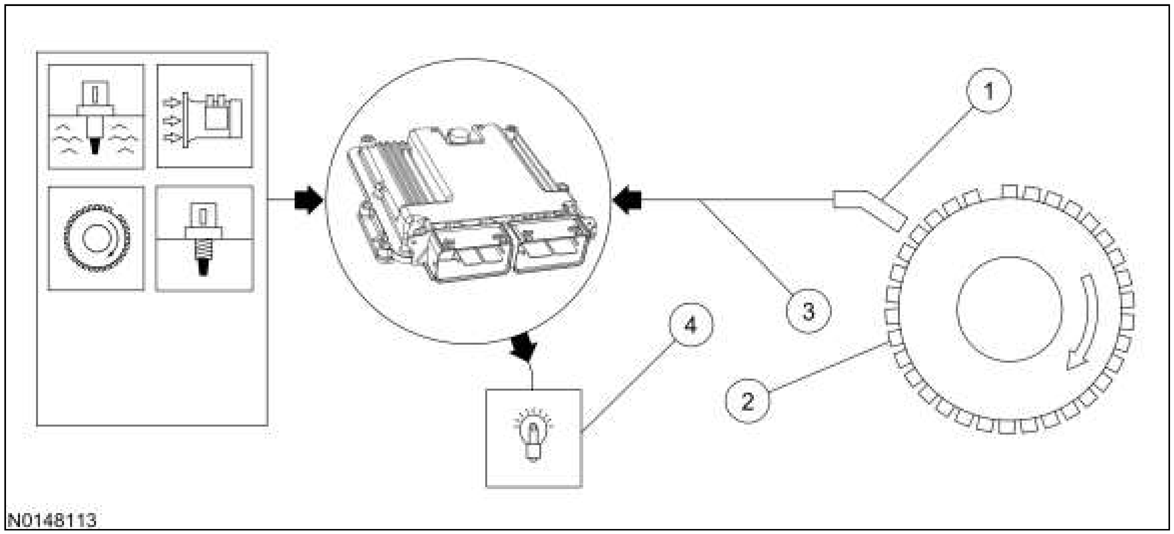
Misfire Detection Monitor

The misfire detection monitor is an on board strategy designed to monitor engine misfire and identify the specific cylinder in which the misfire has occurred. Misfire is defined as lack of combustion in a cylinder due to absence of spark, poor fuel metering, poor compression, or any other cause. The misfire detection monitor is enabled only when certain base engine conditions are first satisfied. Input from the engine coolant temperature (ECT) or cylinder head temperature (CHT), intake air temperature (IAT), and mass airflow (MAF) sensor (if equipped) is required to enable the monitor. The misfire detection monitor is also carried out during an on-demand self-test.

1. The PCM synchronized ignition spark is based on information received from the crankshaft position (CKP) sensor. The CKP sensor signal generated is also the main input used in determining cylinder misfire.
2. The input signal generated by the CKP sensor is derived by sensing the passage of teeth from the crankshaft position wheel mounted on the end of the crankshaft.
3. The input signal to the PCM is then used to calculate the time between CKP sensor signal edges and the crankshaft rotational velocity and acceleration. By comparing the accelerations of each cylinder event, the power loss of each cylinder is determined. When the power loss of a particular cylinder is sufficiently less than a calibrated value and other criteria are met, then the suspect cylinder is determined to have misfired.
4. The malfunction indicator lamp (MIL) is activated after one of the above tests fail on 2 consecutive drive cycles.



Misfire Detection Monitor

Misfire Monitor Operation

The signal from the crankshaft position sensor and timing wheel is processed by the PCM into individual tooth period measurements and provided to the misfire monitor. The misfire monitor uses the tooth period measurements to calculate crankshaft acceleration signals for misfire detection.

A low data rate (LDR) and high data rate (HDR) are the 2 different types of misfire monitoring systems used. The LDR system is capable of meeting the federal test procedure monitoring requirements on most engines and is capable of meeting the full range of misfire monitoring requirements on 3 and 4 cylinder engines. It is also used on 6 cylinder engines with rear mounted crank sensors. The HDR system is capable of meeting the full range of misfire monitoring requirements on 8 cylinder and 10 cylinder engines. The HDR system on these engines meets the full range of misfire phase-in requirements specified in the on board diagnostic (OBD) regulations. The PCM software allows for detection of any misfires that occur 6 engine revolutions after initially cranking the engine. This meets the OBD requirement to identify misfires within 2 engine revolutions after exceeding the warm drive, idle RPM.

The monitor includes a diagnostic check on the crank sensor input that checks the number of tooth period measurements received on each cylinder event. If the monitor receives an invalid number of tooth period measurements, DTC P033F or P1336 will set. This DTC indicates that noise is present on the crank sensor input or there is a lack of synchronization between the camshaft and crankshaft sensors.

Low Data Rate (LDR) System

The LDR misfire monitor uses a low data rate CKP sensor signal which indicates one time measurement signal for each cylinder event. The PCM uses the CKP sensor signal to calculate the crankshaft speed and acceleration for each cylinder. The crankshaft acceleration is then processed to detect a sporadic, single-cylinder misfire patterns or multi-cylinder misfire patterns. The changes in overall engine RPM are removed by subtracting the median engine acceleration over a complete engine cycle. The crankshaft acceleration is then processed by three algorithms. The first algorithm, called pattern cancellation, is optimized for detection of sporadic patterns of misfire. The algorithm learns the normal pattern of cylinder accelerations from the mostly good firing events and is then able to accurately detect deviations from that pattern. The second algorithm, called pattern cancellation by opposing engine revolution, is optimized for single cylinder patterns. The algorithm compares the acceleration of a cylinder to its opposite cylinder on the opposing engine revolution. The algorithm learns the normal patterns that repeat every engine revolution and is then able to accurately detect deviations between the paired cylinders. The third algorithm is a non filtered acceleration signal that is a general purpose signal for all patterns including multi cylinder patterns. The resulting deviant cylinder acceleration values are used in evaluating misfire. Refer to the General Misfire Processing in this section for more information.

High Data Rate (HDR) System

The HDR misfire monitor uses a high data rate CKP sensor signal which indicates 36 position references per crankshaft revolution. This high resolution signal is processed with a digital low pass filter. The low pass filter filters the high resolution crankshaft velocity signal to remove some of the crankshaft torsional vibrations that degrade signal to noise. Two low pass filters are used to enhance detection capability: a base filter and a more aggressive filter to enhance single cylinder capability at higher RPM. This significantly improves detection capability for continuous misfires on single cylinders up to red line. The changes in overall engine rpm are removed by subtracting the median engine acceleration over a complete engine cycle. The crankshaft acceleration is then processed by three algorithms similar to the LDR system. The final stage is to decimate the high resolution signals by selecting the peak acceleration values from within a window location for each cylinder. The resulting deviant cylinder acceleration values are used in evaluating misfire. Refer to the General Misfire Processing in this section for more information.

General Misfire Processing

The acceleration that a piston undergoes during a normal firing event is directly related to the amount of torque that cylinder produces. The calculated piston and cylinder acceleration values are compared to a misfire threshold that is continuously adjusted based on inferred engine torque. Deviant accelerations exceeding the threshold are conditionally labeled as misfires. The cold start emission reduction (CSER) monitor uses a threshold multiplier during startup to compensate for the reduction in the signal amplitude during ignition spark retard conditions. The threshold adjustments may also be applied to compensate for torque reduction during gear shift events, and to compensate for changes in driveline coupling with torque convertor lock status.

The calculated deviant acceleration values are also evaluated for noise. Normally, misfire results in a nonsymmetrical loss of cylinder acceleration. Mechanical noise, such as rough roads or crankshaft oscillations at low rpm or high load conditions, will produce symmetrical positive acceleration variations. Noise limits are calculated by applying a negative multiplier to the misfire threshold. If the noise limits are exceeded, a noisy signal condition is inferred and the misfire monitor is suspended for a brief interval. Noise free deviant acceleration exceeding a given threshold is labeled a misfire.

The number of misfires are counted over a continuous 200 revolution and 1,000 revolution period. The revolution counters are not reset if the misfire monitor is temporarily disabled such as for negative torque mode. At the end of the evaluation period, the total misfire rate and the misfire rate for each individual cylinder is computed. The misfire rate is evaluated every 200 revolution period (Type A) and compared to a threshold value achieved from an engine speed and load table. This misfire threshold is designed to prevent damage to the catalyst due to sustained excessive temperature 899°C (1,650°F) for Pt/Pd/Rh advanced washcoat and 982°C (1,800°F) for Pd-only high tech washcoat. If the misfire threshold is exceeded and the catalyst temperature model calculates a catalyst mid-bed temperature that exceeds the catalyst damage threshold, the MIL blinks at a 1 Hz rate while the misfire is present. If the threshold is again exceeded on a subsequent driving cycle, the MIL is illuminated.

At high engine speed and load operating conditions the monitor continuously evaluates the misfire rate during each 200 revolution period. If a calibrated number of misfire events have been accumulated within a 200 revolution block such that the misfire threshold is already exceeded before the end of the block has been reached, the monitor will declare a fault immediately rather than wait for the end of the block. This improves the capability of the monitor to prevent damage to the catalyst.

If a single cylinder is determined to be consistently misfiring in excess of the catalyst damage criteria, the monitor will initiate failure mode effects management (FMEM) to prevent catalyst damage. The fuel injector to that cylinder is disabled for a calibrated period of time, typically 30 to 60 seconds. Up to 2 cylinders may be disabled at the same time on 6, 8 and 10 cylinder engines and 1 cylinder on 3 and 4 cylinder engines. The fuel control will go open loop and target lambda as slightly lean. The software may also use the throttle to limit the airflow (limit boost) on GTDI engines for additional exhaust component protection. After the calibrated period of time, typically 30 seconds, the injector is enabled and the system returns to normal operation. On some vehicles, the software may continue FMEM beyond 30 seconds if the engine is operating at high speed or load at the end of the 30 second period. The software will wait for a low airflow condition to exit from FMEM. This protects the catalyst should the misfire fault still be present when the fuel injector is turned back on. If a misfire is detected on that cylinder again after 200 revolutions (about 5 to 10 seconds), the fuel injector is disabled again and the process repeats until the misfire is no longer present. Note that ignition coil primary circuit failures trigger the same type of fuel injector disablement. For additional information, refer to Comprehensive Component Monitor (CCM) in this section.

If fuel level is below 15%, the misfire monitor continues to evaluate misfire over every 200 revolution period to determine if catalyst damaging misfire is present so that the fuel shut off FMEM can be utilized to control catalyst temperatures. When a misfire occurs at low fuel levels, DTC P0313 will set in place of DTCs P0300 to P0310.

The misfire rate is also evaluated every 1,000 revolution period and compared to a single (type B) threshold value to indicate an emission threshold concern, which can be either a single 1,000 over revolution event from startup or 4 subsequent 1,000 over revolution events on a drive cycle after startup. Many vehicles set DTC P0316 if the type B threshold is exceeded during the first 1,000 revolutions after engine startup. This DTC P0316 is stored in addition to the normal P03xx DTC that indicates the misfiring cylinder. If the misfire is detected but it can not be attributed to a specific cylinder, DTC P0300 is stored.

Rough Road Detection

The misfire detection monitor may include a rough road detection system to eliminate false misfire indications due to rough road conditions. The rough road detection system uses data from the anti-lock brake system (ABS) wheel speed sensors for estimating the severity of rough road conditions. This is a more direct measurement of rough road over other methods which are based on drive line feedback via crankshaft velocity measurements. It improves accuracy over these other methods since it eliminates interactions with actual misfire.

In the event of a rough road detection system failure, the rough road detection output is ignored and the misfire detection monitor remains active. A rough road detection system failure could be caused by a failure in any of the input signals to the algorithm. This includes the ABS wheel speed sensors, brake pedal position (BPP) switch, or controller area network (CAN) hardware concerns. Specific DTCs indicate the source of these component concerns.

A redundant check is also carried out on the rough road detection system to verify it is not stuck high due to other unforeseen causes. If the rough road detection system indicates rough road during low vehicle speed conditions where it is not expected, the rough road detection output is ignored and the misfire monitor remains active.

Profile Correction

Profile correction software is used to learn and correct for mechanical inaccuracies in the crankshaft position wheel tooth spacing. Since the sum of all the angles between the crankshaft teeth must equal 360 degrees, a correction factor can be calculated for each misfire sample interval that makes all the angles between individual teeth equal. The LDR system learns one profile correction factor per cylinder (that is, 3 correction factors for a 3 cylinder engine or 4 correction factors for a 4 cylinder engine), while the HDR system learns 36, 40 or 60 correction factors depending on the number of crankshaft wheel teeth (that is, 35 for some V6 and V8 engines, 39 for V10 engines and 58 for some I4 and V6 engines). On some vehicles, the profile correction for both LDR and HDR systems will be common and will learn a separate profile correction factor for each individual tooth on the crankshaft position wheel.

The corrections are calculated from several engine cycles of misfire sample interval data. The correction factors are the average of a selected number of samples. In order to assure the accuracy of these corrections, a tolerance is placed on the incoming values such that an individual correction factor must be repeatable within the tolerance during learning. This is to reduce the possibility of learning incorrect corrections due to crankshaft velocity disturbances.

Since inaccuracies in the wheel tooth spacing can produce a false indication of misfire, the misfire monitor is not active until the corrections are learned.

Two methods of learning profile correction are used. The first is neutral profile correction and non volatile memory and the second is customer drive cycle for profile correction 97 to 64 km/h (60 to 40 MPH deceleration).

Neutral Profile Correction And Non Volatile Memory

Neutral profile learning is used at end of line to learn profile correction through a series of one or more neutral engine RPM throttle snaps. This allows the misfire monitor to be activated at the assembly plant. A scan tool command is required to enable neutral profile correction learning. Learning profile correction factors at high speed (3,000 RPM) neutral conditions versus during 97 to 64 km/h (60 to 40 MPH) decelerations optimizes correction factors for higher RPMs where they are most needed and eliminates driveline or transmission and road noise effects. This improves signal to noise characteristics which means improved detection capability.

The profile correction factors learned at the assembly plant are stored into non volatile memory. This eliminates the need for specific customer drive cycles. However, misfire profiles may need to be relearned using a scan tool procedure if major engine work is done or a new PCM is installed. Relearning is not required for a reflash.

On selected vehicles, the neutral profile correction strategy is the only method used for profile correction learning. In the event of a loss of non volatile memory content (new PCM installed), the correction factors are lost and must be relearned. The P0315 DTC is set until the misfire profile is relearned using a scan tool procedure.

Customer Drive Cycle For Profile Correction (60 To 40 MPH Deceleration)

To prevent any fueling or combustion differences from affecting the correction factors, learning is done during deceleration fuel shut off (DFSO). This can be done during closed throttle, nonbraking, defueled decelerations in the 97 to 64 km/h (60 to 40 MPH) range after exceeding 97 km/h (60 MPH) (likely to correspond to a freeway exit condition). In order to minimize the learning time for the correction factors, a more aggressive DFSO strategy may be used when the conditions for learning are present. The corrections are typically learned in a single 97 to 64 km/h (60 to 40 MPH) deceleration, but may take up to 3 decelerations or a greater number of shorter decelerations.

If the software is unable to learn a profile after three, 97 to 64 km/h (60 to 40 MPH) deceleration cycles, DTC P0315 is set.

Misfire Detection Monitor Specifications

Misfire detection monitor operation: DTCs P0300 to P0310 (random and specific cylinder misfire), P1336 (noisy crank sensor, no crankshaft and camshaft sensor synchronization), P0315 (crankshaft position system variation not learned), P033F or P1336 (misfire detected on startup [first 1000 revolutions]), P0313 (misfire detect with low fuel level). The monitor execution is continuous, misfire rate calculated every 200 or 1,000 revolutions. The monitor does not have a specific sequence. The CKP, CMP, MAF, and ECT or CHT sensors have to be operating correctly to run the monitor. The monitoring duration is the entire driving cycle (see disablement conditions below).

Typical misfire detection monitor entry conditions: Minimum to maximum time since engine startup is 0 seconds, engine coolant temperature is -7°C to 121°C (20°F to 250°F), RPM range is (full-range misfire certified, with 2 revolution delay) 2 revolutions after exceeding 150 RPM below drive idle RPM to red line on tach or fuel cutoff, profile correction factors are learned in KAM, and the fuel tank level is greater than 15%.

Typical misfire temporary disablement conditions: Closed throttle deceleration (negative torque, engine being driven), Fuel shut off due to vehicle speed limiting or engine RPM limiting mode, a high rate of change of torque (heavy throttle tip-in or tip out) and rough road conditions.

The profile learning operation includes DTC P0315 if the profile correction factors are not learned. On selected vehicles, DTC P0315 is set immediately after a new PCM is installed until the scan tool procedure for neutral profile correction is completed. On all other vehicles, DTC P0315 is set if profile learning does not complete during the customer drive cycle for profile correction. The monitoring duration for the customer drive cycle is 10 cumulative seconds in conditions (a maximum of three, 97 to 64 km/h (60 to 40 MPH) de-fueled decelerations). The monitor execution is once per profile learning sequence. The monitor sequence: profile must be learned before the misfire monitor is active, the CKP and CMP sensors are required to be operating correctly; and the CKP and CMP signals must be synchronized.

Assembly plant or repair facility typical profile learning entry conditions from minimum to maximum: The engine in deceleration fuel shut off (DFSO) mode for 4 engine cycles with the vehicle in PARK or NEUTRAL gear. The engine RPM is 2,000 to 3,000 RPM. The learning tolerance is 1%.

Customer drive cycle typical profile learning entry conditions from minimum to maximum: The engine in deceleration fuel shut off mode for 4 engine cycles. The brakes are not applied. The engine RPM is 1,300 to 3,700 RPM and the change is less than 600 RPM. The vehicle speed is 48 to 121 km/h (30 to 75 MPH). The learning tolerance is 1%.