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15

Computer System Diagnosis and Repair

After studying this chapter, you will be able to:

- Retrieve trouble codes.
- Identify trouble code formats.
- Interpret trouble codes.
- Use a scan tool to check components and systems.
- Use a multimeter to check computer system components.
- Identify computer system waveforms.
- Explain how to adjust throttle and crankshaft position sensors.
- Explain how to replace computer control system input sensors.
- Explain how to replace a computer control system ECM.
- Explain how to replace an ECM memory chip.
- Explain how to program an ECM with an erasable PROM.
- Explain how to replace computer control system actuators.

Technical Terms

Electronic control module (ECM)
Maintenance indicator light (MIL)
Flex test
Data link connector (DLC)
Fault designators
Hard codes
Intermittent codes
Datastream values
Snapshot
Zirconia-type sensor
Titania-type sensor
Artificial lean mixture
Artificial rich mixture
Forcing the actuator
Anti-seize compound
EPROM
FEPROM
Flash programming
Direct programming
Indirect programming
Remote programming
Drive-cycle test

The on-board computer controls many vehicle systems. The level of control ranges from simply monitoring system operation to aggressively adjusting components or systems to compensate for changes in vehicle operating conditions. Therefore, even a minor computer control system problem can have a dramatic effect on one or more vehicle systems. Be sure to obtain the vehicle's service manual or equivalent service information before you begin any diagnostic operation.

This chapter discusses the diagnosis and repair of the computer control system. This includes the three main sections of any computer control system: the input sensors, the computer, and the actuators. Studying this chapter will help you understand the basic computer system testing procedures.

Note: There are many names for the on-board computers that control engine and vehicle operation. For simplicity, the term *electronic control module (ECM)* will be used when referring to these computers in this chapter. There are also many names for the dashboard light that illuminates to indicate computer system problems. In this chapter, however, this light will be called the *maintenance indicator light (MIL).*

Diagnosing Computer Control System Problems

Often, a vehicle is brought in for service when the MIL is illuminated, when fuel economy drops, or when the vehicle fails an emissions test or has a driveability problem. As a technician, your first impulse may be to blame the computer control system for these problems. The computer controls, however, should be suspected only after you have checked for more obvious—and more common—problems.

Remember that many noncomputer problems can cause the ECM to set trouble codes, illuminate the MIL, or cause malfunctions that might be blamed on the computer control system. Typical noncomputer-related problems that might be blamed on the computer control system include an engine miss caused by a burned valve or a fouled spark plug, a rough idle caused by a vacuum leak, stalling caused by a plugged fuel filter; and overheating caused by a defective fan clutch. Similarly, the ECM can be fooled into sending improper commands to the actuators by such conditions as a dirty cooling system that results in incorrect temperature sensor readings, or a leaking injector that causes the oxygen sensor to read a rich air-fuel mixture. It is a good idea to check overall engine condition before proceeding to the computer control system. Typical computer control problems and some of the systems they can affect are shown in **Figure 15-1.**

The first step in diagnosing computer control system problems is to check for obvious system defects. Always

Figure 15-1. The computer monitors and controls a variety of vehicle systems. The problems listed here are only of few of the possible malfunctions that can occur in computer-controlled systems. (Oldsmobile)

obtain the correct system schematic and determine which circuits and devices directly affect the ECM. Also check the ECM fuses. The ECM may be powered through more than one fuse, fusible link, or relay. If one of the ECM fuses is blown, the MIL may not illuminate at any time.

Note: Never remove fuses before attempting to retrieve trouble codes. Removing fuses can erase the trouble codes from the ECM's memory. If the MIL is not on when the ignition switch is on and the engine is not running, check the bulb before checking any fuses.

After checking the ECM fuses, check all other vehicle fuses. A blown fuse in an unrelated circuit may cause current to attempt to ground through the ECM, affecting vehicle operation or illuminating the MIL.

Remember that computer input sensors operate on very low voltages and slight wiring problems can cause inaccurate readings. Any arcing or sparking caused by loose electrical connections will affect computer system operation.

Carefully check all electrical connections. Look for disconnected or corroded ground wire connections, **Figure 15-2.** Connector problems can also be caused by water entering the connector and by overheating due to high-resistance connections. One way to check for problems in the connectors and wiring is to perform a ***flex test.*** To make a flex test, pull on the various system electrical connectors and wiggle the related

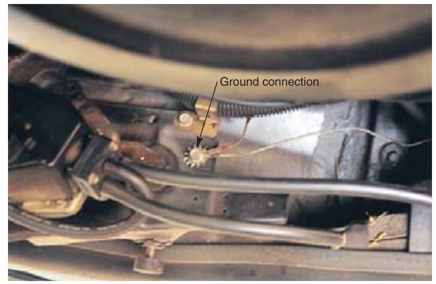


Figure 15-2. Bad grounds are a common source of trouble. Always check grounds by visual inspection and by pulling on the connections. Also try to tighten the attaching bolt when applicable.

wiring as the engine operates. If the engine begins running erratically or the MIL illuminates when the connectors and wires are moved, the connector or the wiring is defective.

Also look for problems in the charging system. Low voltage caused by a defect in the charging system will confuse the ECM and cause erratic operation. Check charging voltage with a voltmeter as the engine idles. Normal charging voltage should be between 12 and 14.5 volts. If charging voltage is low, check the alternator, voltage regulator, battery, and related connections. Also check for a loose or glazed alternator drive belt.

If the voltage at idle is within specifications, increase engine speed to about 2500 RPM and recheck the voltage. If the voltage is above 14.5 volts, suspect a defective voltage regulator. Correct charging system problems before attempting further diagnosis.

Check for any sign of modification or tampering. This includes sensors and output devices that have been removed, unplugged, or disabled in some manner. If a visual inspection does not reveal problems, check for and retrieve any diagnostic trouble codes present in the ECM as outlined in the following section.

Retrieving Trouble Codes

Before performing involved diagnostic routines on computer-controlled vehicles, always check for and retrieve trouble codes from the ECM. If the MIL is on when the engine is running, trouble codes are present in the ECM's memory, **Figure 15-3.** However, it is important to check for trouble codes any time a computer system problem is suspected, since trouble codes may be stored even if the MIL is not on.

To retrieve trouble codes from the ECM, follow the procedures outlined in the factory service manual. Basic procedures for code retrieval are discussed later in this chapter. On most older vehicles, trouble codes can be retrieved without special equipment, although using a scan tool makes the process easier.

For many years, each manufacturer used a different style of diagnostic connector, which is sometimes called a data link connector or data terminal connector. This made accessing diagnostic trouble codes difficult. These connectors could be located almost anywhere, depending on the manufacturer and vehicle model. However, the OBD II diagnostic protocol required manufacturers to use a standardized 16-pin connector located inside the vehicle's passenger compartment. A 16-pin OBD II connector is shown in **Figure 15-4.** In this chapter, we will refer to the diagnostic connector as a ***data link connector (DLC).***

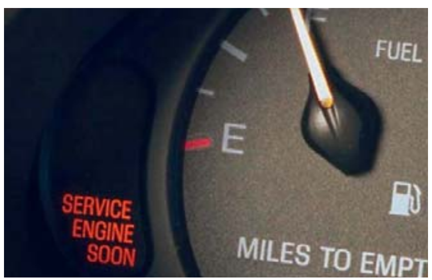


Figure 15-3. The check engine or malfunction indicator light (MIL) is the first place to look when diagnosing any problem. Check the status of this light while test driving the vehicle. (Toyota)

Note: The standard 16-pin DLC is used on some non-OBD II vehicles.

Some older computer systems do not have a DLC, and other methods must be used to access the diagnostic information in the ECM.

The Trouble Code Retrieval Process

Trouble codes are retrieved from the ECM using a two-step process. The first step is to ground a DLC terminal to place the ECM in the diagnostic mode. The second step involves reading the codes that the ECM displays. All methods of trouble code retrieval are variations of these two steps, regardless of whether they are performed manually by the technician or automatically by a scan tool.

Retrieving Trouble Codes without a Scan Tool

In OBD I systems, trouble codes can be retrieved without using a scan tool. In these systems, the most common retrieval method is to ground one terminal of the DLC and then observe a series of flashes from a diagnostic light. The light used may be the MIL, or it may be an LED (light-emitting diode) located on the ECM's case. The sequence of light flashes represents a numerical code. The factory service manual contains instructions for correctly interpreting the light flashes. See **Figure 15-5.**

Another common method of retrieving trouble codes involves connecting an analog voltmeter to specified DLC terminals. Another DLC terminal is grounded and the trouble code output is displayed as a series of deflections of the voltmeter's needle, **Figure 15-6.** Always follow the manufacturer's procedure exactly, since the wrong sequence of steps can erase the trouble codes or, in some cases, cause false codes. Some digital multimeters can display codes as electronic pulses.

The trouble codes on some vehicles can be accessed by turning the ignition switch on and off three times within five seconds. The codes will then be displayed by the MIL. Some trouble codes can be accessed by pressing and holding down a certain sequence of buttons on the radio and/or air conditioner control head for a specified period of time. The codes will appear as numbers on the control head display. This feature is found on only a few vehicles with electronic entertainment and climate control systems.

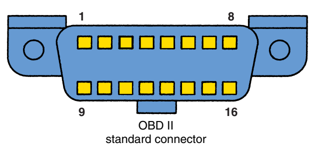


Figure 15-4. This figure shows the standardized data link connector used in OBD II systems. All vehicles built within the last several years use this connector.

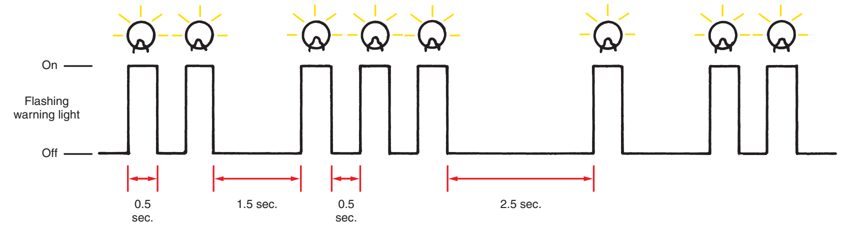


Figure 15-5. Older diagnostic systems made use of the MIL to display codes. The series of flashes is interpreted as numbers. The technician then looks up the numbers in the manufacturer's service literature to determine the problem area.

Reading Trouble Codes

To read the MIL flashes or meter pulses, access the codes as described above and observe the light or the needle. If a code 26 is present in a system that displays codes through the MIL, the light will flash two times, pause momentarily, and then flash six times. If a code of 26 is present in a system that uses an anolog meter, the needle on the meter will move twice, pause, and then move six times. Some systems repeat the same code up to three times before moving on to the next code. Some systems repeat the first code as an indication that there are no more codes stored. Write down the numbers of all codes displayed.

Retrieving Trouble Codes with a Scan Tool

On OBD II–equipped vehicles, the proper scan tool *must* be used to retrieve trouble codes. **Figure 15-7** shows a commonly used scan tool. Never attempt to retrieve trouble codes from an OBD II system by grounding a DLC terminal, as this will damage the ECM.

On OBD I systems, it is far easier to use a scan tool to retrieve codes than to perform the procedures explained earlier. Scan tools display the code numbers on a screen and

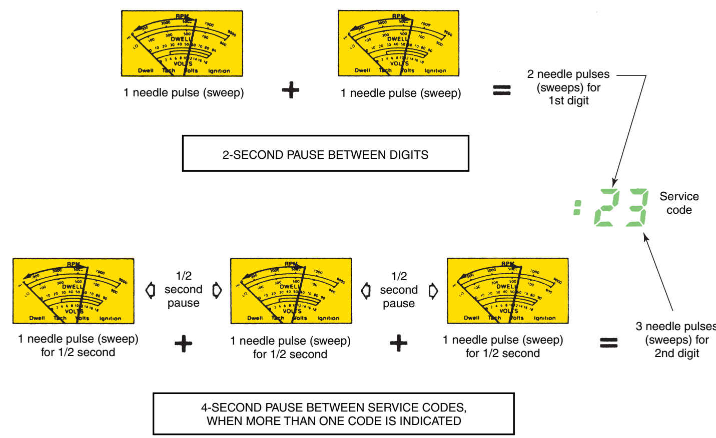


Figure 15-6. An analog meter can be used to read the codes on most OBD I systems. Some digital meters can read codes as digital pulses. (Ford)

Figure 15-7. This scan tool is widely used. It retrieves trouble codes and displays other engine operating data. This tool also provides information about possible causes of the particular trouble code. (Snap-On)

store them for future reference. They also perform the grounding step, placing the ECM in the diagnostic mode. Typical scan tool connectors are shown being attached to vehicle DLCs in **Figure 15-8.** Always follow the manufacturer's instructions when installing the scan tool and retrieving the trouble codes.

In addition to retrieving trouble codes, scan tools often display sensor and output data and test certain output devices. Some scan tools have the capability to identify the type of ECM and/or PROM in use. Others can be used for reprogramming the ECM.

Any trouble code number(s) present should be written down for later comparison with the corresponding numbers in the service manual. If you are unable to retrieve trouble codes or access sensor operating information, make sure that the DLC wiring is properly connected to the ECM and that the scan tool is properly connected to the DLC. If all the connections are good and you still cannot retrieve codes or access operating information, the ECM is most likely defective. Checking for a defective ECM is covered later in this chapter.

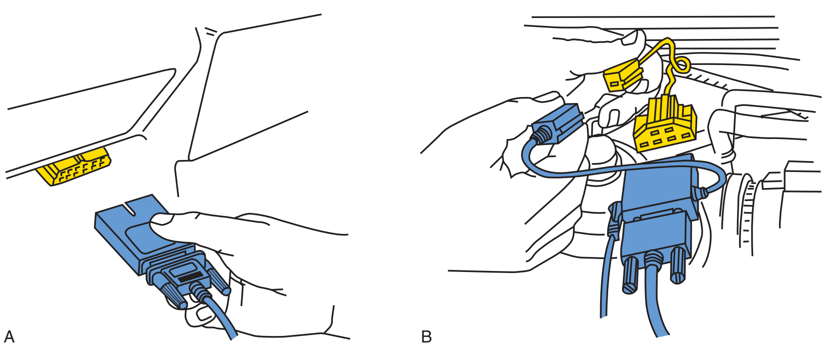
Diagnostic Trouble Code Format

The diagnostic trouble codes for most computer-controlled vehicles are generated as two- or five-character codes that correspond to specific problem areas. Older scan tools displayed trouble codes as numbers and letters. The technician then matched the code to specific problems by looking up the code in the service literature. Newer scan tools are able to process the code letters and numbers, and produce readouts that describe the actual problem. Some scan tool software can also suggest possible solutions and tell the technician if the problem is common on the vehicle being tested.

Note: Remember that trouble code does not necessarily mean that a computer system part or circuit is defective. For example, a constant rich reading from an oxygen sensor may mean the sensor itself is defective. However, it may also mean that a fuel system defect is causing the engine to run rich at all times, triggering the rich sensor reading.

OBD I and OBD II Code Formats

OBD I systems normally display two-digit trouble codes. These codes are correlated to a specific sensor or circuit. In a few cases, the code will specify a certain problem, such as low or high voltage readings. In most cases, however, the code will simply indicate that there is a problem in the system.



A B

Figure 15-8. The best way to read codes on any computer system is to use a scan tool. A—Connecting a scan tool to a GM diagnostic connector. B—Some diagnostic connectors require a separate power lead, such as this Ford connector. (Snap-On Tools)

OBD II systems display five-character alphanumeric codes consisting of one letter and four numbers. The letter identifies the general function of the vehicle system causing the problem. The first number indicates whether the code is a standardized code (code assigned by SAE) or a manufacturer-specific code. The second number indicates the specific system causing the problem. The last two numbers, which are called the ***fault designators,*** identify the specific component (sensor, output device, or ECM) that might be at fault, as well as the type of fault detected. OBD I and OBD II trouble code formats for a coolant temperature sensor problem are shown in **Figure 15-9.**

In OBD I systems, the two-digit format limits the number of trouble codes to 100. In the five-character OBD II format, there are over 8000 potential codes. OBD II trouble codes do not correspond with OBD I codes. Never try to correlate the older trouble codes with OBD II fault designators. For example, there are only two or three codes used by most older computer control systems to indicate a possible oxygen sensor problem. OBD II systems have *thirty* or more standardized codes for the oxygen sensor and may have additional manufacturer-specific codes, depending on the system. A complete list of the SAE-designated, OBD II trouble codes is located in Appendix B of this text.

Interpreting Trouble Codes

Once trouble codes have been retrieved, they can be compared to the trouble code information in the service manual (if this information is not provided by the scan tool). Sometimes, the same trouble code can be caused by more than one problem. Therefore, it is vital to correctly interpret the trouble codes properly. Trouble codes usually indicate one of three things:

- An engine, drive train, or other vehicle problem is causing one of the sensors to transmit a voltage signal that is out-of-range (too high or too low).
- A sensor's ability to perform is starting to deteriorate.
- Another part or circuit in the computer control system is defective.

Multiple codes should be addressed starting with the lowest code number and working sequentially toward the highest number. In cases where multiple codes are stored, one or more of the codes can often be eliminated using this process. For example, a fuel injector defect on the #4 cylinder (P0204) could be the cause of a misfire on cylinder #4 (P0304). If the technician determines the cause of code P0204, it is likely that the cause of code P0304 will also be determined.

Once the problem area has been identified, concentrate your troubleshooting efforts on that particular area. If the trouble code indicates that the problem is a defective output device or the ECM, you will be able to go to the specific component and determine whether the problem is a disconnected or defective part, a mechanical problem with the part, or a wiring problem. In the case of an out-of-range sensor

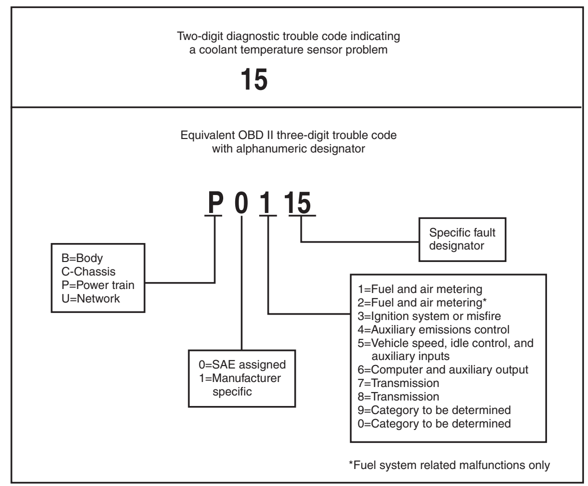


Figure 15-9. OBD I and OBD II systems use different diagnostic code systems. Both systems are distinct and trouble codes from one system should not be correlated with those from the other system.

reading, you must determine whether the problem is a defective sensor or if an abnormal operating condition is causing the out-of-range reading.

Hard and Intermittent Codes

Two types of codes are stored in the ECM memory: ***hard codes*** (permanent) and ***intermittent codes*** (temporary). Hard codes indicate an ongoing problem. These problems are generally easy to track down. Intermittent codes are set by problems that occur occasionally or, in some cases, only once. These problems are sometimes difficult to isolate.

A hard code will illuminate or flash the MIL whenever the engine is running. Intermittent codes will illuminate the MIL only when the problem is occurring, after which time the light will go out.

To differentiate between hard and intermittent codes, record all the trouble codes stored in the ECM's memory. Then erase the stored codes. Most scan tools have the capability to erase trouble codes. On some vehicles, removing electrical power to the ECM for the period of time specified in the service manual will erase the codes. This can be accomplished by disconnecting the negative battery cable or removing the fuse that supplies current to the ECM, **Figure 15-10.** However, the ECM in some OBD II–equipped vehicles can retain trouble codes for several days without battery power. Removing battery power from the ECM on these vehicles may not erase stored trouble codes. Therefore, you must use a scan tool to clear the trouble codes in OBD II systems.

After erasing the codes, restart the engine and allow it to run for the period of time specified by the manufacturer. After the engine has run long enough, stop it and re-enter the diagnostic mode. Hard codes will usually reset almost immediately after the engine is started—when the ECM requests information from a defective sensor or tries to activate a faulty output device. Intermittent codes, on the other hand, will generally not reset immediately.

Hard codes are usually caused by a defective component, an open or shorted circuit, or a faulty connector. In many cases, an intermittent code does not indicate that a sensor or output device is defective, only that it is responding to another problem. An example is an intermittent trouble code for a rich oxygen sensor reading. Although the oxygen sensor may be defective, it is more common for another component, such as a leaking fuel injector or a defective airflow sensor, to be causing the rich mixture problem.

Remember that many sensors in older computer systems can go slightly out-of-range without setting a trouble code. The ECM in an older system often will respond to the incorrect input in the same way it responds to the correct input. OBD II systems are designed to monitor sensor performance and will usually set a diagnostic trouble code if a sensor is slightly out-of-range, even if there is no apparent driveability problem. However, the absence of a trouble code in any computer control system is not absolute proof that a sensor is good.

Other Scan Tool Information

In addition to retrieving diagnostic trouble codes, some late-model scan tools can display ***datastream values.*** For example, the scan tool can access the ECM and monitor sensors inputs to provide the technician with readings of engine idle RPM, as well as the desired (factory set) idle speed. From this information, the technician can instantly determine whether idle speed is correct. Another scan tool feature will give the technician a series of numbers or percentages indicating whether the fuel trim (air-fuel ratio) is correct for both short- and long-term engine operation, **Figure 15-11.** Other inputs provide exact engine timing in degrees, actual temperature reading from the engine temperature sensors, and voltage or duty cycle readings that indicate manifold vacuum, throttle position, EGR position, and many other operating conditions. See **Figure 15-12.**

Some scan tools can interface with the ECM to provide *snapshots* of engine operating parameters. The ***snapshot*** is a method of recording the engine operating conditions present when a malfunction occurs. This allows the technician to determine exactly what is happening to cause the problem. To record the snapshot information, the technician must drive the vehicle with the scan tool attached until the malfunction occurs. The technician can then retrieve the snapshot readings from the scan tool. Some vehicle ECMs save snapshot information when a malfunction occurs, and the technician can access it once the scan tool is attached. **Figure 15-13,** which shows information obtained while looking for the cause of a rough idle, is an example of the type of data obtained using the snapshot feature.

Figure 15-10. The fuse that supplies power to the ECM is usually located in the main fuse block. Pull this fuse to clear stored codes in OBD I systems. Remember that this will not work with most OBD II systems.

Short-term fuel trim	Long-term fuel trim
126	130

Figure 15-11. The ECM uses sensor inputs to determine fuel trim for short- and long-term operation. The fuel trim is broken down into numbers or counts that can be read by a scan tool.

Data Scanned from Vehicle			
Coolant temperature sensor	Intake air temperature sensor	Mass airflow sensor	Throttle position sensor
198°F/92°C	77°F/25°C	2.7 volts	.78 volts
Engine speed sensor	Oxygen sensor	Vehicle speed sensor	Battery voltage
930 rpm	.52 volts	0 mph	13.6 volts
Idle air control valve	Evaporative emission canister solenoid	Short-term fuel trim	Long-term fuel trim
38 percent	Off	125	131
Malfunction indicator lamp	Diagnostic trouble codes	Open/closed loop	Fuel pump relay
Off		Closed	On
PROM ID	Cruise control	AC compressor clutch	Knock signal
5248C	Off	On	No
Ignition timing (°BTDC)	Base timing:	6	Actual timing: 19

Figure 15-12. Typical datastream values. The PROM carries an identification code in its programming. A scan tool can be used to access this code. The programming in OBD II systems can be identified by the date code in the program.

Perform Additional Tests as Needed

A variety of test equipment can be used to check individual computer system components. Many tests can be made using jumper wires, multimeters, or waveform meters. The following sections will quickly review sensor and output device operation and discuss typical testing procedures.

Testing Sensors

Sensors are the inputs to the computer system. If a sensor is defective, the ECM cannot correctly control the related vehicle system(s). The following section covers general test procedures for the most common types of sensors.

Note: What appears to be a sensor problem may be caused by a defect in the engine or another vehicle system. Always make sure that the vehicle has no mechanical or electrical defects that could cause out-of-range sensor readings before condemning a sensor.

Testing Oxygen Sensors

Oxygen sensors measure the amount of oxygen in the exhaust gases and send a signal that represents this amount

Snapshot Data Captured from Vehicle			
Coolant temperature sensor	Intake air temperature sensor	Mass airflow sensor	Throttle position sensor
212°F/100°C	79°F/26°C	3.4 volts	1.99 volts
Engine speed	Oxygen sensor	Vehicle speed sensor	Battery voltage
2476 rpm	.31 volts	40 mph	13.2 volts
Idle air control valve	Evaporative emission canister solenoid	Cooling fan	EGR pintle position
5 percent	Off	On	11 percent
Malfunction indicator lamp	Diagnostic trouble codes	Open/closed loop	Fuel pump relay
On	P0272, P0304	Open	On
Transmission gear	Cruise control	AC compressor clutch	Knock signal
Drive	Off	On	Yes
Ignition timing (°BTDC)	Base timing:	7	Actual timing: 56

Figure 15-13. Data captured when a malfunction occurs can help you find the cause of a driveability problem. Some ECMs will capture this data automatically when a problem occurs. What type of problem does the data in this chart indicate?

to the ECM. The ECM determines the air-fuel ratio based on the oxygen sensor input. Oxygen sensors are sometimes called O_2 sensors.

There are two basic types of oxygen sensors, the electrically heated and the nonheated. Most vehicles made within the last several years are equipped with heated oxygen sensors. Oxygen sensors with three or more lead wires are heated types. Oxygen sensors with one or two lead wires are nonheated types.

If the MIL is on and a trouble code indicates an oxygen sensor problem, check the sensor's wiring harness for a proper connection. Then make a quick check of the oxygen sensor by tapping on the exhaust manifold or exhaust pipe near the sensor with the engine running. If the MIL goes out, the sensor is defective.

STOP Warning: Exercise caution when working around exhaust manifolds. Exhaust systems can reach extremely high temperatures very quickly.

If the MIL remains on after tapping on the manifold, use a scan tool to access the data from the oxygen sensor in question. Late-model vehicles use more than one oxygen sensor, so make sure you are testing the right one. Connect the scan tool to the DLC and enter the necessary vehicle information. Make sure the engine is warm enough for the computer to operate in closed loop before monitoring O_2 sensor output. If the engine is not in closed loop mode, run it at fast idle for a few minutes to raise engine and exhaust temperature. Then allow the engine to stabilize. After the engine stabilizes, monitor the O_2 sensor readings, **Figure 15-14.**

Oxygen sensors use either Zirconia or Titania elements. The signal from either type of sensor will be displayed as a voltage by the scan tool. The sensor's output voltage should oscillate between 100 and 900 millivolts when the ECM is in the closed loop mode. The voltage readout should change very quickly as the amount of oxygen in the exhaust changes. The meter should show a minimum voltage of less than 300 mV, a maximum of more than 600 mV, and should average about 500 mV.

Note: Some manufacturers allow the oxygen sensor to be bypassed by grounding the sensor input to the ECM. Grounding the oxygen sensor input wire should cause the ECM to produce a set voltage reading. If grounding the wire does not produce this reading, the ECM is defective. The technician should only ground the O_2 sensor wire when specifically instructed by the service manual.

Checking Oxygen Sensors using a Multimeter

Remember that a ***Zirconia-type sensor*** will produce a voltage reading, while a ***Titania-type sensor*** will produce a resistance reading. Most oxygen sensors are Zirconia types. To measure the voltage output of a Zirconia-type sensor, you

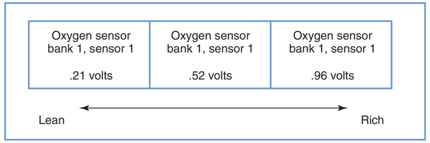


Figure 15-14. Oxygen sensor voltage (or resistance) varies with the content of the oxygen in the exhaust gas. Be sure that you are monitoring the correct sensor on vehicles with multiple oxygen sensors.

must have a voltmeter or multimeter that can read very low voltages (in the 100–900 millivolt (mV) range). To measure the resistance of a Titania-type sensor, you will need an ohmmeter or a multimeter that can measure resistance. For this test to be accurate, the engine must be warm enough for the ECM to be in closed loop mode. Unless the oxygen sensor is a heated type, the exhaust system temperature must be at least 600°F (350°C) before starting the test. When tested on the engine, the sensor must be heated either by its heating element (when used) or by exhaust heat. Heated oxygen sensors can be tested within seconds of start-up if the engine is warm. The service manual will tell you whether the sensor is the heated type. In all cases, the manufacturer's instructions must be followed closely.

Caution: Oxygen sensors are sensitive to excess current flow. They can be destroyed by improper grounding or testing with test lights or low-impedance multimeters. Some manufacturers do not recommend meter tests of the oxygen sensor. Always consult the manufacturer's instructions before testing an oxygen sensor.

After ensuring that the engine is warm enough, connect the meter to the oxygen sensor output wire as shown in **Figure 15-15.** Make sure the meter is connected to the output wire and not to the sensor input or ground wires. One- and three-wire sensors are grounded through the sensor housing. On two- and four-wire sensors, one of the wires is a ground wire. Be very careful to make the proper connections, as slight voltage surges can ruin an oxygen sensor. Observe the meter for several minutes after the ECM enters the closed loop mode. Zirconia oxygen sensors should show a minimum voltage of less than 300 mV and a maximum of more than 600 mV. They should average 500 mV. Titania oxygen sensors should show low resistance when the air-fuel mixture is rich and high resistance when the mixture is lean.

Testing the Oxygen Sensor Heater Circuit

The heater circuit of a heated oxygen sensor must be checked for proper resistance to ensure that the heater resistor is not burned out or shorted. To test the heater, set the multimeter to the ohms range. Then connect the multimeter

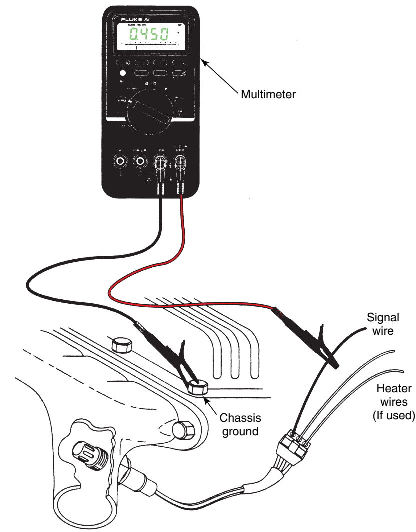


Figure 15-15. A multimeter set to the voltage scale (or resistance) can check an oxygen sensor for proper operation. Be careful when working around hot exhaust parts. (Fluke)

leads to the heater terminals of the oxygen sensor. Polarity is not important, but the leads should not contact the sensor signal terminal. If the resistance is within specifications, the heater circuit is usually good. Set the meter to the voltage scale and test the heater power terminals on the wiring harness. If 12 volts are present, the circuit is good.

Creating an Artificial Lean and Rich Mixture Condition

To test oxygen sensor response time, it is necessary to create artificial lean and rich conditions. To create an ***artificial lean mixture,*** disconnect the PCV hose or another large vacuum hose. Cover the hose opening with your thumb and start the engine. As you remove your thumb from the hose, a lean condition is created due to the vacuum leak. Partially cover the vacuum hose opening if the engine begins to stall. Then observe the meter or scan tool for several minutes. It should show a lower than average voltage or a high resistance as the oxygen sensor reacts to the lean mixture.

Note: The ECM on some fuel-injected engines will react too fast for this test to be effective; the engine speed will just rise and fall.

After making this test, reconnect the vacuum hose and create an ***artificial rich mixture*** with a propane enrichment device, such as that used to adjust carburetors. Do not create a rich mixture with carburetor cleaner or gasoline, as this will simply overload the oxygen sensor. On some vehicles, it is possible to create an artificial rich mixture by blocking the air inlet ahead of the throttle plate. On newer vehicles with idle air control (IAC) solenoids, the IAC will simply open to allow more air into the engine. Blocking the air intake on these engines may not produce definite results. After the enrichment device is in place and operating, check the meter or scan tool. Voltage should be higher than average (or resistance should be low), indicating that the rich condition is being read by the oxygen sensor. If the oxygen sensor does not react, takes longer than two seconds to react, or indicates an out-of-range reading, the sensor is defective and should be replaced.

Checking Oxygen Sensor Waveforms

A waveform meter can be used to detect problems that a voltmeter or scan tool will not reveal. The waveform meter displays a picture of what is happening in the circuit. Some waveform meters require that the wires leading to a particular component be pierced to access the component waveform. Other waveform meters can access needed waveforms through the diagnostic connector.

To check the waveform of an oxygen sensor, attach the waveform meter leads to the proper sensor lead and ground, or to the diagnostic connector. Set the meter to the proper voltage range. Then start the engine and allow the sensor readings to stabilize. Some waveform meter makers recommend running the engine at 2500 RPM for 2 minutes to heat the sensor. Compare the actual waveform with a known good waveform to determine whether the sensor is operating properly. See **Figure 15-16.**

Modern waveform meters can record the operation of two oxygen sensors at the same time. This allows the technician to check the operation of both oxygen sensors and the catalytic converter on OBD II systems. To make this test, attach the meter leads to the upstream oxygen sensor (sensor located ahead of the catalytic converter) and to the downstream oxygen sensor (sensor located after the converter). If the waveform meter uses the vehicle diagnostic connector, attach it now. Set the meter to record the readings of both oxygen sensors. Once the engine is started and allowed to stabilize, compare the two readings. See **Figure 15-17.** The flattened shape of the downstream sensor waveform in Figure 15-17A shows that the converter is operating to clean up the exhaust. In Figure 15-17B, both waveforms have a similar shape. This indicates that the converter is faulty.

Road Testing Oxygen Sensors

If the oxygen sensor tests at idle are inconclusive, perform a road test while monitoring oxygen sensor operation with a scan tool, voltmeter, or waveform meter. A road test will usually uncover a problem that is causing the oxygen sensor to read too lean or too rich, rather than a defective sensor. The

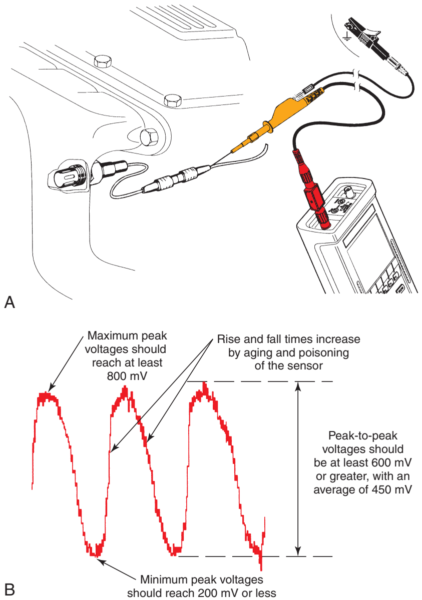


Figure 15-16. A—Waveform meter hookup for testing an oxygen sensor. B—This waveform shows the oscillations of a properly operating oxygen sensor. Lack of oscillations or a pattern that is not consistent indicates a problem. (Fluke)

engine must be completely warmed up before the road test. If a scan tool is used, connect the tool to the DLC. Use an extension lead if the DLC is under the hood. If equipped, use the scan tool's snapshot feature to take a picture of sensor and vehicle operation when the malfunction occurs.

If a multimeter or waveform meter is used, start by connecting the meter to the oxygen sensor through leads that allow the meter to be placed inside the passenger compartment. If the meter you are using has memory and averaging capabilities, follow the manufacturer's instructions to set the meter to record the average reading. Have someone drive the vehicle while you observe oxygen sensor operation. A high average voltage or low resistance reading means that the engine is running too rich, such as when the ECM is leaning out the mixture but cannot compensate for a leaking injector. A low average reading or high resistance indicates too little fuel, such as when the ECM is richening the mixture but cannot compensate for a vacuum leak. After the road test is

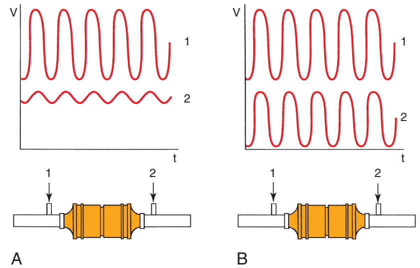


Figure 15-17. Comparing the waveforms of upstream and downstream oxygen sensors allows the technician to determine the condition of the sensors and the converter. 1—Signal from upstream oxygen sensor. 2—Signal from downstream oxygen sensor. Note that the that the signal amplitude from the downstream sensor increases when the efficiency of the catalytic converter declines. (Fluke)

complete, enter the meter's averaging function. This will allow you to get an average reading of the voltage levels.

Note: If the above tests are made with the engine running and the oxygen sensor disconnected, false trouble codes will generally be set. After all tests are complete, be sure to clear the ECM's memory.

Testing Mass Airflow (MAF) Sensors

Mass airflow, or MAF, sensors produce either analog or digital signals. Older MAF sensors are usually analog types, while many newer designs are digital types.

Note: Always check carefully to determine which type of MAF sensor you are dealing with, since analog and digital sensors closely resemble each other. If you are not sure which type of sensor you are testing, check the service manual.

Testing Analog MAF Sensors

A quick test using either a scan tool or a multimeter can be performed on analog MAF sensors. Check the proper service manual to determine if the sensor will respond to this test. If a scan tool is used, connect it to the DLC and set it to monitor MAF sensor input. If a multimeter is used, set it to measure dc volts and attach it to the MAF sensor as shown in **Figure 15-18.** With the ignition key in the *on* position and the engine off, voltage will be about 1 volt. Start the engine and observe the scan tool or voltmeter. Voltage should rise to about 2.5 volts, **Figure 15-19.** Tap on the sensor with a small

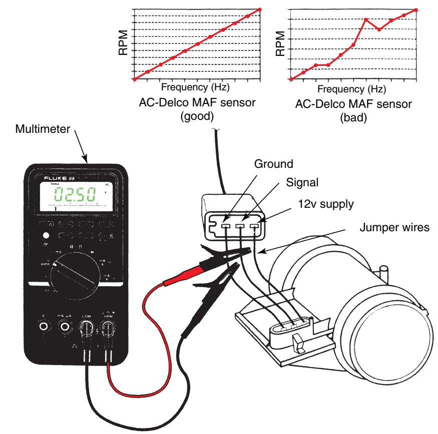


Figure 15-18. A digital meter can be used to check mass airflow sensor operation. Do not use an analog meter to perform this test. (Fluke)

screwdriver handle. There should be no voltage fluctuation or engine misfire. If needed, repeat the test while warming the sensor with a heat lamp. If the voltage fluctuates or engine operation changes dramatically (stalls or idles rough) as the sensor is heated, the sensor is defective and should be replaced.

In a variation of this procedure, the technician can blow through the MAF sensor with the ignition in the *on* position. Voltage should rise, indicating that the sensor is responding to air movement. On some vane-type MAF sensors, the sensor output voltage is determined by inserting an unsharpened pencil into the sensor. The pencil holds the vane in a certain position to produce a specified voltage reading. The sensor voltage output is measured with the ignition *on* and the engine *off.* If the output voltage is not as specified with the pencil inserted, the sensor is defective.

A waveform meter can be used to check the operation of an analog MAF sensor. Attach the waveform meter as instructed by the manufacturer. Start the engine and compare the waveform with a known good waveform for proper shape, frequency, and amplitude (height). See **Figure 15-20.**

Testing Digital MAF Sensors

The output of a digital MAF sensor can be measured by most scan tools, waveform meters, or multimeters capable of reading RPM or duty cycles. Consult the multimeter manual to determine the exact meter capabilities. The test procedure is similar to that for analog MAF sensors. The frequency will be at a set value with the ignition *on* and the engine *off,*

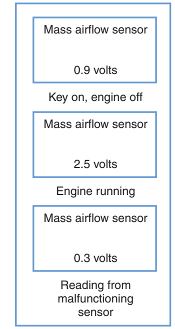


Figure 15-19. Scan tool reading for mass airflow sensor signal. Scan tool readings should be verified using a digital multimeter. (Fluke)

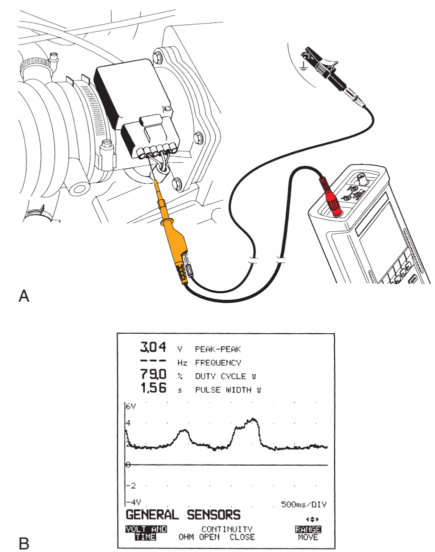


Figure 15-20. A—Connections for testing an analog MAF sensor. B—This waveform indicates correct analog mass airflow (MAF) sensor operation. (Fluke)

Figure 15-21A. When the engine is started, increased airflow through the MAF sensor will cause an increase in the frequency reading, **Figure 15-21B.** If the frequency reading does not change, or if it decreases, the sensor is probably defective.

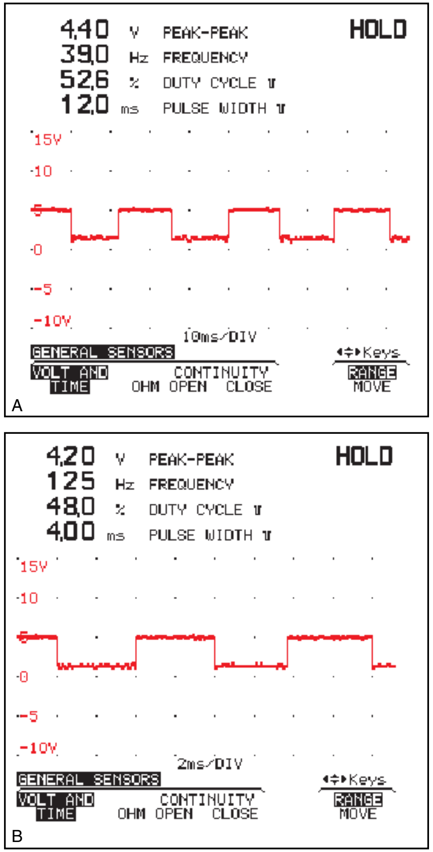


Figure 15-21. A—The frequency of a digital MAF sensor signal can be measured, along with the voltage output. B—Note the increased frequency and pulse width as the engine is started. (Fluke)

Testing Manifold Absolute Pressure (MAP) Sensors

Manifold absolute pressure and similar vacuum and barometric pressure sensors allow the ECM to compensate for manifold vacuum and high altitudes. This sensor is very important in vehicles that use speed density to calculate airflow. Before testing a MAP sensor, check the vacuum hoses for splits or obstructions. Also make sure the engine is providing sufficient manifold vacuum. Consult the service manual to determine whether this test can be made and for the exact procedures.

Begin testing by turning the ignition key *on* without starting the engine. Measure the dc voltage at the ECM and compare it to service manual specifications. Tap the sensor with a small screwdriver while watching for voltage jumps that could signal intermittent problems. Repeat the tapping procedure while warming the sensor with a heat lamp. Next, apply vacuum to the MAP sensor, **Figure 15-22,** while observing the voltage reading. If the voltage reading increases with increases in vacuum, the MAP sensor is probably good. If the MAP sensor fails any of these tests, replace it.

A similar test can be made to the barometric pressure (BARO) sensor on some vehicles. Check the sensor's output voltage at the proper ECM terminals (ignition on, engine not running) and compare it to the specifications for the altitude in your area. A typical altitude compensation chart is shown in **Figure 15-23.** If the voltage is not within specifications, replace the sensor.

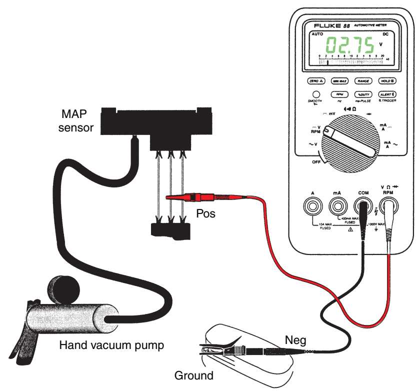


Figure 15-22. Setup for measuring dc voltage from the MAP sensor. Apply vacuum to the sensor to simulate engine vacuum. The readings should be similar to normal readings while the engine is at idle. Compare all readings to service manual specifications. (Fluke)

Altitude Meters	Altitude Feet	Voltage range
Below 305	Below 1000	3.8–5.5v
305–610	1000–2000	3.6–5.3v
610–914	2000–3000	3.5–5.1v
914–1219	3000–4000	3.3–5.0v
1219–1524	4000–5000	3.2–4.8v
1524–1829	5000–6000	3.0–4.6v
1829–2133	6000–7000	2.9–4.5v
2133–2438	7000–8000	2.8–4.3v
2438–2743	8000–9000	2.6–4.2v
2743–3048	9000–10,000	2.5–4.0v

Low altitude = High pressure = High voltage

Figure 15-23. MAP sensor output voltage varies with altitude. The lower the altitude, the higher the voltage. (General Motors)

A scan tool can be used to check MAP sensors. Attach the scan tool to the DLC and set the tool to read MAP sensor output. Turn the ignition switch to the *on* position without starting the engine and note the reading. Some scan tools will display the actual vacuum reading, which should be 0 in hg when the engine is off. Other scan tools will display voltage, which will be near the reference voltage with the engine off. This reading will vary with altitude and must be compensated for. Next attach a vacuum pump to the MAP sensor fitting. Apply vacuum to the sensor with the ignition *on* and the engine *off.* Scan tool readings should vary smoothly with changes in vacuum. Voltage readings should drop or vacuum readings should increase as vacuum is applied. If the MAP sensor fails these tests, replace it.

MAP sensor signals can also be checked with a waveform meter. Begin testing by determining whether the MAF sensor signal is digital or analog. Then make the proper waveform meter connections and start the engine. See **Figure 15-24.** Check the waveform against a known good waveform. **Figure 15-25** illustrates a good analog MAP sensor waveform. Opening the throttle plate should cause the sensor's voltage signal to rise smoothly. **Figure 15-26** is an example of a good digital MAP sensor waveform. The sensor's output frequency should increase as the throttle plate is opened. Always check the waveform for proper shape, frequency, and amplitude.

It is also possible to test MAP sensors with a waveform meter and a vacuum pump. The hookups in the same manner as was done for the voltmeter test. The ignition switch must be in the *on* position. While slowly applying vacuum, make sure the waveform changes smoothly, with no jumping or spikes.

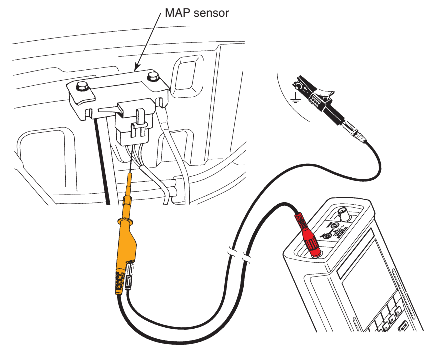


Figure 15-24. Connections for checking a MAP sensor with a waveform meter.(Fluke)

Testing Temperature Sensors

Temperature sensors allow the ECM to compensate for changes in external air temperatures and internal engine temperatures. If a temperature sensor malfunctions, it will usually cause problems that occur when the engine is either

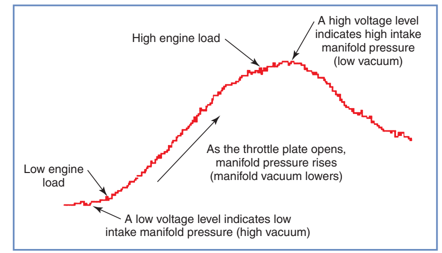


Figure 15-25. Waveform produced by an analog MAP sensor. (Fluke)

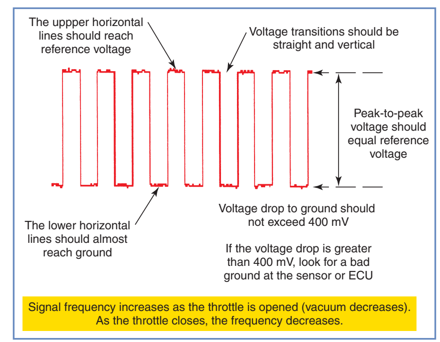


Figure 15-26. Waveform produced by a digital MAP sensor. (Fluke)

hot or cold. The following tests will work with engine coolant, intake air, exhaust gas, and automatic transmission/transaxle fluid temperature sensors.

Note: Before performing tests on an engine coolant temperature sensor, make sure the coolant level in the radiator is correct. The sensor must be in contact with the coolant to operate properly. Also make sure that the sensor electrical connector is attached and that the wiring shows no obvious damage.

Tests Using a Scan Tool

Temperature sensor operation can also be checked using a scan tool. To measure temperature sensor output using this procedure, you must have a scan tool that can convert sensor voltage inputs to temperature readings. This is possible on many scan tools. Follow the manufacturer's instructions.

Begin the test procedure by setting the scan tool to read the temperature as measured by the sensor. Remove the sensor's connector and note the temperature indicated on the scan tool. The scan tool readings should indicate the sensor's lowest reading, usually between -30° and -40°F (-34° and -40°C), **Figure 15-27.** Then, jumper the connector leads to simulate the sensor's highest possible reading, which can be 260°F (127°C) and higher. If the scan tool data shows the output to be correct, the sensor is the likely cause of the problem. If not, there is high resistance in a sensor connection, a shorted or grounded wire, or a problem in the ECM.

Tests Using a Ohmmeter

Most temperature sensors can be checked for a specified resistance at a certain temperature. Unlike most resistors, temperature sensor resistance decreases as temperature rises. To test temperature sensors, you must measure the output resistance in relation to the temperature at the sensor's tip. This will determine whether the sensor is correctly converting the temperature into resistance (which varies the voltage signal) during engine operation.

A temperature sensor can be checked with a digital multimeter or an ohmmeter. If a multimeter is used, set the meter to measure resistance in ohms. Next, disconnect the sensor from the wiring harness and measure the resistance across the sensor leads. Compare the meter readings with the manufacturer's specifications. The readings can be correlated to specific temperatures, **Figure 15-28.** If necessary, a heat gun can be used to raise the temperature to check for resistance variations with temperature. If the resistance measurements are incorrect, the sensor is defective.

If the resistance measurements are correct, the defect is in either the ECM or the wiring. To check the wiring, reinstall the sensor connector, unplug the ECM, and measure the sensor's resistance at the ECM harness. If the resistance is now incorrect, check for a wiring problem. Remember that corroded or loose terminals will cause higher-than-normal resistance readings, while shorts to ground will cause lower-than-normal readings. If the resistance is correct at the harness, the problem is in the ECM.

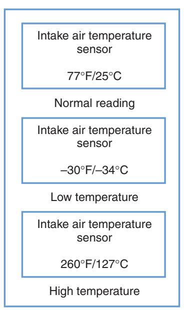


Figure 15-27. Scan tool readings for the intake air temperature sensor. The high temperature reading may be lower than shown here, but it will be much higher than ambient air temperature.

Temperature vs Resistance Valve (Approximate)

°C	°F	Ohms
100	212	177
90	194	241
80	176	332
70	158	467
60	140	667
50	122	973
45	113	1188
40	104	1459
35	95	1802
30	86	2238
25	77	2796
20	68	3520
15	59	4450
10	50	5670
5	41	7280
0	32	9420
–5	23	12,300
–10	14	16,180
–15	5	21,450
–20	–4	28,680
–30	–22	527,000
–40	–40	100,700

Figure 15-28. Most temperature sensors are thermistors. The higher the temperature, the lower the resistance. (General Motors)

Tests Using a Waveform Meter

Coolant and air temperature sensors can be tested with a waveform meter. To check a coolant temperature sensor, connect the meter, start the engine, and then observe the waveform, **Figure 15-29.** Coolant temperature sensors should produce a smooth voltage transition as the coolant temperature increases. There should be no sharp spikes in the waveform. Upward spikes indicate an open in the circuit. Downward spikes indicate a short.

To test an air temperature sensor, remove the sensor from the intake duct. Connect the waveform meter and place the ignition switch in the *on* position. Spray a small amount of water on the sensor and observe the waveform, **Figure 15-30.** A temperature drop should register in an upward movement of voltage as resistance increases. As with the coolant temperature sensor, spikes indicate an open or a short.

Testing Pressure Sensors

Most pressure sensors are simple on-off switches. They can be tested with a scan tool or an ohmmeter. If using a scan tool, connect it to the DLC as specified by the tool manufacturer. Before checking a pressure sensor with an ohmmeter, remove the electrical connector. **Figure 15-31** shows a pressure sensor being tested with an ohmmeter. Note that the placement of the test leads varies, depending on the number of sensor terminals.

If the sensor is normally closed, pressurizing it should cause it to open. The scan tool will indicate that it is open or the ohmmeter will read infinite resistance. The sensor should revert to the closed position, or zero ohms, when the pressure is removed.

If the sensor is normally open, pressurizing it should cause it to close. The scan tool should indicate that it is closed, or the ohmmeter should read zero resistance. The sensor readings should go to the open position, or infinite ohms, when the pressure is removed.

Testing Throttle Position Sensors

The throttle position sensor (TPS) monitors throttle opening and closing so the ECM can adjust fuel and ignition spark timing to match driver demand. Typical TPS voltage can range from 0.2 volts at fully closed throttle to 5.0 volts at wide-open throttle. However, this sensor is adjustable on most vehicles, so depending on the manufacturer and the engine, anything between 0.2 and 1.25 volts might be considered acceptable at closed throttle. Throttle position sensors modify a reference voltage; therefore, an ohmmeter can be used to test these sensors. TPS resistance varies by manufacturer and application.

To test a throttle position sensor, the internal resistance of the sensor must be measured at different throttle openings. Start the test procedure by disconnecting the throttle position sensor's electrical connector. Connect an ohmmeter to the sensor's input and output leads. Next, slowly open the throttle while watching the ohmmeter. The ohmmeter reading should increase smoothly without jumping or skipping. If it does jump or skip, the sensor is defective.

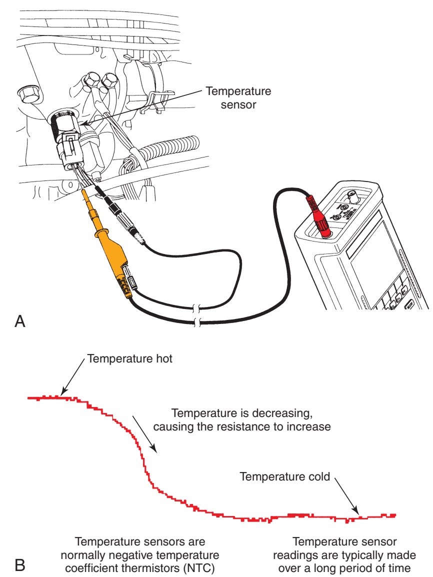


Figure 15-29. A—Setup for testing a temperature sensor with a waveform meter. B—Voltage changes in a temperature sensor as temperature increases. The waveform should show a smooth change with no spikes. (Ferret Instruments)

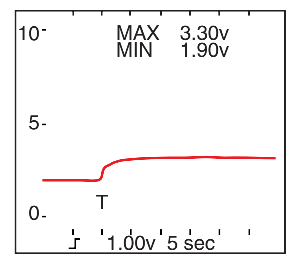


Figure 15-30. Note how the voltage changes in an air temperature sensor. The waveform should rise and fall with changes in temperature, with no spikes or loss of the pattern. (Ferret Instruments)

Using a Scan Tool to Check Operation

The throttle position sensor is another sensor that can be checked with a scan tool. Attach the tool and select the proper settings. With the ignition *on* and the engine *off,* open and close the throttle while observing the TPS voltage. Voltage should rise smoothly as the throttle is opened. The general range of voltage is from 0.5–5 volts. Always check the service literature for exact specifications. Some scan tools read the TPS input as a percentage of throttle opening. If TPS readings are not correct, the sensor should be adjusted or replaced. If the voltage reading fluctuates as the throttle is opened, the TPS is defective and should be replaced.

Testing with a Waveform Meter

The TPS can also be checked with a waveform meter. Connect the meter as specified and place the ignition switch in the *on* position. See **Figure 15-32.** Then observe the waveform while slowly opening the throttle. The meter should show a smooth rise in voltage as the throttle is opened. **Figure 15-33** illustrates the waveform pattern produced by one TPS as the throttle is slowly opened and closed. If there are spikes or breaks in the waveform, the TPS is defective. See **Figure 15-34.**

A

B

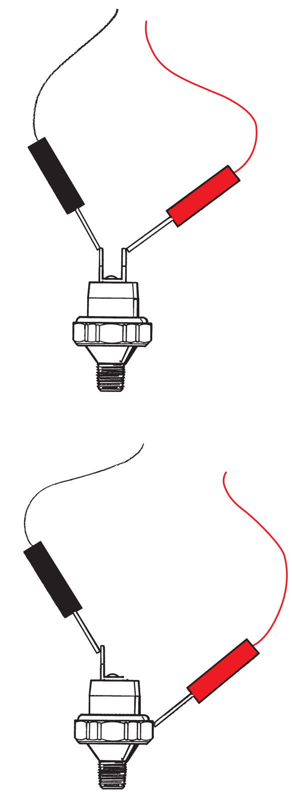


Figure 15-31. Methods of checking a pressure sensor. A—If the sensor has two terminals, check the resistance between the terminals. B—If the sensor has one terminal, check the resistance between that terminal and ground.

Testing Crankshaft and Camshaft Position and Speed Sensors

On most vehicles, the crankshaft and camshaft position and speed sensors provide signals that influence the control of both the fuel and ignition systems. A faulty crankshaft or camshaft sensor may produce either a no-start condition or intermittent stalling. The test procedures for crankshaft and camshaft sensors are similar to those for pickup coils, Hall-effect sensors, and magnetic pickup switches mounted in the distributor. However, their location on or in the engine can make testing difficult.

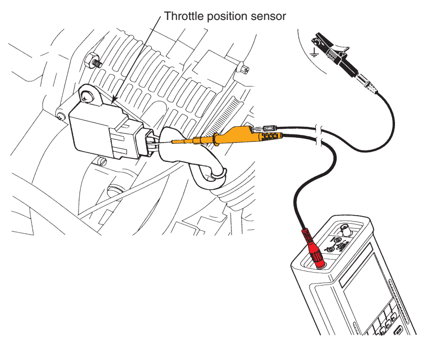


Figure 15-32. Testing a throttle position sensor with a waveform meter. (Fluke)

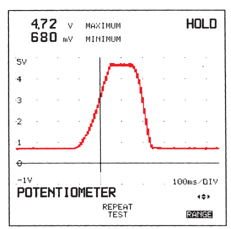


Figure 15-33. This waveform indicates a properly operating throttle position sensor. Note how the pattern rises and falls as the throttle is opened and closed. (Fluke)

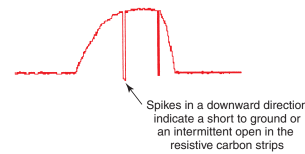


Figure 15-34. This pattern was produced by a defective throttle position sensor. The downward spikes indicate a short to ground or an intermittent open in the sensor. (Fluke)

Note: A problem that appears to be caused by a position sensor can also be caused by problems in the ignition module, ignition coils, fuel injectors, harness wiring, or ECM. The following generalized tests should only be used to narrow down a possible crankshaft or camshaft position sensor problem. If a problem in the position sensor circuits is suspected, it should be verified using tests outlined in the vehicle's service manual.

One test that can be used to check position sensor operation is to crank the engine while monitoring engine rpm using a scan tool. A low rpm reading (or no rpm reading) when the engine is cranking indicates a possible problem in the crankshaft or camshaft sensor circuit, **Figure 15-35.**

To test a position sensor for ac voltage output, disconnect the sensor connector. Obtain a multimeter and connect it to the speed sensor. Set the multimeter to the ac volts range. Crank the engine. The multimeter should read ac voltage as the engine is cranked.

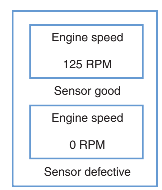


Figure 15-35. A scan tool can be used to quickly check the crankshaft position sensor for proper operation. If the engine has a camshaft sensor, a scan tool reading of engine speed is not reliable, as most ECMs take readings from both sensors to determine engine speed.

Warning: Some engines may start even though the position sensor is disconnected. Keep all tester wires and your hands away from moving parts while making this test.

Check the service literature for the correct specifications. Replace the sensor if it does not produce the proper ac voltage.

A second test involves using a spark tester to check for spark at two or three adjacent spark plug wires. If there is no spark at any of the plug wires, a position sensor circuit problem is possible. If some of the plug wires produce a spark, the problem is most likely in the ignition module or coils.

Another test uses an injector harness "noid" light and a test light. Remove the injector harness connector from one injector, install the light, crank the engine, and note whether the noid light flashes. Repeat this test on two or three adjacent injectors. If injector pulse is present at all the injectors tested, the position sensors are most likely working and the problem is in another circuit. If there is no injector pulse at any of the injectors, either the position sensors or the ECM is defective, or there is a wiring problem. If one or two injectors are not working, use the test light at each injector harness terminal to check for power and ground as instructed by the vehicle's service manual. Injector service will be covered in more detail in Chapter 18, Fuel Injection System Service.

A final test requires a waveform meter. Connect the meter as recommended by the manufacturer. **Figure 15-36** shows some typical crankshaft and camshaft position waveforms. Due to the many variations, always check the manufacturer's service literature for the standard waveform. Any waveform variation indicates that the position sensor is either defective or out of adjustment.

Testing Knock Sensor

The knock sensor allows the ECM to retard ignition timing when spark knock occurs. The knock sensor produces a voltage that is sent to the ECM or modifies a reference voltage from the ECM. Check the service manual for the type of knock sensor you are testing.

Note: Before performing the knock sensor test, make sure that an internal engine problem is not the cause of the knocking condition.

Testing a knock sensor is very easy. All that is needed is a scan tool, voltmeter, or waveform meter and a wrench or other metal object.

To test the sensor using a scan tool, connect the tool to the DLC and set it to monitor knock sensor output. Turn the ignition switch to the *on* position, but do not start the engine. Lightly tap on the engine block with the wrench.

Caution: Tap only on cast iron parts or the block itself. Do not tap on aluminum, plastic, or sheet metal parts.

If the sensor is working properly, the scan tool reading will change, indicating that the ECM is detecting the artificial engine knock, **Figure 15-37.** If the scan tool reading does not change, disconnect the knock sensor connector, connect the voltmeter to the sensor, and repeat the tap test. If the sensor produces a voltage signal, the problem is in the wiring or the ECM. A similar test can be made using a waveform meter. Connect the meter as recommended by the manufacturer. When the engine is tapped, the waveform produced should resemble the pattern in **Figure 15-38.**

A timing light can be used to check the knock sensor circuit on a running engine. Direct the light on the timing marks and tap on the engine. Tapping on the engine should make the timing marks move in the retard direction.

Testing Vehicle Speed Sensors

Most speed sensors produce an alternating current (ac) as they rotate. Therefore, the operation of many vehicle speed sensors can be checked by measuring their output in ac volts. The simplest way to check a speed sensor is to use the proper scan tool. Raise the drive wheels off the ground and shift the vehicle into drive. Modern scan tools can convert the speed sensor output into a speed (miles per hour) reading. If there is no reading, check the speedometer. If the speedometer is indicating speed, a defect exists in the wiring to the ECM or in the ECM itself. If the speedometer is not working, proceed to test the sensor directly with a multimeter

To test the sensor using a multimeter, stop the engine and disconnect the speed sensor connector. Then set the multimeter to the ac volts range and connect it to the speed sensor terminals. Restart the engine and, with the drive wheels off the ground, shift the vehicle into drive and accelerate. The multimeter should start to read ac voltage as the engine begins turning.

This test can also be made using a waveform meter. Look for a pattern similar to the one in **Figure 15-39.** The frequency of the oscillations should increase with vehicle speed.

Some manufacturers call for checking the resistance of the speed sensor winding, but this is done only after other tests have indicated a sensor problem.

Checking the ECM

Diagnosing a defective ECM is sometimes difficult, since it may be too damaged to assist in the diagnostic process. If a scan tool cannot access the ECM's self-diagnostic mode, the ECM is probably faulty. A damaged ECM will sometimes produce false trouble codes. If the ECM produces a trouble code that cannot be confirmed by testing the suspected part,

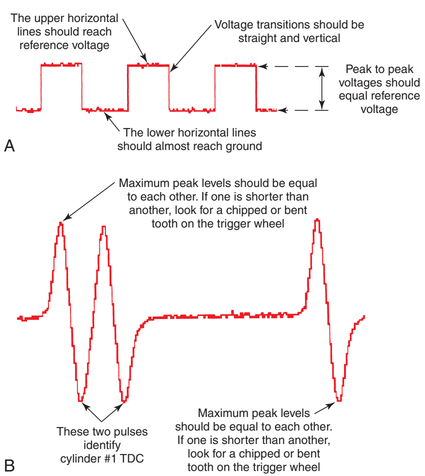


Figure 15-36. Position and speed sensor waveforms vary between types of sensors and manufacturers. Always look up the proper waveform to avoid an incorrect diagnosis. A—Waveform produced by a Hall-effect sensor. B—Waveform produced by a magnetic position sensor. (Fluke)

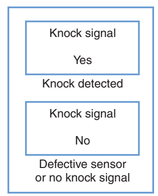


Figure 15-37. The knock sensor signal will show up on most scan tool readouts as a yes (knock present) or no (knock not present).

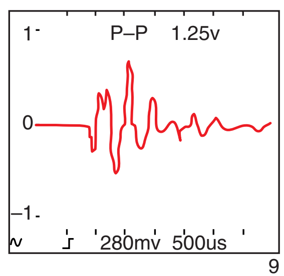


Figure 15-38. Most knock sensor waveforms will resemble this one. (Ferret Instruments)

or if the ECM produces a trouble code number that does exist, it is usually defective.

Often the only way to pinpoint a faulty ECM is through the process of elimination or through substitution. The process of elimination involves checking every other possible cause of a problem and eliminating all of them. If all the sensors, actuators, fuses, wiring, and connectors have been checked and are okay, the problem is most likely in the ECM. Before you determine that the ECM is defective, be sure to thoroughly check every other component and its related wiring.

Substitution involves replacing the suspect ECM with a unit that is known to be good. Before checking by substitution, make sure every related part has been checked. If not, a faulty component could damage the replacement ECM. A shorted actuator, for instance, could destroy the driver in the new ECM.

Note: An ECM-related problem can sometimes be corrected by updating the ECM with new information. This is called reprogramming and is covered later in this chapter.

Checking Actuators

Actuators are the output devices of the computer control system. The following section provides a general overview of common actuator tests.

Testing Solenoids and Relays

Most actuators operated by the computer control system are solenoids or relays. Solenoids are simply wire coils that are energized to move a plunger. Relays are wire coils that are energized to open or close a set of electrical contacts. Some relays are electronic and use transistors in place of the wire coil and contacts.

Many solenoids and relays will make a clicking noise when they are energized. It is often possible to energize the winding and listen for the click. Most solenoids and relays are operated by battery voltage and can be energized with jumper wires from the battery terminals. Be sure to disconnect the actuator's electrical connector before energizing the winding. If the connector is attached, current flow may damage the ECM. Listen for a click as you make and break the circuit with the jumper wires.

It is often possible to determine whether a solenoid or relay clicks without using jumper wires. Park the vehicle in a quiet place and turn the ignition switch to the *off* position. Turn off the radio, air conditioner, and any other noise-producing equipment. Open the hood and locate the actuator. On some vehicles, the actuator may be located under the wheel well. Place your ear close to the actuator and have someone turn the ignition switch to the *on* position without starting the engine. Then listen for a click.

If a solenoid or relay does not click when energized, it may be defective. Make sure the device is being supplied with electricity, usually a reference voltage from the ECM, before deciding that it is defective. Some solenoid plungers, such as those used in the idle speed control or the transmission, may become clogged with carbon or sludge and fail to operate, even when the solenoid is good. Cleaning can sometimes restore these solenoids to proper operation. Electronic relays have no moving parts and will not click. If the solenoid or relay appears to be defective, always follow up by performing the tests outlined in the following sections.

Scan Tool Tests

Most scan tools can be used to check solenoid and relay operation. Examples of these types of solenoids are the idle air control (IAC) solenoid, some transmission solenoids, and mixture solenoids on older vehicles with carburetors. Check the output voltage pulses (usually called counts) as the device operates. The counts can be measured to determine whether the solenoid is operating properly. If readings are within the normal range, the solenoid or relay is working properly. If the counts are not as specified, either the device or ECM is defective, or the ECM is receiving an incorrect input from a sensor.

Some scan tools allow the technician to diagnose actuators by bypassing the ECM and directly operating the devices. This is sometimes called ***forcing the actuator.*** The scan tool then monitors operating voltage during the forcing procedure to determine whether the device is operating properly. Some scan tools can simulate engine and vehicle conditions to check the interaction among various system actuators. Follow the manufacturer's instructions to test solenoids and relays using this method.

Ohmmeter Tests

Solenoid and relay windings can be checked with an ohmmeter as shown in **Figure 15-40.** Solenoid and relay windings have a small range of acceptable resistance. Any reading outside this range means that the actuator should be replaced. Always check the service manual for exact resistance specifications. A reading of zero ohms means the winding is shorted, while an infinite reading indicates an open winding. Either reading means the winding is defective and must be replaced. The circuit in a relay that passes through

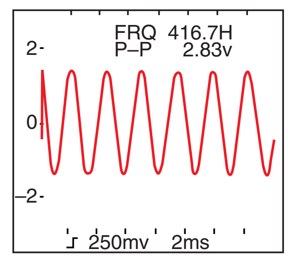


Figure 15-39. Speed sensor waveforms will be a series of oscillations similar to the ones shown here. (Ferret Instruments)

the internal relay contacts should read zero ohms or infinity, depending on whether the contacts are normally open or normally closed. Energizing the relay winding should cause the reading to change to the opposite value.

Figure 15-40. Use an ohmmeter to test solenoid and relay windings. Any reading other than the one specified indicates a defective winding.

Operation of solenoids and relays can also be checked with a waveform meter. Connect the meter and start the engine. Operate the engine as needed to energize the actuator. Observe the waveform. **Figure 15-41** shows some possible waveforms. Always consult the manufacturer's specifications to determine what the waveform should look like for the exact component being tested. If the pattern does not look like it should, or shows spikes or breaks, the component is defective.

Testing Motors

A few vehicles use stepper motors to control idle speed, operate the EGR valve, or provide pressure for the anti-lock brake system. These motors operate in small increments, or steps, to move the throttle plate or provide braking pressure. Some anti-lock brake and automatic level control systems have electric motors that operate pumps. In addition, the radiator fan motors in most late-model vehicles are controlled by the ECM.

Note: Before checking any motor, determine whether the ECM operates it through a relay. If so, check the relay as explained previously.

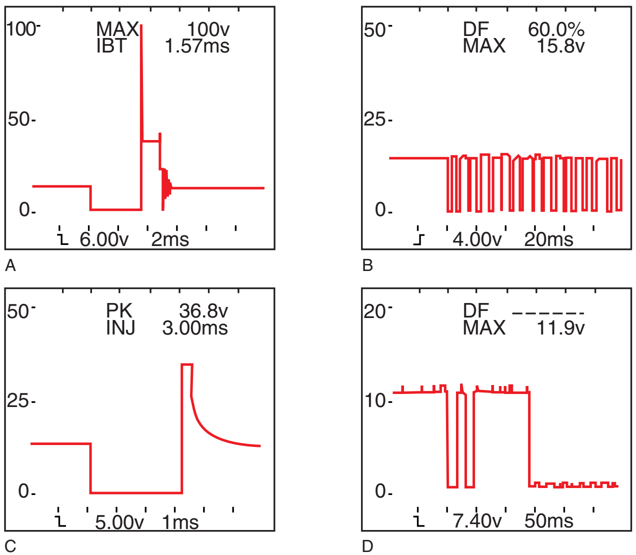


Figure 15-41. Waveforms for various types of actuators. A—Ignition coil. Although the coil is not a solenoid, it is an output device and creates a common pattern. B—EGR valve solenoid. EGR valve solenoids are pulsed on and off rapidly to maintain the proper EGR valve opening. C—Fuel injector. There are many variations of the pattern shown here. D—Idle air control solenoid. (Ferret Instruments)

If the motor is visible, it can be visually checked to determine whether it operates. Some motors can be heard or felt when operating. In some cases, the ECM can be bypassed by using jumper wires to apply voltage directly to the motor. Check the service manual to determine whether the ECM can be bypassed without damaging the motor or the ECM itself.

Motors can also be checked with an ohmmeter. Winding resistance is usually about 0.5–7 ohms for most 12-volt automotive motors. A zero ohms reading indicates that the winding is shorted. If the winding has infinite resistance, it is open. If the winding is defective, the motor must be replaced.

Adjusting Sensors

Some sensors can be adjusted. Typical adjustment procedures for throttle and crankshaft/camshaft position sensors are covered in the following sections. The procedures for adjusting other sensors, such as distributor pickups and ABS wheel speed sensors, are covered in the appropriate chapters.

Throttle Position Sensor Adjustment

A misadjusted throttle position sensor (TPS) can affect ECM operation. A throttle position sensor can go out of adjustment due to linkage wear or changes in the sensor's electrical material. The sensor may also require adjustment when the throttle body is replaced. On most engines, the throttle position sensor is simply mounted on the throttle body, with little or no provision for adjustment. However, some throttle position sensors have slotted mounting holes. The slotted holes allow the sensor to be moved for adjustment. See **Figure 15-42.** With the throttle plate completely closed, rotate the sensor until a specified voltage output is obtained. Specific adjustment procedures are required for some throttle position sensors.

Note: Adjusting some throttle position sensors requires special tools or adjustment procedures. Check the vehicle's service manual for the correct procedure.

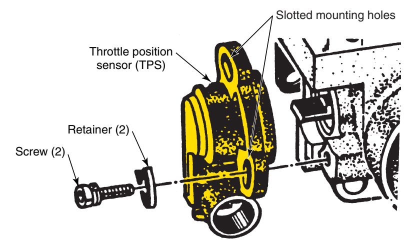


Figure 15-42. In most cases, the throttle position sensor mounts on the throttle shaft and is simply bolted on the throttle body. Note the slotted mounting holes on this TPS. The slotted holes allow the sensor to be turned for adjustment. (General Motors)

To adjust the TPS with a multimeter, obtain the correct voltage specifications and set the meter to a range that will measure these voltages. Using jumper wires to the correct terminals, measure the input and output voltages.

If the input voltage is incorrect, check the wiring and the ECM, and make repairs as necessary. If the output voltage is incorrect, make sure the throttle plate is in the fully closed position. Then loosen the throttle position sensor attaching screws and rotate the sensor until the proper value is shown on the voltmeter.

A scan tool can also be used to adjust the TPS. Plug the tool into the DLC and select the TPS reading from the tool menu. Check the TPS input with the throttle plate in the closed position and compare the input reading to specifications. If necessary, loosen the throttle position sensor attaching screws and rotate the sensor until the proper value is shown on the scan tool.

Adjusting Crankshaft and Camshaft Position Sensors

Most crankshaft and camshaft position sensors do not require adjustment. However, some of these sensors must be adjusted to provide the proper signal to the ECM and prevent damaging contact with rotating engine parts. The adjustment process usually involves the use of a special alignment gauge, as shown in **Figure 15-43.** In this illustration, a special tool is used to adjust a single pickup assembly in relation to the shutter assembly. This positions the shutter precisely between the two parts of the pickup assembly.

If the alignment gauge is not used when specified, damage to the sensor may occur. Consult the vehicle's service manual to ensure that the sensor does not require the use of an alignment gauge.

Some crankshaft sensors use a small piece of cardboard as an adjusting shim between the sensor tip and the toothed wheel. The shim is placed over the sensor's tip before the sensor is installed in the opening. The sensor is tightened into place with the shim holding it in the proper position. When the engine is started, the shim slides from between the sensor and wheel.

Caution: Always check the appropriate service manual for exact procedures before replacing or adjusting any position sensor or pickup. Severe damage can result if the pickup contacts rotating engine parts.

Replacing Computer System Components

This section outlines the general procedures for replacing common computer system components. Many computer system components can be replaced by simply unplugging the electrical connectors and removing the attaching screws. Some devices, such as oxygen sensors, engine temperature sensors, and knock sensors, are

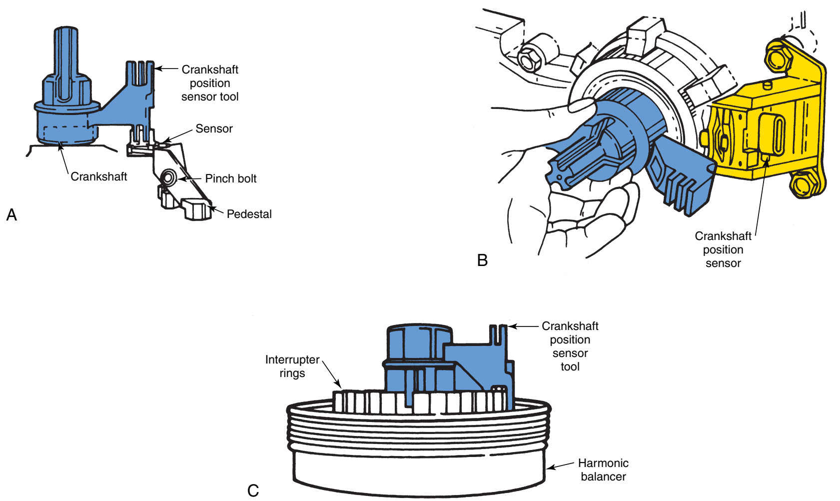


Figure 15-43. Some crankshaft position sensors require adjustment after installation. A and B—Using a position sensor tool to adjust the crankshaft position sensor. C—Using the tool to check the interrupter rings on the crankshaft pulley. (General Motors)

threaded directly into the related component. They must be removed carefully to avoid stripping the threads. Before replacing any computer control system component, always turn the ignition switch to the *off* position and remove the negative battery cable. This will prevent damage to the ECM, the sensors, and other electronic devices from stray electrical charges.

Input Sensor Replacement

The following sections deal with replacing input sensors. There are many different types of input sensors. This makes it necessary to consult the vehicle's service manual for the proper replacement procedures for specific sensors.

Note: The procedures presented in this chapter are general in nature and are meant to describe typical procedures. Always refer to the vehicle's service manual for the exact replacement procedure.

Oxygen Sensor Replacement

The oxygen sensor is probably the most delicate of all the input sensors and should always be handled carefully. Since it is installed in the exhaust manifold or the exhaust pipe, it is subject to high temperatures and corrosion that can cause the threads to seize. Many oxygen sensors require a special socket or tool for removal, **Figure 15-44.** If the oxygen sensor will be reused, always use a special tool to remove it. If the sensor will be replaced and does not require a special tool for removal, loosen it from the manifold using a socket or box end wrench that will contact all sides of the hex.

Figure 15-44. Remove oxygen sensors with the appropriate tool. Be sure you are removing the correct sensor on vehicles with multiple sensors.

Caution: Late-model vehicles have multiple oxygen sensors. Make sure you are removing the correct sensor on these vehicles.

Once the sensor is out, check the manifold or exhaust pipe around the sensor fitting for cracks or pinholes. These will draw in outside air during engine operation, causing a false sensor reading. Replace the manifold or exhaust pipe if any damage is found. Inspect the oxygen sensor for indications of carbon loading, contamination, or poisoning.

Before installing the new oxygen sensor, check the service manual to determine whether the sensor threads should be coated with ***anti-seize compound.*** Some manufacturers recommend a special high-temperature sealant. Use only a light coating of sealant to avoid plugging the external air vents, **Figure 15-45.** Do not overtighten the oxygen sensor, since this may damage the brass shell. If anti-seize compound or sealant is used, wipe off any excess from the exhaust manifold or exhaust pipe and the sensor after tightening.

MAF and MAP Sensor Replacement

The mass airflow and manifold absolute pressure sensors on most vehicles are retained by one or two bolts or clamps and are relatively easy to replace. Start by disconnecting the negative battery cable. Remove any wiring and hoses from the sensor. Loosen the bolts or clamps, and remove the sensor from the vehicle, **Figure 15-46.** Install the new sensor in the reverse order of removal. When installing a MAF sensor, be sure to face the sensor's inlet in the correct direction. See **Figure 15-47.** Tighten all the retaining bolts or clamps. Then reconnect all wiring and hoses. Finally, reconnect the negative battery cable.

Throttle Position Sensor Replacement

To replace a throttle position sensor, make sure the ignition switch is in the *off* position. Then remove the TPS electrical connector. Remove the fasteners holding the throttle position sensor to the throttle body and slide the TPS from the throttle shaft. Slide the new TPS into position; then reinstall the fasteners and electrical connector. **Figure 15-48** shows the sequence used to replace a typical throttle position sensor. After the new sensor is installed, it may be necessary to adjust it using the procedure explained earlier in this chapter.

Figure 15-45. If recommended, apply a thin coat of specified sealant to the oxygen sensor threads.

Temperature Sensor Replacement

Temperature sensors are used in many places on the engine and other vehicle components. With the exception of the coolant temperature sensor, they are relatively easy to replace.

Engine Coolant Temperature Sensor

Engine coolant temperature sensors are threaded into a coolant passage in the engine block or the radiator. They should not be removed until the engine cooling system is depressurized and drained below the level of the sensor. Always leave the radiator cap loose while changing any cooling system part to prevent pressure buildup, **Figure 15-49.**

Coolant temperature sensors have *pipe threads*, which are similar to those in household plumbing systems, and are usually installed in the block. Most coolant temperature sensors can be removed by loosening them from the engine using the proper deep-well socket and a ratchet handle. In some cases, the sensor can be removed with a box-end

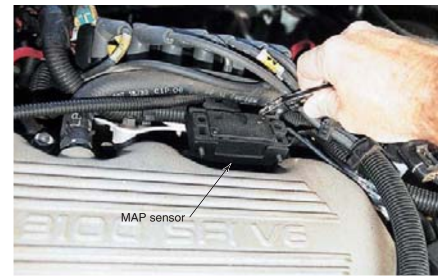


Figure 15-46. When replacing a MAP sensor, disconnect the vacuum line and the electrical connector. Then remove the fasteners and remove the sensor from its mounting.

Figure 15-47. When reinstalling an airflow sensor, make sure it is installed in the correct direction. Note the arrow on this sensor, which indicates the direction of airflow

wrench. A few sensors can only be removed with a special socket. Always disconnect the electrical connector from the wiring harness before installing the socket over the sensor.

Caution: Sensors installed in aluminum parts should not be removed until the engine has cooled for several hours. This cooling period is necessary to prevent damage to the threads in the aluminum part.

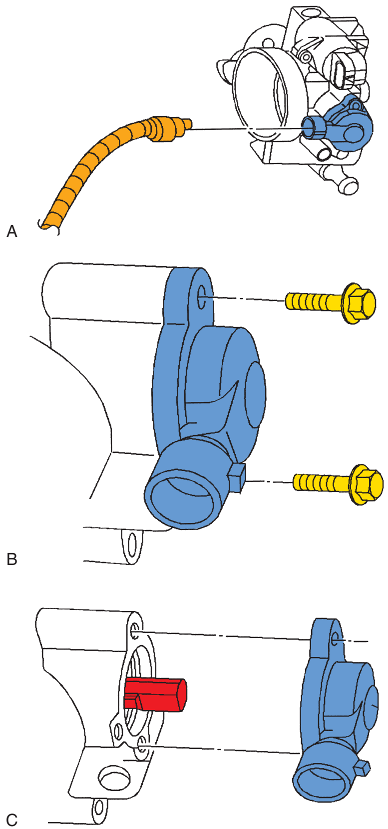


Figure 15-48. This figure shows the sequence of steps necessary to remove a throttle position sensor. A—Remove the electrical connector. B—Loosen and remove the attaching bolts. C—Remove the sensor from the shaft. Note the position of the throttle shaft for reinstallation. (General Motors)

Before installing the new sensor, coat the threads with the proper sealant. When installing the sensor, do not over-tighten it, as this may damage the threads or distort the sensor shell. If the cooling system was drained, refill it before restarting the engine. Leave the radiator cap loose and recheck coolant level after allowing the engine to run for about 10 minutes. A few front-wheel drive engines require a special fill procedure. Follow the manufacturer's recommendations. The bleed valve shown in **Figure 15-50** can be loosened to remove air from the cooling system.

Note: When bleeding air from a cooling system, turn on the heater with the blower fan on high. This will provide additional cooling and fluid circulation during the bleeding process.

Intake Air and Exhaust Gas Temperature Sensors

Intake air and exhaust gas temperature sensors are not under pressure when the engine is not running. Intake air temperature sensors can be removed and replaced without special precautions. To replace a temperature sensor installed in the intake manifold or plenum, disconnect the electrical connector. Then use the proper socket to remove the sensor from the manifold. Coat the new sensor with sealing compound (if necessary), install it in the manifold, and reattach the electrical connector. Check for vacuum leaks and sensor operation.

Figure 15-49. Loosen the radiator cap before servicing any part of the cooling system.

Figure 15-50. After the coolant temperature sensor has been replaced, it may be necessary to bleed air from the cooling system. Some engines are equipped with bleed valves. This one is located on the thermostat housing.

To replace a temperature sensor installed in the air cleaner housing, remove the electrical connector, pull the attaching clip from the sensor, and remove the sensor from the housing. Position the new sensor in the housing, install the clip, and reconnect the electrical connector.

To replace an exhaust gas temperature sensor, allow the exhaust system to cool; then disconnect the electrical connector. Use a special tool or a six-point socket to remove the sensor without damaging its shell. Place anti-seize compound on the threads of the new sensor. Install the sensor and reconnect the electrical connector. Start the engine and check for exhaust leaks and proper sensor operation.

Knock Sensor Replacement

Knock sensors are threaded directly into the engine block, cylinder head, or intake manifold, **Figure 15-51.** This allows them to easily detect and transmit the sound of engine detonation. Knock sensors can be removed and replaced without special precautions. Since the knock sensor shell is usually made of brass, never try to remove this type of sensor with an open-end wrench. Install and tighten the new sensor carefully. Use a socket or box-end wrench to avoid distorting the shell. After tightening, reinstall the electrical connector and check the operation of the knock sensor as explained earlier.

Crankshaft/Camshaft Position Sensors

Most crankshaft and camshaft position sensors are installed on the engine block, timing cover, camshaft housing, or transmission bell housing. These sensors are secured by a clamp and a single bolt or attached to a bracket held by one or more bolts. After removing the electrical connector and bolt(s), pull the position sensor from the engine.

Check the end of the sensor to ensure that it has not contacted the crankshaft or camshaft sensor ring, **Figure 15-52.** If the end of the sensor has been damaged by contact with the sensor ring or other moving parts, determine the cause and make the necessary corrections before installing a new sensor.

To install the new sensor, make sure replacement O-rings or gaskets are in place. Then lightly lubricate the sensor's tip with engine oil and push the sensor into position. Reinstall the clamp and bolt; then install the electrical connector.

ECM Service

Before replacing an ECM, make sure the ignition switch is turned to the *off* position. Disconnect the negative battery cable, if recommended by the manufacturer. After locating the ECM, disconnect the wiring connector(s) and remove the attaching fasteners. Most ECMs are attached to the vehicle

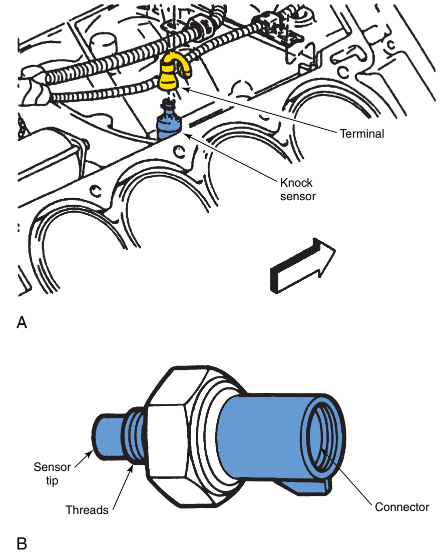


Figure 15-51. A—Knock sensors are threaded into the engine. This one is located under the intake manifold. B—External parts of a knock sensor. (General Motors and Ford)

Figure 15-52. After removing a crankshaft or camshaft position sensor, check its tip for signs of damage. If damage is found, be sure to determine and correct the cause before installing a new sensor.

with bolts or screws, but a few are held in place with clips or plastic rivets.

To replace the ECM, set the unit in place and reinstall the fasteners, being sure to reattach any ground straps. Then reconnect the electrical connectors. On some vehicles, it may be necessary to reconnect the electrical connectors before placing the ECM in position on the vehicle.

Caution: To prevent static discharge from damaging the new ECM, follow the manufacturer's instructions concerning static discharge and unit grounding.

Updating ECM Information

Many ECMs can be restored to proper performance by providing them with updated information. On some older vehicles, the PROM chip (sometimes called a mem-cal chip) can be replaced. On many late-model vehicles, the ECM can be reprogrammed from an outside source. These processes will be outlined in the following sections.

Replacing a PROM

To replace a PROM, make sure the ignition key is in the *off* position. Remove the ECM fuse and remove the access cover over the PROM. See **Figure 15-53.** Special tools are available to help remove and install the PROM safely. Remove the old PROM from the ECM. Then install the new PROM, carefully pushing it into position. Finally, replace the access cover and reinstall the ECM fuse.

Replacing a Knock Sensor Module

In some vehicles, the ECM contains a knock sensor (KS) module. This module can be replaced if it is defective. Additionally, it can be removed from a defective ECM and reinstalled in a new unit, ensuring that the proper timing retard is maintained for engine knock protection.

To replace the knock sensor module, make sure the ignition key is in the *off* position. Remove the ECM fuse and then

Figure 15-53. The PROM or mem-cal can be replaced after removing the cover that protects it from water and dirt.

remove the access cover over the KS module. Pinch the module locking tabs to release them and pull the module from the ECM.

Install the new module carefully, making sure the mounting pins are not bent. When pushing the KS module into position, make sure the module's locking tabs snap into place. Finally, replace the access cover and reinstall the ECM fuse.

Flash Programming a Computer

As mentioned, the ECMs in late-model vehicles can be updated by erasing old information from the computer's memory and reprogramming the unit with new information. The new information often cures engine driveability and transmission shifting problems. The computer memory section that can be updated is generally called the ***EPROM*** (electronically erasable programmable read-only memory) or the ***FEPROM*** (flash erasable programmable read-only memory). Providing the existing memory with updated information is usually referred to as ***flash programming***.

Actual reprogramming details vary between manufacturers, but the basic procedures are the same for all vehicles. One of three methods can be used to reprogram the ECM:

- Direct programming.
- Indirect programming.
- Remote programming.

Direct Programming

Direct programming is the fastest and simplest method of reprogramming an ECM. The new information is downloaded by attaching a shop recalibration device (usually a computerized analyzer) or a programming computer directly to the vehicle's DLC. See **Figure 15-54A.** The erasure and reprogramming is done by accessing the proper menu and

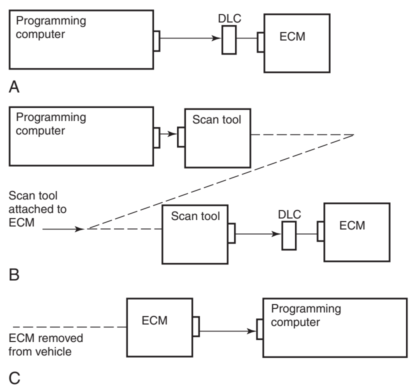


Figure 15-54. Flash programming methods. A—Direct programming. B—Indirect programming. C—Remote programming.

following the instructions as prompted by the recalibration device. Then, the information (often stored in the device's memory, contained on a CD-ROM, or accessed through a connection to the manufacturer's database) is entered into the ECM through the DLC. The shop recalibration device is not a scan tool, and a scan tool is not needed for this programming procedure.

Indirect Programming

To perform ***indirect programming,*** the proper scan tool is used to transfer information from a separate *programming computer* to the ECM. See **Figure 15-54B.** The scan tool can also be used to reset some computer-controlled vehicle systems after programming is complete. The programming computer may resemble a personal computer used in the home, or it may be a computerized analyzer that is similar to the one used for direct programming.

In indirect programming, the scan tool is connected to the programming computer and programming information is downloaded from the computer to the scan tool. Most scan tools use a high-capacity memory cartridge to store the programming information. Some newer scan tools have enough fixed memory to hold the programming information and do not use a separate memory cartridge. Once the programming information has been downloaded, the scan tool can be disconnected from the programming computer, taken to the vehicle, and connected to the DLC. Programming information is then downloaded from the scan tool to the ECM through the data link connector.

Remote Programming

Remote programming is done with the ECM removed from the vehicle. See **Figure 15-54C**.This procedure is used when changes must be made through a direct connection to a manufacturer's database. Remote programming can also be done in cases where normal direct or indirect programming is not practical or possible. Special connectors and tools are required for remote programming. In most cases, this procedure is done only at new-vehicle dealerships.

To perform remote programming, remove the ECM from the vehicle as described earlier in this chapter. Once the ECM has been removed, take it to the programming device. The programming device is generally a computer located in the shop. This device may contain the new ECM information, or it may be used with a modem to connect to a remote database. Attach the programming device's electrical connectors to the ECM. Access the device's programming menu and follow instructions given in the menu to program the ECM. Programming normally takes only a few minutes. When programming is complete (as indicated on the menu), remove the programming device's electrical connectors from the ECM and reinstall the ECM in the vehicle.

Actuator Replacement

Replacing an actuator is often easier than diagnosing the original problem. As you learned in earlier sections, the ECM operates a wide variety of actuators. The following procedures are general examples of actuator replacement. The replacement of specific actuators is covered in the applicable chapters. Always consult the proper service literature when removing and replacing any actuator.

Replacing a Solenoid

Several solenoids are used on modern vehicles, including fuel injectors, idle controls, EGR solenoids, and transmission solenoids. To replace a solenoid, make sure the ignition switch is in the *off* position. Then, remove any parts that block access to the solenoid. Disconnect the electrical connector, remove the fasteners holding the solenoid, and remove the solenoid. Inspect the solenoid. Sometimes solenoid problems are the result of carbon or sludge buildup in the valve and passages. It may be possible to clean the solenoid and restore it to service. If the solenoid is definitely bad, it must be replaced.

Compare the new solenoid to the old one to ensure that the replacement part is correct. Install any needed gaskets or seals on the new solenoid and place it in position. Install the fasteners and the electrical connector. Finally, install any other parts that were removed, start the engine, and check solenoid operation.

Replacing a Relay

Relays are usually installed in one of the vehicle fuse boxes, **Figure 15-55.** To replace a relay, make sure the ignition switch is in the *off* position. Then locate the relay in the fuse box and pull it from its socket. Compare the old and new relays; then install the new relay. Start the engine and check relay operation.

Replacing a Motor

Some vehicles make use of motors as actuators. For example, a motor is sometimes used to control idle speed on fuel injected engines, **Figure 15-56.** To replace a motor, make sure the ignition switch is in the *off* position. Then disconnect

Figure 15-55. Relays are installed in one of several fuse boxes. Be sure that you are replacing the correct relay.

the electrical connector and remove the fasteners holding the motor in position. Transfer any brackets or other hardware from the old motor to the new one; then install the new motor. Install and tighten the fasteners and replace the electrical connector. Start the engine and check motor operation.

Follow-up for Computer Control System Repairs

After replacing computer system parts or reprogramming the ECM, recheck system operation to ensure that the repairs have been successful. After making computer system repairs, erase any trouble codes from the ECM's memory. Then road test the vehicle to ensure that the MIL does not come on. Finally, make sure that none of the trouble codes has been reset. If the repair involved correcting a lean or rich condition, verify that the exhaust emissions output is within specifications.

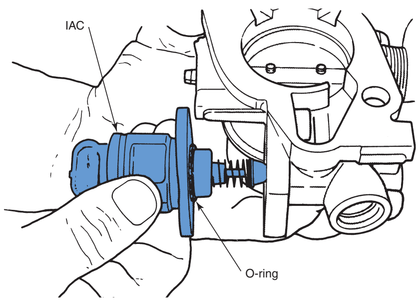


Figure 15-56. The IAC is a commonly replaced motor located on the throttle body, near the throttle plate. It can usually be removed and replaced easily. (General Motors)

ECM Relearn Procedures

After service, the computer system may require a **relearn procedure,** which is a period of vehicle operation that allows the system to adapt to new components and updated programming information. The relearn procedure can often be accomplished by driving the vehicle at various speeds for about ten minutes. Some vehicles require a specific relearn procedure, which may include idling in drive for a specified amount of time or until the engine reaches its normal operating temperature. Always check the manufacturer's service literature for specific relearn procedures. Ignore any unusual engine and transmission conditions until the relearn procedure is complete.

OBD II Drive-Cycle Test

OBD II–equipped vehicles must pass a ***drive-cycle test*** when the ECM or the battery has been replaced, or after trouble codes have been erased. The drive cycle test is also part of some states' I/M emissions testing procedures. The test is performed before the actual emission testing begins.

The drive-cycle test involves attaching a scan tool to the vehicle and driving the vehicle for a set time. The drive cycle consists of specific acceleration, cruising, and deceleration steps. The drive-cycle test is designed to tell the technician whether the OBD II system is operating and whether the vehicle is operating efficiently enough to have a reasonable chance of passing an emissions test. **Figure 15-57** is a chart showing a typical drive cycle and the OBD II systems monitored. Note that the entire test takes 12–15 minutes, starting with a cold engine. If the vehicle fails the drive-cycle test, the technician can use the data gathered by the scan tool to quickly isolate the defective system or component. Once the system has been repaired, the drive-cycle test can be repeated to check OBD II system operation. Emissions testing procedures are covered in more detail in Chapter 20, Emission System Testing and Service.

Typical OBD II Drive Cycle

Diagnostic Time Schedule for I/M Readiness	
Vehicle Drive Status	What Is Monitored?
Cold start, coolant temperature less than 50°C (122°F)	—
Idle 2.5 minutes in drive (auto) neutral (man), A/C and rear defogger ON	HO_2S heater, misfire, secondary air, fuel trim, EVAP purge
A/C off, accelerate to 90 km/h (55 mph), 1/2 throttle	Misfire, fuel trim, purge
3 minutes of steady state—cruise at 90 km/h (55 mph)	MIsfire, EGR, secondary air, fuel trim, HO_2S, EVAP purge
Clutch engages (man), no braking, decelerate to 32 km/h (20 mph)	EGR, fuel trim, EVAP purge
Accelerate to 90-97 km/h (55-60 mph), 3/4 throttle	Misfire, fuel trim, EVAP purge
5 minutes of steady state cruise at 90-97 km/h (55-60 mph)	Catalyst monitor, misfire, EGR, fuel trim, HO_2S, EVAP purge
Decelerate, no braking. End of drive cycle	EGR, EVAP, purge
Total time of OBD II drive cycle 12 minutes	–

Figure 15-57. The OBD II drive-cycle test should be performed to prepare the vehicle for emissions inspection and to reset systems after the battery or ECM has been disconnected. (General Motors)

Tech Talk

About 35 years ago, the only electronic part on an automobile was the radio. The first electronic ignition systems and electronic voltage regulators were introduced in the mid 1960s and did not become common until almost ten years later. Technicians who understood point-type ignition systems and five or six circuits in the carburetor were considered current. Technicians in those days could keep up with things by keeping their eyes open and gaining some trial-and-error experience as newer cars came into the shop.

Of course, all of this has changed. The modern technician must understand electronic ignitions, fuel injection, emission controls, on-board computers, and all sorts of government rules and regulations. Just keeping up from year to year takes considerable reading and study.

So what does this mean to you, the future technician? For starters, trial-and-error learning is out. One error on a computer-controlled system will destroy several hundred dollars worth of computer equipment.

The only way to troubleshoot and repair late-model vehicles properly and efficiently is to get your hands on every bit of new information you can and study it thoroughly. Now is the time to begin collecting information about modern vehicles and taking time to read about the latest developments.

Summary

The first step in diagnosing computer control system problems is to check for obvious defects. Look for problems in the wiring, damaged parts, and other vehicle problems that may be confused with the computer control system malfunctions.

Before performing any other diagnostic steps, retrieve trouble codes from the ECM memory. Trouble codes may be stored even if the MIL is not on. To retrieve trouble codes, follow the procedure outlined in the factory service manual. On OBD I vehicles, trouble codes can be obtained without a scan tool. On OBD II vehicles, a scan tool must be used to retrieve the codes. OBD I and OBD II code formats are different. The next step is to separate the hard codes from the intermittent codes. Then interpret the codes to arrive at a defective system or part.

After the trouble codes have been retrieved and interpreted, check the computer control system devices. Sensors to be tested include the oxygen sensor, mass airflow (MAF) sensor, manifold absolute pressure (MAP) sensor, temperature sensor, throttle position sensor, crankshaft and camshaft position and speed sensors, knock sensor, and vehicle speed sensor. Testing can be done with a multimeter, a scan tool, or a waveform meter.

A faulty ECM can be identified by substituting a known good ECM for the questionable unit or through the process of elimination. If every sensor, actuator, and system fuse, as well as all wiring and connectors, have been checked and are okay, the problem is most likely in the ECM. The ECM will occasionally produce a trouble code that cannot be confirmed by testing or a trouble code that does not exist. This indicates that the ECM is defective.

Actuators include solenoids and relays, and motors. Actuators can be tested with scan tools, ohmmeters, or waveform meters. Sometimes the actuator can be tested by observing whether or not it operates.

Some sensors, such as throttle position and crankshaft/camshaft position sensors, can be adjusted. Check the vehicle's service manual for correct procedures.

Replacing sensors is relatively easy. Some are threaded into the engine. Others are installed on brackets near the engine. Most vehicles have multiple oxygen, temperature, knock, and pressure sensors. Be sure you are removing the correct sensor. Once the sensor has been replaced, it will be necessary to operate the engine to allow the ECM to recalibrate itself.

ECM service involves replacing defective parts or reprogramming the ECM itself. PROMS must be replaced carefully to avoid damaging the ECM. Reprogramming installs new information to cure driveability and other engine problems.

Solenoids, relays, and motors can be replaced without major disassembly. Once the new parts have been installed, start the engine and allow the ECM go through its relearn procedure

Always recheck system operation after performing computer control system service. If possible, road test the vehicle to ensure that it operates properly. After completing the road test, recheck for trouble codes.

Review Questions—Chapter 15

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

1. A vehicle is brought to your shop with a suspected computer system problem. Which of the following should be done *first?*
   (A) Obtain the vehicle's service manual.
   (B) Check for obvious problems.
   (C) Retrieve trouble codes.
   (D) Road test the vehicle.
2. A vehicle has a driveability problem and the charging system voltage is low. Which should be diagnosed and corrected first, the driveability problem or the low charging system voltage?
3. An OBD II computer system will have all of the following, *except:*
   (A) a 16-pin diagnostic connector.
   (B) an oxygen sensor mounted behind the catalytic converter.
   (C) a two-digit trouble code format.
   (D) hard and intermittent trouble codes.
4. Trouble codes in most OBD II systems should be cleared by _____.
   (A) disconnecting the negative battery cable
   (B) using a scan tool
   (C) removing a fuse to disconnect battery power from the ECM
   (D) All of the above.

5. Which of the following sensors can be checked with a scan tool?
   (A) Oxygen sensor.
   (B) MAP sensor.
   (C) MAF sensor.
   (D) All of the above.
6. The waveform meter provides the technician with a _____ of what is happening in the circuit.
7. The two types of MAF sensors are the _____ type and the _____ type.
8. A MAP sensor measures engine _____.
9. A temperature sensor can be checked with a(n) _____.
   (A) scan tool
   (B) ohmmeter
   (C) waveform meter
   (D) All of the above.
10. A pressure sensor can be checked with a(n) _____.
   (A) voltmeter
   (B) ohmmeter
   (C) ammeter
   (D) All of the above.
11. A noid light is used to check which of the following sensors?
   (A) Crankshaft position sensor.
   (B) Throttle position sensor.
   (C) Temperature sensor.
   (D) Knock sensor.
12. Throttle position sensors can go out of adjustment because of _____.
   (A) linkage wear
   (B) changes in the ECM
   (C) changes in the sensor material
   (D) Both A and C.
13. Throttle position sensors are adjusted by attaching what type of meter to the sensor?
   (A) Voltmeter.
   (B) Ammeter.
   (C) Ohmmeter.
   (D) All of the above.
14. What two methods are often the only ways to check an ECM that is suspected of being defective?
15. To check a solenoid, energize it and listen for a _____.
16. Define the process of forcing an actuator.
17. The service manual gives a solenoid winding resistance specification of 0.5–0.7 ohms. Which of the following readings indicates that the winding has the correct resistance?
   (A) 0 ohms.
   (B) 0.5 ohms.
   (C) 7 ohms.
   (D) Infinity.
18. Removing and installing an oxygen sensor usually requires a special _____.
19. Which of the following can cause a false oxygen sensor reading?
   (A) A crack in the exhaust manifold.
   (B) Excessive anti-seize compound on the sensor threads.
   (C) Tight electrical connectors.
   (D) A discolored sensor shell.
20. To install a coolant temperature sensor, the cooling system must be _____.
21. The cooling system bleed valve is used to remove _____ from the cooling system.
   (A) coolant
   (B) air
   (C) sealant
   (D) rust
22. Knock sensors are threaded directly into the _____.
   (A) engine block
   (B) cylinder head
   (C) intake manifold
   (D) All of the above.
23. When changing an ECM, the first thing to remove is the _____.
   (A) negative battery cable
   (B) ECM retaining bolts
   (C) ECM electrical harness
   (D) ROM or PROM
24. When an ECM must be flash reprogrammed, which of the following should be removed?
   (A) PROM.
   (B) ECM.
   (C) ECM wiring harness.
   (D) All of the above.
25. Relays are usually installed in one of the vehicle _____ _____.

ASE-Type Questions

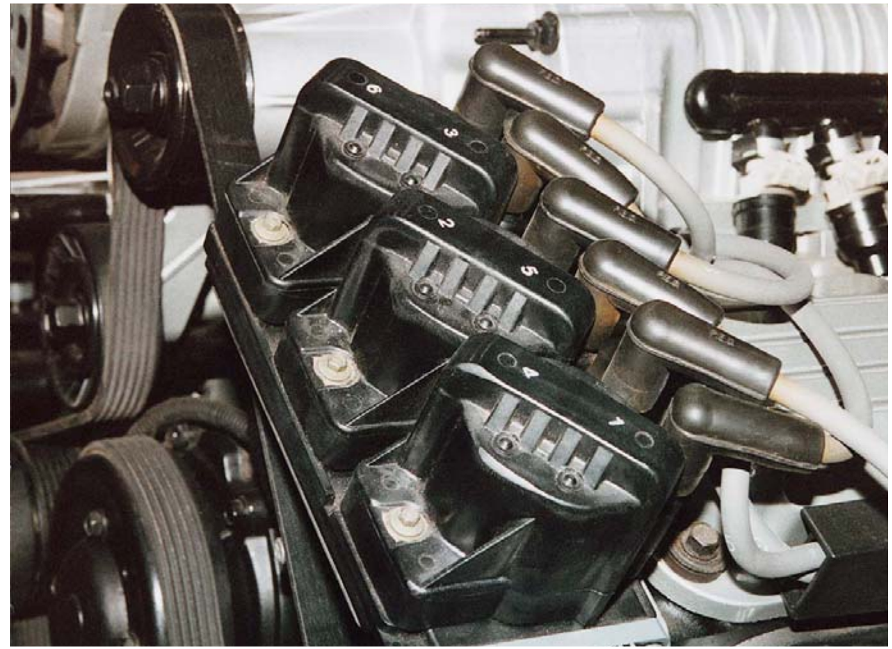
1. Trouble codes on most modern vehicles can be read only by using which of the following?
   (A) The MIL.
   (B) A voltmeter.
   (C) A scan tool.
   (B) A waveform meter.

2. Technician A says that grounding one of the diagnostic terminals on an OBD II system will cause the engine to go into closed loop operation. Technician B says that a scan tool is needed to retrieve trouble codes from an OBD II system. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. Hard trouble codes are being discussed. Technician A says that hard codes will cause the MIL to illuminate only when the key is on and the engine is off. Technician B says that hard codes will cause the MIL to be on whenever the engine is running. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
4. An excessively rich reading from the oxygen sensor can mean all of the following, *except:*
   (A) the oxygen sensor is defective.
   (B) a leaking fuel injector.
   (C) the gasoline is the wrong octane rating.
   (D) a defective airflow sensor.
5. The heater circuit of an oxygen sensor can be checked with which of the following?
   (A) Ohmmeter.
   (B) Voltmeter.
   (C) Ammeter.
   (D) Jumper wires.
6. The output of a frequency-type MAF sensor can be measured by using a _____.
   (A) scan tool
   (B) multimeter that can read RPM
   (C) multimeter that can read duty cycles
   (D) All of the above.
7. Technician A says that testing a BARO sensor requires a vacuum tester. Technician B says that testing a MAP sensor requires a vacuum tester. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
8. Technician A says that most pressure sensors are on-off switches. Technician B says that most pressure sensors can be tested with a voltmeter. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Technician A says that tapping an engine block with a metal tool will cause the ignition timing to retard. Technician B says that tapping the engine block with a metal tool will cause the knock sensor circuit to operate. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. All the following statements about speed sensors are true, *except:*
   (A) the output of some vehicle speed sensors is measured in ac volts.
   (B) some vehicle speed sensors are checked by measuring resistance.
   (C) the output of some speed sensors is measured as a pulsed dc signal.
   (D) some speed sensors can be checked with a scan tool.
11. Which of the following computer control system components can be adjusted?
   (A) MAF sensor.
   (B) MAP sensor.
   (C) TPS.
   (D) IAC.
12. Some ECMs have internal memory devices that can be replaced to update the ECM. Which of the following internal parts *cannot* be replaced?
   (A) PROM.
   (B) ROM.
   (C) Mem-cal.
   (D) Knock sensor.
13. All the following are methods of reprogramming the ECM, *except:*
   (A) direct programming.
   (B) indirect programming.
   (C) remote programming.
   (D) mechanical programming.
14. An engine runs rough during the first few minutes of the ECM relearn procedure. Technician A says this indicates another system problem. Technician B says this indicates that the ECM is adjusting to new engine operating conditions. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

15. Technician A says that a drive-cycle test is performed before the emissions are checked. Technician B says that a drive-cycle test is performed after the ECM or battery has been disconnected. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

Suggested Activities

1. Using factory service information, locate the computer diagnostic test connectors on several different makes and years of vehicles. Make a chart comparing the connector locations by manufacturer and the type of equipment needed to access the trouble codes.
2. Obtain a vehicle with an on-board computer and retrieve trouble codes. Use the procedure outlined in the service manual. If your instructor okays it, create trouble codes by disconnecting a computer sensor or an output device and briefly running the engine. What codes were found? What do the codes indicate?
3. Based on the preceding activities, consult the appropriate factory service manual to determine the next steps to be taken to isolate a computer problem.
4. Determine the effect on the computer system of disconnecting a non-computer device. For instance, what happens to the fuel mixture when the air injector (smog) pump belt is removed? What happens to the timing advance if a vacuum leak develops on an engine with MAP sensor? What happens to the computer open and closed loop cycle if the cooling system thermostat is removed? Discuss you findings with the other members of the class and try to figure out how one system affects another.



A coil pack, such as the one shown here, is commonly used on vehicles with distributorless igniton. This particular coil pack is for a 6-cylinder engine. Each coil fires two spark plugs.