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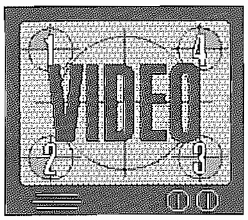


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# INTRODUCTION TO OBD II

Welcome to OBD II. While you may be familiar with the term OBD II, you undoubtedly have questions about how it will affect you, what type of equipment you'll need before you can work on OBD II-equipped vehicles, and how steep the learning curve will be as you attempt to master this major change in automotive technology.

Before we get to the heart of the matter, we want to take a moment to explain the approach we'll be using in this course. This won't take long, and it may improve the quality of your learning experience, so please bear with us.

One of the most intimidating aspects of OBD II is the mountain of printed matter that accompanies it. If you start trying to read through all the SAE papers and manufacturer-specific documentation before you understand what OBD II is actually trying to accomplish, you'll get discouraged in a hurry. So rather than drag you through an entire history of on-board diagnostic development and reams of documentation only an attorney could love, we're going to start by giving you simplified answers to the most common questions associated with OBD II. Along the way, we'll mention the most critical OBD II regulations, but only as they apply to the subject matter. Small boxed side-bars will be sprinkled throughout the text, and some pages will contain mini-glossaries that define the terms used on a given page. That way you won't need to go back to the main glossary every time you can't remember a definition.

We don't want to imply that the reference material isn't important, because it is. The long charts and tables, a brief history of OBD II development, and descriptions of the SAE papers that define OBD II will be placed in appendices at the end of the book. You won't need to dig through them until you know what they mean or need to put them to use in an actual repair.

The last aside we want to offer is a word of encouragement. OBD II carries the mystery of any new technology, but its purpose is straightforward. This will take fresh thought, some study time, and the experience that comes with actual repairs of real vehicles, but we'll all master it.

## *QUESTIONS*

In this section, we'll try to provide some simplified answers to common questions about OBD II. The explanations provided here will be brief, and many will be discussed in greater detail later in the course book. For starters, however, we want to give you a general feel for the basic changes you'll see in OBD II vehicles, compared to their predecessors. This will give you an overview to work with as we proceed.

### What is OBD II?

OBD II is an enhanced diagnostic monitor, built right into the vehicle's PCM. It's designed to alert the driver when emission levels are greater than 1.5 times the emission levels for the car as it was originally certified by the EPA. The name On-Board Diagnostics is actually a very accurate description of the system. The *II* added to the OBD name tells us that it is the second generation, the successor to the OBD I systems used on EPA-certified cars starting in 1988.

### Where does OBD II come from?

The regulations that added OBD II controls to some new vehicles in 1994 and 1995 and all 1996 and later models sold in the United States, are based on environmental goals established in the Clean Air Act Amendments and regulations written by the California Air Resources Board (CARB). There is a difference between the regulations originally proposed by the Federal EPA and those established by CARB. The EPA agreed to accept the CARB OBD II standards until 1998. Figure 1-1 shows the major differences between the EPA and CARB standards.

**Federal Versus CARB**

| Federal | CARB |
|---|---|
| 1. Allows use of CARB regulations for 1994-98 vehicles | 1. Allows use of Federal OBD on vehicles from 1999 |
| 2. Monitors include<br>Catalyst<br>Oxygen sensor<br>Misfire | 2. Monitors include<br>Catalyst<br>Oxygen sensor<br>Misfire<br>Canister Purge Flow<br>Fuel Correction<br>Secondary Air<br>EGR<br>Component |
| 3. Any other item that results in any emission increase | 3. Defines an unacceptable emission increase as emissions greater than 1.5 times FTP |

*Fig. 1-1. As you can see, the original EPA and CARB standards were not identical. CARB requires more monitoring, and defines the limits for any increase in emission levels.*

### How is OBD II different from OBD I?

Unlike OBD I, OBD II is designed to detect *electrical, chemical, and mechanical* failures in the vehicle emission control system that might affect vehicle emission levels. Here's an example: On an OBD I vehicle, if everything in the emission control system is functioning properly, but the catalytic converter stops working chemically, the vehicle owner won't know it. The car will run properly, and the dashboard Malfunction Indicator Light (MIL) won't come on. (We used to call this the Check-Engine or Service-Engine-Soon light, but now it's simply referred to as the MIL).

In this example, all of the electrical inputs to the vehicle computer are correct. The vehicle computer (PCM) is making all the necessary adjustments, and the vehicle is running in closed loop. Electrically, the vehicle is perfect. And the engine is sound mechanically. So what's the problem? The *chemical* cleaning of the exhaust by the catalytic converter has stopped. Maybe the vehicle has a ton of miles on it and the converter has finally accumulated enough contaminants to keep it from working. Maybe it's been doused in a gallon of antifreeze from a blown head gasket. Whatever the cause, the catalyst is chemically dead, and the stuff coming from the exhaust manifold never gets scrubbed and cleaned before it leaves the tailpipe. OBD II won't accept this.

OBD II takes the next logical step in emission control. It uses all of the diagnostic features we associate with previous diagnostic tests of the electrical components, and adds a monitor to test the chemical action of the catalyst. This is an *indirect* test that uses the normal pre-catalyst oxygen sensor, but adds another oxygen sensor to monitor the oxygen content at the catalyst outlet.

We'll discuss the particulars of catalyst monitoring a little later, but for now, it's important to remember the change in the *purpose* of on-board diagnostic tests. It is the major difference between OBD I and OBD II. OBD I alerted us to a failure that could cause a driveability problem. OBD II is more concerned with catching an emission problem. An increase in emissions may certainly be caused by a problem in the fuel and ignition system that would result in a driveability complaint. And many of the failures we associated with a driveability problem in an OBD I vehicle, will still set a code in an OBD II vehicle. But unacceptable emissions—not driveability—is the major concern of the OBD II monitoring system.

**Why did the government make this change?**
By now, you're pretty familiar with the uneven history of vehicle emission testing. Various tailpipe emission test programs have been started, stopped, redesigned, and generally hated by the motoring public. In addition to the inconvenience of waiting in a long test lane, nobody really likes the idea of digging into their personal beer and pizza fund to pay for a tailpipe test—just so they can pay out more for their license plates. On the political popularity list, emission testing is a half-step behind a major tax increase.

OBD II places the emission tester IN THE VEHICLE COMPUTER. Buy a car, get an on-board emission analyzer. Take it with you wherever you go. It's portable, it runs its own set of tests on a regular basis, and it will alert the owner of the vehicle with the dead catalyst that he is becoming an environmental menace. Whether he chooses to heed the warning is an entirely different issue.

**Does this mean we need to learn fuel and engine management systems all over again?**
Not really. One of the great myths associated with OBD II is that all of us will have to scrap what we already learned about engine management systems. That simply isn't the case. Modern fuel injection systems haven't been redesigned in terms of their basic operation. Admittedly, there are some new technical changes taking place in fuel system design. And some additional sensors are used on OBD II vehicles. But many system improvements and refinements would have probably happened without OBD II. Your hard-earned skill and experience with diagnosis and repair of OBD I vehicles will be even more important as you tackle OBD II problems.

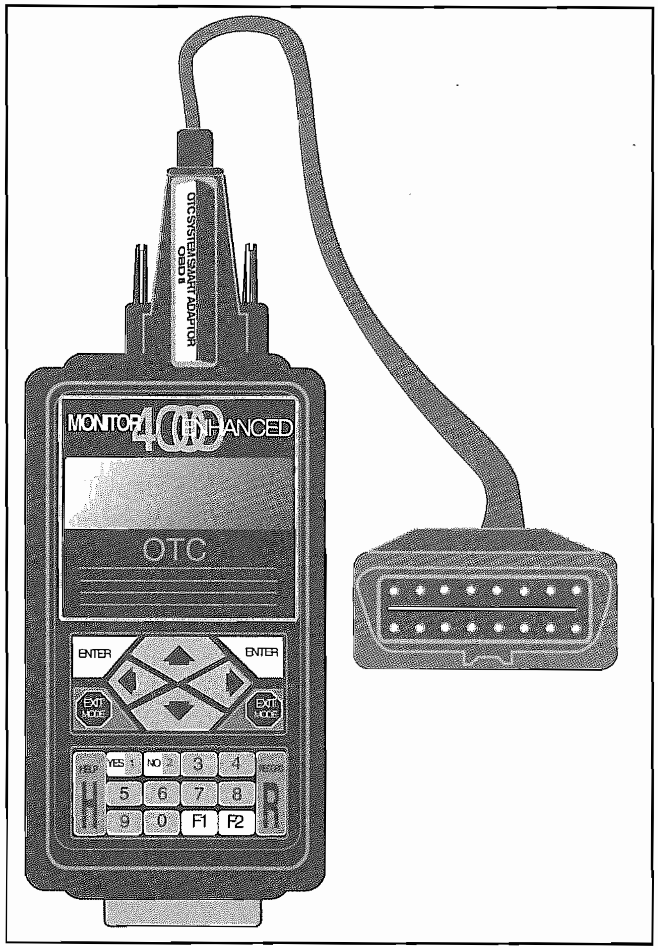



*Fig. 1-2. A scan tool with the correct connector cable and OBD II software is a minimum requirement if you need to work on OBD II vehicles.*

**What special tools will I need to work on OBD II vehicles?**
A scan tool or PC with an OBD II software interface is the biggest single addition you'll need to make in your equipment inventory (Fig 1-2). In fact, an OBD II scanner interface is essential. The

scan tool interface not only lets you to retrieve and erase DTCs, it stores vital information that can help you diagnose problems and verify repairs.

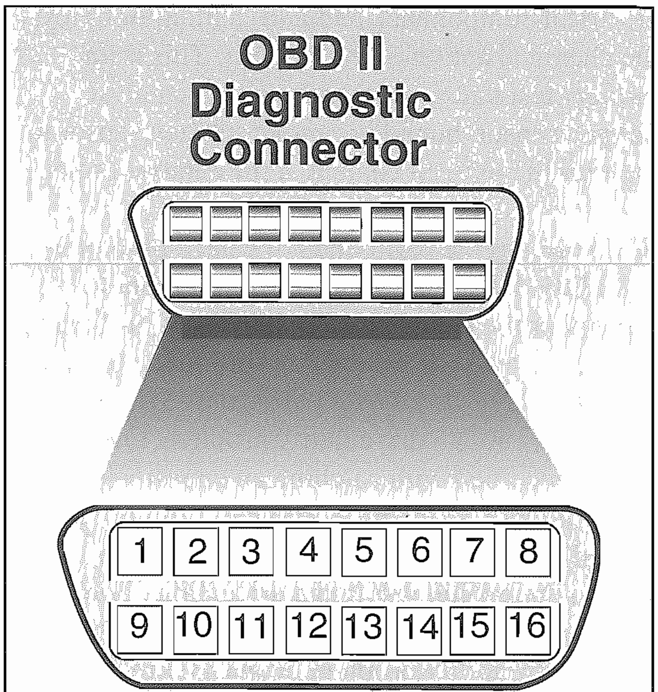
Those of you who specialize in the repair of GM and Chrysler vehicles, or Toyotas with serial data for that matter, may assume that scan tools and their use are the norm in the industry. Prior to OBD II, that has not been the case by any means. Many manufacturers have gotten by before OBD II without any serial data.

Honda and Ford are good examples. Ford added serial data long after GM and Chrysler were using it, and Honda didn't use a diagnostic test interface before OBD II, relying on flash codes from the MIL and pin-by-pin circuit tests to isolate and correct faults in computers or circuits that could affect performance. The good news for technicians, is that all OBD II vehicles from 1996 on will have some serial data. They are required to display a minimum amount of information about DTCs and system status.

**I've never used a scan tool. What is serial data?**
Serial data is a series of pulsed voltage signals sent by the PCM to your scan tool. Pulses and combinations of pulses are used like letters of the alphabet to form data words. The pulses arrive one at a time, in series, like cars in a freight train. That's why it's called serial data.

The PCM receives electrical signals from various sensors, interprets that information, and then creates the serial data words it sends to the scan tool. This takes time. It also takes time to send the data once it's been compiled. So what you see on the scan tool is not live data.

**Where do you connect the scanner?**
OBD II standardizes the test plug (Fig 1-3). All manufacturers will provide a basic amount of serial data, and that data will be available by connecting your OBD II scan tool to a standard OBD II Diagnostic Link Connector, or DLC. Seven of the 16 pins in the DLC have a standardized definition, including grounds and battery voltage terminals. Three kinds of communication are available: The SAE J1850 standard lists two: a single-wire Variable Pulse-Width signal on a 7-volt bus, communicating at 10,400 bits/second, or a two-wire Pulse-Width-Modulated 5-volt bus communicating at 41,600 bits/second. The third option is a protocol established by the International Standards Organization, or ISO, transmitting at 10,400 bits/second on a 12-volt bus. The generic scan tool interface is supposed to identify the protocol used and respond accordingly. The other nine terminals in the DLC are reserved, and




Pin 1 = Discretionary
Pin 2 = Communication Bus (+)
Pin 3 = Discretionary
Pin 4 = Chassis Ground
Pin 5 = Signal Ground
Pin 6 = Discretionary
Pin 7 = ISO K Line
Pin 8 = Discretionary
Pin 9 = Discretionary
Pin 10 = Communications Bus (-)
Pin 11 = Discretionary
Pin 12 = Discretionary
Pin 13 = Discretionary
Pin 14 = Discretionary
Pin 15 = ISO L Line
Pin 16 = Battery

*Fig. 1-3. The Communication Bus lines are used for data transmission. ISO lines provide data transfer for many vehicles, both domestic and foreign. Discretionary terminals can be used for any purpose the manufacturer chooses, including non-OBD II-related systems.*

may be used by the manufacturers for any purpose they choose. On some vehicles, you'll find only the battery, ground, and required data terminals supported in the DLC. The location of the test receptacle (Diagnostic Link Connector, or DLC) is also *supposed* to be standardized.

DLCs are supposed to be located on the driver's side of the cabin, below the dash. A few manufacturers chose to get creative, and placed the DLC slightly out of bounds. Some DLCs have been located on the passenger side of the cabin or in the center console, behind the ashtray (Fig. 1-4).

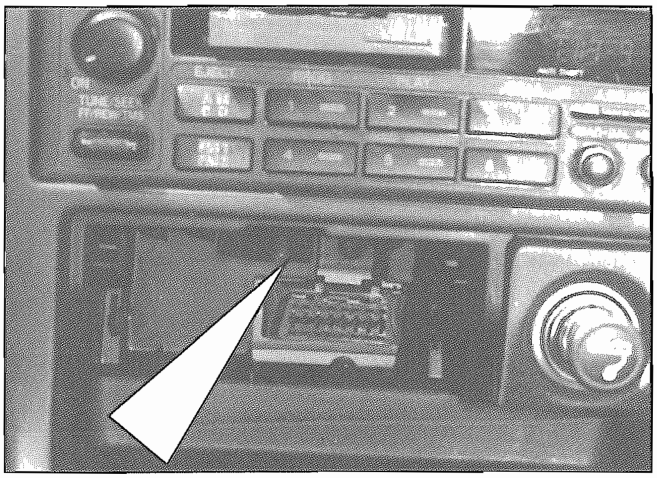


*Fig. 1-4. The OBD II connector in this 1996 Honda Accord is cleverly hidden behind the ashtray in the center console. Standardization can be an uphill battle.*

The EPA has told the OEs to place it in the mandated location, or provide a sticker that will guide you to its exact location. Look for the DLC or sticker to be located below the dash to the left of the vehicle centerline.

**When did these regulations become standard on all vehicles?**
OBD II started being phased in on some 1994 vehicles. This transition continued through the 1995 model year. All 1996 and newer vehicles had to be fully OBD II compliant. OBD II transition systems used in the 1994-1995 time frame were sometimes a hybrid that used some OBD II controls, modified to make them work with existing systems that didn't dovetail exactly with OBD II software. Others were fully OBD II compliant before the 1996 model year deadline.

An example of a transitional hybrid would be a 1994-95 vehicle that used a transmission control module that was not fully compatible with the OBD II software or interface. Even more confusing is the possibility that a manual transmission version of this same vehicle type might be fully OBD II compliant, even though its A/T-equipped version is not.

Some vehicles were equipped with the 16-pin DLC test plug during this time, but were not fully OBD II-compliant versions. And others came equipped with the 16-pin plug, but did not support *any* OBD II functions. You may see some cars from this period that have both the OBD II DLC and the older test connector used on OBD I vehicles.

Inconsistencies in vehicles produced during 1994-95 will undoubtedly lead to confusion, so be on the lookout for them, not only across car lines, but within different models manufactured by the same manufacturer. Your best bet, especially on a car you aren't familiar with, is to look at the underhood sticker that will identify the EPA system installed, and then reference specific repair data for that particular vehicle. Sorry to have to tell you that. Please don't kill the messenger.

**How will Diagnostic Trouble Codes be displayed?**
DTCs have traditionally been displayed by a timed, sequential flashing of the MIL, similar to Morse Code. Retrieving codes usually required a scan tool or a special procedure involving a jumper wire that activated the flash sequence. Code designations varied by manufacturer, since each could assign his own numbers to given faults. Prior to OBD II there was no standardized list of DTCs. (Many of you are already painfully aware of these inconsistencies.) On OBD I cars, a code 12 might stand for a given fault on one vehicle, but have an entirely different meaning on another.

**Another BIG difference: For years, we've erased codes right off the bat and then looked for them to reset during the next trip to determine if they were hard faults. That is no longer a good approach.** The tests used to turn on the MIL and the definition of a trip are changed. And

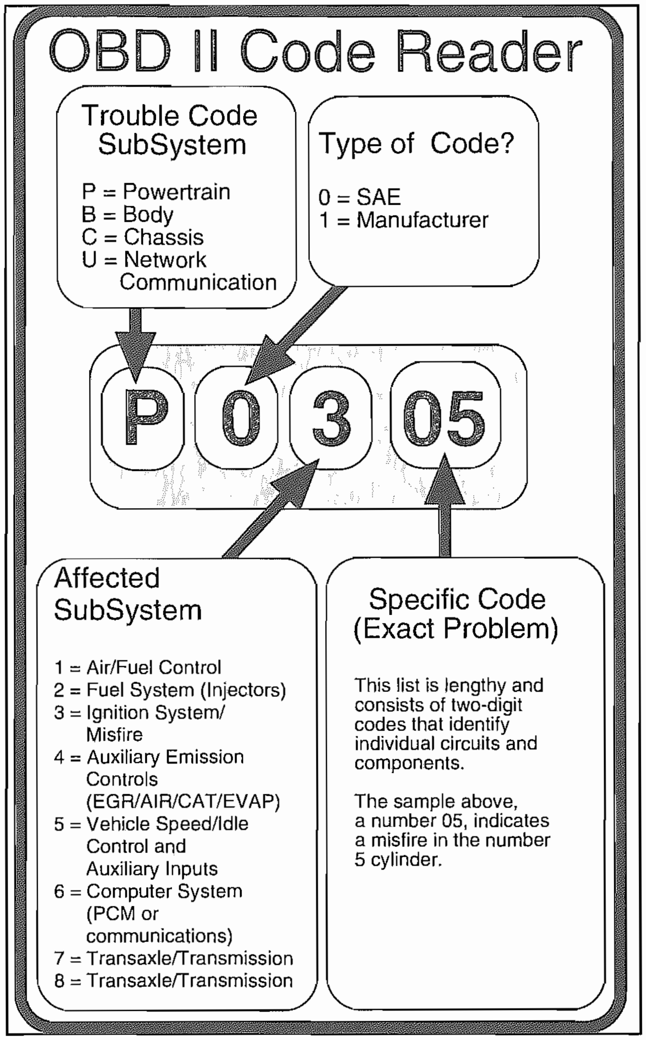



*Fig. 1-5. OBD II codes are easy to read once you understand how they are set up.*

erasing the DTC will also erase valuable diagnostic information stored in the system when the DTC set. More on this later, but keep it in mind.

OBD II uses standardized DTCs for the most common faults. The new codes have five digits, and are referred to as *alphanumeric*, since they are made up of a letter character followed by numbers. The letter designation represents the subsystem that contains the offending component or circuit. Numbers after the letter are used to describe the origin of the code (SAE or manufacturer-specific) and the exact code description. Figure 1-5 shows how the codes are set up, and lists the possible combinations of these letter and number designations.

Please refer to the chart in Figure 1-5 as we explain how to interpret a sample code: **P0305**

- **Each code has a total of five characters.**
- **The first character of this code (P0305) is a letter designation to indicate the general subsystem that sets the code.**

PXXXX - Powertrain System DTC
BXXXX - Body System DTC
CXXXX - Chassis System DTC
UXXXX - Network Communication DTC

Using this chart, we see that we have a Powertrain System Code.

- **The second digit (P0305) tells us if this is a generic (SAE) or a manufacturer-specific code. Each code will have one of these prefixes.**

X0XX - indicates a generic code
X1XX - indicates a manufacturer-defined code
X2XX and P3XX are reserved for future use

- **The third digit (P0305) tells us which subsystem is affected.**

XX1XX - a Air/Fuel Control imbalance
XX2XX - a Fuel (injector) problem
XX3XX - an Ignition System Misfire (which is what we have with code P0305)
XX4XX - an auxiliary emission component (EGR/AIR/CAT/ or EVAP problem)
XX5XX - a vehicle speed/idle control problem
XX6XX - a computer problem
XX7XX - a transaxle/transmission problem
XX8XX - a transaxle/transmission problem

- **The final two numeric digits (P0305) indicate a code number that identifies a specific fault in a circuit or component, and will often define the type of fault being experienced**. In our illustration, the **05** in P0305 stands for a misfire detected in the number 5 cylinder. (A complete list of generic codes can be found in Appendix A of this course book. As you'll see, it was a bit too big to squeeze in here without sidetracking our introduction.)

**What kinds of information can I get from the scanner?**

That depends on your scan tool software and the monitors used by the vehicle. Yeah, we know, nothing is ever totally simple. For starters, a generic scan tool interface is supposed to provide a minimum amount of critical information about the system. Enhanced scan tool software will allow your scan tool to display additional information. This type of data will be available if your scanner has enhanced software, above and beyond the generic interface. Finally, the OEM-specific scanners used by dealership techs may provide manufacturer-specific codes and information about systems not directly related to emissions.

If that all sounds a bit confusing, it's because it IS a little confusing. An analogy might be made to your television set to clarify the issue. If you plug in your TV and hook up an antenna, you can get all the local programming everyone else gets. That's generic. Want to get more channels? Pay for an addressable converter and cable service, and the enhanced interface will add all those extra channels above and beyond the generic offerings picked up by your antenna. The cable service you use and the added programs you pay for will determine which programs you receive. You can receive even more channels with a satellite dish.

It's the same TV, but the "programs" you get will depend on the software and interface. Unfortunately, once you get past generic information, the question of what data you receive will depend on the vehicle, your scanner, and its software.

Whether or not you consider generic data to be an improvement depends on how much data you're accustomed to getting on pre-OBD II vehicles. If you routinely view the 50-plus data categories available from some OBD I cars with serial data, you'll probably be very disappointed with the data available on a generic scan tool. Figure 1-6 compares the data you may have seen on an OBD I scanner to the information available on the OBD II generic display.

On the other hand, if you work on vehicles that had NO serial data at all prior to OBD II, you may view the generic data as a big improvement. Those of you who do a lot of diagnostic troubleshooting won't be satisfied with the reduced number of test categories provided by the generic scan tool, and want a scanner that offers the best enhancements for the vehicles you see most often.

**Data Categories**

| **OBD I** vs | **OBD II** (generic) |
|---|---|
| A/C Clutch | Airflow (gm/sec) |
| A/C Request | Coolant (temp) |
| A/F Learned | Engine Load (%) |
| A/F Ratio | Fuel Press (PSI) |
| Airflow | L/T Trim |
| Asynch Pulse | MAP (in/Hg) |
| BARO (kPa) | MAT (temp) |
| BARO (V) | O2 (mv) |
| Base PW (ms) | Open/CLSD Loop |
| Battery (V) | RPM |
| Block Learn | S/T Trim (%) |
| Cat Conv (temp) | Secondary Air |
| CC Brake Switch | Spark Adv (deg) |
| CC Enabled | Throttle (%) |
| CC Engaged | Veh Speed (mph) |
| CC ON/OFF Switch | |
| CC Res/Acc Switch | |
| CC Set/CST Switch | |
| Clear Flood | |
| Coolant (temp) | |
| Cooling Fan | |
| Cranking A/F | |
| Cranking RPM | |
| DCEL Fuel C/OFF | |
| Desired IAC | |
| Desired Idle | |
| Exhaust Oxygen | |
| HI PS Pressure | |
| High Battery | |
| Idle Air Control | |
| Integrator | |
| Manifold temp | |
| MAP (kPa) | |
| MAP (V) | |
| MAT | |
| O2 Cross counts | |
| O2 Ready | |
| O2 (mv) | |
| Open/CLSD Loop | |
| P/N Switch | |
| PROM ID | |
| RPM | |
| Safety Fuel C/O | |
| Spark ADV (deg) | |
| Start CLNT (deg) | |
| TCC Command | |
| Throttle (%) | |
| Time | |
| TPS | |
| Veh Speed (MPH) | |

*Fig. 1-6. That big empty space in the lower right is what you don't get from a generic OBD II interface that you might have seen on an OBD I vehicle with serial data.*

**What types of system maintenance and operational commands can be performed with a generic interface?**
A generic OBD II scan tool should be able to do the following:
- Plug into the standard 16-pin OBD II connector
- Retrieve a minimum amount of data from the serial data port in the connector
- Retrieve Freeze Frame data
- Read any 5-digit OBD II codes stored in the PCM memory
- Erase any codes stored in the PCM's memory

**What do you mean by Freeze Frame data?**
One of the nicer additions to the OBD II diagnostic program is a feature that stores important information about the system condition at the instant a DTC is stored. This is not a multiple frame picture like the one you may now get from your OBD I scanner in snapshot mode. The data stored in the single frame is designed to help you duplicate the conditions under which the fault occurred in the first place and to determine the reason the DTC was stored.

A sample of Freeze Frame data is shown in Figure 1-7.

**Typical Freeze Frame Data Stored With DTC:**
- Calculated engine load in (percent)
- Engine RPM
- Short and Long Term fuel trim (in percent)
- Fuel pressure (if available)
- Vehicle speed
- Engine coolant temperature
- Intake manifold pressure
- Closed/open loop status
- Manifold absolute pressure
- The DTC that caused the freeze frame data to be stored
- If the code stored is for misfire, the offending cylinder may be identified

*Fig. 1-7. If the PCM decides to set a DTC, it must take a moment to pose for the camera and record what was happening in these critical areas at the instant the code is set.*

**How fast is the OBD II data transmission to a generic scan tool?**
Not very fast. Sorry about that. The mandated minimally acceptable speed for data transmission to a generic scan tool is 10 parameters per second. If you're displaying all the available parameters at once, each parameter's update slows down. Some scan tools allow you to display a single data parameter or limit the number of parameters to speed the update of those selected items. And the scan tool must determine which data protocol is used before it can even request data. If you're looking for instant gratification, look elsewhere.

Perhaps the biggest thing to keep in mind the first time you hook up a generic scanner is that patience is a virtue. Don't assume you don't have a connection just because the system response doesn't show up immediately. Also expect some delay when viewing "live" data. Data updates on a "bare bones" scanner may lag behind actual changes taking place at monitored components.

**How does the ODB II monitoring system differ from OBD I?**
The OBD II monitoring system is much more complex than it was in OBD I. OBD I was passive. It sat there and waited for any of the signals sent by various sensors to go out of range. Codes were set for failed electrical signal inputs from monitored circuits. Some PCMs would also look at the amount of fuel correction needed to keep the engine running in closed loop. This allowed OBD I systems to set a code when fuel correction got so excessive that it suggested an extreme over-rich or over-lean condition.

OBD I systems commonly monitored the EGR, oxygen sensor, fuel trim, and electrical inputs to the PCM from various sensors (Fig. 1-8).

Here's an example. An OBD I system knew that the voltage from the coolant sensor on a given car should fall *between* zero and 5 volts. It's the old 90-10 rule. A rule of thumb for sensors is that low voltage should never go below 10 percent or above 90 percent of reference voltage. If an open circuit in the coolant sensor ground circuit resulted in a full 5 volts at the PCM signal wire, the

PCM said, "sorry Charlie, that just isn't right," and set a code. This voltage signal was called out-of-bounds. A similar condition existed if the signal wire shorted to ground and the reference voltage at the PCM coolant sensor signal terminal dropped to zero volts. Again, the signal would be so far out of range, that it set a fault.

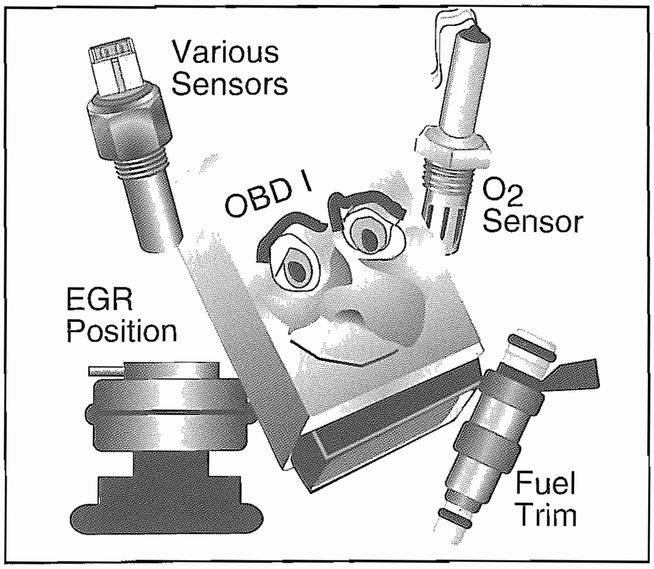



*Fig. 1-8. OBD I had to keep track of a limited amount of information compared to OBD II.*

OBD I didn't need to know what the other sensors were doing when a code was set for one sensor or circuit. In fact, it didn't care. All it cared about was that the coolant sensor was out of its normal operating range—electrically speaking. Or that the TPS circuit was open. Or that the MAP signal was shorted to ground, and so forth. And OBD I had no way to monitor exhaust emission levels.

OBD I monitored individual components and hoped that everything would work out okay in the emissions department. OBD II, on the other hand, goes a step further. It is both a passive and an active system that performs tests to determine if there is an unacceptable increase in emissions, or detect a failure that will result in an emission increase or damage to the catalytic converter.

The OBD II system also takes a more critical look at the entire system than OBD I did. It runs a series of tests, which are called *monitors*. This is really different. OBD II monitors don't just test individual electrical circuits, they can compare information from several sensors to see if the sensor information is logical. Signals coming to the PCM don't just need to be within specs electrically, they also need to *make sense* when compared to one another and the overall operation of the emission control system. This is called a *rationality* check. The OBD II computer is very much like Mr. Spock. Things better make sense, or it's not at all happy.

**Monitors** are carefully planned experiments performed by the PCM to see if all the sensors in a subsystem are working together to produce acceptable emissions. Here are the monitors that may be run by an OBD II system:

- **Comprehensive Component Monitor**
- **Misfire Detection Monitor**
- **Fuel System Monitor (adaptive fuel correction)**
- **Catalyst Efficiency Monitor**
- **EGR System Monitor**
- **Evaporative System Monitor**
- **Heated Oxygen Sensor Monitor**
- **Secondary Air Injection Monitor**
- **Heated Catalyst Monitor**

**What exactly are Monitors?**

Monitors are PCM-controlled tests of various systems that are performed under very specific conditions. Heck, you've been running monitors for years and probably didn't even realize it! Have you ever reached down and manually opened an EGR valve to see if the engine stalls at idle? Have you ever lied to a PCM with a sensor simulator to see if the injector pulse width changed? Have you ever compared four gas readings before and after the catalyst, or compared the catalyst inlet and outlet temperatures to see if it was getting hot?

Then you've performed your own monitors. You compared measurements and causes and effects: an oxygen sensor voltage change compared to injector pulse width, for example. Or you created a different set of conditions to see how the system responded, as in manually opening the EGR valve. You run a monitor each time you look for the system to respond as you change an engine operating condition or substitute a signal input of your own. If the system doesn't respond, you know something is wrong because the lack of a response—or the wrong response—just isn't logical. The system ought to respond.

The ability to run tests (monitors) of multiple components and make judgments about system efficiency is a big change in OBD II compared to OBD I. We'll discuss monitors individually, and in greater detail later. But for now, just remember that the monitors are similar to the experiments you already perform when you need to test how various components interact to affect system operation and efficiency.

**When do the monitors run?**

Three of the monitors run continuously:

- **Comprehensive Component Monitor (CCM)**
- **Misfire Detection Monitor**
- **Fuel System Monitor**

The CCM is similar to the old OBD I sensor monitor. It tests signal inputs and control outputs not tested by any of the other monitors. If a sensor monitored by the CCM goes out of range, the CCM is there to catch the failure and set a code. The other two monitors; Misfire Detection and Fuel System, are designed to prevent conditions that would damage the catalytic converter.

Notice that we said that these monitors run "continuously," not "constantly." Once the enabling criteria are met for continuous monitors, they will keep looking for a component failure (electrical failure or illogical response), or Fuel or Misfire fault that might occur at any time. The remaining monitors run once per trip.

Why the difference? Monitors have different priorities and different responsibilities. If the PCM in an OBD II vehicle leaves the factory with one clear order, it's this: "Don't let anything damage the catalyst!" So regardless of whether or not the conditions are right to perform tests of catalyst efficiency, oxygen sensor operation, EGR, or secondary air, the PCM needs to be sure that there isn't a major problem in the sensor input/output circuits or in the fuel/ignition systems that could destroy the catalytic converter (Fig. 1-9). And, since over-fueling and engine misfire are the two biggest causes of job-burnout for the catalyst, they are monitored continuously.

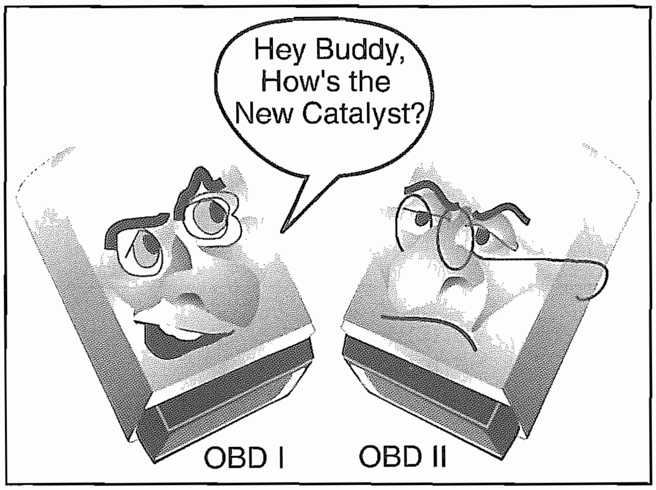



*Fig. 1-9. If the OBD II PCM looks a little grumpy, its because he has a lot more on his mind than his OBD I predecessor did.*

**When do the other monitors run?**

That depends on their ***enabling criteria***. Monitors are designed to run under certain very closely defined conditions. For example, it wouldn't do much good to test the oxygen sensor voltage or $O_2$ cross counts before the engine and oxygen sensor are warm enough to enter closed loop, would it? In similar fashion, it's not going to do much good to test EGR flow with the engine idling, since the EGR is closed at idle. And some monitors must wait for the results from other monitors before they can run.

So the PCM picks its spots. It knows that any tests it runs should logically take place when a given component or system is actually working. It also knows that unless the engine operating conditions are just right, the component or system may fail the test simply because the test is inaccurate, or the conditions aren't fair to the system. So the PCM waits for conditions that are just right before running its monitors. Once again, the conditions that allow the PCM to run a monitor successfully and are called *enabling criteria*.

**How does the PCM know when conditions are right so it can run its tests?**

The PCM looks for a specific list of conditions that must be present for each monitor to run. The PCM will wait until the test conditions (enabling criteria) are just right to run a monitor. These tests are run during something called a ***trip***.

In the simplest sense, a trip is a Key ON/Engine Run/Key OFF cycle. But not all trips are the same in OBD II. **In fact, the definition of a trip will be different depending on the type of monitor that the PCM wants to run.** We've already talked about the need for certain operating conditions to exist before a monitor is run. So a trip exists when the engine is started, run in such a fashion and under such conditions that the enabling criteria are all present to run a given monitor, and then shut off. It's important to remember that it is possible for the enabling criteria to be present for one monitor but not for another during a given period of vehicle operation. The definition of a trip depends on the monitor it affects.

The whole subject of trips is another potentially confusing subject, especially if you dealt with a pre-OBD II system that defined a trip as nothing more or less that start-to-run and then shutting off the engine. Just remember that an OBD II trip is a start-to-run and engine shutoff ***that meets the enabling criteria for a monitor to run***.

**Why are trips so important?**

Trips are very important for a couple of reasons:

- **First, some faults will turn on the MIL in only one trip.** A severe misfire or electrical failure of a signal input are common "one-trip" faults. If it's a one-trip fault, the PCM will "request" that the MIL be turned ON as soon as the fault is detected.
- **Other monitors require two-trips before they turn on the MIL.** The first detection of a failure that would set a two-trip fault is stored in the PCM memory, but doesn't turn on the MIL. If the PCM detects the first occurrence of a two-trip fault, information about the failure is stored in the PCM memory as a maturing fault. For most two-trip faults, the MIL won't come ON unless the fault is repeated during the next **consecutive** trip when it *matures*.
- **Fuel and Misfire DTCs fall into their own special category.** If a Fuel or Misfire system fault is detected, the PCM will look for a repeated failure that occurs within a *similar conditions window* (the fault occurs again under similar load, engine temperature, and engine speed conditions). If this happens at any time during the next 80 trips, a DTC will be stored. Fuel and Misfire two-trip DTCs do not have to be seen on *consecutive* trips within this 80 trip time frame to set a DTC.

As soon as the MIL is requested ON, the PCM turns on the ***trip counter***, and starts keeping track of how many trips are made after the fault is recorded. *Once again, this is very similar to the monitors you run to test a car. Sometimes, you run a test and get results that indicate a problem. Just to be sure, you repeat the test, especially if you aren't sure the test was valid. The PCM is doing the same thing to see if the fault is real, so it repeats the test during the next three trips.*

If the fault is not detected again during the next three trips, the MIL will be turned OFF. If the enabling criteria are not present to run the monitor for the circuit that set the fault during the next three trips the MIL will stay ON.

**Are the codes automatically erased when the MIL goes off?**

No, in fact, the DTC and its Freeze Frame will stay in the computer memory even if the PCM turns off the MIL. If you erase DTCs with the scan tool, the DTC and Freeze Frame are gone. If the PCM turns the MIL off, however, the DTC and Freeze Frame stay in memory and can be viewed with the scan tool (Fig. 1-10).

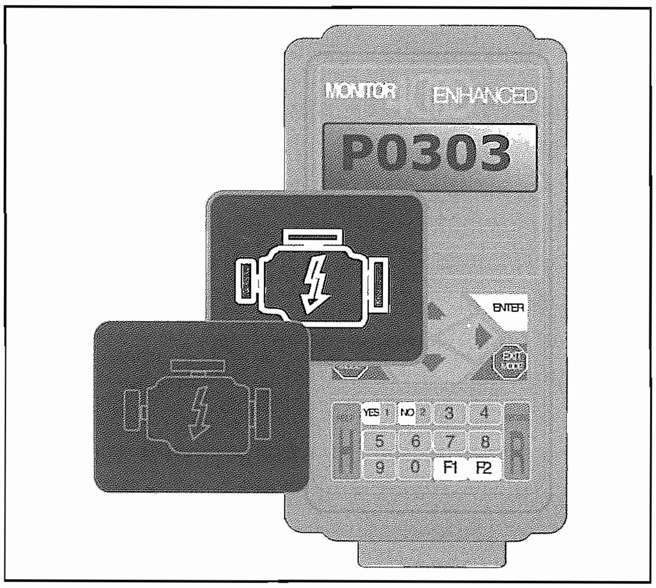



*Fig. 1-10. Just because the MIL isn't on, doesn't mean that there isn't some potentially important information stored inside the PCM's memory.*

**How important is the Task Manager (or Diagnostic Executive) to OBD II operation?**
In a word, *extremely*. Here's why. When you sniff the emissions coming from the tailpipe with an emission analyzer, you're making direct measurements of the individual gases making up the exhaust gas content, expressed as a percent or in parts-per-million. The OBD II vehicle doesn't have a gas bench installed. So it needs to look at various sensor inputs and compare them before it can *infer* that the system is either working properly, or failing to properly clean the exhaust.

So the *order* in which the tests are run and the *conditions* under which they are run are really important, or the results will be bogus. If a specific sensor input is needed to perform a test, and that sensor is out to lunch, it's pretty obvious that the test can't be run. This takes us back to the concept of comparing different measurements to evaluate the system's performance.

But there's more to the Task Manager's job than simply making sure all the sensors are working. It must also make sure that the operating conditions are correct or the test won't have much meaning. And in this day of the Customer Satisfaction Index, or CSI for short, the manufacturer of the vehicle knows that customer satisfaction erodes every time the MIL comes on. So the Task Manager really doesn't want to turn on the light unless it's sure there's really a problem.

**How long will the DTC stay in memory?**
That depends on the type of fault and the system design. Generally, here's how it works. As soon as the MIL is requested OFF by the PCM after three good trips, another counter starts, called the warm-up counter. Each time the PCM sees a warm-up completed, it adds one to the counter. When the warm-up counter gets to 40, the DTC will be erased (if the fault has not been repeated during that time). Some faults may require even more warm-up cycles. For example, some Fuel and Misfire faults may require 80 warm-up cycles before the DTC and Freeze Frame are erased.

**What is the definition of a warm-up?**
A warm-up is counted when the engine is started and run, and the engine coolant temperature reaches 160 degrees F AND the PCM sees an increase of 40 degrees F in coolant temperature.

Here's an example of a start-to-run that would **not** count as a warm-up:

- **If you start an engine with an initial temperature of 140 degrees F and drive it only until the coolant temperature reaches 170 degrees F before shutting the engine off, it won't be counted as a warm-up.** The engine coolant temperature may have crossed the 160 degree threshold, but the total increase in coolant temperature is less than 40 degrees.

**How does the OBD II PCM manage all this information?**
The PCM is equipped with software that acts as a combination scheduler and air traffic controller. This software decides if enabling criteria are present, and also manages the sequence for running different monitors. Since tests need certain inputs before they can run—and since the results of some tests depend on the results of other tests—things have to be done in the correct order or the tests won't be valid.

Ford and GM call this software the Diagnostic Executive. Chrysler calls it the Task Manager, and that's the term we'll use since Task Manager seems like a pretty accurate job description. Figure 1-11 lists the functions of the task manager.

**Task Manager Functions:**
- To manage the operation of monitors to keep them from affecting vehicle performance
- To make sure that the monitors are run at the correct times
- To make sure the monitors are run in the correct order
- To prevent conflicts between individual monitors
- To provide proper communications with the scan tool

*Fig. 1-11. The Task Manager has a list of fairly complicated responsibilities.*

**How does the Task Manager establish these priorities?**
There are a few terms you ought to be familiar with that describe various modes of operation as the Task Manager establishes test priorities:

- **Pending.** If a failed sensor is needed to run a monitor, the test won't be run, pending repair of the sensor or its circuit.
- **Conflict.** The Task Manager knows that there can be a conflict if two monitors are run at the same time, so if it sees a conflict between two monitors, it will act as a traffic cop, holding one monitor off until another has been completed. For example, if the Task Manager wants to run the catalyst monitor, but the EGR monitor is running, there is a conflict. The very act of running the EGR monitor will affect engine performance very slightly, and this could screw up the test results from the catalyst monitor.
- **Suspend.** One test may be *suspended* until another test has been run successfully. If the system knows that it needs a properly functioning oxygen sensor to run the catalyst test, but the oxygen sensor monitor hasn't been successfully completed, the Task Manager will *suspend* the catalyst monitor to keep it from running until the oxygen sensor test has passed. (In similar fashion, if your DMM or lab scope has a dead battery, you suspend the test you were going to run until the tester's battery has been replaced or recharged.)

It becomes obvious that some monitors must be run in a very specific sequence, especially when the PCM needs information from one monitor before it can run another. The Task Manager is extremely picky about correct procedures, looks for all signal inputs and results from other monitors, and will not count a test drive as a trip until all enabling criteria are met.

- **There was some mention of the EGR test affecting engine performance. Can the monitors cause a driveability problem?**

This is one of the tougher problems faced by the engineers who designed these systems. Some tests are *passive*. The system simply watches what's going on and takes measurements. Other tests are *active*, and the PCM actually runs a diagnostic of its own. Finally, some active tests are *intrusive*. In an intrusive test, a component like the EGR is activated by the PCM just so it can see how the system will respond. (The system may also be watching the short term fuel trim corrections or MAP voltage at the same time, to see how they change when the EGR is opened.)

Ideally, intrusive tests are run under conditions where the small change in performance they cause won't result in a noticeable change in performance.

**Time Out**

Let's take a moment to stop and recap what we've talked about so far.

1. The OBD II PCM is more concerned with **emissions-related** problems than it is with driveability problems, although a system failure may affect both driveability and emissions.

2. The PCM compares information from various sensors and expects them to be within limits electrically. It also expects the information from some sensors to be **logical** when compared to one another.

3. A standardized test connector (DLC) must provide a minimum amount of generic serial data including DTCs and Freeze Frame data.

4. SAE DTCs are standardized, so all vehicles use the same DTC number for any fault that is assigned a fault code number. Whether they are SAE or manufacturer-specific, **all OBD II alpha numeric codes have 5 characters.** Some DTCs will store as soon as a monitor fails. Other DTCs require two trips before they will set a code.

5. A **monitor** is a test performed by the PCM to verify the operation of a component or subsystem.

6. A **trip** is a start-to-run combined with a specific set of driving conditions that enable a monitor to run. The definition of a trip depends on the monitor it affects.

**Do the decisions of the Task Manager affect trips as well as monitors?**
Yes. In fact, the Task Manager needs to decide if a trip has been successfully completed before it will run its monitors. It will look at a number of conditions before a trip is counted. If the enabling criteria for a trip definition are not met, then there will be no trip, even though the engine was started, driven, and shut off. This is really important, especially when we consider that it takes three good trips for the PCM to turn off the MIL once it's been turned on.

Please refer to Figure 1-12 on the opposite page as we discuss Task Manager operation. (A mini-glossary is provided on this page to help you with terminology.)

- **As soon as the PCM sees a key ON condition, it asks one simple question, namely, "Can I run my tests?"**

- **If all the enabling criteria are met, then the Task Manager will start running its tests.** Remember that enabling criteria for various monitors are different, so until a trip meets the enabling criteria, the test will not be run.

Follow the chart down the left side of the page in Figure 1-12. Notice that the test may be interrupted. If the enabling criteria say that the brake switch must be off, and someone hits the brake pedal, the test will have to run again.

- **If a specific monitor would like to run, but needs the information from another monitor that hasn't completed yet, the test results will be delayed (suspended).** When all the enabling criteria are present, including any information that is needed from another monitor, the trip will be complete, the monitor will run, and the information it gathers will be stored in the PCM memory.

**What if there is a bad sensor or stored DTC?**
The Task Manager won't play any game it can't win. For example, if there's a DTC stored for a faulty MAP sensor input, and the MAP signal is part of the enabling criteria for a monitor, the Task Manager won't even bother to run the monitor, even though all the other enabling criteria are correct. Why bother? It knows the test can't pass until the MAP signal is restored and the DTC is erased. The monitor will stop, **pending** a resolution of the problem.

Similarly, if the Task Manager knows that there will be a **conflict** if two tests run at once, it will stop one of the monitors until the other monitor has completed. The concept of a conflict and the suspension of a test are very similar. Just remember that some monitors must be run in the proper sequence, and that if the information from a sensor or monitor is missing, it can prevent another monitor from running and storing its test results. The net effect is that the Task Manager can't run the monitors if it doesn't have the information or tools to do the job successfully.

Finally, if the key is turned OFF at any time, the obvious result is that the PCM cannot continue.

As you can probably see, it will be a lot tougher to perform partial repairs on OBD II systems. Monitors and components rely on one another to do their jobs, and a component failure or lack of information will put the skids on monitor operation.

**MINI Glossary**

- **Conflict**—A condition where incorrect or missing information, or the current operation of another monitor, prevent a monitor from completing its tests
- **Enabling Criteria**—Operating conditions that allow monitors to run
- **Monitor**—A test performed by the PCM to check the operation of a subsystem
- **Pending**—A condition where the Task Manager must wait for other traffic before it can proceed
- **Suspend**—To stop a monitor because there is insufficient information to continue
- **Trip**—A Key ON and start-to-run that provides the operating conditions necessary to satisfy the enabling criteria, followed by Key-OFF. The purpose of a trip (or trips) is to allow monitors to run.

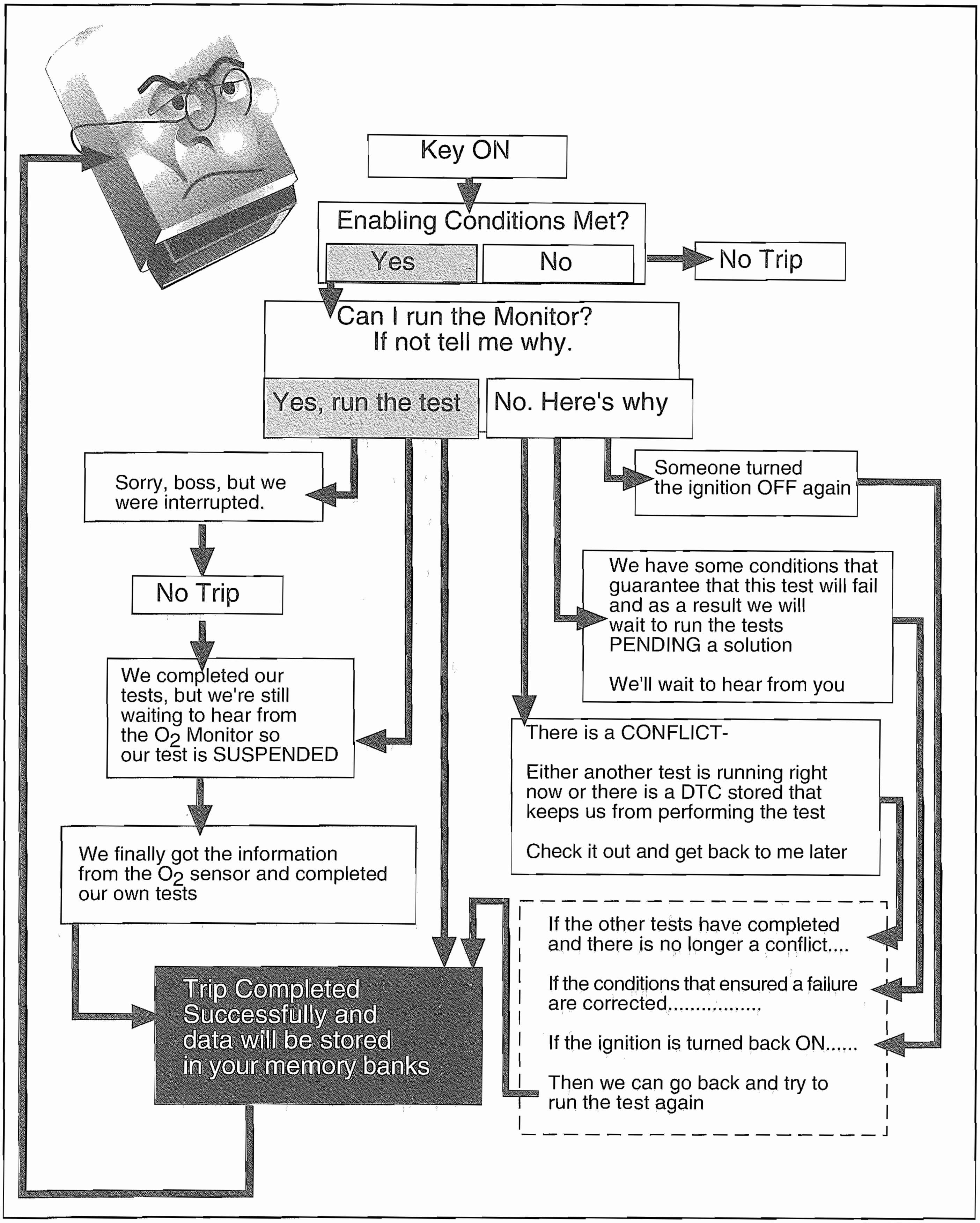



*Fig. 1-12. The Task Manager must ensure that it has all the information it needs to run its monitors, that all the monitors are working, and that the test sequence is followed to the letter.*

**How important is it for all the monitors to run?**

For us, as repair technicians, it can be very important to have all the monitors run successfully. If the vehicle is started and driven in such a fashion that it satisfies **all** of the enabling criteria needed to run **all** the monitors, and it passes every test, the Task Manager places a check mark next to all the monitors indicating that they have passed. These check marks are commonly referred to as ***readiness flags***.

To run all of the monitors and set all the flags, however, the vehicle must be driven through an entire OBD II ***Drive Cycle***. To describe what a Drive Cycle is, we'll make comparisons to two concepts you may already know: The Federal Test Procedure and an OBD I relearn driving sequence. While neither is identical to the OBD II Drive Cycle, they do share some very important features.

First, the Federal Test Procedure, or FTP, for short, is the mandated certification test that a new car must pass for it to win the EPA's mark of approval. Figure 1-13 shows some of the types of tests involved in the FTP.

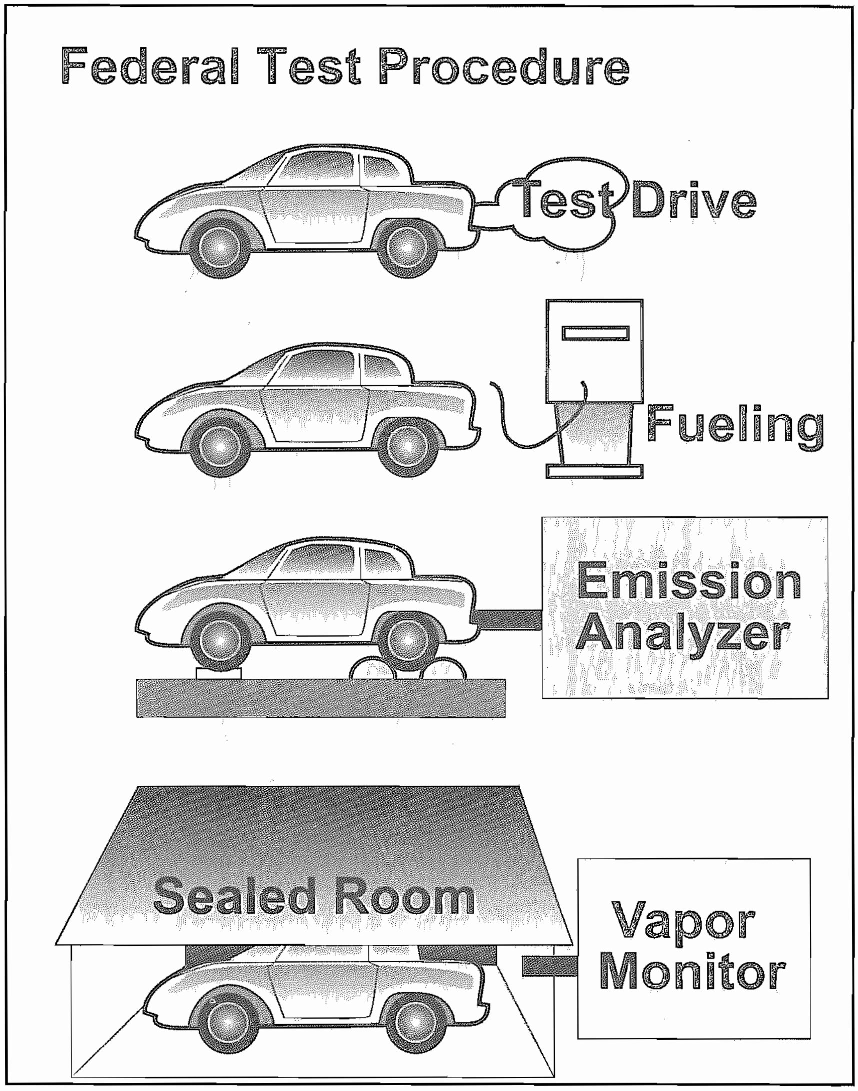



*Fig. 1-13. The original FTP ensures that the vehicle complies with emission regulations when new. OBD II is designed to keep the vehicle in compliance by running test monitors throughout the vehicle's life.*

**1)** The vehicle is driven and its fuel economy is measured. **2)** It is refueled and the vapor recovery system is tested. **3)** It is driven on a dyno, and its emissions are recorded under various engine speed and load conditions. **4)** It is placed in a sealed, temperature-regulated room as various tests are run, especially those that concern the efficiency of the fuel vapor recovery system.

This simplified description of the FTP shows how the vehicle is asked to perform under simulations of real world conditions. But the dyno tests are of special interest to us when we think about the OBD II Drive Cycle. The FTP treadmill forces the system to operate under the driving conditions it will experience out on the road. This is often referred to as a "loaded" drive cycle since the dyno makes the engine work against types of resistance that are similar to what it will face during actual driving. The engine is tested during acceleration, at cruise, and during closed throttle deceleration with various loads applied.

If you're familiar with I/M 240 and have ever seen the printout of the modes of engine operation (called a trace) while it's on the dyno, then you have a reasonable idea of the FTP dyno test, since the I/M 240 test is patterned after the FTP. These are precisely the modes of operation that OBD II systems want to monitor for the life of the vehicle, not just when it undergoes the FTP.

Since OBD II wants to continue to verify emission compliance, it must continue to run the same types of tests that were used during the FTP.

You'll notice we said "same types of tests," not *identical* tests. None of us is going to be lugging around a two-ton-full-blown-constant-volume-sampling emission analyzer, are we? So the system runs alternate tests (monitors) designed to reach the same general conclusions about overall vehicle emissions. To do that, it must run its monitors under conditions that are similar to the original FTP conditions.

***The Drive Cycle is the OBD II system's equivalent of the FTP.*** That's because during an OBD II drive cycle all of the conditions will be present for the Task Manager to run all of the monitors. Figure 1-14 shows a typical drive cycle. You'll notice that the engine is warmed up and driven under the types of conditions that it is apt to see in normal use. This allows the monitors to test the following:

- **COLD START** — The PCM compares the engine coolant and air temperature signals to see if the engine is cold. The coolant temperature is normally about 122 degrees F, or less.

- **IDLE AND WARM-UP** — During the warm-up period, the PCM will monitor components that come to life during the warm-up period, like the Oxygen Sensor Heater. Misfire and Fuel Control may also be monitored during this period. The CCM looks for any component failures that might set a code and prevent further monitor operation. *(Some manufacturers may make additional recommendations to ensure accurate tests. Since combustion is erratic during warm-up due to the normal inefficiency of a cold engine, the manufacturer may suggest that you turn on accessory loads like the A/C and rear defroster. This places an added load on the crankshaft and dampens minor fluctuations in crankshaft speed that might be interpreted as a misfire.)*

- **ACCELERATION (PART ONE)** — After the warm-up is completed and the system enters closed loop, the vehicle is accelerated at half throttle with accessory loads off. Misfire and Purge Flow will continue to be monitored. The system is in closed loop, and the WOT override is not active, so Fuel Trim may also be monitored. Since the engine is loaded, misfire detection may turn up a problem that was not present at idle. Notice that many of the same conditions are being

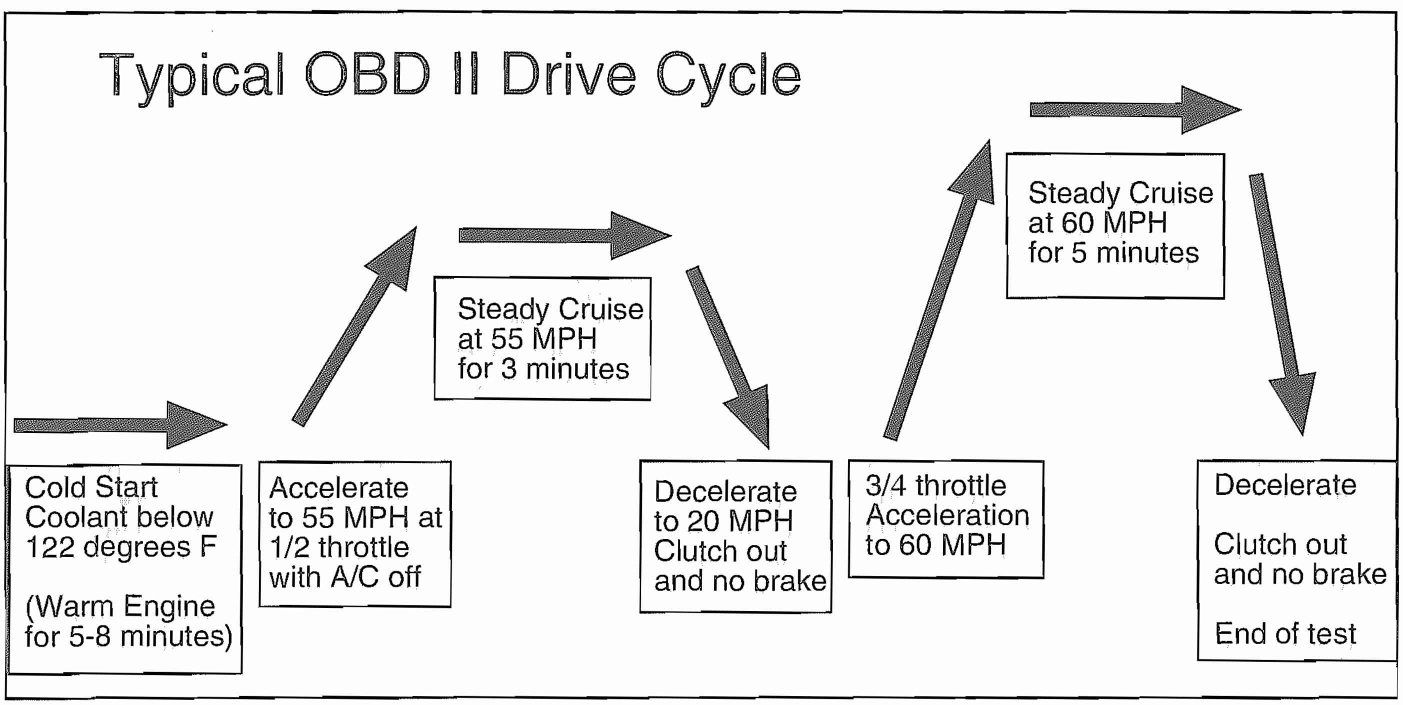



*Fig. 1-14. The FTP and OBD II Drive Cycle have a lot in common. Both are designed to test the system under a wide range of operating conditions considered typical of normal vehicle operation.*

monitored, but that they are now being tested under different operating conditions.

- **STEADY-STATE CRUISE (PART ONE)** — During this part of the Drive Cycle, the PCM will commonly try to detect problems with $O_2$ sensor response, Purge, Fuel Trim, and Misfire. Some vehicles may monitor EGR during this period.
- **DECEL (PART ONE)** — The monitoring system expects to see fuel delivery shut off during closed throttle deceleration. EVAP purge and EGR monitors may also run during this part of the cycle.
- **ACCELERATION (PART TWO)** — Once again, the vehicle is accelerated, but this time under a greater load. The throttle is usually held farther open, somewhere between 1/2 and 3/4 throttle. Tests are similar to what they were during the first acceleration, but a greater load is placed on the engine.
- **STEADY-STATE CRUISE (PART TWO)** — The Steady-State Cruise is repeated for a slightly longer period. It is during this time that the Catalyst Monitor will probably run, since the catalyst should now be warm enough to operate at maximum efficiency, and has the best chance of passing the test.
- **DECEL (PART TWO)** — The deceleration is repeated and the decel tests are performed again. Some manufacturers won't want the clutch or brake pedal depressed during the test.

If you add up all the individual time intervals for the individual tests, you'll come up with a figure of about 12-15 minutes to complete the entire Drive Cycle.

**There was a mention of the drive cycle used to allow OBD I vehicles to re-learn and the similarity to the OBD II Drive Cycle. What is the similarity?**

The Readiness Status display indicates when the monitors have run to completion. If the monitor Readiness Flags are all reset with the scan tool or by powering down the system until they are erased from memory, the system needs to see an entire Drive Cycle to run all the monitors and place a check mark next to each one. Some I/M programs may perform a preliminary test to make sure all the Readiness "Flags" are set before running an emissions test. The assumption is that if all monitors have run to completion, and there are no DTCs set, the vehicle is ready for testing.

The Readiness Status display is a very important consideration during any repair sequence. In addition to DTC and Freeze Frame data, the status of the monitors can provide clues about why a certain monitor won't run to completion. Let's say Monitor A never finishes. If you know that Monitor A won't run until Monitor B has completed its tests successfully, you can backtrack to Monitor B, and see if it's run completely. Notice that we are now comparing signal inputs and monitors during diagnosis. For OBD II to pass as a system, each monitored subsystem must run and pass.

Figure 1-15 shows a common Readiness Status display. Notice that the monitors displayed here are at different stages of readiness and completion. If the catalyst monitor won't run on this car, it may be because the oxygen sensor monitor is either incomplete or its results are being held up pending the solution of a separate problem.


*Fig. 1-15. The Readiness Status display provides information on the current status of the monitors supported by the system, and can provide clues about conflicts that may be preventing the system from giving all monitors a passing grade.*

**What hardware changes have been made to OBD II systems?**

Hardware changes are less significant than software changes. Many of the OBD II sensors are carry-over components from pre-OBD II fuel systems. The signals they send have added importance for some monitors in OBD II, however.

The crankshaft sensor is a good example. Previously, crank sensors were used to provide crankshaft angle and crank speed information to the PCM so it could calculate things like fuel delivery and spark timing. The crankshaft sensor signal has an added duty in OBD II, however, since it is also used by the Misfire Monitor to detect changes in crankshaft speed that would accompany a misfire.

Another sensor that has added importance in OBD II is the fuel level sensor. This might sound strange, but many OBD II systems will suspend certain monitors when the fuel level in the tank gets so low that it could cause a misfire or fuel control problem, or so high that it could affect EVAP system operation.

Some sensors are new. Pressure sensor switches have been added so the EVAP, or canister purge monitor can detect leaks in the evaporative recovery system. Other sensors have been duplicated. Perhaps the most noticeable duplication in the sensor roster is the use of at least two oxygen sensors—one at the inlet of each catalytic converter—and one at each outlet (Fig. 1-16).

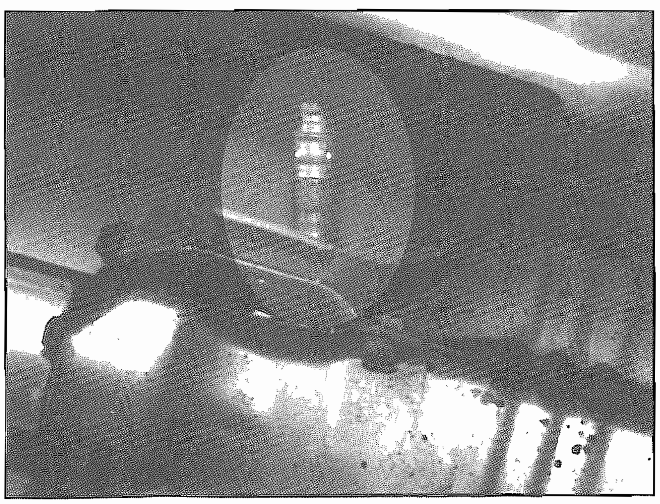


*Fig. 1-16. This oxygen sensor has a twin mounted upstream, ahead of the catalyst. Voltage signals from the two sensors are compared by the PCM to measure catalyst efficiency.*

## SUMMARY

- The addition of OBD II enables the vehicle PCM to continue monitoring vehicle emissions over the entire life of the vehicle.
- OBD II is concerned with an increase in emissions, not a driveability problem, although they may be the same.
- Some faults that will turn on the MIL will require only one trip to store a DTC. Others will need to be seen by the PCM on two consecutive trips to set a DTC and turn on the MIL.
- When the PCM stores an emission DTC, the MIL comes on. The EPA mandates that at least one Freeze Frame be stored.
- Once the MIL is on, it can be turned off by erasing DTCs with the scan tool, or by removing power from the PCM long enough for it to lose its memory. Erasing DTCs also erases Freeze Frame, and resets the Readiness Status records.
- The PCM can also turn off the MIL if the monitor that set the DTC runs and passes on three consecutive trips. Once the MIL is turned off by the PCM, DTC and Freeze Frame data are stored in the PCM memory for a predetermined number of warm-up cycles.
- A warm-up is counted by the PCM when the engine is started, the coolant temperature reaches 160 degrees F, and there is an increase in coolant temperature of at least 40 degrees F.
- A trip is defined as a start-to-run, drive cycle that provides enabling criteria for a monitor to run, and engine shutdown. Since enabling criteria are different for different monitors, the definition of a trip depends on the monitor.
- A Drive Cycle is completed when the vehicle is driven and satisfies the enabling criteria for all the individual monitors. If all monitors run successfully, the Readiness Status display will mark them with the words "DONE" or complete, depending on the scan tool.
- A scan tool is the only way to retrieve all data about a DTC including Freeze Frame. The scan tool must be capable of erasing DTCs and displaying the status of individual monitors.

## *MINI QUIZ*

1. OBD II is:
    a. An entirely new fuel and ignition control system used by all manufacturers
    b. A monitoring system used to detect driveability problems
    c. A monitoring system used to detect an increase in vehicle emissions above 1.5 times the emission levels established during the FTP
    d. A monitor that detects only electrical faults in the fuel control system

2. The MIL is on. What does this tell us?
    a. There is a DTC stored in memory
    b. The vehicle has to be experiencing a driveability problem
    c. The vehicle will not start
    d. There must be an electrical failure in a sensor or circuit

3. If you erase DTCs with the scan tool:
    a. Freeze Frame data will still be stored in memory for the next 40 warm-ups
    b. The DTC is stored in memory for the next 40 warm-ups
    c. The Readiness Status for all monitors will stay the same
    d. You will also erase Freeze Frame data

4. A trip is:
    a. Turning the ignition off and then turning it back on
    b. Starting the engine and allowing it to run for 5 minutes in PARK
    c. A set of driving conditions that provide enabling criteria for a monitor or monitors to run successfully
    d. Identical for all vehicles and for all monitors

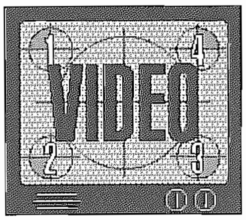
5. A Drive Cycle is:
    a. A driving procedure that enables all monitors to run
    b. A start-up and run cycle that allows the engine to enter closed loop
    c. A start-up and run cycle where the engine coolant temperature crosses over 160 degrees F and increases by 40 degrees F
    d. A start-to-run and engine shutdown

6. The MIL comes on:
    a. For all driveability problems
    b. When any system failure is detected on the first trip
    c. Only when an electrical circuit fails
    d. When an emission-related DTC matures

**Answers**

1. c
2. a
3. d
4. c
5. a
6. d

2




Watch video module #2 now.

# MAJOR MONITORS

In the first section, we admittedly painted our overview picture with a broad brush. Now it's time to go back and start filling in some of the detail, especially in the areas of monitors, trips, and drive cycles.

Although the repair of no-starts and driveability concerns is not the primary intent of OBD II, there are some features of its diagnostic routine that could be very helpful in fixing these types of problems. In Section One, we listed the relatively short list of generic data parameters for OBD II. While there are fewer generic categories for data display than there were for an OBD I systems with serial data, the short list represents a big leap forward for vehicles that had no serial data at all before OBD II. In addition, the Freeze Frame data parameters list critical system operating conditions at the instant the first, or highest priority DTC is stored. For specific component failures, the Comprehensive Component Monitor will be there with its extremely long list of DTCs to help you identify the bad apple in the component barrel. OBD II does offer diagnostic help.

In some cases, generic OBD II codes will provide you with more information than you might have received from an OBD I code. (Compare an OBD I code XX that simply says "EGR system failure" to a generic OBD II DTC P0401 that says "Exhaust Gas Flow Insufficient," for instance.)

When it comes to repairs of failed components and faulty circuits, your diagnostic approach may be very similar to what it was with OBD I.

The really knotty problem is going to be the MIL. Let's face it, turning off the MIL, and keeping it off, is going to be a big, big consideration for those customers who actually heed its warning and seek your assistance.

The only reason a customer may have for bringing you the vehicle in the first place is that the darned light is on. Some will really take the MIL to heart, and view it as an omen of impending doom and destruction for driver and vehicle alike. Others will find the light more of an annoyance than an immediate concern. In any event, if a customer brings you a car with the MIL on, his only reason for coming to you may be that he wants the MIL off. Before we can assure him that the MIL is not only off, but that it will stay OFF, we need to understand how it got on in the first place, how the PCM uses trips to turn it ON and OFF, and how to verify the repair.

Since OBD II is concerned with emissions first and driveability second, the OBD II PCM will turn the light ON if it thinks the system is polluting above 1.5 times its EPA fresh-from-the-showroom certified level. Go ahead, tell OBD II that a polluting vehicle runs fine, and it will tell you that it doesn't care—period—end of story.

All the OBD II system cares about is that its surveillance of monitored systems has turned up evidence of unacceptable emissions. It wants the problem fixed or it will turn the light back ON!

## A CLOSER LOOK AT MONITORS

In this section we'll look at some common enabling criteria and test strategies for OBD II monitors. There are similarities in OBD II monitor operation throughout the industry. This is based largely on the fact that the engine management systems found on current vehicles have become very similar. Not identical—similar. ***Similarities aside, all manufacturers do not need to select the same test strategies to make individual monitors run.*** There's more than one way to skin an emissions problem, and even more ways to test them.

We've broken down the major monitors into general groups and will show some of the common enabling criteria and test conditions you'll see. These are provided to give you a flavor for the types of tests that may be run.

Why is this all so important? Because the monitors are what will turn the MIL ON in the first place, and under the proper conditions, turn the MIL OFF. Monitors not only set a code when they fail, they can self-erase under the proper circumstances. Even more importantly, an understanding of monitor operation can help you verify a repair. We'll get to things like DTC priorities and the specifics of how the monitors control the MIL in the next section. But before we can do that we need to understand the basics of major monitor operation.

The purpose of this section is to familiarize you with the general operation of monitors and to get you thinking of the ODB II diagnostics as an integrated system.

## THE MISFIRE MONITOR

We're going to start with the Misfire Monitor for the simple reason that misfires are death on the catalyst. Unburned fuel in the cat from a misfire can result in a chemical action so violent that it literally burns the catalyst innards to a crisp. Some may remember the early days of carbureted catalyst-equipped cars that caught on fire when the catalyst overheated the carpeting located directly above it. Several late 70s vehicles went *up in smoke* faster than you can say Cheech and Chong.

OBD II is the first system to use a misfire monitor, so unlike other system monitors, there was no existing OBD I diagnostic strategy to build on.

Here's the basic approach the engineers came up with: Every time a cylinder ***fires***, the crankshaft picks up speed. Every time a cylinder ***misfires***, the crankshaft slows down. The crankshaft will speed up again when the next cylinder fires (assuming there is good combustion from the next cylinder).

The crankshaft sensor sends a signal to the PCM based on engine speed. If the signals are consistent in frequency and/or amplitude, no misfire is detected. A decrease in frequency and/or amplitude means that the crankshaft has slowed down, and this will be interpreted as a misfire (Fig. 2-1). Sounds, pretty simple, right?

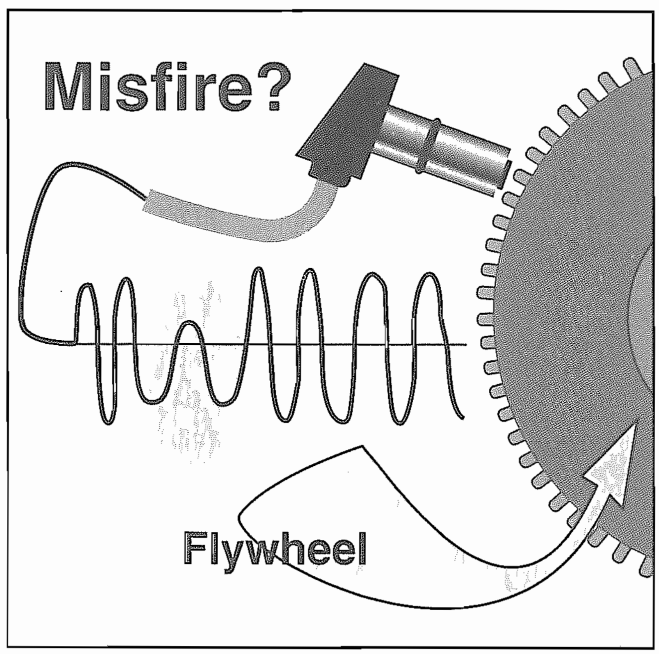



*Fig. 2-1. Can you spot the donkey in this picture?*

But wait a minute, are there other possible reasons for a change in crankshaft speed that wouldn't be caused by misfire?

- What about backfeed through the driveshaft as the vehicle travels over rough roads, and changes in wheel speed fight back against engine torque?
- What happens when the throttle is blipped, causing a short change in crankshaft speed?
- What about the normal inefficiency of a cold engine? Will the irregularities in firing be detected as a misfire?
- Won't the inertia of the flywheel tend to minimize the measured effects of a misfire at higher engine speed?

These are tough questions. Don't think the guys with the slide rules and pocket protectors didn't lose a few hairs over this one! They needed to build on the speed sensor concept, but build in enough filters and controls to allow the PCM to know the difference between real and imagined misfire conditions. They attacked the problem several ways, and here are the most common approaches:

- **Program the computer software** to measure engine speed, load, and throttle position, and compare those inputs to the crankshaft speed signal.
- **Don't let the Misfire Monitor run under conditions, such as a cold start, where it is apt to receive a false indication of a misfire.**
- **On some ABS-equipped vehicles**, wheel sensor signals are used to tell the PCM that the road is rough, and that it shouldn't misinterpret driveline backfeed as a misfire condition.
- **On A/T equipped vehicles with lockup converters**, the lockup can be temporarily disabled if a misfire is detected. This breaks the mechanical connection between the driveshaft and crankshaft. The torque converter fluid coupling dampens road harshness transmitted by the driveshaft until the PCM can decide if there's a real misfire, or just the appearance of one.

There are other conditions beyond the control of the PCM that could trigger the Misfire Monitor that are taken into consideration by the PCM as it decides whether or not a misfire actually exists. Under the following types of conditions, the Misfire Monitor may be suspended:

- The fuel level in the gas tank is below 15 percent of capacity, usually under one gallon. (We told you that fuel level sensing is now an important part of the OBD II monitoring system.)
- Temporary MAP voltage fluctuations
- The throttle is opened and closed rapidly
- While the engine is being cranked over
- During closed throttle deceleration
- When engine speed exceeds a predetermined RPM
- During cold start and when the engine is extremely cold or extremely hot
- Before the PCM timer runs out

### *MISFIRE MONITOR OPERATION*

The PCM Misfire Monitor, like the other monitors, is looking for any emission-related failure that will cause an unacceptably dirty exhaust. In addition, the PCM will classify the degree of misfire into one of two general categories: 1) a misfire that would cause the engine to fail either a CARB or an EPA emission test and, 2) A misfire so bad that it will damage the catalyst if the severity of the misfire is not reduced.

Enabling criteria for the Misfire Monitor include inputs about engine speed, load, and temperature (Fig. 2-2). Other criteria include a start-to-run condition, the amount of time the engine has been running (Time-in-Run), and may include a camshaft sensor and/or vehicle speed sensor input.

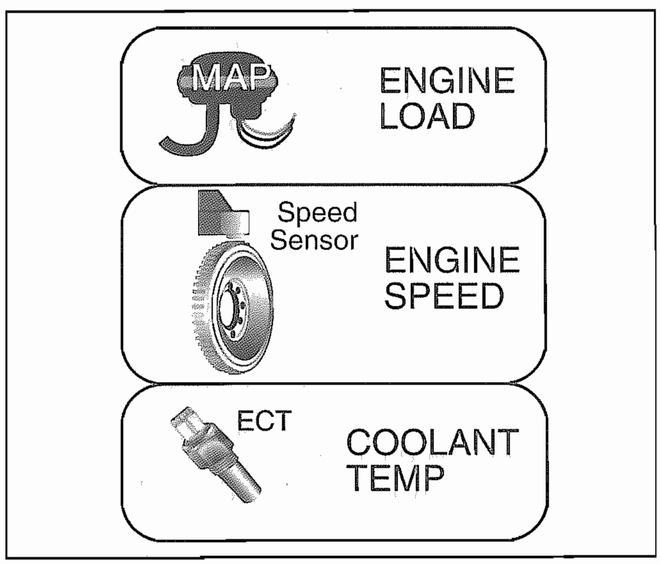



*Fig. 2-2. If a PCM detects a misfire, it wants to know the exact conditions under which the misfire occurs.*

If there is a DTC stored in memory that would affect the results of the Misfire Monitor, it won't run. Let's go back to our generic list of Enabling Conditions, and Pending, Conflict, and Suspend modes to see how a manufacturer could proceed through the misfire detection process.

**Enabling Criteria**

- MAP is at a specified voltage
- RPM falls in a specified range (example: between idle and 2800 RPM)
- Engine Coolant temperature is above a specified temperature
- The engine has been running for a specified time
- Vehicle speed is within a specified range

**Pending**

The Misfire Monitor may not run if the MIL is ON due to a DTC that affects one of the sensors it needs to run the test: MAP, TPS, camshaft or crankshaft position sensors, or the engine coolant temperature sensor. If the MIL is ON, correcting the cause for the sensor input DTC becomes priority number one.

**Conflict**

If the PCM has recorded a one-trip maturing code for fuel, purge, or the EGR system, it will assume that the misfire monitor could be affected by the conditions that stored the fault in the first place, and it will not run. For example, if the EGR is stuck wide open all the time, or there is a dead injector, it's obvious that the test is very apt to fail.

**Suspend**

Since the Misfire Monitor does not depend on the test results from any other monitor, there are no Suspend conditions. Test results will be sent to the PCM whenever the misfire monitor is running.

## DEGREES OF MISFIRE

Earlier, we mentioned that the Misfire Monitor would store a code if the misfire would cause the vehicle emissions to increase. When an emission-related misfire is first detected, the PCM will store the data, but not turn on the MIL. This is classified as a *pending* or *maturing* fault. (This type of misfire is classified as one that causes a 2 percent change in a crankshaft speed in a 1000 RPM interval.) If the same emission-related misfire is detected on the next trip, the MIL comes ON. The first instance was a *maturing* code. The second, the one that turns on the MIL, is a *matured* code.

But what happens when the misfire is so bad that the catalyst is endangered? When an extreme misfire occurs, the MIL won't wait for the Misfire Monitor. An extreme misfire is one that occurs in more than 15 percent of cylinder firings during any 200 RPM interval. An extreme misfire should cause the MIL to flash ON and OFF *as long as the catalyst-damaging misfire is detected.* The flashing light warns the driver that he really ought to break down and get the car fixed before he breaks down the catalyst into black, crispy chunks.

On most vehicles, even after the misfire decreases to a point where the flashing stops, the MIL will stop blinking but stay on as an indication that a DTC has been stored.

Getting the PCM to turn off the MIL for a misfire is not the easiest thing to do. If the Misfire Monitor runs successfully on three consecutive trips after a code is set, it will turn off the MIL. But for the Misfire Monitor to run and pass on those three trips, the monitor must see driving conditions very similar to the ones that were present when the code set in the first place.

The monitor must run under conditions that are within 10 percent of the calculated load value, and also within 375 RPM of the engine speed when the misfire occurred. If these conditions are met, and the PCM doesn't see a recurrence of the misfire in a 1000 RPM interval, it will record one good trip. After three consecutive trips with no misfire detected in the same window of operating conditions, the PCM will request the MIL off.

DTC and Freeze Frame data stored at the instant the DTC set will be stored in the PCM memory, typically for the next 40 to 80 warm-up cycles before being erased.

Figure 2-3 shows the general conditions that are needed for the Misfire Monitor to run successfully, and lists the components most often associated with a misfire condition.

# Misfire Monitor

### Enabling Criteria

- MAP at specified voltage
- RPM in a specified range
- Coolant Temperature at specified range
- Engine in start-to-run
- Vehicle speed in specific range

### Pending Conditions

Vehicle is in limp-home or waiting for a missing signal from a critical input. Look for a DTC for MAP, TPS, camshaft or crankshaft sensor, or coolant sensor

- A speed sensor DTC may be stored

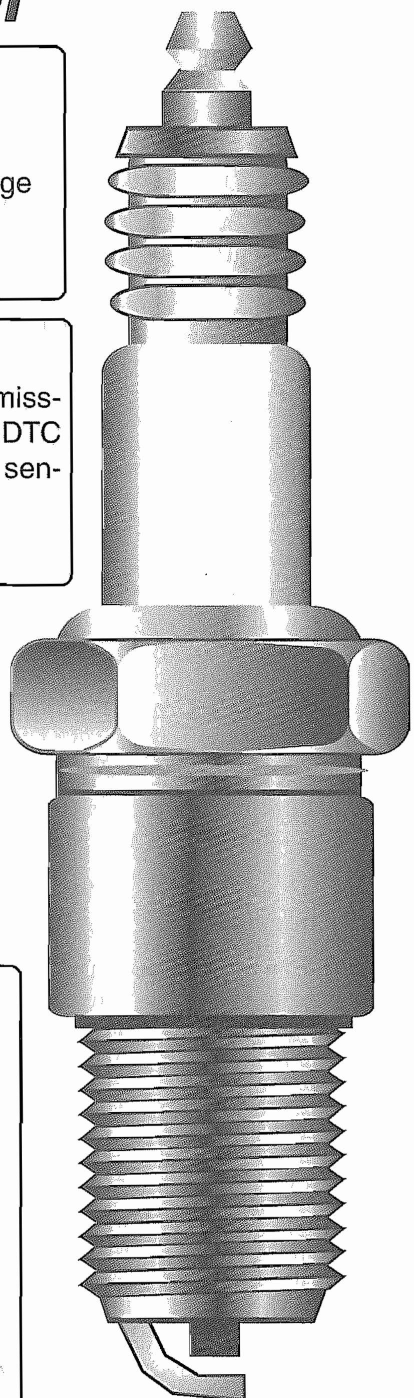
### Conflict

The misfire monitor may be unable to run because there is a 1 trip maturing code stored for:

- Fuel system rich
- Fuel system lean
- Purge failure
- EGR failure

### Misfire Monitor is commonly disabled under the following conditions:

- Cold starts
- During cranking
- Deceleration fuel cutoff
- Fuel tank level extremely low
- Throttle toggle rapidly between open and closed
- MAP voltage fluctuates rapidly
- Extremely high engine RPM
- Rough road detected (may be used with ABS wheel sensors or be software driven)
- The PCM has not learned the characteristics of the crankshaft (More on this later)



### Common Causes for a Misfire Condition

- Worn or failed spark plugs and/or secondary wiring
- Loose spark plugs
- High secondary ignition circuit resistance
- Low available voltage at ignition coil positive terminal
- Ignition coil
- Failed crankshaft position sensor
- Improperly timed cam belt
- Worn camshaft lobes
- Improperly adjusted valve lash
- Sticking valves
- Burned or leaking valves
- Worn rings
- Leaking head gasket
- Low fuel level (starvation)
- Weak fuel pump (starvation)
- Plugged fuel filter (starvation)
- Low fuel pump voltage
- Faulty fuel pressure regulator (starvation or fuel dumping)
- Contaminated fuel
- Leaking injectors
- Clogged injectors
- Disconnected injector
- Open circuit or short in injector or wiring
- Improper PCM fuel control output signal caused by faulty input from MAP or coolant sensor
- Excessive EGR
- EGR passages partially restricted
- Plugged exhaust
- Cracked engine block or cylinder head

*Fig. 2-3. The list of possible cause for a misfire haven't gotten any shorter just because it's an OBD II vehicle. A misfire is still a misfire, and the list of potential causes includes items that may not be listed here. The spark plug shown here is the first thing you may think of when you think of a misfire condition, but it is only one of many possible causes.*

### *THE FUEL SYSTEM MONITOR*

The Fuel System Monitor, like the Misfire and Comprehensive Component Monitors will test continuously. Like the Misfire Monitor, Freeze Frame data will be stored in the PCM memory when a Fuel Monitor failure is detected. In addition to normal concerns about emissions, the PCM knows that a major failure of the fuel correction system can damage the catalyst, especially if it gets so bad that it results in misfire.

Figure 2-4 suggests that closed loop is needed to run the Fuel System Monitor. Closed loop parameters are similar to the ones we saw in OBD I vehicles, namely that the engine and oxygen sensor are both warm enough for closed loop operation. A timer tells the PCM when enough time has elapsed since a start-to-run, and the amount of time needed to trigger the timer may be indexed to the coolant temperature when the engine was started.

To understand how the Fuel System Monitor works, we must understand the difference between short- and long-term fuel trim.

- **Short-Term Fuel Trim (STFT)** adjusts injector pulse width to keep the system in closed loop, based on information received from various sensors. The system starts at a base figure and goes richer or leaner from that point. There are limits to the corrections STFT can make. If the engine management and engine mechanical conditions are right-on, the amount of correction needed should be fairly small. If the system gets too lean or too rich, the short-term fuel corrections must increase. Short-term memory is erased each time the ignition is turned OFF.

- **Long-Term Fuel Trim (LTFT)** is a shift in the starting point, or baseline, for fuel corrections. If the short term corrections are repeatedly pegged at their limits, then the long-term memory shifts. The starting point for short term fuel trim moves closer to the actual corrections that are needed. The system must be in closed loop to store changes in long-term fuel corrections. These values are stored in memory even after the ignition is switched OFF.

The PCM uses the short and long term fuel trim factors to calculate *total* fuel correction, or the combined STFT and LTFT correction needed to maintain closed loop. If the system gets too lean or too rich, fault data will be stored in the PCM memory as a *maturing* fault.

If the limit is exceeded on two consecutive trips, the fault *matures*, and the MIL comes on. A DTC and related Freeze Frame data are stored in memory.

The PCM can turn the MIL off again, but the conditions needed for this to happen are precise. The PCM must see three consecutive trips where the Fuel System Monitor passes. The tricky part is that load and engine speed conditions during these trips must be very close to the load and engine speed conditions that were present when the code set in the first place. Just like the Misfire Monitor.

The monitor must remain in the window long enough to run to completion and pass on three consecutive trips.

IMPORTANT: The same common causes for a misfire condition listed in Figure 2-4 can affect the test results of the Fuel System Monitor. Fuel and ignition have become separate but related components in a centralized monitoring system.

**Time Out**

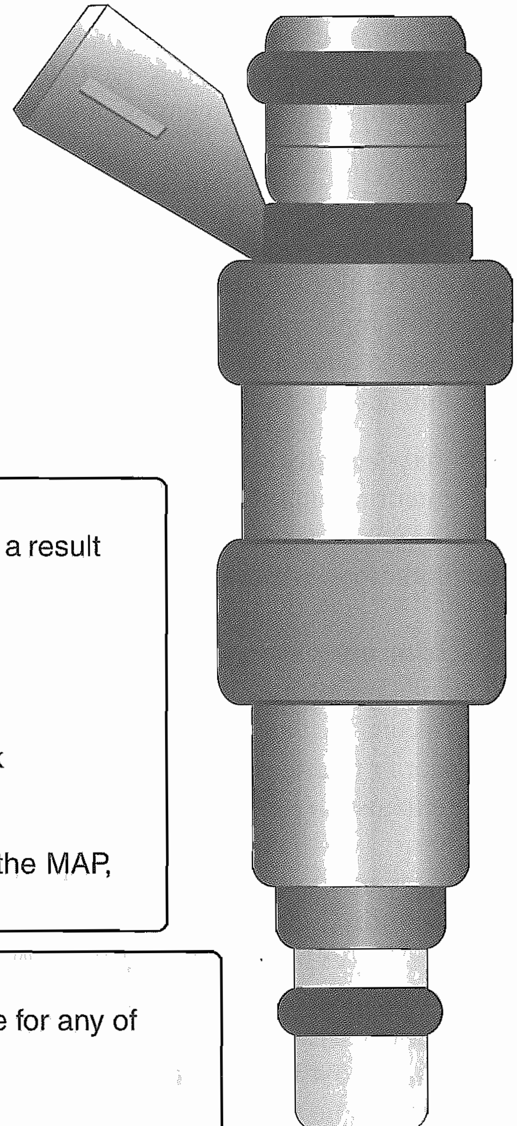
Let's go back to our television set analogy to better explain the difference between Short and Long-Term fuel correction.

Let's say you have a small table right next to your favorite chair, and that you've placed the TV remote control on the table within easy reach. To change channels or adjust the volume, you simply drop your hand and make a short-term adjustment with a press of a button.

But somebody decides to rearrange the furniture one day (we won't say who!), and the table is moved four feet away. Now you have to get up and walk to the table every time you want to channel surf or turn down the volume on an obnoxious commercial.

Long term? You'll probably move the chair closer to the table (or vice versa) so your short-term corrections become fast and convenient again.

# Fuel System Monitor



### Enabling Criteria
- Engine is warm
- System is in closed loop
- MAP, ECT, IAT, TPS, Vehicle speed sensor, BARO, RPM signals are present
- Long term fuel trim data
- Short term fuel correction information based on injector pulse width

### Pending
The Fuel System Monitor may not run if the MIL is ON as a result of a failure in one of the following:
- A Misfire DTC is stored
- An EVAP monitor DTC is stored
- An EVAP solenoid DTC is stored
- An upstream $O_2$ sensor heater DTC is stored
- The upstream $O_2$ sensor has failed its rationality check
- An EGR Monitor DTC is stored
- An EGR solenoid DTC is stored
- The system is in limp-home mode due to a failure of the MAP, ECT, or TPS

### Conflict
The Fuel System Monitor may not run if a maturing code for any of the following is present:
- Misfire
- EVAP monitor
- Upstream $O_2$ sensor heater
- EGR monitor

### Suspend
Generally speaking, the information from the Fuel System Monitor will be sent to the PCM memory. Like the Misfire and Comprehensive Component Monitors, the Fuel System Monitor is a *continuous* monitor. Once the enabling criteria have been met, the monitor will run. Some systems will prevent the monitor from running if the fuel level is too low.

It is important to remember that since the Fuel System Monitor carefully compares fuel delivery rates (short and long-term fuel correction) to oxygen sensor response, the PCM has various test modes based on engine load and speed, vehicle speed, and the operation of the EVAP system that might affect the monitor test results.

*Fig. 2-4. The Fuel System Monitor relies on many of the same sensor inputs used by the Misfire Monitor, and may not be able to run successfully when those inputs are inaccurate or missing.*

### *THE OXYGEN SENSOR MONITOR*

Earlier, we said that none of us would be carrying around a two-ton, constant-volume emissions tester. It isn't practical or cost-effective to equip each vehicle with a full-blown emissions analyzer.

So the OBD II system needs to *infer* emissions since it cannot measure them directly. The Task Manager may monitor existing conditions or run its own tests. And the oxygen sensor becomes the most important single gatherer of information, information used to infer that the vehicle is either running within acceptable emissions limits or not.

Changes in oxygen sensor voltage may be used to test fuel correction, catalyst operation, EVAP, and EGR. If the oxygen sensor is asleep at the switch, some other monitors cannot do their jobs at all.

- **The $O_2$ sensor must start to operate quickly.** That's why the $O_2$ sensor heater has become a monitored circuit. We can't wait for the exhaust to heat the sensor or tolerate periods of sensor inactivity if the exhaust cools during extended idle conditions.
- **The $O_2$ sensor must operate at acceptably high voltage when the system is rich (low oxygen content in the exhaust) or at acceptably low voltage when the system goes lean (high oxygen content in the exhaust).**
- **The $O_2$ sensor must have good reflexes.** It has to switch quickly. The PCM needs timely updates about changes in the oxygen content of the exhaust. If the $O_2$ sensor voltage starts to fall behind the actual changes in oxygen content in the exhaust, the information it sends becomes yesterday's news. That's why the oxygen sensor's response time becomes so important.

The PCM monitors cross counts (the number of times the $O_2$ sensor crosses the center voltage level between rich and lean). But cross counts are partially dependent on engine speed. If you've scoped $O_2$ sensors, you know that cross counts increase as the throttle is opened before leveling off at the system's maximum switching rate. So the OBD II system may monitor the $O_2$ sensor's reflexes, or ***Response Time*** as well as cross counts.

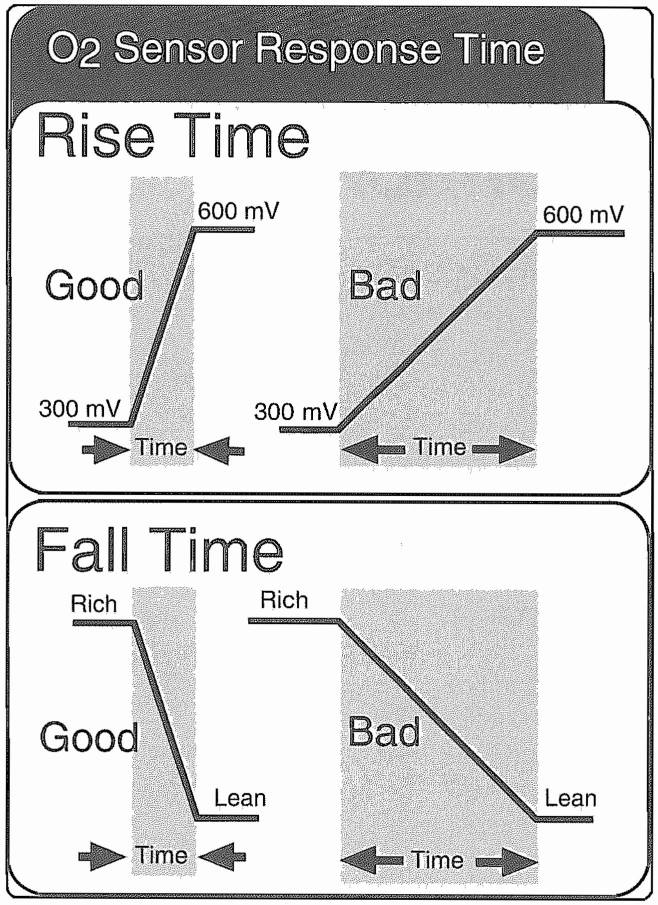


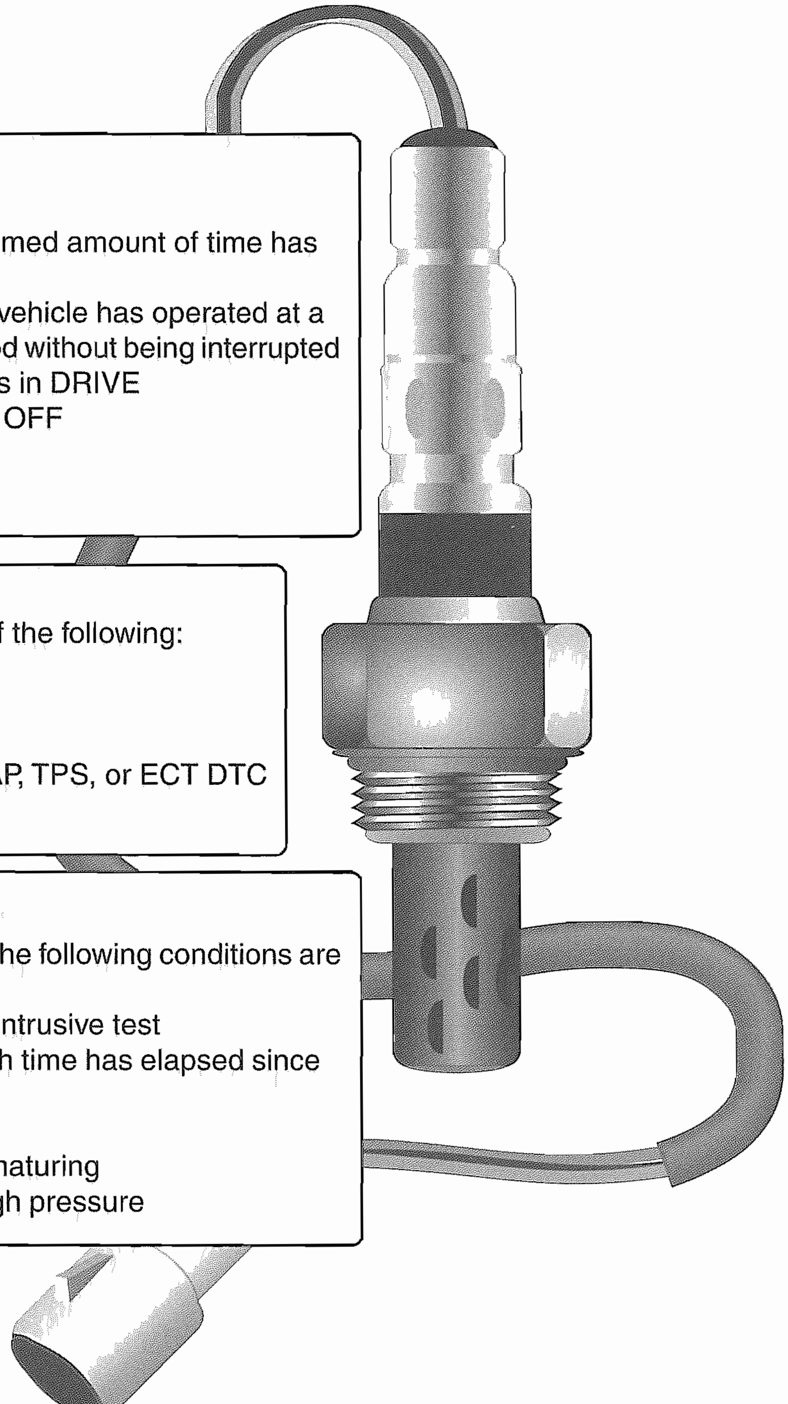

*Fig. 2-5. The oxygen sensor better not take all day switching from rich to lean or lean to rich or the PCM will fail it.*

Figure 2-5 shows how the change from a low voltage to a high one must occur in a short period of time, or the lean-rich transition is no good. A similarly rapid change in oxygen sensor voltage must occur for the sensor to properly signal a rich-lean or lean-rich change. If the sensor takes too long to switch, the PCM will issue it a failing grade. The ability of the PCM to monitor the $O_2$ sensor response rate is critical to $O_2$ sensor testing.

- **The $O_2$ sensor signal cannot be shorted or open.** The PCM looks for sensor voltage levels that are stuck high, stuck low, or just plain stuck in limbo, as an indication that the sensor is dead or its circuit is open or shorted.

Figure 2-6 on the facing page lists general test conditions that may be used for the Oxygen Sensor Monitor. Be aware that there may be minor differences in system strategies and applications, not only across car lines, but within each manufacturer's models and systems.

# Oxygen Sensor Monitor



### Enabling Criteria

- Engine warm
- The PCM timer indicates that a programmed amount of time has elapsed since start up
- Vehicle speed sensor indicates that the vehicle has operated at a specified speed for a minimum time period without being interrupted
- PRNDL input indicates that the vehicle is in DRIVE
- High pressure Power Steering Switch is OFF
- TPS within a specified range
- Purge is not likely to affect results

### Pending

When the MIL is illuminated due to one of the following:

- A Misfire DTC is stored
- An upstream $O_2$ sensor DTC is stored
- A vehicle speed sensor DTC is stored
- The vehicle is in limp-home due to a MAP, TPS, or ECT DTC
- The PRNDL input fails

### Conflict

The oxygen sensor monitor will not run if the following conditions are present:

- The Fuel System monitor is running an intrusive test
- The PCM timer does not indicate enough time has elapsed since start-to-run
- A Misfire DTC is maturing
- An upstream $O_2$ sensor heater DTC is maturing
- The Power Steering Switch indicates high pressure

### Suspend

There is no suspend for the $O_2$ sensor tests. If the enabling criteria are met, the results of the $O_2$ sensor test will be stored in the PCM memory since the results are needed before other monitors like EVAP, Catalyst, Fuel correction, and EGR can run.

*Fig. 2-6. The input from the Oxygen sensor(s) is extremely critical to other monitors. Common system checks include oxygen sensor switching speeds and tests of the oxygen sensor heater.*

## THE COMPREHENSIVE COMPONENT MONITOR

OBD I systems had a close equivalent to the CCM, or Comprehensive Component Monitor. In fact, the CCM is the one monitor that you'll probably identify with most readily, since it mirrors the sensor monitoring system that used to turn the Check Engine light ON when the system detected an open or short in a critical circuit.

Basically, the CCM runs continuously (like the Misfire and Fuel Monitors) to detect failed sensor inputs and output circuits that are not tested by another monitor. This is a difference from OBD I. Certain components have their own monitors. The $O_2$ sensor, for example, is not included in the CCM list, because it is tested directly by the Oxygen Sensor Monitor. So is the EGR. Figure 2-8 shows common components monitored by the CCM.

CCM faults may be either one- or two-trip faults depending on the sensor type and system design. That brings up another big difference between OBD II and its predecessors. Inputs are evaluated in different ways:

- A sensor input circuit is monitored for circuit continuity and out-of-range values similar to the OBD I monitor. This is referred to as a ***functionality test***.
- The sensor circuits may also be monitored to make sure they make sense. This is the ***rationality test***. If one signal contradicts another, it is considered irrational, and fails the rationality test.
- The PCM will also run its stopwatch on some sensor inputs to ensure that they satisfy enabling criteria within a specified time.

The ECT is one example. If the ECT doesn't reach a temperature level that allows closed loop operation within a specified time, the PCM can flag it. Be careful with this one. Low coolant can create conditions that prevent the ECT from reaching its normal temperature within the specified time.

The PCM may temporarily disable ECT monitoring during cold starts at extremely low temperatures. That's because the resistance curve of the ECT may be unstable at extremely low temperatures. This could cause the PCM to mistake a normal condition for a fault. Finally, the PCM may disable the ECT monitor if it sees a vehicle speed signal of zero MPH. This keeps the system from setting a code during a normal service operation such as a coolant flush.

The PCM also tests outputs with a parallel test circuit connected to the voltage output to the device (Fig 2-7). Normally, when a solenoid at an output device is energized, the voltage signal sent to the solenoid is pulled to a low voltage. When the PCM energizes the solenoid by applying power to it, it looks for the voltage to go low. If the solenoid or its ground are open circuited, the voltage sent to the solenoid will stay high, and the test circuit will pass that information along to the PCM.

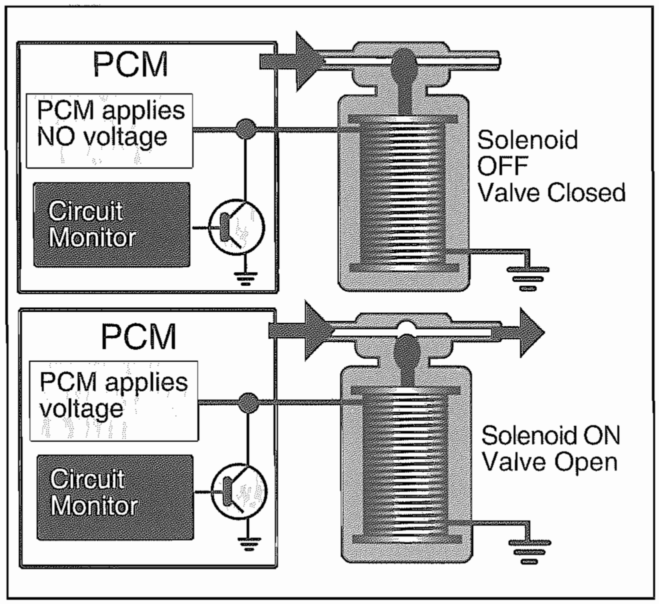


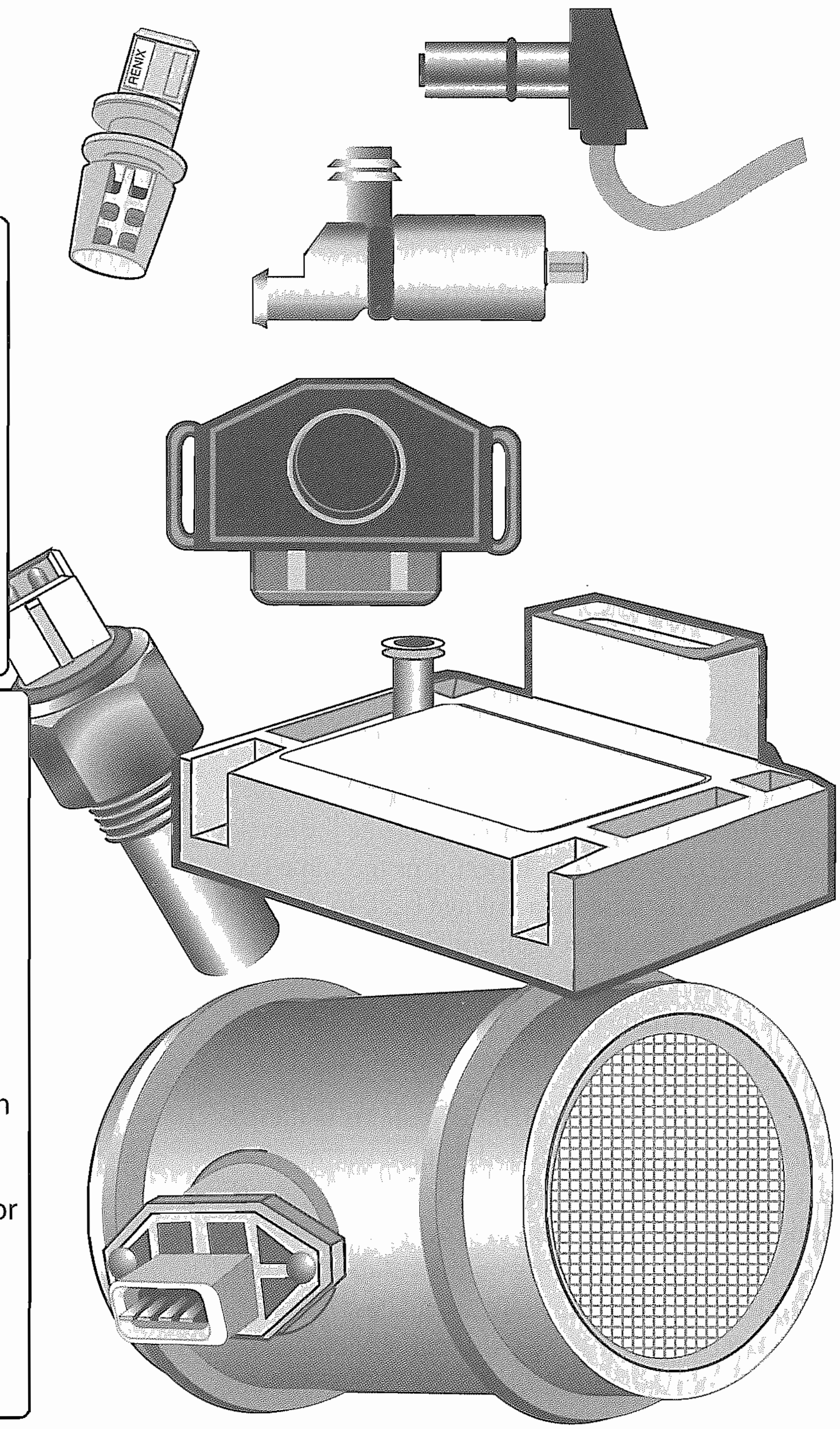

*Fig. 2-7. Basically, as soon as the PCM applies voltage to the output device, it expects to see the voltage signal pulled to a low voltage, indicating that the solenoid winding and solenoid ground circuit are not open.*

Here's another thing to keep in mind. While an electrical failure in a monitored component will customarily turn on the MIL right away, it may take two trips to turn on the MIL for a *rationality* fault. In other words, if one sensor input contradicts another sensor input, but both are within limits electrically, it may take two trips to turn on the MIL. This keeps the MIL off for special conditions that might be falsely interpreted as a fault; conditions that may be gone on the next trip.

# Comprehensive Component Monitor (CCM)

**Enabling Criteria**
- Some components tested at Key ON.
- Some components cannot be tested until the engine has reached operating conditions where the monitored device would normally operate.
- Component tests will vary depending on the design of the system and the types of components installed.

**Commonly Monitored Inputs**
- Brake Switch
- Camshaft sensor
- Crankshaft sensor
- Cruise Control Servo Switch
- ECT
- EVAP Purge Switch
- Four Wheel Low Switch
- IAT
- Knock Sensor
- MAP Sensor
- Manual Transmission Clutch Switch
- Mass Air Flow Sensor
- TPS
- Transmission Turbine Speed Sensor
- Transmission PRNDL Mode Pressure Switch
- Transmission Temperature Sensor
- Vacuum Sensor
- Vehicle Speed Sensor




**Commonly Monitored Outputs**
- EVAP Canister Purge Solenoid
- EVAP Purge Vent Solenoid
- IAC Solenoid
- Ignition Control System
- Transmission Converter Clutch Solenoid
- Transmission Shift Control Solenoids
- Transmission Enable Solenoid

Not all vehicles will have all of the Input and Output devices listed above

*Fig. 2-8. The Comprehensive Component Monitor is a continuous testing procedure. Once the enabling criteria have been met, the CCM runs until it detects a fault.*

## *CATALYST MONITOR*

The catalyst is the heart and soul of the OBD II vehicle's ability to comply with emission standards. Without an effective conversion of harmful emissions to harmless gases and water by the catalytic converter, the emission levels of a good running vehicle will still be too high to be considered acceptable. The vehicle will exceed 1.5 times the FTP standard, and the MIL will come ON.

The first thing the PCM does is determine if the conditions are right for the catalyst monitor to run. Engine temperature, load, throttle position, the air/fuel ratio, and closed loop status among others are all evaluated before the PCM will run the catalyst monitor. If DTCs are stored that prevent proper operation of the catalyst monitor, the test results are suspended. The test may also be delayed if the PCM sees wide open throttle, closed throttle decel, or other conditions outside closed loop.

Each catalyst has two heated oxygen sensors. A heated upstream sensor is used, just like the sensor used on OBD I vehicles. It performs the same task it did before by sending a voltage back to the PCM to signal changes in oxygen content as the fuel mixture switches rich-lean and lean-rich. The PCM uses this information to maintain the air/fuel ratio at stoichiometric. Nothing radically different here.

But a key difference in OBD II systems is the addition of a separate heated $O_2$ sensor at the catalyst output (Fig. 2-9). Why? Because catalyst efficiency depends in part on how well it can store oxygen. A special coating on the catalyst grid has the ability to catch and store any excess oxygen that's left over after the catalyzing process. This lets the catalyst continue oxidizing the exhaust when the oxygen content of the exhaust is low.

One way to infer catalytic converter potential is to measure how much oxygen *doesn't* get captured and stored in the catalyst. In simplest terms, the amount of oxygen, and the rate of change from high to low oxygen content should be much smaller at the outlet than at the inlet—if the catalyst is working properly. Compare the voltage change and rate of change between the upstream and downstream oxygen sensors in Figure 2-9.

As the catalyst deteriorates or becomes contaminated, its ability to store oxygen decreases. It won't have any reserve of oxygen stored for times when exhaust gas oxygen content drops too low to support proper oxidation of the other exhaust gases.

As the storage capacity of the catalyst decreases, more oxygen will exit the catalyst, and the switching rate of the *downstream* $O_2$ sensor will start to look just like the switching rate of the *upstream* sensor. When the switching rate of the downstream sensor reaches a point where it is almost the same as the switching rate of the upstream sensor, a code will be stored, and the MIL will come on. Threshold levels for the downstream sensor will be measured as a percentage of upstream sensor's activity rate. The thresholds will not be identical for all cars, and may be different for manual transmission and A/T-equipped versions of the same vehicle type.

Since the information from the sensors is so critical to the proper operation of the catalyst monitor, the results of the Catalyst Monitor test will be suspended (won't be recorded with a passing grade in the PCM memory) until the PCM knows the Oxygen Sensor Monitor has passed.

Catalyst monitoring must occur once per trip, and is usually a two-trip or three-trip failure. If the MIL comes on, the PCM can turn it off if the catalyst monitor passes on the next three trips.

By definition, a catalyst does not get consumed during a chemical conversion process. It promotes the chemical action without being altered. So the biggest enemies of the catalyst as it ages are contamination and excessive heat, usually caused by misfire and improper fuel/air ratio. When a catalyst fails, suspect contamination or internal damage from overheating. Oil and antifreeze from a failed head gasket, cracked engine castings, and leaking rings and valve guides are still the most likely causes of contamination. The oil and antifreeze coat the catalyst material, clog its pores, and reduce its ability to absorb oxygen. **Warn your customers that repairing a blown head gasket on an OBD II vehicle may include the price of a new oxygen sensor, or sensors.**

# Catalyst Monitor

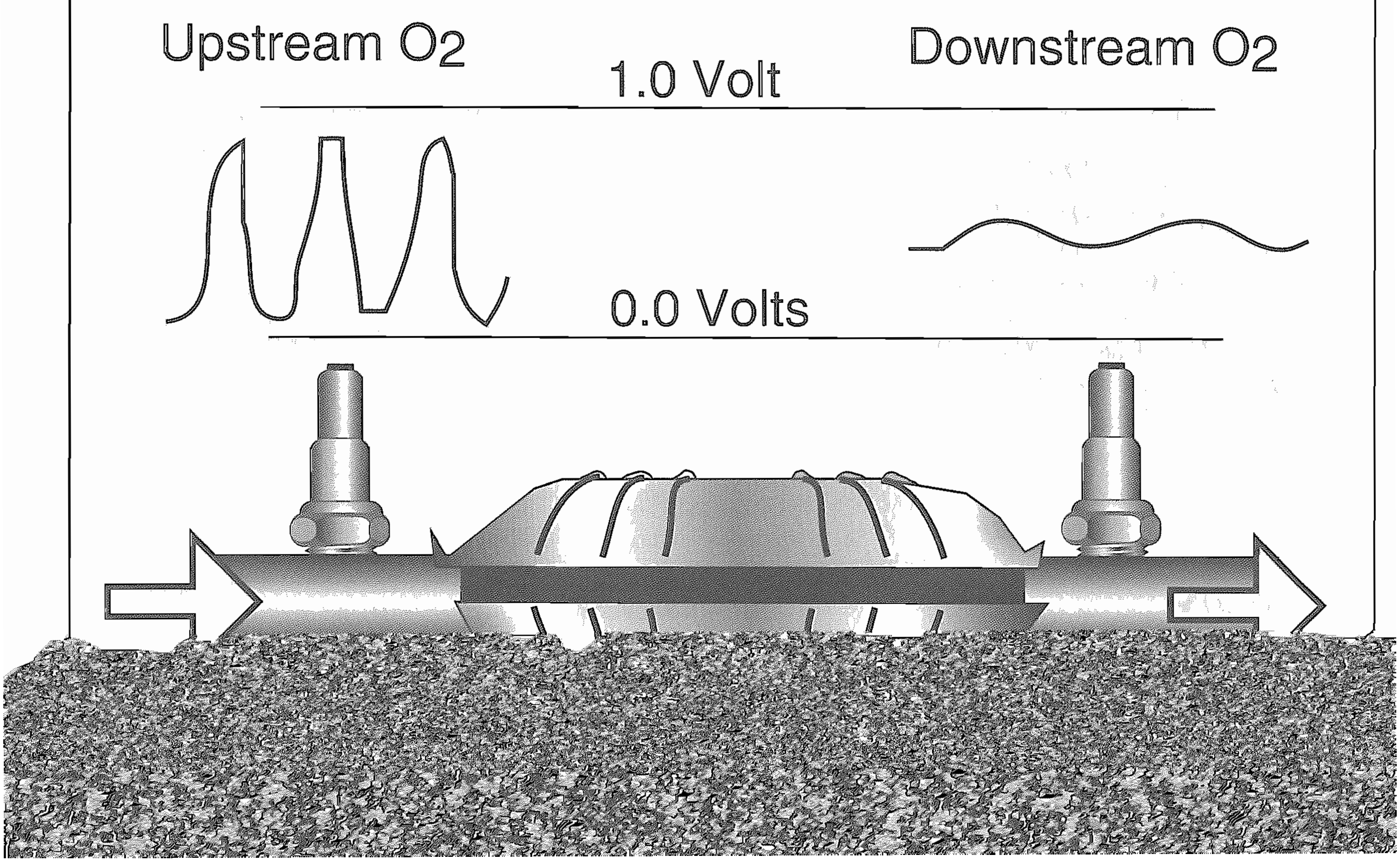
**Enabling Criteria**
- Engine warm (ECT above a specified temp)
- Throttle open
- Engine in closed loop
- Engine at a specified RPM
- MAP voltage at specified level

**Pending**
The catalyst monitor will not run if certain conditions exist that would cause the test to fail or provide inaccurate results.
These normally include the following:
- A Misfire DTC is stored
- An $O_2$ Sensor DTC is stored
- An upstream $O_2$ sensor rationality DTC is stored
- A Downstream $O_2$ Heater DTC is stored
- A Downstream $O_2$ sensor rationality DTC is stored
- A Fuel Monitor Rich DTC is stored
- A Fuel Monitor Lean DTC is stored
- The vehicle has a component DTC stored that has caused it to operate in limp-home mode (MAP, TPS, or ECT for example)

**Conflict**
- The Catalyst Monitor will not run if the Task Manager senses any of the following:
- The EGR Monitor test is in progress
- The Fuel System intrusive test is in progress
- The Purge Monitor test is in progress
- The timer inside the PCM indicates that the engine has not been running long enough since it was started

A Conflict will also be present if there is a **1 trip maturing** code in memory for any of the following:
- Misfire
- $O_2$ Monitor
- Upstream $O_2$ heater
- Upstream $O_2$ sensor
- Downstream $O_2$ heater
- Fuel system rich
- Fuel system lean

**Suspend**
The results of the Catalyst monitor will not be recorded in the PCM memory until the $O_2$ Monitor has passed its test



### *THE EGR MONITOR*

The EGR Monitor performs electrical tests of the EGR control circuits. It looks for shorts and opens in control solenoids and switching valves. An EGR circuit electrical fault can result in a DTC.

But testing EGR operation is almost as tough as Misfire Monitoring. Evaluating EGR *performance* is no easier for the PCM than it has been for repair techs diagnosing EGR problems on OBD I vehicles. Adding inert exhaust gases to the combustion chamber is a delicate proposition. It's a little like adding spices to your favorite recipe. For the EGR to control NOx emissions, an exact amount of exhaust must be added to the combustion chamber(s) at the correct time, or the effects on combustion become unpalatable from a performance and emissions standpoint.

We still aren't dragging around a five-gas analyzer. So the PCM has no direct way to measure NOx emissions. But the PCM does know that EGR operation is essential to controlling NOx inside the combustion chamber, so it needs some way to at least make sure the EGR is functioning. If EGR flow rates are high enough to reduce peak combustion temperatures, NOx formation is reduced and the reduction catalyst does the rest.

Several different EGR monitor types are used:

- Some use a **motorized** EGR valve with a position sensor to operate the EGR and detect how far it's open.
- Others use **vacuum control** of the EGR, regulated by a vacuum switching valve that receives a pulse-width-modulated signal from the PCM. An EGR position sensor indicates valve opening.
- An **exhaust gas temperature sensor** may be used to sense changes in temperature in the EGR feed tube as the valve is opened and closed.
- A **Differential Pressure Feedback** sensor (DPFE) may be used to compare exhaust pressure to EGR flow as the valve is opened.

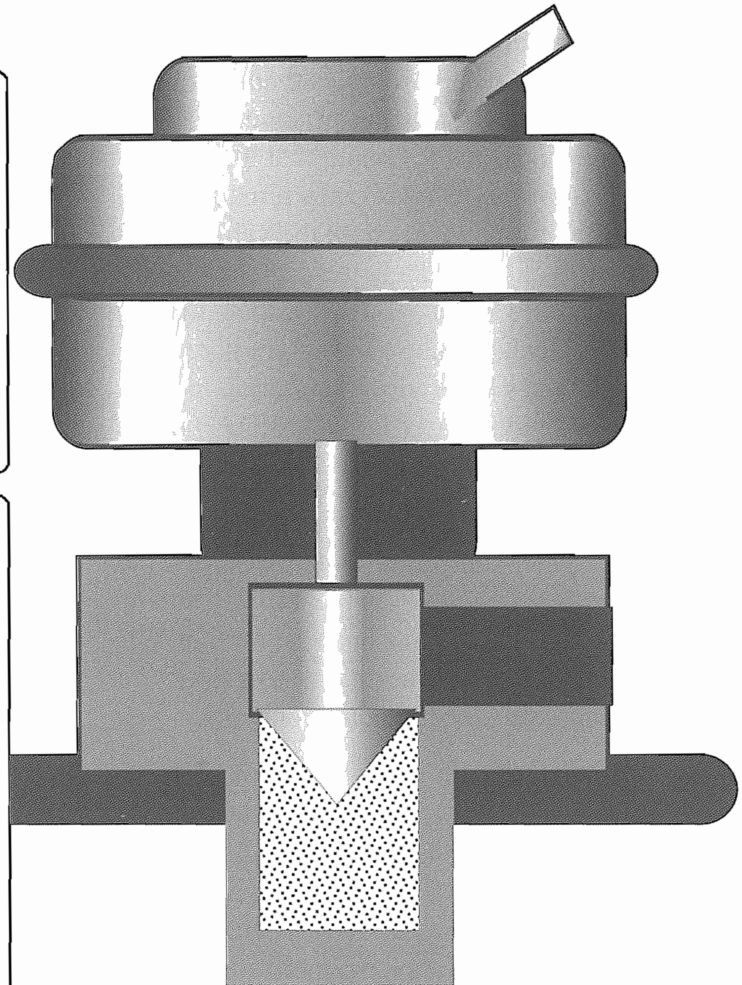
In addition to different components, different test strategies are used for the EGR monitor. Some EGR tests may be classified as intrusive. Here's an example of how an EGR monitor could switch the EGR on and off and then use other sensor inputs to test EGR operation:

- **The engine is warm and the PCM determines that it has been running for a specified time,** say three minutes.
- **The PCM waits until the engine is running fast enough that opening the EGR won't result in a stumble** that would be noticed by the driver.
- **The throttle is partially open**, and the vehicle speed sensor tells the PCM that the vehicle is moving. MAP indicates a partial load.
- **The PCM looks at the Short-Term Fuel Trim (STFT)** and makes sure that the adjustment being made is not excessive. The reason? The PCM is about to look at STFT and see how it *changes* as the EGR is turned on and off. If the STFT is near its limits, then it may not be able respond to the change caused as the EGR is opened or closed.
- **Enabling criteria like these indicate that this manufacturer's EGR test will take place at a steady state cruise with partial load, at highway speeds of about 55 MPH.** The slight change in engine performance that occurs when the test is run will be less noticeable under these conditions.
- **The EGR will normally be open under these conditions, so the PCM turns it OFF.** This allows more air into the combustion chambers (less exhaust). The added air should be sensed by the $O_2$ sensor, and the STFT should increase slightly to compensate. If the PCM doesn't see STFT increase, it assumes that the EGR is not making any change, whether it's commanded ON or OFF.

As you can see, the OBD II system not only checks the operation of the electrical and vacuum controls that activate the EGR, it wants some reassurance that the EGR valve is functioning, that the exhaust gas passages between the valve and combustion chamber are open, and that there's a change taking place in STFT when the EGR opens and closes. This is a closed loop strategy similar to the relationship between the oxygen sensor and fuel correction (Fig. 2-10).

If the monitor fails, the PCM stores failure data. If it fails again on the very next trip, the MIL comes on and a DTC is stored. EGR flow rate tests take two-trips to set a code and turn on the MIL.

# EGR Monitor



**Enabling Criteria**
- Engine is warm
- The PCM timer determines that a specified time has passed since startup
- Engine speed is within a specified range
- Engine load is within a specified range
- Throttle position is within a specified range
- Vehicle speed is within specified range
- Short term fuel trim (STFT) is within a specified range

**Pending**
The EGR Monitor may not run when:
- The EVAP Monitor is running
- The Catalyst Monitor test is in progress
- The PCM timer indicates that the engine has not been running long enough since startup
- A Misfire DTC is stored or maturing
- An $O_2$ Monitor DTC is stored or maturing
- An upstream $O_2$ heater DTC is stored or maturing
- A Fuel System rich DTC is stored or maturing
- A Fuel System lean DTC is stored or maturing

**Conflict**
The EGR Monitor may not run if any of the following are present. The types of component or monitor failures that will affect the operation of the EGR monitor will vary since not all manufacturers will test the EGR the same way.
- A Misfire DTC is stored
- Vehicle is in limp-home mode due to failure of MAP, TPS, or ECT
- An upstream $O_2$ sensor heater DTC is stored
- A Fuel System DTC is stored
- An upstream $O_2$ sensor DTC is stored
- A Vehicle Speed sensor DTC is stored
- A camshaft or crankshaft sensor DTC is stored

**Suspend**
The results of the EGR Monitor will not be stored in the PCM memory until the $O_2$ monitor passes, since the $O_2$ monitor determines if the $O_2$ sensor can be relied on to provide accurate test results.

*Fig. 2-10. The EGR monitor is fairly complex. The items shown in this diagram are typical of the types of inputs required and the various conditions that can prevent monitor operation. If the EGR monitor needs information about oxygen sensor voltage and STFT, they must both be operating in acceptable limits for the monitor to run successfully.*

## *THE EVAP MONITOR*

Canister Purge is one subsystem that gets a lot closer scrutiny on OBD II vehicles than it did with OBD I. A no-nonsense, take-no-prisoners EVAP Monitor has been added to ensure that the fuel storage and vapor recovery systems remain intact, and remain functional throughout the vehicle's life. If you've ever tackled a home plumbing job, especially in an old house, you know that stopping all those pesky leaks can be a real nightmare. Old cars and old houses have a lot in common in that respect, and old houses aren't driven 15,000 miles a year over rough roads in all types of weather.

Under OBD I, leaking fuel storage systems were not usually detected unless they actually spilled raw gas on the ground or caused a driveability problem. An electrical fault might have been set for a failed purge solenoid, but there was no way to monitor the system, including the fuel tank, for leaks.

This is a little ironic, since one of the most stringent parts of the FTP is the fuel vapor test. During the FTP, the vehicle is fueled and placed in a sealed enclosure, called a shed, and the air in the shed is monitored for the presence of fuel vapors. Acceptable limits are extremely low. An OBD I vehicle might never undergo a similar test again, regardless of how badly it eventually leaks raw hydrocarbons to the atmosphere.

Fuel obviously expands when heated, and containing pressurized fuel vapors is not easy. Most fuel tanks have a 10 percent expansion area, and some actually add a separate expansion tank between the main fuel tank and charcoal canister. But there are yards of plumbing in these systems, and a lot of it is exposed to road hazards and the elements.

EVAP Monitors may use several different diagnostic routines to check for leaks. A common approach is to use a vacuum sensing switch/sensor in the purge line from the fuel tank, or a pressure sensor mounted right at the fuel tank.

- Both ON/OFF switches and variable resistance sensors may be used. Variable resistance sensors usually have three wires, similar to the setup used on a TPS. Vacuum sensing switches normally have two wires, and receive a reference voltage that is pulled low when the switch closes.

- A vacuum switching valve (or valves) is used to open and shut purge and manifold vacuum lines. This allows the vacuum sensor to test individual parts of the purge system.

Figure 2-11 shows how a sample EVAP Monitor might be set up to test various legs of the EVAP system plumbing.

- **Vacuum switch B opens and closes on commands from the PCM.** If it closes the line between the fuel tank and canister, the sensor tests pressure in the vapor line from the fuel tank.
- **Vacuum Switch B then closes the line between the vacuum sensor and fuel tank, and opens the line to the canister.** This tests that leg of the plumbing.
- **When purge is enabled, the PCM opens Vacuum Switch A and manifold vacuum draws vapors from the canister.** In this mode, the vacuum sensor/switch looks for a change in pressure as purge takes place.

The PCM compares information about vacuum switch status and expects to see a change in pressure at the vacuum switch/sensor as the vacuum switches toggle. In this way, it can divide the system, and test segments of the purge plumbing individually.

Another monitor strategy is to use an *intrusive* test. When the vehicle enters closed loop, the purge may be enabled. Then the PCM looks for expected changes in STFT and Idle Air Control. (The purge may be opened in increments to avoid driveability problems that might result if the purge solenoid opened wide all at once.)

If there's a lot of fuel vapor stored in the canister during purge, the system should "see rich" and "go lean." If there isn't any vapor stored, the purge becomes a vacuum leak that leans the mixture. In either case, the system should notice the change and make adjustments. This style of monitor needs the information from the oxygen sensor and STFT, so if the Fuel System Monitor and Oxygen Sensor monitors haven't passed, the test may be suspended until they do.

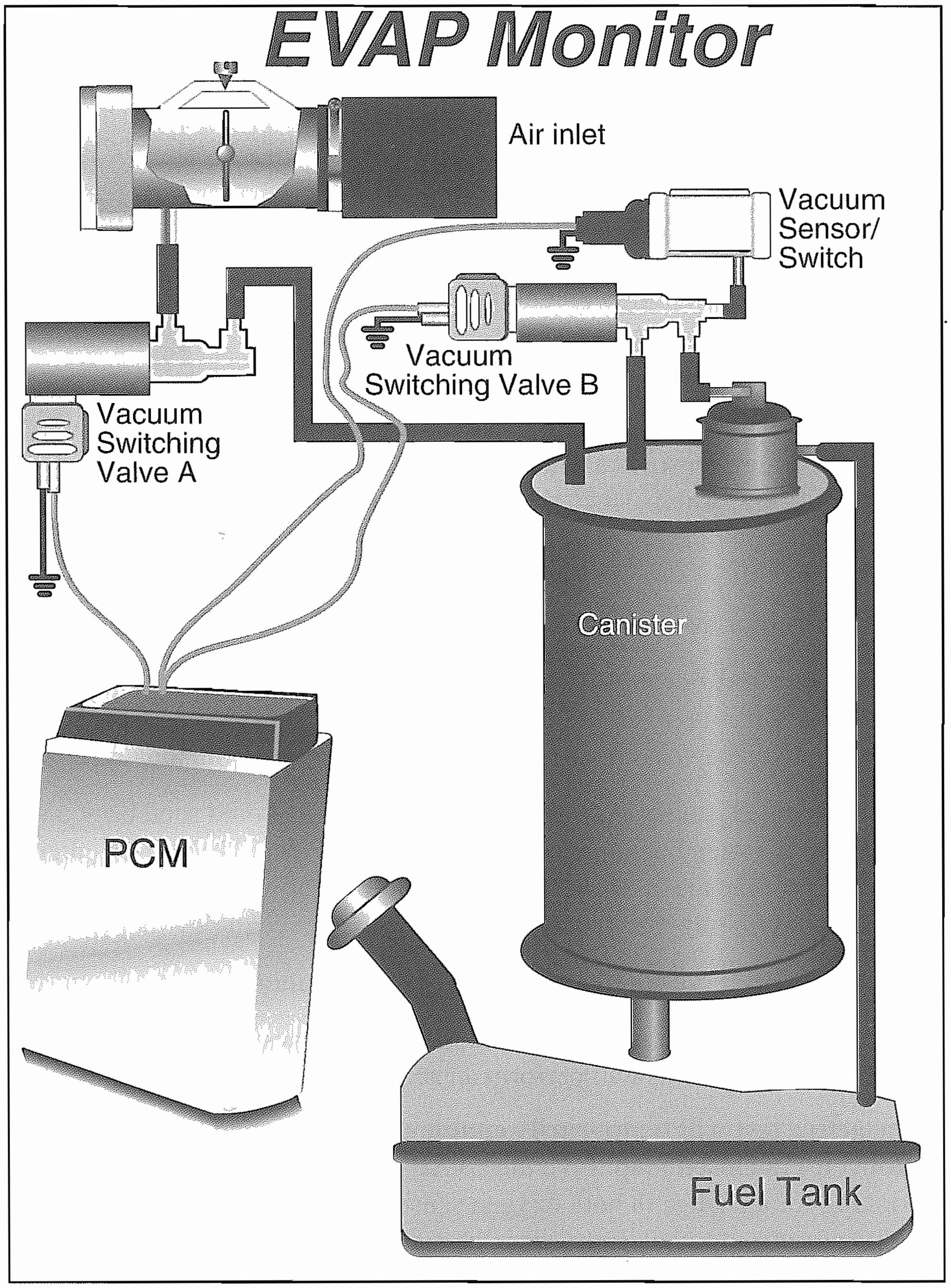



*Fig. 2-11. The EVAP Monitor has added switches and sensors to let it test the operation of the EVAP purge and also ensure that the system hasn't developed any leaks.*

Here's another way a manufacturer can test the EVAP system, that uses a small pressure pump and canister vent valve.

On command from the PCM, a pressure pump runs and pressurizes the EVAP system. At a specific pressure, a valve moves, and the pump stops running. The PCM knows how long the pump should have to run to reach that pressure based on the storage capacity of the fuel recovery system.

- **If the pump shuts down too quickly,** the PCM figures that it did so because it didn't need to pressurize the entire system. This would commonly happen if a line in the EVAP system was pinched closed, blocking off part of the system.

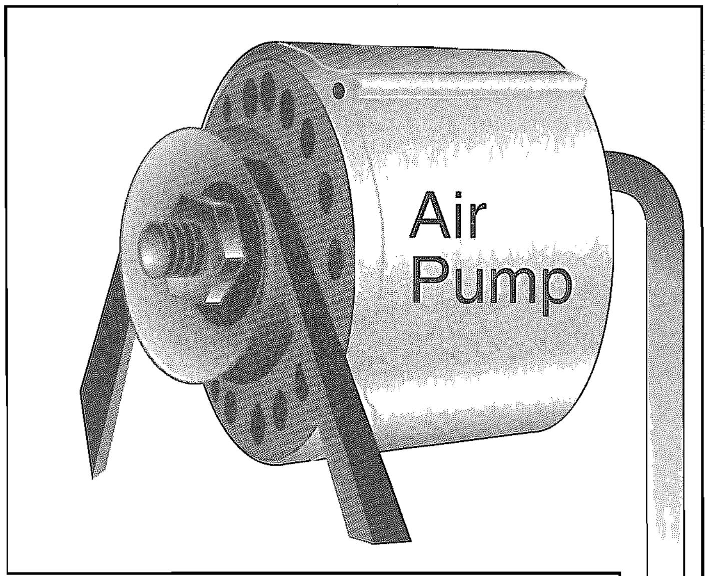
- **If there's a leak in the system, the pressure will fall and the pump will start again.** If the leak is really big, the pump may never generate enough system pressure to stop running. This is why some vehicles will turn on the MIL if the gas cap isn't replaced properly after fueling.

- **If the leak is small, the pump will start and stop—start and stop—as it attempts to maintain the proper pressure.** The PCM watches the pump cycling rate. Based on system capacity and cycling rate, it will calculate the *size* of the leak. If a large enough leak is detected (commonly 0.040 to 0.080 inch depending on tank size), the monitor fails. This is pretty darned precise monitoring of the EVAP system, regardless of the monitoring system used. OBD I might catch a faulty purge solenoid, but didn't begin to test EVAP this closely.

The OBD II system monitors for leaks and also for changes in fuel correction as the EVAP purge is turned OFF and ON. You'll need to keep this in mind as you troubleshoot a MIL-ON condition related to the EVAP system.

Some EVAP monitors won't run if the fuel in the tank is above 75 percent, or below 15 percent of tank capacity. There's that fuel level sensor again.

### *THE AIR MONITOR*




Some vehicles have an air pump or pulse air system that adds oxygen into the oxidation bed of the catalytic converter (Fig. 2-12). Our illustration shows a conventional, belt-driven pump, but some systems now use an electrical motor-driven pump, so look closely. OBD II regulations require that the air injection system be monitored, including the operation of any vacuum switching valves.

In some respects, the AIR Monitor intrusive test is similar to the intrusive EVAP test. Not too surprisingly, the oxygen sensor is a key component of the AIR Monitoring system, since it signals changes in exhaust gas content as the AIR control system is turned on and off.

The AIR monitor may include both passive and active (intrusive) tests.

- **The passive test doesn't do anything to the system.** It just sits back and looks at $O_2$ sensor voltage from start-up to closed loop. Normally, air is added upstream during cold start and warm-up to help oxidize excess hydrocarbons in the exhaust before they reach the catalyst.

As soon as the $O_2$ sensor is warm enough to work, it should send back a low voltage in response to the added oxygen being injected to the exhaust. When the system enters closed loop and the PCM turns off the air injection, it may also look at $O_2$ voltage toggling as an indication that the air is no longer being injected.

If the PCM sees these conditions, it passes the AIR monitor.

If there's any doubt in the PCM's mind that the AIR system isn't adding air during warm up, some systems will perform an active, or intrusive test.

- **The active test will temporarily enable the AIR system after the system enters closed loop.** Like the EVAP test, the PCM is looking for a change in both oxygen sensor voltage and STFT as the air is added. Extra air in closed loop should drive the $O_2$ sensor voltage low and result in fuel being added to compensate.

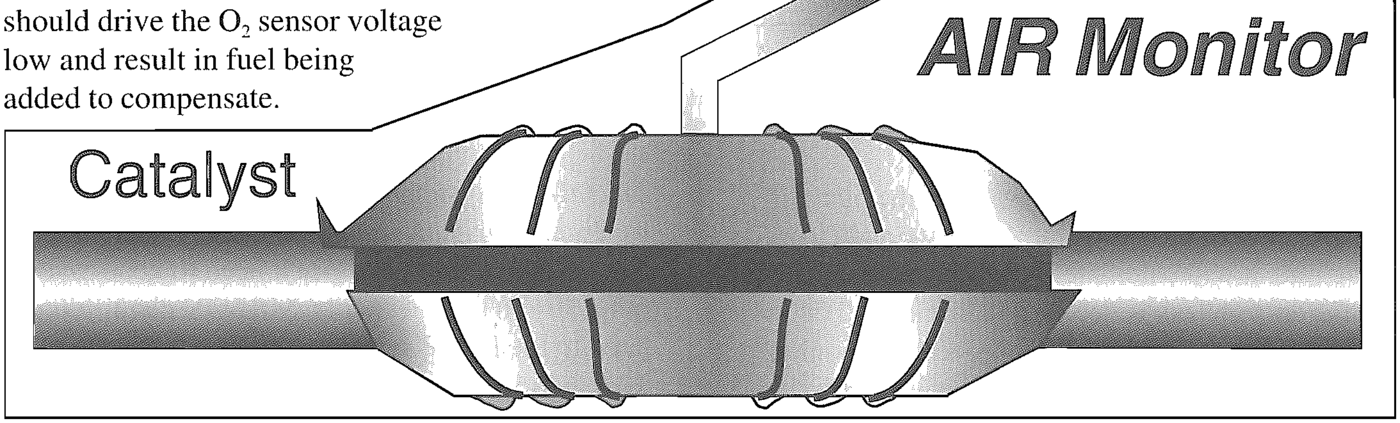



*Fig. 2-12. The AIR Monitor is responsible for ensuring that the air pump, its plumbing, and any control solenoids are operational. The system may be tested with a passive or active test. In most cases, if the passive test records a passing grade, the active test will not even be run.*

### *TIME OUT*

We really need to stop here and catch our collective breath. While we got more specific about major monitors and their general intent in this section of the course book, we'll need to become even more specific in the next section. But you have to start somewhere.

That's pretty much how we need to learn about the OBD II system. We start with the broadest possible overview, then move to a more detailed description that shows how the major monitors work. Finally, we get down to the nitty gritty of vehicle specifics.

The long lists of enabling criteria, and the various modes of monitor operation listed in this section have attempted to show you some of the different diagnostic approaches that are used by individual manufacturers.

Here's a recap of what we've talked about to this point in the course:

- **The Major Monitors work individually or together** to monitor for Misfire, Fuel Correction, EGR, EVAP, Secondary AIR, Catalyst, and Oxygen sensor problems. The Comprehensive Component Monitor combines traditional fault detection of electrical circuit shorts and opens with rationality tests to make sure compared signal inputs make sense.

- **In some cases, monitors depend on other monitors.** For some tests, either the monitors work together in the proper sequence, or they don't work at all.

- **A special program inside the PCM organizes the order of various tests and then evaluates a test situation to decide if a given monitor can run successfully.** Commonly known as the Task Manager, or Diagnostic Executive, this program directs traffic and evaluates test data to determine if the results of a test are valid and ought to be stored in the PCM's memory.

- **Some faults will store a DTC and related Freeze Frame data in only one trip.** Others will record failure data on the first occurrence of a failure, but not turn on the MIL until the second occurrence of the fault.

- **A trip creates a set of driving conditions that allow a monitor to run.** These conditions are referred to as enabling criteria. If the enabling criteria are not present, a trip is not counted and the monitor does not run.

- **The purpose of a trip is to control the MIL.** If a DTC is stored, the PCM can self-erase the DTC, but it must see three consecutive trips where the affected monitor runs and passes, or it won't turn off the MIL. Without good trips, the PCM cannot determine if a fault has been corrected.

- **Even after the MIL is requested OFF by the PCM after three passes, it will take a specified number of warmup cycles before Freeze Frame data is erased.** A common figure is 40 warm-ups to erase Freeze Frame, but some monitors may require even more, up to 80 warm-ups before erasing Freeze Frame data.

- **Freeze Frame data is a single frame snapshot of critical engine conditions stored in memory at the instant a fault is detected.** Failure data will be stored for the first occurrence of a two-trip fault that does not turn on the MIL. Freeze Frame data will be stored when a DTC is set and the MIL comes ON.

- **While OBD II generic scan data stored in Freeze Frame provides a smaller list that was available on some OBD I systems, it does provide serial data on some vehicle makes that did not have any serial data prior to OBD II.**

### *TIME TO MOVE ON...*

Of course, there's more to this story. In Section Three we'll look at scan tools. Section Four deals with DTCs and diagnostics, and shows how to use scan data to evaluate problems. Section Five will go into greater depth about monitor components and strategies, and show ways to diagnose individual circuit failures. But the summary on this page will form the basis for those discussions, so we suggest that you review this information and get comfortable with it before moving on.

## MINI QUIZ

1. Which of the following OBD II monitors has no equivalent test procedure in OBD I?
   a. Comprehensive Component Monitor
   b. Fuel System Monitor
   c. Misfire Monitor
   d. EGR Monitor

2. Which of the following sensors can affect the Misfire Monitor operation?
   a. The fuel level sensor
   b. The crankshaft sensor
   c. The MAP sensor
   d. All of the above

3. Which one of the following monitors can cause the MIL to flash?
   a. The Comprehensive Component Monitor
   b. The Fuel System Monitor
   c. The Misfire Monitor
   d. The EVAP Monitor

4. Which of the following monitors does not run continuously?
   a. The Fuel System Monitor
   b. The Comprehensive Component Monitor
   c. The Catalyst Monitor
   d. The Misfire Monitor

5. The oxygen sensor has stopped working from contamination. Which of the following monitors **MAY NOT** run as a result?
   a. The Catalyst Monitor
   b. The EVAP Monitor
   c. The EGR Monitor
   d. All of the above

6. An OBD II vehicle uses an intrusive EGR test as part of the EGR monitor. The PCM commands the EGR to open, but sees no change in short-term fuel trim.
   Of the following, what could cause this?
   a. The vacuum line to the EGR is disconnected
   b. The EGR valve is stuck shut
   c. The EGR passage is plugged with carbon
   d. All of the above

**Answers**
1. c
2. d
3. c
4. c
5. d
6. d

## *SHOP EXERCISES*

One of the best ways to learn how a specific vehicle turns on the MIL is to "bug" the car and see how it responds. Some systems will turn on the MIL the very first time they detect a certain type of failure (a disconnected injector, for instance), while other monitored components and subsystems must fail a second time to turn on the MIL and store a DTC. This may be normal, but you need to be aware of the differences.

- Using an OBD II test vehicle that doesn't have any stored emission codes to start with (the MIL is off), disconnect a component monitored by the CCM (one fuel injector, for instance). These are normally one-trip codes, and give you the quickest feedback as a result. Then start the engine. Does the MIL come on right away? If not, drive the vehicle a short distance, since the monitor may need to see a vehicle speed sensor or other input as part of its enabling criteria. If the MIL doesn't come on, shut off the engine and restart it. Does it come on now? Remember that a trip includes a Key-OFF at the end, and some one-trip codes won't turn on the MIL until the engine is restarted.

*(Use some discretion here. You don't want to drive the vehicle for any extended period with an injector unplugged, for obvious reasons, including possible vehicle damage and questions of personal safety. Testing away from traffic in a large, empty parking lot or other traffic-free area is a good idea.)*

Try similar tests with other CCM monitored components and try to set multiple codes. Disconnect the MAP or EVAP solenoid and try to set a code. Use the scan tool to view Freeze Frame when the multiple codes are set. Note the exact data stored in the Freeze Frame and see which of the codes the Freeze Frame corresponds to.

- **Do not erase DTCs.** Reconnect any components you disconnected to set the codes originally, and take the vehicle for a drive. Try to simulate the Drive Cycle. Does the MIL go out? If not, repeat the Drive Cycle and see just how many trips it takes for the PCM to be satisfied that all systems are go, and that the MIL can be turned OFF.

- **Repeat the tests.** Bug the car again. Set the same codes. This time, however, erase DTCs. Before you drive the vehicle, look at the Readiness Status display. Did the Readiness Flags reset when you erased DTCs? Next, perform a complete drive cycle.

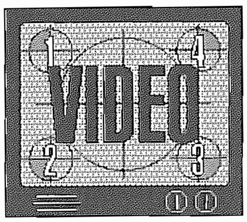
*This simple exercise compares turning the MIL off manually by erasing DTCs to allowing the PCM to turn off the MIL on its own. Erasing DTCs with the scan tool is obviously a lot faster, but you may notice that doing so has returned the Readiness Status flags to an incomplete or pending status. Normally this is not a problem, since they will reset over time during normal driving that simulates the various parts of the Drive Cycle.*

*Also pay special attention to any changes in engine performance as the engine re-learns during the Drive Cycle. Depending on the complexity of the Fuel system's re-learn strategies, you may notice a temporary deterioration in engine performance during the re-learn. Some manufacturers recommend that any vehicle that has had DTCs erased manually should be driven through at least one complete Drive Cycle to allow repair verification, and also to allow a re-learn.*

Notes:

# 3

# SCAN TOOLS AND OTHER VAGARIES OF OBD II




Watch video module #3 now.

It's about time you import-repair specialists get to know the guys who work on domestics, and vice versa. You come from pretty different worlds when it comes to diagnostics. Now, for the first time, we all have some common ground, provided by OBD II. Our combined experience with OBD I diagnostics has a direct bearing on a discussion of scan tools.

For years now, domestic scan tool manufacturers have concentrated on providing some pretty sophisticated scan interfaces for Ford, GM and Chrysler. This is only logical, since GM started the serial data ball rolling with its original ALDL test interface, and Detroit is a lot closer than Munich or Tokyo. Since that first Assembly Line Data Link was installed, serial data capabilities have improved year by year. These capabilities eventually included bidirectional controls that allowed the scan tool to send commands to test components and the circuits that control them. Really sophisticated stuff.

When it came to Asian imports, however, most scan tools were limited, since many Asian vehicles didn't have serial data to access. For a scan tool, it was like dialing a phone number that didn't exist. Nobody was going to answer. As a result, for a long time, import software cartridges for scan tools from domestic manufacturers were little more than glorified jumper wires used to coax flash codes from closed-mouthed Asian makes. This changed gradually as manufacturers like Toyota and Subaru finally started using serial data. Some Asian makes with links to domestic manufacturers simply adopted systems from the domestic manufacturer with whom they had a working relationship. Isuzu, with links to GM that predate GEO, and Mazda, with its Ford connection, are examples.

European cars are a horse of a different color. VW/Audi techs have a tool called a V.A.G. 1551 and 1552. Volvo techs have their Autodiagnos, complete with Volvo factory software. And Saab techs have had their ISAT. The Bosch Hammer was yet another scan tool that had varying diagnostic and even reprogramming capabilities—with the correct software. Finally, there are the BMW and Mercedes factory testers with inner workings more secretive than the affairs of a Senate finance committee.

The development of each of these diagnostic tools has reflected the changes in the vehicles they were designed to test. If you were lucky or rich enough to beg, borrow, or buy the right tester for every car, you were a member of an elite minority.

So when the first OBD II scan tools came onto the market, it's wasn't too surprising to find that most offered two levels of diagnostics:

- The new OBD II software interface and,
- The old OBD I interface, sometimes labeled as OEM tests in the scanner menu. This was largely a carry-over from the OBD I interfaces used with GM, Chrysler, and some Ford and Asian vehicles. (That's also why some 1994-95 transition vehicles came with separate connectors beneath the dash: the new DLC, and a few inches away beneath the dash, the old OBD I connector.)

Meanwhile, back at the ranch, now that the old test connectors have been replaced with a single DLC, the scan tool gives you the option of viewing OBD II data in one scanner menu, and on vehicles that support it, OE data displays you used with OBD I.

In other words, if you had access to data stream and actuator tests on certain vehicles with OBD I, you don't necessarily lose those capabilities with the addition of OBD II. This applies even to some European and Asian vehicles that did support serial data at the OBD I level. For example, the Autodiagnos diagnostic tool with the factory chip for Volvo adds a new interface box, and a new OBD II cable. Even with the addition of OBD II, its capabilities still include a separate test menu that allows actuator tests of various system components (Fig. 3-1).

Remember that OBD II is an add-on monitoring system. It's what the name implies, an On-Board Diagnostic system, ***not a fuel management system***. While OBD II interfaces with the engine management computer as it runs its tests, it does not replace it. That's how some scan tools can interface at two separate levels, especially on vehicles that supported serial data *before* OBD II. If they talked to the fuel management system before OBD II, they probably still have this ability. OE-level scan software communicates **directly** with the powertrain management system, not with the OBD II software.

For vehicles that didn't support any serial data before OBD II, the situation is quite different. If there was no serial data on a vehicle before OBD II, there isn't a preexisting scan interface that talks directly to the vehicle's engine management system. Until software enhancements open the OBD II data door wider, you may be limited to a generic OBD II interface for all your serial data diagnostics on some vehicles. That door has been opened slightly now, and you can expect the scan tool manufacturers to open it wider over time.

*Fig. 3-1. The Autodiagnos is one example of a factory diagnostic tool that provides traditional OBD I level communication with OBD II functions.*

## *OBD II OR OEM INTERFACE?*

The next logical question is: If you have access to two levels of communication, which one do you use? That depends on what information you want. Since some scan tools communicate with the PCM at two different levels, we can expect to get two separate kinds of information.

Where both are available, select the test mode based on the information you want to gather and the tests you want to run. If you want to run actuator tests, and the OE interface will do that for you, by all means use the OE scanner function. For MIL-ON problems or to gather OBD II DTCs, use the scan tool's OBD II functions.

**One last time. The OBD II monitoring system and powertrain control system are related to one another, but they are not the same.**

For general troubleshooting, OBD II does offer some diagnostic advantages over the OE level interface with its addition of the new DTCs and Freeze Frame.

Remember that the SAE-defined DTCs for OBD II have been standardized, and that individual DTC descriptions are more specific than they were in OBD I. So don't just dive in and start pulling OE codes using the OE test interface. The OE code probably won't give you as much information as the OBD II DTC for the same fault.

In cases where the vehicle didn't previously offer the equivalent of snapshot testing that captured a frame or several frames of data on the scan tool, the Freeze Frame data in OBD II may be your only window to the condition of the system when a fault occurred.

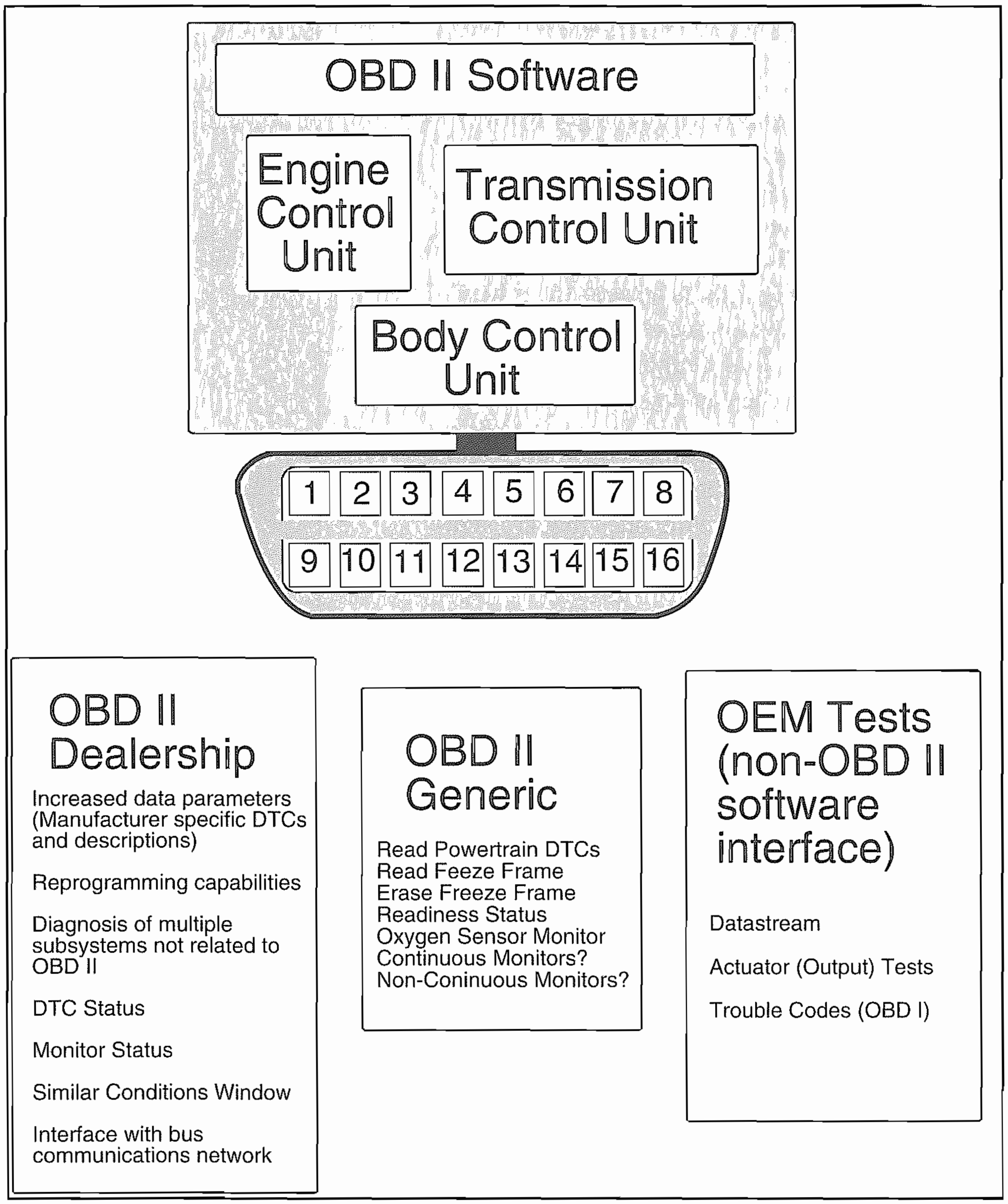



*Fig. 3-2. The types of data you retrieve will depend on the scan interface you're using.*

To these two general scan interface classifications, we must add one more class—the scan software available at the local new car dealership (Fig. 3-2). These scan interfaces perform not only OBD II emission-related functions, they are designed to interface with other controllers in the vehicle, and in many cases, support reprogramming functions to reflash the computer with the latest, upgraded software revisions. Perhaps most importantly, they have technical support and current documentation—direct from the manufacturer.

The state of scan tool development mirrors the state of OBD II. You have the law, which defines OBD II, the actual implementation of the law by the vehicle manufacturers, and the realities faced by scan tool manufacturers and repair technicians alike as they scramble to keep pace.

In the remainder of this section, we'll try to sort through some of gray areas of scan tool capabilities, show you what to look for in a scan tool, and how to handle communications problems.

## *TYPES OF TRAFFIC THROUGH THE DLC*

As Figure 3-3 shows, a lot more is going on at the DLC than simply retrieving DTCs and erasing codes. After satisfying the legislative requirements at the designated pins in the DLC, the manufacturer has the option of using (or not using) the remaining pins as he sees fit. If he wants to hook up headphones to a discretionary pin and play a little Led Zepplin for the tech working on the car, he can do so.

Figure 3-3 displays two samples from Ford and Chrysler showing how the pins at the DLC can be used. Boldfaced items are the ones that are standard, and the remaining items are used at the manufacturer's discretion.

If you do have access to a DRB III (Chrysler), NGS (Ford), or the Tech-1A or Tech II (GM), or any other dealer-level scanner equipped with the factory software for that matter, then you can get at all sorts of information about various computer-controlled systems, not just OBD II.

Note that the information at the DLC in our examples goes beyond emissions-only concerns, and includes an interface for testing multiplexed systems.

In a multiplexed system, individual input and output devices are connected by a network, usually consisting of a single pair of twisted wires. Dashboard information displays, trip computers, engine, body, and transmission controllers, can all communicate with one another like personal computers on a network. Signals—some of them shared inputs—are broadcast over the network for any controller that needs the information.

The reference to the Collision Detection bus in the Chrysler example in Figure 3-3 has nothing to do with Air Bags. Collision Detection is Chrysler's reference to the *collision of data* as signals from multiple controllers and displays try to share the same communication bus, and how the signal traffic is prioritized. A scan interface that permits diagnosis of this type system can be a big help when you're trying to resolve PCM conflicts or bus circuit problems that prevent communication among various controllers and displays.

**Chrysler DLC Example**

| Pin | Terminal Assignment |
|---|---|
| 1 | Keyless Entry Enable |
| **2** | **Generic Serial Data (+) Line** |
| 3 | Collision Detection Bus (+) Line |
| **4** | **Chassis Ground** |
| **5** | **Signal Return Ground** |
| 6 | SCI Engine Calibration Flash Line |
| **7** | **ISO "K" Bus Line** |
| 8 | Switched Battery Power (Ignition) |
| 9 | Not Used |
| **10** | **Generic Serial Data Bus (-) Line** |
| 11 | Collision Detection Bus (-) Line |
| 12 | Chassis Calibration Flash Line |
| 13 | Not used |
| 14 | Transmission SCI Receive |
| **15** | **ISO "L" Line** |
| **16** | **Unswitched Battery Power (+)** |

**Ford DLC Example**

| Pin | Terminal Assignment |
|---|---|
| 1 | Ignition Control |
| **2** | **Generic Serial Data (+) Line** |
| 3 | Not Used |
| **4** | **Chassis Ground** |
| **5** | **Signal Return Ground** |
| 6 | Class C Data Communication Bus (+) |
| **7** | **ISO "K" Bus Line** |
| 8 | Multiple Input Trigger Signal |
| 9 | Switched Battery Power |
| **10** | **Generic Serial Data Bus (-) Line** |
| 11 | Not Used |
| 12 | EEPROM Flash Programming |
| 13 | EEPROM Flash Programming |
| 14 | Class C Data Communication Bus (-) |
| **15** | **ISO "L" Line** |
| **16** | **Unswitched Battery Power (+)** |

*Fig. 3-3. This chart shows sample DLC terminals. Remember, not all the pins may be used, and the choice of ISO or J1850 data protocols is up to the manufacturer.*

Take that dedicated, factory special tool for a Chevy and plug it into a Honda in the scanner's generic test mode. Not quite the same, is it? Unless you have a dedicated scan software interface for each manufacturer, you **will** be limited. No ifs or maybes about that one. Scan tool manufacturers are working hard to add enhancements, and you can expect the process to evolve and for software to improve. It looks like automotive software is running a parallel course with software development for personal computers.

You can also expect to see new PC-based software interfaces coming to market. EASE Simulation's PC scan interface is one example, and Baum Tool's OBD2 Scan is another. Computers talking to computers may be the new wave in diagnostics. These interfaces come with diagnostic software, and a cable connection that goes between the PC serial port and the DLC. Upgrades and enhancements to this kind of interface will involve changes in software, not scan tool hardware (Fig. 3-4).

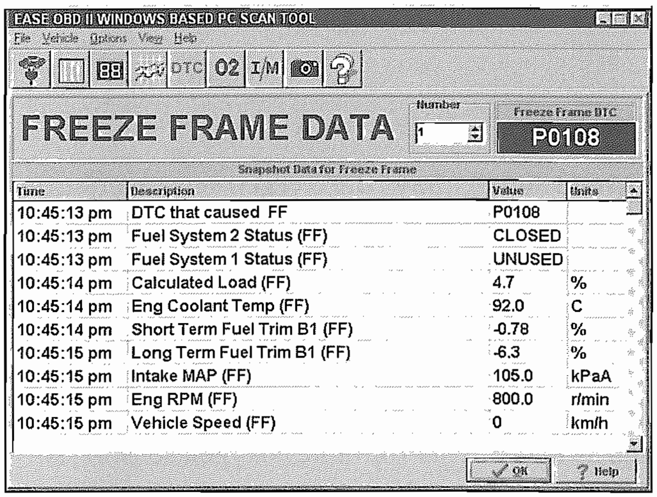



*Fig. 3-4. This type of software interface may become more popular as automotive diagnosis becomes increasingly computer-intensive.*

In a moment, we'll start looking at various modes of scan tool operation. Keep the following in mind as we proceed:

- **The type of information you get from the scan tool affects the entire diagnostic procedure.** It's very difficult for us to prescribe a troubleshooting procedure when we don't know how much data will be available to a technician.

- **It affects how you purchase your scan tool.** If you work on Fords 90 percent of the time, it will obviously make more sense for you to purchase a scan tool that includes as much Ford-dedicated software as you can get. If you do nothing at all but Fords, then you may even consider springing for the Ford NGS with factory software.

## Time Out

The first time we looked at SAE documentation related to OBD II, we noticed that there were many references to scan tool modes of operation and individual data parameters that were identified by something known as a *hexadecimal* number. While most of us won't be doing any computer programming in the near future, we felt a brief explanation would keep you from scratching your head each time you see a number preceded by a dollar sign. All the $ sign does is identify a number as a hexadecimal number.

Hexadecimal numbers are often used by computer-types in place of the base ten numbers you and I use to count our money and balance our check books. (It all has to do with bits and bytes.) They are a form of notation that fits the way a computer operates, and eliminates the need to fill a page with Ones and Zeros, another form of notation known as *binary*, that only a computer and a programmer can relate to.

Hex (for the number *six*) and decimal (for the number *ten*) combine to form a numbering system that is base 16. Hexadecimal numbers are also alphanumeric since they're made up from combinations of the numbers 1-9 and letters of the alphabet from A-F.

Counting to 16 in hexadecimal goes as follows: $01, $02, $03, $04, $05, $06, $07, $08, $09, $0A, $0B, $0C, $0D, $0E, $0F, and $10. Zero is still zero, and is used only as a place holder to indicate—you guessed it—Nothing! Using this combination of 16 characters, the computer guys can list all numbers from 1 through 255 using only two characters. (Funny, but that's the range often used to describe fuel trim, with 128 being the midpoint! See, it does have a use.)

To convert Hex to base 10, multiply the left number by 16 and add that to the hex value for the right number. The number $E6 = 230 in base 10.

**(Since E = 14, we have 14 x 16 = 224 + 6 = 230.)** This works for any hexadecimal number. You may not be doing any programming soon, but we did want you to know what all those dollar signs mean because some documents and scan tool displays will use them.

## *SCAN TOOL MODES OF OPERATION*

For the OBD II scan tool to do its job, it must first dial the correct number and get the PCM to pick up the phone. The scan tool is powered through the DLC, so all communications take place KOEO (and in a few cases KOER). Once communication is established, the scan interface requests and displays data. The scan tool also needs to send messages back to the PCM to erase codes.

In this section we'll go through the various scanner modes outlined by SAE technical paper J1979, "Diagnostic Test Modes." Here we go:

- **Mode $01 is used to identify what Powertrain information is available to the scan tool.** This includes:
- **Sensor information,** including data about both analog and digital inputs and outputs
- **Monitor Status** (the Readiness Status Monitor) to tell you which monitors have run
- **Calculated values** from various sensors (such as calculations of engine load, expressed as a percentage of throttle opening)

All values should represent true measurements and values that are calculated from sensor inputs, not substituted values used to compensate for a failed sensor or sensor circuit.

Not all parameters are used by all manufacturers. The scan tool should tell you which parameters can be displayed. The individual sensor readings are sometimes referred to as Parameter Identifications or PIDs, for short, each identified by a separate hex number in some scan tool displays.

- **Mode $02 displays Freeze Frame data.** The amount of Freeze Frame data shown depends on the sensors installed in the vehicle, and the number of parameters the vehicle will display. All parameters displayed in the Freeze Frame should represent actual values, not fail-safe substitutions.

- **Mode $03 lists the total number of powertrain or emissions-related DTCs stored. It also displays exact numeric, 5-digit codes identifying the faults.** The scan tool may be limited to displaying a certain number of DTCs at one time, and you may need to scroll down a list to see them all. Make sure you compare the total number of DTCs stored to DTCs currently displayed so you don't miss any. The scan interface should also tell you which processor stored a code if multiple processors are installed in the vehicle.

- **Mode $04 is used to clear DTCs and Freeze Frame.** This is a multilevel request, and includes the following:
- Erase DTCs (including information about the total number of DTCs stored)
- Erase DTCs for Freeze Frame
- Erase Freeze Frame data
- Erase the oxygen sensor test data
- Reset the Readiness Status monitors
- Erase the results of any on-board monitoring test results

Some modules may be able to execute these commands only at KOEO, not KOER.

- **Mode $05 displays the oxygen sensor monitor screen and the test results gathered about the oxygen sensor(s).** This is an enhancement of the oxygen sensor information displayed in Mode $01, and can be an extremely valuable tool. It saves you the time of sampling $O_2$ sensor voltages directly. All OBD II vehicles have at least two, and as many as six (or more) oxygen sensors, so data displayed on this screen can save lots of time.

This is another instance where some OBD II data is more specific than the data you'll get from previous OEM-level software. The information displayed, and how it is displayed, varies by scan tool and vehicle. Oxygen sensor info may include specific information about the characteristics of the oxygen sensor voltage signal, including: critical measurements of Minimum and Maximum voltages recorded during the monitor test cycle; time between voltage crosses; and the rich-lean, lean-rich switching speed of the sensor.

Some scan software can display Mode $05 information as a graphic pattern (Fig. 3-5).

Specifications for acceptable oxygen sensor operation are not identical. In fact, they may be different for individual models from the same manufacturer. Some of this is a function of fuel system design, and some of it is determined by the engine used and $O_2$ sensor placement(s). That's why we need to know exactly how the sensor is *supposed* to react in a specific application during troubleshooting.

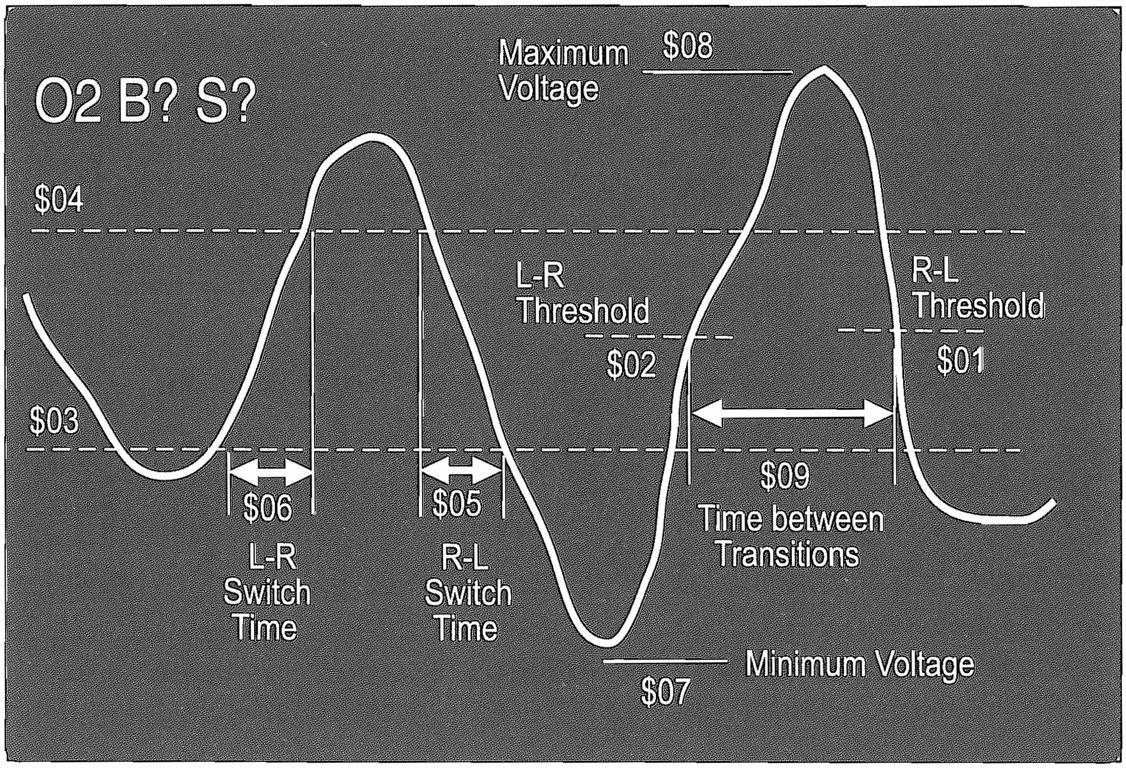



*Fig. 3-5. OBD II is concerned with the rate of $O_2$ sensor switching, time between transitions, and the sensor's ability to operate over an acceptably wide voltage range.*

Figure 3-5 shows that some very exact measurements are being taken of oxygen sensor voltage, and being compared to some equally exact voltage standards, known as *thresholds*. Thresholds are the precise standards for $O_2$ sensor operation in a specific vehicle.

Various items in Figure 3-5 are marked with a word or letter description and also with a *hexadecimal* number that describes each parameter. These hex designations are standard.

**The Lean-Rich Threshold ($02) and the Rich-Lean ($01) Threshold are the voltage points the oxygen sensor voltage must cross over to signal a Rich-Lean or Lean-Rich transition.** This is probably familiar to you if you're already measuring $O_2$ sensor cross counts to identify sluggish sensors. These values are usually equal to one another as they represent the bias voltage sent out by the fuel system computer on the $O_2$ sensor signal line. A common value for this threshold is 450 millivolts (0.450 V) although this figure is not universal.

The time interval between a R-L and L-R cross is measured at **$09** as the time between sensor transitions, and this value will change with sensor activity.

**Now look at the dotted lines marked $03 and $04.** These are also constants indicating $O_2$ sensor voltage under lean and rich conditions. Let's say **$03** is assigned a value of 300 mv and **$04** is 600 mv. When sensor voltage is traveling from lean to rich, the monitor measures *the time it takes* for the sensor signal to cross over 300 mv and reach the 600 mv level. This is the Lean-Rich sensor switch time (**$06**), expressed in ms.

The time it takes for the $O_2$ sensor voltage to cross **$04** (600 mv) and reach **$03** (300 mv) as it goes from rich to lean is also measured as an indication of the sensor's Rich-Lean switch time (**$05**).

The time between crosses (**$09**) indicates overall sensor activity during closed loop operation. The Lean-Rich (**$06**) and Rich-Lean transitions (**$09**) are indications of the sensor's ability to make a quick response to a change in exhaust oxygen content.

The final two categories are Minimum sensor voltage for the test cycle (**$07**) and the Maximum sensor voltage for the test cycle (**$08**). These are like using the Min/Max setting on your DMM and recording oxygen sensor voltage for an exact time period. Min/Max $O_2$ sensor signal voltages are recorded for the monitor test cycle, and are used to detect an oxygen sensor signal that is shorted to voltage or to ground.

Each of these individual tests and thresholds is called a Test ID or TID for short, and each TID has its own hexadecimal designation in some documentation. Let's recap and start by listing the *constants* used to measure sensor activity:

- **$01** - R-L sensor threshold voltage (constant)
- **$02** - L-R sensor threshold voltage (constant)
- **$03** - Low sensor voltage threshold for switch time measurement (constant)
- **$04** - High sensor voltage threshold for switch time measurement (constant)

Then we have *actual* values indicating sensor voltage activity and the time it requires to make its corrections measured in milliseconds (ms):

- **$05** - Rich-to-Lean switch time in ms
- **$06** - Lean-to-Rich switch time in ms
- **$07** - Minimum Voltage for test
- **$08** - Maximum Voltage for test
- **$09** - Time between voltage transitions (measured in ms)

The first four TIDs ($01-$04) are measurement *standards*. The final five TIDs are *actual measurements* using these standards, and will be expressed in voltage or time. They are used by the Oxygen Sensor Monitor to evaluate sensor activity and response.

Figure 3-5 showed a graphic display of these values. A scan tool will display the values a little differently. Since there are nine critical TIDs to evaluate, you may need to scroll down the display when the scan tool display does not allow all test parameters to be displayed simultaneously (Fig. 3-6). Some scan tools display all the information on a single screen (Fig. 3-7). The top four parameters shown on the screen are the constants, and the remaining values are calculated and will vary by sensor response.


*Fig. 3-6. Whether it's a graphic display of sensor activity, or numeric values displayed on a scan tool, the oxygen sensor monitor tests display can save you a lot of trouble-shooting time.*

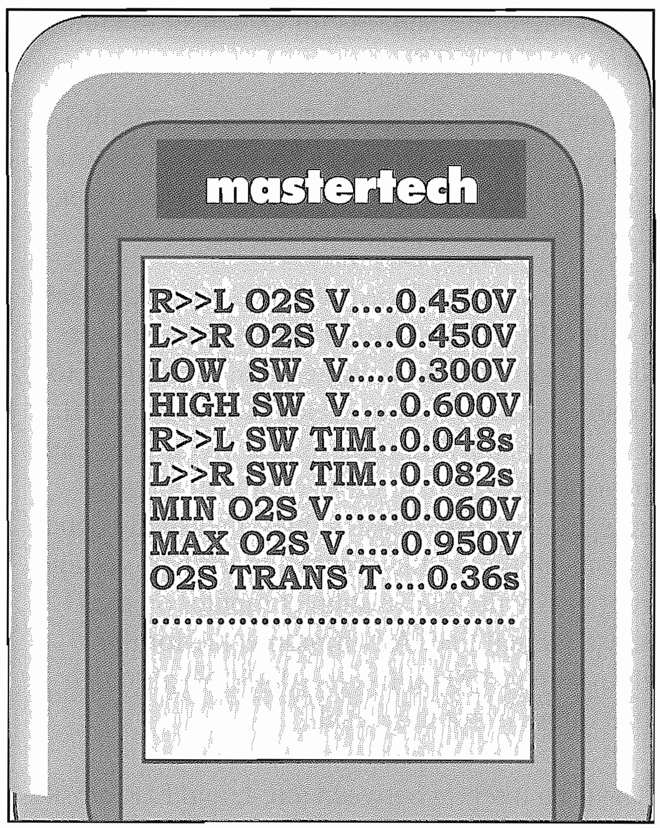



*Fig. 3-7. This scan tool displays all the information about the oxygen sensor supported in Mode $05 operation on a single screen.*

## *MORE ON OXYGEN SENSORS*

Before we move on to the remaining modes of scan tool operation, we need to pause here and clarify several issues we raised when we described Mode $05.

The oxygen sensor, or sensors as the case may be, are the heart and soul of the OBD II system. Without proper operation of the oxygen sensors, all bets are off when it comes to closed loop fuel control as well the operation of several OBD II emission monitoring strategies.

The oxygen sensors aren't responsible just for maintaining closed loop fuel correction anymore. The information they supply is used by several other monitors. Without that information, the catalyst monitor cannot run. Some EGR and Secondary AIR monitoring strategies also rely on $O_2$ sensor accuracy and rapid response times or they can't run.

To operate properly, the oxygen sensor must perform well in the following areas:

- **It must be able to generate a sufficiently high voltage to indicate the low oxygen content in the exhaust that comes with a rich mixture.** Normally, a sensor that reaches 900 mV or more when the system is driven full-rich is acceptable.
- **It must be able to indicate the oxygen content in the exhaust that comes with a lean mixture.** Normally, a sensor that will drop to 100mV or less when the system is driven to its lean stop, is considered acceptable.
- **It must stay centered between these extremes of full-rich and full-lean during normal operation.** If the sensor range "shifts" far enough it will favor the rich side or the lean side, and this will skew average fuel delivery corrections.
- **It must have good response time.** Conventional wisdom suggests that a really good sensor should be able to switch from a rich-to-lean threshold in about 20-40 milliseconds (that's 20-40 *thousandths* of a second). A lean-to-rich transition should take slightly longer, about 60-80 milliseconds. Either way, that's pretty darned quick when things are going well, and the sensor isn't clogged with contaminants that slow it down.
- **The number of transitions from lean to rich and back again must occur often enough to promote good catalyst activity.** For the oxidation and reduction catalysts to work, the oxygen content in the exhaust must switch between lean and rich often enough to alternately deprive the reduction catalyst of oxygen and add oxygen to the oxidation bed. You may call this $O_2$ switching *cross counts*. The frequency of switching varies according to the fuel system type. Port-fueled engines are the fastest. You may see switching rates of 5 Hz (5 times/second) from a good sensor in a port-injected engine running at 2500 RPM.

Clearly, the total operating range and response speed of the oxygen sensor will affect the total number of crosses the sensor voltage will make above and below the rich-lean and lean-rich threshold in a given time period.

That's why the threshold values are so important. They set the standards for acceptable sensor activity. In many cases they are fairly liberal when compared to ideal specifications. Normally, if the sensor can go below 300 millivolts and above 600 mV it will pass that part of the Monitor. But be careful, thresholds are very calibration specific.

Here are two examples of acceptable Rich-Lean and Lean-Rich transitions that will set a code P0133 (Oxygen Sensor Slow Response) if they are exceeded.

**Vehicle A will set this code for average responses that are:**

- Greater than 100 ms from L-R
- Greater than 75 ms from L-R measured between 300 mV and 600 mV.

**Vehicle B, from the same manufacturer, has a different engine.** It will set a P0133 for the following $O_2$ sensor response times:

- Greater than 150 ms from L-R
- Greater than 150 ms from R-L

Scan test Mode $05 allows precise measurements of oxygen sensor activity for comparison to actual threshold specifications used to evaluate sensor activity. Rules of thumb may not be enough during actual repairs. Sensors aren't cheap, and Mode $05 reduces guesswork.

## *MODES $06 AND $07*

Modes $06 and $07 allow you to retrieve test results for Non-Continuous monitors (those that run once per trip) and from Continuous monitors. While these test modes are defined by SAE paper J1979, they aren't available on all scan tools. Even if the scan tool or scan interface can operate in Modes $06 and $07, the types of data displayed will not be identical in all vehicles. This is only logical, since monitor strategies vary by make and sometimes model. Service manual information for the vehicle at hand becomes very important when you need to interpret and evaluate test data retrieved in these modes.

- **Test Mode $06** is a Request for On-Board Monitoring Test Results for **Non-Continuously** Monitored Systems.
- **Test Mode $07** is a Request for On-Board Monitoring Test Results for **Continuously** Monitored Systems.

Under the Functional Description for Mode $07 in SAE paper J1979, we find the following:

> **The purpose of this mode is to enable the off-board test device to obtain results for emission-related powertrain components/ systems that are continuously monitored during normal driving conditions. The intended use of this data is to assist the service technician after a vehicle repair, and after clearing diagnostic information, by reporting test results after a single driving cycle.**

**This is very important stuff.** You've repaired the vehicle to your satisfaction. But have you satisfied the OBD II monitor that set the DTC originally? Maybe yes, maybe no. Do you want to drive the vehicle until a two-trip fault turns on the MIL again to be sure? Probably not.

So Modes $06 and $07 will report back on how things are going in the pass-fail department as soon as the monitor runs. It's a sneak preview of DTCs that are about to set. This feature lets you determine if the PCM is seeing things that can cause it to store a DTC. The monitoring system informs you if the individual monitors are passing or failing as they run.

Non-Continuous monitor displays may appear on the scan tool as hex numbers. Each manufacturer can assign specific Test IDs (TIDs) and Component IDs (CIDs), depending on the types of monitors installed. If your scan tool displays the hex code, you'll need a reference sheet for that vehicle to help you identify which monitor and component is passing or failing. The TID describes the monitored system (test) and the CID identifies the exact component being tested (Fig. 3-8).

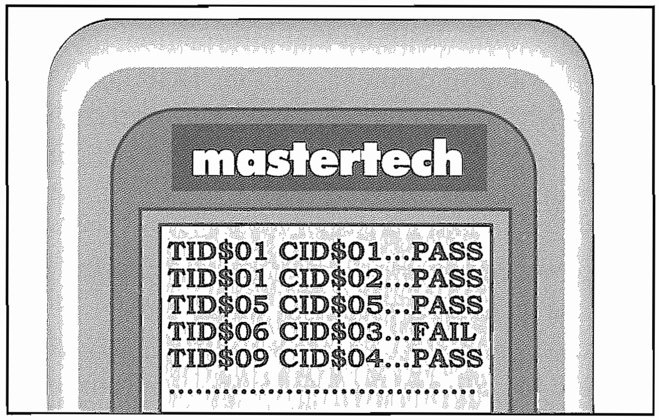



*Fig. 3-8. The Non-Continuous monitor display provides information about the current status of individual monitors and individual components providing information to those monitors.*

Test results can be gathered from different controllers. A submenu may ask you to identify the controller you want to monitor if multiple controllers are used in the vehicle.

There is another display option that goes with the Non-Continuous monitor display. If the scan tool and vehicle PCM support it, you can also retrieve information from the PCM about the measurement standards it is using to determine pass-fail status of the monitor or component under test. Display information will identify the ECU that's reporting, and show minimum and maximum values for the CID test, and may even display the actual measured value of the input.

Figure 3-9 shows a sample of this display. Obviously, if you can identify the component being tested, the measurement standards, and the actual values, you'll have a much better idea of how to repair the problem.

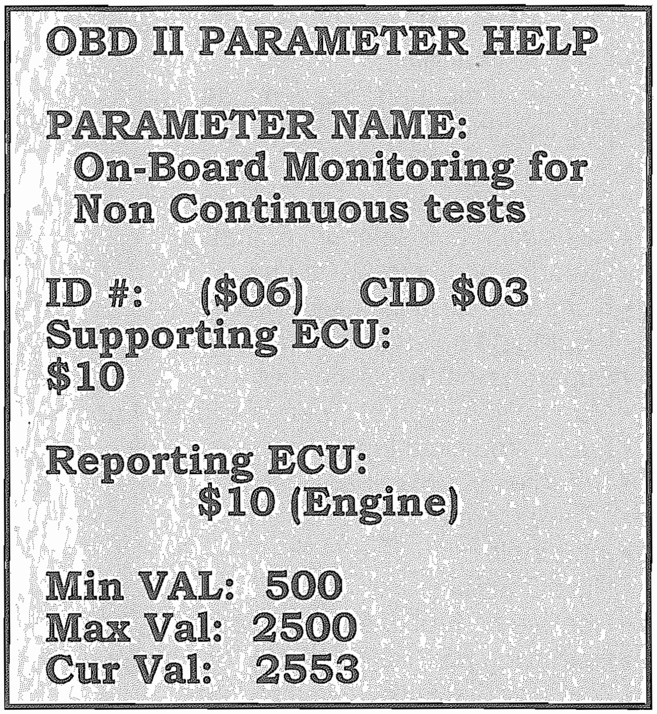



*Fig. 3-9. If TIDs and CIDs are displayed in hex, you'll need a reference sheet from the manufacturer to interpret them. Actual test values may also be displayed as hex numbers on certain scan tools.*

As critical as this information can be during repair verification, Non-Continuous tests are not available from all vehicles and all scan interfaces. Scan tools with dedicated-factory software will normally include a database of hex-to-English conversions, but without that, you will need to make the conversions yourself to determine which TIDs and CIDs are being displayed.

*Repair information becomes every bit as important as the data retrieved when the display comes through as hexadecimal numbers.* Unless you have access to a "code breaker" to interpret the signals being measured and their values, the display might as well be shown in ancient Sumerian.

J1979 allows the vehicle manufacturer to use Mode $06 to display oxygen sensor information instead of using Mode $05. If the scan tool doesn't seem to have an oxygen sensor tests display, check to see if you can find the data in the Non-Continuous tests display.

## *MORE ON MODE $07*

Mode $07 is a little easier for scan tool manufacturers to display in plain English since there are three, and only three, Continuous Monitors to be identified: Fuel, Misfire, and the Comprehensive Component. For a technician, however, continuous monitors can pose special problems when it comes to repair verification.

To better understand Modes $06 and $07, we need to remember that Continuous Monitors run *continuously*, and Non-Continuous Monitors run *once-per-trip*. A separate scan tool display, called the Readiness Status display, will tell you when the non-Continuous monitors have run to completion. **(This does not mean that they have run and passed, just that they have finished.)**

Since Continuous Monitors don't run and then stop at a certain point, they may not be displayed as DONE on the Readiness Status display.

That's why the Request for On-Board Monitoring Test Results for Continuously Monitored Systems becomes a useful window for spotting a two-trip DTC that's about to turn on the MIL. After repairing the vehicle and erasing codes, a failing test in a continuously monitored system will be reported to the PCM as a DTC during the **first** trip. Without this information, you would need a second trip (and failure) to store a DTC as an indication that the problem still exists.

Figure 3-10 shows that two problems are being detected in continuously monitored systems, one related to ignition, the other to fuel.

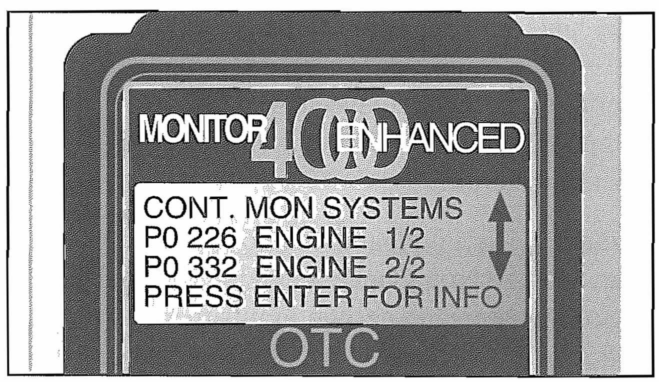



*Fig. 3-10. This scanner display of Continuous Monitor tests tells us which controller is reporting the DTCs and how many DTCs are stored.*

Mode $08 is entitled **Request Control of On-Board System, Test or Component** by SAE paper J1979. The purpose of this mode is to enable the off-board test device to control the operation of an on-board system, test, or component. Mode $08 allows the scan interface to send commands back to the OBD II system, and the buzz word you'll hear used to describe it is "bi-directional controls."

You may be using these types of tests now. Actually, they've been available on some OE system interfaces for years. Essentially, the scan tool instructs the vehicle computer to issue a command. It may be a single command to activate a solenoid, or a repetitive command to pulse an ignition coil or fuel injector(s).

Bi-directional controls let a tech test the controller's response to the command, and also test the circuit and output device that ought to respond. Some scanners will also display the results of the test as a parameter value to let you see if there was a change in voltage at the actuator.

These types of command-response tests can really cut troubleshooting time since the controller and output circuit can be activated and monitored right from the scan interface. How many tests can be run this way? It all depends on the vehicle system and scan interface, but the list is very comprehensive on some vehicles.

In addition to individual circuit tests, bi-directional controls can allow you to gain access to critical information about installed software versions, force the PCM to re-learn new values, coax an OBD II monitor to run, reset odometers, and even drive the PCM into its fail-safe modes of operation. Some systems can actually perform a diagnostic to check the integrity of the MIL electrical circuit.

Figure 3-11 is a typical list of common output-state tests. As you glance down the list, you'll notice that there are certain inputs that could open a wide door of liability for manufacturer and technician alike if they were used incorrectly. Reprogramming of critical values inside the PCM memory could affect emissions and MIL operation. The vehicle manufacturers are aware of these liabilities, and have been reluctant to provide bi-directional control functions that could compromise vehicle safety or emissions compliance. This has been a hotly contested part of the regulation. Vehicle manufacturer's have installed or are installing safeguards to head off these kinds of problems.

## Typical Types of Output Tests

- Remote control of Transmission Converter Clutch Solenoid and various shift solenoids
- Cooling Fan relay
- Resets of maintenance reminder lights
- MIL circuit diagnostic
- A/C relay and circuit control
- Canister Purge and EVAP solenoids
- AIR switch and solenoid operation
- Electrically driven AIR pump
- Control of variable intake runners
- Wastegate solenoid
- Supercharger Boost control
- Manual selection of Open or Closed Loop
- Fuel pump/circuit tests
- Remote control of Fuel Pump
- Cruise Control
- Intercooler
- Ride Control
- Remote control of engine speed
- Retrieving EEPROM/PROM/VIN information
- Fail-safe (backup) fuel/spark tests
- Remote control of Idle Speed Control Valve
- Final drive reprogramming
- Reset odometer
- Command fuel correction full rich
- Command Fuel system full lean
- Command Idle Learn
- Remote control of EGR
- Fuel trim reset
- Transmission adaptive functions reset
- Perform injector balance test
- Set or correct base timing
- Test $O_2$ sensor heater
- Run on-board diagnostics
- Remote control of charging system

*Fig. 3-11. Scan tool inputs can be used for simple tests, but can also make critical changes in software.*

**Time Out**

Boy, you deserve a time out after that last section.

You probably came here hoping we would offer you a much simpler definition of the state of scan tools and how they can help you fix cars. Sorry. No magic bullets here. The scan tool issue, like the evolution of OBD II is precisely that—an evolution.

Nobody has ever tried this type of vehicle system monitoring before, and there are sure to be inconsistencies in both system operation and the ability of scan tools to perform the individual functions described in Modes $01-$08. As we've already warned you, some scan tools and some vehicles won't support all the modes.

The government, vehicle manufacturers, and the manufacturers of scan interfaces for OBD II systems are traveling on uncharted ground. Like Wilbur and Orville Wright at Kitty Hawk, they thought it would fly, but had no way of being sure until they wound it up and cut it loose.

It didn't crash and burn, but there has been some turbulence. Corrections are constantly being made to vehicle software to address particular concerns, usually related to premature or phantom illumination of the MIL. And the implementation of the OBD II regulations is being reviewed and revised as the need arises.

In the meantime, you're faced with the unenviable problem of selecting a scan tool or software interface that will suit your particular needs. Unfortunately, you're traveling the same uncharted course and don't have a wealth of OBD II experience to fall back on. Now that OBD II vehicles are accumulating enough mileage to leave the dealer and show up at your doors, you need to update your scan tool to meet the demand.

We've outlined a list of recommendations that we would look for in a scan tool or scan software purchase. (By the way, products shown in this course are presented as examples, not as advertising. N.I.A.T. is not endorsing any scan tool, whether it's sold through NAPA or elsewhere.)

### *TOP TEN*

Here's our top ten list of things to look for when you evaluate a scan tool or scan interface.

**1) Ask for a printed list of the functions the scan tool supports, and on which vehicles those functions will work.** Ask for specifics. Okay, so it does OBD II and ABS. But on which makes, models, and years are the ABS tests supported? What types of data will be displayed? Will it support bi-directional controls?

**2) Look at the documentation that accompanies the scan tool.** Is it complete, well illustrated, and fairly comprehensive? Or, is it a pamphlet? Does it offer any charts and tables you might need for reference? Can you use the owner's manual to operate and access various scanner functions without any additional assistance? Does the owner's manual raise as many questions as it answers? Are the controls easy to understand?

**3) Ask about technical support.** If there's a hotline set up by the manufacturer, call it and see what type of response you get.

**4) Take it for a test drive.** You drive a car before you buy it, do the same with a scan tool. Hook it up and see how easily it makes the connection with the PCM. Compare the types of data you can view on different vehicles. Compare the scan tool's operation to the various modes we've described in this section. See how many modes are supported and compare the amount of information provided in each mode as you connect to different vehicles. (If a scanner won't perform certain functions on a specific vehicle, try to find out if it's a limitation of the scanner or of the OBD II software installed in the vehicle PCM.)

**5) If possible, use the scan tool on an actual repair.** How easy is it to scroll through various menus? Can you get to where you want to be easily? Are there shortcuts between menus or do you have to backtrack through multiple menus to get to different functions? What is the ease of use? Does it help you verify the repair, or just pull and erase codes and Freeze Frame? Does it display code definitions or just DTC numbers?

**6) Can you customize parameter displays?** Since displaying multiple parameters slows the update of each individual parameter, you may want the option of selecting one or two parameters for viewing, and ignore the rest temporarily. This speeds the update of the selected parameters. If you find yourself using a specific set of parameters regularly, can you set up a user-defined display that automatically grabs your favorites?

**7) Ask about service and warranty.** If the scan tool needs repair, how long does it take, and how hard is it to get service? An eternal truth of retail purchase is "Read the fine print." Buying your scanner off the back of a 1964 Ford pickup with expired, out-of-state license plates is not a good place to start if you're looking for extended service after the sale! Joking, just joking. But there's an element of truth here. You already know who supports you after the sale from personal experience. If you buy solely on price, you may be stepping over a dollar to pick up a dime.

**8) Evaluate your current scan tool if you're considering an upgrade.** Some scan tools will require additional memory and processor speed to get the most from the new interface. If you've ever tried running a complex piece of computer software on a personal computer with limited memory and a clock speed like an hour glass, you know exactly what we're talking about. Stuffing a complicated OBD II cartridge in an underpowered scan tool is like buying mag wheels for a Yugo.

**9) Ask about upgrades and the addition of added capabilities as they become available.** Promises made in haste can always be repented at leisure, but scan tool technology is changing rapidly. Knowing how the scan tool manufacturer intends to keep you current is an important consideration and extends the product's usefulness.

**10) Evaluate your needs and personal skills.** We left the toughest one for last. You know what kinds of vehicles you work on. Do you want broad coverage for all vehicles? Do you need very specific data for certain kinds of vehicles that you see regularly? Do you have a specialty area of repair like brake work that requires a dedicated ABS interface supporting multiple functions? Maybe you're a transmission shop and want enhanced diagnostic features for transmission controls. It's your call here, and only you can tell which enhanced functions you need the most. The purchase of a scan interface, whether it be a dedicated, freestanding tool, or a PC-based interface will require some homework on your part.

## I CALLED BUT NOBODY ANSWERED

Occasionally, you'll experience a communications problem between the scanner and the vehicle. OBD II scan tools are powered by the vehicle through the DLC. You won't need a separate cigarette lighter or battery connection for power, but the ignition will have to be ON for communication to take place. Once the scan tool or interface is connected and powers up, it sends a request to the vehicle computer asking for data.

(If any part of your diagnosis requires you to cycle the ignition, you may need to wait while the scanner and vehicle reestablish communication.)

But what happens if you connect to the DLC and don't get **any** response? And what do you do when the MIL doesn't work at all, or stays on all the time, even when you erase DTCs? You've probably seen this type of problem before, and troubleshooting is similar to the type of diagnosis you used to perform when an old Check Engine light acted up or you had trouble retrieving serial data from a pre-OBD II vehicle.

Here's a list of quick checks:

- **Make sure the ignition is on.** A few vehicles will have to be running. Also note that some vehicles have TWO ignition-on positions in the ignition switch. You may need to turn the ignition one more "notch" to establish communications on these vehicles.

- **Check the connection.** If you can't communicate, but the MIL lights during bulb check when the ignition is first switched on, unplug the scan tool and check all the pin connectors in the scan tool interface cable. Then check the condition of the mating pins at the DLC. Make sure none of the pins is bent or pushed out of place.

◦ **Make sure the vehicle is OBD II.** Remember those transition years? Some cars with the OBD II DLC are not OBD II.

◦ **Try another scan tool.** Honest. It may sound stupid, but there are documented cases of some scan tools having problems with some vehicles. Hopefully, these kinds of problems are being corrected even as we speak.

◦ **If you're still having problems, check the voltage and ground terminals at the DLC.** This vehicle's schematic shows us that DLC pins 4 and 5 have a common ground point. An open ground can affect both scan tool and MIL operation. Check for battery voltage at pin 16 (Fig. 3-12).

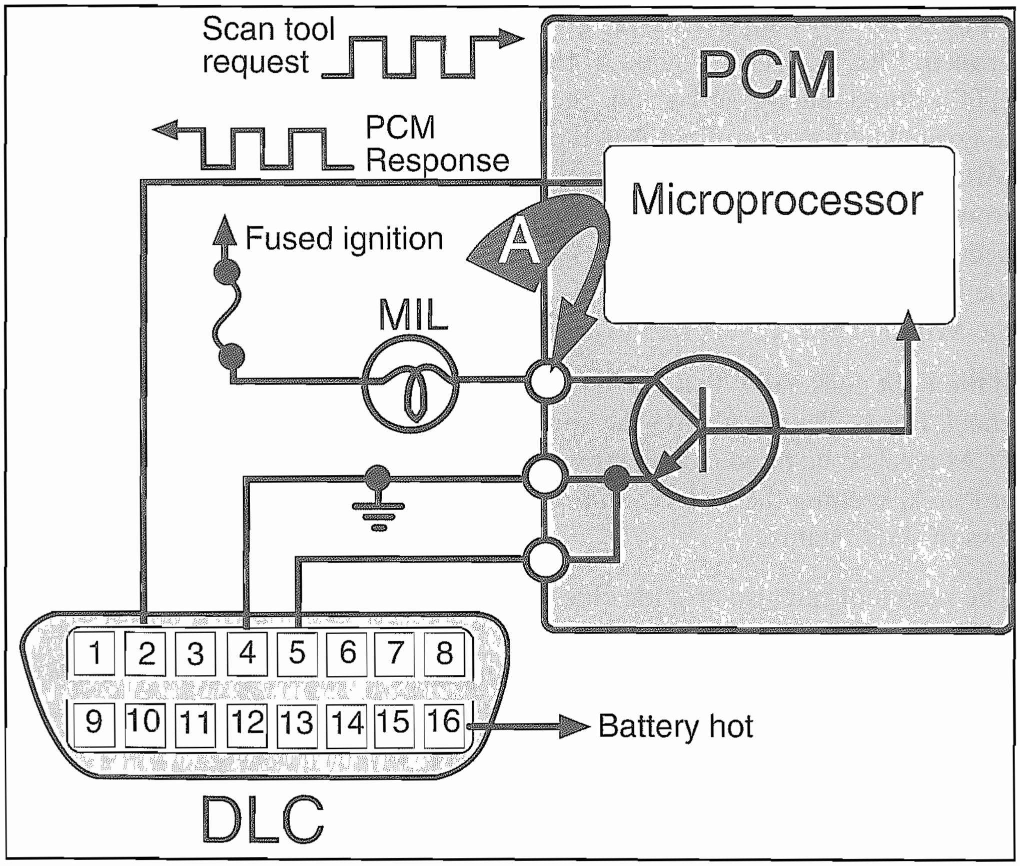



*Fig. 3-12. The MIL circuit is not extremely complicated. Basic tests for shorts and opens will usually uncover the cause for a communication or MIL status problem.*

Then connect the scan tool, turn the ignition on, and backprobe the data terminal used by the vehicle using a ***high impedance*** DMM or scope. Set the DMM to measure frequency and see if you have a reading indicating activity at the communications port. If you're using a scope, look for a square wave signal at the data line.

Figure 3-12 is one example of a DLC schematic, but it won't apply to all vehicles. Check the wiring schematic for the vehicle to identify the serial communication terminal(s). ISO 9141 vehicles use pins 7 and/or 15 and J1850 vehicles use pins 2 and/or 10 for data communication. Expect to see either a variable pulse width or pulse-width-modulated signal when testing with a scope.

If the DLC ground and voltage terminals check out okay, and you have data on the signal line, we come full circle to "try another scan tool." Minor variations in data transmission have resulted in a lack of communication between the scan tool and PCM, or a loss of data transfer.

Here are some general guidelines for troubleshooting MIL problems:

◦ **The MIL never comes on.** Maybe the bulb is burned out. Simple, but always effective.

Normally, the MIL receives ignition voltage KOEO and is grounded by a microprocessor-controlled switching circuit inside the PCM. Turn on the ignition. Check for voltage at the terminal connected to the ground side of the MIL (terminal A in Figure 3-12). If the PCM isn't providing a ground to the MIL during bulb check after the ignition is first switched ON, and the bulb and ignition circuit are okay, you'll find ignition voltage at pin A. (This check of the MIL circuit saves disassembling the dash to check the bulb.)

If pin A is being grounded by the PCM but the MIL still won't come on, look for a blown fuse between the ignition and MIL, a dead ignition feed from the ignition switch (or the circuit that powers the ignition switch), or a burned-out bulb.

• **The MIL stays on, even after all codes are erased.** Check for DTCs again. If there are no DTCs stored, but the MIL is on, check for a short to ground between terminal A at the PCM and the MIL. Turn off the ignition and disconnect the wire from the MIL to Pin A. With the wire disconnected, the MIL should not come when you switch the ignition back on. If it does, the circuit between the MIL and Pin A is shorted to ground.

If the light goes out with the wire disconnected, check Pin A. There's always the chance that the PCM has lost its mind, and is providing a ground at Pin A, keeping the MIL on all the time, regardless of DTC status.

The scan tool can also provide clues about MIL operation. If the scan tool has a data line for MIL status, look to see if the PCM is requesting the MIL on or not. If the PCM request is "MIL OFF" but the MIL is on anyway, you know the PCM is making the correct request. This condition would probably point you to an electrical problem, although a faulty PCM is a last-chance possibility.

Finally, if you're letting the PCM turn off the MIL by performing trips to verify a repair, you may encounter a situation where the scan tool indicates that the PCM has requested the MIL OFF—but it's still on. This will happen if you test for MIL status after a test drive KOEO.

The MIL may be *latched*, a situation corrected by cycling the ignition. As soon as the key is turned OFF and the engine is restarted, the command to the MIL will be updated, and it should go off.

## JOKERS IN THE DECK

Here's what we can't wrap up in a tidy little box for you:

• **The quality of the scan tool software above and beyond the generic minimums is still evolving and sometimes incomplete.** This whole OBD II *thing* is based on computer software changes. Hardware changes are secondary. There has been trial and some amount of error in the development of scan tool software, especially software that goes above and beyond the basics of generic scan tool operation.

• **OEMs have some discretion about the kinds of monitoring strategies used.** EPA and CARB want the OEMs to paint a prettier emissions picture, but don't say whether to use a paint brush, paint sprayer, roller, or a cotton swab, for that matter. It's up to each OEM to design and implement a system strategy that falls within general guidelines, the emphasis being on the word *general*. The strategies used by individual manufacturers may be as different as the individual code numbers they assigned to OBD I DTCs, and are more complex.

• **Bi-directional controls and reprogramming capabilities will continue to evolve.** Some scan interfaces already provide bi-directional control, but the individual components and operating strategies used by each make and model will require dedicated scan tool software to make bi-directional testing possible. In that respect, the new interface is similar to the bi-directional strategies used before OBD II.

Original equipment manufacturers have been ordered to provide both the hardware and software information needed for flash reprogramming to manufacturers of scan tools. Specific software upgrades will be provided on CD ROM, or may be available as a download via modem.

There are three common ways to reprogram the PCM in use:

- Direct connection to a reprogramming interface
- Downloading information to a scan tool that transmits the new data to the PCM
- Off-Board reprogramming, where the PCM is physically removed from the vehicle and taken to a reprogramming device.

• **Calibration of PCM software is more important than ever.** Many monitors require extremely sophisticated programs with subroutines and filters designed to keep them from setting false codes.

The dust hasn't settled on this issue yet. Current information from trade publications may be your best source of information over the next months and years as this situation evolves.

### *MINI QUIZ*

1. OBD II:
   a. Is responsible for all the fuel delivery operations
   b. Is responsible for all ignition system operations
   c. Is responsible for coordination of fuel and ignition operations
   d. Is an add-on monitoring system

2. In a multiplexed system:
   a. All controllers receive sensor inputs on individually wired circuits
   b. Only the trip computer and information displays are connected
   c. Several component displays, and controllers are connected in a single network
   d. Shared inputs are always identical at individual components on the network

3. Hexadecimal numbers are:
   a. Always preceded by a dollar sign ($)
   b. Are base 16
   c. Can be converted to base 10
   d. All of the above

4. In scan tool Mode $05, the Rich-Lean Threshold and the Lean-Rich Threshold are constants used to measure:
   a. Cross counts
   b. Oxygen sensor Rich-Lean Switch time
   c. Oxygen sensor Lean-Rich Switch time
   d. Maximum oxygen sensor voltage during the test

5. During bulb check, the MIL does not illuminate. Of the following, which is the **least** likely cause for this condition?
   a. The bulb is burned out
   b. The fuse supplying power to the MIL is open
   c. There is a short to ground between the ground side of the MIL and the PCM
   d. There is an open in the circuit between the ground side of the MIL and the PCM

**ANSWERS:**
1. d
2. c
3. d
4. a
5. c

## SHOP EXERCISE

Get a scan tool (or even better, scan tools) and two or three different model vehicles from the same manufacturer. This works better when your vehicle sample includes a simple economy level vehicle and a more expensive, well-equipped midline or fully-loaded luxury model. Use each scan tool in different test modes. Compare the differences in data from each vehicle in each scan mode. Pay special attention to how many control modules are installed in each vehicle and to the types of data you can retrieve from each.

Do you get different amounts of data from the same scan tool when you test different models and from the same manufacturer?

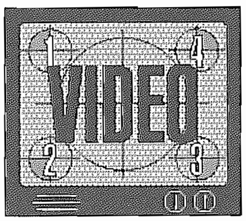
*This exercise illustrates that the amount of data you view on the scan tool is a combined function of the scan tool software, and the vehicle's complexity and ability to transmit data. Simpler vehicles may have a single powertrain controller, while more expensive models with many options will have two or more additional control modules, each of which can store and transmit data.*

*You may also discover that more expensive, fully equipped models will support enhanced diagnostic modes for the powertrain controller, such as exact oxygen sensor data displays in mode $05, and test results for both continuous and non-continuous monitors.*

Notes:

# 4

# DTCs AND DIAGNOSTICS




Watch video module #4 now.

Now that you have a general familiarity with both the Major Monitors and scan tool modes of operation, let's take a closer look at how the OBD II system actually uses the monitors to control the MIL and how the scan tool can help with repairs.

Remember, only emissions-related DTCs will turn on the MIL. That's important. If the MIL is on, you can be sure you have an emissions-related DTC and Freeze Frame data stored in memory. That doesn't mean you shouldn't check for DTCs with your scan tool just because the MIL isn't on. Vehicles can store codes for non-emissions problems, and some systems will store manufacturer-specific DTCs as a diagnostic aid. Neither type will turn on the MIL.

Based on what we've studied so far, there are two basic categories of emissions-related DTCs that will turn on the MIL:

- **Type A faults are emissions-related, and turn on the MIL the first time they are recorded as a fault.** Unlike OBD I, once the MIL is on, it will stay on, even if the ignition key is cycled off and on again. One-Trip DTCs are most often associated with a failed electrical input (open or short) that is detected by the CCM (Comprehensive Component Monitor), or for *extreme* fuel correction or misfire. As you can see, Type A faults are those that require immediate attention. Also note that Comprehensive Component, Misfire, and Fuel monitors are the ones that run continuously, so they can set a code at almost any time.

Unfortunately, there is no standard list of one-trip faults that apply to all vehicles. For example, a manufacturer may decide to turn on the MIL in only one-trip for a CCM-monitored *electrical* fault, but use two-trip logic to test for CCM-monitored sensor signals that fail a *rationality* test.

- **Type B faults are also emissions-related, but use Two-Trip logic detection.** The MIL won't come on when the PCM detects the first instance of a two-trip failure. The first instance of the fault is called a *maturing* fault. The second time the fault is seen, the fault *matures*, and the DTC is stored. A matured fault is also referred to as a *history fault*.

Type B faults can be stored by any system monitor. Monitors other than CCM, Fuel, and Misfire run once per trip, and are classified as Non-

Continuous monitors. Most codes are Type B and use two-trip detection for the obvious reason that the OBD II monitoring system wants to be sure there's a repeat fault before turning on the MIL.

The other fault types are called C and D types are one trip codes, but don't turn on the MIL. **Type C** DTCs will turn on a separate warning light, and indicate a fault in a non-emissions component or system. Transmission overdrive (O/D) and A/C warning lights are examples. The driver information display is used to indicate problems in non-emissions systems on some vehicles.

**Type D** faults store a DTC and are usually designed as an aid to diagnosis. The code stored will be a manufacturer-specific code. Like Type C, Type D DTCs will not turn on the MIL. You'll need to reference a list of manufacturer-specific codes to interpret Type D DTCs.

## A CLOSER LOOK AT TRIPS

The purpose of a trip, from our perspective as repair techs, is to ***turn off the MIL***. If the MIL isn't on and the car isn't driven in such a way that enabling criteria allow a monitor to run, the monitor simply ***doesn't run***. If it doesn't run, it can't fail. If it can't fail, then no DTC will be set. The MIL stays off, even if a fault is present.

Here's an example: We disconnected the vacuum line to an EGR valve on a vehicle that normally runs an intrusive EGR test. In other words, on this particular vehicle, the EGR monitor opens the EGR valve at cruise with the engine in closed loop. Throttle position, MAP, ECT, and vehicle speed are parts of the enabling criteria for this monitor to run. Then the system looks for changes in $O_2$ sensor voltage and STFT caused by the addition of exhaust gas to the combustion chambers.

We drove this car around for a week in stop-and-go traffic and never went over 40 MPH. The enabling criteria for a highway cruise condition were never satisfied. The EGR monitor never ran. The MIL never came ON, and no EGR DTC was set.

Then we warmed up the car and took it for a couple of long drives on the Interstate. Sure enough, the MIL came on after a few trips. Once the enabling criteria for the EGR monitor were met, the monitor ran, and failed. Until the MIL came on, however, we didn't *care* if the trip provided the enabling criteria or not. Figure 4-1 shows how monitor status information might be compared to a report card sent to the PCM.

**Monitor Report Card (Results sent to PCM)**

| Student | Test | Grade |
|---|---|---|
| Cat Monitor | Completed | Pass |
| EGR Monitor | Incomplete | ? |
| AIR Monitor | Completed | Fail |

*Fig. 4-1. There isn't a column marked "works and plays well with others," but there could be.*

Once the MIL was on, however, the definition of a trip became very important. We reconnected the EGR vacuum line, and drove the car under the highway cruise conditions that provided the enabling criteria for the EGR monitor to run. We performed several start-to-run drive cycles followed by a key-OFF. Sure enough, the PCM eventually turned OFF the MIL. We had driven the vehicle in such a way that we recorded three trips, trips that allowed the PCM to run and eventually **pass** the EGR monitor and turn off the MIL.

This next part is really important. We've mentioned this before, but it is a critical part of any repair verification. ***Monitors do not all use the same definition of a trip.*** And different manufacturers may have different definitions of a trip for a given monitor type. The requirements for a trip depend on the system being tested, the enabling criteria required for the monitor to run, and maybe the status of another monitor or monitors. (For example, if the $O_2$ sensor monitor hasn't run, but must pass before the EGR monitor can run, the EGR monitor won't run, because it ***can't*** run.)

If all the enabling conditions are met for a monitor to run and pass, the passing grade is recorded for the monitor. This run and pass is different from the basic definition of a trip. During a trip, the monitor runs to completion. But to turn off the MIL, the monitor must run AND pass, just like John Elway. The PCM is performing some pretty intense scrutiny of the monitor that stored the DTC. While your scan tool won't necessarily display this DTC report card (although some do), it looks something like what's shown in Figure 4-2.

**DTC Monitor Report Card (Results sent to PCM)**

| Student | RUN | Grade |
|---|---|---|
| P0101 | NO | - |
| P0102 | NO | - |
| P0502 | YES | PASS |
| P0400 | NO | - |
| P0143 | YES | FAIL |
| P0756 | YES | INT |

*Fig. 4-2. As monitors run, passing and failing grades are issued that will either leave the MIL on or eventually turn it off by erasing the DTC.*

***Simply performing a trip (allowing the monitor to run), doesn't necessarily mean the monitor receives a passing grade. The monitor must run and pass on three consecutive trips to turn off the MIL.***

If the test results are inconsistent, the PCM may be informed that the problem is intermittent. This is an important consideration when you're trying to get the PCM to turn off the MIL by recording three passing grades on three consecutive trips. There may be instances where you've looked up the exact enabling criteria for a specific monitor and performed three trips "by the book" that don't turn off the MIL.

Ideally, the operating conditions experienced during a Drive Cycle should provide various enabling criteria needed to run all the monitors and store test results of the individual monitors as passing or failing grades in memory. But inconclusive test results are just as bad as failing grades when you're logging trips to turn off the MIL.

Missing sensor inputs can also keep a monitor from running. A stored DTC for the oxygen sensor can keep the catalyst monitor from running (let alone passing). ***If multiple codes are stored in the vehicle, and some of the codes indicate that a sensor, or sensors, has failed or is out of range, fix the sensor input(s) first and get rid of those DTCs if you want the PCM to turn off the MIL.***

Trips will issue passing grades only when enabling criteria are present and a monitor runs and passes. Those criteria include sensor inputs.

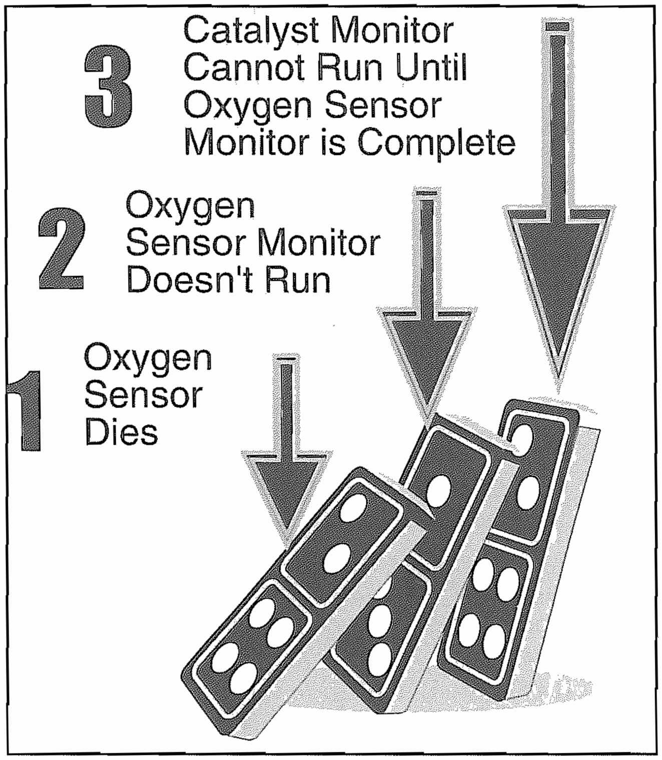



*Fig. 4-3. A single component failure can cause problems in multiple subsystems.*

It's really important to think of the *system* when we attack OBD II problems. For a monitor to run successfully, it needs proper inputs from individual sensors and, sometimes the test results from another monitor. A failure of a single component can ripple throughout the system. Figure 4-3 shows how a domino effect can start when one signal input goes bad.

Unless the monitor that set the DTC runs to completion and passes on three consecutive trips, the PCM will not request that the MIL be turned off. If the tests are interrupted or test results are inconclusive, the monitor will have to run again.

### GETTING THE MOST FROM DTCS

Now that we have the new 5-digit DTCs, we want make sure we get the most from them.

Some DTCs will readily identify the exact component or circuit that failed. Figure 4-4 shows a list of SAE codes that identify faults in individual injector circuits.

**DTC Identifies Exact Circuit for Multiple Components**

P0200 Injector Circuit Malfunction
P0201 Injector Circuit Malfunction CYL 1
P0202 Injector Circuit Malfunction CYL 2
P0203 Injector Circuit Malfunction CYL 3
P0204 Injector Circuit Malfunction CYL 4
P0205 Injector Circuit Malfunction CYL 5
P0206 Injector Circuit Malfunction CYL 6
P0207 Injector Circuit Malfunction CYL 7
P0208 Injector Circuit Malfunction CYL 8
P0209 Injector Circuit Malfunction CYL 9
P0210 Injector Circuit Malfunction CYL 10
P0211 Injector Circuit Malfunction CYL 11
P0212 Injector Circuit Malfunction CYL 12

*Fig. 4-4. Each injector has its own separate DTC, and there are enough DTCs assigned to cover everything from four-bangers to 12-cylinder engines.*

OBD II DTCs will also give you a much clearer picture of *how* a circuit failed. Figure 4-5 shows four separate types of failures that can affect the ECT circuit, from a general malfunction, to shorts and opens causing signal voltage that is too high or too low to be considered acceptable. The CCM is responsible for tests of the ECT.

**DTC Identifies Type of Failure for Individual Component**

P0115 ECT Circuit Malfunction
P0116 ECT Range/Performance Problem
P0117 ECT Circuit Low Input
P0118 ECT Circuit High Input

*Fig. 4-5. The DTC not only identifies the sensor/circuit, that set the DTC, but also tells you how it failed.*

Sometimes, there are multiple sensors of the same type installed. We may have only one ECT, but we will always have at least two, and maybe more $O_2$ sensors. The DTC will identify which oxygen sensor failed, and add a failure description similar to what we saw with the ECT (Fig. 4-6).

**DTC Identifies Component and Failure for Multiple Sensors**

P0130 O2 Sensor Bank 1 Sensor 1 Malfunction
P0131 O2 Sensor Bank 1 Sensor 1 Low Voltage
P0132 O2 Sensor Bank 1 Sensor 1 High Voltage
P0133 O2 Sensor Bank 1 Sensor 1 Slow Response
P0134 O2 Sensor Bank 1 Sensor1 Circuit Inactive
P0135 O2 Sensor Bank 1 Sensor 1 Heater Malfunction

*Fig. 4-6. For multiple sensors, the DTC will identify the affected sensor and give us a description of the failure.*

If you're still not impressed with the added information you get with OBD II DTCs, please cast a glance at Figure 4-7. If this doesn't impress you, nothing will.

In the left column in Figure 4-7, we see representative OBD I code numbers for common failure conditions shown next to them in the center column. The two-digit OBD I codes shown here could apply to any vehicle, and might even apply to more than one vehicle from the same manufacturer in the same model year, so we've assigned definitions to each. Our code 11 identifies ANY type of crankshaft sensor failure the PCM might detect. It doesn't say how the sensor failed.

In the right column, we see precisely defined OBD II DTCs that send us right to the nature of the problem. One, P1390, is a manufacturer-defined DTC that gets *really* specific. We would never get this kind of information from an OBD I code 11 listed as "crankshaft sensor failure."

Moving down the list, we see codes 14 and 22. With OBD I, these codes would have set for a high or low voltage, but we wouldn't be sure which. The OBD II codes highlighted with gray boxes show how DTCs tell us *how* the sensor or its circuit failed.

| OBD I Code | Condition | OBD II Code |
|---|---|---|
| 11 | No Crank signal | P0335 |
| | Timing Belt Skipped tooth | P1390 |
| 14 | MAP Sensor Voltage Low | P0107 |
| | MAP Sensor Voltage High | P0108 |
| | MAP Sensor Circuit Malfunction | P0105 |
| | MAP Sensor Circuit Range/ Performance | P0106 |
| 22 | ECT Voltage High | P0117 |
| | ECT Voltage Low | P0118 |
| | ECT Circuit Malfunction | P0115 |
| | ECT Range/Performance | P0116 |
| 24 | Throttle Sensor Voltage Low | P0122 |
| | Throttle Sensor Voltage High | P0123 |
| | Throttle Sensor Circuit Malfunction | P0120 |
| | Throttle Sensor Range/ Performance (does not agree with MAP) | P0121 |

*Fig. 4-7. Use this chart to give yourself a feel for the additional information provided for many possible circuit/sensor failures by OBD II DTCs.*

Code 24 on our chart shows possible failures in the Throttle Position Switch/Sensor Circuit. Again, we see that an OBD I code simply flags the TPS but doesn't say why. Not OBD II. In addition to codes for high and low voltage, we get separate codes for a general malfunction and another (P0121) for a sensor that fails a rationality test.

Code P0121 tells us that the TPS signal doesn't make sense. For example, if the MAP signal and tach signal indicate high engine load and speed, but the TPS signal indicates that the throttle is closed, the PCM will compare the information and politely suggest that the TPS is a liar. It isn't just measuring the circuit electrically. It wants the signal to make sense compared to other sensor inputs and engine operating conditions.

The enlarged list of DTCs and their very specific definitions are a valuable diagnostic tool. Use the information wisely. If you do pull a manufacturer-specific code, look it up. In many cases, manufacturers have added some codes for the sole purpose of speeding diagnosis.

## *FREEZE FRAME DATA*

Once a DTC is stored, the Freeze Frame data stored with it can be used to recreate the conditions under which the DTC was stored. You will find that some sensors fail only under certain operating conditions.

A good example would be a secondary ignition component (an ignition wire or spark plug) that fails under specific engine speed and load conditions. Another would be a MAP sensor that fails in a certain range. Letting the car sit and idle for an hour, a week, or a month may not recreate the conditions that were present when a monitor failed and set the DTC.

### Freeze Frame Data from a Sample Scan Tool

| | |
|---|---|
| • **Cal Load** (Calculated Load) | % |
| • **DTC Set** (number of DTCs stored) | # |
| • **DTC-FF** (DTC that stored Freeze Frame) | P0XXX |
| • **ECT** (engine Coolant Temp) | °F |
| • **FSS1** (Fuel System Status Bank 1) | Closed/Open |
| • **FSS2** (Fuel System Status Bank 2) | Closed/Open |
| • **LTFT 1** (Long Term Fuel Trim Bank 1) | % |
| • **STFT 1** (Short Term Fuel Trim Bank 1) | % |
| • **LTFT 2** (Long Term Fuel Trim Bank 2) | % |
| • **STFT 2** (Short Term Fuel Trim Bank 2) | % |
| • **Spark ADV** (Spark Advance) | Deg |
| • **MAP** | "HG |
| • **MIL Light** (ON or OFF) | ON |
| • **O2 B1 S2** ($O_2$ sensor Bank 1 Sensor 1) | VDC |
| • **STFT B1 S2** | % |
| • **O2 B2 S2** ($O_2$ sensor 2 Bank 2 Sensor 2) | VDC |
| • **STFT B2 S2** | % |
| • **RPM** | RPM |
| • **Speed** (Vehicle Speed) | MPH |
| • **TPS** (Throttle position in %) | % |
| • **PCM Conflict** (PCM Conflict) | |

*Fig. 4-8. Freeze Frame data will define many engine conditions when a failure was detected.*

Freeze Frame information is designed give you an overall picture of critical engine operating conditions **when the DTC was stored** (Fig. 4-8). Okay, so the Freeze Frame data list may be shorter than snapshot data storage films available on a scan tool connected to some OBD I vehicles. But the most important engine operating conditions are included in Freeze Frame. Improved DTC and Freeze Frame information should be compared. They are a team.

Think of the DTC as a profiler, whose job it is to help you capture a culprit. It provides the basic information about the suspect, like height, weight, color of eyes, and distinguishing marks.

Freeze Frame is designed to identify *when and where* the failed component or subsystem stepped outside the law. To verify the cause of the fault, we often need to identify the guilty party, return to the exact scene of the crime, and recreate the event.

## *USING FREEZE FRAME DATA*

If you've taken the ASE L1 advanced engine performance test, you know that part of the test is based on your ability to compare data and arrive at a diagnosis based on the information provided in a sample scan data list. It's the old, "Can you find the donkey in this picture?" routine.

Using Freeze Frame data is no different. Use it to view various inputs and outputs, and then compare that information to the exact failure. When you have multiple DTCs, start with the DTC that stored the Freeze Frame. The very existence of a DTC, especially for a sensor input, can prevent a monitor from running. If it doesn't run, it can't pass and turn off the MIL. You need to eliminate the DTC and Freeze Frame, especially one that involves a sensor input, and then verify the repair.

In a nutshell, you may have to simulate the conditions under which the failure occurred to find the problem and verify the repair.

A dyno can speed this process by allowing you to recreate the exact engine speed and load conditions present when the DTC turned on the MIL.

***Freeze Frame will help you duplicate the operating conditions present when the DTC set.***

This brings us to the sticky proposition of turning off the MIL by erasing the DTC(s) with the scan tool. This method sure gets that light out in a hurry. But will it stay out after the vehicle is returned to the customer?

On OBD I vehicles, we routinely erased DTCs and then drove the vehicle to see if they reset, indicating that the problem was a hard fault. In some cases, simply a restart after a repair was enough to verify that the fault was gone. If the light didn't come back on, we assumed that the fault was no longer present. But there are problems with this approach when we diagnose an OBD II vehicle.

Let's say you erase the code. Then you drive the vehicle to see if it resets. But if it's a Type B (two-trip code), you'll need to perform at least *one trip* just to run the monitor for the system that set the code in the first place. And think about this: A Type B code won't turn on the MIL again the first time the monitor runs, even if the fault is seen by the PCM on the first trip after the repair.

***If you erase DTCs, don't assume that the fault is gone just because the MIL didn't come back on during the next trip.***

- **When you erase DTCs, you erase Freeze Frame (Fig. 4-9).** Make sure you've recorded all Freeze Frame data before erasing DTCs, or the judge may give you 90 days for destroying evidence that could help you apprehend and convict the reason the MIL came on in the first place.

- **When you erase DTCs you may be resetting some or all of the Readiness Status flags.** The Readiness Status window may inform you that some or *none* of the monitors has run to completion after you erase DTCs. This varies by vehicle. Some systems will reset only the monitor that set the DTC, while others will reset all of them. The monitors must all be run again from scratch when this happens, and that requires at least one complete Drive Cycle. Notice we said *at least* one complete Drive Cycle. Some software strategies require multiple samplings of sensor data to establish a statistical baseline for reference. More on that in a moment.

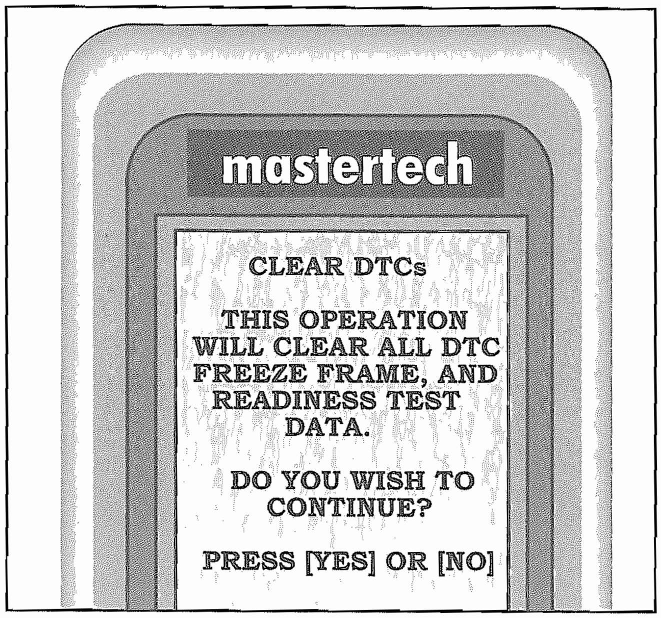



*Fig. 4-9. Erasing DTCs with the scan tool also erases valuable diagnostic information stored with the DTC.*

Clearly, there are some conditions where erasing DTCs is the fastest but not the best way to turn off the MIL. Use as much information as you can gather from the DTC, Freeze Frame, and data stream to evaluate the system conditions that caused the fault before you erase DTCs.

Whether or not you erase DTCs—and when you choose to do so—will usually depend on how sure you are that you fixed the problem that caused the MIL to illuminate in the first place. Simple electrical problems caused by shorts and opens, or just plain missing signals caused by a failed sensor can usually be isolated with a DMM or scope. This kind of troubleshooting is ***no different from component tests on OBD I vehicles***.

If you aren't lucky enough to find a clear-cut solution to your problem, use Freeze Frame data to duplicate the conditions that were present when the DTC was stored.

Even if you're sure you fixed the problem, don't just erase the Freeze Frame and forget about it. Save the Freeze Frame data and attach it to the

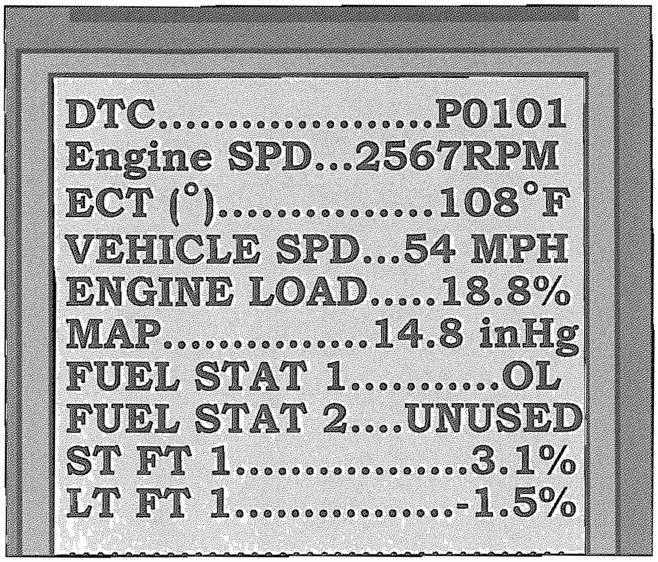



*Fig. 4-10. Saving the Freeze Frame data, and attaching it to the work order can save diagnostic time if a vehicle returns with the same MIL-on condition.*

work order (Fig. 4-10). Some scan tools can be connected to a printer. Also, a software interface that stores the data to a file can also save time. Either way, if the vehicle does return with the MIL on and the same DTC stored, you can compare old and new Freeze Frames, and look for clues.

When you work on several cars each day, can you imagine trying to remember the specific Freeze Frame data for a vehicle you worked on three days ago if it returns with the MIL on again?

### *FREEZE FRAME AND SIMILAR CONDITIONS*

Fuel- or Misfire-related DTCs show how useful Freeze Frame data can be, especially if you're on the trail of a Fuel- or Misfire-related failure. If it's important to know when and how a DTC set for other monitors, it's absolutely essential when diagnosing Fuel or Misfire DTCs. These two fall into a separate category we mentioned earlier, and it has to do with something called a *similar conditions window*.

Let's look at a typical OBD II response to a DTC caused by Fuel or Misfire. If the system detects a fault in either of these monitors that is not catalyst-damaging, it will store the fault in memory, but not turn on the MIL. This is a first occurrence of a Type B (two-trip) fault.

If the fault is seen again on the very next trip, however, a DTC will be stored and the MIL will come on. Two consecutive trips, two consecutive failures of a two-trip code, and the MIL is on. In this respect, two-trip Fuel and Misfire DTCs are similar to other two-trip codes.

But—and this is a big but at that—if a Fuel or Misfire fault isn't seen on the next ***consecutive*** trip, it doesn't simply disappear from the PCM memory. The Fuel or Misfire Monitor is "armed" by the first occurrence—and may stay "armed" for the next **80 trips**. It goes to hair-trigger mode, and if the Fuel or Misfire fault occurs again ***in a similar conditions window*** at any time during the next 80 trips, the MIL comes on and a DTC is stored.

- **Failure of Fuel or Misfire on two consecutive trips sets a DTC and turns on the MIL.**
- **After a first failure for Fuel or Misfire, they are monitored for the next 80 *nonconsecutive* trips, and the next occurrence of a similar fault in a similar conditions window in that monitoring period will store a DTC and turn on the MIL.**

There are other special conditions you ought to be aware of about misfire monitoring:

- **Misfire is to be monitored under positive torque conditions (during engine acceleration).**
- **The PCM monitors by counting engine revolutions. A typical GM system counts them in 3200 crankshaft revolution *blocks* that are stored in memory and are constantly updated.**

That way, the PCM always knows what's happened in the most recent 3200 revolutions. These main blocks are divided into 16 smaller blocks, each containing misfire information about 200 engine revolutions.

As information from each new 200-revolution block is added to memory, the oldest 200-revolution block is thrown away. That way, the misfire information in the big 3200-revolution block is the most current. As a result, the information contained in memory will always represent *the most recent* 3200 engine revolutions. If the number of misfires in any 200-revolution block gets high enough to cause catalyst damage, the MIL flashes as long as catalyst-damaging misfire continues. If the misfire decreases below catalyst-damaging levels, the MIL stops flashing, but stays lit.

*Once again, we have exceptions to this rule to consider. If the manufacturer uses a fuel control strategy to protect the catalyst during extreme misfire, the MIL may not flash. That's why it's important to know the strategy used by the manufacturer. Don't assume that just because the MIL isn't flashing, there can't be a catalyst-damaging misfire occurring.*

Figure 4-11 shows that as each new 200-revolution misfire block enters the PCM, the oldest block gets dumped in the trash.

Notice that there are three kinds of blocks shown:

1) Blocks containing enough misfires to be catalyst-damaging,
2) Blocks with enough misfire events to increase emissions, and
3) Blocks that pass with little or no misfire.

We're explaining this to help you understand several special conditions and revisions to the misfire monitor that have taken place since the very first OBD II vehicles.

• **First,** if the PCM detects a misfire that will not damage the catalyst, but will cause increased emissions, it will store the fault in memory and arm the misfire similar conditions monitoring system for the next 80 trips. However, if the similar conditions aren't seen in the next 80 trips, or if the misfire monitor runs again and passes under similar conditions during that time, the temporary code ***may be***

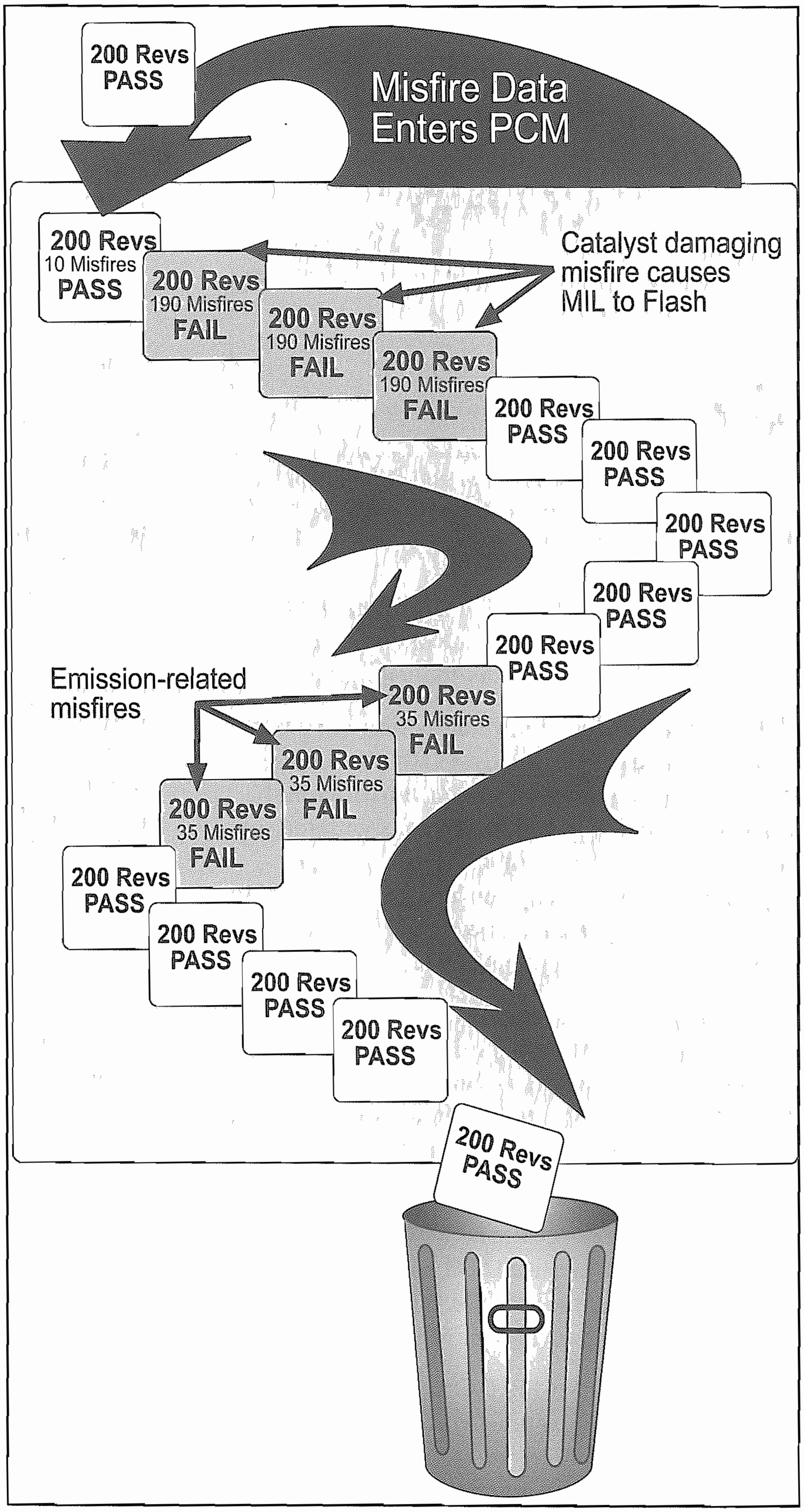



*Fig. 4-11. The PCM will store misfire information about the most current 3200 engine revolutions. As each new 200-revolution block is delivered to the PCM, the oldest 200- revolution block goes into the trash.*

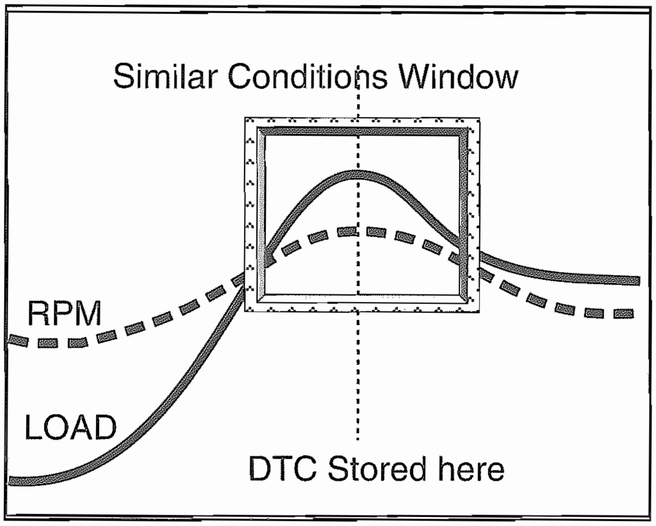



*Fig. 4-12. If we chart engine load and RPM at the point where the DTC is set, we can frame the data to provide the window of conditions present when the DTC set originally.*

erased. The event that caused the original fault may have resulted from extreme operating conditions, not as the result of a component failure.

- **The standards for misfire detection have been relaxed slightly since the first OBD II vehicles hit the streets.** Something called "misfire relief" allow for more 200-revolution blocks with misfire in each 3200-revolution block. Some original strategies were extremely sensitive, and this wider tolerance is being used in new vehicles, and has been added to earlier systems by reprogramming.

- **Once again, the system may not flash the MIL during catalyst-damaging misfire if the engine management system has a fuel strategy that protects the catalyst when extreme misfire occurs.** You may see this form of catalyst protection in a vehicle with a seemingly significant misfire that does not cause the MIL to flash.

- **For the PCM to erase a DTC and turn off the MIL, the monitor that set the DTC must run and pass on the next three consecutive trips.**

However, Fuel and Misfire DTCs are special in this regard, too. ***For a Fuel or Misfire Monitor to run and pass after the MIL is on, the monitor must run and pass within the similar conditions window.*** The vehicle must be operated at a similar temperature within 375 RPM and 10 percent of the calculated load at the time the DTC was set. The Fuel/Misfire Monitor must run in this window long enough for the monitor to run and record a passing grade (Fig. 4-12).

As you can see, Fuel or Misfire DTCs present special concerns if we want the PCM to turn off the MIL as a verification that we have indeed repaired a fuel/misfire problem. (Some scan software will actually tell you when you're "in the window," and that is a really great feature.)

Without an enhanced scan tool interface to tell you you're in the same window, you'll need to *approximate* the driving conditions that were present when the DTC set during your test drive. Admittedly, this can be a little like playing pin the tail on the donkey. You'll need to drive the vehicle and attempt to approximate the similar conditions window, and then keep the vehicle in the window long enough for the Misfire Monitor to complete its tests. This can be very tough to do.

If you're limited to generic scan tool data, and you're trying to get into that window, the only information about the size of the similar conditions window available to you will be the information stored in Freeze Frame.

## MISFIRE COUNTERS

Some scan tools can save information about the total number of misfires that have occurred in each cylinder. General Motors calls this diagnostic feature the **History Misfire Counter**. Once the first occurrence of misfire arms the monitor, it starts counting individual cylinder misfires. As long as the monitor is armed it keeps adding to the list of total misfires for each cylinder (Fig. 4-13).

Another display, called the **Current Misfire Counter** will show the number of misfires logged in the last 200-revolution block. To better explain why this can be an important diagnostic tool, let's say that you have a vehicle with a MIL-ON. The DTC stored is P0300, or a *random* misfire condition. This code will be stored in cases when the PCM is unable to assign a misfire DTC for a single cylinder due to the fact that two cylinders are experiencing a similar problem. If you look only at Current Misfires, however, you may see that none of the cylinders shows any significant misfire. The stored information about total misfires recorded for each cylinder in the History Misfire display can lead you in the direction of the offending cylinder or cylinders.

Misfire History will tell you that even though a significant misfire is not present right now, one or more of the cylinders has experienced a significant misfire since the Misfire Monitor was armed. Use this information to narrow your search and concentrate on specific cylinders.

Current misfire data is updated whenever the engine is running and is erased at Key-OFF. It is volatile. Misfire History is a cumulative total that stays in (nonvolatile) memory until it is erased with the scan tool.

**Current Misfire by Cylinder**

| | |
|---|---|
| Misfire Current Cyl. #1 | 0 |
| Misfire Current Cyl. #2 | 10 |
| Misfire Current Cyl. #3 | 0 |
| Misfire Current Cyl. #4 | 0 |
| Misfire Current Cyl. #5 | 0 |
| Misfire Current Cyl. #6 | 0 |

**Misfire History**

| | |
|---|---|
| Misfire History Cyl. #1 | 0 |
| Misfire History Cyl. #2 | 21788 |
| Misfire History Cyl. #3 | 10 |
| Misfire History Cyl. #4 | 3 |
| Misfire History Cyl. #5 | 0 |
| Misfire History Cyl. #6 | 5 |

*Fig. 4-13. Misfire History can point you to a cylinder with problems, even if it isn't experiencing those problems right now.*

## QUICK REVIEW

Let's stop here and summarize what we know about DTCs and the MIL.

**Type A Faults**

- Are always emissions-related
- Request the MIL ON after a first-trip failure
- Store a DTC on a first-trip failure
- Store Freeze Frame with the DTC (assuming no Freeze Frame is currently stored ahead of it)

**Type B Faults**

- Are always emissions-related
- Are "armed" on a first-trip failure
- Will store a DTC if the failure occurs on the next consecutive trip after the DTC is armed
- Request the MIL ON when the DTC is stored
- Store Freeze Frame with the DTC (assuming no Freeze Frame is currently stored ahead of it)

**Type C Faults**

- Are not emissions-related
- Do not turn on the MIL, but may display a warning on the driver information display or with a separate warning light
- Do not store Freeze Frame
- Are a one-trip fault

**Type D Faults**

- Are not emissions-related
- Don't turn on any lights
- Store a DTC in one trip with a failure

We're about to move on to Parameter Display and Readiness Monitor scan tool functions. But before we do, it's important that you have a good understanding of how the PCM watches individual monitors run, stores DTCs and Freeze Frame, and also controls MIL operation. On the next two pages, in Figures 4-14 and 4-15, you'll find charts describing those concepts.

The charts are designed to give you a simplified review of how A and B type faults are stored, and how the PCM controls the MIL.

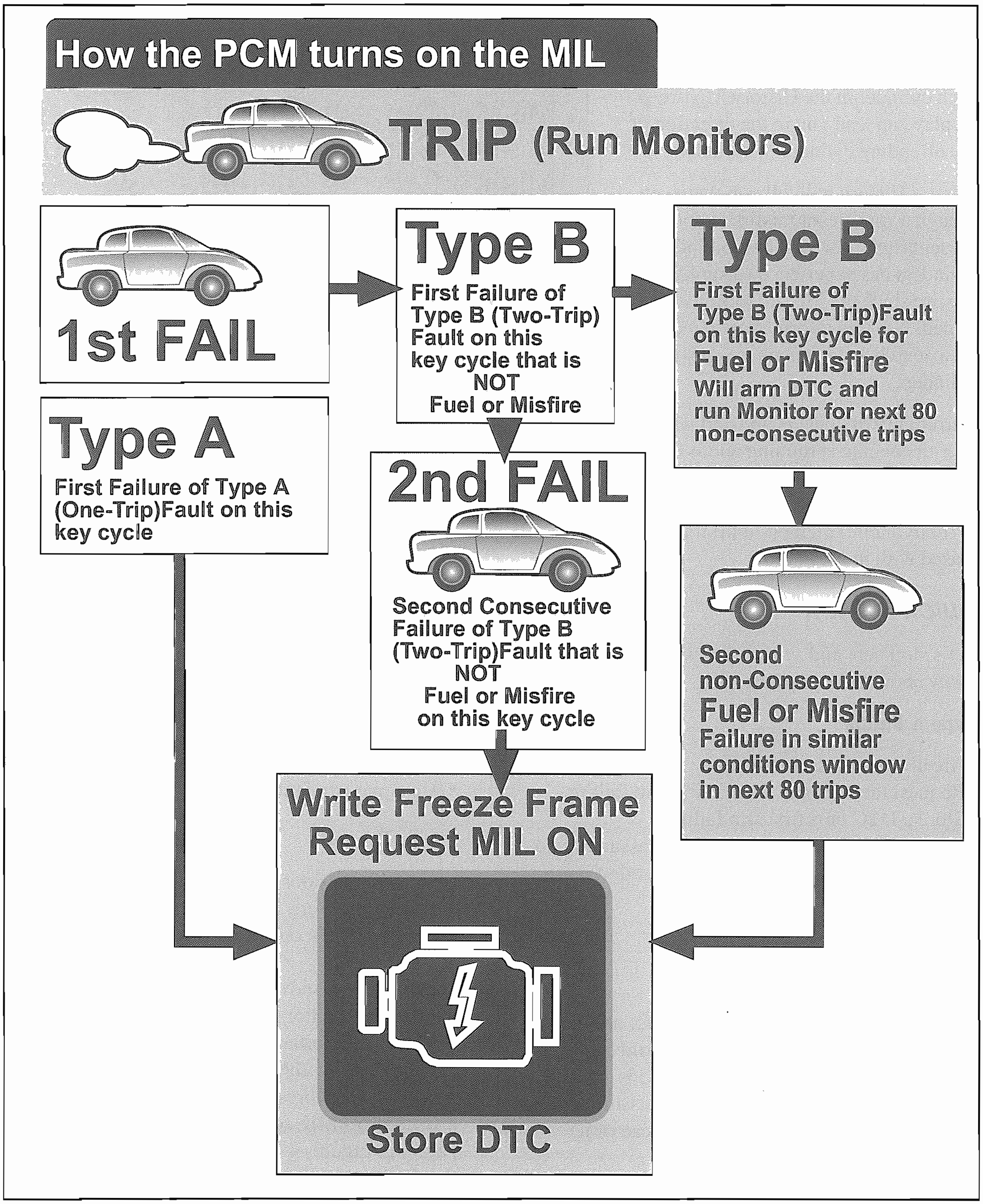



*Fig. 4-14. This chart shows how the PCM requests the MIL ON. Notice that a Type A fault turns the MIL on in only one trip, while a Type B fault must fail on two consecutive trips to turn on the MIL. Also note the difference between type B codes (two-trip) or fuel and misfire and the other type B codes.*

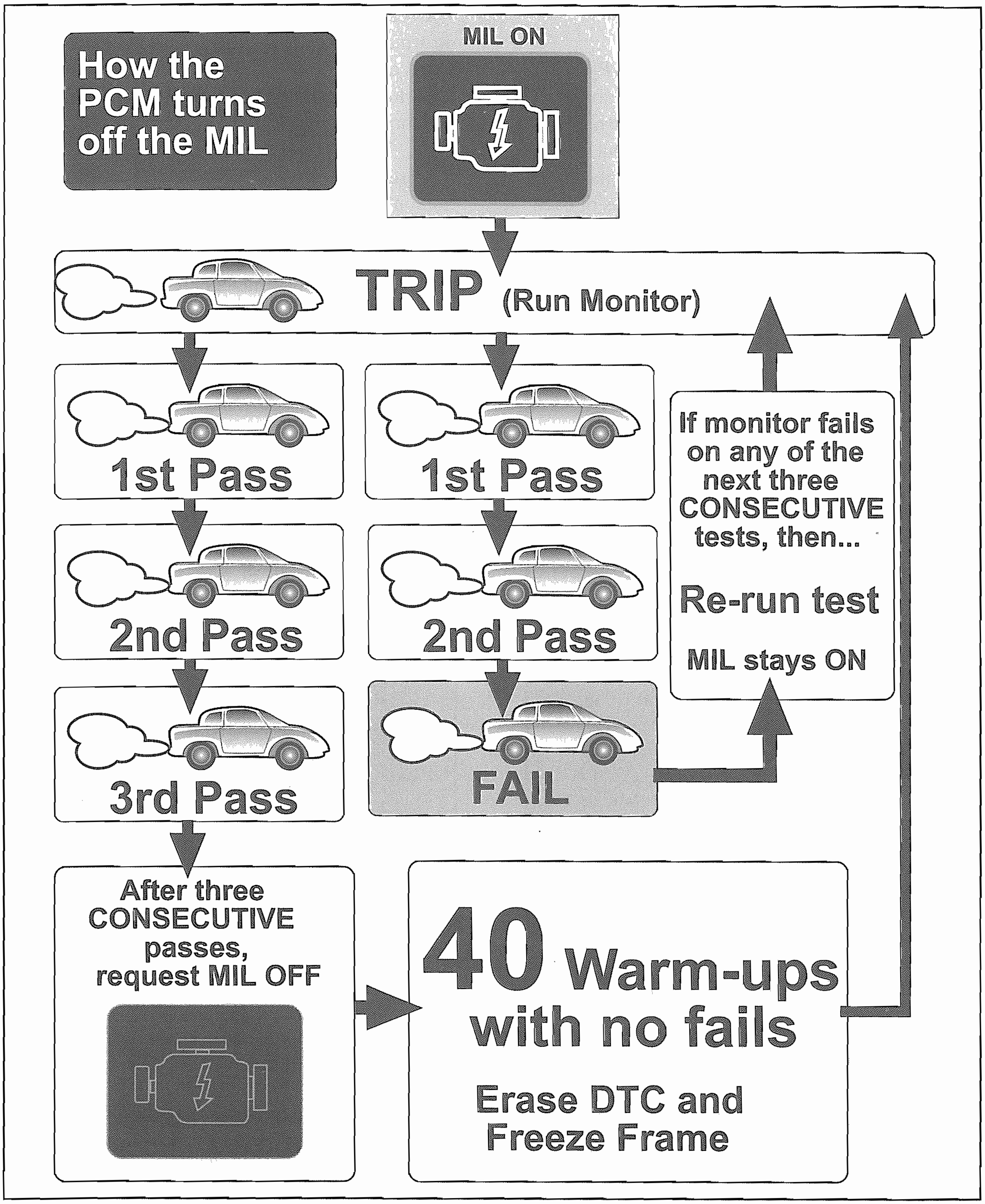



*Fig. 4-15. The PCM controls the MIL. As you look at this chart, remember that three passing trips for fuel and misfire must be recorded with the engine operating in a similar conditions window. If any of the three consecutive tests is incomplete, inconclusive, or fails, before three passing grades are recorded, the monitor must run again.*

### *DATA PARAMETER DISPLAY*

You may have heard someone talk about PIDs if you've been exposed to any information about OBD II. PID is just shorthand for *Parameter Identification*. Each PCM input and output is called a parameter. The scan tool can display exact measurement information about the status of each parameter. Figure 1-6 in Section One of this course book shows a comparison of common serial data parameters for OBD I and OBD II. Figure 4-16 shows four typical PIDs displayed on a scan tool.

**Time Out**

We discussed scan tools in the last section of the course book, and showed how scan interfaces can display different kinds of information about various inputs and outputs. Remember that the amount and type of information you can retrieve from a scan tool will be defined largely by the sophistication of your scan interface, and the actual components used in the vehicle.

The PCM in the OBD II vehicle is capable of gathering and displaying tons of information. In fact, there is probably more information trapped inside the PCM than you may ever need or care to know. For now, we'll start with data gathered with a generic interface and work our way up to enhanced software, since the generic scan tool interface may be all you have available to you during the repairs on some vehicles.

During this discussion, we'll show how to make the best of limited OBD II generic scan data, and later on we'll build on that by telling you what you can do with enhanced scanner software.

So far, we've gathered DTCs and Freeze Frame. But now we need to go to the data display menu in the scan tool and look at the PIDs. In addition to the items listed back in Figure 1-6, you may also see display information about things like MIL status, the number of DTCs stored, and the number of processors installed in the system, among other kinds of information

The scan tool's Data Display menu will provide information about individual sensors and the status of the system, such as closed-loop versus open-loop operation, and corrections to both short and long term fuel trim.

Be careful how you select and evaluate information on the data list. Displaying all the possible data parameters for the vehicle will slow the update of *each individual* parameter. If all the data for all supported parameters are being retrieved, a data traffic jam can result. You can speed the update rate for each parameter by selecting fewer parameters for display at a given time. Removing some parameters from data line highway speeds up data traffic.

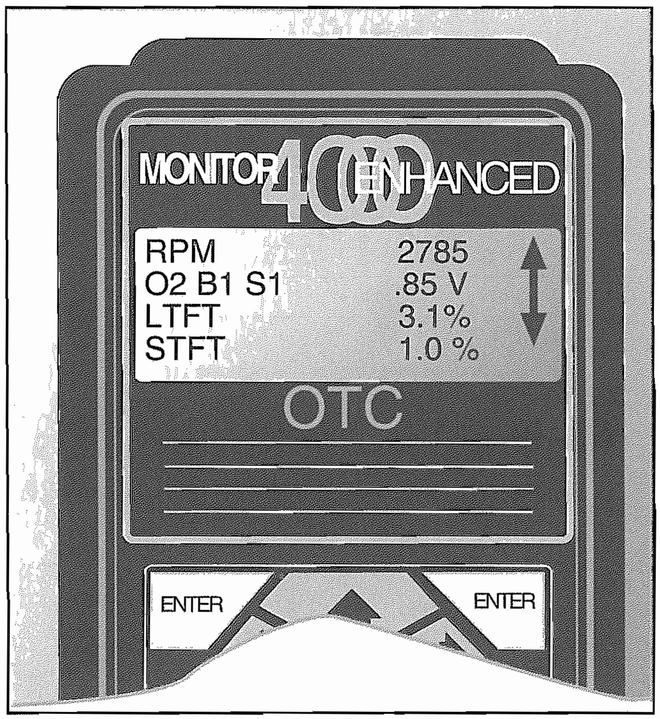



*Fig. 4-16. The data display menu on the scan tool is your window into the input/output status of various components, and can provide valuable information about the system as a whole.*

Start your evaluation of the data parameters by looking for data values that are clearly wrong, like an ECT reading on a warm engine of -40 degree F! Select parameters for viewing that may be directly related to the DTC or DTCs stored in memory. For example, if you have a fuel system code, you may want to take a closer look at STFT and LTFT.

Look for cause and effect relationships. Look to see how STFT responds to changes in TPS, MAP, and $O_2$ sensor inputs. ***This part of our diagnosis is just like the data stream evaluation you used to do in OBD I vehicles with serial data stream.***

Those of you who have never had the luxury of viewing serial data before will obviously enjoy this new window to the inner workings of the system. Techs who have been saddled with the difficulties of no-code, no-data stream diagnosis will now be able to compare several data parameters in the time it takes to hook up the scan tool and scroll through the list.

For those of you who have never used serial data before, we need to offer a few quick cautions about its use:

- **The biggest thing to remember about serial data is that it is the PCM's version of what it *thinks* is actually going on in the system.** PCMs have been known to get fog-brained at times, and they have lied on the witness stand before. Delicate computer circuits can be damaged by mishandling, static discharge, improper battery charging (or battery jumping, especially to a 24 volt source), and high current flow caused by a low-resistance actuator. Computers can lie.

- **Data displayed on the scan tool is several steps removed from raw voltage changes in live circuits.** The PCM must gather raw data and transform it to serial data before it can transmit that data to the scan tool. Then the data must be converted by the scan tool before it can be displayed on the scan tool screen. By definition, there is a delay between an actual event and the parameter display on the scan tool screen. Some scan interfaces are faster than others, but some translation and delay are inevitable.

- **Finally, while OBD II has created some standardization, you will still need access to specific repair data to compare to actual readings.** Sources include factory shop manuals, and aftermarket data bases from various suppliers of repair information. OBD II has not eliminated this final step in any troubleshooting process.

## READINESS STATUS

We need to add another common source of information available through the scan tool. The Readiness Status monitor display lists the monitors supported for a given vehicle. (All OBD II vehicles will monitor Comprehensive Components, Misfire, Fuel, Oxygen sensor, and catalyst operation.)

But there are vehicles with no EGR or Secondary AIR, so they won't have these monitors in the OBD II software. Use the Readiness display to tell you which systems are installed, and whether the installed monitors have run their tests to completion. You should expect your scan interface to provide the following minimum information:

- **The types of monitors installed**
- **The status of those monitors** (Have they run to completion, or haven't they?)
- **How many processors are installed in the vehicle, and which one is currently being viewed?** Vehicles with separate computers for transmission, body control, and sound may actually *share* information from various sensors, so you need to know if the vehicle uses more than one controller.

***The Readiness Status display does not tell us if the monitor or monitors have passed or failed, only whether or not they have run to completion. The Readiness Status display is not an indication of a monitor's pass-fail status. The MIL and DTCs are used to indicate system faults.***

The Readiness Status display does not affect vehicle operation. If fact, it's not necessary for all the monitors to have run completely, except when the display is used at an emission test facility to screen vehicles before an actual emission test.

Displayed information may be used as part of a system evaluation, and to verify certain repairs. The assumption is that if all monitors have run to completion without storing a DTC, then the system is operating properly.

Individual monitor displays are also referred to as ***Flags***. As each monitor runs to completion, the flag changes from an *INCOMPLETE* status to

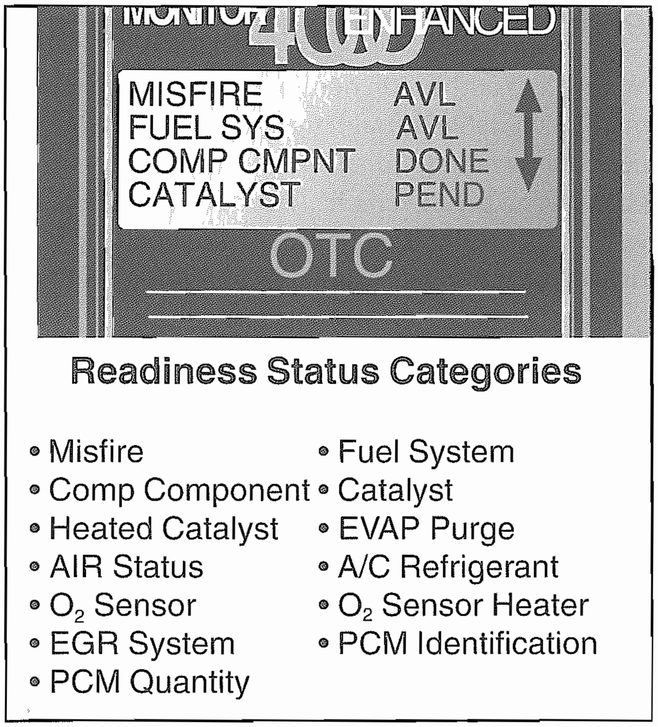



*Fig. 4-17. The scan tool will identify which systems are monitored, and tell you about their current status.*

*DONE*. On some displays, an incomplete will be shown as a *NO*, and a completed monitor will be shown as a *YES*.

Figure 4-17 illustrates a typical screen display showing a list of Readiness Status items. Next to each item, a description of its current status is listed. On this scan tool, if the system is installed on the vehicle, it will be listed as Available (AVL). If that type of monitor is not supported, N/A will be shown. A display of PEND may be seen on some scan tools if the monitor is pending and has not completed and passed. Check the scanner documentation.

Scroll arrows on this scanner's screen display indicate that there are more Readiness Status lines viewable by pushing the UP or Down arrows on the scanner console.

Notice that there are some additional categories listed in Figure 4-17 called PCM Quantity and PCM Identification. Since some vehicles have more than one computer processor, we need to identify which controller data is displayed. Some vehicles have separate modules in separate boxes for engine and transmission control. Others incorporate engine, transmission, and even ABS controllers in a single module. The scan tool should tell you how many processors are installed.

Let's look at a vehicle with separate engine and transmission controllers (Fig. 4-18). Since the engine and the A/T controllers share some inputs, a conflict exists if the one gets the original signal but the other one doesn't. The signal sent by the TPS is a good example of a sensor input commonly shared by both the engine and transmission controllers. It's like identical copies of a letter mailed to two addresses. Sometimes one arrives, while the other gets mangled in handling. If the engine controller thinks the throttle is closed, but the A/T controller sees WOT, a conflict exists.

The scanner should identify this type of problem in a display line labeled PCM Conflict. Resolving conflicts may require backtracking the affected circuit(s) to isolate the cause of the signal conflict, usually a short or open. Compare the signal sent by a sensor to the signals received at the individual processors to find out which one is wrong.

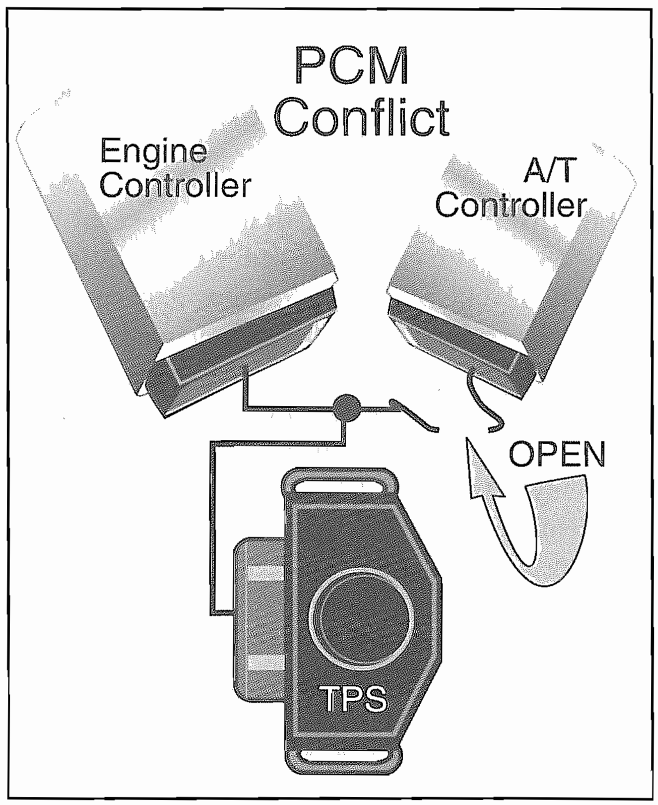



*Fig. 4-18. Just because the TPS is sending out the correct signal doesn't mean it arrives at separate destinations in the same condition. This results in a PCM conflict.*

## TROUBLESHOOTING STEPS

We've thrown around a lot of individual terms and concepts in this section. Perhaps this is a good time to stop and start connecting some of these concepts. The point of this exercise is to fix cars, after all.

You have a vehicle with the MIL on. Or maybe you have a vehicle with a problem that isn't accompanied by a lighted MIL. Where do you start?

> **Time Out**
>
> Since individual techs each have their own diagnostic styles, we won't start telling you how to fix cars. And troubleshooting trees aren't bulletproof, as we all know. We don't want a trouble tree to limit our thought process.
>
> Troubleshooting trees have a tendency to take us down narrow, linear diagnostic paths. Sometimes that's good. But sometimes the fix is just *off* the path, within easy reach, but missed because the trouble tree is too limited. The following diagnostic routine is offered as a guideline, a list of things that ought to be considered during diagnosis of an OBD II vehicle that has the MIL on. Start with this routine, but be ready to improvise, and look at things just off the path from time to time. That way, you can select the best diagnostic sequence from many possible diagnostic choices available to you.
>
> Fortunately, the diagnostic routine we're presenting is not radically different from OBD I diagnostics, except for the fact that you have different scan data to evaluate.

### STEP ONE

Talk to the vehicle owner to determine if there are any driveability problems. Even though OBD II turns on the MIL for emissions, not driveability concerns, a misfire is still a misfire. An improperly installed timing belt is still out of time, and a plugged exhaust is...well, you get the idea.

Since vehicle maintenance will play an increasingly important role with OBD II vehicles, service records and repair history can also save duplication of effort. Poorly maintained vehicles may require basic service as a prerequisite to more involved troubleshooting. In many cases, routine inspection and maintenance procedures will resolve an emissions problem that's setting a DTC. Until and unless you are forced to do otherwise—keep it simple.

Trying to turn off the MIL in an OBD II vehicle that has a bulletproof air filter, a crankcase filled with an oil derivative that now resembles asphalt patch, and worn or leaking secondary ignition components can quickly turn into a needless exercise in futility.

Check the vehicle records to see if any parts have been replaced recently. Many replacement parts will be calibration specific, not only for the engine management system, but also for the OBD II monitoring systems. Installation of the wrong part for a previous concern may be causing the current problem. Vehicle history and input from the customer about the exact nature of the problem are more important than ever during preliminary diagnosis.

### STEP TWO

Perform a thorough inspection of the vehicle. This was important with an OBD I vehicle. It's even more important with an OBD II vehicle.

- **Check fluid levels and the condition of the crankcase oil and coolant.** Fuel-contaminated engine oil can drive borderline fuel correction over the edge. Low coolant or insufficient coolant flow will produce bogus ECT readings that will skew system response in a number of areas.

- **Look at the engine and exhaust.** Are there any disconnected, cracked, or missing vacuum hoses? Is the exhaust intact? False air from an intake leak, or pulse air drawn in by a leaking exhaust will fool the $O_2$ sensor. Are there any fuel leaks, massive engine oil leaks, or signs that the vehicle has undergone major collision repair?

It may seem strange to perform a visual inspection before pulling DTCs, but there's no sense performing brain surgery when the patient has tennis elbow. You may discover obvious problems up front. You may decide that the vehicle ought to be in a landfill somewhere, and doesn't merit closer diagnosis without written approval from the customer and hefty dose of CUF (Cash Up Front).

• **Check the battery condition, charging rate, and voltage drops at the main engine and chassis grounds.** Don't shortcut this part or you may get bitten in the backside. These tests are more important than ever. Both the engine management and OBD II systems must have steady voltage at acceptable levels, and good grounds. It takes less than five minutes to check battery post voltage (Fig. 4-19), charging voltage, and the engine and main chassis grounds. It is the wisest investment of time you can make.

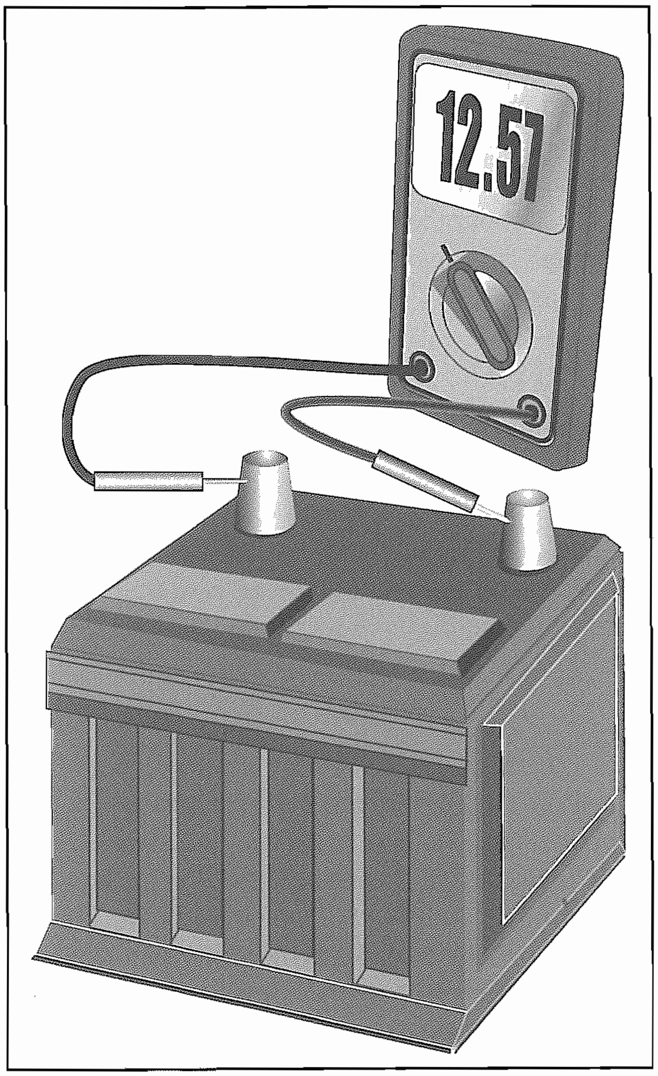



*Fig. 4-19. If an engine runs on gasoline, then a computer runs on electricity. If battery post voltage is too low, stop and find out why.*

Some factory-level technical reference manuals still suggest using an ohmmeter to check grounds. Our clear preference for checking grounds is a voltage drop test, since it tests ground integrity with the circuit loaded.

Most sensor inputs are based on comparisons of voltage and ground reference. If the grounds are bad, signals sent to the PCM will be skewed or totally out of range. The sensor ground, not the sensor, may be the problem.

• **Listen to the engine.** You know a threshing machine when you hear one. Listen for a dead miss or noises from engine mechanical components that are self-destructing from lack of lubrication or excessive wear. Wet the secondary wires and listen for the crackle of secondary spark that's broken loose and run amuck.

### *STEP THREE*

Hook up the scan tool and pull DTCs. Look at Freeze Frame. Look at Data Parameters and try to spot any that are totally whacky or at least bear closer scrutiny based on the exact DTC or DTCs stored in memory. Go to the Readiness Status display and see which monitors have run successfully. Use any and all information provided by your scan tool, and compare it to the information gathered in Steps One and Two.

### *STEP FOUR*

Whether or not you perform this step will depend on several factors:

• **If your preliminary inspection and scan data don't show any clear-cut cause for the DTC(s) or a driveability concern, and you have access to a database that provides Technical Service Bulletins, check to see if there are any TSBs listed for this particular vehicle.** Since OBD II is so software intensive, there will be vehicles that cannot be fixed without reprogramming with the latest software update. This is especially important on vehicles with a MIL-on condition but no driveability concerns. This is a gray area, and hopefully, any cars you see will have had software glitches corrected at the dealership level before you see them.

Sometimes, a software update is needed to keep the MIL from illuminating when it shouldn't. Some original OBD II software was overly-sensitive to certain operating conditions, especially misfire at cold startup. One example is early misfire monitoring strategies on some vehicles that began to run as soon as the engine was started cold. Since all engines experience some misfire when cold, these tests would turn on the MIL for a condition that was normal. Revisions to software commonly address this issue by allowing the engine to warm for a minute or two before the misfire monitor starts.

### *STEP FIVE*

Assuming you don't have a software reprogramming problem, or one that might be corrected with an updated, recalibrated part listed in a TSB, attack the problem as you did with OBD I. (We told you you'd need your old skills and experience with fuel/ignition control systems.)

Zero in on the affected circuit or subsystem, based on the information provided by the DTC. If you're dealing with a specific sensor failure, the monitor will send you to the affected circuit with a specific DTC. Fix sensor failures first.

For individual component DTCs, use the same diagnostic approach you use to evaluate a circuit in an OBD I vehicle. You may need to use your DMM or lab scope and perform voltage, voltage drop, and resistance tests of individual circuits. For misfire problems, use your engine analyzer.

### *STEP SIX*

Verify the repair. This may be the toughest part of any OBD II repair. The method you use to verify that the MIL won't come on again after the repair depends on several factors, the most important being the scan tool software and the types of information it can display.

- **The surest way to verify a repair is to get the PCM to turn off the MIL itself.** This will require three successful trips where the monitor for the affected system runs successfully and records its passing grade in the PCM memory.

- **The second option is to erase DTCs, especially if you are sure you corrected the fault that set the DTC and the vehicle runs properly.** Return the vehicle to the customer and let him do the test drive. You work in the real world, and in the real world, there are only so many hours in a workday. Depending on your shop's location, getting a clear stretch of road to perform a complete Drive Cycle may be difficult or impossible.

For some monitors, like fuel, misfire, and CCM, use the scan tool's continuous monitor display to see if a fault is being detected again after one drive cycle. Since the Drive Cycle will simulate most driving conditions, you have a reasonable chance of duplicating the conditions that were present when a DTC was stored. You can also use Freeze Frame to better duplicate the exact conditions to see if the continuous monitor is still seeing a system fault.

- **The Readiness Status display can also be used with the Non-Continuous monitor display for repair verification.** If a monitor runs to completion, there is no Non-Continuous failure information stored in the PCM, and the MIL isn't coming back on, the condition has been probably been corrected (Fig. 4-20).

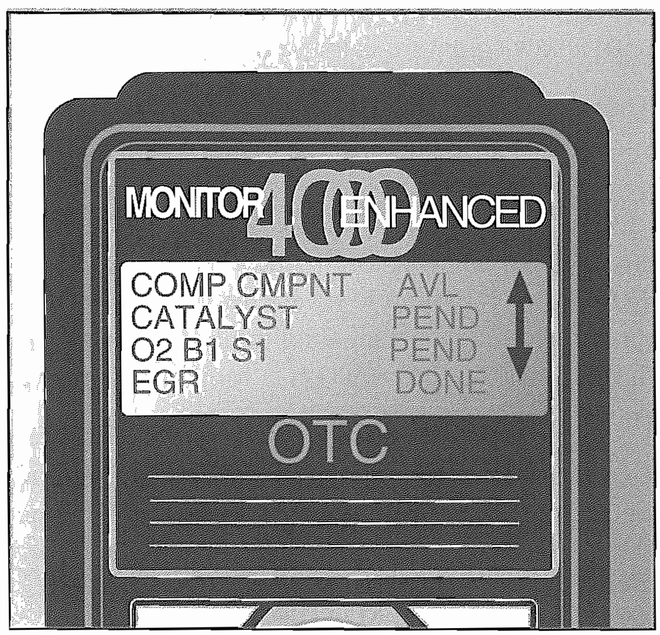



*Fig. 4-20. While the Readiness Status display doesn't indicate a pass or fail of a monitor, it does tell you if the monitor ran to completion. Non-Continuous monitor results will tell you if a problem still exists.*

Be careful how you evaluate information from the Readiness Status display. When you erase DTCs on most OBD II systems, you also reset the Readiness Flags. Some systems reset only the monitor that stored the DTC. Resetting the Readiness flags can be helpful, however. If you see the monitor change from incomplete to complete after a reset and a Drive Cycle, you'll at least know the monitor ran to completion.

The flip side is that you may not be able to get all the monitors to run on a single drive cycle. There are complex subroutines run by the software as part of the enabling criteria. You don't see these because they are buried deep inside the system's diagnostic routine. In addition to the data parameters you can see on the scan tool and specific information about the monitor's enabling criteria, there are things happening in the background—inside the computer strategies—that you won't know about. We'll call these *conditioning factors*.

For instance, most OBD II systems need to learn the *signature* of the crankshaft sensor signal. The signature varies slightly due to variations in crankshaft machining tolerances, and may also be affected by things as simple as replacement of the crankshaft sensor or installation of a new timing cover. The Misfire Monitor may not run at all until a new signature is learned.

There are other ***pretests*** run by the PCM before some monitors can run successfully. Monitors may need to learn normal operating conditions for a specific engine. Engine characteristics vary from engine to engine when new, and change over time. The system may sample several tests from a monitor before it knows what conditions are normal for that engine. This information is sometimes called a *statistical baseline*, or *statistical filter*.

**Erasing DTCs may erase all statistical baseline and conditioning data as well as Freeze Frame.**

Why are we discussing this? For the simple reason that you may not always be able to get the PCM to turn off the MIL, even though you've completed what you *think* are three good trips. And you may not be able to reset all the Readiness Flags in a single drive cycle.

Once again, if you are reasonably sure you've fixed the vehicle, give it back and let the customer drive it. The flags should change from incomplete to complete with normal driving over a few days.

Finally, make sure you turn the ignition OFF as a part of any trip used to verify a repair, especially when you're trying to turn off the MIL by completing three trips that pass the monitor. This is ***extremely*** important. Remember that a trip is a Key-ON, start to run, drive cycle, followed by a Key-OFF. If you drive the car three times, but never shut it off between drives, you won't record three separate trips.

If you do complete three successful trips, the MIL may stay on until the engine is switched OFF and then restarted. While the PCM may have requested the MIL OFF, the command won't be executed until the next start-up.

## MONITOR DISABLERS

To avoid false DTCs, there are several operating conditions that can disable monitors. Aside from missing enabling criteria, ***disablers*** can prevent monitors from running for a number of special conditions, including: high altitude, extremes in engine coolant temperature, and fuel level. Under extreme conditions, the results of the monitor tests may be inaccurate, so the monitor may not run at all, or its test results may be suspended.

***The amount of fuel in the tank may be the one disabler we'll have to deal with most often.***

If the fuel level is *above* a certain level, some monitors like the EVAP monitor may not run at all. Fat chance your getting a car with too much gas, eh? Far too often, we get a car for repair that wouldn't run at all if it weren't for the combustible nature of fumes!

Don't waste your time with a vehicle that has an empty fuel tank. Unless you experience a perverse joy from pumping gas, tell the customer when he calls for an appointment to make sure the tank is ***at least*** half full when he brings the vehicle to you. Low fuel (below about 15 percent of total capacity) can keep a monitor from running at all.

## *MINI QUIZ*

1. A type A fault will turn on the MIL:
   a. For any electrical fault in any computer installed in the vehicle
   b. Only after the fault is seen on two-consecutive trips
   c. As soon as an electrical short or open is seen in an emissions-related component
   d. For all CCM-monitored components that fail a rationality test

2. Look at the following samples from a Freeze Frame data list. Of the following, which one of the following DTCs would you expect to find stored, based on this information?

| | |
|---|---|
| CAL Load | 20% |
| ECT | 360 °F |
| FSS1 | Closed |
| MAP | 18"Hg |
| O2 B1 S1 | .485 V |
| TPS | 30% |
| RPM | 2100 |

   a. P0131 - O2 Sensor B1 S1 Low Voltage
   b. P0134 - O2 Sensor B1 S1 High Voltage
   c. P0112 - ECT Circuit Low Voltage
   d. P0322 - IGN/DIST Circuit No Signal

3. The PCM will turn off the MIL and self-erase a misfire DTC:
   a. After 40 warm-up cycles
   b. When the Misfire Monitor does not detect a repeat of the misfire condition during the next three consecutive trips where the vehicle is operated within 375 RPM and 10% of the load condition stored with the Freeze Frame
   c. If the key is cycled ON and OFF after the misfire is repaired
   d. If the vehicle is driven through one complete Drive Cycle

4. Which of the following is **NOT** true of trips?
   a. They are not all the same
   b. They include a Key-OFF after the vehicle is driven
   c. They will always reset the Readiness Flags after one drive cycle
   d. They are used by the PCM to turn off the MIL when a monitor that set the DTC runs and passes on three consecutive trips

**ANSWERS**
1. c
2. c
3. b
4. c

## SHOP EXERCISES

1. Get an OBD II vehicle and set an ECT code by disconnecting the ECT. See what code is stored. Then erase the DTC and set another by installing a jumper across the terminals of the ECT connector plug.

*Note the exact ECT data displayed on the Freeze Frame for each code and write it down for future reference on a similar vehicle. That way, you'll know the exact data display for the sensor that you can expect to see for a shorted or open ECT circuit on that particular vehicle type.*

2. Go to the parameter display on the scan tool and select all parameters supported by the vehicle. Look carefully at the speed with which the parameters are updated. Then select a single parameter and compare the update rate.

*This exercise shows how to limit the number of displayed parameters to speed the update of the selected parameters. When all parameters are displayed, each parameter update slows.*

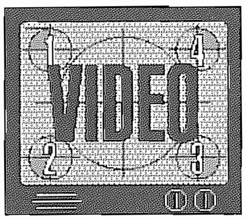
3. Backprobe the TPS signal wire with a high impedance DMM. Go to the parameter display and select all parameters. Compare the voltage change on the DMM to the displayed value on the scanner.

*This exercise allows you to compare live voltage changes at the TPS signal wire to the changes displayed on the scan tool, and also lets you compare TPS signal voltage to the percent-of-throttle opening measurement you'll see in Freeze Frame.*

Notes:

5

# OBD II TROUBLESHOOTING TIPS




Watch video module #5 now.

Way back in Section One of the course book, we tossed a wide lasso over the neck of this OBD II bull to identify him from the rest of the on-board diagnostic herd. In each succeeding section, we've attempted to pull the rope a little tighter, and draw the beast closer so we could view him from different angles. Taming any new technology, especially one as complex and spirited as this one, is not a linear process. That's because there is a lot of bucking and twisting going on as multiple components and monitors interact inside the OBD II monitoring system. We need more than one view, more than one perspective of the animal, or we risk seeing nothing but the bottoms of its hooves as it runs us over.

The OBD II system compares a lot of data—a lot more than OBD I did—all the time. We have to do the same. To fix these vehicles, we need to get inside OBD II's head, and think like it does. And that means thinking *deep*—and *wide*—at the same time.

In this section, we're going to talk about several items that we didn't get to earlier, including specific test procedures that will dovetail with the new DTCs. At the same time, we'll go back to some issues we discussed only in general terms. If we'd gotten bogged down in vehicle specifics and exceptions to rules before understanding the big picture, the exceptions would have confused the issues. Now, however, it's time to yank the rope, tighten the noose, and reel the bull in towards us for a closer look. (Besides, as scary as it may sound, we're starting to understand how it thinks.)

Let's start by making ourselves a brief list of the general types of problems we'll see on an OBD II vehicle. These bear a striking similarity to the problems you see every day:

**Scenario Number One: The vehicle is overworked, under-appreciated, totally neglected, and just plain broke-busted, disgusted.** These are the "project" vehicles that come to you in desperation. Vehicles that won't start at all, that experience intermittent stalling, or suffer from extremely poor performance are nothing new. Just because they have "OBD II" stamped on the underhood sticker doesn't make them any different from any other down-at-the-mouth vehicle, so don't treat them differently.

Use whatever information you can gather from the on-board diagnostic system, and add it to your usual list of tests. Think of the OBD II diagnostic information as one more tool in your trouble-shooting arsenal. OBD II is an inspection and maintenance monitor concerned with emissions, so don't make things overly complicated unless a thorough maintenance and replacement of failed components fail to solve your problems.

**Scenario Number Two: The vehicle in question isn't a basket case, but the MIL is on and it does have some type of driveability complaint.** If the DTC sends you to a failed component, fix the component and verify the repair. Again, keep it simple as long as you can.

If careful examination of the sensor inputs and circuits associated with the DTC won't send you to the root cause for an illuminated MIL, however, remember this:

**Some DTCs will be caused by a failure in a component that is not directly monitored by OBD II.** Sometimes the information sent by a sensor is accurate, even though it's out of range! If the throttle is coked and sticking open, TPS voltage at idle will be wrong. If the intake and exhaust valves are sticking, or the piston rings are worn, a misfire may result. Not all DTCs will be set by components directly associated with the monitoring systems. Don't forget to include the usual suspects like vacuum or exhaust leaks, low fuel level, low fuel volume or pressure, contaminated fuel, improperly adjusted cam or ignition timing, or an engine mechanical problem.

**Scenario Number Three: The vehicle has no driveability concerns at all, but the MIL is on.** We've all seen vehicles before OBD II that ran well, but wouldn't pass an emission test because the catalyst was dead. You can definitely have a MIL-on condition that is not accompanied by a driveability concern.

Since OBD II is an emissions monitor, anything that makes it think the vehicle emissions have gone above acceptable levels will turn on the MIL. A *failing* component can turn on the MIL before it causes a driveability concern.

### *GETTING THE MOST FROM DTC AND PARAMETER DISPLAY INFORMATION*

Let's circle back to the general overview we presented earlier describing how monitors operate. While it's nice to have a feel for how monitors work in general, when we repair vehicles to keep the MIL off we'll need to know exactly which components are installed to repair them.

We'll start with something as simple as a TPS. Figure 5-1 shows a schematic for a typical three-wire throttle position sensor.

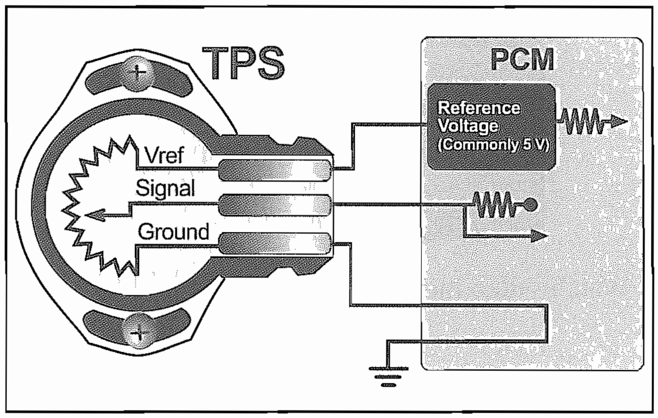



*Fig. 5-1. Before we diagnose a circuit, we need to know how it's wired.*

Let's say we have a DTC **P0123**, defined as **TP Sensor Circuit High Voltage**. Even though the code is an SAE-defined DTC, each manufacturer may have a slightly different specification for the maximum allowable voltage and the test conditions used by the monitor.

Figure 5-2 shows the DTC, the Enabling Criteria, and the conditions necessary to set a code P0123 from three separate manufacturers. Note that the test conditions and test specifications for this particular code are very similar, but not identical. Some manufacturers may choose not to use the P0123 code at all, and rely on a less specific DTC like P0120 (TP Circuit Malfunction) to indicate either an open or a short in the TP sensor circuit.

That's why we need to refer to manufacturer specifications to make sure we know the exact test conditions and the types of codes that may, or may not be available. TP sensor test conditions are fairly consistent due to the wide use of a three-

| DTC & Description | | Enabling Criteria and Test Conditions to set DTC |
|---|---|---|
| **P0123** TP sensor Circuit High Input | 1994-96 Ford Cars, Trucks, and Vans | KOEO, KOER, the PCM detects a TPS input of more than 4.60 volts (92.3% throttle opening). |
| **P0123** TP sensor Circuit High Input | 1996 Isuzu | Key on and then test started. PCM detected a TPS signal of more than 4.88 volts for 0.78 second over a 1.5 second time period. |
| **P0123** TP sensor Circuit High Input | 1995-96 GM- S/T Truck Body Vin W 1996 G, L, M, C/K, Truck Body: Vins L, M, R, and W | Engine running, the PCM detected a TPS input of more than 4.9 volts |
| | Note: The GM example shown above is one of several different specifications used for defining test conditions and enabling criteria for various GM vehicles. Specifications for the P0123 DTC are very similar but not identical for other GM applications. | |

*Fig. 5-2. Common components like the TPS will have similar test conditions and enabling criteria, although they won't be identical from manufacturer to manufacturer, or even from model to model.*

wire sensor with a 5 volt reference voltage. But some sensors are unique, and found on only one make or model. These require an exact knowledge of the sensor's design and its operating range.

Once we use the DTC to determine how a component has failed, we need to perform a mental diagnosis of the circuit before uncoiling our first test lead. This is no different from the tests we've always performed on individual components and circuits. **Many OBD II component DTCs will be caused by the same types of simple electrical circuit faults and momentary sensor glitches that we have all seen on pre-OBD II vehicles.**

In addition to tests for proper charging and reference voltages, we need to pay special attention to ground side problems. Sensor grounds will have an obvious and immediate effect on sensor signal voltage when they skew signal voltage to higher-than-normal levels. The main PCM grounds are also cause for concern since they are used by the PCM to regulate reference voltage. Without a good ground, reference voltage will also be inaccurate and cause erroneous signal voltage.

Keep these simple warnings in mind. If the accuracy of sensor inputs is the building block for monitor operation, and the quality of these signals is dependent on accurate voltage and ground connections, then any repair of a component DTC must include tests for both stable, accurate voltage and good grounds. We can't stress this too strongly.

Let's move on to other common sensor inputs, and variations of monitoring strategies.

## TEMPERATURE SENSORS

Temperature sensor inputs are used by the PCM as a part of its fuel calculations. The ECT is a particularly high priority input since it is used to adjust fuel delivery rates in both open and closed loop.

Intake Air and Engine Coolant Sensors will set P, or Powertrain, codes. The OBD II monitor may be used to store faults for any or all of the following:

- **High sensor voltage**
- **Low sensor voltage**
- **A circuit fault**
- **High or low temperature readings**
- **System takes too long to reach normal operating temperature**

## TEMPERATURE SENSOR DESIGNS

Most temperature sensors are two-wire, NTC, or Negative Temperature Coefficient type sensors. Unlike three-wire analog sensors, they do not have any moving parts, and cause a change in signal voltage as their internal resistance changes.

NTC resistance is high when cold and decreases as they warm. Traditional, single-range resistance-type sensors have used a single voltage divider circuit inside the PCM to compare the changing resistance of the ECT to a fixed resistance value (Fig. 5-3). Signal voltage from a single-range sensor can be monitored with a voltmeter at the PCM to look for radical changes in the sensor input caused by shorts or opens.

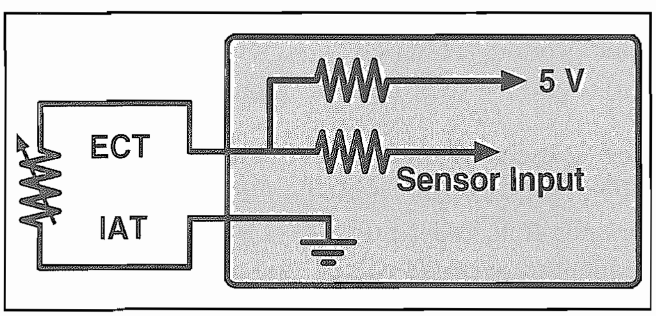



*Fig. 5-3. Many ECT circuits still use a single voltage divider to compare reference voltage to signal voltage.*

If there's a problem with single-range sensors, it's that they measure temperature changes over such a wide range, that they aren't extremely accurate at higher temperatures where more accuracy is required. It's like the difference between a yard stick and a micrometer. You don't measure lumber with a micrometer, and you wouldn't dream of checking piston pin diameters with a yardstick or tape measure.

To allow greater ECT accuracy when the engine is warm, some manufacturers use a dual-range sensor. At a temperature specified by the manufacturer, a transistor in the PCM switches to a reference voltage circuit with a lower resistor. This lets the PCM measure changes in engine temperature at a higher resolution (Fig. 5-4).

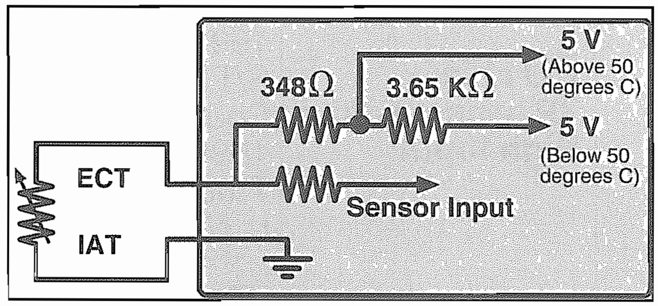



*Fig. 5-4. Some systems use a dual range voltage divider that is switched by the PCM at a specified temperature.*

Be careful how you test this type sensor circuit. While the NTC resistor will change its resistance gradually as the engine warms, there will be a shift in signal voltage when the PCM switches resolution. Figure 5-5 shows how signal voltage changes when this occurs. If you're looking at signal voltage, you may mistake the voltage shift for a sensor or sensor circuit failure.

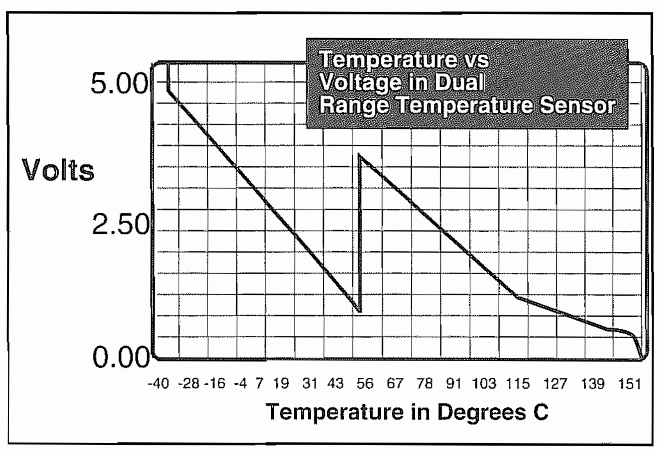



*Figure 5-5. The shift in ECT or IAT signal voltage is a normal occurrence on dual range sensor circuits.*

Your scan tool is probably a better choice for testing this type circuit for intermittents than a DMM for a couple of reasons:

• **The normal shift in signal voltage won't appear on the scan tool in a properly operating circuit.** As soon as the PCM shifts to a higher resolution it automatically makes the "mental" adjustment to the different range. The ECT or IAT temperature displayed on the scan tool should reflect the true coolant or air temperature.

• **The normal operation of the Comprehensive Component Monitor should detect any glitches in the circuit that would indicate an abnormal voltage shift.** If a temperature sensor is failing high or low, it should be accompanied by a DTC. This takes us full circle to using the DTC and scan tool parameter display to diagnose the circuit based on the DTC description.

There's another important aspect of ECT operation that needs to be mentioned. Some ECT monitors keep track of how long it takes to reach normal operating temperature so the system can enter closed loop (Fig. 5-6). Timers are like a stop watch in the PCM used to measure the time it takes to enter closed loop. Some systems set a code if the monitor doesn't see the fuel system enter closed loop within a specified time.

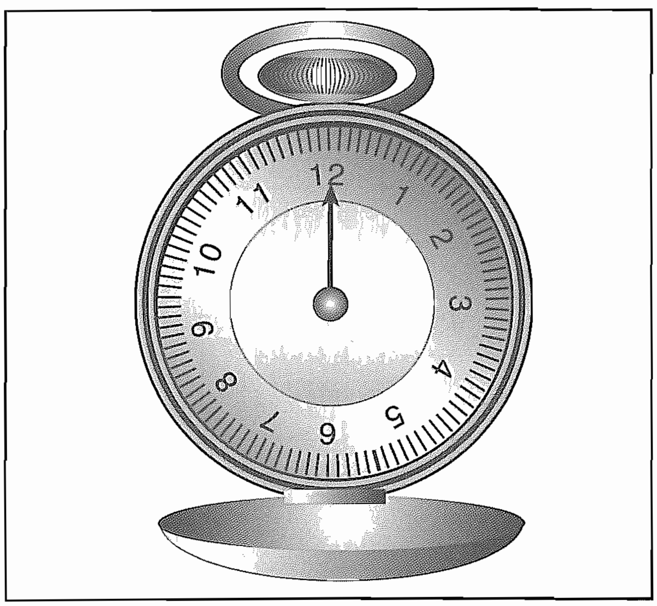



*Fig. 5-6. Timers may be used by any number of monitors to measure elapsed time since start up and the time it takes for the system to enter closed loop.*

Know how the manufacturer defines the sensor test. One may list test conditions for a **P0125** (Insufficient Coolant Temperature for Closed Loop Operation) as follows:

• **No codes stored in PCM; ECT temperature sensor input is less than 140 degrees F with the IAT temperature of 68 degrees F; a vehicle speed of 5 mph is detected; and the engine has been running for more than 363 seconds.**

However, another manufacturer lists the following test conditions for the same P0125 DTC:

• **No PCM codes stored; engine running over 1500 RPM; vehicle speed over 5 mph; startup IAT over 32 degrees F at startup; ECT between -5 and 84 degrees F; and engine does not reach a temperature of 84 degrees F within 2 minutes after startup.**

Same DTC, but each test is defined differently based on the design of the engine and cooling system. The condition of the cooling system has a lot to do with ECT operation. Sticking thermostats, low coolant levels, or air trapped in the cooling system can all delay the system from reaching *target* operating temperature in a specified time.

Keep the following in mind as you diagnose temperature sensor range or performance problems:

• **Determine the enabling criteria for the test.** Compare the test conditions to actual conditions on the parameter display to verify temperature sensor operation.

• **Make a direct measurement of coolant temperature at the ECT sensor with a temperature probe.** The measurement should match the value for the ECT shown on the parameter display.

• **Compare ECT and IAT resistance to a reference chart that shows sensor resistance at a given temperature.**

• **Some manufacturers will provide specifications for the scan tool ECT display with the ECT plug open-circuited or disconnected and jumpered.** For example, one manufacturer shows an ECT data display of -22 degrees F with the ECT disconnected, and a reading of 266 degrees F with the ECT connector pins jumpered. This is a good quick test for opens and shorts.

### *LOAD SENSORS*

Use the same types of tests with three-wire sensors that you'd use with two-wire sensors when diagnosing opens and shorts in the sensor or sensor circuit. We've already talked about TPS shorts and opens, and the same problems can affect three-wire MAP and Mass Air Flow (MAF) sensors. (Four-wire analog MAF sensors work similarly, but have two grounds.)

MAP, BARO, and Mass Air Flow sensor DTCs can also set for an improper signal range that can't be traced directly to a short or open. MAP sensors are actually a bit easier to diagnose in many cases, since we can compare actual manifold pressure to the displayed value for the MAP sensor shown on the scanner. Charts from manufacturers like the one shown in Figure 5-7 can be used for reference. These give an exact MAP pressure-to-voltage conversion for comparison to actual readings.

MAF sensors can be tougher to diagnose, since we don't commonly have any way to take a direct measurement of intake air mass for comparison to the sensor signal.

We're presented with a whole new set of monitored inputs when we diagnose a MAF *range-performance* problem. The CCM is looking at several inputs to test MAF. These commonly include engine speed, throttle position, ECT, and IAT. Based on what it knows about the design of the engine and these inputs, the PCM *expects* to see a certain air flow through the meter. When it doesn't, it sets a code.

Some manufacturers publish specs for mass air meters showing how anticipated mass air flow should correspond to these parameters. The specifications aren't always easy to come by, however, and sometimes appear in a plus-or-minus range that is large enough to leave you wondering if the MAF really is bad. In many cases, published specifications are not accurate enough for you to grade the sensor on a pass-fail basis. Worse still, the spec may be given only for idle conditions. This isn't much help on a vehicle that idles properly but experiences lean surge or hesitation when the throttle is opened.

What do you do when you have a situation like this? One good option is to see how changes in air flow affect fuel correction. That's what the MAF sensor is supposed to be doing. A MAF sensor that seems normal at idle may not be responding quickly enough when the throttle is opened and the cylinders get a big gulp of air. In fact, some MAF sensors may be slightly rich at idle but lean the mixture when the throttle is opened. This is often caused by MAF contamination.

• **Look at the BARO reading KOEO.** See if it matches the voltage specification for your altitude.

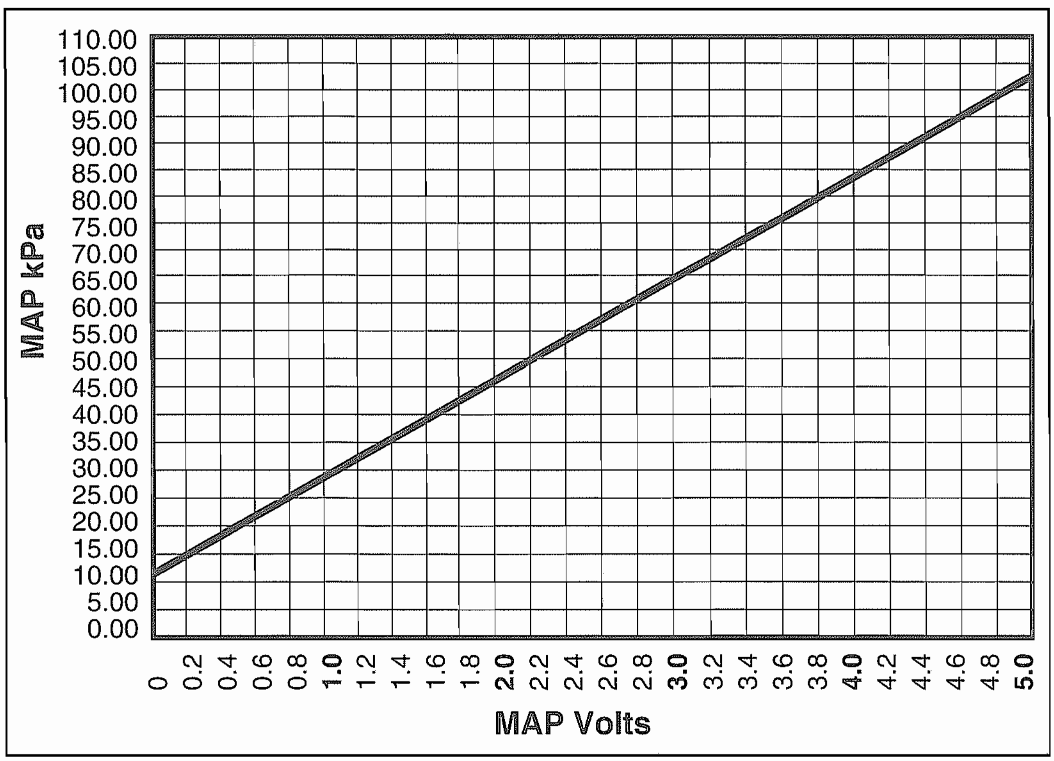



*Fig. 5-7. Charts like this one allow us to make accurate comparisons of actual manifold pressure readings to the voltage signal from an analog MAP sensor.*

An out of range BARO reading from a system that uses MAF voltage at KOEO to measure BARO is a likely indication that the MAP sensor is skewed.

- **Watch the injector pulse width and STFT at different throttle openings. Test during both gradual and rapid throttle changes.** The system should be increasing pulse width, and the enrichment should be noticeable as an increase in STFT. If the increase is very slight when the throttle is opened rapidly, or if the STFT is low or shows a negative reading, the sensor is probably not accurate. (These tests assume that there are no other engine mechanical or vacuum leaks that would affect the readings.)

- **Watch STFT at WOT.** Under WOT conditions, most systems go to open loop. When this happens, fuel calculations ignore oxygen sensor inputs. If a system goes lean at WOT, the MAF sensor is probably out to lunch.

- **On many vehicles, disconnecting the MAF sensor will throw the system into a fail-safe mode of operation.** The PCM will substitute TPS and engine speed inputs to calculate enrichment. If the problem disappears with the MAF disconnected, it's obvious that the engine is mechanically sound, and that it is capable of acceleration when it gets the proper enrichment.

We'd be remiss if we didn't emphasize the importance of eliminating false air leaks between the MAF sensor and throttle. Cracked duct work and loose duct clamps are still a *chronic* cause for lean mixtures caused by out-of-range MAF signals that are not the fault of the MAF sensor itself.

## *FUEL TRIM BY THE NUMBERS*

Both STFT and LTFT are monitored to ensure that the system doesn't exceed the system's ability to maintain closed loop.

A lean mixture results in an increase in fuel trim, indicated as a *positive* percentage, while rich conditions cause a decrease in fuel trim. You may be accustomed to looking at fuel trim expressed in a numeric range from 0-255, with the midpoint at 128 representing no fuel correction at all. STFT numbers will normally fluctuate within a narrow range around 128 in closed loop.

With OBD II, however, we're presented with a new display that indicates fuel trim as a *percentage*. To make the conversion from the 0-255 range to a percentage, use the chart shown in Figure 5-8.

Even without the chart, we can still convert numeric fuel trim readings to a percentage with a couple of simple formulas: **Multiply the percent-**

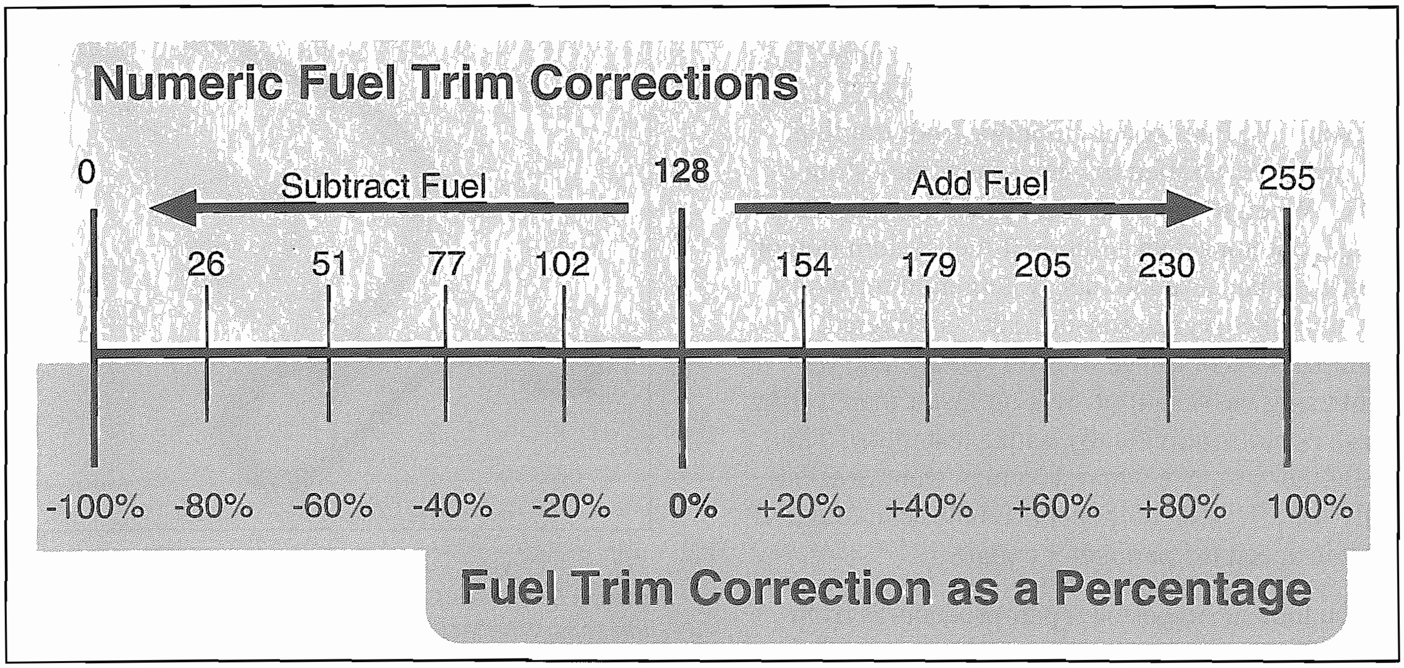



*Fig. 5-8. Conversions between fuel trim expressed as a number or a percentage are not difficult.*

**age fuel correction shown on the scan tool by 128 and add it to 128.**

**Example:** A +20 percent fuel trim equals a fuel-added number of:

(128 x 20%) + 128 =
26 + 128 = **154**

To convert a decreased numeric fuel trim reading to a percentage: **Multiply the percentage fuel correction on the scan tool by 128 and subtract it from 128.**

**Example:** A -20 percent fuel trim equals a fuel-subtracted number of:

128 - (128 x 20%) =
128 - 26 = **102**

### *FUEL TRIM STRATEGIES*

The PCM uses a combined STFT and LTFT analysis to set a DTC. When the STFT goes beyond its limit, LTFT will be affected. If the STFT correction continues, LTFT will experience a major change. When the combined STFT and LTFT correction exceed a specified level, a DTC will be stored. The maximum allowable combined fuel adjustment will vary slightly by manufacturer, but you can expect to see the little light come on when combined corrections are greater than 25-35 percent on most vehicles.

Fuel correction problems will often be caused by a component failure that sets a separate DTC. This prevents the Fuel system monitor from running. For instance, a failed oxygen sensor may store a DTC. When it does, the fuel system may be out of range, but not set an additional fuel system rich or lean code because the fuel system monitor won't run until the oxygen sensor fault is corrected. Comparisons of oxygen sensor voltage and fuel trim using the scan tool are a lot faster than testing these circuits individually with a test meter. This is another instance where you may want to select only the affected components on the scan tool display to speed the parameter update.

If you look at suggested repair procedures from most manufacturers, you'll see a list of common causes for fuel system DTCs that include all the things you currently check for excessively rich or lean fuel mixtures. These are especially important when you don't have a component DTC for a signal input that would affect fuel correction, such as a MAF, MAP, ECT, or oxygen sensor.

Fuel system faults are a great example of how components not directly monitored by the OBD II system can cause a fault. Include the following in a diagnosis:

- **Leaking, plugged injectors**
- **Plugged fuel filters**
- **Weak fuel pumps and faulty pressure regulators**
- **Fuel line obstructions**
- **False air leaks between the MAF sensor and throttle body that reduce air flow through the MAF sensor**
- **High levels of fuel dilution in the crankcase**
- **Faulty PCV valves or plumbing**
- **Plugged air filters or other obstructions in the air intake duct work**
- **Worn engine components**
- **Improperly adjusted valve or ignition timing**
- **A restricted exhaust**
- **Exhaust or vacuum leaks that provide extra oxygen to the $O_2$ sensor or sensors (Fig. 5-9).**

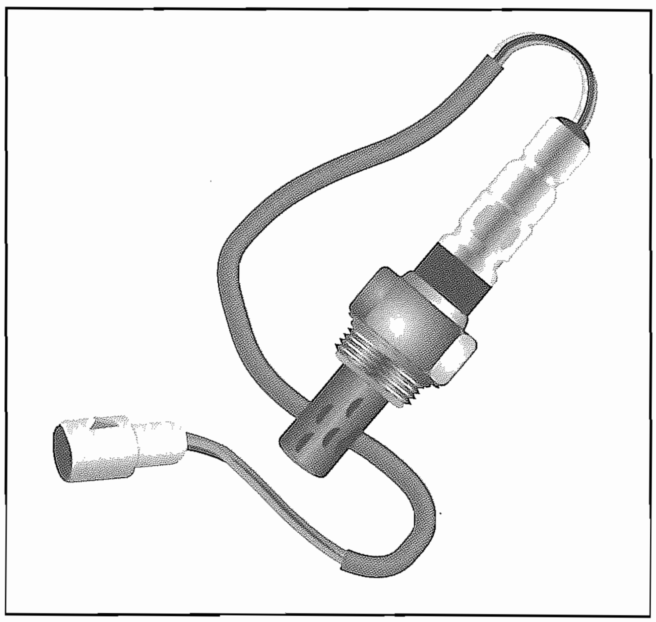


*Fig. 5-9. Oxygen sensors don't care where the oxygen comes from, so intake leaks and exhaust leaks ahead of the sensor that act like a small pulse air system will cause the sensor to provide inaccurate information about true exhaust gas oxygen content.*

We're sure there are probably other things that might be included in this list. The important thing to remember here is that none of the potential problems listed above is *directly monitored* by the OBD II system on most cars. Their operation is inferred, and the failure of one or more may be detected only as a radical shift in fuel correction.

**Common *component* failures that will cause fuel correction problems and can set their own DTC include any and all sensors directly involved in fuel control: temperatures sensors, oxygen sensors, load sensing devices (MAP or MAF), and fuel or ignition component failures.**

There are several other things about OBD II monitoring to keep in mind:

- **Fuel system test strategies are fairly complex.** The list of enabling criteria for the fuel trim monitor to run is usually pretty long, and very specific. Here's an example of a list of enabling criteria for the fuel system monitor on one vehicle:

- **BARO above 70 kPa**
- **ECT between 140 and 239 degrees F**
- **IAT between -13 and 239 degrees F**
- **Engine speed between 750-3400 rpm**
- **EVAP purge OFF**
- **Fuel trim is within a specified range**
- **MAP input more than 28 kPa**
- **Throttle position less than 80 percent**
- **Vehicle speed sensor below 70 mph**
- **All the conditions above are present for at least 4 seconds**

Enabling criteria affect how you verify repairs. If you think you've tracked down and repaired the cause for the fuel correction problem, look at alternate ways to verify your repair short of driving the vehicle all day hoping the PCM will turn off the light. Use Freeze Frame data stored with the fuel system DTC to determine when the fault occurred. Store that information and look up the exact enabling criteria. Then erase the code.

Reset the fuel trim learned values to their base settings. Use the manufacturer's recommendations for doing this. Some will allow a fuel trim reset using the scan tool.

Then drive the vehicle in a similar conditions window as an assistant monitors STFT and $O_2$ sensor inputs on the parameter display (Fig. 5-10). If the system maintains closed loop and STFT stays within an acceptable range, you'll have a good indication that the problem is really corrected. The STFT and LTFT parameter displays are a clear indicator of the system's response to various inputs.

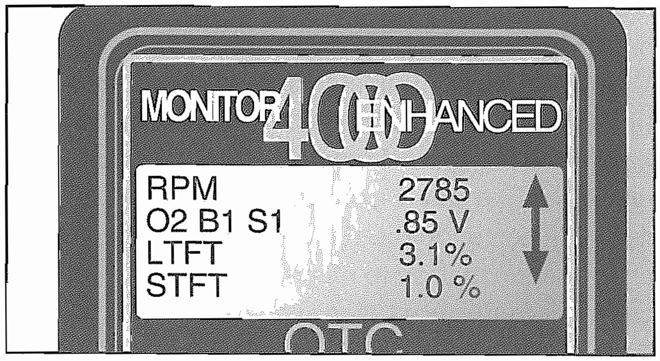



*Fig. 5-10. Watching the system adjust fuel delivery rates is a fast way to make sure that all inputs used to calculated fuel trim are working properly.*

**Time Out**

That scan tool is looking a lot more important as we go along, isn't it. That's because we're starting to combine traditional troubleshooting techniques with the specific repair data available only through the scanner. The use of a good scan tool interface and exact specifications for individual components and enabling criteria is the only way to perform OBD II repairs in a reasonable amount of time.

- Without a DTC identification, we don't know where to start when the MIL is on
- Without knowledge of enabling criteria, we don't know how to make the monitor run
- Without Freeze Frame, we can't duplicate the conditions present when the code set
- Without the data parameter display, we're stuck with testing individual components using multiple meters and test connections to see if we have correct system response after a repair

An acquaintance suggested recently, that without access to the correct repair data and a good scan tool interface, the next logical addition to the traditional trouble tree would be a bottom line that says "Replace with known good car."

### *OXYGEN SENSOR IDENTIFICATION*

All OBD II vehicles have at least two, and sometimes more than two, oxygen sensors. The number of oxygen sensors and their exact locations in the vehicle vary both by manufacturer and system design within a vehicle line.

When you dial up the parameter display on your scan tool to look at individual oxygen sensors, you need to know which $O_2$ sensor you're looking at. While we can't anticipate all possible combinations that might be used, we've included illustrations showing typical oxygen sensor placements on both inline and V-configuration engines (Fig. 5-12). When in doubt, refer to manufacturer specific documentation to identify the number and location of multiple oxygen sensors.

- **In our figure, the A-type sensor configuration is fairly straightforward, since there is only one cylinder bank to monitor.** This setup is common on inline engines, whether they're mounted longitudinally or transversely.
- **With the B-types, the two cylinder banks in a V-type engine require additional sensors.** These engines are mounted longitudinally, and may have single or dual exhausts. They may even have dual catalytic converters. Compare the difference in sensor placement and the numbering used to identify the sensors.
- **Finally, the C-type shows how transversely mounted V-type engines may use an individual upstream sensor for each bank, or simply mount a single sensor in the downpipe connecting the banks to the catalyst.** Other configurations are possible, but these types are representative of common oxygen sensor placement options.

There's a reason to identify the number and exact location of the oxygen sensors. Upstream sensors are supposed to work just as they always did, and should be tested for speed, range, and reflexes. Downstream sensors work the same as the upstream sensors but, due to their placement, they should output signal voltage in a much narrower voltage range and with far less frequency than their upstream partners when the catalyst is working properly. If you mistake a downstream $O_2$ sensor for an upstream sensor, you may think it's bad, due to its slow response and narrow voltage range.

There's another reason to know where the sensors are located. In our illustration, note that our type-B configuration places an individual sensor in each cylinder bank, instead of using a shared sensor for both banks. Watching both sensors lets you compare sensor activity and STFT in each bank. This is useful when you're trying to isolate the exact location of a leaking or plugged injector, or any other problem that might affect only one bank.

Figure 5-11 shows us a special concern when we test four-wire sensors. Traditionally, single-wire $O_2$ sensors grounded through the sensor body. Now, however, four-wire sensors have a separate sensor and heater ground connections, provided through a circuit inside the PCM. If you disconnect this type of sensor to check its signal voltage, follow the manufacturer's recommendations for providing an external ground with a jumper wire, or the sensor won't work properly (Fig. 5-11).

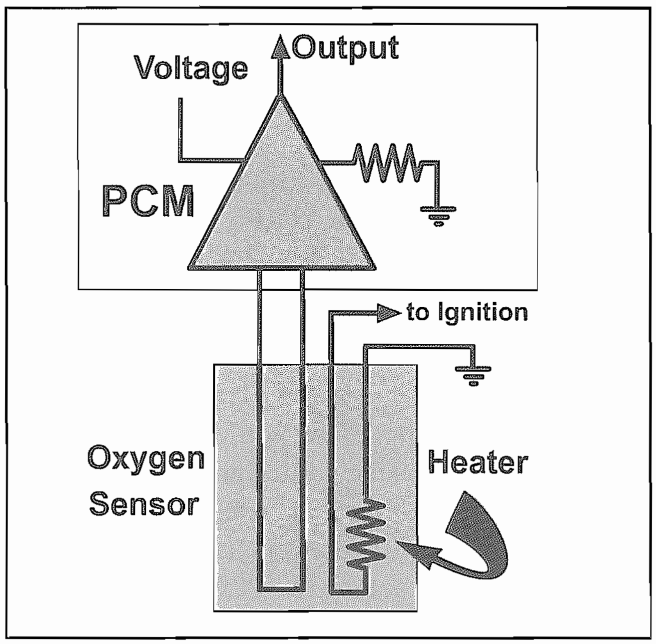
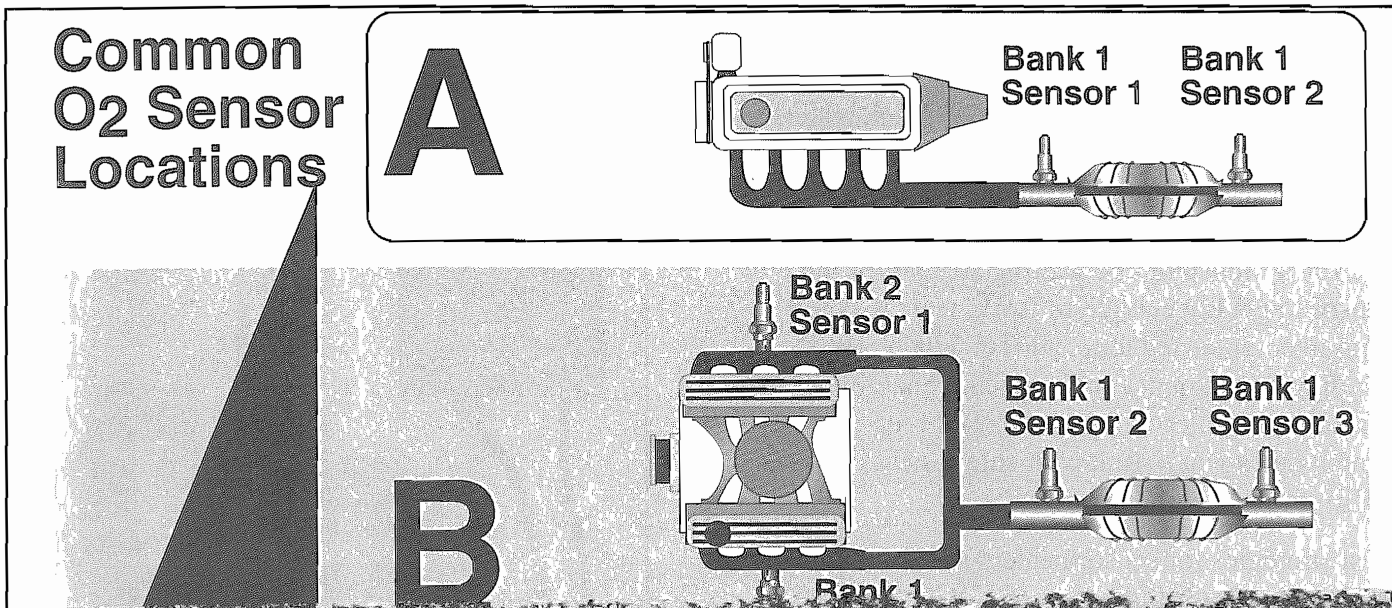



*Fig. 5-11. Not all oxygen sensors ground through the sensor body. Always follow recommended test procedures for checking disconnected oxygen sensors.*

Some PC-based scan interfaces provide a graphic showing a picture of the sensor locations. A database in the program lists the number and exact location of the sensors used in a specific model.


Common
$O_2$ Sensor
Locations
A
Bank 1
Sensor 1
Bank 1
Sensor 2
B
Bank 2
Sensor 1
Bank 1
Sensor 2
Bank 1
Sensor 3

## OXYGEN SENSOR HEATERS

The use of heated oxygen sensors enables the OBD II system to enter closed loop much faster than it did when sensors were heated only by the exhaust gas. It better! Remember that the stop-watch is running every time the vehicle is started, and the system can't be waiting around for the sensor to get hot enough to work. If it takes too long to enter closed loop, a DTC will be set. Depending on ambient conditions and enabling criteria, some vehicles will get to closed loop in the time it takes you to find your sunglasses, change radio stations, and buckle up.

Test strategies for sensor heaters are not identical by any means. Some monitors will look at the time it takes for the $O_2$ sensor to start working after a cold start as an indication that the heater is working. Others will use a separate voltage comparison circuit inside the PCM to check the heater and its circuit. Chrysler actually uses a heater and oxygen sensor test that works *after* the engine is shut down (a handy thing to know when you can't get the $O_2$ sensor heater Readiness Flag to set after two hours of driving).

The easiest way to test a heater, assuming your scan tool supports it, is to use an enhanced parameter display and actually look at the voltage at each individual heater to tell if it's working.

Most manufacturers provide resistance specifications for the $O_2$ sensor heater element (Fig. 5-13). Identify the correct terminals for the heater in the $O_2$ sensor connector plug. Use an ohmmeter to make sure the heater resistor is within specs. Figure 5-11 also reminds us that many $O_2$ heaters are powered as soon as the ignition is switched on, normally through a fuse. Check the hot and ground sides of all $O_2$ sensor heater circuits, especially when the heater resistance is within specs but still fails the monitor test.

## THE CATALYST MONITOR

Catalyst monitoring strategies are complex. The list of enabling criteria is long, and the catalyst monitor may take multiple samples of $O_2$ sensor voltages before issuing a passing or failing grade.

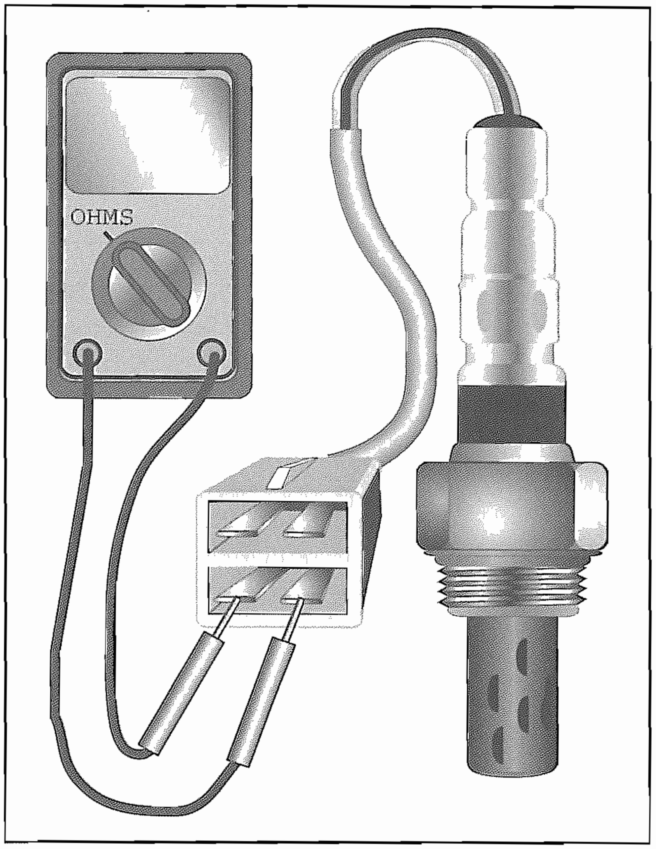



*Fig. 5-13. A simple resistance test should be enough to identify a failed heater element in the oxygen sensor.*

Basically, the enabling criteria will establish that the catalyst is hot enough for testing using various inputs, including: closed loop operation, temperature, engine speed and load, and the length of time the engine has been running (time-in-run).

When the enabling criteria are met, the monitor compares upstream $O_2$ sensor activity to downstream sensor activity. When the downstream sensor starts switching as actively as the upstream sensor (or close to it), the PCM decides that the catalyst is no longer storing oxygen. It may then repeat its tests in a different, enhanced mode to verify the test results before setting a code.

This is all pretty software-intensive. You won't even know what's going on behind the scenes. In some cases, the PCM will actually control fuel delivery at a fixed level to provide an additional constant for the test. The rest of the system has to be working properly for the monitor to run. Catalyst enabling criteria are complicated, and almost any DTC will keep the monitor from running. Fix component DTCs first!

### *EGR MONITORS*

The EGR test strategy section of the OBD II monitor cookbook is a long one. Always refer to exact enabling criteria and determine the type of EGR system used before you troubleshoot.

The rather wide range of EGR test strategies is a function of the bewildering number of EGR designs. Getting an EGR to work over the long haul is a royal pain in the neck for just about everybody, from OEM to repair tech. Just about the time a manufacturer figures out how to both control and monitor EGR, the valve gets coked up and sticks. Many manufacturers have had chronic, and not unexpected, problems with coking, not only of the EGR valve itself, but of connecting pipes and internal passages in the intake manifold.

Due to the very nature of the EGR's lousy working environment, it can easily end up stuck, stuck out of position, or slow to respond. Even if the valve opens and closes properly, there's no guarantee that the passage it controls is not gummed shut itself.

To ensure continued EGR operation, manufacturers have designed various methods for monitoring exhaust flow. While NOx emissions are not measured directly, the monitoring system knows that every time the EGR is opened, there should be a change in manifold pressure, oxygen sensor response, and fuel trim.

The EGR monitor is usually an intrusive test as a result. One common EGR test opens the EGR valve under conditions when it would normally be closed, and then looks at MAP and/or STFT changes at the same time. This stimulus-response type of test results in a noticeable change in engine speed on some vehicles, a potentially annoying, but normal characteristic. (Add consumer education to the list of OBD II concerns.)

The EGR monitor usually takes several samples and averages them to prevent misdiagnosis. The EGR test may run during closed-throttle deceleration on some vehicles and during steady-state cruise on others. The enable criteria list for the vehicle should identify when the test runs.

In addition to dynamic testing of EGR effects on combustion, systems run KOEO tests of any electrical components used in the EGR system. These are similar to the CCM electrical tests of inputs such as the ECT and TPS signals. (This is important to remember. Not all electrical signal and command circuits are monitored by the CCM. Some, like EGR, EVAP, and $O_2$ sensor circuits, have their own separate component monitors.)

Some codes for component tests of EGR electrical controls will set manufacturer-specific codes, not SAE codes. Fords, for instance, can set a P1400 or P1401 code for an electrical failure of its Differential Pressure Feedback sensor (DPFE). The codes are manufacturer-specific, because the valve is unique to Fords. Ford uses a similar approach to compare the ON/OFF status of the EGR EVR control solenoid (Engine Vacuum Regulator Solenoid Circuit) to an electrical feedback signal from the EGR valve position sensor on sonic EGR systems (Fig. 5-14).

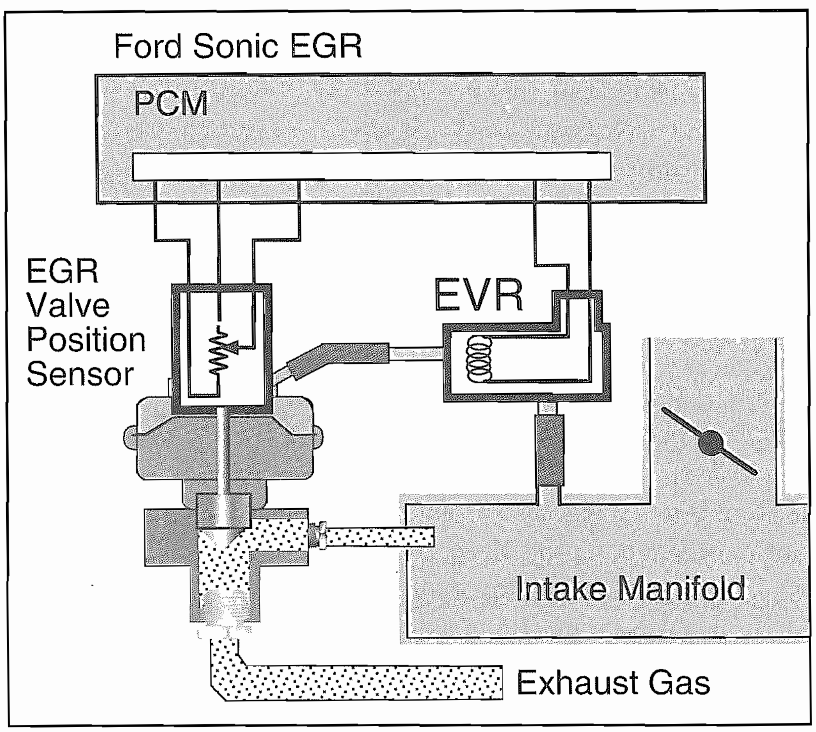



*Fig. 5-14. When the Ford PCM sends a command to the EVR to open the vacuum passage to the EGR valve, it wants a confirmation from the EGR position sensor that the valve actually moved.*

Another approach is to incorporate a motor-driven pintle and position sensor into a single housing. The PCM "steps" the valve open and closed and the position sensor sends back a confirmation. A GM example, known as a linear EGR, is shown in Figure 5-15.

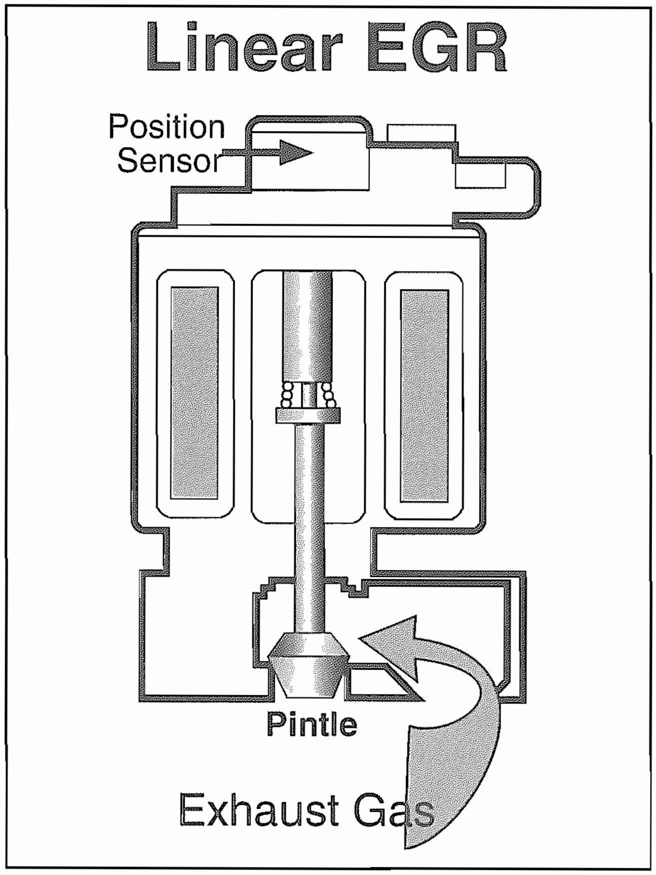



*Fig. 5-15. A linear EGR combines a motor-driven pintle and position sensor in a single housing.*

Some OEMs have chosen to combine more traditional vacuum control of the EGR valve with an EGR temperature sensor. Toyota does this, placing a resistive temperature sensor in the EGR passage between the EGR valve and intake manifold. It works like an ECT, only here it verifies the temperature change in the EGR-to-intake manifold passage as the EGR opens and closes (Fig. 5-16).

Our purpose here isn't to discuss all possible combinations of EGR valve operation, but to show that many of the old EGR system designs are still used. This is a course on OBD II, not the various system designs used by various manufacturers. That means that we need to compare our understanding of how those systems work to the OBD II monitoring strategy used to test them.

Test options should match the EGR design. Once again, the scan tool can be a big help here. If the system allows you to use actuator tests to exercise the EGR, then by all means do so. Even if the vehicle doesn't support actuator tests, we can always look at Freeze Frame, duplicate driving conditions when insufficient EGR flow was detected, and compare EGR operation under similar conditions to changes in STFT on the data display.

If there is no change in STFT as the valve opens and closes, we have a good indication that the EGR or its connecting passage between the EGR valve and intake are plugged. This sure beats tearing the vehicle apart hoping we'll find the problem.

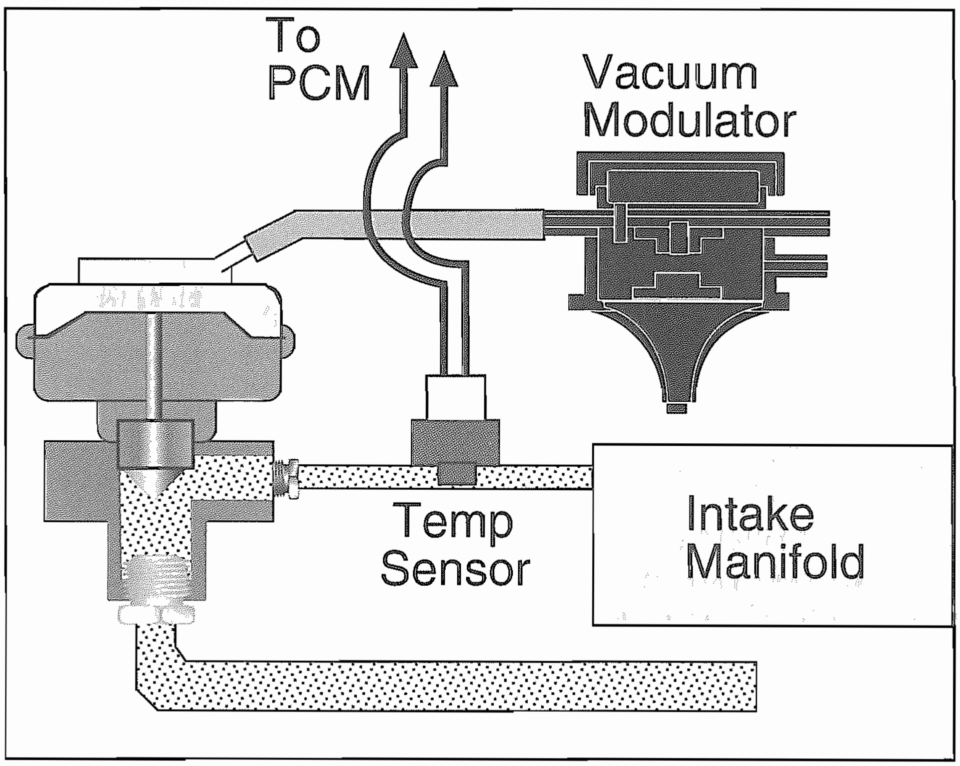



*Fig. 5-16. By measuring the temperature of the exhaust passage between the EGR and intake manifold, the monitor can tell if the EGR valve opened.*

**Time Out**

We suggested earlier that the monitoring system in an OBD II vehicle is similar to the tests we perform in the shop every day to check a component or subsystem. We've all opened an EGR valve manually to see if an engine stalls at idle. We change something and look for a response.

Unfortunately, the OEM can't do that to test EGR. Can you imagine a warning display on the dash that says "The engine is about to stall at a stop light as the EGR is opened?" Right.

That's why many of the tests run by the monitoring system are performed under operating conditions that will create the *smallest possible change* in engine performance.

To duplicate the test, we need to duplicate the *test conditions* any way we can, and watch the same things the monitor watches, to see if they respond.

This is all a big circle. OBD II performs diagnostic tests all the time. They are automatic. When something fails a test, we will have to duplicate those conditions, look for clues, repair the fault, and then repeat the test to make sure the next time the monitor runs it gets a passing grade. Round and round we go.

## *EVAP MONITORING*

There was some monitoring of the fuel recovery components on select pre-OBD II systems, but most of it was limited to simple electrical tests of purge control solenoids to see if they were working. EVAP test strategies are a lot tougher with OBD II, including purge flow rate and EVAP system leak tests. Leaks can be tough to isolate due to the amount of plumbing and various sensors and control valves used in the EVAP system. This is something we didn't have to worry about before OBD II.

The EVAP monitoring system may include a wide range of solenoids, switches, and pressure sensors. The EVAP monitor tests for purge flow and leaks by isolating different parts of the EVAP system while measuring changes in pressure.

It may surprise you to know that EVAP leak detection testers and fuel cap adapters have been available for some time now. Due to the uneven implementation of I/M testing, they haven't exactly been big sellers, to put it mildly. That's because leaks in fuel vapor recovery systems don't normally create driveability problems unless the leak starts letting water or other contaminants into the fuel system.

**OBD II EVAP systems can set codes for:**
- Any electrical fault in a solenoid, pressure sensor, or pressure switch
- Low, or insufficient canister purge flow
- Leaks in the system caused by a missing or poorly sealing fuel cap, cracked or broken hoses, or any other rupture in the fuel recovery system, including the fuel tank

**Common problems with EVAP monitors include:**
- Loose or missing gas caps (check this first)
- Plugged filters in vacuum vent solenoids or a plugged breather filter in the charcoal canister
- Loose connecting hoses
- Kinked connecting hoses
- Electrical faults in switches, solenoids, and related circuits
- Reversed hose connections
- Fuel composition or operating conditions that cause abnormally high fuel vapor pressure

**Common enabling criteria for the EVAP monitor purge and pressure tests include any or all of the following:**
- Proper fuel level in the tank (normally between 15 and 85 percent of tank capacity)
- BARO range
- ECT and IAT values
- MAP
- RPM
- TPS

Clearly, there's more to the OBD II EVAP monitor than simple electrical tests of the purge solenoid. Long lengths of connecting hoses, many of which are located beneath the vehicle where they're more exposed to road hazards, make leak detection an important part of OBD II EVAP diagnosis.

### *EVAP CODES*

Here's a sample list of SAE-defined EVAP DTCs:

**P0440 - EVAP system fault**
**P0442 - Small leak in EVAP system**
**P0443 - EVAP Control Solenoid Fault**
**P0446 - EVAP Canister Vent Solenoid Fault**
**P0452 - Fuel Tank Pressure sensor Low**
**P0453 - Fuel Tank Pressure sensor High**
**P0455 - Large leak in EVAP system**

**Manufacturer-defined codes will also be used on certain vehicles and systems, some of which are designed as a diagnostic aid.** These P14XX codes will apply to specific component failures. They may also be stored after a single trip to indicate a failure that was detected, but has not turned on the MIL yet. As always, use the DTCs to isolate your test area.

### *TESTING FOR EVAP LEAKS*

Before we start talking about EVAP system diagnosis, let's establish a couple of safety rules:

> **Safety Caution Number One:** Since we haven't been spending as much time testing vapor recovery systems for leaks in the past, it's easy to get wrapped up in the diagnosis and forget how combustible fuel vapor is until it's too late. Please exercise extreme caution. **No smoking, no sparks.** Under certain conditions, static discharge can also ignite these volatile vapors, so a grounding strap is a worthwhile ounce of prevention.

> **Safety Caution Number Two:** Never overpressurize any fuel recovery system by blowing shop air into a vapor line or filler neck. In addition to potential damage to the system and its components, the blast of high-pressure air increases the risk of combustion. Always refer to exact manufacturer's specifications before pressurizing any system.

Leaks in the EVAP system aren't much different from leaks in any other sealed system. We currently apply pressure to cooling systems to look for leaks, or evacuate an air conditioning system to see if it holds vacuum. These are the same strategies used by the EVAP monitor leak detection test.

Whether the system uses a small vehicle-mounted pressure pump to pressurize the system, or relies on engine vacuum to pull EVAP pressure below atmospheric pressure, the principle is the same—create a pressure differential in the EVAP system by applying positive or negative pressure. Then measure the time it takes for the pressure differential to equalize, and compare it to specifications.

The pressure differential we create between the EVAP system and the atmospheric pressure surrounding it ***is much smaller*** than it is with cooling or refrigerant system testing. **One pound** of pressure is plenty for test purposes.

One low-pressure test device, the ***slack tube tester***, has been available for years. It consists of a U-shaped tube filled with mercury, and has a small hand pressure pump attached to it. If we remove the canister vapor line and pressurize the line with the hand pump, we create a pressure differential between the vapor line and atmospheric pressure. As we apply pressure, the mercury level in one leg of the U-shaped tube will rise as the other falls by an equal amount (Fig. 5-17).

If there's a leak in the system, the two mercury levels will equalize. Some manufacturers will give exact specifications for the time it takes for the pressure to equalize. If you do detect a leak with this type tester, apply pressure with the hand pump and use soapy water to find the leak.

This approach is accurate, but may be tedious. And finding the exact location of a small leak with soapy water may be all but impossible at inaccessible hose connections on some vehicles.

Dedicated EVAP testers are also available from several sources that combine various gas cap and hose fitting adapters to allow direct measurements of purge flow rates. EVAP test sets may also include regulators and ultrasound leak detectors.

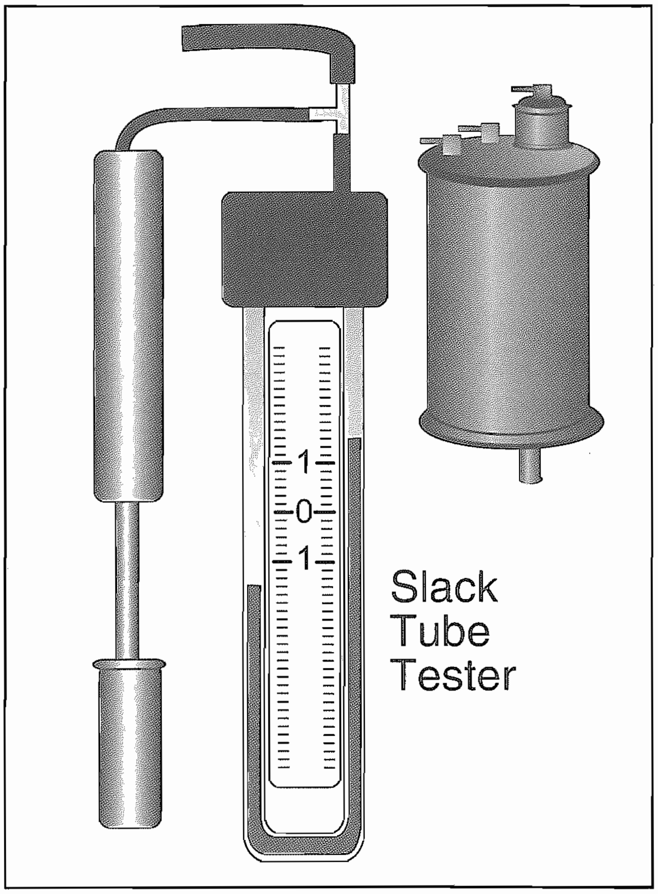



*Fig. 5-17. A slack tube tester can be used to check for leaks by comparing test pressure to atmospheric pressure*

The pressure regulators in these kits let you create a small pressure in the system with an inert gas, like nitrogen. The ultrasound leak detector is then used to locate the leak. **Never put more than one pound of pressure in any fuel tank/EVAP system to test it using an inert gas!**

Gas tank fill neck adapters that allow you to pressurize the system with an inert gas may also be used with one caution—they test everything but the gas cap! Since the cap is an integral part of the EVAP sealing system, pressure check the gas cap separately when this type of test is used.

Some OBD II vehicles have a test port with a Schraeder valve, similar to the test port for the air conditioning system. Look for a tag attached to the valve to identify it and warn you about the maximum allowable test pressure. If the vehicle has such a port, we suggest you use it, since the gas cap remains in place during the test, and is automatically checked with the rest of the system.

If you have a Vacutec machine, the manufacturer, EMI-TECH, has a separate test adapter that lets you connect the machine directly to the test port. The Vacutec works at one pound of pressure, and you can look for smoke to pinpoint leaks.

When used according to instructions, dedicated EVAP test equipment can prevent dangerous overpressurization of the fuel system during tests. Like scan tools, the availability of a dedicated diagnostic leak station with test port and fuel cap adapters becomes one more test option to help pinpoint the exact cause for a DTC (Fig. 5-18).

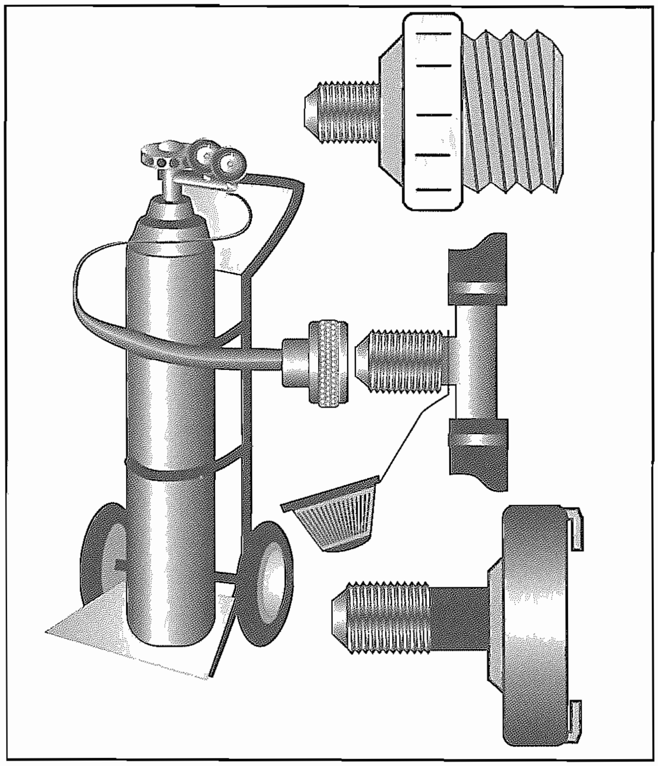


*Fig. 5-18. A test cart with an inert gas bottle and test adapters is available from several sources to make EVAP pressure test hookups faster.*

- **Pressure test specifications may be given in inches of water, not inches of mercury.** This is a more accurate scale of measurement, since 26 inches of water is equal to one psi. Always match a manufacturer's exact test specifications to actual system performance when performing EVAP pressure tests.

- **Some manufacturer-recommended EVAP test procedures require you to alternately open and close vacuum switching and vent solenoids with a scan tool during EVAP leak testing.**

### *A SAMPLE EVAP SYSTEM*

Figure 5-19 shows an EVAP system with controls and sensors commonly used by the EVAP monitor to test for system leaks. The fuel tank is fitted with a pressure sensor (although not all vehicles have one), and uses the fuel level sensor to determine the amount of fuel in the tank. If the fuel level is too high or too low, the test will not run. Common figures for min/max tank thresholds are 15 and 85 percent of capacity. *This is extremely important when you're trying to set a readiness flag. If the fuel level is too low or too high, the monitor won't run. Always check enabling criteria for the vehicle.*

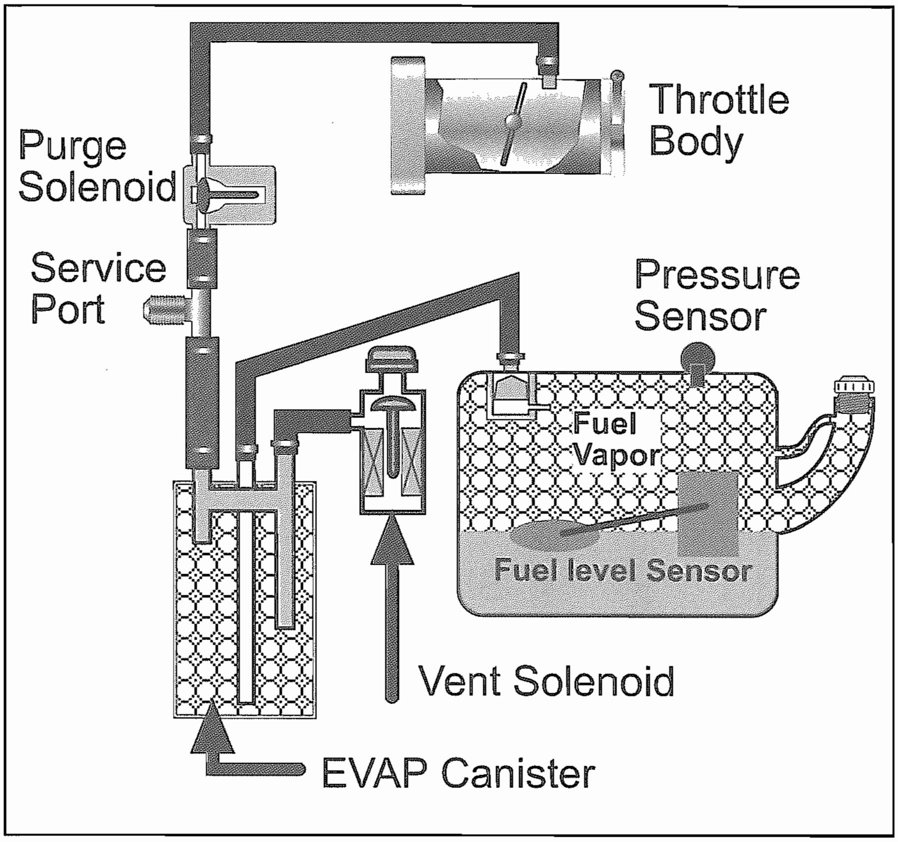



*Fig. 5-19. An EVAP component and hose routing diagram is as important to diagnosing EVAP DTCs as a wiring diagram is to electrical problems.*

Make sure the fuel level sender is the correct one for the vehicle. Changes have already been made in some fuel sender designs and applications since OBD II was introduced. Differences in calibration and design may make the sender from one model year incompatible with a similar vehicle system from a different model year or VIN range.

In our sample system, the PCM runs several tests:

• **KOEO, the system should not detect any pressure or vacuum in the system.** The fuel tank pressure sensor provides this information. If there is pressure or vacuum in the tank, the PCM suspects that there is a blockage in the vent path between the tank and the rest of the system.
• **KOER the system looks for vacuum in the tank with the vent solenoid open during purge.** Vacuum above a certain level indicates a restriction in the vent lines or system. A plugged vent filter could also cause this type of problem.
• **A vacuum test is performed when the vent solenoid is closed during purge.** This time, however, the monitor wants to see an *increase* in vacuum as an indication that the vacuum vent valve is closing and sealing properly.

• **If the vacuum test passes, a leak test follows.** Both the vent and purge solenoids are closed to see if the system can maintain the vacuum created in the previous test for a specified time.

• **The purge solenoid may also be tested for leaks.** KOER, the vacuum and purge solenoids are both closed. If the purge solenoid is sealing properly, there shouldn't be an increase in tank vacuum. If vacuum does increase, tank pressure will fall. This indicates that the purge valve is leaking and allowing manifold vacuum to reach the tank.

• **To determine canister fuel saturation levels, the system will look for changes in oxygen sensor voltage and STFT during purge.**

Please look at the diagram on this page, and compare each of the common tests listed here to the components shown. Our sample system is just that—one example of how EVAP system components can be arranged, and common tests that can be performed by the EVAP monitor.

### *ORVR*

Onboard Refueling Vapor Recovery is separate from EVAP, but is also responsible for controlling HC vapor loss. Phased into production, staring in 1998, this system is designed to limit the amount of fuel vapor that can escape to the atmosphere during refueling. Figure 5-20 shows two typical samples of how the fuel tank and filler neck modifications make this system work.

• **Fuel vapors that used to escape the atmosphere during refueling are captured and stored in a charcoal canister.** Expect the ORVR canister to be slightly larger than those on vehicles without ORVR. The canister may get warm to the touch as fuel vapor concentrations rise during refueling. This is due to chemical action, and is normal.

• **The diameter of the fill pipe is smaller than before.** The smaller diameter helps keep the tube filled with liquid during refueling. With the pipe filled with liquid, it's more difficult for vapors to be forced back up the fill tube to the atmosphere. Some fill pipes use a pipe-within-a-pipe double-wall construction. A check valve between the double walls allows fuel vapor to be recirculated back to the tank through the outer cavity during refueling.

• **Some systems also use an external vent between the tank and fill neck that sends excess fuel vapor back to the fill neck.** This prevents over-saturation of the canister with fuel vapor as tank pressure rises during fueling.

• **A check valve in the fill neck acts as an anti-spit-back valve to keep fuel from backing up and coming out of the fill neck during refueling.** This makes siphoning fuel very difficult, since the siphon hose may get trapped by the valve after it's inserted, and refuse to come back out. (That's assuming you have the perseverance to force it in there in the first place.) You may be asked to surgically remove a length of garden hose from a fill neck as a result.

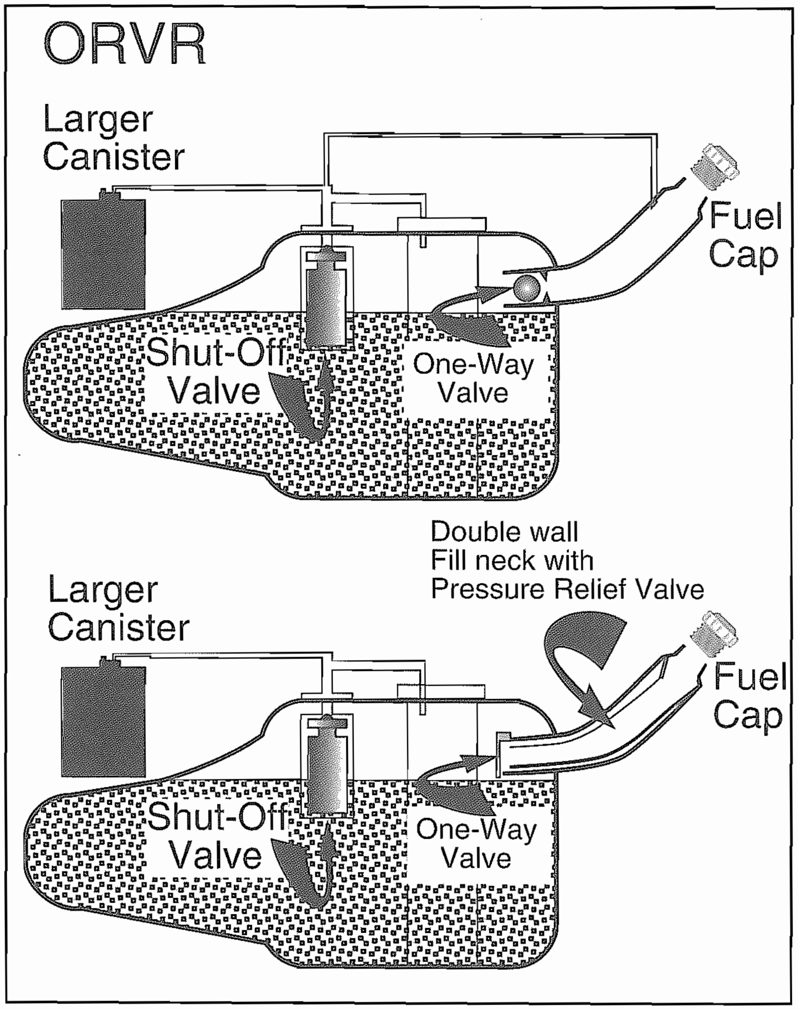



*Fig. 5-20. The ORVR sytem is designed to capture fuel vapors that were previously vented to the atmosphere.*

• **A shut-off valve in the tank will close the vent when the tank reaches a certain level.** This prevents over-filling of the tank, and may double as a safety measure during a vehicle roll-over following an accident. It is also designed to keep liquid fuel from entering the canister.

• **Tell your customers to shut off the engine during refueling.** Fueling the vehicle with the engine running may make it hard to fill. If the EVAP monitor happens to be running during refueling, the higher than normal vapor pressure in the system may cause the EVAP monitor to store a code.

• **On vehicles that do not have a drain plug installed in the tank, make sure you check the manufacturer's recommendations for draining the tank whenever you need to perform repairs to the tank or replace an in-tank fuel pump.**

### COMMON EVAP CONCERNS

When confronted with an EVAP DTC:

- **Fix all component DTCs first.** Failed sensors or solenoids and related wiring faults must be repaired before other testing.

- **If the system detects a leak, check the gas cap.** Make sure it's properly installed. Dealers are seeing a lot of these vehicles with gas caps that are not properly tightened. Some of the caps are a little tricky, and require more force to close them completely. Make sure the correct cap is installed.

- **If you're trying to run a monitor to set a readiness flag, refer to exact enabling criteria for the EVAP monitor for that vehicle.** Make sure the tank isn't above or below the fuel level specified in the EVAP monitor enabling criteria.

- **Check the filters in the canister and any vent solenoids to see if they are plugged.** This is especially important when the monitor opens the vent solenoid and the system still pulls a vacuum.

- **If the EVAP system has a service port, use it.** This tests the gas cap as a part of the system and reduce the dangers of fuel vapor.

- **When you're trying to locate a leak, look at the system schematic first!** Compare the definition of the DTC to the schematic and locate the part of the EVAP system that's leaking or obstructed. This is a lot easier than checking the *entire* system. Divide the system into parts. Isolate a part of the system most likely to cause the DTC and test it separately.

- **If the scan tool interface allows you to send commands to the control solenoids, exercise them.** You can always simulate test conditions manually, but why bother if you don't have to? If a PCM command is ignored by a vent or purge solenoid, use a DMM to test the component/circuit.

- **Make sure the correct components are installed in the vehicle.** Improperly calibrated replacement parts and mismatched salvage yard transplants will make repairs impossible. Make sure all connecting hoses are open, properly routed to the correct ports, and clamped tightly.

### BATTERY DISCONNECTS

When the power is removed from the PCM for a long enough time, data stored in the PCM Keep-Alive Memory will be lost. This will include long term fuel correction values and any other adaptations the system has stored in memory. Sometimes you inherit a vehicle in this condition as the result of a dead battery, or when the PCM is disconnected from the vehicle for any reason.

A manufacturer may actually recommend what we'll call a "Master Re-learn" in some cases. Some PCM designs will go into what GM refers to as "Quick Learn" if they lose all learned values. The PCM will respond by using an accelerated learning mode with different re-learn strategies when it's powered up again.

If a vehicle has been driven for an extended period of time with multiple problems, and you've corrected those problems, an accelerated re-learn can sometimes help the PCM acclimate to its new surroundings in less time. It doesn't have to "unlearn" its old habits. It starts from scratch with a fresh sheet to write on. (Always include a complete Drive Cycle as the finishing touch to any repair that follows a master re-learn.)

A master re-learn can also be beneficial on certain vehicles with very complicated computer maps. Computer maps are rather complicated tables of data that are cross-referenced by the PCM as it makes calculations and adjustments (Fig. 5-21).

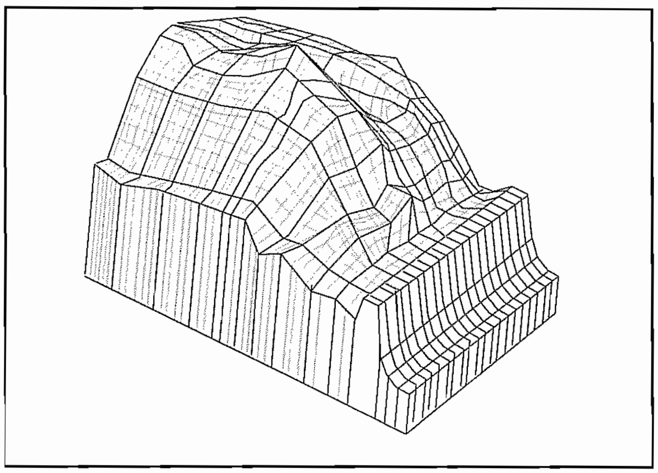


*Fig. 5-21. If we play connect the dots by drawing lines between individual pieces of data, we get a graphic picture of a computer map.*

Data is stored in the maps in the computer memory, and there is a big difference in the complexity of these maps that varies by manufacturer. Some PCMs have more places to store data and have more complicated maps than others.

You've probably noticed that disconnecting the battery on some OBD I vehicles will result in a major drop in performance until a re-learn is completed, while other vehicles may not suffer at all during the re-learn. The difference lies in the complexity of the maps and the amount of data normally stored. Those with simpler maps and less data storage learn faster than those with complicated maps because they have less to learn.

Some systems with extremely complicated maps can even experience conditions where they wander in circles like an amnesia victim. One wrong turn in a software program, and they start chasing their tails, displaying totally whacked out data stream parameters in the process. (Those of you who work with personal computers have seen this happen.) This is usually the point in the vehicle diagnosis where someone suggests replacement with a known good PCM. (You have several, thousand-dollar PCMs sitting in the back room collecting dust, right?)

What do you do when your PC goes crazy? You don't order a new computer—you reboot. Sometimes that's all it takes. The data glitch that caused the foolishness is erased, and the computer starts from scratch. Then it runs properly again—until the next time.

Powering down the vehicle PCM by removing its power long enough to erase Keep-Alive memory can erase learned values that actually contributed to the problem. This forces the PCM to start from scratch. A master re-learn is a good last-ditch effort when a vehicle computer gets a case of the stupids and you're about to start pricing a replacement.

## BAD LESSONS, EASILY LEARNED

One final note about the PCM's ability to learn from its surroundings can save a lot of anguish during certain types of repairs. The lesson here is, "Be careful what you teach the PCM."

The very first time some PCMs see the engine started, they store information about cam and crankshaft sensor timing. The PCM not only samples the voltage signals sent by the individual sensors, it calculates the *relationship* between the timing of the cam and crankshaft signals. This allows some systems to detect a timing belt that's jumped. If the timing belt jumps far enough, the cam sensor signal arrives at the wrong time, relative to the crankshaft sensor signal, and the PCM codes up. But what happens when the PCM learns the *wrong* information?

Let's say you just installed a new PCM in a vehicle, and also installed a new timing belt. Unfortunately, you get the cam timing wrong, and the car runs like a brick. You discover the error, reset the cam timing, and start the engine. Now, however, the MIL is on. What gives?

The DTC stored is probably a manufacturer-specific (a P1XXX code) that says the cam and crank sensors are out of synch. Even though you went back and corrected the timing belt installation, the PCM had already learned the ***wrong value*** at the first start up. It now swears the **wrong** value is the **correct** one.

Use the manufacturer's recommendations for resetting this part of the learning mode if this type of problem occurs. In some cases, you may need a scan tool to reset the learned information, although powering down the system may work.

Powering down a PCM ain't what it used to be. First of all, some of these systems have capacitance ratings like stun guns! You might think that simply pulling the negative battery terminal for a few seconds will reset the system, when it won't. Even if you disconnect the battery overnight, you run the risk of losing memory for theftproof radios and other on-board controllers with memory. Some manufacturers will recommend that you unplug the main PCM harness connector and others will have you pull a designated fuse for a specified time period to power down a PCM.

We strongly suggest that you refer to manufacturer specific recommendations for performing a master re-learn before powering down the entire vehicle.

## *OBD II DIAGNOSTIC TOOL BOX*

This final section is an assortment of miscellaneous tips and hints from several sources, including dealership technicians on the front lines of the OBD II battle. They cover an assortment of concerns, some vehicle specific, others generic:

- **Check PCV valves closely.** Unfortunately, there are some aftermarket service providers who are installing "one size fits none" PCV valves. The valves are improperly calibrated. Several dealership techs told us they found these valves installed on vehicles with very low mileage, so don't assume that the factory PCV hasn't been replaced, just because the vehicle is still under warranty.

- **Ford sets a P1000 code for any vehicle that hasn't set all its readiness flags.** This won't cause any driveability concerns or turn on the MIL, but it may cause problems in areas of the country that check Readiness Status as a prerequisite to an enhanced emission test.

- **Don't be surprised to see some newer vehicles that don't have a fuel return line or external fuel pressure regulator in the engine compartment.** There a couple of different systems like this. One uses a pressure sensor to detect fuel line pressure, and then controls fuel pressure with a pulse-width modulated voltage to the pump. Another design places the fuel pressure regulator inside the fuel tank. Excess pressure is dumped inside the tank instead of using a separate, external fuel return line.

- **Washing engines can cause problems. We've seen this in the past as sensors filled with water and quit working.** But secondary ignition components, especially plug wires with long spark plug connectors sitting down in tubes, can trap enough moisture to set a misfire DTC.

- **Be careful with a general misfire code (P0300—Random or Multiple Cylinder Misfire).** Some vehicles **won't** set a cylinder-specific DTC identifying the exact cylinder causing the misfire. This can lead you to confuse a general misfire condition with one that is affecting a specific cylinder or cylinders.

- **Misfire DTCs can set for non-ignition problems.** We have reports of some GM engines setting misfire DTCs for high oil pressure caused by a sticking oil pump relief valve. The misfire occurs when the high oil pressure causes the hydraulic lifters to keep the valves open. Other possible causes for false misfire codes include accessory belt noise, gear noise, or loud tires! ***Not all misfire DTCs are caused by ignition components.***

- **A misfire DTC can overwrite lower priority DTCs.** The Freeze Frame data accompanying the DTC may not be for the first DTC that was set as a result. Look at all the DTCs when multiple codes are stored with a misfire DTC to see if a component failure could be contributing to the misfire condition.

- **When diagnosing misfire conditions, especially those that set a DTC for a specific cylinder, determine the type of ignition system used.** Waste ignition systems, for example, fire two plugs from a single coil. High secondary resistance, a coil malfunction, or low primary voltage can all affect *multiple* cylinders on waste spark ignitions. Look for high secondary voltage on the exhaust plug firing event as a common indication of high secondary resistance.

- **We also have reports of spark plug-related misfires.** Incorrect plug applications and improper plug gaps can set misfire DTCs, even when there's no noticeable performance problem. Several sources said that some engines prefer copper to platinum plugs, and vice versa.

- **Some DTCs are setting for the same problems that caused characteristic driveability problems on various makes.** The big difference is that the DTCs may set *before* the driveability complaint deteriorates to noticeable levels. Neglected fuel filters seem to be a big problem. Sludged throttle bores, coked EGR valves, dirty injectors, and fuel contamination were also mentioned by sources as low-tech fixes for seemingly high-tech problems. This ought to be somewhat reassuring, since personal experience with certain makes and models can still provide a good starting place for your diagnosis. Start with what you already know.

## MINI QUIZ

1. An OEM scan interface shows a STFT of 179. How will the scan tool display this STFT in a Freeze Frame?
   a. - 20%
   b. +20%
   c. - 40%
   d +40%

2. The parameter display for the ECT shows a temperature of -22 degrees F after the engine has been running for several minutes. Of the following, which is the **LEAST** likely cause for this reading?
   a. The ECT is disconnected
   b. The ECT is open
   c. The ECT is shorted
   d. The ECT ground is open

3. A DTC P0171 (Bank 1 Fuel System too Lean) is stored. It is the only code stored. Of the following, what is the **MOST** likely cause for this code?
   a. High fuel pressure
   b. Leaking injectors
   c. Plugged injectors
   d. A short to ground in the MAP sensor signal wire to the PCM

4. A vehicle has a P0300 DTC (Random or Multiple Misfire) stored in memory.
   Technician A says the problem must be in the ignition primary since all cylinders are affected.

   Technician B says to check the list of codes used by that vehicle to determine if the system will differentiate between a general misfire and individual cylinder misfire conditions before beginning the diagnosis.

   Who is right?
   a. Technician A
   b. Technician B
   c. Both Technicians A and B
   d. Neither Technician

**Answers**
1. d
2. c
3. c
4. b

### *SHOP EXERCISES*

Connect a scan tool to an OBD II vehicle with a V-type engine that has one oxygen sensor per bank, and go to the parameter display on the scan tool.

1. Watch STFT as you slowly add propane through the main air intake using a propane enrichment tool. Watch STFT. What happens? Slowly increase the propane and watch both STFT and LTFT. What happens?

*As you richen the mixture, STFT should decrease at both banks as the system reduces fuel delivery to each bank. At a certain level of enrichment, STFT will reach its maximum correction. LTFT should start to change. If you can drive the fuel system rich enough, you'll reach a point where combined STFT and LTFT can no longer maintain fuel control and set a DTC.*

2. Repeat the test, only this time, create a **localized** vacuum leak that will affect one bank more than the other by removing a vacuum hose closer to one bank. Watch STFT and oxygen sensor data for each bank as you alternately create and then close the leak. What happens?

*This is similar to what we saw in the first test, but illustrates how the scan tool can be used to identify one bank that has a fuel control problem as opposed to a* ***general*** *over-rich or over-lean condition. Oxygen sensor voltage should decrease at the lean bank sensor, and STFT for that bank should respond by increasing fuel delivery.*

3. Manually open the EGR valve by applying a small amount of vacuum to it, or use the scan tool actuator test for EGR (if the actuator test is available on both the vehicle and scan tool). Have the engine fully warm, and set the engine to a high, stable idle about 500-600 RPM above normal curb idle speed. Open the EGR valve ***slowly*** while you watch STFT. What happens? What happens to MAP?

*Some systems monitor EGR by looking for changes in STFT as the EGR is either opened or closed. These systems will look for a brief increase in STFT as the EGR is closed, since the exhaust gas is suddenly replaced with air. Other system EGR monitors will look for a decrease in MAP voltage as the EGR is closed. Make sure you know how the system is designed to operate before you start interpreting parameter display information.*

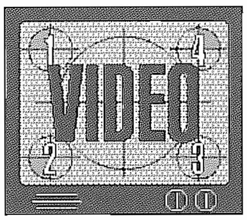
4. With the engine fully warm and idling, use a vacuum gauge teed into the MAP vacuum line to measure engine vacuum at idle. View the MAP sensor data on the scan tool at the same time. Shut the engine off, and install a long length of vacuum hose on the tee in place of the gauge. Plug the teed line, leaving the normal vacuum circuit to the MAP intact. Start the engine. Then slowly create a leak in the teed vacuum hose as you watch the scan tool MAP display. What happens to STFT?

*You should see STFT increase as you create the leak. By allowing atmospheric pressure to reach the MAP sensor, you simulate what happens when the throttle is opened and manifold pressure increases. The system should go rich.*

What do these tests have in common? They all used the scan tool and data display to let you see how the system might respond to common problems that could set a code. More importantly, you've done all these tests without major component disassembly or backprobing a single connection with a DMM or lab scope. The scan tool can be a real time saver when used properly.

# 6




Watch video module #6 now.

# GATHERING AND USING INFORMATION

To a large extent, your repair success will ultimately depend on information. Many of the repairs you perform to OBD II vehicles will be similar to the types of repairs you've performed before. You'll match a DTC to a failed component or circuit, make the repair, clear the codes, go for a test drive, and get on to the next vehicle. In some respects, vehicle repair won't be radically different from what you're doing now, and we don't want to create a monster, real or imagined, out of OBD II.

For those vehicles that don't respond to simple component repairs, the biggest hurdle to overcome will be getting the correct repair data. Access to exact enabling criteria and descriptions of system strategies will be absolutely, positively essential for cars that have a *system*, not a *component* failure. To say that the volume of information generated by OBD II is large and growing would be an understatement of colossal proportions. As we said in the video, we don't have a single source of reference to send you to for all your informational needs.

That's why this section will deal with information and how to use it.

The following list includes types of information that should be considered minimum requirements:

- **The owner's manual.** The average vehicle owner reads his owner's manual about as often as he reads the Congressional Record. Many owners manuals have cautions and recommendations about the use of the vehicle, recommended maintenance, and generally useful tips about vehicle operation that might contribute to a MIL-ON condition if they are ignored. If you think we're kidding, ask the local dealership techs how many cars they've seen with the MIL on because of a loose gas cap.

- **Accurate, vehicle-specific, wiring diagrams, and vacuum and vapor hose routing schematics**. Include specifications for the operating parameters of individual components connected by any wires or hoses.

- **In areas where vehicle emissions testing is used**, we'll need to determine how local authorities are using Readiness Status as a part of the emission test regimen.

• **Descriptions of manufacturer DTCs.** SAE-defined DTCs will identify many types of failures, but a manufacturer's reference guide to DTCs will be a mandatory code-breaker, in some cases.

• **Enabling criteria for different monitors.** No less important than DTCs, enabling criteria will define the conditions necessary for a trip to occur and for a monitor to run. Jendham has published a series of reference manuals that we recommend as reference for parameter specifications, pin designations at the PCM, and enabling criteria. They also include schematics for different circuits. We have used these manuals on real repairs and found the information to be both useful and accurate. Jendham can be reached at 1-800-233-3182.

## USING TECHNICAL INFORMATION TO INFORM YOUR CUSTOMERS

Reference information can do more than fix cars. ***Use reference materials and the information from your scan tool display to sell the customer on the concept of a complete repair.***

• **Print out the scan data for reference.**

• **Compare the printout to the enabling criteria, and show it to the customer.** The average motorist has NO IDEA what OBD II is. He has no idea how the system works. He has no idea what it takes to diagnose a problem and satisfy the mysterious inner workings of a monitoring software program. He has no idea what it takes to keep the MIL off (Fig. 6-1).

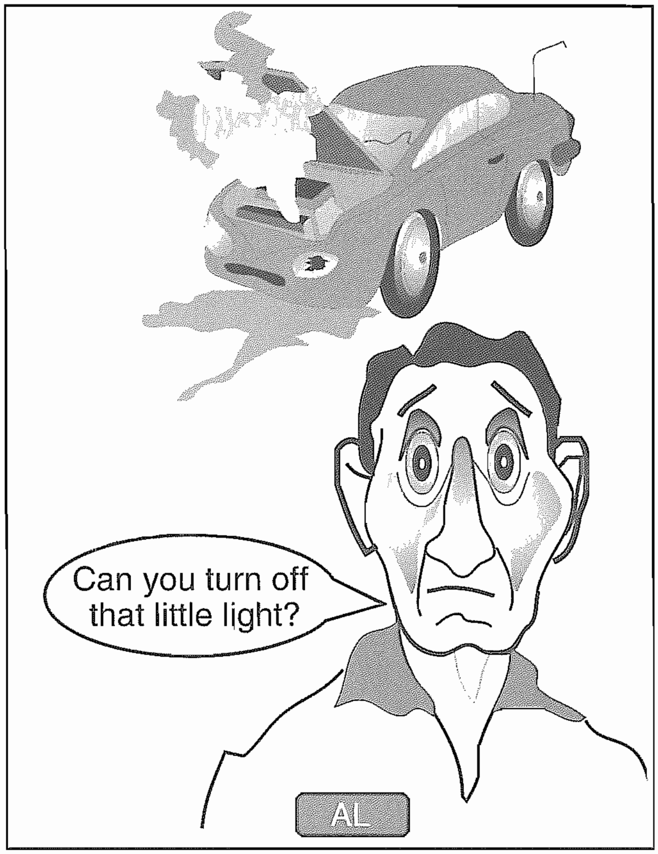



*Fig. 6-1. Many consumers have no idea what OBD II really means to them, and have even less information about the integrated designs of fuel and emission-monitoring systems installed in their vehicles. Guess who gets to inform them?*

Don't blow customers away with too much detail, but let them know that some repairs are more complicated than they were before OBD II. Get them on your side. Consumer education can save you a lot of grief if the consumers think they're helping solve the problem. If they're on the outside looking in, they get suspicious, and we all know that the fun *really* starts when that happens!

***Consumers take printed material and computer displays literally, in many cases.*** If it's right there in black and white, it's factual. You'll spend time and money locating and purchasing repair data, so put it to work as a marketing tool. Getting paid for what you ***know*** is just as important as getting paid for what you ***do***.

And how do we do this? First, the Freeze Frame and DTC displays on the scan tool can do far more than point you in the direction of the fault that turned on the MIL. They can, and should, be used to inform the customer *why* the MIL is on. So don't hesitate to show the scan display or a printout to the vehicle owner.

It's pretty hard for the customer to argue with clearly defined faults like the ones shown in Figure 6-2. No more guesswork about where a diagnosis must begin. Each fault, either stored or pending is clearly defined. This information can be used to prepare the customer for a reasonable diagnostic charge. Inform him of the normal tests that are involved with diagnosing his problem. Figure 6-2 shows both stored and pending DTCs, and warns of multiple problems.

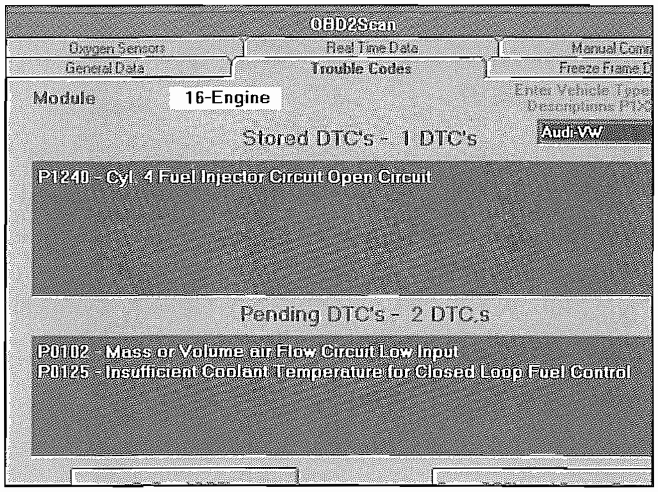



*Fig. 6-2. DTC information is proof that the vehicle problem is real, and prepares a customer for a diagnostic charge.*

Some MIL-ON conditions will be accompanied by a noticeable driveability problem. That's where Freeze Frame becomes useful. One of the repair steps we mentioned in Section Four includes asking the vehicle owner about the exact nature of the problem. Use Freeze Frame to jog his memory, if necessary, and show him when the problem set the DTC. Ask if the driveability concern has occurred before, under similar driving conditions.

If you use this approach, OBD II diagnostics can actually help you fix those nasty intermittent problems. Remember, just because one component went haywire long enough to set a code, the fault can still be intermittent. Even if the fault isn't present at the moment, the MIL will still be on.

Now you can better understand why we cautioned against blowing codes away with the scan tool before retrieving Freeze Frame. ***If Freeze Frame is erased, all this evidence is gone, and you won't see it again unless you're able to reset the code by driving the vehicle.*** Lost time, lost money.

## JUSTIFYING DIAGNOSTIC TIME

Everyone is in a big hurry these days, and many customers will want a good explanation if a diagnosis takes longer than they expected. (What they expect is usually two to three minutes.) Now you have proof, in black and white, that some diagnoses will be more complicated, and that repair verification may take longer than it did in the past.

That uncontestable truth is printed in the enabling criteria for the monitor. Take a look at Figure 6-3; it's a list of enabling criteria for a complex catalyst monitor.

**DTC P0420**
Catalyst System Low Efficiency
(Bank 1 Sensor 2)

**Conditions to Set DTC**

- No engine or transaxle system codes set
- P0420 test not run this ignition cycle
- ECT 167-185 degrees F
- IAT over -18 degrees F
- Throttle angle over 3.2%
- VSS from 30-70 m.p.h.
- Engine speed under 3000 rpm
- Air flow 15-35 gm/s
- A/F ratio 14.7:1
- Average MAP under 47.7-59.3 kPa
- Current and average MAP differs less than 4-8 kPa
- Closed loop enabled
- Front and rear O2 sensors ready
- STFT not fixed by PCM

**The DTC set for the following reasons:**

- The Bank 1 Sensor 2 average oxygen sensor voltage was only ±8 mv from the voltage signal from B1S3. (In other words, the sensor signal from the post-catalyst sensor is almost equal to the sensor voltage from the upstream sensor. The catalyst does not seem to be storing oxygen during the test period, and that's why the DTC set.)

*Fig. 6-3. You can't argue with the computer. If you know what the test is and how the vehicle failed, there's evidence to support you.*

Mr. Customer is the one facing the tough decision here, not you. He can cough up a large chunk of his next paycheck (and maybe the one after that) and have you bolt on a new catalytic converter.

When he hears the price, he'll want several things:
- Two aspirin and a glass of water,
- Proof the catalyst is really bad,
- And assurance that whatever killed his catalyst won't kill the new one in short order.

You already know the catalyst didn't just wear out. Catalysts fail from overwork or contamination. But the consumer doesn't necessarily know that. There's a *reason* the catalyst failed, and unless Mr. Customer wants to become a charter member in the Catalyst of the Month Club, he'd better let you find out *why* the first catalyst died, or he'll have a chance to buy another.

We also know that many consumers want a second opinion before approving repairs. That's only natural. The technician lucky enough to be asked for a second opinion usually gets the job, however, especially if his findings match your original diagnosis. Why wait? If the consumer wants a second opinion, let the scan tool testify on your behalf. Sell the concept of scan data as a second opinion by an expert witness.

It's not your word against the car's anymore if you have the data to substantiate your diagnosis—and share it with Mr. Customer. ***If there's one real beauty to the OBD II monitoring system, it's that it will provide you with a convincing diagnosis.*** But you need to share and interpret the information, or you've lost the best opportunity you have to ease the customer's skepticism and fears.

**Time Out**

Right now, you might be asking yourself, "What the heck does all this customer-talk have to do with fixing OBD II vehicles?"

In a word, ***everything***.

- Mr. Customer is the one who saw the MIL first
- Mr. Customer is the one who knows if there's an accompanying driveability problem
- Mr. Customer is the one who will see the MIL first if it comes on again tomorrow
- Mr. Customer will be the one who won't be able to pass an emission test in some areas if the Readiness Flags aren't set
- Mr. Customer is the one you'll ask to drive the vehicle for a few days while the Readiness Flags all have a chance to set
- Mr. Customer is paying for the fix

The sooner you can get him on your side, and get his help, the better.

## *USING PARAMETER DISPLAY REFERENCE DATA TO SPEED THE REPAIR*

We aren't nearly finished with information. Once you've been asked to make the repair, you'll need exact parameter specifications to determine why a monitor failed. Earlier, we talked about shorts and opens in circuits. These will often be easy to spot on the scan tool because they are so far out of range that they stick out like a sore thumb.

Range/performance problems are tougher. Some shifted sensor inputs can affect the system without setting a component DTC. Figure 6-4 shows a list of sample parameters listed by a manufacturer for a specific application. We've selected a few of the parameters for discussion.

Comparisons of actual parameter values to recommended specifications for individual parameters eliminates guesswork. Compare individual parameters to specifications and ***also to overall system operation***. Parameters require careful interpretation. Even if a parameter falls within the specified range, we need to evaluate other conditions that may not show up on a scan tool.

Let's run down the list:

- **Parameter 1:** Voltage between 12 and 14 volts (battery and charging voltage). That's a pretty wide margin, and you may need additional information about the exact charging rates for the system. This measurement of DC voltage does not tell you if you have AC voltage in the circuit at high enough levels to cause a problem inside the PCM. Voltage spikes probably won't show up on a scan tool or DMM. A thorough charging system analysis and measurements of AC voltage content may be needed to discover a problem like a failing alternator diode that's driving the PCM crazy.

- **Parameter 2:** Look at the parameter closely, and it will give you clues about how the circuit is wired. This one tells us that our brake switch is a switch-to-voltage, not a switch-to-ground circuit. When the brake is on, the switch closes, connecting pin 2 to voltage, not ground. If you have a constant 12 volts at the PCM on pin 2, disconnect the switch and look again. If the voltage is still

| PCM Pin # | Circuit Description | Nominal Value |
|---|---|---|
| 1 | Keep Alive Power | 12-14 V |
| 2 | Brake On/OFF Switch | Brake ON:12 V, OFF:0V |
| 3 | Vehicle Speed Sensor | At 55 mph:125 Hz |
| 7 | ECT | 3.06 V at 68 degrees F |
| 12 | Fuel Injector Number 6 | Hot Idle: 5.0-5.6ms |
| 43 | Heater Oxygen Sensor B1S1 | Hot idle - 0-1V,<br>Acceleration 0.5-1.0 V<br>Deceleration 0.0-0.5V |
| 60 | Power Ground | < 0.1V |

*Fig. 6-4. Parameter display reference specifications should always be evaluated very carefully.*

high, then the problem is in the wiring between the switch and PCM, or it's being caused by a short in the brake switch connector. The switch is not at fault. (You didn't have to pull a wiring diagram for this one, and it shows how interpretation of the parameter display can save you diagnostic time.)

• **Parameter 3:** Speed sensors of all kinds can cause problems when the signal is weak or arrives full of interference. Check the amplitude of the signal, and compare it to detailed specifications that list minimally acceptable voltage. Some types of speed sensor inputs are digital signals as opposed to AC signals. In some cases, a misshapen square wave can confuse the PCM, even though the frequency of the voltage changes seems normal. If the VSS keeps setting a DTC, it's time to dig deeper.

• **Parameter 7**: Manufacturers will commonly list ECT (or IAT) voltage values for a specified temperature as a general reference. That doesn't mean the ECT can't get stupid at temperatures above or below the reference standard. Compare the manufacturers chart for ECT voltage values at different temperatures to Freeze Frame data to determine if this is happening. The specification shown here isn't much help when it's 10 below zero outside, and the DTC was set right after the engine was started cold.

• **Parameter 12:** Fuel Injector Number six has a recommended range shown here as its on-time, measured in milliseconds. Maybe injector six is perfect electrically, and is getting the correct signal from the PCM. But it may also be clogged!

• **Parameter 43:** This is a pretty vague specification, especially if you have a range or performance problem with an oxygen sensor. Remember that the criteria for oxygen sensor operation is a lot more complicated on OBD II vehicles than it was before. This parameter may be too wide for an accurate appraisal of whether or not the sensor passes all of its tests. To perform detailed tests of the sensor, you'll need the additional specifications for rise and fall times, cross counts, MIN/MAX limits, etc.

• **Parameter 60:** Test grounds while current is flowing through them using voltage drop test procedures. Some manufacturers still insist on providing simple resistance values for grounds. Don't trust them. Check grounds for changes in voltage drops during cranking and when the charging system is putting out at its maximum rated voltage. Changes in current flow through the grounds will affect the voltage dropped across any resistance in the ground circuits.

The parameter display may not tell the whole story. Don't assume that scan data will uncover all possible problems. Other conditions may cause improper circuit operation that won't be evident in the parameter list.

## GETTING BACK TO MR. CUSTOMER

Now that you've outsmarted the problem that set the DTC, it's time to make a tough decision about repair verification. Let's say you're reasonably sure you've fixed the problem. DTCs accompanied by a noticeable driveability symptom are actually easier to verify. If the driveability concern is gone after a repair, you have a good indication that your fix was a good one. But you can't be sure until all monitors have run.

After any repair, go for a test drive. See if the MIL comes on again. Try to compare the Freeze Frame data stored with the original DTC to currently displayed parameter information as you simulate the driving conditions that set the DTC in the first place, just to be sure. If your scan tool and the vehicle support it, look at pending codes. These can tell you if there's trouble still brewing. No, pending codes? That's a good sign the repairs have been a success.

Now it's time to involve Mr. Customer. If he's been properly informed to this point, getting him to verify the repair for you will be easier. We know that erasing DTCs reset the Non-Continuous monitors to an incomplete status (Fig. 6-5). So you won't be sure the repair was a total success until all monitors have run without resetting any DTCs. You really don't want to drive the vehicle long enough to reset all the Readiness Flags.

The customer will need to drive the vehicle long enough to allow all the monitors to run to completion. Tell him that while the driveability concern is gone, the final judge of the repair is the OBD II monitoring system. Explain that the monitors are complex, and that they may take some time to run during normal driving.

If you don't prepare the customer, you risk hearing a few choice remarks from him in the event that the MIL comes back on. But a professional approach, supplemented with information from the scan tool and repair data for the vehicle will help the customer accept the normal operation of the monitoring system. (If he has any experience with personal computers, he'll be able to relate to the situation in terms that are not automotive.)

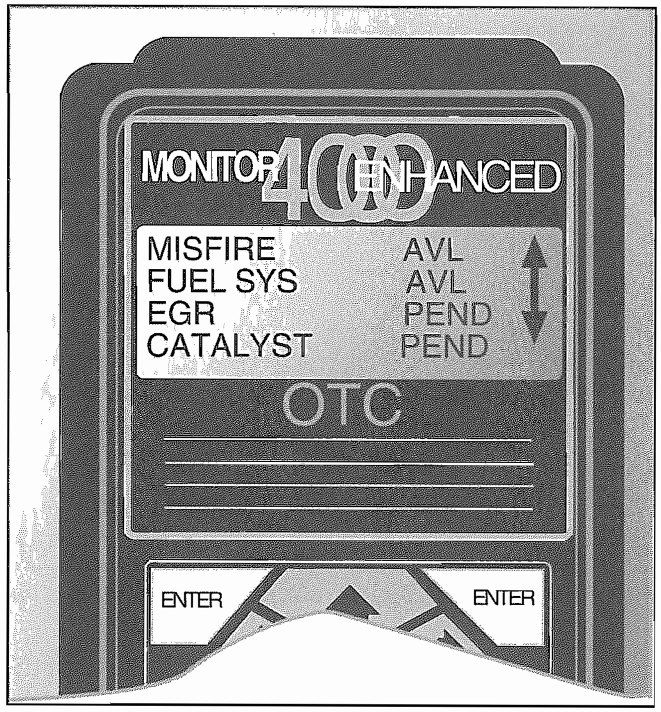



*Fig. 6-5. Until all the monitors have had a chance to test the system, you won't know if the OBD II monitoring system will approve the repair.*

If this all seems like a lot to keep track of, you may want to print out some repair sheets just for OBD II vehicles. A repair sheet like the sample shown in Figure 6-6, will help you proceed with a standard routine for OBD II repairs. This eliminates duplication of effort and missed steps in the diagnostic procedure.

Show the customer a form like this *before* you work on the vehicle. If good customers know what's involved in the diagnosis, they are much more apt to reimburse you for your diagnosis—without an argument.

A copy of a diagnostic form, attached to the repair order after the repair, will inform the customer of the work that was done—and why. It will act as a future reference if the MIL does come on again later, and document your efforts.

Information and communication go hand in hand in ensuring customer satisfaction and cooperation. OBD II has the potential to change the relationship between you and your customers if you use the tools it provides wisely and with skill. An ounce of prevention has never been more useful than it is with OBD II concerns.

# Al's Garage - OBD II Vehicle Repair Sheet

## Pre-Repair Evaluation

Date_____Customer Name_______________________ Phone_________

Vehicle Type_______________Model_______Engine___________Mileage_________

VIN__ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

Current MIL status:

☐ MIL ON with no driveability complaint

☐ MIL-ON accompanied by driveability complaint (List symptoms)_______________________________________

_______________________________________________________________________________

**DTCs Stored:**

DTC 1)_____________(Description)_______________________________________

DTC 2)_____________(Description)_______________________________________

DTC 3)_____________(Description)_______________________________________

DTC 4)_____________(Description)_______________________________________

DTC 5)_____________(Description)_______________________________________

DTC that stored Freeze Frame:_____________

**Freeze Frame Data (Fill in all spaces before erasing DTCs; or attach printout)**

Fuel System Status ☐ Open Loop ☐ Closed Loop

Calculated Load_________________________%

Short Term Fuel Trim Bank 1____________% Bank 2______________%

Long Term Fuel Trim Bank 1_____________% Bank 2______________%

Engine Speed____________RPM

Vehicle Speed____________MPH

Engine Coolant Temperature__________degrees (F/C)

If single-cylinder misfire is detected, indicate cylinder(s)_________________

**Current Parameter Display Information**

Fuel System Status ☐ Open Loop ☐ Closed Loop

Calculated Load_________________________%

Short Term Fuel Trim Bank 1____________% Bank 2______________%

Long Term Fuel Trim Bank 1_____________% Bank 2______________%

Engine Speed____________RPM

Vehicle Speed____________MPH

Calculated Load___________%

Engine Coolant Temperature__________degrees (F/C)

**Visual and Maintenance Inspection (Check fluid levels and note any abnormal conditions)**

1) Engine oil level and condition_______________________

2) Battery Voltage______________Charging Voltage___________

3) Condition of all belts and hoses________________________

4) Note any and all additional maintenance and repair items that indicate a potential problem______________

_______________________________________________________________________________

_______________________________________________________________________________

*Fig. 6-6. A worksheet like this one can organize your thought process, prevent loss of vital repair data, and educate the customer about the nature of the repairs. It also prevents misunderstandings with the customer, and provides a reference for future repairs.*

# Al's Garage - OBD II Vehicle Repair Sheet

## Repair and Customer Information

Date______Customer Name____________Address_______________ Phone__________

Vehicle Type_______Model________Engine____________Mileage_________

VIN_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Repairs have been performed to your vehicle in the following areas based on Diagnostic Trouble Codes (DTCs) stored in the vehicle computer:

### Original DTCs and related repairs:

1)_____________(Cause for Code and repair)________________________________________

_______________________________________________________________________

2)_____________(Cause for Code and repair)________________________________________

_______________________________________________________________________

3)_____________(Cause for Code and repair)________________________________________

_______________________________________________________________________

4)_____________(Cause for Code and repair)________________________________________

_______________________________________________________________________

5)_____________(Cause for Code and repair)________________________________________

Every effort has been made to repair your vehicle in a timely and cost-effective manner. All diagnostic trouble codes have been erased following repairs. When trouble codes are erased, test results for individual vehicle test monitors in the vehicle computer are reset, and must run again during the course of normal driving over the next few days. The time this process takes varies by vehicle and driving habits. The vehicle will self-monitor during this time, and alert you by illuminating the Malfunction Indicator Light (MIL) if additional faults are detected.

These are normal functions of the vehicle's monitoring system. Following a test drive and review of current data in the vehicle computer, we are confident that your concerns have been addressed. However, due to the complexity of the vehicle monitoring software, the MIL may illuminate for reasons we cannot anticipate at this time. We ask for your support and assistance in this matter, and request that you inform us if the MIL illuminates during this period. Further diagnosis may be required at that time to determine if additional repairs are required.

*Fig. 6-7. Feel free to customize this sample to suit your needs. A customer information sheet like this creates trust, and enhances your image as a skilled professional.*

## USING A CUSTOMER INFORMATION SHEET

In addition to the worksheet you prepare for your own use, you may want to prepare an additional sheet to give to the customer.

A sample of an information sheet is shown in Figure 6-7. It's designed to inform the vehicle owner of the exact repairs performed to the vehicle based on diagnostic information gathered with the scan tool during the preliminary diagnosis. The goal is to eliminate misunderstandings.

The sheet won't be much help if the customer doesn't understand its content. Take a moment to explain the "fine print." If your repairs are well documented, and you enlist the customer's assistance, anxiety over any future illumination of the MIL will be reduced—for all concerned.

From this point on, you become the information provider. Professionalism and good documentation are important to customer satisfaction; the final standard by which all your repairs will ultimately be judged.

### *FEDWORLD DOWNLOADS*

For the rest of this section, we'll concentrate on ways to gather information. The first is by downloading files from the internet. OEMs have placed lists of training materials, technical service bulletins, and special tools on the internet at a site called FedWorld (*www.fedworld.gov*).

You will, of course, need a modem to download this information. We'll warn you that the site is not what you'd call user friendly. Each manufacturer has placed individual files in large, downloadable files that are "zipped." A part of the main index is shown in Figure 6-8.

The entire main index can be downloaded and printed out for reference. In addition to manufacturer's files, an unzip utility is also stored in the main index along with a help file and a copy of the government regulation that mandated this information service.

Downloading the main files from individual manufacturers can take some time, since some are extremely large. After the download, you'll need to "unzip" the large files to gain access to individual files. Individual files contain a brief description of their contents, usually the title of a repair manual or TSB. In each of these smaller files, you'll find a part number, a

AUTO Library

| File Name | Size | Description |
|---|---|---|
| =========== ===== | ======== | ================================================ |
| 00-INDEX.TXT | 6.0K | List of all files in the AUTO Library |
| ABOUT.TXT | | About this rule - This file (an excerpt from the federal register notice) describes the background and purpose of this rule. If you are looking for the entire rule, download file mandate.txt in this library. |
| ALFROMEO.ZIP | 2.0K | Alfa Romeo. This is the collection of indexes from Fiat's Alpha Romeo. There are only a few files in this collection due to the fact that the Alpha Romeo will not be sold in the U.S. after 1995. This will be the only index available. |
| ASTON.ZIP | 1.3K | Aston Martin Lagonda of N.A. Inc. |
| AUTO.HTM | 9.5K | HTML list of all files in the AUTO library |
| BMW.ZIP | 118K | BMW Service Information Files - COMPLETE |
| BMWNEW.ZIP 10K | | BMW Service Information Files - |
| NEW CR.ZIP | 1.4M | Chrysler Corporation Service and Technical Pubs |
| CRNEW.ZIP | 359K | |
| FERRANEW.ZIP | 9.6K | NEW-Ferrari Technical Information |
| FERRARI.ZIP | 12K | Ferrari Technical Information. Contains a listing of Workshop Manuals and Service Bulletins. |
| FORDCORP | 817K | |
| FORDCORP.ZIP | 1.4M | File containing Ford Motor Co. Service Literature |
| GM1.ZIP | 2.0M | Part 1 of 2 zip files - All service information for General Motors, includes 1988 to present |
| GM2.ZIP | 2.4M | Part 2 of 2 zip files - All service information for General Motors, includes 1988 to present |
| HONDA.ZIP | 339K | American Honda Motor Co. This file contains American Honda's emissions-related service technical information. |
| HOW.TXT | 5.8K | The Clean-Air Act User guide for FedWorld. This file will provide you with some hints on how to best use the system |

*Fig. 6-8. This partial listing of the main index at the FedWorld download site gives you a flavor for how the site is organized. Note the relative sizes of the zipped files.*

purchase price, and information about how to order. Figure 6-9 shows a sample of one file to give you an idea of how the files look.

DESCRIPTION.: ELECTRICAL WIRING DIAGRAMS

MANUFACTURER: TOYOTA

MAKE........: TOYOTA

MODEL(S)....: LANDCRUISER

YEAR(S).....: 1995

PART NUMBER.: 00400-WD230

PRICE......$60.00 (PLUS TAX, SHIPPING AND HANDLING)

ORDERING INFORMATION: CALL 1-800-622-2033 7:00 AM - 4:30 PM PST MONDAY THROUGH FRIDAY. WE ACCEPT MASTER CARD, VISA AND CHECKS. ALL ORDERS SHIPPED WITHIN 24 HOURS. OVERNIGHT OR SECOND DAY SERVICE AVAILABLE AT ADDITIONAL COST. FAX SERVICE AVAILABLE FOR DOCUMENTS UNDER 20 PAGES AT ADDITIONAL COST.

*Fig. 6-9. After downloading a manufacturer's main file and unzipping it, view individual files to determine the type of repair information they provide.*

Unfortunately, there's a hitch. Once the files are unzipped for viewing, you'll find that there is no manufacturer's index. So you'll have to open files individually for viewing, which is a tedious and time-consuming task. (This is a good thing to do some evening when there's nothing on the tube except reruns, and you're trying to avoid fixing that dripping kitchen faucet!)

With a little practice, however, you'll find that most manufacturers group their offerings by type. In many cases, repair manuals will be arranged in a consecutively numbered group, as will technical service bulletins. With a little practice, we were able to group selections to speed our search, and find many useful reference materials, some of which were purchased for the preparation of this course.

Hopefully, the inefficiencies of this site will be remedied to enable you to find the information you need with greater speed. In any event, you ought to know it's there.

## *IF YOU KNOW THE NUMBER...*

There's more than one way to skin the proverbial cat. Several dealership techs provided us with the correct part numbers for training materials they recommended from personal use. Then it was simply a matter of dialing the manufacturer or service provider responsible for distribution and give them the part number.

Figure 6-10 is a list of phone numbers for OEMs and service providers.

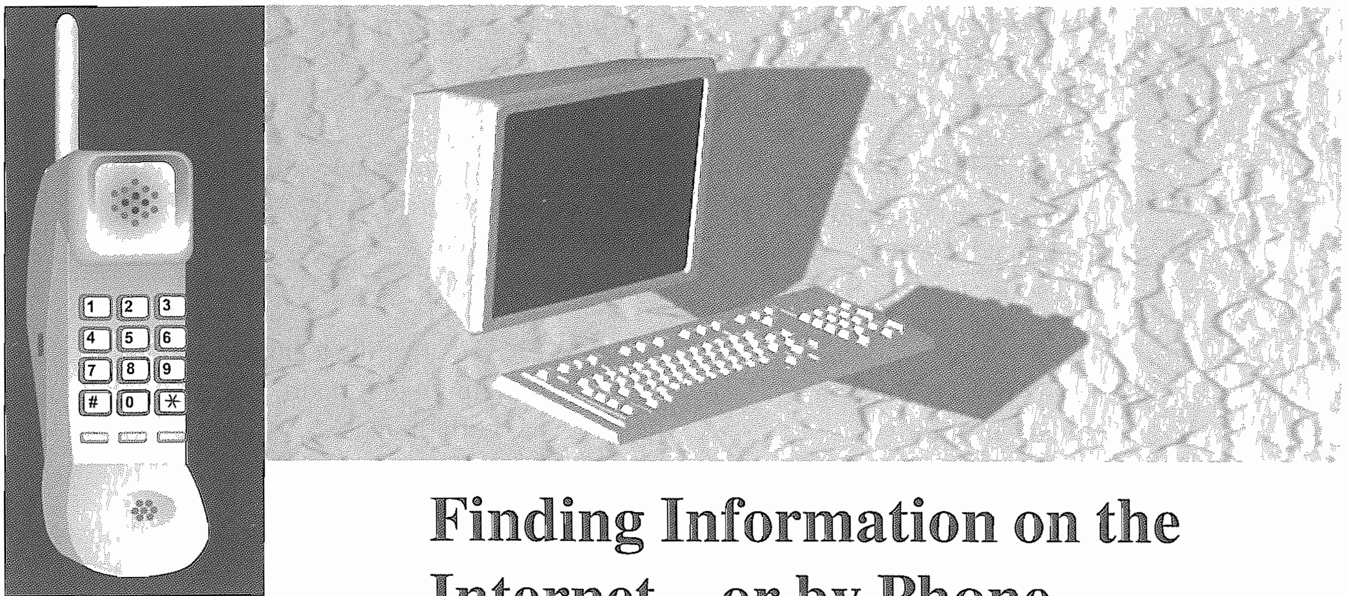
**Helm** represents several manufacturers and will also send you a catalog for the OEMs they represent.

The folks at **Kent-Moore** have a list of training materials for both Saab and BMW.

An additional source of GM training manuals is **MascoTech**. They'll send you a free catalog of training manuals on various GM systems if you call 1-800-393-4831.

**BMW** - (Kent-Moore will send you a list of training materials on request) 1-800-345-2233
**Chrysler** - (Dyment Distribution will send you a catalog on request) 1-800-423-7915
**Ford** - (Helm) 1-800-782-4356
**GM** - (Helm) 1-800-782-4356
**Honda** - (Helm) 1-800-782-4356
**Hyundai** - (Helm) 1-800-782-4356
**Mazda** - Contact your local dealership
**Mercedes** - 1-800-FOR-MERCEDES
**Mitsubishi** - 1-714-372-6154
**Nissan** - 1-310-427-7000
**Saab** - (Kent-Moore will send you a list of training materials on request) 1-800-345-2233
**Subaru** - (Helm) 1-800-782-4356
**Toyota** - 1-800-622-2033
**VW/Audi** - (Dyment Distribution will send you a catalog on request) 1-800-216-6856
**Volvo** - 1-800-25-VOLVO

*Fig. 6-10. Some OEMs handle their own service publications distribution, while others use a distribution service.*




# Finding Information on the Internet—or by Phone

## SOURCES OF INFORMATION

Information on the next two pages was gathered during the preparation of this course. By phone or on the internet, this is just a sampling of information sources available to you.

- **ALLDATA** - Automotive informational database on CD ROM
1-800-697-2533
*www.alldata.com*

- **ASA** - Automotive Service Association publishes an on-line monthly magazine providing information on legislative changes and other issues
1-800-272-7467
*www.asashop.org*

- **Autodiagnos** - Manufacturers of scan tool for European makes, including Volvo factory software
1-330-668-1518
*www.autodiagnos.com*

- **Babcox Publications** - Trade publications, including ***Underhood Digest*** and ***Import Car***
*www.aftermarketworld.com*
1-330-535-6117

- **Baum Tool** - OB2Scan software and publications on European vehicle service information
1-800-848-6657

- **California Air Resources Board** - All sorts of information, from the history of air quality control to the latest regulations
*http//arbis.arb.ca.gov*

- **Dyment Distribution Services** - Distributors of training information and technical service bulletins for Volkswagen/Audi and Chrysler products
1-800-544-8021

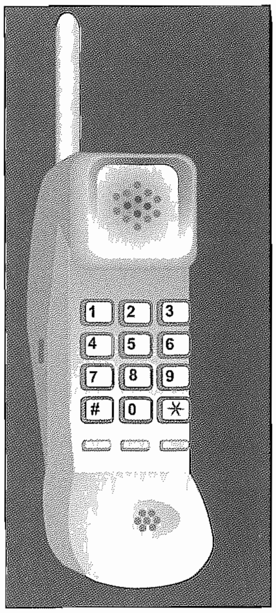
- **EASE Software** - Manufacturers of the Quickscan software shown in this course
1-888-366 (EASE) 3273
*www.ease.com*

- **EPA** - Government regulations, OEM training information, and TSBs
*www.epa.gov*

- **FedWorld** - A site that provides downloadable listings of manufacturer's technical service information
*www.fedworld.gov*

- **Gemini Communications** - ***Import Service Magazine*** - For subscription information
1-330-666-9553

- **Helm, Inc.** - Distributors of manufacturers' service information for several manufacturers
1-800-782-4356



- **Hickock, Inc. -** Manufacturers of the Ford factory New Generation Star tester (NGS). Also available through NAPA (P/N 392-3051). Ford dealers will provide tool and software upgrades
1-216-541-8060

- **I-ATN -** The International Automotive Technician's Network - Over 10,000 technicians and trainers meet to discuss automotive repairs and related issues using discussion forums and e-mail
*(www.i-atn.com)*

- **Jendham -** OBD II training and information publications and on-site training
1-800-233-3182

- **Kal Equip -** Manufacturers of Kal Equip Scan II (NAPA P/N 392-3039)
1-800-228-7667
*www.actron.com*

- **Kent-Moore -** Distributors of Saab and BMW service information
1-800-345-2233

- **MascoTech -** Distributors of General Motors training manuals and technical service bulletins. Bulletins are available on a subscription basis
1-800-393-4831

- **Miller Special Tool -** Distributors of the D.A.R.T. reprogrammer and scan interface for Chrysler vehicles
1-800-801-5420

- **Mitchell Repair -** database informational systems on CD ROM
*www.mitchellrepair.com*

- ***Motor*** magazine subscriptions on-line and reprints of current and past articles
*www. Motor.com*

- ***Motor Age*** magazine subscriptions on-line and reprints of current and past articles
*www.motorage.com*

- ***Motor Service*** magazine subscriptions on-line and reprints of current and past articles
1-609-786-7364
*www.MotorService.net*

- **NAPATECH** - Hotline technical support from NAPA including live support, Diagrams On-Line, and service bulletin index
1-800-288-6210

- **OTC Division/SPX** - Manufacturers of the OTC Enhanced Monitor (NAPA P/N 700-1620)
1-800-533-6127

- ***Professional Tool and Equipment News* -** Information on new tools and equipment
1-847-830-7520
*www.bodyshop.com/PTEN*

- **Service Technicians Society -** A membership of automotive professionals with technical services and information exchange between members
*www.sts.sae.org*

- **Snap-on Tools -** Manufacturers of the Snap-on MT2500 scan tool
1-800-424-7226
*www.snapondiag.com*

- **Society of Automotive Engineers** - If you want copies of any or all J-papers issued regarding OBD II, they're available for sale here
*www.sae.org*

- **Vetronix -** Manufacturers of the Mastertech and Tech 1A scan tools, and dedicated software interface cards that support enhanced levels of diagnostics for GM, Acura/Honda, Toyota/Lexus, Suzuki, and Kia. Vetronix also sells a "Pass-Thru" reprogramming device that supports reprogramming of all Flash-type control modules on GM vehicles from model years 1993-98 (except Catera)
1-800-321-4VTX
*www.vetronix.com*

## *BRAVE NEW WORLD*

To suggest that things are changing rapidly in the world of automotive repair would make us clear favorites for first-place honors in the "Understatement of the Year" competition. The technology of the 21st century is upon us. You're about to find that you'll need to add a personal computer to your list of essential tools.

Some of the software upgrades for various vehicles will arrive via modem or be shipped on compact disk. The volume of information and the frequency of updates make traditional printed material cumbersome and costly. And the time it takes to print and distribute repair data this way will date some materials in the time it takes to print and ship them.

There will also be many new tools coming to market to assist you in both diagnosis and reprogramming vehicle software.

- The Diagnostic and Reprogramming Tool (D.A.R.T.) from Miller Special Tool is one example. It supports various OBD II diagnostic and reprogramming capabilities on Chrysler vehicles. Software upgrades will arrive to you through a modem that comes with the tool, and the original tool purchase includes a one-year subscription for software for both the tester and Chrysler vehicles.

- Vetronix offers a software system called "Pass Thru" that will allow you to reprogram the onboard computer in GM vehicles using a Tech 1A or Mastertech. Software will be loaded to a personal computer from a compact disk, and then transferred to the scan tool by the computer for download to the vehicle.

In addition to the information sources we've listed, many new car dealer service and parts departments will also be involved in the distribution of special tools and equipment.

Ford is one example. Your Ford dealer can supply you with the necessary software upgrades for your New Generation Star (NGS) tester and can also provide software upgrades for the Ford vehicles you service. Upgrades and service information will be available electronically on a subscription basis.

Test equipment and the information needed to use it properly is available from a number of sources. There are a large number of variables for any technician or shop owner to consider, so use your favorite trade publications to keep you informed as the process evolves.

In the meantime, please use the information in this course as a starting point to master the general concepts behind OBD II. Expect to see exceptions to rules, especially as they apply to specific makes and models. Vehicle manufacturers will seek, and may receive exemptions for some system strategies. We all need to stay on our toes to be prepared for the unexpected.

Following this section, you'll find three appendices that provide additional information about the history of OBD II, a list of SAE-defined DTCs, and descriptions of important SAE J-Documents.

Thank you for joining us. We sincerely hope that the information contained in this training course will be beneficial to you and help you fix cars right the first time—in less time.

Notes:

Notes:

# APPENDICES

There are volumes of printed matter to wade through that apply to OBD II. Some of it is informative, but not essential to your repair efforts on OBD II-equipped vehicles, and some of it is very critical indeed.

In this section, we've gathered reference materials that provide general information about OBD II.

Here's the list:

- **Appendix A** - SAE-defined Diagnostic Trouble Codes

- **Appendix B** - SAE J-Documents. These are the technical papers written by SAE to define various features of OBD II

- **Appendix C** - A brief history of emissions regulations and how they brought us OBD II

# APPENDIX A—SAE Diagnostic Trouble Codes

| Code | P01XX Section (Fuel and Air Metering) |
|---|---|
| P0100 | Mass or Volume Air flow Circuit Malfunction |
| P0101 | Mass or Volume Air flow Circuit Range/ Performance Problem |
| P0102 | Mass or Volume Air flow Circuit Low Input |
| P0103 | Mass or Volume Air flow Circuit High Input |
| P0104 | Mass or Volume Air flow Circuit Intermittent |
| P0105 | Manifold Absolute Pressure/ Barometric Pressure Circuit Malfunction |
| P0106 | Manifold Absolute Pressure/ Barometric Pressure Circuit Range/ Performance Problem |
| P0107 | Manifold Absolute Pressure/ Barometric Pressure Circuit Low Input |
| P0108 | Manifold Absolute Pressure/ Barometric Pressure Circuit High Input |
| P0109 | Manifold Absolute Pressure/ Barometric Pressure Circuit Intermittent |
| P0110 | Intake Air Temperature Circuit Malfunction |
| P0111 | Intake Air Temperature Circuit Range/ Performance Problem |
| P0112 | Intake Air Temperature Circuit Low Input |
| P0113 | Intake Air Temperature Circuit High Input |
| P0114 | Intake Air Temperature Circuit Intermittent |
| P0115 | Engine Coolant Temperature Malfunction |
| P0116 | Engine Coolant Temperature Range/ Performance Problem |
| P0117 | Engine Coolant Temperature Circuit Low Input |
| P0118 | Engine Coolant Temperature Circuit High Input |
| P0119 | Engine Coolant Temperature Circuit Intermittent |
| P0120 | Throttle/ Pedal Position Sensor/ Switch A Circuit Malfunction |
| P0121 | Throttle/ Pedal Position Sensor/ Switch A Circuit Range/ Performance Problem |
| P0122 | Throttle/ Pedal Position Sensor/ Switch A Circuit Low Input |
| P0123 | Throttle/ Pedal Position Sensor/ Switch A Circuit High Input |
| P0124 | Throttle/ Pedal Position Sensor/ Switch A Circuit Intermittent |
| P0125 | Insufficient Coolant Temperature for Closed Loop Fuel Control |
| P0126 | Insufficient Coolant Temperature for Stable Operation |
| P0130 | Oxygen Sensor Circuit Malfunction (Bank 1 Sensor 1) |
| P0131 | Oxygen Sensor Circuit Low Voltage (Bank 1 Sensor 1) |
| P0132 | Oxygen Sensor Circuit High Voltage (Bank 1 Sensor 1) |
| P0133 | Oxygen Sensor Circuit Slow Response (Bank 1 Sensor 1) |
| P0134 | Oxygen Sensor Circuit No Activity Detected (Bank 1 Sensor 1) |

| Code | P01XX Section (Fuel and Air Metering) |
|---|---|
| P0135 | Oxygen Sensor Heater Circuit Malfunction (Bank 1 Sensor 1) |
| P0136 | Oxygen Sensor Circuit Malfunction (Bank 1 Sensor 2) |
| P0137 | Oxygen Sensor Circuit Low Voltage (Bank 1 Sensor 2) |
| P0138 | Oxygen Sensor Circuit High Voltage (Bank 1 Sensor 2) |
| P0139 | Oxygen Sensor Circuit Slow Response (Bank 1 Sensor 2) |
| P0140 | Oxygen Sensor Circuit No Activity Detected (Bank 1 Sensor 2) |
| P0141 | Oxygen Sensor Heater Circuit Malfunction (Bank 1 Sensor 2) |
| P0142 | Oxygen Sensor Circuit Malfunction (Bank 1 Sensor 3) |
| P0143 | Oxygen Sensor Circuit Low Voltage (Bank 1 Sensor 3) |
| P0144 | Oxygen Sensor Circuit High Voltage (Bank 1 Sensor 3) |
| P0145 | Oxygen Sensor Circuit Slow Response (Bank 1 Sensor 3) |
| P0146 | Oxygen Sensor Circuit No Response Detected (Bank 1 Sensor 3) |
| P0147 | Oxygen Sensor Heater Circuit Malfunction (Bank 1 Sensor 3) |
| P0150 | Oxygen Sensor Circuit Malfunction (Bank 2 Sensor 1) |
| P0151 | Oxygen Sensor Circuit Low Voltage (Bank 2 Sensor 1) |
| P0152 | Oxygen Sensor Circuit High Voltage (Bank 2 Sensor 1) |
| P0153 | Oxygen Sensor Circuit Slow Response (Bank 2 Sensor 1) |
| P0154 | Oxygen Sensor Circuit No Response Detected (Bank 2 Sensor 1) |
| P0155 | Oxygen Sensor Heater Circuit Malfunction (Bank 2 Sensor 1) |
| P0156 | Oxygen Sensor Circuit Malfunction (Bank 2 Sensor 2) |
| P0157 | Oxygen Sensor Circuit Low Voltage (Bank 2 Sensor 2) |
| P0158 | Oxygen Sensor Circuit High Voltage (Bank 2 Sensor 2) |
| P0159 | Oxygen Sensor Circuit Slow Response (Bank 2 Sensor 2) |
| P0160 | Oxygen Sensor Circuit No Response Detected (Bank 2 Sensor 2) |
| P0161 | Oxygen Sensor Heater Circuit Malfunction (Bank 2 Sensor 2) |
| P0162 | Oxygen Sensor Circuit Malfunction (Bank 2 Sensor 3) |
| P0163 | Oxygen Sensor Circuit Low Voltage (Bank 2 Sensor 3) |
| P0164 | Oxygen Sensor Circuit High Voltage (Bank 2 Sensor 3) |
| P0165 | Oxygen Sensor Circuit Slow Response (Bank 2 Sensor 3) |
| P0166 | Oxygen Sensor Circuit No Response Detected (Bank 2 Sensor 3) |
| P0167 | Oxygen Sensor Heater Circuit Malfunction (Bank 2 Sensor 3) |
| P0170 | Fuel Trim Malfunction (Bank 1) |
| P0171 | System Too Lean (Bank 1) |
| P0172 | System Too Rich (Bank 1) |
| P0173 | Fuel Trim Malfunction (Bank 2) |

| Code | P01XX Section (Fuel and Air Metering) |
|---|---|
| P0174 | System Too Lean (Bank 2) |
| P0175 | System Too Rich (Bank 2) |
| P0176 | Fuel Composition Sensor Circuit Malfunction |
| P0177 | Fuel Composition Sensor Circuit Range/ Performance |
| P0178 | Fuel Composition Sensor Circuit Low Input |
| P0179 | Fuel Composition Sensor Circuit High Input |
| P0180 | Fuel Temperature Sensor A Circuit Malfunction |
| P0181 | Fuel Temperature Sensor A Circuit Range/ Performance Problem |
| P0182 | Fuel Temperature Sensor A Circuit Low Input |
| P0183 | Fuel Temperature Sensor A Circuit High Input |
| P0184 | Fuel Temperature Sensor A Circuit Intermittent |
| P0185 | Fuel Temperature Sensor B Circuit Malfunction |
| P0186 | Fuel Temperature Sensor B Circuit Range/ Performance |
| P0187 | Fuel Temperature Sensor B Circuit Low Input |
| P0188 | Fuel Temperature Sensor B Circuit High Input |
| P0189 | Fuel Temperature Sensor B Circuit Intermittent |
| P0190 | Fuel Rail Pressure Sensor Circuit Malfunction |
| P0191 | Fuel Rail Pressure Sensor Circuit Range/ Performance |
| P0192 | Fuel Rail Pressure Sensor Circuit Low Input |
| P0193 | Fuel Rail Pressure Sensor Circuit High Input |
| P0194 | Fuel Rail Pressure Sensor Circuit Intermittent |
| P0195 | Engine Oil Temperature Sensor Malfunction |
| P0196 | Engine Oil Temperature Sensor Range/ Performance |
| P0197 | Engine Oil Temperature Sensor Low |
| P0198 | Engine Oil Temperature Sensor High |
| P0199 | Engine Oil Temperature Sensor Intermittent |
| **2** | **P02XX Section (Fuel and Air Metering)** |
| P0200 | Injector Circuit Malfunction |
| P0201 | Injector Circuit Malfunction - Cylinder 1 |
| P0202 | Injector Circuit Malfunction - Cylinder 2 |
| P0203 | Injector Circuit Malfunction - Cylinder 3 |
| P0204 | Injector Circuit Malfunction - Cylinder 4 |
| P0205 | Injector Circuit Malfunction - Cylinder 5 |
| P0206 | Injector Circuit Malfunction - Cylinder 6 |

| Code | P02XX Section (Fuel and Air Metering) |
|---|---|
| P0207 | Injector Circuit Malfunction - Cylinder 7 |
| P0208 | Injector Circuit Malfunction - Cylinder 8 |
| P0209 | Injector Circuit Malfunction - Cylinder 9 |
| P0210 | Injector Circuit Malfunction - Cylinder 10 |
| P0211 | Injector Circuit Malfunction - Cylinder 11 |
| P0212 | Injector Circuit Malfunction - Cylinder 12 |
| P0213 | Cold Start Injector 1 Malfunction |
| P0214 | Cold Start Injector 2 Malfunction |
| P0215 | Engine Shutoff Solenoid Malfunction |
| P0216 | Injection Timing Control Circuit Malfunction |
| P0217 | Engine Overtemp Condition |
| P0218 | Transmission Overtemp Condition |
| P0219 | Engine Overspeed Condition |
| P0220 | Throttle/ Pedal Position Sensor/ Switch B Circuit Malfunction |
| P0221 | Throttle/ Pedal Position Sensor/ Switch B Circuit Range/ Performance |
| P0222 | Throttle/ Pedal Position Sensor/ Switch B Circuit Low Input |
| P0223 | Throttle/ Pedal Position Sensor/ Switch B Circuit High Input |
| P0224 | Throttle/ Pedal Position Sensor/ Switch B Circuit Intermittent |
| P0225 | Throttle/ Pedal Position Sensor/ Switch C Circuit Malfunction |
| P0226 | Throttle/ Pedal Position Sensor/ Switch C Circuit Range/ Performance |
| P0227 | Throttle/ Pedal Position Sensor/ Switch C Circuit Low Input |
| P0228 | Throttle/ Pedal Position Sensor/ Switch C Circuit High Input |
| P0229 | Throttle/ Pedal Position Sensor/ Switch C Circuit Intermittent |
| P0230 | Fuel Pump Primary Circuit Malfunction |
| P0231 | Fuel Pump Secondary Circuit Low |
| P0232 | Fuel Pump Secondary Circuit High |
| P0233 | Fuel Pump Secondary Circuit Intermittent |
| P0235 | Turbocharger Boost Sensor A Circuit Malfunction |
| P0236 | Turbocharger Boost Sensor A Circuit Range/ Performance |
| P0237 | Turbocharger Boost Sensor A Circuit Low |
| P0238 | Turbocharger Boost Sensor A Circuit High |
| P0239 | Turbocharger Boost Sensor B Circuit Malfunction |
| P0240 | Turbocharger Boost Sensor B Circuit Range/ Performance |
| P0241 | Turbocharger Boost Sensor B Circuit Low |
| P0242 | Turbocharger Boost Sensor B Circuit High |

| Code | P02XX Section (Fuel and Air Metering) Continued |
|---|---|
| P0243 | Turbocharger Wastegate Solenoid A Malfunction |
| P0244 | Turbocharger Wastegate Solenoid A Range/ Performance |
| P0245 | Turbocharger Wastegate Solenoid A Low |
| P0246 | Turbocharger Wastegate Solenoid A High |
| P0247 | Turbocharger Wastegate Solenoid B Malfunction |
| P0248 | Turbocharger Wastegate Solenoid B Range/ Performance |
| P0249 | Turbocharger Wastegate Solenoid B Low |
| P0250 | Turbocharger Wastegate Solenoid B High |
| P0251 | Injection Pump A Rotor/ Cam Malfunction |
| P0252 | Injection Pump A Rotor/ Cam Range/ Performance |
| P0253 | Injection Pump A Rotor/ Cam Low |
| P0254 | Injection Pump A Rotor/ Cam High |
| P0255 | Injection Pump A Rotor/ Cam Intermittent |
| P0256 | Injection Pump B Rotor/ Cam Malfunction |
| P0257 | Injection Pump B Rotor/ Cam Range/ Performance |
| P0258 | Injection Pump B Rotor/ Cam Low |
| P0259 | Injection Pump B Rotor/ Cam High |
| P0260 | Injection Pump B Rotor/ Cam Intermittent |
| P0261 | Cylinder Number 1 Injector Circuit Low |
| P0262 | Cylinder Number 1 Injector Circuit High |
| P0263 | Cylinder Number 1 Contribution/ Balance Fault |
| P0264 | Cylinder Number 2 Injector Circuit Low |
| P0265 | Cylinder Number 2 Injector Circuit High |
| P0266 | Cylinder Number 2 Contribution/ Balance Fault |
| P0267 | Cylinder Number 3 Injector Circuit Low |
| P0268 | Cylinder Number 3 Injector Circuit High |
| P0269 | Cylinder Number 3 Contribution/ Balance Fault |
| P0270 | Cylinder Number 4 Injector Circuit Low |
| P0271 | Cylinder Number 4 Injector Circuit High |
| P0272 | Cylinder Number 4 Contribution/ Balance Fault |
| P0273 | Cylinder Number 5 Injector Circuit Low |
| P0274 | Cylinder Number 5 Injector Circuit High |
| P0275 | Cylinder Number 5 Contribution/ Balance Fault |
| P0276 | Cylinder Number 6 Injector Circuit Low |
| P0277 | Cylinder Number 6 Injector Circuit High |
| P0278 | Cylinder Number 6 Contribution/ Balance Fault |

| Code | P02XX Section (Fuel and Air Metering) Continued |
|---|---|
| P0279 | Cylinder Number 7 Injector Circuit Low |
| P0280 | Cylinder Number 7 Injector Circuit High |
| P0281 | Cylinder Number 7 Contribution/ Balance Fault |
| P0282 | Cylinder Number 8 Injector Circuit Low |
| P0283 | Cylinder Number 8 Injector Circuit High |
| P0284 | Cylinder Number 8 Contribution/ Balance Fault |
| P0285 | Cylinder Number 9 Injector Circuit Low |
| P0286 | Cylinder Number 9 Injector Circuit High |
| P0287 | Cylinder Number 9 Contribution/ Balance Fault |
| P0288 | Cylinder Number 10 Injector Circuit Low |
| P0289 | Cylinder Number 10 Injector Circuit High |
| P0290 | Cylinder Number 10 Contribution/ Balance Fault |
| P0291 | Cylinder Number 11 Injector Circuit Low |
| P0292 | Cylinder Number 11 Injector Circuit High |
| P0293 | Cylinder Number 11 Contribution/ Balance Fault |
| P0294 | Cylinder Number 12 Injector Circuit Low |
| P0295 | Cylinder Number 12 Injector Circuit High |
| P0296 | Cylinder Number 12 Contribution/ Balance Fault |
| 3 | P03XX Section (Ignition System or Misfire) |
| P0300 | Random/ Multiple Cylinder Misfire Detected |
| P0301 | Cylinder 1 Misfire Detected |
| P0302 | Cylinder 2 Misfire Detected |
| P0303 | Cylinder 3 Misfire Detected |
| P0304 | Cylinder 4 Misfire Detected |
| P0305 | Cylinder 5 Misfire Detected |
| P0306 | Cylinder 6 Misfire Detected |
| P0307 | Cylinder 7 Misfire Detected |
| P0308 | Cylinder 8 Misfire Detected |
| P0309 | Cylinder 9 Misfire Detected |
| P0310 | Cylinder 10 Misfire Detected |
| P0311 | Cylinder 11 Misfire Detected |
| P0312 | Cylinder 12 Misfire Detected |

| Code | P03XX Section (Ignition System or Misfire) Continued |
|---|---|
| P0320 | Ignition/ Distributor Engine Speed Input Circuit Malfunction |
| P0321 | Ignition/ Distributor Engine Speed Input Circuit Range/ Performance |
| P0322 | Ignition/ Distributor Engine Speed Input Circuit No Signal |
| P0323 | Ignition/ Distributor Engine Speed Input Circuit Intermittent |
| P0325 | Knock Sensor 1 Circuit Malfunction Bank 1 (or Single Sensor) |
| P0326 | Knock Sensor 1 Circuit Range/ Performance Bank 1 (or Single Sensor) |
| P0327 | Knock Sensor 1 Circuit Low Input Bank 1 (or Single Sensor) |
| P0328 | Knock Sensor 1 Circuit High Input Bank 1 (or Single Sensor) |
| P0329 | Knock Sensor 1 Circuit Input Intermittent Bank 1 (or Single Sensor) |
| P0330 | Knock Sensor 2 Circuit Malfunction (Bank 2) |
| P0331 | Knock Sensor 2 Circuit Range/ Performance (Bank 2) |
| P0332 | Knock Sensor 2 Circuit Low Input (Bank 2) |
| P0333 | Knock Sensor 2 Circuit High Input (Bank 2) |
| P0334 | Knock Sensor 2 Circuit Input Intermittent (Bank 2) |
| P0335 | Crankshaft Position Sensor A Circuit Malfunction |
| P0336 | Crankshaft Position Sensor A Circuit Range/ Performance |
| P0337 | Crankshaft Position Sensor A Circuit Low Input |
| P0338 | Crankshaft Position Sensor A Circuit High Input |
| P0339 | Crankshaft Position Sensor A Circuit Intermittent |
| P0340 | Camshaft Position Sensor Circuit Malfunction |
| P0341 | Camshaft Position Sensor Circuit Range/ Performance |
| P0342 | Camshaft Position Sensor Circuit Low Input |
| P0343 | Camshaft Position Sensor Circuit High Input |
| P0344 | Camshaft Position Sensor Circuit Intermittent |
| P0350 | Ignition Coil Primary/ Secondary Circuit Malfunction |
| P0351 | Ignition Coil A Primary/ Secondary Circuit Malfunction |
| P0352 | Ignition Coil B Primary/ Secondary Circuit Malfunction |
| P0353 | Ignition Coil C Primary/ Secondary Circuit Malfunction |
| P0354 | Ignition Coil D Primary/ Secondary Circuit Malfunction |
| P0355 | Ignition Coil E Primary/ Secondary Circuit Malfunction |
| P0356 | Ignition Coil F Primary/ Secondary Circuit Malfunction |
| P0357 | Ignition Coil G Primary/ Secondary Circuit Malfunction |
| P0358 | Ignition Coil H Primary/ Secondary Circuit Malfunction |
| P0359 | Ignition Coil I Primary/ Secondary Circuit Malfunction |
| P0360 | Ignition Coil J Primary/ Secondary Circuit Malfunction |

| Code | P03XX Section (Ignition System or Misfire) Continued |
|---|---|
| P0361 | Ignition Coil K Primary/ Secondary Circuit Malfunction |
| P0362 | Ignition Coil L Primary/ Secondary Circuit Malfunction |
| P0370 | Timing Reference High Resolution Signal A Malfunction |
| P0371 | Timing Reference High Resolution Signal A Too Many Pulses |
| P0372 | Timing Reference High Resolution Signal A Too Few Pulses |
| P0373 | Timing Reference High Resolution Signal A Intermittent/ Erratic Pulses |
| P0374 | Timing Reference High Resolution Signal A No Pulses |
| P0375 | Timing Reference High Resolution Signal B Malfunction |
| P0376 | Timing Reference High Resolution Signal B Too Many Pulses |
| P0377 | Timing Reference High Resolution Signal B Too Few Pulses |
| P0378 | Timing Reference High Resolution Signal B Intermittent/ Erratic Pulses |
| P0379 | Timing Reference High Resolution Signal B No Pulses |
| P0380 | Glow Plug/ Heater Circuit Malfunction |
| P0381 | Glow Plug/ Heater Indicator Circuit Malfunction |
| P0385 | Crankshaft Position Sensor B Circuit Malfunction |
| P0386 | Crankshaft Position Sensor B Circuit Range/ Performance |
| P0387 | Crankshaft Position Sensor B Circuit Low Input |
| P0388 | Crankshaft Position Sensor B Circuit High Input |
| P0389 | Crankshaft Position Sensor B Circuit Intermittent |
| 4 | **P04XX Section (Auxiliary Emission Controls)** |
| P0400 | Exhaust Gas Recirculation Flow Malfunction |
| P0401 | Exhaust Gas Recirculation Flow Insufficient |
| P0402 | Exhaust Gas Recirculation Flow Excessive |
| P0403 | Exhaust Gas Recirculation Circuit Malfunction |
| P0404 | Exhaust Gas Recirculation Circuit Range/ Performance |
| P0405 | Exhaust Gas Recirculation Sensor A Circuit Low |
| P0406 | Exhaust Gas Recirculation Sensor A Circuit High |
| P0407 | Exhaust Gas Recirculation Sensor B Circuit Low |
| P0408 | Exhaust Gas Recirculation Sensor B Circuit High |
| P0410 | Secondary Air Injection System Malfunction |
| P0411 | Secondary Air Injection System Incorrect Flow |
| P0412 | Secondary Air Injection System Switching Valve A Circuit Malfunction |
| P0413 | Secondary Air Injection System Switching Valve A Circuit Open |

| Code | P04XX Section (Auxiliary Emission Controls) Continued |
|---|---|
| P0414 | Secondary Air Injection System Switching Valve A Circuit Shorted |
| P0415 | Secondary Air Injection System Switching Valve B Circuit Malfunction |
| P0416 | Secondary Air Injection System Switching Valve B Circuit Open |
| P0417 | Secondary Air Injection System Switching Valve B Circuit Shorted |
| P0420 | Catalyst System Efficiency Below Threshold (Bank 1) |
| P0421 | Warm Up Catalyst Efficiency Below Threshold (Bank 1) |
| P0422 | Main Catalyst Efficiency Below Threshold (Bank 1) |
| P0423 | Heated Catalyst Efficiency Below Threshold (Bank 1) |
| P0424 | Heated Catalyst Temperature Below Threshold (Bank 1) |
| P0430 | Catalyst System Efficiency Below Threshold (Bank 2) |
| P0431 | Warm Up Catalyst Efficiency Below Threshold (Bank 2) |
| P0432 | Main Catalyst Efficiency Below Threshold (Bank 2) |
| P0433 | Heated Catalyst Efficiency Below Threshold (Bank 2) |
| P0434 | Heated Catalyst Temperature Below Threshold (Bank 2) |
| P0440 | Evaporative Emission Control System Malfunction |
| P0441 | Evaporative Emission Control System Incorrect Purge Flow |
| P0442 | Evaporative Emission Control System Leak Detected (Small Leak) |
| P0443 | Evaporative Emission Control System Purge Control Valve Circuit Malfunction |
| P0444 | Evaporative Emission Control System Purge Control Valve Circuit Open |
| P0445 | Evaporative Emission Control System Purge Control Valve Circuit Shorted |
| P0450 | Evaporative Emission Control System Pressure Sensor Malfunction |
| P0451 | Evaporative Emission Control System Pressure Sensor Range/ Malfunction |
| P0452 | Evaporative Emission Control System Pressure Sensor Low Input |
| P0453 | Evaporative Emission Control System Pressure Sensor High Input |
| P0454 | Evaporative Emission Control System Pressure Sensor Intermittent |
| P0455 | Evaporative Emission Control System Leak Detected (Large Leak) |
| P0460 | Fuel Level Sensor Circuit Malfunction |
| P0461 | Fuel Level Sensor Circuit Range/ Performance |
| P0462 | Fuel Level Sensor Circuit Low Input |
| P0463 | Fuel Level Sensor Circuit High Input |
| P0464 | Fuel Level Sensor Circuit Intermittent |
| P0465 | Purge Flow Sensor Circuit Malfunction |
| P0466 | Purge Flow Sensor Circuit Range/ Performance |
| P0467 | Purge Flow Sensor Circuit Low Input |
| P0468 | Purge Flow Sensor Circuit High Input |

| Code | P04XX Section (Auxiliary Emission Controls) Continued |
|---|---|
| P0469 | Exhaust Pressure Sensor Malfunction |
| P0470 | Purge Flow Sensor Circuit Intermittent |
| P0471 | Exhaust Pressure Sensor Range/ Performance |
| P0472 | Exhaust Pressure Sensor Low |
| P0473 | Exhaust Pressure Sensor High |
| P0474 | Exhaust Pressure Sensor Intermittent |
| P0475 | Exhaust Pressure Control Valve Malfunction |
| P0476 | Exhaust Pressure Control Valve Range/ Performance |
| P0477 | Exhaust Pressure Control Valve Low |
| P0478 | Exhaust Pressure Control Valve High |
| P0479 | Exhaust Pressure Control Valve Intermittent |
| 5 | **P05XX Section (Vehicle Speed, Idle Control, Auxiliary Input)** |
| P0500 | Vehicle Speed Sensor Malfunction |
| P0501 | Vehicle Speed Sensor Range/ Performance |
| P0502 | Vehicle Speed Sensor Circuit Low Input |
| P0503 | Vehicle Speed Sensor Intermittent/ Erratic/ High |
| P0505 | Idle Control System Malfunction |
| P0506 | Idle Control System RPM Lower Than Expected |
| P0507 | Idle Control System RPM Higher Than Expected |
| P0510 | Closed Throttle Position Switch Malfunction |
| P0530 | A/C Refrigerant Pressure Sensor Malfunction |
| P0531 | A/C Refrigerant Pressure Sensor Circuit Range/ Performance |
| P0532 | A/C Refrigerant Pressure Sensor Circuit Low Input |
| P0533 | A/C Refrigerant Pressure Sensor Circuit High Input |
| P0534 | Air Conditioner Refrigerant Charge Loss |
| P0550 | Power Steering Pressure Sensor Circuit Malfunction |
| P0551 | Power Steering Pressure Sensor Circuit Range/ Performance |
| P0552 | Power Steering Pressure Sensor Circuit Low Input |
| P0553 | Power Steering Pressure Sensor Circuit High Input |
| P0554 | Power Steering Pressure Sensor Circuit Intermittent |
| P0560 | System Voltage Malfunction |
| P0561 | System Voltage Unstable |
| P0562 | System Voltage Low |

| Code | P05XX Section (Vehicle Speed, Idle Control, Auxiliary Input) Cont. |
|---|---|
| P0563 | System Voltage High |
| P0565 | Cruise Control On Signal Malfunction |
| P0566 | Cruise Control Off Signal Malfunction |
| P0567 | Cruise Control Resume Signal Malfunction |
| P0568 | Cruise Control Set Signal Malfunction |
| P0569 | Cruise Control Coast Signal Malfunction |
| P0570 | Cruise Control Accel Signal Malfunction |
| P0571 | Cruise Control/ Brake Switch A Circuit Malfunction |
| P0572 | Cruise Control/ Brake Switch A Circuit Low |
| P0573 | Cruise Control/ Brake Switch A Circuit High |
| P0574 | through P0580 Reserved for Cruise Control Codes |
| **6** | **P06XX Section (Computer and Auxiliary Output Devices)** |
| P0600 | Serial Communication Link Malfunction |
| P0601 | Internal Control Module Memory Check Sum Error |
| P0602 | Control Module Programming Error |
| P0603 | Internal Control Module Programing Error |
| P0604 | Internal Control Module Keep Alive Memory (KAM) Error |
| P0605 | Internal Control Module Read Only Memory (ROM) Error |
| P0606 | PCM Processor Fault |
| **7** | **P07XX Section (Transmission)** |
| P0700 | Transmission Control System Malfunction |
| P0701 | Transmission Control System Range/ Performance |
| P0702 | Transmission Control System Electrical |
| P0703 | Torque Converter/ Brake Switch B Circuit Malfunction |
| P0704 | Clutch Switch Input Circuit Malfunction |
| P0705 | Transmission Range Sensor Circuit Malfunction (PRNDL) |
| P0706 | Transmission Range Sensor Circuit Range/ Performance |
| P0707 | Transmission Range Sensor Circuit Low Input |
| P0708 | Transmission Range Sensor Circuit High Input |
| P0709 | Transmission Range Sensor Circuit Intermittent |
| P0710 | Transmission Fluid Temperature Sensor Circuit Malfunction |

| Code | P07XX Section (Transmission) Continued |
|---|---|
| P0711 | Transmission Fluid Temperature Sensor Circuit Range/ Performance |
| P0712 | Transmission Fluid Temperature Sensor Circuit Low Input |
| P0713 | Transmission Fluid Temperature Sensor Circuit High Input |
| P0714 | Transmission Fluid Temperature Sensor Circuit Intermittent |
| P0715 | Input/ Turbine Speed Sensor Circuit Malfunction |
| P0716 | Input/ Turbine Speed Sensor Circuit Range/ Performance |
| P0717 | Input/ Turbine Speed Sensor Circuit No Signal |
| P0718 | Input/ Turbine Speed Sensor Circuit Intermittent |
| P0719 | Torque Converter/ Brake Switch B Circuit Low |
| P0720 | Output Speed Sensor Circuit Malfunction |
| P0721 | Output Speed Sensor Circuit Range/ Performance |
| P0722 | Output Speed Sensor Circuit No Signal |
| P0723 | Output Speed Sensor Circuit Intermittent |
| P0724 | Torque Converter/ Brake Switch B Circuit High |
| P0725 | Engine Speed Input Circuit Malfunction |
| P0726 | Engine Speed Input Circuit Range/ Performance |
| P0727 | Engine Speed Input Circuit No Signal |
| P0728 | Engine Speed Input Circuit Intermittent |
| P0730 | Incorrect Gear Ratio |
| P0731 | Gear 1 Incorrect Ratio |
| P0732 | Gear 2 Incorrect Ratio |
| P0733 | Gear 3 Incorrect Ratio |
| P0734 | Gear 4 Incorrect Ratio |
| P0735 | Gear 5 Incorrect Ratio |
| P0736 | Reverse Incorrect Ratio |
| P0740 | Torque Converter Clutch Circuit Malfunction |
| P0741 | Torque Converter Clutch Circuit Performance or Stuck OFF |
| P0742 | Torque Converter Clutch Circuit Stuck ON |
| P0743 | Torque Converter Clutch Circuit Electrical |
| P0744 | Torque Converter Clutch Circuit Intermittent |
| P0745 | Pressure Control Solenoid Malfunction |
| P0746 | Pressure Control Solenoid Performance or Stuck OFF |
| P0747 | Pressure Control Solenoid Stuck ON |
| P0748 | Pressure Control Solenoid Electronic |
| P0749 | Pressure Control Solenoid Intermittent |

| Code | P07XX Section (Transmission) Continued |
|---|---|
| P0750 | Shift Solenoid A Malfunction |
| P0751 | Shift Solenoid A Performance or Stuck OFF |
| P0752 | Shift Solenoid A Stuck ON |
| P0753 | Shift Solenoid A Electrical |
| P0754 | Shift Solenoid A Intermittent |
| P0755 | Shift Solenoid B Malfunction |
| P0756 | Shift Solenoid B Performance or Stuck OFF |
| P0757 | Shift Solenoid B Stuck ON |
| P0758 | Shift Solenoid B Electrical |
| P0759 | Shift Solenoid B Intermittent |
| P0760 | Shift Solenoid C Malfunction |
| P0761 | Shift Solenoid C Performance or Stuck OFF |
| P0762 | Shift Solenoid C Stuck ON |
| P0763 | Shift Solenoid C Electrical |
| P0764 | Shift Solenoid C Intermittent |
| P0765 | Shift Solenoid D Malfunction |
| P0766 | Shift Solenoid D Performance or Stuck OFF |
| P0767 | Shift Solenoid D Stuck ON |
| P0768 | Shift Solenoid D Electrical |
| P0769 | Shift Solenoid D Intermittent |
| P0770 | Shift Solenoid E Malfunction |
| P0771 | Shift Solenoid E Performance or Stuck OFF |
| P0772 | Shift Solenoid E Stuck ON |
| P0773 | Shift Solenoid E Electrical |
| P0774 | Shift Solenoid E Intermittent |
| P0780 | Shift Malfunction |
| P0781 | 1-2 Shift Malfunction |
| P0782 | 2-3 Shift Malfunction |
| P0783 | 3-4 Shift Malfunction |
| P0784 | 4-5 Shift Malfunction |
| P0785 | Shift/ Timing Solenoid Malfunction |
| P0786 | Shift/ Timing Solenoid Range/ Performance |
| P0787 | Shift/ Timing Solenoid Low |
| P0788 | Shift/ Timing Solenoid High |
| P0789 | Shift/ Timing Solenoid Intermittent |
| P0790 | Normal/ Performance Switch Circuit Malfunction |

# APPENDIX B

## J- Documents

J-Documents are those that have been prepared by SAE to define the standards that regulate OBD II. These J-Documents include the standards that produced the DTC list in Appendix A, as well as defining the various test modes and testers used on OBD II systems.

## J 1930 Standardized List of Common Components

If there's a paper that you are already familiar with, it's probably this one. This paper was intended to standardize the list of terms, definitions, acronyms, and abbreviations used with OBD II to eliminate confusion about how certain components are named. These J1930 terms have been showing up for some time in technical publications and trade press articles, so you've seen some of them already. Why do this? Over the years, each manufacturer has used his own particular name for a common component, and it was pretty confusing trying to figure out what these letter designations stood for, especially when you were working on an unfamiliar vehicle. For instance, J1930 says that if manufacturer A called the powertrain computer an ***ECU*** and manufacturer B called the computer an ***ECA***, both now have to call it a ***PCM***.

It may take some time to become totally familiar with these terms, especially if you've been in the habit calling a given component by a different name. Be careful about some of them. You may be in the habit of referring to a distributorless ignition system as DIS. The new J1930 term is simply EI. The term DI stands for a Distributor-type Ignition. It's important that you become familiar with these terms, since they will be used as the standard on generic scan tool displays. The good news, is that you no longer have several different lists to memorize.

| Component | OBD II Term | Common OBD I Terms |
|---|---|---|
| 3-2 Timing Solenoid | 3-2TS | |
| 4X4Low | 4X4L | 4X4L |
| Accelerator Pedal | AP | Accelerator Pedal |
| Accelerator Pedal Position | APP | |
| Air Cleaner | ACL | Air Cleaner |
| Air Conditioning | A/C | A/C or Air Conditioning |
| Air Conditioning Clutch | ACC | A/C or Compressor Clutch |
| Air Conditioning Clutch Switch | ACCS | Compressor Clutch Cycling Switch |
| Air Conditioning Demand | ACD | |
| Air Conditioning ON | ACON | |
| Ambient Air Temperature | AAT | |
| Automatic Ride Control | ARC | |
| Automatic Transaxle | A/T | |
| Automatic Transmission | A/T | |
| Barometric Pressure | BARO | Barometric Pressure Sensor/BARO |
| Battery Positive Voltage | B+ | Battery Positive |
| Blower | BLR | Blower |
| Brake On/OFF | BOO | Brake On/Off or BOO |
| Brake Pedal Position | BPP | |

| Component | OBD II Term | Common OBD I Terms |
|---|---|---|
| Calculated Load Value | LOAD | |
| Camshaft Position | CMP | Camshaft or CID sensor |
| Canister Purge | CANP | |
| Carburetor | CARB | Carburetor |
| Central Multiport Fuel Injection | CMFI | |
| Charge Air Cooler | CAC | |
| Closed Loop | CLL | |
| Closed Throttle Position | CTP | Throttle Position Switch |
| Clutch Pedal Position | CPP | CES or Clutch Engage Switch |
| Coast Clutch Solenoid | CCS | |
| Computer Controlled Dwell | CCD | |
| Constant Control Relay Module | CCRM | |
| Continuous Fuel Injection | CFI | |
| Continuous Trap Oxidizer | CTOX | |
| Crankshaft Position | CKP | Crank Angle or Crankshaft Position Sensor |
| Critical Flow Venturi | CFV | |
| Cylinder Identification | CID | Cylinder Identification or CID |
| Data Link Connector | DLC | ALCL, ALDL, Check Connector |
| Data Negative | DATA- | |
| Data Output Line | DOL | |
| Data Positive | DATA+ | |
| Diagnostic Trouble Code | DTC | |
| Direct Fuel Injection | DFI | |
| Distributor Ignition | DI | Capacitive discharge, Closed Bowl, ESAC, HEI, TFI |
| Early Fuel Evaporation | EFE | |
| EGR Temperature | EGRT | |
| Electrically Erasable Programmable Read-Only Memory | EEPROM | EEPROM, Flash EPROM |
| Electronic Ignition | EI | Distributorless Ignition, Integrated Direct Ignition, Direct Ignition, DIS, EDIS |
| Engine Control | EC | |
| Engine Control Module | ECM | ECM,ECU, ECA |
| Engine Coolant Level | ECL | |
| Engine Coolant Temperature | ECT | CTS, coolant sensor |
| Engine Modification | EM | |
| Engine Oil Pressure | EOP | |
| Engine Oil Temperature | EOT | |
| Engine Speed | RPM | |
| Erasable Programmable Read-Only Memory | EPROM | |
| Evaporative Emission | EVAP | |
| Exhaust Gas Recirculation | EGR | |
| Exhaust Pressure | EP | |
| Fan Control | FC | |
| Flash Electrically Erasable Programmable Read-Only Memory | FEEPROM | |
| Flexible Fuel | FF | Flex Fuel sensor, Alcohol Concentration sensor Percent Alcohol sensor, Variable Fuel sensor |
| Fourth Gear | 4GR | |
| Freeze Frame | FRZF | |
| Front-Wheel Drive | FWD | |
| Fuel Level Sensor | Fuel Level Sensor | |

| Component | OBD II Term | Common OBD I Terms |
|---|---|---|
| Fuel Pressure | Fuel Pressure | |
| Fuel Pump | FP | |
| Fuel Pump Module | FP Module | |
| Fuel System Status | Fuel SYS | |
| Fuel Trim | FT | Adaptive fuel strategy |
| Generator/Alternator | GEN | Alternator |
| Glow Plug | GLOW PLUG | |
| Governor | GOVERNOR | |
| Governor Control Module | GCM | |
| Grams Per Mile | GPM | |
| Ground | GND | |
| Heated Oxygen Sensor | HO2S | HEGO, HO2, HOS |
| High Speed Fan Control Switch | High Speed FC Switch | |
| Idle Air Control | IAC | |
| Idle Speed Control | ISC | |
| Ignition Control | IC | |
| Ignition Control Module | ICM | |
| Indirect Fuel Injection | IFI | |
| Inertia Fuel Shutoff | IFS | |
| Input Shaft Speed | ISS | |
| Inspection and Maintenance | I/M | |
| Intake Air | IA | |
| Intake Air Temperature | IAT | ACT (Air Charge Temperature), IAT (Intake Air temperature, MAT, TBT, VAT |
| Intake Manifold Runner Control | IMRC | |
| Knock Sensor | KS | |
| Malfunction Indicator Light | MIL | Check Engine Light, Service Engine Soon (SES) Light, OXS light |
| Manifold Absolute Pressure | MAP | Manifold Absolute Pressure |
| Manifold Differential Pressure | MDP | |
| Manifold Surface Temperature | MST | |
| Manifold Vacuum Zone | MVZ | |
| Mass Air Flow | MAF | |
| Mixture Control | MC | |
| Multiport Fuel Injection | MFI | D-Jetronic, DFI, EFI, L-Jetronic, LH-Jetronic MFI, Motronic, MPI, PFI, PGM-FI, TPI |
| Non-Volatile Random Access Memory | NVRAM | KAM (Keep Alive Memory), NVM |
| On-Board Diagnostic | OBD | Self-Test |
| Open Loop | OL | |
| Output Shaft Speed | OSS | |
| Oxidation Catalytic Converter | OC | |
| Oxygen Sensor | O2S | Oxygen sensor, EGO, EGOS, EGS, EOS, Lambda sensor |
| Parl/Neutral Position | PNP | Neutral Safety Switch, Neutral Drive Switch |
| Parameter Identification | PID | |
| Positive Crankcase Ventilation | PCV | |
| Power Steering Pressure Switch | PSP | |
| Powertrain Control Module | PCM | ECA, ECU, EEC, MCU, PCM SBEC, SMEC |
| Programmable Read-Only Memory | PROM | |
| Pulsed Secondary Air Injection | PAIR | Pulse Air, Reed Valve, Thermactor |
| Pulse Width Modulated | PWM | |
| Random Acess Memory | RAM | |

| Component | OBD II Term | Common OBD I Terms |
|---|---|---|
| Read-Only Memory | ROM | |
| Rear-Wheel Drive | RWD | |
| Relay Module | RM | |
| Scan Tool | ST | |
| Secondary Air Injection | AIR | |
| Selectable Four-Wheel Drive | S4WD | |
| Sequential Multiport Fuel Injection | SFI | SEFI, Sequential Multiport Fuel Injection |
| Service Reminder Indication | SRI | EMR, Check Engine Light |
| Shift Solenoid | SS | |
| Short Term Fuel Trim | Short Term FT | Integrator (INT) |
| Smoke Puff Limiter | SPL | |
| Spark Advance | SPARK ADV | |
| Supercharger | SC | |
| Supercharger Bypass | SCB | |
| System Readiness Test | SRT | |
| Thermal Vacuum Valve | TVV | |
| Third Gear | 3GR | |
| Three-Way Catalyst | TWC | |
| Throttle Body | TB | |
| Throttle Body Fuel Injection | TBI | Central Fuel Injection, Monotronic, Single Point Fuel Injection, Throttle Body (TBI) |
| Throttle Actuator Control | TAC | |
| Throttle Position | TP | |
| Throttle Position Sensor | TP sensor | TP, TPS |
| Throttle Position Switch | TP switch | TP, TPS |
| Torque Converter Clutch | TCC | Lock up, CCC, CCO, TCC |
| Torque Converter Clutch Pressure | TCCP | |
| Transmission Control Module | TCM | |
| Transmission Fluid Pressure | TFP | |
| Transmission Fluid Temperature | TFT | |
| Transmission Range | TR | |
| Turbine Shaft Speed | TSS | |
| Turbocharger | TC | |
| Vane Air Flow | VAF | AFC, VAF, Air Flow sensor, Vane Air Flow sensor, Air Flow Meter |
| Variable Control Relay Module | VCRM | |
| Vehicle Control Module | VCM | |
| Vehicle Identification Number | VIN | |
| Vehicle Speed Sensor | VSS | Pulse generator, Vehicle Speed sensor |
| Voltage Regulator | VR | |
| Warm-up Oxidation Catalytic Converter | WU-OC | |
| Warm Up Three-Way Catalytic Converter | WU-TWC | Light-off catalyst |
| Wide Open Throttle | WOT | |

# APPENDIX B (cont)

## SAE J-Documents

**J1850 - Scan Tools**

This paper establishes the protocols used for data transmission between the PCM and scan tool. There are three general classifications of serial data transfer, referred to as Class A, Class B, and Class C.

When the scan tool is connected to the vehicle, it is programmed to scan the communication protocol being used, and then select the correct protocol to allow communication between the scan tool and PCM. Manufacturers may use a Variable Pulse-width (VPW) signal operating at 10.4 kBaud, a Pulse-Width-Modulated signal operation at 41.6 kBaud, or use a standard known as ISO 9142-2 that operates at 10.4 kBaud.

**J1930 - Terms and definitions**

This paper standardizes terminology. Refer to Appendix B for a list of these terms and the OBD I terms they replace.

**J1962 - Diagnostic Connector Standard**

This paper defines the size and shape of the OBD II diagnostic connector. Some refer to this connector as the DDL (Diagnostic Data Link) or as the DLC (Diagnostic Link Connector). You may see both terms used. The standard also specifies the number of possible pins used in the connector (16) and requires uniform numbering of the pins. Of the 16 total pins, 7 are reserved and have standard assignments as grounds, voltage supplies, and data transmission connection points. The remaining pins may be used at the discretion of the manufacturer.

The mandated generic scan tool interface will permit a technician to retrieve generic data stream information. Enhanced data about other non-OBD II systems may be available right at the DLC or may be accessible at a remote, separate connector. In most cases, retrieving enhanced information will require vehicle-specific software and a separate interface where a remote connector is used.

The paper also recommends that the connector be located inside the vehicle below the dash between the steering column and centerline of the vehicle no more than 12 inches past the centerline of the vehicle. (Expect to see some variation from this standard, especially on 1994-95 transition vehicles.)

**J1979 - Diagnostic Test Modes**

This paper establishes the minimum requirements for data transmission and the types of tests and commands supported in the generic scan tool interface. Here are the minimum capabilities and modes of operation that must be supported for the generic scan tool:

- **Request Current Powertain Diagnostic Data.** This mode displays data stream parameters for individual emissions-related inputs and outputs. Data values are required to be actual readings, not values that may have been substituted if the PCM enters a fail-safe mode of operation.
- **Request Powertrain Freeze Frame data.** This mode allows the technician to view any Freeze Frame data that was stored with a DTC. Freeze Frame is a single-shot picture of general engine conditions that were present when the DTC set, not a movie consisting of several frames. Only one Freeze Frame is mandated, and may accompany the highest priority DTC when multiple DTCs are stored in memory.
- **Request Emissions-related DTCs.** This mode displays codes, or DTCs stored in the PCM memory on most vehicles.
- **Clear-reset Emissions-related Diagnostic Information.** This mode allows the technician to erase DTCs. Erasing DTCs also erases any related Freeze Frame data.
- **Request Oxygen Sensor Monitor Test Results.** The purpose of this mode is to allow the technician to look at the results of the oxygen sensor monitor. This is an enhancement of the general data stream parameter for the $O_2$ sensor, since it displays precise information about the operation of the oxygen sensor monitor.
- **Request on-board monitoring of Continuously and Non-Continuously monitored tests.** This mode allows the technician to view informa-

tion about monitor status as a verification that monitors have run successfully. Some monitors run once per trip, and others run continuously once their enabling criteria have been met. Monitoring test results allows for verification of a repair following a test drive.

**J2012 - DTC Definitions**
This paper standardizes the format used to display DTCs and also standardizes the definitions used with each SAE-defined DTC. All OBD II DTCs are 5 characters in length and contain a letter prefix followed by 5 numbers. Generic DTCs with a second character of "0" are defined by SAE, although manufacturers may add their own vehicle or system specific codes. A second character of "1" identifies a manufacturer's code. Interpretation of manufacturer-specific codes will require a list of those codes from each manufacturer. For a more detailed explanation of OBD II DTC interpretation, refer to Section Four of this course book.

**J2190 - Enhanced Diagnostic Test Modes**
This allows manufacturers to use the DLC for other, enhanced communications protocols that may not be OBD II-related. This eliminated the need to add a separate test connector for tests of other vehicle systems with the factory scan tool. While this is viewed as a convenience by some manufacturers, others have chosen to install separate test interface connectors for enhanced tests.

**J2008 - Electronic Information Access and Data Format**
This standard establishes guidelines for distribution of repair information deemed necessary for repair of emissions-related problems. Manufacturers have the option of making this information available on CD ROM or through electronic means over the internet, using a modem. The information contained in Fed World is a listing of technical repair, training, and technical service bulletins available from various manufacturers.

Notes:

# APPENDIX C

## *A BRIEF HISTORY OF OBD II*

California has always been the leader in addressing vehicle emissions. We can trace the history of emissions regulations back to those established by the California Bureau of Air Sanitation in the early 1950s.

In 1960, California formed the Motor Vehicle Pollution Control Board (MVPCB) to regulate tailpipe emissions. In 1964, the first emissions controls were mandated for 1966 vehicles to be sold in the state. This brought us our old friend the PCV valve, and positive crankcase ventilation was introduced to eliminate crankcase vapors from being discharged to the atmosphere. As California goes, so goes the nation. In 1968, Congress required that crankcase ventilation be used on all 1968 federally sold vehicles.

In 1968, two years before the establishment of the EPA, California led the way again by establishing the California Air Resources Board, or CARB. CARB combined the work of Bureau of Air Sanitation with that of the MVPCB to form an agency responsible for the monitoring and regulation of all air pollution threats. CARB took an active role in ensuring cleaner vehicles, and established test procedures and regulations that moved the rest of the nation toward increasingly tough emission regulation, especially for motor vehicles.

Once again, Congress said, "me too" and passed the first major Clean Air Act (CAA). It also set up the Environmental Protection Agency (EPA). Like CARB, the EPA was given responsibility for regulation of emissions, and set out to effect a 90 percent reduction in vehicle emissions. HC and CO emissions were targeted first, and the standards were to apply to 1975 model vehicles. NOx standards were set for 1976 production vehicles.

Other regulations followed:

- In **1971**, all new vehicles were required to meet evaporative emission standards for the first time. Charcoal vapor canister recovery systems were installed.

- In **1972**, EGR valves were introduced.

- In **1974**, Congress delayed the HC and CO standard until 1978 to give manufacturers more time to comply with the new regulations.

- In **1975**, we said hello to catalytic converters and unleaded gasoline. Unfortunately, vehicle engine management strategies were still very primitive compared to today's computerized systems, and it was very difficult for OEMs to get carbureted vehicles with complex add-on emission systems to meet the standards.

- In **1977**, Congress revised the Clean Air Act, delaying the HC standard until 1980 and the CO and NOx standards until 1981.

- In the **late 70s and early 80s**, the EPA began enforcing the standards, and emission recalls were ordered for vehicles that did not comply with regulations.

- In **1981**, new vehicles met the amended standards for the first time. Three-way catalytic converters and oxygen sensors began appearing on vehicles. The use of closed-loop systems required the addition of on-board vehicle computers. Some vehicles started using on-board diagnostics.

- In **1983**, Inspection and Maintenance (I/M) programs were established in 64 cities in the U.S. For the first time, vehicles were forced to pass an emission test in the field. The idea was to catch gross polluters, and get them fixed. Lack of maintenance, component failures, and tampering were all listed as reasons for these tests.

- In **1985**, CARB, SAE, and the EPA were working on standardizing and regulating emission systems.

- In **1988**, OBD I compliance became mandatory for 1988 models sold in California. In the same year, California proposed a set of regulations that became known as OBD II. California passed the Clean Air Act of 1988.

- In **1989**, California adopted the OBD II targets. The goal was to have 100 percent compliance by the 1996 model year.

- In **1990**, Congress said, "me too" again. It amended the Clean Air Act, requiring further reductions in vehicle emissions. This was a very comprehensive bill, and addressed many emission concerns in greater detail than previous legislation had. Tightened standards for CO and NOx were proposed.

- In **1991**, California formed the California Environmental Protection Agency (CA/EPA), and included CARB under its general umbrella of responsibility for regulation of all state environmental organizations.

In **1993**, California adopted even tighter emission standards, including requirements for zero-emission vehicles.

- In **1994**, the first OBD II vehicles were produced. Due to difficulties with certain monitoring strategies and problems encountered in getting existing software in other vehicle systems to work with emission control strategies, exemptions were granted, and vehicles produced in 1994-95 have varying degrees of OBD II compliance as a result.

- In **1996**, all vehicles are supposed to be fully OBD II-compliant.

- In **1997**, all OEMs were mandated to provide the aftermarket with software reprogramming capabilities, access to emissions-related technical information, training materials, and necessary test equipment.

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