MY04-05
Vehicle: S60, V/XC70, S80, XC90
Engine: B5234T, B5254T, B6294T/S

Functional Description

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System overview

The following modules communicate with the Engine Control Module (ECM) via the network:

- Electronic Throttle System (ETS) including Electronic Throttle Module (ETM) and Accelerator Pedal Module (APM),
- Continuously Variable Valve Timing (CVVT)
- Transmission Control Module (TCM)
- Anti-lock Braking System (ABS)
- Central Electronic Module (CEM)
- Data Link Connector (DLC) for connection to VADIS/VIDA (Volvo Aftersales Diagnostic and Information System / Vehicle Information and Diagnostics for Aftersales)
- Driver Information Module (DIM), combined instrument panel
- Climate Control Module (CCM)
- Steering Wheel Module (SWM)

Central Electronic Module (CEM) is the central computer in the network, which handles the exchange between the network's high speed and low speed sections. The high-speed section covers the following modules: Engine Control Module (ECM), Electronic Throttle Module (ETM), Transmission Control Module (TCM), Anti-lock Braking System (ABS) and the Central Electronic Module (CEM).

ME 7.01 contain a large number of sensors that send information by analog signals directly to the ECM.

DIAGNOSE FUNCTIONS – OVERVIEW

General
The Engine Control Module (ECM) in itself diagnoses internal signals and functions, together with signals and functions from connected components.

Conditions for diagnosis
To start a diagnosis of a component or function, specific conditions must be fulfilled. The conditions for a diagnosis are different depending on which component or function being diagnosed. To be able to complete the diagnosis its driving cycle has to be performed. A driving cycle varies depending on which component or function being diagnosed.

Certain diagnoses only demand ignition on and ignition off in order to have a driving cycle performed. Other diagnoses demands several different conditions to be fulfilled, for example concerning:

- Vehicle speed
- Engine temperature
- Time passed after start
- Different load ratio and ratio of revolutions during the same driving
- A certain event (for instance the EVAP-valve is regulating).

When Engine Control Module (ECM) has performed all implemented diagnoses it is called the ECM has run a “trip”. To run a “trip” it demanded long time driving during different working conditions. Also, it can be demanded the engine be off during a specific time and then be driven again.

Emission related diagnosis functions
The Engine Control Module (ECM) controls that the emission related systems are worked properly. These systems are controlled by performing a diagnose function. In the diagnose function the included components and the very system function are controlled.

Fault code memory
When the Engine Control Module (ECM) detects a fault the fault code with qualifier and status is stored in the fault code memory of the ECM. At certain fault codes the failed signal is replaced with a substitute value so the system is able to continue working.

If a fault is healed the fault code will be still in the fault code memory a time period, but the status on the fault code will change.

Lighting of Check engine lamp
At emission related fault codes when the fault code is set, even a counter is stored which counts down to determine when check engine lamp shall be lighted. The conditions of check engine lamp lighting vary depending on which fault cod is set.

Input signals

Component	Signal type/explanation
Ignition switch + 50 supply	Provides early information to the Engine Control Module (ECM) to prepare for start.
Brake light switch	Informs ECM that the car is braking. The signal is a safety feature in addition to the brake pedal sensor. The ECM carries out a range test between the signals from both sources.
Electronic Climate Control (ECC) Manual Climate Control (MCC)	Provides information if the A/C is switched on or not. The ECM controls connection/ disconnection of the compressor dependent on load, engine speed (RPM), engine coolant temperature etc.
Oil pressure switch	Provides information about engine oil pressure. The information is sent to Driver Information Module (DIM) which via the display informs the driver to stop the engine and/or check the oil level.
A/C pressure sensor (linear)	Provides information using a linear signal about any pressure changes on the high-pressure side. Depending on the pressure the ECM can activate the engine Cooling Fan (FC) at high/low speed and shut off the A/C compressor.
Front Oxygen Sensor (HO2S) Bank 1, (linear signal)	Provides information about the oxygen level in the exhaust gases downstream of combustion and upstream of the catalytic converter.
Rear Oxygen Sensor (HO2S) Bank 1	Provides information about the oxygen level downstream of the catalytic converter (TWC).
Front Oxygen Sensor (HO2S) Bank 2, (linear signal)	Provides information about the oxygen level in the exhaust gases upstream of the catalytic converter (TWC). (Only 6 cylinder engines)
Rear Oxygen Sensor (HO2S) Bank 2	Provides information about the oxygen level downstream of the catalytic converter (TWC). (Only 6 cylinders engine)
Engine coolant temperature sensor	Provides information about engine coolant temperature (ECT).
Mass Air Flow (MAF) sensor (heated film principle)	Provides information about the intake air mass. The Mass Air Flow (MAF) sensor for turbo charged engines has no resistor for the intake air temperature, but is complemented instead by a separate sensor downstream of the Charge Air Cooler (CAC).
Camshaft Position (CMP) sensor	Provides information about cylinder intake and compression phase.
Knock Sensor (KS) 1 Knock Sensor (KS) 2	Provides information if the engine knocks.
Engine speed (RPM)/position sensor	Informs about the crankshaft position and engine speed (RPM). Has flywheel adaptation for mechanical faults/damage.
Accelerator Pedal (AP) position sensor	Provides information about accelerator pedal position. The signal is sent via two separate cables at the same time, one analog signal and one digital signal.
Engine coolant level switch	Provides information about engine coolant level. The information is sent to Driver Information Module (DIM) which informs the driver via the display to stop the engine and/or check the engine coolant level.
Intake Air Temperature Sensor	Informs about the intake air actual temperature after Charge Air Cooler (CAC). Used for Boost Pressure Control (BPC). The sensor is used together with intake air pressure sensor. Turbos only.
Intake air pressure sensor	Provides information about the intake air actual pressure after Charge Air Cooler (CAC). The most important sensor for Boost Pressure Control (BPC). The sensor is used together with intake air pressure sensor. Turbochargers only.
Diagnosis Module Tank Leakage (DMTL) module	Provides information about changes of the currents in the fuel tank system. Used for leak diagnostic.
Ambient air temperature sensor (located in left door mirror)	Provides information about ambient air temperature. Affects control of the engine Cooling Fan (FC).
Clutch pedal position sensor	Provides information that the clutch pedal is depressed.
CAN communication	Exchange of information between the ECM and the following: BCM, TCM, CCM, CDM and DLC.

Output signals

Component	Signal type/explanation
Air Conditioning (A/C) relay	Connecting and disconnecting A/C compressor.
Fuel Pump relay	Signal for Fuel Pump (FP) on/off switch. In a collision where the SRS is deployed it also sends a signal via the Central Electronic Module (CEM) to the Engine Control Module (ECM) to turn off supply to the Fuel Pump (FP).
System relay	Controlled by the ECM and provides sensors and functions with voltage supply.
Transmission Control Module (TCM)	Engine load, throttle opening, torque limiting, MIL request, constant idle speed compensation.
Electronic Climate Control (ECC) Manual Climate Control (MCC)	Signals engine coolant temperature to climate control system which can then determine how the blower fan should be controlled after cold start.
Electronic Throttle Actuator	Controls the air flow to the engine.
Electronic Fan Control Module	Electronic fan speed.
Central Electronic Module (CEM)	Controls communication between other modules.
Front Oxygen Sensor (HO2S) Bank 1, signal	Power supply for heating PTC element.
Rear Oxygen Sensor (HO2S) Bank 1, signal	Power supply for heating PTC element.
Front Oxygen Sensor (HO2S) Bank 2, signal	Power supply for heating PTC element. (Only 6 cylinder engines)
Rear Oxygen Sensor (HO2S) Bank 2, signal	Power supply for heating PTC element. (Only 6 cylinder engines)
Fuel Injectors	Controlled individually (sequentially).
Diagnosis Module Tank Leakage (DMTL) module	Provides information about changes of the currents in the fuel tank system. Used for leak diagnostic.
Canister Purge (CP) valve	Continuously controlled, it controls the flow from EVAP canister to engine intake side.
Continuously Variable Valve Timing control valve	Continuously controlled, it regulates camshaft setting. On turbocharged engines it regulates the exhaust camshaft and on normally aspirated it regulates the intake camshaft.
Turbocharger (TC) control valve	Controls turbocharger (TC) boost pressure, see turbocharger (TC) control system description section S0805.
Ignition coil/Ignition Discharge Module (IDM) for cylinders 1 – 5 (1 – 6 for 6 cylinder engines)	Separate ignition coil with integrated Ignition Discharge Modules (IDM) for each cylinder. Gives shorter charging interval and more power.
Malfunction Indicator Lamp (MIL) USA/CDN = Check Engine Other = Engine symbol	The lamp lights up for faults affecting the emissions. The lamp flashes for misfires, which cause risk of damage to the catalytic converter. Can also light up when requested by the Transmission Control Module (TCM).

Via CAN-communication

Brake Control Module (BCM):
Provides information so that the ECM can determine whether any misfiring is due to road condition or to a fault in the engine management system. Also provides a vehicle speed signal.

Climate Control Module (CCM):
Informs the ECM about A/C selection and requests A/C activation.

Central Electronic Module (CEM):
Is the "main computer" in the network and coordinates required information between other modules. It also controls diagnostic function by connecting the Data Link Connector (DLC) to the network for programming and reading off diagnostic trouble codes (DTCs) and parameters. The CEM also includes the Immobilizer.

Steering Wheel Module (SWM):
Provides information to the ECM that the cruise control is selected and that the driver requests changing the cruise control speed.

Transmission Control Module (TCM):
The Transmission Control Module (TCM) is only implemented in automatic transmission cars. The following signals are being sent on the network from the ECM and picked up by the TCM:
- Engine load
- Throttle opening
- Response to torque limiting
- Accelerator pedal position
- Cruise control status

The following signals are sent out on the network from the TCM and taken up by the ECM:
- Request for torque limiting step I and II
- Request to light Malfunction Indicator Lamp (MIL)
- Signal for constant idle speed compensation (P/N position)
- Engaged gear

Data Link Connector (DLC) (OBD II):
The serial communication via the Data Link Connector (DLC) is used when reading off the Volvo on-board diagnostic (OBD) system.

Serial communication:
The ECM communicates serially with the Data Link Connector (DLC).

Misfire diagnostic

With the crankshaft sensor the segment time deviation between two following ignitions is measured. The crankshaft is divided into 5 or 6 segments depending on engine cylinder type. Each segment corresponds to a specific ignition/cylinder. To avoid incorrect segment time deviations, due to manufacturing tolerances, a crankshaft adaptation must be accomplished. The crankshaft adaptation is performed during fuel-on and fuel-off..

Misfire detection is shut-off for loads below the Zero Load-line at engine speeds up to 3000 rpm, and also shut-off for loads under the 4"Hg-line from 3000 rpm up to redline. It is also shut-off during rough road operation, which is determined by signal from the ABS control unit.

Misfire detection is enabled when the engine speed has reached 150 rpm below warm idle speed plus two crankshaft revolutions or after nine ignitions, depending on which occurs first.For detection of emission related misfires, the number of misfires which have occurred within the first interval of 1000 engine revolutions or the 4th exceedance (for the rest of DCY) over the emission threshold value after the first 1000 engine revolutions are relevant. If the number is so high that the exhaust emission standard is exceeded by a factor of 1.5, then the emission related misfire rate has been reached and exceeded a fault code will be stored. If misfires occur and the threshold is exceeded in the following DCY, MIL illuminates.

For detection of catalyst damaging misfires, the numbers of misfires that have occurred during an interval of 200 engine revolutions are relevant. If the number of misfires are so high that the catalyst is endangered (by various number of misfires depending on actual engine operating range), then the cat. Damaging misfire rate has been reached and exceeded. The the fuel will be cut off to the misfirering cylinder and a fault code will be stored. MIL will blink with one Hertz as long as the engine has catalyst-damaging misfires. The fuel is cut off until engine is restarted.

Misfire Diagnostic Operation			Corresponding Monitor ID
DTCs	P0300 – P0306 P0300 – P0306	Misfire, Emission related Misfire, Catalyst damage	A2, A3, A4, A5, A6, A7
Monitor Strategy description	Misfire detected, emission related, Cylinder 1-6 (P0301-306). Misfire detected, catalyst damage Cylinder 1-6 (P0301-306).		

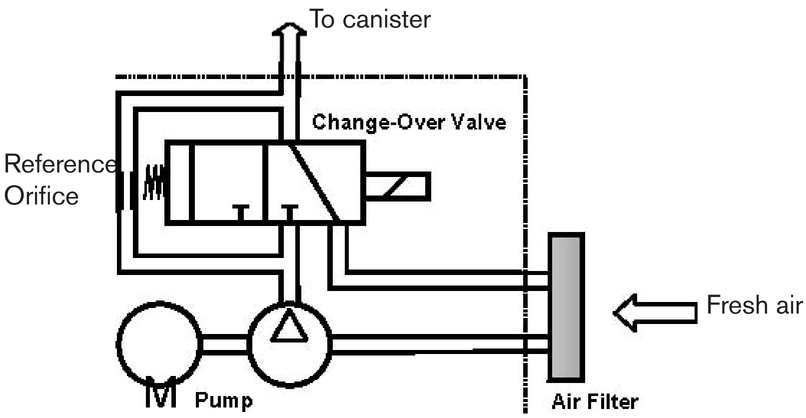
Typical misfire diagnostic enable conditions		
Enable condition	*Minimum*	*Maximum*
Intake air temp	-48°C	
Engine speed	480 rpm	6580 rpm

Typical misfire diagnostic malfunction thresholds	
Malfunction criteria	*Threshold value*
Counts misfire of all cylinders	> 36 per 1000 engine revolutions corresponds to 1.44 % misfire

Leakage diagnostic

Vapor that evaporates from the fuel in the fuel tank is routed to and stored in the EVAP canister from where it is introduced into the combustion process via the Canister Purge (CP) valve.

A leak diagnostic has been introduced in certain markets to ensure that there are no leaks in the fuel tank system. The diagnostic is designed to detect leakage corresponding to a 0,20 inch or larger hole. The fuel tank system consists of fuel tank, fuel filler pipe, EVAP canister, CP valve and all pipes between these components. To be able to diagnose the fuel tank system, it is also equipped with a diagnostic module (DMTL = Diagnostic Module Tank Leakage) including the electrical driven air pump.



Leakage diagnostic (LD) is performed in after run mode, when key off.

The diagnostic is divided into different phases as follow:

- Reference leak measurement, performed every LD
- Rough leak test, performed every DCY
- Small leak test performed every second DCY when enabling conditions are met.

The diagnostic is performed by measuring the motor current and then compares it to a specified reference current. If a fault is detected in any of the phases the diagnostic is interrupted and the diagnostic trouble code (DTC) for the component identified is stored. Diagnosis is carried out in the following stages:

- While fuel level sensors are working correctly and the fuel level is higher than 85 % all leakage tests and healing attempts are aborted.

- While the fuel level sensors are not working correctly, the test is aborted if the initial rate of change is higher than a calibrated level due to a combination of high fuel level and high evaporation. In case of healing when the fuel level sensor are not working correctly the attempt is aborted if the initial rate of change is higher than a calibrated level due to a combination of high fuel level and high evaporation. This level is calibrated to approximate 70 %.

1. Reference leak measurement phase
For the reference current measurement, the motor-pump is switched on. In this mode fresh air is pumped through a 0.02-inch reference orifice, situated internally in the module, and the pump motor current is measured. At some unusual operating conditions the pump current may not stabilize. In this case the leak check is aborted and a new leak check will be performed in the next after run. To prevent a permanent disablement of the leak check due to a DM-TL module problem, the number of subsequent irregular current measurements is counted and a module error is set as soon as the counter exceeds a calibrated value.

2. Rough leak test phase
In this monitoring mode the changeover valve is switched over (the purge control valve remains closed). The motor current drops to a zero load level. Fresh air is now pumped through the canister into the tank. This creates a small overpressure at a tight evaporative system, which leads to a current increase.

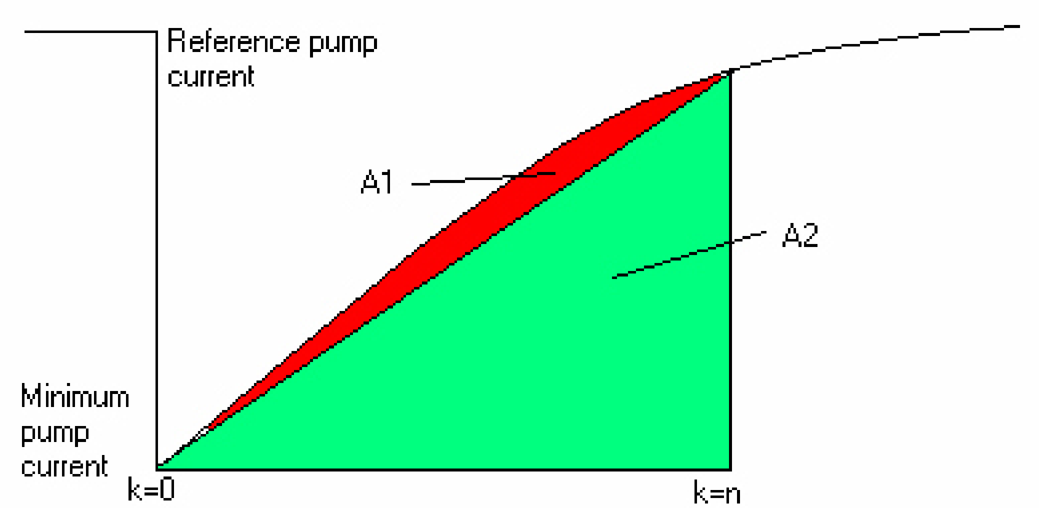
The rough leak check (≥ 0.04-inch) is performed by monitoring the pump motor current gradient. Relative pump motor current is created by using minimum pump motor current and reference pump motor current. Area ratio is created by dividing integrated relative current with ideal area, which is the linear integrated area from minimum pump current to current sample of the current. If the relative current has increased above an upper limit but not exceeded a calibrated area, within a calibrated time, the rough leak check has passed without a fault. If the calibrated area ratio is reached before the relative pump current limit, within the calibrated time, a rough leak fault code is set.
The integrated relative pump current area *Aint* is defined by;

$Aint = A1 + A2$

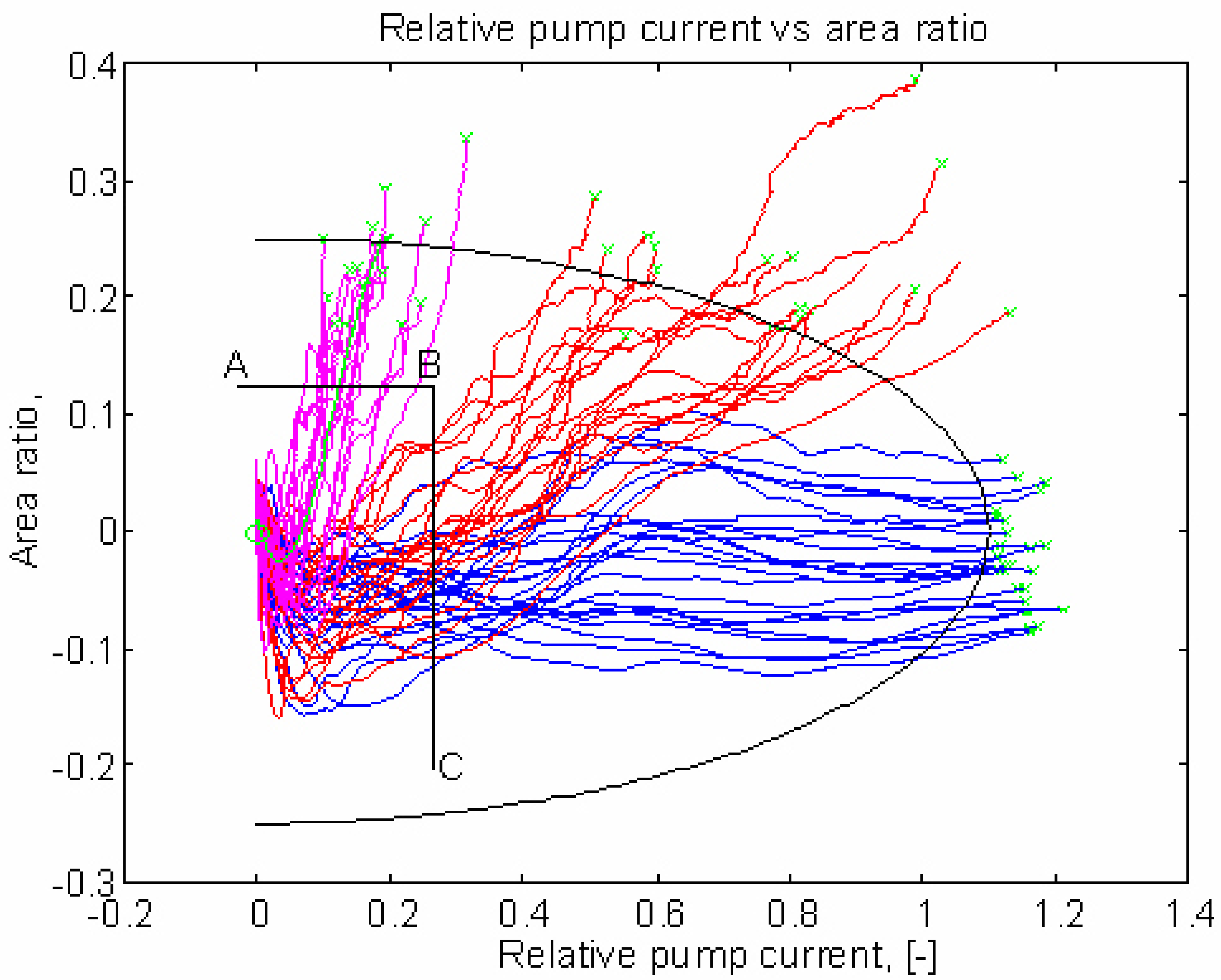
and the ideal area *Aideal* ,

$Aideal = A2$.

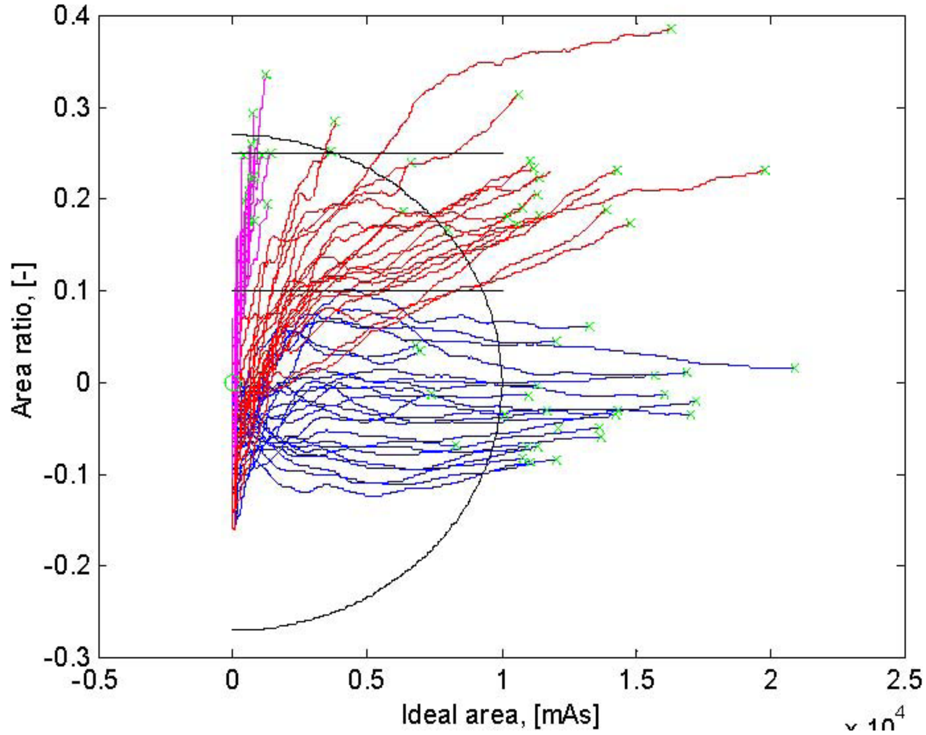
See figure below.



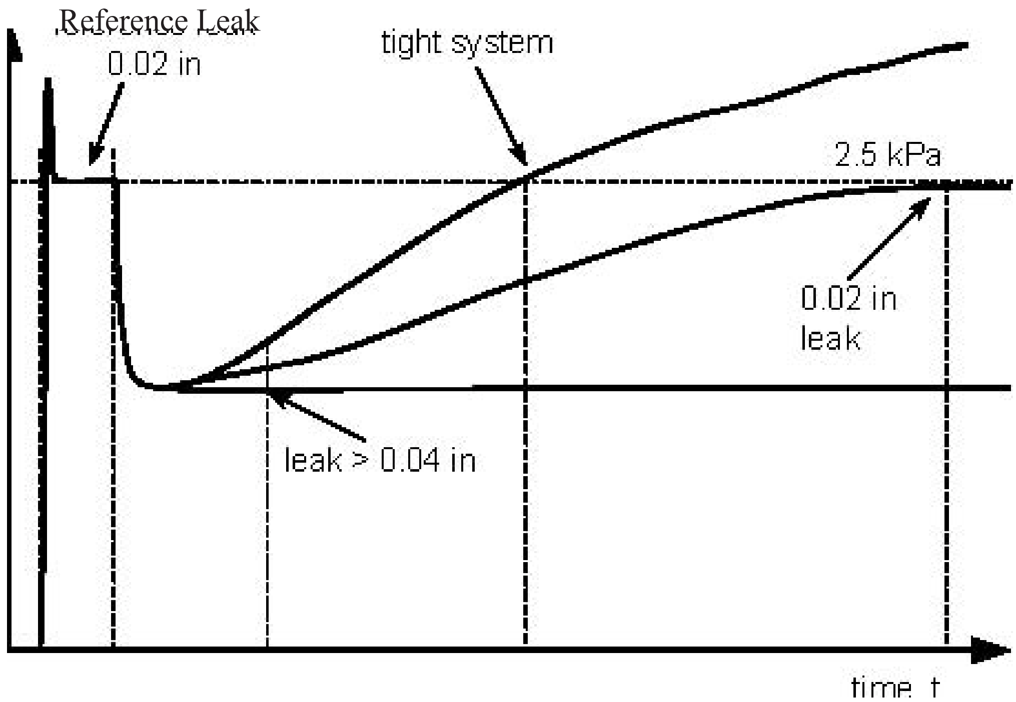
3. Small leak test phase
If the conditions for a small leak check (≥0.02-inch) are set the pump motor remains on in monitoring mode until an elliptic combination of the relation pump current and area ratio are fulfilled, or a maximum time limit has been reached.The judgment is based on a test value which is a combination of the actual area ratio and gradient of area ratio with respect to relative pump current.



Results from simulation using old measurements and creating the area ratio and relative pump current and plot them versus each other.Blue curves correlates to no leakage, red curves to 0,5 mm leakage and the magenta to 1,0 mm leakage.



Results from simulation using old measurements and plotting the area ratio vs. the ideal area.Blue curves correlates to no leakage, red curves to 0,5 mm leakage and the magenta to 1,0 mm leakage.



If the motor current decreases or increases too much during one of the tests, the test is aborted and a new leak test will be performed in the next afterrun.

Monitoring conditions

To carry out the leak diagnostic it is necessary that:

- Engine-on time is at least 10 minutes and last engine-off time is more than 5 hours.
- ECM (=Engine Control Module) is in after run mode
- Engine speed is 0 rpm
- Vehicle speed is 0 km/h
- Altitude is less than (or equal to) 2500 meters
- Engine coolant temperature is above (or equal to) -5°C
- Ambient temperature is between -5°C and +35°C
- Fuel level between 0% to 85%
- Concentration of fuel vapor in the EVAP canister is not excessive
- Battery voltage between 11.0 V and 14.5 V
- Purge valve is closed

With the following errors the leakage detection monitoring can not be performed. These errors will therefore disable the leakage detection monitoring and the MIL (and the corresponding fault code) will be set. The disable conditions are:

- Error on power stages DM-TL pump (E_dmpme)
- Error on power stage purge valve (E_teve)
- Error on purge valve (E_tes)
- Error on change-over valve (E_dmmve)
- Error on vehicle speed signal (E_vfz)
- Error on coolant temperature sensor (E_tm)
- Error on altitude sensor (E_dsu).

Leakage Diagnostic Operation			Corresponding Monitor ID
	Evaporative Emission System	*Monitor Strategy description*	
DTCs	P2404 Plausibility error	Current drop check when switching from reference leak to tank measurement.	3D
	P2405-2406 Max and min error	Reference leak current limit check	3D
	P2407 Signal error	Current fluctuation check	3D

Typical leakage diagnostic enable conditions

Enable condition	*Minimum*	*Maximum*
Engine on time	600 s	
Ambient air temperature	-5°C	+35°C
Battery voltage	11.0 V	14.5 V

Typical leakage diagnostic malfunction thresholds

Malfunction criteria		*Threshold value*
Reference current, lower limit	Min error	≤ 15 mA
Reference current, upper limit	Max error	≥ 40 mA

Canister purge valve diagnostic

The task of the canister purge valve diagnosis is to detect a defective purge control valve. The purge control valve is checked with regard to controllability of the flow rate such as permanently open as well as permanently closed. In this cases purge control valve is detected. Minor leaks or slightly blocked valves are not detected if the valve is still controllable to a large extent. A check for absolute tightness must be performed separately or it can be derived from a possibly given canister leak test.

The diagnosis is used in addition to the electrical diagnosis. Provided the electrical diagnosis has already detected a fault, the canister purge valve diagnosis remains inactive. If the electrical diagnosis should not yet have detected a fault it will be detected by the canister purge valve diagnosis.

There are two possibilities for an OK check:

1. From active check at idle. A deviation of the Lambda controller from its value prior to opening, the purge control valve indicates that the purge control valve can be controlled and thus is OK.

2. If a stoichiometric mixture is coming there is no deviation of the Lambda controller.
a) Only the reaction of the idle control, which closes the throttle valve, can be evaluated.
b) Indication for an OK check is the decrease of the air mass flowing through the throttle valve
c) If the valve cannot close any further the ignition angle efficiency is worsened. This is also detected.

There is one possibility for defective purge control valve check:

1. If neither a reaction of the Lambda controller or of the idle controller can be observed during the active check by controlling the purge control valve open. Then the purge control valve can no longer be controlled (jammed at closed or open position), so the purge control valve is defective. The canister purge valve diagnosis is depending on lambda controller, throttle angle and ignition efficiency.

Monitoring conditions

To carry out the purge valve diagnosis it is necessary that:

- Ambient temperature is above -7.5°C
- Engine temperature is above +65°C
- Altitude is less than (or equal to) 4000 meters
- Vehicle speed is 0 km/h
- Condition for Lambda closed loop control fulfilled
- Critical misfire or limp home on velocity pick-up signal not detected

With the following errors the purge control monitoring can not be performed. These errors will therefore disable the purge control diagnosis and the MIL (and the corresponding fault code) will be set. The disable conditions are:

- Condition for fault type ”implausible signal” detected in the DM-TL module.
- Error on DM-TL change-over valve power stage, short circuit to ground.

Canister purge valve diagnostic			
	Evaporative Emission System	*Monitor Strategy description*	Corresponding Monitor ID
DTCs	P0496 Max error P0497 Min error	Incorrect purge flow	3D

Typical canister purge valve diagnostic enable conditions		
Enable condition	*Minimum*	*Maximum*
Engine temperature at start	65.25°C	
Altitude		4000 meters
Ambient air temperature	-7.5ºC	

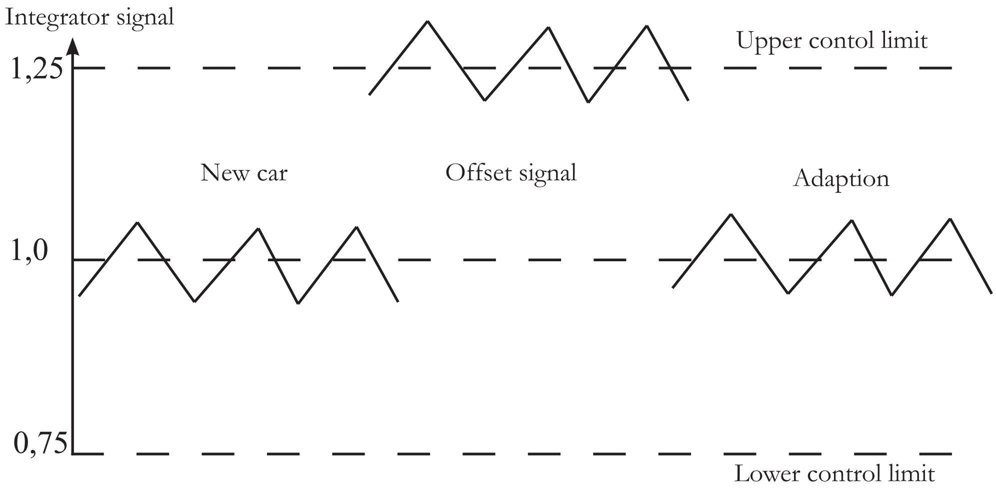
Typical canister purge valve diagnostic malfunction thresholds	
Malfunction criteria	*Threshold value*
Delta resistant torque from resistant torque adaptation	<-2.99 %

Fuel system monitoring

The fuel injection system has a function which compensates for changes in the lambda (λ) control which occur slowly over its service life. It is called λ adaptation and its purpose is to keep the integrator signal within its limits of control (see figure below).

The integrator signal controls the fuel injection time, in a new car the integrator signal oscillates about 1 (equivalent λ=1).

Integrator signal shift



The amount of λ integrator offset is calculated when the set λ is equal to 1 and the canister close valve is closed.

The fuel adaptation will compensate the fuel amount so that the λ integrator will remain in the middle (λ=1.0).

The λ control adaptation is divided into two adaptation areas: The additive adaptation at idle conditions (ora) and the multiplicative adaptation area at loaded engine (frau).

The correction of the fuel amount = calculated fuel amount * frai + ora. The speed of the fuel adaptation is depending on the λ integrator offset (big offset is equal to high adaptation speed). The amount of the λ integrator offset is also used in calculation of the physical urgency. The purge functionality is also calculating a physical urgency (dependant of charcoal canister load). This means that the fuel adaptation will get more time for adaptation if there is an offset and/or low charcoal canister load.

Fuel pressure system diagnosis

New fuel pressure system diagnosis function is implemented. It is due to new hardware design for this model year, with a variable fuel pump, a fuel pressure sensor and a fuel temperature sensor. The function target is to be able to point out the fuel pressure system as incorrect due to performance specification and fulfill legal requirements. The function will detect the fuel pressure to be stuck high (higher pressure than target), stuck low, noisy pressure signal or plausibility.

The function, fuel temperature sensor diagnosis will detect min and max error.

The function, fuel pressure sensor diagnosis will detect min and max error.

And the function fuel power stage diagnosis will detect min, max and signal error.

Fuel Monitor Operation		Corresponding Monitor ID
DTCs	ora: P2187 Lean P2188 Rich frau: P2177 Lean P2178 Rich	81 81 81 81
Monitor Strategy description	Long term fuel trim correction value is updated to maintain the short-term fuel trim at desired set value (0 % correction). The value of the long term fuel trim correction is monitored.	

Typical fuel monitor enable conditions

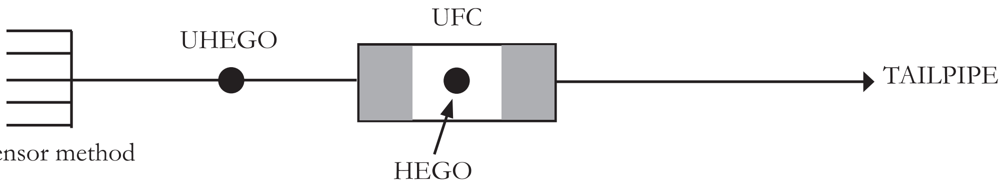
Enable condition	*Minimum*	*Maximum*
Filtered air mass flow	27 kg/h	325 kg/h
Engine temperature	69.8°C	
Intake air temperature		80.3°C

Typical fuel monitor malfunction thresholds

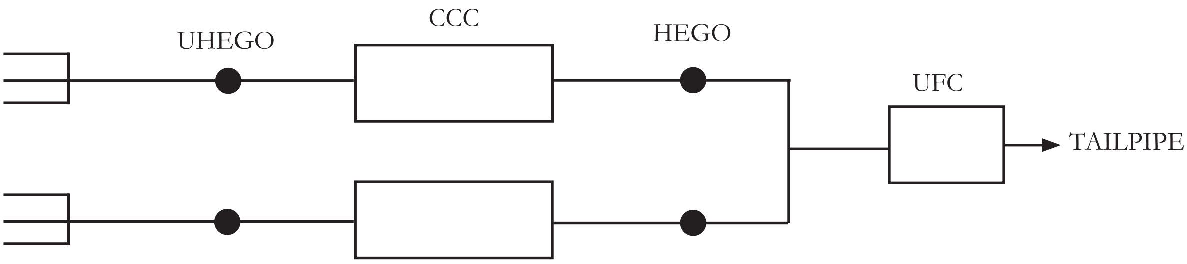
Malfunction criteria	*Threshold value*
Multiplicative correction factor: frau, Lean frau, Rich	 ≥ 1.234985 ≤ 0.82
Additive correction: rkat, Lean rkat, Rich	 ≥ 8.531 % ≤ -7.406 %

Catalyst monitoring

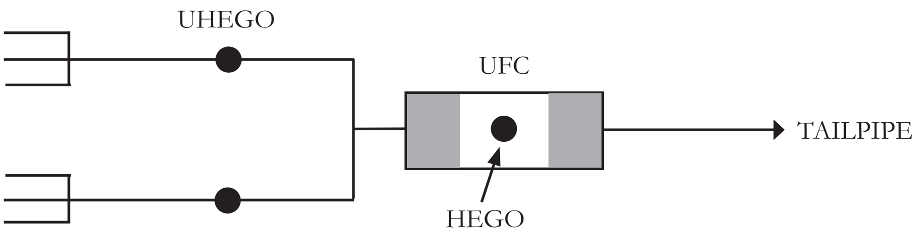
General Description



2-sensor method



2-sensor method stereo



3-sensor method

HEGO = Universal Heated Exhaust Gas Oxygen Sensor = ”Binary sensor”
UHEGO = Universal Heated Exhaust Gas Oxygen Sensor = ”Linear sensor”
CCC = Close Coupled Catalyst
UFC = Under Floor Catalyst

Sensor methods

- The two-sensor method makes use of one upstream and one downstream oxygen sensor, one sensor (UHEGO) before the catalytic converter and one sensor (HEGO) inserted into the catalytic converter, monitoring the front part of the catalyst.

- The two-sensor method stereo makes use of one upstream and one downstream oxygen sensor for each cylinder bank, each bank has one sensor (UHEGO) before the catalytic converter and one sensor (HEGO) after.

- The three-sensor method makes use of two upstream and one downstream sensor, two sensors (UHEGO) before the catalytic converter and one sensor (HEGO) inserted into the catalytic converter, monitoring the front part of the catalyst.

Catalyst monitoring is based on monitoring the oxygen storage capability. The (nonlinear) correlation between conversion efficiency and storage capability has been shown in various investigations.

The engine mixture control results in regular Lambda oscillations of the exhaust gas. When using a linear sensor Lambda control, Lambda oscillations are artificially created during catalyst monitoring.

These oscillations are dampened by the storage activity of the catalyst. The amplitude of the remaining Lambda oscillations downstream the catalyst indicates the storage capability. This information is evaluated during one single engine load and speed range. According to the described operating principle the following main parts can be distinguished:

- Computation of the amplitude of the downstream Lambda sensor
- Modeling of a borderline catalyst and of the signal amplitudes of the downstream Lambda sensor
- In the 3-sensor case, an additional modeling of a single air fuel mixture corresponding to the two front sensors, before the catalytic converter.
- Signal evaluation
- Fault processing
- Check of monitoring conditions

Heated oxygen sensor diagnostic

Heated oxygen sensors are used in the system. These sensors are checked as usual for short-circuits and open-circuits. When these faults occur, corresponding errors are stored for each sensor.

Function of oxygen sensors

The basic functionality of these sensors is the concept of a pump current of the oxygen in fuel-air mixtures, from where the sensor system can compute the actual fuel-air mixture. Heating of the sensors is also undertaken in order to decrease the internal resistance and to further improve the performance of the sensors.

The internal resistance of the front sensors is constantly monitored for the heating diagnosis. A comparison is therefore made with a reference in order to consider aging and sample deviations. Also, power stage diagnosis is made for the front sensors where a comparison of the control signal (input) and the output signal is made. Through this procedure all various possible types of short-circuits will be detected.

Diagnosis of oxygen sensors

Diagnosis of incorrect lambda measurements due to shunting effects is performed through a lambda offset of the downstream-control if a difference of air-fuel mixture exceeds a threshold (3%). By monitoring the voltage output of the specific processor CJ125 a check is made that it operates correct, avoiding hardware errors. Insufficient heating of the LSU, i.e., the front sensor, and disconnection of the pump current are detected through a comparison of the fuel-air mixture with the rear sensors. The criterion is that if the front sensor indicates a fuel-air mixture with a ratio of 1, while the rear sensor indicates a lean or rich mixture, one of these failures has occurred. Through different comparisons of the front and rear sensors, also short-circuits and high resistance to battery and ground, are detected for the front sensors. Low resistance connection between heater and the sensor, i.e. the heater coupling, is detected by monitoring lambda changes due to the heater pulse rate. A decrease of the actual performance, known as the dynamics, of the sensor due to aging or fouling can be detected through a comparison of the estimated (model based) signal and the actual measured signal.

Similar testing as these above are also undertaken for the rear sensors, where the major differences in the diagnosis can be found through oscillation checks, checking of the sensor voltage and the dynamics during fuel cut-off, for the rear sensors.

During active oxygen sensor aging diagnosis the sensor signal (shape and frequency) can be considered as characteristic for the quality of the installed upstream sensor. Thus, for this purpose several parameters are calculated continuously. These calculated values are then provided via a tester interface (Scan Tool), together with the correction value of the downstream controller, the dynamic property value of the upstream continuous sensor and different constants by this tester interface. It is by this functionality the legislative authorities (for instance CARB) determine the standard of the oxygen sensor system.

Catalyst Monitor Operation		Corresponding Monitor ID
DTCs	P0420 Main Catalyst, Bank 1 P0430 Main Catalyst, Bank 2 (6-cyl. stereo-sys.)	21 22
Monitor Strategy description	Efficiency below threshold (oxygen storage)	

Typical Catalyst monitor enable conditions

Enable condition	*Minimum*	*Maximum*
Engine speed	1000-1440 rpm	2000-2520 rpm
Modeled bed catalyst temperature	470°C	719.991°C
Ambient air start temperature	-24.0°C	143.3°C

Typical Catalyst monitor malfunction thresholds

Malfunction criteria	*Threshold value*
Normalized catalyst quality factor Sum of catalyst quality factors from cylinder bank 1 and 2	> 0.1992-0.5313 > 0.398-0.461
Cumulative catalyst monitoring time	> 60-80 s

Oxygen sensor check Operation - Bank 1

	Lambda sensor upstream catalyst	*Monitor Strategy description*	Corresponding Monitor ID
DTCs	P0040: oxygen sensor signals swapped (sensor 1)	Exchange of lambda sensors upstream catalyst, detection	
	P0041: oxygen sensor signals swapped (sensor 2)	Exchange of lambda sensors upstream catalyst, detection	
	P0131-P0132: control circuit input lines	IC CJ125 internal errors are detected by a voltage comparator check and sent to the main processor	
	P1646: evaluation IC	Circuit Range / Performance	
	P2096-P2097: lean / rich plausible test	Front sensor is detected as shifted erroneously to lean side	01
	P2195-P2196: lean / rich plausible test	Front sensor signal characteristic lean / rich	
	P2237: pumping current pin	Line interruption on IP	
	P2251: virtual ground	Line interruption on VM	
	P2414: outside exhaust system	Front sensor is out of exhaust gas system	
	P2626: pumping current trim	Circuit Range / Performance	
	P2243: lambda sensor upstream cat, reference voltage output	Line interruption on UN	
	P0133: front sensor	Circuit Slow Response	01
	P2231: front sensor heating	Circuit Cross-coupling to sensor heating	42
	P0141: O2 sensor heater	Circuit	42

Oxygen sensor check Operation - Bank 2			
	Lambda sensor upstream catalyst	*Monitor Strategy description*	Corresponding Monitor ID
DTCs	P0151-P0152: control circuit input lines	IC CJ125 internal errors are detected by a voltage comparator check and sent to the main processor	
	P1647: evaluation IC	Circuit Range / Performance	
	P2098-P2099: rich plausible test	Front sensor is detected as shifted erroneo-usly to rich side	05
	P2197-P2198: lean / rich plausible test	Front sensor signal characteristic lean / rich	
	P2096-P2097: lean / rich plausible test	Front sensor is detected as shifted erroneo-usly to lean side	01
	P2240: pumping current pin	Line interruption on IP	
	P2254: virtual ground	Line interruption on VM	
	P2415: outside exhaust system	Front sensor is out of exhaust gas system	
	P2629: pumping current trim	Circuit Range / Performance	
	P2247: lambda sensor upstream cat, reference voltage output	Line interruption on UN	
	P0153: front sensor	Circuit Slow Response	05
	P2234: front sensor heating	Circuit Cross-coupling to sensor heating	

Typical Oxygen sensor enable conditions		
Enable condition	*Minimum*	*Maximum*
Battery voltage	10,7 V	16,0 V

Typical Oxygen sensor malfunction thresholds	
Malfunction criteria	*Threshold value*
Sensor voltage upstream of the catalyst	> 4.81 V

Continuous Variable Valve Timing (CVVT)

The Engine Control Module (ECM) infinitely variable controls the CVVT valve which in turn controls the CVVT unit with engine oil pressure.

The CVVT unit is mounted either on the exhaust camshaft or the intake camshaft or both, depending on which engine it is. The CVVT unit is used on all 5 and 6 cylinder engines.

The variable camshaft is hydraulically controlled by the engine oil. (The camshaft rotation takes place by the engine oil, using the CVVT valve it is transferred to either the CVVT unit front or rear chambers.) The chambers are divided by a piston.

When oil presses the piston back or forward it results in a rotating motion in the piston because it is installed in the CVVT unit cover with splines. The tooth wheel for the timing belt is located on the CVVT unit outer cover.

The control is fast and exact, it only takes approximately 500 ms to transfer between the outer positions.

The variable camshaft main task is to minimize exhaust emissions, mainly at cold start, but also gives an improved idling quality.

Before the engine starts an internal check occurs as follows:

1. When the ignition is switched on an electrical check is carried out on the signal cable, the power supply cable and the solenoid. The check is carried out for a short-circuit to supply voltage/ground and open-circuit.

2. The camshaft checks if it is in the correct position compared to the flywheel, when the camshaft is in its 0-position (mechanical resting position). This can be done by comparing the signals from The Camshaft Position (CMP) sensor and the engine speed (RPM)/position sensor. This is being done while the engine is running and is saved until the next start.

If the deviations are too large between these the CVVT valve does not activate and the diagnostic trouble code (DTC) is stored.

3. In case of larger controlled deviations at the variable camshaft the time taken to regulate to the control value is measured. This time is used partially to determine how long it takes to alter the camshaft angle and partially to switch off the variable camshaft if the time exceeds a certain maximum time. The camshaft uses the engine oil and oil pressure to turn. The rotation time depends on engine speed (RPM), oil pressure, viscosity etc. which in turn depends on oil temperature and quality etc.

4. To check that the Camshaft Position (CMP) sensor is correct it is compared to the signal from the engine speed (RPM)/position sensor when the engine turns. If the check gives faulty values a DTC is stored and CVVT control ceases.

Engine speed (RPM) sensor

The periphery of the flywheel/flex plate is provided with a series of holes. As it passes, each transition between hole and metal induces a voltage in the pick-up coil of RPM sensor. The resulting signal is an A/C signal whose frequency is a function of the number of holes passing per second and whose voltage can vary between 0.1 V and 100 V AC, depending on the engine speed and the air gap. Voltage and frequency increases with engine speed. The engine control module (ECM) determines the engine speed and of the crankshaft by detecting the voltage pulses.

At approximately 90° before TDC for cylinder 1 there is a section without any gap. When this longer metal section (= missing holes) passes the RPM sensor, voltage pulses stop and the ECM can calculate angular crankshaft position.

Camshaft position (CMP) sensor

The sensor consists of an MRE (Magnetic Resistance Element). It is a permanent magnet with 2 special semiconductor resistors, which are connected in series with each other, as described in the picture above. The output signal is an analog sine curve which passes through an analog/digital converter in the Camshaft Position (CMP) sensor before being sent on to the Engine Control Module(ECM).

When a tooth on the pulse wheel nears the sensor the magnetic field is bent and affects the resistor located nearest to the ground, resistance affects the voltage and the output signal to the ECM is low. When the same tooth continues past the sensor the magnetic field follows and so affects the other resistor that is located nearest to the voltage supply, this resistor affects the voltage so that the output signal to the ECM is high.

The magnetic field swings backwards and forwards between the teeth on the pulse wheel and the ECM senses the signals between the teeth, partly before and partly after the sensor.

The pulse wheel has 4 teeth. The ECM calculates the time interval from one tooth to the next and can decide exactly which cylinder must be supplied with fuel and ignition spark respectively.

Faults in the CMP sensor:

- The engine can still be started and driven in event of faults in the CMP sensor.

- The engine may need to be cranked for a long time before the ECM sends a spark to the correct cylinder and the engine starts.

Camshaft position sensor Operation		
	Sensor 1 (P0340-344), Sensor 2 (P0345-49)	*Monitor Strategy description*
DTCs	P0340: Signal error	Circuit
	P0342, P0343: Min, Max error	Circuit Low Input, Circuit High Input
	P0344: Plausibility error	Circuit Intermittent
	P0345: Signal error	Circuit
	P0347, P0348: Min, Max error	Circuit Low Input, Circuit High Input
	P0349: Plausibility error	Circuit Intermittent

Typical Camshaft position sensor enable conditions		
Enable condition	*Minimum*	*Maximum*
Clear fault path PH	TRUE	

Typical Camshaft position sensor system constant		
Enable condition	*Minimum*	*Maximum*
Detection of reversed rotation of the engine	TRUE	

Typical Camshaft position sensor malfunction thresholds	
Malfunction criteria	*Threshold value*
Sum of phase edges last 3 working cycles	> 11 and < 13
Number of camshaft sensor signal slopes permanently low	≥ 4

Mass air flow meter (MAF)

The mass air flow (MAF) sensor supplies the engine control module (ECM) with a signal describing the intake air mass.
This information is for instance used to:

- Regulate fuel/air conditions
- Regulate emission
- Calculate torque.

The MAF sensor consists of a plastic housing containing a connector, electronic circuitry and an aluminum heat sink. The MAF sensor measuring device is a heated film mounted in a pipe which is cooled by the intake air to the engine.

The heated film consists of four resistors. The MAF sensor is supplied with battery voltage and has separate power and signal ground points. The sensor signal varies from 0 V to 5 V, depending on the air mass. Voltage increases with air flow.

The ECM will adopt substitute (limp home) values if the MAF sensor signal is missing or faulty.

The MAF sensor is located between the air cleaner cover and the intake air hose.

MAF meter operation

	Mass Air Flow	*Monitor Strategy description*
DTCs	P0102: Max error	Circuit low input
	P0103: Min error	Circuit high input

Typical MAF enable conditions

Enable condition	*Minimum*	*Maximum*
Time after engine start	0.40 s	
Throttle potentiometer fault	FALSE	

Typical MAF malfunction thresholds

Malfunction criteria	*Threshold value*
Unfiltered MAF sensor value (min error)	< -38.1 kg/h
Unfiltered MAF sensor value (max error)	> 940.0 kg/h

Engine coolant temperature sensor

The engine coolant temperature (ECT) sensor transmits a signal to the engine control module (ECM) describing the temperature of the engine coolant. This gives the ECT sensor a measurement of engine temperature and influences the control of:

- Injection period
- Idling speed
- Engine coolant fan (FC)
- Ignition timing
- On-board diagnostic (OBD) functions.

The sensor incorporates a temperature-sensitive resistance with a negative temperature coefficient (NTC). The sensor is supplied with a stabilized voltage of 5 V from ECM.

The voltage across the sensor is a function of engine temperature and, therefore, of sensor resistance. Voltage can be between 0 V and 5 V.

The ECM uses substitute values if the signal from the ECT sensor is missing or faulty, however, substitute values can cause starting problems in very cold weather.

The sensor is mounted in the thermostat housing.

Engine coolant temperature operation

	Engine Coolant Temperature	Monitor Strategy description
DTCs	P0116: Plausibility error	Circuit Range/Performance
	P0117: Max error	Circuit low input
	P0118: Min error	Circuit high input
	P0125: Signal	Insufficient Coolant Temp. for Closed Loop Fuel Control

MY04-05
Vehicle: S60, V/XC70, S80, XC90
Engine: B5234T, B5254T, B6294T/S

Request on-board monitoring test results for specific monitored systems

The purpose of this service is to allow access to the results for on-board diagnostic monitoring tests of specific components / systems that are continuously monitored (e.g. mis-fire monitoring) and non-continuously monitored (e.g. catalyst system).

The request message for test values includes an On-Board Diagnostic Monitor ID (see below) that indicates the information requested.

The latest test values (results) are to be retained, even over multiple ignition OFF cycles, until replaced by more recent test values (results). Test values (results) are requested by On-Board Diagnostic Monitor ID. Test values (results) are always reported with the Minimum and Maximum Test Limits. The Unit and Scaling ID included in the response message defines the scaling and unit to be used by the external test equipment to display the test values (results), Minimum Test Limit, and Maximum Test Limit information.

If an On-Board Diagnostic Monitor has not been completed at least once since Clear/reset emission-related diagnostic information or battery disconnect, then the parameters Test Value (Results), Minimum Test Limit, and Maximum Test Limit shall be set to zero ($00) values.

The diagnostic communication for external Scan Tools follows ISO 15765-4.

Mode $06 Data

Monitor ID	Test ID	Description	DTCs
01	83	Front O2 sensor slow response.	P0133
	84	Difference between front and rear oxygen sensors.	P2096/P2097
02	81	O2 sensor Bank 1 Sensor 2 max. sensor voltage of oscillation check	P0140
	82	O2 sensor Bank 1 Sensor 2 mimimum sensor voltage of oscillation check	P0140
	83	02 for sensor diagnosis Bank 1 Sensor 2 sensor voltage of fuel cut-off	P0140
05*	83	Front O2 sensor Bank 2 slow response	P0153
	84	Difference between front and rear oxygen sensors Bank 2	P2098/P2099
06*	81	O2 sensor Bank 2 Sensor 2 max. sensor voltage of oscillation check	P0160
	82	O2 sensor Bank 2 Sensor 2 mimimum sensor voltage of oscillation check	P0160
	83	02 for sensor diagnosis Bank 2 Sensor 2 sensor voltage of fuel cut-off	P0160
21	80	Catalyst monitor Bank 1	P0420
22*	80	Catalyst monitor Bank 2	P0430
3B	81	1.0mm leak check (tank leak diagnosis)	P0442
3C	81	0.5mm leak check (tank leak diagnosis)	P0442
3D	80	CPV-Diagnosis	P0496/P0497
	83	CPV-Diagnosis	P0496/P0497
	86	TEV-Diagnosis	P0496/P0497
	8B	Component Check	P2407
	8C	AAV-Diagnosis	P2404
	8D	Component Check	P2406/P2405

* Only for 6 cyl engines

Mode $06 Data

Monitor ID	Test ID	Description	DTCs
41	85	Bank1 Sensor1 heater power	P0053
42	81	O2 sensor Bank 1 Sensor 2, resistance of ceramic	P0141
45*	85	Bank2 Sensor1 heater power	P0059
46	81	O2 sensor Bank 2 Sensor 2, resistance of ceramic	P0161
81	80	Fuel System Monitor Bank 1 (Additive correction of the mixture adaptation)	P2187/P2188
	82	Fuel System Monitor Bank 1 (Multiplicative correction of the mixture adaptation)	P2177/P2178
82*	80	Fuel System Monitor Bank 2 - Additive correction of the mixture adaptation	P2189/P2190
	82	Fuel System Monitor Bank 2 - Multiplicative correction of the mixture adaptation	P2179/P2180
A2	0B	Misfire counts for complete driving cycle (Cylinder 1)	P0300/P0301
	AC	Exponential weighted moving average of the misfire counts for the last 10 driving cycles	P0300/P0301
A3	0B	Misfire counts for complete driving cycle (Cylinder 2)	P0300/P0302
	AC	Exponential weighted moving average of the misfire counts for the last 10 driving cycles	P0300/P0302
A4	0B	Misfire counts for complete driving cycle (Cylinder 3)	P0300/P0303
	AC	Exponential weighted moving average of the misfire counts for the last 10 driving cycles	P0300/P0303
A5	0B	Misfire counts for complete driving cycle (Cylinder 4)	P0300/P0304
	AC	Exponential weighted moving average of the misfire counts for the last 10 driving cycles	P0300/P0304
A6	0B	Misfire counts for complete driving cycle (Cylinder 5)	P0300/P0305
	AC	Exponential weighted moving average of the misfire counts for the last 10 driving cycles	P0300/P0305
A7	0B	Misfire counts for complete driving cycle	P0300/P0306
	AC	Exponential weighted moving average of the misfire counts for the last 10 driving cycles	P0300/P0306

* Only for 6 cyl engines