

Driveability Diagnostics, OBD I & II

By Steve Zack - SPX Technical Trainer and Chuck Eaves -Technical Specialist, JA Echols & Assoc

Since the dawn of on-board diagnostics (OBD) in motor vehicles, the process of diagnosing driveability problems are the same as always, and very different, too. When OBD I evolved into OBD II in 1996, the electronic part of diagnosing driveability problems became a little easier. This is because the electronic network on OBD II vehicles became much more comprehensive and changed almost all mechanical functions that controlled the powertrain into electro/mechanical functions.

There are three indispensable tools to diagnose OBD system problems and make the proper repairs. These tools and how to use them will be explored in some detail.

Scan Tool Diagnostics

The first tool we'll talk about is the scan tool. In general terms, there are two types of "scan tools". One is referred to as a Code Reader. These simple electronic tools are useful and will read and erase all OBD emissions codes. Some will also give the code description, but not all code readers do this. A true scan tool, however, will read and clear OBD codes, and will do the same on "enhanced" and "sub-system" codes. These enhanced codes are OEM-specific, with OEM assigned numbers. These codes cover the entire electronic control spectrum beyond purely emissions. Beyond driveability, the codes will cover the HVAC, IPC, BCM, ABS, SRS, and electronic-bus communication systems. The true scan tool will also do many other important and useful things, and these will be discussed later.

Most of you have already noted the superior functionality of the OBD II system compared to the OBD I system. Some of the enhanced capability of the OBD II system will be found on OBD I. Most, however, will not. As already mentioned, OBD II was adopted across the board in 1996. You will find a couple of models of each manufacturer that introduced OBDII as early as 1994. These early OBD II vehicles were early production models, and usually employed both the OBD II 16 pin connector and the vehicle-specific connector to access the other systems.

Just remember, the scan tool reads and reports to you what the vehicle's computer system is doing and saying. If the computer system in the vehicle can't know or do a certain thing, like reading ignition kV, the scan tool cannot give you this information. The scan tool, then, is the interface between you and the vehicles' computer system.

There are two other tools, both of which have been around for quite a while, which are very important in diagnosing OBD problems. One is the technician; in other words, YOU. There will never come a day when the technician will not be absolutely essential to diagnose and repair OBD problems. No scan tool can fix the vehicle, and the scan tool will often only point you to the problem area. Your job is secure if you are willing to keep up with ever-advancing technology. This requires an on-going investment in education and tools. This will never change. Scan tools don't fix cars, you do! If you do your job well, you will make a very nice living fixing everything, but nothing more, than your customer's vehicle requires.

Part of your investment in your diagnostic future is in updating your scan tool. The electronic world will never stop moving and improving. Do not get angry with your scan tool distributor for offering you the latest update when it becomes available. Out-of-date software or hardware is like having only three points on your Philips screwdriver. It will still work, sort of, for a while maybe. **Don't wait.** Update your tool every chance the manufacturer gives you. You'll appreciate the difference the first time you use your tool, especially if you've just updated your *OTC Pegisys, Genisys, or Nemisys*. The functionality improvements *OTC* has added to the additional diagnostic information year-to-year in the *OTC family* of scan tools are nothing short of remarkable.

The third and last electronic diagnostic tool that we will address is the oscilloscope, or “scope” for short. Simply put, the purpose of a scope is to put a picture on a screen of the electrical activity that is going on in whatever you are testing. This picture is a constantly moving line trace, or graph, called a “pattern”. The scope info on the screen is “live”, not processed as with a scan tool. This fact makes scope information more accurate and more current than scan tool data, which first has to be processed by the vehicles computer, then again by the scan tool. Scan tool data is almost always reliable, but should be verified by a scope (or a digital multi-meter) before the repair is made. Otherwise, you may find yourself reading codes and pulling parts, over and over. This approach will be very unpopular with your customer, and will cost you money.

A high-quality scope can be expensive, and many techs simply don’t know how to use one. The *Genisys and Pegisys*, by *OTC*, are very easy to use, full-function scan tools with a 2 or 4-channel lab/engine analyzer scope. The price is surprisingly reasonable, especially when compared to the competition. *OTC’s* scope module for the *Genisys* is a full-function 4-channel 4-color scope that accurately presents all automotive voltage from mV through kV levels. The new *OTC Pegisys* has an ultra-high speed 2 channel scope built in, with all the advanced capability of the *Genisys’* 4 channel model, but with 2 channels for easier operation.

Before beginning the in-depth discussion of how to best use your scan tool, a few basic understandings are in order. You ASE Master Techs out there, just bear with us a little bit.

OBD I codes (early 1980’s through 1995) use two and three digit numbers without letters. They are all manufacturer assigned. OBD II codes (1996 up) consist of a letter followed by four numbers. There are four different letters for OBD II, and they are as follows:

- P – Powertrain codes, meaning engine and transmission. All emission codes start with P.
- B – body codes
- C – chassis codes
- U – communication-bus/network codes

In the “P” code group, if the first number is “0” (zero), all the codes are “generic”. This means that any light truck and car sold in America from 1996 on share the same P0 codes. The codes mean the exact same thing on all vehicles. P1 codes, however, are OEM assigned, and mean whatever the manufacturer wants them to mean as long as they are powertrain related.

The meaning of the second number in the P0 codes is as follows:

- 1 – Fuel metering, things like MAF, MAP, O2 sensors, etc.
- 2 – Fuel metering, but injector and injector circuit only
- 3 – Misfire and ignition
- 4 – Emission controls, like EVAP, EGR, CAT, etc.
- 5 – Vehicle and idle speed control
- 6 - and 7 – Transmission

The last two numbers give you the specific identification within the general system. Example: P0101. This means powertrain, OBD II emissions, fuel metering, mass air flow meter.

In the OBD II system, there are three types of codes. These are “Current”, “Pending”, and “History”. A current code will set the check engine light after one, two, or three “consecutive similar trips”, depending on which Monitor detects the problem. The conditions that the Monitor evaluates before deciding to illuminate the Check Engine Light are called “Enabling Criteria”. This fancy term simply refers to the process the vehicles’ computer goes through in deciding whether the problem is reoccurring and serious enough to set a code and turn on the light.

The “check engine light” is correctly called a “MIL”, or “Malfunction Indicator Light”. We’ll call it a MIL (not MIL light). The MIL only illuminates if the problem is a P code, emissions related. All “check engine light” codes are correctly called “diagnostic trouble codes”, or “DTC’s”. Let’s just use “codes” for DTC. It’s easier.

Current, Pending, and History codes (OBD II only)

Many current codes will set the MIL when it comes out of Pending and into Current. If the MIL illuminates as a result of an emissions code, a History code will be recorded, and a “Freeze Frame” recording will be stored. A Freeze Frame recording saves one frame of data on several PID items such as RPM, VSS, MAP and/or MAF, IAT, ECT, etc. Accessing the Freeze Frame recording will give you an idea of just what the vehicle was doing when the MIL set. DO NOT clear your codes first. All Pending and Freeze Frame info will disappear when your code/s are cleared.

If you are using the *OTC Pegisys, Genisys or Nemisys*, you can save the codes and Freeze Frame to tool memory before you clear your codes. The *Pegisys and Genisys* will automatically record a datastream list if a MIL sets while you are communicating with the vehicle. The *Genisys and Nemisys* recording is a staggering *1,000 frames*, approximately 82 before, and 918 after the MIL illuminates, and the *Pegisys* can record an infinite number of frames. This Automatic Data Stream Recording will not disappear when the codes are cleared, and can be saved to your *OTC Pegisys or Genisys*, printed, transferred to a USB jump drive, and/or your shop computer.

NOTE: If the battery in the vehicle is disconnected for any reason, the PCM will lose any Code information it had stored. Of course, all radio, mirror, seat, and HVAC memory will be cleared also. I recommend a Memory Saver if the vehicles’ battery has to be disconnected. Your tool and equipment distributor has a variety of these devices available, at a reasonable cost. Be sure to get one with enough amperage to last as long as the vehicles’ battery is to be disconnected.

A Pending Code can erase itself before the light comes on if the problem goes away and stays away for two or three consecutive similar trips. If this happens, no History code or Freeze Frame will be stored.

A History code is the medium and long-term storage of a Current code in the computers’ memory, and is strictly for the use of the technician in analyzing a new problem. The History code provides the tech a record of code activity in the recent past. The History code is not an active code; it is a recorded event. The History code carries no Freeze Frame data with it.

The History code will self-clear from the computers’ memory after 80 trips (for Continuous Monitors), or 40 trips (for Non-Continuous Monitors). However, some vehicles’ software will keep the History codes for 256 key-starts. Chrysler is an example of key-start count for History code memory.

There are four specific levels of codes. These levels indicate the priority of the code, and are explained as follows. Of course, a priority letter is only assigned to a code when there are multiple codes at the same time.

Type A codes: The MIL will be triggered on the first trip with the type A codes, and will record a freeze-frame record. Type A’s should be repaired first.

Type B codes: The MIL will trigger on the second or third trip with Type B, and a freeze-frame will be recorded. Type B codes should be addressed after the type A codes have been dealt with.

Type C codes: Non-emissions related, these codes will store a History record, and should have a third place priority.

Type D codes: Non-emissions related, and will not store a freeze frame or a History record. Repair these codes last.

Code Categories

There are three categories of codes within the OBD II system. They are Electrical, Mechanical, and Rational. Each type of code is specific in its setting criterion.

Electrical codes deal with the electrical circuit and its supply source. These codes can be set by a below-standard voltage supply and ground issues, as well as actual circuit failures. An Electrical code will set when extreme or sudden changes in voltage data is noticed when no changes in engine load or circuit operation are observed. An example is a TP sensor which suddenly shows a voltage of less than .2v. This type of fault is monitored by the Comprehensive Components Monitor, and therefore sets a code instantly upon parameter failure.

Mechanical codes deal with devices having a mechanical function, such as the passing of fluids or opening and closing of passages. A good example is an EGR passage that may be partially plugged, not allowing the correct volume of exhaust gas to flow. This mechanical code is monitored by the EGR Readiness Monitor. This Monitor uses several EVAP and engine sensors to watch for a change in value outside the pre-set parameters, setting a code on the second trip cycle.

Rational codes are set when a sensor does not meet its criterion of operation. An example of a Rational code would be the MAF sensor showing a very high volume of air flow with low engine RPM, a small throttle opening, and no indication of an increase in engine load. This type of MAF PID would indicate an out-of-calibration MAF based on what the other sensors show. In this example, the MAF sensor would not be used by the PCM for fuel control.

Each of the above three code types is tested by the Readiness Monitor dedicated to the particular emissions system involved. When a component fails to meet the standard set by the manufacturer during its trip cycle, the component is further monitored for a given period of time. When the component parameters are still not met after the drive cycle is satisfied, a failure is recorded and the MIL is illuminated. The particular components' parameters are recorded and shown in the "Component Parameters" (Mode 6) section of "Special Tests".

Failure Type Byte DTC

There is now a new DTC numbering system in town. An example of this new system is "P0110:1C-AF". The additional digits at the end of the DTC indicate the "Failure Type Byte". When a FTB appears on the end of the DTC it will be used by the PCM to give more information about the failure. Many DTC numbers provide enough of a description with the alpha and 4 digits. However, many do not and as a result it is sometimes difficult to determine the exact failure from the DTC without a lot of diagnostic work. An FTB will be added to certain DTC's when necessary to add a more detail description of the failure leading you to a simpler diagnosis. In the past, P0110 indicated an 'Intake Air Temperature Sensor Circuit' which may be problems with any of the wiring between the sensor and the PCM, or the sensor itself are at fault. With the new indicator at the end of the fault code (1C-AF), the DTC now gives a more complete description of the failure. This example is indicating the Intake Air Temperature Sensor itself is out of range.

Monitors (OBDII only)

Another significant difference between OBD I and II is the onboard diagnostic testing called "Monitors". The Monitors are active tests of up to eleven electronic systems in the OBD system. Not all OBDII vehicles support all 11 Monitors, however. In fact, two Monitors in particular have never been activated. One is the A/C Monitor, planned before R-134 became the standard mobile refrigerant used in the US. R-134 was judged to be much less harmful to the atmosphere compared to R-12, so the AC monitor has never been used.

The other Monitor never activated is the Heated Catalyst. The engineering principal behind heating the catalytic converter quickly is the same as heating the O2 sensors: get the cat and the O2 sensors on line within seconds, not minutes. However, the electrical current required to get a catalytic converter up to operating temperature with a heater, and within seconds, is still waiting on the 42v system. This relatively high-voltage electrical system is sure to become a reality one day, but technical and cost challenges have to be overcome first.

The Monitors that the OBDII system runs are divided into two groups: Continuous, and Non-Continuous. The Continuous Monitors run their diagnostic tests on three emission control systems continually as long as we have key-on, engine running. These Monitors are:

- 1 - Misfire
- 2 - Fuel System
- 3 - Comprehensive - The Comprehensive Monitor looks for open or shorted circuits, and data that is out of range. All OBDII compliant vehicles run these three Monitors.

The Non-Continuous Monitors run their diagnostic tests once per trip, but not continuously. These Monitors include:

- 1 - Oxygen sensor
- 2 - Oxygen sensor heater
- 3 - Catalyst
- 4 - Heated catalyst (not used)
- 5 - EGR system (not universally used)
- 6 - EVAP system
- 7 - Secondary air system (not universally used)

OBD II compliant vehicles run all Continuous Monitors and most of the Non-Continuous monitors. A very few OBD II engines do not need an EGR valve, so do not run that Monitor. Almost all California-compliant systems use secondary air systems, so they will run that Monitor. Most Federal-compliant engines do not.

As already stated, when a MIL is illuminated as a result of an emissions related code, an action called "Freeze Frame" is initiated by the PCM. A freeze frame is a snapshot of 8 or 10 PID items. These recordings are required by EPA regulation to capture loop status (open or closed), engine load, coolant temperature, and fuel trim, manifold vacuum (MAP), RPM, and DTC priority. Some PCM's may add vehicle speed, throttle position, ignition advance, and trips since the MIL was last cleared.

Advantage *Pegisys*, *Genisys* and *Nemisys*

An extremely useful and unique function of the *OTC Pegisys*, *Genisys*, and *Nemisys* is **Automatic DTC Datastream Recording**. If an *OTC* scan tool is communicating with the vehicle while in Datastream when a code happens to set, much of the datastream list will be recorded into the *Pegisys*, *Genisys*, or *Nemisys* memory. This recording will not be erased when the codes are cleared and can contain from 11 to 45 or more PID items. Unlike the freeze frame feature of all OBD II PCM's, the *Genisys* DTC Datastream recording captures up to 1,000 frames, and the *Pegisys* an infinite amount of frames, not just one. Every recorded PID can then be graphed and printed to plain paper using a regular HP type inkjet printer. With available ConnectTech software, all *Genisys* recordings can be uploaded into your desktop or laptop computer and stored in a file of your choice. The *OTC Nemisys* offers uploading its recorded information into a computer via an included CD ROM. The *OTC Pegisys* and *Genisys* can off-load their recordings onto a USB drive plugged into the tools' USB port.

OBD System Hardware

In both the OBDI and II systems, the vehicles' computer (PCM from now on) deals with three main pieces of hardware: actuators, sensors, and switches. The PCM **receives data** from sensors and switches, and **commands** and actuators accordingly. The PCM is programmed by the manufacturer with

algorithms to compare what it sees to what it expects to see. A pre-determined difference in expected input or output for a given length of time or trip count will trigger a code. However, the PCM is *only so smart!* It can't "think outside of the box" (get it?). Verify the code before you start yanking parts. Your **OTC** scope or meter is your best friend here.

Incidentally, some literature and technicians refer to the PCM as the ECM (Electronic Control Module). The two are the same thing. The term ECM, though, is more often used when referring to OBDI systems.

A note of interest: PCM's from the 1980's until 1993 or so had their operational memories loaded on a replaceable "PROM". To correct or update one of these early PCM's you would replace the existing PROM with the correct new one. As a rule, no special tools are needed, except a wrist grounding strap. After 1993, the PCM's had to be reprogrammed or "reflashed", to correct or update its operation. The new system, known by its SAE number, J2534, is a web-based reflash method. **Great news: OTC** will offer the J2534-2 multi-vehicle, all modules reflash program as optional software for the **OTC Pegisys**.

Modes of Vehicle Operation

Both OBD I and II systems operate with two basic modes: open loop then closed loop. Open loop is the mode in use when the engine is first started, and remains in effect until the oxygen sensors (referred to as O2 sensors) begin to operate. In open loop, the fuel mixture is richer than normal so the engine will run smoothly until the ECT (engine coolant temp sensor) tells the PCM the engine has warmed up. This rich mode works like the choke on a carburetor-equipped engine. The HC and CO emissions are very high in this mode, but the O2's don't start operating until the exhaust stream reaches 600-650 degrees. When the O2's do come online, the vehicle switches to the closed loop mode where the O2's now control the fuel trim. In cold-weather conditions, it may take up to 15 minutes for the O2's to come online. It's even possible for working O2's to kick out if the vehicle idles for a good while allowing the exhaust stream to cool down below 600 degrees. If this happens, the vehicle will return to open loop, and this may increase exhaust emissions. However, some OEM's use embedded PCM information to take over fuel trim when and if open loop occurs.

In about 1990, the OEM's began installing O2 sensors with heaters built into them. These heaters bring the O2 sensors on line in as little as 15 seconds, and they stay on as long as the engine is running. Since the average trip time is quite short in the US, the tailpipe pollution per trip is reduced significantly, as the vehicle stays in closed loop longer.

When OBD II became law in 1996 on most autos and light trucks sold in America, significant changes and improvements were built into the new on-board diagnostic system. One very important change was the addition of a second O2 sensor. This second sensor was located in the exhaust pipe at the outlet of the catalytic converter. V-6 and V-8 engines with true-dual exhaust will have two of each. The additional O2 sensor/s enabled the PCM to closely and accurately monitor the condition and efficiency of the catalytic converter. A P0420 (bank one), or a P0430 (bank two) code will be set if the PCM sees the trailing O2 sensor indicating a rich mixture similar to the front sensor for a given length of time.

A brief glossary of a few key OBD system component terms will make the following sections easier to understand.

AIR: Also referred to as Secondary Air System (or SAS), used to enhance cat converter efficiency.

ECT: Engine Coolant (sensor) Temperature. Sometimes known as CTS: Coolant Temperature Sensor.

MAP: Manifold Absolute Pressure. This refers to the pressure (vacuum) in the intake manifold.

BARO: Barometric (ambient) pressure sensor, used to set a baseline pressure to calibrate the MAP.

MAF: Mass Air Flow meter. Not found on all vehicles, the MAF meter is a real-time real-volume meter, which reports actual airflow through the engine. A MAF equipped vehicle can compensate for increases or decreases in intake air flow and exhaust flow and adjust fuel trim accordingly. A MAP-only system cannot do this. The fuel delivery in a MAP-only system is programmed into the PCM by the OEM engineers. This system can only adjust to expected conditions within the factory-programmed values.

TPS: Throttle Position Sensor. Note: The new “throttle-by-wire” systems use two sensors, comparing one against the other.

VSS: Vehicle Speed Sensor.

HO2S: Heated Oxygen Sensor. We’ll just call them O2 sensors. All of them are heated these days.

CKP: Crankshaft position sensor, used to report RPM, monitor ignition timing and misfire.

CPS: Camshaft Position Sensor, used to identify cylinder #1.

EGR: Exhaust Gas Recirculation.

KNS: Knock Sensor, used to retard timing to eliminate pre-ignition and spark knock.

PID: Parameter Identification – aka Datastream

Before we address a few specific repair strategies, let’s look at an overview of what the OBD system is doing during three different trips. The first trip we’ll look at will have the vehicle fully warmed up, and driving at a steady cruise of around 55 or so mph.

Steady cruise: The engine is at operating temperature, so the OBD system is in closed-loop. The PCM is relying on inputs from the MAP, TPS, ECT, and CNK, and CPS. The TPS shows only slight variations as the driver (or cruise control) adjusts power to maintain the desired cruise speed. When the driver adds a little power to climb a slight grade or to increase cruise speed slightly, the PCM sees a drop in vacuum (MAP) and a slight rise in TPS voltage. The PCM commands an increase in injector pulse width and retards the timing. This latter adjustment increases dwell time, improving fuel burn. If the vehicle is equipped with a MAF sensor, the MAP is referenced primarily to verify MAF and TPS signals.

When the demand for more power is satisfied, the PCM reverses everything it did above. The injector pulse width narrows and the timing advances. These actions return the vehicle to cruise/fuel mileage mode.

The O2 sensors are looking at all this activity, and are sending data to the PCM continually. The lead O2 sensor(s) (sensor 1) sends a varying voltage to the PCM several times a second. When the oxygen content of the exhaust stream is rich (low O2 content), the voltage signal sent to the PCM can be close to 1 volt. The full rich signal is actually about 800 mV to 900 mV. When the PCM sees such a signal, it will then narrow the pulse width to full lean, driving the O2 sensor to about 100mV to 200 mV. The length of time the pulse width is held wide or narrow determines the actual fuel delivery. Take note that an O2 sensor should cross between rich and lean at least 7 times a second on OBDII systems at 2500 rpm or greater. O2 sensors will get tired over time and the “cross counts” will fall to a level that hinders efficiency. If you are working on a high-mileage engine with the original O2 sensor(s), it may be money well spent if your customer will authorize you to replace them. Even with no codes in the PCM, fresh O2’s can produce a noticeable improvement in performance, mileage, and emissions.

In OBD II, the trailing O2 sensor (sensor 2) is in place to send a signal to the PCM, which *should* show a much lower content of fuel (high O2) than sensor 1 is reporting. The voltage swings for O2/2 should be between 430mV and 470mV. However, if the exhaust coming out of the cat closely resembles the

exhaust going in for three consecutive trips, the PCM will store a P0420 (bank one) and/or P0430 code (bank two), and illuminate the MIL.

The full rich to full lean cycle may seem to be a rather primitive strategy to handle fuel delivery (called “fuel trim”). However, the catalytic converter has to have it this way. The catalytic converter is designed to oxidize HC and CO into H₂O and CO₂, and reduce NO_x to CO₂, H₂O, and N₂. When the O₂ sensor approaches a rich condition the PCM will command a lean injector pulse width, causing combustion to release the unused O₂. The catalytic converter will store this O₂ in its ceramic substrate. As the O₂ sensor approaches a lean condition, the PCM will command a rich injector pulse width, producing CO. This causes the catalyst temperature to rise dramatically, causing the NO_x, CO, and HC to vaporize, separating into individual elements of C, H, N, and O. As this occurs, the O₂ in the ceramic substrate will oxidize with the C element to form CO₂, and a single O element will oxidize with two H elements to become H₂O. The N element will then attach with another N to form N₂.

At steady cruise, the PCM will command the EGR to crack open just a bit. The EGR gas is rich in HC, allowing the PCM to reduce pulse width and alter the ignition timing. The EGR gas causes the HC to oxidize, lowering combustion temperature, much like adding luke-warm water to boiling water until the boiling stops. With these results there will be an improvement in emissions and highway fuel mileage.

For a more detailed treatment of the exhaust stream and how you can use it to diagnose driveability issues, please see “5 Gas Diagnostics”, by Steve Zack, available at www.genisysotc/training.

Acceleration: What happens when the driver wants to accelerate? The PCM strategy calls this “acceleration enrichment mode”. On many V8 and high performance V6 engines, the PCM keeps the O₂ sensors in closed loop, even during moderately heavy throttle opening. But many engines will briefly revert to open loop during acceleration, especially WOT. Here’s how acceleration enrichment mode works in those engines:

During hard acceleration, the PCM relies on voltage data, first from the TPS, then from the MAF (if equipped), MAP, and CKS/CPS. When the driver drops the hammer, TPS will peg at about 4.3v to 4.7v. The MAP voltage signal will increase (vacuum decrease), and MAF frequency will increase because of the increased air volume. Engine RPM aids the PCM in knowing just how much additional fuel the engine needs to meet the drivers’ power demands. The injector pulse width will increase to keep the air-fuel ratio correct for maximum acceleration. The timing will be retarded and dwell will increase. The increased dwell will provide additional voltage available at the coil to allow a longer oxidation process needed by the spark plug. This process also lessens spark knock. The transmission controller will delay up-shift points to hold a lower gear allowing a higher engine speed for more power and vehicle speed. The shift feel will be firmer and quicker. The torque converter will disengage as necessary to allow more RPM, adding torque and horsepower.

The MAP sensor is a very sensitive device, and can even sense a slight change in vacuum between individual cylinders. Because of the MAP’s ability to do this, this sensor is a primary sensor in fuel control. The engineering program that accomplishes this is a seldom talked about PCM strategy called “Timing MAP”. Timing MAP uses vacuum variations between cylinders to adjust individual cylinders’ pulse width as well as control individual ignition timing, keeping the cylinders in relative balance.

During hard acceleration, a greater amount of fuel will be used. This sudden increase in fuel will cause an increase in unburned HC and CO. The increases are moderate, and the ignition timing is retarded to compensate. The bigger problem is an increase in NO_x due to a sharp increase in combustion temperature. The EGR is used to control combustion temperatures that will cause the formation of NO_x. The EGR flow is tightly controlled, so the small amount of EGR diluting the fresh air/fuel mixture will cause no reduction in engine performance.

Deceleration lean-out mode: In DLOM, open loop, the PCM utilizes the TPS, MAP and CKP sensors to maintain proper fuel trim. As the driver begins to slow the vehicle, the first input to the PCM, just as in

acceleration mode, is the TPS. The TPS tells the PCM that the throttle is closed to slow the vehicle. Injector pulse width is decreased and timing is advanced. As air volume decreases, the engine vacuum will rise. MAP sensor voltage will begin to drop, and the PCM continues to command a leaner air fuel mixture. As the vacuum begins to stabilize, the MAP sensor will report that the vacuum level has returned to normal. At this point, the fuel trim reverts to Closed Loop, returning fuel trim settings to the O₂ sensors.

As mentioned before, OBD II control strategies differ primarily from OBD I by the constant testing and evaluation of the emissions related parameters, sensors, switches, and actuators, and the electrical circuits that serves them. This testing is done by a series of Monitors. All this testing and evaluating is done to ensure the vehicle is performing to the minimum emissions standards set forth by the EPA. To trigger emissions DTC and set the MIL, the component or system must exceed 1.5 times the standard. The government certification test is known as FTP, or Federal Test Procedure. This is an approximately 7 minute version of the 4 minute IM (Inspection and Maintenance) test.

The emissions Monitors operate much like a Ford KOER self-test. The difference is that the Monitor testing is performed during a normal driving period with speeds and times similar to the Federal IM240 inspection routine. (IM means "inspection-maintenance")

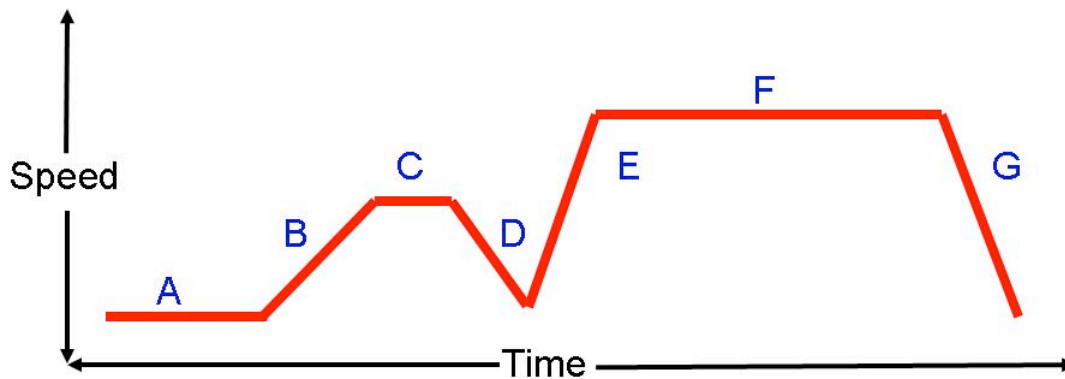
The IM240 Emissions Test satisfies the EPA standards for emissions system performance. This test procedure consists of a 7-part drive cycle, all done with the drive wheels secured between the two rollers of a chassis dynamometer and a tailpipe probe feeding a gas analyzer.

Before the testing is started, the engine is warmed up at least 40 deg. F, reaching 160 deg. F. This step puts the vehicle in closed loop. A Monitor watches for this and will only let the testing begin after these steps are done successfully.

A drive cycle occurs over a period of time, with varying speeds and loads. A Trip is a completion from start up to shut down. All Monitors must be run, or the trip is invalid. A "similar trip" is a second trip taken immediately after the first trip. The RPM must be within 375 of the previous trip, and the load must not vary more than 20% of all previous conditions. This "similar trip" is required for any Monitor that requires two or three trip cycles to set two or three flags which will illuminate the MIL.

In addition, before the test can begin, the following must be in good operating condition: RPM, ECT, BMAP, and IAT. The Monitors will not run until the vehicle is in Closed Loop mode. The effected Monitor will run if the MIL is on. In addition, the Monitors will not run if the TPS or MAP is fluctuating, indicating varying speed and load. The Acceleration Enrichment or the Deceleration modes cannot be operating.

For the first part of the test, Part A, the vehicle idles for exactly 2.5 minutes, with the A/C and rear defroster turned on. During this time, the O₂ sensor heaters, the AIR system (if equipped), Misfire, and the EVAP purge Monitors are run. In Part B, the vehicle accelerates to 55 mph at ½ throttle. Here, the misfire, fuel systems, and purge Monitors are run. In Part C the vehicle runs at a steady 35 mph for 3 minutes where the HO₂S, EGR, purge, Fuel Trim, and AIR monitors are run. In Part D, the vehicle decelerates from 55 to 20 mph where the EGR, Fuel Trim, and purge Monitors are run. In Part E, the vehicle accelerates to 55 to 60 mph at ¾ throttle. Here the misfire, Fuel Trim, and purge Monitors are run. In Part F, the vehicle operates at a steady 55 to 60 mph for approximately 5 minutes. The catalyst, misfire, HO₂S, EGR, purge, and fuel trim monitors are run. In Part G, the vehicle decelerates, ending the test drive cycle while running the purge and EGR monitors. If all Monitors run successfully, the vehicle will pass its emissions testing, and all Monitors will indicate "ready".



For OBDII testing, no tailpipe emissions are directly tested. All the information gathered by the test is communicated to the IM machine and the State government by the PCM through the OBDII port under the dash. No dyno is needed for OBD II testing, and the results cannot be successfully tampered with.

More on Monitors and how they work

Continuous Monitors

Misfire Monitor: This Monitor can pick up a misfire in the engine and set one of two codes. A P0300 is a “random misfire” (multiple cylinders). A P03?? is a specific-cylinder id. The Monitor cannot provide the reason for the misfire, e.g. ignition, fuel, or mechanical. The CKP, using an algorithm programmed into the PCM, detects the tiny slowing of the crankshaft when incomplete combustion takes place in the affected cylinder/s. After a sample of from 200 to 1,000 crankshaft revolutions (depending on OEM strategy), if the problem persists, the MIL is turned on.

Note: There are actually three separate Misfire Monitors, Types One, Two, and Three. The differences in the three are as follows:

The OEM’s and SAE assigned misfire types one and three as “two-trip” misfire monitors. This two-trip strategy acts exactly like all two-trip events. That is, on the first misfire detected by the PCM, the misfire will be recorded as a Pending Code, with no MIL. If the second-trip misfire is detected, the MIL will come on, and the code will be stored as active.

A Type Two misfire indicates a much more severe misfire problem. As such, the MIL will be commanded on during misfire trip one. The one-trip MIL will be either steady or flashing. If the MIL is flashing, the catalytic converter is in imminent danger of severe damage. Diagnose and repair the cause of a flashing MIL immediately. It can happen that a flashing MIL can revert to a steady presentation. If this happens, there is no longer an immediate danger to the cat. However, the severe problem can suddenly reoccur, so do not let the vehicle out of the shop without repairing the misfire problem first.

Fuel System Monitor: This Monitor verifies that the O2 sensor cross-counts are quick enough, at least 7 times per second at 2,500 rpm or more. This applies in both short-term and long-term fuel trim modes. This Monitor requires two consecutive similar trips to set the MIL

Comprehensive Component Monitor (CCM): This Monitor scans for open or short circuits and electrical parameters that are out of range. This Monitor is either a one or two trip MIL, depending on the component.

Non-Continuous Monitors

HO2S Monitor: Closed loop will occur only when the exhaust stream reaches 600-650 degrees. When closed loop occurs, this Monitor forces the fuel trim to “full rich” and watches for a voltage response of

at least 600mV. The Monitor then forces the mixture to “full lean”, and watches for the voltage to go below 300mV. If the voltages are inadequate, or the cross-counts are too slow, an MIL will be set. This Monitor requires two similar trips to set the MIL.

Catalyst Monitor: This Monitor will only run when the vehicle is running at a cruise speed for a minimum of 3 to 6 minutes. The Monitor watches the cross rates of HO2S 1 compared to HO2S 2. The downstream O2 must not cross more than 30% of the upstream O2. Mostly, HO2S 2 will stay in the “lean” range, reflecting a catalyst that is burning the residual HC and CO out of the exhaust stream. This Monitor requires three similar trips to set an MIL if a problem exists.

EGR Monitor: Steady cruise or deceleration is required to run this Monitor. When the PCM commands the EGR to open, total intake manifold volume will be increased. The MAP watches for a vacuum drop when this happens. If this vac drop is not detected by the MAP, a MIL will be commanded after two similar trips.

Readiness Status

Readiness Status is a test that reviews the condition of the Monitors. If the Readiness Status records a Monitor that did not run because of an active or pending code, that Monitor will show “not ready”. When the condition that caused the failure is corrected, and the vehicle is driven in accordance with the applicable Drive Cycle, the Monitor will then run its test, and show the message, “ready”.

The State OBDII IM programs require all Readiness Monitors to run successfully before a vehicle can pass the IM test. However, some states will allow two Monitors to read “not ready” on 1999 and older vehicles and one “not ready” on 2000 and newer vehicles, as long as the MIL is not on. Check your State regulations for details. If the MIL is illuminated, the vehicle will not pass.

Freeze Frame

This is a “snapshot” of one frame of data for several vehicle parameters that existed when the MIL was triggered. The PCM is required to record the following items: Loop Status, Calculated Load (expressed as a percent of 100), ECT, Short and Long Fuel Trim, MAP, RPM, and VSS. Some vehicle manufacturers add a few items to this recording such as TPS, IAT, and MAF.

Note: The Freeze Frame is set the instant the MIL is illuminated. Keep in mind that the PCM always delays setting the MIL until it is satisfied the problem is persistent (this is known as Enable Criteria). This may take several seconds to several minutes for the Enable Criteria to set the MIL. Therefore, the Freeze Frame may reflect conditions that may no longer be current.

Mode Six

Mode 6 is a very sophisticated function that displays, along with min/max specs, the test results of each emission Monitor. Mode 6 information is the actual test result of the individual drive-cycle readiness tests of both continuous and non-continuous monitors.

During each drive cycle, the PCM will monitor and evaluate the Mode 6 test results and store them in the KAM (keep alive memory). The PCM uses a value called the “Exponentially Weighted Moving Average” or EWMA, to judge whether the test result is within the acceptable parameters. As the Monitor data is gathered by the PCM, the EWMA value is applied to the test, causing the points of the data to become more important as the problem becomes closer to failing the test. This allows for the latest test results to be of greater value in determining pass or fail conditions.

Note: be sure to read your Mode 6 info before you switch the vehicle off. Many vehicles may reset Mode 6 at key-off.

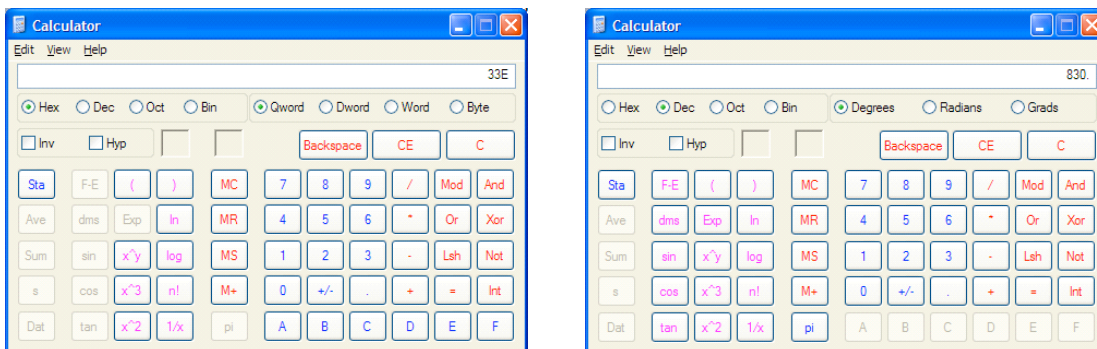
Most aftermarket scan tools cannot read or display Mode 6 information at all. The *OTC Pegisys* and *the Genisys* do a remarkable job of displaying the “TID” (test i.d.) and the “CID” (component i.d.) test information. When the OEMs’ began the switch to CAN in 2003 they changed the name of Mode 6 “CID”

to “MID” (Monitor ID). You will find Component Parameters on the Diagnostic Menu of the *Pegisys* and *Genisys*. Scroll to “Component Parameters (mode 6)”, and press “enter”. Then scroll down through all the Monitors.

Many of the Mode 6 data PIDS are only given a number and not identified in plain English. The OEM’s assign these TID and CID numbers to suit them and do not readily give out this information. And there is no standard for what a TID or CID number refers to. OTC is identifying and adding English explanations to these numbers as quickly as we can learn them. The website “iatn.net” is a wealth of Mode 6 information, especially for Ford and Toyota. IATN.net is available to anyone with a computer.

To cloud the issue further, the actual test result numbers may be given not in the familiar decimal system, but in a scientific number system called “hexadecimal”. Hexadecimal values are reported with a combination of numbers and letters, and are identified as Hexadecimal with a dollar symbol (\$) prefix.

If you have identified what TID and CID you are dealing with, your standard Windows computer has a calculator that will convert Hexadecimal to decimal. To do this translation, click All Programs, and then click on Accessories. Next, select Calculator, and then click on View and select “Scientific”. Next, click on “Hex”. Then enter the Hexadecimal value (let’s use 33E as an example) in the value box. Then select the “Dec” button. Voila! 33E becomes 830! Compare 830 to the min/max limit in the Mode 6 test to determine the health of the Monitor results.



Incidentally, GM has a DTC function called “Failure Records”, for OBD II vehicles. This info is essentially the same as Mode 6, and is easily read and understood. The information given in Failure Records, as well as in Mode 6, can be used to predict if a system is about to store a two trip failure before the MIL is set. This info can be used as repair verification, saving you a lot of time or even a comeback.

In Part Two of this series, we will delve into several repair strategies on the three domestic vehicle makes. Of course, our examples will also apply to most OBDII vehicles, domestic and otherwise. These examples are all based on real-world, common-failure events that you should find familiar, and we hope our repair ideas will be helpful. Stay tuned...