU through the **OBD II data link connector (DLC)**. The currently stored ECU programming is erased and a new program is uploaded through the DLC to the ECU.

Analog and Digital Signal Processing

Some sensor data monitored by the ECU are analog and some are digital. Remember, analog signals are a varying voltage while digital signals are made up of on and off pulses (see the Instrument Cluster, Non-ECU-Controlled chapter to review if necessary). The ECU requires that all data are in a digital format for processing. Analog signals must pass through an analog-to-digital converter so the data can be interpreted and processed. The digital signals are then processed using data tables, usually called **look-up tables**. The look-up table data are stored in the ECU memory chips (**FIGURE 13-4**). Data from the ambient temperature sensor as a voltage signal are converted to a digital value and then "looked up" to equate the voltage to the related temperature. For example, a sensor voltage of 3.51 volts equates to 50°F.

▶ TECHNICIAN TIP

ECU reprogramming is most often done using the manufacturer's scan tool in the dealer shop environment. Manufacturers are required by law to provide certain updates to non-OEM independent repair facilities, although there may be a cost for accessing and downloading the update programming. Also, most manufacturers only provide access to ECU updates to their senior level diagnostic technicians because the ECU could be damaged if the update procedure is not performed following all designated steps. Since this procedure is usually restricted, there is no related skill drill.

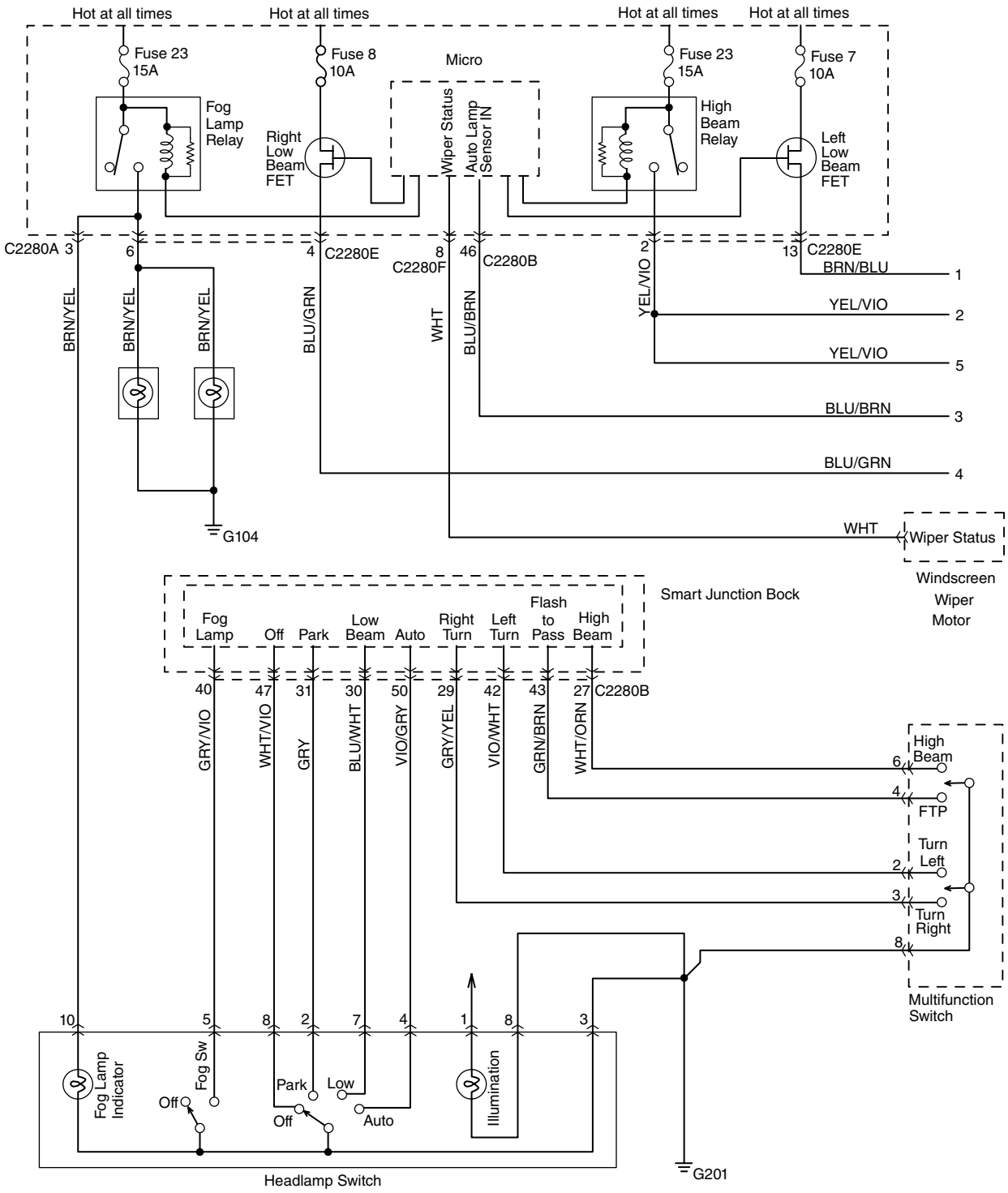


FIGURE 13-2 A variety of inputs are used in ECU-controlled circuits, including switches.

Data Mapping

Data maps are usually a three-dimensional representation of parameters used to provide intersecting points from two or more input sensor values (**FIGURE 13-5**). The data maps are created by software engineers working with system engineers. The system is tested over many hours and varying conditions to determine the best output action for each data point on the map.

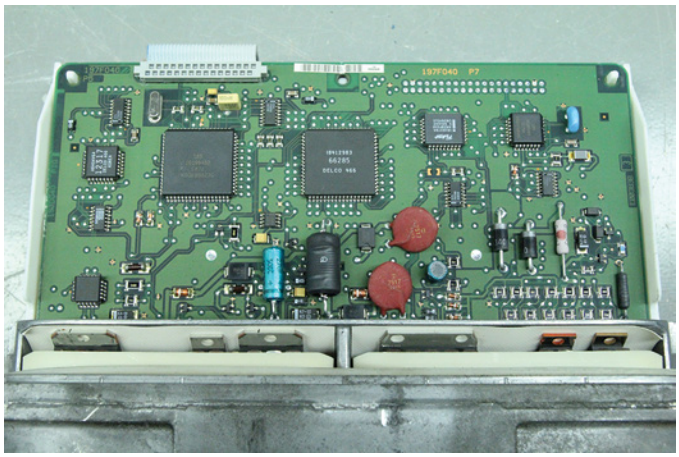


FIGURE 13-3 ECU circuit board.

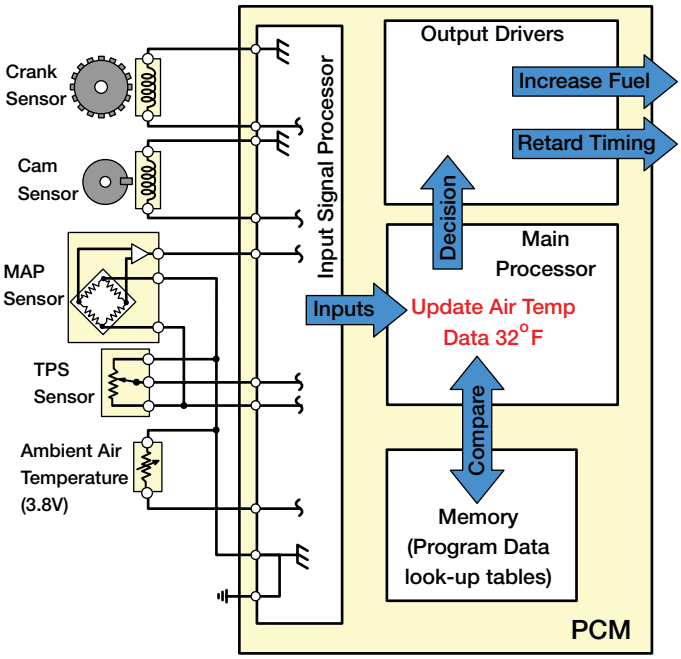


FIGURE 13-4 ECU processors use data maps and look-up tables that are stored in the read-only memory to determine what action is required.

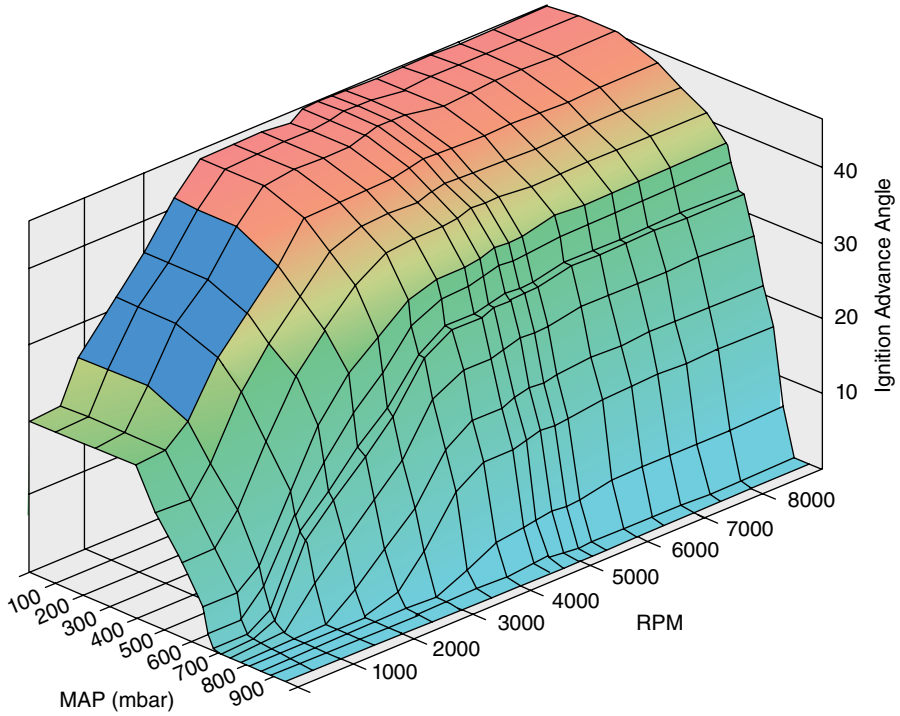


FIGURE 13-5 Data mapping is used to determine the correct ECU output command using two or more sensor data parameters.

▶ TECHNICIAN TIP

You can review logic gate types in the Electronic Components chapter. Logic gates can also be connected to form complex input and output instruction programming for ECU-controlled system operation. An automotive software engineer uses logic gates and other programming tools to create the programming to operate vehicle systems. There is a large demand for automotive software engineers; if this interests you, your experience as a technician with vehicle systems offers you a very solid knowledge foundation for continuing your education toward becoming a software engineer.

Logic Gates in Signal Processing and Output Control

Logic gates are also used in processing data (**FIGURE 13-6**). Let's apply the AND gate to system operation for the headlights. One input to the logic gate is from the headlight switch and one is from the light sensing photo diode. When the headlight switch is off and the light sensing diode signal output indicates there is a sufficient amount of ambient light, the input is interpreted as a "0" or "off" signal. When the headlight switch is turned to "Auto," the input signal changes to a "1" or "on" signal. The lights still do not turn on until the ambient light sensor input indicates it is dark enough to require headlight use. This input data then changes from a "0" to a "1." The AND gate requires both input data to be in the "on" or "1" for an output command to turn on the headlights.

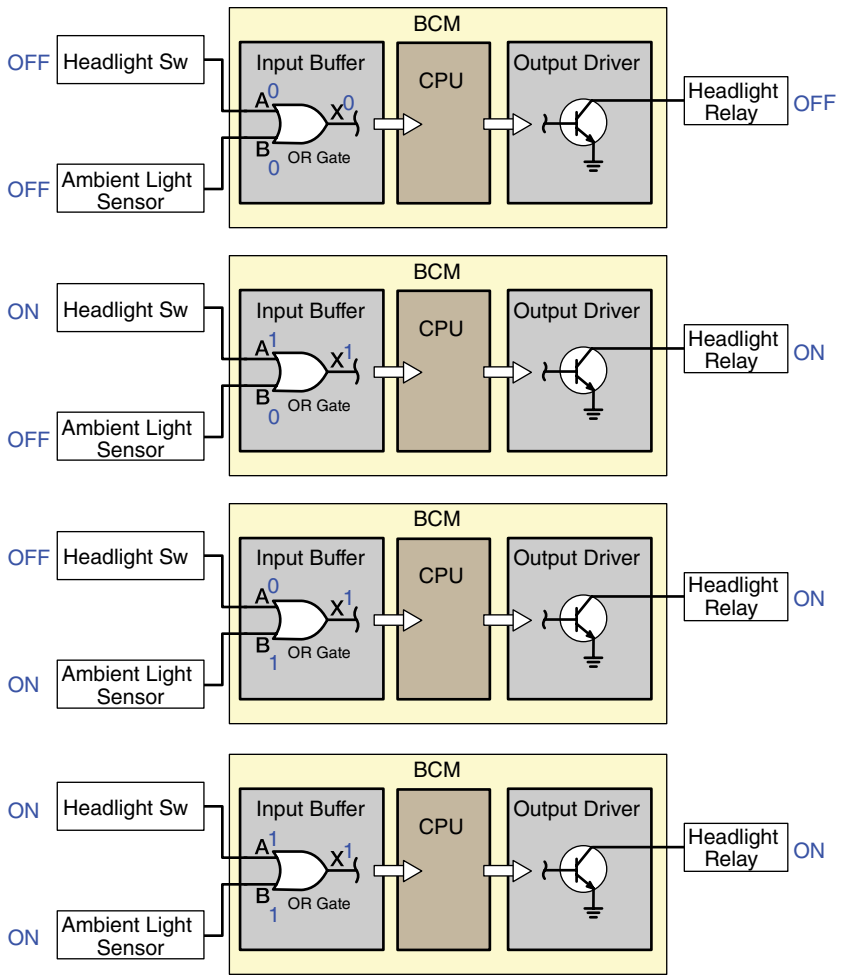


FIGURE 13-6 Logic gates are used in ECU programming to monitor system parameters and determine output action.

ECU Output Control Operation

ECU output control may be similar to a switch that is electronically controlled. The fog light circuit shown is an example of this type. The fog light switch provides an input signal to the ECU. The Smart Junction Box (SJB) turns a transistor "on" to provide a path to ground for the fog lamp relay and the fog lights illuminate. The headlight circuit is a good example (**FIGURE 13-7**). The fog lamp switch provides an input to the smart junction box (ECU). The processor then provides a ground path for the fog lamp relay by turning on a transistor. Other output circuits are duty cycled to control the output voltage to the actuator (e.g., the blower motor). For example, providing only an on or off signal to the blower motor would only provide one blower speed. Using a duty cycle output, the voltage to the blower motor can be controlled providing several speeds.

System Initialization

Some ECU-controlled systems may require initialization when the vehicle is first prepped for delivery at the point of sale or if the system power or battery is disconnected. Examples may include auto up/down power window function, power seat memory, and power sliding door/tailgate or trunk operation. These systems need to learn the position of the motor or other component(s) so the automatic functions can operate correctly. Initialization procedures are provided in the service information and usually the vehicle owner's manual. The initialization data are stored in the keep alive memory of the related system ECU. This is why removing a fuse or disconnecting the battery can erase this data.

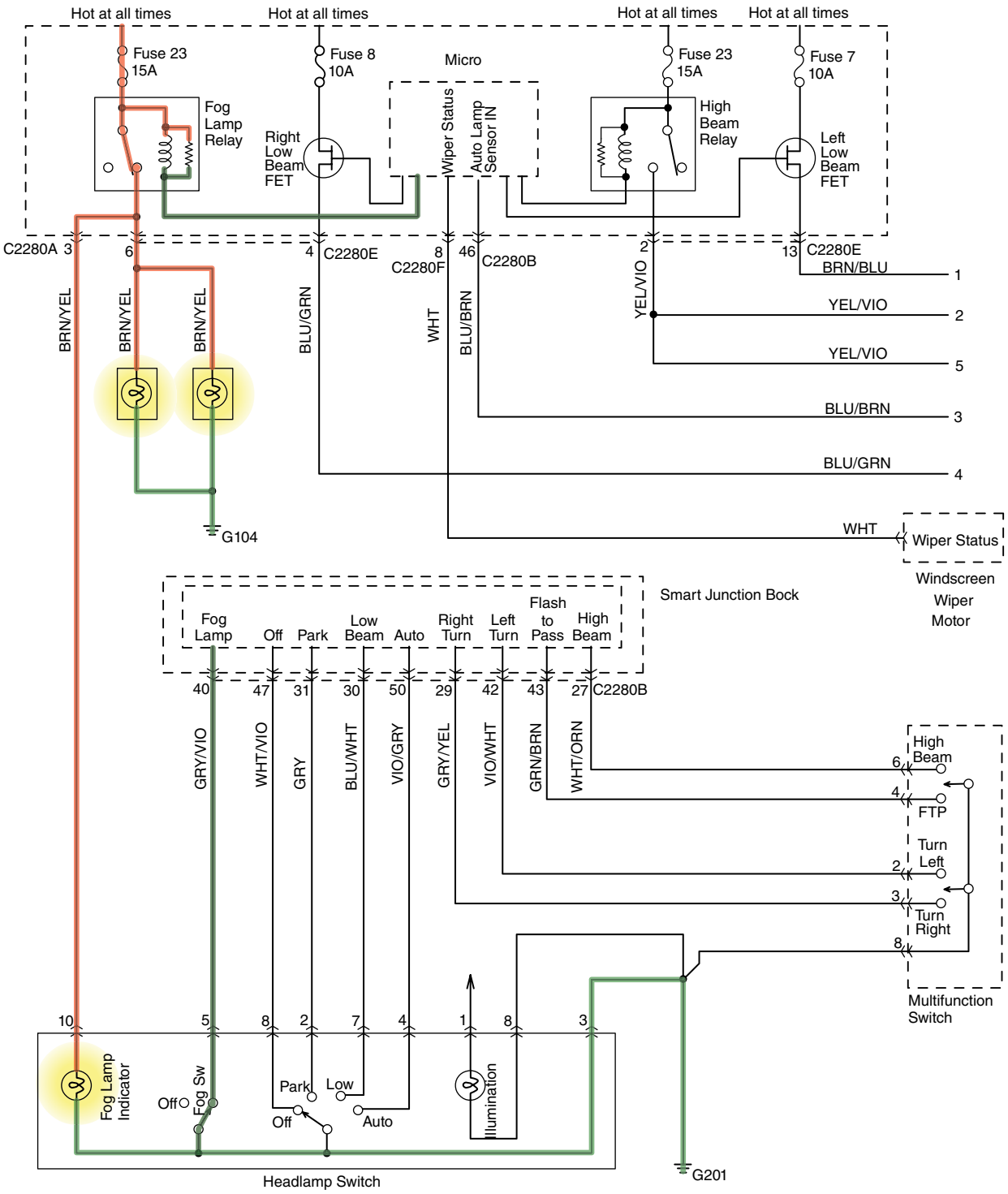


FIGURE 13-7 ECU output control may have the processor turning on a transistor which then controls a relay to turn on the fog lamps.

Some vehicles have the ability to store this data when performing service that requires disconnecting the battery and this is outlined in the service information. Always check ECU-controlled circuits after replacing the battery or after disconnecting power by removing a fuse or other component. Failure to do so can lead to repairing the customer concern but creating a "new" problem, prompting customer frustration and disappointment with your service work.

K13002 Explain the diagnostic process for ECU-controlled body electrical circuit faults.

S13001 Perform diagnostic tests on ECU body electrical circuit inputs and outputs using the DMM, DSO, and scan tool.

▶ ECU-Controlled Body Electrical System Diagnostic Tools

Digital Multimeter (DMM)

The digital multimeter (DMM) continues to be an important tool for ECU-controlled circuit diagnosis, primarily for measuring voltage (**FIGURE 13-8**). As discussed in the Instrument Cluster, Non-ECU-controlled chapter, advanced DMM features for measuring frequency and duty cycle are necessary for diagnosing ECU input and output signals.

FIGURE 13-8 Advanced DMM features, including measuring frequency and duty cycle, may be required when diagnosing ECU-controlled circuits.

Scan Tools

The scan tool is often used when diagnosing body ECU circuits (**FIGURE 13-9**). The scan tool offers several functions including obtaining diagnostic trouble codes (DTCs), viewing input and output data, recording data to review after a test drive, controlling ECU outputs, customizing parameters, and in some cases reflashing (reprogramming) ECUs with updated software.

Body ECU DTC Retrieval and Interpretation

Diagnostic trouble codes are stored by most body electrical ECUs. You can usually view which ECU-controlled systems are available from the scan tool system select screen. OBD II vehicles (1996 and newer) usually use five-character alphanumeric DTC identification. The first character is a letter that identifies the area of the vehicle the ECU is related to—P for powertrain, B for body systems, C for chassis systems, and U for network systems. The letters and numbers which follow the letter usually follow OBD II naming conventions. One of the goals for OBD II was to standardize DTCs and the design of the data link connector. The OBD II DLC is a trapezoid shape and has 16 pins (**FIGURE 13-10**). Most of the pin locations are for specific functions and are the same for all vehicles. A few pin locations are open to manufacturer-specific functions (labeled as discretionary). Note that the scan tool is supplied battery source and ground (pins 16 and 4).

Obtain body electrical DTCs by selecting the applicable ECU or system from the scan tool system select menu. Once the system is communicating with the scan tool, select the DTC function and the scan tool will communicate with the ECU to display and DTCs. If a DTC is stored, refer to the service information to continue diagnosis. DTC diagnosis requires that you follow the service information steps. Note that in step 1, you are directed to view another scan tool function—data list (**FIGURE 13-11**). The data list shows you input sensor values and output state data. For this example, if the data are out of range, you continue to step 2. If the data are in the normal range, you are directed to replace the ECU. It is worth noting that the data list values for input sensor data displayed on the scan tool may not be accurate if there is a resistance-related fault in the input circuit. Most ECUs can detect an open or short circuit, but sensor data that are skewed due to resistance in the harness is unlikely to store a DTC. For this reason, if the inspection procedure leads to replacing the ECU, it may be prudent to check related circuits (the ambient light sensor in this example) to ensure there is no resistance or other fault. Replacing an ECU often requires performing a software upload, so you want to be sure the ECU is actually at fault. Otherwise, you may go through a lot of effort only to find there was another fault causing the condition.

Scan Tool Active Test

The scan tool may also offer active test functions for many body electrical systems. This is a quick way to narrow your search for the circuit fault. In the example (**FIGURE 13-12**), you can turn on the headlights, taillights, daytime running lights, and select high or low beams.

▶ TECHNICIAN TIP

Diagnosis of ECU-controlled body electrical systems will require the application of all your vehicle circuit knowledge. Tests for resistance, open circuits, and other faults are still required. Although your testing may begin with the scan tool, the accuracy of your diagnosis still depends on your review of the service information and application of your knowledge of system operation. Do not head to the parts department to obtain a new component until you are confident that your diagnostic work has accurately isolated the cause.

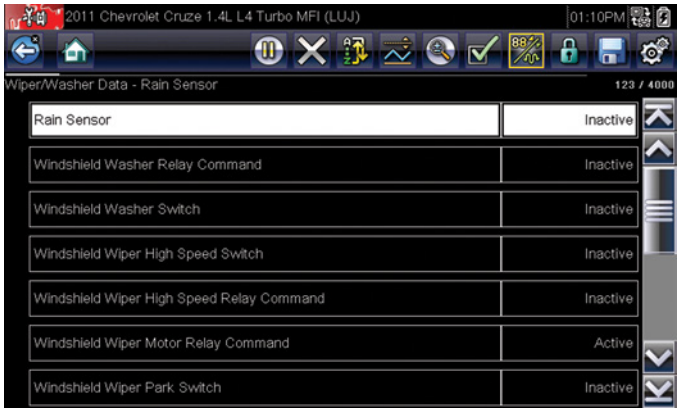
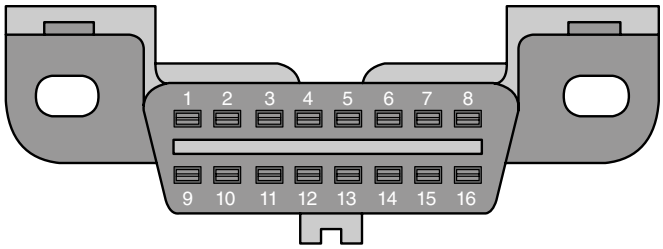


FIGURE 13-9 Scan tools are used when diagnosing ECU-controlled circuits.



1 - Manufacturers Discretion
2 - SAE J1850 Bus +
3 - Manufacturers Discretion
4 - Chassis Ground
5 - Sensor Ground
6 - SAE J2284 CAN High
7 - ISO 9141-2 K Line
8 - Manufacturers Discretion
9 - Manufacturers Discretion
10 - SAE J1850 Bus -
11 - Manufacturers Discretion
12 - Manufacturers Discretion
13 - Manufacturers Discretion
14 - SAE J2284 CAN Low
15 - ISO 9141-2 L Line
16 - Manufacturers Discretion

FIGURE 13-10 Vehicles manufactured since 1996 use a standardized scan tool data link connector.

INSPECTION PROCEDURE

PROCEDURE

1.	READ VALUE USING TECHSTREAM

(a) Connect the Techstream to the DLC3.
(b) Turn the ignition switch to ON.
(c) Turn the Techstream on.
(d) Enter the following menus: Body Electrical / Main Body / Data List.
(e) Read the display on the Techstream.
Main Body

TESTER DISPLAY	MEASUREMENT ITEM/RANGE	NORMAL CONDITION	DIAGNOSTIC NOTE
Illumination Rate Info	Illumination rate information/0.00 ms to 2142.45 ms	Value is output according to ambient light levels	

OK:
Normal condition listed above is displayed.

NG ▶ GO TO STEP 2

OK ▶ REPLACE MAIN BODY ECU (MULTIPLEX NETWORK BODY ECU)

2.	CHECK HARNESS AND CONNECTOR (MAIN BODY ECU - AUTOMATIC LIGHT CONTROL SENSOR)

(a) Disconnect the 161*1, 1185*2 or 1183*3 automatic light control sensor connector.
(b) Disconnect the I13 main body ECU (multiplex network body ECU) connector.
(c) Measure the resistance according to the value(s) in the table below.

Standard resistance:
for Automatic Air Conditioning System, 10 Speaker

TESTER CONNECTION	CONDITION	SPECIFIED CONDITION
I13-22 (CLTE) - 116-3 (CLTE)	Always	Below 1 Ω
I13-21 (CLTS) - 116-5 (CLTS)	Always	Below 1 Ω
I13-20 (CLTB) - 116-6 (CLTB)	Always	Below 1 Ω
I13-22 (CLTE) - Body Ground	Always	10 kΩ or higher
I13-21 (CLTS) - Body Ground	Always	10 kΩ or higher

FIGURE 13-11 DTCs are diagnosed by following the related inspection procedure or troubleshooting tree in the service information.

You are commanding the body ECU to turn these systems on or off with the scan tool. If the systems work, then you know the ECU can control the outputs and the output portion of the circuit is OK. Your focus should then move to the input portion of the system. If one or more outputs do not work with the active test, your diagnostic focus will be in the output-related section of the circuit.

SAFETY TIP

Never drive alone with the scan tool in the vehicle. Have an assistant drive so you can operate the tool. Driving distracted can lead to a serious or fatal accident, and distracted driving is illegal in many states. There are numerous examples of technicians losing their own life trying to drive and operate the scan tool, as well as examples of accidents that left others injured or dead. Do not take any chances with your safety or the safety of others.

Body Electrical System Customizable Features

Manufacturer and some aftermarket scan tools offer access to customizable features. These are settings that offer additional system functions or a special function based on customer desire. The example (**FIGURE 13-13**) offers several settings for keeping the headlights on after the ignition is turned off. Some of these settings may also be accessed through a user interface that is part of the instrument cluster or the infotainment interface on many newer vehicles. As part of your diagnosis, it may be helpful to refer to the owner's manual if you are unfamiliar with the vehicle.

The scan tool can also record data list items. This may be useful if a system has no stored or active DTCs and is currently operating normally during your diagnosis. Use of this function during a test drive requires that one technician drives and a second operates the scan tool. Recording data during a test drive may uncover a fault that is intermittent and is affected by vehicle speed or rough road conditions.

2. ACTIVE TEST

Hint:
Using the Techstream to perform Active Tests allows relays, VSV's, actuators and other items to be operated without removing any parts. This non-intrusive functional inspection can be very useful because intermittent operation my be discovered before parts or wiring is disturbed. Performing Active Tests early in troubleshooting is one way to save diagnostic time. Dats list information can be displayed while performing Active Tests.

(a) Connect the Techstream to the DLC3.
(b) Turn the ignition switch to ON.
(c) Turn the Techstream on.
(d) Enter the following menus: Body Electrical / Main Body / Data List.
(e) Perform the Active Test according to the display on the Techstream.
Main Body

TESTER DISPLAY	TEST PART	CONTROL RANGE	DIAGNOSTIC NOTE
Daytime Running Light	Daytime running lights	ON/OFF	
Taillight Relay	Tail relay	ON/OFF	
Headlight Relay	Headlight relay (low beam headlights)	ON/OFF	
Head Light Hi	High beam headlights	ON/OFF	
Dimmer Signal	Dimmer signal	ON/OFF	

FIGURE 13-12 Most body electrical systems offer active tests to turn outputs on and off—a quick way to verify if that part of the circuit is OK.

CUSTOMIZE PARAMETERS

1. CUSTOMIZE LIGHTING SYSTEM (EXT)

NOTICE:
When the customer requires a change in a function, first make sure that the function can be customized.
Be sure to make a note of the current settings before customizing.
When troubleshooting a function, first make sure that the function is set to the default setting.

Hint:
The following items can be customized.

(a) Customizing with the Techstream
(1) Connect the Techstream to the DLC3.
(2) Turn the ignition switch to ON.
(3) Turn the Techstream on.
(4) Enter the following menus: Body Electrical / Main Body / Data List.
(5) Select the setting by referring to the table below.
Light Control

DISPLAY	DEFAULT	CONTENT	SETTING	RELEVANT ECU
Disp Ex ON Sen	NORMAL	Changes the ambient brightness level required to dim the lights such as the indicator lights of the combination meter, A/C indicator light and clock. *A	LIGHT2, LIGHT1, NORMAL, DARK1 or DARK2	
Disp Ex OFF Sen	NORMAL	Changes the ambient brightness level required to cancel the dimming the lights such as the indicator lights of the combination meter, A/C indicator light and clock. *B	LIGHT2, LIGHT1, NORMAL, DARK1 or DARK2	
Light Auto OFF Delay*3	30 s	Keeps the headlights on for a certain period of time after turning the ignition switch off and closing all doors with the low beam headlights on.	OFF, 30 s, 60 s or 90 s	
Response Time*1	Normal	Changes the delay timing of lighting the taillights/rear side markers when going into a tunnel when the light control control switch is in the AUTO position.	Normal or Long	
Sensitivity	Normal	Adjusts the sensitivity of the automatic light control system. *C	LIGHT2, LIGHT1, NORMAL, DARK1 or DARK2	
DRL Function*2	ON	ON/OFF of the DRL function.	ON or OFF	

*1: w/Side Turn Signal Light.
*2: Headlight dimmer switch with DRL OFF function.
*3: w/o Side Turn Signal Light.

FIGURE 13-13 Customizable parameters offer operation settings for many body electrical systems.

SKILL DRILL 13-1 Testing ECU-Controlled Circuits with the Scan Tool

1. Connect the scan tool to the DLC of your assigned vehicle.
2. Follow the menu prompts to enter the required vehicle data (some newer vehicles can communicate this data to the scan tool).
3. At the scan tool system select menu, select the vehicle main body ECU.
4. Select view DTCs from the body ECU menu. List any DTCs that may be stored.
5. Return to the body ECU menu. Select data list to view parameter data.
6. Return to the body ECU menu. Select active (or output state) test. Select an item to control using the scan tool to turn it on or off.
7. Return to the body ECU menu. Select "customize features" if applicable for your assigned vehicle. (Note that this feature may only be available on some vehicles and only with the manufacturer's scan tool.) View any customizable parameters that may be available.
8. Exit from the body ECU menu and follow menu prompts to power down the scan tool. Disconnect the scan tool from the vehicle and return it to your instructor for tool check-in. Verify the vehicle is turned off and return the key to your instructor.

To use a scan tool to test ECU-controlled circuits, follow the steps in SKILL DRILL 13-1.

Logic Probe

A **logic probe** can be used to quickly determine if an input or output signal is present in ECU-controlled circuits (FIGURE 13-14). The logic probe has LEDs to indicate the presence of a low signal (binary 0), high signal (binary 1), or if there is a rapidly changing pulsed signal. Connect the logic probe to a ECU-controlled output circuit (or a varying voltage input signal) to determine whether a signal is present and if the signal is steady, low, high, or pulsing. Connect the logic probe by placing the positive lead to the B+ portion of the circuit and the negative lead to the ground portion of the circuit you are testing. Place the probe tip onto the portion of the circuit that sends or receives a signal from the ECU and note the reading. Some logic probes emit a tone that indicates if the signal is low, high, or pulsing so you do not need to see the LEDs—this is helpful if you are working in very tight spaces.

To test ECU-controlled circuits with logic probes, follow the steps in SKILL DRILL 13-2.

FIGURE 13-14 A logic probe can quickly detect the presence of input and output signals of ECU-controlled circuits.

Digital Storage Oscilloscope

The digital storage oscilloscope (DSO) was covered in the Instrument Cluster, Non-ECU-Controlled chapter. The DSO is an excellent tool to verify the actual signal from an input sensor or view the output signal from the ECU (FIGURE 13-15). You will have a chance to use the DSO during some of the on-vehicle activities in this chapter.

Sample ECU-Controlled Body Electrical Circuit Operation

The following sections of this chapter cover some of the ECU-controlled circuits you will encounter in today's vehicles. The operation and diagnostic strategies presented will provide a strong foundation that you can apply to all types of ECU-controlled circuits.

S13002 Diagnose ECU-controlled body electrical circuits that may have an input, output, or ECU-related fault.

SKILL DRILL 13-2 Testing ECU-Controlled Circuits with a Logic Probe

1. Connect the logic probe power leads. Place the positive lead on the battery source of the circuit assigned by your instructor. Place the negative lead on the ground side of the circuit being tested. You may need to use a back probe tool at an applicable circuit connector to connect the logic probe power leads.
2. Ensure the circuit is on. Place the test probe to the wire in the circuit that sends or receives a signal to the related ECU. Refer to the wiring diagram and related service information to determine which wire is the signal wire. Note, you may have to use a back probe tool in the sensor or actuator connector so that the logic probe can make correct contact with the circuit.
3. Note the signal type as displayed by the logic probe LEDs and beep tone (if applicable). Review your results with your instructor.

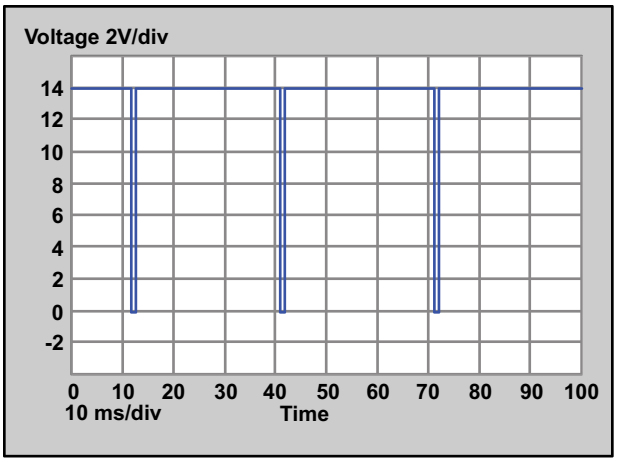


FIGURE 13-15 A digital storage oscilloscope displays voltage or current signals on a time-based graph.

ECU-Controlled Lighting Circuits

The headlight circuit shown is typical of many ECU-controlled lighting circuits (**FIGURE 13-16**). The main light switch (headlight switch) is an input to an ECU, called a smart junction box (SJB) in this vehicle.

Most ECU switch inputs are located on the ground side of the circuit (**FIGURE 13-17**). The headlight circuit shown uses a light switch that provides a path to ground when the switch is turned on. When the switch is off, voltage is present after the dropping resistor inside the ECU. The ECU logic gate sees this as a binary 1 and does not turn the headlights on.

When the switch is moved to the headlight position, the circuit is turned on and the voltage drops to very close to 0 volts after the dropping resistor (Figure 13-17). The logic gate interprets this low voltage as a binary 0 and then commands the headlight field effect transistors (FETs) to turn on and provide source voltage to the left and right headlights (**FIGURE 13-18**).

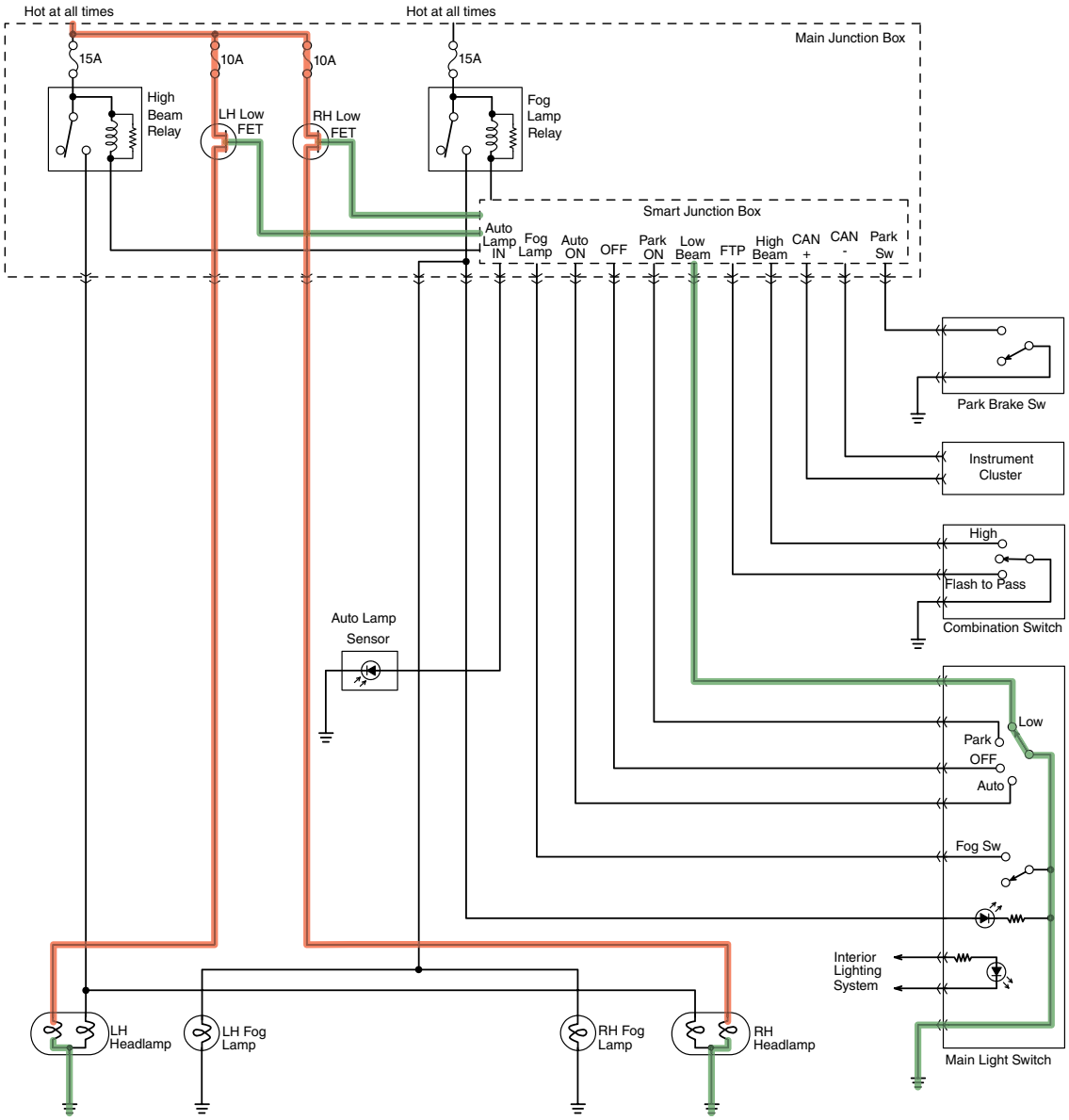


FIGURE 13-16 ECU-controlled lighting circuits use a switch as an input to an ECU, and the ECU then controls turning on the lights.

Circuit diagnosis is similar to a non-ECU-controlled headlight circuit with respect to verifying the concern and obtaining service information. Differences include using a scan tool for the following:

- Checking for DTCs
- Viewing input and output data
- Using an output/active test function to command an output on or off

Your diagnostic strategy will follow a diagnostic flowchart if a DTC is stored. When no DTC is stored, the service information provides a problem symptoms table that can assist in isolating the cause of the fault.

To check for circuit voltages you must understand ECU circuit operation. The headlight switch is an input to the ECU, so there should be system voltage at switch pin 10 (yellow/blue wire) when the switch is off and there should be less than 50mV when the switch is in the low (beam) position. The headlights should have source voltage at bulb connector pin 1 at each bulb when the switch is in the low (beam) position. A quick test to verify if the switch or the related ground(s) may be at fault is to use a fused jumper lead at pin 10 of the switch that is connected to a known good ground. Grounding the yellow/blue wire is the same as operating the switch, and the headlight low beams should turn on. You can also use the scan tool active or output

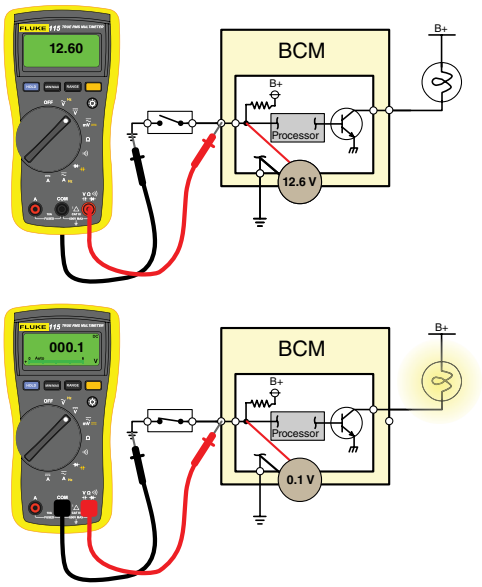


FIGURE 13-17 Switch inputs provide a digital signal for on and off inputs to the ECU.

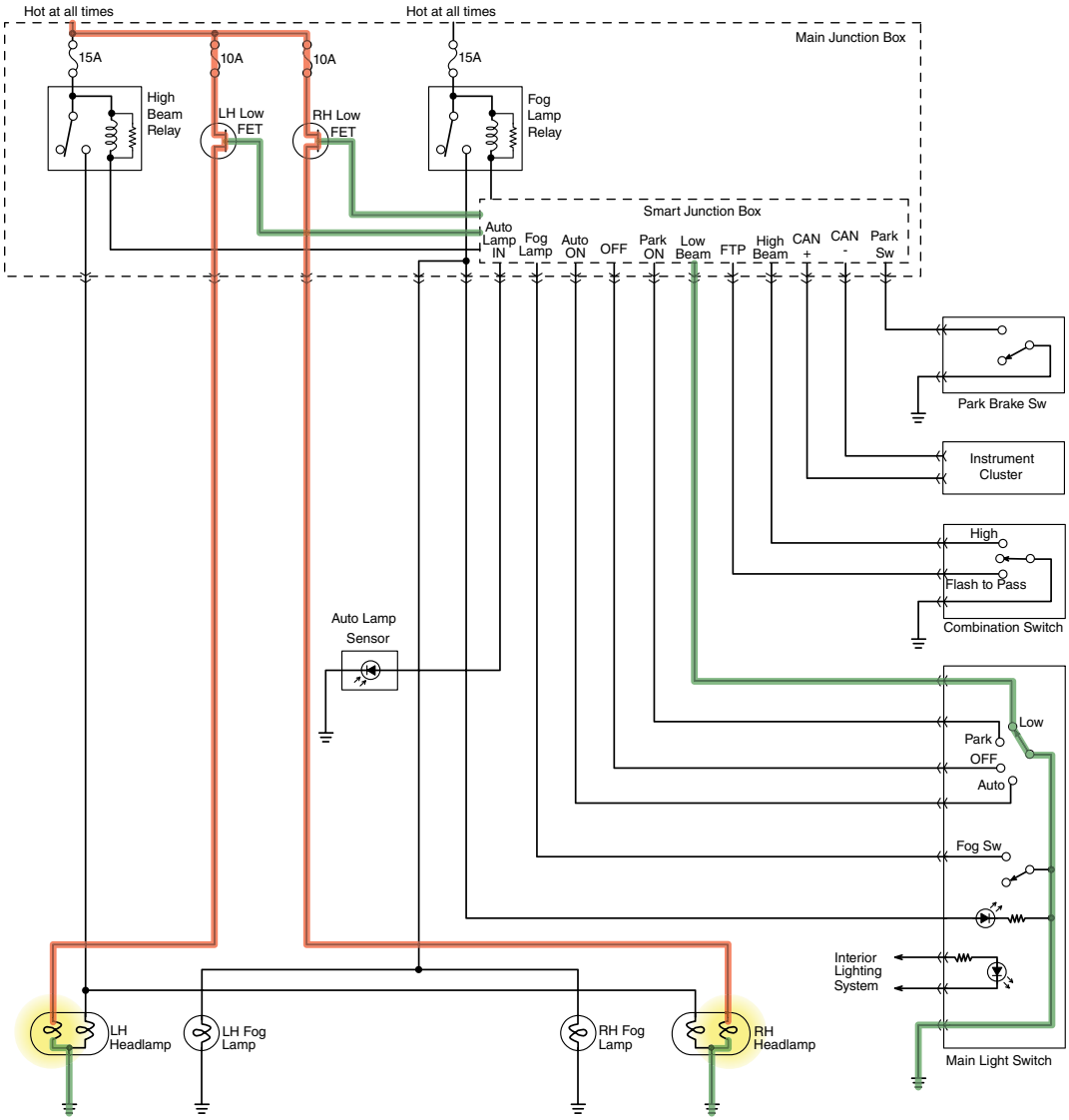


FIGURE 13-18 Field effect transistors provide source voltage to the headlights when commanded on by the processor logic circuits.

▶ TECHNICIAN TIP

ECU input circuits are usually very low current circuits. Resistance in the wiring, connector pins, or ground that measure more than a total of 50mV (0.05V) in the circuit may cause operational faults. It is critical that you measure the voltage drop on the ECU ground and the related input circuit grounds, wiring, connector pins, and in this case the switch, with the ignition on, engine running, and the circuit on. Poor grounds and other resistance present in ECU input circuits must be corrected to ensure proper circuit operation. Remember that voltage only drops in the presence of current, so the circuit must be on when measuring voltage drop.

state test to command the ECU to turn on the headlight low beams. Diagnosis will center on determining if there is a component fault in the switch, ECU, headlights, or wiring. Use of the DMM, scan tool, and service information will ensure you isolate the fault cause quickly.

To perform ECU-controlled lighting system circuit testing, follow the steps in **SKILL DRILL 13-3**.

ECU-Controlled Blower Motor Circuit

The blower motor in many vehicles is ECU controlled using a duty cycled output to control blower speed (**FIGURE 13-19**). The blower motor circuit discussed in the Diagnosing Motor Controlled Circuits chapter uses resistors in a series circuit with the blower motor to create three speeds that are slower than high speed. ECU-controlled blower motor circuits many have seven or more speeds allowing for greater passenger comfort. The sample circuit shown has three wires that connect to the blower motor. The white wire supplies source voltage to the blower motor. The white wire with black trace is the blower motor ground. The red wire is the output signal wire from the HVAC ECU (sometimes called an A/C system amplifier) to control blower motor speed.

The HVAC ECU outputs a pulsed voltage signal at a fixed frequency. This is a duty cycle signal as covered in the Advanced Diagnostic Tools chapter (**FIGURE 13-20**). The greater the duty cycle on time, the faster the blower motor speed. This signal wire can be checked with the DMM using the voltage or duty cycle setting or with a digital storage oscilloscope. Some service information may offer a specific duty cycle value that should be present at each fan speed. The duty cycle output for this blower motor is an input to a small circuit that uses a J-FET transistor that is part of the blower motor assembly; however, this part is not separately serviceable.

▶ TECHNICIAN TIP

Each ECU-controlled circuit, including the blower motor, will vary by manufacturer. Always refer to the applicable service information to determine how the system you are diagnosing operates.

Diagnosing this blower motor circuit is very straightforward. Use the DMM to verify source voltage at pin 3 and ground at pin 1 of the blower motor. You can use the DMM or DSO (oscilloscope) to monitor the duty cycle signal. The blower motor input can be checked using the scan tool active/output state test. If the scan tool can activate the blower motor, then the input control is most likely at fault.

To perform ECU-controlled blower motor circuit testing, follow the steps in **SKILL DRILL 13-4**.

ECU-Controlled Rear Window and Mirror Defogger Circuit

The rear window and mirror defogger circuit in this example uses a switch on/off input signal to the HVAC ECU which then outputs a source voltage signal to the rear defogger relay (**FIGURE 13-21**). Many ECUs control outputs by switching the voltage on the ground side of an actuator; however, this example has the ECU supplying source voltage to

SKILL DRILL 13-3 Testing the ECU-Controlled Lighting System Circuit

1. Obtain the lighting system wiring diagram and related system operation information for your assigned vehicle.
2. Trace the circuit paths for the input and output portions of the circuit using different color highlighters. Refer to the service information to determine what voltage or signal should be present on the input circuits. Predict the voltage on the lighting system outputs and note the readings on the wiring diagram.
3. Scan tool: Connect the scan tool to the vehicle and follow the applicable menu prompts to access the ECU that controls lighting system functions and then do the following:
   a. Check for DTCs
   b. View system data list parameters
   c. Operate actuators with the active/output state test
4. Jumper lead test on ground-controlled input circuit: Obtain a fused jumper lead. Locate the wire/pin location at the headlight switch that is the input circuit for headlight operation using the wiring diagram and then locate it on the vehicle (you may have to remove the switch or trim panels to reach the component). Connect the jumper lead using an appropriate back probe tool to the wire at the connector and then touch the other end to ground. The headlights should turn on, indicating the ECU and headlights are operating normally.
5. DMM testing: Perform voltage testing of the headlight input and output circuits and compare your DMM test results with what you predicted in step 2. Measure the voltage drop of the input circuit and ECU ground. Review your findings for all tests with your instructor.
6. Return the vehicle to customer-ready condition by reinstalling any removed trim panels or components you accessed for lighting system testing.

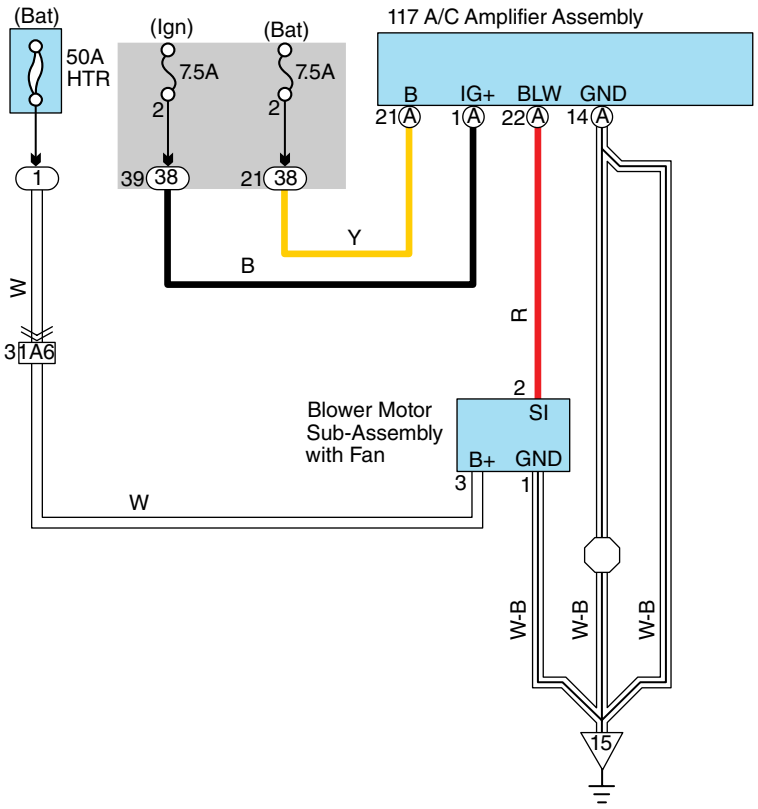


FIGURE 13-19 Many vehicles now use ECU-controlled HVAC blower motors to provide many fan speeds that allow for precise system control.

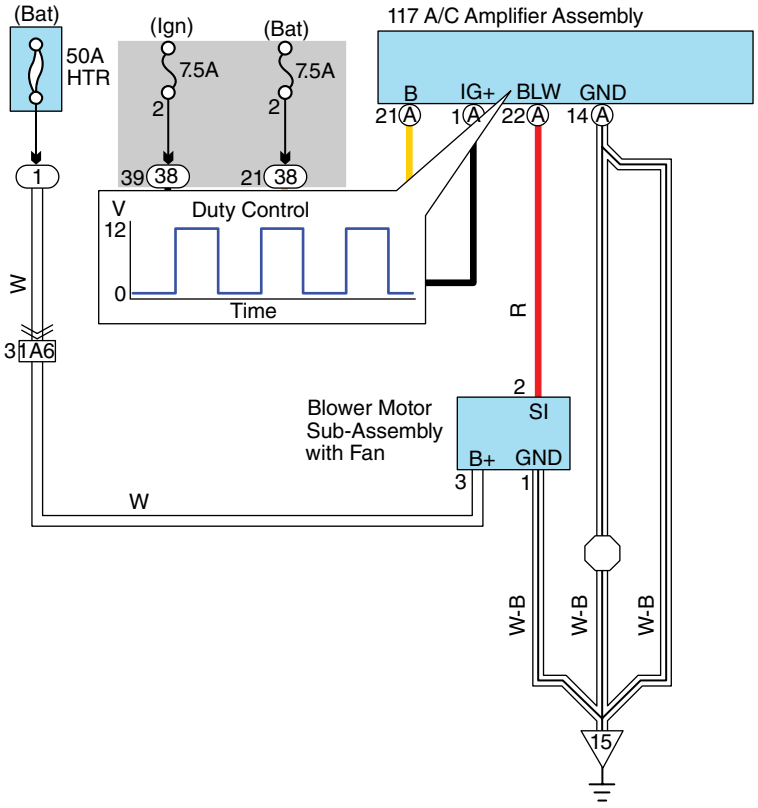


FIGURE 13-20 The signal wire from pin 2 to pin 22 sends the ECU-controlled output duty cycle signal to the blower motor.

the actuator, a relay in this case. This demonstrates the importance of reviewing the wiring diagram, tracing current paths, and predicting voltages in preparation for circuit diagnosis.

The rear defogger switch is a momentary contact switch. This means that when the driver pushes the button, the switch contacts close, and then they open when the driver

SKILL DRILL 13-4 Testing the ECU-Controlled Blower Motor Circuit

1. Obtain the blower motor system wiring diagram and related system operation information for your assigned vehicle.
2. Trace the circuit paths for the input and output portions of the circuit using different color highlighters. Refer to the service information to determine what voltage or signal should be present on the output control circuit.
3. Scan tool: Connect the scan tool to the vehicle and follow the applicable menu prompts to access the ECU that controls HVAC system functions and then do the following:
   a. Check for DTCs
   b. View system data list parameters
   c. Operate the blower motor with the active/output state test
4. DMM testing: Perform voltage testing of the blower motor circuit and compare your DMM test results with what you predicted in step 2. Use the DMM to measure duty cycle for each blower speed. Review your findings for all tests with your instructor.
5. DSO testing: Connect the DSO to the blower motor signal wire. Set up the DSO according to the service information on the DC volt setting. Observe the duty cycle waveform for each fan speed.
6. Return the vehicle to customer-ready condition by reinstalling any removed trim panels or components you accessed for blower motor testing.

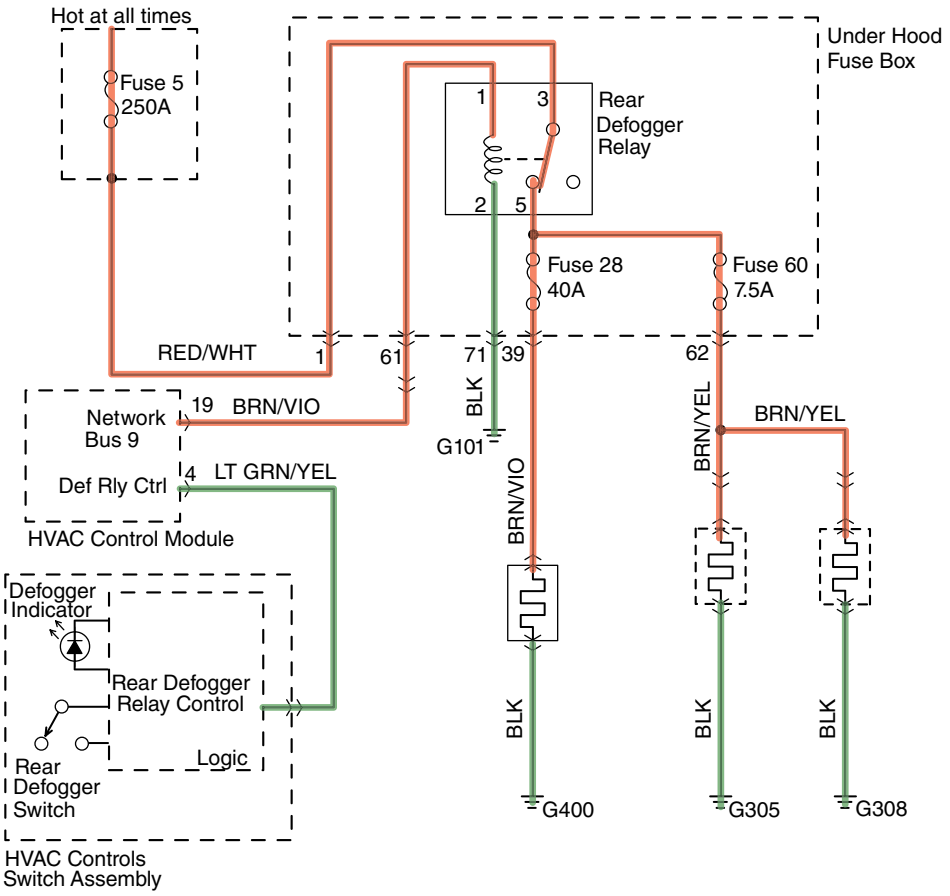


FIGURE 13-21 The rear window and mirror defogger in this circuit uses a switch input to the HVAC ECU.

releases the button. This action creates a one-time off-to-on pulse signal to the HVAC control module. The HVAC ECU then operates the relay on a timer so that once the rear window and mirrors are clear, the electrical load they create is turned off. Circuit testing for this circuit can be done with the scan tool using the active/output state test to verify whether the ECU can output voltage to operate the relay. If yes, then the system fault may be in the defogger switch or the harness from the switch assembly to the HVAC ECU. The rest of the circuit is diagnosed like any non-ECU-controlled circuit would be. Predict the voltages and perform voltage tests to determine the cause of the fault.

ECU-Controlled Power Window Circuit

Power window circuits may be non-ECU or they may use various forms of body ECU or network control. The sample circuit shown uses ECU control to offer auto down function (**FIGURE 13-22**). The auto down function operates if the driver holds the window button down for more than about 1.5 seconds and then releases it. The ECU sees this input from the master window driver side switch source voltage input signal. If the ECU detects the switch input for about 1.5 seconds, the ECU logic interprets the voltage signal as an auto down request and continues to supply the power window motor with source voltage from pin 14 of the ECU. Some vehicles use a master window switch assembly with a very small ECU built into it that provides the auto up/down function for the windows. Many vehicles with networks use network communication for some or all power window functions

ECU-controlled circuits use various types of electronic control units to provide a greater range of control. They also help reduce wiring complexity, which can reduce cost and vehicle weight. This chapter provides a foundation for you to apply to ECU-controlled circuits. Being familiar with the diagnostic procedures required and the related tools you will use ensures you accurately diagnose ECU-controlled circuit concerns.

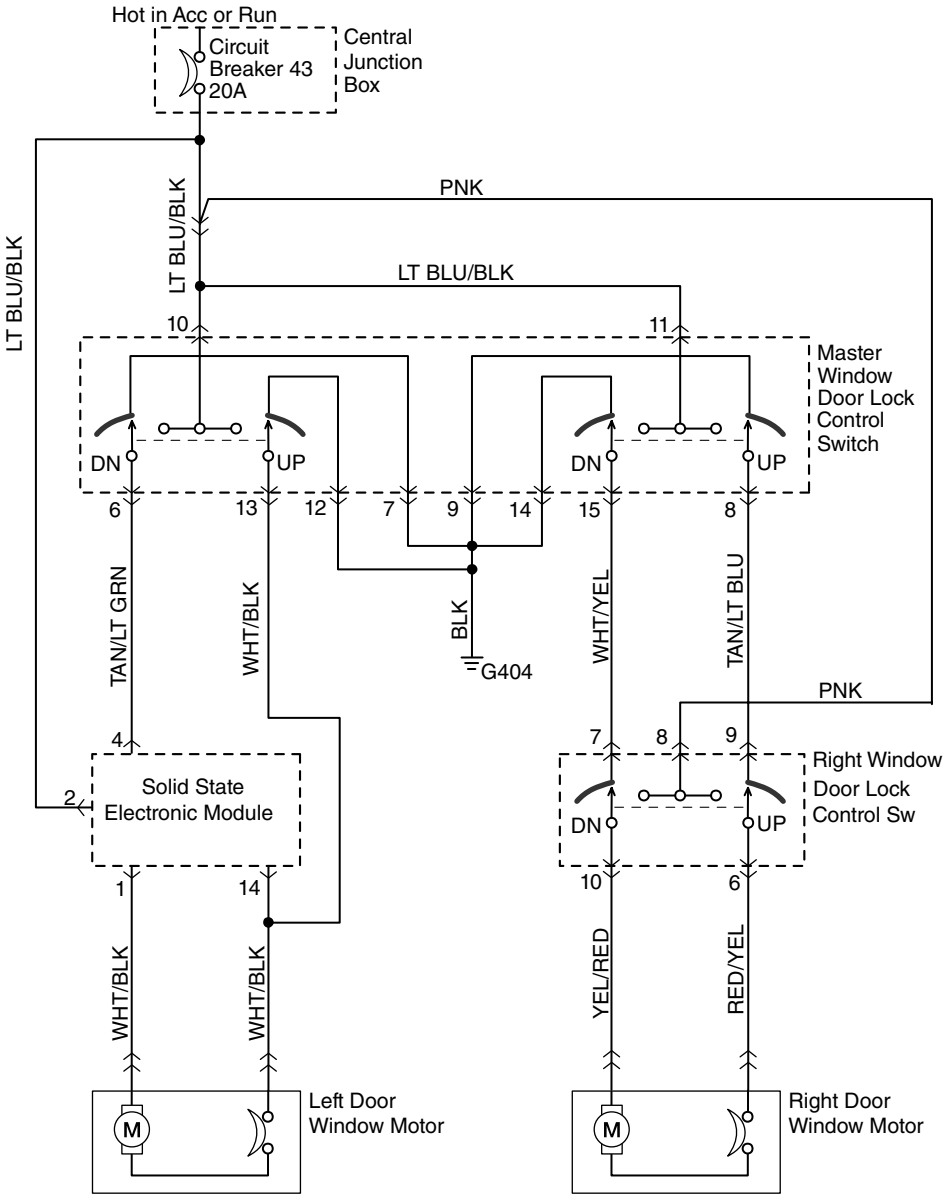


FIGURE 13-22 This power window circuit uses ECU control for auto window down function on the driver's window.

Wrap-Up

Ready for Review

- ECU-controlled circuits are now the most common type used in today's vehicles. Using an ECU offers enhanced control of the various systems, including automatic headlights, rain sensing wipers, and the ability to share data with other vehicle systems.
- ECUs operate on the principles of sense, decide, and act. The ECU monitors system inputs, processes the data from the inputs, and then acts by turning a device on or off. Systems can seem very basic, like the interior lights. The door switch is an input to the body ECU. Opening the door creates a voltage change on the switch input. The ECU processes this data and then provides a ground path to turn on the interior lights. After closing the door, the lights usually remain on for a short period and then slowly dim to off. The body ECU provides this added function compared to a non-ECU circuit where closing the door would turn the interior lights back off. This added feature may not seem like much until you are trying to insert the key in the ignition or connect your phone to the USB port in a very dark interior.
- ECU-controlled circuits require additional diagnostic tools. Usually a scan tool is used to check for any stored diagnostic trouble codes. The scan tool may also provide live system input and output data. Some systems allow the scan tool to operate the system outputs. This allows you to quickly verify whether the ECU can turn a device on or off. This helps you pinpoint whether the customer concern is being caused by a fault on the input portion of the circuit or on the output portion.
- ECU diagnosis may require the use of advanced DMM functions and use of the digital storage oscilloscope. These tools allow you to fully analyze input and output signals, especially intermittent faults that a voltmeter would not be able to capture and display during your diagnosis.
- Diagnosing ECU circuits continues to rely on your skills with service information, including use of the wiring diagram and your related circuit tracing. You may have to refer to specialized service information to predict voltages on the input or output portions of the circuit. Most manufacturers provide the expected voltage or other reading you should obtain when testing that portion of the circuit. Use of this information ensures your diagnosis will be accurate and the concern is corrected the first time.

Key Terms

data maps Similar to look-up tables; however, the data are more complex. Two or more input data parameters may be used to determine what output command is required.

electronically erasable programmable read-only memory (EEPROM) This feature allows for updates to provide enhanced customer satisfaction or to correct software programming that at times does not function as intended.

keep alive memory (KAM) This memory is a special version of the RAM. The data are still temporary but are important enough that the ECU provides battery power to keep the memory data stored when the vehicle is turned off. This data are then available immediately when the vehicle is started and the system will be ready for any customer use. An example of this is the auto up/down feature for the windows.

logic probe A tool that can quickly inform you if there is an electronic signal present at a component or related wiring. The tool detects the output pulses that are present when an output actuator or pulsed input signal are active.

look-up table A data table the ECU processor uses to determine what action is required based on the related input data.

OBD II data link connector (DLC) A standardized scan tool connection point that has been used on almost every vehicle since 1996.

random-access memory (RAM) This memory is used to temporarily store data that are needed while the vehicle or vehicle system is in use. An example is the position of a power sliding door. The related ECU monitors door position so it can operate the various door actuators in the right sequence to open or close the door.

read-only memory (ROM) The section of memory where the software programming is stored. This memory is permanent and will not erase even if the vehicle battery is disconnected.

Review Questions

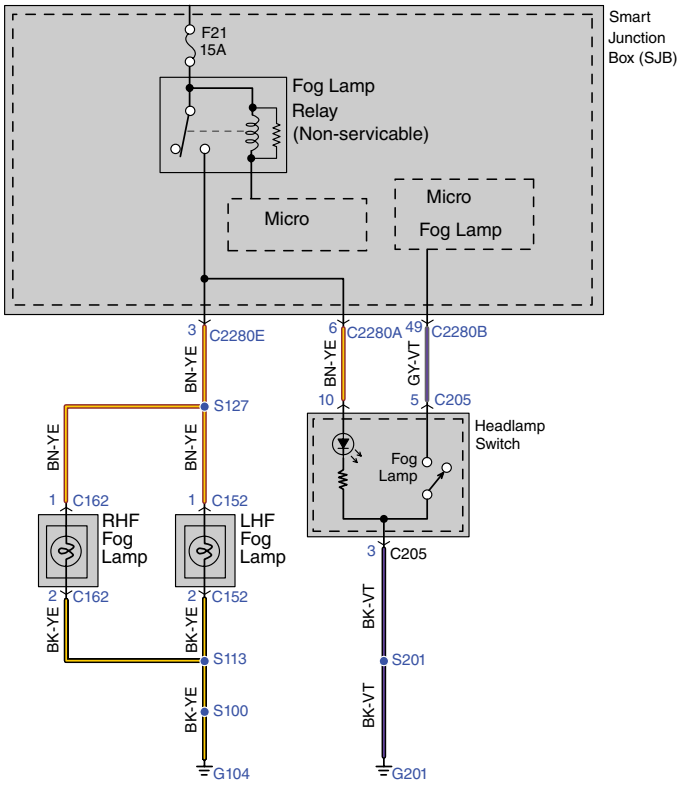
1. To have an understanding of the inputs and outputs in the ECU-controlled circuits, refer to the:
   a. system diagram.
   b. technical service bulletins.
   c. parts manual.
   d. network diagram.
2. The ECU records data related to system settings and other data that are learned from use in:
   a. logic gates.
   b. keep alive memory (KAM).
   c. random-access memory (RAM).
   d. read-only memory (ROM).
3. ECU updating is done using the scan tool through a:
   a. data map.
   b. look-up table.
   c. digital link connector.
   d. analog-to-digital converter.
4. The scan tool offers all of the below functions *except*:
   a. obtaining diagnostic trouble codes (DTCs).
   b. viewing input and output data.

c. customizing parameters.
d. measuring the voltage drop of the input circuit and ECU ground.

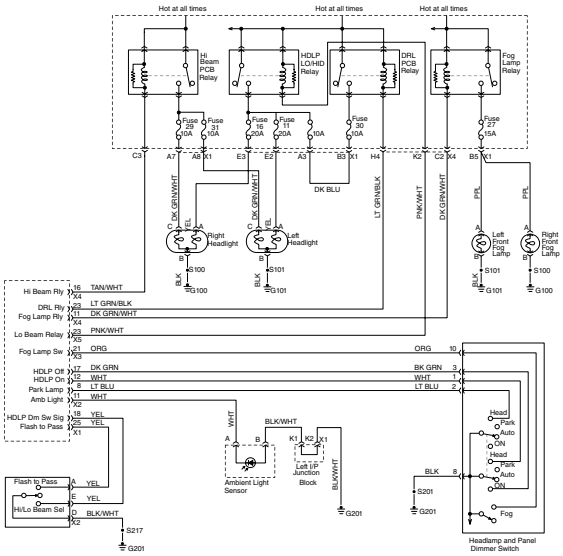
5. In OBD II vehicles, the first character in the five-character alphanumeric DTC identification code indicates:
   a. the area of the vehicle the ECU is related to.
   b. the severity of the fault.
   c. whether a software update is necessary.
   d. the type of scan tool required.
6. The data list values for input sensor data displayed on the scan tool may not be accurate if there is a(n):
   a. open circuit.
   b. short circuit.
   c. high voltage.
   d. resistance-related fault.
7. Which of the following instruments can be used to quickly determine whether a signal is present and if the signal is steady, low, high, or pulsing?
   a. DMM
   b. GMM
   c. Logic probe
   d. Scan tool
8. When diagnosing blower motor circuits, which of the following can be used to check blower motor input?
   a. DMM
   b. DSO
   c. Scan tool
   d. Logic probe
9. When performing the active/output state test, if the scan tool can activate the blower motor, then where is the problem most likely to lie?
   a. Input control
   b. Output control
   c. ECU
   d. Blower motor
10. Which of these is particularly useful in diagnosis if a system has no stored or active DTCs and is currently operating normally during your diagnosis?
    a. Look-up table
    b. Data list
    c. Data map
    d. Logic probe

ASE Technician A/Technician B Style Questions

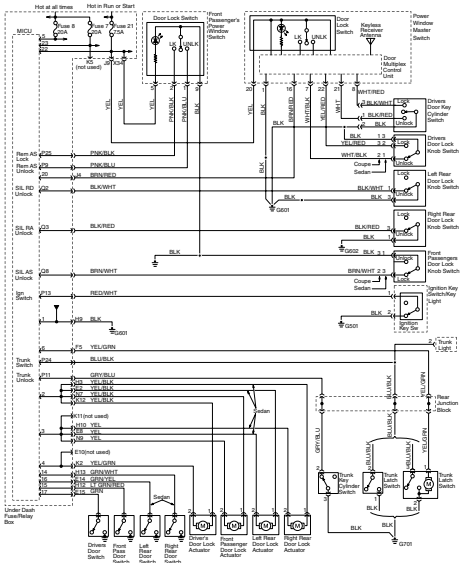
1. Tech A says a switch input to the body control ECU that connects to ground will have 0 volts when the switch is open. Tech B says switch inputs are an analog input to the ECU and require an analog-to-digital converter for signal processing. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says a logic probe can be used to determine if an ECU output signal is present. Tech B says a DSO can visually display an ECU output signal. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. This question references the fog light diagram shown. The fog lights do not operate. Tech A says you can use a fused jumper lead to connect pin 5 of the headlamp switch to a known good ground and see if the fog lights turn on. Tech B says you may be able to use the scan tool to view the input state of the fog light switch. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



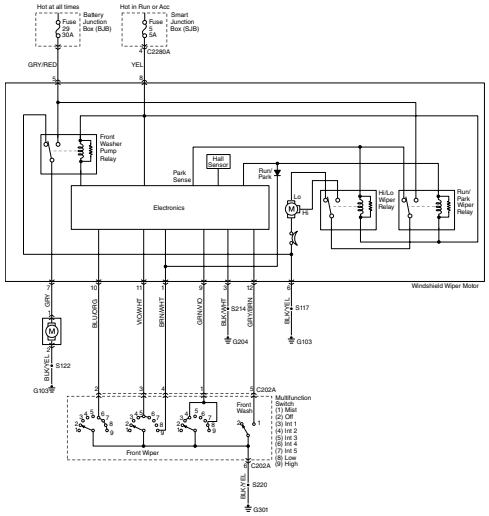
4. This question refers to the headlight circuit shown. The parking lamps do not operate in park but do operate when the headlights are turned on. Tech A says there may be a short to ground on the light blue wire that connects to pin 2 of the headlight switch. Tech B says there may be high resistance at ground 201. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



5. Tech A says all body ECU circuits store DTCs when there is a faulty output component. Tech B says some features of ECU-controlled circuits can be customized using the scan tool for some vehicles. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. This question refers to the power door lock circuit shown. Tech A says the front passenger door lock switch directly connects to the door lock motors for locking and unlocking the doors. Tech B says the under-dash fuse relay box and the driver's door master switch have ECUs inside them. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



7. Tech A says abnormal resistance in an input circuit to the body ECU may cause erratic or no operation of the desired output. Tech B says ECU grounds should have no more than a 0.5 volt (500mV) drop to a known good ground. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. This question references the windshield wiper circuit shown. The wipers do not operate on high speed. Tech A says you could use a fused jumper lead at wiper switch pin 1 and if the wipers work on high speed, the switch may be at fault. Tech B says fault may be an open in the blue/orange wire connecting pin 2 of the multifunction switch to the wiper motor assembly. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



9. Tech A says some ECU-controlled circuits require initialization after power is restored to the circuit, during a battery replacement, for example. Tech B says some ECU-controlled systems have customizable features that can be accessed using the scan tool or infotainment controls. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Two technicians are discussing inoperative parking lights in an ECU-controlled lighting circuit. Tech A says the light control switch usually provides a path to ground on the parking light input signal wire to the body ECU. Tech B says a switch input that connects to ground can be tested by connecting a fused jumper lead at the related input pin at the body ECU and ground which should command the ECU to turn on the related output. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

CHAPTER 14
Vehicle Network Systems

NATEF Tasks

There are no NATEF tasks in this chapter.

Knowledge Objectives

After reading this chapter, you will be able to:

- **K14001** Describe the operation of bus, ring, and star vehicle network systems.
- **K14002** Explain network and communication protocols.
- **K14003** Describe the function of vehicle network systems.
- **K14004** Explain the diagnostic strategies used to isolate the cause of vehicle network system faults.
- **K14005** Describe vehicle network repair.

Skills Objectives

After reading this chapter, you will be able to:

- **S14001** Perform a CAN-bus system check with the scan tool.
- **S14002** Test CAN-bus resistance at the DLC.
- **S14003** Demonstrate use of network block and wiring diagrams as part of the diagnostic process.
- **S14004** View network signals using a digital storage oscilloscope.

You Are the Automotive Technician

Several warning lights are illuminated on the instrument panel, including check engine, vehicle stability control (VSC), and electric power steering. The scan tool shows several network-related DTCs, and a bus check shows several ECUs are not communicating with the network.

1. What could cause this customer concern?
2. How do you determine where to begin your diagnostic tests?
3. What precautions should be observed when testing these circuits?

▶ Introduction

Vehicle ECUs saw first use in the 1970s and were common for engine control functions by the early 1980s. ECUs were sometimes referred to as engine control units since this was most often the only ECU on the vehicle. By the late 1980s, many vehicles had ECUs for transmission, ABS, HVAC, and body electrical systems. Adding ECUs to a vehicle meant that certain input sensor data (like vehicle speed and engine coolant temperature) were required by the engine ECU, the transmission ECU, and the ABS ECU. Some vehicles used multiple sensors to deal with this, but it quickly became obvious that using several sensors added expense, weight, and cost to the vehicle. The solution is to share data between ECUs; this is called networking.

You may be familiar with networking using your phone, tablet, or laptop to connect to a wireless Internet connection at a school, library, or coffee house. Vehicle networks are physically connected networks using copper wire or fiber optic cable. This allows input sensor data and ECU output commands to be shared between two or more ECUs (e.g., allowing engine coolant temperature data from one sensor to be shared by any vehicle ECU that requires this data).

▶ TECHNICIAN TIP

The connected vehicle is coming. Some vehicles are already able to connect to the wireless Internet through a cell phone. Vehicle collision avoidance systems will soon add vehicle-to-vehicle data sharing—for example, if one vehicle is changing lanes, the other nearby vehicles will react to avoid a collision. These systems will soon be followed by others that will allow the vehicle to drive itself.

▶ Network Architecture

K14001 Describe the operation of bus, ring, and star vehicle network systems.

Vehicle networks generally use three design types: ring, star, and bus (**FIGURE 14-1**). Almost all vehicles use a primary bus-type network and may also use ring and star networks for systems that do not require the fastest data sharing speeds. The architecture design is important because it affects your diagnostic approach when a network fault is present.

Bus Network Topology

S14001 Perform a CAN-bus system check with the scan tool.

Bus networks have been used in vehicles for many years (**FIGURE 14-2**). The most common is the **controller area network** bus developed by Bosch and used by almost all vehicle manufacturers under license. Beginning with model year 2008, CAN is the required communication protocol for vehicle-to-scan tool communication through the data link

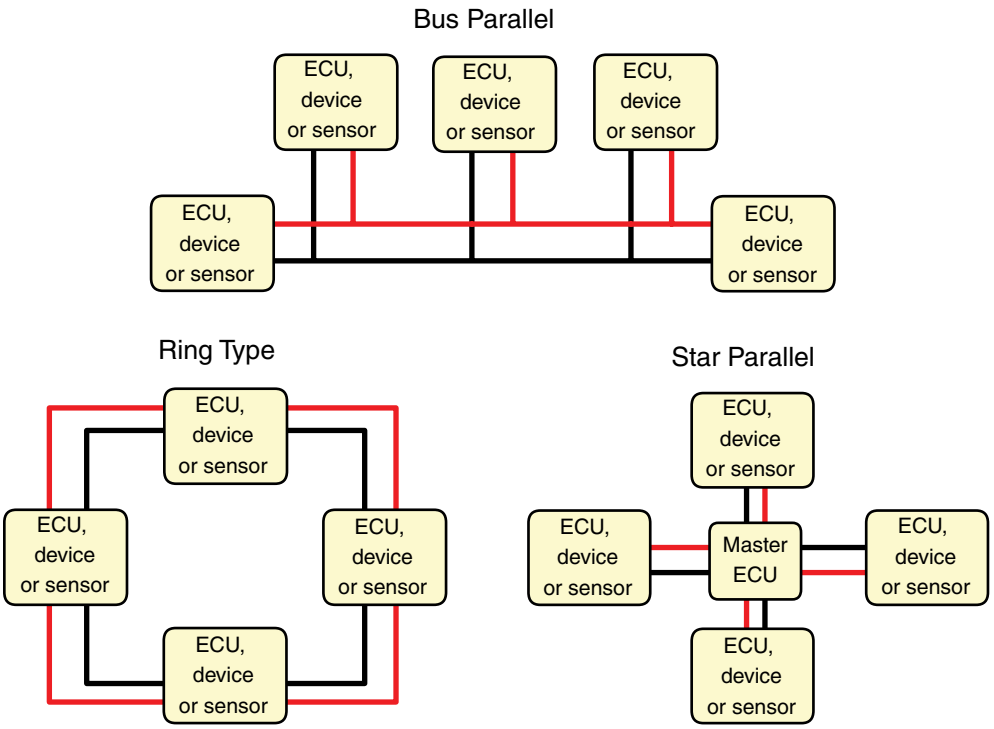


FIGURE 14-1 Vehicle networks are bus, ring, or star **topology** designs.

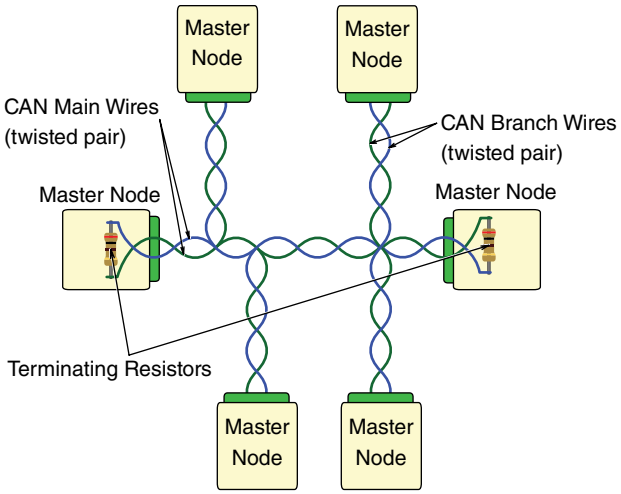


FIGURE 14-2 Bus networks connect the ECUs to a main communication line or lines.

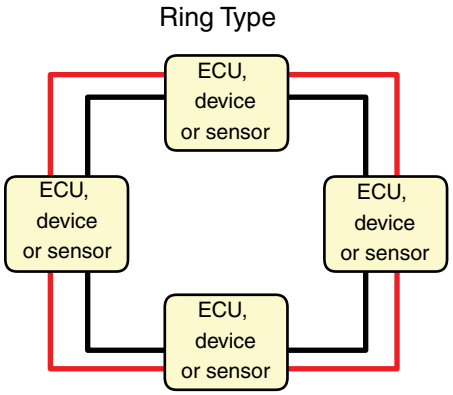


FIGURE 14-3 A ring network has all the ECUs connected to a single communication line.

connector (DLC). Manufacturers can use another network type for vehicle communication, but almost all use the CAN-bus as the primary high-speed network. Bus networks use a common communication line. The CAN-bus uses a twisted-pair two-wire system. Other networks may use two-wire, two-wire shielded, or single-wire communication line types.

Ring Network Topology

A **ring network** uses a single communication line; each ECU is connected to the line to form a closed communication loop, or ring. The advantage of this design is that the communication can flow from ECU to ECU in either direction, so an open in the communication line will not affect network operation (**FIGURE 14-3**).

Star Network Topology

Star networks use a main or master ECU and sub-ECUs that connect using a single-wire communication line. The sub-ECUs cannot communicate directly with each other. Shared data must be sent from a sub-ECU to the master ECU, and the master ECU must then send data to another ECU. This network architecture is usually for vehicle systems that need to receive data but generally do not need to share data. For example, the combination meter (instrument panel) ECU requires data to operate the gauges and warning lights from various vehicle systems that communicate with the master ECU, but it does not need to share very much, if any, data back into the network (**FIGURE 14-4**).

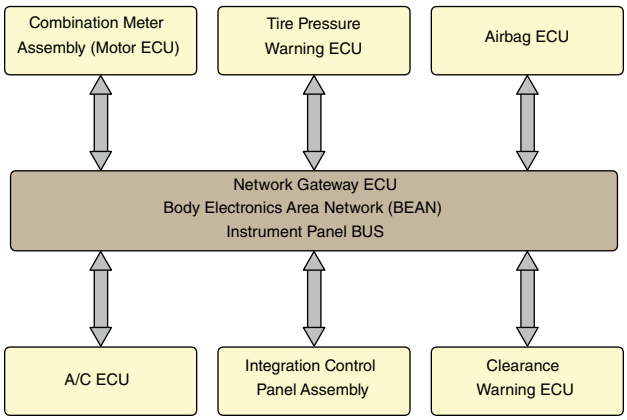


FIGURE 14-4 Star networks use a master ECU and sub-ECUs that each connect to the master ECU but not to each other.

Network Communication

K14002 Explain network and communication protocols.

Vehicle network communication follows standards set by the International Standards Organization (ISO) and the Society of Automotive Engineers. Networks have been used in vehicles since the late 1980s. This text will focus on network and communication protocols that have been in use since OBD II (On-Board Diagnostics Level II) was adopted in 1996. OBD II standardized the data link connector (DLC) design, assigned DLC pin locations for specific functions, and standardized scan tool communication for most vehicle systems. Scan tool communication initially followed ISO 9141-2 protocol and used one wire called the K line (pin 7) to receive information from applicable vehicle ECUs and a wire called the L line (pin 15) to allow the scan tool to send commands to the applicable ECU(s). This standard was replaced for model year 2008 with CAN OBD II based on ISO 15765-4/SAE J2284 requiring scan tool communication using pins 6 and 14 of the DLC (**FIGURE 14-5**).

Most domestic and Asian vehicles use the OBD II DLC for all system communication to the technician. Some European manufacturers use the OBD II DLC for required scan tool communication but continue to use a proprietary DLC for systems that are not part of the required OBD II scan tool communications, including some network system access. The systems outside of the CAN OBD II protocol require the use of the manufacturer's scan tool or a scan tool with the correct software and data link connector.

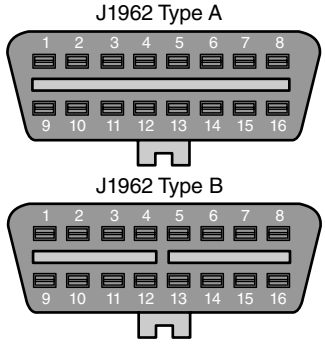
Network data communication follows protocols set by the ISO or SAE so that the coding follows shared industry standards. This reduces the cost of the technology since parts like ECUs can easily be adapted between different manufacturers and technicians can use common scan tool software to diagnose most vehicles. A **protocol** sets the communication parameters including data transmission speed and how the message is created. Some systems use a fixed pulse generating frequency while others use varying frequency.

TECHNICIAN TIP

Most vehicles use a **serial interconnect line (SIL)** that provides communication between the scan tool and certain ECUs on the vehicle for either specific functions or to communicate with specific ECUs when another network is down.

Network Data Messages

Network data messages are created using voltage pulses on the signal wire. Networks are designed to have a specific at-rest (no signal present) voltage. The specifics will be covered for each network, but for now let's use a network that has an at-rest/no-signal voltage of 0 volts. Each ECU on the network has a circuit that applies voltage to the signal line to send a message (**FIGURE 14-6**). The voltage is pulsed to form a message of zeros and ones. In this case, 0 volts equals a 0 and 10+ volts equals a 1. The pulsing creates binary coded messages that are sent to ECUs on the network. The messages are then decoded by the ECUs that



1 - Manufacturers Discretion
2 - SAE J1850 Bus +
3 - Manufacturers Discretion
4 - Chassis Ground
5 - Sensor Ground
6 - SAE J2284 CAN High
7 - ISO 9141-2 K Line
8 - Manufacturers Discretion
9 - Manufacturers Discretion
10 - SAE J1850 Bus -
11 - Manufacturers Discretion
12 - Manufacturers Discretion
13 - Manufacturers Discretion
14 - SAE J2284 CAN Low
15 - ISO 9141-2 L Line
16 - Manufacturers Discretion

FIGURE 14-5 The OBD DLC has designated pins for scan tool-to-vehicle network communication.

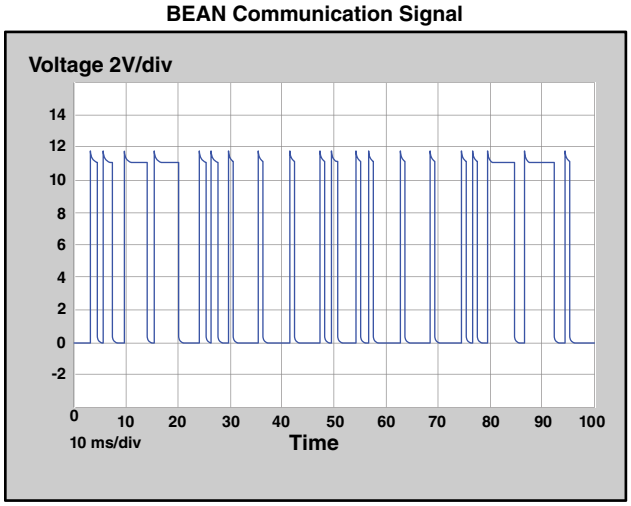


FIGURE 14-6 Toyota's body electrical area network (BEAN) signal line is at 0 volts when no message is present.

need the data or ignored by those that do not. The messages contain the data, like vehicle speed for example, along with code that lets each ECU determine if the message is relevant or should be ignored. Most messages also contain a beginning and end code so the ECUs are able to interpret the messages correctly.

Data transmission may be one way only or both ways. For example, the engine control ECU transmits and receives data from the vehicle stability control ECU, so there is two-way communication between them. The power window master switch for some vehicles provides a signal to the main body ECU when a window is operated; however, the main body ECU does not communicate with the power window master switch.

Data transmission must be timed so that collision between data is prevented or can be handled when it occurs. Generally, data are sent by an ECU when it detects that no data are being sent. For some networks, if two ECUs attempt to send data at the same time, then the ECU that has less priority stops sending data until it determines that the data line is clear for transmission. Some networks transmit data that include levels of priority to control the flow of data and prevent data collisions during transmission. On networks where data are only sent out from one ECU, that ECU controls the data flow so there is no need to use data control or collision detection protocol. Data can also be sent to all ECUs on a network, called **broadcasting**. Data that are sent to one specific ECU are called a **unicast**. A message sent to a particular group of ECUs on the network is called multicast (**FIGURE 14-7**).

Network Data Signal Transmission Lines

Some networks use a single communication line, some use twisted-pair wiring, and some use fiber optic cable. Single-wire systems are just that, using a single wire for data communication from ECU to ECU. Some single-wire networks use shielded cable to prevent outside electrical noise from interfering with data transmission. Twisted-pair wiring and fiber optic transmission are very resistant, by their design, to voltage spikes from nearby vehicle components or radio frequency interference (e.g., one or more cell phones in the vehicle).

ECUs have a keep alive memory that consumes battery voltage even when the vehicle is off. Also, ECUs that are networked communicate with each other, but they are programmed to go into a low current or "sleep" mode when the vehicle ignition is turned off and a certain amount of time has passed without any communication. Some ECUs must remain in a low power mode due to their function, including the anti-theft system ECU and smart key ECU. An ECU that does not go into sleep mode can create a large current draw that can drain the battery voltage after several hours.

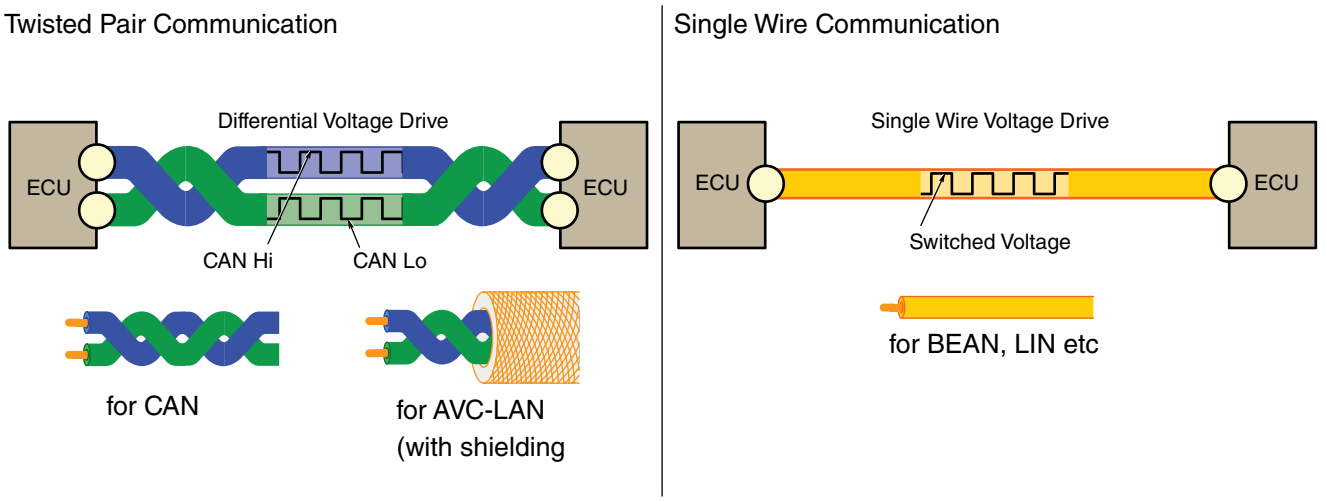


FIGURE 14-7 Bus networks may use two-wire or one-wire architectures.

K14003 Describe the function of vehicle network systems.

S14002 Test CAN-bus resistance at the DLC.

▶ Vehicle Networks

Controller Area Network Operation

The controller area network (CAN) is a system developed by Bosch and used under license by most vehicle manufacturers (**FIGURE 14-8**). Many vehicles use two CAN networks, one for high-speed and another for medium-speed communication. CAN is used when high-speed or very high-speed data transmission is required—for example, the powertrain control module (PCM) and the vehicle stability control system which includes anti-lock braking functions (VSC and ABS) require very fast and reliable data to operate their related systems properly. The CAN system uses two communication wires in a twisted-pair harness. This generally has each wire in adjacent connector pin locations, and the twisted-pair wiring is routed to avoid wiring that routes to coils or other inductors that may carry inductive kickback voltage spikes. Each data line has a no-signal voltage of 2.5 volts. One line is CAN-High; one line is CAN-Low.

Data are transmitted over both lines in a mirror fashion (**FIGURE 14-9**). Both lines are pulsed at approximately 1 volt with the CAN-High line increasing to 3.5 volts and the CAN-Low line decreasing to 1.5 volts. The mirror image allows the ECU to interpret data even if the waveform is affected by a voltage spike or other interference. Also, if one CAN line is open, data transmission can continue on the other functioning line, although data error correction is greatly reduced. CAN communication is usually interrupted if one or both lines short to power or ground or when both lines are open. The CAN system uses terminating resistors located in two of the ECUs on the CAN network. The resistors drop the signal voltage at each end of the network to essentially delete the message. Each resistor is 120 Ω and they are in a parallel circuit with each other.

A CAN **breakout box (BOB)** can be used at the DLC to measure the resistance of pin 6 (CAN-High) and pin 14 (CAN-Low), which should be approximately 60 Ω (**FIGURE 14-10**). Note that some vehicles use more than two terminating resistors so this will reduce

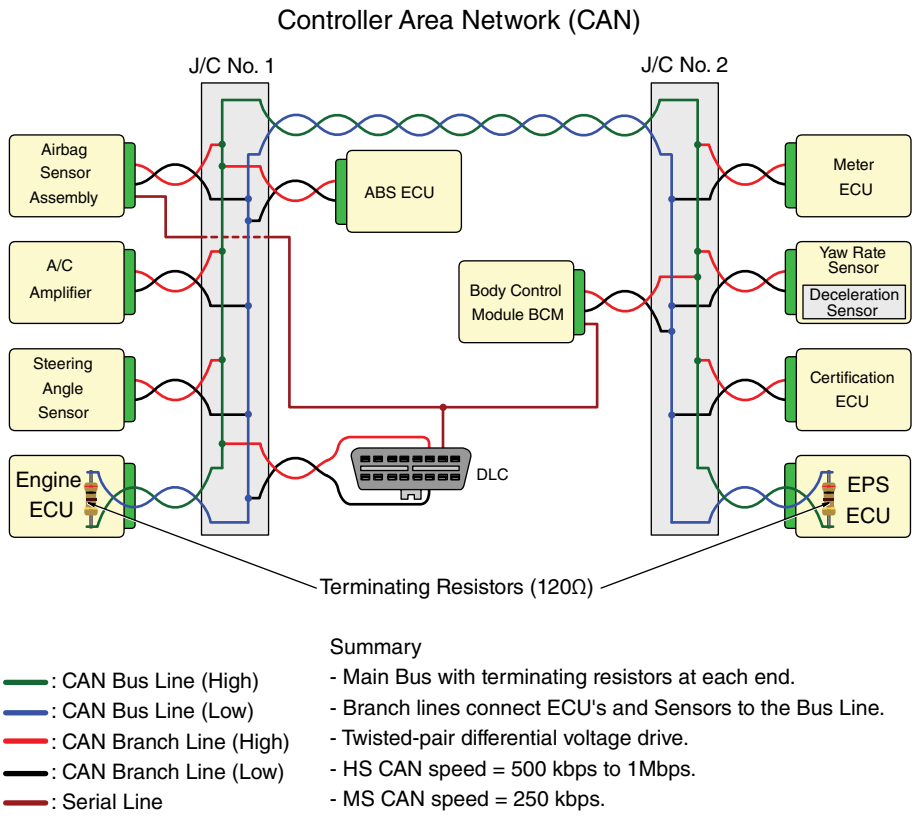


FIGURE 14-8 The CAN system can transmit data at up to 1 **megabit** per second (Mbps) for systems that need continuous data updates.

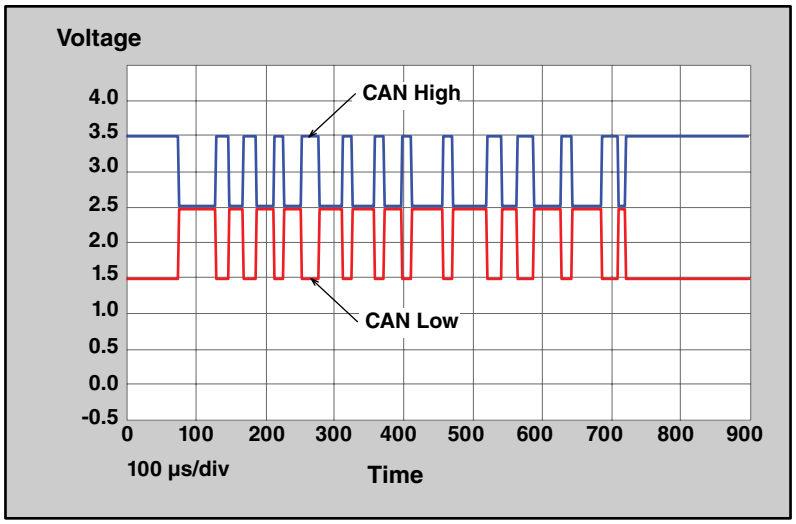


FIGURE 14-9 CAN communication has one line for the high voltage signal and one for the low voltage signal that mirror each other.

FIGURE 14-10 A CAN breakout box can be connected to the DLC to assist in measuring voltage and resistance of the CAN signal lines.

the resistance measured at pins 6 and 14 of the DLC. The breakout box can also assist in checking for an open circuit, short to ground, or other issues related to the DLC itself. The CAN system is very robust; however, it requires additional diagnostic strategies. These will be covered in the network diagnosis portion of this chapter.

Local Interconnect Network (LIN) Operation

The **local interconnect network (LIN)** is a low-speed network for body electrical system functions. Body electrical systems must share data with many systems, for example a door switch input is needed by the anti-theft ECU, the body ECU for the interior lights, and the instrument cluster ECU to turn on the door ajar warning indicator. This data does not require the high speed of the CAN network. Also, the CAN network is limited in the number of ECUs that can connect to it, and there is a cost associated with its use since it is a licensed system from Bosch. LIN was developed by vehicle manufacturers working together to create a lower cost alternative to CAN that allows for standardized communication protocols. Component suppliers can reduce costs since they do not need to create a customized communication protocol for each vehicle manufacturer's ECU.

The LIN topography is a star network in which the primary ECU can transmit data to any LIN connected sub-ECU (**FIGURE 14-11**). The sub-ECUs cannot transmit data to

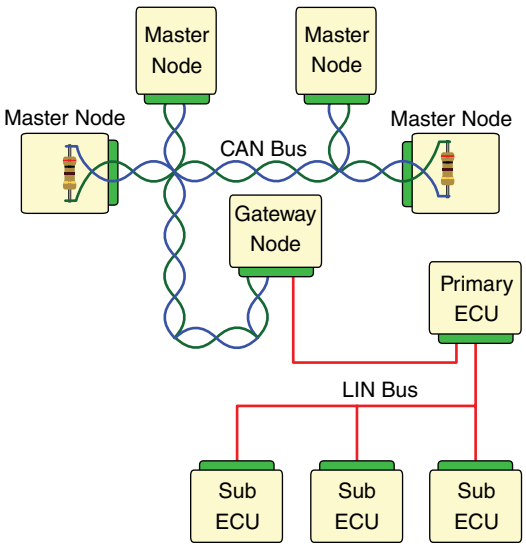


FIGURE 14-11 The local interconnect network is a low-speed network that allows most body electrical ECUs to share data with the main body ECU.

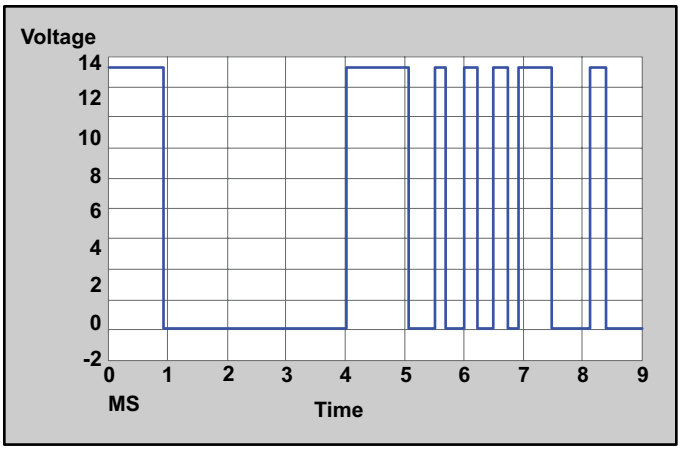


FIGURE 14-12 The LIN signal voltage is near source voltage when no message is being sent.

other sub-ECUs on the LIN, only to the primary ECU and only after a request for data is sent by the primary ECU to the sub-ECU. The primary ECU may function as a gateway module so it can connect directly to CAN and other applicable networks. For other vehicles, the primary ECU may connect to a **gateway module**, often in the instrument cluster, to share data with CAN and other applicable vehicle networks. A gateway module is like a United Nations interpreter for the vehicle networks. It receives data messages from one network and can translate them so they can be used in another network. For example, the HVAC system is on the LIN and needs to know the engine coolant temperature so it can control the blower motor speed as the heater core warms up on a cold morning. The CAN system sends engine coolant temperature to the gateway module which translates the data to the LIN protocol. It is then sent to the primary LIN module which then shares the data with the HVAC module. Gateway modules for most vehicles store network-related DTCs and customizable features for body electrical systems. The CAN gateway module also blocks the sharing of data with other networks when the data have not been requested.

The LIN signal line is at source voltage when at rest and is pulled to 0 volts to create the message (**FIGURE 14-12**). The ECU communication circuit uses a resistor to pull the line voltage to 0 volts and then back to source voltage. The pulses create the signal of zeros and ones for binary code that can be interpreted by each ECU.

Media Oriented System Transport (MOST) Operation

The **media oriented system transport (MOST)** network was developed to handle vehicle infotainment and driver assist functions like the back-up camera and voice commands (**FIGURE 14-13**). The MOST network is usually a fiber optic cable network; early systems were capable of speeds of 25Mbps, and more recent systems are even faster with speeds approaching 125Mbps. The MOST network topography is set up as ring network, and one ECU functions as a gateway module to connect with the other vehicle networks. Some MOST networks can be set up to use single- or twisted-pair wiring. MOST uses a standardized communication protocol so that many manufacturers can take advantage of the system's features without having to develop a proprietary system for their vehicles.

Fiber optic communication uses LEDs to create light pulses that are then interpreted by photo diodes. Each ECU has an LED to send messages and a photo (light-sensitive) diode to interpret the messages.

Other Networks and Smart Components

Many vehicle manufacturers have created proprietary networks for use in their vehicles, with most being systems that predate CAN, LIN, and MOST. Examples include Toyota's BEAN and AVC-LAN body and entertainment networks and Ford's DCL and Chrysler's CCD primary vehicle networks. These are mostly installed in vehicles that are aging quickly. Refer to the applicable service information for service procedures. It is important to remember that CAN, LIN, and MOST have evolved from these networks, so if you understand these, you can follow the diagnostic strategies laid out in the service information for the other network types. They all send data via a pulsing signal over a wire or wires.

FlexRay™ is a new network system that provides much higher data transmission speeds than the CAN type, with speeds of 10Mbps. FlexRay wiring is similar to CAN but can use an additional set of twisted-pair wiring for higher error protection and additional data transfer. FlexRay is most often set up as a bus network but can use star type topology. It can also be configured using bus and star topologies together. The high-speed capabilities of FlexRay will enable the vehicle-to-vehicle communication, drive by wire, active safety, and autonomous driving technologies soon to be found on automobiles.

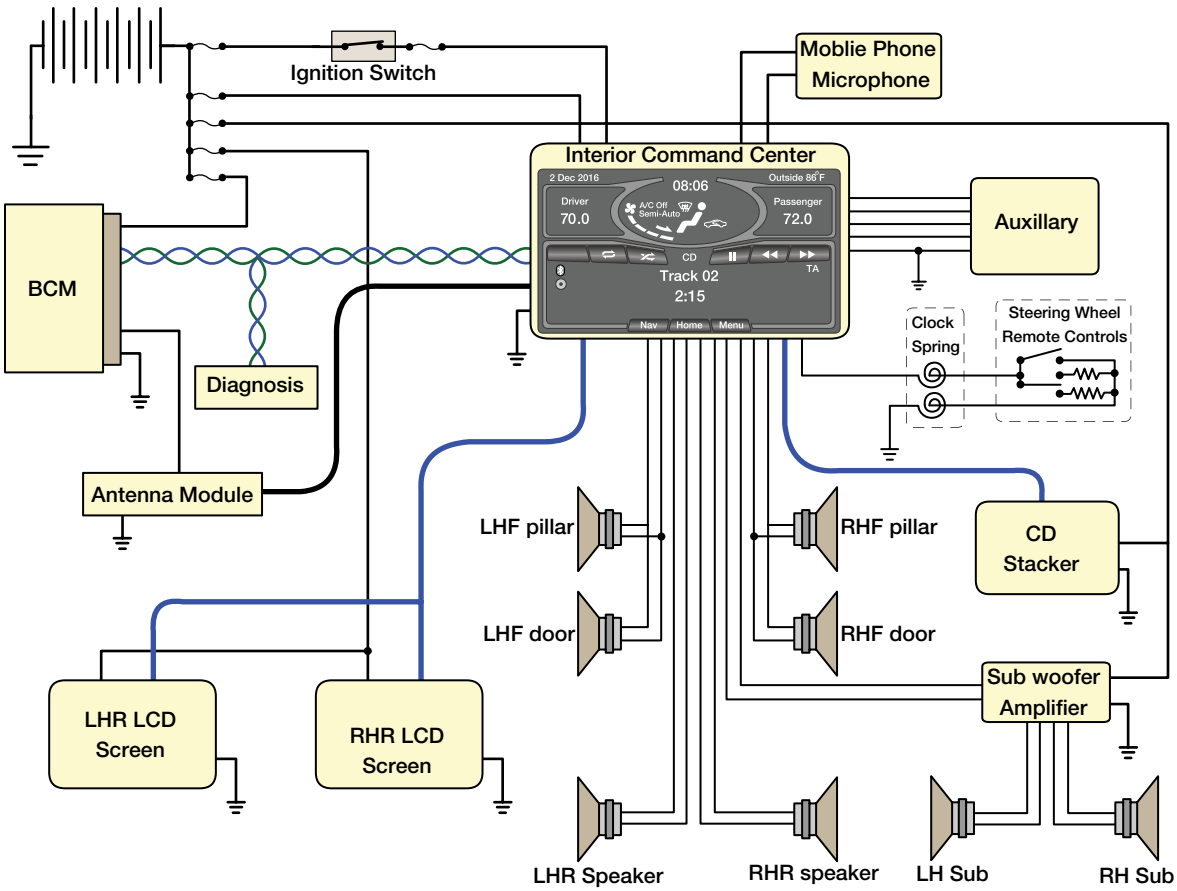


FIGURE 14-13 The media oriented system transport (MOST) network is used for infotainment and driver assist functions.

Smart Component Technology

Another technology is being used in the network/multiplex environment—smart components. These are components that perform a function, such as controlling the position of a blend air door to control HVAC outlet temperature with a servomotor, and also interpret signals from an ECU and send data back to the ECU. An ECU-controlled blend air door motor in a non-multiplex environment requires five wires: two for motor control and three for position sensor feedback of the motor position. A smart component uses an ECU-controller type chip so only three wires are needed: one for power, one for ground, and one for communication. The smart component communicates with the controlling ECU for operation and relays data about what the component is doing. More and more of these components are being developed. From an operational standpoint, while they are not part of a network, they communicate in a similar manner so your knowledge of network communication will help you when diagnosis is required.

▶ Vehicle Network Diagnosis

Vehicle network diagnosis follows the five-step process outlined earlier in this text. Network faults are most often caused by wiring and harness connector issues. A faulty ECU can also cause network faults. Accurate diagnosis of a network-related fault requires your electrical and electronic system knowledge; use of test equipment including the scan tool, advanced DMM functions, and the DSO; and use of wiring diagrams and network-specific service information. The service information contains block diagrams which lay out how the ECUs in a network are arranged and which ECUs connect to more than one network (**FIGURE 14-14**). Use of the block diagram can help pinpoint where a connector or wiring fault may be located when some of the ECUs are active on the network and others are not.

K14004 Explain the diagnostic strategies used to isolate the cause of vehicle network system faults.

S14003 Demonstrate use of network block and wiring diagrams as part of the diagnostic process.

S14004 View network signals using a digital storage oscilloscope.

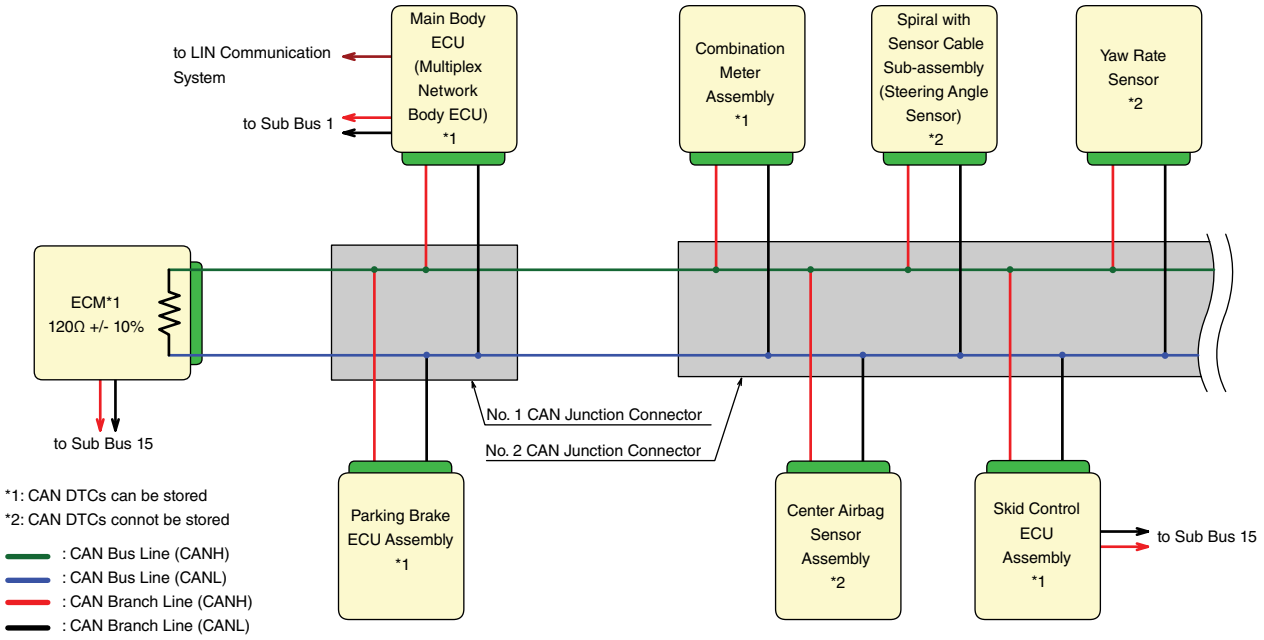


FIGURE 14-14 Network diagnosis requires use of specific service information including network block diagrams.

TABLE 14-1 Network Systems Store DTCs

DTC Code	Detected Condition	Inspection Procedure
B0121	Seatbelt #1 Sw Monitor Circuit Range/Performance	Inspection Procedure 14
B0316	A/C Pressure #1 Circuit Range/Performance	Inspection Procedure 32
B0332	Outside Air Temp Circuit Low Input	Inspection Procedure 33
B0337	Inside Air Temp Sensor #1 Circuit Low Input	Inspection Procedure 34
B0342	Inside Air Temp Sensor #2 Circuit Low Input	Inspection Procedure 35
B0347	Solar Load Sensor 1 Circuit Low Input	Inspection Procedure 36
B0372	A/C High Side Temp Low Input	Inspection Procedure 39
B0437	A/C Request Circuit Low Input	Inspection Procedure 30
B0517	Speedometer Circuit Low Input	Inspection Procedure 42
B0522	Tachometer Circuit Low Input	Inspection Procedure 43
B0527	Temperature Gauge Circuit Low Input	Inspection Procedure 45
B0532	Fuel Level Gauge Circuit Low Input	Inspection Procedure 46
B0547	Door Ajar #1 Indicator Low Input	Inspection Procedure 23
B0552	Door Ajar #2 Indicator Low Input	Inspection Procedure 24
B0607	Internal Error	Inspection Procedure 58

Network diagnosis begins after verifying the concern. Use the scan tool and perform a network system check. The scan tool will attempt to communicate with each ECU on the various networks and then display which ECUs are active, which are not, and any related DTCs (**TABLE 14-1**). If one or more DTCs are present, refer to the applicable service information and follow the related inspection procedures. Use the network block diagram(s) and related wiring diagrams to assist in isolating where the fault may be located. The junction connectors are usually a good place to perform DMM- and DSO-related tests to view signal voltages and scope patterns.

Network faults like an open or short circuit do not affect all networks in the same manner. An open on the LIN network shown in **FIGURE 14-15** by the red arrow would result

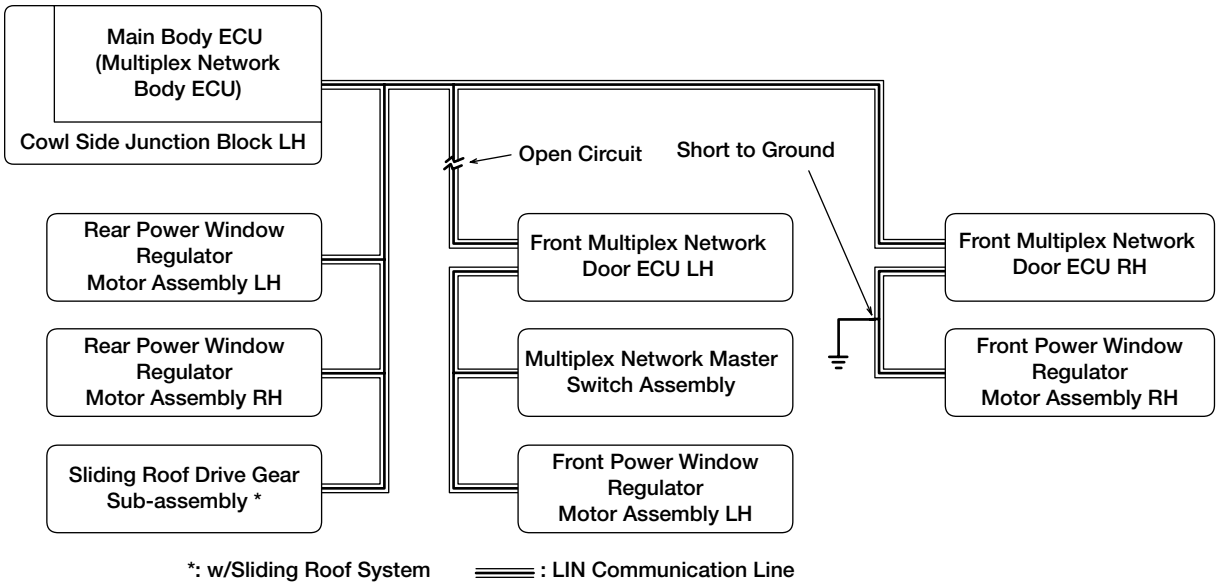


FIGURE 14-15 Open and short circuits affect networks differently depending on location of the fault and the type of network topography.

in no communication to or from the ECUs after the open LIN wire. The other ECUs would continue to communicate with the main body ECU. As a result of an open on the LIN wire at the green arrow, the front multiplex network door ECU on the left side (along with the multiplex master switch and left-hand front power window regulator motor assembly ECUs) would be cut off from the main body ECU. Note that the block diagram shows the master switch and power window regulator communicate to the front multiplex network door ECU and are not connected directly to the main LIN line from the main body ECU. This is an example of why the use of the block diagram along with scan tool data is so important for accurate network diagnosis.

An open circuit in a ring network between two of the ECUs may not show any symptoms since communication can still take place. An open in a star network will isolate that particular ECU from the primary ECU. An open on one of the main CAN-bus wires usually allows communication to continue but there is a loss in error detection capability. An open on both main bus wires may allow some communication between ECUs before the wire breaks, but there will be a great deal of "noise" in the data since one or more terminating resistors are no longer present in the circuit. An open on both wires that connect an ECU to the CAN-bus will isolate the ECU from the network, but other ECUs will continue to communicate. A short to ground or power will usually cause network communication to cease on the network. You can test for a short to ground or power using the DMM and testing at the DLC or a junction connector related to the network. Perform any of these tests as part of the service information's diagnostic steps related to either the network-related DTC or problem symptoms table.

A quick test can be made on the CAN network using a DLC breakout box (**FIGURE 14-16**). Systems with two terminating resistors should have a resistance between DLC pins 6 and 14 of about 60 Ω. Vehicles with additional terminating resistors will have slightly different readings. But if the resistance is OL, there is an open; if it is close to 0 Ω, there is a short between the signal lines.

Vehicle manufacturers also provide specific training on their systems with support in the form of printed or electronic instructional materials and online learning courses for technicians who work at their dealerships. Many networks still use copper wire and pulsed voltage signals to communicate. This means that most of your electrical and electronic skills will be used as part of the diagnosis, including viewing the signals with the DSO to determine if they are OK, if they are not present, or if they have a great deal of noise that inhibits accurate communication. Add these skills to the specific network diagnostic procedures and you will be able to isolate the cause of the concern.

FIGURE 14-16 Use the DLC breakout box to quickly determine if an open or short is present in the CAN wiring.

▶ Vehicle Network Repair

K14005 Describe vehicle network repair.

Once you isolate the cause of the concern you must effect a repair. Many manufacturers require replacing the vehicle harness if there is a fault while the vehicle is under warranty. Verify the applicable procedures where you are working. Unlike repairing a wire or connector in a lighting or motor circuit, network wiring is often in shielded sheathing or a twisted-pair format, or both. This can make repairs difficult or ineffective. Refer to the service information as it will usually provide the action required to effect a repair (**FIGURE 14-17**).

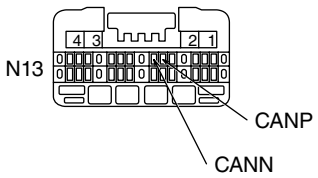
Vehicle network diagnosis builds upon your multiplex circuit understanding. A vehicle network connects ECUs together so they can share input data or provide an output request to one or more ECUs on the network. The use of a breakout box at the DLC in conjunction with your DMM and DSO can help you determine if an open or short condition exists and allow you to view the applicable data transmission waveforms. Many network faults store body or network-related diagnostic trouble codes. Follow the service procedures to diagnose these faults.

2.	CHECK FOR OPEN IN CAN-BUS WIRE (MAIN BODY ECU CAN MAIN WIRE)

(a) Disconnect the cable from the negative (-) auxillary battery terminal.

(b) Disconnect the main body ECU (multiplex network body ECU) connector.

(c) Measure the resistance according to the value(s) in the table below.



Standard Resistance

TESTER CONNECTION	CONDITION	SPECIFIED CONDITION
N13-9 (CANP) - N13-10 (CANN)	Cable disconnected from negative (-) auxillary battery terminal	108 to 132 Ω

Text in Illustration

*a	Rear view of wire harness connector (to Main Body ECU (Multiplex Network Body ECU))

NG ▶ REPAIR OR REPLACE MAIN BODY ECU CAN MAIN WIRE OR CONNECTOR (CANP, CANN)

FIGURE 14-17 Network wiring or harness faults may require repairing or replacing the harness or related connector.

Wrap-Up

Ready for Review

- Vehicle networks are not new. They have been used for many years and the controller area network has been required for scan tool interface in new vehicles since 2008. There are different network communication protocols, topologies, wiring/communication line types, and data transmission speeds.
- Vehicle networks are laid out in bus, ring, or star topologies. Scan tool communication is made through the 16 pin DLC. CAN network pins in the DLC are #6 and #14. Other vehicle networks may be accessed through one of the manufacturer's proprietary pin locations. Some vehicle manufacturers use a separate DLC for some of their system communication functions.
- A ring network has ECUs connected together to form a communication circle. The advantage of a ring network is communication continues even if the data line is open between two of the ECUs since data travel in either direction.
- A star network uses a primary ECU with sub ECUs that connect to the primary ECU using a single transmission line. All communication between sub ECUs is controlled by the primary ECU. An open data line between a sub ECU and the primary ECU prevents a data transmission to or from the isolated sub ECU.
- A bus network uses a main communication line and the ECUs on the network connect to the main line. The CAN and LIN usually use a bus topology.
- The local interconnect, controller area, and media oriented system networks are designed and shared by automotive manufacturers. This reduces cost and improves system performance since components can be developed for each vehicle company using a standard communication protocol.
- Network diagnosis relies on use of the system diagram which shows how the network is arranged, the wiring diagram, and use of the scan tool to check for DTCs. Most network faults are identified by a U-type DTC, and there is a related diagnostic flowchart in the service information. Most manufacturers use junction connectors to link ECUs into the network and these can be a good location to perform diagnostic tests.

Key Terms

breakout box (BOB) A tool that connects an ECU and the harness to allow pin testing. An OBD II data link BOB allows quick testing of network signals and resistance readings.

broadcast A message from one ECU that is sent to all ECUs on the network.

bus network The communication line(s) are laid out in-line and the ECUs connect to the bus with their own dedicated wiring. This layout provides very fast communication across the network.

controller area network (CAN) A Bosch-developed communication system that has been used since the 1990s. CAN has been required since 2008 for scan tool communication on most vehicles. CAN uses twisted-pair wiring and offers medium- and high-speed communication for engine and chassis control systems.

gateway module A module/ECU that serves to connect two or more networks together. The module functions to translate the data from one network to another so data can be shared from the CAN to the LIN, for example.

local interconnect network (LIN) A network designed by a consortium of automakers to provide the benefits of CAN but at a lower speed and lower cost. LIN uses a single-wire communication line.

media oriented system transport network (MOST) An infotainment network design and communication protocol that primarily functions to provide data sharing between the user interface for the phone, audio/video system, navigation, and other systems that are integrated into the center stack (center instrument panel area) for driver and passenger access.

megabit Mega is the term for 1,000,000 and 1Mb equals 1,000,000 bits. CAN may communicate up to 1Mbps (per second) and FlexRay up to 10Mbps.

protocol The communication parameters set up for a particular network. This is important so the scan tool software is able to communicate with the various networks on the vehicle.

ring network The ECUs are connected one after another forming a circular communication flow. The data can be transmitted in either direction and goes from ECU to ECU on the network. If a data line is open between two ECUs, the network can still function since the data can still be sent to every ECU on the network though the speed will be affected.

serial interconnect line (SIL) A back-up communication line in case the CAN communication fails. Manufacturers have leeway to use one of the proprietary lines or they can use the K or L line for some systems.

star network The ECUs are arranged with a primary ECU and each sub ECU communication line connected to the primary ECU. All communication must go through the primary ECU. This layout is often used for infotainment systems.

topology Describes the type of network layout used: bus, star, or ring type.

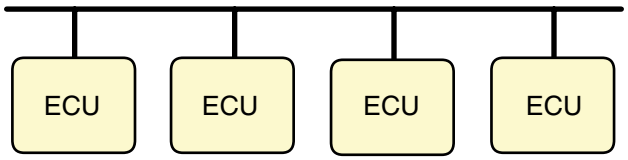
unicast A message from one ECU that is sent to a designated ECU on the network.

Review Questions

1. All of the following are part of the CAN *except*:
   a. arranged in a ring network.
   b. has medium- and high-speed versions.
   c. was developed by Bosch.
   d. uses gateway modules to communicate with other networks.
2. The LIN is used for which of the following?
   a. SRS functions
   b. Body control systems
   c. CAN gateway module
   d. High-speed data communication
3. All of the following may affect network communication *except*:
   a. open network signal line.
   b. an ECU has an internal fault that shorts the signal line to ground.
   c. the signal line between the main bus signal wire and the one ECU is open.
   d. the ECU fails to go into sleep mode.
4. Which of these networks is the fastest in data sharing?
   a. Bus type
   b. Ring type
   c. Star type
   d. LIN type
5. The communication line system used for high-speed controller area network/bus systems is:
   a. two-wire.
   b. twisted-pair two-wire.
   c. two-wire shielded
   d. single-wire.
6. The topology in which an open in the communication line will not affect network operation is:
   a. bus network.
   b. star network.
   c. ring network.
   d. LIN network.
7. CAN OBD II based on ISO 15765-4/SAE J2284 requires scan tool communication using pins:
   a. 7 and 15 of the DLC.
   b. 6 and 14 of the DLC.
   c. 5 and 13 of the DLC.
   d. 8 and 16 of the DLC.
8. When data/message is only sent out to one ECU in a network, it is usually called:
   a. pulsing.
   b. broadcasting.
   c. unicast.
   d. multicast.
9. Choose the correct statement with respect to signal transmission lines.
   a. Twisted-pair wiring and fiber optic transmission are not resistant to nearby voltage spikes.
   b. ECUs don't have a keep alive memory, which consumes battery voltage only when the vehicle is off.
   c. When a certain amount of time has passed where no communication has occurred, the ECUs send a test signal.
   d. Anti-theft ECUs are in low power mode when the ignition is off.
10. The twisted-pair wiring is routed to avoid wiring that route to coils or other inductors that may carry inductive kickback voltage spikes. Each data line has a no signal voltage of:
    a. 0 volt.
    b. 0.5 volt.
    c. 1.5 volts.
    d. 2.5 volts.

ASE Technician A/Technician B Style Questions

1. Refer to the network shown. Tech A says this is a star network. Tech B says data on this network can only transmit in one direction. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B



2. Tech A says the CAN network uses pins 6 and 14 of the DLC. Tech B says some vehicles have pins of the DLC that are reserved for specific manufacturer functions. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says network DTCs are designated by the letter N as part of the DTC. Tech B says a DTC may be stored when the network signal line is open or shorted. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
4. Tech A says the tool shown can prove access to vehicle network signal wiring. Tech B says a DSO can connect to this tool to view network data transmission signals. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

5. Tech A says the resistance between DLC pins 6 and 14 may be approximately 60 ohms. Tech B says several system warning indicators that illuminate at the same time may be caused by a network communication fault. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says a ring network can have an open on the signal wire between two of the network ECUs and still have communication between all ECUs. Tech B says an ECU that is part of a bus type network and is not communicating may have an open circuit between the ECU and bus line. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. Tech A says CAN communication may continue if only one line is an open circuit. Tech B says most networks stop communication if the signal line is shorted to ground. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. Two technicians are viewing a network data signal on a DSO. The no-data signal of this network should be source voltage but the waveform is at 0 volts. Tech A says there may be an open circuit on the signal wire. Tech B says there may be a short to ground on the signal wire. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. Two technicians are discussing the CAN bus signal. Tech A says CAN high has a signal voltage of 3.5V. Tech B says that at rest or no signal voltage of CAN is 0V. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Tech A says network diagnosis relies on use of the related block diagram. Tech B says the LIN network uses two data lines with voltage signals that mirror each other. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B

CHAPTER 15
Vehicle SRS Systems

NATEF Tasks

- **N15001** Diagnose operation of safety systems and related circuits (such as: horn, airbags, seat belt pretensioners, occupancy classification, wipers, washers, speed control/collision avoidance, heads-up display, park assist, and back-up camera); determine needed repairs. (AST/MAST)

Knowledge Objectives

After reading this chapter, you will be able to:

- **K15001** Describe the operation of the vehicle supplemental restraint system (SRS).
- **K15002** Explain the diagnostic strategies used to isolate the cause of SRS faults.
- **K15003** Describe SRS system repair.

Skills Objectives

After reading this chapter, you will be able to:

- **S15001** Test an SRS impact sensor for proper operation.
- **S15002** Remove and install the SRS spiral cable (clock spring).
- **S15003** Perform an SRS check with the scan tool.
- **S15004** Demonstrate use of SRS DTC flowcharts as part of the diagnostic process.

You Are the Automotive Technician

The customer states the SRS warning light is on. You verify the concern and check for SRS DTCs. You discover that a DTC is stored for the steering wheel spiral cable.

1. What could cause this customer concern?
2. Which types of diagnostic tests are appropriate and which are not?
3. What precautions should be observed when testing SRS circuits?

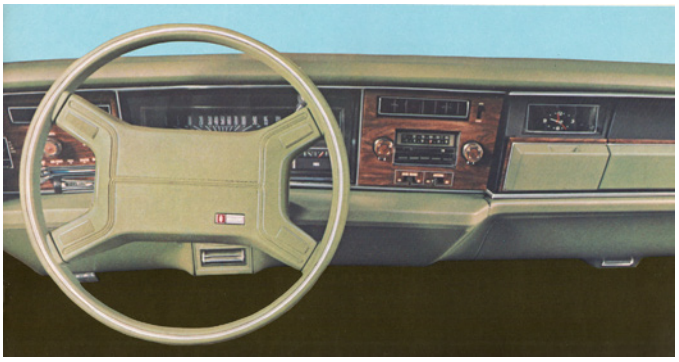


FIGURE 15-1 General Motors offered airbags as an option for a few years during the 1970s.

Courtesy of General Motors LLC.

▶ Introduction

Automotive airbags were first introduced in select General Motors vehicles in 1974 and offered through the 1976 model year (**FIGURE 15-1**). This first system was called the air cushion restraint system and was released in 1973 in a pilot group of 1000 vehicles before becoming an option in full-size GM vehicles. The system was very advanced for the time. It used a driver side airbag mounted in the steering wheel and a very large airbag that deployed from under the glove box area to protect the center and right front passengers. This system did away with the shoulder belt and retained the lap portion of the seat belt. The system also used a dual deployment system for the passenger airbag depending on vehicle speed. The system had a relatively low price tag as an option, about $255 in 1974, but only 10,000 vehicles were built with the option through 1976.

Various restraint systems were developed through the 1980s. Some of these systems were designed to deploy automatically (sometimes referred to as passive restraint systems) and included driver side airbag systems and automatic seat belts. All vehicle manufacturers offered some type of **passive restraint** system to meet U.S. government standards by the late 1980s and 1990s. This phase-in period required all manufacturers to offer airbag type front passenger passive restraint systems in all of their vehicles by 1999.

Seat belts secure and restrain the occupant within the seat and vehicle cabin, and in minor collisions they perform their task well (**FIGURE 15-2**). In a more severe impact, inertia causes the occupant to move farther and with greater force. This increases the possibility of injury caused by the restraining force exerted by the seat belt or from the occupant striking interior equipment. In these situations, airbags provide additional protection for the occupants.

The modern vehicle has several **supplemental restraint** systems (SRS) which can include front driver and passenger airbags for upper body and knee locations, side airbags, seat belt pre-tensioners, and airbags mounted in rear passenger seat belts (**FIGURE 15-3**). Some vehicles offer other systems to reduce vehicle occupant injury, and some vehicles now offer airbags that deploy on the front exterior of the vehicle to reduce injury if the vehicle strikes a pedestrian or bike rider.

K15001 Describe the operation of the vehicle supplemental restraint system (SRS).

N15001 Diagnose operation of safety systems and related circuits (such as: horn, airbags, seat belt pretensioners, occupancy classification, wipers, washers, speed control/collision avoidance, heads-up display, park assist, and back-up camera); determine needed repairs. (AST/MAST)

▶ SRS Operation

The SRS monitors vehicle speed, deceleration forces, and input from impact sensors; it then determines within milliseconds if one or more airbags should be deployed during a collision event. The SRS uses an ECU along with impact sensors, vehicle speed data,

FIGURE 15-2 Seat belts are designed to keep vehicle occupants restrained during a collision event.

Leolintang/Shutterstock

FIGURE 15-3 Airbags deploy in less than 0.03 seconds after a collision is detected.

and a g-force sensor to determine if a collision is occurring. The SRS ECU determines the potential severity of the collision and whether it is a front or side impact, and then it activates the airbags (and other safety devices if equipped) that are best suited to protect the vehicle occupants.

SRS Component Function, Design, and Operation

Impact Sensor Design and Operation

S15001 Test an SRS impact sensor for proper operation.

S15002 Remove and install the SRS spiral cable (clock spring).

Impact sensors detect when a collision may be occurring. Impact sensors may be electro-mechanical or fully electronic (**FIGURE 15-4**). Most impact sensors detect deceleration forces. Early SRS systems used electro-mechanical sensors. Some of these sensors use a steel ball held in place by a magnet. The ball is held in place in a tube that has two switch contacts at the other end. Impact forces great enough to require airbag and other safety systems to deploy will dislodge the ball from the magnet. The ball will then roll forward as the deceleration event occurs and make contact with the switch contacts at the end of the tube. This completes the circuit, and the SRS detects the change in impact sensor voltage indicating that a collision event is occurring. Another type of electro-mechanical impact sensor uses a rotating cam to close the switch contacts. The cam moves forward during an impact pushing on one switch contact forcing it to touch the other and complete the circuit.

Fully electronic impact sensors use **piezoelectric** elements that detect acceleration forces, called **g (gravity) forces**. The piezoelectric material is attached to a mass (small weight). The mass reacts to the deceleration forces during a collision event and moves inside the sensor putting a strain on the piezoelectric material it is attached to. This changes the output signal. Most of these sensors include a signal conditioning circuit that outputs a digital signal to the SRS ECU. The digital signal duty cycle varies according to the amount of deceleration detected by the sensor.

Impact sensors are located at the front and each side of the vehicle (for vehicles with side airbags). The number of impact sensors located at the front of the vehicle will vary, though most vehicles have a left and right front impact sensor.

To test the left side impact sensor, follow the steps in **SKILL DRILL 15-1.**

▶ TECHNICIAN TIP

Some side impact sensors incorporate a pressure sensor along with the g-force sensor. The pressure sensor reacts to the air pressure change inside the door during an impact. This can help improve side airbag deployment time to better protect vehicle occupants.

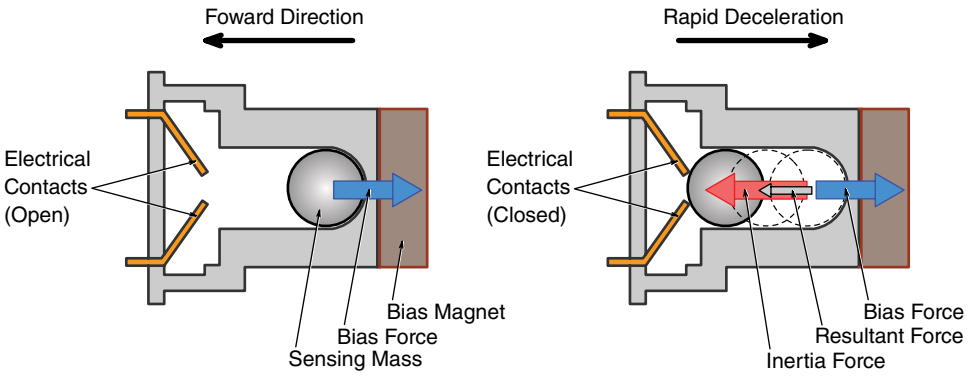


FIGURE 15-4 A ball-type impact sensor completes the circuit when impact forces dislodge it and it rolls forward across the electrical contacts.

SKILL DRILL 15-1 Testing the Left Side Impact Sensor

1. Use the service information for your assigned vehicle to locate the side impact sensor location and inspection procedure.
2. Disconnect the vehicle battery and wait at least 90 seconds for the SRS ECU capacitors to discharge.
3. Inspect the impact sensor per the service information. Some manufacturers provide DMM resistance test readings. Others may have you swap the left and right sensors to see if the fault changes position to the opposite side.
4. Reinstall the sensor if you removed it. Reconnect the impact sensor harness and any other components and trim panels. Have your instructor verify your work.

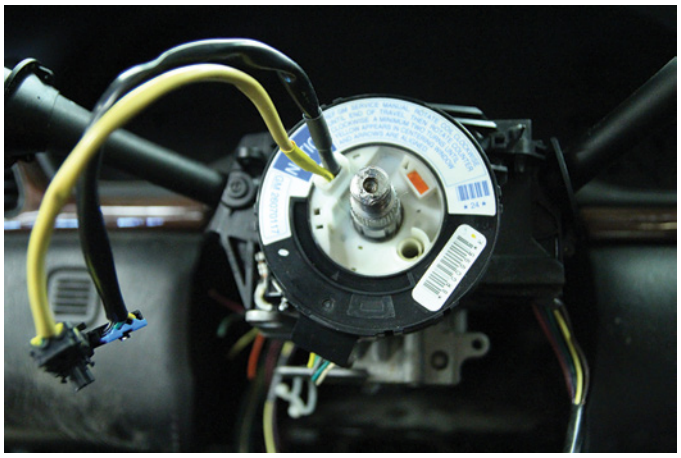


FIGURE 15-5 A clock spring, or spiral cable, keeps the driver side airbag connected to the SRS ECU.

Clock Spring Design and Operation

A **clock spring** type electrical cable is used to maintain the electrical connection between the SRS ECU and driver side airbag at all times (**FIGURE 15-5**). The steering wheel rotates as the vehicle is steered. The spiral cable uses a ribbon type wiring harness inside the housing. This ribbon harness extends and retracts as the steering wheel is turned left or right. The clock spring is not repairable if the ribbon harness fails. When installing a replacement spiral cable, the front wheels be must in the straight-ahead position and the arrow on the spiral cable must line up with the arrow on the steering column. Incorrect installation can result in damage to the ribbon cable by extending it too far.

To remove and install the clock spring, follow the steps in **SKILL DRILL 15-2.**

Occupant Detection System Design and Operation

Almost immediately after the first airbag safety systems were installed in vehicles it was discovered that smaller occupants and infants in rear-facing child safety seats were at risk for injury or death from an airbag deployment. The first remedy was to inform vehicle owners of this risk and recommend that infants in child seats must be in the second row of seating only; children who do not fit the seat belt system properly without a booster seat should also ride in the second (or third) row of seating. Vehicles with only front seats (pickup trucks and two-seat sport cars) may have a switch operated by the ignition key to turn off the passenger airbag. Placing the switch in the off position illuminates a warning indicator that this airbag is off and will not deploy during a collision event. These remedies have been replaced by an **occupant detection system** (**FIGURE 15-6**). The system uses a sensor in the passenger seat cushion and some also use a seat position sensor. The sensor data are sent to the SRS ECU to determine if the passenger seat occupant is within the size limits that would allow for safe deployment of the passenger airbag.

The sensor is built into the bottom seat cushion. Some systems use a silicone filled bladder with a pressure sensor built in. An occupant positioned in the seat exerts pressure on the bladder and the sensor data are processed by the SRS ECU. A child or small adult

SKILL DRILL 15-2 Removing and Installing the Clock Spring

1. Position the vehicle in your shop stall and steer the front wheels to the straight-ahead position with the steering wheel at 12 o'clock. (Note, check with your instructor if the steering wheel is not at 12 o'clock with the front wheels pointed straight-ahead.)
2. Locate the service information for removing and installing the clock spring for your assigned vehicle. Follow the steps in the service information. General steps are listed below, but other steps may be required so follow the directions in the service information.
3. Remove the negative battery cable and wait at least 90 seconds for the SRS system capacitors to release their charge.
4. Remove the driver side airbag following the service information procedure.
5. Remove the steering wheel using a steering wheel puller. Follow the related service information and never strike the steering shaft with a hammer to try and loosen the steering wheel from the steering wheel shaft.
6. Remove the clock spring noting the alignment marks. Once the clock spring is removed, DO NOT rotate the two sections; this will lead to misalignment internally, and it may not be possible to reinstall it without causing the flexible coiled harness to extend or retract beyond limits and break.
7. Install the clock spring with the centering installation marks aligned. Note, new clock spring assemblies often come with a tear-off adhesive that holds the inner and outer portions of the assembly in place during installation. Tear off this item when installing a new clock spring if equipped.
8. Install the steering wheel and torque the fastener nut to specification. Reinstall any disconnected harness connectors.
9. Install the airbag and torque the fasteners to specification.
10. Reconnect the battery cable. Turn the ignition on and verify the SRS system does its self-check and the warning icon then turns off. If it does, start the engine and turn the wheel fully to the left and fully to the right to ensure the clock spring was installed correctly. Verify your work with your instructor.

FIGURE 15-6 Seat weight sensors are used by the SRS ECU to calculate the occupant's approximate size and determine airbag deployment strategies.

FIGURE 15-7 The occupant classification system is used to determine whether an occupant is in the front passenger seat and whether the occupant is within the weight range for safe airbag deployment.

that is below the threshold level will cause the SRS ECU to disable the passenger side airbag and a warning indicator will illuminate—Passenger Airbag OFF (**FIGURE 15-7**).

Another sensor type uses strain gauges mounted at each corner of the bottom seat cushion frame. Each strain gauge outputs a signal that is then processed and sent to the ECU. A third type of seat sensor uses a grid on the bottom seat cushion that produces an electrostatic charge. A person seated on the sensor changes the capacitance value of the sensor to determine if the airbag should be deployed or not. Placing objects on the seat, even if they have significant weight, does not affect the capacitance value the same as the human body so the airbag will usually remain off.

Some vehicles also employ a front passenger seat belt pressure sensor. This sensor is used to detect that a child safety seat has been installed in the front passenger seat. The extra pressure exerted by the belt to secure the child seat could create enough downward pressure that the occupant classification system could falsely detect that a passenger is in the seat. The seat belt pressure sensor detects the high tension on the belt and the SRS ECU uses this data to disable the passenger airbag.

Seat Position Sensor Design and Operation

Seat position sensors may be used to provide data to the SRS ECU for airbag deployment strategies (**FIGURE 15-8**). This data can allow the SRS ECU to diminish the strength of the deployment when a customer's size requires them to be closer to the steering wheel and knee airbags. The passenger seat may be fitted with a position sensor also. The sensors are usually Hall-effect sensors that monitor the seat position as it is moved fore and aft. The sensor is mounted to the fixed portion of the seat frame that bolts to the vehicle floor pan. The seat rail has small Hall-effect IC chips on one side and a magnet on the opposite side.

▶ TECHNICIAN TIP

Most occupant classification system components, including the passenger seat weight sensor, require initialization if a new component is installed. Perform the initialization procedure when installing a new OCS module or seat sensor by following the related service information procedures. These may require placing a specific amount of weight on the seat so the OCS module can learn the sensor input values.

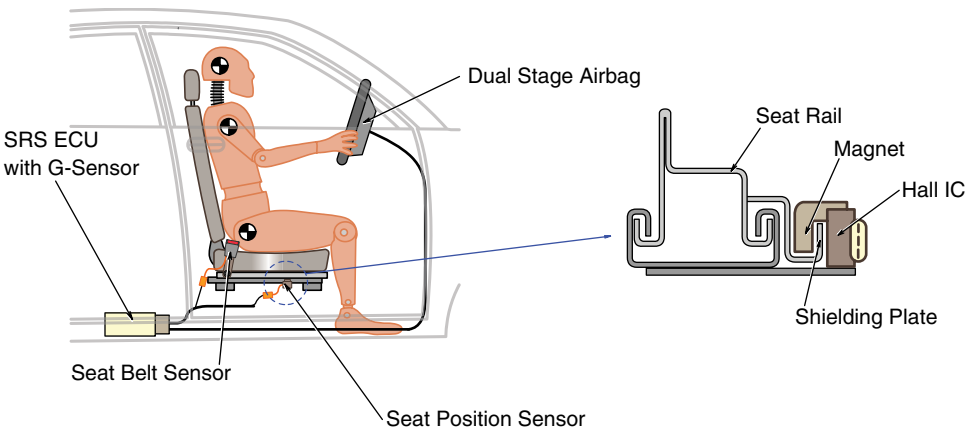


FIGURE 15-8 Seat position sensors may be used to provide data to the SRS ECU on how far the seat is from the airbags to control deployment strategy.

SAFETY TIP

Most vehicle manufacturers state a child safety or booster seat should never be used in the front seating position in the vehicle. Doing so could cause injury or death to an infant or small child. Refer your customers to the SRS section in their owner's manual for specific use instructions.

As the seat is adjusted by the driver, a vane interrupter moves along the seat track. The seat sensor determines how many consecutive Hall-effect IC chips are not obstructed by the vane interrupter and can then determine the seat position. This allows the SRS ECU to adjust the deployment strategy of the driver side airbag(s) during a collision event.

The seat occupant and position sensors are usually inputs to the occupant classification unit (OCU). Rather than using a network connection, this ECU usually connects directly to the SRS ECU to ensure accurate and uninterrupted data transfer.

Seat Belt Pre-Tensioner Design and Operation

The seat belt is an integral part of the safety systems in the vehicle. It is designed to keep occupants in the vehicle and restrained against the forces that occur during a collision event. Front outboard position seat belts use a pre-tensioner to help keep the occupants in place during a collision (**FIGURE 15-9**).

The **seat belt pre-tensioner** uses a small explosive charge to deploy (**FIGURE 15-10**). The charge pushes against a pin inside a tube that exerts force on the belt to tighten against

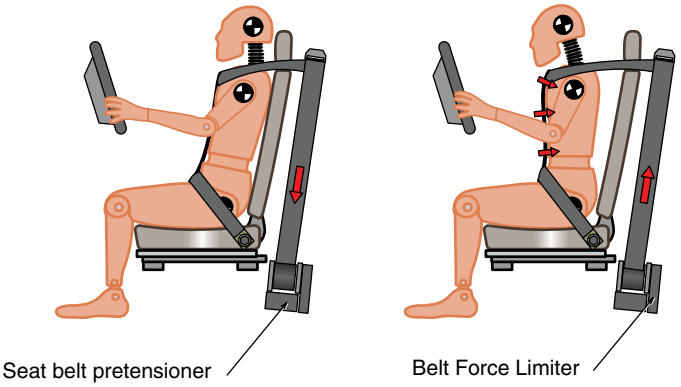
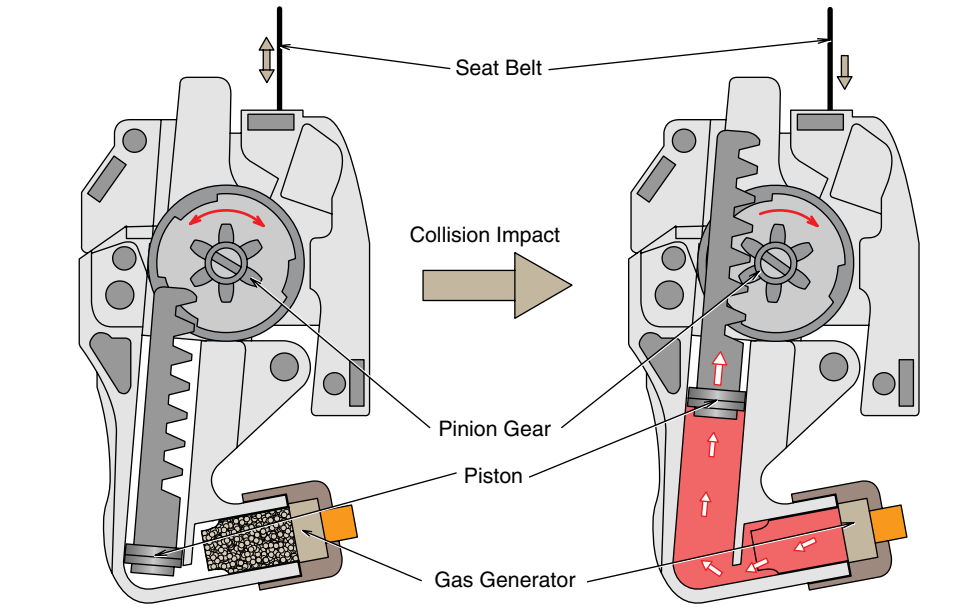


FIGURE 15-9 Seat belt pre-tensioners deploy to limit forward movement during airbag deployment. Some seat belts use a force-limiting system that allows the seat belt webbing to extend after the pre-tensioner deploys if forces are high enough.



Initial State
- The pinion gear is free to rotate allowing the seat belt to extend and retract.

Collision State
- The gas generator is ignited creating a large volume of gas.
- Expanding gas drives the piston into mesh with the pinion.
- The pinion gear is driven to tension the seat belt against the occupant.

FIGURE 15-10 The pre-tensioner may be located in the seat belt retractor or in the buckle assembly.

the passenger's body during the collision event. The pre-tensioner is deployed by the SRS ECU so that it times properly with airbag deployment. The two components work together to keep the occupants in place and protected as much as possible during the collision event.

Seat Belt Webbing Design and Operation

Most front seat belts also use webbing that can extend if g-forces are high enough. The added belt length helps prevent injury as the energy from the collision event distributes through the vehicle structure and the occupants. Some belts use webbing that is folded over and sewn in place. The extreme g-forces the occupant exerts on the belt during the collision cause the thread to give way and the belt webbing can extend (**FIGURE 15-11**).

Other systems use a belt retractor that is designed to give way for a certain distance when forces on the belt are great enough. Some use a mounting mechanism that gives way and others use a limiter on the retractor spool that allows it to extend enough to allow movement that may reduce injury (**FIGURE 15-12**).

Airbag Design and Operation

Modern airbag systems began to appear in the 1986 model year. The National Highway Traffic Safety Administration (NHTSA) began adopting requirement rules on airbag systems that continue to the present day. The first of the modern systems only provided a driver side airbag. Driver and passenger airbags became the norm in the early 1990s. Accident data began to show that while many people benefitted from airbag deployment

▶ TECHNICIAN TIP

LATCH anchor points can be found in the vehicle owner's manual and may be identified by round imprints or a "LATCH" icon embossed into the lower seat cushion of the rear seat.

FIGURE 15-11 Front seat belts may be designed to extend their length during the crash event to help prevent injury.

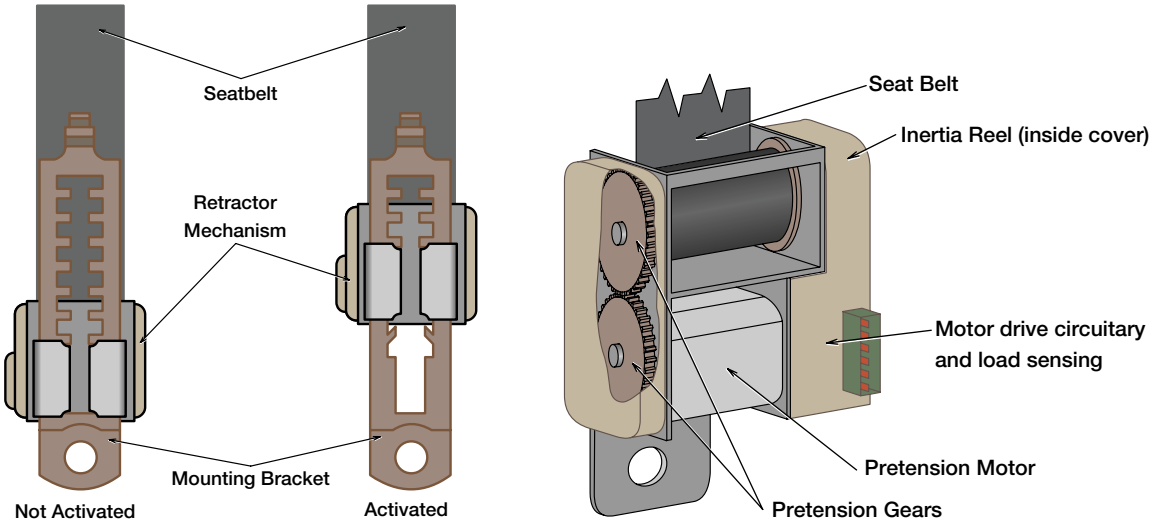


FIGURE 15-12 Load limiters may be located on the retractor mounting assembly or inside the retractor mechanism.

FIGURE 15-13 Airbags provide protection for vehicle occupants in most seating positions.

FIGURE 15-14 Airbags are found in several vehicle interior locations including the seat belts of rear seat passengers.
Rebecca Cook/REUTERS

during a collision, infants, children, and adults who are shorter or weigh less than average actually had an increase in death rates and injuries. This led to the adoption of airbag systems with g-force sensors, using speed sensor, brake input, and other data to deploy the airbags in stages (**FIGURE 15-13**). The first smart airbag systems used inflator assemblies that had two propellant charges; they could be fired together for the maximum force or one would fire first followed by the second a few milliseconds later to reduce the inflation force of the airbag. This airbag system, along with informing customers that small children and infants should ride in the second row seat positions rather than the front passenger seat, helped reduce injuries and fatalities. Infants should always be in an approved child safety seat that uses the LATCH (lower anchor and tethers for children) system connecting points.

Airbags are now located in the steering wheel and instrument panel for the front passengers. They may also be found along the roof, door panels, and seat backs for side impact and rollover protection. Some vehicles also use knee airbags to reduce leg injury, and some place airbags in rear seat occupant seat belts (**FIGURE 15-14**).

Airbag Inflator Operation The airbag contains a specially designed bag that inflates and a canister that houses the inflator propellant and an igniter (**FIGURE 15-15**). The igniter is often referred to as a **squib**, which is a munitions and pyrotechnic term for a device that sets off an explosion. The igniter, when activated by the SRS ECU, starts the chemical reaction that ignites the propellant pellets in the airbag canister. The propellant ignites and generates primarily nitrogen gas and heat. A filter and heat sink in the canister help keep the heat within the canister so it can function to deploy the airbag. The expanding gases from the propellant fill the airbag causing it to quickly expand and deploy from within the outer airbag cover. This all happens in just a few milliseconds. Most airbags have large holes so that the airbag deflates quickly after deployment. Deployed airbags cannot be reused and are discarded through your parts department or by following state and federal disposal guidelines.

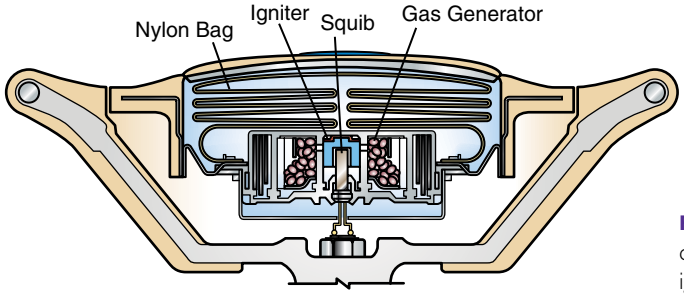


FIGURE 15-15 The airbag inflator is constructed of the propellant and an igniter called a squib.

SRS ECU Design and Operation

The SRS ECU is the brain of the system. Sensor data from impact sensors, vehicle speed, brake application, and internal g-force sensors are inputs for the ECU's processor. The SRS ECU has internal capacitors that provide power backup should the vehicle's electrical system begin to fail during a collision event. Electrical failure may be caused by the engine stopping along with wiring harness damage and the battery being disconnected or damaged during the collision. The capacitors retain their voltage charge long enough for the ECU to process the collision event data and deploy the airbags.

The SRS ECU monitors all sensor inputs and outputs. During vehicle start, the SRS ECU performs a system self-check. The self-check can be noted by watching the SRS system icon in the instrument cluster. The icon illuminates and flashes to indicate the self-check is in progress. The SRS ECU turns the icon off to indicate the system is OK. An SRS icon that remains on or continues to flash indicates there is a system fault and a DTC has stored.

The ECU monitors sensor input and airbag output control circuits for faults including open or short circuits. Note that ECU-related wiring uses yellow connectors and wire sheathing.

SRS G-Force Sensor Design and Operation The g-force sensor in most SRS ECUs is an electronic accelerometer. It is mounted in a housing on the SRS circuit board (**FIGURE 15-16**). Older SRS ECUs may have used mechanical g-force sensors, sometimes called safing sensors. These usually have a steel ball that is either attached to a metal spool or held in place by a magnet. A collision event that requires airbag deployment is detected when the g-forces from the deceleration cause the steel ball to move in a forward direction and then make contact with the safing pins. The SRS ECU deploys the related airbags when the g-force sensor in the ECU and one or more crash sensors indicate a collision event is occurring.

▶ TECHNICIAN TIP

Airbag recalls require the technician's attention and focus. A VIN check must be performed on any vehicle in for repair to see if the vehicle has an airbag or other safety-related recall campaign, inspection, and/or repair. Recent recalls of certain airbags focus on the canister, which could fracture and/or disintegrate upon deployment leading to severe injury or death. Be sure to input the VIN into the recall database at your dealership or use the NHTSA website if you are at an independent repair facility. It is good practice to make notations on the repair order (RO) indicating that you have checked for any open recalls or safety campaigns. If there are any, have your service advisor or customer contact person discuss the need for the recall work with the vehicle owner.

▶ SRS Diagnosis

The customer is alerted to SRS faults when the instrument panel icon continuously flashes or remains on after vehicle start (**FIGURE 15-17**). Some vehicles may also provide an SRS fault message through the vehicle information system display. The SRS system stores DTCs to assist your diagnosis. Once you verify the SRS icon indicates a fault is present, begin by connecting the scan tool to the DLC and obtain system DTCs. The service information has diagnostic flowcharts for each DTC. Follow each step carefully. Most of the diagnosis time is spent disconnecting harness sections and then measuring continuity through the wiring or ensuring that there is not a short to ground or another part of the harness. Continuity is

K15002 Explain the diagnostic strategies used to isolate the cause of SRS faults.

S15003 Perform an SRS check with the scan tool.

S15004 Demonstrate use of SRS DTC flowcharts as part of the diagnostic process.

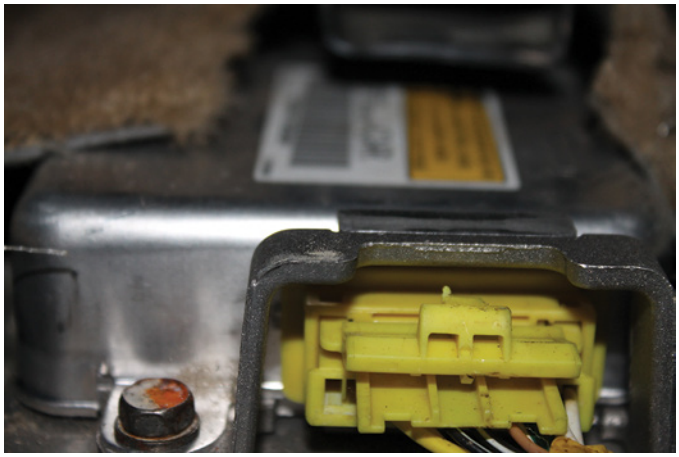


FIGURE 15-16 The SRS ECU monitors sensor data. It incorporates a g-force or impact sensor and also has a power backup in case of electrical system failure during a collision.

FIGURE 15-17 An SRS icon that continually flashes or remains on indicates there is a system fault.

SKILL DRILL 15-3 Using the Scan Tool for SRS DTC Retrieval

1. Connect the scan tool to the DLC of your assigned vehicle.
2. Follow the menu prompts to enter the required vehicle data (some newer vehicles can communicate this data to the scan tool).
3. At the scan tool system select menu, select the supplement restraint system.
4. Select view DTCs from the SRS menu. List any DTCs that may be stored.

SKILL DRILL 15-4 Testing SRS Wiring

1. Your instructor will assign you a section of the SRS harness to inspect.
2. Obtain the service information for the SRS circuit you will be inspecting.
3. Disconnect the battery and wait at least 90 seconds for the SRS ECU capacitors to discharge.
4. Access the wiring harness connectors you will be testing. It may be helpful to use a sorting tray or plastic storage bags you can label to keep track of fasteners and where they go for reinstallation.
5. Use your DMM to test the harness for continuity from one end to the other.
6. Use your DMM to test if the harness has no continuity to ground on each wire in the SRS circuit you are testing.
7. Verify your results with your instructor.
8. Reinstall the harness connectors and any trim or components you had to remove to access the harness connectors.

usually indicated when the resistance is very low, below 1 ohm. An open circuit is usually indicated when the resistance reading is over 1 mega ohm.

For some components, like impact/crash sensors, the repair manual directs you to swap sensors from one location to another to see if the fault then moves with it.

To use the scan tool for SRS DTC retrieval, follow the steps in **SKILL DRILL 15-3.**

To test SRS wiring, follow the steps in **SKILL DRILL 15-4.**

▶ SRS System Repair

K15003 Describe SRS system repair.

SRS repairs must be followed exactly as detailed in the service information. Replace a faulty component with the correct new part. The SRS ECU, impact/crash sensors, seat belt components, and airbags require that the bolts be torqued properly to ensure correct operation. These components should not be installed with power tools of any kind. Also, impact sensors and the SRS ECU g-force sensor can be damaged if dropped.

SRS Service after Airbag Deployment

Front Airbag Replacement Service

Restoring the SRS to normal operation is possible after a collision event if the vehicle can be repaired (**FIGURE 15-18**). The airbag modules will require replacement. The driver side airbag module requires that you test fit the new module to the steering wheel to ensure it fits properly. It is possible that the steering wheel was damaged during the collision event. Replace the steering wheel if the new airbag module does not fit the steering wheel correctly, and use new fasteners that are torqued to service specifications. The passenger side airbag may be a separate module in the dash assembly or it may be integral and require replacing the dash pad along with the airbag assembly. Knee airbags usually can be removed and replaced with a new assembly. The trim panel color is often integral so be sure to obtain the correct color if required.

Side Impact Airbag Replacement Service

Side impact related airbags may be integral to the seat and/or door panel. These are usually replaced by installing a new panel and or seat back. Side curtain airbags that deploy from the headliner often damage the headliner. The headliner may have to be replaced, which may involve removal of the windshield or rear backlight. The support structure of the roof must be in correct factory alignment after repair to ensure that the side curtain airbag

SAFETY TIP

SRS diagnosis does not rely on voltage testing like other system circuits. Performing voltage tests using jumper leads, test lights, or power probes rather than following the test methods detailed in the DTC flowchart can result in accidental airbag deployment. This can lead to the severe injury or even death of the technician performing the repair. Most SRS wiring tests are performed with the ignition off and the vehicle battery disconnected. It is imperative that you follow the service information procedures exactly as described. If you have difficulty determining the fault, seek assistance from another technician or your manufacturer's technical assistance center.

FIGURE 15-18 The SRS system can be repaired after a collision event.

fasteners and related support structure install correctly. Forcing components into position can lead to incorrect airbag deployment in a collision event.

SRS Electrical/Electronic Component Replacement Service

SRS electrical components usually require a thorough visual and DMM resistance/continuity test based on service information inspection procedures. Impact sensors at the point of impact are almost always replaced. Most manufacturers also require replacement of the SRS ECU after any airbag deployment, as the collision forces and deployment current can damage internal components. As stated earlier, damaged SRS wiring and connecters must be replaced; never repair them. The steering wheel clock spring/spiral cable may be reused if it moves freely and passes continuity checks, but always refer to the service information. If the service information requires the replacement of an SRS component, then it must be replaced.

Seat Belt/Seat Belt Pre-Tensioner Replacement Service

Seat belts with pre-tensioners, load limiters, or internal airbags must be replaced after a collision event. Inspect other seat belts in the vehicle to ensure they are not damaged and that they buckle properly.

Document your SRS repairs thoroughly on the repair order. Attach related service information so there is documentation that you followed the repair procedures to ensure the SRS system is fully restored to proper operation. Verify that the SRS icon flashes during self-check and then turns off. If it does not turn off, check DTCs to continue diagnosis and repair.

SAFETY TIP

SRS wiring and connectors should never be repaired. A wiring harness problem requires replacing the related wiring harness with a new one. Repairing a harness may cause improper or no airbag deployment at some later date due to an improper repair that did not provide proper system voltage and current through the harness.

Wrap-Up

Ready for Review

- Airbag systems first appeared on General Motor vehicles in the 1970s. The technology formed the basis for the systems of today; however, these systems as an optional accessory were not popular with the buying public.
- Passive restraint systems led the way to the modern airbag systems. Passive restraints include airbag systems, however those were preceded by automatic seat belt systems of various designs. Many of these passive seat belt systems were not well received by the buying public.
- A driver side airbag as standard equipment began to see use in the mid-1980s. Passenger side airbags came into use in the early 1990s and side airbags in the late 1990s. New systems include side curtain canopy airbags, knee airbags, airbags in rear seat shoulder belts, and sophisticated sensors and ECU software to control deployment to maximize safety and reduce injury to the vehicle occupants.

- SRS systems rely on the SRS ECU, airbag assemblies, and impact sensors working together to detect when a collision is occurring and to deploy the applicable airbag system with the right amount of deployment force to minimize occupant injury.
- The SRS ECU monitors vehicle speed data along with a g-force sensor to determine whether deceleration forces are high enough that a collision event is occurring and that airbag deployment is required. The airbags will not deploy if the g-forces and vehicle speed are not high enough. This prevents the airbags from actually causing an injury during a low-speed collision with minimal g-forces present.
- Side impact sensors are usually located in the B pillar on each side of the vehicle and detect a side impact collision event. Side airbags may be located in the B pillar or in the seat back. Many vehicles now use side airbags and side curtain airbags that deploy from the roof area at the edge of the headliner.
- Front belt positions on the left and right side (not center position) usually use a pre-tensioner that deploys during impact. The pre-tensioner tightens the seat belt on the occupant during the collision event to help keep them in place. It also reduces movement that would have to be absorbed by the airbag deployment.
- Airbags are deployed using a squib. A squib is an igniter assembly that starts the chemical reaction in the propellant. The reaction creates a great amount of heat very quickly and this heat expands the gases, primarily nitrogen, to expand the airbag and fully deploy it. There are usually large holes created in the airbag that allow it to quickly deflate after deployment.
- The SRS ECU uses many capacitors which store battery voltage. This allows the ECU to continue operation even if the battery is damaged or disconnected during a collision.
- SRS diagnosis is primarily DTC based. Almost every customer concern will state the SRS light is illuminated or flashing. This indicates one or more DTCs are stored. Use the scan tool to obtain the DTCs, then refer to the service information and follow the applicable diagnostic flowchart to isolate the cause of the fault. SRS circuit and component testing is different than most other body system circuits. Up to this point, diagnosis relied on tracing current and predicting voltage on the circuit wiring diagram, and then measuring voltage at applicable circuit test points. SRS circuits and components cannot be tested this way as it would require the circuit to be live during testing and this could lead to an airbag deployment. SRS diagnosis is done by performing resistance and continuity tests of wiring and components as specified in the DTC-based diagnostic flowchart while the battery is disconnected.
- Airbag-related components are usually installed using new fasteners. Fasteners can be damaged during a collision event so use of new fasteners ensures that all components are installed correctly and the fasteners are able to torque to specification correctly.
- Occasionally airbags may have to be deployed on a vehicle that has been totaled and is going to be scrapped. Follow the manufacturer's procedures for disposing of airbags and use the special service tools if deployment is required.

Key Terms

clock spring The component that maintains connection with the steering wheel mounted airbag and the SRS ECU. The clock spring wiring is able to extend and retract inside its housing as the steering wheel is turned left or right.

g-force Gravitational force exerted by acceleration, deceleration, and turning left or right in a vehicle.

impact sensor Impact sensors are usually located at the front of the vehicle near the grill or bumper and on each side of the vehicle in the "B" pillar. The impact sensors provide input signals to the SRS ECU that a collision event is occurring. The SRS ECU then determines if air bag deployment is required based on impact "G" forces, vehicle speed and other factors.

LATCH The lower anchors and tethers for children's seat mounting points. These are usually in the back or second row of a vehicle's seating area. The LATCH points are marked on the lower seating surface and there is a mounting anchor above the rear seat to attach an upper strap that creates a three-point mounting system for a child seat.

occupant detection system A system that detects whether a passenger is seated in the right front seat. Most systems can also detect the weight of the occupant and will only allow passenger airbag operation if the weight is above a minimum threshold.

passive restraint A vehicle occupant safety device that functions without any action by the occupant.

piezoelectric Materials that are able to generate an electrical charge when stress or pressure is applied to them. These materials are used in creating the g-force sensor used in the SRS ECU.

seat belt pre-tensioner A squib operated charge in the left and right front seat belt retractors that provides additional support to keep the occupant positioned correctly in their seat during a collision event.

seat position sensor A sensor that detects the location of the driver seat (and on some vehicles the passenger seat). This data is used by the SRS ECU to determine the airbag deployment strategy and timing based on how far the occupant(s) are seated from the airbags.

supplemental restraint The SRS system (the airbags that are used) are supplemental to the primary restraint, the seat belt.

squib Used to ignite a device, like the propellant in an airbag module. While the device does not explode, it does create a very aggressive chemical reaction that creates the heat to expand and deploy the airbag from within its storage packaging.

Review Questions

1. All of the following are usually input data to the SRS ECU *except*:
   a. vehicle speed.
   b. brake pedal application.
   c. LATCH anchors are in use.
   d. occupant classification status.
2. The g-force sensor is used for which of the following?
   a. Deceleration rate
   b. First trigger that airbag deployment is required
   c. Determining passenger weight
   d. Providing power if there is an electrical system failure during a collision event
3. All of the following may affect SRS operation *except*:
   a. faulty impact sensor.
   b. SRS wiring harness short to ground.
   c. airbag squib open circuit.
   d. the impact sensor data cannot be sent over the CAN system.
4. What do fully electronic impact sensors use to detect acceleration forces?
   a. A steel ball held in place by a magnet
   b. A rotating cam
   c. Piezoelectric elements
   d. Integrated circuits
5. A clock spring type electrical cable is used to maintain the electrical connection between the SRS ECU and driver side airbag at all times. Installing a replacement spiral cable requires that the:
   a. front wheels be in the straight-ahead position.
   b. steering wheel is at 3 o'clock.
   c. rear wheels be in the straight-ahead position.
   d. steering wheel is at 6 o'clock.
6. The sensors that usually monitor the seat position and give inputs to the occupant classification unit are:
   a. parking sensors.
   b. MAP sensors.
   c. Hall-effect sensors.
   d. heat sensors.
7. Which of the following is used to determine if the passenger seat occupant is within the size limits that would allow for safe deployment of the passenger airbag?
   a. Occupant detection system
   b. Inflator propellant
   c. Safing sensors
   d. Impact sensors
8. The design used in the seat belts to protect the driver if the g-forces are high enough is:
   a. explosive pre-tensioner.
   b. webbing.
   c. belt retractor.
   d. limiter on the retracting pool.
9. Which of the following may be able to be reused after a collision?
   a. Seat belts with pre-tensioners
   b. Load limiters
   c. Internal airbags
   d. Clock spring/spiral cable
10. Which of the following can act as a power back-up for the airbags in case the vehicle electrical system fails?
    a. Battery
    b. UPS
    c. Internal capacitors
    d. Inductors

ASE Technician A/Technician B Style Questions

1. Tech A says SRS diagnosis is very similar to testing for voltage in body electrical circuits. Tech B says the SRS ECU stores DTCs for sensor and wiring harness faults. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says SRS wiring can be repaired using correct soldering methods. Tech B says the clock spring/spiral cable should be indexed with the front wheels in the straight-ahead position. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says SRS DTCs are designated by the letter B as part of the DTC. Tech B says a DTC may store when the network signal line is open or shorted. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
4. Tech A says SRS diagnosis may require disconnecting the battery. Tech B says a test light or power probe should not be used when testing SRS wiring. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. Tech A says the SRS occupant classification system may use a seat position sensor. Tech B says the SRS warning indicator flashes during system self-check and then remains on to indicate the system is working correctly. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says it is solely the service advisor's duty to do a VIN check to determine if a vehicle in for service has any open recalls. Tech B says airbags are often installed using new fasteners and torquing them to specification. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

7. Two technicians are discussing an SRS DTC for the left side impact sensor. Tech A says the service information may have you swap the right and left side impact sensors to see if the DTC stores for the right side which may indicate a faulty sensor. Tech B says there may be a short to ground on the signal wire. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. Tech A says the occupant detections system may require calibration if a new seat weight sensor is installed. Tech B says the occupant detection system illuminates the passenger airbag off light if a child sits in the passenger seat and weighs more than the minimum required. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. Tech A says the g-force sensor is usually located in one of the front impact sensors. Tech B says the SRS ECU (sometimes called a squib) must always be mounted with new bolts that are torqued to specification. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Two technicians are discussing an SRS DTC for the clock spring (sometimes called spiral cable). Tech A says the clock spring may be back probed to measure system voltages to determine if the circuit is operating correctly. Tech B says the front wheels/tires must be in the straight-ahead position when installing a new clock spring. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B

CHAPTER 16
Body Electrical Accessories

NATEF Tasks

- **N16001** 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. (AST/MAST)

Knowledge Objectives

After reading this chapter, you will be able to:

- **K16001** Describe the function of the infotainment systems.
- **K16002** Describe the operation of the back-up camera.
- **K16003** Describe the operation of cruise control systems.
- **K16004** Describe the operation of the collision avoidance system.
- **K16005** Describe the operation of the blind spot monitoring system.
- **K16006** Describe the operation of other driver assist systems.
- **K16007** Detail the applicable procedure for diagnosing various accessory systems.

Skills Objectives

After reading this chapter, you will be able to:

- **S16001** Demonstrate pairing a phone to the vehicle.
- **S16002** Set the home address in the navigation system as you would for a customer.
- **S16003** Perform a DTC check with the scan tool on applicable accessory circuits.

You Are the Automotive Technician

The customer states their phone will not work with the vehicle's infotainment system. You verify that the customer's phone is not connected to the vehicle.

1. What could cause this customer concern?
2. Which types of diagnostic tests are appropriate and which are not?
3. How can you fully satisfy the customer when resolving this concern?

▶ Introduction

Automotive accessories in the 1950s and 1960s included seat belts, outside rearview mirrors, dual windshield wipers, and passenger side arm rests and sun visors (**FIGURE 16-1**). Today, all those and more are found on almost every vehicle, including systems covered in previous chapters like power windows and door locks. Accessories that are available on most vehicles include Bluetooth connection to the customer's phone, controls for music playing devices, navigation systems, adaptive cruise control, smart key systems, and security systems.

▶ Infotainment Systems

K16001 Describe the function of the infotainment systems.

N16001 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. (AST/MAST)

Infotainment systems integrate functions of on-vehicle systems like the navigation and HVAC system through voice commands and touch screen controls (**FIGURE 16-2**). They also integrate features from the customer's cell phone, allowing the driver to take and place phone calls, hear a text message and make a basic response, and access the music stored or streamed through the phone so it can be controlled and played through the vehicle's audio system.

The basic infotainment system primarily integrates voice commands and pairs the customer's phone to the system. These systems often use buttons to control system functions along with a range of voice commands; the most basic systems may not have a touch screen. Some vehicle manufacturers have partnered with providers like Microsoft, Android, and Apple to integrate phone functions which then expand the features of the system through a variety of applications (apps). Another feature of these systems is that their software can often be upgraded by downloading the update to a USB flash drive and then uploading software to the vehicle through a USB port. Vehicles with Wi-Fi (wireless Internet connection) may offer update capabilities once connected to the Internet. This offers the ability to improve features and even add new capabilities.

Pair Customer's Phone to Vehicle

One of the first setup procedures that occurs during the sales process is pairing the customer's phone to the vehicle (**FIGURE 16-3**). The customer accesses the phone menu and then selects the "connect to phone" function. The phone must have the Bluetooth function turned on and the applicable Bluetooth menu must be displayed. The infotainment system will display a code to enter on the phone. The phone sends this code back to the infotainment system to indicate it is ready to be programmed into the system. The phone should connect to the vehicle automatically upon every start cycle after a successful pairing process. The primary customer concern with infotainment systems is pairing the customer's

FIGURE 16-1 Vehicle accessories used to include windshield wipers and outside rearview mirrors. Today's accessories include adaptive cruise control and a range of media controls located on the steering wheel or touch screen.

FIGURE 16-2 Infotainment systems often use voice commands and a touch screen to control the audio system and connect the customer's phone to the system.

FIGURE 16-3 Infotainment systems use wireless communication to connect the phone to the system.

phone to the system. Usually the sales associate will **pair** the customer's phone during vehicle delivery; however, technicians may be asked to assist if there is some difficulty. Also, you may need to assist the customer if they purchase a new phone and are unable to successfully pair it to the system. The phone pairing is basically creating a wireless Bluetooth connection between the phone and infotainment system. The phone can also be connected through the USB port of the system so it can be charged and provide wired access to the media library of the phone.

Audio Sources That Connect with Infotainment Systems

Many customers prefer the wired connection when listing to music that is stored on the phone, as the sound quality is usually better than through a Bluetooth connection. The system is able to access the customer's playlists or selected artists using menus or voice commands. Features such as destination directions programmed into the phone can be heard through the speakers providing a phone-based navigation system for the customer. **Apps** (software applications) like Pandora and other music services allow the customer to have a wide range of options for audio entertainment. In addition to standard **AM and FM reception**, many systems also offer **HD Radio** and **satellite radio**, which are digital audio broadcasts that can be received with built-in receivers. HD Radio is usually free to listen to and offers alternative station choices that are focused on a certain type of music or talk radio topics. Satellite radio is a subscription-based service that the customer must pay to receive. Some satellite radio broadcasts have limited bandwidth and their sound quality may be poor compared to similar music played through the USB connection, CD, or HD radio. Some systems have a built in CD/DVD/MP3 disc player on which audio or video can be played.

▶ TECHNICIAN TIP

Video viewing is usually restricted to rear seat viewing screens unless the vehicle is parked. For safety reasons, the front seat viewing screen is disabled for video when the vehicle is in motion.

Infotainment Voice Command User Interface Operation

Voice commands are usually integrated with the infotainment system. The idea behind voice commands is they allow the driver to continue to focus on driving while using the system to answer the phone, place a call, change the radio station, or set a navigation destination. The systems vary in functionality and their ability to adapt to differing speech patterns. Also, the system is built upon a basic but often lengthy list of commands, such as "Audio Tune FM 106 point 7" to select a radio station. Some commands build upon other commands. Setting a navigation destination may require many separate voice commands as follows:

1. Destination street address, system responds, "Say street address and city name"
2. 123 Main Street, Anytown, system responds, "Press the voice button when ready to set the destination"

▶ TECHNICIAN TIP

Some infotainment systems offered a built-in storage drive for music. These were very popular a few years ago, but as phone data storage increased along with the ability to control the phone through the infotainment system, the hard drive storage feature has been eliminated in many systems.

Drivers are often frustrated when the system responds incorrectly. Difficulties can arise with ambient noise from traffic, other conversations in the vehicle, the HVAC blower motor on high speed, or when the system is unable to interpret the customer's speech pattern due to their accent. Voice recognition software is rapidly improving, but customers will likely continue to encounter frustrations with the system for the next several years. Most systems now integrate a voice learning function to help improve response. This feature is usually accessed through the settings menu. Once selected, the system asks the customer to repeat a series of voice commands. This allows the system to learn the speech patterns of the customer so the voice command function is more likely to respond with the desired action.

Integration of Applications That Increase Infotainment System Functions

Infotainment systems are increasingly relying on the phone and any related applications (apps) to customize the features of the system. Examples include reading text messages and sending simple responses; integrating the phone's operating system, like Apple Car Play and Android Auto, as the infotainment user interface; and integrating the voice command function of the phone to integrate with the system. This allows customers to maintain a familiar user interface and operating system while in the vehicle. It also allows the customer to connect to music services that may not be part of the infotainment system along with accessing the music library stored on the phone.

Infotainment System Diagnosis

S16001 Demonstrate pairing a phone to the vehicle.

S16002 Set the home address in the navigation system as you would for a customer.

To diagnose these systems, first the technician must determine if the concern is based on a fault in the vehicle or in the customer's phone. These systems have now been around for enough time that each manufacturer has technical service bulletins to address many known issues along with a dedicated website for the customer to seek operating info and system updates. As a technician, it is recommended you familiarize yourself with the customer support website for these systems and stay aware of any system updates. Customers are requesting very reliable systems that accurately respond to their voice and touch commands (some systems are now using hand gesture controls). Issues often arise when software updates occur on the phone side that the infotainment system is not able to adapt to. This may then require an update of the infotainment system, if one is available. Other issues arise when the vehicle system is essentially an extension of the phone, like using Siri for voice commands. The limitations of the phone are often misinterpreted as a problem with the vehicle's system. The good news is the vehicle systems are quickly becoming updatable through the phone's Wi-Fi, and in some cases the Wi-Fi is built in. Many software issues, therefore, can be quickly corrected with an update that can often be performed by the customer, thus avoiding a visit to the service bay.

Issues that may not be software or phone related require use of the scan tool to check for DTCs, including network DTCs. It is also important to follow any full system reset procedures and verify that the infotainment software is at the most recent software update level.

To pair a phone to the vehicle, follow the steps in **SKILL DRILL 16-1**.

To set the navigation home address, follow the steps in **SKILL DRILL 16-2**.

SKILL DRILL 16-1 Pairing a Phone to the Vehicle

1. Use the service information for your assigned vehicle to locate the phone pairing instructions.
2. Select the infotainment menu prompts to access the phone pairing function.
3. Verify Bluetooth is turned on for the phone.
4. Select the applicable vehicle system on the phone and then input the code displayed on the infotainment interface.
5. Verify the phone successfully connected.
6. Show your instructor that the phone is now connected to the vehicle.

SKILL DRILL 16-2 Setting the Navigation Home Address

1. Access the navigation system on your assigned vehicle using the user interface or voice command.
2. Select the "Store Home Address" function.
3. Enter the home address using the user interface or voice commands.
4. Verify the home address is stored.
5. Show your instructor that the home address is now stored.

▶ Back-Up Camera Operation

K16002 Describe the operation of the back-up camera.

Back-up cameras have been optional on many vehicles but will soon be required on all vehicles sold in the United States (FIGURE 16-4). Vehicles with an infotainment user interface screen often display the images there. Other systems display the image in the rearview mirror. The system uses a small camera with a very wide-angle lens to capture the image that is located at the rear of the vehicle. The display may or may not use grid lines that are color coded to help determine how close the vehicle is to obstacles. Obstacle distance detection is achieved with ultrasonic sensors that emit sound waves and then detect how long it takes the sound waves to bounce back off objects. Some systems tie the grid lines into the steering angle sensor to indicate the direction the vehicle is headed when backing up.

Some vehicles use several cameras to create a 360° view of the vehicle surroundings (FIGURE 16-5). This can be very helpful when maneuvering through very tight spaces. Other vehicles have a camera in the front of the vehicle to help the customer see a wider view of oncoming traffic, pedestrians, and bicyclists as they try to pull out of driveways or into traffic where parked vehicles, buildings, trees, or shrubs block full view (FIGURE 16-6). Some vehicles also offer a blind spot detection that utilizes a rear facing camera to display an image of the rear of the vehicle on the center display in the dash. It activates the camera when the turn signal is turned on and shows what is in your rear blind spot when trying to negotiate a turn or switch lanes in traffic.

▶ TECHNICIAN TIP

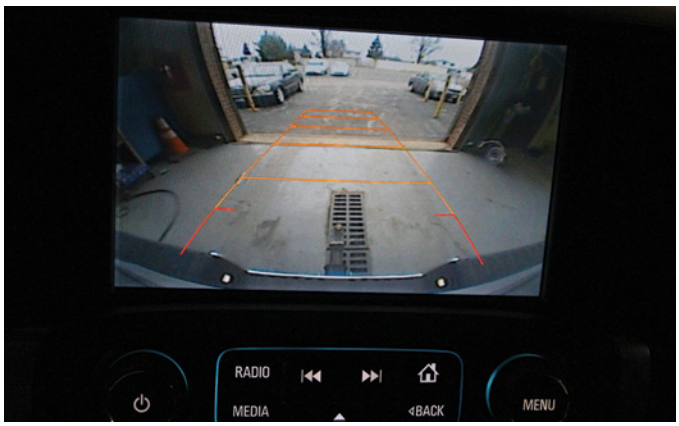
Some manufacturers' back-up camera systems require system initialization in order to view the grid lines on the rear-view camera image. Be sure to review the service information for system initialization requirements if the customer states the grid lines have disappeared or after disconnecting or replacing the battery.

▶ Cruise Control Systems

Early Cruise Control System Operation

K16003 Describe the operation of cruise control systems.

Cruise control first appeared on vehicles in the late 1950s and was a very simple device that held the throttle open at a constant setting (FIGURE 16-7). This worked okay as long as the road was relatively flat, but it could not hold a steady speed up or down hills. Also, the system did not release when the driver applied the brakes. Electro-mechanical systems appeared that monitored vehicle speed at the driveshaft or transmission output shaft and used a servo to operate the throttle. These systems have controls for on, off, set speed, and increase or decrease speed; the brake light switch (and on manual transmissions, the clutch pedal switch) is an input that releases the cruise control throttle control when the brakes are applied (or the clutch pedal is applied to release the clutch).



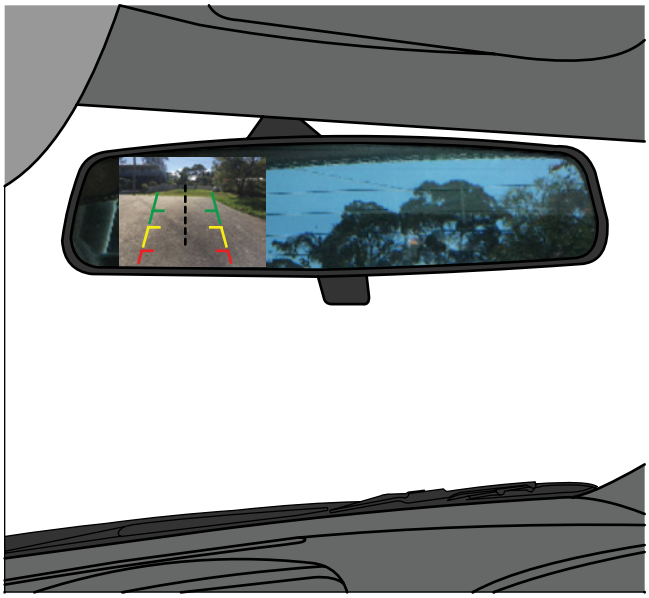


FIGURE 16-4 Back-up camera images may be displayed in the user interface screen or in the rearview mirror.

FIGURE 16-5 Some vehicles feature cameras that essentially create a 360° view of the vehicle surroundings.

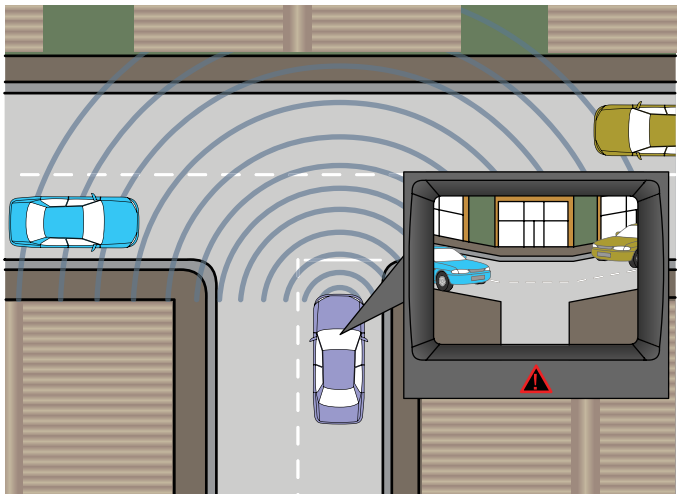


FIGURE 16-6 Some vehicles offer cameras in the front that can see around obstacles that may block the driver's view.

FIGURE 16-7 Cruise control with the ability to maintain a set speed appeared in the late 1950s. Today's systems are quickly adding adaptive strategies so the vehicle can reduce and increase speed when following another vehicle.

Many vehicles without electronic throttle control use a cruise control servo to operate the throttle to maintain vehicle set speed (**FIGURE 16-8**). The cruise control ECU monitors vehicle speed using a sensor on the driveshaft, axle, speedometer, or transmission output shaft. The driver turns the system on, accelerates to the desired speed, and selects the set button. The ECU stores the speed signal in its memory and then operates the throttle control servo to maintain the set speed. Most servos used engine vacuum to control servo movement. The cruise control ECU controls applied vacuum to hold the throttle or increase throttle opening. It also controls a vent to decrease throttle opening or fully release the throttle when the off, cancel, or decrease speed buttons are selected or if the brakes (or clutch pedal) are applied. The increase/decrease button can be held to increase or decrease the set speed. Some systems will change the set speed up or down 1 mph with each approximate 1 second push of the increase/decrease button.

Electronic Throttle Based Cruise Control Operation

Electronic throttle control (ETC) eliminated the need for a throttle servo and related control unit in the cruise control system.(**FIGURE 16-9**). The powertrain control module (PCM) now uses inputs from the cruise control–related switches and the wheel speed sensor shared over the CAN to control the throttle for cruise control operation. The actuator side of the system is much simplified. Diagnosis of this type of cruise control system centers around verifying correct ETC operation and using the scan tool to verify cruise

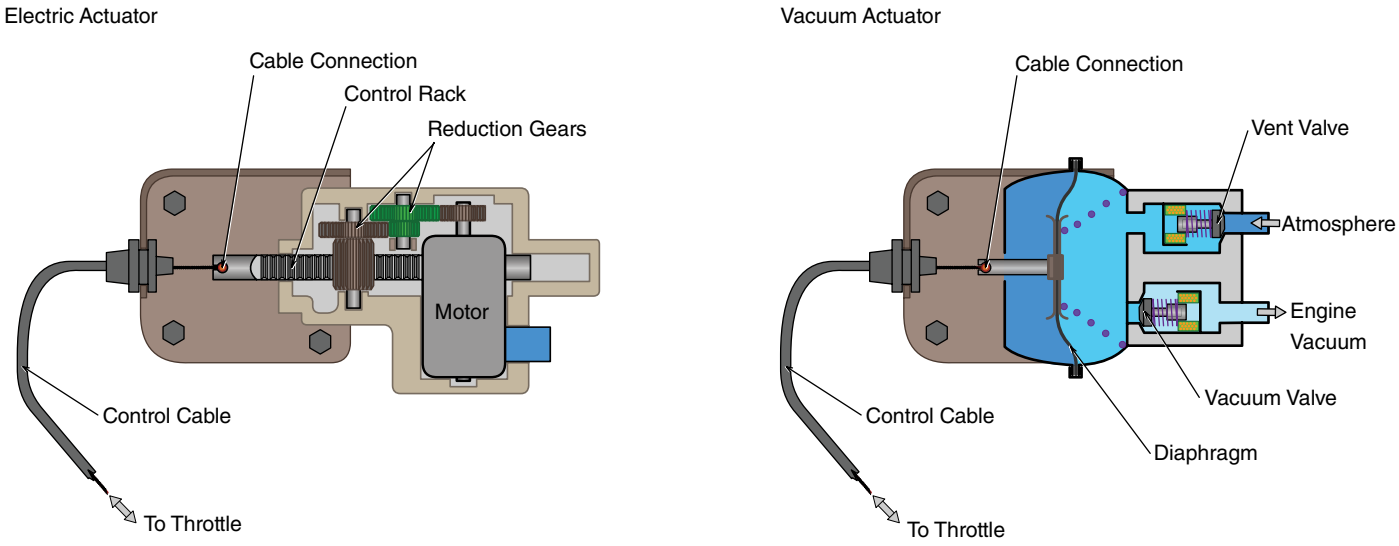


FIGURE 16-8 Older cruise control systems often used vacuum or electrically operated throttle servomotors to control throttle position.

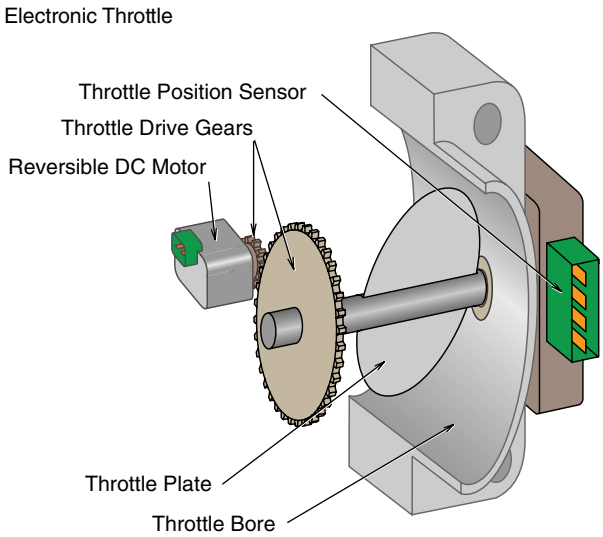


FIGURE 16-9 Electronic throttle control eliminated the vacuum servo and cruise control ECU.

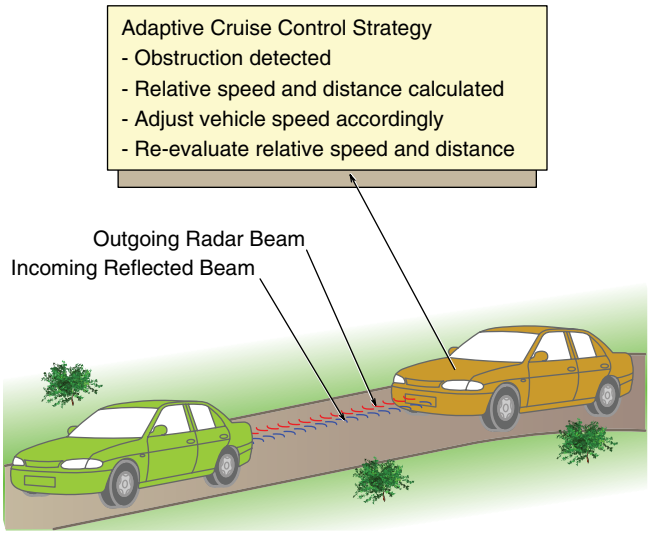


FIGURE 16-10 Adaptive cruise control automatically controls speed to keep a set distance between vehicles.

control–related switch input signals. Verify there are no ETC DTCs and that the ETC is not in fail-safe mode, usually indicated by a warning light on the instrument cluster. The service information provides a problem symptoms table and diagnostic flowchart to follow. Switch inputs can be checked with the scan tool data list and by following service information procedures to verify switch input signals with a DMM or, for some vehicles, to view the signal on a DSO.

Adaptive Cruise Control Operation

Adaptive cruise control uses laser beams to track a vehicle or vehicles that are ahead (**FIGURE 16-10**). The driver is able to select the desired distance to maintain between their vehicle and the vehicle ahead using a control button and a related indicator on the instrument cluster, usually a bar graph that indicates how many seconds of time it would take to close the gap between each vehicle (**FIGURE 16-11**). Adaptive cruise control integrates a sensor to monitor the distance from the vehicle ahead.

Most vehicles use a radar unit integrated in the grill emblem or mounted behind the grill or lower bumper opening (**FIGURE 16-12**). Some vehicles use a laser-based unit and

FIGURE 16-11 Adaptive cruise control usually has indicators in the instrument cluster to show the selected distance between the driver's vehicle and the vehicle it is following.

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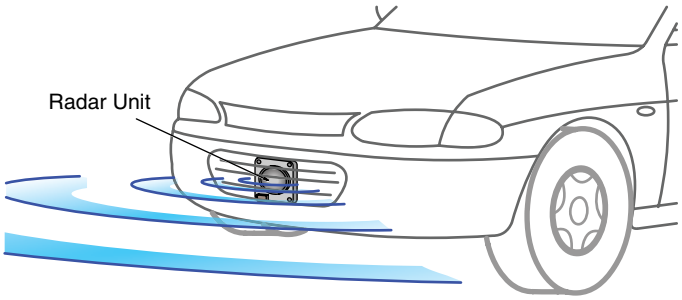

FIGURE 16-12 Most adaptive cruise control systems use a radar-based distance sensor to maintain a safe distance between the driver and the vehicle ahead, even as traffic speeds increase and decrease.

some use optical sensors to monitor vehicle distance. The distance sensor sends out its signal to monitor the distance and sends data as an input shared over the CAN with the PCM and VSC ECU to control throttle and brake action. An ECU-operated brake light relay or a command to the ECU that controls brake light operation is used to turn on the brake lights when the system applies the brakes. Since the system may be applying the brakes rather than the driver, there must be a way to illuminate the brake lights to alert drivers behind the vehicle. Most of these systems have increased in operational sophistication to the point that they now integrate collision avoidance technology to slow the vehicle, or in some case completely stop it, when the vehicle approaches a stopped vehicle or other obstacle.

Radar adaptive cruise control sends out radar waves from the detection unit and then monitors how long they take to bounce back from the vehicle ahead. The radar waves bounce back at a steady rate when the vehicle ahead is traveling at the same speed as the customer's vehicle. The radar waves take longer to bounce back if the vehicle ahead increases its speed. The adaptive system will then increase the vehicle speed up to the preset limit the driver set. The radar waves bounce back at an increasingly faster rate as the vehicle ahead slows down. The detection unit data are used by the PCM to reduce throttle, and it uses data from the VSC ECU to determine when it is necessary to apply the brakes in order to maintain a safe distance. Some systems have the ability to control the vehicle and bring it to a complete stop; however, most systems only provide control to speeds as low as 20–25 mph. This reduces system cost so these systems are available on a wider range of vehicles. Reduction in component costs and mandates by NHTSA that all vehicles have collision avoidance systems in the near future will bring adaptive cruise control to almost every vehicle.

Laser- and optical-based systems operate in a manner similar to the radar-based systems. Laser-based systems have the greatest limits when used in heavy rain or snow; however, even radar-based systems can be impaired by bad weather. It should also be noted that cruise control of any type is not recommended for use in rain, snow, icy conditions, or on unpaved roads where traction is not consistent.

▶ Collision Avoidance System Operation

K16004 Describe the operation of the collision avoidance system.

Collision avoidance systems often use the same sensors as the adaptive cruise control system (**FIGURE 16-13**). The system functions to slow the vehicle, or for some vehicles bring it to a complete stop, if another vehicle or traffic ahead has rapidly slowed or stopped. The system applies the brakes using the VSC system in the event the driver has not applied them or has not applied them at a sufficient rate. Additional sensors may be used to detect if the object is a vehicle or a pedestrian.

It is important to note that not all of these systems are designed with the same capabilities. Some are designed to only slow the vehicle while others will actually bring the

FIGURE 16-13 Collision avoidance systems use sensors similar to, or for some vehicles the same as, the adaptive cruise control distance sensors.

vehicle to a stop. Some in the industry feel the technology works best by fully stopping the vehicle. Others feel that slowing the vehicle will refocus the driver's attention and the driver can then determine the best evasive action to take. This can be helpful if vehicles behind are not slowing quickly enough and there is an open lane to either side that can be maneuvered into rather than the vehicle stopping and being hit by one or more vehicles from behind. Some of the most advanced systems also monitor the perimeter around the vehicle and can steer the vehicle around an obstacle as well as apply the brakes.

Some weather conditions like very heavy rain, hail, or snow can hamper the system's ability to detect distance and obstacles correctly. Also these weather conditions affect traction resulting in increased stopping distances and possible loss of control when abrupt steering maneuvers are attempted.

▶ Blind Spot Monitoring System Operation

K16005 Describe the operation of the blind spot monitoring system.

The **blind spot monitoring system** (sometimes abbreviated as BLIS for blind spot information system) lets the driver know if a vehicle is approaching in a neighboring lane (**FIGURE 16-14**). The system usually alerts for vehicles that are on the left or right side and helps the driver know when a vehicle is in the next lane but is difficult to see due to the angle of the rearview mirrors or visibility that is blocked by the "C" pillar (the vehicle body area after the rear side windows).

Sensors located in the mirror, in the rear bumper cover, or both are used to detect a vehicle in the blind spot area. The sensors may use radar or emit ultrasonic waves, depending on the system. An amber light in or near the mirror illuminates to alert the driver that a vehicle is in the adjacent lane. The light turns off when the vehicle is no longer in the zone

FIGURE 16-14 Blind spot monitoring systems use sensors that detect a vehicle and alert the driver through an indicator on or near the rearview mirror.

that makes it unsafe to change lanes. Some systems also offer driver feedback by vibrating the steering wheel if the driver attempts to change lanes when a vehicle is detected in the blind spot zone.

Some vehicles integrate the blind spot monitoring system sensors with the back-up camera to provide cross traffic alert. The system will emit a beep alert tone if a vehicle is approaching while the driver is in reverse. There are some vehicles that will also apply the brakes to stop the vehicle if the driver keeps moving rearward when a vehicle is approaching.

▶ Other Driver Assist Systems

Night Vision System Operation

K16006 Describe the operation of other driver assist systems.

Night vision systems are based on technology used in the military that allow humans to see images at night that they normally could not (**FIGURE 16-15**). The system uses an infrared camera to view the road ahead. The images appear for the driver on a heads-up style display in the windshield. The technology used for these systems is still expensive, so these systems are usually found on luxury type vehicles. System costs will decrease and complexity eventually will simplify, so this technology may appear on more vehicles in the near future.

Lane Assist System Operation

Lane assist systems use sensors similar to adaptive cruise control sensors and add cameras that can view the painted lines on the roadway (**FIGURE 16-16**). The cameras are usually located in the front bumper cover. The system alerts the driver if the vehicle drifts toward either side of the lane. The alert may be an audible tone along with a message in the instrument cluster or it may shake the steering wheel. There are more sophisticated systems that are the forerunner of self-driving vehicles. These systems use the adaptive cruise control, collision avoidance, and lane assist systems together for a type of auto-pilot driving mode. The vehicle will follow the traffic until the driver takes over to change lanes, exit the highway, or make a turn.

Lane assist systems have several limitations not caused by the system but rather the environment. Rain, snow, and faded paint lines on the road all have a negative effect on system operation. For this reason, this feature is in limited use in today's vehicles, but this will change as roadways adapt to the technology and engineers overcome the weather issues that affect system performance.

FIGURE 16-15 Night vision systems display images in the windshield that otherwise would be very difficult to see until it may be too late to take evasive action.

FIGURE 16-16 Lane assist systems may alert the driver when the vehicle is about to cross out of the lane or may help keep the vehicle in the lane.

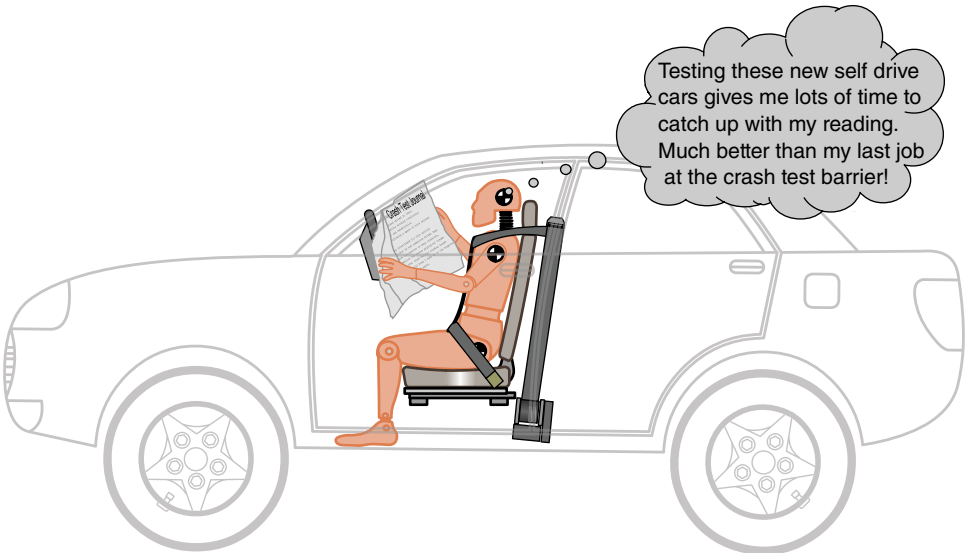

FIGURE 16-17 Autonomous vehicle technology is one of the most active new areas automotive and technology companies are working on today.

Autonomous Driving System Operation

Autonomous (self-driving) vehicles are predicted to be consumer ready very soon (**FIGURE 16-17**). Most vehicle manufacturers have test fleets built and are evaluating their performance. Some vehicle manufacturers offer systems that allow the vehicle to stay on course under limited conditions, such as the type of road surface and certain weather conditions. Tesla offers an "Auto Pilot" function that allows the vehicle to drive itself on the highway and some roadways with light traffic. The technology is based around the driving assist technologies discussed in this chapter along with linking to satellites for navigation coordinates and very sophisticated cameras that monitor all around the vehicle. This technology may reshape the industry and the way customer's interact with their vehicle. New traffic rules and laws will be required, and it will not be long before technicians are diagnosing a customer concern that the driver provided a voice command to go to the grocery store but the vehicle took them to the hardware store instead.

▶ Advanced Vehicle System Diagnosis

Diagnosing advanced vehicle systems will focus around use of the scan tool to retrieve system DTCs and any relevant operating data. Most of these systems require medium- or high-speed network communication, so your knowledge of network diagnosis may be required. Always check for TSBs that may address the customer's concern. Many of these systems are new, and it is very common for updated software or a system reset (powering down the system by removing the fuse) to correct the concern. The service information will provide diagnosis flowcharts for you to follow based around DTCs or a problem symptoms table. Perform each test as described to narrow down what is working and what is not. Like any electrical/electronic circuit, the system must have source and ground voltage to the components, resistance-free wiring and connections, and the hardware components must be functioning correctly.

K16007 Detail the applicable procedure for diagnosing various accessory systems.

S16003 Perform a DTC check with the scan tool on applicable accessory circuits.

Wrap-Up

Ready for Review

- Infotainment systems incorporate audio (and video for rear seat entertainment), phone, navigation, and other center stack features into a graphic user interface. The system uses Bluetooth to connect the driver's phone providing voice activation to send and receive calls and to access music and other applications stored on the phone. Some systems allow the driver to hear text messages and send a basic response, like "I will get back to you soon. I am driving." While almost all drivers want the infotainment system, there are frequent customer concerns with system operation from difficulty in pairing phones to misinterpretation of voice commands by the system.
- Back-up camera systems are now required by law; however, they have been available for several years. The rear camera may be all that is used and the image appears in the rearview mirror or the infotainment display. Some systems incorporate lines to indicate distance from an object and others move the lines to indicate the direction the vehicle is steering. Some systems also incorporate sensors that can detect objects in the path, how close the vehicle is to another vehicle, and if a vehicle or cross traffic is approaching while the vehicle is in reverse.
- Some vehicles offer a camera system in the front of the vehicle that operates in a similar manner to the back-up camera. The image is very useful when the driver is pulling forward out of an access drive and there are vehicles or trees/bushes blocking their view of oncoming traffic. Some vehicles offer 360° views of the vehicle. This feature is found on some pickup trucks and is very helpful when connecting to a trailer or parking the truck and trailer.
- Cruise control systems have been used on vehicles since the 1960s to maintain vehicle speed automatically. Early systems used a speed sensor on the vehicle driveshaft or axle and a vacuum operated actuator to operate the vehicle throttle. Modern cruise control systems are integral with the vehicle Power Train Control Module and include the electronic throttle, vehicle speed sensor data, brake switch (and clutch switch if applicable), and the control switches on the steering wheel. Integrates a radar or laser to monitor distance between the vehicle and the vehicle in front. This system not only maintains a set speed but also can slow down based on traffic ahead without the driver providing input. Many systems have integrated braking with these systems using the anti-lock brake/vehicle stability system.
- Collision avoidance technology began to appear along with adaptive cruise control. The systems vary in design strategies. Some function to bring the vehicle to a full stop while others will slow the vehicle or alert the driver that they are quickly approaching an object and will pre-charge the anti-lock brake/vehicle stability unit in preparation for a panic stop situation. These systems will be required on all vehicles in the near future.
- Blind spot monitoring systems use sensors to detect vehicles or objects that are on the side of the vehicle (e.g., obstructions that are out of sight due to the side view blind spots from the vehicle "C" pillar area or are out of the range the outside mirrors can reflect to the driver). The system uses an amber LED to alert the driver that a vehicle or object is near.
- Lane assist systems use cameras and sensors to monitor the lanes on the road. Some systems offer a heads-up display with a visual and audible alert if the vehicle drifts too close to one side of the lane. Some systems will provide a shake of the steering wheel to alert the driver to focus attention on the road and to make an adjustment to stay in their lane.
- Night vision systems use cameras that are able to pick up images in the darkness. These cameras use expensive technology created for the military, limiting this feature to very high end luxury vehicles. The system uses a heads-up display on the windshield to augment the driver's view of the road with the headlight illumination. This feature is very useful where wildlife, like deer, are common and may suddenly run across the road.
- Autonomous driving is one of the most talked about issues in the automotive industry at this time. The goal of many manufacturers is to have vehicles with autonomous driving capabilities within the next four to six years. There are many issues that must also be considered and new laws must be created. For example, will the occupant need a driver's license? How will vehicles that are older share the road with vehicles that have these autonomous features? This is also an area of great opportunity—these systems require much engineering and testing, providing more employment opportunities than there are qualified people to do the work.

Key Terms

AM/FM radio Vintage technology, though still in use. AM stands for amplitude modulation and FM stands for frequency modulation. These describe how the radio broadcast is transmitted through the air to the radio receiver in the vehicle.

apps An abbreviation for applications that a customer has on their smartphone.

autonomous The term that describes fully self-driving vehicles. This technology is quickly making its way to the vehicle customer and with it will come a great deal of change not just with the vehicle but also rules of the road.

blind spot monitoring system A system that uses sensors to detect vehicles that are in the blind spot area of the rear quarter

of the vehicle. An amber LED in the outside rearview mirrors is usually used to alert the driver that a vehicle is present on that side.

cruise control A system that maintains vehicle speed based on a set speed selected by the driver. Newer systems may integrate adaptive features that allow the vehicle to slow and brake as highway traffic speeds decrease and increase.

HD radio High definition radio is a by-product of digital radio signal transmission. The sound has much better quality and the same station frequency can offer several different formats.

infotainment A driver (and passenger) graphic user interface with related ECU support that integrates phone functions, audio system functions, navigation system, and other applicable vehicle system controls into a central hub for their operation. Much of the operation can be done with voice commands, although many customers still prefer to use a touch screen or knobs and buttons.

lane assist A system that uses cameras and sensors to help the driver maintain lane control. The system uses the painted lane stripes along with steering wheel position to alert the driver if the vehicle is drifting off center in the lane.

night vision A technology that uses cameras and sophisticated imaging software to display objects on the road and nearby that would normally not be visible with just the headlights. This technology was developed for the military; it is still very expensive and is just now seeing use in vehicles.

pair The function of connecting the customer's phone to the infotainment system. Some systems require inputting a code that appears on the phone to complete the process.

satellite radio Broadcast using satellites and is usually subscription based. The advantage is a very wide range of station selections with all types of music, news, and information programs. The signal also is present across the 48 states making it possible to travel all day listening to favorite stations.

Review Questions

1. Which of the following is least commonly used to control a vehicle's infotainment system?
   a. Hand gesture controls
   b. Voice commands
   c. Touch screen
   d. Buttons
2. What is the most preferred form of connection when listening to music that is stored on the phone?
   a. Wi-Fi
   b. Wired
   c. Bluetooth
   d. Radio wave
3. Voice commands can be used to perform all of the following functions *except*:
   a. answer the phone.
   b. place a call.
   c. accelerate the vehicle.
   d. set a navigation destination.
4. Which of these factors does the voice learning function address?
   a. Ambient noise from traffic
   b. Other conversations in the vehicle
   c. Noise from the HVAC blower motor
   d. The customer's speech pattern
5. After a successful pairing process, the phone should connect to the vehicle:
   a. automatically on every start cycle.
   b. whenever it is idle.
   c. whenever the user initiates a pairing.
   d. whenever the phone number changes.
6. Back-up cameras gauge distance using:
   a. radio waves.
   b. ultrasonic sensors.
   c. heat sensors.
   d. motion sensors.
7. Cameras that essentially create a 360° view of the vehicle surroundings help in:
   a. maneuvering through very tight spaces.
   b. maintaining the correct distance with the vehicle in front.
   c. maintaining the correct distance with the vehicle behind.
   d. deciding the vehicle's speed.
8. When an ETC is used, the throttle for cruise control operation is controlled using:
   a. engine vacuum.
   b. inputs from the cruise control related switches and wheel speed sensor data.
   c. cruise control servo.
   d. vehicle speed at the driveshaft or transmission output shaft.
9. The driver is able to select the desired distance to maintain between their vehicle and the vehicle ahead using a(n):
   a. adaptive cruise control.
   b. lane assist system.
   c. back-up camera.
   d. autonomous driving system.
10. Which of the following systems lets the driver know if a vehicle is approaching in a neighboring lane?
    a. Adaptive cruise control
    b. Lane assist system
    c. Blind spot monitoring system
    d. Autonomous driving system

ASE Technician A/Technician B Style Questions

1. Tech A says adaptive cruise control often integrates brake light operation when the vehicle brakes are automatically applied by the system. Tech B says cruise control inputs include the set speed selected by the driver. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

2. Tech A says the voice activation system automatically learns dialects in all systems. Tech B says most infotainment systems offer a touchscreen and buttons and switches for system functions. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says the back-up camera always displays on the infotainment screen when the vehicle is in reverse. Tech B says some vehicles use a front-mounted camera that performs similar functions as the back-up camera. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
4. Tech A says many customers have infotainment system concerns but the cause of these concerns is often an issue with phone software. Tech B says some infotainment systems require inputting a code when pairing a phone to the system. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. Tech A says the cruise control system integrates powertrain control module functions to operate the system. Tech B says adaptive cruise control uses cameras to monitor traffic ahead of the vehicle and to keep the designated distance between the customer's vehicle and the one it is following. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. A vehicle is in the shop with a back-up camera that has an image frozen on the display screen. Tech A says there may be a TSB for this concern. Tech B says doing a system reboot may correct this condition. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. The customer states the infotainment system does not understand their voice commands. Tech A says that there are some system limitations and demonstrates the system features for the customer to illustrate this. Tech B says the system may have a voice learning feature that can correct this concern. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. A customer states their audio system is not operating correctly. The sound quality when using their phone is poor. Tech A says one way to test this is to try the phone's Bluetooth streaming in a similar vehicle. Tech B says better sound can be obtained by using the USB port to connect the phone. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. Two technicians are discussing cruise control systems. Tech A says the system is ECU-controlled and relies on vehicle speed data from wheel speed sensors. Tech B says the brake light switch is an input to the system. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Tech A says the customer's phone offers several functions that integrate with the audio system on most new vehicles. Tech B says phone software is being developed to specifically integrate with vehicle infotainment systems. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B

APPENDIX A

2017 NATEF AUTOMOBILE ACCREDITATION TASK LIST CORRELATION GUIDE

Task List	MAST	AST	MLR	Chapter
ENGINE REPAIR				
General: Engine Diagnosis; Removal and Reinstallation (R & R)				
Complete work order to include customer information, vehicle identifying information, customer concern, related service history, cause, and correction.	P-1	P-1		
Research vehicle service information including fluid type, internal engine operation, vehicle service history, service precautions, and technical service bulletins.	P-1	P-1	P-1	
Verify operation of the instrument panel engine warning indicators.	P-1	P-1	P-1	
Inspect engine assembly for fuel, oil, coolant, and other leaks; determine needed action.	P-1	P-1	P-1	
Install engine covers using gaskets, seals, and sealers as required.	P-1	P-1	P-1	
Verify engine mechanical timing.	P-1	P-1	P-2	
Perform common fastener and thread repair, to include: remove broken bolt, restore internal and external threads, and repair internal threads with thread insert.	P-1	P-1	P-1	4
Inspect, remove and/or replace engine mounts.	P-2	P-2		
Identify service precautions related to service of the internal combustion engine of a hybrid vehicle.	P-2	P-2	P-2	
Remove and reinstall engine on a newer vehicle equipped with OBD; reconnect all attaching components and restore the vehicle to running condition.	P-3			
Cylinder Head and Valve Train Diagnosis and Repair				
Remove cylinder head; inspect gasket condition; install cylinder head and gasket; tighten according to manufacturer's specification and procedure.	P-1	P-1		
Clean and visually inspect a cylinder head for cracks; check gasket surface areas for warpage and surface finish; check passage condition.	P-1	P-1		
Inspect pushrods, rocker arms, rocker arm pivots and shafts for wear, bending, cracks, looseness, and blocked oil passages (orifices); determine needed action.	P-2	P-2		
Adjust valves (mechanical or hydraulic lifters).	P-1	P-1	P-3	
Inspect and replace camshaft and drive belt/chain; includes checking drive gear wear and backlash, end play, sprocket and chain wear, overhead cam drive sprocket(s), drive belt(s), belt tension, tensioners, camshaft reluctor ring/tone-wheel, and valve timing components; verify correct camshaft timing.	P-1	P-1		
Establish camshaft position sensor indexing.	P-1	P-1		
Inspect valve springs for squareness and free height comparison; determine needed action.	P-3			
Replace valve stem seals on an assembled engine; inspect valve spring retainers, locks/keepers, and valve lock/keeper grooves; determine needed action.	P-3			
Inspect valve guides for wear; check valve stem-to-guide clearance; determine needed action.	P-3			
Inspect valves and valve seats; determine needed action.	P-3			
Check valve spring assembled height and valve stem height; determine needed action.	P-3			
Inspect valve lifters; determine needed action.	P-2			
Inspect and/or measure camshaft for runout, journal wear and lobe wear.	P-3			
Inspect camshaft bearing surface for wear, damage, out-of-round, and alignment; determine needed action.	P-3			
Identify components of the cylinder head and valve train.			P-1	
Engine Block Assembly Diagnosis and Repair				
Remove, inspect, and/or replace crankshaft vibration damper (harmonic balancer).	P-1	P-2		
Disassemble engine block; clean and prepare components for inspection and reassembly.	P-1			

(*continued*)

Task List	MAST	AST	MLR	Chapter
Inspect engine block for visible cracks, passage condition, core and gallery plug condition, and surface warpage; determine needed action.	P-2			
Inspect and measure cylinder walls/sleeves for damage, wear, and ridges; determine needed action.	P-2			
Deglaze and clean cylinder walls.	P-2			
Inspect and measure camshaft bearings for wear, damage, out-of-round, and alignment; determine needed action.	P-3			
Inspect crankshaft for straightness, journal damage, keyway damage, thrust flange and sealing surface condition, and visual surface cracks; check oil passage condition; measure end play and journal wear; check crankshaft position sensor reluctor ring (where applicable); determine needed action.	P-1			
Inspect main and connecting rod bearings for damage and wear; determine needed action.	P-2			
Identify piston and bearing wear patterns that indicate connecting rod alignment and main bearing bore problems; determine needed action.	P-3			
Inspect and measure piston skirts and ring lands; determine needed action.	P-2			
Determine piston-to-bore clearance.	P-2			
Inspect, measure, and install piston rings.	P-2			
Inspect auxiliary shaft(s) (balance, intermediate, idler, counterbalance and/or silencer); inspect shaft(s) and support bearings for damage and wear; determine needed action; reinstall and time.	P-2			
Assemble engine block.	P-1			
Lubrication and Cooling Systems Diagnosis and Repair				
Perform cooling system pressure and dye tests to identify leaks; check coolant condition and level; inspect and test radiator, pressure cap, coolant recovery tank, heater core, and galley plugs; determine needed action.	P-1	P-1	P-1	
Identify causes of engine overheating.	P-1	P-1		
Inspect, replace, and/or adjust drive belts, tensioners, and pulleys; check pulley and belt alignment.	P-1	P-1	P-1	
Inspect and/or test coolant; drain and recover coolant; flush and refill cooling system; use proper fluid type per manufacturer specification; bleed air as required.	P-1	P-1	P-1	
Inspect, remove, and replace water pump.	P-2	P-2		
Remove and replace radiator.	P-2	P-2		
Remove, inspect, and replace thermostat and gasket/seal.	P-1	P-1	P-1	
Inspect and test fan(s), fan clutch (electrical or mechanical), fan shroud, and air dams; determine needed action.	P-1	P-1		
Perform oil pressure tests; determine needed action.	P-1	P-1		
Perform engine oil and filter change; use proper fluid type per manufacturer specification.	P-1	P-1	P-1	
Inspect auxiliary coolers; determine needed action.	P-3	P-3		
Inspect, test, and replace oil temperature and pressure switches and sensors.	P-2	P-2		
Inspect oil pump gears or rotors, housing, pressure relief devices, and pump drive; perform needed action.	P-2			
Identify components of the lubrication and cooling systems.			P-1	
AUTOMATIC TRANSMISSION AND TRANSAXLE				
General: Transmission and Transaxle Diagnosis				
Identify and interpret transmission/transaxle concerns, differentiate between engine performance and transmission/transaxle concerns; determine needed action.	P-1	P-1		
Research vehicle service information including fluid type, vehicle service history, service precautions, and technical service bulletins.	P-1	P-1	P-1	
Diagnose fluid loss and condition concerns; determine needed action.	P-1	P-1		
Check fluid level in a transmission or a transaxle equipped with a dip-stick.	P-1	P-1	P-1	
Check fluid level in a transmission or a transaxle not equipped with a dip-stick.	P-1	P-1	P-1	

Task List	MAST	AST	MLR	Chapter
Perform pressure tests (including transmissions/transaxles equipped with electronic pressure control); determine needed action.	P-1			
Diagnose noise and vibration concerns; determine needed action.	P-2			
Perform stall test; determine needed action.	P-2	P-2		
Perform lock-up converter system tests; determine needed action.	P-3	P-3		
Diagnose transmission/transaxle gear reduction/multiplication concerns using driving, driven, and held member (power flow) principles.	P-1	P-1		
Diagnose electronic transmission/transaxle control systems using appropriate test equipment and service information.	P-1			
Diagnose pressure concerns in a transmission using hydraulic principles (Pascal's Law).	P-2	P-2		
Demonstrate knowledge of pressure test including transmissions/transaxles equipped with electronic pressure control.		P-3		
Diagnose electronic transmission/transaxle control systems using appropriate test equipment and service information.		P-2		
Check transmission fluid condition; check for leaks.			P-2	
Identify drive train components and configuration.			P-1	
In-Vehicle Transmission/Transaxle Maintenance and Repair				
Inspect, adjust, and/or replace external manual valve shift linkage, transmission range sensor/switch, and/or park/neutral position switch.	P-1	P-1	P-2	
Inspect for leakage; replace external seals, gaskets, and bushings.	P-2	P-2	P-1	
Inspect, test, adjust, repair, and/or replace electrical/electronic components and circuits including computers, solenoids, sensors, relays, terminals, connectors, switches, and harnesses; demonstrate understanding of the relearn procedure.	P-1	P-1		
Drain and replace fluid and filter(s); use proper fluid type per manufacturer specification.	P-1	P-1	P-1	
Inspect, replace and align powertrain mounts.	P-2	P-2	P-2	
Off-Vehicle Transmission and Transaxle Repair				
Remove and reinstall transmission/transaxle and torque converter; inspect engine core plugs, rear crankshaft seal, dowel pins, dowel pin holes, and mounting surfaces.	P-2	P-2		
Inspect, leak test, flush, and/or replace transmission/transaxle oil cooler, lines, and fittings.	P-1	P-1		
Inspect converter flex (drive) plate, converter attaching bolts, converter pilot, converter pump drive surfaces, converter end play, and crankshaft pilot bore.	P-2	P-2		
Describe the operational characteristics of a continuously variable transmission (CVT).	P-3	P-3	P-3	
Describe the operational characteristics of a hybrid vehicle drive train.	P-3	P-3	P-3	
Disassemble, clean, and inspect transmission/transaxle.	P-1			
Inspect, measure, clean, and replace valve body (includes surfaces, bores, springs, valves, switches, solenoids, sleeves, retainers, brackets, check valves/balls, screens, spacers, and gaskets).	P-2			
Inspect servo and accumulator bores, pistons, seals, pins, springs, and retainers; determine needed action.	P-2			
Assemble transmission/transaxle.	P-1			
Inspect, measure, and reseal oil pump assembly and components.	P-2			
Measure transmission/transaxle end play and/or preload; determine needed action.	P-1			
Inspect, measure, and/or replace thrust washers and bearings.	P-2			
Inspect oil delivery circuits, including seal rings, ring grooves, and sealing surface areas, feed pipes, orifices, and check valves/balls.	P-2			
Inspect bushings; determine needed action.	P-2			
Inspect and measure planetary gear assembly components; determine needed action.	P-2			
Inspect case bores, passages, bushings, vents, and mating surfaces; determine needed action.	P-2			

(*continued*)

Task List	MAST	AST	MLR	Chapter
Diagnose and inspect transaxle drive, link chains, sprockets, gears, bearings, and bushings; perform needed action.	P-2			
Inspect measure, repair, adjust or replace transaxle final drive components.	P-2			
Inspect clutch drum, piston, check-balls, springs, retainers, seals, friction plates, pressure plates, and bands; determine needed action.	P-2			
Measure clutch pack clearance; determine needed action.	P-1			
Air test operation of clutch and servo assemblies.	P-1			
Inspect one-way clutches, races, rollers, sprags, springs, cages, retainers; determine needed action.	P-2			
MANUAL DRIVE TRAIN AND AXLES				
General: Drive Train Diagnosis				
Identify and interpret drive train concerns; determine needed action.	P-1	P-1		
Research vehicle service information including fluid type, vehicle service history, service precautions, and technical service bulletins.	P-1	P-1	P-1	
Check fluid condition; check for leaks; determine needed action.	P-1	P-1	P-2	
Drain and refill manual transmission/transaxle and final drive unit; use proper fluid type per manufacturer specification.	P-1	P-1	P-1	
Identify manual drive train and axle components and configuration.			P-1	
Clutch Diagnosis and Repair				
Diagnose clutch noise, binding, slippage, pulsation, and chatter; determine needed action.	P-1	P-1		
Inspect clutch pedal linkage, cables, automatic adjuster mechanisms, brackets, bushings, pivots, and springs; perform needed action.	P-1	P-1		
Inspect and/or replace clutch pressure plate assembly, clutch disc, release (throw-out) bearing, linkage, and pilot bearing/bushing (as applicable).	P-1	P-1		
Bleed clutch hydraulic system.	P-1	P-1		
Check and adjust clutch master cylinder fluid level; check for leaks; use proper fluid type per manufacturer specification.	P-1	P-1	P-1	
Inspect flywheel and ring gear for wear, cracks, and discoloration; determine needed action.	P-1	P-1		
Measure flywheel runout and crankshaft end play; determine needed action.	P-2	P-2		
Describe the operation and service of a system that uses a dual mass flywheel.	P-3	P-3		
Check for hydraulic system leaks.			P-1	
Transmission/Transaxle Diagnosis and Repair				
Inspect, adjust, lubricate, and/or replace shift linkages, brackets, bushings, cables, pivots, and levers.	P-2	P-2		
Describe the operational characteristics of an electronically-controlled manual transmission/transaxle.	P-2	P-2	P-2	
Diagnose noise concerns through the application of transmission/transaxle powerflow principles.	P-2			
Diagnose hard shifting and jumping out of gear concerns; determine needed action.	P-2			
Diagnose transaxle final drive assembly noise and vibration concerns; determine needed action.	P-3			
Disassemble, inspect, clean, and reassemble internal transmission/transaxle components.	P-2			
Drive Shaft and Half Shaft, Universal and Constant-Velocity (CV) Joint Diagnosis and Repair (Front, Rear, All-wheel, and Four-wheel drive)				
Diagnose constant-velocity (CV) joint noise and vibration concerns; determine needed action.	P-1	P-1		
Diagnose universal joint noise and vibration concerns; perform needed action.	P-2	P-2		
Inspect, remove, and/or replace bearings, hubs, and seals.	P-1	P-1	P-2	
Inspect, service, and/or replace shafts, yokes, boots, and universal/CV joints.	P-1	P-1	P-2	
Check shaft balance and phasing; measure shaft runout; measure and adjust driveline angles.	P-2	P-2		
Inspect locking hubs.			P-3	
Check for leaks at drive assembly and transfer case seals; check vents; check fluid level; use proper fluid type per manufacturer specification.			P-2	

Task List	MAST	AST	MLR	Chapter
Drive Axle Diagnosis and Repair				
Ring and Pinion Gears and Differential Case Assembly				
Clean and inspect differential case; check for leaks; inspect housing vent.	P-1	P-1	P-1	
Check and adjust differential case fluid level; use proper fluid type per manufacturer specification.	P-1	P-1	P-1	
Drain and refill differential case; use proper fluid type per manufacturer specification.	P-1	P-1		
Drain and refill differential housing.			P-1	
Diagnose noise and vibration concerns; determine needed action.	P-2			
Inspect and replace companion flange and/or pinion seal; measure companion flange runout.	P-2	P-2		
Inspect ring gear and measure runout; determine needed action.	P-3			
Remove, inspect, and/or reinstall drive pinion and ring gear, spacers, sleeves, and bearings.	P-3			
Measure and adjust drive pinion depth.	P-3			
Measure and adjust drive pinion bearing preload.	P-3			
Measure and adjust side bearing preload and ring and pinion gear total backlash and backlash variation on a differential carrier assembly (threaded cup or shim types).	P-3			
Check ring and pinion tooth contact patterns; perform needed action.	P-3			
Disassemble, inspect, measure, adjust, and/or replace differential pinion gears (spiders), shaft, side gears, side bearings, thrust washers, and case.	P-3			
Reassemble and reinstall differential case assembly; measure runout; determine needed action.	P-3			
Limited Slip Differential				
Diagnose noise, slippage, and chatter concerns; determine needed action.	P-3			
Measure rotating torque; determine needed action.	P-3			
Drive Axles				
Inspect and replace drive axle wheel studs.	P-1	P-1	P-1	
Remove and replace drive axle shafts.	P-1	P-1		
Inspect and replace drive axle shaft seals, bearings, and retainers.	P-2	P-2		
Measure drive axle flange runout and shaft end play; determine needed action.	P-2	P-2		
Diagnose drive axle shafts, bearings, and seals for noise, vibration, and fluid leakage concerns; determine needed action.	P-2			
Four-wheel Drive/All-wheel Drive Component Diagnosis and Repair				
Inspect, adjust, and repair shifting controls (mechanical, electrical, and vacuum), bushings, mounts, levers, and brackets.	P-3	P-3		
Inspect locking hubs; determine needed action.	P-3	P-3		
Check for leaks at drive assembly and transfer case seals; check vents; check fluid level; use proper fluid type per manufacturer specification.	P-3	P-3		
Identify concerns related to variations in tire circumference and/or final drive ratios.	P-2	P-2		
Diagnose noise, vibration, and unusual steering concerns; determine needed action.	P-3			
Diagnose, test, adjust, and/or replace electrical/electronic components of four-wheel drive/all-wheel drive systems.	P-2			
Disassemble, service, and reassemble transfer case and components.	P-2			
SUSPENSION AND STEERING				
General: Suspension and Steering Systems				
Research vehicle service information including fluid type, vehicle service history, service precautions, and technical service bulletins.	P-1	P-1	P-1	
Identify and interpret suspension and steering system concerns; determine needed action.	P-1	P-2	P-1	

(*continued*)

Task List	MAST	AST	MLR	Chapter
Steering Systems Diagnosis and Repair				
Disable and enable supplemental restraint system (SRS); verify indicator lamp operation.	P-1	P-1	P-1	
Remove and replace steering wheel; center/time supplemental restraint system (SRS) coil (clock spring).	P-1	P-1		
Diagnose steering column noises, looseness, and binding concerns (including tilt/telescoping mechanisms); determine needed action.	P-2	P-2		
Diagnose power steering gear (non-rack and pinion) binding, uneven turning effort, looseness, hard steering, and noise concerns; determine needed action.	P-2	P-2		
Diagnose power steering gear (rack and pinion) binding, uneven turning effort, looseness, hard steering, and noise concerns; determine needed action.	P-2	P-2		
Inspect steering shaft universal-joint(s), flexible coupling(s), collapsible column, lock cylinder mechanism, and steering wheel; determine needed action.	P-2	P-2		
Remove and replace rack and pinion steering gear; inspect mounting bushings and brackets.	P-2	P-1		
Inspect rack and pinion steering gear inner tie rod ends (sockets) and bellows boots; replace as needed.	P-1	P-1	P-1	
Inspect power steering fluid level and condition.	P-1	P-1	P-1	
Flush, fill, and bleed power steering system; use proper fluid type per manufacturer specification.	P-2	P-2	P-2	
Inspect for power steering fluid leakage; determine needed action.	P-1	P-1	P-1	
Remove, inspect, replace, and/or adjust power steering pump drive belt.	P-1	P-1	P-1	
Remove and reinstall power steering pump.	P-2	P-2		
Remove and reinstall press fit power steering pump pulley; check pulley and belt alignment.	P-2	P-2		
Inspect, remove and/or replace power steering hoses and fittings.	P-2	P-2	P-2	
Inspect, remove and/or replace pitman arm, relay (centerlink/intermediate) rod, idler arm, mountings, and steering linkage damper.	P-2	P-2	P-1	
Inspect, replace, and/or adjust tie rod ends (sockets), tie rod sleeves, and clamps.	P-1	P-1	P-1	
Inspect, test and diagnose electrically- assisted power steering systems (including using a scan tool); determine needed action.	P-2			
Identify hybrid vehicle power steering system electrical circuits and safety precautions.	P-2	P-2	P-2	
Test power steering system pressure; determine needed action.	P-2			
Inspect electric power steering assist system.		P-3	P-2	
Suspension Systems Diagnosis and Repair				
Diagnose short and long arm suspension system noises, body sway, and uneven ride height concerns; determine needed action.	P-1	P-1		
Diagnose strut suspension system noises, body sway, and uneven ride height concerns; determine needed action.	P-1	P-1		
Inspect, remove, and/or replace upper and lower control arms, bushings, shafts, and rebound bumpers.	P-3	P-3	P-1	
Inspect, remove, and/or replace strut rods and bushings.	P-3	P-3		
Inspect, remove, and/or replace upper and/or lower ball joints (with or without wear indicators).	P-2	P-2	P-1	
Inspect, remove, and/or replace steering knuckle assemblies.	P-3	P-3		
Inspect, remove and/or replace short and long arm suspension system coil springs and spring insulators.	P-3	P-3		
Inspect, remove, and/or replace torsion bars and mounts.	P-3	P-3	P-1	
Inspect, remove, and/or replace front/rear stabilizer bar (sway bar) bushings, brackets, and links.	P-3	P-3	P-1	
Inspect, remove, and/or replace strut cartridge or assembly, strut coil spring, insulators (silencers), and upper strut bearing mount.	P-3	P-3	P-2	
Inspect, remove, and/or replace track bar, strut rods/radius arms, and related mounts and bushings.	P-3	P-3	P-1	
Inspect rear suspension system leaf spring(s), spring insulators (silencers), shackles, brackets, bushings, center pins/bolts, and mounts.	P-1	P-1	P-1	

Task List	MAST	AST	MLR	Chapter
Inspect front strut bearing and mount.			P-1	
Inspect rear suspension system lateral links/arms (track bars), control (trailing) arms.			P-1	
Related Suspension and Steering Service				
Inspect, remove, and/or replace shock absorbers; inspect mounts and bushings.	P-1	P-1	P-1	
Remove, inspect, service and/or replace front and rear wheel bearings.	P-1	P-1		
Describe the function of suspension and steering control systems and components, (i.e. active suspension and stability control).	P-3	P-3	P-3	
Wheel Alignment Diagnosis, Adjustment, and Repair				
Diagnose vehicle wander, drift, pull, hard steering, bump steer, memory steer, torque steer, and steering return concerns; determine needed action.	P-1	P-1		
Perform prealignment inspection; measure vehicle ride height; determine needed action.	P-1	P-1	P-1	
Describe alignment angles (camber, caster, and toe).			P-1	
Prepare vehicle for wheel alignment on alignment machine; perform four-wheel alignment by checking and adjusting front and rear wheel caster, camber and toe as required; center steering wheel.	P-1	P-1		
Check toe-out-on-turns (turning radius); determine needed action.	P-2	P-2		
Check steering axis inclination (SAI) and included angle; determine needed action.	P-2	P-2		
Check rear wheel thrust angle; determine needed action.	P-1	P-1		
Check for front wheel setback; determine needed action.	P-2	P-2		
Check front and/or rear cradle (subframe) alignment; determine needed action.	P-3	P-3		
Reset steering angle sensor.	P-2	P-2		
Wheels and Tires Diagnosis and Repair				
Inspect tire condition; identify tire wear patterns; check for correct tire size, application (load and speed ratings), and air pressure as listed on the tire information placard/label.	P-1	P-1	P-1	
Diagnose wheel/tire vibration, shimmy, and noise; determine needed action.	P-2	P-2		
Rotate tires according to manufacturer's recommendation including vehicles equipped with tire pressure monitoring systems (TPMS).	P-1	P-1	P-1	
Measure wheel, tire, axle flange, and hub runout; determine needed action.	P-2	P-2		
Diagnose tire pull problems; determine needed action.	P-1	P-1		
Dismount, inspect, and remount tire on wheel; balance wheel and tire assembly.	P-1	P-1	P-1	
Dismount, inspect, and remount tire on wheel equipped with tire pressure monitoring system sensor.	P-1	P-1	P-1	
Inspect tire and wheel assembly for air loss; perform needed action.	P-1	P-1	P-1	
Repair tire following vehicle manufacturer approved procedure.	P-1	P-1	P-1	
Identify indirect and direct tire pressure monitoring system (TPMS); calibrate system; verify operation of instrument panel lamps.	P-1	P-1	P-1	
Demonstrate knowledge of steps required to remove and replace sensors in a tire pressure monitoring system (TPMS) including relearn procedure.	P-1	P-1	P-1	
BRAKES				
General: Brake Systems Diagnosis				
Identify and interpret brake system concerns; determine needed action.	P-1	P-1		
Research vehicle service information including fluid type, vehicle service history, service precautions, and technical service bulletins.	P-1	P-1	P-1	
Describe procedure for performing a road test to check brake system operation including an anti-lock brake system (ABS).	P-1	P-1	P-1	
Install wheel and torque lug nuts.	P-1	P-1	P-1	
Identify brake system components and configuration.			P-1	

(*continued*)

Task List	MAST	AST	MLR	Chapter
Hydraulic System Diagnosis and Repair				
Diagnose pressure concerns in the brake system using hydraulic principles (Pascal's Law).	P-1	P-1		
Measure brake pedal height, travel, and free play (as applicable); determine needed action.	P-1	P-1		
Describe proper brake pedal height, travel, and feel.			P-1	
Check master cylinder for internal/external leaks and proper operation; determine needed action.	P-1	P-1	P-1	
Remove, bench bleed, and reinstall master cylinder.	P-1	P-1		
Diagnose poor stopping, pulling or dragging concerns caused by malfunctions in the hydraulic system; determine needed action.	P-1	P-3		
Inspect brake lines, flexible hoses, and fittings for leaks, dents, kinks, rust, cracks, bulging, wear; and loose fittings/supports; determine needed action.	P-1	P-1	P-1	
Replace brake lines, hoses, fittings, and supports.	P-2	P-2		
Fabricate brake lines using proper material and flaring procedures (double flare and ISO types).	P-2	P-2		
Select, handle, store, and fill brake fluids to proper level; use proper fluid type per manufacturer specification.	P-1	P-1	P-1	
Inspect, test, and/or replace components of brake warning light system.	P-3	P-3		
Identify components of hydraulic brake warning light system.	P-2	P-2	P-3	
Bleed and/or flush brake system.	P-1	P-1	P-1	
Test brake fluid for contamination.	P-1	P-1	P-1	
Drum Brake Diagnosis and Repair				
Diagnose poor stopping, noise, vibration, pulling, grabbing, dragging or pedal pulsation concerns; determine needed action.	P-1	P-1		
Remove, clean, and inspect brake drum; measure brake drum diameter; determine serviceability.	P-1	P-1	P-1	
Refinish brake drum and measure final drum diameter; compare with specification.	P-1	P-1	P-1	
Remove, clean, inspect, and/or replace brake shoes, springs, pins, clips, levers, adjusters/self-adjusters, other related brake hardware, and backing support plates; lubricate and reassemble.	P-1	P-1	P-1	
Inspect wheel cylinders for leaks and proper operation; remove and replace as needed.	P-2	P-2	P-2	
Pre-adjust brake shoes and parking brake; install brake drums or drum/hub assemblies and wheel bearings; perform final checks and adjustments.	P-1	P-1	P-1	
Disc Brake Diagnosis and Repair				
Diagnose poor stopping, noise, vibration, pulling, grabbing, dragging, or pulsation concerns; determine needed action.	P-1	P-1		
Remove and clean caliper assembly; inspect for leaks, damage, and wear; determine needed action.	P-1	P-1	P-1	
Inspect caliper mounting and slides/pins for proper operation, wear, and damage; determine needed action.	P-1	P-1	P-1	
Remove, inspect, and/or replace brake pads and retaining hardware; determine needed action.	P-1	P-1	P-1	
Lubricate and reinstall caliper, brake pads, and related hardware; seat brake pads; inspect for leaks.	P-1	P-1	P-1	
Clean and inspect rotor and mounting surface; measure rotor thickness, thickness variation, and lateral runout; determine needed action.	P-1	P-1	P-1	
Remove and reinstall/replace rotor.	P-1	P-1	P-1	
Refinish rotor on vehicle; measure final rotor thickness and compare with specification.	P-1	P-1	P-1	
Refinish rotor off vehicle; measure final rotor thickness and compare with specification.	P-1	P-1	P-1	
Retract and re-adjust caliper piston on an integrated parking brake system.	P-2	P-2	P-2	
Check brake pad wear indicator; determine needed action.	P-1	P-1	P-1	
Describe importance of operating vehicle to burnish/break-in replacement brake pads according to manufacturer's recommendations.	P-1	P-1	P-1	

Task List	MAST	AST	MLR	Chapter
Power-Assist Units Diagnosis and Repair				
Check brake pedal travel with and without engine running to verify proper power booster operation.	P-2	P-2	P-2	
Identify components of the brake power assist system (vacuum and hydraulic); check vacuum supply (manifold or auxiliary pump) to vacuum- type power booster.	P-1	P-1	P-1	
Inspect vacuum-type power booster unit for leaks; inspect the check-valve for proper operation; determine needed action.	P-1	P-1		
Inspect and test hydraulically-assisted power brake system for leaks and proper operation; determine needed action.	P-3	P-3		
Measure and adjust master cylinder pushrod length.	P-3	P-3		
Related Systems (i.e. Wheel Bearings, Parking Brakes, Electrical) Diagnosis and Repair				
Diagnose wheel bearing noises, wheel shimmy, and vibration concerns; determine needed action.	P-1	P-2		
Remove, clean, inspect, repack, and install wheel bearings; replace seals; install hub and adjust bearings.	P-2	P-2	P-1	
Check parking brake system and components for wear, binding, and corrosion; clean, lubricate, adjust and/or replace as needed.	P-1	P-1	P-2	
Check parking brake operation and parking brake indicator light system operation; determine needed action.	P-1	P-1	P-1	
Check operation of brake stop light system.	P-1	P-1	P-1	
Replace wheel bearing and race.	P-3	P-3	P-2	
Remove, reinstall, and/or replace sealed wheel bearing assembly.	P-1	P-1		
Inspect and replace wheel studs.	P-1	P-1	P-1	
Electronic Brake Control Systems: Antilock Brake (ABS), Traction Control (TCS), and Electronic Stability Control (ESC) Systems Diagnosis and Repair				
Identify and inspect electronic brake control system components (ABS, TCS, ESC); determine needed action.	P-1	P-1		
Identify traction control/vehicle stability control system components.			P-3	
Describe the operation of a regenerative braking system.	P-3	P-3	P-3	
Diagnose poor stopping, wheel lock-up, abnormal pedal feel, unwanted application, and noise concerns associated with the electronic brake control system; determine needed action.	P-2			
Diagnose electronic brake control system electronic control(s) and components by retrieving diagnostic trouble codes, and/or using recommended test equipment; determine needed action.	P-2			
Depressurize high-pressure components of an electronic brake control system.	P-2			
Bleed the electronic brake control system hydraulic circuits.	P-1			
Test, diagnose, and service electronic brake control system speed sensors (digital and analog), toothed ring (tone wheel), and circuits using a graphing multimeter (GMM)/digital storage oscilloscope (DSO) (includes output signal, resistance, shorts to voltage/ground, and frequency data).	P-2			
Diagnose electronic brake control system braking concerns caused by vehicle modifications (tire size, curb height, final drive ratio, etc.).	P-1			
ELECTRICAL/ELECTRONIC SYSTEMS				
General: Electrical System Diagnosis				
Research vehicle service information including vehicle service history, service precautions, and technical service bulletins.	P-1	P-1	P-1	5
Demonstrate knowledge of electrical/electronic series, parallel, and series-parallel circuits using principles of electricity (Ohm's Law).	P-1	P-1	P-1	
Use wiring diagrams to trace electrical/electronic circuits.			P-1	5

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Task List	MAST	AST	MLR	Chapter
Demonstrate proper use of a digital multimeter (DMM) when measuring source voltage, voltage drop (including grounds), current flow and resistance.	P-1	P-1	P-1	6
Demonstrate knowledge of the causes and effects from shorts, grounds, opens, and resistance problems in electrical/electronic circuits.	P-1	P-1	P-1	6
Demonstrate proper use of a test light on an electrical circuit.	P-1	P-1	P-2	
Use fused jumper wires to check operation of electrical circuits.	P-1	P-1	P-2	6
Use wiring diagrams during the diagnosis (troubleshooting) of electrical/electronic circuit problems.	P-1	P-1		5
Diagnose the cause(s) of excessive key-off battery drain (parasitic draw); determine needed action.	P-1	P-1		6
Measure key-off battery drain (parasitic draw).			P-1	6
Inspect and test fusible links, circuit breakers, and fuses; determine needed action.	P-1	P-1	P-1	
Inspect, test, repair, and/or replace components, connectors, terminals, harnesses, and wiring in electrical/electronic systems (including solder repairs); determine needed action.	P-1	P-1	P-1	
Check electrical/electronic circuit waveforms; interpret readings and determine needed repairs.	P-2			11
Repair data bus wiring harness.	P-1			
Identify electrical/electronic system components and configurations.			P-1	5
Battery Diagnosis and Service				
Perform battery state-of-charge test; determine needed action.	P-1	P-1	P-1	
Confirm proper battery capacity for vehicle application; perform battery capacity and load test; determine needed action.	P-1	P-1	P-1	
Maintain or restore electronic memory functions.	P-1	P-1	P-1	
Inspect and clean battery; fill battery cells; check battery cables, connectors, clamps, and hold-downs.	P-1	P-1	P-1	
Perform slow/fast battery charge according to manufacturer's recommendations.	P-1	P-1	P-1	
Jump-start vehicle using jumper cables and a booster battery or an auxiliary power supply.	P-1	P-1	P-1	
Identify safety precautions for high voltage systems on electric, hybrid, hybrid-electric, and diesel vehicles.	P-2	P-2	P-2	
Identify electrical/electronic modules, security systems, radios, and other accessories that require reinitialization or code entry after reconnecting vehicle battery.	P-1	P-1	P-1	
Identify hybrid vehicle auxiliary (12v) battery service, repair, and test procedures.	P-2	P-2	P-2	
Starting System Diagnosis and Repair				
Perform starter current draw tests; determine needed action.	P-1	P-1	P-1	
Perform starter circuit voltage drop tests; determine needed action.	P-1	P-1	P-1	
Inspect and test starter relays and solenoids; determine needed action.	P-2	P-2	P-2	
Remove and install starter in a vehicle.	P-1	P-1	P-1	
Inspect and test switches, connectors, and wires of starter control circuits; determine needed action.	P-2	P-2	P-2	6
Differentiate between electrical and engine mechanical problems that cause a slow-crank or a no-crank condition.	P-2	P-2		
Demonstrate knowledge of an automatic idle-stop/start-stop system.	P-2	P-2	P-3	
Charging System Diagnosis and Repair				
Perform charging system output test; determine needed action.	P-1	P-1	P-1	
Diagnose (troubleshoot) charging system for causes of undercharge, no-charge, or overcharge conditions.	P-1	P-1		
Inspect, adjust, and/or replace generator (alternator) drive belts; check pulleys and tensioners for wear; check pulley and belt alignment.	P-1	P-1	P-1	
Remove, inspect, and/or replace generator (alternator).	P-1	P-1	P-2	
Perform charging circuit voltage drop tests; determine needed action.	P-1	P-1	P-2	

Task List	MAST	AST	MLR	Chapter
Lighting Systems Diagnosis and Repair				
Diagnose (troubleshoot) the causes of brighter-than-normal, intermittent, dim, or no light operation; determine needed action.	P-1	P-1		
Inspect interior and exterior lamps and sockets including headlights and auxiliary lights (fog lights/driving lights); replace as needed.	P-1	P-1	P-1	8
Aim headlights.	P-2	P-2	P-2	8
Identify system voltage and safety precautions associated with high-intensity discharge headlights.	P-2	P-2	P-2	8
Instrument Cluster and Driver Information Systems Diagnosis and Repair				
Inspect and test gauges and gauge sending units for causes of abnormal readings; determine needed action.	P-2	P-2		10
Diagnose (troubleshoot) the causes of incorrect operation of warning devices and other driver information systems; determine needed action.	P-2	P-2		10
Reset maintenance indicators as required.	P-2	P-2		
Body Electrical Systems Diagnosis and Repair				
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, back-up camera, park assist, cruise control, and auto dimming headlamps); determine needed repairs.	P-2	P-3		9
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.	P-2	P-3		
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.	P-3	P-3		16
Diagnose operation of safety systems and related circuits (such as: horn, airbags, seat belt pretensioners, occupancy classification, wipers, washers, speed control/collision avoidance, heads-up display, park assist, and back-up camera); determine needed repairs.	P-1	P-3		15
Diagnose body electronic systems circuits using a scan tool; check for module communication errors (data communication bus systems); determine needed action.	P-2	P-3		
Describe the process for software transfer, software updates, or reprogramming of electronic modules.	P-2	P-3		
Disable and enable supplemental restraint system (SRS); verify indicator lamp operation.			P-1	
Remove and reinstall door panel.			P-1	
Describe the operation of keyless entry/remote-start systems.			P-3	
Verify operation of instrument panel gauges and warning/indicator lights; reset maintenance indicators.			P-1	
Verify windshield wiper and washer operation; replace wiper blades.			P-1	
HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)				
General: A/C System Diagnosis and Repair				
Identify and interpret heating and air conditioning problems; determine needed action.	P-1	P-1		
Research vehicle service information including refrigerant/oil type, vehicle service history, service precautions, and technical service bulletins.	P-1	P-1	P-1	
Identify heating, ventilation and air conditioning (HVAC) components and configuration.			P-1	
Performance test A/C system; identify problems.	P-1	P-1		
Identify abnormal operating noises in the A/C system; determine needed action.	P-2	P-2		
Identify refrigerant type; select and connect proper gauge set/test equipment; record temperature and pressure readings.	P-1	P-1		
Leak test A/C system; determine needed action.	P-1	P-1		
Inspect condition of refrigerant oil removed from A/C system; determine needed action.	P-2	P-2		
Determine recommended oil and oil capacity for system application.	P-1	P-1		
Using a scan tool, observe and record related HVAC data and trouble codes.	P-3	P-3		

(*continued*)

Task List	MAST	AST	MLR	Chapter
Refrigeration System Component Diagnosis and Repair				
Inspect, remove, and/or replace A/C compressor drive belts, pulleys, tensioners and visually inspect A/C components for signs of leaks; determine needed action.	P-1	P-1	P-1	
Inspect, test, service and/or replace A/C compressor clutch components and/or assembly; check compressor clutch air gap; adjust as needed.	P-2	P-2		
Remove, inspect, reinstall, and/or replace A/C compressor and mountings; determine recommended oil type and quantity.	P-2	P-2		
Identify hybrid vehicle A/C system electrical circuits and service/safety precautions.	P-2	P-2	P-2	
Determine need for an additional A/C system filter; perform needed action.	P-3	P-3		
Remove and inspect A/C system mufflers, hoses, lines, fittings, O-rings, seals, and service valves; perform needed action.	P-2	P-2		
Inspect for proper A/C condenser airflow; determine needed action.	P-1	P-1		
Inspect A/C condenser for airflow restrictions; determine necessary action.			P-1	
Remove, inspect, and replace receiver/drier or accumulator/drier; determine recommended oil type and quantity.	P-2	P-2		
Remove, inspect, and install expansion valve or orifice (expansion) tube.	P-1	P-1		
Inspect evaporator housing water drain; perform needed action.	P-1	P-1		
Diagnose A/C system conditions that cause the protection devices (pressure, thermal, and/or control module) to interrupt system operation; determine needed action.	P-2			
Determine procedure to remove and reinstall evaporator; determine required oil type and quantity.	P-2	P-2		
Remove, inspect, reinstall, and/or replace condenser; determine required oil type and quantity.	P-2			
Heating, Ventilation, and Engine Cooling Systems Diagnosis and Repair				
Inspect engine cooling and heater systems hoses and pipes; perform needed action.	P-1	P-1	P-1	
Inspect and test heater control valve(s); perform needed action.	P-2	P-2		
Diagnose temperature control problems in the HVAC system; determine needed action.	P-2			
Determine procedure to remove, inspect, reinstall, and/or replace heater core.	P-2	P-2		
Operating Systems and Related Controls Diagnosis and Repair				
Inspect and test HVAC system blower motors, resistors, switches, relays, wiring, and protection devices; determine needed action.	P-1	P-1		
Diagnose A/C compressor clutch control systems; determine needed action.	P-2	P-2		
Diagnose malfunctions in the vacuum, mechanical, and electrical components and controls of the heating, ventilation, and A/C (HVAC) system; determine needed action.	P-2	P-2		
Inspect and test HVAC system control panel assembly; determine needed action.	P-3	P-3		
Inspect and test HVAC system control cables, motors, and linkages; perform needed action.	P-3	P-3		
Inspect HVAC system ducts, doors, hoses, cabin filters, and outlets; perform needed action.	P-1	P-1	P-1	
Identify the source of HVAC system odors.	P-2	P-2	P-2	
Check operation of automatic or semi-automatic HVAC control systems; determine needed action.	P-2	P-2		
Refrigerant Recovery, Recycling, and Handling				
Perform correct use and maintenance of refrigerant handling equipment according to equipment manufacturer's standards.	P-1	P-1		
Identify A/C system refrigerant; test for sealants; recover, evacuate, and charge A/C system; add refrigerant oil as required.	P-1	P-1		
Recycle, label, and store refrigerant.	P-1	P-1		

Task List	MAST	AST	MLR	Chapter
ENGINE PERFORMANCE				
General: Engine Diagnosis				
Identify and interpret engine performance concerns; determine needed action.	P-1	P-1		
Research vehicle service information including vehicle service history, service precautions, and technical service bulletins.	P-1	P-1	P-1	
Diagnose abnormal engine noises or vibration concerns; determine needed action.	P-3	P-3		
Diagnose the cause of excessive oil consumption, coolant consumption, unusual exhaust color, odor, and sound; determine needed action.	P-2	P-2		
Perform engine absolute manifold pressure tests (vacuum/boost); determine needed action.	P-1	P-1	P-2	
Perform cylinder power balance test; determine needed action.	P-2	P-2	P-2	
Perform cylinder cranking and running compression tests; determine needed action.	P-1	P-1	P-2	
Perform cylinder leakage test; determine needed action.	P-1	P-1	P-2	
Diagnose engine mechanical, electrical, electronic, fuel, and ignition concerns; determine needed action.	P-2	P-2		
Verify engine operating temperature; determine needed action.	P-1	P-1	P-1	
Verify correct camshaft timing including engines equipped with variable valve timing systems (VVT).	P-1	P-1		
Remove and replace spark plugs; inspect secondary ignition components for wear and damage.			P-1	
Computerized Controls Diagnosis and Repair				
Retrieve and record diagnostic trouble codes (DTC), OBD monitor status, and freeze frame data; clear codes when applicable.	P-1	P-1	P-1	
Access and use service information to perform step-by-step (troubleshooting) diagnosis.	P-1	P-1		
Perform active tests of actuators using a scan tool; determine needed action.	P-1	P-2		
Describe the use of OBD monitors for repair verification.	P-1	P-1	P-1	
Diagnose the causes of emissions or driveability concerns with stored or active diagnostic trouble codes (DTC); obtain, graph, and interpret scan tool data.	P-1			
Diagnose emissions or driveability concerns without stored or active diagnostic trouble codes; determine needed action.	P-1			
Inspect and test computerized engine control system sensors, powertrain/engine control module (PCM/ECM), actuators, and circuits using a graphing multimeter (GMM)/digital storage oscilloscope (DSO); perform needed action.	P-2			
Diagnose driveability and emissions problems resulting from malfunctions of interrelated systems (cruise control, security alarms, suspension controls, traction controls, HVAC, automatic transmissions, non-OEM installed accessories, or similar systems); determine needed action.	P-2			
Ignition System Diagnosis and Repair				
Diagnose (troubleshoot) ignition system related problems such as no-starting, hard starting, engine misfire, poor driveability, spark knock, power loss, poor mileage, and emissions concerns; determine needed action.	P-2	P-2		
Inspect and test crankshaft and camshaft position sensor(s); determine needed action.	P-1	P-1		
Inspect, test, and/or replace ignition control module, powertrain/engine control module; reprogram/initialize as needed.	P-3	P-3		
Remove and replace spark plugs; inspect secondary ignition components for wear and damage.	P-1	P-1		
Fuel, Air Induction, and Exhaust Systems Diagnosis and Repair				
Diagnose (troubleshoot) hot or cold no-starting, hard starting, poor driveability, incorrect idle speed, poor idle, flooding, hesitation, surging, engine misfire, power loss, stalling, poor mileage, dieseling, and emissions problems; determine needed action.	P-2			
Check fuel for contaminants; determine needed action.	P-2	P-2		

(*continued*)

Task List	MAST	AST	MLR	Chapter
Inspect and test fuel pump(s) and pump control system for pressure, regulation, and volume; perform needed action.	P-1	P-1		
Replace fuel filter(s) where applicable.	P-2	P-2	P-2	
Inspect, service, or replace air filters, filter housings, and intake duct work.	P-1	P-1	P-1	
Inspect throttle body, air induction system, intake manifold and gaskets for vacuum leaks and/or unmetered air.	P-2	P-2		
Inspect, test, and/or replace fuel injectors.	P-2	P-2		
Verify idle control operation.	P-1	P-1		
Inspect integrity of the exhaust manifold, exhaust pipes, muffler(s), catalytic converter(s), resonator(s), tail pipe(s), and heat shields; perform needed action.	P-1	P-1	P-1	
Inspect condition of exhaust system hangers, brackets, clamps, and heat shields; determine needed action.	P-1	P-1	P-1	
Perform exhaust system back-pressure test; determine needed action.	P-2	P-2		
Check and refill diesel exhaust fluid (DEF).	P-2	P-2	P-2	
Test the operation of turbocharger/supercharger systems; determine needed action.	P-2			
Emissions Control Systems Diagnosis and Repair				
Diagnose oil leaks, emissions, and driveability concerns caused by the positive crankcase ventilation (PCV) system; determine needed action.	P-3	P-3		
Inspect, test, service, and/or replace positive crankcase ventilation (PCV) filter/breather, valve, tubes, orifices, and hoses; perform needed action.	P-2	P-2	P-2	
Diagnose emissions and driveability concerns caused by the exhaust gas recirculation (EGR) system; inspect, test, service and/or replace electrical/electronic sensors, controls, wiring, tubing, exhaust passages, vacuum/pressure controls, filters, and hoses of exhaust gas recirculation (EGR) systems; determine needed action.	P-2	P-3		
Inspect and test electrical/electronically-operated components and circuits of secondary air injection systems; determine needed action.		P-3		
Diagnose emissions and driveability concerns caused by the secondary air injection system; inspect, test, repair, and/or replace electrical/electronically-operated components and circuits of secondary air injection systems; determine needed action.	P-2			
Diagnose emissions and driveability concerns caused by the evaporative emissions control (EVAP) system; determine needed action.	P-1			
Diagnose emission and driveability concerns caused by catalytic converter system; determine needed action.	P-2	P-3		
Interpret diagnostic trouble codes (DTCs) and scan tool data related to the emissions control systems; determine needed action.	P-2	P-2		
REQUIRED SUPPLEMENTAL TASKS				
Shop and Personal Safety				
Identify general shop safety rules and procedures.	R	R	R	2
Utilize safe procedures for handling of tools and equipment.	R	R	R	3
Identify and use proper placement of floor jacks and jack stands.	R	R	R	
Identify and use proper procedures for safe lift operation.	R	R	R	
Utilize proper ventilation procedures for working within the lab/shop area.	R	R	R	2
Identify marked safety areas.	R	R	R	
Identify the location and the types of fire extinguishers and other fire safety equipment; demonstrate knowledge of the procedures for using fire extinguishers and other fire safety equipment.	R	R	R	2
Identify the location and use of eye wash stations.	R	R	R	
Identify the location of the posted evacuation routes.	R	R	R	2
Comply with the required use of safety glasses, ear protection, gloves, and shoes during lab/shop activities.	R	R	R	2

Task List	MAST	AST	MLR	Chapter
Identify and wear appropriate clothing for lab/shop activities.	R	R	R	2
Secure hair and jewelry for lab/shop activities.	R	R	R	
Demonstrate awareness of the safety aspects of supplemental restraint systems (SRS), electronic brake control systems, and hybrid vehicle high voltage circuits.	R	R	R	
Demonstrate awareness of the safety aspects of high voltage circuits (such as high intensity discharge (HID) lamps, ignition systems, injection systems, etc.).	R	R	R	
Locate and demonstrate knowledge of safety data sheets (SDS).	R	R	R	2
Tools and Equipment				
Identify tools and their usage in automotive applications.	R	R	R	
Identify standard and metric designation.	R	R	R	3
Demonstrate safe handling and use of appropriate tools.	R	R	R	3
Demonstrate proper cleaning, storage, and maintenance of tools and equipment.	R	R	R	3
Demonstrate proper use of precision measuring tools (i.e. micrometer, dial-indicator, dial-caliper).	R	R	R	3
Preparing Vehicle for Service				
Identify information needed and the service requested on a repair order.	R	R	R	1
Identify purpose and demonstrate proper use of fender covers, mats.	R	R	R	
Demonstrate use of the three Cs (concern, cause, and correction).	R	R	R	1
Review vehicle service history.	R	R	R	1
Complete work order to include customer information, vehicle identifying information, customer concern, related service history, cause, and correction.	R	R	R	
Preparing Vehicle for Customer				
Ensure vehicle is prepared to return to customer per school/company policy (floor mats, steering wheel cover, etc.).	R	R	R	
Workplace Employability Skills				
Personal Standards (see Standard 7.9)				
Reports to work daily on time; able to take directions and motivated to accomplish the task at hand.	R	R	R	
Dresses appropriately and uses language and manners suitable for the workplace.	R	R	R	
Maintains appropriate personal hygiene.	R	R	R	
Meets and maintains employment eligibility criteria, such as drug/alcohol-free status, clean driving record, etc.	R	R	R	
Demonstrates honesty, integrity and reliability.	R	R	R	
Work Habits/Ethic (see Standard 7.10)				
Complies with workplace policies/laws.	R	R	R	
Contributes to the success of the team, assists others and requests help when needed.	R	R	R	
Works well with all customers and coworkers.	R	R	R	
Negotiates solutions to interpersonal and workplace conflicts.	R	R	R	
Contributes ideas and initiative.	R	R	R	
Follows directions.	R	R	R	
Communicates (written and verbal) effectively with customers and coworkers.	R	R	R	
Reads and interprets workplace documents; writes clearly and concisely.	R	R	R	
Analyzes and resolves problems that arise in completing assigned tasks.	R	R	R	
Organizes and implements a productive plan of work.	R	R	R	
Uses scientific, technical, engineering and mathematics principles and reasoning to accomplish assigned tasks.	R	R	R	
Identifies and addresses the needs of all customers, providing helpful, courteous and knowledgeable service and advice as needed.	R	R	R	

GLOSSARY

3 Cs A term used to describe the repair documentation process of 1st documenting the customer concern, 2nd documenting the cause of the problem, and 3rd documenting the correction.

aftermarket A company other than the original manufacturer that produces equipment or provides services.

Allen wrench A type of hexagonal drive mechanism for fasteners.

AM/FM radio Vintage technology, though still in use. AM stands for amplitude modulation and FM stands for frequency modulation. These describe how the radio broadcast is transmitted through the air to the radio receiver in the vehicle.

analog For gauges, refers to the type that use a needle or pointer that varies position to indicate the related reading (e.g., fuel level). Analog can also refer to the type of signal used in a circuit. Analog signals are based on a varying voltage.

apps An abbreviation for applications that a customer has on their smartphone.

arc joint pliers Pliers with parallel slip jaws that can increase in size. Also called Channellocks.

armature The motor rotor is divided into segments that contain loops of copper wire. Segments 180 degrees apart are energized by a positive and negative brush that is attached to the source voltage (positive) or ground (negative) in the circuit. This energizes that segment of the rotor to create a magnetic field that interacts with the magnetic field created by the field winding around the pole shoe. The armature has several segments which allow the magnetic field to be essentially continuous. As one set of armature segments rotate away from brush contact, another set takes their place to provide smooth motor speed and torque output.

autonomous The term that describes fully self-driving vehicles. This technology is quickly making its way to the vehicle customer and with it will come a great deal of change not just with the vehicle but also rules of the road.

aviation snips A scissor-like tool for cutting sheet metal.

ballast A device that increase lighting voltage substantially and controls the current to the bulb.

ball-peen (engineer's) hammer A hammer that has a head that is rounded on one end and flat on the other; designed to work with metal items.

barrier cream A cream that looks and feels like a moisturizing cream but has a specific formula to provide extra protection from chemicals and oils.

baud rate The speed at which input data is reviewed by the ECUs processor.

bench vice A device that securely holds material in jaws while it is being worked on.

binary code A computer language based on zeros and ones. Zeros represent low or zero voltage and ones represent a high voltage, which can vary depending on the system, from 2 volts to 12 volts. Each zero or one is called a bit, and eight bits form a byte.

blind rivet A rivet that can be installed from its insertion side.

blind spot monitoring system A system that uses sensors to detect vehicles that are in the blind spot area of the rear quarter of the vehicle. An amber LED in the outside rearview mirrors is usually used to alert the driver that a vehicle is present on that side.

blower motor A motor used to circulate air through the heating, ventilation, and air conditioning system in the vehicle. The blower motor speed may be controlled by adding resistors in series with the motor depending on the blower motor switch position. Most newer vehicles use electronic circuits to control current or voltage to a transistor that is in series with the blower motor and can provide eight or more different fan speeds.

bolt A type of threaded fastener with a thread on one end and a hexagonal head on the other.

bolt cutters Strong cutters available in different sizes, designed to cut through non-hardened bolts and other small-stock material.

bottoming tap A thread-cutting tap designed to cut threads to the bottom of a blind hole.

box-end wrench A wrench or spanner with a closed or ring end to grip bolts and nuts.

breakout box (BOB) A tool that connects an ECU and the harness to allow pin testing. An OBD II data link BOB allows quick testing of network signals and resistance readings.

broadcast A message from one ECU that is sent to all ECUs on the network.

bus bar A bus bar may be used in switch panels that have two or more switches in them. The bus bars provide a path to source or ground to control the circuit. Motor circuits that reverse direction often use bus bars to control circuit polarity depending on switch position. The power window switch connects to the bus bar in two ways, one to control the motor to lower the window and in reverse polarity to raise the window.

bus network The communication line(s) are laid out in-line and the ECUs connect to the bus with their own dedicated wiring. This layout provides very fast communication across the network.

cause Part of the 3Cs, documenting the cause of the problem. This documentation will go on the repair order, invoice, and service history.

C-clamp A clamp shaped like the letter C; it comes in various sizes and can clamp various items.

center punch Less sharp than a prick punch, the center punch makes a bigger indentation that centers a drill bit at the point where a hole is required to be drilled.

clock spring The component that maintains connection with the steering wheel mounted airbag and the SRS ECU. The clock spring wiring is able to extend and retract inside its housing as the steering wheel is turned left or right.

coarse (UNC) Used to describe thread pitch; stands for Unified National Coarse.

cold chisel The most common type of chisel, used to cut cold metals. The cutting end is tempered and hardened so that it is harder than the metals that need to be cut.

combination pliers A type of pliers for cutting, gripping, and bending.

combination wrench A type of wrench that has a box-end wrench on one side and an open end on the other.

concern Part of the 3Cs, documenting the original concern that the customer came into the shop with. This documentation will go on the repair order, invoice, and service history.

controller area network (CAN) A Bosch-developed communication system that has been used since the 1990s. CAN has been required since 2008 for scan tool communication on most vehicles. CAN uses twisted-pair wiring and offers medium- and high-speed communication for engine and chassis control systems.

correction Part of the 3Cs, documenting the repair that solved the vehicle fault. This documentation will go on the repair order, invoice, and service history.

crankshaft A vehicle engine component that transfers the reciprocating movement of pistons into rotary motion.

cross-arm A description for an arm that is set at right angles or 90 degrees to another component.

cross-cut chisel A type of chisel for metal work that cleans out or cuts key ways.

cruise control A system that maintains vehicle speed based on a set speed selected by the driver. Newer systems may integrate adaptive features that allow the vehicle to slow and brake as highway traffic speeds decrease and increase.

curved file A type of file that has a curved surface for filing holes.

data maps Similar to look-up tables; however, the data are more complex. Two or more input data parameters may be used to determine what output command is required.

dead blow hammer A type of hammer that has a cushioned head to reduce the amount of head bounce.

depletion layer The depletion layer is very thin and acts like an insulator.

depth micrometer A measuring device that accurately measures the depth of a hole.

diagonal cutting pliers Cutting pliers for small wire or cable.

dial bore gauge An accurate measuring device for inside bores, usually made with a dial indicator attached to it.

dial indicator An accurate measuring device where measurements are read from a dial and needle.

die Used to cut external threads on a metal shank or bolt.

die stock A handle for securely holding dies to cut threads.

digital For gauges, refers to numeric readouts or electronic bar graph indicators for vehicle speed or fuel level. Digital can also refer to signals created using pulsed voltage signals that are either low or high. The signal is sometimes referred to as on/off pulses, duty cycle, pulse width, or a binary signal.

digital storage oscilloscope Displays voltage over a time allowing the technician to see the signal. The DSO has a very fast refresh rate and is able to catch even the smallest signal error or fault. A DSO connects to a circuit in the same manner as using a DMM to measure available voltage. Technicians become skittish around the DSO because it requires setting the voltage and time scales to display the signal correctly. There are many other features including data recording and setting a trigger to start or stop recording.

DIN The country of Germany's standards organization. DIN standards are often used for terminal pin designations on relays.

diode The most basic of semiconductor components which acts like one valve to control current in a circuit. A diode may be used in a relay to control the voltage spike that occurs when the relay coil is turned off.

diode The most basic semiconductor device is a diode. A diode is made by joining P-type silicon and N-type silicon at a junction called the depletion zone. The positive end of a diode is the anode and the negative end is the cathode. The cathode is identified by a stripe on the body of the diode near the related lead. A diode can block current in one direction and allow it to pass when current is reversed. A diode is often referred to as a one-way valve for current.

DMM Digital multimeter, used to measure voltage amperage and resistance along with several other electrical measurement functions.

DMM "zero" function Used during resistance testing. Touch the DMM test leads together and select the zero function. The meter will "learn" the resistance of the test leads and then display 0 ohms on the display. This provides a more accurate test result when measuring resistance of a component or isolated sections in the circuit.

double flare A seal that is made at the end of metal tubing or pipe.

double insulated Tools or appliances that are designed in such a way that no single failure can result in a dangerous voltage coming into contact with the outer casing of the device.

drift punch A type of punch used to start pushing roll pins to prevent them from spreading.

drill vice A tool with jaws that can be attached to a drill press table for holding material that is to be drilled.

duty cycle A method for an ECU to control an output device. Rather than turning the device on or off, the ECU can modulate the voltage by using duty cycle. A device that is always on would

have a duty cycle of 100% on, 0% off. If we wanted to operate the device at a lower rate, the ECU could turn it on 50% of the time and the other 50% it is off. Doing this allows the body ECU to slowly dim the interior lights from full on to off, for example.

ear protection Protective gear worn when the sound levels exceed 85 decibels, when working around operating machinery for any period of time, or when the equipment you are using produces loud noise.

ECU Common abbreviation for an electronic control unit. ECUs are used to control various vehicle systems including body control systems, internal combustion engine functions, vehicle stability control, and many others. The average vehicle has 15 to 30 ECUs and some luxury vehicles may use more than 80 ECUs for various system controls.

elasticity The amount of stretch or give a material has.

electrical schematic (electrical diagram) Another name for the wiring diagram.

electro-mechanical A device which makes use of electrical and mechanical properties. A relay uses electricity to create a magnetic field that acts upon a mechanical switch to open or close the switch contacts.

electronically erasable programmable read-only memory (EEPROM) This feature allows for updates to provide enhanced customer satisfaction or to correct software programming that at times does not function as intended.

engineering and work practice controls Systems and procedures required by OSHA and put in place by employers to protect their employees from hazards.

Environmental Protection Agency (EPA) Federal government agency that deals with issues related to environmental safety.

fasteners Devices that securely hold items together, such as screws, cotter pins, rivets, and bolts.

feeler gauge A thin blade device for measuring space between two objects.

field windings Loops of wire wound around metal that is curved in shape to be as close as possible to the motor armature/rotor. The field windings create a magnetic field that is focused around the metal they wrap around. This metal, usually iron, is called a pole shoe. This magnetic field interacts with the magnetic field in the armature to create the rotating motion and torque output of the motor.

fine (UNF) Used to describe thread pitch; it stands for Unified National Fine.

finished rivet A rivet after the completion of the riveting process.

first aid The immediate care given to an injured or suddenly ill person.

flare nut wrench A type of box-end wrench that has a slot in the box section to allow the wrench to slip through a tube or pipe. Also called a flare tubing wrench.

flat blade screwdriver A type of screwdriver that fits a straight slot in screws.

flat-nose pliers Pliers that are flat and square at the end of the nose.

forcing screw The center screw on a gear, bearing, or pulley puller. Also called a jacking screw.

forward bias The term used when a diode has current moving through it.

freeze frame data Refers to snapshots that are automatically stored in a vehicle's power train control module (PCM) when a fault occurs (only available on model year 1996 and newer).

frequency Frequency is the measure of cycles per second, measured in hertz (Hz). An alternating current (AC) cycle is based on one cycle of AC current, starting at 0 volts, increasing to a peak positive voltage, going back to 0, going to a peak negative voltage, and then ending back at 0. Frequency of DC signals is based on a cycle that has low voltage (usually 0 volts) and a high voltage (can be 5 volts or 12 volts, but other values are also used). The most common DC-based frequency signal is duty cycle which has a fixed frequency. Some automotive systems may use a varying DC voltage frequency.

fused jumper leads Incorporate a replaceable fuse. This allows for safe circuit testing in case the test lead creates an excessive current condition during a circuit test.

gas welding goggles Protective gear designed for gas welding; they provide protection against foreign particles entering the eye and are tinted to reduce the glare of the welding flame.

gasket scraper A broad sharp flat blade to assist in removing gaskets and glue.

gateway module A module/ECU that serves to connect two or more networks together. The module functions to translate the data from one network to another so data can be shared from the CAN to the LIN, for example.

gear pullers A tool with two or more legs and a cross bar with a center forcing screw to remove gears.

g-force Gravitational force exerted by acceleration, deceleration, and turning left or right in a vehicle.,

graphing multimeter A DMM with a graphic display similar to a DSO. The voltage (or amperage) signal is displayed as a waveform on the display. GMMs usually cannot capture data as quickly as a DSO so they may not be able to display very fast waveforms that are used in vehicle networks. They do offer a great deal of features and some are based around a scan tool architecture which makes them very popular with diagnostic technicians.

ground points (ground location) diagram A wiring diagram that shows the current path to ground for each circuit. Ground points are identified and this information can be used with the ground location diagram to locate the applicable ground point of a circuit.

halogen lamp A type of bulb that produces a bright white light.

hard rubber mallet A special-purpose tool with a head made of hard rubber; often used for moving things into place where it is important not to damage the item being moved.

hazardous material Any material that poses an unreasonable risk of damage or injury to persons, property, or the environment if it is not properly controlled during handling,

storage, manufacture, processing, packaging, use and disposal, or transportation.

HD radio High definition radio is a by-product of digital radio signal transmission. The sound has much better quality and the same station frequency can offer several different formats.

headgear Protective gear that includes items like hairnets, caps, or hard hats.

heat buildup A dangerous condition that occurs when the glove can no longer absorb or reflect heat, and heat is transferred to the inside of the glove.

high-intensity discharge (HID) A type of lighting that produces light with an electric arc rather than a glowing filament.

hollow punch A punch with a center hollow for cutting circles in thin materials such as gaskets.

impact driver A tool that is struck with a hammer to provide an impact turning force to remove tight fasteners.

impact sensor Impact sensors are usually located at the front of the vehicle near the grill or bumper and on each side of the vehicle in the "B" pillar. The impact sensors provide input signals to the SRS ECU that a collision event is occurring. The SRS ECU then determines if air bag deployment is required based on impact "G" forces, vehicle speed and other factors.

incandescent lamp The traditional bulb that uses a heated filament to produce light.

inductive amperage pickup Used to measure amperage in a circuit. Most DMMs are limited to direct amperage measurements of less than 10 amps max. Many automotive circuits operate at higher amperage levels and an inductive pickup can be used to do this. The tool is placed around the circuit conductor anywhere in the applicable circuit. The DMM will display a reading in mV and this is multiplied by the factor selected on the tool. The result indicates the amount of amperage present in the circuit.

infotainment A driver (and passenger) graphic user interface with related ECU support that integrates phone functions, audio system functions, navigation system, and other applicable vehicle system controls into a central hub for their operation. Much of the operation can be done with voice commands, although many customers still prefer to use a touch screen or knobs and buttons.

initialize Some body electrical systems require initializing for proper operation. This is usually required after the battery is disconnected during battery replacement or as part of a service procedure like diagnosing an SRS (airbag) fault. Auto up/down power windows may require initialization for this feature to function. Follow the procedures outlined in the service information under "Initialization." Failure to do this can lead to vehicle comebacks because the customer believes the windows or other system is no longer working as it did before your vehicle service.

inside micrometer A micrometer designed to measure internal diameters.

instrument cluster The unit that houses the gauges and warning lights.

insulated gate bipolar transistor (IGBT) IGBTs offer the precise control of a MOSFET with very little heat generated in their operation. This offers greater packaging options in ECU design and can increase the service life of the ECU.

integrated circuit A complete circuit that is formed at a micro level. Processor chips include thousands of integrated circuits.

intermediate tap One of a series of taps designed to cut an internal thread. Also called a plug tap.

intermittent faults A fault or customer concern that you cannot detect all of the time and only occurs sometimes.

junction field effect transistor (J-FET) A J-FET is similar to a bipolar transistor but has a gate instead of base, a source instead of a collector, and a drain instead of an emitter. The core difference is that a J-FET uses voltage to control the depletion layer that forms the gate. No voltage allows current to flow through the J-FET. Applying very small amounts of voltage creates a depletion layer to control current.

keep alive memory (KAM) This memory is a special version of the RAM. The data are still temporary but are important enough that the ECU provides battery power to keep the memory data stored when the vehicle is turned off. This data are then available immediately when the vehicle is started and the system will be ready for any customer use. An example of this is the auto up/down feature for the windows.

lane assist A system that uses cameras and sensors to help the driver maintain lane control. The system uses the painted lane stripes along with steering wheel position to alert the driver if the vehicle is drifting off center in the lane.

LATCH The lower anchors and tethers for children's seat mounting points. These are usually in the back or second row of a vehicle's seating area. The LATCH points are marked on the lower seating surface and there is a mounting anchor above the rear seat to attach an upper strap that creates a three-point mounting system for a child seat.

light-emitting diode (LED) A type of lighting used in various automotive applications, such as warning indicators and alphanumeric displays.

light-emitting diode (LED) LEDs are made of materials that illuminate when forward biased. LED technology has quickly progressed from use as small indicator lights to their current high tech use in exterior lighting circuits, including headlights.

local interconnect network (LIN) A network designed by a consortium of automakers to provide the benefits of CAN but at a lower speed and lower cost. LIN uses a single-wire communication line.

locking pliers A type of pliers where the jaws can be set and locked into position.

lockout/tag-out A safety tag system to ensure that faulty equipment or equipment in the middle of repair is not used.

logic gates Logic gates form the internal connections that allow a processor to use input data and, along with programming software, determine the desired output for system operation.

logic probe A tool that can quickly inform you if there is an electronic signal present at a component or related wiring. The tool detects the output pulses that are present when an output actuator or pulsed input signal are active.

look-up table A data table the ECU processor uses to determine what action is required based on the related input data.

lug wrench A tool designed to remove wheel lugs nuts and commonly shaped like a cross.

magnetic pickup tools An extending shaft, often flexible, with a magnet fitted to the end for picking up metal objects.

magnetic pickup tools Useful for grabbing items in tight spaces, it typically is a telescoping stick that has a magnet attached to the end on a swivel joint.

mandrel The shaft of a pop rivet.

mandrel head The head of the pop rivet that connects to the shaft and causes the rivet body to flare.

measuring tape A thin measuring blade that rolls up and is contained in a spring-loaded dispenser.

mechanical fingers Spring-loaded fingers at the end of a flexible shaft that pick up items in tight spaces.

media oriented system transport network (MOST) An infotainment network design and communication protocol that primarily functions to provide data sharing between the user interface for the phone, audio/video system, navigation, and other systems that are integrated into the center stack (center instrument panel area) for driver and passenger access.

megabit Mega is the term for 1,000,000 and 1Mb equals 1,000,000 bits. CAN may communicate up to 1Mbps (per second) and FlexRay up to 10Mbps.

metal oxide semiconductor field effect transistor (MOSFET) A MOSFET is similar to a J-FET but is made of different materials. Using metal oxide rather than silicon offers very precise control in ECU driver circuits.

micrometer An accurate measuring device for internal and external dimensions. Commonly abbreviated as "mic."

needle-nose pliers Pliers with long tapered jaws for gripping small items and getting into tight spaces.

network A system that connects vehicle ECUs so data and commands can be shared between them.

night vision A technology that uses cameras and sophisticated imaging software to display objects on the road and nearby that would normally not be visible with just the headlights. This technology was developed for the military; it is still very expensive and is just now seeing use in vehicles.

nippers (pincer pliers) Pliers designed to cut protruding items level with the surface.

nut A fastener with a hexagonal head and internal threads for screwing on bolts.

OBD II data link connector (DLC) A standardized scan tool connection point that has been used on almost every vehicle since 1996.

occupant detection system A system that detects whether a passenger is seated in the right front seat. Most systems can also detect the weight of the occupant and will only allow passenger airbag operation if the weight is above a minimum threshold.

Occupational Safety and Health Administration (OSHA) Government agency created to provide national leadership in occupational safety and health.

offset screwdriver A screwdriver with a 90-degree bend in the shaft for working in tight spaces.

offset vice A vice that allows long objects to be gripped vertically.

oil filter wrench A specialized wrench that allows extra leverage to remove an oil filter when it is tight.

open-end wrench A wrench with open jaws to allow side entry to a nut or bolt.

original equipment manufacturer (OEM) The company that manufactured the vehicle.

output driver A device, usually a type of transistor, that controls an output device like the blower motor, interior light, or a fuel injector.

outside micrometer A micrometer designed to measure the external dimensions of items.

pair The function of connecting the customer's phone to the infotainment system. Some systems require inputting a code that appears on the phone to complete the process.

parallax error A visual error caused by viewing measurement markers at an incorrect angle.

park switch A switch that is integral to the rotating gear in the wiper motor. This switch allows the motor to operate after the wiper switch is turned off. The switch opens when the wipers reach their parked position at the lower edge of the windshield and the motor then stops.

passive restraint A vehicle occupant safety device that functions without any action by the occupant.

peening A term used to describe the action of flattening a rivet through a hammering action.

permanent magnet Permanent magnets do not require a field winding to create a magnetic field. These are essentially permanently magnetized pole shoes that surround the armature. Permanent magnets are created using rare earth metals blended together to form a magnetized metal. Permanent magnet motors can be smaller and lighter since field coils are not required.

personal protective equipment (PPE) Safety equipment designed to protect the technician, such as safety boots, gloves, clothing, protective eyewear, and hearing protection.

Phillips head screwdriver A type of screwdriver that fits a head shaped like a cross in screws.

photo diode Photo diodes react to light. They block current when no light is present but allow current when light of sufficient brightness is present.

piezoelectric Materials that are able to generate an electrical charge when stress or pressure is applied to them. These materials are used in creating the g-force sensor used in the SRS ECU.

pin punch A type of punch in various sizes with a straight or parallel shaft.

pipe wrench A wrench that grips pipes and can exert a lot of force to turn them. Because the handle pivots slightly, the more pressure put on the handle to turn the wrench, the more the grip tightens.

pliers A hand tool with gripping jaws.

policy A guiding principle that sets the shop direction.

pop rivet gun A hand tool for installing pop rivets.

position sensor A sensor that monitors the position of a component. The sensor may be analog or digital. Some sensors monitor the movement of a component, like an HVAC blend air door or the engine throttle blade, as it moves from one position to another. Other position sensors monitor the location of rotating components like the crankshaft.

power source diagram A wiring diagram that provides the current paths from the battery positive post (+) and related circuit protection for all vehicle circuits. Use this diagram when several circuits are not operating or when diagnosing a parasitic (ignition off) draw concern.

prick punch A pinch with a sharp point for accurately marking a point on metal.

procedure A list of the steps required to get the same result each time a task or activity is performed.

processor A solid state device that incorporates electronic components like resistors, diodes, and transistors on a mega miniature level. The processor circuits integrate logic gates that are used, along with software programming, to process the input data and then control the system outputs. The processor action is often referred to as sense – decide – act.

protocol The communication parameters set up for a particular network. This is important so the scan tool software is able to communicate with the various networks on the vehicle.

pry bar A high-strength carbon steel rod with offsets for leveraging and prying.

puddle lights Used to illuminate the area around the entry doors to make entry safer from objects or pooled water on the ground. The light usually comes from the outside rearview mirror assembly and may be in the form of an image or logo.

pullers A generic term to describe hand tools that mechanically assist the removal of bearings, gears, pulleys, and other parts.

pulse width modulation (PWM) PWM is a very precise control method for an output device on a varying frequency. Usually only fuel injectors are operated in this format as the software programming and related circuits are very complex. Most other components are duty cycled on a fixed frequency.

punches A generic term to describe a high-strength carbon steel shaft with a blunt point for driving. Center and prick punches are exceptions and have a sharp point for marking or making an indentation.

random-access memory (RAM) This memory is used to temporarily store data that are needed while the vehicle or vehicle system is in use. An example is the position of a power sliding door. The related ECU monitors door position so it can operate the various door actuators in the right sequence to open or close the door.

ratchet A generic term to describe a handle for sockets that allows the user to select direction of rotation. It can turn sockets in restricted areas without the user having to remove the socket from the fastener.

ratcheting box-end wrench A wrench with an inner piece that is able to rotate within the outer housing, allowing it to be repositioned without being removed.

ratcheting screwdriver A screwdriver with a selectable ratchet mechanism built into the handle that allows the screwdriver tip to ratchet as it is being used.

read-only memory (ROM) The section of memory where the software programming is stored. This memory is permanent and will not erase even if the vehicle battery is disconnected.

reed switch A reed switch uses metal contacts housed inside a glass housing. The switch is opened and closed when a magnetic field passes by the contacts. Reed switches were used in some instrument clusters to create a vehicle speed sensor signal from the rotating speedometer drive wheel.

reluctor or tone ring A reluctor or tone ring is used in many rotating position sensor applications. The ring is made up of teeth that are usually evenly spaced. Some reluctors have a missing tooth which is used to identify a specific location, like top dead center of cylinder 1 on the crankshaft.

repair order The document that is given to the repair technician that details the customer concern and any needed information.

respirator Protective gear used to protect the wearer from inhaling harmful dusts or gases. Respirators range from single-use disposable masks to types that have replaceable cartridges. The correct types of cartridge must be used for the type of contaminant encountered.

reverse bias The term used when a diode is blocking current.

ring network The ECUs are connected one after another forming a circular communication flow. The data can be transmitted in either direction and goes from ECU to ECU on the network. If a data line is open between two ECUs, the network can still function since the data can still be sent to every ECU on the network though the speed will be affected.

roll bar Another type of pry bar, with one end used for prying and the other end for aligning larger holes, such as engine motor mounts.

rotor The rotating portion of the motor may be referred to as a rotor (or armature in electromagnetic type motors).

safety data sheet (SDS) A sheet that provides information about handling, use, and storage of a material that may be hazardous.

safety glasses Safety glasses are protective eye glasses with built-in side shields to help protect your eyes from the front and side. Approved safety glasses should be worn whenever you are in a workshop. They are designed to help protect your eyes from direct impact or debris damage.

satellite radio Broadcast using satellites and is usually subscription based. The advantage is a very wide range of station selections with all types of music, news, and information programs. The signal also is present across the 48 states making it possible to travel all day listening to favorite stations.

screw extractor A tool for removing broken screws or bolts.

seat belt pre-tensioner A squib operated charge in the left and right front seat belt retractors that provides additional support to keep the occupant positioned correctly in their seat during a collision event.

seat position sensor A sensor that detects the location of the driver seat (and on some vehicles the passenger seat). This data is used by the SRS ECU to determine the airbag deployment strategy and timing based on how far the occupant(s) are seated from the airbags.

semiconductor A device usually made from silicon that has been doped with boron and phosphorus to create two or more distinct layers. The layers can be laid out to create components like diodes and transistors. A semiconductor has four valence electrons, and the doping creates a layer that has more positive charge carriers and a layer with more negative charge carriers. Current and voltage are used to manipulate the charge to provide various functions in a semiconductor.

sending unit A sending unit is the device that changes a temperature, fluid level, or pressure into a varying resistance. This varying resistance is in series with the related instrument cluster gauge, and the resulting voltage drop across the sending unit is what causes the needle on the gauge to indicate the related temperature, fluid level, or pressure.

serial interconnect line (SIL) A back-up communication line in case the CAN communication fails. Manufacturers have leeway to use one of the proprietary lines or they can use the K or L line for some systems.

service advisor The person at a repair facility that is in charge of communicating with the customer.

service history A complete listing of all the servicing and repairs that have been performed on that vehicle.

servomotor A motor with built-in electronic circuitry and components to monitor motor position and speed.

single flare A sealing system made on the end of metal tubing.

sledgehammer A heavy hammer, usually with two flat faces, that provides a strong blow.

sliding T-handle A handle fitted at 90 degrees to the main body that can be slid from side to side.

smart charger A battery charger with microprocessor control that manages voltage and amperage during charging that is matched to the type of battery being charged. This prevents over charging and any resulting damage that it could cause.

smart junction block (SJB) A junction block with an integrated ECU.

snap ring pliers A pair of pliers for installing and removing snap rings or circlips.

socket An enclosed metal tube commonly with 6 or 12 points to remove and install bolts and nuts.

speed brace A U-shaped socket wrench that allows high-speed operation. Also called a speeder handle.

split ball gauge A measuring device used to accurately measure small holes.

square file A type of file with a square cross section.

square thread A thread type with square shoulders used to translate rotational to lateral movement.

squib Used to ignite a device, like the propellant in an airbag module. While the device does not explode, it does create a very aggressive chemical reaction that creates the heat to expand and deploy the airbag from within its storage packaging.

star network The ECUs are arranged with a primary ECU and each sub ECU communication line connected to the primary ECU. All communication must go through the primary ECU. This layout is often used for infotainment systems.

stator The stationary part of the motor that contains the field windings and pole shoes. These components usually mount to the inside of the motor case or housing.

steel hammer A hammer with a head made of hardened steel.

steel rule An accurate measuring ruler made of steel.

stepper motor A specialized DC motor that has a rotor that is operated by a series of coils that surround the rotor. The rotor is stepped, or moved incrementally, by pulsing the coils in sequence causing the rotor to move in a specific direction and amount of rotation. The coils can be pulsed in either direction so the rotor can move clockwise or counterclockwise. These motors are often used to move a component a very specific amount for precise control of the related output system, like the heating and air conditioning duct work. A stepper motor may be used to operate the outlet doors to control where the air is directed inside the passenger compartment.

straight edge A measuring device generally made of steel to check how flat a surface is.

Strategy-Based Diagnostic Process A systematic process used to diagnose faults in a vehicle.

stud A type of threaded fastener with a thread cut on each end rather than having a bolt head on one end.

supplemental restraint The SRS system (the airbags that are used) is supplemental to the primary restraint, the seat belt.

symbols Wiring diagrams primarily use automotive and electronic industry standard symbols for circuit components. Most manufacturers provide a "How to Use the Wiring Diagram" section in their service information that provides a definition for the various symbols used.

tap A term used to generically describe an internal thread-cutting tool.

taper tap A tap with a tapper; it is usually the first of three taps used when cutting internal threads.

tap handle A tool designed to securely hold taps for cutting internal threads.

technical service bulletin (TSB) Service notifications and procedures sent out by the manufacturers to dealer groups alerting technicians about common issues with a particular vehicle or group of vehicles.

telescoping gauge A gauge that expands and locks to the internal diameter of bores; a caliper or outside micrometer is used to measure its size.

tensile strength In reference to fasteners, the amount of force it takes before a fastener breaks.

thermistor A variable resistor that changes its resistance based on temperature. Most thermistors used in automotive applications have a negative temperature coefficient, meaning that their resistance decreases as temperature increases.

thread file A type of file that cleans clogged or distorted threads on bolts and studs.

thread pitch The coarseness or fineness of a thread as measured by either the threads per inch or the distance from the peak of one thread to the next. Metric fasteners are measured in millimeters.

thread repair A generic term to describe a number of processes that can be used to repair threads.

threaded fasteners Bolts, studs, and nuts designed to secure parts that are under various tension and sheer stresses. These include bolts, studs, and nuts, and are designed to secure vehicle parts under stress.

threshold limit value (TLV) The maximum allowable concentration of a given material in the surrounding air.

thyristor A thyristor is similar to a transistor; however, once current turns it on, it remains on even after base current is turned off.

timer circuit Timer circuits are used in many body electrical circuits. The example in this chapter refers to the timer that operates the windshield wiper intermittent function. The timer circuit uses resistors to control the charge rate of capacitors. When the capacitors reach full charge, they trigger a transistor to provide voltage to the wiper motor. The resistance is varied by the customer selecting the rate of intermittent wiper action from short to longer interval selections on the wiper control switch.

tin snips Cutting device for sheet metal, works in a similar fashion to scissors.

topology Describes the type of network layout used: bus, star, or ring type.

torque Twisting force applied to a shaft that may or may not result in motion.

torque angle A method of tightening bolts or nuts based on angles of rotation.

torque specifications Supplied by manufacturers and describes the amount of twisting force allowable for a fastener or a specification showing the twisting force from an engine crankshaft.

torque wrench A tool used to measure the rotational or twisting force applied to fasteners.

torque-to-yield A method of tightening bolts close to their yield point or the point at which they will not return to their original length.

torque-to-yield (TTY) bolts Bolts that are tightened using the torque-to-yield method.

toxic dust Any dust that may contain fine particles that could be harmful to humans or the environment.

transistor A transistor is usually made with three layers of doped silicon material. Bipolar transistors can be constructed as PNP or NPN types. A transistor has a base, collector, and emitter. Current at the base controls current through the collector and emitter. The emitter is denoted by an arrow. The arrow usually points toward the ground portion of the circuit.

triangular file A type of file with three sides so it can get into internal corners.

trigger A setting on a DMM, GMM, or DSO that starts or stops a recording or signal display event. The trigger usually has several options that allow one time or repeat functions.

tube flaring tool A tool that makes a sealing flare on the end of metal tubing.

tubing cutter A hand tool for cutting pipe or tubing squarely.

unicast A message from one ECU that is sent to a designated ECU on the network.

V blocks Metal blocks with a V-shaped cutout for holding shafts while working on them. Also referred to as vee blocks.

vehicle speed sensor (VSS) A vehicle speed sensor creates a voltage signal when the sensor gear drive is rotated by the transmission/transaxle output shaft. The output signal may be analog or digital, and the signal is used to operate the speedometer/odometer in the instrument cluster.

vernier calipers An accurate measuring device for internal, external, and depth measurements that incorporates fixed and adjustable jaws.

voltage spike A rapid increase in circuit voltage. Relay coils and other inductive devices create a very high voltage spike when they are turned off and the related magnetic field collapses. The collapsing magnet creates a very high voltage spike, opposite in polarity to source voltage, which can damage electronic components if not controlled with a suppression device like a diode or resistor in parallel with the relay coil.

wad punch A type of punch that is hollow for cutting circular shapes in soft materials such as gaskets.

warding file A type of thin, flat file with a tapered end.

warning light An icon in the instrument cluster is illuminated to indicate there is a problem with a system or the status of a system (e.g., being on or off). A temperature warning light turns on to indicate the engine coolant temperature is exceeding normal range. A low fuel level light turns on when the fuel in the

tank is very low and alerts the driver that refueling is required very soon.

waveform The voltage or amperage reading displayed on a DSO, and to a lesser extent on a GMM, is called a waveform. A waveform is created by connecting each signal data point together on a graphic-based display so the signal can be viewed for analysis. Most GMMs and DSOs allow you to alter the voltage and time scales to view the waveform with the best detail for your diagnosis.

welding helmet Protective gear designed for arc welding; it provides protection against foreign particles entering the eye, and the lens is tinted to reduce the glare of the welding arc.

wiring diagram A schematic drawing and symbol representation of the wiring and components; also called electrical schematic.

wrenches A generic term to describe tools that tighten and loosen fasteners with hexagonal heads.

yield point The point at which a bolt is stretched so hard that it will not return to its original length when loosened; it is measured in pounds per square inch of bolt cross section.

Zener diode A Zener diode operates like a normal diode when it blocks current but will conduct current when a designated voltage threshold is met.

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