Chapter 24

On-Board Diagnostics and Scan Tools

After studying this chapter, you will be able to:

- Discuss the purpose and operation of on-board diagnostic systems.
- Explain the use of scan tools to simplify reading of trouble codes.
- Compare OBD I and OBD II system capabilities and procedures.
- Locate the data link connector on most makes and models of cars.
- Activate on-board diagnostics and read trouble codes with and without a scan tool.
- Use a trouble code chart in a service manual or code conversion by a scan tool.
- Erase diagnostic trouble codes.
- Correctly answer ASE certification test questions concerning late-model on-board diagnostics and scan tool use.

No longer can the untrained "shade tree mechanic" hope to repair modern vehicles. It takes the skill of a well-trained technician versed in on-board diagnostics to troubleshoot and repair today's vehicles. Today, the first thing a technician often does when diagnosing a problem in a computerized system is check for diagnostic trouble codes with a scan tool.

On-board diagnostics refers to a vehicle computer's ability to analyze the operation of its circuits, and to store and output data showing any problems. All late-model cars and light trucks have this self-monitoring feature. To save time and effort finding problems, it is critical that you know how to use this vital troubleshooting aid.

A ***scan tool*** is used to communicate with the vehicle's computers to retrieve trouble codes, display circuit and sensor electrical values, run tests, and give helpful hints for finding problems. This can all be done quickly and easily, without disconnecting wires or removing parts.

This chapter will summarize on-board diagnostic capabilities and explain the fundamental use of any make of scan tool. It will prepare you for other text chapters on troubleshooting and servicing vehicle systems.

Tech Tip

This chapter provides the basics of using scan tools and reading trouble codes. More advanced scan tool functions are explained at the beginning of most service chapters and are covered in detail in later chapters.

On-Board Diagnostic Systems

Modern automotive computer systems are designed to detect problems and indicate where they might be located. The computer is programmed to detect abnormal operating conditions. It actually scans its input and output circuits to detect an incorrect voltage, resistance, or current.

Today's on-board diagnostics will check the operation of almost every electrical–electronic part in every major vehicle system. A vehicle's engine control module can detect engine misfiring and air-fuel mixture problems. It monitors the operation of the fuel injectors, ignition coils, fuel pump, catalytic converter, and other major components that affect vehicle performance and emissions.

You can scan for problems in the engine and its support systems, the transmission, the suspension system, the anti-lock brake system, and other vehicle systems. This has greatly simplified the troubleshooting of complex automotive systems.

If the on-board computer finds any abnormal values, it will store a trouble code and light a malfunction indicator light on the instrument panel. This will inform the driver and the technician that something is wrong and must be fixed.

Early On-Board Diagnostic Systems

Most early on-board diagnostic systems can check only a limited number of items. Although these older systems are able to detect a major problem in the circuit, they are unable to detect weak or partially failed circuits and components. Also, there is little or no standardization among these early systems. A wide range of connectors and methods are used to retrieve stored trouble codes.

Early diagnostic systems are often referred to as ***OBD I (on-board diagnostics generation one) systems***. There are still millions of vehicles on the road that use OBD I systems.

OBD II Systems

A malfunctioning automobile engine can be a significant source of air pollution. For this reason, the Environmental Protection Agency (EPA) recommended and passed vehicle pollution laws. They require on-board diagnostic systems to detect potential problems *before* they result in the production of harmful exhaust emissions. These regulations also require auto manufacturers to standardize the monitoring systems on their cars and light trucks.

OBD II (on-board diagnostics generation two) systems are designed to more efficiently monitor the condition of hardware and software that affect driveability emissions. OBD II systems detect part deterioration (changes in performance), not just complete part failure. For example, if a sensor becomes lazy or remains in the low end of its normal operating range, this problem is stored as a trouble code in the computer memory for retrieval at a later date. Refer to **Figure 24-1**.

OBD II systems are designed to keep the vehicle running efficiently for at least 100,000 miles (160,000 km). The on-board computers used in OBD II systems have greater processing speed, more memory, and more complex programming than computers used in OBD I systems.

OBD II systems can produce over 500 engine-performance-related trouble codes. They check the operation of switches, sensors, actuators, in-system components, wiring, and the computer itself.

OBD II systems also have standardized data link connections, trouble codes, sensor and output device terminology, and scan tool capabilities. In the past, one manufacturer required over a dozen different connectors for the ECMs used in their vehicles. This made it very difficult for the small repair shop to purchase all the necessary adapters. To solve this problem, the federal government and the Society of Automotive Engineers (SAE) have set standards for all automakers to use.

Malfunction Indicator Light (MIL)

If an unusual condition or electrical value is detected, the computer will turn on a warning light in the instrument panel or the driver information center. The warning light will notify the driver that the vehicle needs service. Some vehicles have a silhouette of an engine on their warning lights.

In OBD II systems, the engine warning light is referred to as a ***malfunction indicator light (MIL)***. If the MIL glows continuously, the trouble is not critical but should be repaired at the vehicle owner's convenience. If the MIL light comes on and then goes out, the problem may be intermittent.

A flashing MIL in an OBD II equipped vehicle means that the trouble could damage the catalytic converter and is, therefore, considered critical. For example, an engine misfire (engine not completely burning fuel mixture) or a fuel system malfunction will generally cause the malfunction indicator light to flash on and off. This warns the driver that the catalytic converter may be overheated and burned if the vehicle is not serviced immediately. The MIL will flash on and off every second when conditions that could damage the converter exist.

Whenever the MIL is illuminated, drivers should be advised to bring the vehicle in for service as soon as possible. The technician can then use a scan tool to retrieve information about the problem.

A ***trouble code chart*** in the service manual will state what each number code represents. Most scan tools can perform trouble code conversion. ***Trouble code conversion*** means the scan tool is programmed to automatically convert the number code into abbreviated words that explain the potential problem. The technician can then use service information to further isolate the problem.

Diagnostic Trouble Codes

Diagnostic trouble codes (DTC) are digital signals produced and stored by the computer when

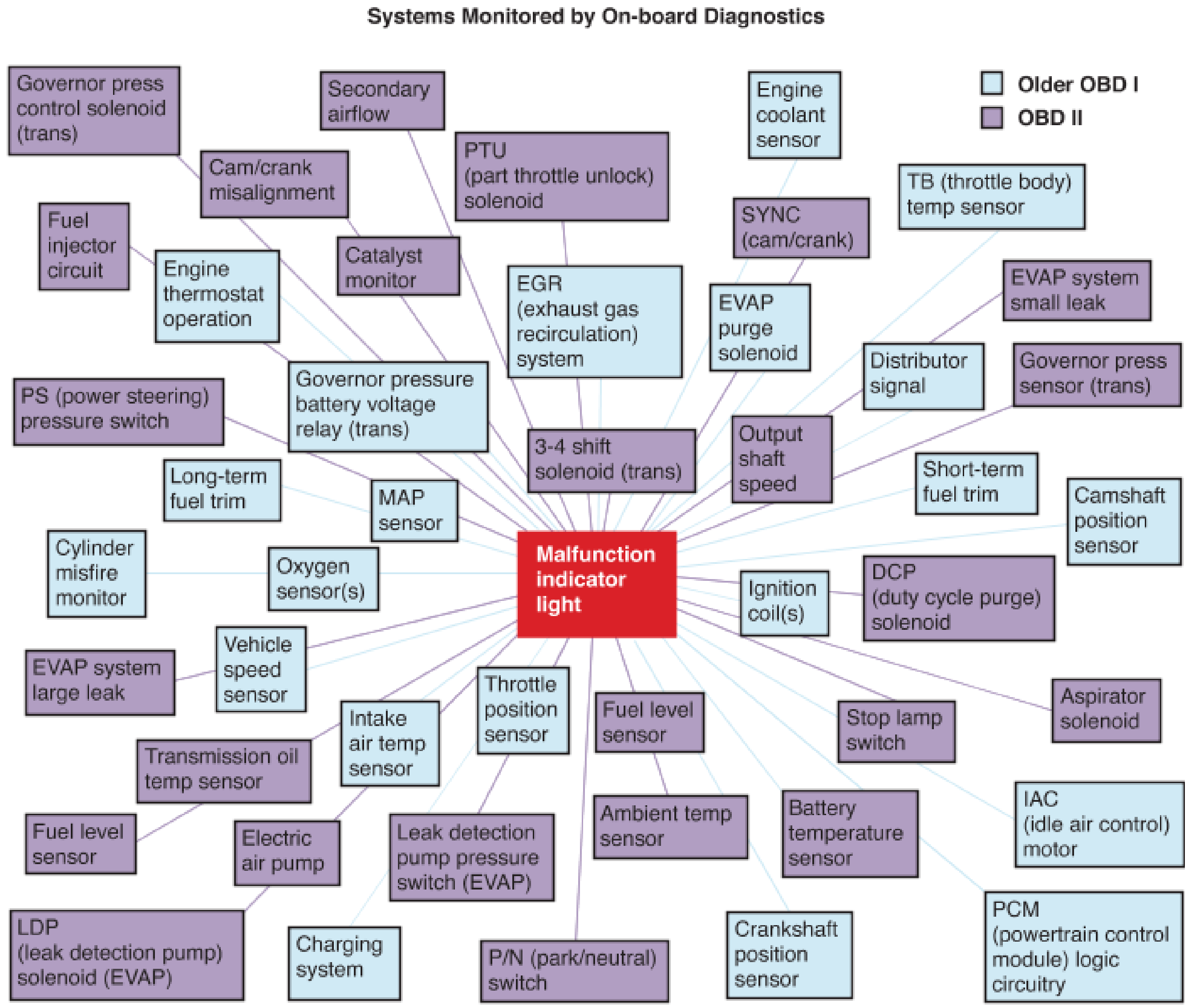

Figure 24-1. Compare the OBD I diagnostic system's capabilities with the OBD II system's abilities.

an operating parameter is exceeded. An ***operating parameter*** is an acceptable minimum and maximum value. The operating parameter might be an acceptable voltage range from the oxygen sensor, a resistance range for a temperature sensor, current draw from a fuel injector coil winding, or an operational state from a monitored device. In any case, the computer "knows" the operating parameters for most inputs and outputs. This information is stored in its permanent memory chips.

Computer System Problems

Common problems that can affect vehicle performance and cause the computer system to set a code and light the MIL in the dash are shown in **Figure 24-2**. These problems include:

- Loose electrical connection—This problem can cause an input signal from a sensor to not reach the computer properly, or an actuator may not respond to the computer's output control current.
- Corroded electrical connection—This problem can result in high resistance in a wiring connector, upsetting sensor input or actuator output.
- Failed sensor—This problem occurs when an opened or shorted sensor or other sensor malfunction prevents normal computer system operation.
- Failed actuator—This involves a solenoid, servo motor, relay, or display that shorted, is open, or does not react to computer signals.

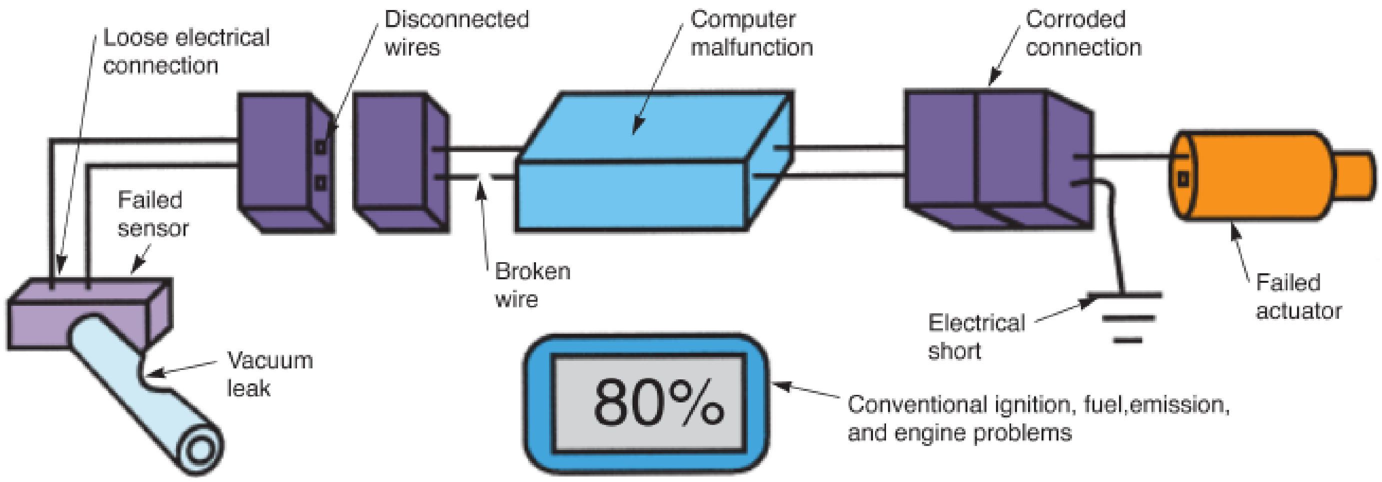

Figure 24-2. Always remember that about 80% of all performance problems are not caused by the computer, its sensor, or its actuators. Most problems are the result of conventional problems, such as loose connections, broken wires, vacuum leaks, mechanical problems, etc.

- Leaking vacuum hose—This problem is a vacuum leak to a vacuum-operated actuator that reduces engine or system performance.
- Electrical short—This problem occurs when wires touching ground or each other cause a current increase or incorrect current path.
- Ignition system problems—Problems include open spark plug wires, fouled spark plugs, weak ignition coil voltage, bad crankshaft sensor, etc. For example, a spark plug misfire causing unburned fuel to enter the exhaust can trick the oxygen sensor into trying to create a leaner mixture. The misfire upsets computer system operation and can be detected in OBD II systems by variations in the crankshaft sensor signal.
- Fuel system problems—Problems include leaking or clogged injectors, bad pressure regulator, faulty electric fuel pump, or other problems.
- Emission system problems—These are problems with the catalytic converter, EGR valve, vapor storage system, etc. Many emission components are monitored electronically and will set a trouble code if a malfunction occurs.
- Engine problems—These are mechanical problems that cannot be compensated for by the computer modifying system operation. Engine misfire due to mechanical wear will also trip a trouble code on OBD II systems.
- Computer malfunction—This problem results from an incorrect PROM, wrong internal programming, internal failure of an integrated circuit, or failure of other components can disable the computer and alter the operation of related systems.
- Weak or lazy component—This includes any sensor, actuator, or computer that is not outputting normal operating values. In some cases, a sensor's current, voltage, or resistance values are within specs, but the component is sending weak or incorrect signals to the ECM. A lazy sensor can trick the computer system into compensating for an artificial lean or rich condition; it may trip codes on OBD II-equipped vehicles.
- Transmission problems—Electronically controlled transmissions and transaxles are monitored and will trip trouble codes if a problem is detected. Transmission problems include a bad vehicle speed sensor, a faulty shift sensor or solenoid, or faulty wiring.
- Anti-lock brake system problems—Problems include bad wheel speed sensors, faulty wiring, or a malfunctioning hydraulic unit.
- Air conditioning problems—These include problems with faulty pressure and temperature sensors.
- Air bag problems—Problems include faulty impact sensors, a malfunctioning arming sensor, or a damaged air bag module, will trip trouble codes.
- Hybrid electric drive train part and circuit malfunctions—These types of problems include an HV battery malfunction or a faulty HV power cable.

> **Tech Tip**
> Most computer system problems are conventional (loose electrical connection, mechanical problem, etc.). Only about 20% of all performance problems are caused by an actual fault in the computer or one of its sensors. For this reason, always check for the most common problems before testing more complex computer-controlled components.

Scanning Computer Problems

A scan tool is an electronic test instrument designed to retrieve trouble codes from the computer's memory and display these codes as a number and words identifying the problem. Also called a diagnostic readout tool, the scan tool makes it easier to read diagnostic trouble codes. In most cases, it is the only way to access the computer's diagnostic system.

A scan tool is by far the most common way to use on-board diagnostics. It will save time and effort. A scan tool is now the most important tool of the automobile technician, **Figure 24-3**.

A basic scan tool is designed to read and erase vehicle trouble codes but cannot perform as many functions as an advanced scan tool.

An advanced scan tool often has plug-on cartridges to add more functions than a basic scan tool, including troubleshooting guides, and more manufacturer specific tests and circuit readings, **Figure 24-4**.

To use any scan tool, read the operating instructions for the specific tool. Operating procedures vary slightly. Most scan tools have simple buttons

Figure 24-3. A scan tool is now the most important tool of the automotive technician. It will tell you where problems are located. *(OTC/SPX Corp.)*

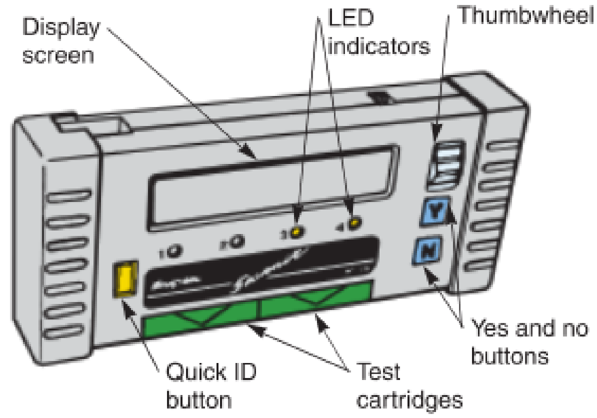

Figure 24-4. Scan tool designs vary. Always read the owner's manual that comes with the tool before use. *(Snap-on Tool Corp.)*

or a scroll wheel to control test functions. With modern scan tools, plug the cord into the connector under the dash and follow scanner on-screen instructions.

> **Tech Tip**
> Some late-model vehicles are equipped with CAN-compliant computer systems. While the diagnostic techniques for these systems are similar to those for conventional computer systems, a CAN-compliant scan tool must be used to retrieve diagnostic information from CAN-equipped vehicles.

Data Link Connector (Diagnostic Connector)

The ***data link connector (DLC)*** is a multipin terminal used to link the scan tool to the computer. In the past, this connector was identified by a variety of names, including ***diagnostic connector*** and ***assembly line diagnostic link (ALDL)***.

OBD I data link connectors came in various shapes and sizes, and were equipped with a varying number of pins or terminals, **Figure 24-5**. With OBD II, the DLC is a standardized 16-pin connector. The female half of the connector is on the vehicle, and the male half is on the scan tool cable. Some of the most common locations for the diagnostic connector are shown in **Figure 24-6**.

With OBD II diagnostic systems, you should be able to connect a scan tool to the vehicle's data link connector with one hand while sitting in the driver's seat or kneeling outside the vehicle.

Figure 24-5. This advanced scan tool does not require cartridges. All important data for OBD II vehicles is stored in the memory. *(Snap-on Tool Corp.)*

> **Tech Tip**
> Some OBD I vehicles are equipped with a 16-pin, OBD II–style data link connector. Do not assume that a vehicle equipped with a 16-pin connector is OBD II compliant.

Connecting the Scan Tool

On late-model vehicles, the vehicle's data link connector should be mounted under the dash in a location that is easy to access from the driver's seat. The scan tool cable should slide easily into the data link connector, **Figure 24-7**. If not, something is wrong. Never force the two together or you could damage the pins on the tool cable or the data link connector. With an older vehicle, you will need an ***adapter*** so the scan tool connector will fit the vehicle's pre-OBD II pin configurations.

Late-model cars power the scan tool through the vehicle's diagnostic connector. With a pre-OBD II, you may have to connect your scan tool to battery power. Use a cigarette lighter adapter plug or alligator clips on the battery to connect the 12-volt power to the scan tool.

> **CAUTION**
> Make sure you are connecting the scan tool to the vehicle properly. Some technicians have mistakenly connected scan tools to the wrong connector (tach connector, for example), which can damage the scan tool.

Using Scan Tools

Modern scan tools will give ***prompts***, or step-by-step instructions, in their display windows. The prompts tell you how to input specific vehicle information and run diagnostic tests. These procedures and specifications are programmed into the scan tool circuitry or its cartridge. See **Figures 24-8** through **24-10**.

The scan tool may ask you to input VIN information (numbers or letters) from the plate on the top of the dash.

The VIN data lets the scan tool know which engine, transmission, and options are installed on that car or truck. With some makes, however, the on-board computer will contain this data and will automatically download it into the scan tool. Then, you will be able to select the information that you would like the scan tool to give you, **Figure 24-11**.

Some of the information a scan tool can request includes:

- Stored diagnostic trouble codes—This is a number that represents the general area (body, chassis, powertrain, network) and specific system or part that is not functioning normally in the vehicle.
- Fault description—This explains what each stored diagnostic trouble code means by pinpointing specific fuel injectors, ignition coils, sensors, actuators, or other parts and circuits that are operating out of specification.
- Datastream information—This displays the operating values of all monitored circuits and sensors (engine speed, engine temperature, ignition timing, injector pulse width, and other values).
- Run tests—These read datastream circuit values for sensors and actuators while they are operating. If an actuator fails to move or fire during the run tests, the scan tool will inform you of any problem.
- Oxygen sensor monitoring—This performs detailed tests of the O_2 sensors signals under normal operating conditions. This helps find a weak or sluggish oxygen sensor.
- Failure record—This lists the number of times a particular trouble code has occurred by key-starts or warm-ups. This will help you find intermittent or irregular problems.

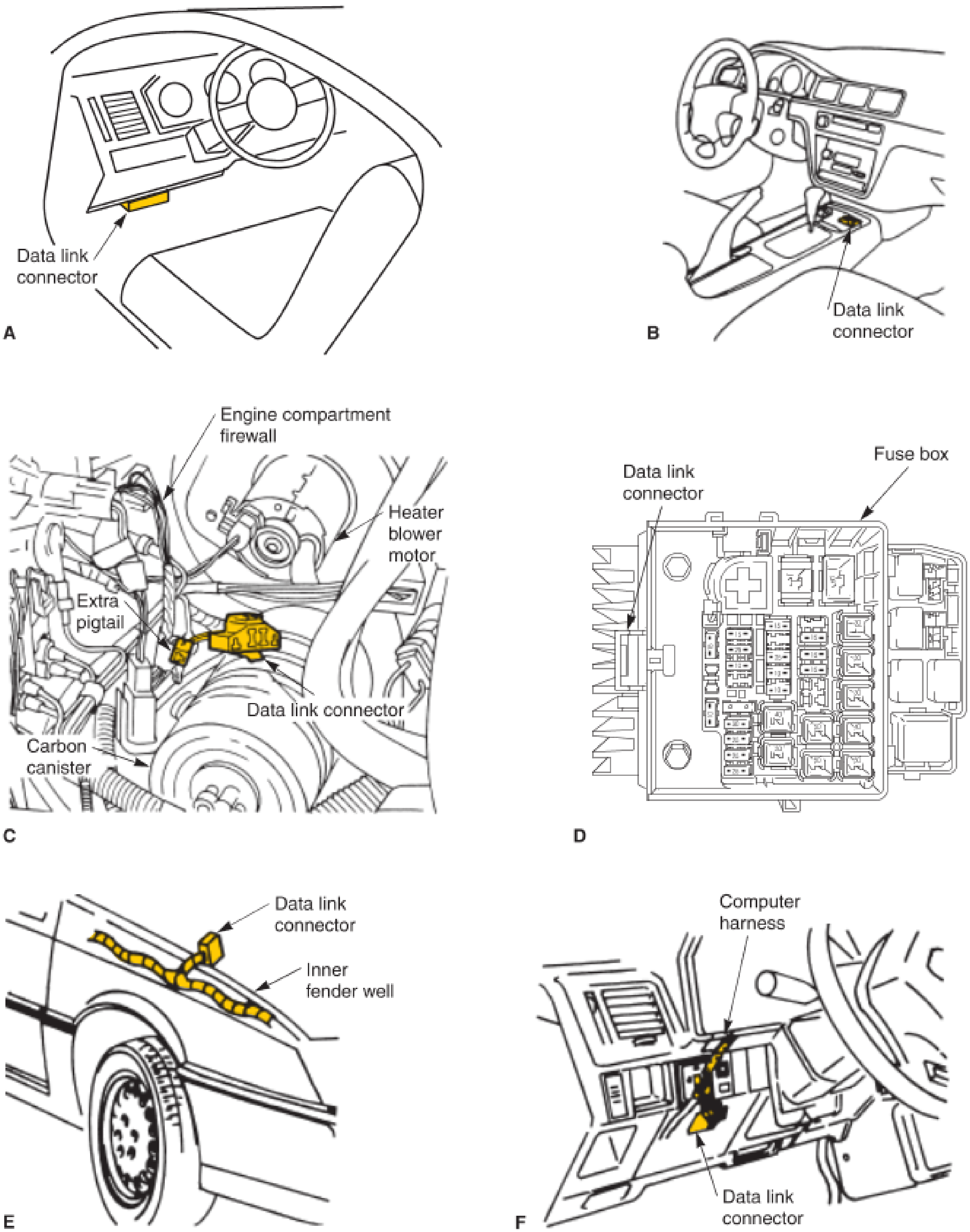

Figure 24-6. Data link connector locations vary. A—OBD II vehicles have their data link connector below the dash, within easy reach of the driver's seat. B—The OBD II connector is sometimes located in the center console. C—Some Ford diagnostic connectors are on the firewall, near the back of the engine. D—Some early General Motors connectors are next to the fuse box. E—Early Chrysler diagnostic connectors are located in the engine compartment. F—Other data link connectors may be located behind the dash, in or behind the glove box, under the center console, etc. Refer to the service manual if needed. *(Ford, Toyota, and Snap-on Tool Corp.)*

A B C

Figure 24-7. The OBD II test connector is under the dash. It should be visible as you lean down and look under the dash. A—The OBD II connector has 16 male pins and a power plug to the power scan tool. B—The OBD II connector under the dash has a 16-pin female plug. C—Slide scan tool connector straight into the vehicle data link connector so the pins slide smoothly together.

- *Freeze frame*—This takes a snapshot of sensor and actuator values when a problem occurs or when triggered during a test drive. This also helps find problems that do not set hard trouble codes. This records the values from all monitored components so they can be further evaluated, letting you locate and correct intermittent problems more easily.
- Troubleshooting—This feature provides help and instructions for diagnosing faults once you have read a trouble code.

Figure 24-12 gives the general sequence for using a scan tool. You can ask the scan tool to give more information on a trouble code, and the tool will display words that give sensor resistance values, identify common problems, and provide other useful information.

Figure 24-8. Once plugged into the vehicle, scan tools will quickly check the vehicle for stored trouble codes. *(Snap-on Tool Corp.)*

Tech Tip

Most technicians check for stored diagnostic trouble codes before performing tests on specific components. This is a quick way to pinpoint any hard failures, so they can be repaired first.

Always correct the cause of the lowest number diagnostic trouble code first. Sometimes, fixing the cause of the lowest code will clear other codes because of component interaction. If not, you can use other scan tool features to find and solve more complex problems. A trouble code does not mean that a certain component is bad. It simply indicates that a possible problem has been detected in that particular device or circuit.

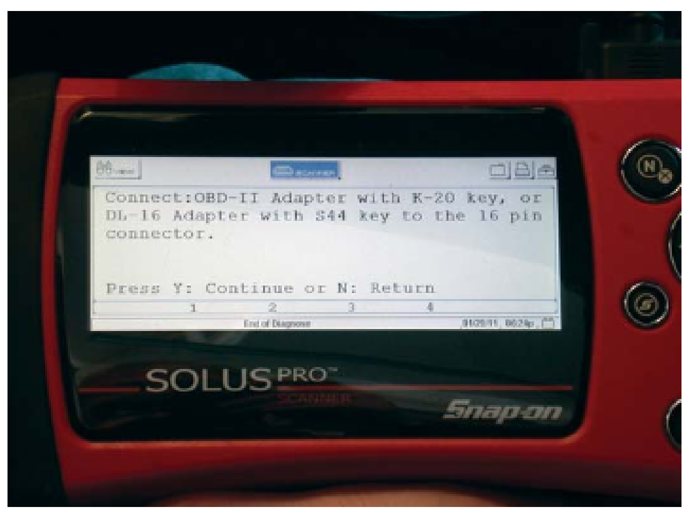

Figure 24-9. This advanced scan tool is prompting the user to install an OBD II connector and a specific key adapter for that vehicle. *(Snap-on Tool Corp.)*

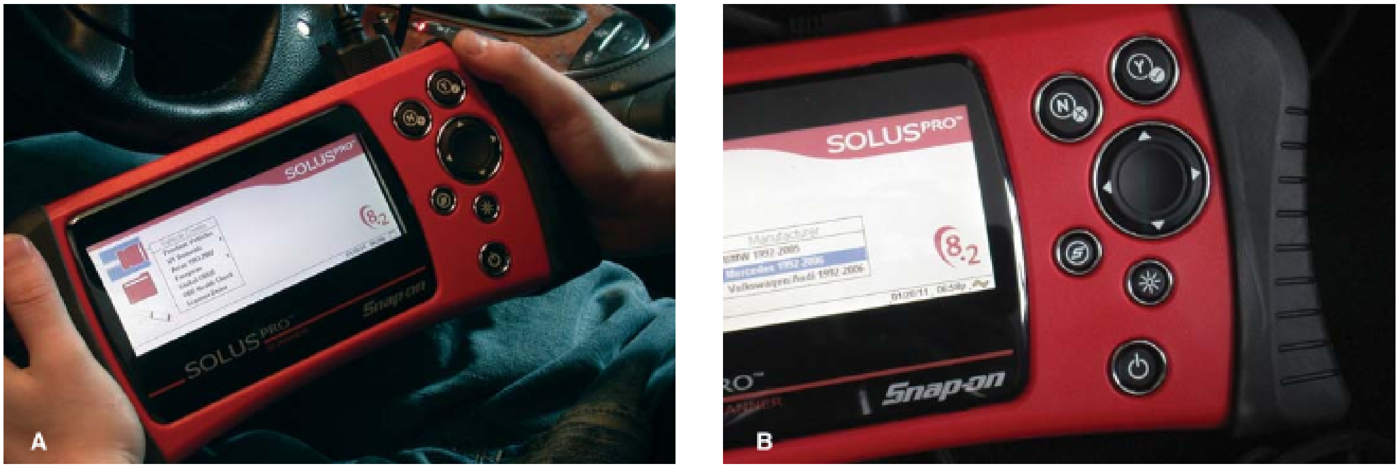

Figure 24-10. Always read the operating manual fully before attempting to use any model of scan tool. A—Scan tool controls vary from one manufacturer to another. B—Note the simple yes-no buttons that allow the user to quickly respond to the scan tool's prompts. *(Snap-on Tool Corp.)*

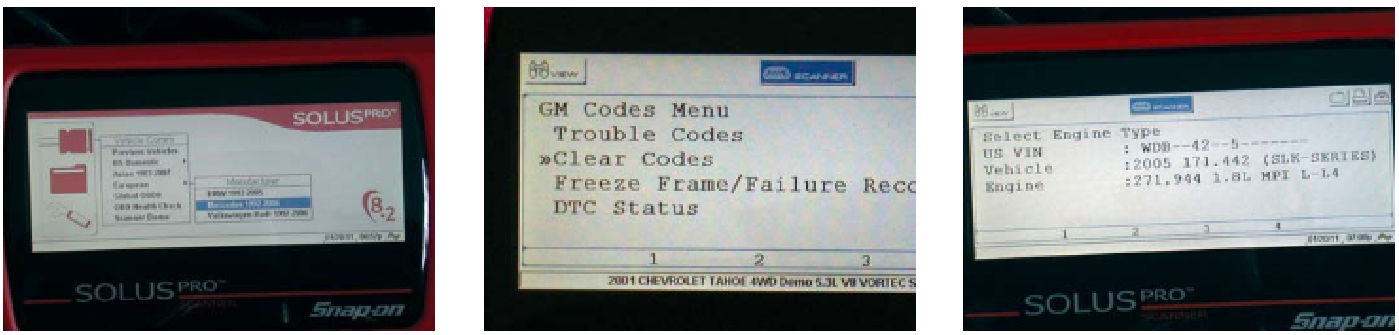

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Figure 24-11. A full-featured scan tool can perform complex testing and troubleshooting procedures. A—This advanced scan tool does not require cartridges. You can quickly navigate to the exact make, model, and year car to be tested. B—Here the scan tool is asking the technician to input VIN information. This lets the tool know how the vehicle is equipped—engine type, transmission type, computer configuration, etc. C—You can then proceed to read stored trouble codes, or erase codes by scrolling through the menu. *(Snap-on Tool Corp.)*

Most ECMs count the number of times a trouble code has occurred. This information is stored in a ***failure record***, or failure recorder. The failure recorder in OBD II systems counts the number of times the engine reached operating temperature since the last time the trouble code was set. The failure recorder in OBD I systems counts the number of keystarts since the last trouble code occurred. If one code has occurred more frequently than the others, investigate this code first. In many cases, the lowest number code and the most frequently stored code are the same.

Diagnostic Trouble Code Identification

As mentioned, early on-board diagnostic systems were not standardized. Often, technicians would have to refer to the service manual to find out what a particular code number meant. OBD I and earlier codes were different for each manufacturer.

To simplify troubleshooting, OBD II requires all auto manufacturers to use a set of standardized alpha-numeric trouble codes. Each trouble code identifies the same problem in all vehicles, regardless of the manufacturer.

OBD II codes contain a letter and a four-digit number. The letter in all OBD II codes indicates the general function of the affected system (power train, chassis, etc.).

The first digit of the number indicates whether the code is a standard trouble code or a nonuniform code. Standard trouble codes, or SAE codes, are indicated by the number *0*. Nonuniform codes (nonstandard OBD II codes that are assigned by the auto manufacturers) have the number *1* after the system

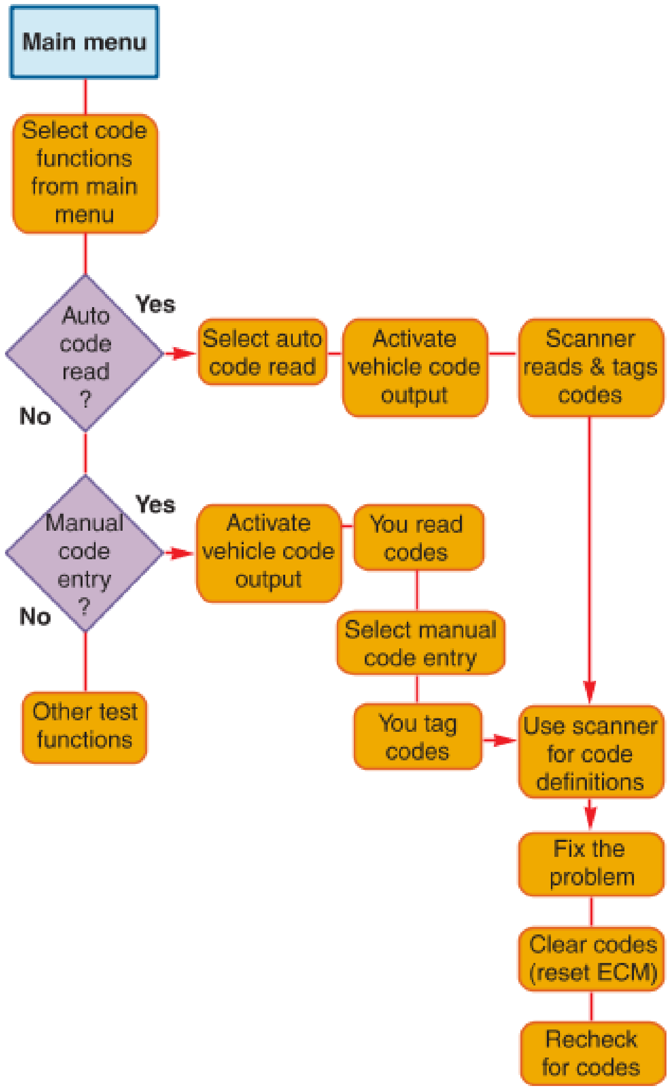


Figure 24-12. This flowchart shows the basic steps for using a scan tool. *(Snap-on Tool Corp.)*

letter. The second digit of the OBD II code number indicates the specific function of the system where the fault is located, such as fuel, computer, etc.

The code's last two digits refer to the specific fault designation. The ***fault designation*** pinpoints exactly which component or circuit of the system might be at fault, as well as the type of problem. Regardless of the type of vehicle being serviced, the standard trouble code numbers will be the same. The scan tool must explain the code and, in some cases, may describe how to fix the problem.

Figure 24-13 gives a breakdown of the OBD II diagnostic code. Study it carefully. **Figure 24-14** shows the display of a scan tool that has found a stored trouble code.

Failure Types

There are two general types of computer system failures: hard failures and soft failures. A ***hard failure*** is a problem that is always present in a computer system. An example of a hard failure is a disconnected wire or another problem that would cause a general circuit failure. A hard failure does not come and go with varying conditions. After the computer memory is cleared, any hard failures will usually reset as soon as the engine is started or the affected system is energized.

A ***soft failure***, or intermittent failure, is a problem that only occurs when certain conditions are present. It might be present one minute and gone the next. Soft failures will usually be stored in memory for 30–50 keystarts or engine warm-ups. An example of a soft failure is a loose terminal that connects and disconnects as the vehicle travels over bumps in the road. Low-input, high-input, and improper range failures are usually classified as soft failures.

Computer system failure types can be further broken down into four general categories:

- ***General circuit failure***—The circuit or component has a fixed value, no output, or an output that is out of specifications. This is the most severe fault, but it is the easiest to locate. It is caused by disconnected wires, high-resistance connections, shorts, or a component constantly operating out of parameter.
- ***Low-input failure***—A failure that produces a voltage, current, or signal frequency below normal operating parameters. A weak or abnormally low signal is being sent to the on-board computer. This type of failure is often caused by high circuit resistance, a poor electrical connection, a contaminated or failed sensor, or a similar problem.
- ***High-input failure***—This results when the signal reaching the on-board computer has a much higher voltage, current, or frequency than normal. This type of failure is often caused by a faulty sensor, a high charging voltage, or a mechanical fault that is "fooling" the computer system.

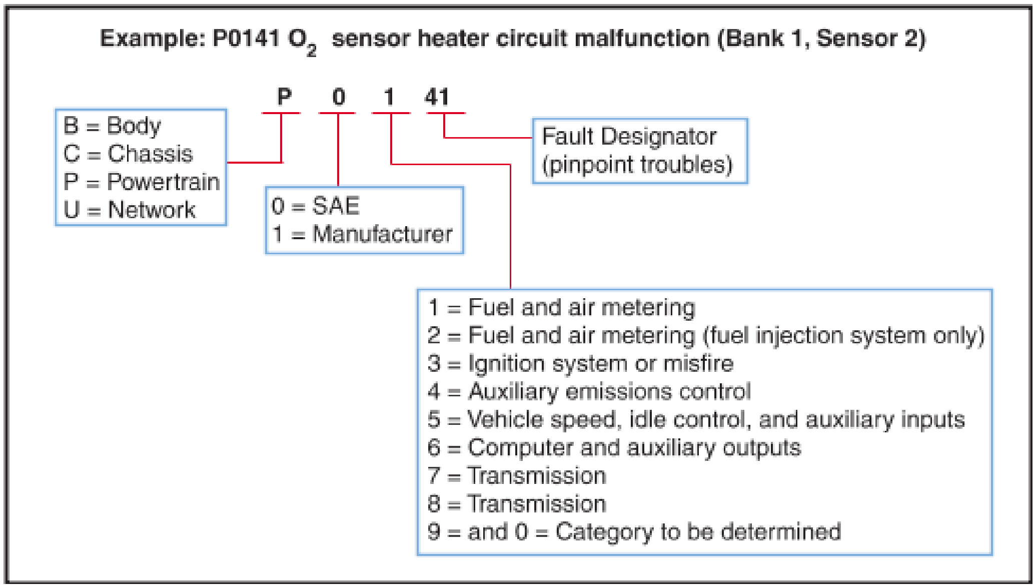


Figure 24-13. OBD II trouble codes are alphanumeric. Note what each part of the trouble code means. The first part of the code tells you which system is having problems. The last part of the code identifies the specific problem circuit or component.

- ***Improper range/performance failure***—This occurs when a sensor or actuator is producing values slightly lower or higher than normal. The circuit is still functioning, but not as well as it should under normal conditions. This type of failure can be caused by a contaminated sensor, a partial sensor failure, a poor electrical connection, and similar problems. Improper range/performance failures were not detected in OBD I systems and were often difficult to find. OBD II systems can detect improper range/performance failures.

Datastream Values

Datastream values, or diagnostic scan values, produced by the vehicle's computer give electrical operating values of sensors, actuators, and circuits. These values can be read on a scan tool's digital display and compared to known normal values in the service manual. Datastream values give additional troubleshooting information when trying to locate a problem.

Key-On/Engine-Off Diagnostics

In order to access the ECM data on most vehicles, it is necessary to turn the ignition key on. ***Key-on/engine-off diagnostics*** are performed by triggering the ECM's on-board diagnostic system with the ignition key in the *on* position but without the engine running. This allows you to access any stored trouble codes in the computer's memory chips. Key-on/engine-off diagnostics are usually performed before key-on/engine-on diagnostics. Look at **Figure 24-15**.

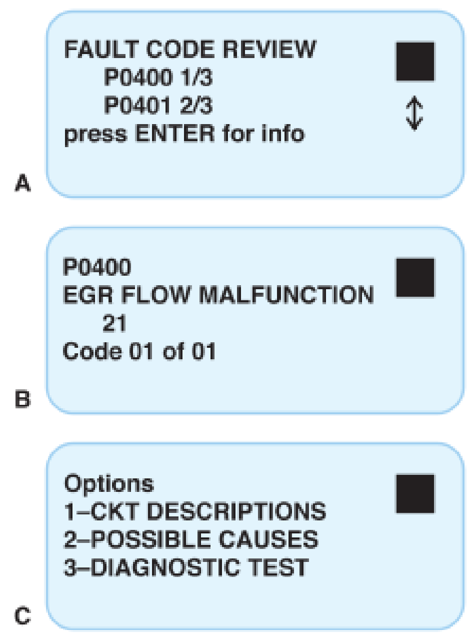
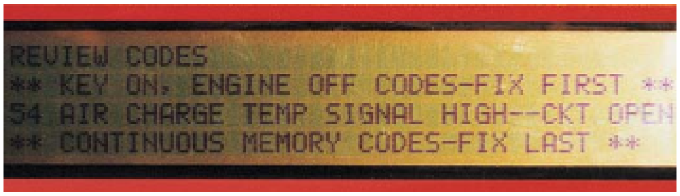


Figure 24-14. This is an example of what you might see on the display of a scan tool. A—The scan tool will give you the trouble code numbers. B—If you request information on the stored trouble codes, the tool will explain what each code means. C—Options will allow you to use the scan tool to get detailed descriptions of each code, list possible causes, or perform diagnostic tests. *(OTC/SPX Corp.)*



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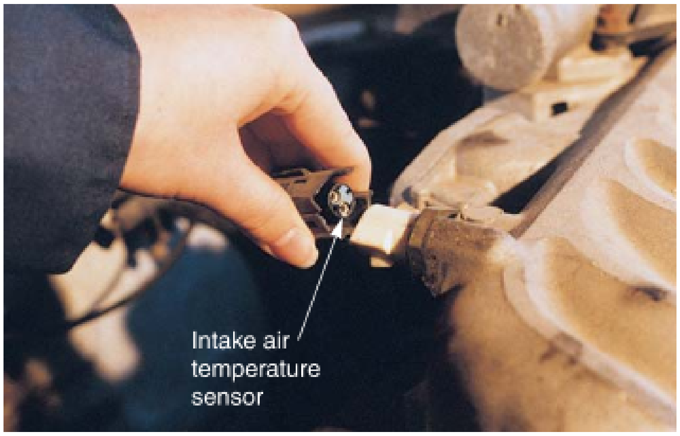

B

Figure 24-15. Most technicians check for stored trouble codes first. A—This scan tool readout shows a problem with the intake air (air charge) temperature sensor. B—You would then know to check that sensor and its wiring for problems. *(Snap-on Tool Corp.)*

If you anticipate working in the key-on/engine-off diagnostic mode for over 30 minutes, connect a battery charger to the vehicle. This will prevent the extended current draw from draining the battery and upsetting the operation of the computer while in the diagnostic mode. False trouble codes could result from a partially drained battery.

Wiggle Test

Many computer system failures, especially intermittent failures, are caused by loose, dirty, or corroded connections, **Figure 24-16.** These failures can be found by performing a ***wiggle test***, or "flex" test.

Service Procedure

To perform a wiggle test:

1. Connect a scan tool to the vehicle and choose the appropriate test options. Refer to the instructions provided with the scan tool.
2. Place the vehicle in the key-on/engine-off diagnostic mode.
3. Flex wires and wiggle harness connectors while scanning for problems.
4. If wiggling a wire or connector produces a new diagnostic trouble code, check the wire or electrical connection more closely. It may be loose, corroded, or damaged.

Some technicians perform a wiggle test while the engine is running. If engine operation changes suddenly (stalls or idles high, for example) when a connector or wire is flexed, the problem is located at or near that point. Be careful when performing a wiggle test on a running vehicle.

You might also want to use a heat gun to heat potentially faulty components during a wiggle test. For example, electronic amplifiers and modules tend to malfunction when hot. This could help find an intermittent problem.

CAUTION

Exercise care when using a heat gun. The heat generated by the gun can easily melt most plastics and damage electronic components.

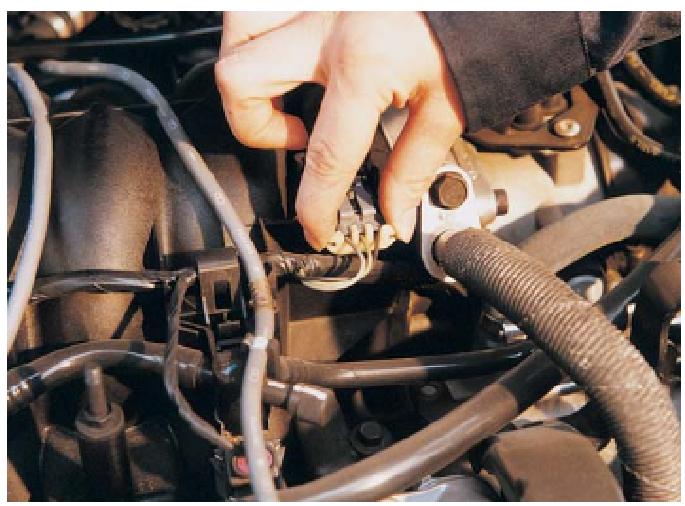

Figure 24-16. The wiggle test involves moving wires and connectors while scanning for trouble codes. If wiggling a wire trips a code, you found the location of the problem.

Key-On/Engine-On Diagnostics

Key-on/engine-on diagnostics are performed with the engine running at full operating temperature. These tests check the condition of the sensors, actuators, computer, and wiring while they are operating under normal conditions.

Switch Diagnostic Test

A ***switch diagnostic test*** involves activating various switches while using a scan tool. The scan tool will tell you which switch to move and will monitor its operation. The scan tool will quickly indicate if the switch is working normally, **Figure 24-17**.

For example, you might be told to shift the transmission shift lever through the gears, press on the brake pedal, and turn the air conditioning on and off. As each step is performed, the scan tool will indicate if the affected switch is okay and whether or not the ECM is reading the switch input. Refer to the service manual for details of the switch diagnostic test.

Actuator Diagnostic Test

An ***actuator diagnostic test*** uses the scan tool to order the vehicle's computer to energize specific output devices with the engine on or off. This will let you find out if the actuators are working. Most actuator diagnostic tests are considered intrusive tests, since engine or vehicle operation will be drastically affected while the device is being tested. Actuator diagnostic tests might:

- Fire or prevent the firing of the ignition coil.
- Open and close the fuel injectors.
- Cycle the idle speed motor or solenoid.
- Energize the digital EGR valve solenoids.

You can then watch or listen to make sure these actuators are working. With OBD II, the scan tool will give readouts showing whether there is trouble with any actuators.

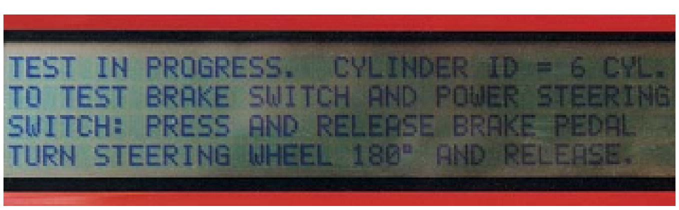

Figure 24-17. Most scan tools will also perform switch and actuator tests. This is sometimes done automatically. You may be prompted to close different switches to make sure each one is working. The scan tool may also be able to perform additional actuator tests. *(Snap-on Tool Corp.)*

Switch and actuator diagnostic tests cannot be performed on all vehicles. Refer to the service manual or scan operating manual for details.

Scanning during a Test-Drive

With a modern scan tool, you can also check for problems while driving the vehicle to simulate the conditions present when the trouble happens, **Figure 24-18**. For example, if the problem occurs only while driving at a specific speed when the engine is cold, you can scan under these conditions. Start the cold engine and drive at the specified speed while scanning for problems. You can then take a snapshot (if the scan tool has this feature) when the problems occur.

Energizing OBD I Systems without a Scan Tool

If you do not have a scan tool and are working on an OBD I–equipped vehicle, there are several ways to activate the computer's on-board diagnostics and retrieve trouble codes. The most common methods include:

- Using a jumper wire to ground one of the data link connector terminals and then reading the flashing code on the dash-mounted check engine light.
- Connecting an analog voltmeter to vehicle ground and to one terminal on the data link connector while jumping from the pigtail (extra wire) to the data link connector. The code is produced by the meter's needle movement.

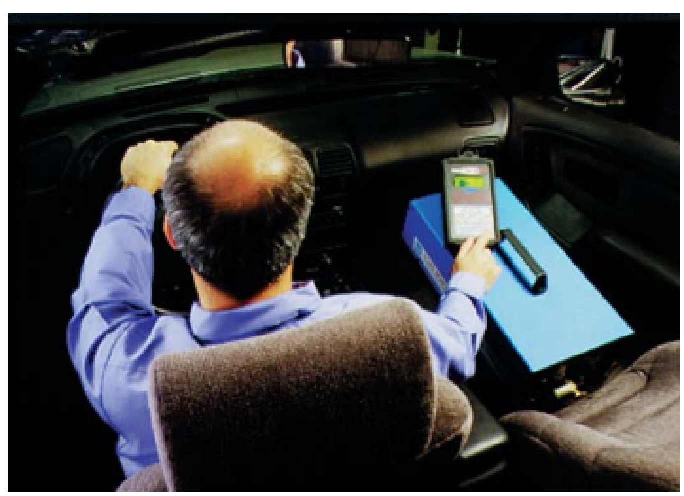

Figure 24-18. Scan tools are sometimes used while test-driving vehicles. This will allow you to check engine and vehicle operating parameters while duplicating the conditions present when the problem occurred. *(OTC/SPX Corp.)*

- Turning the ignition key on and off several times within a few seconds and reading the flashing code on the dash-mounted check engine light.
- Pushing two dash-mounted climate control buttons at the same time and reading the dash display.

Always refer to the service manual for detailed instructions. Procedures vary from model to model, as well as from year to year. These methods will not work on vehicles equipped with OBD II.

Reading Trouble Codes without a Scan Tool

Reading trouble codes manually involves noting the computer output after the on-board diagnostics have been energized. There are different ways trouble codes can be read on older vehicles. The most typical methods include:

- Observing the check engine light as it flashes on and off.
- Noting an analog voltmeter's needle as it deflects back and forth.
- Watching a test light connected to the data link connector flash on and off.
- Reading the digital display in a climate control panel or driver's information center.
- Observing the LED display on the side of the ECM.

Trouble Code Charts

A trouble code chart in the service manual explains what each trouble code number means, **Figure 24-19**. This will help you know where to start further tests on specific components.

Tech Tip
Trouble code charts are not generally needed with OBD II systems. Most OBD II scan tools display the code meaning.

Erasing Trouble Codes

Erasing trouble codes, also termed clearing diagnostic codes, removes the stored codes from computer memory after system repairs have been made. In most cases, codes will be automatically erased after 30–50 engine starts or warm-ups. However, codes should be erased after repairs are made to prevent a possible misdiagnosis by the next technician who works on the vehicle. There are various methods used to erase trouble codes from the computer:

- Use a scan tool to remove stored diagnostic codes from the on-board computer. This is the best way to remove old codes after repairs. In OBD II systems, the ECM may retain stored codes for several days without battery power. See **Figure 24-20**.
- Disconnect the battery ground cable or strap. However, this will also erase the digital clock memory, all radio presets, and any adaptive strategy information from the computer.
- Unplug the fuse to the ECM. This will also erase all other information stored in the computer's temporary memory.

Trouble code No.	Code detecting condition	Trouble area
P0171	When the air-fuel ratio feedback is stable after engine warming up, the fuel trim is considerably in error on the RICH side.	• Air intake (hose loose) • Fuel line presure • Injector blockage • Heated oxygen sensor malfunction • Mass airflow meter • Engine coolant temperature sensor
P0171	When the air-fuel ratio feedback is stable after engine warming up, the fuel trim is considerably in error on the LEAN side.	• Fuel line pressure • Injector leak, blockage • Heated oxygen sensor malfunction • Mass airflow meter • Engine coolant temperature sensor

Figure 24-19. This is a trouble code chart for one type of vehicle. Study how different code numbers show possible problems and causes.

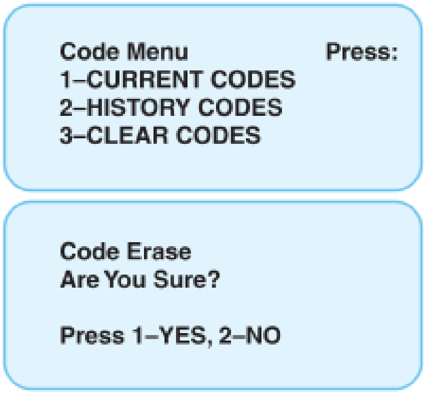

Figure 24-20. Using a scan tool is the fastest and easiest way to erase stored trouble codes. With most scan tools, simply choose the menu selection to clear codes and then press yes. *(OTC/SPX Corp.)*

CAUTION

Some auto manufacturers warn against unplugging or plugging in the computer harness connector with the ignition key on or the engine running. This could cause a voltage spike that could damage the computer.

After erasing trouble codes, reenergize the on-board diagnostics and check for diagnostic trouble codes. If no trouble codes are displayed, you have corrected the problem.

Tech Tip

The OBD II system performs a series of checks, or monitors, to verify the proper operation emissions-related components. Erasing trouble codes may also erase monitor status records stored in the computer's memory. If this occurs, the monitors must be reset before the vehicle is emission tested. This can be done by performing the appropriate OBD II drive cycle or by simply driving the vehicle until all the monitors reset. However, the vehicle may have to be driven 100 miles or more under varying conditions to reset the monitors.

DIAGNOSTIC CASE STUDY

Concern: Ms. Figuroa says that a light is glowing in the dash of her 2010 GMC pickup truck.

Cause: Duff questions Ms. Figuroa as to the nature of the problem, but she says she has noticed nothing wrong other than the glowing light. Duff starts the vehicle and notes that the malfunction indicator light in the dash is glowing. He test-drives the vehicle to try to find problem symptoms. He notices that the vehicle seems to miss slightly and lack normal power. He makes a note of his findings and turns the repair over to the shop's master technician.

After analyzing the symptoms, the technician connects a scan tool to the truck's data link connector. The scan tool readout indicates a problem with one of the oxygen sensors. The technician then performs pinpoint tests to verify the scan tool findings. As expected, the sensor's output is not within specifications. The technician removes the oxygen sensor using a special sensor socket. He notices that the sensor is covered with a heavy deposit of carbon. He then looks for possible causes of oxygen sensor contamination and discovers an extremely dirty air filter. The technician determines that the filter is restricting airflow into the engine, causing an overly rich mixture. The rich mixture most likely caused the sensor contamination.

Correction: The technician installs a new oxygen sensor and air filter. He then erases the stored trouble codes and rechecks the system for codes. No problems are found and the MIL light no longer glows. Upon returning the truck to Ms. Figuroa, the technician reminds her to change her air filter at recommended intervals to help prevent further problems.

Summary

- On-board diagnostics refers to a vehicle computer's ability to analyze the operation of its circuits and output data showing any problems.
- A scan tool is used to communicate with the vehicle's computers to retrieve trouble codes, display circuit and sensor electrical values, run tests, and give helpful hints for finding problem sources.
- OBD I and earlier on-board diagnostic systems could check only a limited number of items.

- OBD II systems are designed to more efficiently monitor the condition of hardware and software that affect emissions. New vehicle diagnostics detect part deterioration and not just complete part failure.
- If an unusual condition or electrical value is detected, the computer will turn on a malfunction indicator light (MIL) in the dash instrument panel or driver information center.
- Code conversion means the scan tool is programmed to automatically convert trouble codes into abbreviated words that explain what might be wrong without referring to a service manual.
- Diagnostic trouble codes (DTCs) are digital signals produced by the computer when an operating parameter is exceeded.
- The data link connector (DLC) is a multipin terminal for reading computer trouble codes or scanning problems.
- A scan tool freeze frame is a snapshot of operating parameters at the time of a malfunction.
- OBD II codes contain a letter and a four-digit number.
- The letter in all OBD II codes indicates the general function of the affected system.
- The first digit of the number in OBD II codes indicates whether the code is a standard trouble code or a nonuniform code.
- The second digit of the number in the OBD II code indicates the specific function of the system where the fault is located.
- The last two digits in the OBD II code refer to the specific fault designation.
- A wiggle test is done by moving wires and harness connectors while scanning to find soft failures.
- If you do not have a scan tool or are working on older computer-controlled vehicles, there are several other ways to activate computer on-board diagnostics to pull out trouble codes.

Technical Terms

Write the definitions for the following terms on a separate sheet of paper.

actuator diagnostic test
adapter
assembly line diagnostic link (ALDL)
data link connector (DLC)
datastream values
diagnostic connector
diagnostic trouble codes (DTC)
failure record
fault designation
freeze frame
general circuit failure
hard failure
high-input failure
improper range/performance failure
key-on/engine-off diagnostics
key-on/engine-on diagnostics
low-input failure
malfunction indicator light (MIL)
on-board diagnostics
OBD I (on-board diagnostics generation one) system
OBD II (on-board diagnostics generation two) system
operating parameter
prompts
scan tool
soft failure
switch diagnostic test
trouble code chart
trouble code conversion
wiggle test

Activities

1. Demonstrate the proper method for using a scan tool.
2. Videotape a service technician using a scan tool to "check out" an engine performance problem. Ask the technician to explain each step as he or she performs the work. Show the completed video to the class.

Review Questions

Answer the following questions using the information provided in this chapter.

1. What is computer on-board diagnostics?
2. What is the first thing most technicians look at when diagnosing a computer system problem?
3. If an unusual condition or electrical value is detected, most computer systems will turn on a(n) _____.

4. List and summarize 17 types of problems that can affect computer system operation.
5. Only about _____ of all performance problems are caused by the computer, sensors, and actuators.
6. Where is a typical OBD II scan tool connector located?
7. Summarize the OBD II alpha-numeric diagnostic code.
8. Which of the following is a standardized OBD II code for a malfunction in the computer or auxiliary outputs?
   (A) P0605.
   (B) P1600.
   (C) P0141.
   (D) P0505.
9. Name the four general types of computer system failures.
10. A(n) _____ is always present and a(n) _____ is intermittent.
11. Explain key-on/engine-off diagnostics.
12. What is a wiggle test?
13. An OBD II vehicle comes in the shop with the engine trouble light glowing. Technician A says to connect a scan tool to the vehicle first to read stored trouble codes. Technician B says to test-drive the vehicle first even with the trouble light ON. Who is correct?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. An _____ diagnostic test uses the scan tool to order the vehicle's computer to energize specific output devices with the engine on or off.
15. What are trouble code charts?

ASE-Type Questions

1. Technician A says an automotive computer can scan its input and output circuits to detect incorrect voltage problems. Technician B says an automotive computer can scan its input and output circuits to detect an incorrect resistance problem. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technician A says if an automotive computer system detects an abnormal condition, the car's malfunction indicator light will normally be activated. Technician B says if an automotive computer system detects an abnormal condition, the car's low oil warning light will normally be activated. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. The malfunction indicator light in an OBD II system is flashing. Technician A says this means the problem could be damaging the catalytic converter. Technician B says that this simply indicates a soft problem. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. Technician A says a faulty actuator can affect the operation of an automotive computer system. Technician B says a leaking vacuum hose can affect the operation of an automotive computer system. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

5. Technician A says a spark plug misfire can affect the operation of an automotive computer system. Technician B says an automotive computer system is not affected by a spark plug misfire. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. An automobile has a small fuel tank leak. Technician A says this problem may activate the car's computer system "malfunction indicator light." Technician B says this type of problem has no effect on the car's computer system. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Technician A says about 50% of all automotive engine performance problems are caused by the computer system. Technician B says about 80% of all automotive engine performance problems are caused by something other than a computer system malfunction. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Which of the following is a possible location for an automotive computer system's data link connector?
   (A) Under the dash.
   (B) Near the firewall in the engine compartment.
   (C) Under the center console.
   (D) All of the above.
9. A trouble code indicates that there is no activity in an oxygen sensor circuit. Technician A says to test the sensor and its circuit. Technician B says to replace the sensor. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. Technician A says the term "hard failure" refers to an intermittent automotive computer problem. Technician B says the term "hard failure" refers to a constant automotive computer problem. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. A wiggle test is being performed on an automotive computer system. Technician A performs this test with the engine off and the ignition key off. Technician B performs this test with the engine off and the ignition key on. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
12. All of the following can normally be performed during an automotive computer system actuator self-test *except*:
    (A) open and close injectors.
    (B) fire the ignition coil.
    (C) operate the reed valve.
    (D) activate the idle speed motor.
13. Technician A says a switch diagnostic test involves energizing specific output devices. Technician B says an actuator diagnostic test involves the scan tool giving orders to the vehicle's computer. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
14. Which of the following can be used to read OBD I trouble codes?
    (A) Flashing check engine light.
    (B) Voltmeter.
    (C) Scan tool.
    (D) All of the above.

15. Trouble codes need to be erased from an OBD II computer system. Technician A wants to accomplish this by unplugging the ECM fuse. Technician B wants to accomplish this by using the shop's scan tool. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.