REVIEW QUESTIONS

1. What are two advantages of gasoline direct injection compared with port fuel-injection?
2. What are two disadvantages of gasoline direct injection compared with port fuel-injection?
3. How is the fuel delivery system different from a port fuel-injection system?
4. What are the basic modes of operation of a GDI system?

CHAPTER QUIZ

1. Where is the fuel injected in an engine equipped with gasoline direct injection?
   a. Into the intake manifold near the intake valve
   b. Directly into the combustion chamber
   c. Above the intake port
   d. In the exhaust port
2. The fuel pump inside the fuel tank on a vehicle equipped with gasoline direct injection produces about what fuel pressure?
   a. 5 to 10 PSI **c.** 20 to 40 PSI
   b. 10 to 20 PSI **d.** 50 to 60 PSI
3. The high-pressure fuel pumps used in gasoline direct injection (GDI) systems are powered by _____.
   a. Electricity (DC motor) **c.** The camshaft
   b. Electricity (AC motor) **d.** The crankshaft
4. The high-pressure fuel pressure is regulated by using _____.
   a. An electric pressure-control valve
   b. A vacuum-biased regulator
   c. A mechanical regulator at the inlet to the fuel rail
   d. A non-vacuum biased regulator
5. The fuel injectors operate under a fuel pressure of about _____.
   a. 35 to 45 PSI **c.** 500 to 2,900 PSI
   b. 90 to 150 PSI **d.** 2,000 to 5,000 PSI
6. The fuel injectors used on a gasoline direct-injection system are pulsed on using what voltage?
   a. 12 to 14 V **c.** 100 to 110 V
   b. 50 to 90 V **d.** 200 to 220 V
7. Which mode of operation results in a richer air–fuel mixture near the spark plug?
   a. Stoichiometric **c.** Stratified
   b. Homogeneous **d.** Knock protection
8. Some engines that use a gasoline direct-injection system also have port injection.
   a. True
   b. False
9. A gasoline direct-injection system can be used to start an engine without the need for a starter.
   a. True
   b. False
10. A lack of power from an engine equipped with gasoline direct injection could be due to _____.
    a. Noisy injectors
    b. Carbon on the injectors
    c. Carbon on the intake valves
    d. Both b and c

chapter 80

ELECTRONIC THROTTLE CONTROL SYSTEM

OBJECTIVES: After studying Chapter 80, the reader will be able to: • Prepare for ASE test content area "E" (Computerized Engine Controls Diagnosis and Repair). • Describe the purpose and function of an electronic throttle control (ETC) system. • Explain how an electronic throttle control system works. • List the parts of a typical electronic throttle control system. • Describe how to diagnose faults in an electronic throttle control system.

KEY TERMS: Accelerator pedal position (APP) sensor 893 • Coast-down stall 898 • Default position 894 • Drive-by-wire 893 • Electronic throttle control (ETC) 893 • Fail safe position 894 • Neutral position 894 • Servomotor 894 • Throttle position (TP) sensor 893

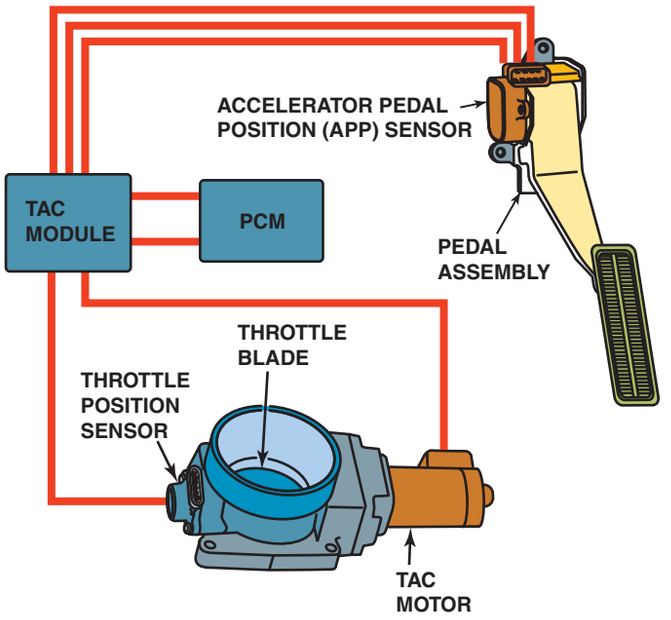


FIGURE 80–1 The throttle pedal is connected to the accelerator pedal position (APP) sensor. The electronic throttle body includes a throttle position sensor to provide throttle angle feedback to the vehicle computer. Some systems use a Throttle Actuator Control (TAC) module to operate the throttle blade (plate).

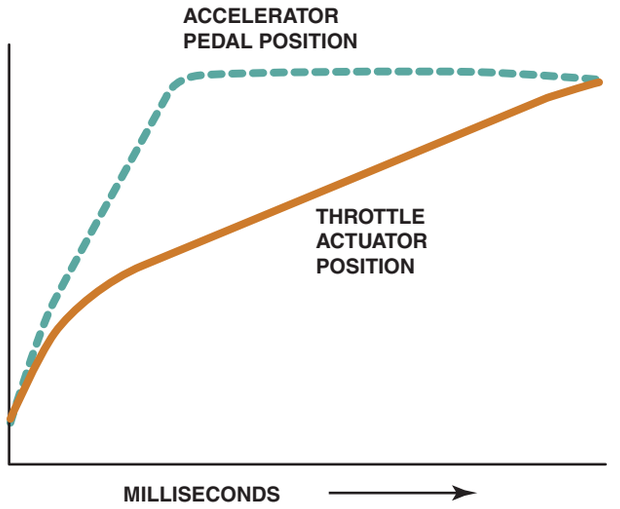


FIGURE 80–2 The opening of the throttle plate can be delayed as long as 30 milliseconds (0.030 sec.) to allow time for the amount of fuel needed to catch up to the opening of the throttle plate.

ELECTRONIC THROTTLE CONTROL (ETC) SYSTEM

ADVANTAGES OF ETC The absence of any mechanical linkage between the throttle pedal and the throttle body requires the use of an electric actuator motor. The electronic throttle system has the following advantages over the conventional cable:

- Eliminates the mechanical throttle cable, thereby reducing the number of moving parts.
- Eliminates the need for cruise control actuators and controllers.
- Helps reduce engine power for traction control (TC) and electronic stability control (ESC) systems.
- Used to delay rapid applications of torque to the transmission/transaxle to help improve driveability and to smooth shifts.
- Helps reduce pumping losses by using the electronic throttle to open at highway speeds with greater fuel economy. The electronic throttle control (ETC) opens the throttle to maintain engine and vehicle speed as the powertrain control module (PCM) leans the air–fuel ratio, retards ignition timing, and introduces additional exhaust gas recirculation (EGR) to reducing pumping losses.
- Used to provide smooth engine operation, especially during rapid acceleration.
- Eliminates the need for an idle air control valve.

The electronic throttle can be called **drive-by-wire,** but most vehicle manufacturers use the term **electronic throttle control (ETC)** to describe the system that opens the throttle valve electrically.

PARTS INVOLVED The typical ETC system includes the following components:

1. **Accelerator pedal position (APP)** sensor, also called accelerator pedal sensor (APS)
2. The electronic throttle actuator (servomotor), which is part of the electronic throttle body
3. A **throttle position (TP) sensor**
4. An electronic control unit, which is usually the powertrain control module (PCM)

● **SEE FIGURE 80–1.**

NORMAL OPERATION OF THE ETC SYSTEM

Driving a vehicle equipped with an electronic throttle control (ETC) system is about the same as driving a vehicle with a conventional mechanical throttle cable and throttle valve. However, the driver may notice some differences, which are to be considered normal. These normal conditions include:

- The engine may not increase above idle speed when depressing the accelerator pedal when the gear selector is in PARK.
- If the engine speed does increase when the accelerator is depressed with the transmission in PARK or NEUTRAL, the engine speed will likely be limited to less than 2000 RPM.
- While accelerating rapidly, there is often a slight delay before the engine responds. ● **SEE FIGURE 80–2.**
- While at cruise speed, the accelerator pedal may or may not cause the engine speed to increase if the accelerator pedal is moved slightly.

ACCELERATOR PEDAL POSITION SENSOR

CABLE-OPERATED SYSTEM Honda Accords until 2008 model year used a cable attached to the accelerator pedal to operate the APP sensor located under the hood. A similar arrangement

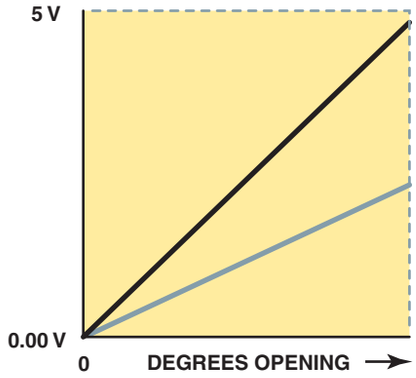


FIGURE 80–3 A typical accelerator pedal position (APP) sensor, showing two different output voltage signals that are used by the PCM to determine accelerator pedal position. Two (or three in some applications) are used as a double check because this is a safety-related sensor.

was used in Dodge RAM trucks in 2003. In both of these applications, the throttle cable was simply moving the APP sensor and not moving the throttle plate. The throttle plate is controlled by the PCM and moved by the electronic throttle control motor.

TWO SENSORS The accelerator pedal position sensor uses two and sometimes three separate sensors, which act together to give accurate accelerator pedal position information to the controller, but also are used to check that the sensor is working properly. They function just like a throttle position sensor, and two are needed for proper system function. One APP sensor output signal increases as the pedal is depressed and the other signal decreases. The controller compares the signals with a look-up table to determine the pedal position. Using two or three signals improves redundancy should one sensor fail, and allows the PCM to quickly detect a malfunction. When three sensors are used, the third signal can either decrease or increase with pedal position, but its voltage range will still be different from the other two. ● **SEE FIGURE 80–3.**

? FREQUENTLY ASKED QUESTION

What Is the "Spring Test"?

The spring test is a self-test performed by the PCM whenever the engine is started. The PCM operates the throttle to check if it can react to the command and return to the default (home) position. This self-test is used by the PCM to determine that the spring and motor are working correctly and may be noticed by some vehicle owners by the following factors:

- A slight delay in the operation of the starter motor. The PCM performs this test when the ignition switch is turned to the "on" position. While it takes just a short time to perform the test, it can be sensed by the driver that there could be a fault in the ignition switch or starter motor circuits.
- A slight "clicking" sound may also be heard coming from under the hood when the ignition is turned on. This is normal and is related to the self-test on the throttle as it opens and closes.

? FREQUENTLY ASKED QUESTION

Why Not Use a Stepper Motor for ETC?

A stepper motor is a type of motor that has multiple windings and is pulsed by a computer to rotate a certain number of degrees when pulsed. The disadvantage is that a stepper motor is too slow to react compared with a conventional DC electric motor and is the reason a stepper motor is not used in electronic throttle control systems.

THROTTLE BODY ASSEMBLY

The throttle body assembly contains the following components:

- Throttle plate
- Electric actuator DC motor
- Dual throttle position (TP) sensors
- Gears used to multiply the torque of the DC motor
- Springs used to hold the throttle plate in the default location

THROTTLE PLATE AND SPRING The throttle plate is held slightly open by a concentric clock spring. The spring applies a force that will close the throttle plate if power is lost to the actuator motor. The spring is also used to open the throttle plate slightly from the fully closed position.

ELECTRONIC THROTTLE BODY MOTOR The actuator is a DC electric motor and is often called a **servomotor.** The throttle plate is held in a **default position** by a spring inside the throttle body assembly. This partially open position, also called the **neutral position** or the **fail safe position,** is about 16% to 20% open. This default position varies depending on the vehicle and usually results in an engine speed of 1200 to 1500 RPM.

- The throttle plate is driven closed to achieve speeds lower than the default position, such as idle speed.
- The throttle plate is driven open to achieve speeds higher than the default position, such as during acceleration. ● **SEE FIGURE 80–4.**

The throttle plate motor is driven by a bidirectional pulse-width modulated (PWM) signal from the PCM or electronic throttle control module using an H-bridge circuit. ● **SEE FIGURE 80–5a, b.**

The H-bridge circuit is controlled by the powertrain control module (PCM) by:

- Reversing the polarity of power and ground brushes to the DC motor
- Pulse-width modulating (PWM) the current through the motor

The PCM monitors the position of the throttle from the two throttle position (TP) sensors. The PCM then commands the throttle plate to the desired position. ● **SEE FIGURE 80–6.**

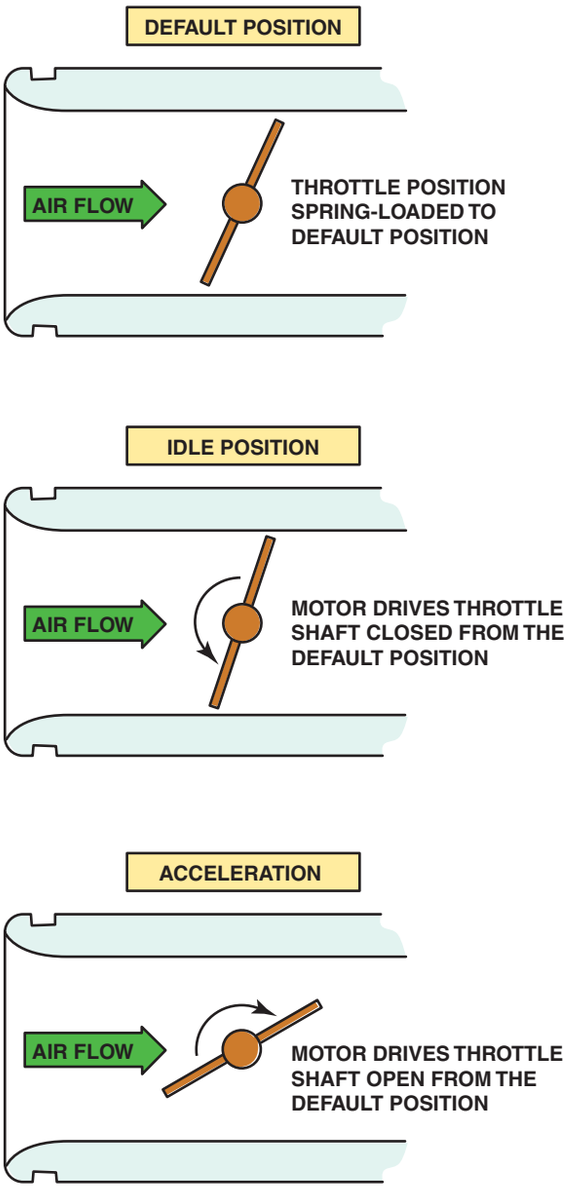


FIGURE 80–4 The default position for the throttle plate is in slightly open position. The servomotor then is used to close it for idle and open it during acceleration.

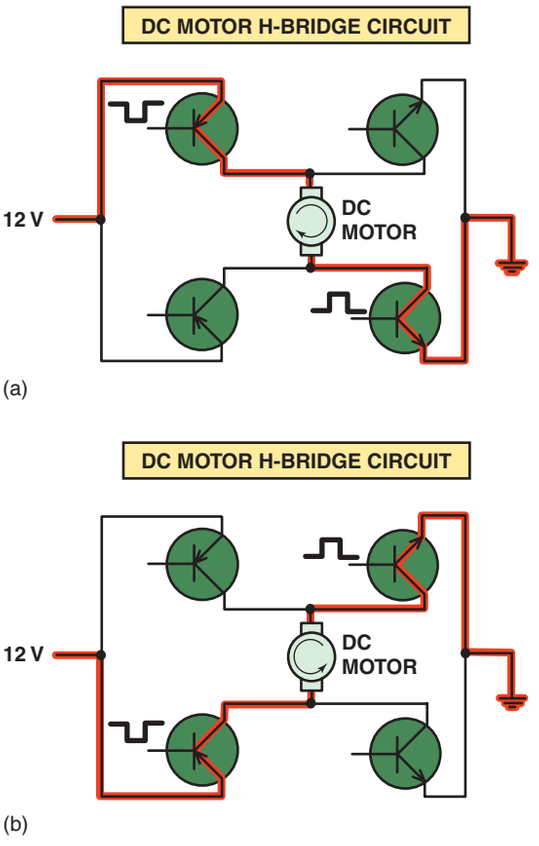


FIGURE 80–5 (a) An H-bridge circuit is used to control the direction of the DC electric motor of the electronic throttle control unit. (b) To reverse the direction of operation, the polarity of the current through the motor is reversed.

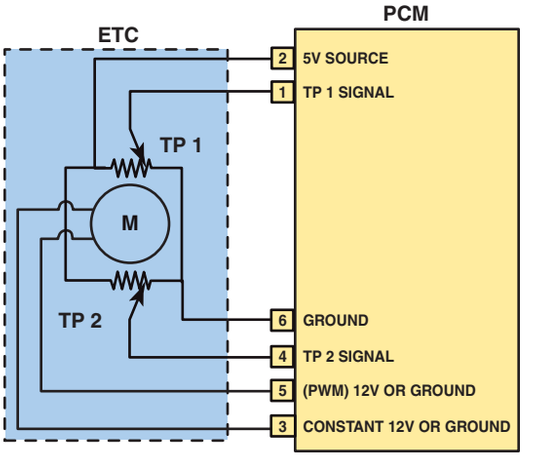


FIGURE 80–6 Schematic of a typical electronic throttle control (ETC) system. Note that terminal #5 is always pulse-width modulated and that terminal #3 is always constant, but both power and ground are switched to change the direction of the motor.

THROTTLE POSITION (TP) SENSOR

Two throttle position (TP) sensors are used in the throttle body assembly to provide throttle position signals to the PCM. Two sensors are used as a fail-safe measure and for diagnosis. There are two types of TP sensors used in electronic throttle control (ETC) systems: potentiometers and Hall-effect.

THREE-WIRE POTENTIOMETER SENSORS These sensors use a 5-volt reference from the PCM and produce an analog (variable) voltage signal that is proportional to the throttle plate position. The two sensors produce opposite signals as the throttle plate opens:

- One sensor starts at low voltage (about 0.5 V) and increases as the throttle plate is opened.
- The second sensor starts at a higher voltage (about 4.5 V) and produces a lower voltage as the throttle plate is opened. ● **SEE FIGURE 80–7.**

HALL-EFFECT TP SENSORS Some vehicle manufacturers, Honda for example, use a non-contact Hall-effect throttle position sensor. Because there is not physical contact, this type of sensor is less likely to fail due to wear.

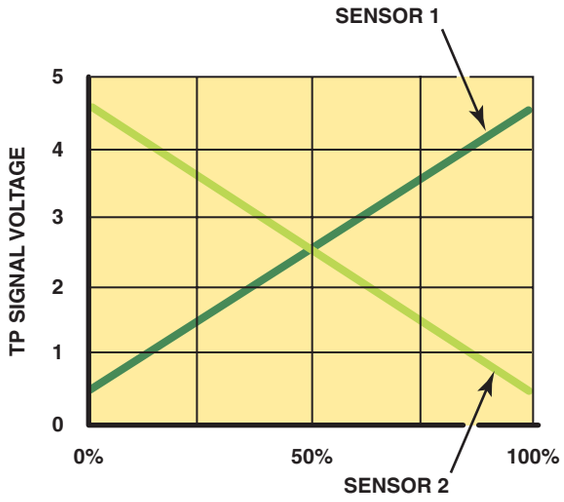
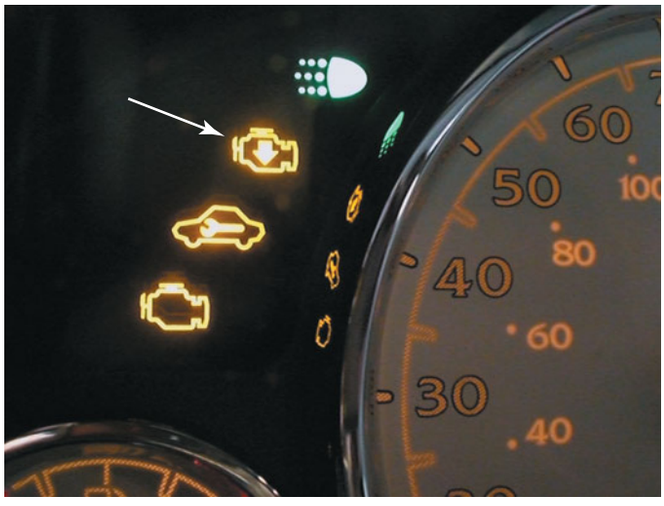


FIGURE 80–7 The two TP sensors used on the throttle body of an electronic throttle body assembly produce opposite voltage signals as the throttle is opened. The total voltage of both combined at any throttle plate position is 5 volts.

(a)



(b)

FIGURE 80–8 (a) A "reduced power" warning light indicates a fault with the electronic throttle control system on some General Motors vehicles. (b) A symbol showing an engine with an arrow pointing down is used on some General Motors vehicles to indicate a fault with the electronic throttle control system.

? FREQUENTLY ASKED QUESTION

How Do You Calibrate a New APP Sensor?

Whenever an accelerator pedal position (APP) sensor is replaced, it should be calibrated before it will work correctly. Always check service information for the exact procedure to follow after APP sensor replacement. Here is a typical example of the procedure:

STEP 1 Make sure accelerator pedal is fully released.
STEP 2 Turn the ignition switch on (engine off) and wait at least 2 seconds.
STEP 3 Turn the ignition switch off and wait at least 10 seconds.
STEP 4 Turn the ignition switch on (engine on) and wait at least 2 seconds.
STEP 5 Turn the ignition switch off and wait at least 10 seconds.

DIAGNOSIS OF ELECTRONIC THROTTLE CONTROL SYSTEMS

FAULT MODE Electronic throttle control (ETC) systems can have faults like any other automatic system. Due to the redundant sensors in accelerator pedal position (APP) sensors and throttle position (TP) sensor, many faults result in a *"limp home"* situation instead of a total failure. The limp home mode is also called the *"fail-safe mode"* and indicates the following actions performed by the powertrain control module (PCM).

- Engine speed is limited to the default speed (about 1200 to 1600 RPM).
- There is slow or no response when the accelerator pedal is depressed.
- The cruise control system is disabled.
- A diagnostic trouble code (DTC) is set.
- An ETC warning lamp on the dash will light. The warning lamp may be labeled differently, depending on the vehicle manufacturer. For example:
  - General Motors vehicle–Reduced power lamp (● **SEE FIGURE 80–8**)
  - Ford–Wrench symbol (amber or green) (● **SEE FIGURE 80–9**)
  - Chrysler–Red lightning bolt symbol (● **SEE FIGURE 80–10**)
- The engine will run and can be driven slowly. This limp-in mode operation allows the vehicle to be driven off of the road and to a safe location.

The ETC may enter the limp-in mode if any of the following has occurred:

- Low battery voltage has been detected
- PCM failure
- One TP and the MAP sensor have failed
- Both TP sensors have failed
- The ETC actuator motor has failed
- The ETC throttle spring has failed

FIGURE 80–9 A wrench symbol warning lamp on a Ford vehicle. The symbol can also be green.

FIGURE 80–10 A symbol used on a Chrysler vehicle indicating a fault with the electronic throttle control.

FIGURE 80–11 The throttle plate stayed where it was moved, which indicates that there is a problem with the electronic throttle body control assembly.

FIGURE 80–12 A corroded electronic throttle control assembly shown with the cover removed.

REAL WORLD FIX

The High Idle Toyota

The owner of a Toyota Camry complained that the engine would idle at over 1200 RPM compared with a normal 600 to 700 RPM. The vehicle would also not accelerate. Using a scan tool, a check for diagnostic trouble codes showed one code: P2101–"TAC motor circuit low."

Checking service information led to the inspection of the electronic throttle control throttle body assembly. With the ignition key out of the ignition and the inlet air duct off the throttle body, the technician used a screwdriver to push gently to see if the throttle plate worked.

Normal operation–The throttle plate should move and then spring back quickly to the default position.

Abnormal operation–If the throttle plate stays where it is moved or does not return to the default position, there is a fault with the throttle body assembly.

● **SEE FIGURE 80–11.**

Solution: The technician replaced the throttle body assembly with an updated version and proper engine operation was restored. The technician disassembled the old throttle body and found it was corroded inside due to moisture entering the unit through the vent hose.

● **SEE FIGURE 80–12.**

VACUUM LEAKS The electronic throttle control (ETC) system is able to compensate for many vacuum leaks. A vacuum leak at the intake manifold for example will allow air into the engine that is not measured by the mass airflow sensor. The ETC system will simply move the throttle as needed to achieve the proper idle speed to compensate for the leak.

DIAGNOSTIC PROCEDURE If a fault occurs in the ETC system, check service information for the specified procedure to follow for the vehicle being checked. Most vehicle service information includes the following steps:

STEP 1 Verify the customer concern.

STEP 2 Use a factory scan tool or an aftermarket scan tool with original equipment capability and check for diagnostic trouble codes (DTCs).