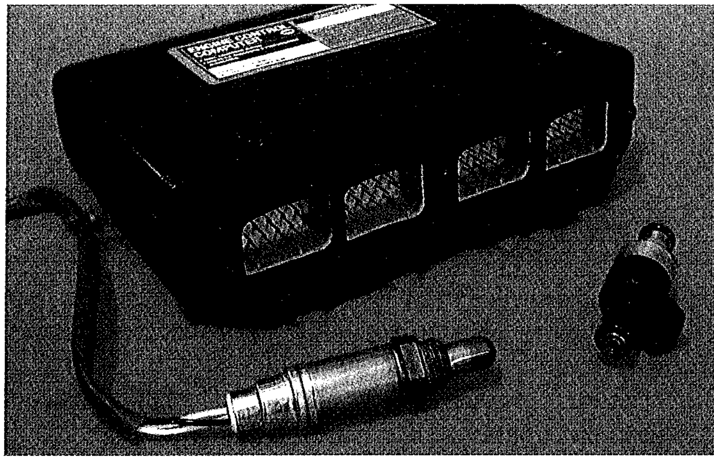


18 On-Board Diagnostics and Scan Tools

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.

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

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.

Introduced in Chapter 4, 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 recent changes in on-board diagnostic capabilities and explain the fundamental use of scan tools. It will prepare you for other text chapters on troubleshooting and servicing vehicle systems.

Note!
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 Chapter 46, *Advanced Diagnostics.*

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, emissions system parts, and other major components that affect vehicle performance and emissions control.

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.

Since some vehicles have six or more computers, on-board diagnostics can be a time-saver when trying to narrow down possible problems. The computers can interact with dozens of sensors and actuators and, in some cases, with each other.

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.

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 problem in the circuit, they were unable to determine what type of problem the circuit has (faulty wiring, defective component, etc.). Technicians who are unfamiliar with a particular manufacturer's line of vehicles may find it difficult to accurately diagnose problems caused by a computer system fault.

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. This makes it confusing for tool manufacturers and technicians. It also makes it necessary for the shop or technician to purchase a variety of harness adapters, program cartridges, and service literature. Even the names of the systems and their components differ from manufacturer to manufacturer, making part identification difficult.

Early diagnostic systems are often referred to as ***OBD I (on-board diagnostics generation one) systems***. See **Figure 18-1**. 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. It can produce several times the normal amount of harmful exhaust emissions. For this reason, the Environmental Protection Agency (EPA) recommended and passed regulations that 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 performance monitoring systems on their cars and light trucks.

As mentioned, OBD I systems simply store a code and illuminate a dash light once a sensor or circuit stops working completely. The new standard requires on-board diagnostic systems to go a step further by monitoring how efficiently each part of the system is operating.

OBD II (on-board diagnostics generation two) systems are designed to more efficiently monitor the condition of hardware and software that affect 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 18-1**.

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.

New vehicles now monitor more functions and can warn of more problems that affect driveability and emissions. 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. OBD I systems use a red- or amber-colored ***check engine light***, service engine soon light, or other indicator light with a similar name. 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

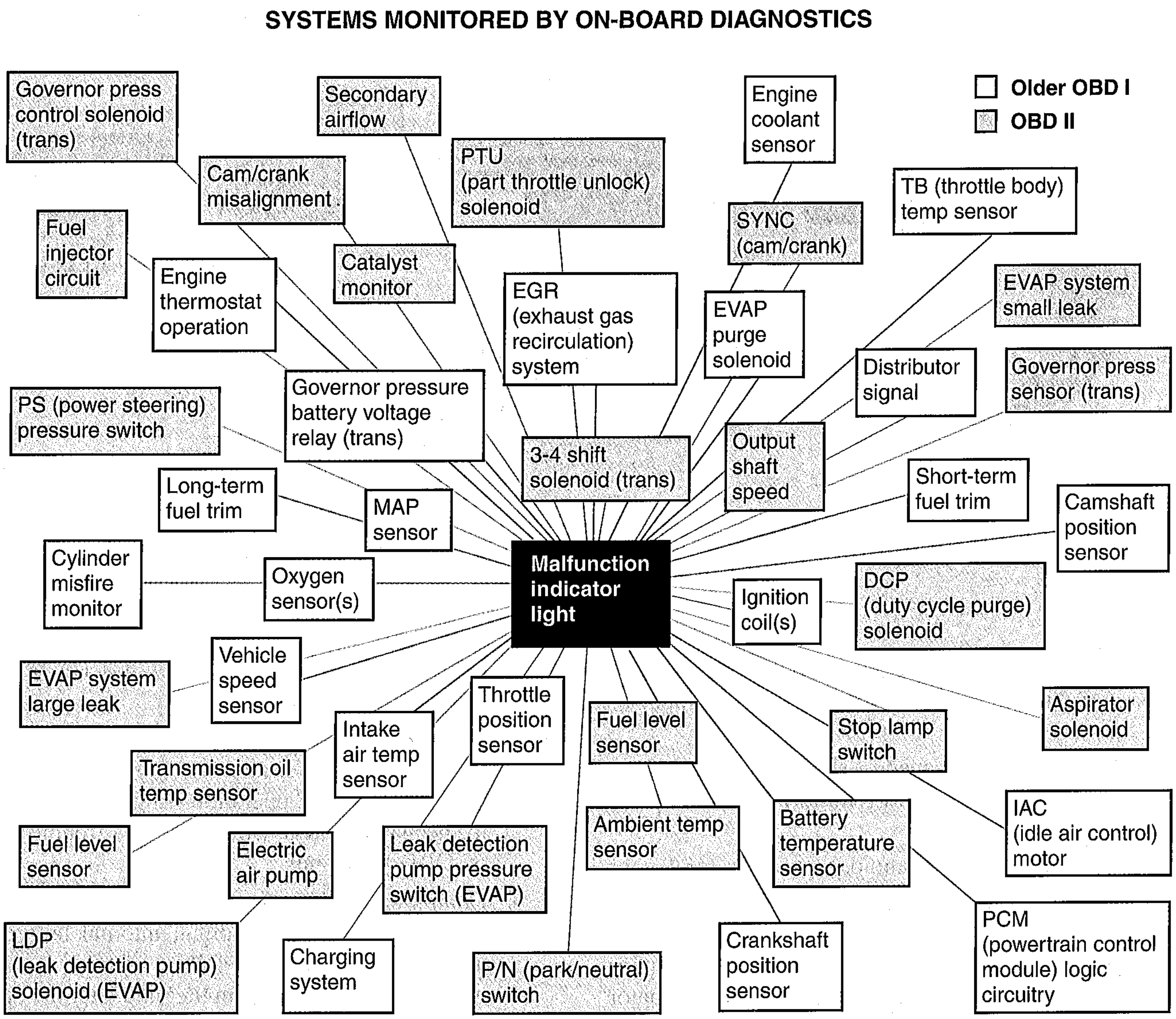


Figure 18-1. Compare the OBD I diagnostic system's capabilities with the OBD II system's abilities.

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 an operating parameter is exceeded. An ***operating parameter*** is an acceptable minimum and maximum value. The 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 18-2.** These problems include:

- *Loose electrical connection*—input signal from a sensor not reaching the computer properly or an actuator not responding to the computer's output.

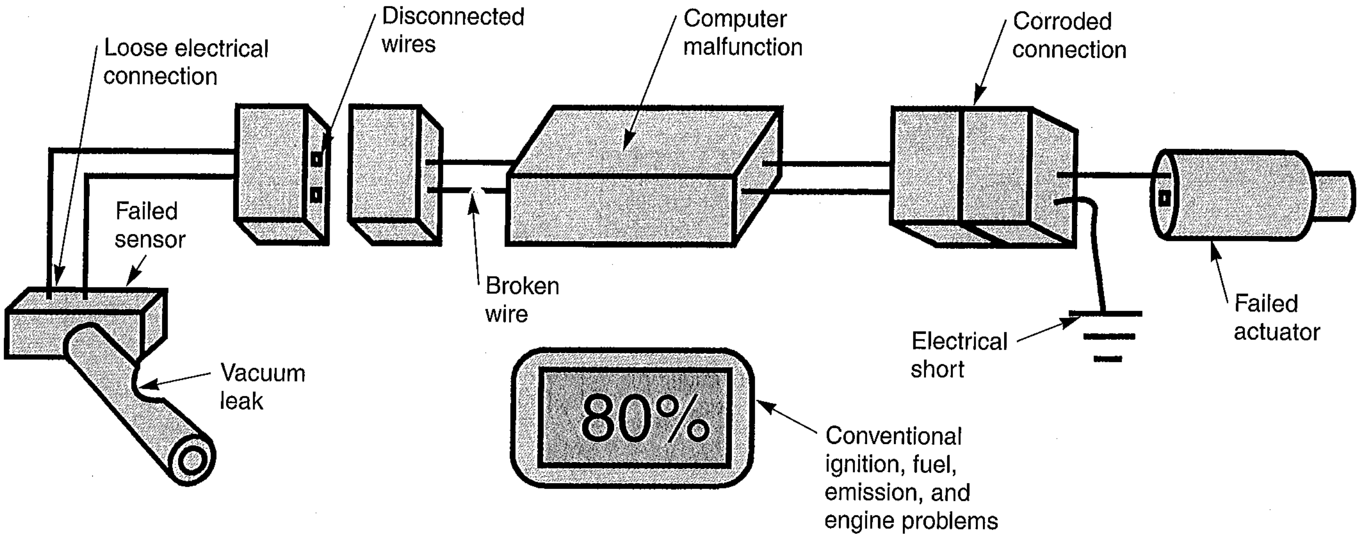


Figure 18-2. Always remember that about 80% of all performance problems are *not* caused by the computer, its sensor, or its actuators. Most problems are the result of conventional problems, such as loose connections, broken wires, vacuum leaks, mechanical problems, etc.

- *Corroded electrical connection*—high resistance in a wiring connector, upsetting sensor input or actuator output.
- *Failed sensor*—opened or shorted sensor or other sensor malfunction preventing normal computer system operation.
- *Failed actuator*—solenoid, servo motor, relay, or display shorted, open, or does not react to computer signals.
- *Leaking vacuum hose*—vacuum leak or poor operation of engine or vacuum-operated actuator that reduces engine or system performance.
- *Electrical short*—wires touching ground or each other to cause a current increase or incorrect current path.
- *Ignition system problems*—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*—leaking or clogged injectors, bad pressure regulator, faulty electric fuel pump, or other problems.
- *Emission system problems*—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*—mechanical problem 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*—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*—sensor, actuator, or computer 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 signals to the ECM at a reduced rate of speed. 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 there is a mechanical problem. Transmission problems include a bad vehicle speed sensor, a faulty shift sensor or solenoid, or faulty wiring.
- *Anti-lock brake system problems*—modern anti-lock brakes are monitored by an on-board computer. Anti-lock brake system problems include

bad wheel speed sensors, faulty wiring, or a malfunctioning hydraulic unit.

- *Air conditioning*—today's air conditioning systems are also monitored electronically for operational state, leaks, and high pressure. Typical problems include faulty pressure and temperature sensors.
- *Air bag problems*—problems with the air bag system, such as faulty impact sensors, a malfunctioning arming sensor, or a damaged air bag module, will trip trouble codes.
- *Other system faults*—most other vehicle systems have some monitored functions that will trip a trouble code.

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 to display the 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 some cases, it is the only way to access the computer's diagnostic system. Refer to **Figure 18-3.**

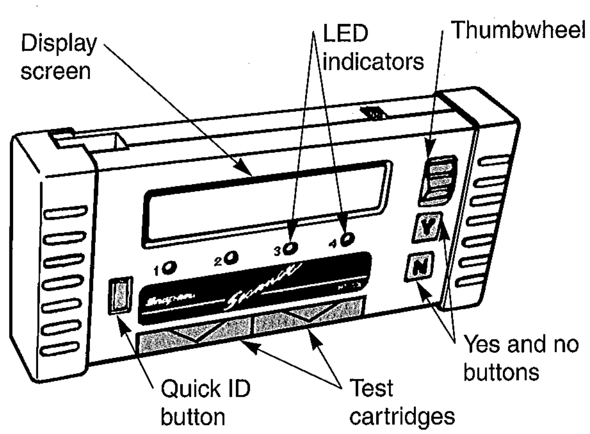


Figure 18-3. A scan tool is now the most important tool of the automotive technician. It will tell you where problems are located. (Snap-on Tools)

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 18-4.**

To use the scan tool, read the operating instructions for the specific tool at hand. Operating procedures vary. Some scan tools have buttons to control functions. Others have a rotary knob that lets you scroll down through scan tool functions.

Note!
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 vehciles.

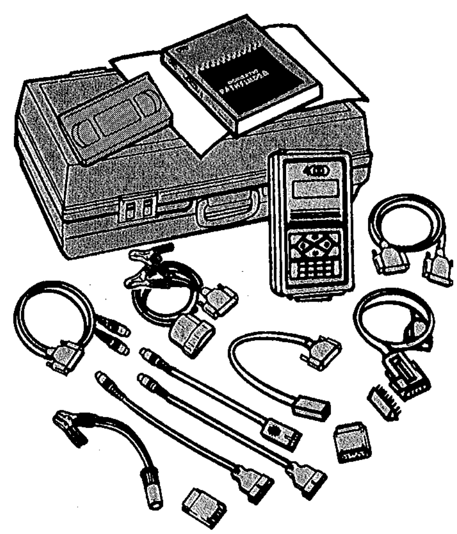


Figure 18-4. Scan tool designs vary. Always read the owner's manual that comes with the tool before use. (OTC)

Scan Tool Program Cartridges

Most scan tools come equipped with several ***program cartridges.*** These removable cartridges house one or more computer chips that contain specific information about the vehicle to be scanned, **Figure 18-5.**

One type of scan tool cartridge is a *vehicle program cartridge.* This type of program cartridge provides data for one or more vehicle manufacturers (GM, Ford, Chrysler, Asian, European, etc.). Scan tool cartridges must match the model year (vehicle manufacturing date). Program cartridges are also available for certain systems, such as anti-lock brakes, automatic transmissions, etc.

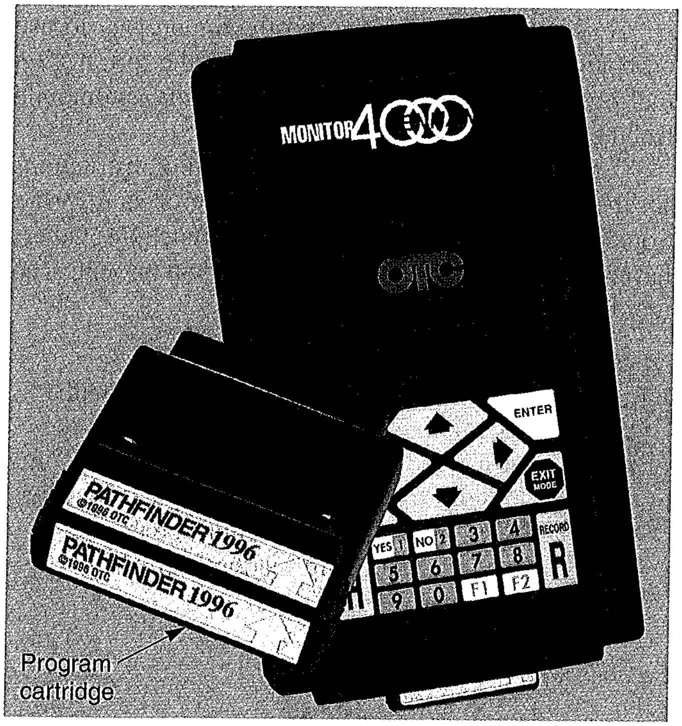


Figure 18-5. Scan tool cartridges contain stored information for troubleshooting a specific make, model, and year of vehicle. Troubleshooting cartridges sometimes give added instructions to help solve a problem. (OTC)

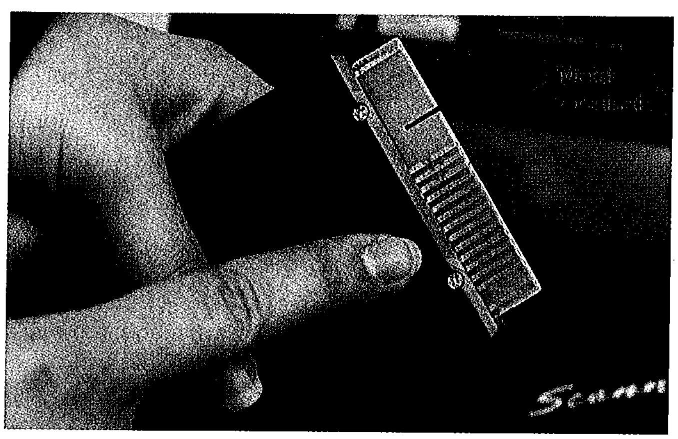


Figure 18-6. When installing a cartridge into a scan tool, do not touch the metal terminals. Static electricity could damage the cartridge's internal chips or electronics. (Snap-on Tools)

New cartridges must be purchased as the on-board diagnostic systems are modified. Some scan tool manufacturers now offer generic storage cartridges that can be updated by downloading the up-to-date specifications to the scan tool from a computer.

Caution!
Avoid touching the cartridge or scan tool terminals. Static electricity can destroy the delicate electronics in these units. See **Figure 18-6.**

A few scan tools also come with a ***troubleshooting cartridge,*** which gives additional information on how to verify the source of various trouble codes. This is a handy device that can help guide you to the most common sources of trouble. However, the troubleshooting cartridge must be used in conjunction with the vehicle cartridge. This makes it necessary to have a scan tool that can access two cartridges at the same time.

Figure 18-7. Install the correct cartridge(s) into the scan tool. Make sure it is fully seated. (Snap-on Tools)

Many scan tools will hold two cartridges, one for the vehicle being tested and another for added convenience. However, most scan tools can access the information from one cartridge at a time. A few scan tools can access both cartridges at the same time. This capability allows for the use of the troubleshooting cartridge discussed earlier. Install the right cartridge(s) into the scan tool. Slide the cartridge straight into the tool to prevent damage. Look at **Figure 18-7.**

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. 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 include:

- Under the dash or the center console, within arm's reach when sitting in the driver's seat, **Figures 18-8A** and **18-8B.** These are the standard OBD II locations.

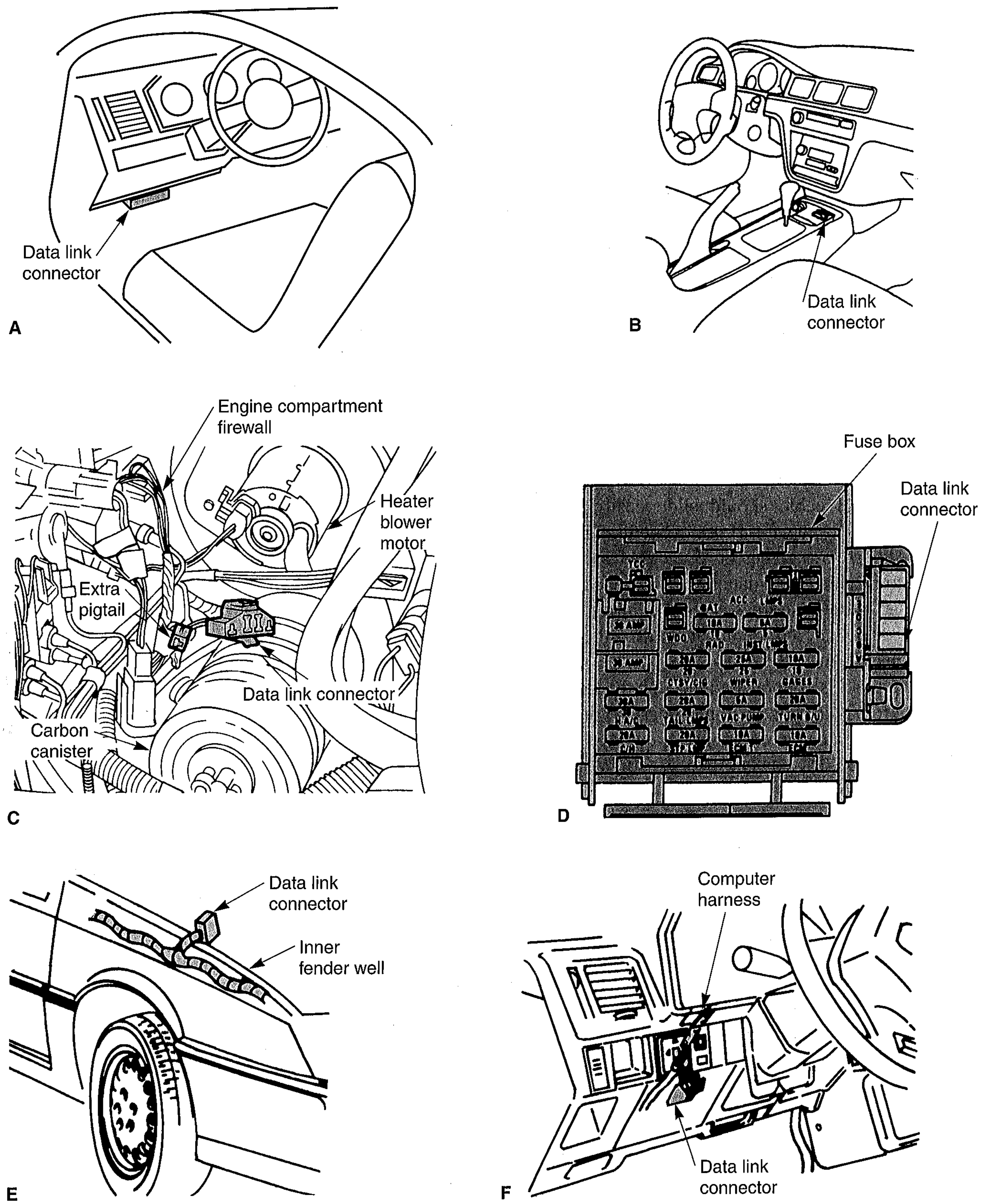


Figure 18-8. Data link connector locations vary. A—OBD II vehicles have their data link connector below the dash, within easy reach of the driver's seat. B—The OBD II connector is sometimes located in the center console. C—Some Ford diagnostic connectors are on the firewall, near the back of the engine. 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.
(General Motors, Ford, and Snap-on Tools)

- Behind the dashboard, **Figure 18-8F.**
- Near the firewall in the engine compartment, **Figure 18-8C.**
- Near or on the side of the fuse box, **Figure 18-8D.**
- Near the inner fender panel in the engine compartment, **Figure 18-8E.**

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.

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

The scan tool cable should slide easily into the vehicle's data link connector. 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. You may have to use an ***adapter*** so the scan tool connector will fit the vehicle's DLC or communicate with different pin configurations, **Figure 18-9.**

If the scan tool is not powered through the DLC, connect the tool to battery power. In most cases, you can use a cigarette lighter adapter to connect power to the scan tool. See **Figure 18-10.** You can also use alligator clips to connect the tool to the battery.

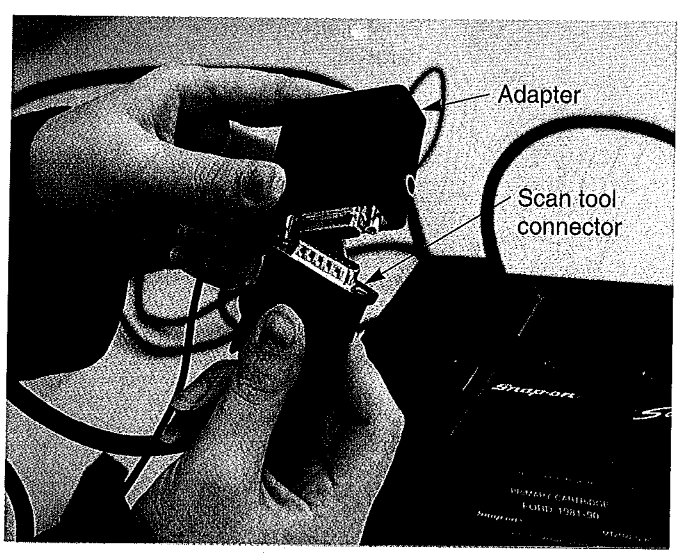


Figure 18-9. An adapter is sometimes needed between the scan tool cable and the vehicle's data link connector. As OBD II–equipped vehicles become more commonplace, these adapters will be needed less. (Snap-on Tools)

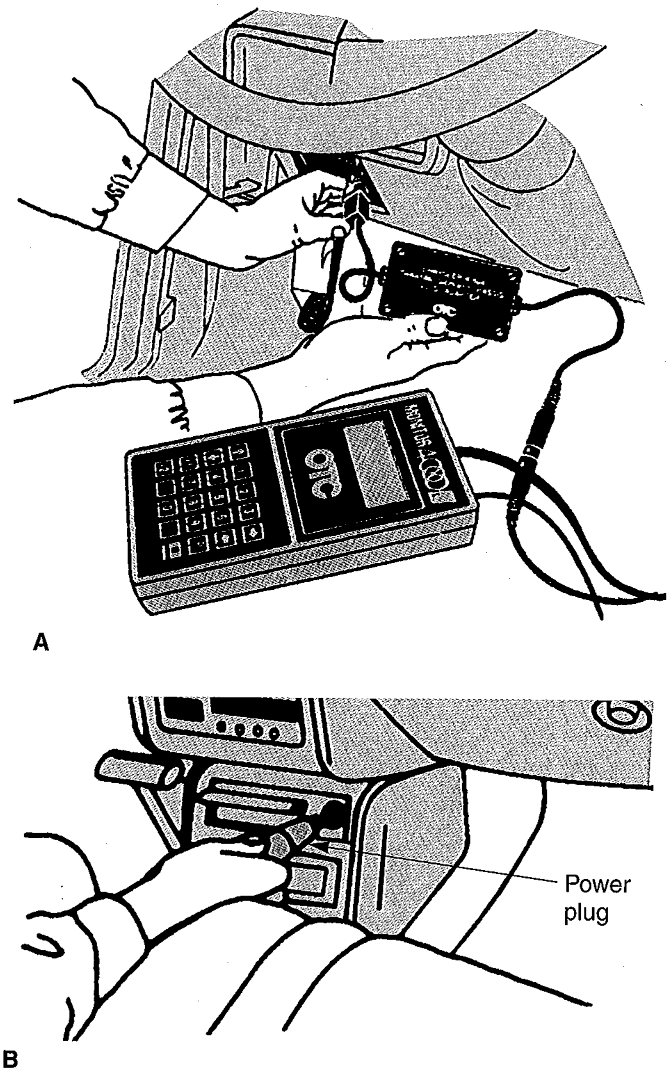


Figure 18-10. A—Connect the scan tool cable to the vehicle's data link connector. Make sure the pins match up. Do not force them together. B—If necessary, scan tools can be powered by a cigarette lighter plug or connected directly to the battery. (OTC)

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. See **Figure 18-11.** Scan tool instructions are procedures and specifications programmed into the cartridge.

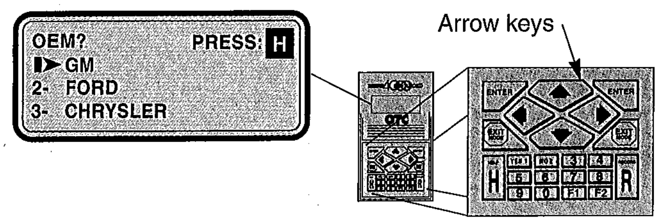


Figure 18-11. Controls on a scan tool will vary by manufacturer. A—This scan tool uses a keypad and arrow keys for inputting requested information about the vehicle and desired tests. B—This scan tool has an easy-to-use rotary knob and yes–no buttons for inputting requested data. (OTC and Snap-on Tools)

First, the scan tool may ask you to input VIN information from the plate on the top of the dash. You may be asked to input specific numbers and letters from the VIN. Refer to **Figure 18-12.**

The VIN data lets the scan tool know which engine, transmission, and options are installed on the vehicle. 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. Some of the information you can request includes:

- *Stored diagnostic trouble codes*—gives trouble codes.
- *Fault description*—explains what each stored diagnostic code means. This information is given with the trouble codes on most scan tools.
- *Datastream information*—displays the operating values of all monitored circuits and sensors.
- *Run tests*—performs sensor and actuator tests.
- *Oxygen sensor monitoring*—performs detailed tests of the O_2 sensor signal.
- *Failure record*—lists the number of times a particular trouble code has occurred by keystarts or warm-ups.
- *Freeze frame*—takes a snapshot of sensor and actuator values when a problem occurs.

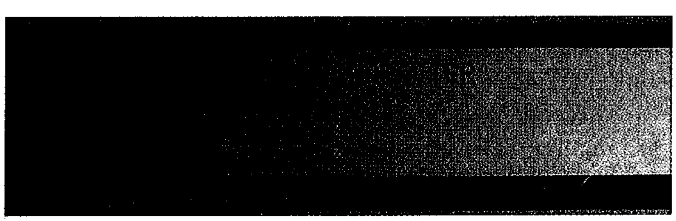


Figure 18-12. The scan tool may ask you to input VIN information. This lets the tool know how the vehicle is equipped—engine type, fuel system type, computer configuration, etc. (Snap-on Tools)

- *Troubleshooting*—Provides help and instructions for diagnosing faults.

Figure 18-13 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. **Figures 18-14** and **18-15** show some examples of scan tool troubleshooting tips.

As stated earlier, some scan tools are able to take a snapshot, or ***freeze frame,*** of sensor and actuator values when a problem occurs. The tool records the values from all monitored components so they can be further evaluated. This helps you locate and correct intermittent problems more easily.

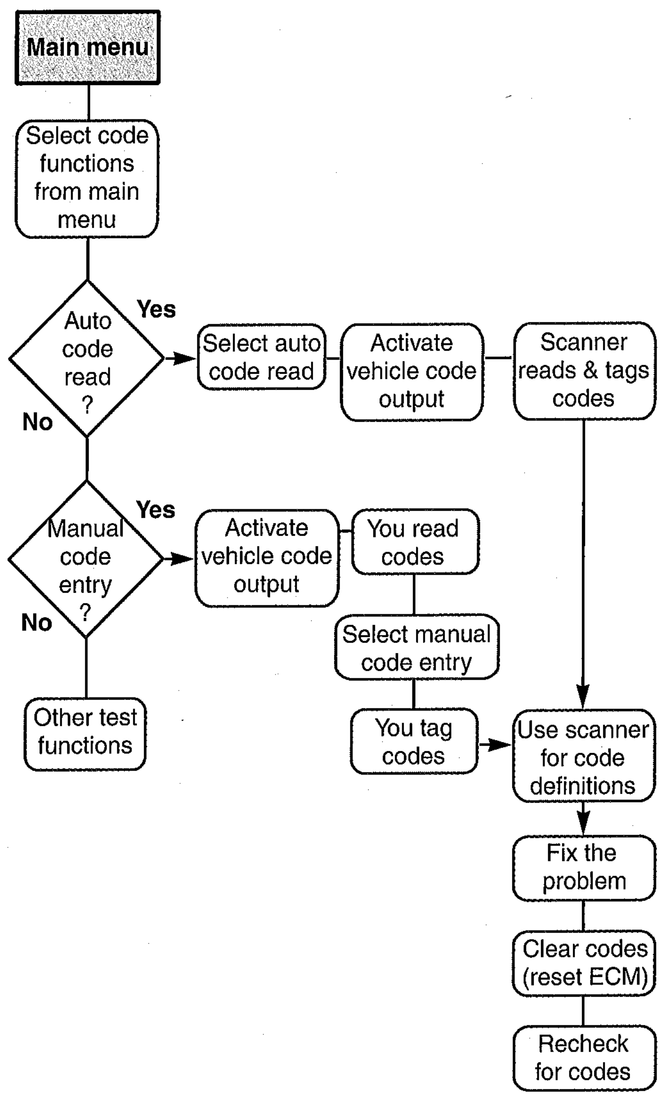


Figure 18-13. Flowchart showing the basic steps for using a scan tool. (Snap-on Tools)

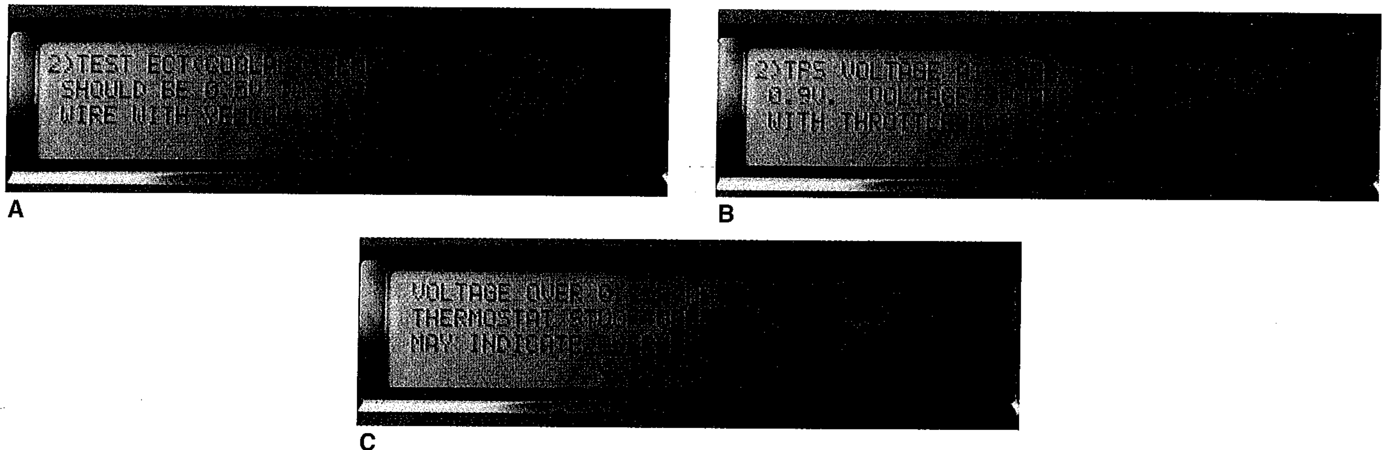


Figure 18-14. Here are examples of how scan tools will give specifications and tips for finding the source of a problem. A—The scan tool is showing normal sensor voltage and which wire to probe when measuring actual voltage. B—This scan tool is giving more information for testing the throttle position sensor. C—Scan tools can also give hints on how engine overheating or overcooling can fool the computer into signaling a problem with the engine coolant temperature sensor.

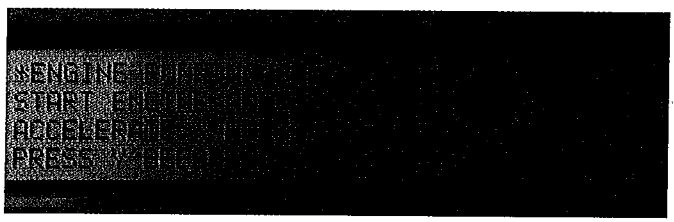


Figure 18-15. A key-on/engine-on test is sometimes needed to further diagnose problems. You must allow the engine to reach operating temperature first so all sensors are operating normally.

Tech Tip!
Most technicians check the ECM 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.

Most ECMs count the number of times a trouble code has occurred. This information is stored in a ***failure record,*** or *failure recorder,* that also indicates the number of keystarts since the last time the trouble code occurred. The failure recorder in OBD II systems counts the number of times the engine reached operating temperature, rather than keystarts, since the last time the code was set. 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 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 core 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 18-16 gives a breakdown of the OBD II diagnostic code. Study it carefully. **Figure 18-17** 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:

- A ***general circuit failure*** means 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.

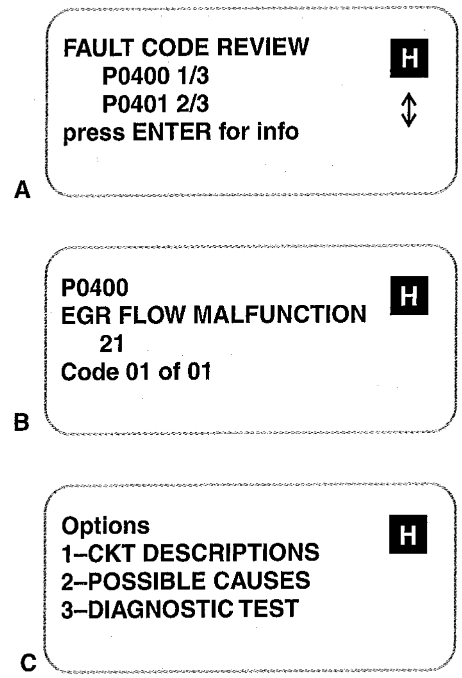


Figure 18-17. This is an example of what you might see on the display of a scan tool. A—The scan tool will give you the trouble code numbers. B—If you request information on the stored trouble codes, the tool will explain what each code means. C—Options will allow you to use the scan tool to get detailed descriptions of each code, list possible causes, or perform diagnostic tests. (OTC)

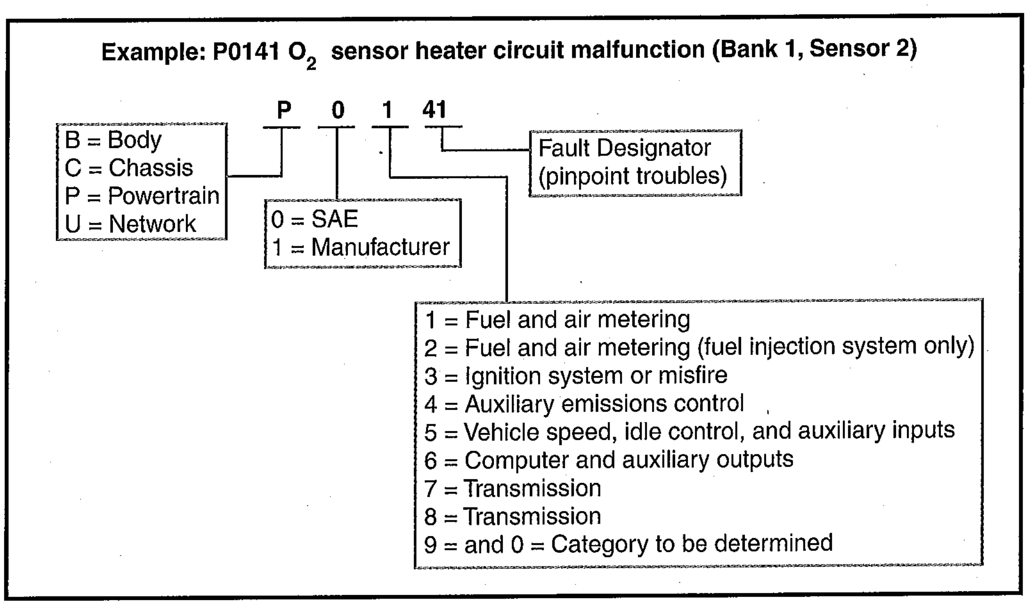


Figure 18-16. OBD II trouble codes are alpha-numeric. Note what each part of the trouble code means. The first part of the code tells you which system is having problems. The last part of the code identifies the specific problem circuit or component.

- A ***low-input failure*** is one 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.
- A ***high-input failure*** 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.
- An ***improper range/performance failure*** 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.

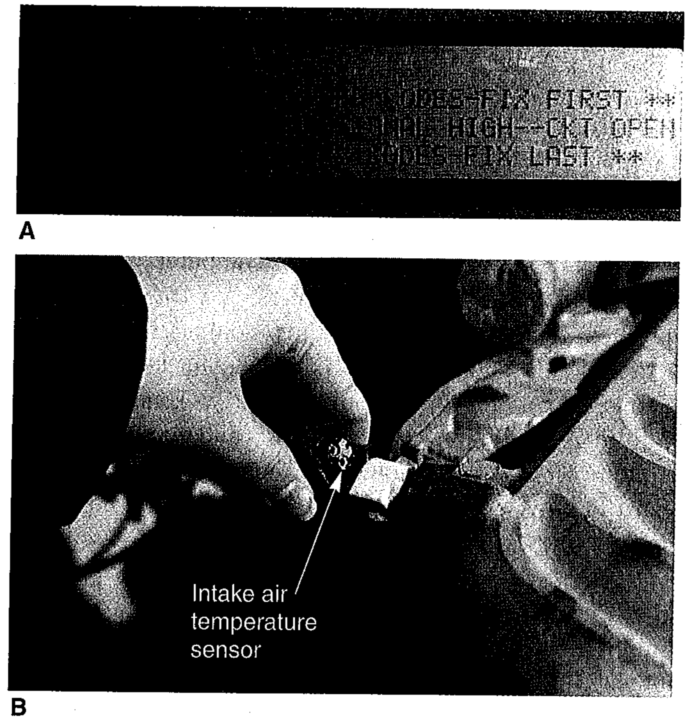


Figure 18-18. Most technicians check for stored trouble codes first. A—This scan tool readout shows a problem with the intake air (air charge) temperature sensor. B—You would then know to check that sensor and its wiring for problems. (Snap-on Tools)

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.

Note!
For more information on scan tools and datastream values, see Chapter 46, *Advanced Diagnostics.*

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 18-18.**

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. These failures can be found by performing a ***wiggle test,*** or "flex" test.

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, **Figure 18-19.**

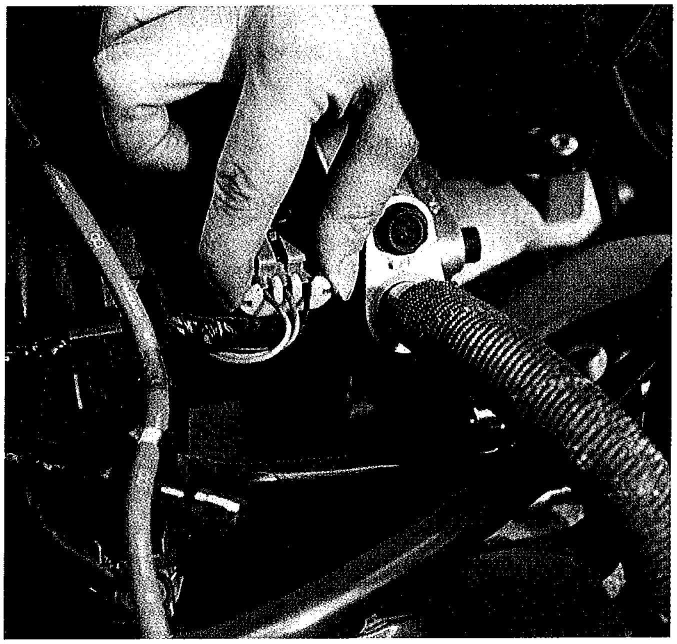


Figure 18-19. The wiggle test involves moving wires and connectors while scanning for trouble codes. If wiggling a wire trips a code, you found the location of the problem.

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.

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 18-20.**

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 *OK 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 Tests

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.

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 18-21.** For example, if the problem occurs only while driving

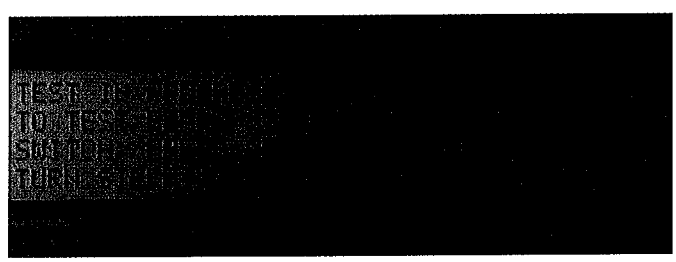


Figure 18-20. Most scan tools will also perform switch and actuator tests. This is sometimes done automatically. You may be prompted to close different switches to make sure each one is working. The scan tool may also be able to perform additional actuator tests. (Snap-on Tools)

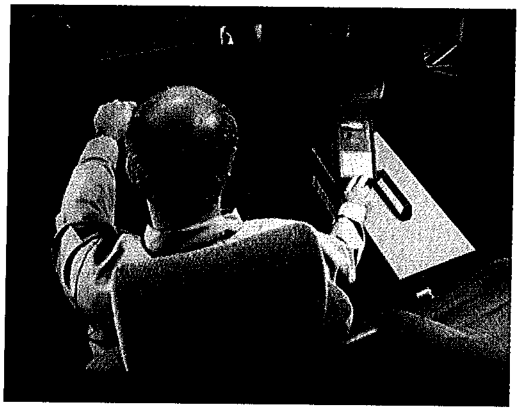


Figure 18-21. Scan tools are sometimes used while test driving vehicles. This will allow you to check engine and vehicle operating parameters while duplicating the conditions present when the problem occurred. (OTC)

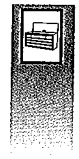
at a specific speed when the engine is cold, you can scan under these conditions. Start the cold engine and drive at the specified speed while scanning for problems. You can then take a snapshot, or freeze-frame, (if the scan tool has this feature) when the problems occur. For more information on advanced diagnostics, refer to Chapter 46.

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, **Figure 18-22.** 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, **Figure 18-23.**
- 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.
- 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. See **Figure 18-23.**
- 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.



Tech Tip!
Some older vehicles with on-board computers do *not* have on-board diagnostics. You must use conventional testing methods to pinpoint problems on these vehicles.

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 several different ways that 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.

Reading the Flashing Check Engine Light

The check engine light displays trouble codes as it flashes on and off. Some codes are single-digit numbers and others are two-digit numbers. With single-digit codes, the number of pulses equals the code number. When there are multiple one-digit codes, there is a distinct pause between code numbers.

Reading a two-digit code is a bit more complex. If, for example, the light flashes once, pauses, and then flashes two more times, the trouble code would be 12 (1 pause 2). See **Figure 18-24**. If the check engine light blinks twice, pauses momentarily, and then blinks three more times, the trouble code would be 23 (2 pause 3). When there are multiple two-digit codes, there will be a relatively long pause between codes.

Reading Voltmeter Needle Deflections

An analog voltmeter code is read by counting the number of needle deflections between each pause. This is similar to the light flashes. However, the computer usually produces 5-volt pulses for the test meter.

An example of a two-digit code would be if the needle deflected once, paused, and then deflected four more times. The first digit would be one and the second

RETRIEVING OBD I TROUBLE CODES (WITHOUT SCAN TOOL)

The three major auto makers use different procedures to make their car's on-board computer spit out trouble codes. The computer can actually detect if a sensor or actuator has failed or if a bad electrical connection has developed. This will help you know where to test for possible computer system problems.

The following is a summary of typical methods used to make an on-board computer produce these codes:

General Motors Corporation Trouble Codes

1. Locate diagnostic connector. It is usually under dash near fuse panel or steering column.
2. Use a jumper wire or paper clip to short across designated terminals in connector.
3. Watch engine light flash on and off in a Morse type code. Count number of flashes between each pause and note them. Three flashes, a pause, and two flashes would equal code 32.
4. Refer to trouble code chart in service manual for a explanation of code number.
5. Test suspected component or circuit with a digital VOM. Compare your test readings to factory specs.
6. Note that some GM cars require you to press two climate control buttons on dash at same time to enter self-diagnosis. Then, trouble code number will appear in dash. You would then need to find the same number in service manual trouble code chart.

Ford Motor Company Trouble Codes

1. Locate diagnostic connector. It is usually in engine compartment on firewall, fenderwall, or near engine intake manifold.
2. Connect an analog or needle type VOM to designated terminals in diagnostic connector.
3. Use a jumper wire to connect extra pigtail near connector to service-manual-designated terminal in connector.
4. Observe needle fluctuations on voltmeter as you did when watching engine light for a GM car. Count needle movements between each pause. Two needle movements, a pause and then six needle movements would equal code 26.
5. Refer to service manual trouble code chart to find out what number code means.
6. Use conventional testing methods and your VOM to pinpoint cause for problem.

Chrysler Corporation Trouble Codes

1. Chrysler provides a diagnostic connector in engine compartment on late model cars. However, connector is NOT needed to energize self-diagnosis. It is provided so a scanner-tester can be connected to system.
2. To trip trouble codes, simply turn ignition key on and off three times within five seconds. Turn key on, off, on, off, and then leave it ON.
3. Observe engine light flashing on and off. Count number of flashes between each pause. Three flashes, a pause, and then one flash would equal a trouble code of 31.
4. Refer to the service manual trouble code chart to find out which component or circuit is indicated by the trouble code.
5. Use conventional VOM tests to find the source of the trouble. Test the sensor or actuator and the wiring between the device and the computer.

Note! computer self-diagnosis systems and procedures can vary from the methods just described. Always refer to a factory service manual when in doubt!

Figure 18-22. Study the basic methods for reading OBD I trouble codes without a scan tool. (TIF Instruments)

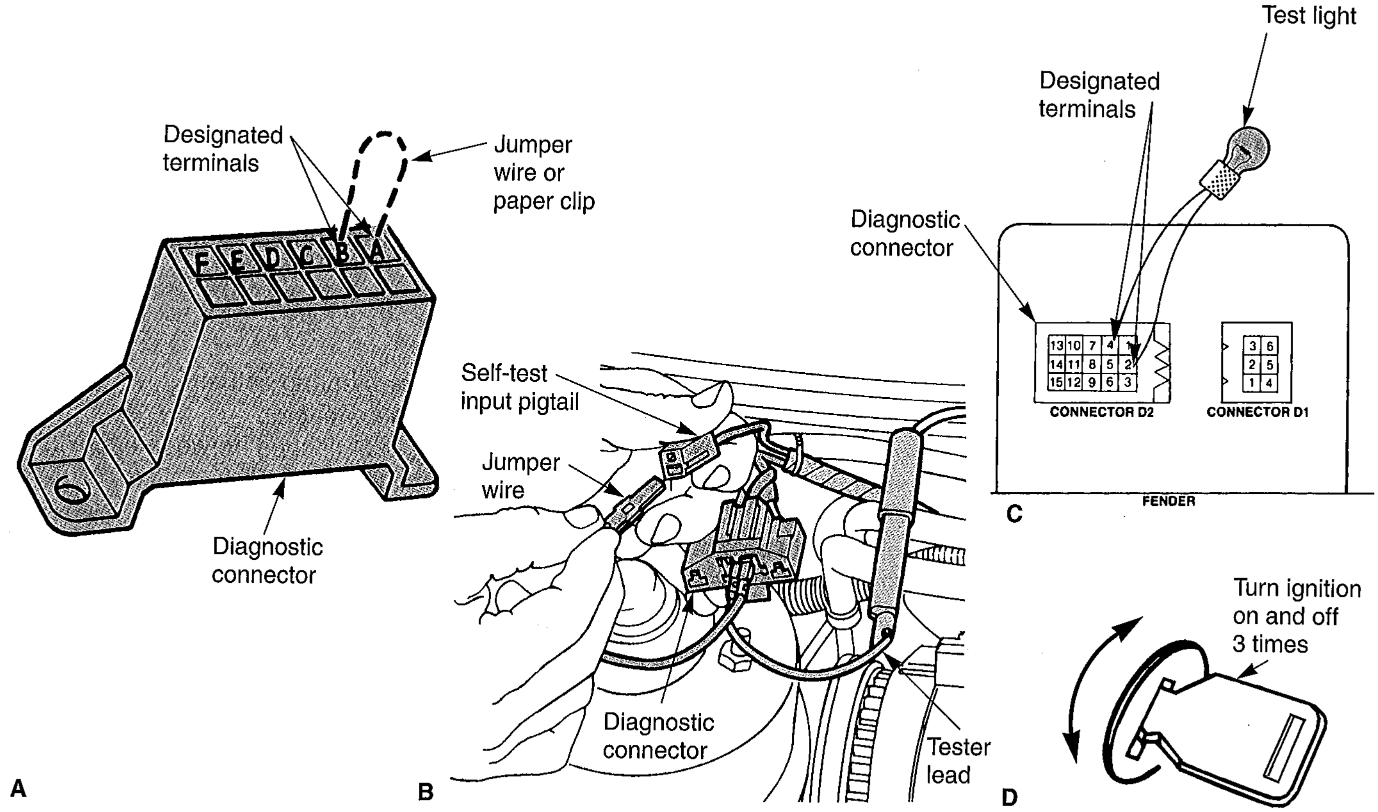


Figure 18-23. Various methods are used to energize OBD I systems. A—Use a jumper wire or paper clip to ground specified terminals in most GM connectors. B—Jump from the extra pigtail to a specified terminal in many Ford connectors. C—Connect a test light across specified terminals in this connector. D—Turning the ignition key on, off, on, off, and then on within five seconds will energize on-board diagnostics with some Chrysler cars. (DaimlerChrysler, General Motors, and Ford)

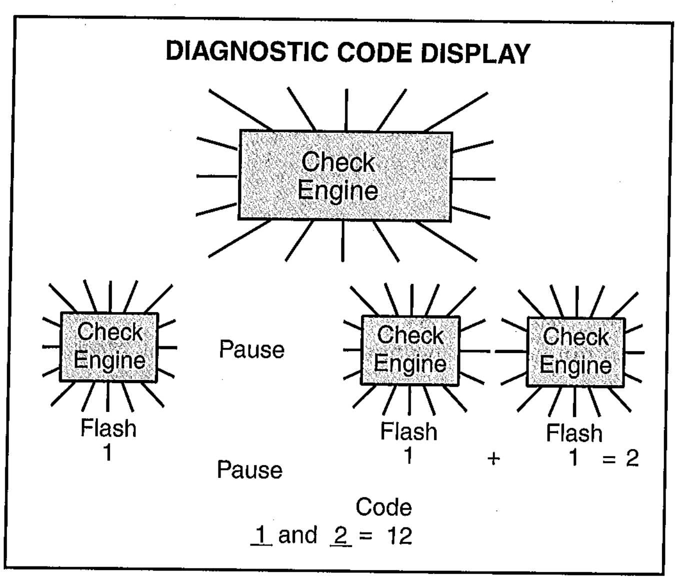


Figure 18-24. A dash indicator light will normally glow if the computer detects a potential fault. This tells the driver and technician something is wrong. After energizing the computer's diagnostic mode, the dash light may flash on and off to produce a number code. Note how this code is read. (General Motors)

would be four. This trouble code would be 14. A few digital test meters have a bar graph that will show trouble code pulses. However, most digital meters cannot read trouble codes.

Caution!
Use only a high-impedance (10 megohms or higher) test light or multimeter when testing computer circuits. A high current draw from a conventional test light could shorten electronic circuit life or even destroy delicate integrated circuits.

Reading Digital and LED Displays

Dash digital codes are read like scan tool codes. These codes are retrieved after pressing two dash buttons, usually climate control buttons, at the same time. The climate control or temperature readout will then show any trouble codes.

An LED trouble code is produced by indicator lights on the side of the computer. This is a less common method to display computer trouble codes.

DTC. No.	DTC dectecting 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 18-25. This is a trouble code chart for one type of vehicle. Study how different code numbers show possible problems and causes. (General Motors)

Trouble Code Charts

A trouble code chart in the service manual will explain what each trouble code number means, **Figure 18-25.** This will help you know where to start further tests on specific components.

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 18-26.**
- 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.

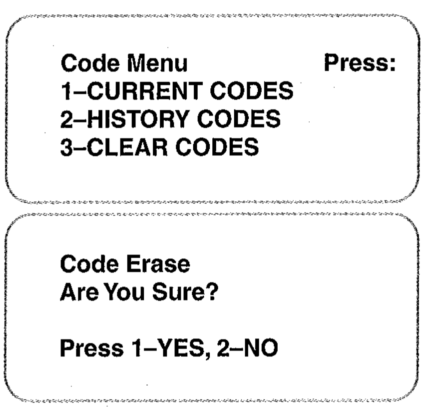


Figure 18-26. Using a scan tool is the fastest and easiest way to erase stored trouble codes. With most scan tools, simply choose the menu selection to clear codes and then press YES. (OTC)

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!
A memory saver, which consists of a small battery and alligator clips, can be connected across the battery terminals before disconnecting the battery. It will provide enough power to keep the clock, stereo, and computer from losing the information stored in their memories. When using a memory saver, turn off all accessories (radio, blower, etc.). The current drain from these devices, combined with even the smallest voltage drop, could cause electronic devices (computer, clock, radio, etc.) to lose their preprogrammed data.

Duff's Garage

Problem: Ms. Figuroa says that a light is glowing in the dash of her 2006 GMC pickup truck.

Diagnosis: 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.

Repair: 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.
- Most scan tools come equipped with different program cartridges. A scan tool cartridge contains information about the specific make of vehicle to be scanned.
- The data link connector (DLC) is a multipin terminal for reading computer trouble codes or scanning problems.
- A scan tool snapshot or freeze frame is an instantaneous readout 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.

Important Terms

On-board diagnostics	Prompts
Scan tool	Freeze frame
On-board diagnostics generation one (OBD I)	Failure record
On-board diagnostics generation two (OBD II)	Standardized alpha-numeric trouble codes
Malfunction indicator light (MIL)	Standard trouble codes
Check engine light	Nonuniform codes
Service engine soon light	Fault designation
Trouble code chart	Hard failure
Trouble code conversion	Soft failure
Diagnostic trouble codes (DTC)	General circuit failure
Operating parameter	Low-input failure
Program cartridges	High-input failure
Troubleshooting cartridge	Improper range/performance failure
Data link connector (DLC)	Datastream values
Diagnostic connector	Key-on/engine-off diagnostics
Assembly line diagnostic link (ALDL)	Wiggle test
Adapter	Key-on /engine-on diagnostics
	Switch diagnostic test
	Actuator diagnostic test

Review Questions—Chapter 18

Please do not write in this text. Place your answers on a separate sheet of paper.

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. Give five locations for the data link connector.
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. A non-OBD II car enters the shop with the computer warning light on. Technician A says that to trigger on-board diagnostics, you may have to connect a jumper wire across specified terminals in the diagnostic connector. Technician B says that to trigger on-board diagnostics, you may have to turn the ignition key on and off a specified number times. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
14. Explain several ways to read OBD I trouble codes without a scan tool.
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 not caused by the computer system. Technician B says about 80% of all automotive engine performance problems are not caused by the computer system. 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 right side of dash.
   (B) Near the firewall in the engine compartment.
   (C) Under the center console.
   (D) All of the above.
9. When a trouble code number is looked up in a service manual, the trouble code chart says oxygen sensor. 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.