MY01-02
Vehicle: S60, C70
Engine: B5234T, B5244T

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 VIDA
- 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 sectioncovers 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).

The diagnostic communication for external Scan Tools follows ISO 9141-2.

Communication on the internal network

CAN communication
ECM (Engine Control Module) sends out and receives the following signals via the network:

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 onboard diagnostic (OBD) system. The Volvo proprietary communication system uses a different protocol e.g. not ISO 9141-2, which is only used for legislated communication with a Scan tool. The ECM communicates serially with the Data Link Connector (DLC).

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).

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. Nowadays the crankshaft adaptation is performed during fuel-on, unlike previously 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 number 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 a fault code will be stored. MIL will blink with one Hertz as long as the engine has catalyst-damaging misfires.

Misfire Diagnostic Operation		
DTCs	P0300 – P0306 P0300 – P0306	Misfire, Emission related Misfire, Catalyst damage
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	-30°C	
Engine speed	480 rpm	< 6240 rpm (AUT), 6480 rpm (MAN)

Typical misfire diagnostic malfunction thresholds	
Malfunction criteria	*Threshold value*
Counts misfire of all cylinders	> 25 per 1000 engine revolutions corresponds to 1 % misfire

Leakage diagnostic

Vapor which 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 and negative pressure in the intake manifold. 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 1 mm or larger hole. The fuel tank system consists of fuel tank, fuel filler pipe, EVAP canister, Canister Purge (CP) valve and all pipes between these components. To be able to diagnose the fuel tank system, it is also equipped with fuel tank pressure sensor and EVAP canister shut-off valve.

Leak diagnostic different stages

The diagnostic is divided into different phases in which the various components are tested. 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:

1. The fuel tank pressure sensor is checked for an unstable signal. Diagnostic trouble code (DTC) for a faulty fuel tank pressure sensor is stored if the signal deviates more than 1kPa more than 5 times in 5 seconds. The fuel tank pressure is checked so that it is stable and that the short-term Lambda Control is not too low.

2. The EVAP canister shut-off valve closed and an evaporation check is carried out. By gauging how much fuel tank pressure increases value for how much fuel evaporates is provided, and this value is used later to calculate leakage flow. If fuel tank pressure sinks, this indicates that the Canister Purge (CP) valve is leaking and diagnostic trouble code (DTC) for an open Canister Purge (CP) valve is stored.

3. The EVAP canister shut-off valve opens, the tank system is open. The Canister Purge (CP) valve is pulsed and because of the negative pressure in the intake manifold the engine starts to suck air through the EVAP canister. Because EVAP canister shut-off valve is open, the fuel tank pressure sinks slowly. If fuel tank pressure sinks rapidly this indicates that the EVAP canister shut-off valve is clogged and the diagnostic trouble code (DTC) for EVAP canister shut-off valve shut is stored.

4. EVAP canister shut-off valve closes and the Canister Purge (CP) valve pulses with a duty cycle of approximately 17%. The pressure in the tank then falls to about - 1 kPa. If this pressure is not reached within 10 seconds it indicates a larger leak in the fuel tank. and the diagnostic trouble code (DTC) for a large leak is stored. If the fuel tank pressure does not change within about 10 seconds it indicates a defective fuel tank pressure sensor or clogged piping .The diagnostic trouble code (DTC) for a large leak is stored.

5. The Canister Purge (CP) valve is closed and the EVAP canister shut-off valve is still closed and there is negative pressure in the fuel tank. This negative pressure will decrease slowly. The decrease rate depends on fuel level, fuel evaporation and any leaks. Leakage flow is calculated by comparing pressure increase speed with the pressure decrease speed from stage 4 and by compensating for the evaporation measured in stage 2. If the calculated leakage flow exceeds a certain level this indicates a smaller leakage in the fuel tank system and diagnostic trouble code for small leak is stored.

6. The EVAP canister shut-off valve opens, the EVAP function is enabled and the diagnostic test is finished.

During the different phases when the system gauges whether the fuel tank system pressure acts normally or not, there are a number of circumstances which are taken account of, for example:

- Amount of fuel in the tank
- Car's altitude above sea-level
- Fuel temperature and evaporation

The system can determine this information through various calculations. Therefore it is not possible to describe how quickly or how much the pressure is permitted to increase or fall in the different phases. To carry out the diagnostic it is necessary that:

- Lambda control is active
- The engine is at idling speed
- Speed is 0 km/h
- Altitude is less than 2500 meters
- Outside temperature is above 4°C
- Engine coolant temperature is above 4°C and less than 120°C
- Fuel tank pressure exceeds -1kPa
- Concentration of fuel vapor in the EVAP canister is not excessive

The diagnostic test starts at the earliest 10 minutes after the engine has started when all conditions have been fulfilled, and takes approximately 30 seconds.

If the diagnostic is interrupted for any reason, the Engine Control Module (ECM) will try to start again the next time all conditions are met. The Engine Control Module (ECM) performs a maximum of 8 diagnostic attempts during an operating cycle. If no faults are detected the diagnostic is not active again until the engine is switched off and on again. If a fault is detected two further attempts are made to evaluate the fault.

When stages 1-6 above has been run through without detecting any 1 mm leak and at least 1400 s has passed since engine start, then stages 1-6 is run again for detection of 0.8 mm leak. The stages for small leak are the same as for large leak with certain modifications regarding measuring times.

Leakage Diagnostic Operation			Corresponding Test ID
	Evaporative Emission System	*Monitor Strategy description*	
DTCs	P2404 P2405-2406 Max and min error P2407 Signal error	If pump current decrease is smaller than within time window AND module diagnosis. Reference leak current limit check Current fluctuation check	05

Typical leakage diagnostic enable conditions

Enable condition	*Minimum*	*Maximum*
Engine on time	> 20 min	
Ambient air temperature	2.3°C	+37.5°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 -20°C
- Engine temperature is above +65°C
- Altitude is less than (or equal to) 4000 meters
- Vehicle speed is 0 km/h
- Canister load is below 3
- 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	05

Typical canister purge valve diagnostic enable conditions		
Enable condition	*Minimum*	*Maximum*
Engine temperature at start	60°C	
Altitude		4000 meters
Ambient air temperature	-20.3°C	

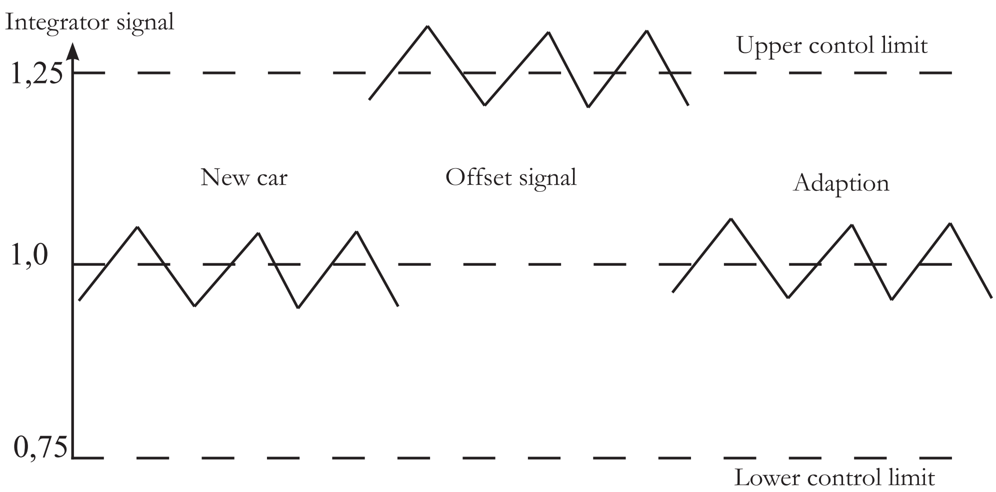
Typical canister purge valve diagnostic malfunction thresholds	
Malfunction criteria	*Threshold value*
Delta resistant torque from resistant torque adaptation	< -1.2%

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.

Catalytic converter monitoring

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 (Lambda = normalized air fuel ratio). In case of using a UEGO-based 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.
The procedure compares the signal amplitudes obtained from the downstream sensor to the modelled signal amplitudes. The modelled signal amplitudes are derived from the model of a borderline catalyst. In case the measured amplitudes exceed those of the model, the catalyst is considered as defective. This infomation 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
- Modelling of a borderline catalyst and of the signal amplitudes of the downstream Lambda sensor
- Signal evaluation
- Fault processing
- Check of monitoring conditions

Catalyst Monitor Operation		**Corresponding Test ID**
DTCs	P0420 Main Catalyst, Bank 1 P0430 Main Catalyst, Bank 2 (6-cyl. stereo-sys.)	01
Monitor Strategy description	Efficiency below threshold (oxygen storage)	

Typical Catalyst monitor enable conditions		
Enable condition	*Minimum*	*Maximum*
Engine speed	1400 rpm	2520 rpm

Typical Catalyst monitor malfunction thresholds	
Malfunction criteria	*Threshold value*
Normalized catalyst quality factor	> 0.3438
Cumulative catalyst monitoring time	> 70 s

Oxygen sensor check Operation - Bank 1		
DTCs	*Lambda sensor upstream catalyst*	*Monitor Strategy description*
	P0132: Circuit Lambda Offset	Comparision O2S 1 versus O2S 2
	P0133: front sensor	Circuit Slow Response
	P0141: O2 sensor heater	Circuit

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		
DTCs	*Sensor 1 (P0340-344), Sensor 2 (P0345-49)*	*Monitor Strategy description*
	P0340: Signal error	Circuit
	P0342, P0343: Min, Max error	Circuit Low Input, Circuit High Input
	P0344: 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		
DTCs	*Mass Air Flow*	*Monitor Strategy description*
	P0102: Max error	Circuit low input
	P0103: Min error	Circuit high input

Typical MAF enable conditions		
Enable condition	*Minimum*	*Maximum*
Time after engine start	0.50 s	
Throttle potentiometer fault	FALSE	

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		
DTCs	Engine Coolant Temperature	Monitor Strategy description
	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