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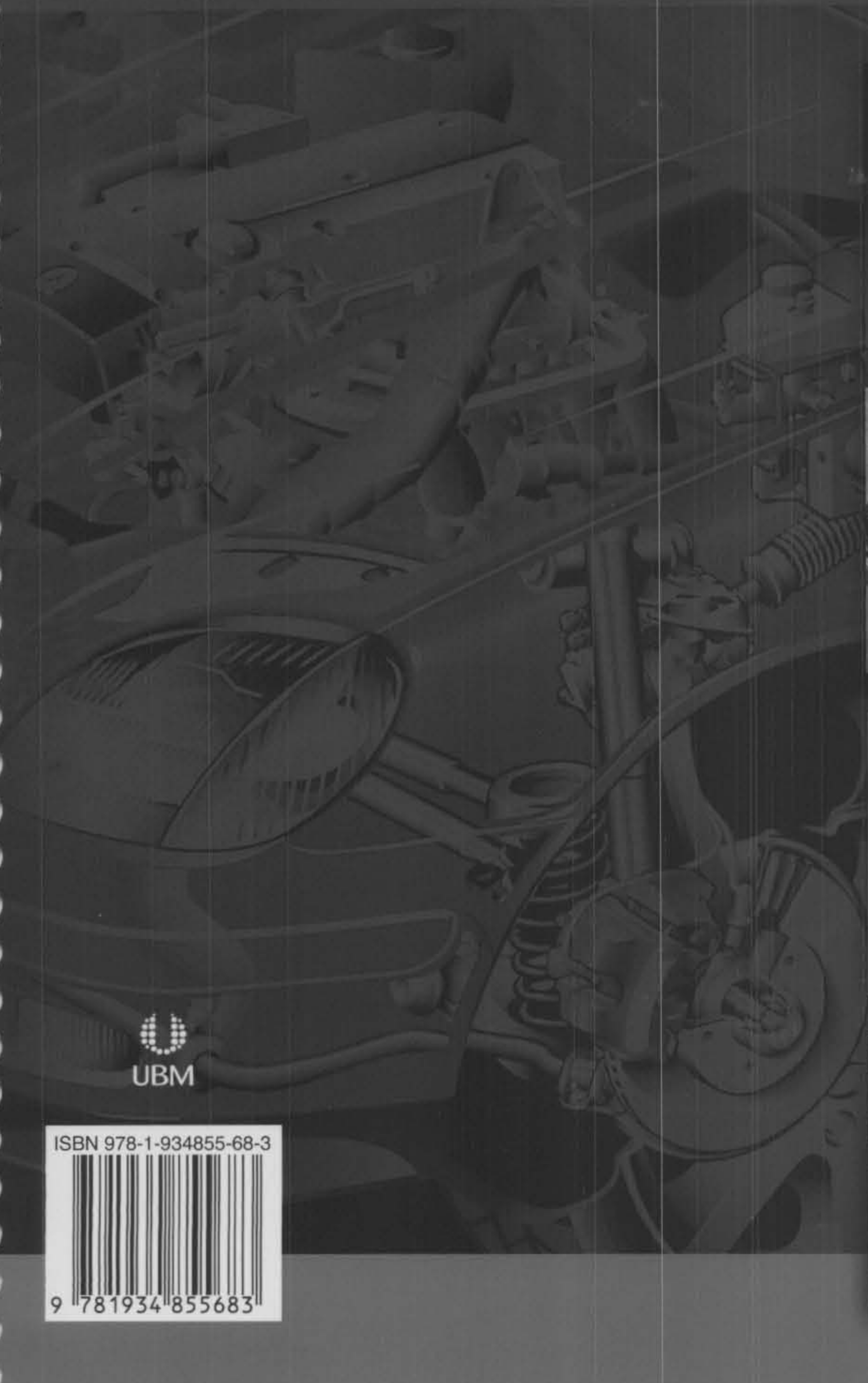
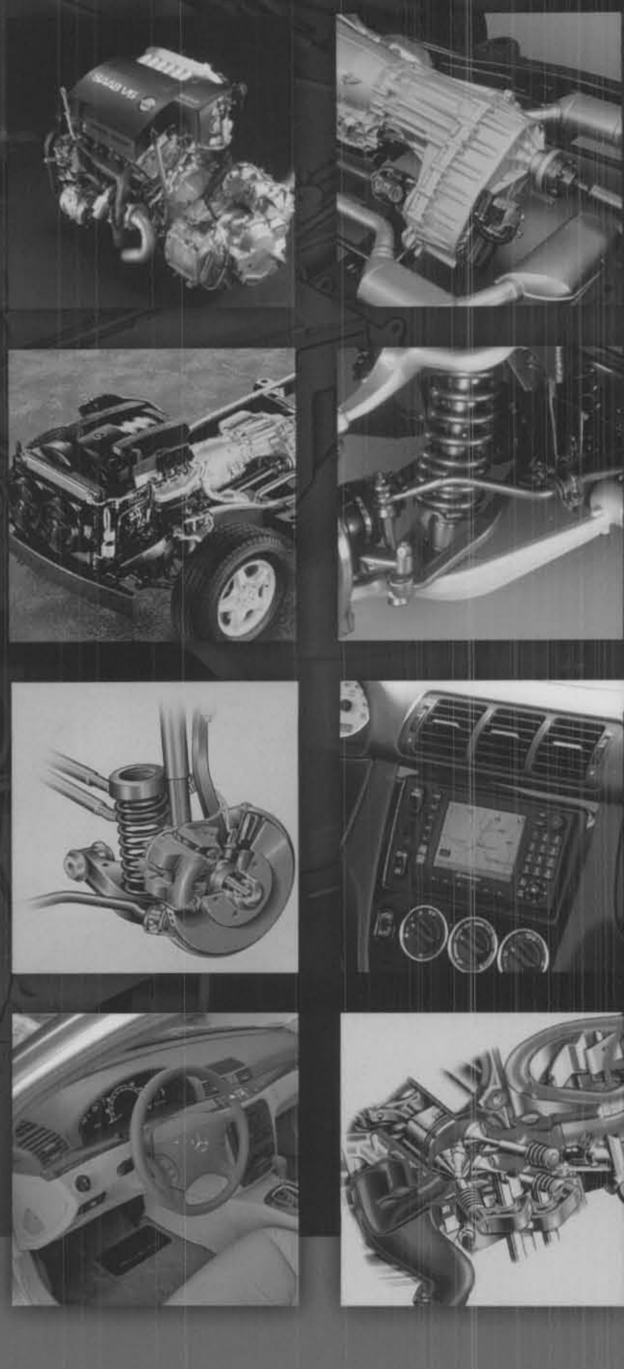
Self-Study Guides for ASE Certification

SPECIALIST SERIES

L1 Advanced Engine Performance





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Taking An ASE Certification Test

This study guide will help prepare you to take and pass the ASE test. It contains descriptions of the types of questions used on the test, the task list from which the test questions are derived, a review of the task list subject information, and a practice test containing ASE style questions.

ABOUT ASE

The National Institute for Automotive Service Excellence (ASE) is a non-profit organization founded in 1972 for the purpose of improving the quality of automotive service and repair through the voluntary testing and certification of automotive technicians. Currently, there are over 400,000 professional technicians certified by ASE in over 40 different specialist areas.

ASE certification recognizes your knowledge and experience, and since it is voluntary, taking and passing an ASE certification test also demonstrates to employers and customers your commitment to your profession. It can mean better compensation and increased employment opportunities as well.

ASE not only certifies technician competency, it also promotes the benefits of technician certification to the motoring public. Repair shops that employ at least one ASE technician can display the ASE sign. Establishments where 75 percent of technicians are certified, with at least one technician certified in each area of service offered by the business, are eligible for the ASE Blue Seal of Excellence program. ASE encourages consumers to patronize these shops through media campaigns and car care clinics.

To become ASE certified, you must pass at least one ASE exam and have at least two years of related work experience. Technicians that pass specified tests in a series earn Master Technician status. Your certification is valid for five years, after which time you must retest to retain certification, demonstrating that you have kept up with the changing technology in the field.

THE ASE TEST

An ASE test consists of forty to eighty multiple-choice questions. Test questions are written by a panel of technical experts from vehicle, parts and equipment manufacturers, as well as working technicians and technical education instructors. All questions have been pre-tested and quality checked on a national sample of technicians. The questions are derived from information presented in the task list, which details the knowledge that a technician must have to pass an ASE test and be recognized as competent in that category. The task list is periodically updated by

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L1 - ADVANCED ENGINE PERFORMANCE SPECIALIST

ASE in response to changes in vehicle technology and repair techniques.

There are five types of questions on an ASE test:

- Direct, or Completion
- MOST Likely
- Technician A and Technician B
- EXCEPT
- LEAST Likely

Direct, or Completion

This type of question is the kind that is most familiar to anyone who has taken a multiple-choice test: you must answer a direct question or complete a statement with the correct answer. There are four choices given as potential answers, but only one is correct. Sometimes the correct answer to one of these questions is clear, however in other cases more than one answer may seem to be correct. In that case, read the question carefully and choose the answer that is most correct. Here is an example of this type of test question:

A compression test shows that one cylinder is too low. A leakage test on that cylinder shows that there is excessive leakage. During the test, air could be heard coming from the tailpipe. Which of the following could be the cause?
A. broken piston rings
B. bad head gasket
C. bad exhaust gasket
D. an exhaust valve not seating

There is only one correct answer to this question, answer D. If an exhaust valve is not seated, air will leak from the combustion chamber by way of the valve out to the tailpipe and make an audible sound. Answer C is wrong because an exhaust gasket has nothing to do with combustion chamber sealing. Answers A and B are wrong because broken rings or a bad head gasket would have air leaking through the oil filler or coolant system.

MOST Likely

This type of question is similar to a direct question but it can be more challenging because all or some of the answers may be nearly correct. However, only one answer is the most correct. For example:

When a cylinder head with an overhead camshaft is discovered to be warped, which of the following is the most correct repair option?
A. replace the head
B. check for cracks, straighten the head, surface the head
C. surface the head, then straighten it
D. straighten the head, surface the head, check for cracks

The most correct answer is B. It makes no sense to perform repairs on a cylinder head that might not be usable. The head should first be checked for warpage and cracks. Therefore, answer B is more correct than answer D. The head could certainly be replaced, but the cost factor may be prohibitive and availability may be limited, so answer B is more correct than answer A. If the top of the head is warped enough to interfere with cam bore alignment and/or restrict free movement of the camshaft, the head must be straightened before it is resurfaced, so answer C is wrong.

Technician A and Technician B

These questions are the kind most commonly associated with the ASE test. With these questions you are asked to choose which technician statement is correct, or whether they both are correct or incorrect. This type of question can be difficult because very often you may find one technician's statement to be clearly correct or incorrect while the other may not be so obvious. Do you choose one technician or both? The key to answering these questions is to carefully examine each technician's statement independently and judge it on its own merit. Here is an example of this type of question:

A vehicle equipped with rack-and-pinion steering is having the front end inspected. Technician A says that the inner tie rod ends should be inspected while in their normal running position. Technician B says that if movement is felt between the tie rod stud and the socket while the tire is moved in and out, the inner tie rod should be replaced. Who is correct?
A. Technician A
B. Technician B
C. Both A and B
D. Neither A or B

The correct answer is C; both technicians' statements are correct. Technician B is clearly correct because any play felt between the tie-rod stud and the socket while the tire is moved in and out indicates that the assembly is worn and requires replacement. However, Technician A is also correct because inner tie- rods should be inspected while in their normal running position, to prevent binding that may occur when the suspension is allowed to hang free.

EXCEPT

This kind of question is sometimes called a negative question because you are asked to give the incorrect answer. All of the possible answers given are correct EXCEPT one. In effect, the correct answer to the question is the one that is wrong. The word EXCEPT is always capitalized in these questions. For example:

All of the following are true of torsion bars **EXCEPT**:
A. They can be mounted longitudi-

nally or transversely.
B. They serve the same function as coil springs.
C. They are interchangeable from side-to-side
D. They can be used to adjust vehicle ride height.

The correct answer is C. Torsion bars are not normally interchangeable from side-to-side. This is because the direction of the twisting or torsion is not the same on the left and right sides. All of the other answers contain true statements regarding torsion bars.

LEAST Likely

This type of question is similar to EXCEPT in that once again you are asked to give the answer that is wrong. For example:

Blue-gray smoke comes from the exhaust of a vehicle during deceleration. Of the following, which cause is **LEAST** likely?
A. worn valve guides
B. broken valve seals
C. worn piston rings
D. clogged oil return passages

The correct answer is C. Worn piston rings will usually make an engine smoke worse under acceleration. All of the other causes can allow oil to be drawn through the valve guides under the high intake vacuum that occurs during deceleration.

PREPARING FOR THE ASE TEST

Begin preparing for the test by reading the task list. The task list describes the actual work performed by a technician in a particular specialty area. Each question on an ASE test is derived from a task or set of tasks in the list. Familiarizing yourself with the task list will help you to concentrate on the areas where you need to study.

The text section of this study guide contains information pertaining to each of the tasks in the task list. Reviewing this information will prepare you to take the practice test.

Take the practice test and compare your answers with the correct answer explanations. If you get an answer wrong and don't understand why, go back and read the information pertaining to that question in the text.

After reviewing the tasks and the subject information and taking the practice test, you should be prepared to take the ASE test or be aware of areas where further study is needed. When studying with this study guide or any other source of information, use the following guidelines to make sure the time spent is as productive as possible:

- Concentrate on the subject areas where you are weakest.
- Arrange your schedule to allow specific times for studying.
- Study in an area where you will not be distracted.
- Don't try to study after a full meal or when you are tired.
- Don't wait until the last minute and try to 'cram' for the test.

REGISTERING FOR ASE COMPUTER-BASED TESTING

Registration for the ASE CBT tests can be done online in myASE or over the phone. While not mandatory, it is recommended that you establish a myASE account on the ASE website (www.ase.com). This can be a big help in managing the ASE certification process, as your test scores and certification expiry dates are all listed there.

Test times are available during two-month windows with a one-month break in between. This means that there is a total of eight months over the period of the calendar year that ASE testing is available.

Testing can be scheduled during the daytime, night, and weekends for maximum flexibility. Also, results are available immediately after test completion. Printed certificates are mailed at the end of the two-month test window. If you fail a test, you will not be allowed to register for the same test until the next two-month test window.

TAKING THE ASE TEST – COMPUTER-BASED TESTING (CBT)

On test day, bring some form of photo identification with you and be sure to arrive at the test center 30 minutes early to give sufficient time to check in. Once you have checked in, the test supervisor will issue you some scratch paper and pencils, as well as a composite vehicle test booklet if you are taking advanced tests. You will then be seated at a computer station and given a short online tutorial on how to complete the ASE CBT tests. You may skip the tutorial if you are already familiar with the CBT process.

The test question format is similar to those found in written ASE tests. Regular certification tests have a time limit of 1 to 2 hours, depending on the test. Recertification tests are 30 to 45 minutes, and the L1 and L2 advanced level tests are capped at 2 hours. The time remaining for your test is displayed on the top left of the test window. You are given a warning when you have 5 minutes left to complete the test.

Read through each question carefully. If you don't know the answer to a question and need to think about it, click on the "Flag" button and move on to the next question. You may also go back to previous questions by pressing the "Previous Question" button. Don't spend too much time on any one question. After you have worked through to the end of the test, check your remaining time and go back and answer the questions you flagged. Very often, information found in questions later in the test can help answer some of the ones with which you had difficulty.

Some questions may have more content than what can fit on one screen. If this is the case, there will be a "More" button displayed where the "Next Question" button would ordinarily appear. A scrolling bar will also appear, showing what part of the question you are currently viewing. Once you have viewed all of the related content for the question, the "Next Question" button will reappear.

You can change answers on any of the questions before submitting the test for scoring. At the end of the examination, you will be shown a table with all of the question numbers. This table will show which questions are answered, which are unanswered, and which have been flagged for review. You will be given the option to review all the questions, review the flagged questions, or review the unanswered questions from this page. This table can be reviewed at any time during the exam by clicking the "Review" button.

If you are running out of time and still have unanswered test questions, guess the answers if necessary to make sure every question is answered. Do not leave any answers blank. It is to your advantage to answer every question, because your test score is based on the number of correct answers. A guessed answer could be correct, but a blank answer can never be.

Once you are satisfied that all of the questions are complete and ready for scoring, click the "Submit for Scoring" button. If you are scheduled for more than one test, the next test will begin immediately. If you are done with testing, you will be asked to complete a short survey regarding the CBT test experience. As you are leaving the test center, your supervisor will give you a copy of your test results. Your scores will also be available on myASE within two business days.

To learn exactly where and when the ASE Certification Tests are available in your area, as well as the costs involved in becoming ASE certified, please contact ASE directly for registration information.

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Advanced Engine Performance

TEST SPECIFICATIONS
FOR ADVANCED ENGINE PERFORMANCE SPECIALIST
(TEST L1)

CONTENT AREA	NUMBER OF QUESTIONS IN ASE TEST	PERCENTAGE OF COVERAGE IN ASE TEST
A. General Powertrain Diagnosis	6	12%
B. Computerized Powertrain Controls Diagnosis (Including OBD II)	16	28%
C. Ignition System Diagnosis	6	12%
D. Fuel Systems And Air Induction Systems Diagnosis	8	14%
E. Emission Control Systems Diagnosis	8	18%
F. I/M Failure Diagnosis	6	16%
Total	**50**	**100%**

There could be additional questions that are included for statistical research purposes only. Your answers to these questions will not affect your test score, but since you do not know which ones they are, you should answer all questions in the test.

The five-year Recertification Test will cover the same content areas as those listed above, and has the same number of scored questions. The following pages list the tasks covered in each content area. Be aware that some of the tasks are broad in scope and typically involve several test questions. In contrast, other tasks focus on one particular activity, in which case one question may cover several tasks.

Be sure to review each task carefully, since this will not only familiarize you with the subject matter on the test, but will also identify your strengths and weaknesses in the area of Advanced Engine Performance.

ADVANCED ENGINE PERFORMANCE SPECIALIST TEST TASK LIST

A. GENERAL POWERTRAIN DIAGNOSIS
(6 questions)

Task 1 - Verify customer concern; determine if the concern is the result of a malfunction or normal system operation.

Task 2 - Inspect and test for *missing, modified, inoperative* or *tampered* powertrain mechanical components.

Task 3 - Locate relevant service information.

Task 4 - Research system operation using technical information to determine diagnostic procedure.

Task 5 - Use appropriate diagnostic procedures based on available vehicle data and service information; determine if available information is adequate to proceed with effective diagnosis.

Task 6 - Determine the relative importance of observed vehicle data.

Task 7 - Differentiate between powertrain mechanical and electrical/electronic problems, including variable valve timing (VVT) systems and variable valve lift (VVL) systems.

Task 8 - Diagnose driveability problems and emission failures caused by cooling system problems.

Task 9 - Diagnose driveability problems and emission failures caused by engine mechanical problems.

Task 10 - Diagnose driveability problems and emission failures caused by problems or modifications in the transmission and final drive, or by incorrect tire size.

Task 11 - Diagnose driveability problems and emission failures caused by intake or exhaust system problems or modifications.

Task 12 - Determine root cause of failures.

Task 13 - Determine root cause of multiple component failures.

Task 14 - Determine root cause of repeated component failures.

Task 15 - Verify effectiveness of repairs.

B. COMPUTERIZED POWERTRAIN CONTROLS DIAGNOSIS - INCLUDING OBD II
(16 questions)

Task 1 - Verify customer concern; determine if the concern is the result of a malfunction or normal system operation.

Task 2 - Inspect and test for missing, modified, inoperative or tampered computerized powertrain

control components.
Task 3 - Locate relevant service information.
Task 4 - Research system operation using technical information to determine diagnostic procedure.
Task 5 - Use appropriate diagnostic procedures based on available vehicle data and service information; determine if available information is adequate to proceed with effective diagnosis.
Task 6 - Determine current version of computerized powertrain control system software and updates; perform reprogramming procedures.
Task 7 - Research OBD II system operation to determine the enable criteria for setting and clearing diagnostic trouble codes (DTCs) (including permanent DTC's), and malfunction indicator light (MIL) operation.
Task 8 - Interpret OBD II scan tool data stream, diagnostic trouble codes (DTCs), freeze frame data, system monitors, monitor readiness indicators, and trip and drive cycle information to determine system condition and verify repair effectiveness.
Task 9 - Determine the relative importance of displayed scan tool data.
Task 10 - Differentiate between electronic powertrain control problems and mechanical problems.
Task 11 - Diagnose no-starting, hard starting, stalling, engine misfire, poor driveability, incorrect idle speed, poor idle, hesitation, backfire, surging, spark knock, power loss, reduced fuel economy, illuminated MIL and emission problems caused by failures of computerized powertrain controls.
Task 12 - Diagnose failures in the data communications bus network; determine needed repairs.
Task 13 - Diagnose failures in the anti-theft/immobilizer system; determine needed repairs.
Task 14 - Perform voltage drop tests on power circuits and ground circuits.
Task 15 - Perform current flow tests on system circuits.
Task 16 - Perform continuity/resistance tests on system circuits and components.
Task 17 - Test input sensor/sensor circuit using scan tool data and/or waveform analysis.
Task 18 - Test output actuator/output circuit using scan tool, scan tool data and/or waveform analysis.
Task 19 - Confirm the accuracy of observed scan tool data by directly measuring a system, circuit or component for the actual value.
Task 20 - Test and confirm operation of electrical/electronic circuits not displayed in scan tool data.
Task 21 - Determine root cause of failures.
Task 22 - Determine root cause of multiple component failures.
Task 23 - Determine root cause of repeated component failures.
Task 24 - Verify effectiveness of repairs.

C. IGNITION SYSTEM DIAGNOSIS

(6 questions)
Task 1 - Verify customer concern; determine if the concern is the result of a malfunction or normal system operation.
Task 2 - Inspect and test for missing, modified, inoperative or tampered components.
Task 3 - Locate relevant service information.
Task 4 - Research system operation using technical information to determine diagnostic procedure.
Task 5 - Use appropriate diagnostic procedures based on available vehicle data and service information; determine if available information is adequate to proceed with effective diagnosis.
Task 6 - Determine the relative importance of displayed scan tool data.
Task 7 - Differentiate between ignition electrical/electronic and ignition mechanical problems.
Task 8 - Diagnose no-starting, hard starting, stalling, engine misfire, poor driveability, backfire, spark knock, power loss, reduced fuel economy, illuminated MIL and emission problems caused by failures in the electronic ignition (EI) systems; determine needed repairs.
Task 9 - Test for ignition system failures under various engine load conditions.
Task 10 - Test ignition system component operation using waveform analysis.
Task 11 - Confirm ignition timing and/ or spark timing control.
Task 12 - Determine root cause of failures.
Task 13 - Determine root cause of multiple component failures.
Task 14 - Determine root cause of repeated component failures.
Task 15 - Verify effectiveness of repairs.

D. FUEL SYSTEMS AND AIR INDUCTION SYSTEMS DIAGNOSIS

(8 questions)
Task 1 - Verify customer concern; determine if the concern is the result of a malfunction or normal system operation.
Task 2 - Inspect and test for missing, modified, inoperative or tampered components.
Task 3 - Locate relevant service information.
Task 4 - Research system operation using technical information to determine diagnostic procedure.
Task 5 - Evaluate the relationships between fuel trim values, oxygen sensor/air fuel ratio sensor readings and other sensor data to determine fuel system control performance.
Task 6 - Use appropriate diagnostic procedures based on available vehicle data and service information; determine if available information is adequate to proceed with effective diagnosis.
Task 7 - Determine the relative

importance of displayed scan tool data.
Task 8 - Differentiate between fuel system mechanical and fuel system electrical/electronic problems.
Task 9 - Differentiate between air induction system mechanical and air induction system electrical/electronic problems, including electronic throttle actuator control (TAC) systems.
Task 10 - Diagnose hot or cold no-starting, hard starting, stalling, engine misfire, spark knock, poor driveability, incorrect idle speed, poor idle, flooding, hesitation, backfire, surging, power loss, reduced fuel economy, illuminated MIL and emission problems on vehicles equipped with multiport fuel injection and direct injection fuel systems; determine needed action.
Task 11 - Inspect fuel for quality, contamination, water content and alcohol content; test fuel system pressure and fuel system volume.
Task 12 - Evaluate mechanical and electrical operation fuel injectors and fuel pump (Including digitally controlled fuel pump systems).
Task 13 - Determine root cause of failures.
Task 14 - Determine root cause of multiple component failures.
Task 15 - Determine root cause of repeated component failures.
Task 16 - Verify effectiveness of repairs.

E. EMISSION CONTROL SYSTEMS DIAGNOSIS
(8 questions)

Task 1 - Verify customer concern; determine if the concern is the result of a malfunction or normal system operation.
Task 2 - Inspect and test for missing, modified, inoperative or tampered components.
Task 3 - Locate relevant service information.
Task 4 - Research system operation using technical information to determine diagnostic procedure.
Task 5 - Use appropriate diagnostic procedures based on available vehicle data and service information; determine if available information is adequate to proceed with effective diagnosis.
Task 6 - Determine the relative importance of displayed scan tool data.
Task 7 - Differentiate between emission control systems mechanical and electrical/electronic problems.

Note: Tasks 8 through 12 refer to the following emission control subsystems: Positive crankcase ventilation, ignition timing control, idle and deceleration speed control, exhaust gas recirculation, catalytic converter system, secondary air injection system, early fuel evaporation control, and evaporative emission control which includes onboard refueling vapor recovery (ORVR) and engine off natural vacuum (EONV).

Task 8 - Differentiate between driveability or emissions problems caused by failures in emission control systems and other engine management systems.
Task 9 - Perform functional tests on emission control subsystems; determine needed repairs.
Task 10 - Determine the effect on exhaust emissions caused by a failure of an emission control component or subsystem.
Task 11 - Use exhaust gas analyzer readings to diagnose the failure of an emission control component or subsystem.
Task 12 - Diagnose hot or cold no-starting, hard starting, stalling, engine misfire, spark knock, poor driveability, incorrect idle speed, poor idle, flooding, hesitation, backfire, surging, power loss, reduced fuel economy, dieseling/run-on, illuminated MIL and emission problems caused by a failure of emission control components or subsystems.
Task 13 - Determine root cause of failures.
Task 14 - Determine root cause of multiple component failures.
Task 15 - Determine root cause of repeated component failures.
Task 16 - Verify effectiveness of repairs.

F. I/M FAILURE DIAGNOSIS
(6 questions)

Task 1 - Verify customer concern; determine if the concern is the result of a malfunction or normal system operation.
Task 2 - Inspect and test for missing, modified, inoperative or tampered components.
Task 3 - Locate relevant service information.
Task 4 - Evaluate emission readings obtained during an I/M test to assist in emission failure diagnosis and repair.
Task 5 - Evaluate HC, CO, NOx, CO2 and O2 gas readings, determine the failure relationships.
Task 6 - Use test instruments to observe, recognize and interpret electrical/electronic signals.
Task 7 - Analyze HC, CO, NOx, CO2 and O2 readings; determine diagnostic test sequence.
Task 8 - Diagnose the cause of no-load I/M test HC emission failures.
Task 9 - Diagnose the cause of no-load I/M test CO emission failures.

Task 10 - Diagnose the cause of loaded-mode I/M test HC emission failures.
Task 11 - Diagnose the cause of loaded-mode I/M test CO emission failures.
Task 12 - Diagnose the cause of loaded-mode I/M test NOx emission failures.
Task 13 - Evaluate the MIL operation for onboard diagnostic I/M testing.
Task 14 - Evaluate monitor readiness status for onboard diagnostic I/M testing.
Task 15 - Diagnose communication failures with the vehicle during onboard diagnostic I/M testing.
Task 16 - Perform functional I/M tests (including fuel cap test).
Task 17 - Verify effectiveness of repairs.

The preceding Task List details all of the related informational subject matter you are expected to know in order to sit for this ASE Certification Test. Your own years of experience as a technician in the professional automotive service repair trade also should provide you with added background.
Finally, a conscientious review of the self-study material provided in this Training for ASE Certification unit also should help you to be adequately prepared to take this test.

Notes

General Powertrain Diagnosis

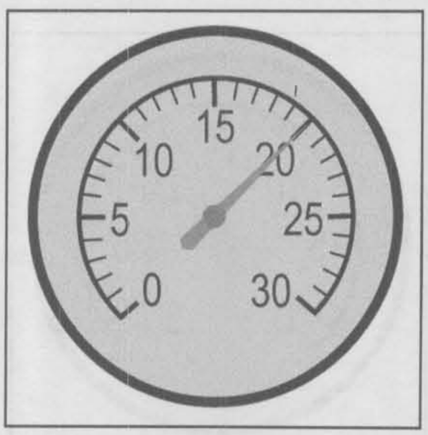
Despite the sophistication of today's powertrain control systems, even the most advanced software program cannot disguise a worn camshaft lobe, a burned valve or a loose timing chain. Unfortunately, even though these types of mechanical failures create recognizable symptoms of poor performance, many technicians get caught up analyzing pulse trains without ever considering the valvetrain! The fact is, illuminated MILs (Malfunction Indicator Lights) and/or stored DTCs (Diagnostic Trouble Codes) are often the result of faulty mechanical components. That's why it is so important to follow a logical diagnostic routine. The most sophisticated engine control system cannot compensate for a worn engine, and basic engine condition must always be verified before condemning electronic components. In this section, we'll look at basic troubleshooting procedures that can effectively isolate the root cause of many powertrain-related failures.

VARIABLE VALVE SYSTEMS

Seasoned technicians are well aware of how camshaft design would affect engine performance, and how cam values that gave a smooth idle would lack performance at the top end of the engine performance curve. Modern electronic controls have solved this compromise through the use of Variable Valve Timing. Actuators controlled by the ECM will increase valve lift and duration as engine speed increases. The actuators often use engine oil as a hydraulic mechanism, although motors may also be used. Where engine oil Is used for actuating purposes, system operation and even performance can be affected by the quality of the motor oil. Variable valve timing is usually only applied to the intake valves.

On the ASE Composite Engine Type 4 oil pressure is put to use by a duty cycle controlled cam position actuator on the front of each intake camshaft. Camshaft position sensors, which are integral to the actuators, provide input to the ECM on valve timing. At idle the camshafts are fully retarded and valve overlap is zero degrees. This is also the default position in the event of a failure. At higher speeds and loads intake valve timing can advance as much as 40 degrees. Once the ECM determines that proper valve timing is achieved it will maintain timing with a commanded 50% duty cycle. The scanner will display the duty cycle of the and the desired cam advance. Cam actuator resistance is 12 ± 2Ω.

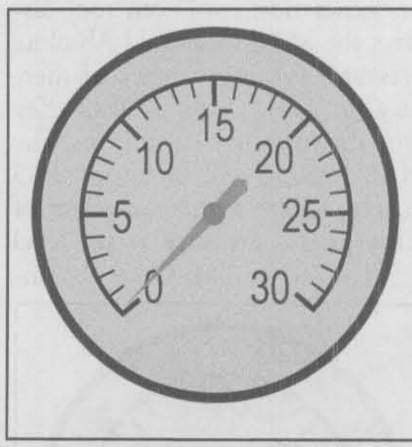
The ASE Composite Engine Type 4 also incorporates a Variable Valve Lift System. A DC motor is controlled by the ECM. The motor operates a rod and fulcrum to change the rocker arm ratio. At high speeds valve lift can increase by as much as 4 millimeters or 0.160 inches. Under the conditions of a malfunction the system will default to the lowest possible valve lift. Scan data will show on/off for the motors, as well as the percentage of additional lift. Valve lift sensor voltage will vary from 0.5 volts at minimum lift to 4.5 volts at full valve lift.



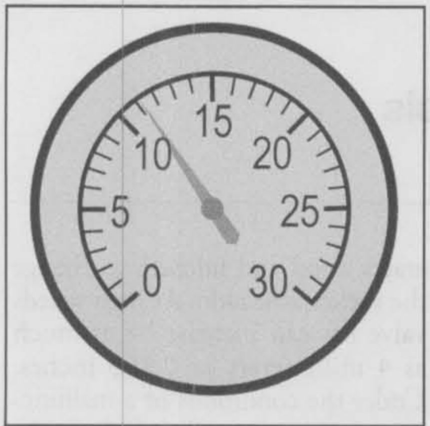
A vacuum gauge will indicate a steady reading of 18-20 in. Hg on an engine in good condition.

CHECKING VACUUM

While it may be low-tech, a vacuum gauge is a powerful diagnostic tool that can help you quickly determine overall engine performance. A 'vacuum' is simply a condition in which the pressure of a gas, in this case air, is less than normal atmospheric pressure. At sea level, atmospheric pressure is approximately 14.75 psi, which corresponds to a barometric pressure of 29.5 in. Hg (inches of mercury). This means that if you placed a long tube into a bowl of liquid mercury and re-



If the vacuum gauge is connected to a source of ported vacuum, it will read practically 0 in. Hg at closed throttle.



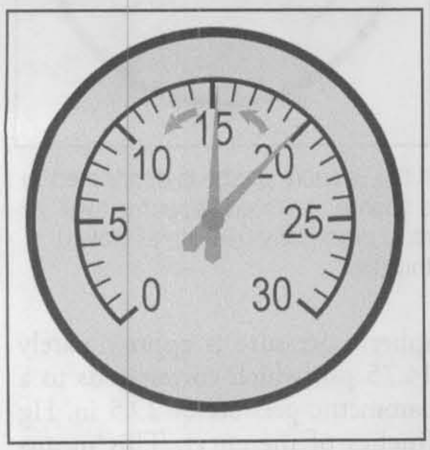
A leaking EGR valve will cause vacuum to be lower than normal at idle, although the gauge needle will be steady.

moved the air from the opposite end, the surrounding air pressure would force the mercury almost 30 inches up the tube. This works out to 2 inches of mercury for every 1 psi of air pressure.

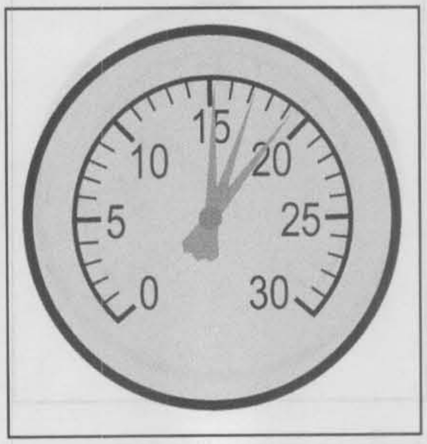
Understanding the relationship between pressure and vacuum is important to avoid misinterpreting certain scan data readings. For example, in the generic mode, an OBD II (On Board Diagnostics generation two) scan tool displays the MAP (Manifold Absolute Pressure) value in inches of mercury (in. Hg). Under KOEO (Key On, Engine Off) conditions, the MAP reading will be about 29.5 in. Hg, which is the equivalent of atmospheric pressure at sea level (29.5 ÷ 2 = 14.75). Once the engine is idling, the MAP reading will drop to about 11.5 in. Hg. At first glance, you may think that this reading is indicative of a serious mechanical problem. However, while this may appear to be a low *vacuum* reading, it is actually a normal *pressure* reading. Remember, the MAP sensor measures *pressure* not *vacuum*. Consequently, the 11.5 in. Hg value reflects the pressure inside the intake manifold. To determine actual engine vacuum, simply subtract the running MAP value from the KOEO value. This means that if the running value is 11.5 in. Hg, actual engine vacuum is 18 inches (29.5 — 11.5 = 18). A healthy engine will typically produce between 18 and 20 inches of vacuum at a no-load idle. With that in mind, let's examine some of the more common causes of abnormal vacuum readings.

Misrouted Vacuum Lines

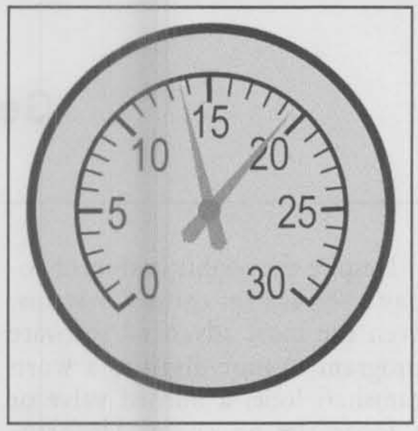
When the MAP value on the scan tool indicates an incorrect reading at closed throttle, misrouted vacuum lines could be the cause. This is especially true if the engine was recently replaced or major engine work was just completed. In these cases, the sensor may be mistakenly connected to a source of ported vacuum. As a result, the MAP sensor will output a high voltage signal, since ported vacuum is practically zero at closed throttle. In order for the MAP signal to reflect actual engine vacuum, the sensor must be connected to a source of manifold vacuum.



A restricted exhaust system can be identified by a steady drop in vacuum as rpm is increased.



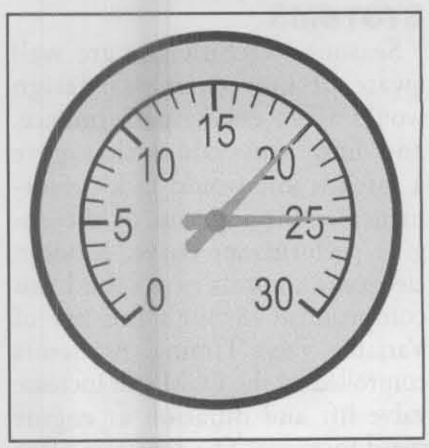
An intermittent fluctuation in the gauge needle is indicative of sticking valves.



A broken valve spring will cause the gauge needle to drop sharply each time the affected valve tries to close.

Leaking EGR Valve

A leaking EGR (Exhaust Gas Recirculation) valve will cause a low but steady vacuum reading at closed throttle. This is because EGR raises manifold pressure (lowers vacuum). While the engine can tolerate metered amounts of EGR as the throttle is opened, volumetric efficiency is too low at idle for the engine to accept exhaust gas dilution. In cases where the EGR valve is stuck wide open, the engine will fail to start. Under this condition, cranking vac-



If the piston rings are sealing properly, vacuum will rise as much as 5 in. Hg during a snap throttle test.

uum will be close to zero, rather than the normal reading of 3 to 5 in. Hg.

Restricted Exhaust System

In order for an engine to operate efficiently, it must discharge combustion gases at the same rate it draws in fresh air. When an exhaust system becomes restricted, this ability is severely diminished. Instead of combustion gases exiting through the open exhaust valve, the gases back up into the cylinder in search of another way out. The path of least resistance then becomes the open intake valve, which allows the high-pressure gases to enter the intake manifold. Under this condition, manifold vacuum drops significantly.

To check for a restricted exhaust system, connect a vacuum gauge to a source of manifold vacuum. Record the vacuum reading with the engine at normal operating temperature and running at 1000 rpm. Next, slowly increase engine speed to 2500 rpm and note the vacuum reading. If the reading gradually drops more than 3 in. Hg from the 1000-rpm reading, the exhaust system is restricted. The most likely cause of a restricted exhaust is a clogged converter, however, don't overlook the possibility of a collapsed pipe or blocked muffler.

Sticking Or Tight Valves

An engine can't develop sufficient vacuum unless the valves seal properly. When the valves hang open because of carbon deposits or over tightened adjusters, air leaks are created in the cylinder. This condition causes the cylinder to partially misfire, resulting in reduced piston speed and a reduction in vacuum. When the valves have been over tightened, the engine will idle rough and the vacuum gauge will show a low but steady reading. Where sticking valves are concerned, the gauge needle will drop abruptly each time the offending valve or valves fails to close.

Broken Valve Spring

A valve spring maintains tension on the valvetrain and ensures that the valve closes when it should. A broken valve spring allows the valve to hang open, resulting in a significant reduction in engine vacuum. This can be seen on a vacuum gauge as a sudden drop in the reading (as much as 10 in. Hg) each time the valve tries to close.

Worn Piston Rings

Vacuum in an engine is created by the downward movement of the pistons on the intake stroke. If the piston rings are sealing properly, manifold vacuum will rise considerably during deceleration. This is because closed-throttle piston speed is higher than normal whenever the wheels are driving the engine. As a result, engine vacuum will spike as much as 5 in. Hg during this time. A snap throttle test will have the same effect on the vacuum reading as long as the rings are doing their job. In addition, vacuum will be higher at a steady 2000 rpm than it is at idle.

POWER BALANCE TESTING

Performing a power balance test is the most effective way to determine if each cylinder is contributing equally to the engine's overall power output. On an engine in good condition, shorting out each cylinder should result in a significant drop in rpm. This is the 'power' part of the test. Cylinders that produce little or no rpm drop need to be checked for fuel or ignition problems, or a more serious condition, such as a burned valve. 'Balance' is evaluated based on the variation in drop between cylinders. Under normal conditions, the variation between cylinders will be less than 50 rpm. Variations greater than this indicate problems such as air leaks, clogged injectors, and/or carbon deposits. Before performing a power balance test, engine speed should be stabilized at 1000 rpm, and the fuel control system should be in open loop.

A power balance test can also be conducted using an exhaust gas analyzer. This is accomplished by measuring the amount of HC (Hydrocarbon) increase each time a cylinder is cancelled. A substantial increase in hydrocarbons tells you that the injector is delivering enough fuel and that the valvetrain is allowing the fuel to enter and exit the cylinder. If HC does not increase or rises only slightly when a cylinder is shorted out, then either the injector is malfunctioning or there is a problem in the valvetrain.

Keep in mind that a power balance test does not provide a specific diagnosis, but instead narrows down which cylinder or cylinders require additional diagnostic attention. The cause of a dead cylinder can range from something as simple as a fouled spark plug to problems as significant as worn piston rings. The power balance test will direct you to the area of the engine that needs attention.

COMPRESSION AND LEAKAGE TESTS

Measuring compression and leakage can isolate the mechanical problems that cause cylinders to misfire. Although these test procedures are relatively basic, neglecting several pre-conditioning steps can lead to misleading test results. To begin a compression test, remove all of the spark plugs. This allows the cylinder under test to reach its maximum pressure, since it will be unaffected by the pressure drop in adjacent cylinders. Next, connect a battery charger so that cranking speeds will remain consistent throughout the test. Finally, be sure to prop the throttle plate wide open so that the engine can take in the maximum amount of air. If the compression reading for a particular cylinder is below normal, perform a 'wet compression' test by squirting about a tablespoon worth of oil into the offending cylinder. If the new reading is normal, or has increased significantly over the initial reading, then the piston rings are worn. If a wet compression test produces the same results as the initial 'dry' test, then a cylinder leakage test should be performed.

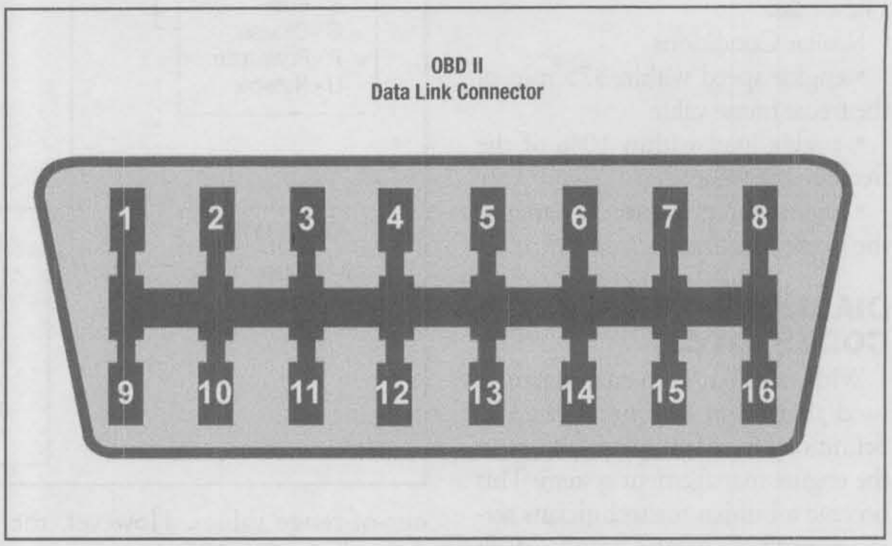
Before doing a leakage test, make sure that the piston is at TDC (Top Dead Center) on the compression stroke. This is a critical, but often overlooked, first step. In many cases, a technician will claim that a cylinder either has a burned valve, or even bent valves, simply because piston position was not checked beforehand. Once the piston is in the right spot, remove the oil fill cap so that excessive ring leakage can be identified. After filling the cylinder with air, look/listen for air escaping out of the tailpipe if the exhaust valve is leaking, or the throttle body if the intake valve is at fault. Excessive leakage from the valve cover indicates that the piston rings are not sealing properly. However, be aware that the rings actually seal better with the engine running. As a result, a small amount of ring leakage is considered normal. Finally, remove the radiator cap to check for air bubbles in the coolant, which would indicate that the head gasket is defective. If compression and leakage tests are both acceptable on the offending cylinder, then the low compression reading is due to problems outside the combustion chamber. Assuming the fuel and ignition systems are OK, look for worn or broken valvetrain components (e.g. worn cam, collapsed lifter, broken rocker, etc.)

MECHANICAL VS. ELECTRONIC PROBLEMS

Determining whether a performance problem is the result of a mechanical or electronic fault requires two important skills. First, you must understand the relationship between mechanical and electronic components. For example, a worn camshaft can easily trigger a DTC since it causes a reduction in engine vacuum (MAP signal). Likewise, a faulty coolant sensor can cause a carbon-coated tailpipe, even if the fuel system components (i.e. pump, filter, regulator, injectors) are in good working order. Secondly, you need to employ a logical diagnostic approach when attempting to find the root cause of the problem. That means to start with a road test (if necessary) to confirm the symptoms, followed by a visual inspection to uncover any obvious faults. Next, check for DTCs, and then refer to the appropriate diagnostic chart in the shop manual. The 'symptom charts' are designed to help you isolate no-code problems or history DTCs, while 'code charts' are used exclusively for diagnosing current DTCs.

Computerized Powertrain Controls Diagnosis (Including OBD II)

Electronic engine control systems have been standard equipment on most cars and light trucks since the early 1980s. While these systems improve both driveability and fuel economy, their primary purpose is emission control. From a service standpoint, many of the early systems were difficult to diagnose due to their limited self-diagnostic capability. However, serviceability improved in 1988 with the implementation of OBD I legislation. This ruling required all vehicles to have a dash-mounted warning light that would illuminate if a failure occurred in the fuel metering system, sensor network, EGR system, and/or computer. While the OBD I ruling improved the functionality of engine control systems, its standards were too lax to make a significant difference in overall air quality or serviceability. As a result, the California Air Resources Board developed new standards for on-board diagnostics in 1989, which eventually resulted in OBD II.



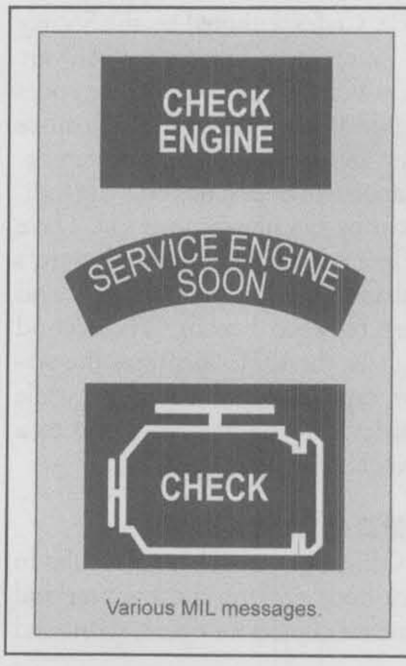
OBD COMMUNICATIONS

Communicating with a vehicle's on-board diagnostic system begins at the DLC (Data Link Connector). On OBD I systems, the shape and location of the connector is unique to each vehicle manufacturer. With OBD II, the DLC has been standardized into a 16-pin design complete with power and ground circuits at pins 4 (ground) and 16 (B+). These circuits eliminate the need for a separate power supply cable when connecting a scan tool. According to OBD II regulations, seven cavities of the DLC are common to all vehicles (as defined by the Society of Automotive Engineers), while the remaining nine are proprietary (manufacturer specific). Unlike the connectors used for OBD I systems, OBD II vehicles are required to have the DLC located close to the instrument panel within the area that extends from the driver's door to 12 inches (300mm) beyond the vehicle centerline. On most vehicles, you should be able to spot the DLC from a crouched position with the driver's door open.

MALFUNCTION INDICATOR LIGHT

Depending on the vehicle, the MIL may be displayed as 'Check Engine,' 'Service Engine Soon,' or the ISO engine symbol. Unlike OBD I systems, the MIL on an OBD II vehicle is not used for 'flash diagnostics.' Consequently, a scan tool must be used to retrieve OBD II trouble codes. On certain OBD II vehicles however, the MIL may be used to 'flash' manufacturer specific, two-digit codes.

In terms of failure detection, OBD I systems operate the MIL based on current failures. In other words, the MIL will only be illuminated at the time a monitored circuit is malfunctioning. If the problem disappears, the MIL will go out. In contrast, the MIL will remain on in an OBD II system until the vehicle completes three consecutive trips without a repeat failure. This means that the MIL may be on even though there are no current failures. For the most serious emissions-related failures, in-



Various MIL messages.

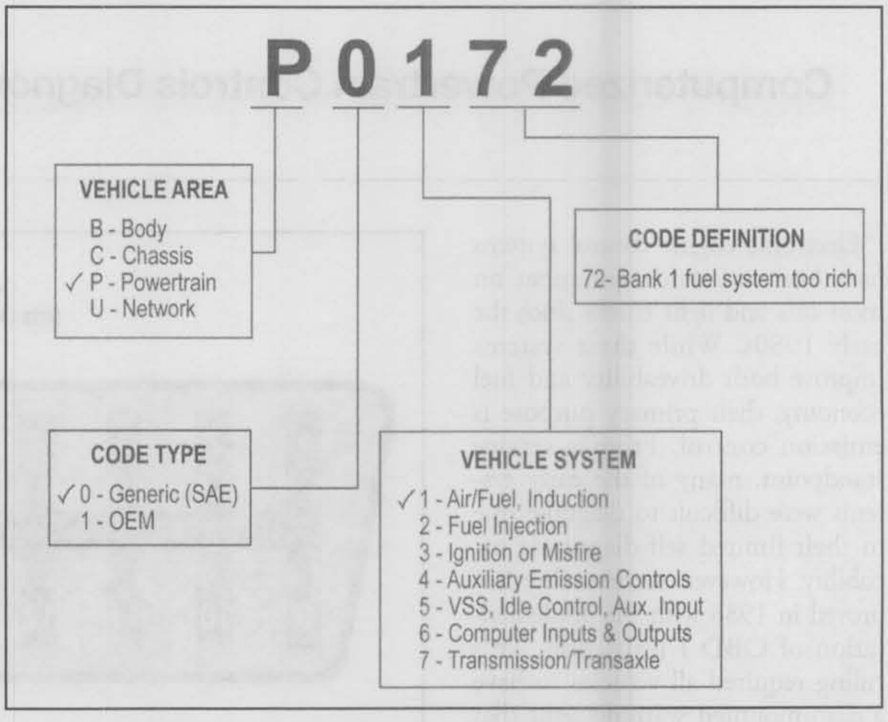
cluding misfires and fuel trim problems, the MIL will stay illuminated until the vehicle completes three consecutive trouble-free trips under nearly the same conditions that occurred during the initial failure. This 'similar conditions' strategy prevents a false pass.

Similar Conditions

- engine speed within 375 rpm of the freeze frame value
- engine load within 10% of the freeze frame value
- engine temperature the same as the freeze frame value.

DIAGNOSTIC TROUBLE CODES (DTCS)

With OBD I, each manufacturer used their own unique codes and definitions for identifying failures in the engine management system. This became a burden for technicians servicing multiple vehicle brands. With OBD II, common codes and definitions were developed to identify all basic emissions-related failures. OBD II trouble codes consist of one alpha character followed by four digits. The alpha character indicates the area of the vehicle where the failure occurred. This includes (B) Body, (C) Chassis, (P) Powertrain, and (U) Network. The first digit of the DTC denotes the origin of the code. Codes authored by the Society of Automotive Engineers (SAE) are identified by a zero (0). These codes are known as generic DTCs since they are the same for every vehicle. Manufacturer specific codes are indicated by the number one (1). These DTCs are part of the manufacturer's enhanced diagnostic software, and vary between brands. The second digit in the DTC identifies the system experiencing the problem, while the last two digits correspond to a specific code definition.



OBD II MONITORS

OBD I and OBD II are similar in that both systems check sensor and actuator circuits for opens, shorts and out-of-range values. However, the failure limits for OBD I are far more forgiving, since a circuit or component must fail completely before the MIL is illuminated or a DTC is stored. In contrast, OBD II uses a series of monitors (diagnostic tests) that conduct performance evaluations on emission components and subsystems. If a monitored circuit fails to meet minimum performance standards, even though the circuit may still be operational, the ECM (Engine Control Module) or PCM (Powertrain Control Module) will illuminate the MIL and store a DTC. This capability makes it possible for emissions-related problems to be identified and corrected before excessive pollutants are discharged into the atmosphere.

OBD II monitors include:

- Comprehensive Components
- Misfire Detection
- Fuel Control
- Exhaust Gas Recirculation (EGR)
- Catalyst Efficiency
- Oxygen Sensor
- O2 Heater
- Evaporative Emissions (EVAP)
- A/C Refrigerant
- Heated Catalyst
- Positive Crankcase Ventilation (PCV)
- Secondary Air
- Thermostat.

***NOTE:** Not all vehicles use all of the monitors listed.*

OBD II monitors are defined as being continuous or non-continuous. As the name indicates, continuous monitors run all the time. These monitors include Comprehensive Components, Misfire Detection and Fuel Control. The remaining monitors are non-continuous, since they do not run until certain 'enable criteria' has been met. Enable criteria include specific driving and engine operating conditions that must occur before the ECM will execute the monitor. Consequently, if the vehicle is driven in a way that does not satisfy the enable criteria for a particular non-continuous monitor, that monitor will not run.

MONITOR READINESS

Monitor readiness is a required test function for an OBD II scan tool. In this mode, all of the OBD

II monitors are displayed along with corresponding messages indicating their execution status (run/not run). Monitor readiness DOES NOT indicate whether a given monitor has passed or failed. Since continuous monitors run all the time, their status will always be displayed on the scan tool as having run (e.g. YES, READY, COMPLETE). Where non-continuous monitors are concerned, they will be displayed as not having run (e.g. NO, NOT READY, INCOMPLETE) unless the vehicle was operated in a way that satisfied the appropriate enable criteria. Non-continuous monitors will also be displayed as not having run following a battery or ECM disconnect, or if DTCs are cleared with the scan tool.

SCAN DATA

Scan data is a list of Parameter IDs (PIDs) indicating operational values of powertrain components. When diagnosing a system malfunction, scan data should be carefully reviewed under KOEO and KOER (Key On, Engine Run) conditions. OBD II systems provide two forms of scan data: Generic and Enhanced. Generic data, consists of a limited number of PIDs, such as engine coolant temperature and oxygen sensor voltages. All OBD II systems display generic data. Enhanced data, which is manufacturer specific information, is a complete list of parameters covering all of the vehicle's powertrain inputs and outputs. On scan tools with a limited viewing area, PIDs are typically abbreviated to conserve screen space. For example, 'CLOSED LOOP' may be displayed as 'CLOS LP.' Parameter values will also be abbreviated if screen space is tight, as in the case of 'APP' for APPLIED and 'REL' for RELEASED.

Once the scan tool has been connected to the vehicle and programmed properly, check to see if there are any stored codes in the ECM. Even if the MIL was off when the vehicle came in, there may be a history code in memory that can help isolate the root cause of the problem. The next step is to examine the scan data to see if sensor and actuator values are within their intended range. In theory, out-of-range sensor and/or actuator values should always be accompanied by a DTC. However, this is not always the case, especially on OBD I systems. This is why it's important to compare actual scan data readings to the desired values listed in the service manual. Although scan data is a valuable source of diagnostic information, never replace suspect components based on this information alone. This is especially true when diagnosing no-code complaints. Always confirm the accuracy of the scan readings by performing additional tests using the appropriate equipment.

CHECKING VOLTAGE DROP

Using an ohmmeter to evaluate the condition of an electrical circuit is a common mistake made by technicians. To illustrate this, consider using an ohmmeter to check the condition of a battery cable. While a low resistance reading may prove that the cable has continuity, it provides little evidence that the cable could support the high current demands of the starter. This is because an ohmmeter only sends a few milliamps of current through the circuit under test. Consequently, you could get a low ohm reading from a battery cable that only has one strand of wire intact. The problem is, the engine would never crank using a cable in that condition. While an ohmmeter is effective for identifying open or shorted circuits or checking the resistance of electrical components, it cannot measure the energy losses that occur in a live circuit. Anytime electrical energy is consumed in an area other than its intended purpose, the circuit will malfunction. That's why checking voltage drop is so important.

A voltage drop test measures the difference in electrical pressure between two points in a live circuit. In order to obtain accurate test results, the normal maximum current must be flowing. For example, since most powertrain relays and solenoids are energized when the engine is running, computer grounds should always be checked under KOER conditions. Otherwise, excessive voltage drop may not be apparent.

Generally speaking, the closer your test procedures get to normal operating conditions, the more accurate your diagnosis. To check the voltage drop across a computer ground, connect the negative lead to the engine block and the positive lead to the appropriate terminal at the computer. With the engine running, the voltage should not exceed 100 millivolts (0.100V). If voltage is higher than this, move the positive probe to the next closest point in the circuit. This may be a connector, splice, or junction block. Look for a reduction in voltage each time the positive probe is moved to a new location.

Once the voltage reading drops to within limits, it indicates that high resistance exists between the positive probe's current location and the last point checked. If the voltage remains high at all points, check for excessive resistance between the alternator and the engine.

CURRENT DRAW TESTS

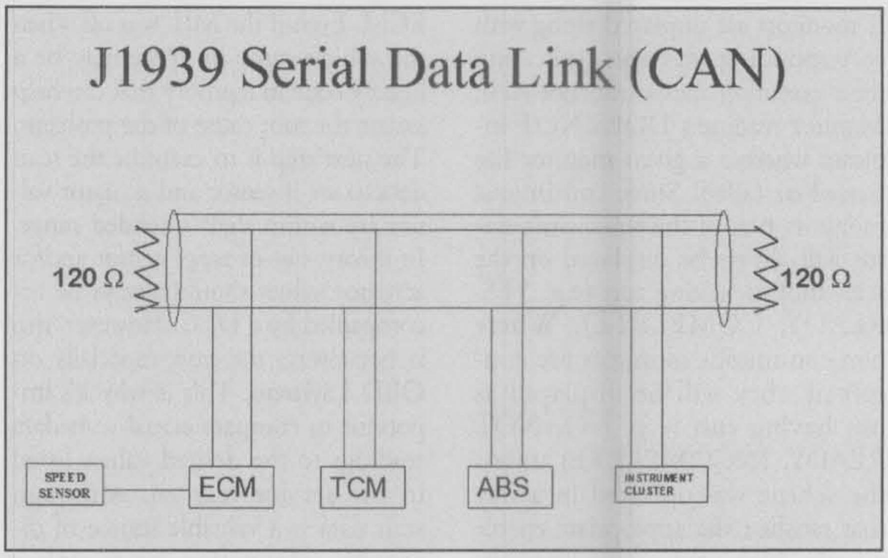
Before replacing an ECM to correct a problem in an actuator circuit (e.g. inoperative cooling fan), always perform a current draw test to ensure that the computer is the root cause of the problem. This is especially important on older OBD I systems, since the computer can become permanently damaged if current in a driver circuit exceeds 750 milliamps. This would be the case if a relay or solenoid were shorted. Although driver circuits are fault-protected to prevent computer damage on late-model systems, excessive current will cause the ECM to shutdown the problem circuit. For example, if the cooling fan relay is shorted, excessive current will flow when the ECM completes the ground for the relay coil. On older OBD I systems, the high current will typically burn the driver open, making it necessary to replace the computer. On a late-model vehicle, the circuit will open automatically. In either case however, the symptom would be an inoperative cooling fan.

To check current draw, set the multimeter to the amps position, and move the positive lead to the amp jack. Next, unplug the appropriate ECM harness connector, and connect the positive probe to the driver terminal you need to check. Attach the negative probe to a good ground, preferably the negative battery terminal. Now, turn the key to the RUN position. At this point, the device should turn on and the meter should indicate the current flow. Under normal conditions, current flow will be less than 750 milliamps. However, if current is greater than this, the appropriate actuator (relay or solenoid) should be replaced. On older vehicles, the computer may also require replacement if circuit current is greater than 750 milliamps.

COMMON AREA NETWORK (CAN)

More and more vehicles are increasingly using another level of electronic control. This protocol is SAE standard J1939, which is referred to as Common Area Network (CAN).

CAN takes advantage of one of the most fundamental advantages of an electronic processor, which is the ability to examine data an infinite number of times as desired to add or enhance features. The use of this protocol allows all controllers on the vehicle to share inputs. For example, a single vehicle speed sensor can be used and wired to provide an input to the engine controller. Through the use of CAN, the transmission controller, the antilock brake controller, and the instrument panel can also use the input from that single sensor. This significantly reduces the amount of wiring and components required on a vehicle.

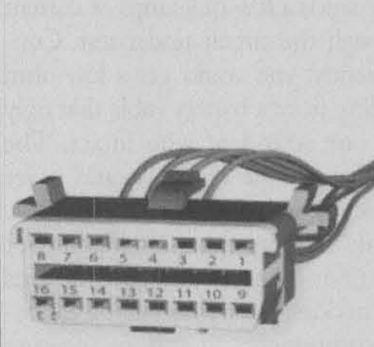


The use of a J1939 serial data link allows all controllers on a vehicle to share inputs. In this illustration numerous controllers use the input from the vehicle speed sensor, which is directly wired only to the engine ECM.

A CAN harness consists of a shielded two-wire twisted pair harness. The use of a twisted pair harness reduces interference that could affect communication on the data link. By twisting the wires, the magnetic field surrounding one wire will cancel the magnetic field surrounding the other wire. This results in an electrical signal that is 'clean' of any magnetic interference. The two wires are called CAN High (CAN H) and CAN Low (CAN L). All controllers on the vehicle are wired in a parallel circuit to the CAN harness.

CAN H has a dormant voltage of 0.25 volts that rises to 0.65 volts when communicating. Data is seen when this signal is at this "high" voltage level. CAN L has a dormant voltage of 11 volts that drops to 4.65 volts when active, and this 'low' voltage is seen as data.

CAN presents the technician with a new set of diagnostic challenges. Up to this point in the advancement of vehicle technology

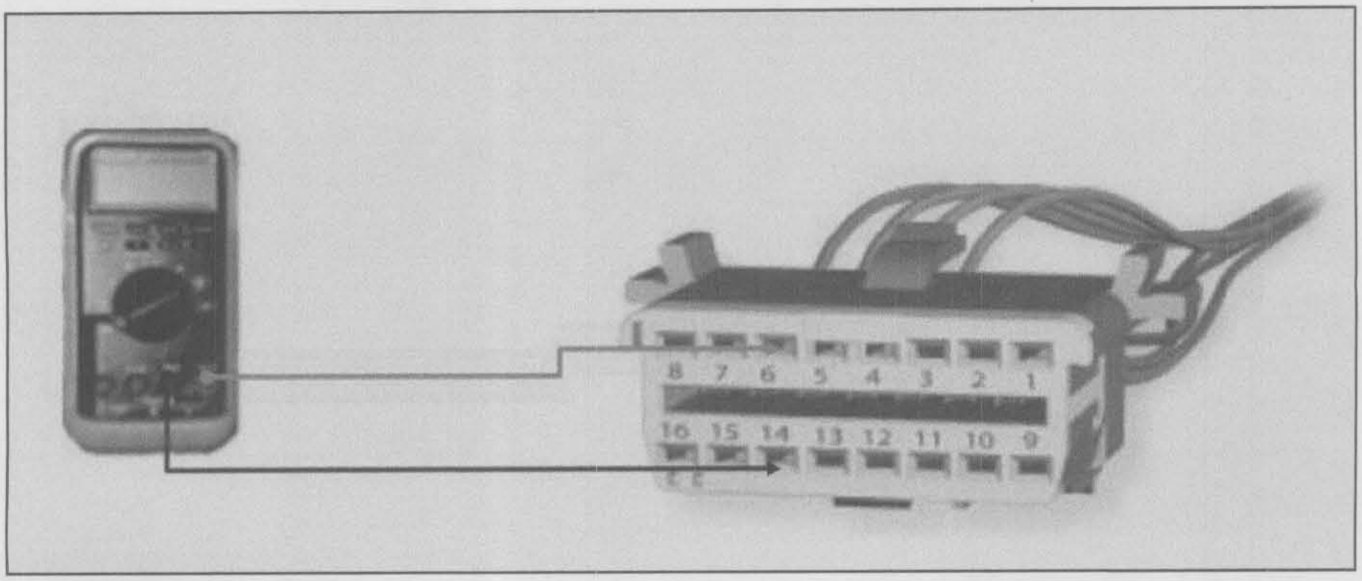


Pin assignment at the 16-Pin Connector T16 (Diagnostic Connection)

Pins not listed are not currently in use.

Pin	Wiring
1	Terminal 15
4	Ground
5	Ground
6	High Diagnosis CAN Data Bus
7	K-Wire
14	Low Diagnosis CAN Data Bus
15	L-Wire
16	Terminal 30

The CAN harness is accessible at the diagnostic data link. This allows the use of diagnostic software to troubleshoot defects. *(Courtesy: Audi of America)*



Measuring CAN harness resistance at the diagnostic connector.

one constant factor existed: One wire carried one electrical value. If all else failed, the technician could always use a lab scope to examine even the fastest of electrical signals. While CAN still carries one signal at a time, the data transmission is too fast to be deciphered on a scope pattern. Some manufacturers have developed diagnostic software to assist the technician in determining the root cause of a defect. This software is usually laptop-based, and the connection is made at the same diagnostic data link used for OBD II troubleshooting.

A terminating resistor is at each end of the data link. Terminating resistors serve to absorb signal 'bounce' and absorb interference. A terminating resistor may be found on the harness, or it may be integral with a controller. While the data link can operate if one resistor fails, the failure of both resistors will usually shut down the data link. In addition, shorted or open harnesses may cause a loss of communication with an individual controller.

The presence and condition of terminating resistors can be easily checked with an ohmmeter at the OBD II diagnostic connector. With all power removed, measure resistance from pin 6 to pin 14 of the diagnostic connector. Normal resistance should be 60 ohms. One open or missing resistor would show a resistance reading of 120 ohms.

Notes

Ignition System Diagnosis

The ignition system is designed to convert battery voltage into the high voltage required to ignite the air/fuel charge in the cylinders. There are two basic types of ignition systems as defined by SAE: Electronic Ignition (EI) and Distributor Ignition (DI). Although both types are electronic, SAE assigned the term 'Electronic Ignition' exclusively to distributorless designs. In contrast, Distributor Ignition (DI) is the term applied to systems that use a cap and rotor to deliver secondary energy to the spark plugs.

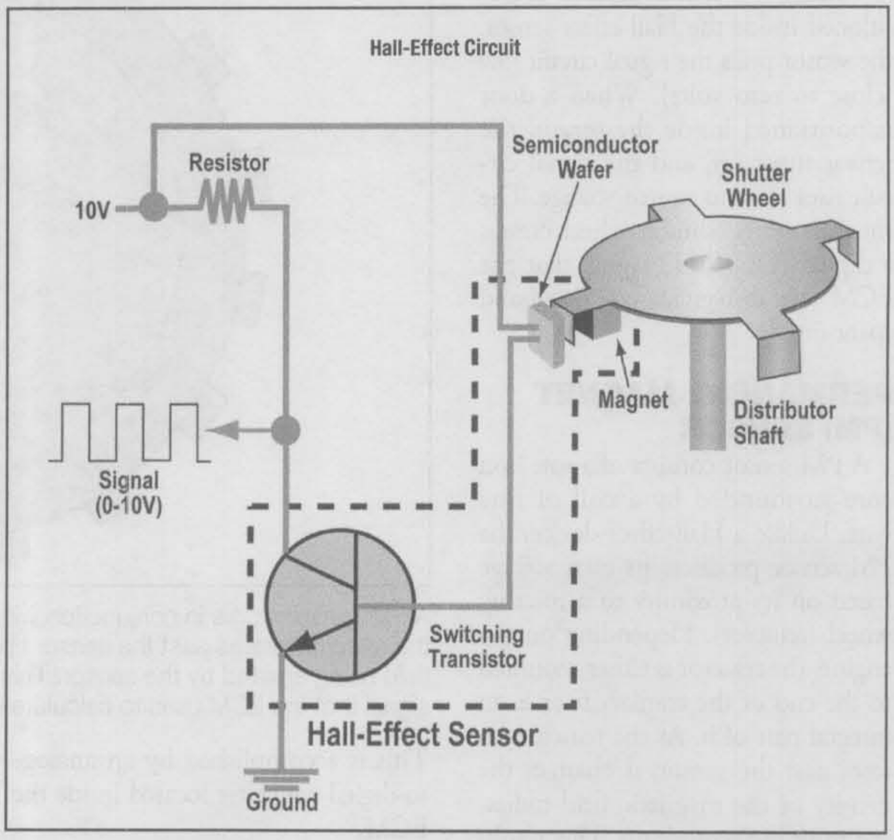
IGNITION SYSTEM BASICS

The ignition system consists of a primary and secondary circuit. The primary circuit is the low voltage portion of the system and includes the battery, ignition switch, primary coil winding, triggering mechanism and switching device. The triggering mechanism detects crankshaft position and relays that information directly to the ECM or to an ignition control module. Depending on the system, this is accomplished using a magnetic sensor and reluctor, a Hall-effect sensor and shutter wheel, or a slotted disc and photo optical sensor. The switching device controls the ground side of the primary coil winding based on the crankshaft signal as well as other sensor inputs (e.g. ECT, IAT, etc).

The secondary circuit is the high-voltage part of the ignition system and includes the secondary coil winding and spark plugs. The additional secondary components needed to distribute high-voltage energy vary according to system type. For example, in a conventional distributor ignition system, a cap, rotor and high-tension wires are used to transfer coil energy to the plugs. However, in a distributorless design, such as Coil-Over-Plug (COP), the cap, rotor, and wires are eliminated.

When current flows through the primary winding of the ignition coil, it creates a magnetic field around the winding. Once the current is interrupted by the switching device (i.e. ignition control module and/or ECM), the magnetic field collapses and induces a voltage into the winding. This 'primary voltage' reaches several hundred volts. At the same time, the collapsing magnetic field induces a voltage into the secondary winding. Since the secondary winding is made up of many turns of fine wire, compared to the few turns of heavy wire used in the primary, 'secondary voltage' is measured in kilovolts (thousands of volts).

Generating adequate secondary voltage to fire the plugs ultimately depends on the condition of the primary circuit. This means that there must be a low resistance path from the battery through the closed ignition switch to the coil and switch-



When a vane is positioned inside the Hall-effect sensor, the switching transistor turns off. Under this condition, the voltage on the signal line equals source voltage. When a window passes through the sensor, the switching transistor turns on, causing source voltage to drop across the resistor. As a result, the voltage on the signal line falls to zero. As the shutter wheel rotates, the sensor produces a digital (ON/OFF) signal used by the ECM for adjusting coil saturation time (dwell).

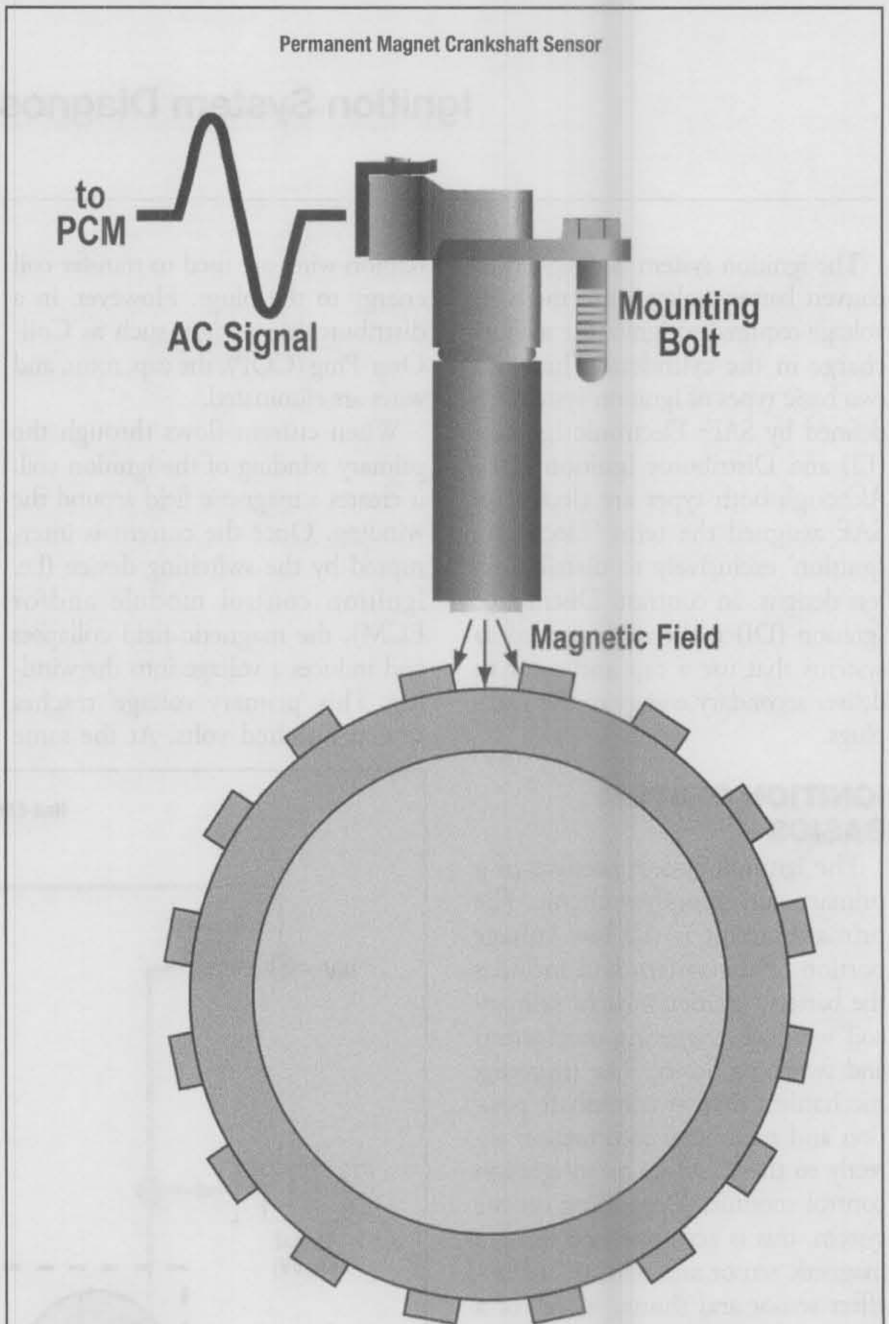
ing device. Excessive voltage drop at any point along this path can cause problems ranging from a misfire to a no-start condition.

HALL-EFFECT SENSOR

Many EI and DI systems use a Hall-effect sensor to detect crankshaft position. This device has three connecting wires including external power, signal and ground. The sensor is triggered by a thin metal ring known as a shutter wheel. On DI systems, the shutter wheel is splined to the distributor shaft. On vehicles with EI, it is an integral part of the crankshaft vibration damper. The shutter wheel consists of a series of vanes that pass through a narrow area on the sensor. The vanes can be thought of as doors, while the space between the vanes can be thought of as windows. When a window is positioned inside the Hall-effect sensor, the sensor pulls the signal circuit low (close to zero volts). When a door is positioned inside the sensor, the sensor turns off, and the signal circuit rises close to source voltage. The rotation of the shutter wheel creates a digital (ON/OFF) signal that the ECM uses to regulate coil dwell and spark timing.

PERMANENT MAGNET (PM) SENSOR

A PM sensor consists of a soft iron core surrounded by a coil of fine wire. Unlike a Hall-effect device, the PM sensor produces its own voltage based on its proximity to a rotating wheel (reluctor). Depending on the engine, the reluctor is either mounted to the end of the crankshaft or is an integral part of it. As the reluctor rotates past the sensor, it changes the density of the magnetic field radiating from the sensor's tip. This results in the production of an AC (Alternating Current) voltage that varies in proportion to engine speed. Since the ECM is a digital computer, the AC signal must be conditioned before it can be used for rpm calculations.



A PM sensor works in conjunction with a toothed wheel called a reluctor. As the reluctor rotates past the sensor tip, it changes the strength of the magnetic field being emitted by the sensor. This results in the production of an AC signal that the ECM uses to calculate engine rpm.

This is accomplished by an analog-to-digital converter located inside the ECM.

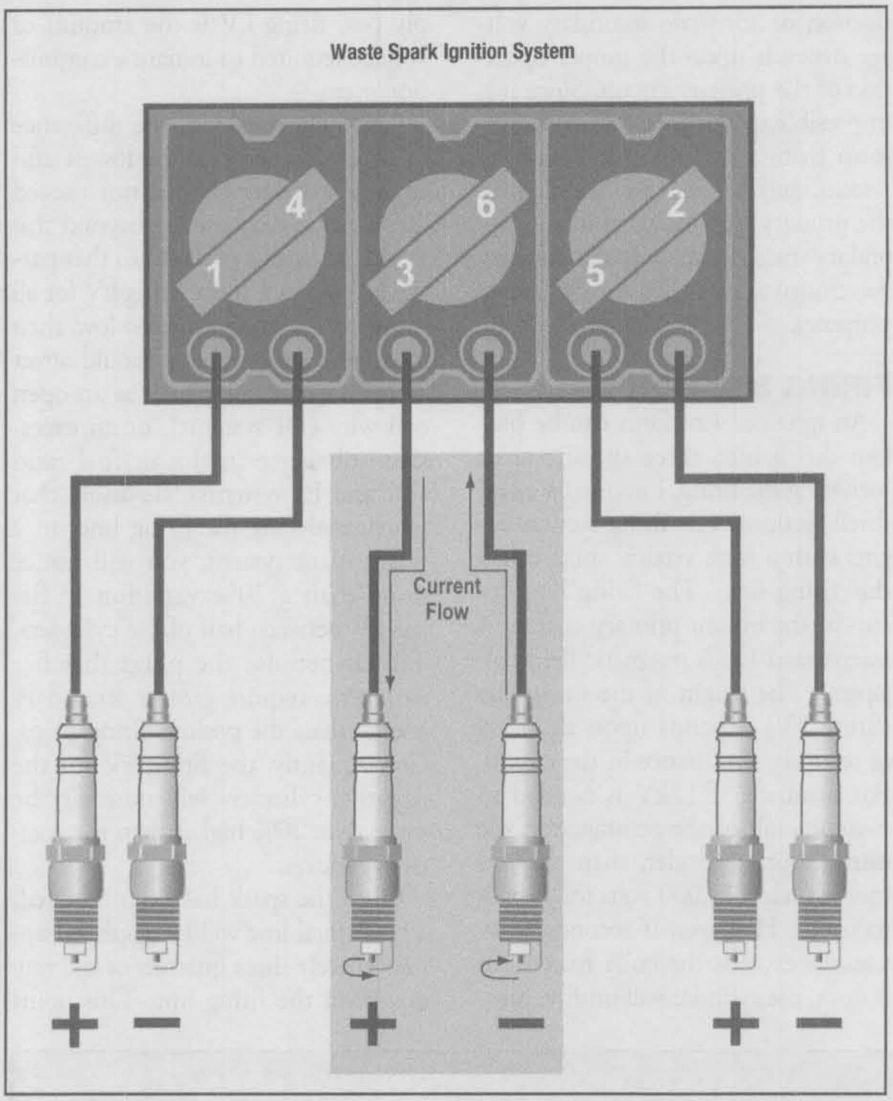
PHOTO-OPTICAL SENSOR

While less popular than the Hall-effect or permanent magnet sensors, photo optical triggering is another technique used in some ignition systems. With this method, a slotted disc rotates between a pair of Light-Emitting Diodes (LEDs) and phototransistors. Depending on the application, the outer diameter of the disc either contains 360 slots, each of which corresponds to one degree of crankshaft rotation, or 350 1-degree slots and a single 10-degree synchronization slot. These slots provide the ECM with a high-resolution signal for precise fuel and spark timing control. The inner section of the disc contains one slot for each engine cylinder, providing a low-resolution (piston position) signal. On systems that use a sync slot on the outer diameter of the disc, the inner slots are of equal size. However, on systems where there are 360 1-degree slots near the edge of the disc, the inner slots are asymmetrical in order to provide cylinder identification.

The optical sensor is typically powered by battery voltage, while the phototransistors control two 5-volt signal circuits from the ECM. As the slots pass between the LEDs and the phototransistors, the light beams from the LEDs are alternately interrupted. When the light beam from the LED strikes the phototransistor, the transistor turns on. This causes the 5-volt signal to be pulled low. When the light beam is blocked by the rotating disc, the transistor turns off, which causes the signal voltage to go high (5 volts).

WASTE SPARK IGNITION

Waste spark ignition is a distributorless system that uses a separate coil to fire one pair of spark plugs. The coils and plugs are grouped according to 'companion cylinders,' which is the term applied to cylinders whose pistons are at top dead center at the same time. For example, in a typical V6, cylinders 1/4, 2/5 and 3/6 are companions. When one piston is at TDC on the compression stroke, the companion cylinder's piston is at TDC on the exhaust stroke. The cylinder on the compression stroke is known as the 'event' cylinder, while the cylinder on the exhaust stroke is referred to as the 'waste' cylinder. Each coil, along with its attached wires and spark plugs forms a series circuit. When a coil discharges, current flows through one spark plug in the normal manner (center electrode to ground electrode). To complete the circuit, current flows through the opposite plug in reverse (ground electrode to the center electrode). Although the plugs are fired simultaneously, most of the available energy is applied to the 'event' cylinder. This is because there is little resistance in the cylinder on the exhaust stroke. When the cylinders reverse roles, the current follows the same path through the spark plugs. However, the majority of secondary voltage is applied to the opposite cylinder, since it is now on the compression stroke.



In a waste spark ignition system, each pair of spark plugs is fired simultaneously. One plug is fired in a forward direction (center electrode to ground electrode), while the plug on the companion cylinder is fired in reverse (ground electrode to center electrode).

DIRECT IGNITION

Direct ignition is a general term used to describe systems that use individual coils for each cylinder. On some engines, the coils are mounted on the rocker cover and connect to the spark plugs using short cables. In Coil-Over-Plug systems, the coils are mounted directly on top of the spark plugs. This design minimizes secondary resistance by eliminating the plug wires. In addition, OBD II Codes will often be specific for the cylinder in question, making it easier for the technician to find the defect.

IGNITION WAVEFORM ANALYSIS

As previously mentioned, the production of adequate secondary voltage depends upon the proper operation of the primary circuit. Since it is impossible to obtain a primary waveform from a distributorless ignition system, and because any problem in the primary will show up in the secondary trace, an analysis of secondary waveforms is sufficient for diagnostic purposes.

FIRING SECTION

An ignition waveform can be broken down into three specific areas including the firing, intermediate and dwell sections. The firing section begins with a high vertical spike called the 'firing line.' The firing line occurs at the instant primary current is interrupted (coil's magnetic field collapses). The height of the firing line (firing kV) depends upon the level of secondary resistance in the circuit. For instance, if 12kV is needed to overcome all of the resistance in the number one cylinder, then the coil must develop 12,000 volts for a spark to occur. However, if secondary resistance exceeds the coil's maximum output, the cylinder will misfire. Simply put, firing kV is the amount of voltage required to initiate a combustion event.

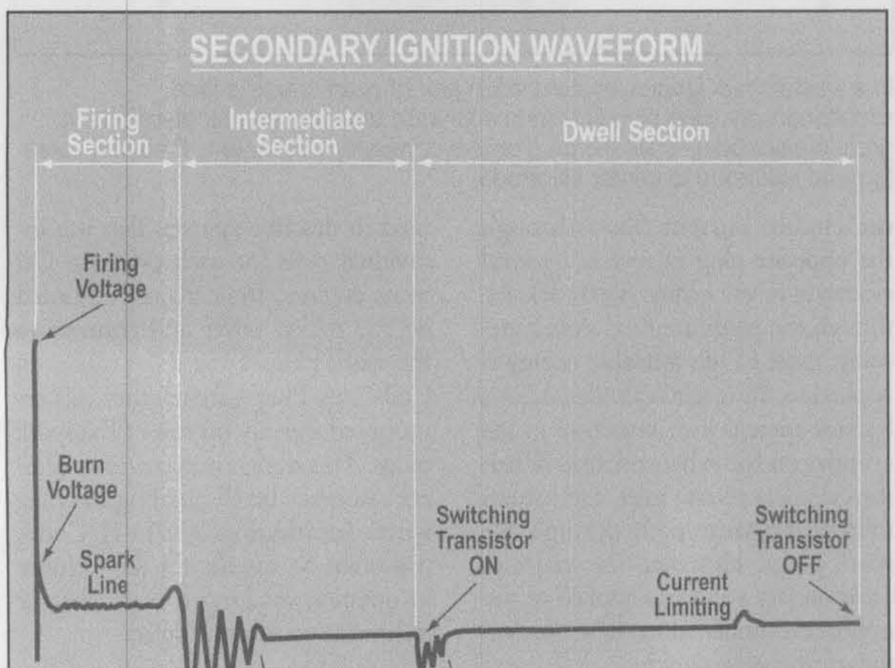
Generally speaking, the difference in firing kV between the lowest and highest cylinder should not exceed 20%. Any firing voltage beyond this range indicates a problem in that particular cylinder. If the firing kV for all cylinders is too high or too low, then look for a problem that would affect all cylinders equally, such as an open coil wire (DI systems), or an excessive imbalance in the air/fuel ratio (DI and EI systems). Be aware that when analyzing the firing lines in a waste spark system, you will notice more than a 20% variation in firing kV between half of the cylinders. This is because the plugs that fire in reverse require greater secondary energy than the positive-firing plugs. Consequently, the firing kV for the negative cylinders will normally be more than 20% higher than the positive cylinders.

Once the spark has been initiated, a horizontal line will be displayed approximately three quarters of the way down on the firing line. This point is called the spark line. The height on the voltage scale that the spark line corresponds to is referred to as the 'burn voltage.' Burn voltage indicates the amount of energy required to sustain the flow of current across the plug electrodes. The duration of the spark, known as the 'burn time,' is dependent upon the amount of secondary resistance and coil reserve. Under normal conditions, a properly functioning coil can maintain current flow for at least two milliseconds, which is vital for good combustion.

Be aware that firing kV and burn time are inversely proportional. This means that any increase in kV demand will result in decreased burn time and vice versa. For example, if one injector is leaking, the affected cylinder will run too rich. Since fuel is more conductive than air, the added fuel will reduce secondary resistance. Consequently, firing kV will be lower and burn time will be longer. If the injector is restricted, the opposite will occur. The lean mixture will cause increased resistance, resulting in a higher kV demand with shorter burn time. High internal resistance, such as a lean mixture or excessive EGR, will cause the spark line to slope upward. This is because these conditions increase the demand for burn voltage. As you can see, observing the spark lines can pinpoint problems affecting individual cylinders. In the event all of the spark lines seem irregular, look for a problem that could affect all cylinders equally. For instance, if all of the spark lines slope upward, the increased resistance may be the result of low fuel pressure or excessive EGR.

Intermediate Section

When viewing the intermediate section of the waveform, you should see a series of diminishing oscillations that represent residual coil energy. Although the primary circuit is still open during this time, there is not enough energy left in the coil to sustain the spark. This residual en-

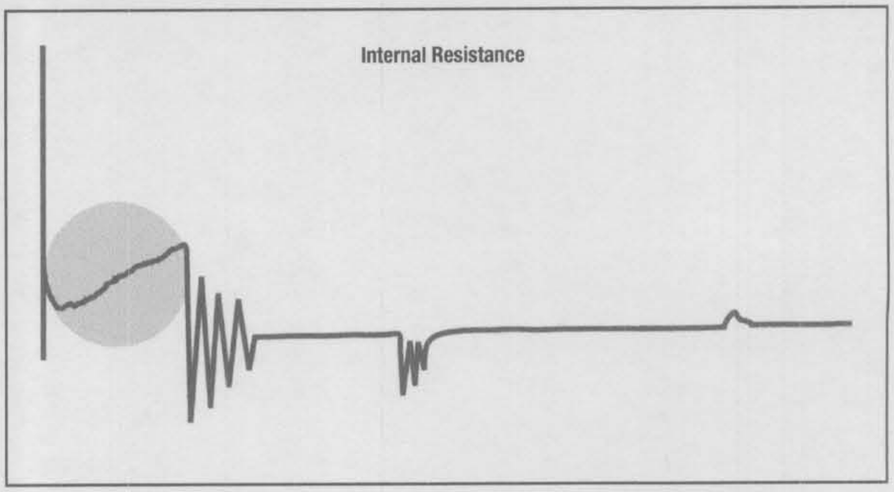


ergy gradually dissipates between the switching device and coil. Under normal conditions, there will be three to four coil oscillations following the burn event. Be aware however, the more voltage required to initiate and sustain the spark, the less energy will remain afterward. Consequently, there will be fewer oscillations in the intermediate section if firing kV or burn voltage is excessive.

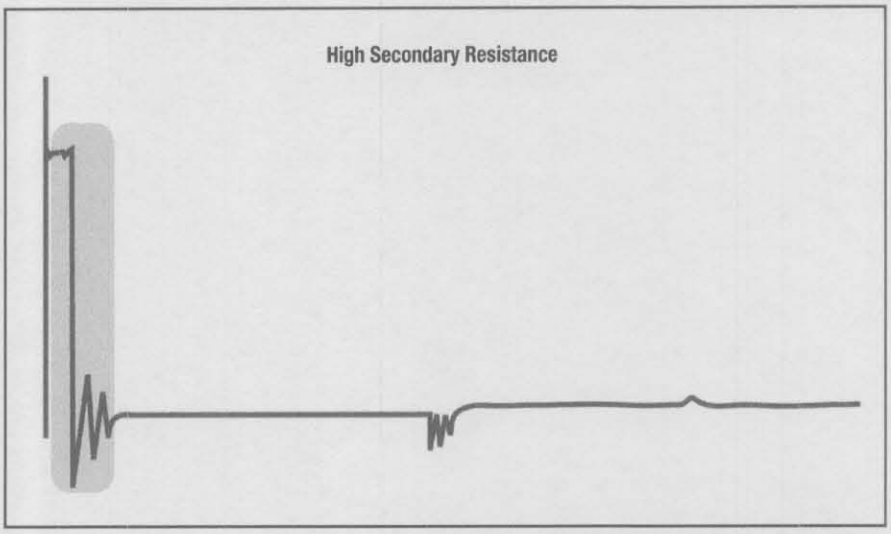
If the intermediate section shows less than normal coil oscillations and the firing and spark lines appear normal, the coil is most likely shorted. The fewer oscillations indicate that there is less residual energy due to a weakened magnetic field. The most likely symptoms of a shorted coil will be a misfire under load, or a hard start cold, since secondary resistance is highest under these conditions.

Dwell Section

The dwell section begins once coil energy has been completely exhausted. A sharp downward spike indicates that the switching transistor has turned on to initiate the flow of primary current. The several oscillations seen at the beginning of the dwell period are the result of a phenomenon known as 'inductive reactance.' In short, this is a normal condition in which the coil resists sudden changes in current flow. Consequently, there is a slight delay before primary current reaches its maximum level. Once the ignition module or ECM determines that coil saturation is sufficient, it begins limiting primary current. This is indicated by the slight hump seen near the end of the dwell period.



High internal resistance, caused by a lean mixture or excessive EGR for example, will cause an increased demand for burn voltage. This can be seen by an upward slope in the spark line.



If secondary resistance is higher than normal, the majority of coil energy will be used to initiate the spark. As a result, the burn time will be brief and there will be fewer coil oscillations seen in the intermediate section.

Anti- Theft Devices

Many modern vehicles use devices to prevent unauthorized vehicle operation. Immobilizer modules are much more advanced than older devices, and are matched the ECM. Replacement of either device will require OEM level scan tools to match the units to each other. Usually a problem with the immobilizer will cause a crank no start. Failure to consider the immobilizer as a potential problem can result in an extensive waste of diagnostic time.

Notes

Fuel And Air Induction Systems Diagnosis

Electronic Fuel Injection (EFI) was introduced to the automotive world in the late fifties, when Chrysler offered the 'Electrojector' system as an option on its Hemi V8. Shortly after its debut, reliability problems forced Chrysler to recall the few systems that were sold. Ironically, recalled vehicles were retrofitted with dual four-barrel carburetors. Three decades later the tide would turn, when manufacturers abandoned the carburetor in favor of electronic fuel injection.

EFI REVIEW

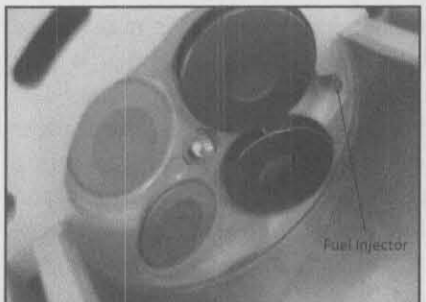
There are two basic types of EFI systems, including Throttle Body Injection (TBI) and Multiport Fuel Injection (MFI). In a TBI system, one or two injectors (depending on engine size) are mounted above the throttle plates of a single or dual barrel throttle body. Like a carburetor, fuel is delivered above the throttle plates and distributed throughout the intake manifold. Although TBI is more efficient than carburetion, it shares the inherent problem of uneven fuel distribution common to the 'wet-manifold' design.

With multiport injection, fuel is delivered directly to each cylinder via individual injectors, while the intake manifold is used exclusively for air induction. The injectors are mounted on the manifold so that the injector nozzles are aimed at the backside of the intake valves. This arrangement provides a significant improvement in overall engine performance over TBI.

On a traditional multiport injection system, the injector is located behind the intake valve and the fuel is injected into the manifold runner for that particular cylinder. When the intake valve opens the air fuel mixture enters the cylinder. A system that is becoming very common is direct injection. In direct injection, the injector delivers the fuel directly into the combustion chamber.

Direct injection offers benefits in emissions and performance. Under light engine loads, the injectors can be pulsed on an ultra-lean strategy to reduce emissions and improve fuel economy. Multiple pulses are also possible under heavier engine load conditions, enhancing power and allowing a more complete burn of the fuel.

Caution: *Direct injection systems operate under high pressure. Failure to follow OEM service and testing procedures could result in personal injury or component damage.*



Combustion chamber showing the position of the fuel injector near the intake valves.

Injector Firing Strategies

Depending on the application, the injectors in an EFI system may be fired simultaneously, in groups, or one at a time. The simplest of these control strategies is simultaneous injection. With this method, each injector is fired once every crankshaft revolution, which results in two shots of fuel per combustion cycle. Simultaneous injection is also used for engines equipped with single TBI. Dual TBI systems, as well as some multiport designs, use group injection. This strategy, also known as 'bank firing,' separates the odd and even numbered cylinders into two separate groups. The injectors in each group are fired simultaneously, while the groups are fired alternately. The most effective strategy for activating the injectors is known as Sequential Fuel Injection (SFI). With this technique, the injectors are fired one at a time in the spark plug firing order. Unlike simultaneous and group injection, SFI systems require a cylinder identification signal to initiate injector sequencing. This signal is typically provided by a camshaft position sensor, or a synchronization slot cut into the crankshaft sensor reluctor. All OBD II systems use sequentially fired injectors.

Speed Density vs. Mass Air Flow

Speed density and mass airflow are two techniques used for determining the amount of air entering the engine. In a speed density system, the ECM calculates airflow based on manifold absolute pressure, intake air temperature, EGR flow, volumetric efficiency and rpm. In contrast, mass airflow systems use a MAF (Mass Air Flow) sensor to provide the ECM with a direct measurement of engine airflow. Be aware that some engines are equipped with both MAP and MAF sensors. On OBD I applications with this arrangement, the MAP signal is used as a backup in the event of a MAF failure. On OBD II systems with this combination, the ECM uses the MAP signal to evaluate EGR performance.

Returnless vs. Continuous Return

Most fuel injected engines use a continuous return system. With this design, fuel is delivered from a high-pressure electric pump to a fuel meter assembly (TBI) or a fuel rail (MFI). The pump is designed to deliver fuel in excess of engine requirements. This ensures that there is more than enough fuel available under extreme loads. A regulator maintains the required level of fuel pressure under all conditions by routing excess fuel back to the tank via a separate return line. On TBI systems, the pressure regulator is part of the fuel meter assembly, while on multiport designs it is a separate component mounted on the fuel rail. The regulator on TBI systems keeps fuel pressure at a constant level. In contrast, most continuous return MFI systems use a vacuum-controlled regulator that adjusts fuel pressure according to changes in engine load.

As the name implies, a returnless system has no return line, and therefore does not recirculate fuel. Instead, fuel in excess of engine needs is returned to the tank through a passage located within a tank-mounted pressure regulator. By eliminating the return path from the fuel rail, fuel temperature is reduced, which lowers evaporative emissions. This allows the use of a smaller charcoal canister as well as a reduction in vapor purge cycles.

FUEL SYSTEM TESTING

There are a variety of test procedures available for diagnosing problems in the fuel delivery system. For a complete fuel system analysis, each of the following tests should be performed.

Fuel Pump Control

Fuel pumps are controlled by various methods. Many high tech vehicles used a simple power connection, in some cases through the oil pressure switch, to control fuel pump operation. In many such cases the fuel pump relay was simply to build up initial fuel pressure in the system. Still other systems used the fuel pump relay to operate the fuel pump. In this design, the fuel pump relay is controlled by the ECM. Still other systems use a fuel pump control module (FPCM) to operate the fuel pump. In this design, the FPCM will control the fuel pump on a duty cycle to regulate fuel pressure. Usually a serial data link will be used to give the ECM information on fuel pressure, and OEM level scan equipment may also provide the technician with a fuel pressure value.

The ASE Composite Engine Type 4 uses a FPCM. It communicates with the ECM by a LAN cable. A 5.0 volt signal from the ECM will enable the fuel pump and fuel volume will be varied by varying the duty cycle of the fuel pump voltage. This is done by the FPCM in response to serial data from the ECM. Fuel pressure is maintained by a pressure regulator that is part of the in-tank fuel pump assembly. For diagnostic purposes, the scanner will display fuel pressure, fuel pump command, fuel pump feedback, and fuel enable. In some cases, the technician may choose to make an actual fuel pressure measurement and compare it to scanner data. Many OEM level scanners will also allow the fuel pump to be commanded on for measuring volume.

Fuel Pressure

Measuring fuel pressure should be among the initial tests performed when looking into an engine performance concern. This is because incorrect pressure is often the root cause of many driveability problems. Although the closed loop system can compensate for slight pressure irregularities, it cannot prevent the symptoms that result when fuel pressure is either too high or too low. On most vehicles, a Schrader valve on the fuel rail provides a parallel test point. However, on some TBI systems, the pressure gauge must be installed in series. This involves disconnecting the fuel supply line and connecting the appropriate adapters. Once the gauge is connected, run the fuel pump until the maximum pressure is reached and record the reading. Low fuel pressure may be the result of a clogged in-tank strainer or inline fuel filter, defective fuel pump, or problems in the fuel pump electrical circuit (high resistance). Excessive fuel pressure can be caused by a restricted return line (continuous return systems), faulty fuel pressure regulator, or a damaged vacuum signal line (continuous return systems).

Fuel Leakdown

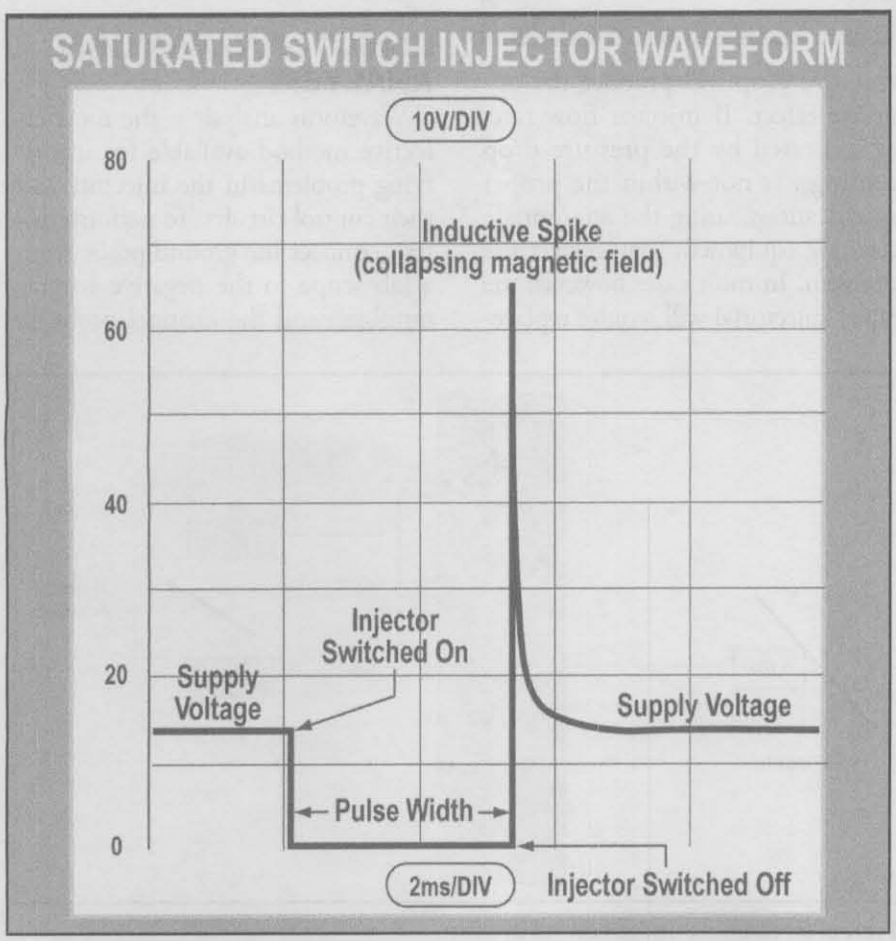
If fuel pressure is normal, recheck the gauge reading after 10 minutes to determine the leakdown rate. Generally speaking, the leakdown rate should not exceed 5 psi in 10 minutes. As leakdown rates become greater than this, engine crank times will increase proportionately, resulting in complaints of hard starting. An excessive leakdown rate can be caused by a faulty fuel pump check valve, a pressure regulator that is stuck open, a leaking fuel line, or leaking injectors.

Fuel Volume

Even if fuel pressure is within specifications, it doesn't necessarily mean that the engine is receiving an adequate supply of fuel. The pressure could be the result of air pockets in the system. This is why checking fuel volume is so important when diagnosing a complaint of poor driveability. With most pressure gauges, you can check fuel volume without opening the system. Simply place the drain hose from the gauge into a clean graduated container, and then activate the fuel pump. Next, collect the fuel by holding the relief valve on the gauge open for 15 seconds while the pump is running. Generally speaking, the pump should deliver one pint of fuel within that time, provided that the battery is fully charged and there is no excessive resistance in the fuel pump electrical circuit. The most likely cause of poor fuel volume is a clogged in-tank strainer or inline fuel filter.

Injector Balance Test Results

Injector	1	2	3	4	5	6	
Initial Pressure	48	48	48	48	48	48	
Final Pressure	31	32	43	33	31	18	
Pressure Drop	17	18	5	15	17	30	Spec (psi) 14.5 to 17.5
Results	OK	OK	Clogged	OK	OK	Leaking	



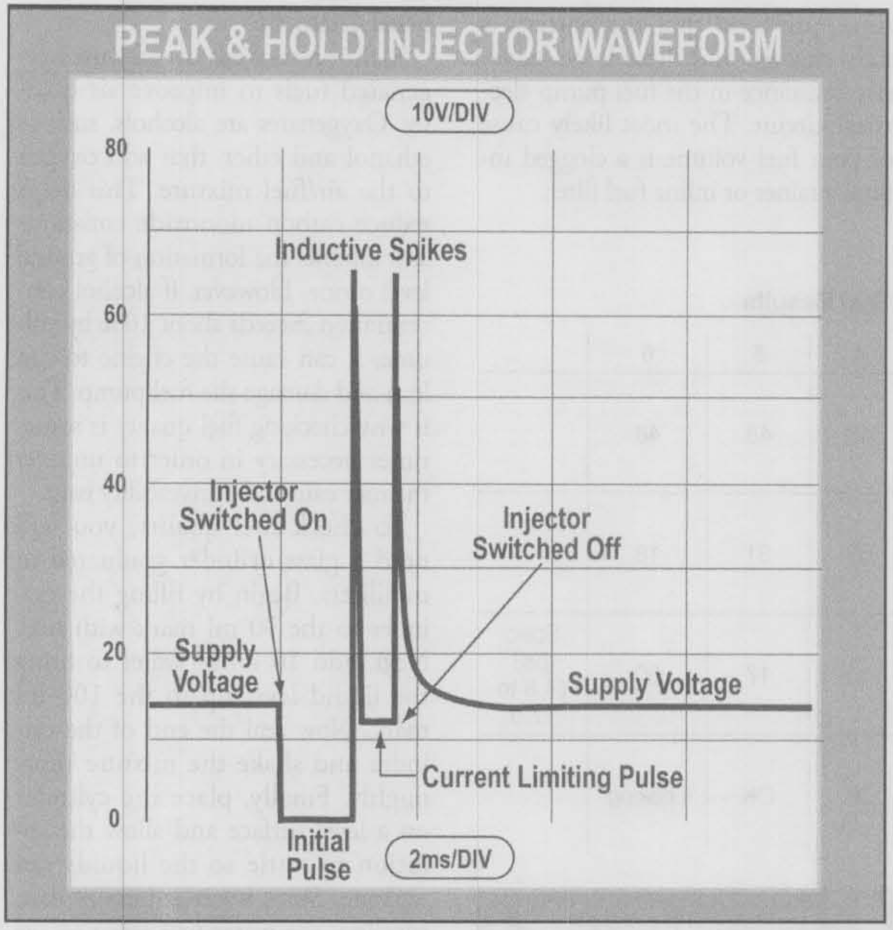
Fuel Quality

Many areas of the country use oxygenated fuels to improve air quality. Oxygenates are alcohols, such as ethanol and ether, that add oxygen to the air/fuel mixture. This helps reduce carbon monoxide emissions and inhibits the formation of ground level ozone. However, if alcohol concentration exceeds about 10% by volume, it can cause the engine to run lean and damage the fuel pump. This is why checking fuel quality is sometimes necessary in order to uncover the root cause of a driveability issue.

To check fuel quality, you will need a glass cylinder graduated in milliliters. Begin by filling the cylinder to the 90 ml mark with fuel. Next, add 10 ml of water to bring the liquid level up to the 100 ml mark. Now seal the end of the cylinder and shake the mixture thoroughly. Finally, place the cylinder on a level surface and allow the solution to settle so the liquids can separate. Since water is heavier than gasoline, the water will settle to the bottom of the cylinder along with any alcohol contained in the fuel. This is known as the 'Water Extraction Method.' If the fuel contains any alcohol, the water level will be greater than its initial reading of 10 ml. If the new water level exceeds the 20 ml mark, it indicates that alcohol concentration is greater than 10%. Under this condition, the tank should be drained and cleaned, and the fuel lines should be flushed using compressed air. In addition, a new in-tank strainer and inline fuel filter should be installed.

Injector Balance

Defective fuel injectors can cause problems ranging from a cylinder misfire to a no-start condition. A balance test allows you to pinpoint faulty injectors by measuring the amount of pressure drop that occurs as each injector is activated. Before conducting the test, allow the engine to cool, since any vapor bubbles



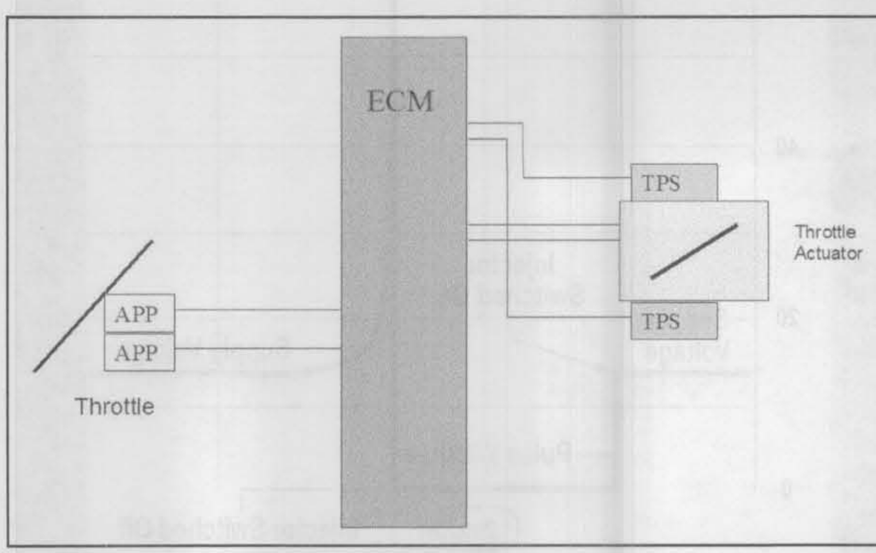
in the fuel rail will yield misleading test results. Begin by connecting the fuel pressure gauge to the Schrader valve, and the leads from the injector balance tester to the battery. Next, unplug the injector harness connectors, and then connect the tool's test plug to an injector. With the test equipment in place, run the fuel pump until the maximum pressure is achieved, and then record the pressure reading. Now activate the balance tester, and then record the new pressure reading the moment the gauge needle stops. The difference in the two readings is the injector's pressure drop (flow rate). Repeat this procedure for each of the remaining injectors, making sure to re-pressurize the fuel system before each test. When the test is complete, compare your results with the manufacturer's specifications for injector drop. Injectors with a lower than normal pressure drop will cause the affected cylinder to run lean, while excessive drop will produce the opposite effect. If injector flow rate, as indicated by the pressure drop readings, is not within the proper specifications, using the appropriate cleaning equipment may correct the problem. In most cases however, the faulty injector(s) will require replacement. Also, be aware that the injectors on some vehicles are not meant to be cleaned. This is because the injector windings can become permanently damaged when exposed to cleaning solutions.

INJECTOR DRIVERS

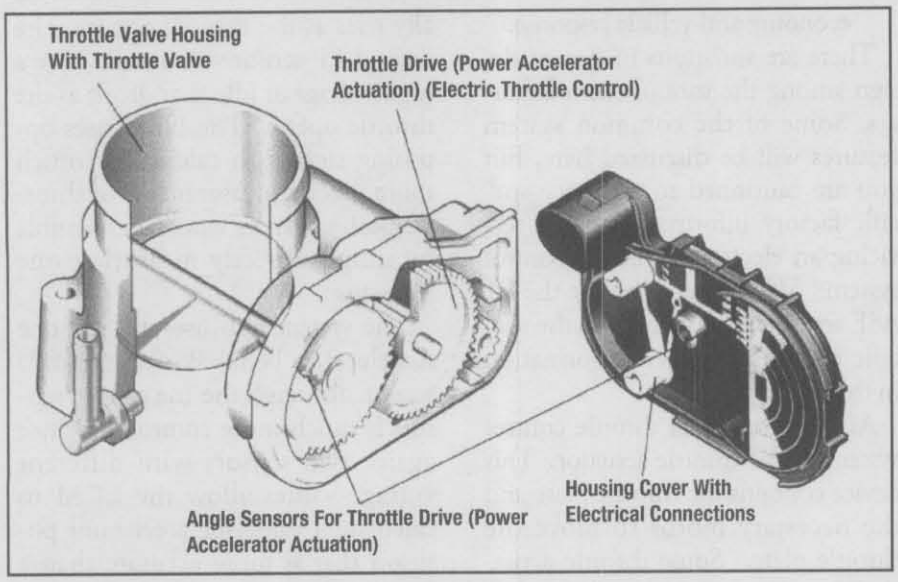
The two most common injector control drivers are the 'saturated switch' and the 'peak and hold' type. With a saturated switch, maximum current is applied to the injector for the duration of the pulse. For this reason, saturated switch drivers are used to control high-impedance injectors (12+ ohms). In contrast, a peak and hold driver allows maximum current to flow just long enough to open the injector (approximately 1.5 ms). At that point, current is reduced to the level required to hold the injector open. Peak and hold drivers are used to control low-impedance injectors, such as the type found on many TBI systems.

INJECTOR WAVEFORM ANALYSIS

Waveform analysis is the most effective method available for identifying problems in the injectors and their control circuits. To perform this test, connect the ground probe from a lab scope to the negative battery terminal, and the channel probe to



Typical electronic throttle control system.

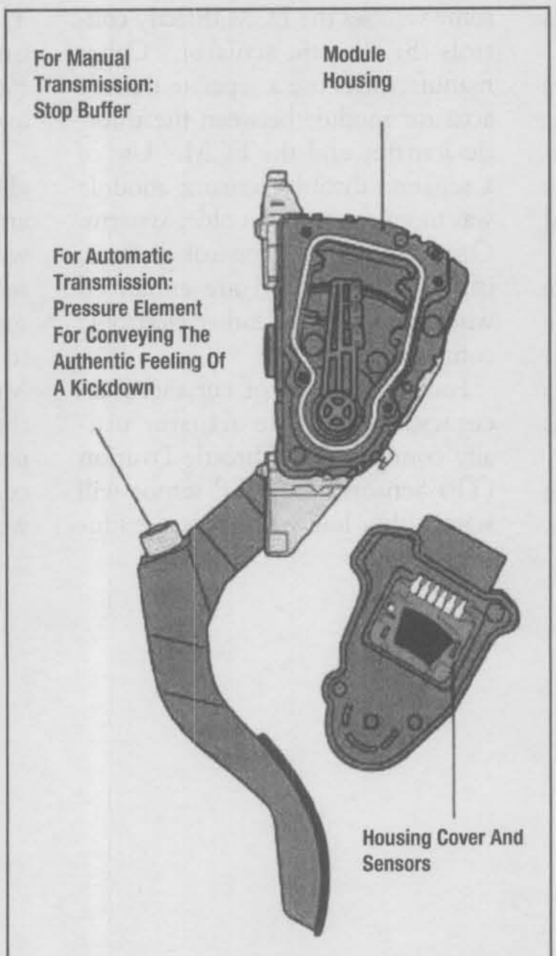


Typical throttle actuator. *(Courtesy: Chrysler Group LLC)*

the control circuit (ground side) of the injector you wish to check. Set the voltage scale to read 10 volts per division and adjust the time base to 2ms per division.

In a saturated switch waveform, the upper horizontal line shows the supply voltage, while the lower horizontal line represents the pulse width (injector ON-time). Supply voltage should be the same as charging system voltage, while the control signal should be within 0.1V of ground. If voltage is incorrect, look for high resistance in the power or ground circuits. Once the injector is turned off, the magnetic field surrounding the solenoid winding collapses. This induces a voltage into the coil approximately five times greater than the supply voltage. If the amplitude of the inductive spike is less than this, and the power and grounds are OK, the coil winding is probably shorted. This condition will cause the affected cylinder to run lean.

In a peak and hold waveform, there are two pulses and two inductive spikes. The first pulse pulls the injector open, and will be approximately 1.2-1.5ms in duration regardless of engine operating conditions. The first inductive spike indicates the start of the current limiting pulse. Unlike the initial pulse, the current limiting pulse varies according to engine speed and load. At the conclusion of this pulse, a second inductive spike occurs. While the height of this spike may appear to be equal to or greater than the first, keep in mind that there is less voltage applied to the injector during the current limiting phase. This is because a portion of the supply voltage is dropped across a current limiting resistor inside the ECM. This voltage drop is represented by the height at which the second pulse occurs. Consequently, the second spike has less amplitude than the first.



Many vehicles with electronic throttle control use an accelerator pedal module with integral Accelerator Pedal Position (APP) sensors. *(Courtesy: Chrysler Group LLC)*

AIR INTAKE SYSTEM

Air induction components consist of the intake manifold, throttle body assembly, ductwork, air filter and air cleaner housing. Depending on the application, parallel air ducts may be used for silencing. On systems that use mass airflow control, the integrity of the ductwork is extremely important. This is because a leak downstream of the MAF sensor will cause the engine to draw in unmetered air. As a result, the air/fuel ratio will become too lean. When checking for air leaks on this type of system, look for improperly installed rigid ductwork and/or cracks in flexible air intake hoses.

While the condition of the intake plumbing may not be critical to mixture balance on speed density systems, missing or damaged ductwork or hoses can cause other performance problems. For example, a missing duct allows the engine to draw in hot underhood air, resulting in higher combustion temperatures. This can cause spark knock as well as excessive NOx emissions.

ELECTRONIC THROTTLE CONTROL

All of us who work with computers have experienced instances when we worked a little too fast and locked up our computer. A computerized control system is similar in function to all computers, and inputs can be received faster than the ECM is capable of processing changes in input values. This is especially true with operator inputs, such as the throttle position sensor. It is possible for the driver to exercise the throttle faster than the ECM could process changes. When this occurs, the usual result is an increase in emissions. In the interest of reducing emissions to the lowest possible levels, electronic throttle controls have been developed.

Electronic throttle control offers several advantages over a conventional mechanical throttle:

- A reduction in moving parts reduces wear, adjustments and maintenance
- The human factor in throttle control is now an input to the ECM rather than an actual change in throttle angle. This helps to keep emissions as low as possible
- A greater accuracy in throttle control improves driveability, economy and vehicle response.

There are variations in system design among the various manufacturers. Some of the common system features will be discussed here, but you are cautioned to reference specific factory information when servicing an electronic throttle control system. When preparing for the L1 ASE test, you should refer to the specific composite vehicle information in this study guide.

At the heart of all throttle control systems is the throttle actuator. This device contains the throttle plate and the necessary motor to move the throttle plate. Some throttle actuators are duty cycle controlled, while others move in response to a voltage signal of the correct polarity. On some vehicles the ECM directly controls the throttle actuator. Other manufacturers use a separate throttle actuator module between the throttle actuator and the ECM. Use of a separate throttle actuator module was more common on older systems. On most throttle control systems, inputs to the ECM are enhanced when compared to earlier electronic control systems.

For the purpose of enhanced accuracy, the throttle actuator usually contains two Throttle Position (TP) Sensors. One TP sensor will start with a low voltage that gradually rises as the throttle opens. The second TP sensor will usually have a high voltage at idle that drops as the throttle opens. The ECM uses opposing signals to calculate a much more precise measurement of throttle position than would be possible by simply directly measuring one TP sensor.

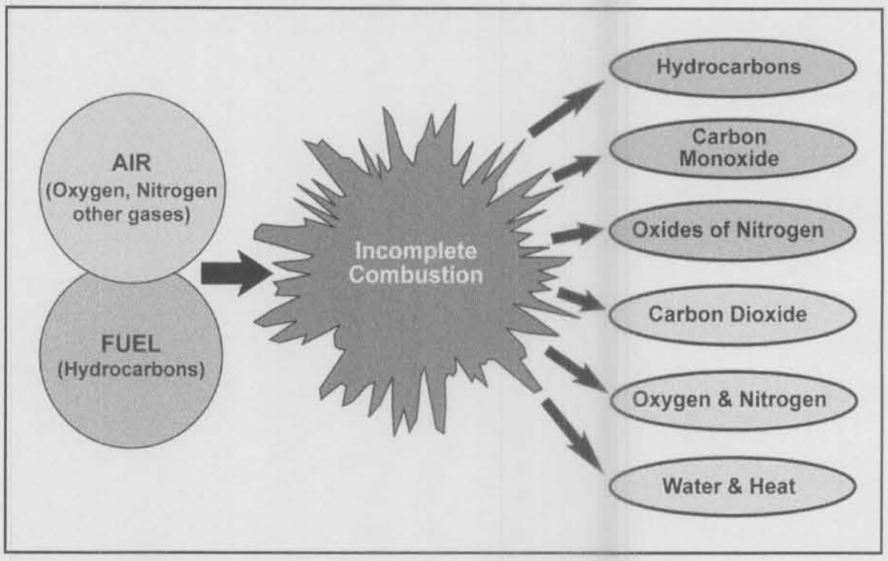
The system also uses at least one Accelerator Pedal Position (APP) sensor, although the use of two sensors is much more common. Once again, two sensors with different voltage values allow the ECM to calculate a value for accelerator position that is more accurate than a single sensor input. The ECM uses the accelerator position sensor input to command the throttle actuator. The APP sensors may be mounted on the accelerator pedal, or they may be part of an integral throttle assembly.

The failure of one sensor will usually set a code and limit throttle operation. The failure of two sensors will usually result in the throttle actuator being disabled. In addition, some systems use additional inputs to enhance throttle control. On Mercedes Benz systems, for example, the throttle opening is closed to a predetermined value if the ECM receives a brake pedal input together with an accelerator pedal input.

Notes

Emission Control Systems Diagnosis

The link between vehicle emissions and air pollution was first identified by studies that began in California during the early 1940s. By the end of that decade, researchers determined that the smog above California's Los Angeles Basin was the result of hydrocarbon and oxides of nitrogen emissions from motor vehicles. As automobile manufacturers looked into isolating the source of these gases, they discovered that vehicle exhaust also contained carbon monoxide (CO). While not a component of smog, CO is a byproduct of the combustion process and a highly toxic gas. In this section, we will study the three primary pollutants; including how they are produced and the systems designed to control them.



Under real world conditions, the combustion process fails to burn the entire air/fuel charge. As a result, several harmful pollutants are generated including unburned Hydrocarbons (HC), Carbon Monoxide (CO) and Oxides of Nitrogen (NOx).

COMBUSTION CHEMISTRY

The air we breathe consists of 78% nitrogen (N_2), 21% oxygen (O_2), and 1% other gases, such as carbon dioxide (CO_2). Gasoline is a liquid hydrocarbon (HC) that consists of a complex arrangement of hydrogen and carbon atoms. The air/fuel mixture that enters the combustion chamber is ultimately transformed through a chemical reaction brought about by heat and pressure. Every engine emits varying levels of the following gases:

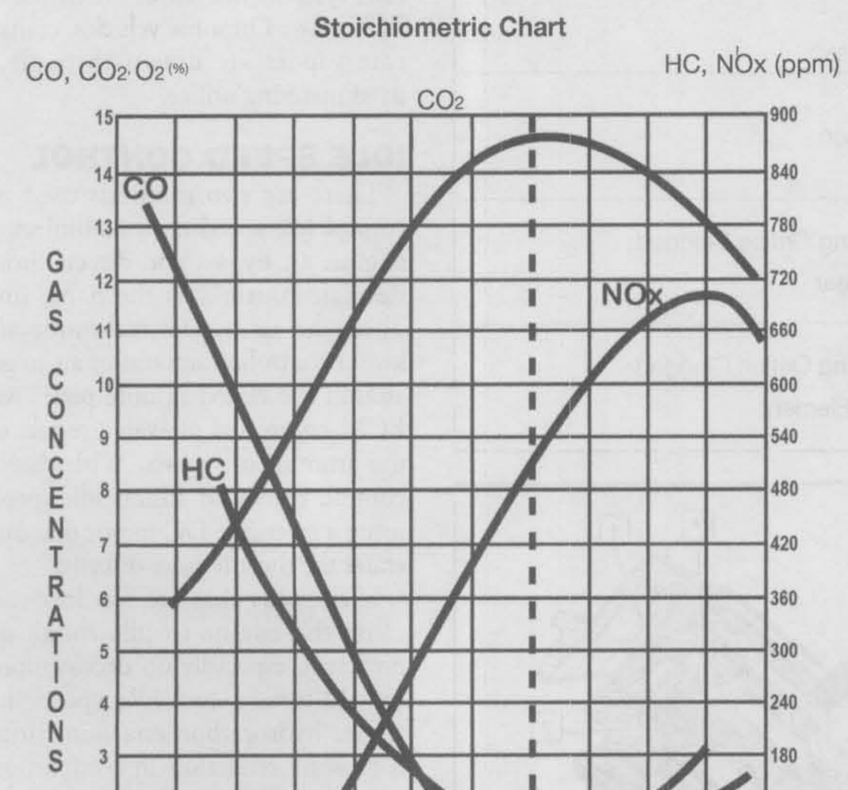
- Hydrocarbons (HC) — fuel molecules that pass through the engine without burning. Acceptable levels of HC are characteristic of the normal combustion process, while excessive HC levels result when a cylinder misfires
- Carbon Monoxide (CO) — forms when there is insufficient oxygen available to support proper combustion. CO is always the result of a rich mixture and can only be produced when combustion takes place. When a cylinder misfires, due to an open plug wire for example, CO cannot be produced since the hydrogen and carbon in the fuel have not been separated
- Carbon Dioxide (CO_2) — not considered a pollutant. However, it is classified as a greenhouse gas (contributes to global warming) because of its ability to absorb heat in the atmosphere. CO_2 is an indicator of combustion efficiency and typically measures between 13% and 17% under ideal conditions. Carbon Dioxide is also used as a verification gas during a state emissions test
- Oxygen (O_2) levels — can be compared to other gases to determine the relative richness or leanness of the mixture, as well as evaluate the condition of the catalytic converter. Oxygen levels will vary depending on the air/fuel ratio and combustion efficiency
- Oxides of Nitrogen (NOx) — result when combustion chamber temperatures exceed approximately 2500°F (1371°C). In this high-temperature environment, nitrogen and oxygen combine to form various NOx compounds such as Nitric Oxide (NO) and Nitrogen Dioxide (NO_2). Under the right atmospheric conditions, these compounds combine with hydrocarbons to form photochemical smog.
- When combustion occurs in a controlled environment, it is a pollutant-free process that yields oxygen, nitrogen, carbon dioxide, water and heat. A controlled environment allows all of the hydrocarbons to separate into their component parts of hydro-

gen and carbon. Both of these elements then combine with the oxygen required to form water and carbon dioxide. Except for absorbing heat, the nitrogen in the air, along with any remaining oxygen, exits the tailpipe unchanged. In the real world however, the air/fuel mixture never burns completely. This is due to variables such as charge density, cylinder temperature, and engine load, among others. Consequently, vehicles emit varying levels of hydrocarbons, carbon monoxide and oxides of nitrogen.

Stoichiometry

'Stoichiometry' is the branch of chemistry that deals with the relationships between compounds involved in a chemical reaction. While the word 'stoichiometry' may be unfamiliar to many technicians, its application to the internal combustion engine is universal. An air/fuel ratio of 14.7:1 represents the chemically correct proportions of air and fuel necessary to become a 'stoichiometric mixture.' This ideal combination of air and fuel allows an engine to produce the most power, best economy and least exhaust emissions per pound of gasoline. This is why modern-day fuel systems are designed to deliver a stoichiometric mixture under most operating conditions.

When the amount of air in the mixture is less than 14.7 lbs., the mixture is said to be 'rich.' Conversely, air in proportions greater than 14.7 lbs. will cause the mixture to be 'lean.' While maintaining the air/fuel ratio at 14.7:1 helps keep emissions at their lowest levels, a stoichiometric mixture is too lean for conditions such as cold starting and acceleration. In these situations, engines require a richer mixture to provide acceptable performance. To understand how emission levels react to changes in the air/fuel ratio, study the accompanying stoichiometric chart.



The stoichiometric chart shows exhaust gas production in relation to changing air/fuel ratios.

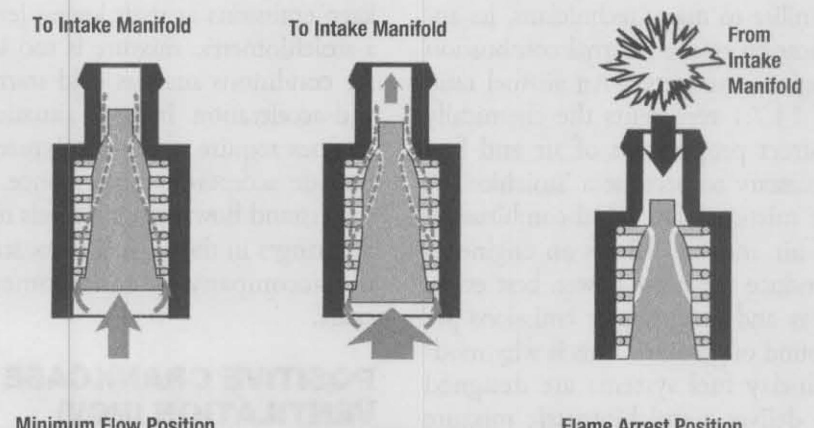
POSITIVE CRANKCASE VENTILATION (PCV)

During the power stroke, a portion of the combustion gases leak past the piston rings into the crankcase. Known as 'blowby,' these gases consist primarily of unburned fuel and water vapor. The purpose of the PCV system is to remove these gases before they condense and combine with the oil to form sludge. The PCV system is also necessary for relieving the pressure that develops in the crankcase as blowby gases are forced past the rings. If left unchecked, crankcase pressure will continue to rise until engine oil is forced past seals and gaskets.

The heart of the PCV system is a vacuum-controlled valve appropriately called the PCV valve. It contains a spring-loaded plunger that regulates the flow of vapors from the crankcase to the intake manifold. The valve is connected to manifold vacuum on one side and the crankcase on the other. At idle, when vacuum is high, the plunger is pulled toward the manifold-side of the valve. With the plunger seated in this position, crankcase vapors are drawn through tiny grooves cut into the plunger body. These grooves provide ample flow area, since the engine produces little blowby at closed throttle.

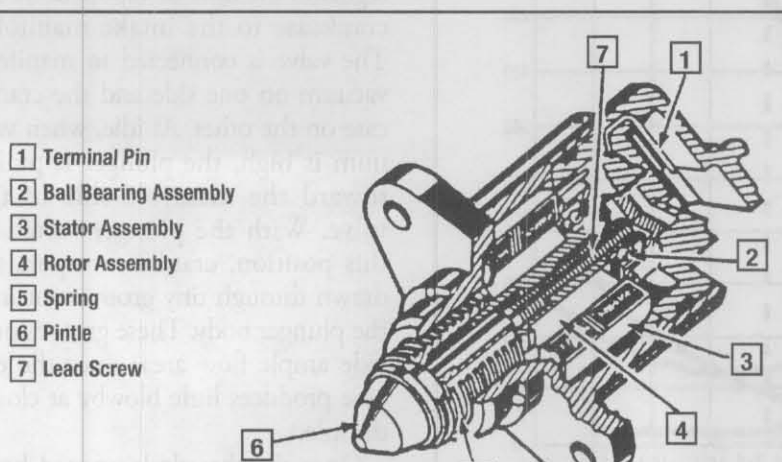
Once the throttle is opened however, the volume of blowby rises significantly. Consequently, more area is required to accommodate the

PCV Valve Operation



PCV Diagnostic Chart

Symptom	Cause
Rough Idle/Stalling	PCV Valve Or Metering Orifice Clogged Incorrect PCV Valve Leaking Vacuum Hose
Oil Siphoning	PCV Valve Stuck Open
Oil In Air Cleaner	PCV Valve Or Metering Orifice Clogged Excessive Engine Wear
Oil Leaks	PCV Valve Or Metering Orifice Clogged Restricted Breather Element



Cutaway of an idle air control valve showing electric motor and pintle.

increased flow. Since manifold vacuum drops during acceleration, the spring inside the PCV valve unseats the plunger to provide the required space. When the volume of blowby exceeds the flow capacity of the PCV valve, as is the case under extreme loads, the increase in crankcase pressure forces the gases through the breather tube into the air cleaner. At this point, the blowby is drawn back into the engine and reburned.

The PCV valve is also used to provide backfire protection. If the mixture should ignite inside the intake manifold, the resulting pressure will force the PCV plunger toward the crankcase end of the valve. This prevents the flame from entering the crankcase and igniting any fuel vapor. While all vehicles are equipped with a crankcase ventilation system, not all of them use a PCV valve. On some vehicles, crankcase vapors are drawn through a fixed metering orifice.

IDLE SPEED CONTROL

There are two methods used to control idle speed on a fuel-injected engine: air bypass and direct throttle plate control. As the name implies, the air bypass technique allows a controlled amount of air to go around the closed throttle plate. An ECM-controlled air valve regulates the amount of bypass. With direct control, the ECM adjusts idle speed using a reversible DC motor that operates the throttle plate directly.

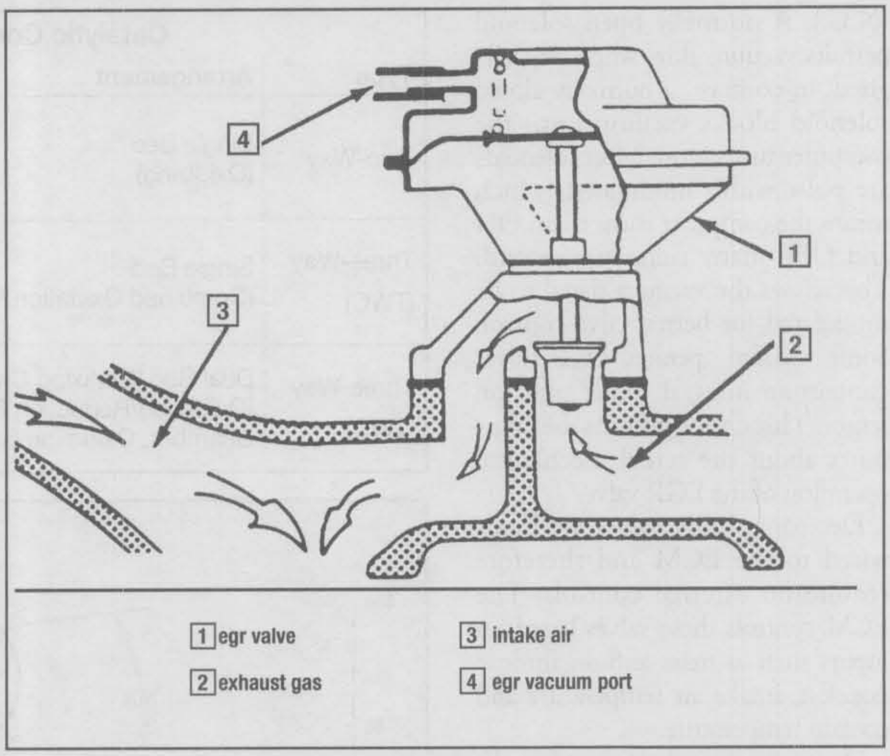
Idle speeds that are too low can cause the engine to idle rough or even stall, especially on deceleration. In addition, a low idle speed increases hydrocarbon emissions since it causes a reduction in combustion efficiency. When idle speed is too low, it is typically the result of throttle body contamination. Higher than normal idle speeds will cause harsh engagement when the transmission is placed into gear. This condition can result from a malfunctioning idle speed device, a binding throttle plate, or a vacuum leak (speed density systems only).

EXHAUST GAS RECIRCULATION (EGR)

Exhaust Gas Recirculation is a process designed to reduce combustion temperatures, which is the key to controlling oxides of nitrogen (NOx) emissions. The process involves the dilution of the air/fuel mixture with metered amounts of exhaust gas. There are two reasons that exhaust gas dilution is effective at reducing NOx. First, exhaust gas is 'inert' (non-reactive), since it does not contain the oxygen necessary to support combustion. Second, diluting the charge allows the inert gas to take up the space normally occupied by additional air and fuel. Consequently, a diluted mixture burns more slowly, reducing combustion temperatures by as much as 300°F (149°C). Because NOx output is relatively low at idle or when the engine is cold, it is not necessary to dilute the air/fuel mixture under these conditions. Rather, exhaust gas recirculation is used during acceleration and part throttle cruise, when combustion temperatures have the greatest tendency to increase.

The heart of the Exhaust Gas Recirculation system is the EGR valve. This device regulates the volume of exhaust gas entering the intake manifold. Depending on the system, the EGR valve may be vacuum-operated or electronic.

In a basic vacuum-operated design, a 'pintle' is attached to a spring-loaded diaphragm. The spring keeps the pintle closed until vacuum is applied to the area on top of the diaphragm. At this point, the diaphragm overcomes spring pressure and raises the pintle off its seat. Pintle travel, and consequently EGR flow, is directly proportional to the strength of the vacuum signal. As a result, there is no EGR at wide-open throttle, since vacuum is zero under this condition.



The EGR valve allows controlled amounts of exhaust gas into the intake manifold to dilute the air/fuel charge (vacuum-operated EGR valve shown).

Electronic EGR valves are hardwired to the computer and therefore require no vacuum signal. These valves contain one or more solenoids that open and close specifically sized metering orifices. The solenoids respond directly to command signals from the ECM.

Vacuum-operated EGR valves are typically used in conjunction with one or more computer-controlled solenoids. The solenoids are used to apply and vent the vacuum signal to the EGR valve. The computer operates the solenoids based on inputs it receives concerning manifold pressure, throttle position and coolant temperature. Control solenoids are typically identified as being normally open (N.O.) or normally closed

EGR Diagnostic Chart

Symptom	Cause
Spark Knock	Clogged Passages and/or Valve Stuck Closed
Rough Idle	Valve Not Seating
No-Start	Valve Stuck Wide Open
Off-Idle Hesitation	Improper Vacuum Control Or Exhaust Backpressure Too High (Positive Backpressure Valves Only)

(N.C.). A normally open solenoid permits vacuum flow when de-energized. In contrast, a normally closed solenoid blocks vacuum until the computer turns it on. Most solenoids are pulse-width modulated, which means the computer turns them ON and OFF many times per second. This allows the vacuum signal to be modulated for better valve control. Some vacuum-operated EGR valves contain an integral pintle position sensor. This device informs the computer about the actual mechanical operation of the EGR valve.

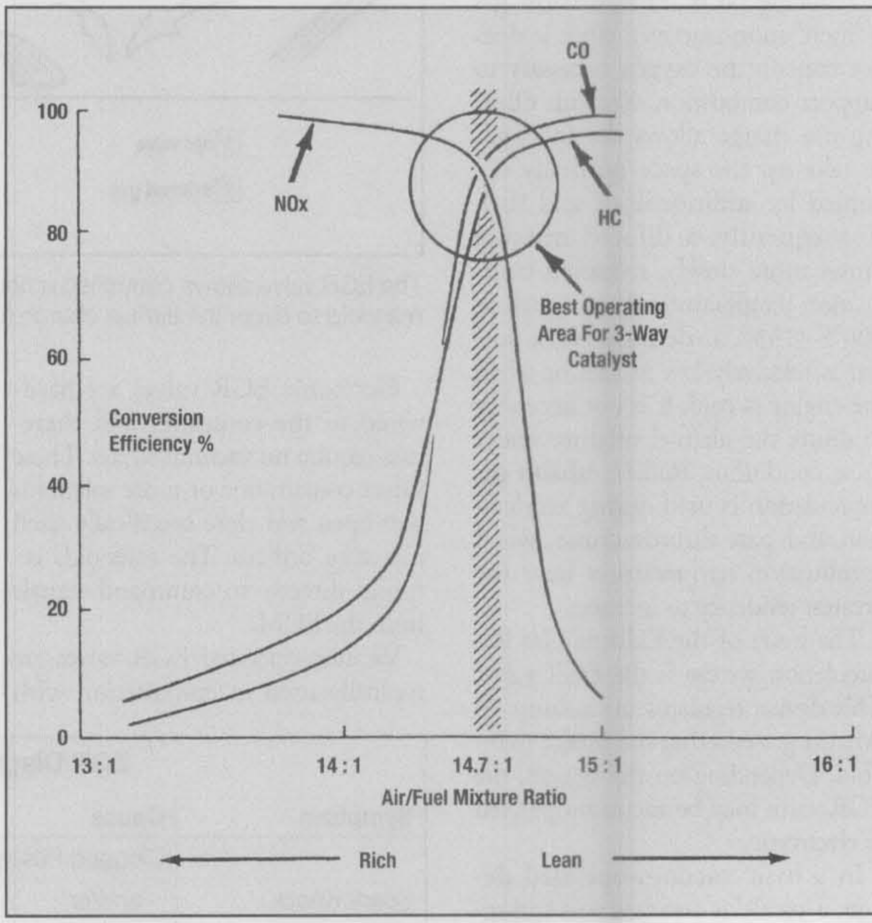
Electronic EGR valves are hardwired to the ECM and therefore require no external controls. The ECM controls these valves based on inputs such as mass airflow, throttle position, intake air temperature and coolant temperature.

Depending on the failure condition, a problem in the EGR system can result in excessive NOx or increased hydrocarbons. For example, if the valve fails to open or the passages become clogged, the lack of exhaust gas recirculation will cause increased combustion temperatures and high NOx emissions. However, if the valve does open but won't seal properly when closed, the engine will misfire at closed throttle. As a result, hydrocarbon emissions will become excessive.

Because of the wide range of controls used by manufacturers to operate the EGR valve, consulting the appropriate service manual is a must for diagnosing an EGR-related problem. Regardless of the system however, the EGR valve should always remain closed at idle, wide-open throttle and whenever the engine is cold.

Catalytic Converter Designs

Type	Arrangement	Controlled
Two-Way	Single Bed (Oxidizing)	HC & CO
Three-Way (TWC)	Single Bed (Combined Oxidation & Reduction)	HC, CO, NOx
Three-Way (TWC)	Dual Bed W/Mixing Chamber (Oxidation/Reduction Bed, Air Injection Chamber, Oxidation Bed)	HC, CO, NOx



A catalytic converter operates at peak efficiency when the air/fuel ratio is maintained at 14.7:1.

CATALYTIC CONVERTER

The catalytic converter is an integral part of the vehicle's exhaust system. Located between the manifold(s) and the muffler, the converter is intentionally placed closer to the engine. This allows it to capture the exhaust gases while they're still very hot. This is important, since the 'light-off temperature' of the typical converter is at least 400°F (204°C). There are two basic types of converters including 'pellet' and 'monolithic.' Monolithic converters are smaller than pellet-type catalysts, produce less exhaust backpressure, and reach light-off temperature more quickly.

A catalytic converter contains small amounts of noble metals that act as 'catalysts.' These metals include platinum, palladium and rhodium. To assist in the oxidation and reduction processes, many converters produced since the early 1990s contain another element from the periodic table known as 'cerium.' Cerium is used to stabilize catalyst operation and enhance the effectiveness of the noble metals. It accomplishes this by storing and releasing oxygen in the exhaust system. The performance of a catalytic converter is directly related to the air/fuel ratio. When the mixture is lean, the converter is more efficient at reducing HC and CO. However, lean mixtures cause an increase in combustion chamber temperature, resulting in higher NOx emissions. In contrast, the lack of oxygen in a rich mixture makes it more difficult for the converter to oxidize HC and CO, while the additional fuel inhibits the production of NOx. That's why a stoichiometric mixture is essential for the converter to operate at peak efficiency.

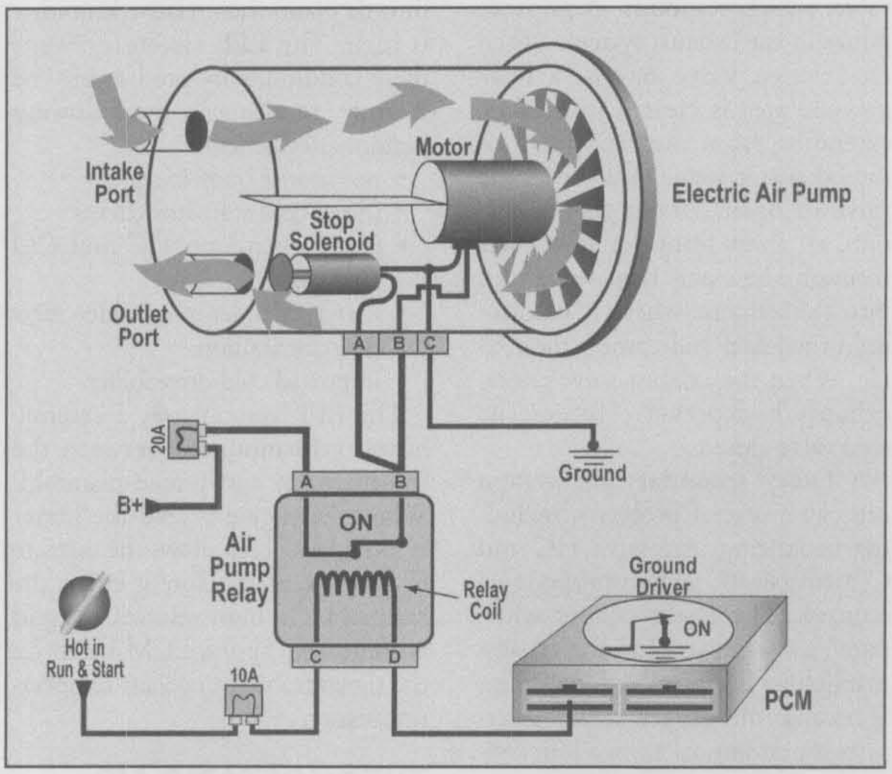
The most common symptom of a defective catalytic converter is the inability to pass a state emissions test. This is especially true regarding NOx failures. Although there are several different tests that can help determine converter efficiency, the best way to be sure the converter is the source of an emissions failure is to eliminate all other possibilities first. On OBD II vehicles, the catalyst efficiency monitor is the best barometer for evaluating converter performance. A defective converter can create other concerns beyond excessive emissions including:

- No-Start/Hard Start (clogged converter)
- Lack of Power (restricted converter)
- Knocking or Rattling (broken monolith).

SECONDARY AIR INJECTION

Secondary Air Injection is a post-combustion emission control system. The heart of the system is the air pump. Under certain conditions, pump air is delivered to the exhaust manifold(s), and on some vehicles, the catalytic converter. Check valves are used to prevent hot exhaust gases from backing up into the pump. When air is being supplied to the exhaust manifold for example, the check valve opens under pump pressure. When pump air is directed away from that location, exhaust system backpressure forces the check valve closed. The addition of air to the post-combustion gases provides secondary oxidation. This process helps convert residual hydrocarbons and carbon monoxide into water vapor and carbon dioxide. There are several types of pumps used by vehicle manufacturers.

A belt-driven pump is a vane-type pump driven by a belt attached to the crankshaft. The pump provides low-pressure air directly to the exhaust manifold and catalytic converter (if applicable). Intake air enters the pump through a centrifugal filter positioned behind the drive pulley. The filter consists of small fins that deflect airborne contaminants away from the pump as it rotates. On most vehicles with this system, computer-controlled solenoids are used to direct airflow to a specific location depending on engine operating conditions. Typically, air is directed to the exhaust manifolds during open loop, and then switched to the catalytic converter during closed loop. Under certain conditions, such as heavy acceleration, the addition of oxygen to the exhaust could cause a backfire. To prevent this, pump air is diverted to the air cleaner or a remote silencer during this time. On some vehicles, the pump is equipped with an electromagnetic clutch, similar to an A/C compressor. The clutch allows the air pump to operate on demand, which reduces engine power losses and fuel consumption. Power to the clutch is provided through a computer-controlled relay.



When the engine is running in open loop, the ECM completes the ground circuit for the Air Pump Relay coil. This causes the relay contacts to close, and allows battery voltage to be applied to terminals A and B of the Electric Air Pump. At this point, the pump is running and the stop solenoid retracts to open the outlet port. Air is now delivered to the exhaust manifolds. (This circuit is typical of most electric air pump systems.)

EFE Diagnostic Chart

Symptom	Cause
Spark Knock and/or Hesitation	Heater grid will not turn off, causing abnormally high mixture temperatures.
Lack of Power	Heater grid melted, causing a restriction below the throttle plate(s).

In the early 1990s, many manufacturers began using electric air pumps on engines that required air injection to meet federal emissions standards. The pump is controlled by the ECM and is typically activated during open loop operation. This is when hydrocarbon and carbon monoxide emissions are greatest.

The pulse-air system eliminates the horsepower penalty associated with a belt-driven pump. The heart of the pulse-air system is the reed valve, which responds to pressure pulses in the exhaust system. When an exhaust valve opens, a low-pressure area is created in the line extending from the reed valve to the exhaust system. This causes the valve to open. Under this condition, air flows from the air cleaner through the open reed valve and into the exhaust where it oxidizes unburned fuel and carbon monoxide. When the exhaust valve closes, exhaust backpressure forces the reed valve closed.

A faulty secondary air system can cause several problems including backfiring, excessive HC and CO emissions, and improper fuel control. The latter occurs when pump air is delivered to the exhaust manifold(s) during closed loop. This is because the oxygen sensor interprets the additional air as a lean condition. In response, the computer commands a rich mixture. Eventually, this condition will lead to poor fuel economy, rotten egg odor, an overheated converter and/or an illuminated MIL.

EARLY FUEL EVAPORATION (EFE)

The EFE system is designed to improve fuel vaporization at low ambient temperatures. It is used on many vehicles equipped with Throttle Body Injection (TBI). In order for a liquid to change to a vapor, a specific quantity of heat is required. Unless a heat source is provided for the mixture when the engine is cold, the fuel will remain in liquid form and pool inside the intake manifold. In addition, moisture can freeze on the cold throttle plate when relative humidity is high. The EFE system prevents these conditions by pre-heating the mixture, resulting in the following performance benefits:

- no throttle body icing
- leaner cold-start fuel curves
- lower open-loop HC and CO emissions
- better cylinder-to-cylinder mixture distribution
- improved cold driveability.

The EFE system uses a ceramic heater grid mounted between the throttle body and intake manifold. When the engine is cold the heater is turned on. This allows the mixture to be pre-heated before it enters the manifold. On most vehicles, the grid is controlled by the ECM based on the signal from the coolant temperature sensor.

THERMOSTATIC AIR CLEANER (TAC)

The thermostatic air cleaner is designed to improve fuel vaporization at low ambient temperatures. It is used on virtually all engines equipped with throttle body injection, and provides the same benefits as the Early Fuel Evaporation system. There are three main components used in the TAC system including a heat stove, hot air supply hose (or pipe), and thermostatic air cleaner assembly. The thermostatic air cleaner incorporates a damper to establish the source of incoming air. The heat stove is a sheet metal enclosure surrounding the exhaust manifold, while the hot air supply hose serves as the link between the stove and air cleaner. There are two types of thermostatic air cleaner systems in use.

Vacuum Operated TAC

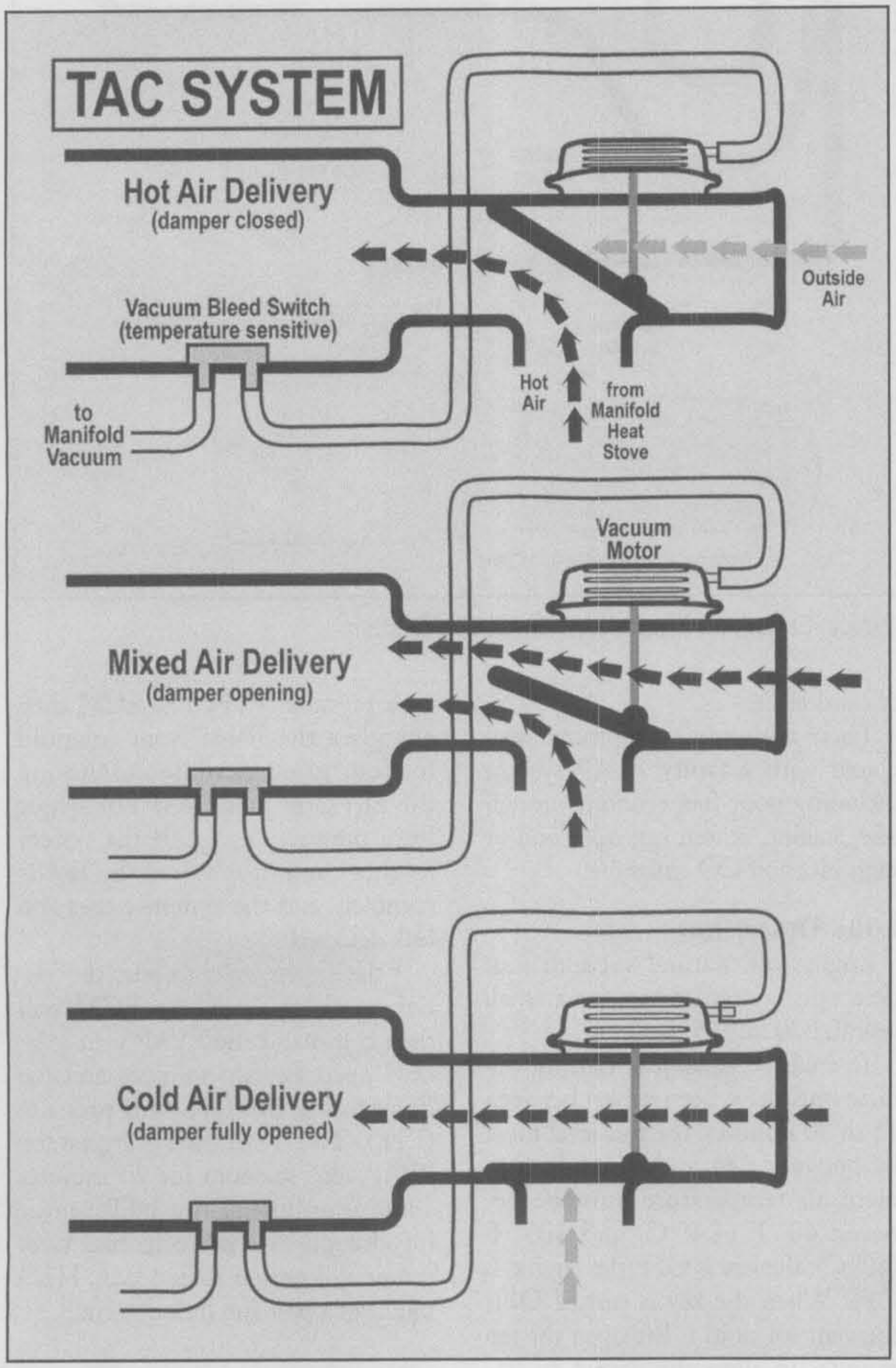
On this system, the damper is controlled by a spring-loaded actuator mounted on top of the air cleaner snorkel. Vacuum to the actuator is regulated by a temperature switch inside the air cleaner. When the engine is cold, manifold vacuum is applied to the actuator and the damper closes off the snorkel. This allows only hot air into the air cleaner. As the heated air acts upon the temperature switch, the vacuum signal is bled off. This causes the actuator to begin opening the damper. During this time, a mixture of heated air from the manifold and cold outside air is drawn into the engine. Once the vacuum signal drops below a calibrated threshold, the damper opens completely. Under this condition, only outside air is drawn into the engine.

Self-Regulating TAC

This system uses a sealed wax actuator to operate a spring-loaded damper. The actuator relies on the expansion and contraction of wax to move an internal piston. When the engine is cold, the wax is solid. Under this condition the piston is relaxed, and the spring keeps the damper closed (no outside air). As hot air from the heat stove acts upon the actuator, the wax inside begins

TAC Diagnostic Chart

Symptom	Cause
Poor Throttle Response and/or Spark Knock	Damper stuck in the closed position
Poor Cold Driveability	Damper stuck in the open position



to melt. This change from a solid to a liquid causes the wax to expand and move the piston forward against spring tension. As a result, the piston begins opening the damper door. During this time, a mixture of heated air from the manifold and cold outside air is drawn into the engine. Once the wax is completely melted, the piston opens the damper door fully. As a result, only outside air is drawn into the engine.

EVAPORATIVE EMISSION CONTROL

The Evaporative Emissions (EVAP) system prevents fuel vapors (hydrocarbons) from being released into the atmosphere. The centerpiece of the system is the charcoal canister, which traps and stores fuel vapors from the tank when the engine is off. In addition, onboard refueling vapor recovery (ORVR) captures fuel vapors as the vehicle is being fueled. Once the engine is running and the conditions are appropriate, the vapors are purged from the canister and drawn into the engine. Here the vapors are burned in the normal combustion process. Once the engine is shut down, the integrity of the EVAP system is monitored. Engine off natural vacuum (EONV) monitors natural changes in the fuel system pressures, and is one method used to detect system leakage.

The following components are used in a typical evaporative emissions system:

Charcoal Canister

The canister contains activated charcoal and serves as the storage receptacle for fuel vapor. Charcoal has the ability to absorb fuel vapors and then release them when fresh air passes over it.

Fill Control Tube

This tube runs along the top of the filler neck. It is used to shut off the pump nozzle during refueling once the tank is approximately 90% filled. This provides an expansion space at the top of the tank.

Gas Cap

The gas cap contains a pressure/vacuum relief valve. This device allows the tank to breathe in the event of a system malfunction, such as a kinked vent line.

Purge Solenoid

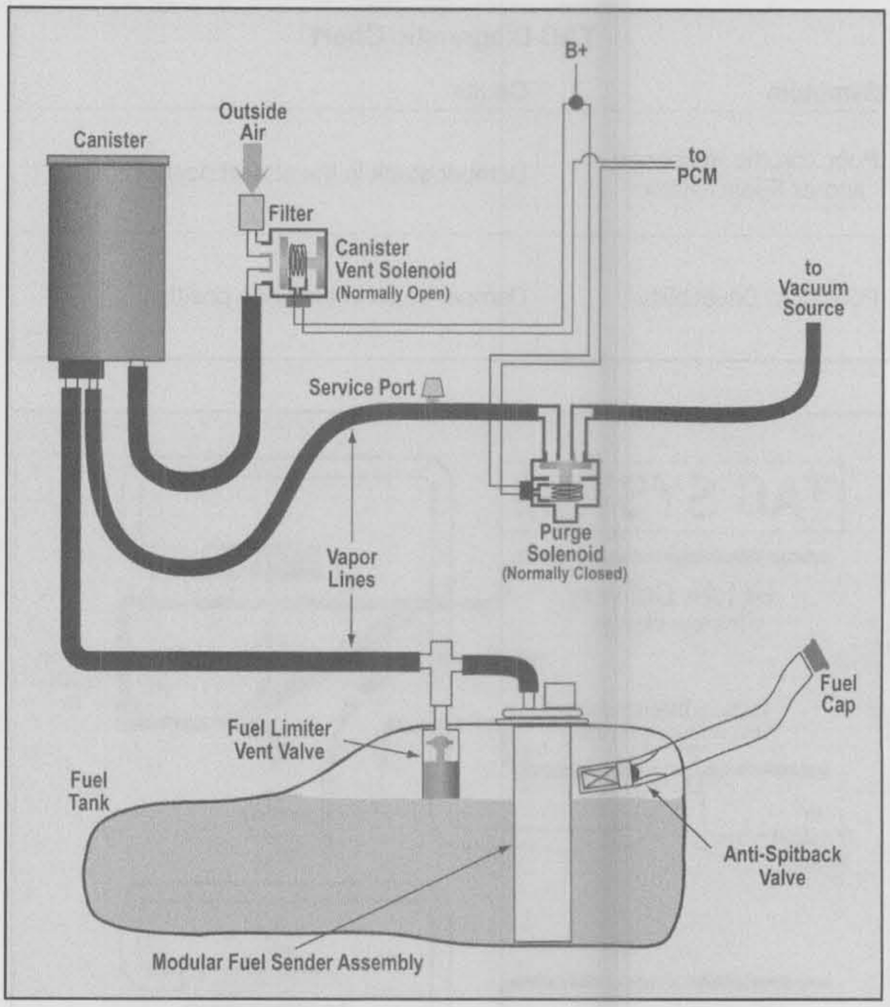
The purge solenoid controls the vacuum signal to the purge valve based on computer commands. Depending on the application, the solenoid may be normally closed (N.C.) or normally open (N.O.). A normally open solenoid permits vacuum flow when de-energized. In contrast, a normally closed solenoid blocks vacuum until it is activated by the computer. The ECM will typically command purge when the engine is warm, the vehicle is traveling above a pre-determined speed, and the throttle is opened a specified amount. Enhanced EVAP systems will also use the purge solenoid to test the system for leaks.

Purge Valve

This is a vacuum-controlled valve that regulates the flow of fuel vapor from the canister into the engine. When the purge valve is opened, the difference between manifold pressure and atmospheric pressure allows outside air to flow through the canister and carry the stored vapors into the engine.

Canister Vent Solenoid

The vent solenoid is only used on vehicles with enhanced EVAP systems (leak detection). The solenoid is located in the fresh air supply hose to the sealed charcoal canister. On a non-enhanced EVAP system, the canister is open to the atmosphere. The canister vent solenoid is normally open, allowing fresh air to be drawn into the canister. The ECM activates the solenoid during the EVAP leak test to block the entrance of outside air.



Typical Enhanced Evaporative Emissions System.

There are several symptoms associated with a faulty EVAP system including poor fuel economy, rough idle, stalling, rotten egg odor and/or high HC and CO emissions.

Leak Detection

Engine off, natural vacuum leak detection is used to test for a small leak (0.020 in./0.5 mm).

To enable a small leak test, the vehicle must have been driven between 15 to 90 minutes, the fuel level must be between 1/4 and 3/4 full, ambient air temperature must be between 40° F (4.4° C) and 105° F (40° C), the key is OFF/the engine is OFF. When the key is turned OFF, the vent solenoid is left open for ten minutes to allow the system to stabilize. The ECM then notes the fuel tank pressure (FTP) The ECM then energizes the EVAP vent solenoid for four minutes while monitoring the fuel tank pressure (FTP) sensor for a pressure change. If the system reaches the target value, the test is complete and the system passes (no leak detected).

If the system fails to pass the initial small leak test, the ECM will then command the EVAP vent solenoid open for two minutes and the ECM notes the fuel tank pressure (FTP). The ECM then energizes the EVAP vent solenoid for 20 minutes while monitoring the FTP sensor for change. A change in fuel tank pressure of greater than 1.0 in. H2O indicates a pass (no leak detected).

***Note:** While leak detection strategies may vary on different vehicles* *the description above would be applicable to the ASE Composite Vehicle Type 4.*

Vacuum decay is used to test for a large leak (.040 in./1.0 mm). The enable criteria for the large leak test are a cold start with engine temperature below 86° F (30° C), fuel level between 1/4 and 3/4 full, ambient air temperature must be between 40° F (4.4° C) and 105° F (40° C), and the engine is running. The ECM turns on the EVAP vent solenoid, blocking the fresh air supply to the EVAP canister. The EVAP purge solenoid is turned on to draw a slight vacuum on the entire EVAP system, including the fuel tank. Then the EVAP purge solenoid is turned off to seal the system. The monitor uses the Fuel Tank (EVAP) Pressure Sensor signal to determine if the EVAP system has any leaks. After the testing is completed, the EVAP vent solenoid is turned off to relieve the vacuum.

A small leak DTC will set if a sufficient change in fuel tank pressure is not achieved during the small leak test. A large leak DTC will set if sufficient vacuum is not created, or decays too rapidly, or does not decay quickly at the conclusion of the large leak test.

I/M Failure Diagnosis

The advances made in engine management and emission control technology over the past two decades have resulted in the steady decline of vehicle pollutants. Unfortunately, while HC, CO and NOx output per vehicle is lower than ever before, emissions reductions have been offset by the extraordinary increase in the number of cars and trucks on the road. However, the vehicle pollution problem is not as much a result of increased volume as it is a consequence of greater numbers of maintenance-neglected vehicles. Inspection/Maintenance (I/M) programs help weed out these vehicles by subjecting them to an annual emissions test. According to the requirements of the 1977 Clean Air Act, implementation of I/M programs is compulsory in those areas of the United States unable to meet the National Ambient Air Quality Standards (NAAQS).

TWO-SPEED IDLE (TSI) TEST

The two-speed idle test is a no-load check of a vehicle's hydrocarbon and carbon monoxide emissions. The test is intended primarily for checking vehicles with all-wheel drive or full-time four-wheel drive, since these systems cannot be operated on a dynamometer. In addition, vehicles with traction control systems may be given a two-speed idle test if the system cannot be deactivated. In some states, two-speed idle testing is used to check 1983 and older vehicles, as well as 1982 and newer trucks with a Gross Vehicle Weight Rating (GVWR) above 8500 pounds.

As the name suggests, the two-speed idle test is performed at different engine speeds while the vehicle is idle (no load applied). During the high-speed phase of the test, the engine is operated between 2200 and 2800 rpm for 30-90 seconds. This is followed by the low-speed mode, in which engine speed is reduced to a maximum of 1100 rpm and the vehicle is tested for an additional 30 seconds. In the event the vehicle fails either phase of the initial test, a 'second chance' test is administered based on the 'first chance' test results. For example, if the vehicle fails the initial high-speed test but passes during the low-speed phase, the engine will be tested again at high speed.

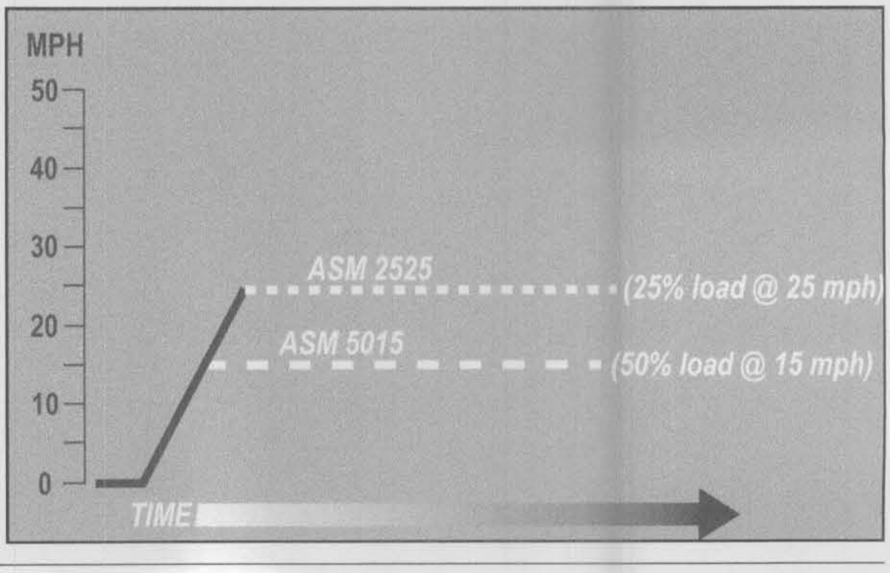
The two-speed idle test is performed using a four-gas analyzer. Gas readings are recorded in the fractional amounts of parts-per-million (ppm) for HC, and percentage (%) for CO, CO2 and O2. The test is automatically aborted if the engine stalls out, or the CO and CO2 readings combined equal less than six percent. If the test is cancelled due to the latter, it indicates that one of the following conditions exist:

- The exhaust probe is not fully inserted into the tailpipe
- Air is being drawn into the exhaust system (leak)
- The air/fuel ratio is too lean.

ACCELERATION SIMULATION MODE (ASM)

Acceleration Simulation Mode is a steady-state, loaded mode test, in which the vehicle is checked for hydrocarbon, carbon monoxide and oxides of nitrogen emissions. The test is performed with the vehicle running on a variable weight dynamometer at a steady speed under a pre-determined load. Since the energy required to overcome inertia varies according to vehicle weight, the variable weight dyno matches the load (roller resistance) to the vehicle's gross weight. The heavier the vehicle, the greater the applied load.

The ASM test can be considered a distant relative of the Federal Test Procedure (FTP). During one phase of the FTP, the vehicle is required to accelerate at 3.3 mph per second. To achieve this rate of acceleration, the

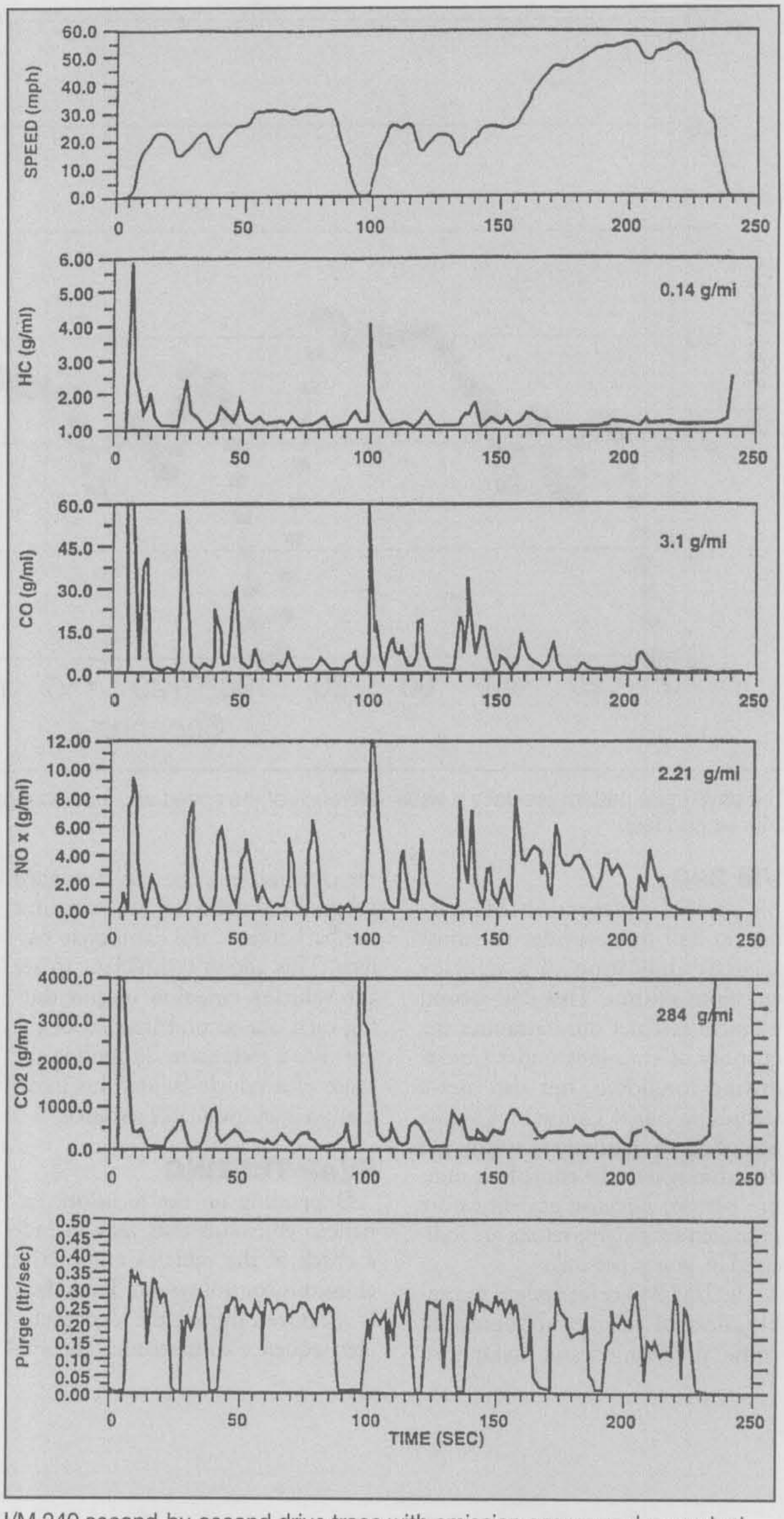


dynamometer applies a specific load to the vehicle based on its GVWR. For an ASM test, the rate of acceleration is far less than that of the FTP. Consequently, the applied load is also less.

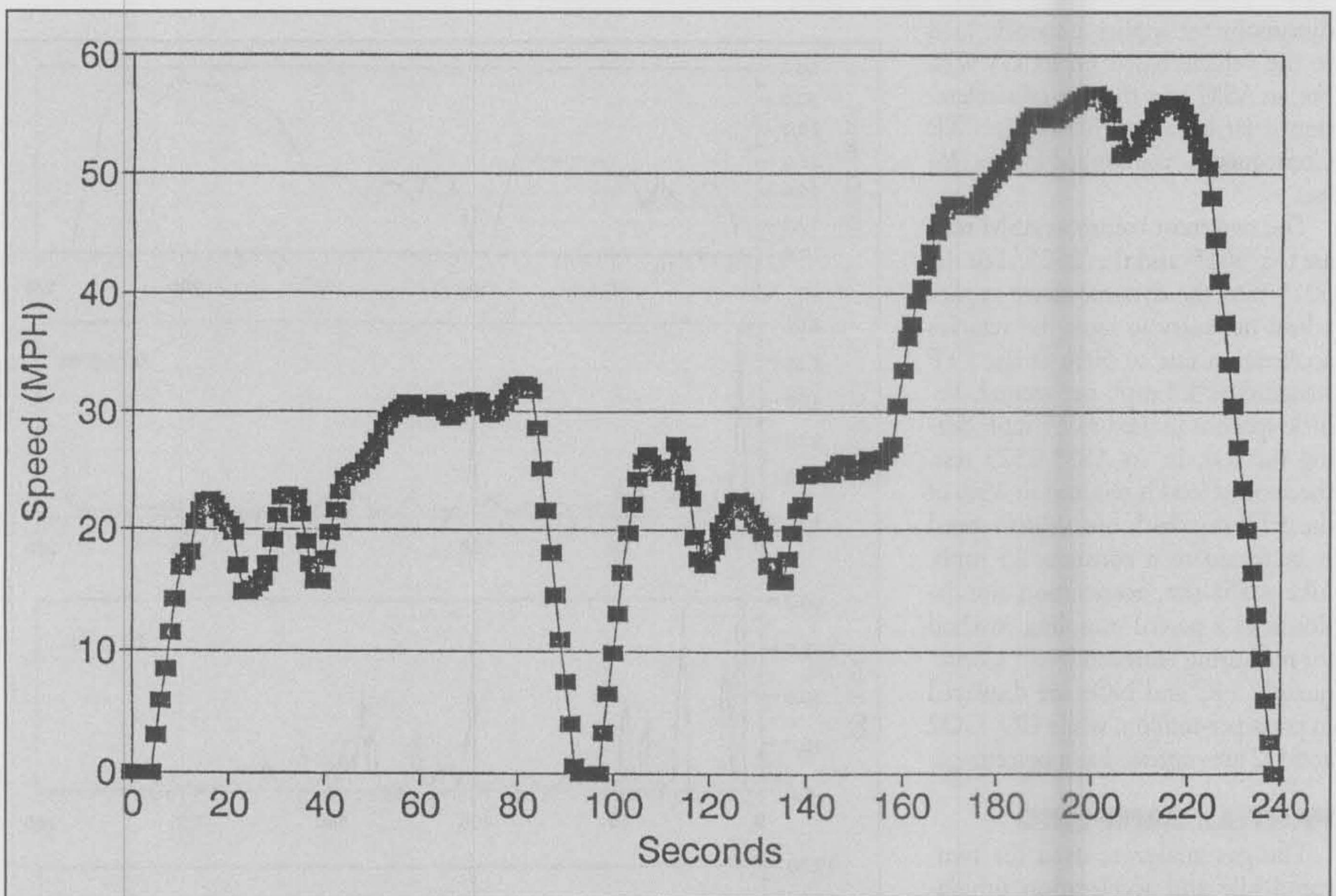
The two most common ASM tests are the '5015' and the '2525.' For the 5015 test, the dynamometer applies a load necessary to limit the vehicle's acceleration rate to 50% of the FTP standard of 3.3 mph per second. Vehicle speed is limited to 15 mph during the test. In an ASM 2525 test, the applied load is reduced to 25% of the FTP standard, but vehicle speed is increased to a constant 25 mph. Like a TSI test, acceleration simulation uses a partial sampling method for measuring emission levels. Consequently, HC and NOx are displayed in parts-per-million, while CO, CO2 and O2 are expressed as a percentage.

PARTIAL SAMPLING

The gas analyzers used for two-speed idle and acceleration simulation tests use 'partial stream sampling' to measure exhaust emissions. With this method, the exhaust sample is evaluated based on gas concentration levels. For example, HC and NOx readings are based on the exhaust sample being divided into one million parts. Therefore, the ppm reading shows how concentrated the gas sample is with either pollutant. Percentage readings essentially indicate the same thing using a different value. However, neither ppm nor percentage indicates the actual mass of pollutants being discharged into the atmosphere. Moreover, the sample itself is only representative of the vehicle's total exhaust gas output. To illustrate this, consider two vehicles; one equipped with a 3.0L V6 and the other with a 6.0L V8. Let's say that the CO reading for each vehicle is 2%. Although the CO readings are identical, the vehicle with the larger displacement engine is actually emitting twice the amount of carbon monoxide into the atmosphere.



I/M 240 second-by-second drive trace with emission gasses and purge test values.



The drive cycle pattern provides a visual reference of the speed and load changes that occur throughout the 240-second test.

I/M 240

The I/M (Inspection/Maintenance) 240 test provides the most accurate indication of a vehicle's emissions output. This 240-second transient test not only measures the quantity of emissions under various driving conditions, but also uses a technique called Constant Volume Sampling to maintain a steady gas flow throughout the entire four-minute period. Because emissions are measured by weight, results are indicated in 'grams-per-mile.'

The I/M 240 drive cycle is a combination of idling, acceleration, cruise, deceleration and braking. At the conclusion of the test, a detailed printout plots the test results against the backdrop of the drive cycle pattern. This allows technicians to see the vehicle's emission output during each one-second interval of the test. For a technician diagnosing the cause of a vehicle failure, this information is an invaluable resource.

EVAP TESTING

Depending on the location, enhanced emissions tests may include a check of the vehicle's evaporative emissions control system. Purge flow is measured during the dynamometer sequence to determine the volume of fuel vapor removed from the canister. As long as the volume exceeds state requirements, the vehicle passes the purge test. The EVAP system may also be checked for leaks. This is accomplished by pressurizing the system to 0.5 psi (14 inches of water) with nitrogen. Once pressurized, the equipment monitors the rate of pressure drop. A pass is recorded as long as the pressure remains above 8 inches of water following the two-minute test period. In some states, the gas cap is also checked for leaks with a tool resembling a cooling system pressure tester.

Notes

ADVANCED ENGINE PERFORMANCE SPECIALIST TEST L1 COMPOSITE VEHICLE TYPE 4

This ASE Composite Vehicle Type 4 was conceived and built by technical committees of industry experts to accommodate high level diagnostic questions on the L1 test. While some aspects of this Composite Vehicle may appear similar to vehicles from a number of manufacturers, it is important to understand this vehicle is a unique design and is NOT intended to represent any specific make or model.

This reference document should be used when answering questions identified as Composite Vehicle questions. It is critical when taking the test to adhere closely to the features and specifications of the composite vehicle.

***Note:** All testing is performed at sea level unless otherwise indicated. The reference materials and questions for this test use terms and acronyms that are consistent with SAE standards J1930 and J2012.*

POWERTRAIN

ENGINE

- Generic, four-stroke, V6 design.
- Equipped with four chain-driven overhead camshafts, 24 valves, hydraulic valve lifters, variable intake camshaft timing, and variable intake valve lift.

TRANSMISSION

- 6-speed, automatic transaxle with overdrive.
- Controlled by a transmission control module (TCM).
- 3 planetary gear sets, 5 clutch packs, and a single one-way clutch.
- 6 forward gears and 1 reverse gear.
- A torque converter transmits power from the engine to the transmission and is capable of lock-up in 3rd, 4th, 5th, and 6th gears.
- Contains an electronic pressure control (EPC) solenoid, 5 shift solenoids, and a torque converter clutch solenoid.

CONTROL MODULES

ENGINE CONTROL MODULE (ECM)

- Calculates ignition and fuel requirements, controls engine actuators and provides inputs to other modules to provide the desired driveability, fuel economy, and emissions control.
- Receives data input from other control modules and sensors.
- Controls the vehicle's charging system.
- Receives power from the battery and ignition switch and provides a regulated 5-volt supply for most of the engine sensors.
- Engine control features include coil-on-plug ignition, mass airflow, sequential port fuel injection, variable valve timing, variable valve lift, electronic throttle actuator control (TAC), air/fuel ratio sensors, a data communications bus, a vehicle anti-theft immobilizer system, a natural vacuum leak detection EVAP system and an onboard refueling vapor recovery (ORVR) system.
- The control system software and OBD diagnostic procedures stored in the ECM can be updated using factory supplied calibration files and PC-based interface software, along with a scan tool or a reprogramming device that connects the PC to the vehicle's data link connector (DLC).
- Contains a 120 Ω terminating resistor for the data bus.

FUEL PUMP CONTROL MODULE (FPCM)

- Communicates with the ECM over a Local Area Network (LAN).
- ECM provides a 5-volt enable signal to the FPCM to enable fuel pump operation: for two seconds with the ignition switch in the RUN position; when the ignition switch is in the START position; when the engine speed (CKP) signal is above 100 rpm.
- FPCM changes the volume of fuel supplied by the fuel pump by varying the duty-cycle of the voltage supplied to the fuel pump.
- LOW fuel pump speed command = fuel pump supply voltage duty-cycled at 50 %.
- HIGH fuel pump speed command = fuel pump supply voltage duty-cycled at 100 %.
- HIGH fuel pump speed is commanded: During key ON/engine OFF prime; with the engine cranking; under high engine load; during operation at low charging system voltage.
- If there is a communication fault on the LAN bus, and the 5-volt enable signal is present at the FPCM, the FPCM will default to HIGH speed fuel

pump operation.

- Actual fuel pump duty cycle is monitored by the FPCM and is reported by the FPCM to the ECM via the LAN bus.

ECM	OFF	LOW	HIGH
FPCM (Feedback)	0%	50%	100%

TRANSMISSION CONTROL MODULE (TCM)

- Provides the correct transmission outputs for desired driveability, fuel economy, and emissions control.
- Receives data input from other control modules and sensors.
- Provides data inputs to other control modules including vehicle speed and gear selection.
- Provides its own regulated 5-volt supply.
- Performs all OBD II transaxle diagnostic routines and stores transaxle DTCs.
- The control system software and OBD diagnostic procedures stored in the TCM can be updated in the same way as the ECM.
- Failures that result in a pending or confirmed DTC related to any of the following components will cause the TCM to default to fail-safe mode: transmission range switch, electronic pressure control (EPC), shift solenoids, turbine shaft speed sensor, and the vehicle speed sensor.
- The TCM will also default to fail-safe mode if it is unable to communicate with the ECM.
- When in fail-safe mode, the TCM commands maximum line pressure and turns off all transmission solenoids. The transmission then defaults to 5th gear and the torque converter clutch will be disabled.

INSTRUMENT CLUSTER MODULE (ICM)

- Receives data input from other control modules to display engine rpm, vehicle speed, fuel level, and coolant temperature.
- Includes a Malfunction Indicator Lamp (MIL) and an immobilizer indicator.
- If the instrument cluster fails to communicate with the ECM and TCM, the MIL is continuously lit.
- Contains a 120 Ω terminating resistor for the data bus.

IMMOBILIZER MODULE

- Communicates with the ECM.
- Provides ignition key information.
- *See IMMOBILIZER ANTI-THEFT SYSTEM on page 50.*

SYSTEMS

ELECTRONIC THROTTLE CONTROL SYSTEM

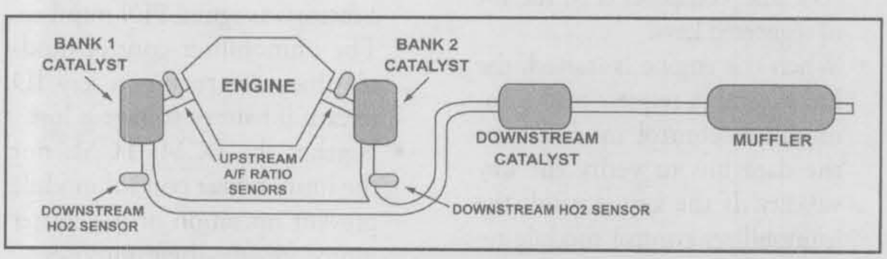
- The vehicle does not have a mechanical throttle cable, a cruise control throttle actuator, or an idle air control (IAC) valve.
- Throttle opening at all engine speeds and loads is controlled directly by a throttle actuator control (TAC) motor mounted on the throttle body housing.
- Dual accelerator pedal position (APP) sensors provide input from the vehicle operator, while the actual throttle angle is determined using dual throttle position (TP) sensors.
- If one APP sensor or one TP sensor fails, the ECM will turn on the malfunction indicator lamp (MIL) and limit the maximum throttle opening to 35 %.
- If both APP sensors or both TP sensors fail, or a correlation error occurs, the ECM will turn on the MIL and disable the electronic throttle control.
- When disabled by the ECM, the electronic throttle control system will default to limp-in operation: the spring-loaded throttle plate will return to a default position of 15 % throttle opening; the TAC value on the scan tool will indicate 15 %; it will have a fast idle speed of 1400 to 1500 rpm, with no load and all accessories off.
- Normal no load idle range is 850 to 900 rpm at 5 % to 10 % throttle opening.
- No idle relearn procedure is required after component replacement or loss of voltage to the ECM.

EXHAUST SYSTEM

A single exhaust system that is configured using a Y-pipe that connects two front catalysts, a single downstream catalyst, and a muffler.

FUEL DELIVERY SYSTEM

- Consists of an ECM, a fuel pump control module (FPCM), a fuel pressure sensor (FPS), and a fuel pump assembly.
- Sequential Multiport Fuel Injection (SFI).
- Returnless fuel supply with the electric fuel pump assembly mounted inside the fuel tank.
- Fuel pressure regulator attached to the fuel pump assembly to



Composite vehicle exhaust system.

control fuel pressure.

- The fuel pump control module (FPCM) supplies duty-cycled, feed-side voltage to the fuel pump.
- The fuel pump control module (FPCM) provides feedback to the ECM via a LAN bus.
- Key ON/engine OFF fuel pressure = 58 to 62 psi (400 to 427 kPa).
- Fuel system pressure should be between 58 to 62 psi (400 to 427 kPa) during all operating conditions.

IGNITION SYSTEM

- Distributorless Ignition (EI) with six ignition coils (coil-on-plug).
- Firing Order: 1-2-3-4-5-6
- Cylinders 1, 3, and 5 are on Bank 1; Cylinders 2, 4, and 6 are on Bank 2.
- Ignition timing is not adjustable.
- Crankshaft position (CKP) sensor input is used for base timing calculation.
- ECM controls ignition timing.
- Ignition coil drivers are integrated into the ECM.

IMMOBILIZER ANTI-THEFT SYSTEM

- When the ignition switch is turned on, the immobilizer control module sends a challenge signal through the antenna around the ignition switch to the transponder chip in the ignition key. The transponder key responds with an encrypted key code. The immobilizer control module then decodes the key code and compares it to the list of registered keys.
- When the engine is started, the ECM sends a request to the immobilizer control module over the data bus to verify the key validity. If the key is valid, the immobilizer control module responds with a "valid key" message. The ECM continues normal engine operation.
- Once the engine is started with a valid key, the immobilizer system cannot cause engine shutdown.
- If an attempt is made to start the vehicle with an invalid ignition key, the immobilizer control module sends a message over the data bus to the instrument cluster to flash the anti-theft indicator lamp.
- Without a "valid key" message from the immobilizer control module within 2 seconds of engine startup, the ECM will disable the fuel injectors to kill the engine. Cycling the key off and cranking the engine again will result in engine restart and stall.
- The immobilizer control module and ECM each have their own unique internal ID numbers used to encrypt their messages, and are programmed at the factory to recognize each other. If either module is replaced, the scan tool must be used to program the replacement module, using the VIN, the date, and a factory-assigned PIN number.
- Up to eight keys can be registered in the immobilizer control module.
- Each key has its own unique internal key code.
- If only one valid key is available, or if all keys have been lost, the scan tool can be used to delete lost keys and register new keys. This procedure also requires the VIN, the date, and a factory-assigned PIN number.
- The immobilizer control module does not require a key ID relearn if battery voltage is lost.
- Neither the ECM, TCM, nor the immobilizer control module prevent operation of the starter motor for anti-theft purposes.

ON-BOARD REFUELING VAPOR RECOVERY (ORVR) EVAP SYSTEM

- Causes fuel tank vapors to be directed to the EVAP charcoal canister during refueling, so that fuel vapors do not escape into the atmosphere.
- The following components have been added to the traditional EVAP system for ORVR capability: a one inch I.D. fill pipe, a one-way check valve at the bottom of the fill pipe, an ORVR vapor control valve inside the fuel tank, and a 1/2 inch I.D. vent hose from the ORVR vapor control valve to the canister.
- The ORVR vapor control valve has a float that rises to seal the vent hose when the fuel tank is full. It also prevents liquid fuel from reaching the canister and blocks fuel from leaking in the event of a vehicle roll-over.

FUEL INJECTION SYSTEM

- Sequential port fuel injection, single injector for each cylinder
- Fuel injectors are located in the intake manifold ports near the intake valves.
- Fuel injectors are ground-side controlled.

STARTING MODE

- When the ignition switch is turned to RUN, the ECM sends a 5-volt enable signal to the FPCM for two seconds to build pressure in the fuel system.
- If an rpm signal is not received by the ECM within two seconds, the 5-volt enable signal to the FPCM is turned OFF.
- After the two second prime, the ECM will maintain the 5-volt enable signal to the FPCM with the ignition switch in the START position, or as long as the engine speed (CKP) is 100 rpm or more.

CLEAR FLOOD MODE

- During cranking, when the accelerator pedal is fully depressed (pedal position of 80 % or greater) and the engine speed is below 400 rpm, the ECM turns off the fuel injectors.

RUN MODES: OPEN AND CLOSED LOOP, FUEL CUT OFF

- OPEN LOOP - In open loop, the ECM does not use the air/fuel ratio sensor signals. Instead, it calculates the fuel injector pulse width based on MAF and engine temperature. The system will stay in open loop until all of these conditions are met: Ten seconds have elapsed since start up; Throttle position is less than 80 %.
- CLOSED LOOP - When the ECM receives valid air/fuel ratio signals and the throttle is open less than 80 %, the system will be in closed loop.
- FUEL CUT OFF MODE - The ECM will turn off the fuel injectors if any of the following are met: Vehicle speed reaches 110 mph; Engine speed exceeds 6000 rpm while driving; Engine speed exceeds 3000 rpm in PARK/NEUTRAL; Vehicle is decelerating with engine speed greater than 1500 rpm, engine temperature is greater than 120° F (49° C), and the throttle is closed (APP less than 10 %).

ABSOLUTE LOAD

- The ECM uses the MAF sensor input and stored engine displacement information versus engine speed to calculate the air charge moving through the engine against a theoretical maximum.
- Values of absolute load correlate with volumetric efficiency at wide open throttle (WOT).
- Displayed as a percentage in scan data.
- Normal absolute load at WOT is 95 %.
- Typical values at normal idle are approximately 15 %.

VARIABLE VALVE LIFT CONTROL SYSTEM

- Variable valve lift is used for improved engine efficiency, performance and emissions control.
- The ECM controls variable valve lift in relation to engine rpm. Below 3000 rpm, the VVL system will command motor position to 0 %, base valve lift. Above 3000 rpm, the VVL system will command motor position to 100 % resulting in an additional 4 mm of valve lift.
- Each bank has its own 2-wire motor with position sensors for feedback.
- The VVL position sensors will read 0.50 V at low lift (0 % command) and 4.50 V at high lift (100 % command).
- On each intake camshaft, a DC motor is attached to a rod which operates a fulcrum attached to the rocker arms, effectively changing the rocker arm ratio.
- If there are any faults detected in the VVL system, the VVL will be commanded to the low lift position.
- Anytime the TAC system is in failsafe mode (disabled), the VVL will also be commanded to the lowest lift position.
- The VVL system is not used to control idle speed.

VARIABLE VALVE TIMING SYSTEM

- A single timing chain drives the intake and exhaust cams of both banks of the engine.
- Intake camshaft timing is continuously variable using a hydraulic actuator attached to the front end of each intake camshaft. Engine oil flow to each hydraulic actuator is controlled by a camshaft position actuator control solenoid.
- The exhaust camshaft timing is fixed.
- Camshaft timing is determined by the ECM using the crankshaft position (CKP) sensor and camshaft position sensor (CMP 1 and CMP 2) signals.
- At idle, the intake camshafts are fully retarded and valve overlap is zero degrees.
- At higher speeds and loads, the intake camshafts can be advanced up to 40 crankshaft degrees.
- Each intake camshaft has a separate camshaft position sensor, hydraulic actuator, and control solenoid.
- If little or no oil pressure is received by a hydraulic actuator (typically at engine startup, at idle speed, or during a fault condition), it is designed to mechanically default to the fully retarded position (zero valve overlap), and is held in that position by a spring-loaded locking pin.

INPUTS – SENSORS

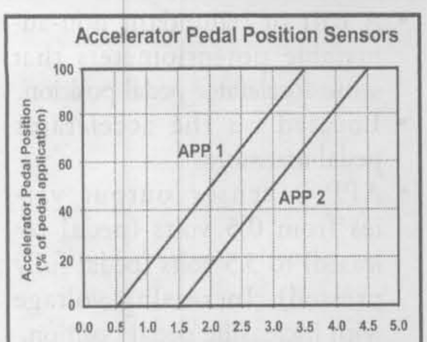
ACCELERATOR PEDAL POSITION (APP 1 AND APP 2) SENSORS

- A pair of redundant non-adjustable potentiometers that sense accelerator pedal position.
- Located on the accelerator pedal assembly.
- APP 1 sensor output varies from 0.5 volts (pedal released) to 3.5 volts (pedal fully pressed); Increasing voltage with increasing pedal position.
- APP 2 sensor output varies from 1.5 volts (pedal re-

leased) to 4.5 volts (pedal fully pressed); Increasing voltage with increasing pedal position, offset from the APP 1 sensor signal by 1.0 volt.

- ECM interprets an APP of 80 % or greater as a request for wide open throttle.
- A circuit failure of one APP sensor will set a DTC and the ECM will limit the maximum throttle opening to 35 %.
- A circuit failure of both APP sensors, or a correlation error, will set a DTC and disable the TAC.
- When disabled, the spring-loaded throttle plate will return to the default 15 % position (fast idle).

Accelerator Pedal Position (% applied)	APP 1 Sensor Voltage	APP 2 Sensor Voltage
0	0.50	1.50
5	0.65	1.65
10	0.80	1.80
15	0.95	1.95
20	1.10	2.10
25	1.25	2.25
40	1.70	2.70
50	2.00	3.00
60	2.30	3.30
75	2.75	3.75
80	2.90	3.90
100	3.50	4.50

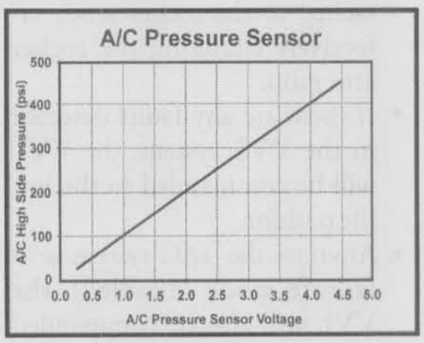


Accelerator pedal position versus APP voltages.

A/C PRESSURE SENSOR

- Three-wire solid-state sensor for A/C system high-side pressure.
- Sensor output varies from 0.25 volts at 25 psi to 4.50 volts at 450 psi.
- Used as input for A/C compressor clutch control, radiator fan control, and idle speed compensation.
- ECM will disable A/C compressor operation if the pressure is below 40 psi or above 420 psi.
- Located on the A/C high-side vapor line.

A/C High Side Pressure (psi)	Sensor Voltage
25	0.25
50	0.50
100	1.00
150	1.50
200	2.00
250	2.50
300	3.00
350	3.50
400	4.00
450	4.50



A/C Pressure Sensor Voltage Graph

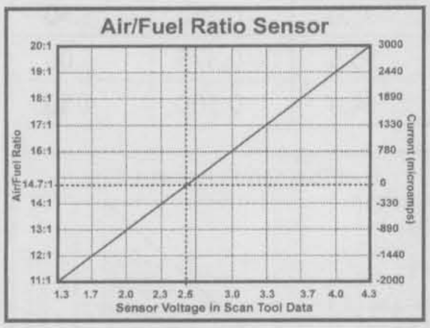
A/C ON/OFF REQUEST SWITCH

- Normally open (N.O.) switch that closes when A/C compressor operation is requested.
- Status is used by ECM.
- Located in the climate control unit on the instrument panel.

AIR/FUEL RATIO SENSORS (AFRS 1/1 AND AFRS 2/1)

- Planar-type AFR sensor used by the ECM to measure the air/fuel ratio of the exhaust stream.
- AFRS 1/1 located on the Bank 1 exhaust manifold (cylinders 1, 3, and 5).
- AFRS 2/1 located on the Bank 2 exhaust manifold (cylinders 2, 4, and 6).
- Perfectly balanced air/fuel mixture at 14.7:1 (Lambda 1) = 2.5 volts displayed on the scan tool.
- Lean air/fuel mixture at 20:1 (Lambda 1.36) = 4.3 volts displayed on the scan tool.
- Rich air/fuel mixture at 11:1 (Lambda 0.75) = 1.3 volts displayed on the scan tool.
- ECM monitors polarity and quantity of current to the sensor to determine air/fuel ratio in the exhaust.
- Perfectly balanced air/fuel mixture at 14.7:1 (Lambda 1) = no sensor current produced.
- Rich air/fuel mixture = the sensor produces a negative current between zero and -2000 microamps.
- Lean air/fuel mixture = the sensor produces a positive current between zero and +3000 microamps.
- Battery voltage is continuously supplied to the air/fuel ratio sensor heaters when ignition switch is ON.
- The ECM supplies a pulse width modulated ground to the heaters to control the temperature of the sensor. The duty cycle displayed on the scan tool represents the percent of heater current on time.
- The ECM monitors the AFR heater current.
- The normal AFRS heater resistance is 2-6 Ω at 68° F (20° C).

Air/ Fuel Ratio	Lambda	Scan Tool Voltage	Current (micro-amps)
20:1	1.36	4.3	+3000
19:1	1.30	4.0	+2440
18:1	1.23	3.7	+1890
17:1	1.16	3.3	+1330
16:1	1.09	3.0	+780
15:1	1.02	2.7	+220
14.7:1	1.00	2.5	0
14:1	0.96	2.3	-330
13:1	0.89	2.0	-890
12:1	0.82	1.7	-1440
11:1	0.75	1.3	-2000



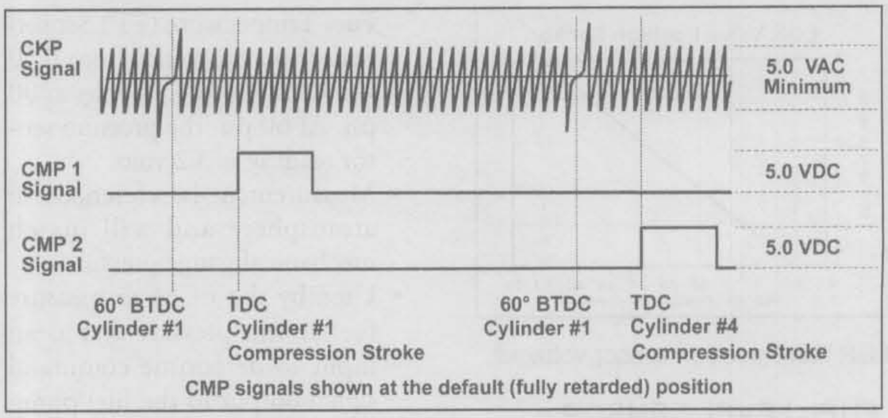
Graph showing voltage and current of the A/F ratio sensor at different air fuel ratios.

BRAKE PEDAL POSITION (BPP) SWITCH

- Normally open (N.O.) switch that closes when the brake pedal is pressed/applied.
- Status is used by TCM.
- Located on the brake pedal.

CAMSHAFT POSITION SENSORS (CMP 1 AND CMP 2)

- A pair of three-wire solid state Hall-effect sensors that generate a signal once per intake camshaft revolution.
- Located at the rear of each valve cover, the sensors are triggered by an interrupter on the intake camshafts.
- The leading edge of the bank 1 CMP signal occurs on the cylinder 1 compression stroke, and the leading edge of the bank 2 CMP signal occurs on the cylinder 4 compression stroke.
- When the intake camshafts are fully retarded (zero valve overlap), the CMP signals switch from 0 to +5 volts at top dead center compression stroke of cylinders 1 and 4 respectively. When the intake camshafts are fully advanced (maximum valve overlap), the signals switch at 40 crankshaft degrees before top dead center. These signals allow the ECM to determine fuel injector and ignition coil sequence, as well as the actual intake valve timing.
- Loss of one CMP signal will set a DTC, and valve timing defaults to the fully retarded position (zero valve overlap). If neither CMP signal is detected during cranking, the ECM stores a DTC and disables the fuel injectors, resulting in a no-start condition.
- The sensors are not adjustable.
- The diagram at the bottom of this page shows the CKP and CMP sensor signal waveforms with the camshafts at the default (fully retarded) position.



CMP signals shown at the default (fully retarded) position

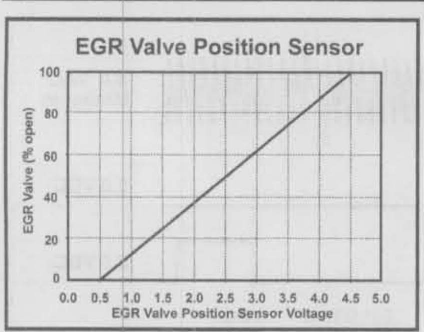
CRANKSHAFT POSITION (CKP) SENSOR

- A magnetic-type sensor that generates 35 pulses for each crankshaft revolution.
- Located on the front engine cover.
- Triggered by a reluctor wheel mounted on the crankshaft, behind the balancer pulley.
- Each tooth is ten crankshaft degrees apart, with one space for a "missing tooth" located at 60 degrees before top dead center of cylinder number 1.
- The diagram at the bottom of this page shows the CKP sensor signal waveform.

EGR VALVE POSITION SENSOR

- A three-wire non-adjustable potentiometer that senses the position of the EGR valve pintle.
- Sensor output varies from 0.50 volts (valve fully closed) to 4.50 volts (valve fully open).
- Located on top of the EGR valve.

EGR Valve (% open)	Sensor Voltage
0	0.50
25	1.50
50	2.50
75	3.50
100	4.50

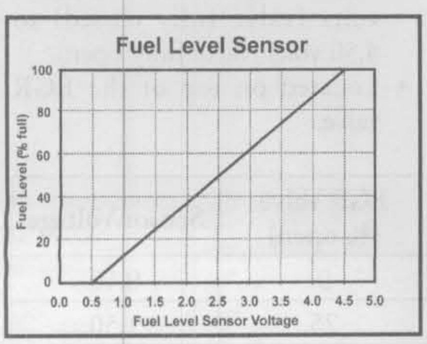


EGR Valve position sensor voltages.

FUEL LEVEL SENSOR

- A potentiometer that is used to determine the fuel level.
- Sensor output varies from 0.5 volts at 0 % (empty tank) to 4.5 volts at 100 % (full tank).
- Fuel tank at 1/4 full = 1.5 volts.
- Fuel tank at 3/4 full = 3.5 volts.
- Used by the ECM when testing the evaporative emission (EVAP) system.
- Located in the fuel tank.

Fuel Level (% full)	Sensor Voltage
0	0.50
25	1.50
50	2.50
75	3.50
100	4.50

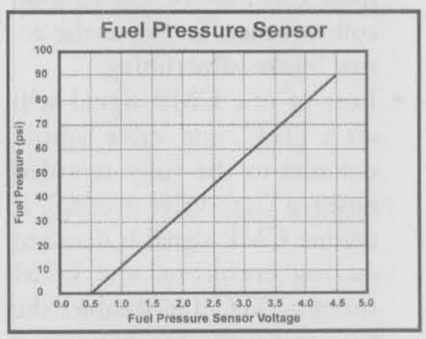


Fuel level sensor voltages.

FUEL PRESSURE (FP) SENSOR

- A five-wire, combined, solid-state sensor used to monitor system pressure.
- Located on the fuel rail. (Also see: Temperature Sensors > Fuel Temperature (FT) Sensor)
- Sensor output varies from 0.50 volts at 0 psi to 4.50 volts at 90 psi. At 60 psi, the pressure sensor reading is 3.2 volts.
- Measurement is referenced to atmosphere and will match mechanical gauge pressure.
- Used by the ECM to measure fuel system pressure and as an input to determine command signal output to the fuel pump control module (FPCM).

Fuel Pressure (psi)	Sensor Voltage
0	0.50
10	0.80
20	1.40
30	1.75
40	2.25
50	2.75
60	3.20
70	3.65
80	4.10
90	4.50

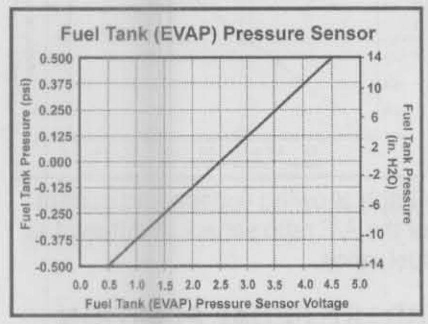


Fuel Pressure Sensor voltages

FUEL TANK (EVAP) PRESSURE SENSOR

- Senses vapor pressure or vacuum in the EVAP system compared to atmospheric pressure.
- Sensor output varies from 0.5 volts at -0.500 psi (-14 in. H2O) when under vacuum, to 4.5 volts at 0.500 psi (14 in. H2O) when pressurized. With no pressure or vacuum in the fuel tank (fuel cap removed), the sensor output is 2.5 volts.
- Used by the ECM for OBD evaporative emission system diagnostics only.
- Located on top of the fuel tank.

Fuel Tank (EVAP) (in.H2O)	Pressure (psi)	Sensor Voltage
-14.0	-0.500	0.50
-10.5	-0.375	1.00
-7.0	-0.250	1.50
-3.5	-0.125	2.00
0.0	0.000	2.50
3.5	0.125	3.00
7.0	0.250	3.50
10.5	0.375	4.00
14.0	0.500	4.50



EVAP sensor voltages

KNOCK SENSORS

- Two-wire piezoelectric sensors that generate an AC voltage spike when engine vibrations within a specified frequency range are present.
- Located on each bank of the engine block.
- The signal is used by the ECM to retard ignition timing when knock is detected.
- The sensor signal circuit normally measures 2.5 volts DC with the sensor connected

HEATED OXYGEN SENSOR (HO2S 1/2 and HO2S 2/2)

- Electrically heated zirconia sensors.

- Mounted in the exhaust pipe (downstream) after the front catalytic converters on each bank.
- Used for OBD monitoring of catalytic converter efficiency.
- Sensor output varies from 0.0 to 1.0 volt.
- No bias voltage is applied to the sensor signal circuits by the ECM.
- With the key ON and engine OFF, the sensor reading is zero volts.
- Battery voltage is continuously supplied to the oxygen sensor heaters when the ignition switch is ON.
- Once the engine is started, the ECM will provide the ground for the downstream oxygen sensor heaters after two minutes of continuous engine operation.
- Normal oxygen sensor heater resistance is 8-12 Ω at 68° F (20° C).

IGNITION SWITCH

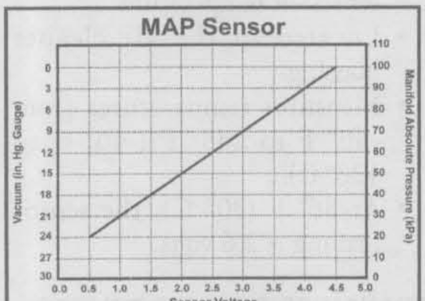
- Provides ignition key position input to the ECM.
- With the key in the RUN position and engine speed greater than 400 rpm, if an ignition switch fault is detected the engine will continue to run.

	IGN SW Pin a / ECM Pin 221	IGN SW Pin b / ECM Pin 222	IGN SW Pin c / ECM Pin 223	IGN SW Pin d / ECM Pin 224
OFF	0.0 V	B+	B+	B+
ACC	B+	0.0 V	B+	B+
RUN	B+	B+	0.0 V	B+
START	B+	B+	B+	0.0 V

MANIFOLD ABSOLUTE PRESSURE (MAP) SENSOR

- Senses intake manifold absolute pressure.
- Located on the intake manifold.
- Used by the ECM for OBD diagnostics and barometric pressure (BARO) calculation.
- ECM determines atmospheric altitude (BARO) during key ON/engine OFF.
- The normal BARO for the vehicle is sea level; 30 in. Hg (101 kPa).
- MAP sensor output varies between 4.5 volts (0 in. Hg vacuum / 101 kPa pressure) to 0.5 volts (24 in. Hg vacuum / 20.1 kPa pressure).
- Sensor output is 4.50 volts (0 in. Hg vacuum / 101 kPa pressure) at key ON/engine OFF at sea level.
- Sensor output is 1.17 volts at sea level with no load idle at 20 in. Hg vacuum (33.5 kPa pressure).
- ECM uses MAP input at wide open throttle (WOT) engine operation to update BARO measurement.

Vacuum at sea level (in. Hg. Gauge)	Manifold Absolute Pressure (kPa)	Sensor Voltage
0	101.3	4.50
3	91.2	4.00
6	81.0	3.50
9	70.8	3.00
12	60.7	2.50
15	50.5	2.00
18	40.4	1.50
21	30.2	1.00
24	20.1	0.50

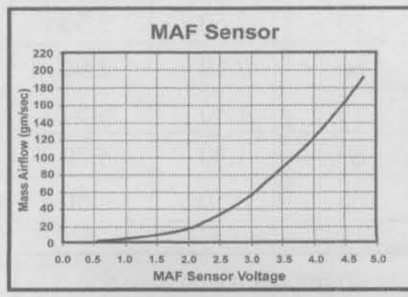


MAP sensor voltages.

MASS AIRFLOW (MAF) SENSOR

- A hot-wire design that senses airflow into the intake manifold.
- Located on the air cleaner housing.
- Sensor output varies from 0.2 volts (0 gm/sec) at key ON/engine OFF, to 4.8 volts (175 gm/sec) at maximum airflow.
- At sea level, no-load idle (850 rpm), the sensor reading is 0.85 volts (3.0 gm/sec).

Mass Airflow (gm/sec)	Sensor Voltage
0	0.20
2	0.70
4	1.00
8	1.50
15	2.00
30	2.50
50	3.00
80	3.50
110	4.00
150	4.50
175	4.80



Mass Airflow (MAF) sensor voltages.

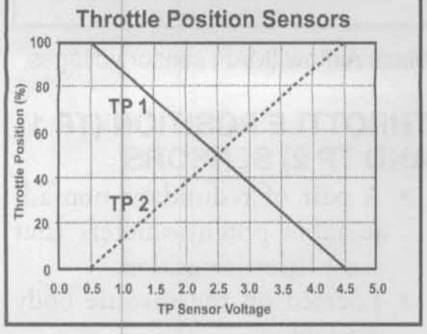
THROTTLE POSITION (TP 1 AND TP 2) SENSORS

- A pair of redundant non-adjustable potentiometers that sense throttle position.
- Located on the throttle body assembly.
- The TP 1 sensor output varies from 4.5 volts at closed throttle to 0.5 volts at maximum throttle opening (decreasing voltage with

increasing throttle position).

- The TP 2 sensor signal varies from 0.5 volts at closed throttle to 4.5 volts at maximum throttle opening (increasing voltage with increasing throttle position).
- A circuit failure of one TP sensor will set a DTC and the ECM will limit the maximum throttle opening to 35 %.
- Circuit failure of both TP sensors, or a correlation error, will set a DTC, and will disable TAC.
- When disabled, the spring-loaded throttle plate returns to the default 15 % position (fast idle).

Throttle Position (% open)	TP 1 Sensor Voltage	TP 2 Sensor Voltage
0	4.50	0.50
5	4.30	0.70
10	4.10	0.90
15	3.90	1.10
20	3.70	1.30
25	3.50	1.50
40	2.90	2.10
50	2.50	2.50
60	2.10	2.90
75	1.50	3.50
80	1.30	3.70
100	0.50	4.50



Throttle position sensor voltages.

TEMPERATURE SENSORS

ENGINE COOLANT TEMPERATURE (ECT) SENSOR

- A negative temperature coefficient (NTC) thermistor that senses engine coolant temperature.
- Located in the engine block water jacket.
- Measures temperatures from -40° F to 248° F (-40° C to 120° C).
- At 212° F (100° C), the sensor reading is 0.46 volts.

FUEL TEMPERATURE (FT) SENSOR

- A five-wire, combined, solid-state sensor used to monitor fuel system temperature. A negative temperature coefficient (NTC) thermistor that senses fuel rail temperature.
- Located on the fuel rail. (Also see Fuel Pressure (FP) Sensor).
- Measures temperatures from -40° F to 248° F (-40° C to 120° C).
- At 86° F (30° C), the temperature sensor reading is 2.6 volts.
- The signal is used by the ECM to measure fuel system temperature and as an input to determine command signal output to the fuel pump control module (FPCM).

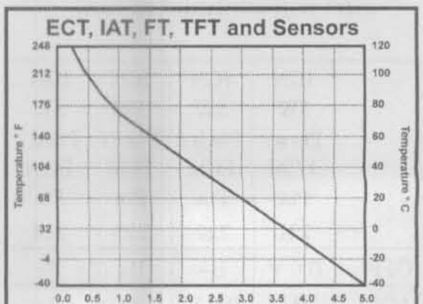
INTAKE AIR TEMPERATURE (IAT) SENSOR

- A negative temperature coefficient (NTC) thermistor that senses air temperature.
- Located in the air cleaner housing.
- Measures temperatures from -40° F to 248° F (-40° C to 120° C).
- At 86° F (30° C), the sensor reading is 2.6 volts.

TRANSMISSION FLUID TEMPERATURE (TFT) SENSOR

- A negative temperature coefficient (NTC) thermistor that senses transmission fluid temperature.
- Located in the transaxle oil pan.
- Measures temperatures from -40° F to 248° F (-40° C to 120° C).
- At 212° F (100° C), the sensor reading is 0.46 volts.
- This signal is used by the TCM to delay shifting when the fluid is cold, and control torque converter clutch operation when the fluid is hot.

Temperature ° F	Temperature ° C	Sensor Voltage
248	120	0.25
212	100	0.46
176	80	0.84
150	66	1.34
140	60	1.55
104	40	2.27
86	30	2.60
68	20	2.93
32	0	3.59
-4	-20	4.24
-40	-40	4.90



Voltage chart for temperature sensors.

TRANSMISSION RANGE (TR) SWITCH

- A five-position switch that indicates the position of the transaxle manual select lever: PARK, REVERSE, NEUTRAL, DRIVE (D), or LOW (L).

- Located on the transaxle housing.
- Used by the TCM to control line pressure, upshifting, and downshifting.

TRANSMISSION TURBINE SHAFT SPEED (TSS) SENSOR

- A magnetic-type sensor that senses rotation of the torque converter turbine shaft (input/mainshaft).
- Located on the transaxle housing.
- Generates a signal that increases in frequency as transmission input speed increases.
- Used by the TCM to control torque converter clutch operation and sense transmission slippage.

VARIABLE VALVE LIFT SYSTEM SENSORS

- Two, three-wire, non-adjustable potentiometers that sense the variable valve lift motor shaft position for each variable valve lift motor.
- Located in the variable valve lift motor assemblies.
- Sensor output will read 0.50 V at low lift (0 % command) and 4.50 V at high lift (100 % command).
- Normal ECM command of the motors at idle is base lift. At wide open throttle (WOT), maximum load, the ECM commands maximum additional lift.

VEHICLE SPEED SENSOR (VSS)

- A magnetic-type sensor that senses rotation of the final drive.
- Located on the transaxle housing.
- Generates a signal that increases in frequency as vehicle speed increases.
- The TCM uses the VSS signal to control upshifts, downshifts, and the torque converter clutch.
- The TCM communicates the VSS signal over the data communications bus to the ECM to control high speed fuel cutoff, and to the Instrument Cluster for speedometer operation.
- The signal is displayed on the scan tool in miles per hour and kilometers per hour.

OUTPUTS - ACTUATORS

CAMSHAFT POSITION ACTUATOR CONTROL SOLENOIDS

- A pair of duty-cycle controlled solenoid valves that modify the valve timing of the intake camshafts by controlling engine oil flow to the camshaft position actuators.
- As duty cycle increases, oil flows from the solenoid to the actuator advancing the camshaft position.
- As the duty cycle decreases, the amount of oil flow from the solenoid is reduced allowing the camshaft to move back towards the rest position.
- When the ECM determines that the desired camshaft position has been achieved, the duty cycle is commanded to 50 % to hold the actuator so that the adjusted camshaft position is maintained.
- The solenoid winding resistance specification is 12 ± 2 Ω.

EVAPORATIVE EMISSION (EVAP) CANISTER PURGE SOLENOID

- Duty cycle controlled regulation of EVAP canister purge vapor flow into the intake manifold.
- Enabled when the engine coolant temperature reaches 150° F (66° C).
- A duty cycle of 0 % blocks vapor flow, and a duty cycle of 100 % allows maximum vapor flow.
- The duty cycle is determined by the ECM, based on engine speed and load.
- Also used for OBD testing of the evaporative emission (EVAP) system.
- A service port with a schrader valve is on the hose between the purge solenoid and the canister.
- Winding resistance specification is 36 ± 4 Ω.

EVAPORATIVE EMISSION (EVAP) CANISTER VENT SOLENOID

- When energized, the fresh air supply hose to the canister is blocked.
- Energized only during OBD testing of the evaporative emission (EVAP) system.
- Winding resistance specification is 36 ± 4 Ω.

EXHAUST GAS RECIRCULATION (EGR) VALVE

- A duty cycle controlled solenoid that controls the spring-loaded EGR valve pintle.
- A scan tool value of 0 % indicates an ECM command to fully close the EGR valve.
- A scan tool value of 100 % indicates an ECM command to fully open the EGR valve.
- Enabled when the engine coolant temperature reaches 150° F (66° C) and the throttle is not closed or wide open.
- Winding resistance specification is 12 ± 2 Ω.

FAN CONTROL (FC) RELAY

- When energized, the relay provides battery voltage (B+) to the radiator/condenser cooling fan motor.
- Energized when engine coolant temperature reaches 220° F (104° C); off when coolant temperature drops to 195° F (90° C).
- Energized when the A/C high

side pressure reaches 300 psi (2068 kPa); off when the pressure drops to 250 psi (1724 kPa).
- Coil resistance specification is 36 ± 4 Ω.

FUEL INJECTORS

- Electromechanical devices used to deliver fuel to the intake manifold at each cylinder.
- Each individually energized once per camshaft revolution, in time with its cylinder's exhaust stroke.
- Winding resistance specification is 12 ± 2 Ω.

GENERATOR

- The ECM supplies a variable duty-cycle signal to ground the field winding of the generator (alternator).
- The ECM receives battery/charging voltage input at pin 219. This pin is a dedicated generator input.
- Increased duty cycle results in a higher field current and greater generator (alternator) output.

IGNITION COILS

- Coil-on-plug (COP) system with six individual coils connected directly to the spark plugs.
- Timing and dwell are controlled by the ECM.
- Coil primary resistance specification is 1 ± 0.5 Ω.
- Coil secondary resistance specification is 10K ± 2K Ω.

MALFUNCTION INDICATOR LAMP (MIL)

- Part of the instrument cluster module (ICM).
- Receives commands from the ECM and TCM over the data communications bus.
- If the ICM is unable to communicate with the communications bus network, the MIL will be lit.
- With no faults present, the MIL is lit for 5 seconds after the ignition switch is turned ON (bulb check).
- An emissions-related fault is present if the MIL stays lit after the bulb check.
- When misfiring occurs that could damage a catalytic converter, the MIL flashes on and off.

STARTER RELAY

- When energized, provides battery voltage (B+) to the starter solenoid.
- Energized based upon ignition switch position (START), transmission range switch position (PARK/ NEUTRAL), vehicle speed (0 mph), and engine speed (0 rpm).
- Coil resistance specification is 36 ± 4 Ω.

THROTTLE ACTUATOR CONTROL (TAC) MOTOR

- A bidirectional pulse-width modulated DC motor that controls the position of the throttle plate.
- Scan tool data value of 0 % = ECM command to fully close throttle plate.
- Scan tool value of 100 % = ECM command to fully open the throttle plate (wide open throttle).
- Any throttle control actuator motor circuit fault sets a DTC and causing the TAC to be disabled, and the spring-loaded throttle plate will return to the default 15 % position (fast idle)
- When disabled, the TAC value on the scan tool will indicate 15 %.
- Maximum throttle actuator control motor current is 6 amps.

TRANSMISSION SOLENOIDS

TORQUE CONVERTER CLUTCH (TCC) SOLENOID VALVE

- This normally low (NL) variable force solenoid controls fluid in the transmission valve body that is routed to the torque converter clutch.
- TCM varies duty cycle to maintain a controlled slip or a full application of the clutch (zero slip).
- Scan tool duty cycle value of 0% = TCC is released.
- When torque converter clutch application is desired, the pulse width increases.
- Scan tool duty cycle value of 100 % = TCC is fully applied.
- The duty cycle is immediately cut to 0 % (released) if the brake pedal position switch closes.
- Enabled when the engine coolant temperature reaches 150° F (66° C), the brake switch is open, the transmission is in 3rd gear or higher, and the vehicle is at cruise (steady throttle) above 35 mph.
- Winding resistance specification is 6 ± 1 Ω.

TRANSMISSION ELECTRONIC PRESSURE CONTROL (EPC) SOLENOID

- This normally high (NH) variable force solenoid controls fluid in the transmission valve body that is routed to the pressure regulator valve.
- TCM varies duty cycle to modify the line pressure of the transmission for best shift quality.
- Scan tool duty cycle value of 10 % = maximum line pressure command.
- Scan tool duty cycle value of 90 % = minimum line pressure is commanded.
- Winding resistance specification is 6 ± 1 Ω.

TRANSMISSION SHIFT SOLENOIDS (SS A, SS B, SS C, SS D, and SS E)

- Control fluid flow to the clutches.

Gear Selector Position	PCM Gear Command	4-5-6 Clutch	3-5-R Clutch	2-6 Clutch	L-R Clutch	1-2-3-4 Clutch	Low/ One-Way Clutch	SS A (VFS) 1-2-3-4 Clutch NL	SS B (VFS) L-R/ 4-5-6 NH	SS C (VFS) 3-5-R NH	SS D (VFS) 2-6 NL	SS E (OFF/ON) NC	Gear Ratio
P	P				Applied			OFF	OFF	ON	OFF	ON	
R	R		Applied		Applied			OFF	OFF	OFF	OFF	ON	2.88:1
N	N				Applied			OFF	OFF	ON	OFF	ON	
D	1				Applied	Applied	Applied	ON	OFF	ON	OFF	ON	4.48:1
	2			Applied		Applied	OR	ON	ON	ON	ON	OFF	2.87:1
	3		Applied			Applied	OR	ON	ON	OFF	OFF	OFF	1.84:1
	4	Applied				Applied	OR	ON	OFF	ON	OFF	OFF	1.41:1
	5	Applied	Applied				OR	OFF	OFF	OFF	OFF	OFF	1:1
	6	Applied		Applied			OR	OFF	OFF	ON	ON	OFF	0.74:1
L	L				Applied	Applied		ON	OFF	ON	OFF	ON	4.48:1

VFS = Variable Force Solenoid NL = Normally Low OR = Over Running
NC = Normally Closed NH = Normally High

Shift solenoid positions in the various gear ranges.

- Located in the transmission valve body.
- SS A and SS D are normally low (NL) variable force solenoids.
- SS B and SS C are normally high (NH) variable force solenoids.
- SS E is an OFF/ON solenoid that is normally closed (NC).
- By modifying the duty cycle of the variable force solenoids and changing the state of the ON/OFF solenoid, the TCM can control the pressure to the clutches to enable a gear change.
- Winding resistance specification is 6 ± 1 Ω, except for SS E which is 22 ± 2 Ω.

Normally Low (NL): When this solenoid type is OFF (not energized), fluid pressure is low, fluid is exhausted from the circuit, and the clutch is not applied. When the solenoid is ON (energized), the TCM increases the fluid pressure by varying the solenoid duty cycle and the clutch is applied.

Normally High (NH): When this solenoid type is OFF (not energized), fluid pressure is high in the fluid circuit and the clutch is applied. When the solenoid is ON (energized), the TCM reduces the fluid pressure by varying the solenoid duty cycle and the clutch is released.

Normally Closed (NC): This solenoid type is either ON or OFF and controls a three-port hydraulic circuit to aid in shift strategy. Regulated line pressure is switched between two hydraulic ports, a default passage, and a primary passage. When this solenoid type is OFF (not energized), oil is blocked from the primary oil passage and fed to a default passage. When the solenoid is ON (energized), the TCM redirects the fluid pressure to the primary oil passage.

VARIABLE VALVE LIFT MOTORS

- A bidirectional DC motor that controls the position of the variable valve lift mechanism.
- DC motor is attached to a rod which operates a fulcrum attached to the rocker arms.
- Changes in rocker arm ratio result in additional lift above the base lift provided by the camshaft lobes.
- Scan tool value below 3000 rpm = 0.5 V (0 %).
- Scan tool value above 3000 rpm = 4.5 V (100 %).

OBD SYSTEM OPERATION

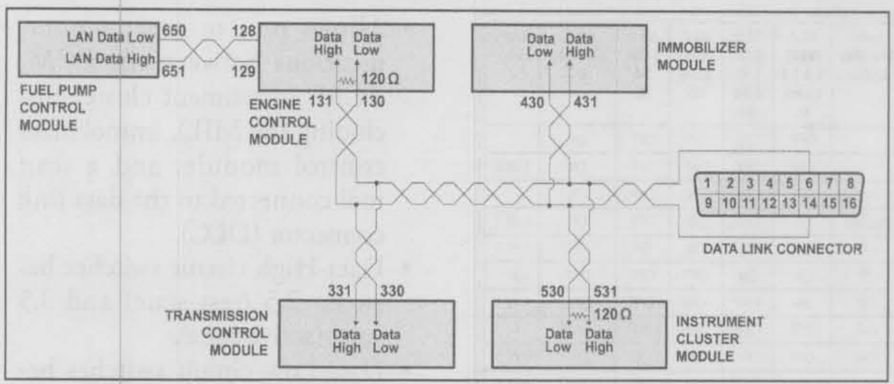
DATA COMMUNICATIONS

POWERTRAIN COMMUNICATIONS NETWORK

- High-speed, serial data bus.
- Two-wire twisted pair communications network.
- Allows peer-to-peer communications between the ECM, TCM, instrument cluster (including the MIL), immobilizer control module, and a scan tool connected to the data link connector (DLC).
- Data-High circuit switches between 2.5 (rest state) and 3.5 volts (active state).
- Data-Low circuit switches between 2.5 (rest state) and 1.5 volts (active state).
- Two, 120-ohm terminating resistors: one inside the instrument cluster and another inside the ECM.
- Any of the following conditions will cause serial data bus communications to fail and result in the storage of network DTCs:
  - Either data line shorted to voltage.
  - Either data line shorted to ground.
  - One data line shorted to the other data line.
  - An open in either data line to a module.
- Data bus remains operational when one of the two modules containing a terminating resistor is not connected to the network.
- Data bus will fail when both terminating resistors are not connected to the network.
- Communication failures will not prevent the ECM from providing control of the ignition system.

FUEL PUMP CONTROL MODULE (FPCM) COMMUNICATIONS NETWORK

- Local Area Network (LAN) bus.
- Two-wire, twisted pair communications network; isolated from the powertrain communications network.
- Allows peer-to-peer communications between the ECM and the FPCM only.



Composite vehicle serial data network.

- LAN Data-High circuit switches between 2.5 (rest state) and 3.5 volts (active state).
- LAN Data-Low circuit switches between 2.5 (rest state) and 1.5 volts (active state).
- Any of the following conditions will cause LAN data bus communications to fail:
  - Either data line shorted to voltage.
  - Either data line shorted to ground.
  - Either data line open.
  - One data line shorted to the other data line.

SYSTEM MONITORS

The OBD diagnostic system also actively tests some systems for proper operation while the vehicle is being driven. Fuel control and engine misfire are checked continuously. Air/fuel ratio sensor response, air/fuel ratio sensor heater operation, oxygen sensor response, oxygen sensor heater operation, catalyst efficiency, EGR operation and EVAP integrity are tested once or more per trip. When any of the System Monitors detects a failure that will result in emissions exceeding a predetermined level on two consecutive trips, the ECM will store a diagnostic trouble code (DTC) and illuminate the malfunction indicator lamp (MIL). Freeze frame data captured during the first of the two consecutive failures is also stored.

AIR/FUEL RATIO & OXYGEN SENSORS

- Checks the maximum and minimum signal output and response times for all air/fuel ratio sensors and oxygen sensors.
- If an air/fuel ratio sensor or oxygen sensor signal remains too low, too high, responds too slowly, or does not respond, a DTC is set.

AIR/FUEL RATIO & OXYGEN SENSOR HEATERS

- Checks the current flow through each air/fuel ratio sensor heater and the oxygen sensor heater.
- If the current flow is too high or too low, a DTC is set.
- Battery voltage is continuously supplied to the air/fuel ratio sensor heaters and oxygen sensor heaters whenever the ignition switch is on.
- The heaters are grounded through the ECM.

CATALYTIC CONVERTER

- Compares the data from the heated air/fuel ratio sensors (upstream) to the heated oxygen sensors (downstream) to determine the oxygen storage capability of the catalysts.
- If a catalyst's oxygen storage capacity is sufficiently degraded, the ECM will store the appropriate DTC and illuminate the MIL.
- Will run only after the air/fuel ratio sensor heater, oxygen sensor heater, air fuel ratio sensor and oxygen sensor monitors have run and passed.

COMPREHENSIVE COMPONENT

- Continuous monitor of all engine and transmission sensors and actuators for shorts and opens, as well as values that do not logically fit with other powertrain data (rationality).
- On the first trip where a failure is detected, the ECM or TCM will store a DTC. The ECM will then store a freeze frame of data and illuminate the MIL.

EGR SYSTEM

- Uses the MAP sensor signal to detect changes in intake manifold pressure as the EGR valve is commanded open and closed.
- If the pressure changes too little or too much as compared to the EGR valve position sensor input, a DTC is set.

ENGINE MISFIRE

- Uses the CKP sensor signal to continuously detect engine misfires, both severe and non-severe.
- If the misfire is severe enough to cause catalytic converter damage, the MIL will flash on and off as long as the severe misfire is detected.

EVAP SYSTEM

- Tests for small leaks (0.020 in./0.5 mm) and large leaks (.040 in./1.0 mm).
- Engine off, natural vacuum leak detection is used to test for a small leak (0.020 in./0.5 mm).
  - Enable criteria for the small leak test: the vehicle must have been driven between 15 to 90 minutes; fuel level must be between

1/4 and 3/4 full; ambient air temperature must be between 40° F (4.4° C) and 105° F (40° C); the key is OFF/the engine is OFF.

- When the key is turned OFF, the vent solenoid is left open for ten minutes to allow the system to stabilize. The ECM then notes the fuel tank pressure (FTP).
- The ECM then energizes the EVAP vent solenoid for four minutes while monitoring the fuel tank pressure (FTP) sensor for a pressure change.
- If the system reaches the target value, a change of greater than 1.0 in. H2O from the stabilized reading, the test is complete and the system passes (no leak detected).
- If the system fails to pass the initial small leak test, the ECM will then command the EVAP vent solenoid open for two minutes. The ECM then notes the fuel tank pressure (FTP).
- The ECM then energizes the EVAP vent solenoid for 20 minutes while monitoring the FTP sensor for change.
- A change in fuel tank pressure of greater than 1.0 in. H2O indicates a pass (no leak detected).

- Vacuum decay is used to test for a large leak (.040 in./1.0 mm).
  - Enable criteria for the large leak test: a cold start with engine temperature below 86° F (30° C); fuel level must be between 1/4 and 3/4 full; ambient air temperature must be between 40° F (4.4° C) and 105° F (40° C); the engine is running.
  - The ECM turns on the EVAP vent solenoid, blocking the fresh air supply to the EVAP canister.
  - The EVAP purge solenoid is turned on to draw a slight vacuum on the entire EVAP system, including the fuel tank.
  - Then the EVAP purge solenoid is turned off to seal the system.
  - The monitor uses the Fuel Tank (EVAP) Pressure Sensor signal to determine if the EVAP system has any leaks.
  - After the testing is completed, the EVAP vent solenoid is turned off to relieve the vacuum.
- A small leak DTC will set if a sufficient change in fuel tank pressure is not achieved during the small leak test.
- A large leak DTC will set if sufficient vacuum is not created, or decays too rapidly, or does not decay quickly at the conclusion of the large leak test.

FUEL CONTROL

- Uses fuel trim and loop status to determine failures in the fuel system.
- Sets a DTC if the system fails to enter Closed Loop mode within 2 minutes of startup.
- Sets a DTC if Long Term Fuel Trim reaches its limit (+30 % or -30 %) indicating a loss of fuel control.

MONITOR READINESS STATUS

- Indicates whether or not the OBD diagnostic monitor has completed.
- If the monitor has not completed, the status on the scan tool displays "NOT COMPLETE."
- If the monitor has completed, the status on the scan tool displays "COMPLETE."
- When DTCs are cleared from memory or the battery is disconnected, all non-continuous monitors will have the readiness status indicators reset to "NOT COMPLETE."
- The readiness status of the following non-continuous system monitors can be read on the scan tool: Catalytic Converter; EGR System; EVAP System; Oxygen Sensors; Oxygen Sensor Heaters

WARM UP CYCLE

- Used by the ECM and TCM for automatic clearing of DTCs and Freeze Frame data (described below).
- Must have an increase of at least 40° F (an increase of 22° C) and reach a minimum of 160° F (71° C).

TRIP

- A key-on cycle in which all enable criteria for a diagnostic monitor are met and the monitor is run.
- The trip completes when the ignition switch is turned off.

DRIVE CYCLE

Most OBD monitors will run at some time during normal operation of the vehicle. However, to satisfy all of the different Trip enable criteria and run all of the OBD diagnostic monitors, the vehicle must be driven under a variety of conditions. The following drive cycle will allow all monitors to run on this vehicle.

- Ensure that the fuel tank is between 1/4 and 3/4 full.
- Engine cold start below 86° F (30° C).
- Engine warm up until coolant temperature is at least 160° F (71° C).
- Accelerate to 40-55 mph at 25 % throttle and maintain speed for 5 minutes.

- Decelerate without using the brake (coast down) to 20 mph or less, and then stop the vehicle. Allow the engine to idle for 10 seconds, turn the key off, and wait 1 minute.
- Restart and accelerate to 40-55 mph at 25 % throttle and maintain speed for 2 minutes.
- Decelerate without using the brake (coast down) to 20 mph or less, and then stop the vehicle. Allow the engine to idle for 10 seconds, turn the key off, and wait 45 minutes.

FREEZE FRAME DATA

- A snapshot (one frame of data) that is automatically stored in the memory of either the ECM or TCM when an emission-related DTC is first stored (pending).
- If a DTC for fuel control or engine misfire is stored at a later time, the newest data is stored, replacing the earlier data.
- All parameter ID (PID) values listed under "Scan Tool Data" are stored in freeze frame data.
- The ECM and TCM store only one single freeze frame record.

STORING AND CLEARING DTCS & FREEZE FRAME DATA, TURNING THE MIL ON & OFF

ONE TRIP MONITORS

- A failure on the first trip of a "one trip" emissions diagnostic monitor causes the ECM or TCM to immediately store a confirmed DTC, capture Freeze Frame data, and turn on the MIL.
- All Comprehensive Component Monitor faults set a confirmed DTC on one trip.

TWO TRIP MONITORS

- A failure on the first trip of a "two trip" emissions diagnostic monitor causes the ECM to store a pending DTC and Freeze Frame data.
- Normally, if the failure recurs on the next trip during which the monitor runs, regardless of the engine conditions, the ECM will store a confirmed DTC and turn on the MIL.
- For the misfire and fuel control monitors, if the failure recurs on the next trip during which the monitor runs and where conditions are similar to those experienced when the fault first occurred (engine speed within 375 rpm, engine load within 20 %, and same hot/cold warm-up status), the ECM will store a confirmed DTC and turn on the MIL.
- If the second failure does not recur as described above, the pending DTC and Freeze Frame data are cleared from memory.
- All of the System Monitors are two trip monitors.
- Engine misfire which is severe enough to damage the catalytic converter is a two trip monitor. The MIL will always flash on and off when the severe misfire is occurring.

AUTOMATIC CLEARING

- When the vehicle completes three consecutive good/passing trips (three consecutive trips in which the monitor that set the DTC is run and passes), the MIL will be turned off, but the confirmed DTC and Freeze Frame will remain stored in ECM/TCM memory.
- For misfire and fuel control monitor faults, the three consecutive good/passing trips must take place under similar engine conditions (engine speed, load, and warm up condition) as the initial fault for the MIL to be turned off.
- If the vehicle completes 40 Warm Up cycles without the same fault recurring, the DTC and Freeze Frame are automatically cleared from the ECM/TCM memory.

MANUAL CLEARING

- Any stored DTCs and Freeze Frame data can be erased using the scan tool, and the MIL (if lit) will be turned off.
- Although not the recommended method, DTCs and Freeze Frame data will also be cleared if the B+ power supply for the ECM/TCM is lost, or the battery is disconnected.

SCAN TOOL

- Can be used to communicate with the ECM, TCM, Immobilizer, and Instrument Cluster modules.
- Module reprogramming and initialization can be performed using the scan tool.
- The ECM, TCM, and instrument cluster are equipped with software that allows requests to be made through the OBD scan tool for output control of components and functional testing of systems.

***Note:** All testing is performed at sea level unless otherwise indicated.*

The information on these two pages are the data values, including minimum-to-maximum ranges, that the OBD II scan tool is capable of displaying for each of the data parameters.

PIN / Component Cross Reference

PIN#	Abbreviation	Diagram
1	+5 V	1 of 4
2	Ign	1 of 4
3	B+	1 of 4
9	A/C Clutch	1 of 4
10	Fan Control	1 of 4
14	Coil 1	1 of 4
15	Coil 3	1 of 4
16	Coil 5	1 of 4
17	Coil 2	1 of 4
18	Coil 4	1 of 4
19	Coil 6	1 of 4
22	TAC	1 of 4
23	TAC	1 of 4
24	TP 1	1 of 4
25	TP 2	1 of 4
28	EGR Position	1 of 4
29	MAP	1 of 4
30	FPS	1 of 4
31	FTS	1 of 4
34	ECT	1 of 4
35	IAT	1 of 4
40	A/C Pressure	1 of 4
41	Fuel Tank Pressure	1 of 4
42	Fuel Level	1 of 4
50	Sensor Ground	1 of 4
60	Ground	1 of 4
101	Gen Field	2 of 4
104	EVAP Vent	2 of 4
108	EGR	2 of 4
110	EVAP Purge	2 of 4
120	INJ 1	2 of 4
121	INJ 1	2 of 4
122	INJ 3	2 of 4
123	INJ 4	2 of 4
124	INJ 5	2 of 4
125	INJ 6	2 of 4
130	Data Low	2 of 4
131	Data High	2 of 4
140	+5 V	2 of 4
141	APP 1	2 of 4
142	Sensor Ground	2 of 4
143	+5 V	2 of 4
144	APP 2	2 of 4
145	Sensor Ground	2 of 4
150	AFRS 1/1+	2 of 4
151	AFRS 1/1-	2 of 4
152	AFRS 1/1 Heater	2 of 4
153	AFRS 2/1+	2 of 4
154	AFRS 2/1-	2 of 4
155	AFRS 2/1 Heater	2 of 4
160	HO2S 1/2+	2 of 4
161	HO2S 1/2-	2 of 4
162	HO2S 1/2 Heater	2 of 4
163	HO2S 2/2+	2 of 4
164	HO2S 2/2-	2 of 4
165	HO2S 2/2 Heater	2 of 4
171	BPP	2 of 4
172	A/C Request	2 of 4
181	MAF	2 of 4
201	Starter Control	3 of 4
203	CMP 1 Sol	3 of 4
204	CMP 2 Sol	3 of 4
205	VVLB1 A	3 of 4
206	VVLB1 B	3 of 4
207	+5 V	3 of 4
208	VVLS 1	3 of 4
209	Sensor Ground	3 of 4
210	VVLB2 A	3 of 4
211	VVLB2 B	3 of 4
212	+5 V	3 of 4
213	VVLS 2	3 of 4
214	Sensor Ground	3 of 4
219	Battery Sense	3 of 4
221	IGN OFF	3 of 4
222	IGN ACC	3 of 4
223	IGN RUN	3 of 4
224	IGN CRANK	3 of 4
240	KS B1	3 of 4
241	KS B2	3 of 4
250	CMP 1	3 of 4
251	CMP 2	3 of 4
252	CKP +	3 of 4
253	CKP -	3 of 4
302	Ign.	4 of 4
303	B+	4 of 4
305	TCC	4 of 4
306	EPC	4 of 4
307	SS A	4 of 4
308	SS B	4 of 4
309	SS C	4 of 4
310	SS D	4 of 4
311	SS E	4 of 4
330	Data Low	4 of 4
331	Data High	4 of 4
336	TFT	4 of 4
337	VSS +	4 of 4
338	VSS -	4 of 4
340	TSS +	4 of 4
341	TSS -	4 of 4
343	P	4 of 4
344	R	4 of 4
345	N	4 of 4
346	D	4 of 4
347	L	4 of 4
348	+5 V	4 of 4
350	Sensor Ground	4 of 4
360	Ground	4 of 4
402	Connector #12	4 of 4
405	Ant. +	4 of 4
406	Ant. -	4 of 4
430	Data Low	4 of 4
431	Data High	4 of 4
460	Ground	4 of 4
502	Connector #25	4 of 4
530	Data Low	4 of 4
531	Data High	4 of 4
560	Ground	4 of 4
605	B+	2 of 4
610	FP Feed	2 of 4
611	FP Ground	2 of 4
649	FP Enable	2 of 4
650	LAN Data Low	2 of 4
651	LAN Data High	2 of 4
660	Ground	2 of 4

Component	Diagram
Connector 1	1
Connector 8	4
Connector 12	4
Connector 25	4

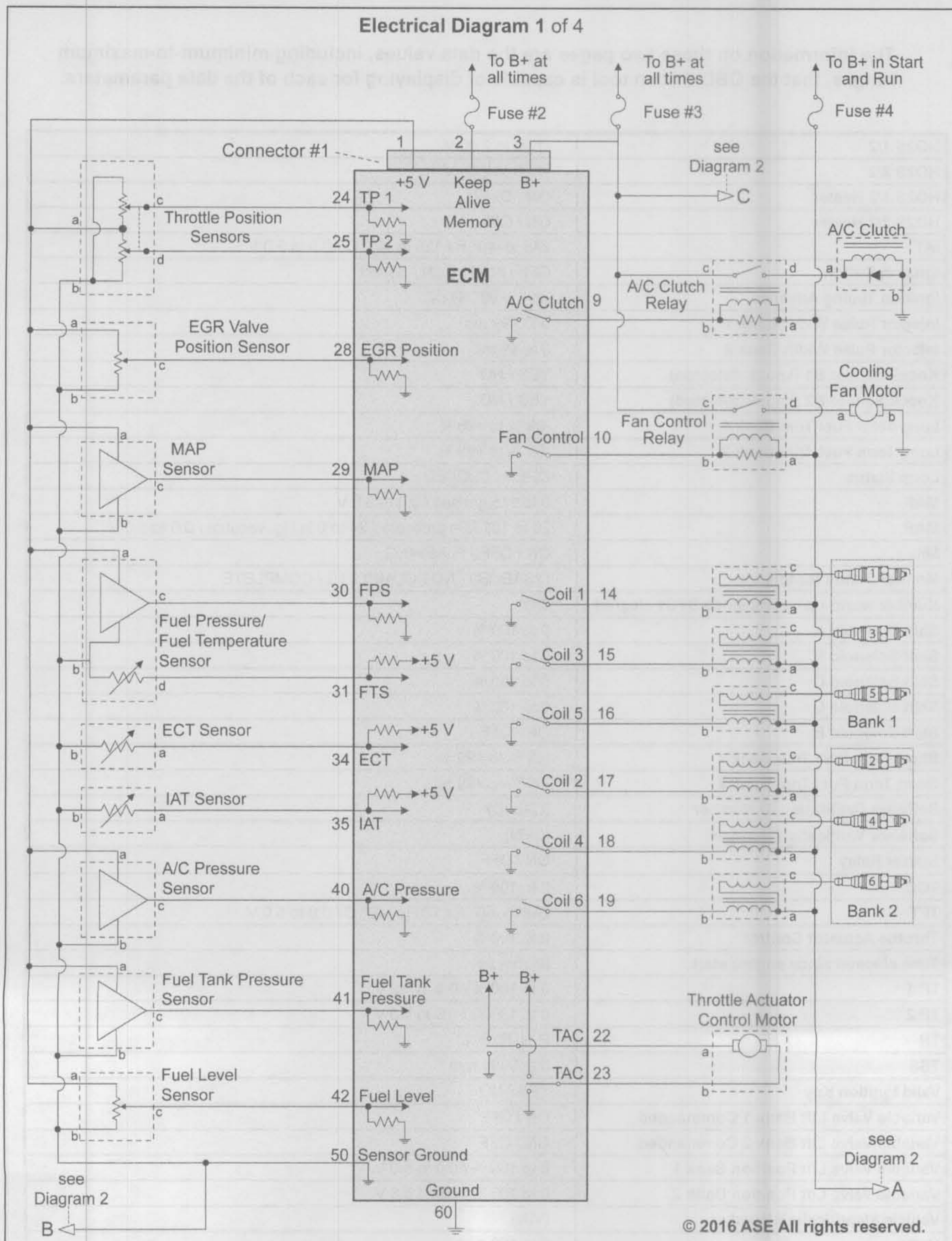
Component	Diagram
Fuse 3	1
Fuse 4	1
Fuse 20	2
Fuse 22	2
Fuse 30	3
Fuse 31	3
Fuse 32	3
Fuse 34	3
Fuse 36	3
Fuse 40	4
Fuse 41	4
Fuse 42	4
Fuse 43	4
Fuse 44	4

The information on these two pages are the data values, including minimum-to-maximum ranges, that the OBD II scan tool is capable of displaying for each of the data parameters.

Absolute Load Value	0 to 100 %
A/C Clutch	ON / OFF
A/C Pressure	25 to 450 psi / 0.0 to 5.0 V
A/C Request	ON / OFF
AFRS 1/1	-1.00 to 5.00 V
AFRS 2/1	-1.00 to 5.00 V
AFRS 1/1 Current	-9999 to +9999 microamps
AFRS 2/1 Current	-9999 to +9999 microamps
AFRS 1/1 Heater	0 to 100 %
AFRS 2/1 Heater	0 to 100 %
Air/Fuel Lambda Bank 1	0.00 to 2.00
Air/Fuel Lambda Bank 2	0.00 to 2.00
APP 1	0 to 100 % / 0.0 to 5.0 V
APP 2	0 to 100 % / 0.0 to 5.0 V
BARO	101 to 67 kPa pressure / 30 to 20 in.Hg. pressure
Battery Voltage	0 to 18 V
Brake Pedal Position Switch	ON / OFF
Cam 1 Desired Advance	0 to 99°
Cam 2 Desired Advance	0 to 99°
Cam 1 Solenoid Control	0 to 100 %
Cam 2 Solenoid Control	0 to 100 %
CMP 1	0° to 99°
CMP 2	0° to 99°
Distance traveled since DTCs cleared	#### miles/km
Distance traveled with MIL on	#### miles/km
DTCs (confirmed)	P####, U####, etc.
DTCs (pending)	P####, U####, etc.
ECT	248 to -40° F / 120 to -40° C / 0.0 to 5.0 V
EGR Position Sensor	0 to 100 % / 0.0 to 5.0 V
EGR Valve Opening Desired	0 to 100 %
Electronic Pressure Control (EPC)	0 to 100 %
Engine RPM	0 to 9999 rpm
Evap Purge Solenoid	0 to 100 %
Evap Vent Solenoid	ON / OFF
Fan Control	ON / OFF
Fuel Enable	YES / NO
Fuel Pressure	0.00 to 5.00 V / 0 to 90 psi
Fuel Pump Command (ECM)	OFF / LOW / HIGH
Fuel Pump Feedback (FPCM)	0 to 100 %
Fuel Tank (EVAP) Pressure	-14.0 to +14.0 in.H2O / -0.5 psi to 0.5 psi / 0.0 to 5.0 V
Fuel Tank Level	0 to 100 % / 0.0 to 5.0 V
Fuel Temperature	248 to -40° F / 120 to -40° C / 0.0 to 5.0 V
Generator Field	0 to 100 %

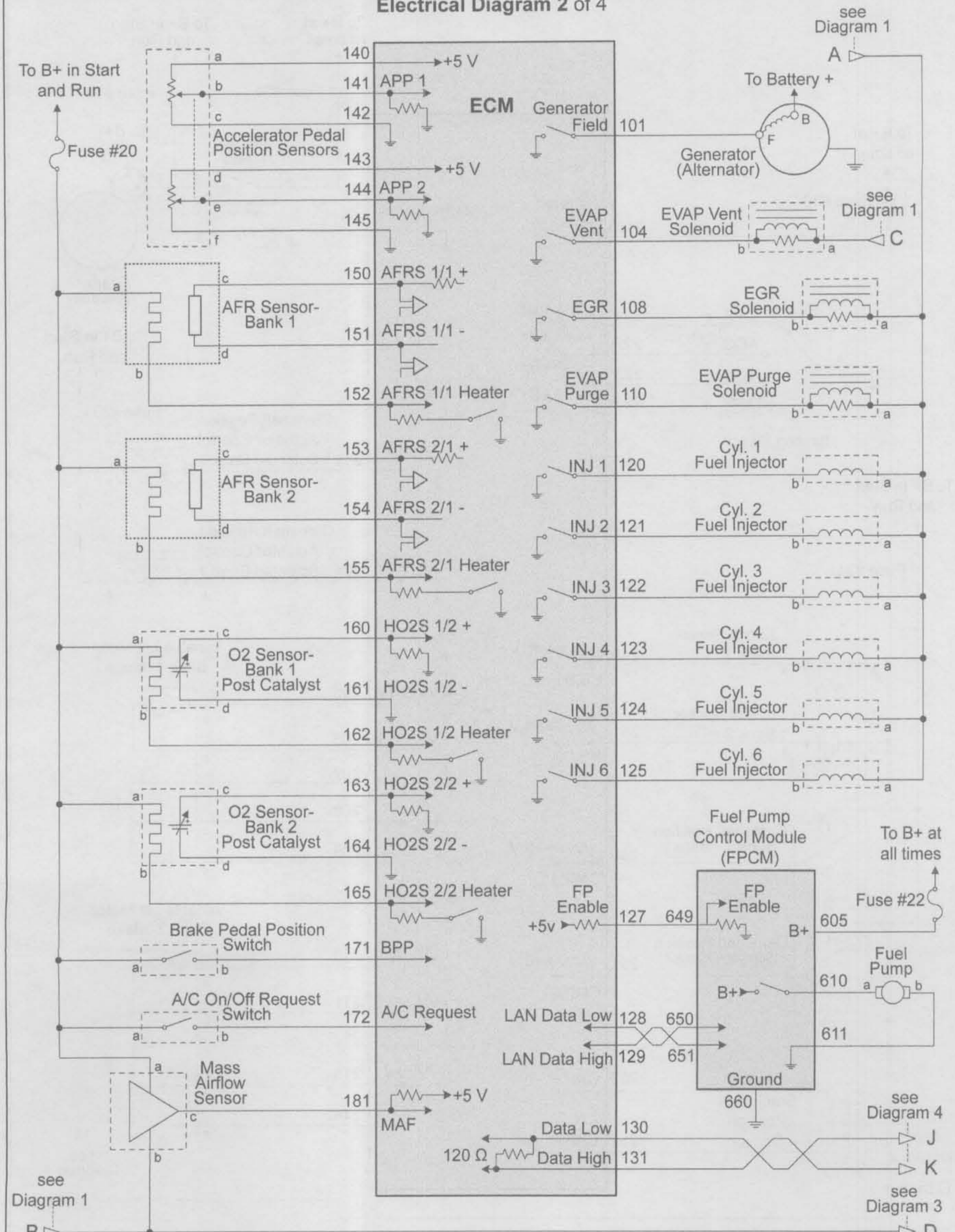
The information on these two pages are the data values, including minimum-to-maximum ranges, that the OBD II scan tool is capable of displaying for each of the data parameters.

HO2S 1/2	-1.00 to 2.00 V
HO2S 2/2	-1.00 to 2.00 V
HO2S 1/2 Heater	ON / OFF
HO2S 2/2 Heater	ON / OFF
IAT	248 to -40° F / 120 to -40° C / 0.0 to 5.0 V
Ignition Switch	OFF / ACC / RUN / START
Ignition Timing Advance	-99° to 99° BTDC
Injector Pulse Width Bank 1	0 TO 99 ms
Injector Pulse Width Bank 2	0 to 99 ms
Knock Sensor B1 (knock detected)	YES / NO
Knock Sensor B2 (knock detected)	YES / NO
Long Term Fuel Trim Bank 1	-99 % to +99 %
Long Term Fuel Trim Bank 2	-99 % to +99 %
Loop Status	OPEN / CLOSED
MAF	0 to 175 gm/sec / 0.0 to 5.0 V
MAP	20 to 101 kPa pressure / 24 to 0 in.Hg. vacuum / 0.0 to 5.0 V
MIL	ON / OFF / FLASHING
Monitor Status for this trip	DISABLED / NOT COMPLETE / COMPLETE
Number warm-up cycles since DTCs cleared	###
Shift Solenoid A	0 to 100 %
Shift Solenoid B	0 to 100 %
Shift Solenoid C	0 to 100 %
Shift Solenoid D	0 to 100 %
Shift Solenoid E	ON / OFF
Short Term Fuel Trim Bank 1	-99 % to +99 %
Short Term Fuel Trim Bank 2	-99 % to +99 %
Software Calibration ID Number	(CAL ID)
Software Verification Number	(CVN)
Starter Relay	ON / OFF
TCC	0 to 100 %
TFT	248 to -40° F / 120 to -40° C / 0.0 to 5.0 V
Throttle Actuator Control	0 to 100 %
Time elapsed since engine start	hh:mm:ss
TP 1	0 to 100 % / 0.0 to 5.0 V
TP 2	0 to 100 % / 0.0 to 5.0 V
TR	P, N, R, D, L
TSS	0 to 9999 rpm
Valid Ignition Key	YES / NO
Variable Valve Lift Bank 1 Commanded	ON / OFF
Variable Valve Lift Bank 2 Commanded	ON / OFF
Variable Valve Lift Position Bank 1	0 to 100 % / 0.0 to 5.0 V
Variable Valve Lift Position Bank 2	0 to 100 % / 0.0 to 5.0 V
Vehicle Identification Number	(VIN)
VSS	0 to 199 mph

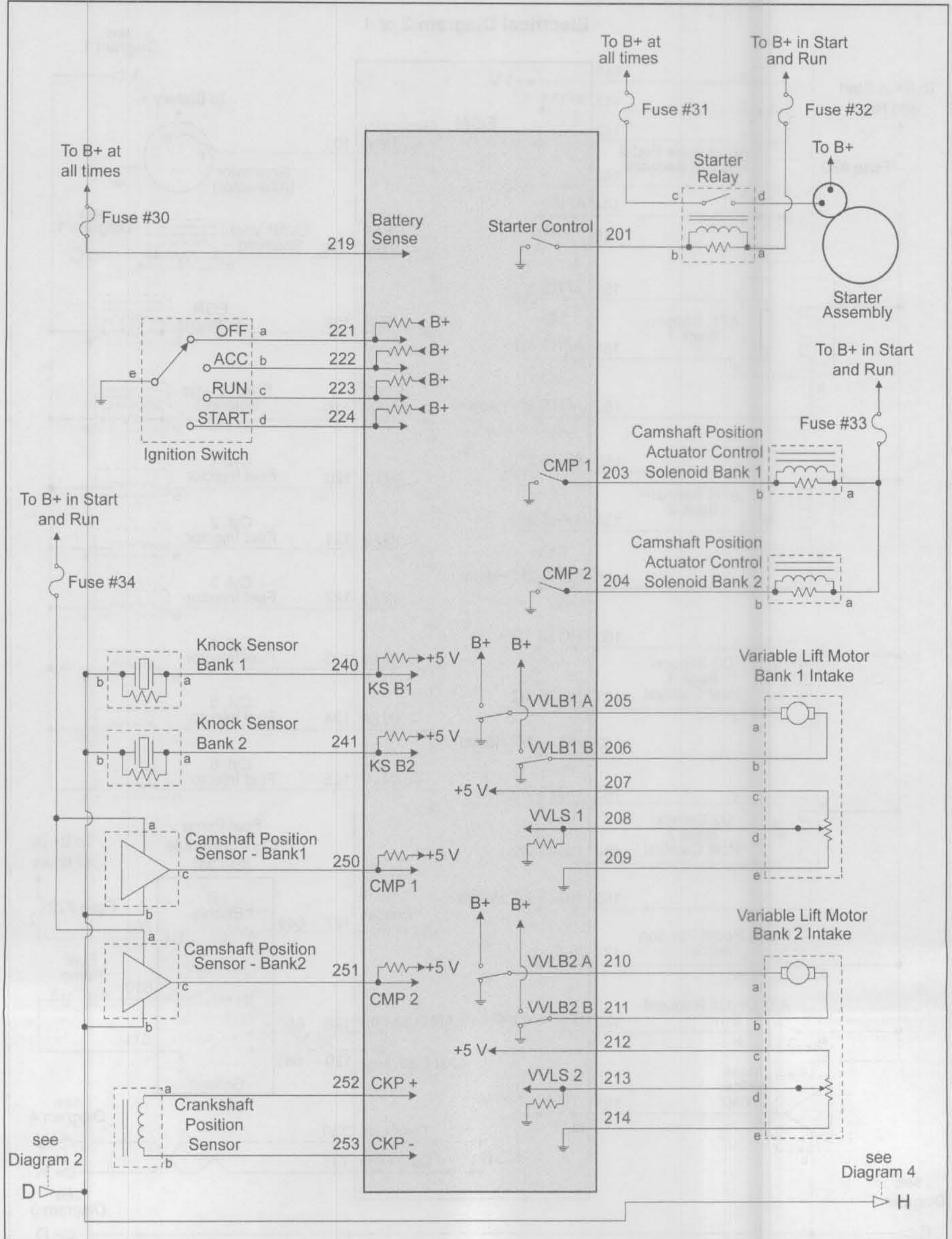


Composite vehicle wiring diagram 1 of 4 *(Courtesy ASE)*

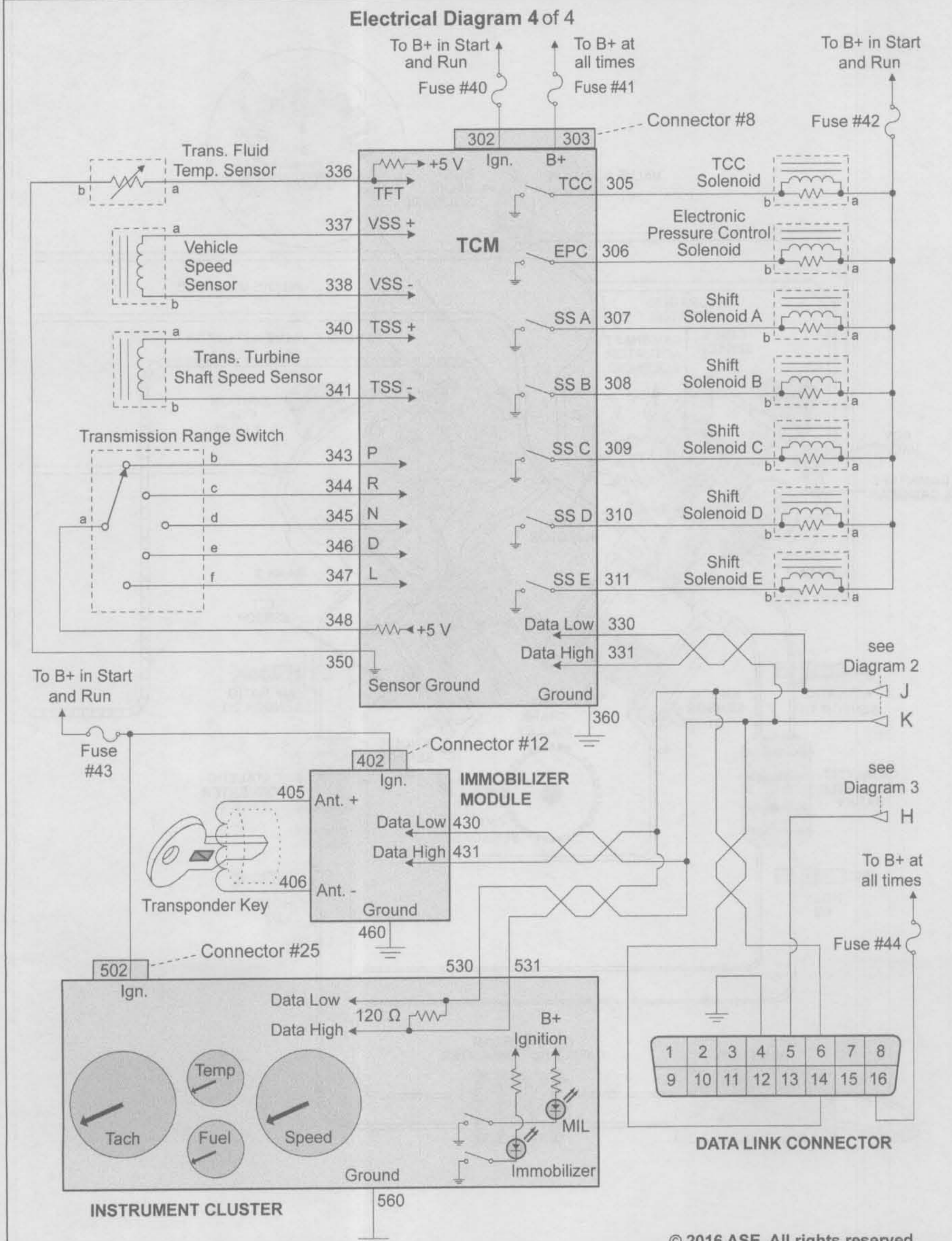
Electrical Diagram 2 of 4



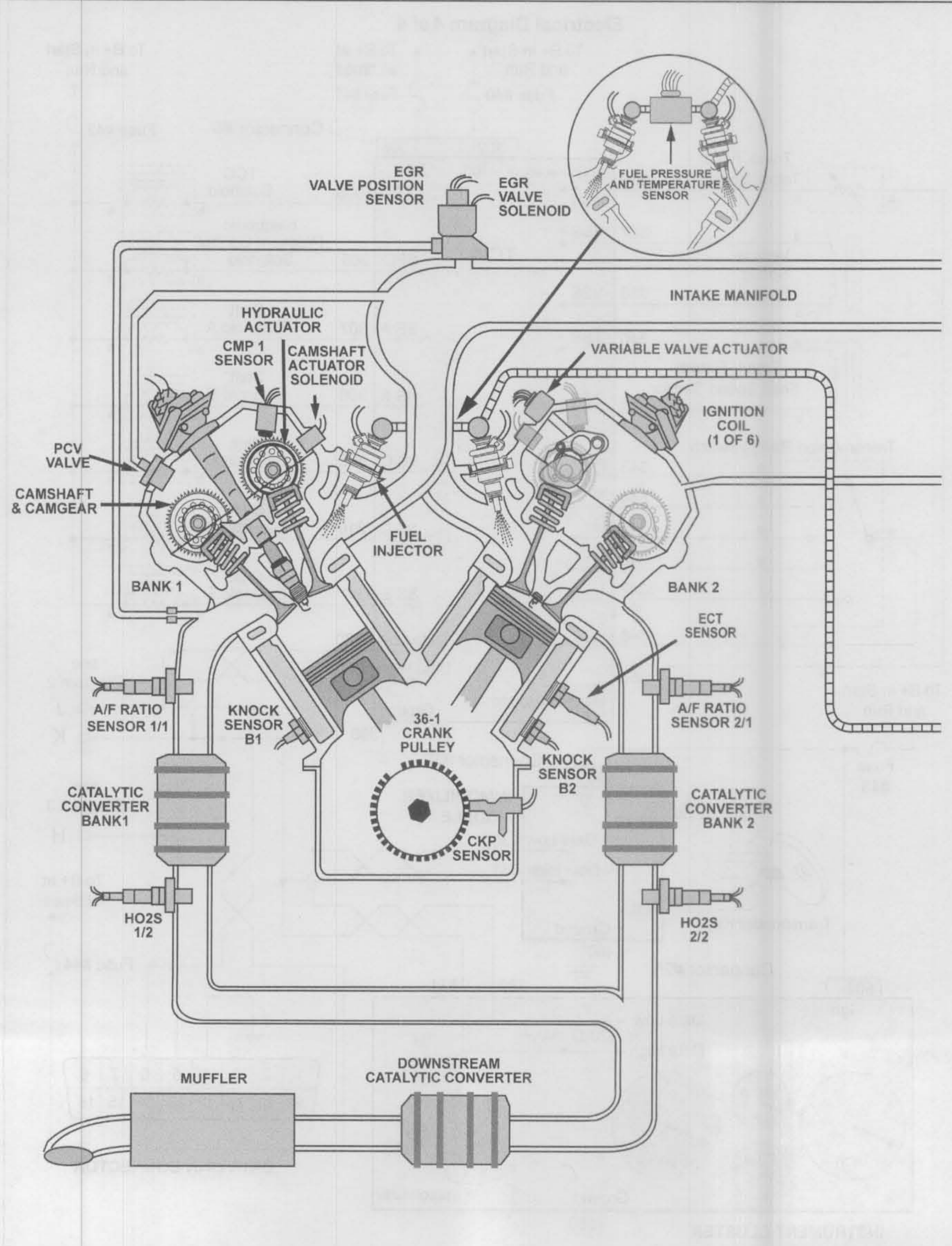
Composite vehicle wiring diagram 2 of 4 *(Courtesy ASE)*



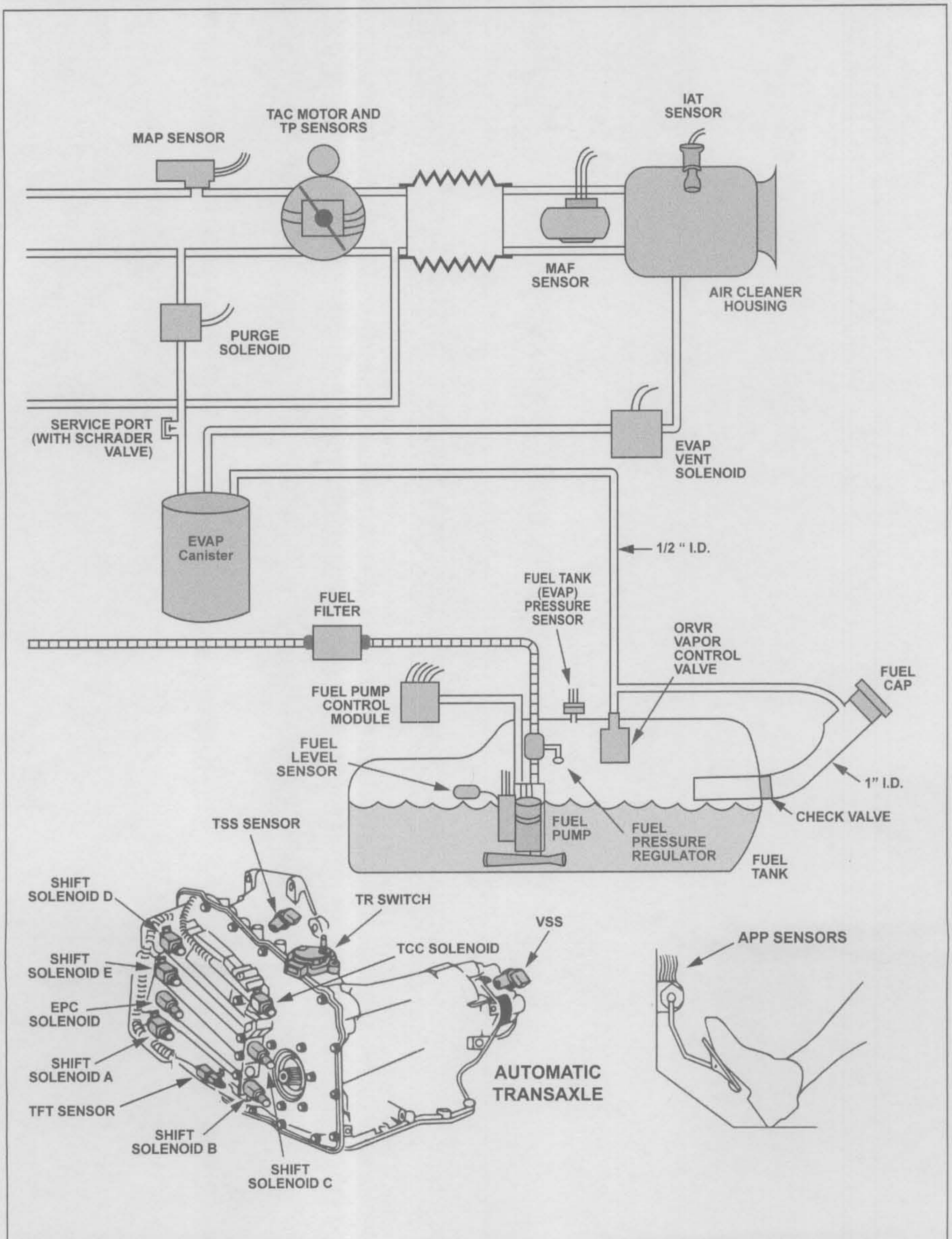
Composite vehicle wiring diagram 3 of 4 *(Courtesy ASE)*



Composite vehicle wiring diagram 4 of 4 *(Courtesy ASE)*



Composite vehicle engine *(Courtesy ASE)*



Composite vehicle sensor positions *(Courtesy ASE)*

Notes

Notes

Prepare yourself for ASE testing with these questions on ADVANCED ENGINE PERFORMANCE SPECIALIST

NOTE: The following questions are written in the ASE style. They are similar to the kinds of questions that you will see on the ASE test, however none of these questions will actually appear on the test.

1. All of the cylinders in an overhead cam engine have low compression. What is the MOST likely cause of this condition?
   A. burned valves
   B. leaking head gasket
   C. worn piston rings
   D. broken timing belt

2. A cylinder leakage test is being performed on an overhead valve V8 engine. When air is applied to the No. 5 cylinder, a hissing noise is heard from the tailpipe. Technician A says that the cam lobe for the No. 5 exhaust valve could be worn down. Technician B says that the No. 5 exhaust valve could be burned. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

3. A customer complains that their vehicle lacks power. What should be the first step in determining the cause of the problem?
   A. analyze scan data
   B. measure fuel pressure
   C. road test the vehicle
   D. check exhaust backpressure

4. An engine pings excessively under load. All of the following conditions could cause this condition EXCEPT:
   A. missing thermostat
   B. improper antifreeze concentration
   C. EGR valve stuck closed
   D. missing catalytic converter

5. A vehicle with multiport fuel injection stalls on deceleration. Technician A says that the problem could be the result of a faulty TCC solenoid. Technician B says that a contaminated throttle body may be the cause. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

6. The ISC motor toggles back and forth at closed throttle on an overhead valve V8 with DI ignition. A permanent magnet sensor inside the distributor is used to generate the rpm signal. Technician A says that a loose timing chain may be causing the problem. Technician B says that the problem may be the result of a worn distributor shaft gear. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

7. The fuel control system on the composite vehicle remains in open loop at all times. Technician A says that this could be the result of a poor connection at ECM terminal 60. Technician B says that a faulty IAT sensor could be the problem. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

8. Once a zirconia oxygen sensor reaches operating temperature, how quickly should it respond to changes in the air/fuel ratio?
   A. 50 microseconds
   B. 100 milliseconds
   C. one second
   D. 1000 milliseconds

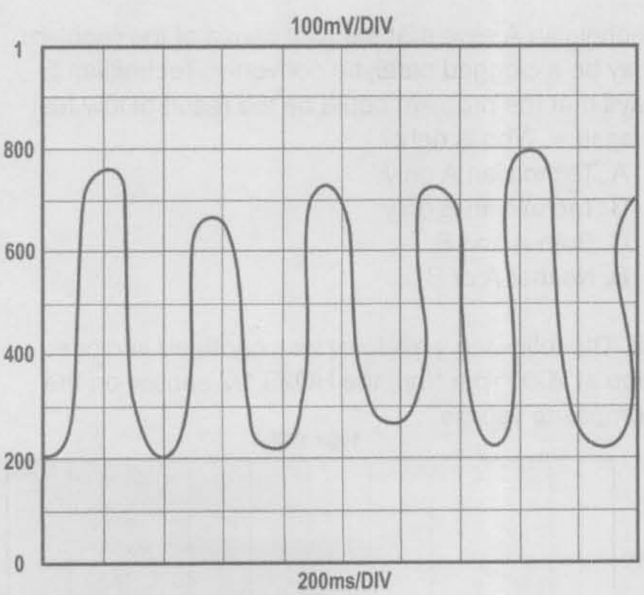
Prepare yourself for ASE testing with these questions on ADVANCED ENGINE PERFORMANCE SPECIALIST

9. The composite vehicle will not start. Cranking speed is above 250 rpm. The following PIDs were observed by two technicians under KOEO conditions at closed throttle.

ECT 68°F	IAT 67°F	MAF 0.2V	APP 1 0.5V
MAP/BARO 101 kPa	LOOP OPEN	TAC 35%	BATT 11.9V
APP2 1.5V	RPM 0	HO2S 1/1 0.00	HO2S 2/1 0.00
HO2S 1/2 0.00	TP 1 4.50V	TP 2 0.5V	FUEL PUMP OFF
Tank LEV 0%	TR P/N	LOAD 0%	

Technician A says that the system is stuck in the clear flood mode. Technician B says that a faulty MAP sensor may be the cause of the no-start. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B



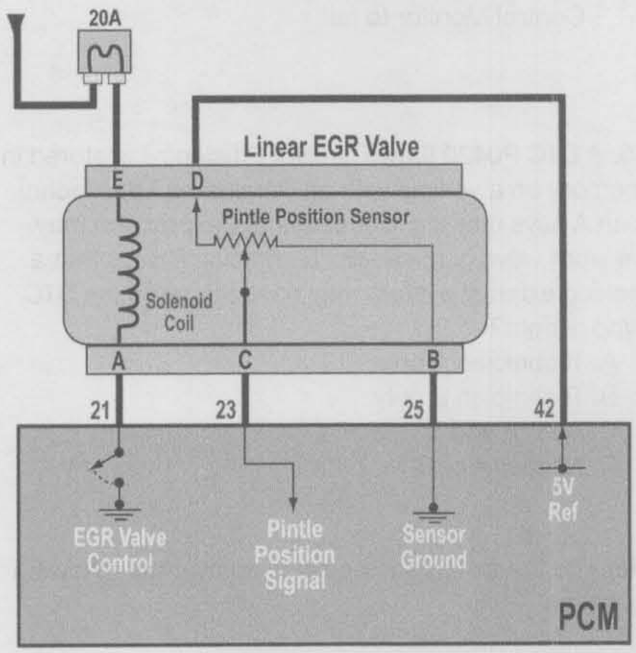
10. The waveform shown above was captured in closed loop at 1500 rpm from the Bank 1 O2 sensor on the composite vehicle. What can be determined by an analysis of the waveform?

A. The engine is running lean.
B. Sensor switching frequency is too slow.
C. Sensor response time is below normal.
D. The sensor is functioning properly.

11. The composite vehicle has an unstable idle, the MIL is on, and a DTC P0300 is stored for a Random Misfire. According to the scan data, which of the following could be the root cause of the problem?

ECT 198°F	IAT 86°F	MAF 0.2V	APP 1 0.5V
MAP/BARO 2.3V	LOOP CLOSED	TAC 15%	BATT 13.2V
APP 2 1.5V	RPM 513	HO2S 1/1 0.86	HO2S 2/1 0.78
HO2S 1/2 0.51	TP 1 4.50V	TP 2 0.5V	
Bank 1 STFT	Bank 2 STFT	Bank 1 LTFT	Bank 2 LTFT
–12%	–9%	–8%	–5%

A. EGR valve not seating
B. faulty ignition coil
C. clogged injector
D. vacuum leak



12. All of the following statements regarding the schematic shown above are true **EXCEPT**:

A. The solenoid coil receives battery power at KOEO and KOER.
B. A blown 20A fuse would result in 0 volts at ECM terminal 23.
C. The EGR valve is shown in the de-energized state.
D. The pintle position sensor is shown at approximately the 2.5V position.

Prepare yourself for ASE testing with these questions on ADVANCED ENGINE PERFORMANCE SPECIALIST

13. The composite vehicle won't shift into third gear. Technician A says that an open No. 3 shift solenoid (SSC) could be the problem. Technician B says that a poor connection at TCM terminal 309 could cause this condition. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

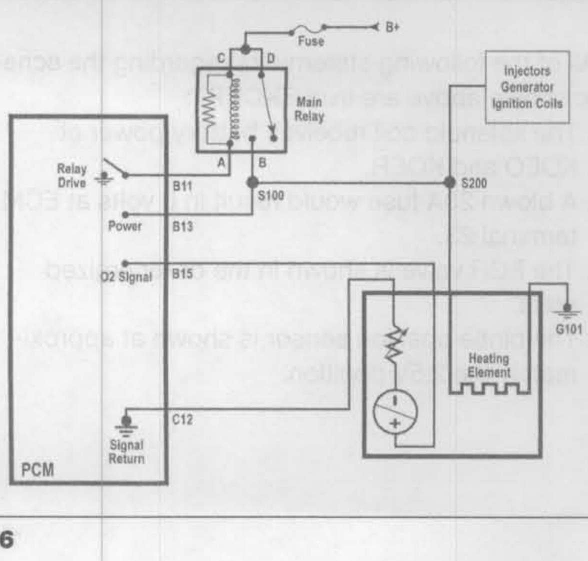
14. All of the following statements regarding the composite vehicle's OBD II monitors are true **EXCEPT**:

A. The Comprehensive Component Monitor is a one-trip test.
B. The Fuel Control, O2 Sensor and Misfire Monitors are run continuously.
C. The EVAP Monitor will not run if engine temperature is above 94°F (34°C).
D. A LTFT reading of –30% could cause the Fuel Control Monitor to fail.

15. A DTC P0420 (Low Catalyst Efficiency) is stored in memory on a vehicle with an illuminated MIL. Technician A says that the root cause of the problem may be worn valve guide seals. Technician B says that a leaking exhaust system may have triggered the DTC. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

Refer to the schematic below to answer the following question:



16. Technician A says that to check the voltage drop across the main relay switch contacts, the voltmeter leads should be connected between terminals B and D with the relay energized. Technician B says that to check the voltage drop in the O2 ground circuit, the voltmeter leads should be connected between PCM terminal B15 and G101. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

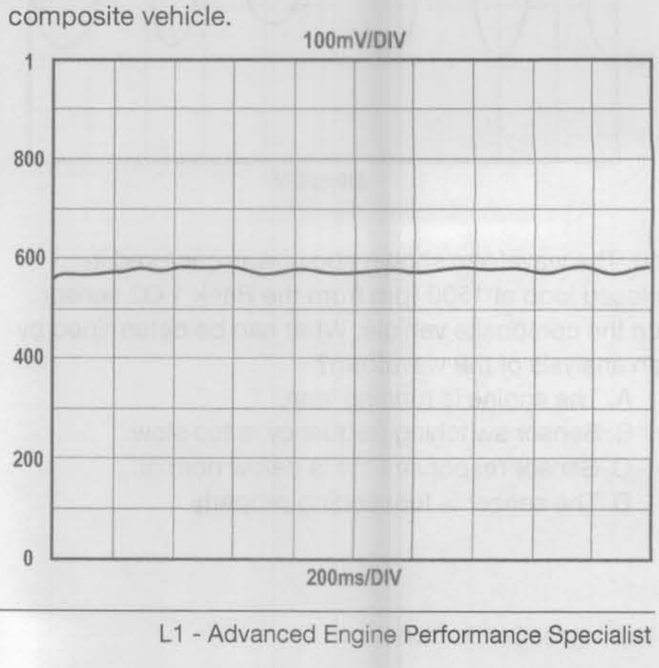
17. The composite vehicle lacks power. The engine has been recently tuned up and the results from a power balance test were good. The following snapshot of scan data was captured at 2500 rpm under no-load. Which analysis of this information is correct?

ECT 209°F	IAT 86°F	MAF 0.3V	APP 1 0.65V
MAP/BARO 3.6V	LOOP CLOSED	TAC 21%	DTC NONE
APP 2 1.65V	RPM 2500	HO2S 1/1 0.89	HO2S 2/1 0.91
HO2S 1/2 0.56	TP 1 4.25V	TP 2 0.88V	
Bank 1 STFT	Bank 2 STFT	Bank 1 LTFT	Bank 2 LTFT
–13%	–15%	–10%	–12%

Technician A says that the root cause of the problem may be a clogged catalytic converter. Technician B says that the problem could be the result of low fuel pressure. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

18. The following waveform was captured in closed loop at 2000 rpm from the HO2S 1/2 sensor on the composite vehicle.



Prepare yourself for ASE testing with these questions on ADVANCED ENGINE PERFORMANCE SPECIALIST

Technician A says that the waveform could be the result of an unintentional ground in the purge flow control circuit (terminal 37 of the ECM). Technician B says that a clogged PCV valve may be generating this pattern. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

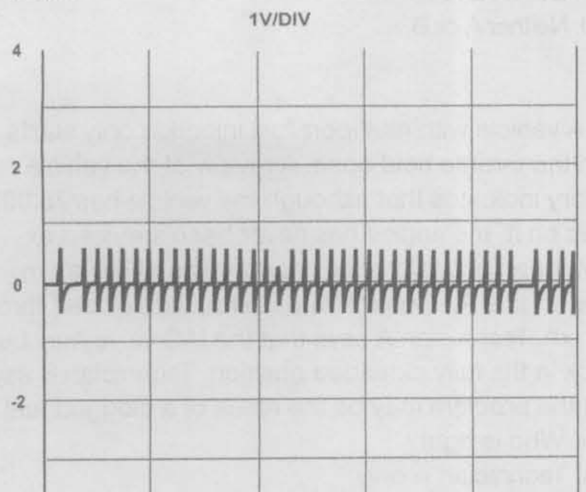
19. An engine with DI ignition becomes harder to start as outside temperature drops. Below freezing, the engine will not start at all. Technician A says that the problem could be a faulty ignition coil. Technician B says that the coil wire may be bad. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

20. The engine in the composite vehicle will not start. A preliminary diagnosis indicates that there is no spark. Technician A says that a defective CKP sensor could be the root cause of the problem. Technician B says that the coil driver could be the root cause of the problem. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

Refer to the graphic below to answer the following question:



21. The CKP waveform shown above was taken from the composite vehicle during cranking. Which of the following best describes the waveform?

A. The CKP sensor is faulty.
B. The reluctor has a chipped tooth.
C. The CKP sensor is misadjusted.
D. The pattern is normal.

22. All of the following could cause an engine with waste spark ignition to misfire **EXCEPT**:

A. low primary circuit resistance
B. faulty generator
C. open plug wire
D. defective ignition control module

23. The composite vehicle fails a loaded mode I/M test for excessive hydrocarbons. Which of the following is the root cause of the problem?

A. shorted CMP signal wire to the ECM
B. open CKP sensor
C. poor connection at ECM terminal 19
D. blown fuse No. 4

24. Two technicians are discussing the merits of a snap throttle test for evaluating ignition system performance. Technician A says that this test is more useful for port-injected engines than it is on vehicles with throttle body injection. Technician B says that using a spark tester is a more effective way to test the ignition system. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

25. The ignition coils on the composite vehicle are being tested with an ohmmeter. Which of the following readings is within specifications for the secondary winding?

A. 5000Ω
B. 11MΩ
C. 1.5Ω
D. 8.25kΩ

Prepare yourself for ASE testing with these questions on ADVANCED ENGINE PERFORMANCE SPECIALIST

26. Fuel pressure on a continuous return injection system is within specifications, but leaks down to zero immediately after the pump stops running. What is the most likely cause of this condition?

A. faulty regulator
B. restricted fuel return line
C. defective pump
D. leaking injector

Injector	1	2	3	4	5	6	
Initial Pressure	55	55	55	55	55	55	
Final Pressure	32	46	33	49	31	34	
Pressure Drop	23	9	22	6	24	21	Spec (psi) 21-24

27. The readings shown above were recorded during an injector balance test. All of the following symptoms are consistent with the test results **EXCEPT**:

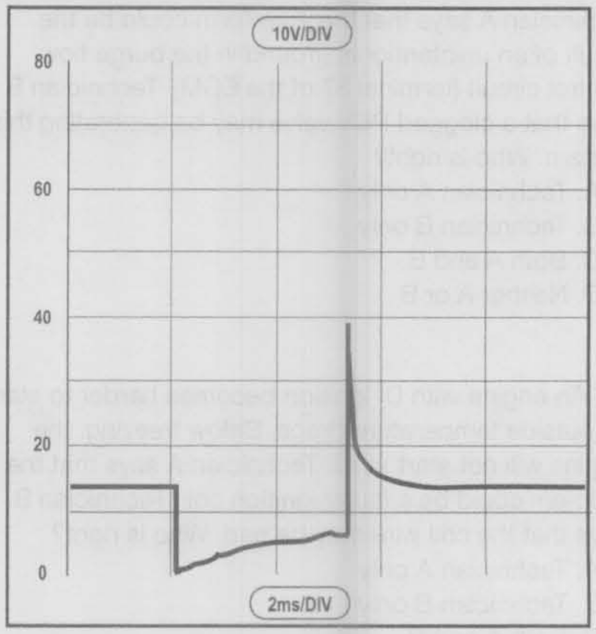
A. lack of power
B. high CO emissions
C. rough idle
D. hard start

28. A kinked vacuum line to the fuel pressure regulator could cause:

A. long engine crank times
B. poor fuel economy
C. high NOx emissions
D. an off-idle hesitation

29. All of the following statements concerning the composite vehicle's fuel system are false EXCEPT:

A. The system is a continuous return design.
B. Fuel pressure ranges between 58 to 62 PSI under all conditions.
C. Fuel pressure should be 45 psi immediately following engine shutdown.
D. The injectors are 'bank fired'.



30. Two technicians are discussing the injector waveform shown above. Technician A says that the waveform is typical of a peak and hold injector. Technician B says that the rise in control circuit voltage is normal. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

31. The composite vehicle has no fuel pressure. Technician A says the problem could be the result of a blown No. 22 fuse. Technician B says that the problem could be a poor connection at ECM terminal 9. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

32. A vehicle with multiport fuel injection only starts with the throttle held open. A review of the vehicle history indicates that although the vehicle has 75,000 miles on it, the engine has never been serviced except for an occasional oil change. The MFI system uses an Idle Air Control Valve to regulate closed throttle rpm. Technician A says that the IAC valve may be stuck in the fully extended position. Technician B says that the problem may be the result of a clogged fuel filter. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

Prepare yourself for ASE testing with these questions on ADVANCED ENGINE PERFORMANCE SPECIALIST

33. Idle speed is too high on an engine with a speed density fuel injection system. Technician A says that someone may have replaced the PCV valve with the wrong type. Technician B says that a leaking throttle body gasket may be causing the problem. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

34. All of the following conditions could cause an increase in hydrocarbon emissions **EXCEPT**:
   A. missing air pump drive belt
   B. EGR valve stuck closed
   C. EVAP system leak
   D. EGR valve not seating

35. The composite vehicle has an illuminated MIL and a stored DTC for an EVAP system failure. Which of the following could be the cause?
   A. blown fuse No. 4
   B. gas cap is too tight
   C. canister vent solenoid resistance is 39 ohms
   D. poor connection at ECM terminal 104

36. The composite vehicle idles rough and stalls when the transmission is put into gear. Technician A says that the throttle body may be contaminated. Technician B says that the circuit to ECM terminal 108 could be shorted to ground. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

37. The EFE heater stays energized all the time on an engine with TBI. Which of the following symptoms would not be associated with this condition?
   A. poor cold driveability
   B. spark knock
   C. lack of power
   D. excessive NOx emissions

38. The composite vehicle fails a two-speed idle test due to excessive carbon monoxide. When the PCV valve is removed from the valve cover, CO emissions drop below the maximum allowable limit. Technician A says that this test proves the PCV system is working properly. Technician B says that the engine may have one or more leaking injectors. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

39. Two technicians are discussing emission controls and related failure symptoms. Technician A says that if the hot air hose is missing on an engine with a thermostatic air cleaner, NOx emissions will be higher than normal. Technician B says that a faulty secondary air system can cause backfiring. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

40. The composite vehicle fails an I/M 240 test due to high carbon monoxide emissions. HC is barely within limits, while NOx is well below the maximum cutpoint. Once the cause of the high CO has been corrected, the vehicle is retested and fails again, only this time for excessive NOx. What is the MOST likely reason for the subsequent failure?
   A. The converter was damaged as a result of the CO failure.
   B. The technician damaged the EGR vacuum line while making the initial repair.
   C. The CO failure masked the NOx problem.
   D. The failed retest was coincidental.

41. What is the most effective way to test the PCV system?
   A. Shake the valve to see if it rattles.
   B. Perform a vacuum draw test.
   C. Perform an rpm drop test.
   D. Measure the vacuum signal at the valve.

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42. Two technicians are discussing the effect air injection has on the carbon dioxide and oxygen readings from a properly functioning vehicle. Technician A says that CO2 reaches its highest point with the air injection system enabled. Technician B says that disabling the air injection system will cause an increase in the O2 reading. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

43. A vehicle with continuous return injection fails the low-speed portion of a two-speed idle test. According to the test results, which of the following conditions caused the vehicle to fail?

IDLE TEST RESULTS	MEASURED	LIMIT
HC (ppm)	855	220
CO (%)	0.14	1.2
CO2 (%)	7.98	
O2 (%)	4.85	
Engine RPM	648	

A. clogged PCV valve
B. faulty pressure regulator
C. restricted fuel return line
D. EGR valve not seating

44. Technician A says that an engine misfire will result in low CO along with high O2 readings. Technician B says that low CO and high O2 readings could be the sign of a lean mixture. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

45. All of the following information is typically entered into the computer prior to performing an I/M test **EXCEPT**:

A. GCWR
B. emissions equipment (based on underhood emissions label)
C. VIN
D. engine size

46. A vehicle fails an I/M 240 test for excessive NOx emissions. Technician A says that a restricted air filter may be causing the problem. Technician B says that the engine may have excessive intake valve deposits. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

47. A vehicle with throttle body injection failed the ASM5015 test based on the following Vehicle Inspection Report (VIR).

MODE	CO %			HC ppm		
Loaded	Limit	Reading	Result	Limit	Reading	Result
ASM5015	0.44	1.32	**FAIL**	78	238	**FAIL**

NOx ppm			RPM	DILUTION
Limit	Reading	Result	Reading	Reading
625	379	**PASS**	1528	12.1%

Technician A says that the gas readings could be the result of a bad catalytic converter. Technician B says that the engine may have a leaking throttle body gasket. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

48. A TSI test is automatically aborted after 10 seconds in the high-speed mode. Refer to the test results to determine the validity of the technicians' statements.

2500 RPM TEST RESULTS	MEASURED	LIMIT
HC (ppm)	4	220
CO (%)	0.00	1.2
CO2 (%)	0.00	
O2 (%)	20.85	
Engine RPM	2558	

Technician A says that the exhaust system may be leaking. Technician B says that the engine could be running too lean. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

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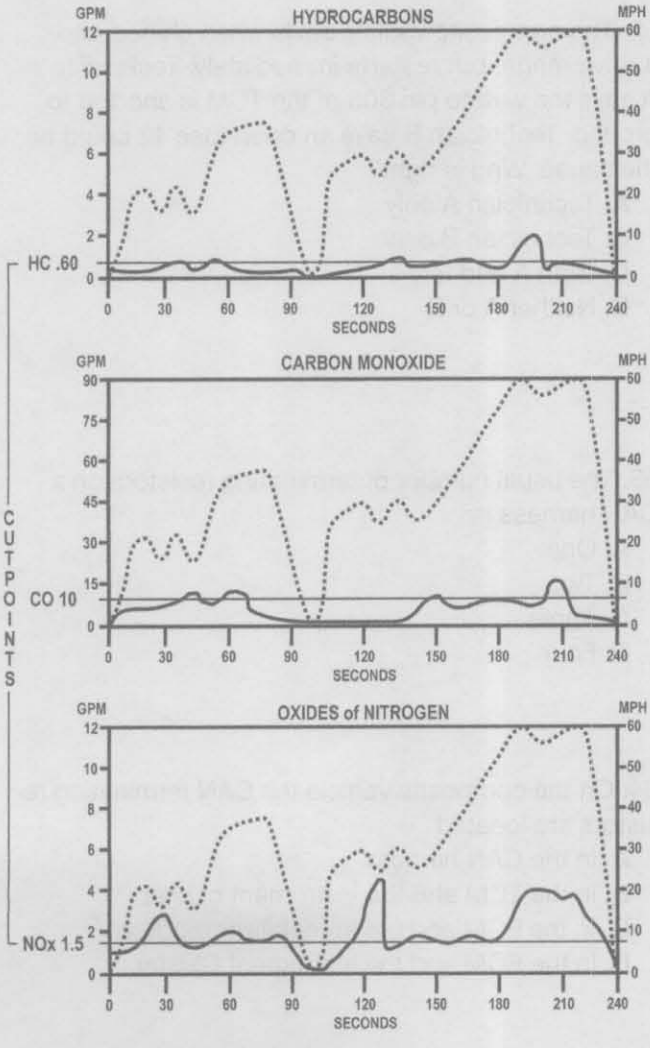
49. The composite vehicle failed an I/M 240 test for excessive NOx. Which of the following conditions could be causing the problem?
   A. weak EGR diaphragm spring
   B. stuck-open thermostat
   C. clogged EGR supply tube
   D. leaking injector

50. What conclusion can be drawn from the I/M 240 inspection report shown below?



   A. The vehicle passed.
   B. The vehicle failed for high HC.
   C. The vehicle failed for high NOx.
   D. The vehicle failed for high HC and CO.

51. The accelerator is disabled on the composite vehicle. Technician A says a broken connection at ECM terminal 141 could be the cause. Technician B says that broken connections at terminals 24 and 25 will create this condition. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

52. The composite vehicle stalls as it comes to a stop. A road test reveals that the torque converter clutch is not releasing. Technician A says a broken connection at ECM terminal 171 could be the cause. Technician B says the problem could be caused by a broken connection at TCM terminal 330. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

53. The default throttle position on the composite vehicle is:
   A. 0%
   B. 15%
   C. 20%
   D. 30%

54. On the composite vehicle, the Immobilizer Module will do all of the following EXCEPT:
   A. stop operation of the starter motor
   B. verify the key code
   C. disable injectors if the keycode is invalid
   D. recognize the ECM ID number

55. The composite vehicle uses two Throttle Position Sensors. Technician A says this is a failsafe in case one sensor fails. Technician B says that the use of two sensors allows for a more accurate measurement of throttle position. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

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56. The composite vehicle is running poorly and has a flashing MIL. Technician A says a broken circuit to ECM pin 16 could be the cause. Technician B says the condition could be due to an open fuse number 4. Who is right?
    A. Technician A only
    B. Technician B only
    C. Both A and B
    D. Neither A or B

57. All of the following will disable the air conditioner compressor clutch on the composite vehicle EXCEPT:
    A. a shorted A/C request switch
    B. an open circuit at pin B of the A/C pressure sensor
    C. an open circuit at pin A of the A/C pressure sensor
    D. an open circuit at pin 9 of the ECM

58. The composite vehicle stalls at idle but restarts. Technician A says an open circuit to ECM pin 108 could be the cause. Technician B says an open circuit at pin A of the EGR solenoid could be the problem. Who is right?
    A. Technician A only
    B. Technician B only
    C. Both A and B
    D. Neither A or B

59. The A/C clutch is inoperable on the composite vehicle. Technician A says an open circuit to ECM pin 9 could be the problem. Technician B says this condition could be due to a refrigerant leak. Who is right?
    A. Technician A only
    B. Technician B only
    C. Both A and B
    D. Neither A or B

60. The Common Area Network (CAN) on a vehicle is disabled. Technician A says an open terminating resistor could be the cause. Technician B says a shorted CAN harness could be the problem. Who is right?
    A. Technician A only
    B. Technician B only
    C. Both A and B
    D. Neither A or B

61. The composite vehicle is overheating. The radiator fan is not turning on and turning on the air conditioner won't turn on the fan. Technician A says a blown fuse number 4 could be the cause. Technician B says that an open circuit to pin 10 of the ECM could be the cause. Who is right?
    A. Technician A only
    B. Technician B only
    C. Both A and B
    D. Neither A or B

62. The composite vehicle stalls when shifted into a drive range, but restarts immediately. Technician A says the wire to pin 305 of the TCM is shorted to ground. Technician B says an open fuse 42 could be the cause. Who is right?
    A. Technician A only
    B. Technician B only
    C. Both A and B
    D. Neither A or B

63. The usual number of terminating resistors on a CAN harness is:
    A. One
    B. Two
    C. Three
    D. Four

64. On the composite vehicle the CAN terminating resistors are located
    A. in the CAN harness
    B. in the TCM and the instrument cluster
    C. in the ECM and the Immobilizer module
    D. in the ECM and the Instrument Cluster

65. The composite vehicle is misfiring on cylinder number 4. All of the following could be the cause EXCEPT:
    A. an open circuit at pin 18 of the ECM
    B. an open circuit at pin 17 of the ECM
    C. an open circuit at pin 123 of the ECM
    D. a faulty ignition coil

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66. The composite vehicle has high emissions and an illuminated Malfunction Indicator Light (MIL). The downstream oxygen sensor voltage is varying consistent with the upstream oxygen sensors. Technician A says a faulty catalytic converter could be the problem. Technician B says the downstream oxygen sensor could be defective. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

67. The composite vehicle is running poorly. The technician has recorded the following data:

Engine Idle Speed	700 RPM
Mass Air Flow sensor	0.7 volts
MAP sensor	2.1 volts

Technician A says a faulty MAP sensor is the cause. Technician B says the Mass Air Flow sensor is defective. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

68. Oxides of Nitrogen begin to form when combustion temperatures exceed:
   A. 1500° F
   B. 2000° F
   C. 2500° F
   D. 3000° F

69. The composite vehicle has poor performance. Technician A says a faulty intake cam position solenoid could be the problem. Technician B says a faulty exhaust cam position solenoid could be the cause. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

70. The composite vehicle will not shift past second gear. The resistance of both shift solenoids is 6 Ohms. Technician A says that the shift solenoids are defective. Technician B says there could be an open circuit to pin 308 of the TCM. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

71. The CAN harness resistance on the composite vehicle is measured at 120 Ohms. Technician A says that a terminating resistor is open. Technician B says this is a normal resistance value. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

72. The composite vehicle has high mileage and a low power complaint. The MAP sensor reads 1.76 volts at idle and at a steady 2000 rpm. Technician A says a compression test should be done to check engine condition. Technician B says the engine should be checked for a vacuum leak. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

73. Two technicians are discussing catalytic converters and their effect on emissions and performance. Technician A says a defective converter will always cause reduced performance. Technician B says a defective catalytic converter can cause high emissions without reducing performance. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on ADVANCED ENGINE PERFORMANCE SPECIALIST

74. The torque converter clutch on the composite vehicle will not engage. Technician A says a short to ground at pin 305 of the TCM may be the cause. Technician B says that a voltage short to pin 171 of the ECM may be the cause. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

75. Technician A says that ohmmeter testing will be required to diagnose the composite vehicle in the previous question. Technician B says a scanner may provide adequate diagnostic capability in this case. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

76. All of the following conditions must be met for the composite vehicle to enter closed loop EXCEPT:
   A. coolant sensor voltage of 2.93 volts
   B. voltage inputs from the oxygen sensors
   C. ten seconds operating time since start-up
   D. MAP sensor voltage between 1.5 and 2.0 volts

77. Oxides of Nitrogen emissions are controlled by the catalytic converter and the:
   A. PCV system
   B. EFE system
   C. EGR system
   D. secondary air system

78. On the composite vehicle all of the following are required to engage the Torque Converter Clutch EXCEPT:
   A. shift solenoid C engaged
   B. transmission temperature at 150°F
   C. vehicle speed over 40 MPH
   D. transmission in 3rd or 4th gear

79. When performing a drive cycle on the composite vehicle, which of the following is required?
   A. start with a warm engine
   B. keep vehicle speed below 50 MPH
   C. fuel tank must be between ¼ and ¾ full
   D. immediate shutdowns with no idle periods

80. The composite vehicle loses fuel pressure immediately on shutdown. Technician A says the pressure regulator on the fuel rail may be defective. Technician B says the fuel tank will have to be removed to repair this problem. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

81. The composite vehicle will shift into drive but not reverse. Technician A says a poor connection at pin 348 of the TCM Could be the cause. Technician B says that a poor connection at Pin 344 of the TCM could be the cause. Who is correct?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

82. Data link resistance can be measured on the composite vehicle at data link connector pins:
   A. 1 and 11
   B. 4 and 7
   C. 6 and 14
   D. 4 and 16

Notes

Answers to Study-Guide Test Questions

1. The correct answer is D. In most overhead cam engines, proper valve timing depends on the integrity of a toothed rubber belt. A broken belt allows the crankshaft to turn independently of the camshaft(s), which causes the valves and pistons to become out of phase. As a result, compression readings will be lower than normal on every cylinder. Although it is possible to have universally low compression due to burned valves, a leaking head gasket, or worn piston rings, the potential for these conditions to be the root cause of the problem is far less than a broken timing belt.

2. The correct answer is B. Burned valves prevent the affected cylinder from sealing properly. When the exhaust valve is at fault, combustion gases will be drawn into the cylinder during the intake stroke, and a portion of the air/fuel charge will be expelled into the exhaust system during the compression stroke. Likewise, when air is applied to a cylinder during a leakage test, it will escape out the tailpipe if the exhaust valve is not sealing. Technician A's suggestion of a worn cam lobe is incorrect, since a worn lobe would prevent the exhaust valve from opening. While worn cam lobes are likely to affect compression readings, they will have no affect on cylinder leakage.

3. The correct answer is C. The first step in solving a performance problem is to confirm that an abnormal condition actually exists. That's why a road test should always precede any diagnostic procedures, such as those mentioned in the list of responses. In some cases, a driveability complaint may turn out to be nothing more than a customer's unrealistic expectation of their vehicle's performance capabilities. A road test will allow you to evaluate the reliability of the complaint, and then determine the appropriate course of action.

4. The correct answer is A. Engine ping, technically known as spark knock, is the result of excessive combustion chamber temperatures. Consequently, any condition that raises engine temperature has the potential to cause spark knock. For example, if the ratio of antifreeze to water is too great, the coolant will not release heat efficiently as it flows through the radiator. As the coolant retains more and more heat, combustion temperatures gradually rise high enough to ignite the air/fuel mixture spontaneously. This condition creates multiple flame fronts in the chamber that eventually collide, resulting in the metallic rattling sound commonly referred to as 'engine ping.' Combustion chamber temperatures are also controlled through EGR (Exhaust Gas Recirculation). At the heart of this process is the EGR valve, which allows metered amounts of exhaust gas to dilute the air/fuel mixture. Since exhaust gas is non-reactive, EGR causes the air/fuel charge to become weaker. Therefore, combustion temperatures remain below the level required for spontaneous combustion. Obviously, if the EGR valve was stuck in the closed position, combustion temperatures would rise quickly, since charge dilution would cease. On many engines, a missing catalytic converter will prevent the EGR valve from opening. This is because many vacuum operated EGR valves require sufficient exhaust backpressure to operate properly. That's why a missing converter can also cause spark knock. A thermostat regulates the engine's minimum operating temperature. In cases where the thermostat is stuck open or has been removed, the engine will run cold. Consequently, a missing thermostat would not cause spark knock.

5. The correct answer is C, both technicians are right. Stalling can result from a variety of conditions, not the least of which are those suggested by both technicians. In the case of a faulty TCC (Torque Converter Clutch) solenoid, the clutch could remain in the applied position. Under this condition, there would be no slip between the engine and transmission, resulting in a closed throttle stall. This condition is similar to bringing a vehicle with a manual transmission to a stop in gear without releasing the clutch. All port-injected engines are vulnerable to throttle body contamination. During hard acceleration, when crankcase pressure is high, blowby gases are released into the intake air stream. These warm vapors condense on the cool surface of the throttle plate. Over time, the condensing vapors form hard deposits that reduce airflow and cause stalling.

6. The correct answer is C, both technicians are right. An idle speed control motor regulates closed throttle rpm by physically changing the position of the throttle lever. This is accomplished using a plunger that extends from the motor housing. A throttle switch, located inside the ISC assembly, closes whenever the throttle lever contacts the plunger. This signals the ECM to take control of engine speed. In turn, the ECM activates the reversible motor as needed to provide the desired rpm. This is a programmed value based on coolant temperature, accessory loading, and other variables. Consequently, if the programmed idle speed is 600 rpm at normal operating temperature and no load, the ECM will extend or retract the plunger until actual engine speed equals 600 rpm ± a predetermined value (e.g. 25 rpm). In order for the ECM to match closed throttle rpm to the programmed value, it must receive a reliable rpm input. This allows the ECM to determine if idle speed needs to be raised or lowered. However, if the rpm signal is erratic, the ECM will be theoretically incapable of matching the actual speed to the desired speed. Consequently, it will continue to chase an elusive rpm by toggling the ISC plunger back and forth. As the question indicated, the rpm signal is produced by a sensor inside the distributor. Since the distributor is driven by the camshaft in an overhead valve engine, a loose timing chain or worn distributor shaft gear could cause an erratic rpm signal. Therefore, either of these conditions could be the root cause of the toggling ISC motor.

7. The correct answer is D, neither technician is right. The fuel control system on the composite vehicle will not enter closed loop until the following conditions have been met:
-- minimum engine-run time of ten seconds
-- throttle position less than 80%
-- AFRS 1/1 and AFRS 2/1 are switching.
Once these requirements are satisfied, the system will make the transition from open loop to closed loop. Terminal 60 of the ECM is ground for the entire ECM. A poor connection here would shut down the ECM. Consequently, technician A's statement is incorrect. Technician B is also wrong. This is because the ECM does not use intake air temperature as a qualifier for closed loop operation on the composite vehicle.

8. The correct answer is B. In order for the ECM to maintain a stoichiometric mixture, it needs to receive the O2 feedback signal quickly. This is why 'response time' is one of the performance standards used for oxygen sensors. The zirconia O2 sensor, which is the most widely used type, generates a signal between zero and one volt once it reaches operating temperature. As the oxygen content in the exhaust gas varies, sensor output voltage rises and falls. Rich mixtures (low oxygen) cause the sensor to generate voltages above 450 millivolts, while lean mixtures (high oxygen) produce voltages below .450V. A properly functioning sensor will typically recognize a change in oxygen content within 100 milliseconds (response B). The times listed in responses C and D (one second and 1000 milliseconds) are not only the same, but are far too slow. In contrast, response A's time of 50 microseconds (50 millionths of a second) is too fast to be realistic.

9. The correct answer is D, neither technician is right. The complexity of today's vehicles often causes technicians to overlook the obvious. The remarks made by both technicians bear this out. Virtually all of the displayed values are normal, with the exception of the 0% reading under the fuel tank level PID. Based on this value, the vehicle is out of fuel, which is the reason the engine cranks but won't start. Technician A's assertion that the system is stuck in the clear flood mode is implausible, since the values for TP1 and TP2 accurately reflect the closed throttle conditions under which the scan data was observed. Likewise, there is no evidence to support technician B's theory. Under KOEO conditions, manifold pressure is equal to atmospheric pressure. This is why the MAP value is 101 kPa (14.7 psi).

10. The correct answer is D. A good zirconia oxygen sensor, which is the type found on the composite vehicle, will typically generate a voltage that switches between 200 and 800 millivolts at a frequency of at least 5 Hz (cycles per second). The time required to make the lean-to-rich and rich-to-lean transitions should be about 100 milliseconds. These performance characteristics are readily apparent in the waveform.

11. The correct answer is A. Although each of the responses describes a condition capable of triggering a misfire code, the only failure consistent with the scan data is an EGR valve that is not seating. The clues to this diagnosis can be found by looking at the HO2S voltages and fuel trim readings. Notice that both upstream oxygen sensor readings are well above 600 millivolts, and fuel trim values are in the negative range. This is because there is less oxygen in an EGR diluted mixture. While these readings are also indicative of a rich condition, this is not one of the available choices. Besides, if the engine were running rich enough to trigger a misfire code, the upstream HO2S voltages would tend to be higher than the displayed values, and the fuel trim readings would be closer to the control limit of –30%. As mentioned earlier, the conditions described in choices B, C, and D could also cause a misfire. However, the response from the closed loop system would be quite different. For example, if one of the ignition coils were bad, combustion would not occur in the affected cylinder, and a high level of oxygen would be discharged into the exhaust. This is because the oxygen normally used in combustion would simply pass through the cylinder unchanged. Under this condition, upstream HO2S voltages would be below 300 millivolts (lean), and fuel trim readings would be well into the positive range (adding fuel). The ECM would take similar action if a clogged injector or vacuum leak were causing a lean misfire. Incidentally, notice that the MAP value of 2.3V is well above the normal closed throttle reading as is the 15% TAC value. The high MAP is due to the reduction in vacuum that occurs during a misfire, while the increase in TAC setting is an attempt by the ECM to achieve the desired idle speed.

Answers to Study-Guide Test Questions

12. The correct answer is B. A Linear EGR Valve is an electro-mechanical device controlled directly by the ECM. As a result, no vacuum signal is required for valve operation. As the schematic shows, fused battery power is supplied to the EGR solenoid coil under Key On Engine Off (KOEO) and Key On Engine Run (KOER) conditions. This is why response A is a true statement. Response C is also true, since the ECM operates the valve through a ground driver shown in the de-energized position. The pintle position sensor is a potentiometer that operates off a 5-volt reference signal from terminal 42 of the ECM. The ECM monitors the feedback from this sensor to maintain precise control of EGR flow. In the schematic, the sensor's wiper arm is shown centered on the resistor strip, which would result in the ECM seeing about 2.5 volts at terminal 23. Consequently, response D is another true statement. If the 20A fuse were blown, the EGR valve would not operate. Under this condition, pintle position voltage would remain at one volt, which is the normal input signal at 0% EGR (valve closed). As you can see, response B is the false statement.

13. The correct answer is D, both technicians are incorrect. The electronic transmission in the composite vehicle uses a pair of TCM-controlled solenoids to control fluid flow to the 1-2, 2-3 and 3-4 shift valves. In second gear the TCM activates all four shift solenoids and shuts off SSC and SSD to engage third gear. Obviously, an open solenoid would prevent engaging second gear, which is why technician A's theory is incorrect. Technician B's suggestion is equally valid. The TCM activates the solenoid through a ground driver at terminal 309. A poor connection here would cause the solenoid to remain off, once again preventing the engagement of second gear.

14. The correct answer is B. The OBD II monitors are diagnostic tests used to evaluate the performance of emissions-related components and subsystems. Where the composite vehicle is concerned, the Comprehensive Component Monitor is a one-trip test (on some real-world vehicles it is a two-trip test). This means that the ECM will illuminate the MIL, store a DTC and freeze frame following the first 'bad' trip. Consequently, response A is a true statement. Response C is also true. The EVAP Monitor will not run unless engine temperature is below 86°F (30°C). If engine temperature is higher than this, as would be the case at 94°F, the ECM will not execute the test. Response D indicated that a LTFT reading of -30% could cause the Fuel Control Monitor to fail. This is a true statement. The key word here is 'could.' The Fuel Control Monitor is a two-trip test. Therefore, LTFT would have to be at the limit for two consecutive trips before the monitor would fail. Response B is the false statement because the O2 Monitor is a non-continuous test (runs once per trip).

15. The correct answer is C, both technicians are right. A catalytic converter contains small amounts of noble metals that initiate chemical reactions. These metals include platinum and palladium for the oxidation of HC and CO, and rhodium for the reduction of NOx. The converters used on OBD II vehicles also contain cerium, which is an element capable of storing and releasing oxygen. Cerium not only enhances the effectiveness of the noble metals, but also helps stabilize catalyst operation. Because there is a direct link between a converter's ability to reduce emissions and its ability to store and release oxygen, the Catalyst Efficiency Monitor evaluates converter performance based on the signals from a pre-catalyst (upstream) and post-catalyst (downstream) oxygen sensor. Under normal conditions, the signal from the upstream sensor will be switching above and below the transition point of .450V, while the output from the downstream sensor will remain relatively stable at about .550V. However, as converter performance deteriorates, there will be more free oxygen in the post converter exhaust gases. As a result, the signal from the downstream sensor will begin switching. Once the number of downstream switches exceeds a calibrated threshold under specific operating conditions, the Catalyst Monitor will fail. A DTC P0420 can be triggered by mechanical problems such as a leaking exhaust system, worn valve seals or a blown head gasket. A leaking exhaust system affects the stability of the oxygen sensor signals, while oil or antifreeze in the combustion gases contaminates the oxygen sensors and converter alike. Over time, these conditions reduce the performance of the sensors and converter to the point of monitor failure.

16. The correct answer is A. With the relay energized, battery voltage is applied to terminal B13 of the PCM, as well as the O2 heating element, injectors, generator, and ignition coils through splices S100 and S200. Under normal conditions, there should be virtually no voltage drop (<0.01V) across the closed relay switch contacts. However, if there is excessive drop in this area, there will be less voltage available to power the previously mentioned devices. This could result in a variety of engine performance problems. To check the voltage drop, the leads would be placed as technician A indicated; between relay terminals B and D with the relay turned on. Excessive voltage drop in the O2 ground circuit (signal return) could create a false rich signal.

To check voltage drop in this area, the voltmeter leads would be connected between terminal C12 at the PCM and G101 with the engine running. Connecting the leads as technician B indicated is incorrect, since this would result in a measurement of O2 output voltage.

17. The correct answer is A. The clues to this diagnosis can be found in the MAP, HO2S and fuel trim readings. Given the high-rpm, no-load conditions under which the snapshot was taken, the MAP reading should be closer to 1.5 volts rather than the indicated value of 3.6V. This high MAP reading shows that manifold pressure is above normal, which is consistent with a clogged converter. A restricted converter causes combustion gases to accumulate inside the cylinders. During the overlap period, in which the intake and exhaust valves are open briefly, the excess gas leaks into the intake manifold. This creates positive pressure and reduces vacuum, in the same way a leaking EGR valve does at closed throttle. Because the accumulated gas dilutes the incoming air/fuel charge, there is less oxygen detected by the O2 sensors. This is why the upstream HO2S readings are high and the fuel trim readings are low. Incidentally, the negative fuel trim response indicates that the ECM is attempting to compensate for what it believes is a rich mixture. As you can see, technician A's suggestion is correct. Although low fuel pressure is a potential cause of poor driveability, in this case a lack of power, the scan data does not support this diagnosis. If fuel pressure were low, as technician B suggested, the HO2S and fuel trim readings would be reversed. This means that the upstream HO2S voltages would be well below 300 millivolts, while fuel trim would be compensating in the positive direction.

18. The correct answer is D, neither technician is right. The statements made by both technicians are incorrect. To begin with, they failed to realize that the sensor in question was the downstream HO2S. In addition, a constant purge problem or clogged PCV valve would cause the upstream HO2S voltages to be much higher than indicated by the waveform. Under normal conditions, the voltage from the upstream sensors switch rapidly above and below .450V in closed loop. If the catalyst has at least 95% conversion efficiency, the signal from the downstream HO2S will be relatively flat by comparison. This can be seen in the waveform, and is due to the stability of the oxygen levels in the post converter exhaust gases. If the catalyst is failing however, the post converter gases will contain varying amounts of oxygen. As a result, there will be a significant variation in the frequency and amplitude of the downstream HO2S signal in closed loop.

19. The correct answer is C, both technicians are right. Although a cold starting problem could be attributed to a variety of conditions, the suggestions made by technicians A and B are among the most likely, and therefore equally correct. This is because falling outside temperatures cause an increase in secondary resistance. To begin with, cranking speed is reduced at low temperatures due to thicker oil and a tighter engine. Since the starter draws more current when the engine is cold, there is less voltage available for the ignition system. Under normal conditions, the module will compensate for the reduced voltage by increasing dwell. However, if the coil is shorted, the developing magnetic field will still be too weak to generate sufficient energy. Consequently, as the outside temperature drops, the engine will be increasingly difficult to start. A high-resistance coil wire could cause the same problem for a different reason. Under this condition, the wire would create an excessive voltage drop, which would consume much of the secondary energy needed to fire the plugs.

20. The correct answer is A. The composite vehicle uses a crankshaft position sensor as the input to the ECM for base timing calculation. If the ECM doesn't see this input. It will not trigger the ignition coils. A quick glance at the composite vehicle schematic shows that Technician B is Incorrect because the composite vehicle uses six individual coil drivers. The failure of a coil driver would only shut down one cylinder.

21. The correct answer is B. The CKP sensor generates an AC voltage that varies in frequency and amplitude as engine speed changes. The 35-tooth reluctor causes the sensor to produce 34 10-degree pulses and one 20-degree pulse each crankshaft revolution. As the pattern shows, sensor output is above the minimum acceptable level of 0.5 VAC, and the 20-degree sync pulse is clearly visible. This eliminates the possibility of a faulty sensor. It also dispels the notion that the sensor is misadjusted. To begin with, the composite vehicle does not use an adjustable CKP sensor. Secondly, the signal produced by a misadjusted CKP sensor would either be too high or too low, which is not the case here. Nevertheless, the pattern shown is abnormal. Notice that the amplitude of one 10-degree pulse is lower than the rest. This could only be the result of a chipped tooth on the reluctor. When that tooth aligns with the sensor, it creates a wider than normal gap. A good reluctor tooth fully compresses the magnetic field radiating from the sensor tip. This creates a strong positive pulse. When the tooth moves away from the sensor, the magnetic field suddenly relaxes, resulting in an equally strong negative pulse. However, when a chipped tooth moves past the sensor, it is unable to affect the magnetic field in the same way. Consequently, sensor output drops, as indicated by the lower pulse.

22. The correct answer is A. In order for a coil to generate sufficient secondary voltage, the primary circuit must provide a low-resistance path for current to flow. Only if the primary circuit had high resistance would it cause a misfire. This is why response A is the right answer. The most common cause of a misfiring cylinder is an open spark plug wire. This is as true for waste spark systems as it is for engines using a distributor. Under this condition, the demand for secondary voltage exceeds the supply. As a result, combustion cannot occur. Low charging system voltage can also cause an engine to misfire, especially under load. This is because the less voltage available to the primary coil winding, the less secondary energy will be produced. Obviously, this would be the case if the generator were undercharging, just as it would if there was high resistance (excessive voltage drop) in the primary circuit. In most waste spark systems, each coil's primary winding is switched on and off through transistors in the ignition control module. Although the ECM determines timing and dwell, the module serves as the actuator. Consequently, a defective module could prevent one or more coils from working. In a waste spark system, this would result in at least two misfiring cylinders.

23. The correct answer is C. Terminal 19 of the ECM is the ground driver for the number six ignition coil. A poor connection here would cause excessive voltage drop in the primary circuit. This would result in low secondary output to the number six spark plug, resulting in a partial misfire at best along with higher than normal hydrocarbons. If the CMP signal were shorted to ground, the engine would take longer to start. This is because the ECM would never see the 5V reference signal required to sequence the injectors and coils. However, once the engine was running, the missing CMP signal would have little effect on exhaust emissions. Therefore, response A is incorrect. Response B is also incorrect because an open CKP sensor would prevent the engine from starting at all. The engine would also fail to start if fuse No. 4 were blown (response D). Under this condition, all of the ECM controlled actuators, including the injectors and ignition coils, would lose battery power.

24. The correct answer is B. A snap throttle test places a load on the ignition system that can help isolate problems such as a bad wire or faulty spark plug. When the throttle is opened suddenly, air rushes into the cylinder while the fuel lags behind. This is because fuel is heavier than air. Since the fuel is the conductive material in the mixture, a snap throttle test drives the engine lean, which creates additional secondary resistance. If the ignition system is operating normally, the firing lines should spike upward 4-6kV. However, if a spark plug is gapped too wide, or a wire has excessive resistance, the firing line from the affected cylinder will rise much higher as the coil attempts to initiate the spark. A snap throttle test is most useful for engines with throttle body injection, since fuel lag time is much greater in a 'wet-manifold.' On port-injected engines, fuel is delivered too quickly for a snap throttle test to be very useful. That's why using a spark tester is a better way to test the ignition system, regardless of fuel system type. A spark tester is essentially a spark plug with a 3/8-in. gap. Since the tester requires 25kV before it will fire, it provides a foolproof method for checking ignition system performance.

25. The correct answer is D. Evaluating the condition of ignition system components requires the right specifications, proper test equipment, and the ability to use both. Specifications can be unclear unless you are familiar with the abbreviations used to express electrical values. In addition, neglected equipment, and/or improperly connected leads, can cause false test results. The former could be something as incidental as a low battery, while the latter usually occurs when a technician picks up a meter to check current, but forgets to move the positive lead to the amp jack. The specifications in the question are all listed in ohms as indicated by the 'omega' (Ω) symbol, which is the last letter in the Greek alphabet. While no secondary resistance specification is given for the composite vehicle, typical resisitance is 10k ± 2k ohms. Response A is obviously incorrect since 5000 ohms is too low. Response B is also wrong, only this time the spec is far too high. A reading of 11M represents 11 million ohms. The letter 'M' is used to denote the prefix 'mega,' which indicates one million. Response C is wrong because it shows the proper resistance for the primary winding, not the secondary. A reading of 8.25k ohms equals 8250 ohms, which falls within the proper resistance range. The letter 'k' stands for the prefix 'kilo,' which means one thousand.

26. The correct answer is A. Although three of the responses are indicative of the types of failures associated with a high leakdown rate, according to the circumstances described in the question, the most likely cause is a faulty regulator. The clue to the correct answer can be found in the word 'immediately,' as it describes how quickly the leakdown occurs. Normally during cranking, the regulator remains closed, which effectively blocks off the return line. This allows the system to operate with maximum fuel pressure for starting. Once the engine is running, the regulator opens due to the vacuum applied at the regulator port. This causes excess fuel to flow back to the tank. Keep in mind that the question indicated that this was a continuous return system! While a leaking injector or bad check valve in the fuel pump would definitely cause a high leakdown rate, neither condition would cause pressure to drop to zero immediately. However, if the regulator were stuck in the open position, system pressure would bleed off as soon as the pump stopped running. In the case of a restricted return line (response B), this would actually prevent immediate leakdown rather than cause it.

27. The correct answer is B. The results of the injector balance test clearly show that injectors No. 2 and No. 4 have poor flow. This is indicated by the low-pressure drop readings of 9 psi and 6 psi respectively. Considering that the specifications call for a minimum pressure drop of 21 psi, it's obvious that the cylinders served by these injectors are being starved of fuel. With two misfiring cylinders, the engine would not only idle rough and lack power, but it would also be harder to start. The lack of fuel in the affected cylinders is causing a lean misfire. Since carbon monoxide is a product of a rich mixture, an increase in CO would not be a symptom consistent with the indicated test results.

28. The correct answer is B. In most continuous return injection systems, the pressure regulator responds to changes in engine load based on a manifold vacuum signal. If the vacuum line to the regulator becomes kinked, fuel pressure will increase. This is because the regulator closes off the fuel return line as vacuum drops (engine load increases). While the increase in fuel pressure rarely creates any driveability problems, attentive drivers will eventually notice a reduction in fuel economy. Long crank times are generally the result of an excessive fuel leakdown rate. The pressure regulator would only lengthen crank times if it were stuck in the open position. Since a kinked vacuum line would prevent the regulator from opening, and because the vacuum signal to the regulator is too low during cranking to affect its operation, response A makes no sense. Where responses C and D are concerned, each describes a symptom of a lean air/fuel ratio, and are therefore both incorrect.

29. The correct answer is B. This type of question tests your ability to locate relevant service information. Based on the composite vehicle data, the fuel system is a returnless design with sequentially fired injectors. This is in sharp contrast to responses A and D, which state that the system is a continuous return design and that the injectors are 'bank fired. Response C is also incorrect, since fuel pressure on the composite vehicle is regulated 58 and 62 psi. under all conditions including key on engine off (KOEO) with no key off specification, although an Immediate drop to 45 PSI would probably point to a problem.

30. The correct answer is D, neither technician is right. The waveform accompanying the question was taken from an injector controlled by a saturated switch driver. This is evident in the single inductive spike immediately following the injector-OFF signal. In contrast, peak and hold injectors generate two inductive spikes; one following the initial pulse, and another less powerful spike that follows the current limiting pulse. As you can see, technician A's statement is wrong. Technician B is also incorrect. Once a saturated switch driver grounds the injector control circuit, voltage should drop to nearly zero and remain there for the duration of the pulse. However, if there is high resistance in the control circuit, a portion of the supply voltage will be applied to the additional resistance. Under this condition, there is less voltage available to activate the injector. This can be seen as a rise in control circuit voltage during the injector pulse. Notice also that the inductive spike is lower than normal due to the voltage drop in the control circuit. High resistance can be caused by several conditions including, any loose or corroded connectors between the injector and ECM, damaged control circuit wiring, or a poor connection at the ECM. If all of the injectors are affected similarly, the most likely cause is a bad ECM ground.

31. The correct answer is A. The fuel pump on the composite vehicle is activated exclusively through a Fuel Pump Control Module (FPCM). There is no redundant control (i.e. oil pressure switch). Consequently, a failure in the FPCM or its control circuit will result in the condition described in the question, which is no fuel pressure. The FPCM receives constant battery voltage at terminal 605 through fuse No. 22. When the FPCM is enabled by the ECM, power is applied to the fuel pump. If fuse No. 22 were blown, the fuel pump would not operate. Technician B's statement is incorrect because terminal 9 of the ECM is the ground control for the A/C clutch relay.

32. The correct answer is A. An IAC valve regulates idle speed by directing air around the closed throttle plate. With the valve fully extended, there is no air bypass. This is the minimum idle position. As the ECM commands a higher idle speed, the IAC valve retracts to open up the air bypass channel. In most cases, an MFI engine will start and run at minimum idle, as long as the throttle body is clean and the idle stop screw is adjusted correctly (if applicable). The information in the question provides an important clue to the validity of technician A's statement. Considering that the vehicle had only received an occasional oil change in 75,000 miles, is reason to suspect that the throttle body was heavily coated with crankcase contaminants. If the IAC valve was stuck in the fully extended position, as technician A correctly suggested, then the engine would not start unless the throttle was held open. While a clogged fuel filter could certainly create a hard start complaint, throttle position would have no effect on easing the condition. Consequently, technician B's statement is false.

33. The correct answer is C, both technicians are right. In a speed density system, the ECM calculates engine airflow based on changes in manifold absolute pressure. The MAP sensor is designed to detect these changes. Under normal conditions, MAP output will be approximately 1-1.5 volts at closed throttle (low manifold pressure), and rise to nearly 5 volts at wide-open throttle (high manifold pressure). When an air leak exists, it causes manifold pressure to increase. As a result, the closed-throttle MAP output will be higher than normal. Since the ECM has no way of identifying the airflow source, it simply increases injector pulse width whenever it sees an increase in MAP. That's why a high idle is a common problem on vehicles with speed density systems. The spring inside a PCV valve is calibrated for a specific flow rate. If the wrong valve is used, the engine can draw in excessive air. Although this type of air leak is not visually identifiable, like a cracked vacuum hose for example, the result is the same. The engine idles too high due to the increase in manifold pressure. The same is true for a leaking throttle body gasket, since it causes the engine to draw in additional air. As you can see, the statements made by both technicians are equally correct.

34. The correct answer is B. Hydrocarbons (HC) are fuel molecules that fail to burn during the combustion process. HC can also be released into the atmosphere due to evaporating fuel. While the introduction of the EVAP system in 1970 eliminated hydrocarbon emissions from evaporative sources, the combustion process is less than perfect. Under normal conditions, an engine will emit a small amount of HC due to temperature variations in the cylinder. Post combustion controls, like secondary air and the catalytic converter, are designed to burn this residual HC. That's why a missing air pump drive belt could cause HC emissions to increase. A leaking EVAP system is another condition that could cause excessive HC, since the evaporative emissions system is designed to contain fuel vapor. Undoubtedly, the most common cause of high hydrocarbons is an engine misfire. Whenever combustion is incomplete or fails to occur at all, high levels of unburned fuel are discharged into the exhaust. While the causes of misfiring are many, they can be broadly defined as being either electrical or mechanical. An EGR valve that fails to seat properly is one of the many types of mechanical misfires. Under this condition, the air/fuel mixture becomes too weak to burn because it is largely displaced by exhaust gas. Keep in mind that mixture volume is low at closed throttle, and exhaust gas does not contain the oxygen necessary to support combustion. Consequently, the engine will misfire and emit high levels of hydrocarbons if the EGR valve is not seated. The purpose of the EGR valve is to reduce oxides of nitrogen (NOx). If the valve is stuck in the closed position, it will have no effect on hydrocarbons. Rather, a valve that is stuck closed will cause NOx emissions to rise dramatically.

35. The correct answer is D. A study of the wiring diagram shows that fuse No. 4 supplies all of the ECM controlled actuators. Obviously, if this fuse were blown, an EVAP system failure would be the least of the problems. The vehicle would not even start! Although an over tightened gas cap may be difficult to remove, it would have no effect on EVAP operation. Only if the gas cap were loose, would the EVAP monitor fail. This is because a loose gas cap would prevent the system from sealing during the EVAP system leak check. As far as the canister vent solenoid is concerned, the normal resistance range is 32-40 ohms (36 ± 4). A reading of 39 ohms is within that specification, and therefore does not indicate a problem. However, the EVAP vent solenoid requires proper power and ground signals in order to operate. Power comes from fuse No. 4, while the ECM provides the ground at terminal 104. Once energized, the canister vent solenoid blocks the fresh air supply to the canister in preparation for the leak test. If there is a poor connection at terminal 104, the vent solenoid will not operate and the leak test will fail.

36. The correct answer is C, both technicians are right. Like all port-injected engines with side-draft induction, the throttle plate on the composite vehicle is exposed to unfiltered crankcase vapors. During hard acceleration, these vapors are released into the intake air stream. Since the engine does not use a crankcase filter, and the air filter is positioned upstream of the breather tube, the warm vapors are deposited directly on the cool throttle plate. As the vapors condense, they coat the throttle plate and eventually seal the gap between the plate and bore. Since this reduces airflow and causes a drop in engine speed, placing the transmission in gear, activating the A/C compressor, or turning the wheels sharply, can trigger a stall. The EGR valve on the composite vehicle is activated by a manifold vacuum signal from the EGR solenoid. When the solenoid is de-energized, vacuum is blocked and the valve remains closed. Once the conditions are right, the ECM activates the EGR valve by grounding the solenoid at terminal 108. If this circuit were shorted to ground, the solenoid would be on all the time and the EGR valve would be open at closed throttle. This would cause the engine to stall, especially when placed under load, such as putting the transmission in gear.

37. The correct answer is A. If the EFE heater remains on all the time, cold driveability will be normal, however, the air/fuel mixture will eventually become superheated. Under this condition, combustion chamber temperatures will increase significantly, resulting in spark knock and higher NOx emissions. A superheated mixture also reduces charge density, and can therefore cause the engine to lack power. If the EFE grid remains on over an extended period of time, the grid can eventually melt. When this occurs, it creates a restriction in the induction system that will dramatically reduce engine performance. Because gasoline does not vaporize well at low temperatures, the air/fuel mixture must be rich when the engine is cold. A rich mixture makes enough fuel available so that even a partially burned charge will allow the engine to run. On port-injected engines, fuel vaporizes easily since it is delivered inside a low-pressure area (above the intake valve). However, on throttle body injected engines, fuel is delivered outside the manifold. To improve fuel vaporization, some TBI engines are equipped with an electric heater between the throttle body and intake manifold. The heater is energized when the engine is cold so that the air/fuel mixture is pre-heated before entering the intake manifold. Once the engine reaches a pre-determined temperature, the heater is turned off. At this point, the incoming fuel is vaporized through engine heat. With EFE, the ECM can be programmed with a leaner open loop fuel curve. This reduces HC and CO emissions. EFE also improves cold driveability by providing better mixture distribution at low engine temperatures.

38. The correct answer is C, both technicians are right. High carbon monoxide emissions are always the result of a rich mixture. This is because rich mixtures lack the oxygen necessary to promote good combustion. As a result, the carbon in the fuel is converted to carbon monoxide (CO), rather than carbon dioxide (CO2). The fact that CO dropped when the PCV valve was removed indicates two things. First, the PCV system is working properly, since it allowed enough air to be drawn into the engine to lean out the mixture and reduce the CO reading. Second, the crankcase is contaminated with fuel. With the PCV valve installed, the fuel-laden crankcase vapors are being drawn into the engine, causing the mixture to become too rich. These facts fully support technician A's statement. Technician B's statement is equally correct, since leaking injectors would be the most obvious cause for crankcase contamination on the composite vehicle.

39. The correct answer is B. A thermostatic air cleaner is used to improve fuel vaporization on throttle body injected engines. When the engine is cold, the damper valve opens the inlet at the base of the air cleaner while simultaneously blocking the opening at the snorkel. This allows hot air from the exhaust manifold heat stove to be drawn into the engine. The hot air flows through a heat-resistant hose. As the fuel comes in contact with the hot air, it vaporizes instantly. Without the TAC system, incoming fuel would condense on the cold throttle plate and puddle inside the intake manifold. If the hot air hose is missing, cold engine performance will be adversely affected, but only when the outside temperature is low. During warm weather, ambient heat provides sufficient fuel vaporization. In order for the TAC system to raise NOx emissions, the hot air hose would need to be in place and the damper stuck in the closed (hot air) position. Consequently, technician A's statement is false. The secondary air system reduces HC and CO emissions by injecting oxygen into the exhaust manifold when the engine is cold. Once the engine reaches a pre-determined temperature, pump air is diverted to the converter or atmosphere, depending on the system. On vehicles with electric pumps, the ECM simply disables the pump after a certain amount of time has elapsed. If pump air is continuously injected into the exhaust manifold, it can cause a backfire under certain conditions. For example, during heavy acceleration, the ECM pulses the injectors longer to provide a richer mixture. If oxygen is pumped into the manifold during this time, a backfire will result as the excess hydrocarbons are oxidized. As you can see, technician B's statement is correct. In some cases, a backfire can occur if pump air is not diverted from the manifold on deceleration. However, this condition is more common on carbureted vehicles, since fuel injection systems typically cut injector pulses during deceleration to reduce HC emissions and improve fuel economy.

40. The correct answer is C. The situation described in this question is not unusual. High CO emissions are always the result of a rich mixture, which is the reason for the composite vehicle's initial failure. However, because a rich mixture lowers combustion temperatures, a CO failure can mask an underlying NOx problem. This is why the NOx problem became apparent only after the CO failure was corrected. Although the other responses are all reasonable possibilities, response C has the highest degree of probability, and is therefore the most likely choice.

41. The correct answer is B. With the exception of response C (rpm drop test), each of the methods listed can be used for testing the PCV system (in whole or part) on a computer controlled engine. The rpm drop test is only effective for testing the PCV system on older engines without feedback control. Although shaking the PCV valve can help uncover a clogged valve, it provides no evidence that the entire system is working properly. Checking the vacuum signal to the PCV valve is another legitimate test, however, it too does not verify the integrity of the entire system. Only a vacuum draw test can determine how well the PCV system is working, and is therefore the most effective method. The draw tester is placed over the oil fill hole (oil fill cap removed). Inside the tester is a ball that responds to the level of crankcase vacuum present. If the PCV system is working properly, it will draw a slight vacuum on the crankcase that pulls the ball into the 'safe' zone. If a draw tester is not available, the same test can be performed using an index card placed over the oil fill hole. If the PCV system is functioning normally, the card should stay in place with the engine idling.

42. The correct answer is D, neither technician is right. Carbon dioxide is an indicator of combustion efficiency, while oxygen is useful for evaluating converter performance and identifying a lean air/fuel ratio. Technician A's statement is incorrect since air injection dilutes the CO_2 sample. Consequently, carbon dioxide will be at its lowest point (not highest) when the air injection system is operating. Technician B's statement is also incorrect. With the air injection system disabled, the only oxygen in the exhaust is the trace amount unused by the converter. Oxygen levels are always higher when air injection is active.

43. The correct answer is D. The readings shown on the inspection report are indicative of an engine misfire. This can be seen in the hydrocarbon level of 855 ppm, which is nearly four times the legal limit. The low CO reading of 0.14% also supports this diagnosis, since carbon monoxide is a product of combustion. When an EGR valve hangs open at closed throttle, it creates excessive charge dilution. As a result, the mixture becomes too weak to burn and the engine misfires. Once the throttle is open, the engine runs normally. This is because volumetric efficiency is greater as throttle angle increases, and because the EGR valve is designed to open during that time anyway. Another clue to the correct response is that the vehicle in question only failed the low-speed portion of the TSI test. The conditions described in responses A, B, and C would cause the engine to run too rich. If this were the case, carbon monoxide would be well over the limit of 1.2%.

44. The correct answer is C, both technicians are right. A stoichiometric chart provides a graphic representation of how the exhaust gases interact at various air/fuel ratios. Where CO and O_2 are concerned, these gases move in opposite directions in relation to the stoichiometric point (14.7:1). On the rich side of 14.7:1, carbon monoxide gradually rises due to the lack of oxygen in the mixture. This is why CO is an excellent indicator of a rich condition. At 14.7:1, CO is approximately 0.1 of one percent. As the mixture becomes leaner, CO is barely measurable. In contrast, O_2 remains at nearly zero percent on the rich side of 14.7:1, and then rises sharply as the air/fuel ratio becomes leaner. The conditions described by both technicians are consistent with low CO and high O_2 readings. With a misfire, the lack of combustion prevents carbon monoxide from forming, while the unused oxygen is simply discharged into the exhaust. When the mixture is lean, there is not enough carbon available to make carbon monoxide. This is why CO virtually disappears on the lean side of the stoichiometric point, and why a lean condition causes an increase in O_2 levels.

45. The correct answer is A. After a preliminary check to ensure the vehicle can be tested safely, the next step in the I/M inspection process is gathering the proper information. Among the data that must be entered into the computer, is the Vehicle Identification Number (VIN), vehicle make, Gross Vehicle Weight Rating (GVWR), and a list of the factory installed emissions equipment. The Gross Combination Weight Rating (GCWR) indicates the maximum allowable weight of a loaded tow vehicle and trailer. This is not applicable to I/M testing and is therefore not required.

46. The correct answer is B. Oxides of nitrogen

(NOx) form when nitrogen and oxygen come together under the heat and pressure of combustion. Consequently, every vehicle produces a certain level of NOx. However, when an engine operates above its normal maximum temperature, which is about 220°F (104°C), the corresponding increase in combustion temperature causes a proportional rise in NOx emissions. Since a restricted air filter would drive the air/fuel ratio rich, and because a rich mixture lowers combustion temperature, technician A's statement is false. Intake Valve Deposits (IVD) not only upset mixture flow, but tend to absorb fuel as well. Consequently, an engine with IVD runs leaner than normal. In addition to reduced performance, a lean mixture causes combustion temperatures to increase, resulting in greater NOx emissions. This is the reason technician B's statement is true.

47. The correct answer is A. Although the HC and CO readings shown on the VIR are indicative of a slightly rich mixture, these elevated readings could just as easily be the result of a failing converter. For example, let's assume the closed loop system is in control. That means the ECM will compensate for any condition that could cause a slight bias in the air/fuel ratio. In the case of a slight rich bias, the ECM will reduce injector pulse width to maintain a 14.7:1 air/fuel ratio. Consider also that while NOx emissions are below the legal limit, a good converter will normally do a better job at reducing NOx than the VIR indicates, especially if the mixture is biased rich. Consequently, technician A's theory, while not conclusive, is certainly valid. When an air leak occurs on a throttle body injected engine, it causes an increase in closed-throttle rpm. This is because the MAP sensor detects the additional airflow and signals the ECM to increase injector pulse width. However, this condition has no real impact on emission levels, since the air/fuel ratio remains the same. This is why technician B's statement is wrong.

48. The correct answer is D, neither technician is right. The two-speed idle test is performed using a four-gas analyzer with partial stream sampling. If the engine stalls out during the test, or the sum of the CO and CO2 readings are less than six percent, the test will be automatically aborted. Since the inspection report shows an rpm reading of 2558, the test was obviously not aborted due to an engine stall. However, notice that CO and CO2 are both zero, while O2 is nearly 21%. These readings indicate that the sampling probe was measuring ambient air and not the exhaust gases. The only explanation for this is that the probe either fell out of the tailpipe or was never inserted to begin with. The slight HC reading shown on the report is typical of ambient shop air, which usually contains airborne hydrocarbons.

49. The correct answer is C. Any condition that raises combustion temperatures will cause an increase in NOx emissions. The temperature increase can come from outside the combustion chamber, as in the case of an inoperative cooling fan for example, or within the combustion chamber, as would be the case if the vehicle had a restricted EGR supply tube. Response A is wrong, since a weak diaphragm spring would result in greater EGR flow. Under this condition, the engine would most likely exhibit an off-idle hesitation, since the EGR valve would open with less applied vacuum. Response B is also wrong. A stuck-open thermostat will cause the engine to run cold, which would cause an increase in hydrocarbon emissions, not oxides of nitrogen. Finally, a leaking injector will drive the air/fuel ratio rich. This will not only cause carbon monoxide emissions to rise, but will actually lower NOx emissions to the reduction in combustion temperature.

50. The correct answer is C. The graphs on the I/M 240 inspection report show the gas trace (solid line) superimposed over the drive cycle pattern (dotted line). The gas trace indicates the vehicle's emissions output for each second of the 240-second test. Cutpoints, which are represented by a thin horizontal line on each graph, are the maximum allowable emissions based on the model year of the vehicle and its GVWR. Although emissions may exceed the cutpoints at certain periods during the test, this doesn't mean that the vehicle will automatically fail. The reason for this is that failures are based on averages. For example, let's say that during the course of the test, carbon monoxide reached 12 gpm for a total of 120 seconds. However, throughout the other 120 seconds of the test, CO levels remained at five gpm. In this case, the average CO reading would be 8.5 gpm (12 + 5 = 17) (17 ÷ 2 = 8.5). Based on a cutpoint of 10 gpm, the vehicle's CO output would be acceptable. While the graphs on the inspection report show that HC and CO exceeded their respective cutpoints at brief intervals, the gas traces clearly show that the overall output of these emissions is within legal limits. However, this is not the case where NOx is concerned. Notice that the NOx trace rides above the cutpoint line throughout most of the drive cycle. Consequently, the vehicle would fail for excessive NOx emissions.

51. The correct answer is B. The throttle on the composite vehicle is of the 'fly by wire' design, using an ECM controlled Throttle Actuator Control (TAC) motor. When this actuator is disabled, the spring-loaded throttle returns to its fast idle position of 15%. This will occur if the ECM loses both inputs from the throttle position sensors at pins 24 and 25. Technician B is therefore correct. The TAC will also be disabled if both Accelerator Pedal Position (APP) sensors are disabled. While technician A is correct in his observation that a loss of APP sensor signals will result in a loss of input to the ECM at pin 141, he failed to notice that the second APP sensor input is received at ECM pin 144. Both inputs must fail for the throttle to be disabled, and technician A is therefore incorrect.

52. The correct answer is A. The Brake Pedal Position (BPP) switch is located on the brake pedal and closes anytime the brake pedal is pressed. This input is used by the TCM to disengage the Torque Converter Clutch (TCC). When the brake pedal is pressed, the ECM will receive a high voltage input at terminal 171. Loss of this input can prevent disengagement of the torque converter clutch, and technician A is therefore correct. Technician B is not correct, even though the schematic seems to support his answer. The input from the BPP is sent to the ECM, but the TCM uses the input to disengage the TCC. The two modules communicate by way of the serial data link so that the BPP input to the ECM is used by the TCM to disengage the TCC. If the technician looks beyond the schematic to the operating strategy of the TCM, however, he will notice that the TCM is programmed to enter a failsafe operating mode if it can't communicate with the ECM. In failsafe mode, the transmission remains in second gear and the TCC is disabled. The serial data link is connected to the TCM at terminals 330 and 331. Loss of the connection at either of these terminals will put the TCM in failsafe mode and the TCC would not engage, therefore eliminating these connections as a possible cause of this problem.

53. The correct answer is B. The default position of the throttle on the composite vehicle is 15%. At this position the engine will be in fast idle and limp in mode. The throttle actuator is operated in response to inputs from the Accelerator Pedal Position Sensors, and throttle position is monitored by two Throttle Position Sensors. If two or more sensors should fail, the TAC will be disabled, and the throttle will return to the spring loaded 15% position.

54. The correct answer is A. The immobilizer module cannot stop operation of the starter motor, so choice A is correct. The immobilizer module requires the use of a coded key, and the module will verify that the correct key is being used. The module will also recognize the ECM by ID number. If the keycode is determined to be invalid, the module will not allow operation of the injectors.

55. The correct answer is B. The composite vehicle uses two throttle position sensors. One sensor has a low voltage at idle, which increases as the throttle is opened. The other sensor has a high voltage at idle, which decreases as the throttle is opened. The ECM uses the opposing measurements of these two sensors to calculate a more accurate value for throttle position. The use of two throttle position sensors is not for failsafe purposes, and technician A is incorrect.

56. The correct answer is A. A flashing MIL indicates a misfire severe enough to damage the catalytic converter. Fuse No. 4 supplies voltage to all six ignition coils. If this fuse opens, all six ignition coils will be inoperable and the engine would not start. Technician B is therefore incorrect. Technician A is correct. Pin 16 is the low voltage connection for coil number 5. Loss of this connection will cause a misfire and shut down the ignition coil.

57. The correct answer is A. The A/C request switch is closed to command the ECM to engage the A/C compressor clutch. If this switch shorted, the A/C clutch would remain on, so a shorted switch would not cause the stated condition. An open circuit at pin 9 of the ECM would prevent engaging the clutch. Pin A of the A/C pressure switch is the 5-volt reference for the sensor. Loss of this connection would result in a low voltage input to the ECM, and the A/C clutch would be disabled. Conversely, loss of the ground connection at pin B would result in a high voltage input to the ECM, and the A/C clutch would once again be disabled.

58. The correct answer is D, neither technician is right. The EGR valve can cause a vehicle to stall at idle, but it would have to be stuck in the open position for this to occur. Technician A is incorrect because the ECM output to the EGR solenoid valve is from pin 108. An open on this circuit would prevent the EGR valve from opening. To cause the EGR to remain open, this connection would have to short to ground. At the same time, an open circuit at pin A of the EGR solenoid would also disable the EGR and would not cause the stalling condition.

59. The correct answer is C, both technicians are right. The A/C clutch is engaged when the ECM sends a low voltage signal from pin 9. An open in this circuit would disable the A/C clutch. At the same time, the A/C pressure sensor would detect the low pressure condition caused by a refrigerant leak, and would send an input to the ECM to prevent clutch engagement.

60. The correct answer is B. The CAN harness typically uses a 120-ohm terminating resistor on each end of the twisted pair harness. These are either integral to the controllers or found as separate resistors on the harness. The network will shut down if both resistors open but will remain operable if only one fails. Technician A is therefore wrong. If a harness becomes shorted, all or part of the network would be inoperable, and technician B is therefore correct.

61. The correct answer is B. The fan relay is energized when the ECM completes a low voltage circuit to the fan control relay from pin10. An open on this circuit would prevent fan operation. Technician B is therefore correct. Fuse No. 4 powers the fan relay, but it also powers numerous other components, including the fuel injectors, fuel pump relay, and ignition coils. A blown fuse No. 4 would prevent the vehicle from starting. Technician A is therefore incorrect.

62. The correct answer is A. Fuse No. 42 supplies voltage to the shift solenoids and the pressure control solenoid as well as the TCC solenoid. If this fuse should fail the transmission would not engage a drive range. Technician B is therefore incorrect. A grounded wire from pin 305 of the TCM would keep the TCC engaged and the vehicle would stall when a drive range is engaged.

63. The correct answer is B. Most CAN harnesses use two terminating resistors, although the technician should always verify this on a wiring diagram for a specific vehicle, since some later vehicles are starting to use additional terminating resistors.

64. The correct answer is D. While terminating resistors can be separate components on the ends of the CAN harness, the schematic for the composite vehicle shows that the CAN terminating resistors are integral to the ECM and the Instrument Cluster.

65. The correct answer is B. A faulty coil could cause the cylinder to misfire. Pin 123 pulses the injector for cylinder No. 4 and could also cause the misfire. Pin 18 triggers the coil for cylinder No. 4 and could also be the cause. However, pin 17 triggers coil No. 2, which would not cause a misfire in cylinder No. 4.

66. The correct answer is A. The downstream oxygen sensor monitors catalytic converter condition and will show steady low voltage readings if the converter is chemically active and reducing emissions. The varying voltage of the downstream sensor consistent with upstream oxygen sensor readings is an indication that the catalytic converter is no longer chemically active. Technician A is correct. The varying voltage indicates that the downstream oxygen sensor is active and functional and therefore technician B is incorrect.

67. The correct answer is D, neither technician is right. This is an example of a vehicle with a vacuum leak. The mass airflow sensor is showing normal idle airflow, while the MAP sensor shows that vacuum is low. Keep in mind that the composite vehicle uses the MAP sensor only for the purpose of OBD II diagnostics and its value will not cause any change in fuel mixture. Both technicians are therefore incorrect.

68. The correct answer is C. The threshold temperature for Oxides of Nitrogen (NOx) to form is 2500°F. Below that temperature nitrogen is inert and this class of emissions will not be produced.

69. The correct answer is A. Exhaust valve timing on the composite vehicle is fixed and there is no exhaust cam position solenoid. Technician B is incorrect. The composite vehicle does use intake cam position solenoids, which allow the ECM to constantly vary intake valve timing. Technician A is therefore correct.

70 The correct answer is D, neither technician is right. 6 Ohms is the correct resistance for the shift solenoids. In addition, all shift solenoids are on in second gear and therefore functional. Technician A is therefore incorrect. Technician B is also incorrect because the connection to pin 308 of the TCM engages shift solenoid B which is functional.

71. The correct answer is A. The CAN harness on the composite vehicle uses two 120 Ohm terminating resistors, which are integral to the instrument cluster and the ECM. When both resistors are intact harness resistance will be 60 Ohms. Technician A is correct and the harness resistance reading of 120 Ohms indicates an open terminating resistor.

72. The correct answer is A. This question exemplifies how knowledge of modern electronics and an understanding of basic engine operation can be blended for effective diagnosis of a defect. The MAP sensor is giving a measurement of engine vacuum, one of the most effective measurements of most engine defects. A MAP voltage of 1.76 volts indicates an engine vacuum of approximately 17 inches of Mercury, which is acceptable at idle speed. A vacuum leak would cause a lower reading than this, so technician B is incorrect. At a steady 2000 rpm vacuum should be higher than it is at idle if the piston rings are sealing properly. In this case it is not, and technician A is correct in wanting to perform a compression test to check engine condition.

73. The correct answer is B. If a catalytic converter becomes chemically inactive it will cause high emissions, but have no affect on performance, so technician A is incorrect. Such a defect would also cause the MIL to come on due to a secondary oxygen sensor code. Performance will only be affected when the converter becomes clogged and causes an exhaust restriction. Technician B is therefore correct.

74. The correct answer is B. The TCM turns on the torque converter clutch by a ground signal at pin 305. If this connection was shorted to ground, the TCC would remain engaged, so technician A is incorrect. When the brake pedal pressure sensor sends a voltage input to pin 171 of the ECM, the TCM disengages the torque converter clutch. If this wire was shorted to a source of voltage, the input to the ECM would be the same as hitting the brake pedal, and the TCC would not engage. Technician B is therefore correct.

75. The correct answer is B. On the composite vehicle the scanner will show a value for the brake pedal pressure sensor input and will be adequate for diagnosing this defect. Technician B is correct. While ohmmeter values can be used to diagnose this defect it is not a requirement. In addition, this is a voltage input to the ECM, which would make the use of a voltmeter quicker and safer. Technician A is therefore incorrect.

76. The correct answer is D. To enter closed loop the composite vehicle must be warmed to at least 160°F, the oxygen sensors must be active, and the engine must be operating for at least ten seconds. The MAP sensor on the composite vehicle is only used for OBD II diagnostic purposes and is not required to enter closed loop.

77. The correct answer is C. Oxides of Nitrogen emissions are reduced by the Catalytic converter and the Exhaust Gas Recirculation (EGR) system. Early Fuel Evaporation (EFE) and PCV systems reduce hydrocarbon emissions. Secondary air systems reduce Hydrocarbon and Carbon Monoxide emissions.

78. The correct answer is A. In order to engage the Torque Converter Clutch the vehicle speed must be over 40 MPH, the transmission must be at a minimum of 150°F, and the transmission must be in 3rd or 4th gear. Shift solenoid C does not have to be engaged and is not required for engaging 3rd gear.

79. The correct answer is C. When performing a drive cycle on the composite vehicle, the test is started on a cold engine and the engine is allowed to warm to a minimum of 160°F, so answer A is incorrect. Answer B is incorrect because the vehicle is allowed speeds up to 55 MPH. Answer D is incorrect because the specification for a drive cycle indicates a 10 second idle period before each shutdown. The drive cycle specifications do indicate that the fuel tank should be between ¼ and ¾ full, so answer C is correct.

80. The correct answer is B. The composite vehicle uses a return-less fuel system with no external pressure regulator. Technician A is therefore incorrect. Technician B is correct since the fuel pump and pressure regulator are in the fuel tank and servicing them will require removal of the fuel tank.

81. The correct answer is B. The shift selector on the TCM sends a 5.0-volt signal from pin 348 to various other TCM connections to engage the desired shift range. A poor connection at Pin #48 will prevent the engagement of all ranges, and technician A is therefore Incorrect. Technician B is correct because the input for reverse from the range selector must be applied to pin 344 to engage reverse. A poor connection at pin 344 will prevent the composite vehicle from engaging reverse gear.

82 The correct answer is C. Looking at the schematic for the composite vehicle shows the data link is connected at pins 6 and 16 and resistance can be measured across those two pins.

Notes

Glossary of Terms

--a--

Acceleration Simulation Mode (ASM) - a dynamometer test that checks a vehicle's HC, CO and NOx emissions at a steady speed under a fixed load.

active test - an OBD II diagnostic strategy in which the ECM takes control over a particular device(s) in order to evaluate the response of a questionable component or sub-system.

actuator - any device controlled by the ECM, such as an injector or relay. Most actuators are controlled by low-side (ground) drivers in the ECM.

amplitude - the peak strength of an electrical signal. When viewed on a scope, the amplitude of a DC signal is the maximum voltage above the zero line. The amplitude of an AC signal is the peak-to-peak (***positive***-to-negative) signal voltage.

ASM 25/25 - a steady load test in which the vehicle runs at 25 mph with a load equivalent to 25% of the power needed to accelerate at 3.3 miles per second.

ASM 50/15 - a steady load test in which the vehicle runs at 15 mph with a load equivalent to 50% of the power needed to accelerate at 3.3 miles per second.

--b--

bandwidth - indicates the number of bits a computer can process in a single instruction. For example, a ***32***-bit computer can process 32 bits of information per instruction.

BAR31 - a 31-second transient load test that includes an acceleration ramp similar to the I/M 240 test.

--c--

calculated load value - indicates the engine's volumetric efficiency (actual airflow divided by maximum airflow).

clock speed - determines the number of instructions a computer can execute in one second. Clock speed is expressed in megahertz (MHz).

Common Area Network (CAN) - a two-wire twisted pair harness that follows SAE standard J1939 protocol and allows all controllers on the vehicle to share inputs.

conflict - a condition in which the simultaneous execution of two monitors would result in one or both monitors failing incorrectly.

--d--

Data communications bus - a communications network that allows peer - to - peer communications between electronic modules on a vehicle (Including scan tools and interface devices)

Data link connector (DLC) - The standardized plug that is used to connect the scan tool, or other test equipment to the vehicle's data communications bus network.

diagnostic executive - the name used by certain manufacturers for the diagnostic management software run by the ECM. The Diagnostic Executive software coordinates the activity of the OBD II monitors including monitor execution, test results, MIL operation, freeze frame data, readiness status and trip counter.

Diagnostic trouble codes (DTC) - When an electronic control module detects a problem, a code may be stored and may be read using a scan tool. Each code corresponds to a particular problem. When a DTC is referred to in an L1 test question both the number and description will be given. For example, P0114 "intake air temperature circuit intermittent".

Distributor Ignition (DI) - an ignition system that uses a distributor.

Driver - A solid state switch contained in an ECM used to control an electrical / electronic component.

--e--

Electronic Ignition - an ignition system that has coils dedicated to specific spark plugs and does not use a distributor; e.g. distributorless ignition, coil on plug (COP), and coil near plug (CNP)

Electronic throttle control - the system that opens and closes the engine throttle plate using an electric throttle actuator control (TAC) motor. Accelerator pedal position (APP) sensors provide Input rom the vehicle operator while the position of the TAC is monitored by throttle position sensors (TPS). Commonly called "drive by wire".

Enable criteria - a specific set of conditions that must be met in order for the ECM to run an OBD II monitor.

Engine control module (ECM) - the electronic computer that controls the operation of the engine. Also called ECU, VCM, ECA, or PCM.

--*f*--

Federal Test Procedure (FTP) - the FTP is actually a series of tests used to measure the emissions output of new cars and light trucks sold in the United States.

fly by wire - slang term for use of an electronic throttle actuator that is controlled by the ECM, eliminating the use of a throttle cable.

Freeze Frame data - a snapshot of information recorded by an OBD II ECM the moment it recognizes an emissions-related failure. Freeze Frame data is recorded for the first failure only, and may be overwritten by a different failure with a higher priority.

frequency - the number of signal periods that occur in one second. Signal frequency is expressed in Hertz (Hz), which represents cycles per second.

Fuel Trim (FT) - fuel delivery adjustments based on closed loop feedback. Values above the central value (>0%) indicate Increased injector pulse width. Values below the central value (0%) indicate decreased Injector pulse width. Short Term Fuel Trim is based upon feedback from the A/F ratio sensor or Oxygen Sensor. Long Term Fuel Trim is a learned value used to compensate for continual deviation of the short term fuel trim from its central value.

--*g*--

generator - OBD-II (J1930 Standard) term for alternator.

GCWR - the Gross Combination Weight Rating indicates the maximum allowable weight of a loaded tow vehicle and trailer.

gpm - grams per mile.

GVWR - the Gross Vehicle Weight Rating indicates the maximum allowable vehicle weight when loaded with driver, passengers and cargo.

--*i*--

I/M - Inspection/Maintenance

Immobilizer module - the electronic system that verifies the validity of the ignition key used to start the engine.

I/M Tests - Inspection and maintenance tests; vehicle emissions tests required by federal, state or local governments. Some common I/M tests include:
- ***No load*** - Tests that measure HC emissions in parts per million (PPM) and CO in percent, while the vehicle is In neutral. Examples are idle and two-speed.
- ***Acceleration Simulation Mode (ASM)*** - Loaded mode steady state tests that measure HC, CO, and NOx emissions while the vehicle is driven on a dynamometer at a fixed speed and load. ASM5015 is a test at 15 MPH with a load equivalent to 50% of the power needed to accelerate the vehicle at 3.3 MPH per second. ASM2525 Is a test at 25 MPH with a load of 25% of the same power.
- ***IM240*** - A loaded mode test that measures HC, CO, CO2, and NOx emissions in grams per mile second by second while the vehicle is driven at various speeds and loads on a dynamometer for 240 seconds.
- ***BAR31*** - a transient load test with a 31 second test cycle that includes an acceleration ramp similar to IM240.
- ***OBD*** - A steady state test that is performed by connecting a cable to the vehicle's data link connector (DLC) and communicating with the ECM. MIL light operation and information stored in the ECM determine the pass / fail status of the vehicle.

Note - All the tests listed above may include a visual Inspection of emission control system components, and functional tests on some components as a part of the I/M test procedures.

intrusive test - an OBD II monitoring strategy in which the ECM takes direct control of a particular device in order to evaluate the response of a questionable component or sub-system. Unlike an active test, an intrusive test may cause a noticeable difference in engine performance.

--*k*--

KOEO - key on, engine off.

KOER - key on, engine run.

--*m*--

Malfunction Indicator Light (MIL) - a lamp on the instrument panel that illuminates when the ECM detects an emission related function. Malfunctions that trigger the MIL may also cause performance defects.

Glossary of Terms

MAP - manifold absolute pressure. The pressure in the intake manifold referenced to a perfect vacuum. Since manifold vacuum is the difference between manifold absolute pressure and atmospheric pressure, all the vacuum readings in the Composite Vehicle Preparation / Reference Book are taken at sea level (where atmospheric pressure equals 101 kPA or 29.92 in. Hg.

Mass Air Flow (MAF) System - A fuel injection system that uses a MAF sensor to measure the mass (weight) of the air drawn into the intake manifold, measured in grams per second.

monitor - the term used for the OBD II diagnostic tests run by the ECM. Monitors are executed on a continuous or a non-continuous basis, and are used to evaluate the performance of emission-related components and subsystems.

--o--

On-board diagnostics (OBD) - A diagnostic system contained In the ECM which monitors computer Inputs and outputs for failures. OBD II is an industry standard, second generation OBD system that monitors emission control systems for degradation as well as failures.

OBD II drive cycle - a driving routine that occurs within one key on, key off period, consisting of various vehicle-operating conditions such as idle, acceleration, cruise and deceleration. A complete drive cycle is required to run all of the OBD II monitors.

On board refueling vapor recovery (ORVR) - an evaporative emissions (EVAP) system that prevents the escape of HC vapors to the atmosphere by directing fuel tank vapors to the charcoal canister during fueling. The ORVR system also prevents fuel loss in the event of a vehicle rollover.

--p--

passive test - an OBD II monitoring strategy in which the ECM checks for obvious failures such as open and shorted electrical circuits.

pending condition - an unresolved failure in a particular system that would interfere with the proper execution of an OBD II monitor. A pending condition prevents the ECM from incorrectly failing a component or subsystem.

pending DTC - a temporary code recorded by the ECM. Pending codes are used to identify the first occurrence of a two-trip failure. If the original failure does not recur on the second consecutive trip, the pending DTC will be automatically removed.

period - refers to the length of time required for one cycle of an electrical signal (ON-time + OFF-time) to be completed.

PID - Parameter Identification

pulse width - refers to the ON-time of an actuator, such as a fuel injector.

pulse width modulation - an electronic signal with an on/off time or duty-cycle.

--r--

Reprogramming - The updating of electronic control system software and OBD diagnostic procedures using factory supplied calibration files.

root cause of failure - this term refers to the underlying cause of a vehicle failure. For example, an engine misfire is traced to an oil-soaked spark plug. Although the plug is causing the affected cylinder to misfire, the fouled plug is simply a consequence of the primary failure, which in this case may be worn valve guide seals or piston rings. Consequently, unless the cause of the fouled plug is corrected (root cause of failure), the engine will begin misfiring within a short time.

--s--

Scan tool - a test instrument that is used to read Information from the control modules on the vehicle, perform system tests, and perform software program updates.

Scan tool data - information from the computers(s) that Is displayed on the scan tool, including data stream. DTC's, freeze frame, systems monitors, and readiness monitors.

Secondary air Injection - a system that provides fresh air to the exhaust system under controlled conditions to reduce emissions.

Sequential multiport Injection - a fuel injection system that uses one electronically pulsed injector for each cylinder. The injectors are pulsed individually.

speed density - a technique used to calculate engine airflow based on changes in manifold absolute pressure, engine rpm, air temperature and volumetric efficiency rather than directly measuring mass or volume of air with an air flow meter.

--t--

Three-way catalytic converter (TWC) - A catalytic converter system that reduces levels of HC, CO, and NOx emissions.

Transmission control module (TCM) - the electronic computer that controls the operation of the automatic transaxle.

trip - a term used to describe a key on, engine run, key off cycle, during which time the vehicle was operated in a way that satisfied the enable criteria for at least one OBD II monitor. A good trip in the ASE Composite Vehicle Type 4 occurs when the necessary enable criteria are met, the monitor runs, no defects are detected and the key is turned off.

--v--

Variable force solenoid - an electro-hydraulic device that controls fluid pressure proportionally or reverse proportionally to a signal from a control module.

Variable valve timing - the control of valve timing achieved by advancing and/or retarding the camshaft(s) relative to the crankshaft.

vehicle control module - an enhanced powertrain control module that manages additional systems such as ABS.

Notes

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