OBD II Diagnosis

These days, it's become relatively unlikely that customers will come to you asking for a 'tune up' for their Subaru vehicles. Like most vehicles on the road today, Subaru vehicles have become far more reliable than might have seemed possible less than a generation ago. They seem to run just fine for years at a time, with a minimal amount of maintenance or attention from their owners or professional repair technicians.

In a more likely scenario, a customer will bring his vehicle in for service because the on-board diagnostic system has detected a fault. Most of the time, the vehicle continues to run as normal. The only indication of a problem is the glowing Check Engine light on the dashboard.

The Check Engine light, also called the Malfunction Indicator light (MIL for short), is the most visible part of the On Board Diagnostics II (OBD II) system that's been an integral part of the Subaru line since the 1995 Legacy. This system has the ability to store engine and automatic transmission diagnostic trouble codes (DTCs) related to operating faults that could have an effect on vehicle emissions.

The number of DTCs and the diagnostic procedures for these DTCs is constantly changing, due to the introduction of new components and constantly improving system operating logic. The key to diagnosing and repairing the OBD II system is an understanding of the components checked. Only then will you be able to apply that understanding to the logic embedded in the OBD II system.

OBD II checks a component and its system for the ability to function (circuitry tests) and the result while functioning (performance tests) for key systems.

Enabling Criteria

Before OBD II can begin to monitor the vehicle systems under its care, the vehicle must meet an assortment of *enabling criteria*. Enabling criteria are the vehicle operating conditions that must exist for the Engine Control Module (ECM) to begin diagnostics.

The enabling criteria will not be the same for all diagnostics. For example, the ECM is ready to check the EGR solenoid as soon as the ignition is turned on. But before the performance of the

EGR system can be checked, the following conditions must be met:

- Engine has been operating for at least 190 seconds.
- EGR solenoid has been energized.
- Engine coolant temperature is equal to or greater than 158°F (70°C).
- Engine speed is 2000-2600 RPM.
- Injection pulsewidth is 4.1-6.92 ms.
- Throttle angle is 5.76-24.96 degrees.
- Throttle angle fluctuation during a period of 100 milliseconds is less than 0.96 degrees.
- Barometric pressure is greater than 507mm HG.

Enabling criteria take other vehicle systems and components into consideration as well. If there are problems in other areas, the enabling criteria won't be met. In our EGR example, failures in any of the following components or circuits will halt the EGR system testing:

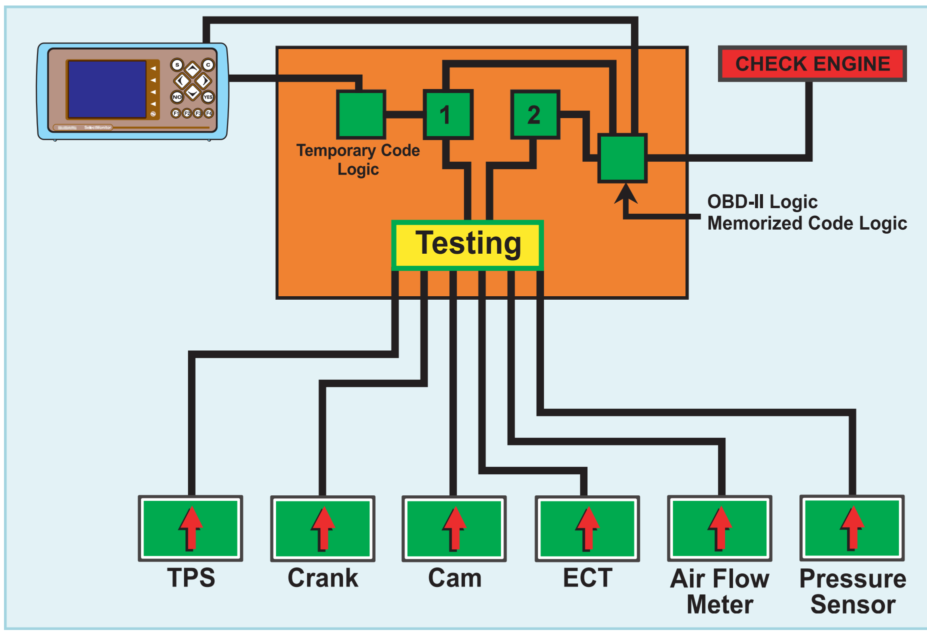
- Air Flow Sensor
- Crank Angle Sensor
- Cam Angle Sensor
- Throttle Position Sensor
- Coolant Temp Sensor, EGR Solenoid.

Confirmation Driving Pattern

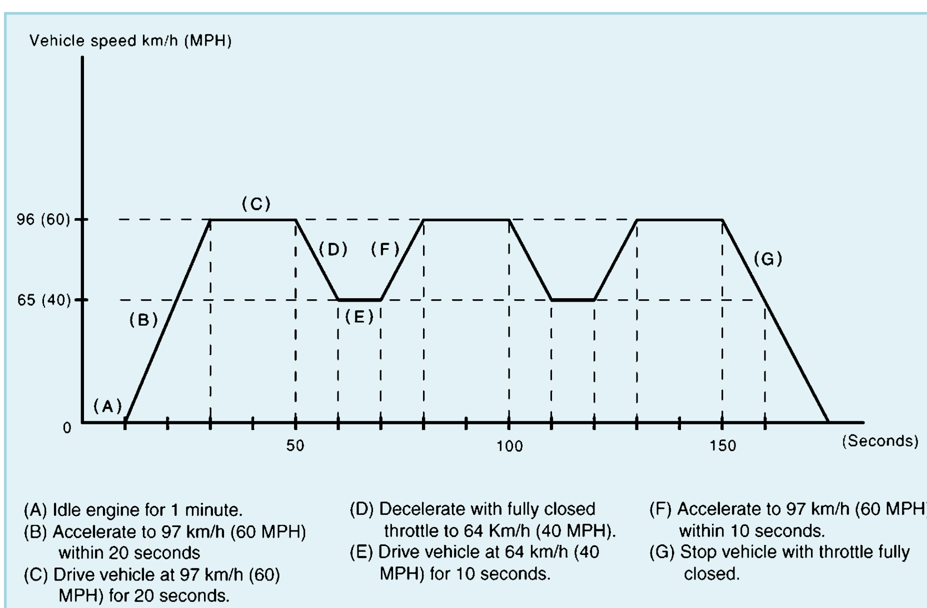
The logic that the ECM uses to determine whether a DTC exists may not be available. What *is* published is the Confirmation Driving Pattern. This is a description of the exact way a vehicle must be driven for the enabling criteria to be met. Driving a vehicle on a lift will not substitute for actual on the road driving. A slight deviation in the confirmation driving pattern will usually cancel the diagnostics until the right conditions can be duplicated.

OBD II checks or monitors various components using two different methods. The first method is called *continuous monitoring*. This process monitors for misfire, fuel system and electrical output devices, any time the vehicle is operating. The second type is *non-continuous monitoring*. This process checks the condition of the catalyst, catalyst heater, evaporative system, secondary air system, a/c system refrigerant, oxygen sensor, oxygen sensor heater and EGR system once per trip.

A trip is completed when the vehicle has been driven in a manner which satisfies the enabling criteria, followed by a period when the ECM has powered down.



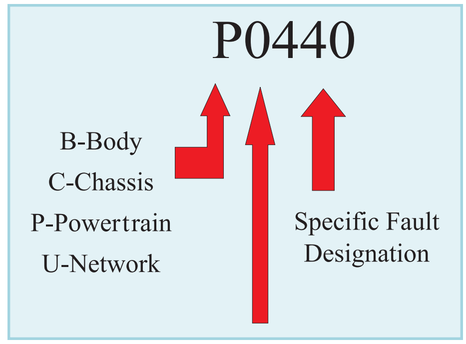
OBD II logic



Confirmation driving pattern

MI(MIL)	OFF
Misfire monitoring	complete
Fuel system monitoring	complete
Component monitoring	complete
Catalyst Diagnosis	incomplete
Heated catalyst	no support
Evaporative purge system	incomplete
Secondary air system	no support
A/C system refrigerant	no support
Oxygen sensor	incomplete
O2 Heater Diagnosis	incomplete
EGR system	no support

Readiness codes incomplete



DTC structure

MI(MIL)	OFF
Misfire monitoring	complete
Fuel system monitoring	complete
Component monitoring	complete
Catalyst Diagnosis	complete
Heated catalyst	no support
Evaporative purge system	complete
Secondary air system	no support
A/C system refrigerant	no support
Oxygen sensor	complete
O2 Heater Diagnosis	complete
EGR system	no support

Readiness codes complete

Readiness Codes

Readiness codes report the availability and status of the continuous and non-continuous monitors through the Select Monitor or an aftermarket equivalent scan tool. While viewing the OBD II section from the engine main menu, the first eight items will indicate *No Support*, *Complete* or *Incomplete*.

No Support indicates that the vehicle is not equipped with that system.

Complete indicates that the diagnostics have been performed for that system.

Incomplete indicates that the vehicle has the system but has not diagnosed the system yet, but will once the enabling criteria have been met.

These values will not default to Incomplete once they are complete, unless the memory has been cleared or battery power has been removed for more than 10 minutes. (1996 vehicles default to Incomplete when the ignition is turned off.) Refer to the Subaru State I/M Program Advisory Bulletin #11-49-97R.

During the actual testing or diagnostics performed by the ECM, vehicle sensors send information to a testing area of the ECM. The information is evaluated to determine if the vehicle has met the enabling criteria and the results of the forced testing of systems are diagnosed.

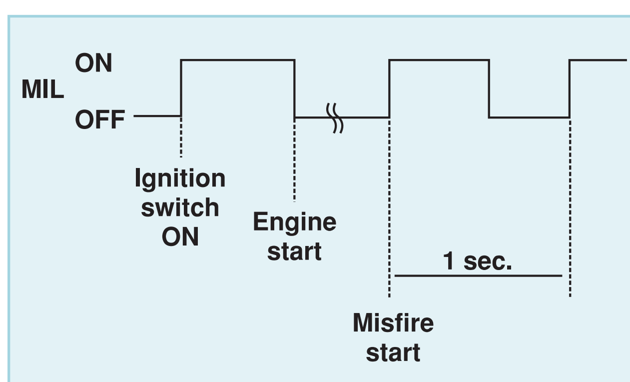
If a fault is detected, each system is assigned to trigger the illumination of the MIL, following either a single fault or double fault occurrence (trip). The single fault trip DTCs will store a memorized DTC and record the vehicle operating conditions (Freeze Frame Data) when the ECM determines a fault exists. The MIL is also illuminating. Double fault trip DTCs will not illuminate the MIL when the first fault is detected. It will register the DTC as a temporary code and wait for the second consecutive failed trip to occur before illuminating the MIL.

The exception to the second fault rule is any DTC that is related to Fuel Trim or Misfire. The second fault trip for these items must occur within 375 rpm and 20 percent of the engine load of the first fault. At that point the MIL will illuminate, and the DTC and Freeze Frame data will be memorized.

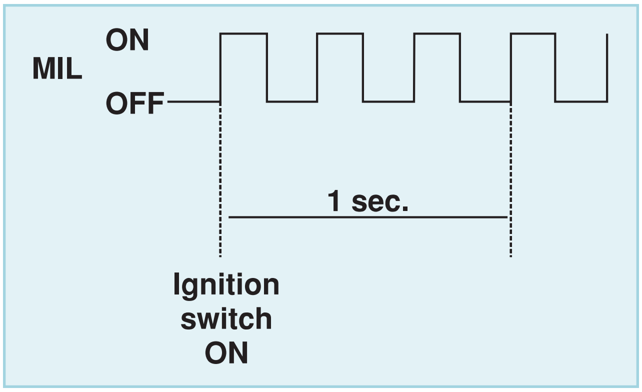
OBD II requirements state that all manufacturers standardize code assignments. Each code consists of five characters.

Malfunction Indicator Lamp Operation

The malfunction indicator lamp (MIL) provides communication to the driver and the technician. Steady illumination of the MIL with the engine running indicates to the driver that there is an existing problem that requires the attention of a service professional. A MIL that is flashing at 1 Hz indicates that an engine misfire exists. Because the misfire may cause catalyst damage and result in an increase in exhaust emission levels, immediate service attention is recommended.



1 Hz MIL pattern



3 Hz MIL pattern

Technician communications via the MIL include three messages. The first is a 3 Hz flash which indicates the inspection mode connectors are connected. The second is a 1 Hz flash which indicates a misfire that will cause catalyst damage exits. The third MIL signal — steady illumination — indicates a problem exists or has recently occurred and a DTC has been set.

DTC Memory

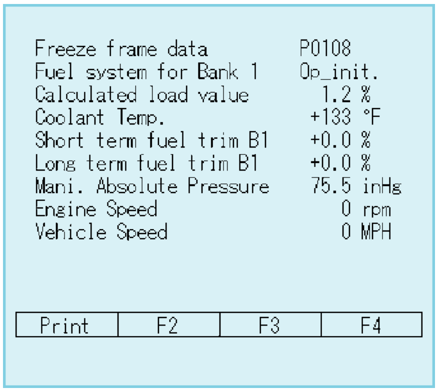
After a fault has been repaired or if it was an intermittent problem, memory of a DTC (as it relates to illuminating the MIL) is maintained until three consecutive passing trips have been made. This indicates that the enabling criteria were reached three times in a row and the tests were performed with good results. The MIL will turn off at this point.

Even though the MIL is no longer illuminated, the original DTC will remain available for viewing with the Select Monitor (or aftermarket equivalent scan tool) and the freeze frame data associated with it will remain in memory for 40 warm up cycles.

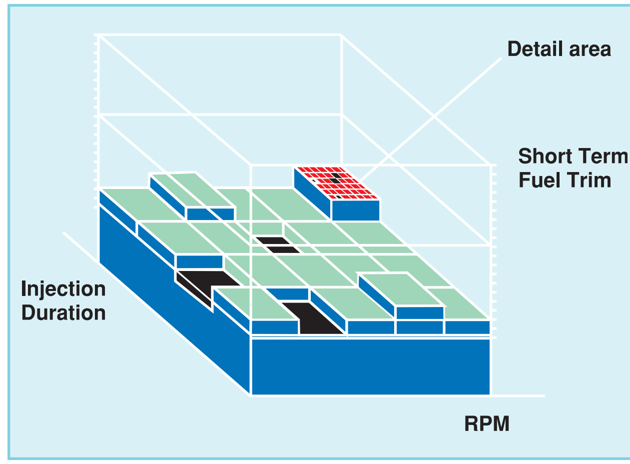
The exception to this rule is if the DTC is associated with an engine misfire or fuel trim fault. In these cases, 80 warm up cycles must be completed before full erasure will occur.

Warm Up Cycle

A warm up cycle occurs when the engine coolant temperature rises to at least 40°F (22.2°C) above the temperature at start up, and reaches a minimum of 160°F (71.1°C).



OBD freeze frame data



Fuel trim map

Freeze Frame Data

Freeze Frame is a record of the vehicle operating conditions at the moment a DTC is set. The data recorded include:

- Engine RPM
- Engine Load
- Fuel Pressure
- Fuel Trim Values
- Coolant Temperature
- Intake Manifold Pressure
- Loop Status
- Number of the DTC causing the MIL to illuminate.

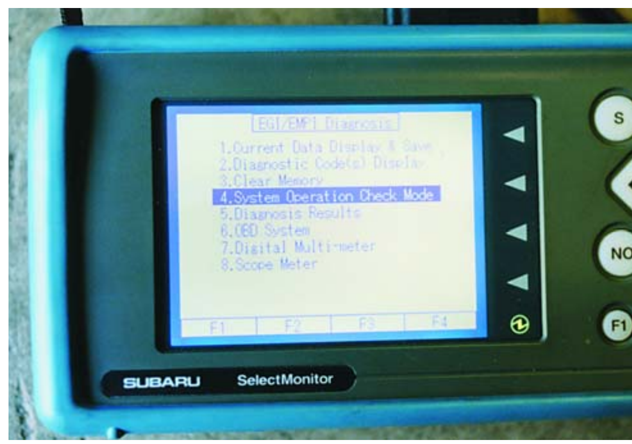
A DTC associated with misfire or fuel trim is considered a high priority. Therefore, the freeze frame data associated with a misfire or fuel trim DTC will overwrite the freeze frame data from all other DTCs.

As you might imagine, freeze frame data can be a very valuable addition to your diagnostic arsenal. Rather than having to ask your customer, "When did the problem occur," you can retrieve the same information from the ECM. As the ECM is always watching, it's unlikely that it will miss a problem when (or if) it occurs.

Fuel Trim

Short-term and long-term fuel trim are visual interpretations on the current (short-term) and historical (long-term) corrections to the air fuel mixture required to give the vehicle the best driveability and lowest emission output.

The ECM continuously monitors the amount of fuel injected and places the information recorded into memory. The ECM places the memorized information into a position that is referenced by engine load and engine rpm. The next time the vehicle is in those same conditions, the memorized information is compared to the amount currently injected. A DTC will be registered if the difference between the two is too great.



Select Monitor

Data link connector

OBD II Failure Diagnosis

Perhaps the primary purpose of the OBD II system is to assure that vehicle emissions remain within accepted limits at all times. That's why the MIL will flash when a problem affecting the catalyst is detected. The ECM knows that a vehicle with a damaged catalyst is unlikely to meet emissions standards. The goal under these circumstances is to get the vehicle owner to bring the vehicle in for service as soon as possible. A flashing red light on the dash tends to get most people's attention, and will achieve that goal.

For the service technician, OBD II offers another benefit. Vehicles have had the ability to store DTCs for quite a while. But before OBD II, those DTCs were just numbers. Each number indicated the possibility of a problem in a specific area — the failed EGR solenoid in our earlier example perhaps. Little was known or revealed as to *why* the DTC had stored. Perhaps there was an open in the system, or perhaps it was a short.

Either way, it was up to the technician to determine the actual cause of the problem. "Trouble trees" from that era, intended to help the technician, often as not ended up leading him astray and possibly replacing components unnecessarily.

Much has changed since the introduction of OBD II. Now, when the ECM detects a fault, it stores a set of freeze frame data that tells you what was happening when the fault occurs. If the problem is intermittent, this data gives you the ability to recreate the original conditions, hopefully leading to a repeat appearance by the intermittent fault.

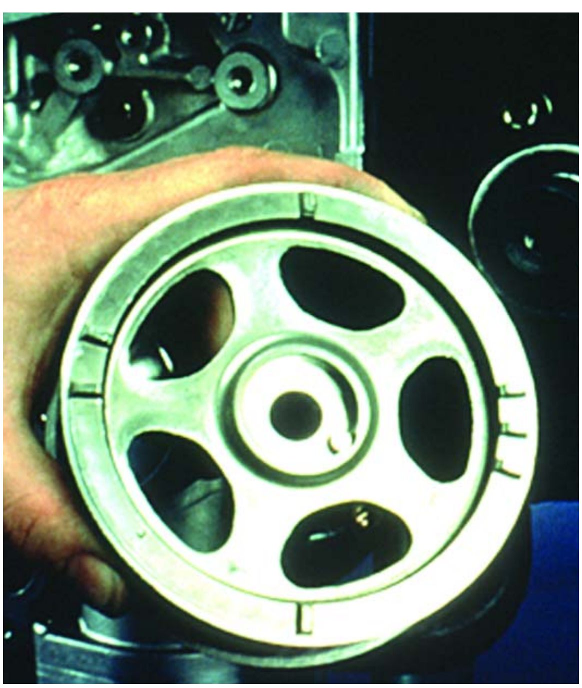
A recent example occurred on a 1995 Subaru Legacy. Although this vehicle was introduced before OBD II requirements came into effect in 1996, it does have a full OBD II system. On an intermittent basis, the engine would refuse to start following a hot soak. The starter would crank just fine, but not start. On most occasions when this occurred, the engine would start normally if it were allowed to cool slightly. A pause of only a few minutes was usually all that was required.

When the engine restarted, the MIL was illuminated, and a DTC P0340 (Camshaft Position Sensor Fault) was stored in the ECM memory. Freeze frame data showed that the fault occurred at cranking RPM and normal engine operating temperature, which was already known from the customer's description of the problem.

The camshaft position sensor determines the camshaft position and speed by sensing pulses created by a reluctor machined into the back side of the left camshaft timing belt sprocket.

The shape of the reluctor teeth is very important to the strength and clarity of the signal produced by the camshaft position sensor. A chip or deformation on any tooth can result in a driveability or no-start condition.

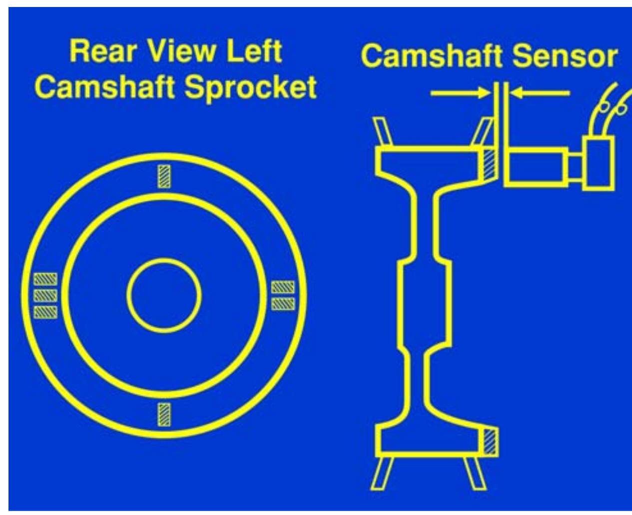
Camshaft position sensor



Camshaft sprocket reluctor

The camshaft position sensor is made from a permanent magnet and a coil of wire. As the camshaft sprocket reluctor teeth pass in front of the camshaft position sensor, a relatively weak alternating current (AC) is generated by the camshaft position sensor.

Due to the unique orientation of the reluctors on the camshaft sprocket, the AC signal produced by the camshaft position sensor has a distinctive signature. Rather than the steady AC sine wave produced by ABS wheel speed sensors, the camshaft position sensor produces a signal that has a series of deliberate gaps. The ECM receives this information, and uses it to make decisions regarding fuel injection sequence and the position of the #1 cylinder.

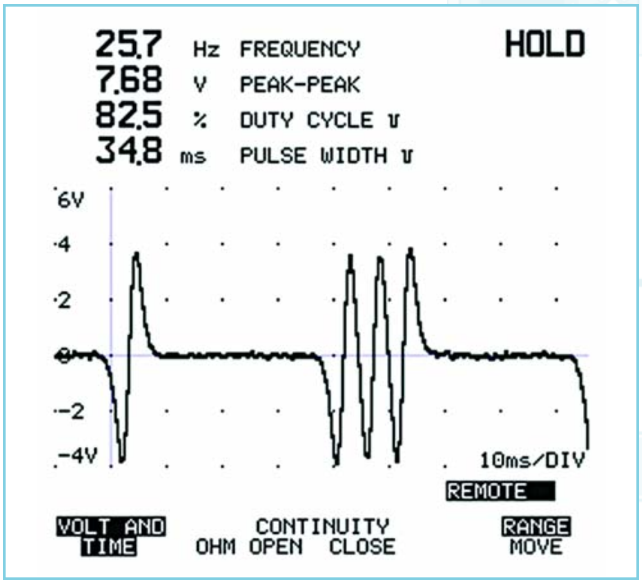


Camshaft position sensor air gap

The OBD II system monitors the camshaft position sensor, to make sure that its signal falls within an expected and acceptable range. Information about the expected range is included in system memory. The main thing the system is watching for is a signal with a certain *amplitude*, or voltage range from high to low. As far as OBD II is concerned, it doesn't matter if there is no signal or a weak signal. Both are considered abnormal. Likewise, the ECM can't work with a weak or non-existent signal from the camshaft position sensor, which is why the vehicle would not start.

On first examination, the pattern appeared normal in all respects. The signature humps produced by the reluctors on the camshaft sprocket were there. The only thing that wasn't there was the signal amplitude necessary to satisfy the PCM and the OBD II system.

The camshaft position sensor was affected by engine temperature, and produced a slightly weaker signal when the engine was hot. Most times, it produced a signal that was just strong enough to get the engine started. Once started, the increased engine RPM had the effect of increasing the camshaft position sensor signal amplitude and everything was normal until the next restart.



Strong camshaft position sensor signal

As the sensor steadily deteriorated, the hot no-start incidents became increasingly frequent. Finally, the owner brought the vehicle in for service. After diagnosing the cause of the no-start and the related OBD II DTC P0340, a new camshaft position sensor was installed. The new sensor produced a noticeably stronger AC signal during cranking (hot or cold), with the amplitude required to satisfy the OBD II system and the ECM. An example of a strong, normal camshaft position sensor signal is shown on this page.