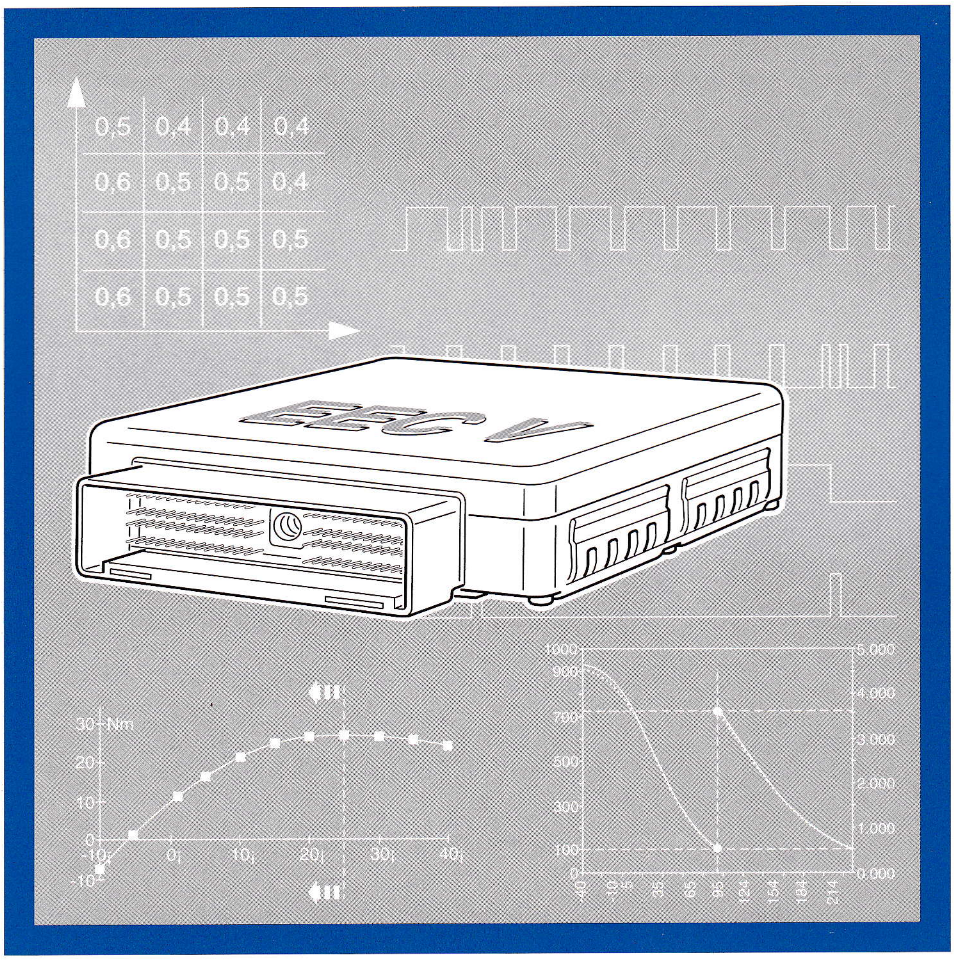
T9

Technical Service Training

Advanced Petrol Engine Management Systems

Curriculum Training TC3043024H

EEC V Engine Management System



Student Information

CG 7834/S en 08/2000

This Student Information publication on the "EEC V Engine Management System" is an addition to the "Petrol Engine Management Systems" course.

Since the training modules for this course were last revised, electronic engine management systems have undergone further development. Stricter exhaust emission standards must be satisfied, operating process and parts have changed, new components have been added, and the EEC V PCM transmits data direct and communicates with other electronic systems and components.

This publication deals with all the measures and modifications implemented in the EEC V engine management system, provides additional information to expand the required basic knowledge and contains a full description of all the new and changed components of the system, supplementing the following existing Student Information publications:

- 29/A "Multiport Fuel Injection (EEC IV/MFI) - Fundamentals", CG 7561,
- 29/C "Sequential Multiport Fuel Injection (EEC IV/EEC V/SFI)", CG 7563,
- 29/F "TFI Ignition Systems and Electronic Ignition (EI) Systems", CG 7564,
- 29/G "Emission Control", CG 7565,
- TC3043027S "European On-Board Diagnostics - EOBD", CG 7856.

Knowledge of systems and practical experience in vehicle and system diagnostics gained from corresponding courses at the Ford Technical Training Center are essential prerequisites for studying this publication.

This Student Information publication is arranged in lessons and designed as a self-learning medium in line with the new Ford global training concept.

Each lesson starts with a list of the objectives to be achieved in the course of the lesson and ends with test questions to check learning progress. The answers to these are to be found at the end of the Student Information publication.

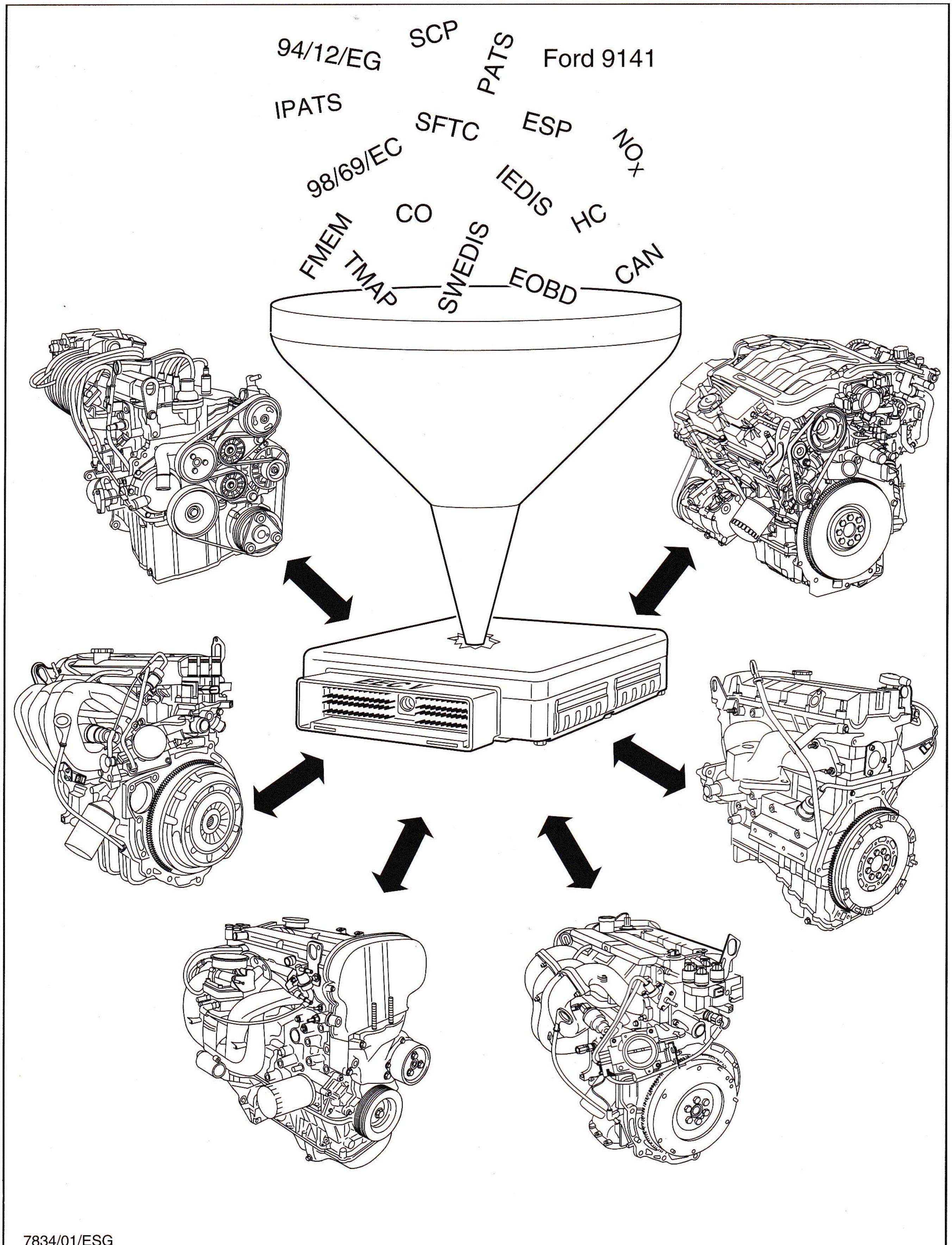
> Please remember that our training literature has been prepared solely for FORD TRAINING PURPOSES.
>
> Repair and adjustment operations **MUST** always be carried out according to the instructions and specifications in the workshop literature.
>
> Please make extensive use of the training courses offered by Ford Technical Training Centers to gain extensive knowledge in both theory and practice.

Page

Objectives

On completing this lesson, you will be able to:

- briefly explain what is meant by "strategy" and "calibration"
- give a general description of the changes and modifications made to Ford engines and the EEC V engine management system over recent years with a few examples
- explain what is meant by "direct data transmission from the EEC V PCM"
- describe how the EEC V PCM communicates with other electronic systems
- name a few reliability measures used to ensure troublefree operation of the EEC V engine management system and describe these briefly


94/12/EG
SCP
PATS
Ford 9141
IPATS
SFTC
ESP
NOx
98/69/EC
IEDIS
CO
HC
FMEM
TMAP
SWEDIS
EOBD
CAN
EEC V

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Strategy and calibration

- Electronic engine management systems are subject to continuous development.
- Some important reasons for this are tighter exhaust emission standards and even stricter statutory regulations, plus increasing environmental awareness and sensitivity of customers to driving comfort and convenience, plus increased demands of high performance engines with low fuel consumption and smooth silent running.
- Extensive modifications to the basic engine and more complex systems, new engine management strategies with corresponding calibration measures, changed operating process and new or changed components have made the engine technology and EEC V engine management system the state of the art. **Strategy** and **calibration** play a particular part in this.
- The **Strategy** is the computer program that is executed by the microprocessor of the EEC V PCM and takes the longest development time.
- **Calibration** means the data with which the strategy works, namely the calibration adapts the strategy to the particular target engine.
- The strategy program and the calibration data are stored in the read only memory (ROM) of the EEC V PCM. It is identified with a base number and the change numbers according to the particular development level.
- The calibration measures and their (also numbered) development levels take account of the vehicle version in addition to the engine type. For example, when there is only one engine management strategy, the calibration engineers can still carry out several different calibrations on the single strategy. The actual strategy status is retained.
- During the calibration development the calibration is progressively modified to **produce the best possible driving characteristics** (performance, fuel consumption, exhaust emissions, etc). The calibration can be adjusted in the light of feedback from the customer or the workshop.

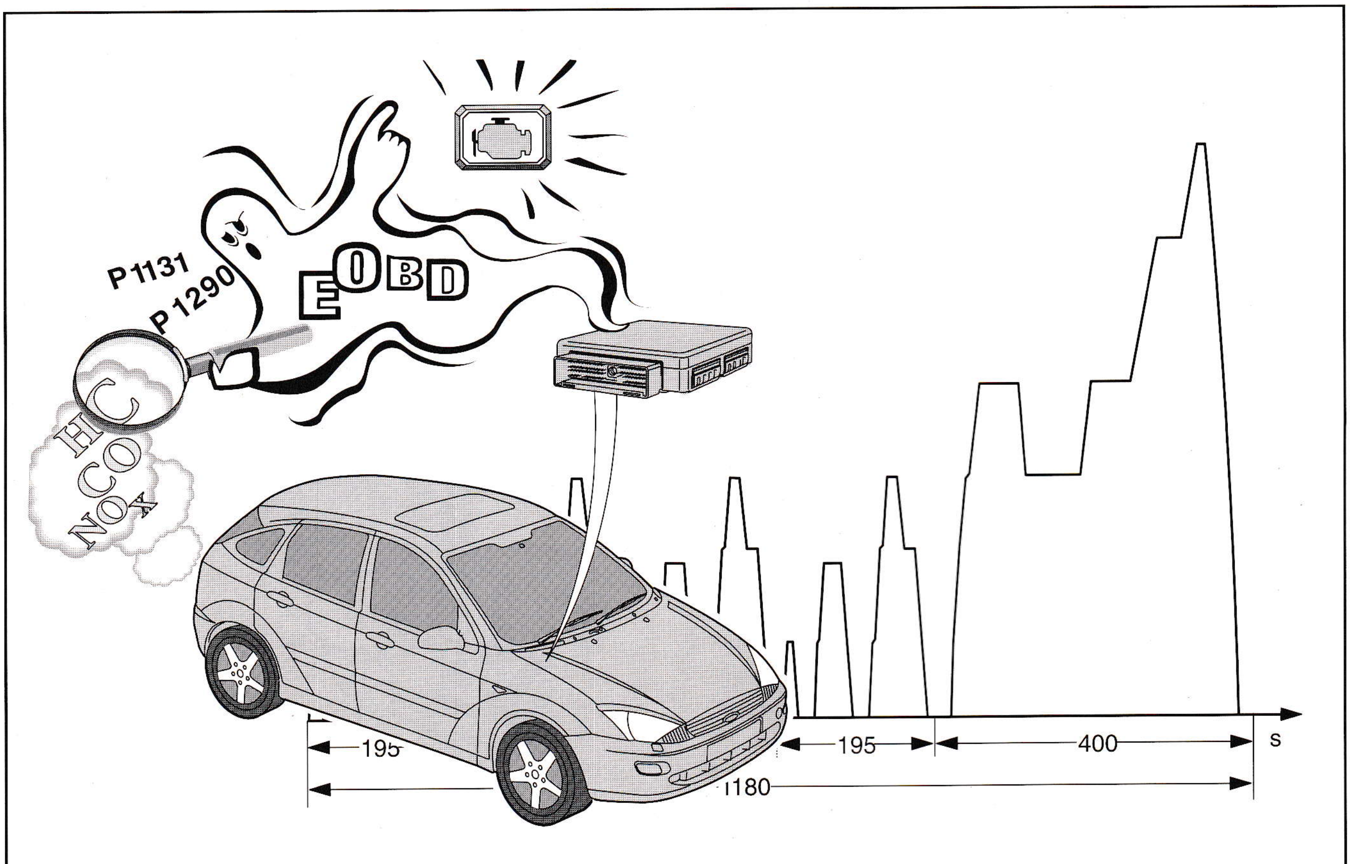
General modifications at a glance

Exhaust emission standards

- Until the new European exhaust emissions standard Stage 3 officially comes into effect, Stage 2 (implementing directive 94/12/EC) is still valid.
- Even now (at the time of printing this publication) all Ford petrol engines produced in Europe meet the exhaust emission limits of **European exhaust emissions standard Stage 3 (implementing directive 98/69/EC).**
- In addition to a new driving cycle, an additional low temperature test and stricter exhaust emission limits, this **Stage 3** includes the European on-board diagnostics system **EOBD** with the emission control malfunction indicator lamp (**MIL**) for continuous monitoring of emission systems and components.
- Dates of introduction of the European exhaust emissions standard Stage 3 (with EOBD):
  - new type approval testing: 01/01/2000
  - vehicle first registration: 01/01/2001
- Apart from the European exhaust emissions standard stage 3, the exhaust emissions standard **D4** is valid **only for Germany**. It is provided for exemption from car tax for a limited time.

Note: Also refer to Student Information

- TC3041015S, "Exhaust and Noise Emissions", CG 7686/S,
- TC3043027S "European On-Board Diagnostics - EOBD", CG 7856/S



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General modifications at a glance (continued)

Basic engine (examples)

- In addition to the engine management strategy and the calibration measures, appropriate changes to the basic engine (for example to reduce exhaust emissions, lower fuel consumption, reduce vibration and improve smooth running) are essential for an overall system which works.

- Basic engine modifications:

  – light alloy construction,

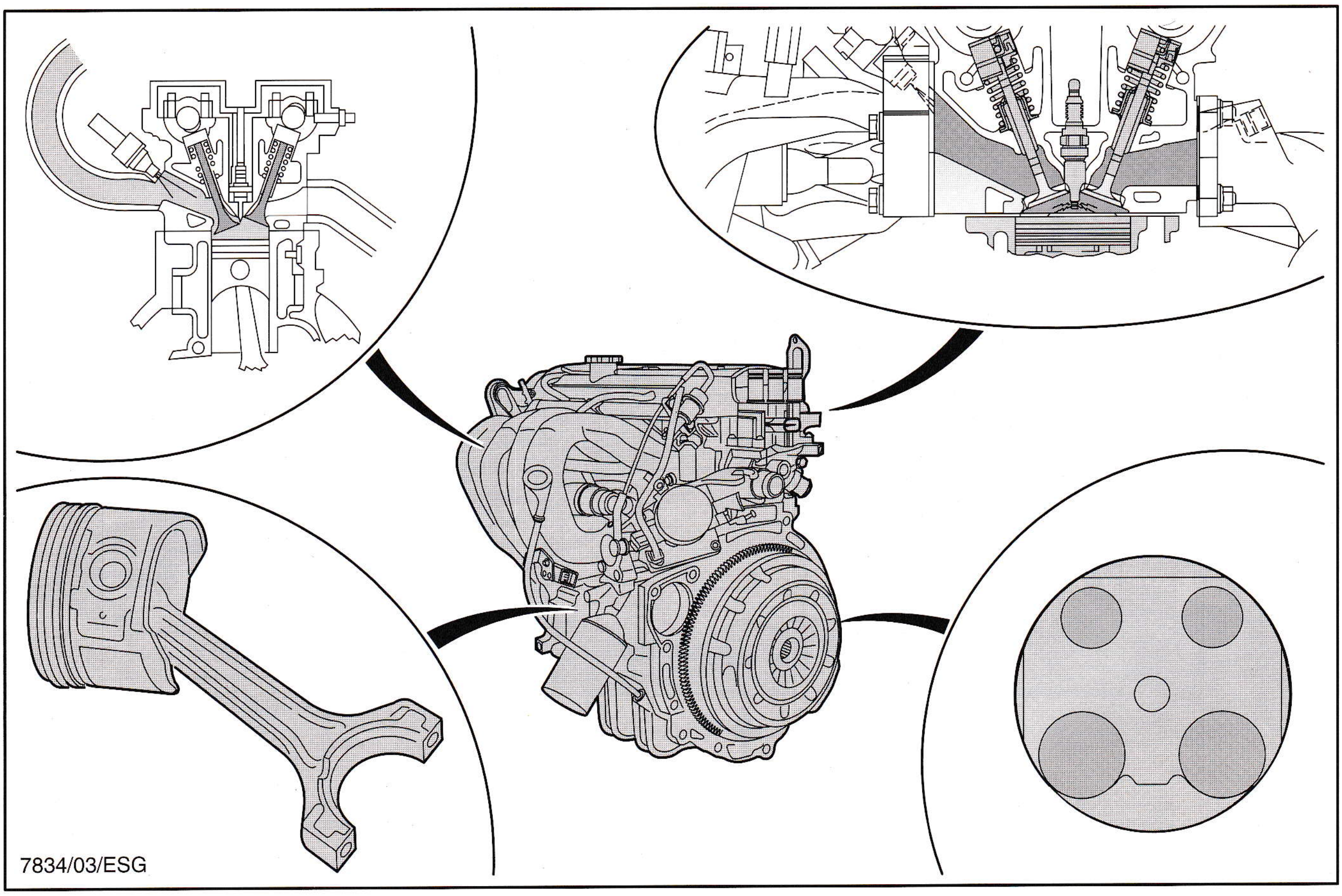
  – shape and length of the intake and exhaust pipes,

  – cylinder head with intake ports providing better gas flow,

  – optimum combustion chamber design,

  – enhanced mixture swirl before combustion,

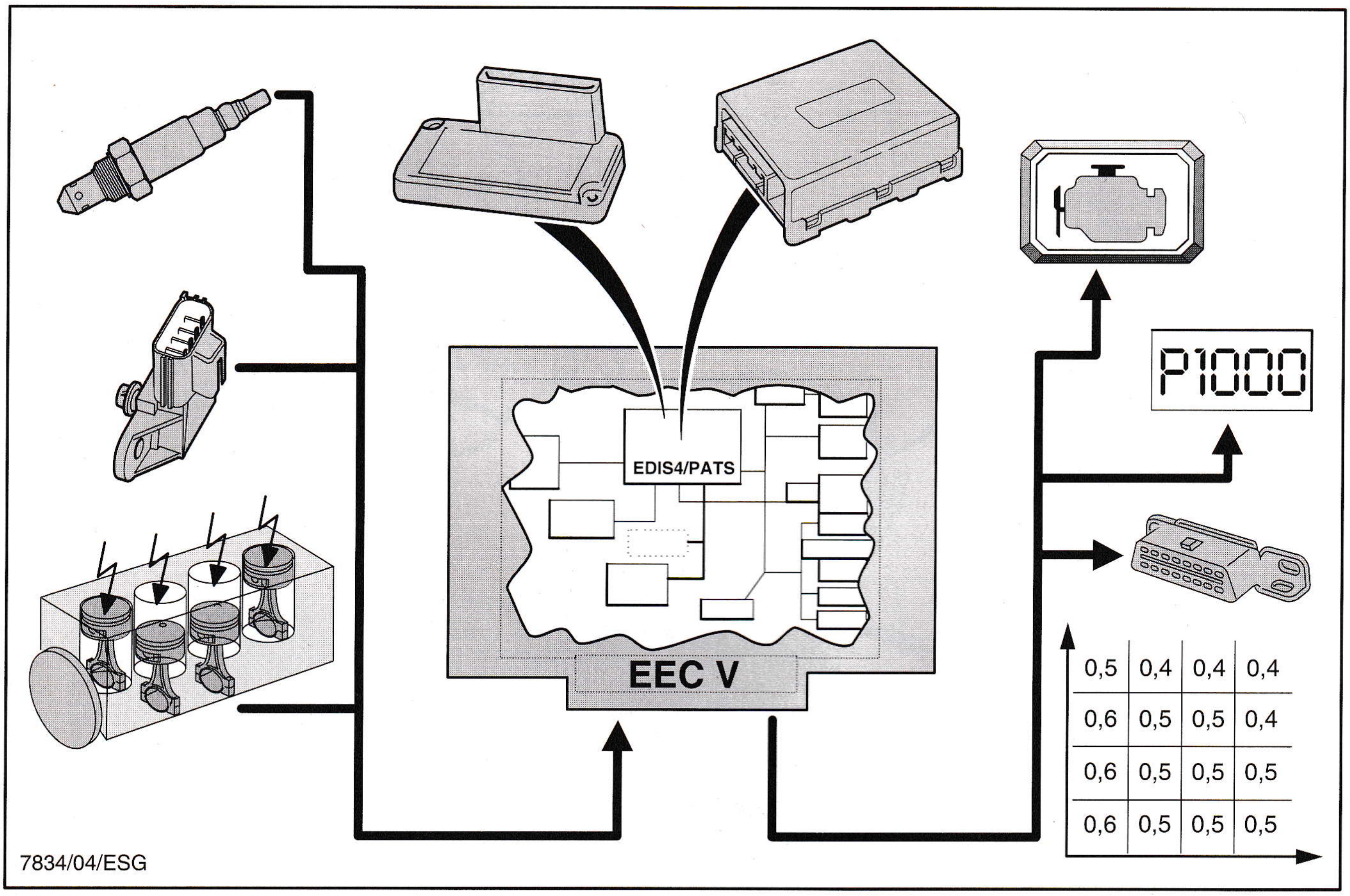
  – optimized piston design, piston rings and reduced piston fire land.



General modifications at a glance (continued)

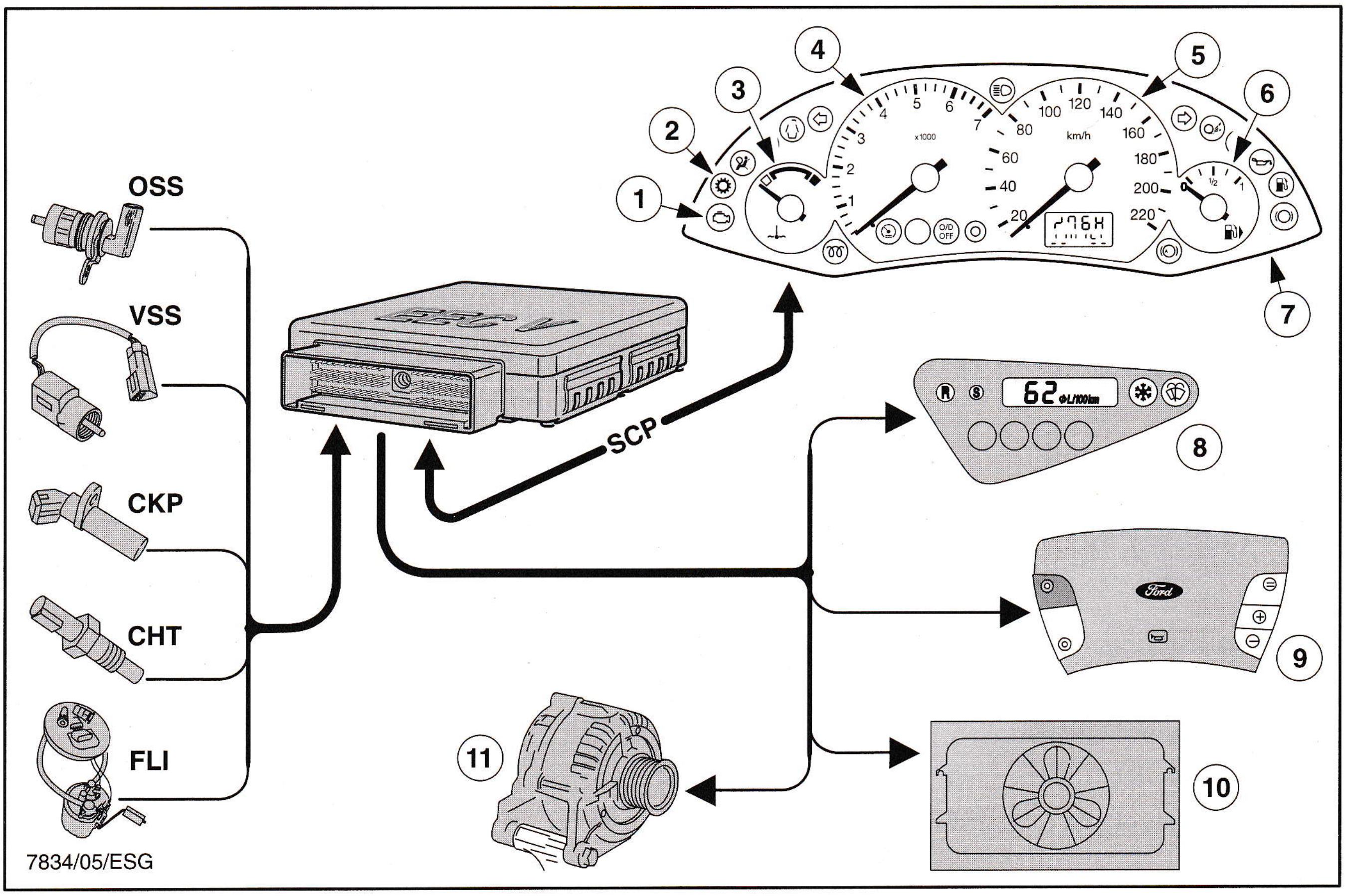
EEC V engine management (examples)

- New and refined engine management strategies with appropriate calibration measures.
- New strategies make secondary combustion systems (AIR/PAIR) superfluous.
- More powerful EEC V PCM (with increased storage capacity among other things).
- Electronic ignition (EI) ignition control module (ICM) and passive anti-theft alarm system (PATS) are integrated in the EEC V PCM:
  - EDIS integrated in the PCM software (software EDIS).
  - PATS integrated in the PCM software software PATS).
- European on-board diagnostic system (EOBD) integrated in the EEC V PCM with emission control malfunction indicator lamp (MIL) for continuous monitoring of emission control systems and components.
- New sensors and actuators.
- More efficient type of catalytic converter.
- Direct data transmission from the EEC V PCM and EEC V PCM communication with other systems.



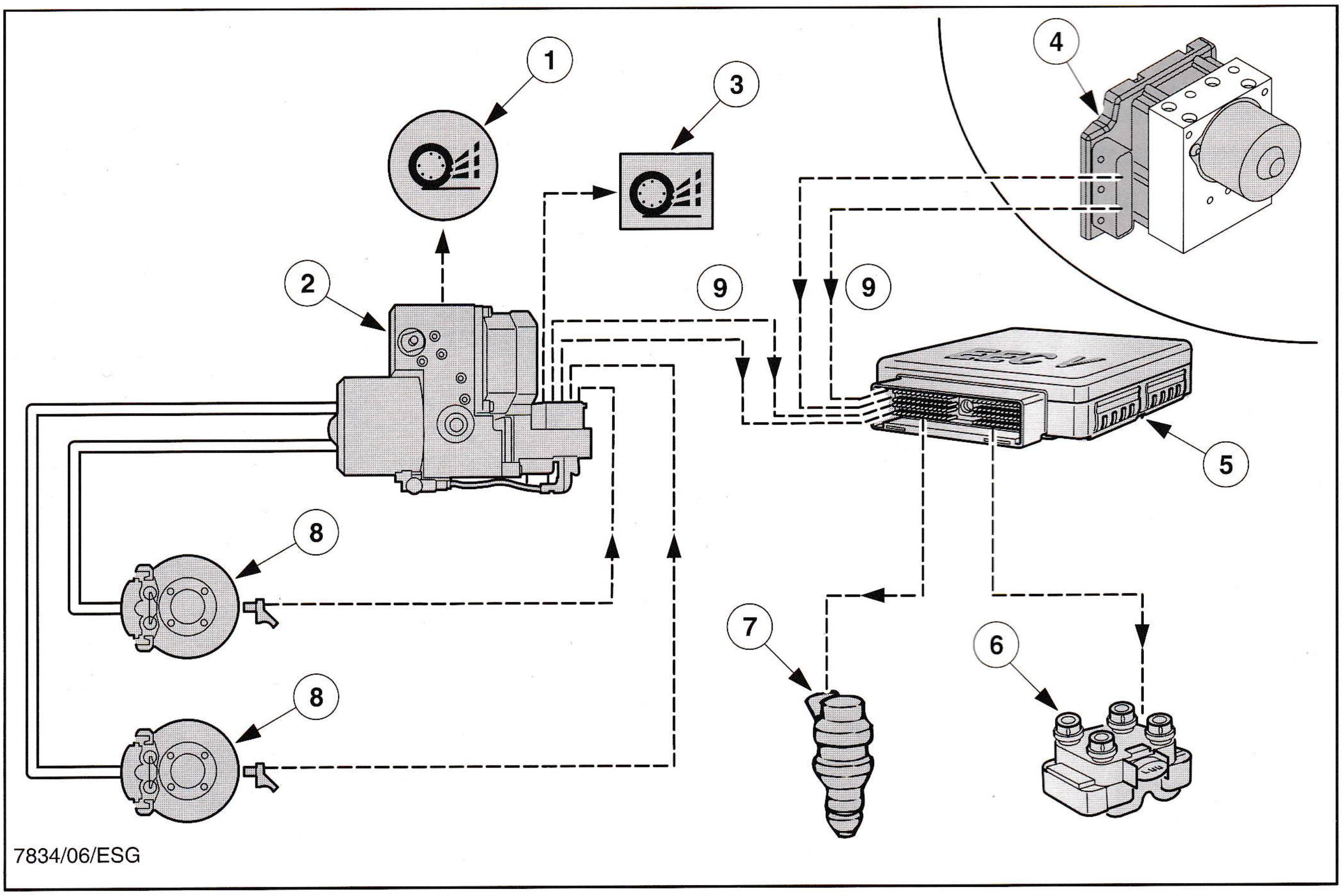
Direct data transmission from the EEC V PCM

- Certain data is transmitted **by the EEC V PCM direct** to the instrument cluster and other vehicle components.
- **Instrument cluster (7) (SCP data bus)**
  - vehicle speed signal (speedometer 5)
  - engine speed signal (tachometer 4)
  - engine temperature signal (temperature gauge 3)
  - fuel input signal (fuel gauge 6)
  - engine overheating safety function and automatic transmission monitoring (powertrain warning indicator 2)
  - continuous monitoring of emission control systems/components (emission control malfunction indicator lamp MIL 1)
- **Trip computer (8)**
  - fuel consumption signal
  - vehicle speed signal
- **Speed control system (9)**
  - vehicle speed signal
- **Cooling fan control (10)**
  - engine temperature signal
- **Generator control (smart charge) (11)**
  - generator load
  - intake air temperature signal



EEC V PCM communication with other vehicle systems

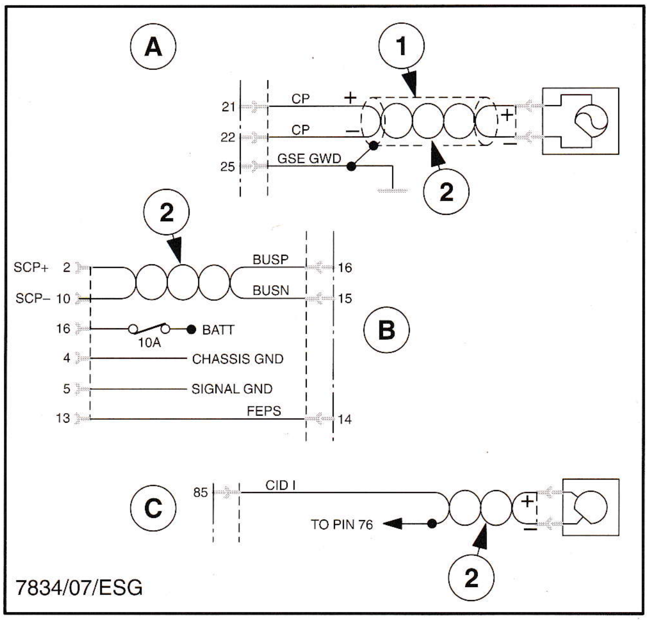
- The exchange of information between the EEC V PCM and other electronic vehicle systems also takes place through the standard corporate protocol (SCP) data bus.
- At present there are anti–lock brake systems (ABS) with spark fuel traction control (SFTC) and the electronic stability program (ESP) which are designed to exchange data with the EEC V PCM.
- In the case of the spark fuel traction control (SFTC) the engine management acts through the EEC V PCM by adapting the spark timing and quantity of fuel.
- The ABS module calculates the required torque during traction control and passes this information to the EEC V PCM.
- The EEC V PCM then calcules the required spark timing and the number of fuel injectors to be deactivated to be able to produce the required torque.



1 SFTC warning indicator
2 ABS control unit (Bosch 5.3)
3 SFTC switch
4 ABS control unit (MK 20E-I with ESP)
5 EEC V PCM
6 EI coil
7 Fuel injectors
8 Front wheel brakes
9 SCP data bus

Reliability measures

- An electronic engine management system must be robust, which means that it must not be prone to interference such as electrical or electromagnetic interference for example. To ensure this, the following reliability measures were carried out on the EEC V engine management system:
  - **Waterproof connectors** with gold-plated pins.
  - **Gold-plated connections** for the low-voltage circuits (EEC V PCM interface).
  - Clean and neat **cable routing**, where possible in cable ducts.
  - Operation of **different circuits** assigned to the different PCM pins with different voltages (for example, 1.5 V, 5 Vref, 12 V etc.).
  - **Several independent ground connections** at the EEC V PCM to separate different currents (for example pins 51, 77, 24 and 103).
  - **Voltage offset** offering a base voltage for example from 0V to 1.5 V (also refer to "Crankshaft position (CKP) sensor" in Lesson 3).
  - **Shielding** of certain cables.
  - **Twisted cables** for sensitive sensors and connections (for example CKP, CMP and DLC).



Twisted cables and shielding (examples)

A CKP sensor

B DLC

C CMP sensor

1 Cable shielding

2 Twisted cables

Find the correct answer or fill in the gaps.

1. **Which factors play a special part in the development of an engine?**

   ☐ a) Build date
   ☐ b) Chassis number
   ☐ c) Strategy and calibration measures
   ☐ d) Sales figures

2. **What requirements must the new European exhaust emission standard Stage 3 cover?**

   ☐ a) Use of three catalytic converters in the vehicle.
   ☐ b) New driving cycle, stricter exhaust emission limits, constant monitoring of emission control systems and components.
   ☐ c) Exhaust gas recirculation (EGR) and air injection (AIR) as standard equipment.
   ☐ d) Emission control components must be changed after a statutory mileage has been covered.

3. **The EEC V PCM transmits data to the following vehicle components/systems:**

   ☐ a) Automatic transmission, steering, A/C compressor, generator, starter motor.
   ☐ b) Anti-theft alarm system, PATS, speed control system, power steering pump.
   ☐ c) Trip computer, instrument cluster, speed control system.
   ☐ d) Fuel pump, navigation system, carbon canister.

4. **The EEC V PCM communicates with:**

   ☐ a) Anti-lock brake systems without traction control.
   ☐ b) Anti-theft alarm systems.
   ☐ c) Speed control systems.
   ☐ d) Anti-lock brake systems with spark fuel traction control.

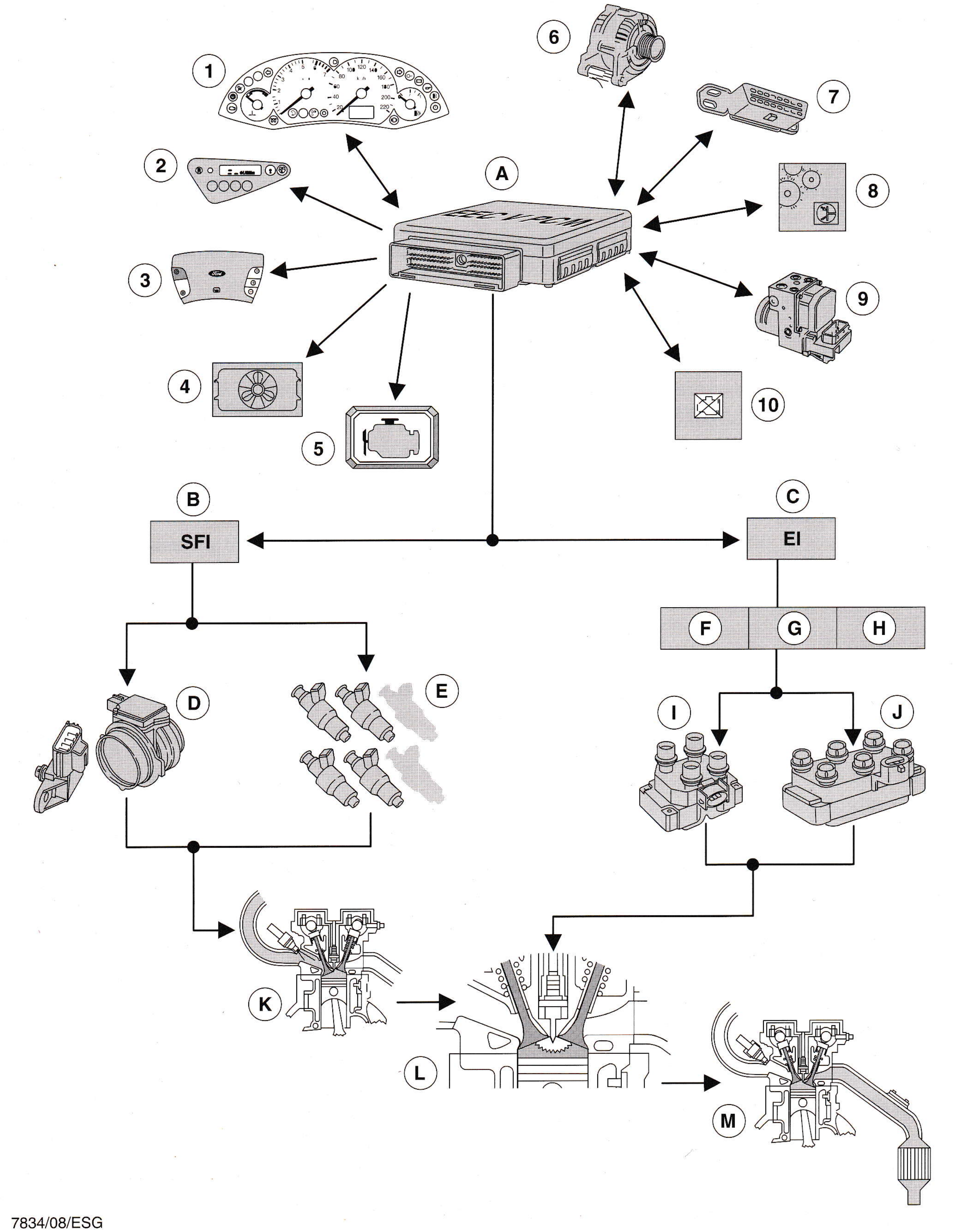
5. **Which of the measures named below was undertaken to make the EEC V system less sensitive to interference?**

   ☐ a) Gold-plated connections for the low-voltage circuits, different circuits with different voltages, waterproof connectors, cable shielding, twisted cables, several ground connections.
   ☐ b) Cables with increased cross-section, reduced numbers of PCM connector pins.
   ☐ c) Locating the EEC V PCM in the engine compartment, enclosing the electronic ignition (EI) coil, enlarging the PCM housing.
   ☐ d) Enclosing the EEC V PCM, using cables with a standard cross-section, a common interface with other electronic systems.

Objectives

On completing this lesson, you will be able to:

- sketch the flow diagram of the EEC V engine management system and provide corresponding explanations
- explain the connections between foreground loop, background loop and PIP signal
- explain the differences between the MAF and MAP air mass calculation
- name and briefly explain important fuel metering features
- explain what is meant by an open loop and a closed loop
- name and briefly explain the most important spark angle calculation features
- explain what is meant by a spark angle and describe its influence on a correctly functioning ignition system
- explain what is meant by pulse width modulation
- explain what a "duty cycle" is
- describe the main features of the generator control ("smart charge") system



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EEC V flow diagram

- **This lesson is intended as a supplement to the fundamentals of the EEC IV/EEC V engine management systems already described in the existing Student Information publications accompanying the "Petrol Engine Management Systems" course (issued 12/95).**
- In addition to a changed EEC V flow diagram, explanations are given of terms and operating processes relating to the EEC V engine management which could not previously be covered in the training literature or are new additions and currently form the basis of all engine management systems.
- The illustration opposite shows the flow diagram for the ECC V engine management system with sequential multiport fuel injection (SFI) for the current generation of Ford engines.

These include:

- 4 cyl. Endura-E engines (1.3L)
- 4 cyl. Zetec-SE engines (1.25L, 1.4L, 1.6L, 1.7L VCT)
- 4 cyl. Zetec-E engines (1.6L, 1.8L, 2.0L)
- 4 cyl. DOHC 8V engines (2.0L)
- 4 cyl. DOHC 16V engines (2.0L, 2.3L)
- 6 cyl. Duratec-VE engines (2.5L)

Earlier engines:

- 6 cyl. Cosworth 24V (2.9L)

Key to the flow diagram opposite

1 Instrument cluster
2 Trip computer
3 Speed control system
4 Cooling fan
5 Emission control malfunction indicator lamp (MIL)
6 Generator control ("smart charge") system
7 DLC (SCP)
8 Automatic transmission
9 ABS systems (SFTC, ESP)
10 PATS (external PATS tranceiver)

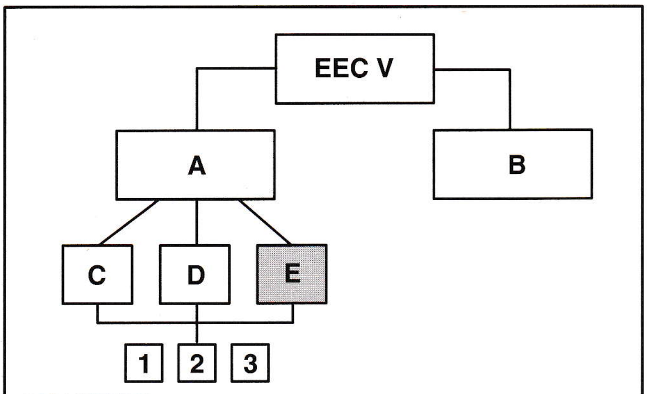
A EEC V PCM
B Sequential multiport fuel injection (SFI)
C Electronic ignition (EI)
D Air mass calculation
E Fuel metering
F External EI system ignition control module (EDIS-4/EDIS-6)
G EI ICM (EDIS-4/EDIS-6) integrated in the PCM
H Software EDIS (only 4-cylinder)
I EI coil (4-cylinder engine)
J EI gnition coil (6-cylinder engine)
K Mixture
L Combustion
M Exhaust

General notes on the EEC V strategy

- The EEC strategy is divided into two segments: open/closed loop engine management and self diagnostics. The illustration shows the three operating areas of open/closed engine management: engine starting, underspeed and engine running (closed, part and wide open throttle).

- The EEC strategy is a computer program which is continuously running in a loop called the **background loop**. This loop lasts between 20 and 100 ms depending on the predetermined strategy and engine operating states.

- Approximately every millisecond (1 ms) the background loop is interrupted by the **foreground loop** to carry out higher priority time critical operations (triggered by sensor signals for example). When this happens, the functions of the background loop are temporarily suspended until completion of the foreground loop.



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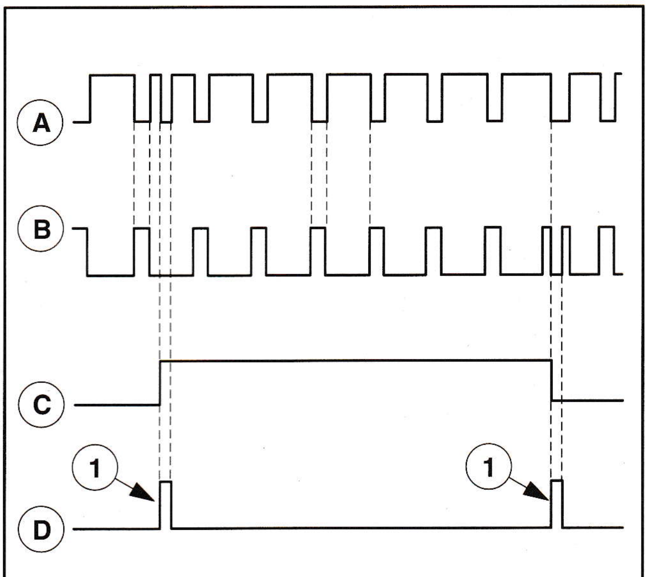
A Open/closed loop engine management
B Self–diagnosis
C Engine starting (cranking up to 600 rpm)
D Under speed (slow running up to idle speed)
E Engine running (most important area of the strategy)
1 Closed throttle (CT)
2 Part throttle (PT)
3 Wide open throttle (WOT)

- In addition, each **PIP signal edge** causes an interruption of even higher priority. This can lead to interruption of both the background and the foreground loop.

- The three most important calculation operations performed by the EEC V strategy are the **air mass calculation, fuel metering** and **ignition angle calculation**.



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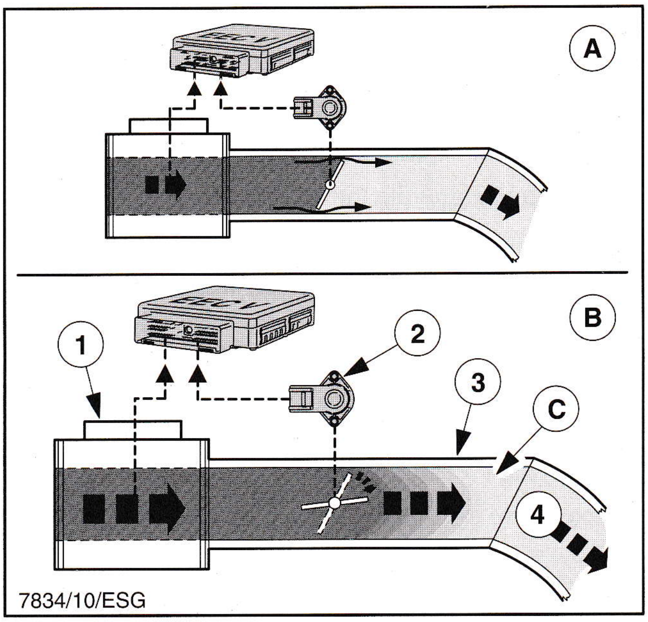
A Background loop
B Foreground loop
C PIP signal
D PIP signal edge (1) causes interruption (highest priority)

Air mass calculation with the MAF sensor

- The following description deals with the EEC strategy for **air mass calculation** and thus forms an addition to the **air mass measurement** function carried out by the MAF sensor and which is already familiar from the relevant training literature.
- The MAF sensor measures the air mass induced by the engine. The air mass value determined by the EEC strategy is used to calculate the required quantity of fuel and engine load.
- This measurement is extremely important as it also forms the basis for other system calculations, such as for example fuel metering, spark control, etc.
- The air mass calculation is carried out both in the foreground and in the background loop.
- During **stable engine running**, namely when the throttle position and engine speed are constant, the air mass measured by the MAF sensor behaves the same as the air flowing into the cylinders of the engine.

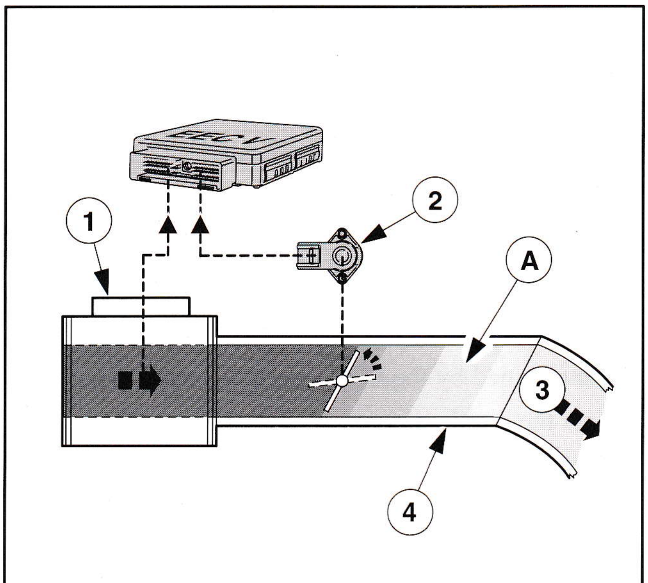


A Stable engine running
B Sudden acceleration („tip-in“)
C Intake manifold charging effect
1 MAF sensor
2 TP sensor
3 Intake manifold
4 To cylinder

- With **throttle movements** the quantity of the air mass flowing through the MAF sensor is determined by the function of the throttle position and intake manifold pressure.
- During **sudden acceleration** („tip-in“) this air mass flow increases the pressure in the intake manifold behind the throttle plate (intake manifold charging effect) and causes a subsequent rise in the air mass flow at the MAF sensor.
- It is this “charge air state” in the intake port in front of the cylinder which is taken into account by the strategy and must be calculated extremely accurately because the air mass measured by the MAF sensor is greater than the air mass available in the cylinder. If this was not taken into account, the quantity of fuel injected during sudden acceleration would be too high.
- The charging efficiency is determined and regulated by this volume (or the size) of the intake manifold in relation to the engine swept volume.

Air mass calculation with the MAF sensor (continued)

- A similar effect, but in the reverse direction, occurs when the accelerator is suddenly released („tip-out“): the air mass measured by the MAF drops fairly rapidly but the intake manifold pressure behind the throttle plate and hence the actual "charge air" in the intake port drop more slowly. This is referred to as "intake manifold emtying effect".
- If effects of this kind are not offset by the strategy, the intake manifold charging ("charging effect") can produce excessive air/fuel discrepancies with throttle movements.
- Therefore, the EEC V PCM calculates a **charging coefficient** from the ratio between the intake manifold pressure and the charge air. This charging coefficient is used to guarantee an accurate calculation of the stream of charge air to the cylinder (resulting from the MAF signal).



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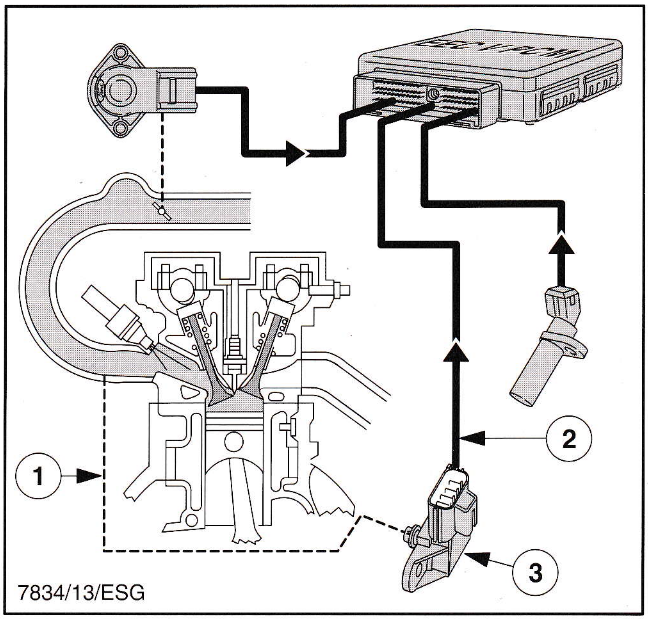
A Intake manifold emptying effect
1 MAF sensor
2 TP sensor
3 To cylinder
4 Intake manifold

- The EEC V PCM carries out a further calculation to prevent the fuel injection being delayed by estimating the air mass two PIP signals in advance.
- This ensures that the fuel injectors have completed fuel injection while the intake valves are still closed.
- While the engine is running, the MAF sensor signal on each edge of the PIP signal is sensed and recorded (foreground loop).
- This analogue measurement is then converted into a digital signal in the analogue/digital transducer of the EEC V PCM and stored in numerical values (counts) (also refer to "EEC V PCM function and operation" in Lesson 3).
- A test is then performed to see if the MAF signal lies within acceptable limits. If this is not the case, a corresponding fault routine is initiated.

Air mass calculation with the MAP sensor (speed density)

- The strategy of air mass calculation based on the **intake manifold absolute pressure** (**MAP**) (also called "speed density") is another method of air mass calculation.
- For this, a manifold absolute pressure (MAP) sensor with an integrated intake air temperature (IAT) sensor, the temperature and manifold absolute pressure (**T-MAP**) sensor, is used instead of the MAF sensor on some engines (also refer to Lesson 3).
- As in the case of the air mass calculation of the MAF sensor, here again certain values are determined by the EEC strategy and used to calculate the required quantity of fuel and engine load.



1 MAP, BARO, IAT measurement
2 MAP, BARO, IAT signals to the EEC V PCM
3 T-MAP sensor

- With the air mass calculation, the EEC V PCM calculates the air mass fed to the cylinders per working cycle from the manifold absolute pressure (MAP), intake air temperature (IAT), engine speed and a calculated value for the charging degree.
- The MAP sensor signal is checked and recorded on each edge of the PIP signal and an average value is calculated for each PIP signal.
- The **barometric pressure** (**BARO**) has a further significance. Barometric pressure means the atmospheric pressure in relation to the height above sea level. The barometric pressure is used for the air mass calculation for the following states:
  - fuel metering when starting
  - EGR and ignition
  - torque converter lock-up clutch
  - shift operations
  - idle speed control
  - adjusting the air mass at full load
- When the ignition is switched on, the BARO is equated to the pressure measured by the MAP sensor, stored in the Keep alive memory (KAM) and used until new calculations are made while the engine is running.
- Then, the air mass calculation is made over the entire engine operating range, in the most varied load states, and BARO is used as the reference pressure for the particular intake manifold pressure.

Fuel metering

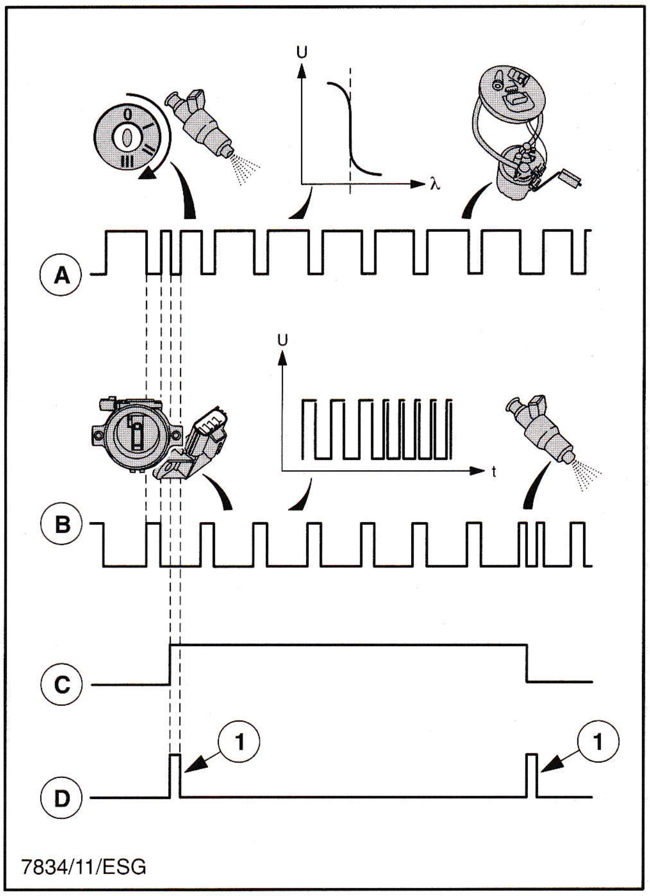
General

- The combustion of the fuel/air mixture in the cylinder is one of a large number of processes which affect and control engine power output, efficiency and emissions. Thefore, the composition of the mixture of the induced air and injected fuel is extremely important.
- The lean burn principle (lean burn engine) has still not established any dominance as the exhaust emissions still cannot be cleaned up to the extent possible when using a catalytic converter with lambda control. In addition, oxides of nitrogen (NOx) values are extremely high at high engine speeds due to the excess of air.
- Therefore, the EEC strategy uses the lambda-controlled three way catalytic converter (TWC) to clean up the exhaust emissions. The fuel metering (and hence the fuel/air mixture) is determined with either an **open** or a **closed loop**.
- The **open loop** is used mainly **to control the fuel injection and exhaust emissions** as long as the signals of the upstream heated oxygen sensor (HO2S) are **not** included in the calculation of the EEC V PCM.
- The two most important reasons why open loop fuel control is needed are the **cold engine** operating state (starting, warm up phase) and **full load** operating state (wide open throttle).
- The **closed loop** ensures close control of the exhaust emissions with the aid of the lambda-controlled TWC and also provides economical fuel consumption.

Fuel metering (continued)

Processing of the fuel metering by the EEC V PCM

- The processing of the fuel metering is carried out by the EEC V PCM in the **background loop** and the **foreground loop**.
- The operations which are not time-critical and are processed by the **background loop** include:
  - calculation of the quantity of fuel when starting (cranking the engine),
  - calculation of the required air/fuel ratio,
  - control of the fuel pump.
- The higher priority time-critical (rapid) operations processed by the **foreground loop** include:
  - MAF or MAP air mass calculation,
  - calculation of the pulse width of the fuel injection signal,
  - calculation of the fuel metering.

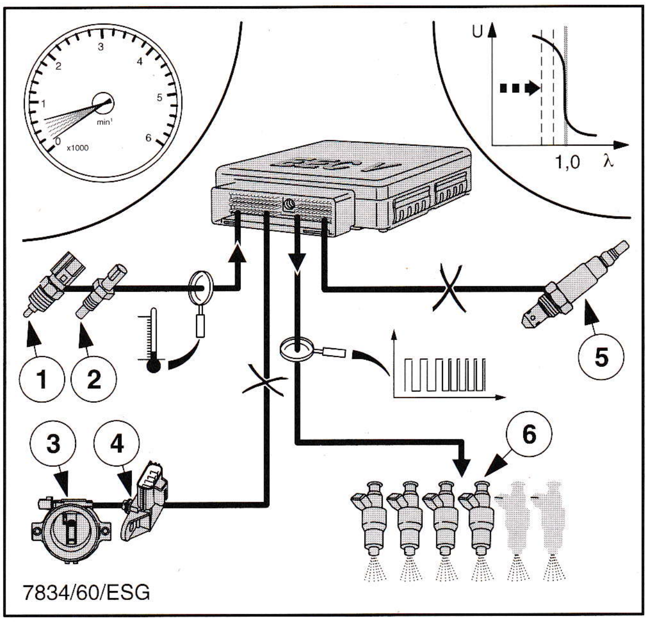


A Background loop
B Foreground loop
C PIP signal
D PIP signal edge (1) can interrupt the background and foreground loop (highest priority)

Fuel metering (continued)

Starting the engine (CRANK)

- When the ignition is switched on, the fuel pump runs for a second to build up the system pressure and is then switched off for safety reasons until cranking takes place.
- The crank mode is from zero rpm..
- The coolant temperature is approximately the same as the ambient temperature (the engine is cold).
- The pulse width of the fuel injection signal is calculated from the engine temperature (ECT or CHT), the number of PIP signals while the engine is cranking and the barometric pressure. The signals from the MAF or T–MAP sensor are **not** included in the calculation.
- The air/fuel ratio is less than 14.1:1 (rich).
- The fuel injectors inject **simultaneously**.



Starting (cranking) engine

1 ECT sensor
2 CHT sensor
3 MAF sensor
4 T-MAP sensor
5 Heated oxygen sensor (HO2S)
6 Fuel injectors

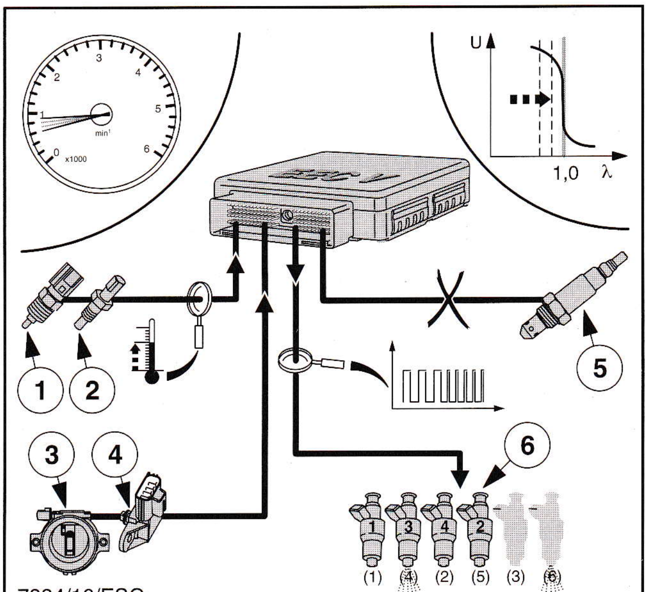
UNDERSPEED and RUN (open loop)

- The engine speed is over 600 rpm, but under idle speed.
- In the background a required air/fuel ratio is calculated.
- The fuel injectors inject **sequentially** when in RUN.
- The engine coolant temperature (ECT) and cylinder head temperature (CHT) rise. The engine is in the warm up phase.

Fuel metering (continued)

UNDERSPEED and RUN (open loop) (continued)

- The fuel metering is determined in the **open loop**, which means that the program is in the open-loop control phase and not in the closed-loop control phase.
- The enrichment of the air/fuel ratio below 14.7:1 ($\lambda < 1$) is effected according to the ECT or CHT and the time.
- The mixture is influenced by the signal from the MAF or T-MAP sensor. These calculations are based on appropriate "spark angle tables" to which the EEC V PCM refers according to the air mass input.
- The fuel consumption is optimized according to the existing operating state.
- The ECT or CHT now lies above the warm up limit (end of the warm up phase).
- The air/fuel ratio is approaching the stoichiometric value of 14.7:1 ($\lambda = 1$).
- The upstream HO2S has still not reached normal operating temperature. Its signal is still not included in the calculation of the EEC V PCM.
- The EEC V PCM derives a **required lambda value (LAMBSE)**, measures or calculates the air mass flow and then calculates the required quantity of fuel.
- The program now switches to the closed loop.



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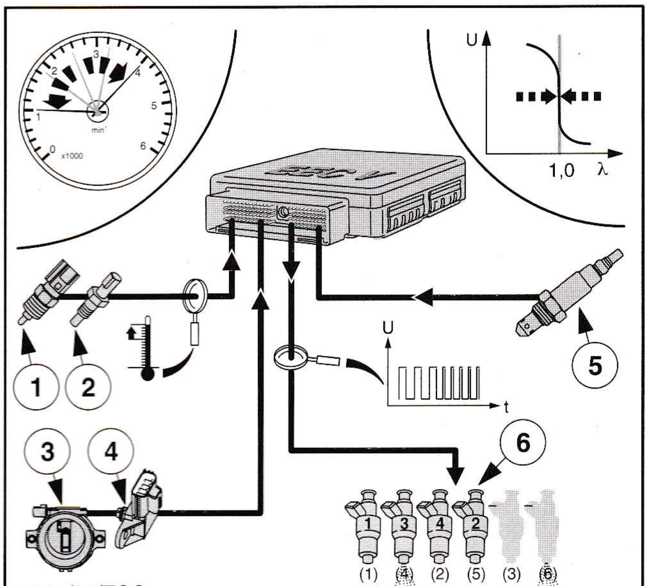
Open loop

1 ECT sensor
2 CHT sensor
3 MAF sensor
4 T-MAP sensor
5 Heated oxygen sensor (HO2S)
6 Fuel injectors

Fuel metering (continued)

UNDERSPEED and RUN (closed loop)

- The engine temperature has stabilized at **normal operating temperature**.
- The fuel metering is now determined in the **closed loop**, which means that the program is now in the closed-loop control phase.
- The signals from the upstream heated oxygen sensor HO2S are received by the EEC V PCM and are now included in the calculation of the opening times of the fuel injectors.
- In the closed loop the voltage of the upstream HO2S fluctuates between 0 V (lean mixture) and 0.9 V (rich mixture), the HO2S switching at approximately 0.45 V, which corresponds to $\lambda = 1$.



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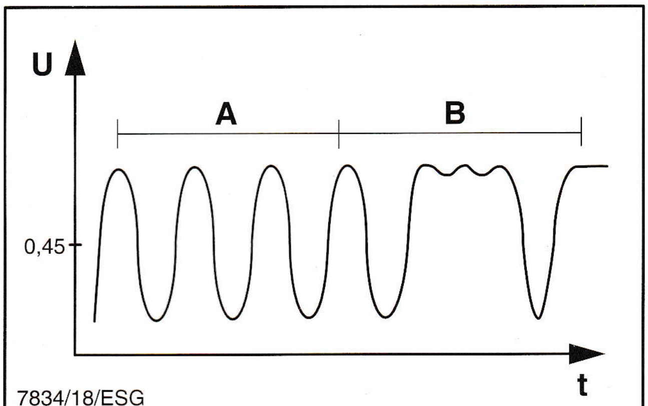
Closed loop

1 ECT sensor
2 CHT sensor
3 MAF sensor
4 T-MAP sensor
5 Heated oxygen sensor (HO2S)
6 Fuel injectors

- The optimum catalytic converter performance depends on this value, which means that the efficiency of the catalytic converter is high when lambda switches between "lean" and "rich".
- After evaluation of the HO2S signals, the EEC V PCM "shifts" the **required** lambda value (LAMBSE) – depending on whether the mixture should be richer or leaner – in a limit cycle manner to control lamda.



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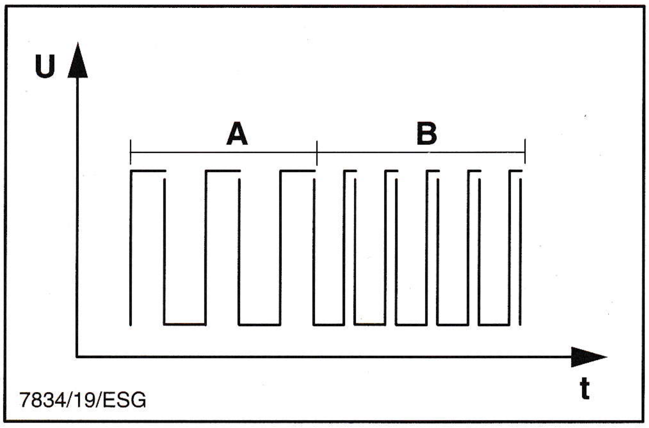
Signals of the upstream HO2S

A Regulated mixture
B Rich mixture

Fuel metering (continued)

UNDERSPEED and RUN (Closed loop) (continued)

- Now a short term fuel trim (**STFT**) is effected, which means that the opening times of the fuel injectors are adjusted.
- Here, an increase in LAMBSE reduces the fuel metering (making the mixture leaner), a decrease in LAMBSE produces the opposite effect.
- The system reverts to the open loop in the following conditions:
  - if the HO2S cools or fails repeatedly,
  - at full load,
  - during acceleration and overrun.



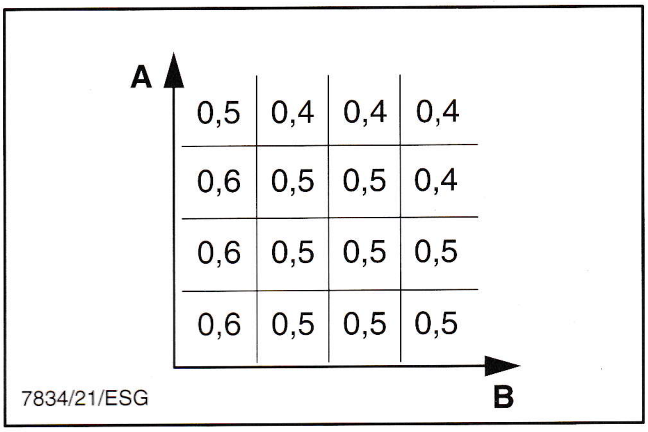
Short term fuel trim (STFT)

A Normal fuel injection

B Fuel injection time shortened

Fuel trim

- Discrepancies can occur in the calculation of the air/fuel ratio by the engine management system due to normal wear of components or changes to the system.
- The fuel trim allows these changes in the system to be offset within certain limits.
- This is achieved by allowing the EEC V system to learn deviations of components and form a **permanent correction factor** from these.
- This is used to calculate the required air/fuel ratio and then stored in the keep alive memory KAM. This is called "Long Term Fuel Trim" (**LTFT**).
- The **KAM** contains a fuel system **trim table** (self-learning table) for most engine speed and load combinations.
- The information gathered for different engine speeds/loads is stored in the cells of the fuel system trim table and used for mixture calculations.
- The value of the trim multiplier for the fuel calculation is 0.5 plus the corresponding value from the trim table.
- The LTFT is calculated by the EEC V PCM from information from the STFT to ensure that the stoichiometric mixture ratio of 14.7:1 (λ = 1) can be maintained.



Example of a trim table

A Load

B Engine speed

Spark angle calculation

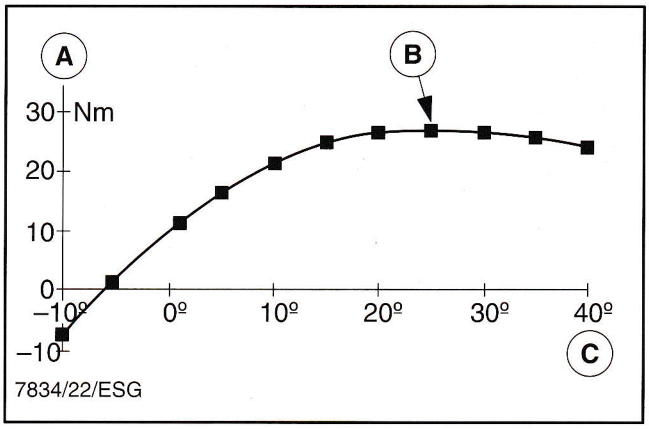
- The objective of every ignition system which is working well is to ignite the mixture at the correct time according to the prevailing conditions such as for example load, engine speed, temperature, change in mixture composition, etc., which means that the **spark angle** has a high priority here.

- Since on average approximately 2 ms elapse between the moment of ignition of the air/fuel mixture and its complete combustion, the **most favourable spark angle** depends on the load and engine speed.

- When the engine speed and throttle position (engine load) are kept constant, while the spark angle varies, the engine efficiency can be represented by the fuel consumption which is dependent on the torque (low fuel consumption = high efficiency).

- The optimum efficiency is achieved at a specific spark angle. The spark advance at which the maximum torque is achieved in the above-named conditions (constant load), is referred to in the EEC ignition strategy as the maximum brake torque (**MBT**) spark angle.

- As the curve in the MBT range is relatively flat, the smallest possible spark angle (minimum spark advance) can be sought for the best possible torque.



MBT ignition angle

A Torque (Nm)

B Maximum torque (MBT)

C Spark angle (degrees before TDC)

Spark angle calculation (continued)

- If fuel consumption and power were the only requirements for good engine running, operation of the engine closely around the MBT point would then naturally be the optimum. However, unfortunately this optimum efficiency is only attainable at low load and part throttle.

- If the ignition angle is **over-advanced**, mixture is also ignited in different areas of the combustion chamber by the pressure wave produced by ignition. The mixture burns unevenly and severe fluctuations in the combustion pressure occur with high peaks.

- When flame speeds in the region of the speed of sound occur in the combustion chamber, the result is **detonating combustion**. This produces high pressure peaks which are propogated in the combustion chamber.

- The detonating or "pinging" effect is clearly audible at low engine speed. At high engine speeds this effect is drowned out by the engine noise but can lead to serious engine damage in this area.

- The severity of detonation depends on its intensity and duration. When the detonation limit is only exceeded briefly (borderline detonation **BDL**), this has little or no effect on engine performance and running characteristics. On the other hand, severe detonation can lead to damage to pistons, cylinder head and cylinder head gasket.

- The tendency to detonation/pinging depends on the shape of the combustion chamber, the fuel characteristics and the high temperatures of the highly compressed mixture towards the end of combustion.

- This detonation tendency can be reduced for example by lowering the intake air temperature (IAT) and retarding the spark angle in relation to the MBT spark angle.

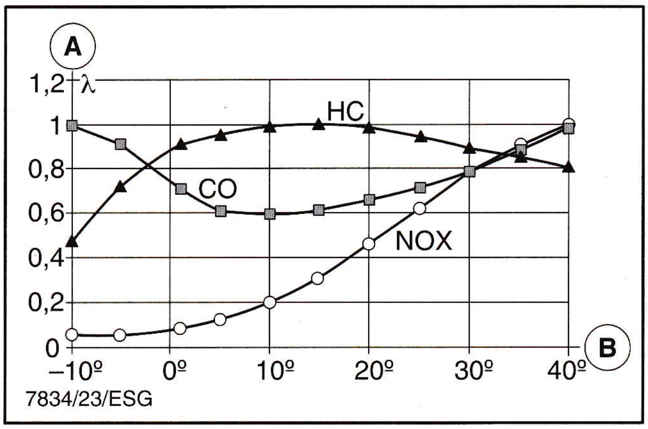
- Ultimately, many factors affect the final choice of spark angle advance. For example, the detonation resistance of the fuel and the compression ratio play a major part.

- When the unburnt mixture in the cylinder is diluted by making the mixture leaner or by using an exhaust gas recirculation (EGR) system, the time which the flame front takes to develop increases and the fluctuations in the combustion process arising from power stroke to power stroke become larger.

- To offset this, the spark timing must be advanced to maintain the MBT spark angle.

Spark angle calculation (continued)

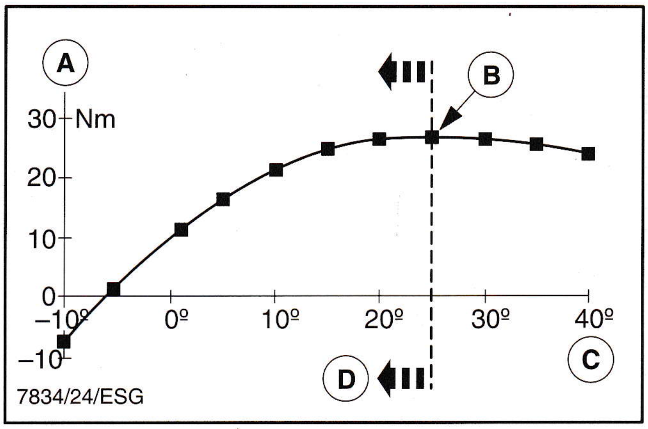
- Another important factor in determining the final spark timing is the effect of the pollutants.
- The emission of unburnt hydrocarbons (HC) increases as the ignition is advanced.
- The oxides of nitrogen (NOx) also increase over the entire range of the air/fuel ratio as the spark is advanced. The reason for this is the higher combustion chamber temperature when the spark is advanced.



A HC, CO and NOx relative to the air factor (λ)

B Spark angle (degrees before TDC)

- To reduce NOx, the advanced spark is retarded away from the optimum MBT point (smaller spark angle). As the torque curve is fairly flat around the MBT point, the loss of torque of approximately 1-2% compared with the maximum value may be acceptable.
- In contrast, carbon monoxide (CO) is almost independent of the spark timing and almost exclusively a function of the air/fuel ratio.
- At low temperatures the spark timing must be advanced (greater spark angle) to maintain MBT.



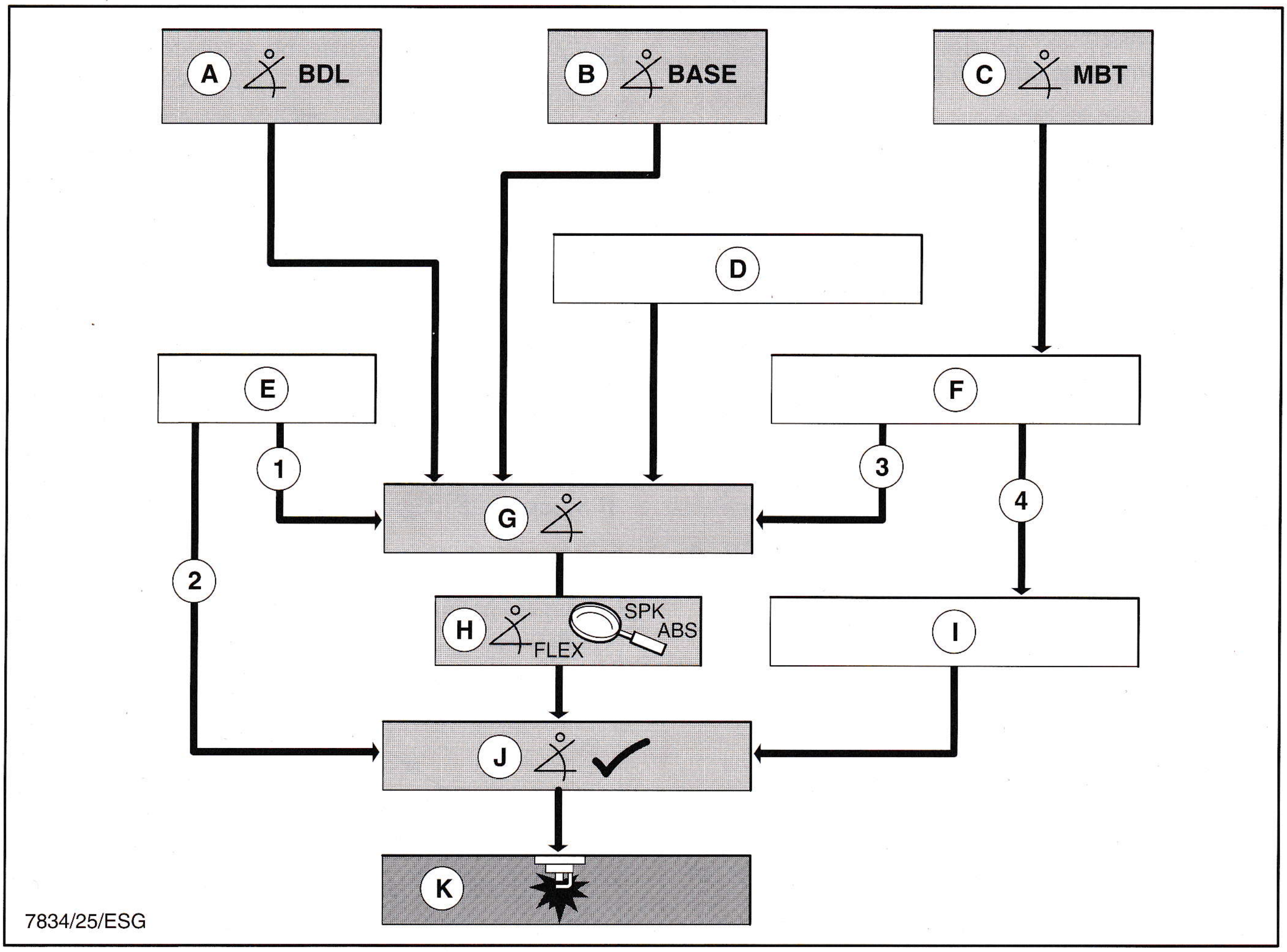
A Torque

B Optimum MBT point

C Spark angle (degrees before TDC)

D Smaller spark angle for reduced NOx

Spark angle calculation (continued)



A Spark angle at borderline detonation limit (BDL)
B Base spark angle (SPK Base)
C Spark angle at maximum torque (MBT)
D Spark angle at low load
E Oscillation/modulation
F Torque reduction through retarded spark
G Selected minimum possible spark angle
H Comparison of SPK-FLEX and SPK-ABS
I Ignition feedback at idle speed depending on torque
J Final spark angle calculation
K Ignition point

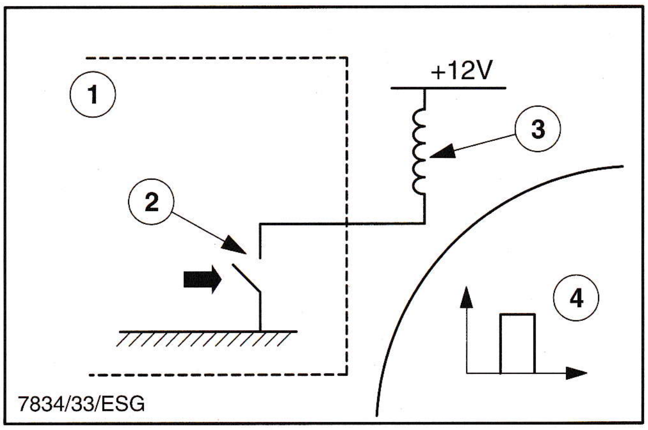
1 Spark angle oscillation “off”
2 Spark angle oscillation/modulation
3 Torque reduction
4 Last used MBT value

Spark angle calculation (continued)

- In the EEC V PCM the PIP signal (in addition to the MAF, MAP and ECT/CHT) serves as the basis for calculation of the spark angle.
- The spark angle calculation produces:
  - the spark angle for maximum torque (MBT spark angle),
  - The spark angle at the borderline detonation limit (BDL) and
  - the base spark angle (SPK base).
- The three advanced calculations are compared with one another and the lowest spark angle value is worked out from these. This is then applied as the absolute maximum spark angle (SPK-ABS) for the final spark angle calculation.
- When starting from cold and at low load a further advance calculation is carried out to determine the "flexible" spark angle limit SPK-FLEX. This uses a later spark timing to heat up the catalytic converter faster.
- SPK-FLEX and SPK-ABS are compared with one another and the smallest possible spark angle is selected for the particular engine operating state from them.
- All the described spark angle calculations are taken into account by corresponding calibration of the electronic ignition (EI) of the EEC V system so that the correct spark angle is available for every operating state or driving situation.
- The highest possible efficiency and low fuel consumption have the highest priority.
- The ignition calibration is always carried out for a particular target engine.
- Reference parameters such as for example intake air temperature (IAT), engine coolant temperature (ECT) or cylinder head temperature (CHT), load, EGR and the air/fuel ratio etc are used during the calibration.
- Once determined, these calibrations are no longer modified unless hardware changes to the electronic ignition make this necessary (also refer to "Electronic ignition (EI) ignition control module (ICM)" in Lesson 3).

EEC V PCM output signals

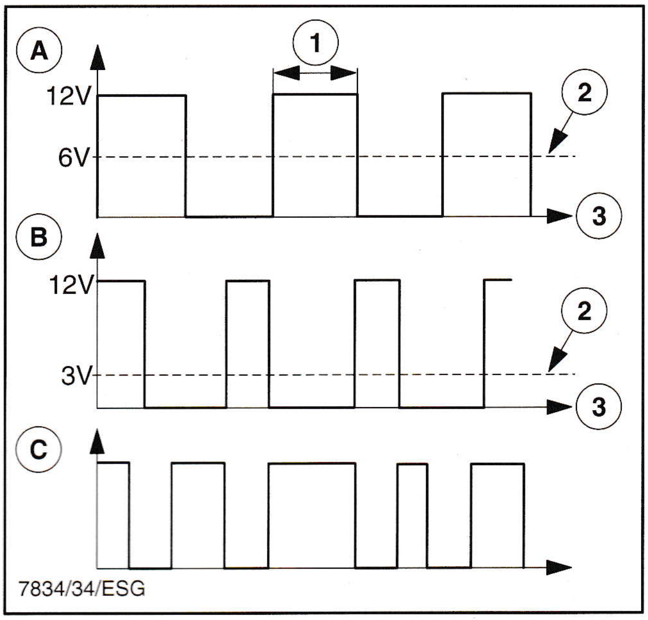
- The EEC V PCM actuates the different actuators of the system with appropriate different output signals.
- The actuators are always actuated digitally, which means that the electronic switch in the PCM is a kind of transistor which is switched on and off, in this case producing a switched output signal.
- For example, the fuel pump relay, the evaporative emission (EVAP) canister purge solenoid valve and the A/C compressor clutch are switched (ON/OFF).



1 EEC V PCM
2 Electronic switch
3 Actuator solenoid
4 Switched output signal

Pulse width modulation (PWM)

- However, some actuators require a variable form of actuation in which the output signal is switched on and off in controlled fashion in the form of **pulse width modulation (PWM)**.
- Pulse width means the pulse duration of the switched on output signal (for example a voltage signal).
- Typical actuators which are controlled by PWM are for example the idle air control (IAC) valve and the fuel injectors.

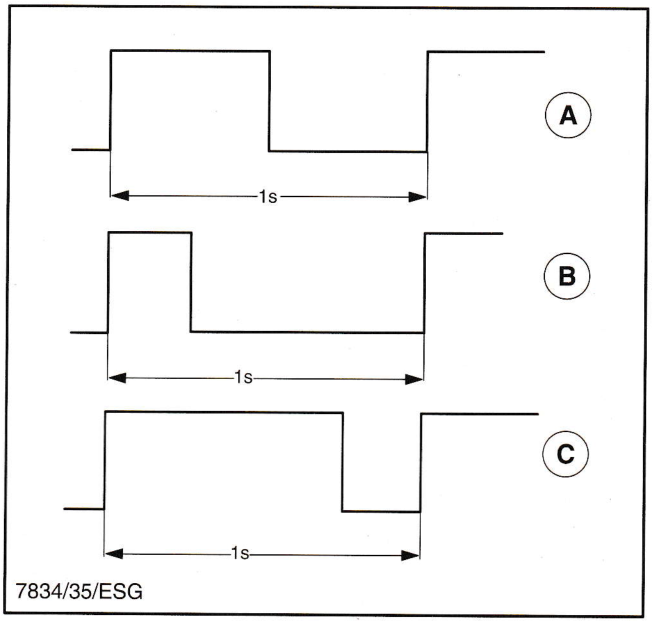


A Higher average voltage (higher control current)
B Lower average voltage (lower control current)
C Typical PWM output signal
1 Pulse width
2 Average voltage
3 Time

EEC V PCM output signals (continued)

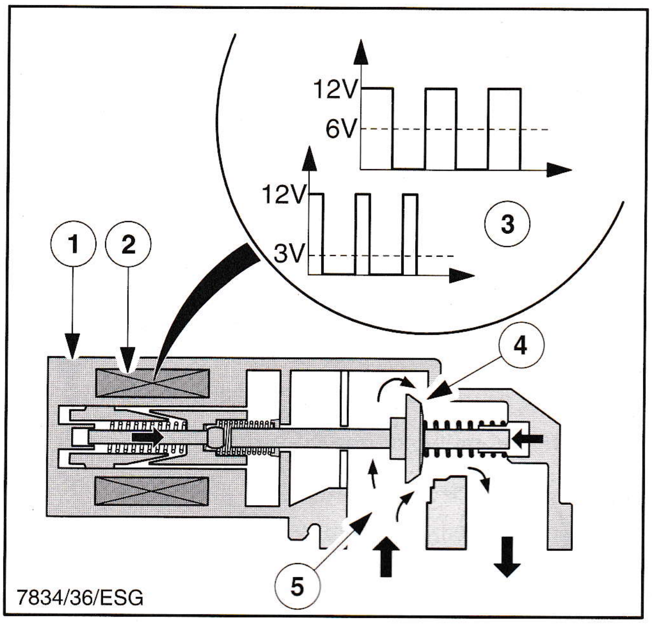
Duty cycle

- Duty cycle means the ratio of the times for which a PWM signal is switched ON and OFF.
- The duty cycle is expressed as a percentage. Thus a 25% duty cycle for example means that a voltage signal is 25% active or is switched on for 250 ms and switched off for 750 ms over 1 second of pulse width modulation.



A 50% active (on 500 ms and off 500 ms)
B 25% active (on 250 ms and off 750ms)
C 75% active (on 750 ms and off 250 ms)

- Applied in practice to the idle air control (IAC) valve, this means that the magnetic force of the solenoid of the IAC valve is determined by controlling the current.
- The control current can be changed by means of the PWM and the duty cycle by grounding a fixed voltage (12 V).
- As a result, the opening cross-section of the IAC valve and hence the throughput of air through the bypass is controlled exactly.



1 Idle air control (IAC) valve
2 Solenoid
3 Control current
4 Opening cross section
5 Bypass air

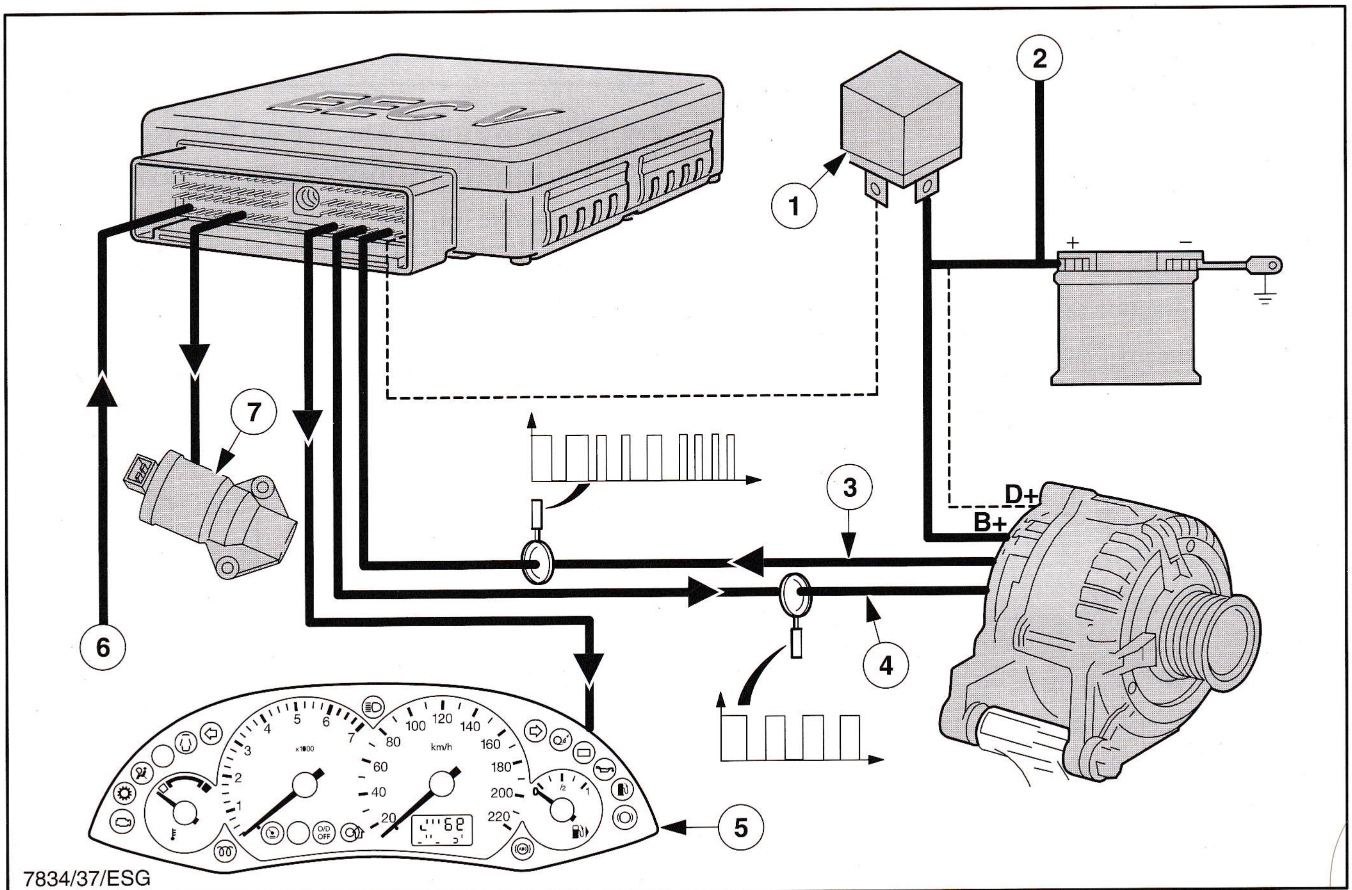
Generator control (smart charge) system

General

- In a conventional generator a fixed voltage value (set value) is predetermined by the internal voltage regulator and thus the system voltage is regulated.
- In the **smart charge generator** the voltage regulator functions are still carried out in the generator but the voltage set value is calculated in advance by the EEC V PCM.
- The smart charge system requires no additional components, has a self-test function in the EEC V PCM and can be tested for faults with the WDS.
- In addition, if the generator load is too high, the EEC V PCM increases the idle speed to boost the generator output.

Operation

- Through the **signal line from the generator output** the EEC V PCM receives a signal from the rotating field winding of the generator to determine the state of load of the generator.



1 Engine run relay
2 Consumers (loads)
3 Generator output (EEC V PCM input)
4 Generator input (EEC V PCM output)
5 Charge warning indicator in the instrument cluster
6 Temperature signal from the integrated intake air temperature (IAT) sensor (MAF or T-MAP)
7 Idle air control (IAC) valve

Generator control (smart charge) system (continued)

Operation (continued)

- The signal is processed in the foreground loop and passed to the background loop for advance calculation of the IAC signal to boost the idle speed. The frequency and the duty cycle of the signal change.
- The frequency range of the voltage signal lies between 100 and 200 Hz, the duty cycle must be 9% to 97%.
  - 9% = low charging current
  - 97% = high charging current = idle speed boost.
- In addition, the EEC V input signal line also monitors the generator output to inform the EEC V PCM of any malfunctions. This can be for example when the duty cycle lies outside the 9-97% range or the generator receives no valid voltage signal.
- If the voltage signal at the PCM input (V batt) is too low, this means that the charging current voltage is too low. More power must be produced by the generator to ensure that the battery is charged sufficiently to maintain the charge balance (by boosting the idle speed).
- Through the **signal line to the generator input** the generator voltage is regulated according to the EEC V PCM input signals (for example insufficient voltage, V batt) and the battery temperature.
- The EEC V PCM detects the instantaneous intake air temperature (IAT) to calculate the battery electrolyte temperature.
- This is compared with the IAT value stored when the engine was last stopped, and then the battery electrolyte temperature required for the new voltage set value is calculated.
- The EEC V PCM now actuates the generator voltage regulator. The frequency is identical to that of the PCM input signal (100-200 Hz). The voltage regulator uses the duty cycle of 15% = 12.5 V to 95% = 16.5 V.
- The PCM then sends the generator a new voltage set value. This is a **one off figure** until the PCM determines a new value again (exception: change of generator load).
- The generator voltage can lie between 12.5 V and 16.5 V.

Operating modes of the "smart charge" system

Normal operation

- The system works starting from a fixed generator voltage set value which is optimum for the particular battery temperature.
- The EEC V PCM actuates the engine run relay. This ensures that certain consumers with a high current comsumption (for example the heated windshield) are only supplied with current when the generator is working.
- The PCM switches the charge warning indicator on when the ignition is on and the engine is off, during starting, when the duty cycle of the EEC V input voltage signal with the engine running is 0% or 100%.

Generator control (smart charge) system (continued)

Operating modes of the "smart charge" system (continued)

Engine starting or underspeed

- The **smart charge generator** is not activated after the ignition is switched on during the following starting operation. As a result, no unnecessary (torque) load is applied to the engine during starting.
- The voltage regulator is **activated** when it receives the first valid PWM signal from the EEC V PCM.
- Therefore, the generator remains deactivated until the EEC V PCM output signal is activated, which takes place at engine speeds outside the starter motor speed or underspeed.

Full load or wide open throttle

- In this operating mode the main objective is to optimise acceleration.
- The torque load from the generator is reduced to the minimum possible by the EEC V PCM by lowering the voltage regulator set value.
- To prevent discharging of the battery, the full load or wide open throttle mode is switched off temporarily, which means that the generator runs for a limited time in **normal operating mode** between successive WOT phases.

Idle speed control

- Through the EEC V input signal line the EEC V PCM continuously receives signals indicating the generator load. This load is produced when consumers with a high current consumption are switched on and may possibly cause the battery to be discharged.
- The EEC V PCM reacts by actuating the idle air control (IAC) valve and boosting the idle speed (higher speed = higher charging current).
- The method of controlling the idle air by means of the IAC valve takes priority. However, with the smart charge system the EEC V PCM is also capable of offsetting the drop in idle speed under high electrical load by controlling the voltage regulator set value in addition.
- The idle speed boost due to excessive generator load does not take place in the "idle" mode. The boosted idle speed is only employed when the vehicle has been driven and the system reverts to the idle mode (with the vehicle stationary).

System malfunction

- In the event of malfunctions in connection with the smart charge system, the voltage set value is regulated to a value fixed in the generator. All the other operating modes do not work in this mode.
- The requirement for a system which is still working is that the generator can still recieve data although there may be a fault in the EEC V input signal line.
- The charge warning indicator is illuminated in the event of malfunctions in the system or the charging voltage being too low.

Find the correct answer or fill in the gaps.

1. Which of the following statements about the program loops running in the EEC V PCM is correct?

☐ a) The background loop has absolute priority and interrupts the foreground loop at regular intervals.

☐ b) The foreground loop runs at the same time as the background loop and the PIP signal.

☐ c) The background loop is interrupted by the foreground loop to carry out operations with a higher priority. In addition, every PIP signal edge can cause an interruption in both loops.

☐ d) The background loop is interrupted by the foreground loop every 20 ms and the functions of the background loop are suspended until two successive PIP signals lead to an interruption in the foreground loop.

2. What is understood by "speed density"?

☐ a) The strategy of air mass calculation based on the air mass flowing through the MAF sensor.

☐ b) The strategy of air mass calculation based on the manifold absolute pressure, intake air temperature and engine speed (for which the barometric pressure BARO is used as reference pressure).

☐ c) The strategy of air mass calculation based on the velocity of the air mass flowing through the intake manifold.

☐ d) The strategy of air mass calculation based on the velocity and temperature of the inflowing intake air.

3. What is understood by an "open" loop during engine operation?

☐ a) The program is in the closed-loop control phase, the HO2S input signals are received by the PCM.

☐ b) The actuation of all the actuators only takes place above a fixed coolant temperature.

☐ c) The sensor signals are only received above a certain coolant temperature.

☐ d) The program is in the open-loop control phase, the HO2S signals are not received by the EEC V PCM.

4. What is understood by a "closed loop" during engine operation?

☐ a) The engine is in the warm-up phase.

☐ b) The engine is running at full load (with a wide open throttle (WOT)).

☐ c) The program is in the closed-loop control phase, the HO2S signals are received by the EEC V PCM.

☐ d) The heated oxygen sensors are only switched on at part throttle.

Find the correct answer or fill in the gaps.

5. What characterises a correctly operating ignition system to ignite the mixture at the correct time according to the prevailing engine operating conditions?

☐ a) Determining a uniform spark angle over the entire engine operating range.
☐ b) Determining a large spark angle.
☐ c) Calculating the optimum spark angle.
☐ d) Calculating the largest possible constant spark angle.

6. Which factors, apart from the usual engine operating conditions, have a particular influence on the calculation of the spark angle?

☐ a) Excessive coolant temperature.
☐ b) Borderline detonation limit, effect of pollutants (HC and NOx), dilution of the unburnt mixture.
☐ c) Influence of carbon monoxide (CO).
☐ d) Driving at part throttle all the time.

7. Which of the named actuators are actuated by pulse width modulation (PWM)?

☐ a) Fuel injectors, idle air control (IAC) valve.
☐ b) EI coil, cooling fan.
☐ c) Air conditioning (A/C) compressor clutch.
☐ d) Evaporative emission (EVAP) solenoid valve.

8. What is understood by a duty cycle?

☐ a) Scanning an analogue input signal.
☐ b) The ratio of the times for which a PWM signal is switched ON and OFF.
☐ c) The pulse duration of a PWM signal.
☐ d) Scanning a digital output signal.

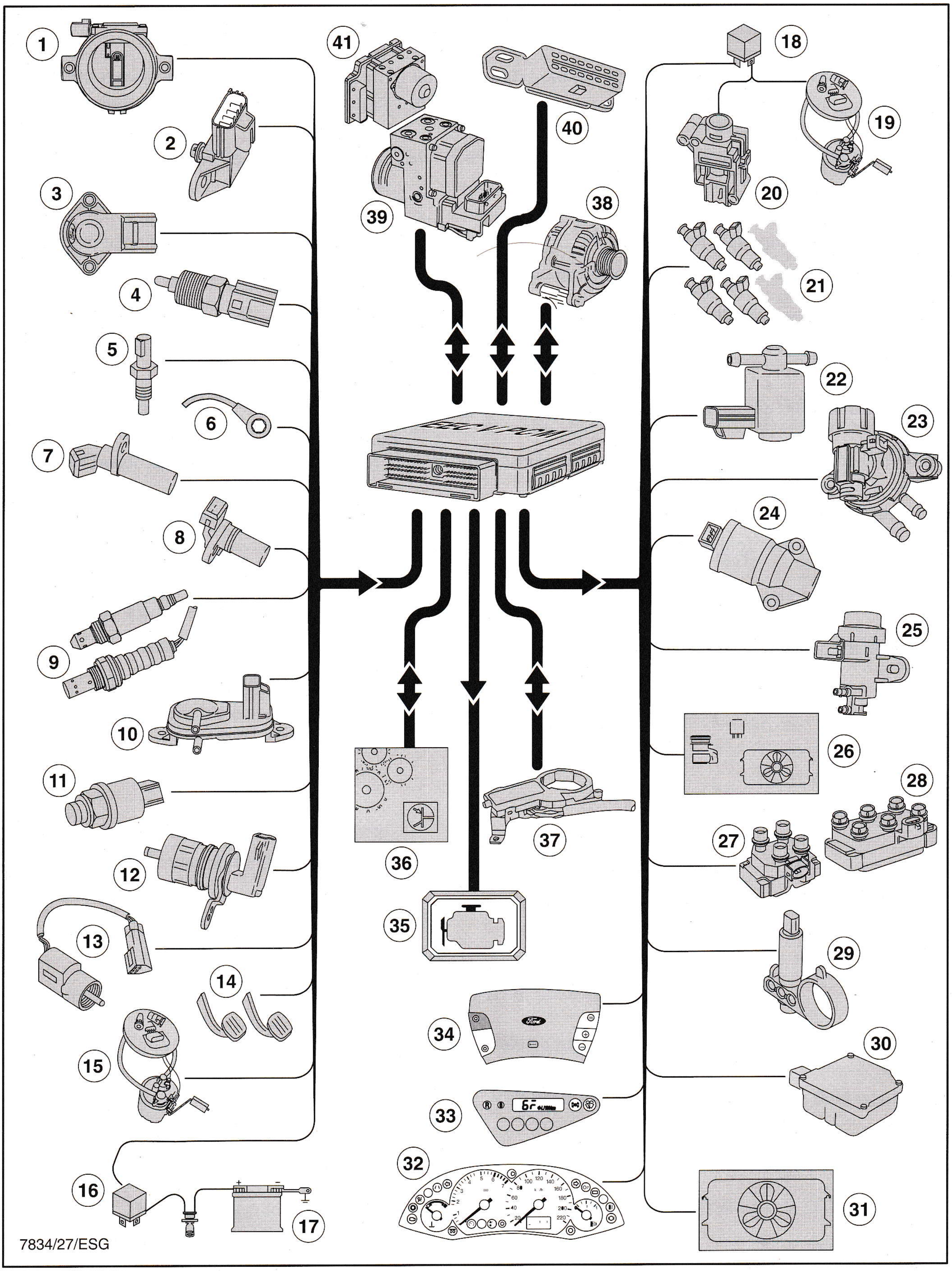
9. What distinguishes the "smart charge" generator from the conventional generator?

☐ a) The smart charge generator no longer has a voltage regulator, the charging voltage is regulated by the EEC V PCM.
☐ b) The voltage regulator is located in the EEC V PCM and is actuated by the rotating field winding of the smart charge generator.
☐ c) The voltage regulator of the smart charge generator emits a fixed voltage set value which is processed further by the EEC V PCM.
☐ d) The voltage regulator regulates the charging voltage independently of the EEC V PCM.

Objectives

On completing this lesson, you will be able to:

- list all the PCM inputs (sensors) and outputs (actuators and other components) of the EEC V engine management system
- explain the most important functions of the EEC V PCM, for example ROM, RAM/KAM, analogue inputs, analogue/digital transducer, digital inputs and outputs (power drivers)
- explain the different methods of controlling the electronic ignition system (external EI-ICM, integrated EDIS, software EDIS)
- describe important unique features of the CKP signal and explain what is meant by "voltage offset"
- provide additional explanations regarding the camshaft position (CMP) sensor and throttle position (TP) sensor
- explain the function and operation of the knock sensor (KS), cylinder head temperature (CHT) sensor and the temperature and manifold absolute pressure (T-MAP) sensor
- describe the design and operation of the planar heated oxygen sensor
- describe the actuation and regulation of the variable camshaft timing (VCT) solenoid valve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EEC V PCM - input and output signals

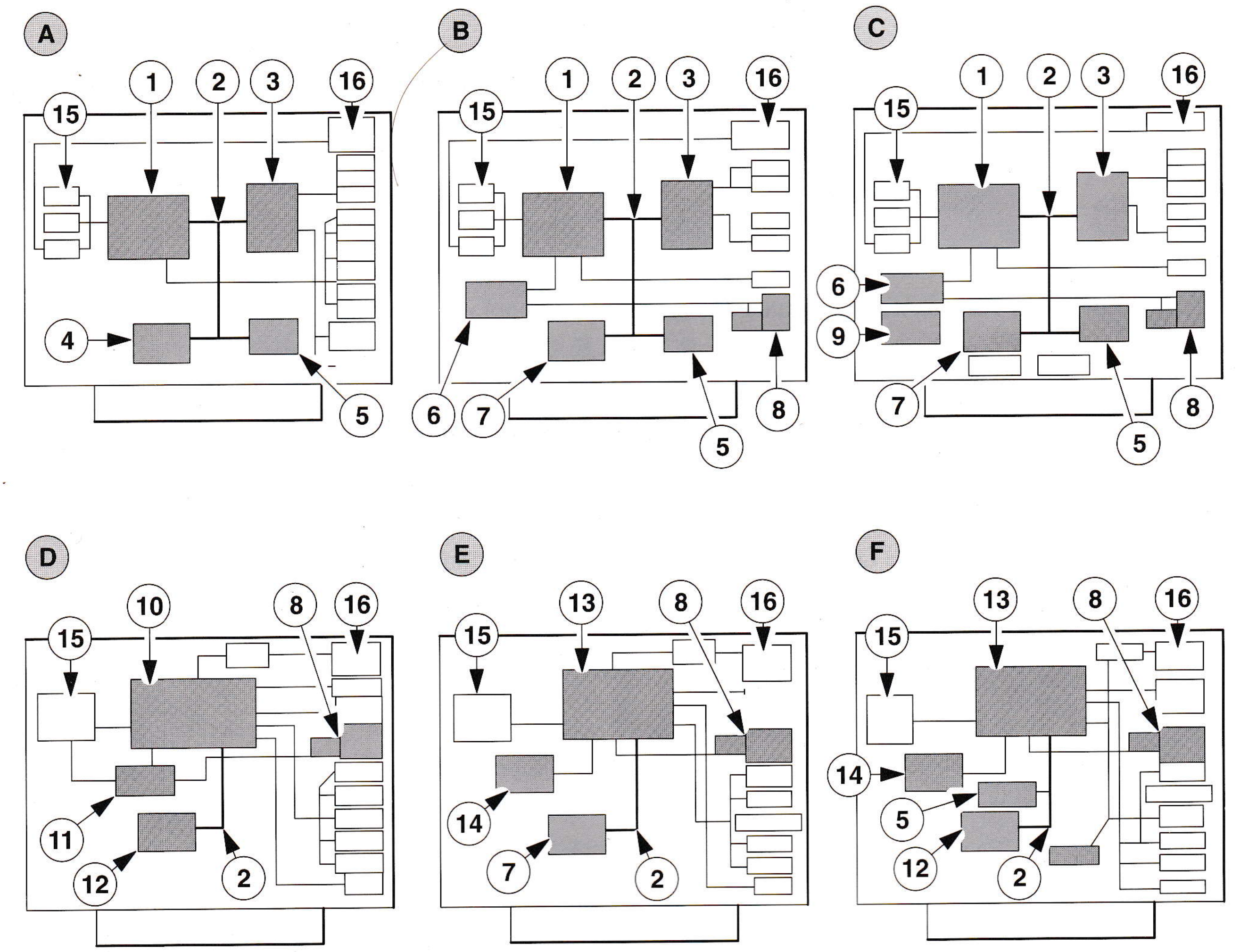
- The illustration opposite shows all the sensors and actuators and the direct data transmission and communication options of the current EEC V engine management system applicable to all engines and vehicles.
- The ignition control module (ICM or EDIS module) is no longer shown separately since it is nowadays generally integrated in the PCM or in the software of the EEC V PCM (software EDIS).

Key to the illustration opposite

1 Mass air flow (MAF) sensor with integrated intake air temperature (IAT) sensor
2 Temperature and manifold absolute pressure (T-MAP) sensor
3 Throttle position (TP) sensor
4 Engine coolant temperature (ECT) sensor
5 Cylinder head temperature (CHT) sensor
6 Knock sensor (KS)
7 Crankshaft position (CKP) sensor
8 Camshaft position (CMP) sensor
9 Heated oxygen sensor (HO2S–11, –12, –21, –22)
10 Exhaust gas differential pressure sensor
11 Power steering pressure (PSP) sensor
12 Output shaft speed (OSS) sensor
13 Vehicle speed sensor (VSS)
14 Clutch pedal position (CPP) switch and brake pedal (BPP) switch
15 Fuel level input (FLI) signal
16 Power supply relay
17 Battery
18 Fuel pump relay
19 In-tank fuel pump (FP)
20 Inertia fuel shutoff (IFS)
21 Fuel injectors
22 Evaporative emission (EVAP) solenoid valve
23 Vapour management valve (VMV)
24 Idle air control (IAC) valve
25 EGR vacuum regulator
26 Air conditioning (A/C) compressor
27 EI ignition coil (4-cylinder engines), EDIS–4
28 EI ignition coil (6–cylinder engines, EDIS-6)
29 Variable camshaft timing (VCT) solenoid valve
30 Intake manifold runner control (IMRC) system
31 Cooling fan
32 Instrument cluster (speedometer, tachometer, temperature gauge, fuel gauge, powertrain warning indicator, exhaust warning indicator)
33 Trip computer
34 Speed control system
35 Emission control malfunction indicator lamp (MIL) (EOBD)
36 Automatic transmission
37 PATS (transceiver)
38 "Smart charge" generator
39 ABS control unit (Bosch 5.3)
40 Data link connector (DLC)
41 ABS/ESP control unit (Mark 20E-I)

EEC V PCM configuration

- The illustrations show the circuit board structure of the 104-pin EEC V PCM configurations of the 1995 to 2000 model years in the simplest and most readily comprehensible form, **based on selected examples**.
- These are predominantly European PCMs. The most important features or changes are marked in gray in the graphics.



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EEC V PCM configuration (continued)

A 1995 model year:

- Scorpio, Galaxy and Transit.

B 1996 model year:

- Fiesta '96 with Endura-E/Zetec-SE,
- Escort with 1.6 Zetec-E/with CTX and 1.8 Zetec-E/manual transmission.

1997 model year:

- Mondeo with Zetec-E/MTX,
- Scorpio with 2.0 DOHC 8V and 2.3 DOHC 16V

C 1996 model year:

- Fiesta '96 with Endura-E/Zetec-SE
- Escort with Endura-E and 1.6/1.8 Zetec-E

1997 model year:

- Mondeo Zetec-E/MTX
- Scorpio 2.0 DOHC 16V, Galaxy 2.0/2.3 DOHC

D 1997 model year:

- Mondeo with Zetec-E/CD4E, Mondeo with 2.5 Duratec

E 1997.5 model year:

- Puma with 1.7 Zetec-SE VCT

F 1998.5 model year:

- Mondeo with Zetec-E MTX or CD4E

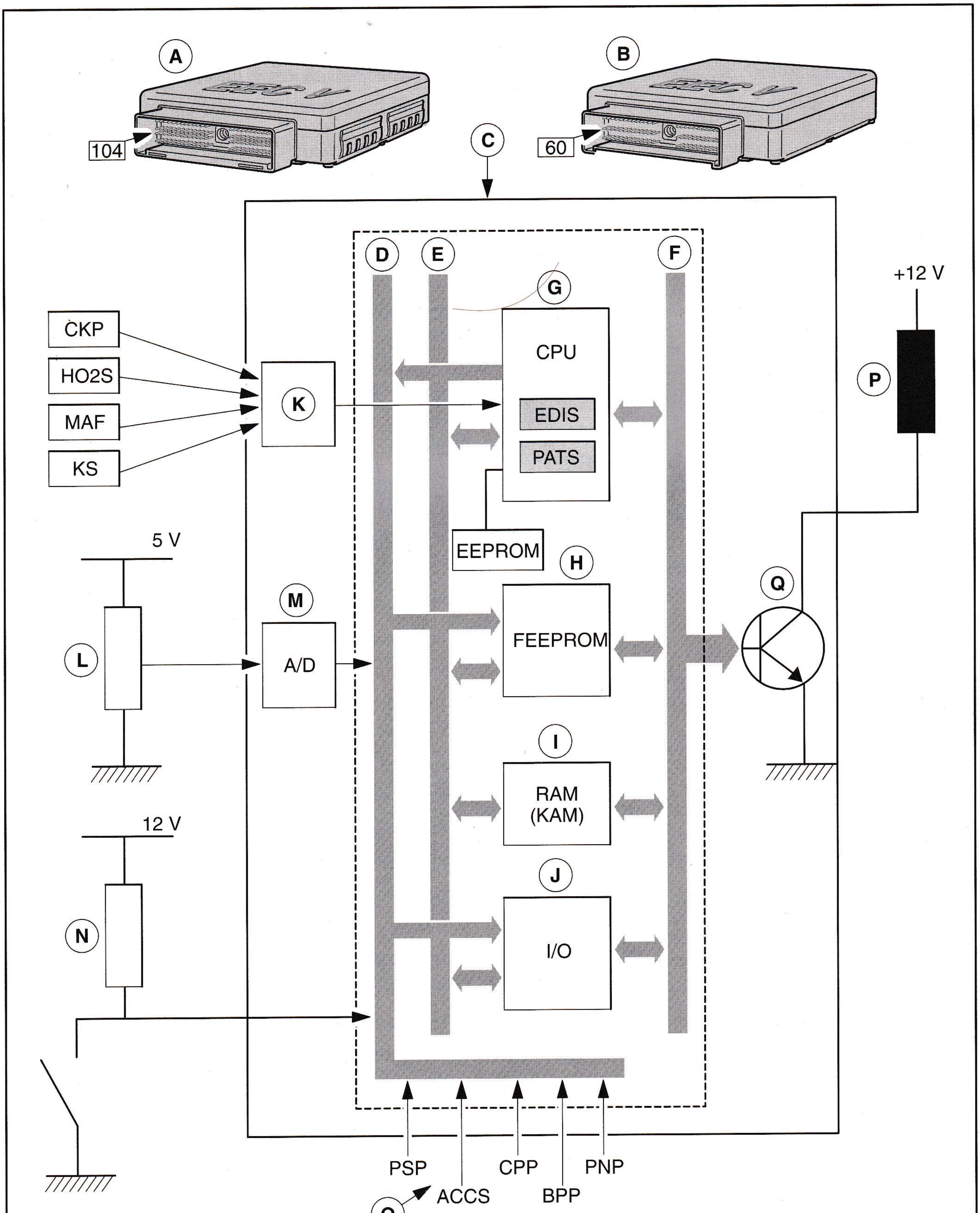
1999 model year:

- Focus with Zetec-SE/Zetec-E with manual transmission.

2000 model year:

- Transit (V184), with 2.3 DOHC,
- Galaxy with 2.3 DOHC.

1 8065 microprocessor
2 Data bus
3 Random access memory RAM, EEC bus controller (SCP), pulse width modulation controller
4 "Flash" electrically erasable programmable read only memory (FEEPROM) (88KByte)
5 Random access memory (RAM)
6 Integrated EI ICM (integriertes EDIS-4)
7 FEEPROM (112 K Byte)
8 Ignition coil driver
9 Integrated PATS
10 Improved integrated powertrain controller(8065 microprocessor, EEC bus controller (SCP), pulse width modulation controller and random access memory RAM)
11 Integrated EI ICM (integrated EDIS-4/6)
12 FEEPROM (216 KByte)
13 Improved integrated power train controller with software EDIS and software PATS
14 Electronically erasable programmable read only memory EEPROM (512 KByte)
15 Input and output signals
16 Power driver


A
B
104
60
C
D
E
F
G
CPU
EDIS
PATS
+12 V
P
CKP
HO2S
MAF
KS
K
EEPROM
H
5 V
M
FEEPROM
Q
L
A/D
I
RAM
(KAM)
12 V
J
N
I/O
PSP
CPP
PNP
ACCS
BPP
O

7834/29/ESG

Function and operation

- The block circuit diagram opposite showing the microcomputer with the bus systems and inputs and outputs illustrates the current state of development of the EEC V PCM.

- Reference: Also refer to old publication 29/A "Multi-port Fuel Injection (EEC IV/MFI) – Fundamentals", page 32.

104-pin EEC V PCM (A)

- These configurations are used generally, above all for vehicles with more powerful engines, automatic transmission and full equipment.

60-pin EEC V PCM (B)

- An inexpensive version for certain vehicle variants with manual transmission and simpler equipment.

EEC V PCM housing (C)

- Standard housing for 104-pin and 60-pin versions.

Address bus (entry) (D)

- Through the address bus the microprocessor (**CPU** = **C**ontrol **P**rocessing **U**nit) determines which inputs are read in and the memory locations to which they are sent. It also determines the memory location from which data is read and to which address it is output.

- The data only runs in one direction on the address bus since the complete management of the address lines comes solely from the CPU.

Data bus (E)

- The data bus is used for exchanging data between the input, output and memory with the CPU. It can convey data in both directions viewed from the CPU (bi directional bus). The data bus of the EEC V PCM has a bus width of 16 bit.

Control bus (F)

- The control bus transmits commands to the individual actuators. Through the control bus it is possible to determine whether a memory cell in the RAM should send data to the data bus or whether the memory cell should store or read the information on the data bus.

Function and operation (continued)

(continuation of block circuit diagram on page 46)

Microprocessor (CPU) (G)

- The EEC V PCM works with a type 8065 microprocessor. This is a 16-bit microcomputer which also contains the memory unit.
- The ignition control module (ICM) and the passive anti-theft system (PATS) can be integrated in the software of the microprocessor (software EDIS and integrated PATS).

Read only memory ROM (H)

- The strategy program and the calibration data are loaded into this non-volatile memory and stored in it by the manufacturer. The contents of the memory can only be read from the CPU (read only memory).
- In the current EEC V PCM the read only memory takes the form of a **FEEPROM.** This is a flash electrically programmable read only memory. If the engine calibration is changed, this read only memory can be erased electronically with a voltage of 18 V and reprogrammed using the WDS.

Keep alive memory KAM (I)

- The keep alive memory is a random access memory which among other things holds the fuel system trim table, the permanent correction factor for calculating the air/fuel ratio and the barometric pressure (BARO).

I/O-ports (I/O signals) (J)

- The system works for the stabilised voltage of 5 V to avoid errors when reading in the input signals (analogue/digital/switch signals).
- The outputs of the EEC V PCM do not emit voltages. The connected actuators are switched to 0 V by means of the PCM (ground control). A voltage of 0 V measured at the output generally indicates that the actuator is switched on.

Function and operation (continued)

(continuation of block circuit diagram on page 46)

Analogue input signal adapting unit for EEC V (K)

- This takes the place of the usually separate analogue input circuits for:
  - mass air flow (MAF) sensor
  - crankshaft position (CKP) sensor
  - heated oxygen sensor(s) (HO2S–11, –12, –21, –22)
  - knock sensor (KS)
- The incoming signals are digitized before they are actually processed by the CPU and adapted to the prevailing conditions (conditioned).

Analogue inputs (L)

- The input voltage can lie between 0 V and 5 V. The analogue inputs include the following sensors in addition to those named in "K":
  - integrated intake air temperature (IAT) sensor of the MAF and T-MAP sensor,
  - throttle position (TP) sensor,
  - camshaft position (CMP) sensor,
  - engine coolant temperature (ECT) sensor,
  - cylinder head temperature (CHT) sensor,
  - exhaust differential pressure sensor,
  - fuel level input (FLI).

Function and operation (continued)

(continuation of block circuit diagram on page 46)

Analogue/digital converter (M)

- In the analogue/digital converter the analogue input signals (input voltages) are converted into digital values (counts).
- These are calculated in bits or binary digits. "Binary" means "consisting of two units" (1 or 0 = "on" or "off").
- For example, the input voltage values of 0-5 volts are converted into digital values of 0-1023 counts (refer to the table opposite).
- The CPU can only work with these values fixed in the ROM. For example, if it receives the digital value 511 from the analogue/digital converter (through the address bus), this is a voltage value of 2.5 volts.

A										B	
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
0	0	0	0	0	0	0	0	0	0	0	C
0	0	0	0	0	0	0	0	0	1	1	
0	0	0	0	0	0	0	0	1	0	2	
0	0	0	0	0	0	0	0	1	1	3	
0	0	0	0	0	0	0	1	0	0	4	
0	0	0	0	0	0	0	1	0	1	5	
0	0	0	0	0	0	0	1	1	0	6	
0	0	0	0	0	0	0	1	1	1	7	
0	0	1	1	1	1	1	1	1	1	255	
0	1	0	0	0	0	0	0	0	0	256	
0	1	0	0	0	0	0	0	0	1	257	
0	1	0	0	0	0	0	0	1	0	258	
0	1	0	0	0	0	0	0	1	1	259	
0	1	1	1	1	1	1	1	1	1	511	D
1	0	0	0	0	0	0	0	0	0	512	
1	0	0	0	0	0	0	0	0	1	513	
1	0	0	0	0	0	0	0	1	0	514	
1	0	0	0	0	0	0	0	1	1	515	
1	1	1	1	1	1	1	1	1	1	1023	E

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Example: Conversion of analogue input signals into digital values

A 10 bits

B Digital values (counts)

C 0 counts = 0 volts

D 511 counts = 2.5 volts

E 1023 counts = 5 volts

Function and operation (continued)

(continuation of block circuit diagram on page 46)

Digital inputs (N)

- The input voltage can only be **on** or **off**. Usually ON is 12 volts and OFF is 0 volts.
- The digital inputs include:
  - PIP signal, but only with an external EI-ICM (the PIP signal is not displayed with the EI-ICM integrated in the software),
  - vehicle speed sensor (VSS),
  - manifold absolute pressure (MAP) sensor.

Switch input signals (O)

- Power steering pressure (PSP) switch
- Air conditioning cycle switch (ACCS)
- Clutch pedal position (CPP) switch
- Brake pedal position (BPP) switch
- Park Neutral Position (PNP)

Outputs (actuators) (P)

- The outputs usually have a digital character. A digital output is switched so that an active output has a measurable voltage of approximately 0.5 V and an inactive output an output voltage of approximately 12 V.
- The symbol shown in the block circuit diagram on page 46 shows the solenoid of the particular actuator representing all actuators.
- Examples of digital outputs are the fuel injectors, the trip computer and the idle air control (IAC) valve.

Power drivers (Q)

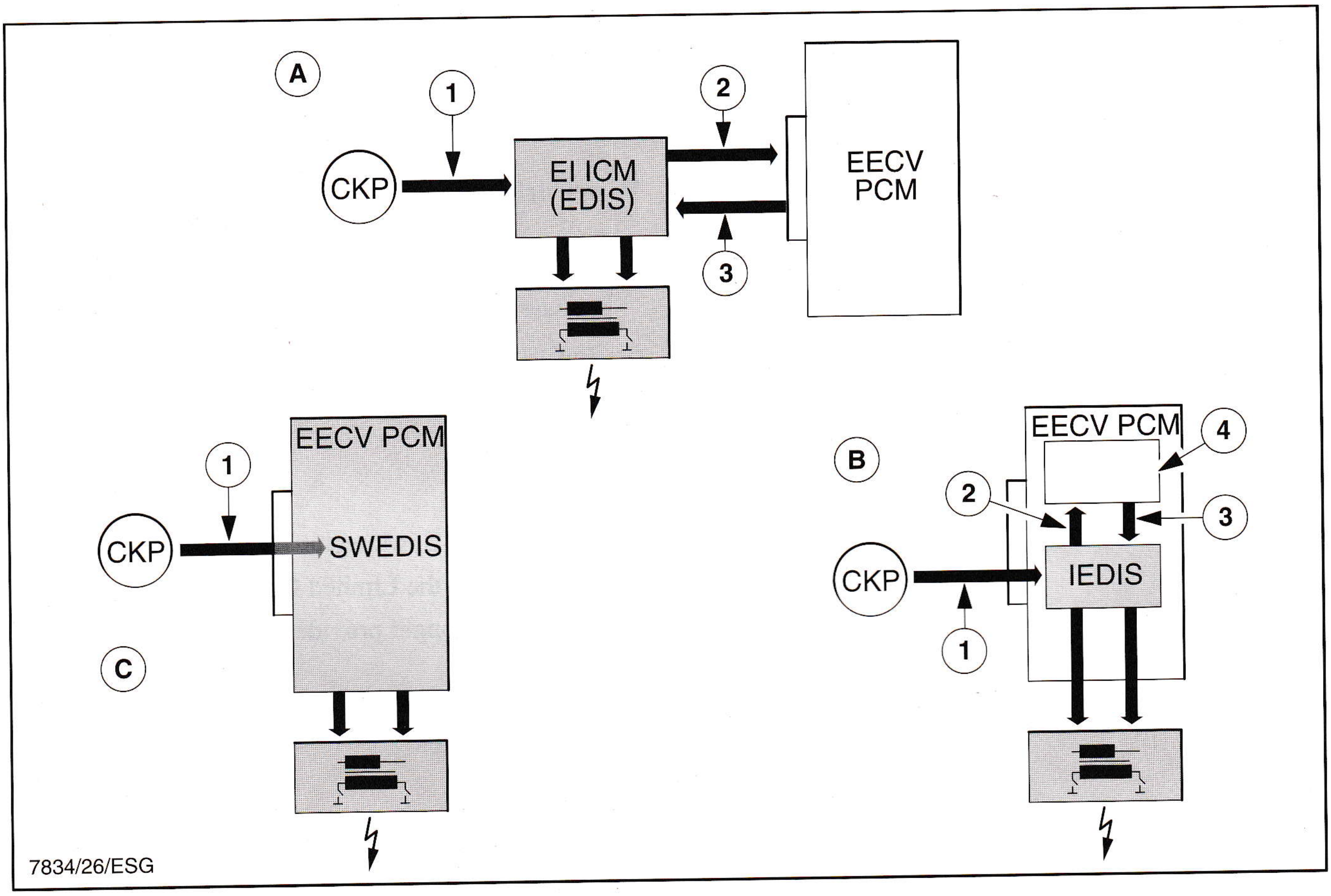
- Most outputs require amplification so that they can actuate electromagnetic actuators. Special transistors are used for this; these are very rapid contactless and thus low wear-switches.

Software PATS

- When the PATS is integrated in the software of the EEC V PCM, the Limited Operation Strategie (LOS) is no longer provided.
- If the EEC V PCM should fail, the vehicle **can no longer** be driven.

Electronic ignition (EI) ignition control module (ICM)

- When the earlier engines are also taken into account, currently the following methods are in use for controlling the electronic ignition:
  - EEC V PCM in conjunction with **external** EI-ICM (EDIS-4/EDIS-6),
  - EEC V PCM with **integrated** EI-ICM (EDIS-4/EDIS-6) (**integrated** EDIS),
  - EEC V PCM with **software** EDIS (currently only for 4-cylinder engines).



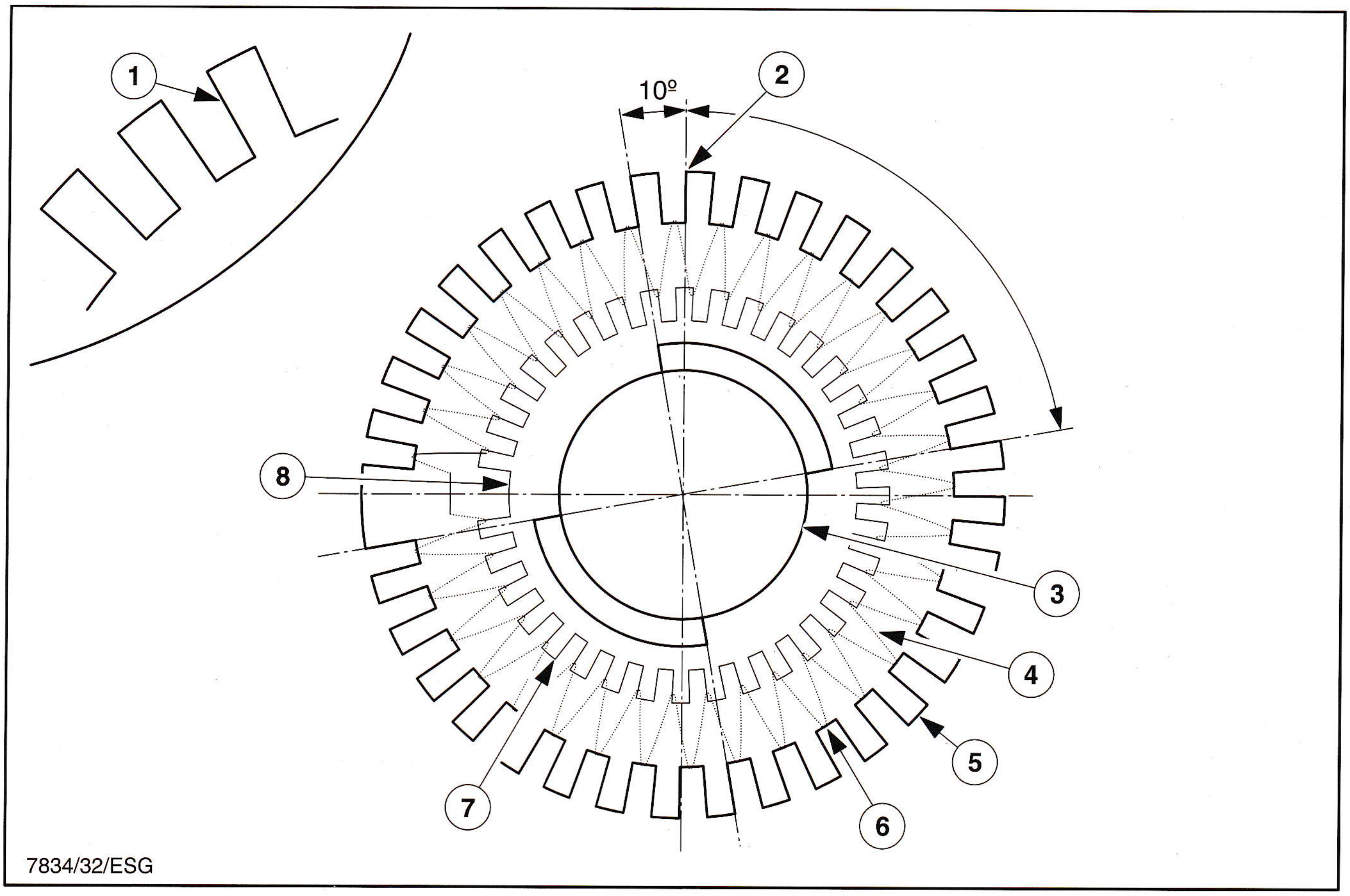
A External EI-ICM
B Integrated EI-ICM
C Software EDIS

1 CKP signal
2 PIP signal
3 SAW signal
4 Microprocessor

Electronic ignition system ignition control module (EI-ICM) (continued)

Software EDIS (SWEDIS)

- The current EEC V hardware and strategy makes it possible to work fast enough to process the incoming CKP signals directly, calculate the spark angle and control the primary circuit of the EI coils.
- The incoming (analogue) CKP signal is converted into a (digital) rectangular signal, produced on the negative edge of the CKP signal. The rising edge of the rectangular signal is used by the EEC V PCM to calculate the engine speed and crankshaft position in relation to the gap in the teeth on the flywheel or pulse rotor.
- PIP is no longer an input signal and must be produced in the PCM software. It can no longer be measured externally since it is no longer visible. It is set 10 degrees before top dead center (TDC) and its state is determined afresh every 90 crankshaft degrees (4-cylinder engine).
- A calculation is made for every PIP edge. This means that each PIP edge has the highest priority and the air mass, fuel metering etc. are calculated anew.



1 Rising edge
2 TDC position
3 PIP
4 CKP signal
5 Rectangular signal
6 Production of rising edge of rectangular signal
7 Ring gear
8 Gap in teeth 90 degrees before TDC

Crankshaft position (CKP) sensor

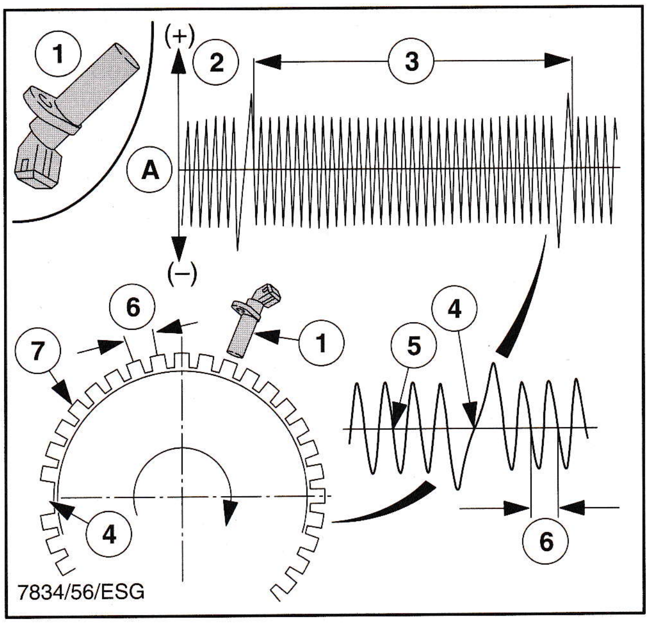
Additional information!

- An inductive sinusoidal voltage signal can best be illustrated and described by scanning a uniform tooth structure on the circumference of a wheel with the CKP sensor. Therefore, a flywheel with 36–1 teeth is used in the following description.

- Depending on the type of engine, at present Ford use either flywheels with 36 – 1 cast teeth on the outer edge of the flywheel or a ringear with 36 – 1 teeth on the crankshaft. The CKP signal is produced in the same way in both applications.

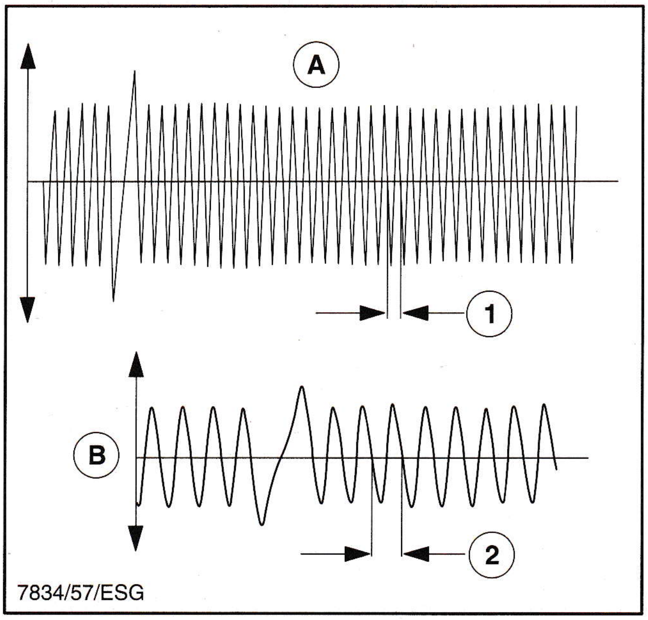
Illustration of a CKP signal

A CKP signal (sinusoidal voltage)
1 CKP sensor
2 Voltage (volts)
3 36–1 pulses per crankshaft revolution (360 degrees)
4 Reference mark (gap in the ring gear with 36–1 teeth) 90 degrees before TDC (4–cylinder) or 60degrees before TDC (6–cylinder)
5 Center of tooth
6 10 degrees tooth spacing
7 Ring gear with 36–1 teeth (flywheel or toothed ring)



Crankshaft position (CKP) sensor (continued)

- As the engine speed changes, the CKP voltage signal also changes.
- The engine speed is determined by the distance between the zero crossings of this voltage signal. The smaller this distance, the higher the engine speed. Thus, the frequency of the CKP signal changes as the engine speed rises and falls. The signal amplitude also increases proportionally to the engine speed.
- The signal amplitude depends greatly on the air gap between the sensor and the tooth and on the size of the tooth. A large tooth spacing (distance between the centre of the teeth) means a high amplitude. The reference mark (gap between the teeth) is recognized by the broad gap between the origins and produces a much higher voltage.
- In addition, the acceleration of the flywheel during every working stroke produces a change in the CKP signal.
- During the working stroke the combustion pressure acting on the piston accelerates the crankshaft and hence the flywheel. This can be recognized by the variation in the voltage at the higher frequencies of the CKP signal and higher amplitudes.

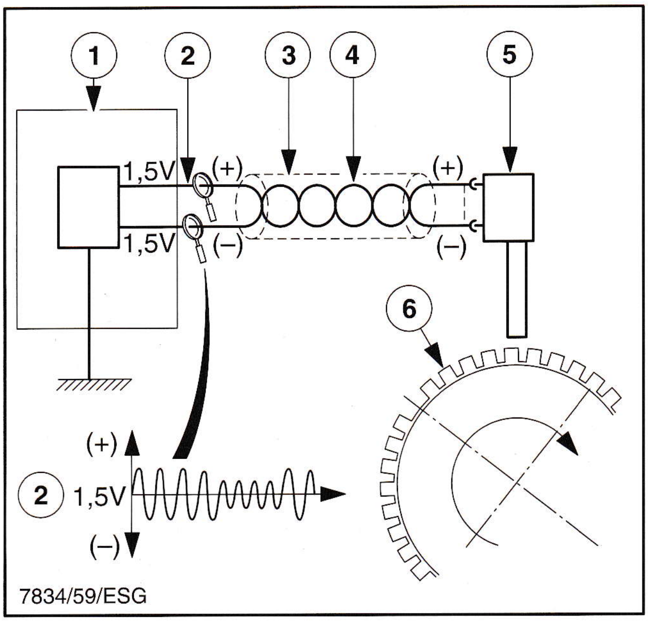


A Higher engine speed
B Lower engine speed
1 Origins: tiny gap
2 Origins: larger gap

Crankshaft position (CKP) sensor (continued)

Voltage offset

- The CKP sensor is a sensitive sensor in which the induced voltage would normally fluctuate between (+) and (–) around the 0 volt level.
- Therefore, to make the system less sensitive, the 0 volt level was moved by a **voltage offset** to a 1.5 volt level for both pins in the CKP sensor. This restricts the influence of the voltage fluctuations to a minimum.
- In addition, both cables of the CKP sensor can be shielded to protect against external influences such as voltage and radio interference by using screened cables or twisting the cables together so as to be unaffected by electromagnetic fields.

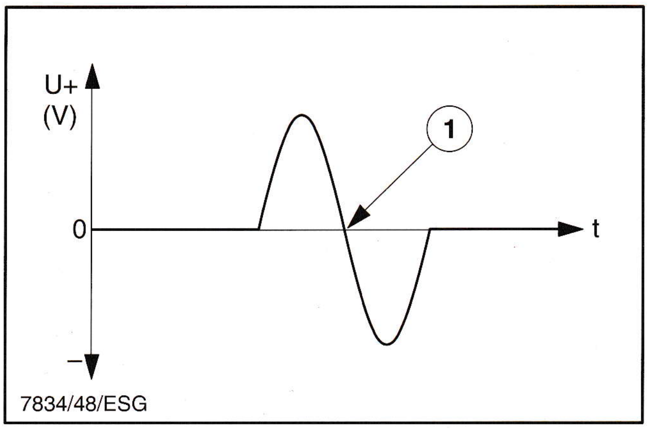


1 EEC V PCM
2 Voltage offset to 1.5 volts
3 Cable shielding
4 Twisted cables
5 CKP sensor
6 Flywheel/ring gear (36-1 teeth)

Camshaft position (CMP) sensor

Additional information!

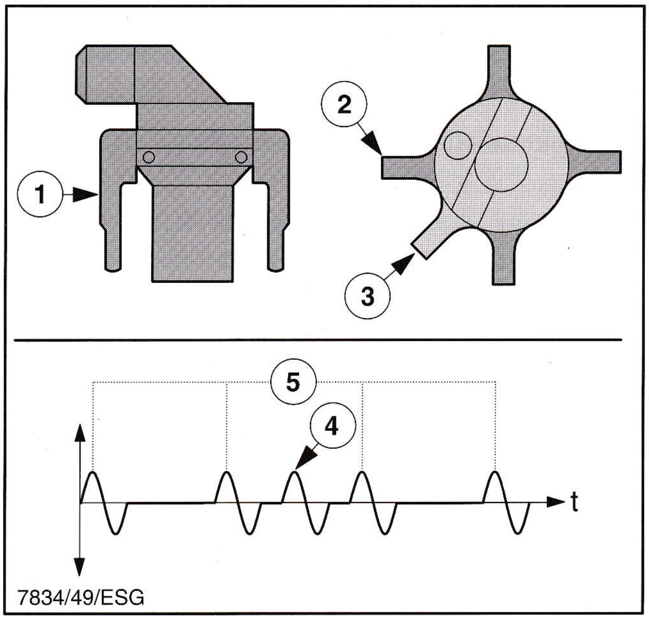
- The EEC V PCM detects the zero crossing of the CMP signal (center of the reference cam) to identify cylinder No. 1 at 46 degrees after TDC.
- The fuel injectors inject sequentially at an engine speed of more than 600 rpm (4-cylinder) and more than 400 rpm (6-cylinder).



1 Identification of cylinder no. 1 46 ° after TDC

CMP - Variable camshaft timing (VCT)

- In addition to the reference cam for identification of cylinder No. 1, four additional cams offset at 90 degrees are used by the CMP sensor to determine the position of the camshaft in relation to the position of the crankshaft.
- The PCM determines the required camshaft adjustment angle depending on the engine operating conditions as follows:
- At idle (low engine speed and closed throttle) the adjustment angle is based on the intake air temperature (IAT) and the engine coolant temperature (ECT) or cylinder head temperature (CHT).
- At part throttle and wide open throttle (WOT) the adjustment angle is based on the engine speed, engine load and throttle position.

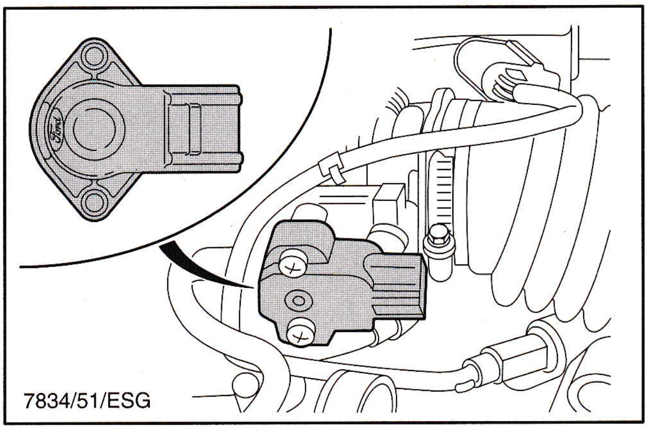


1 CMP sensor
2 VCT reference cam (4 cams)
3 Reference cam for cylinder No. 1 identification
4 Signal – cylinder No. 1 identification
5 Camshaft position reference signal

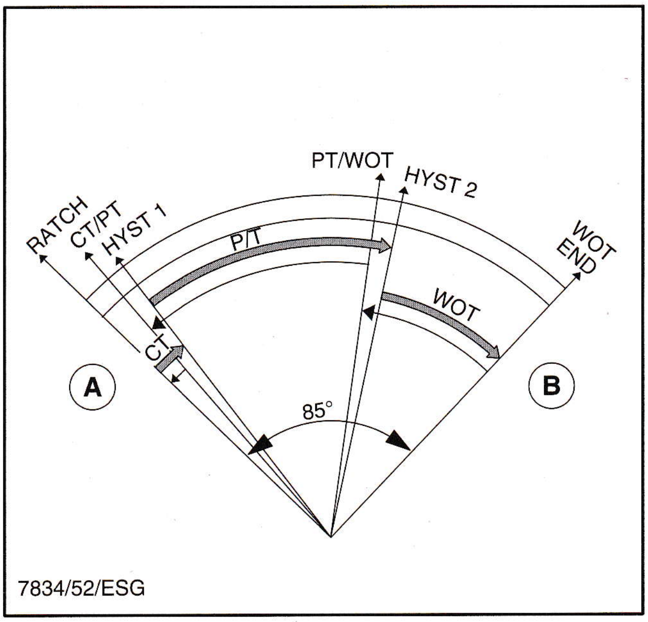
Throttle position (TP) sensor

Additional information!

- Starting from a reference voltage of 5 volts, the output voltage of the TP sensor is approximately 0.8 to 4.7 volts.
- This corresponds to a sensor potentiometer measuring range of 0 to 85 angular degrees.
- The analogue output voltage of the TP sensor is digitized in the EEC V PCM, a 1 degree movement of the throttle plate corresponding to approximately 9.6 counts, which means 85 degrees= 816 counts.
- "Ratch" means the lowest throttle position (shaft on the stop = idle). In this position the PCM counts 170 counts for example (= 17,7 degrees) and knows that the engine is idling.
- This value is stored in the KAM and used as a reference point for all possible throttle positions.
- The hysterisis ensures that the transition from PT to CT and from WOT to PT is not so abrupt. This transitional range acts like a buffer so that movements of the accelerator pedal do not lead directly to a change in mode.
- The EEC V PCM continuously compares the TP signal with the MAF or T-MAP signal (plausibility check).



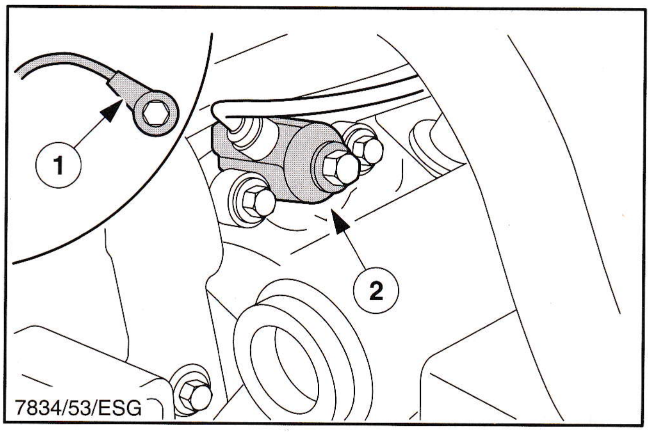
Throttle position (TP) sensor



A	Throttle position equals approx. 0.8 V
B	Throttle position equals approx. 4.7 V
RATCH	Idle position
CT	Closed throttle
PT	Part throttle
WOT (END)	Wide open throttle
HYST1	Hysterisis 1 (transition PT → CT)
HYST2	Hysterisis 2 (transition WOT → PT)

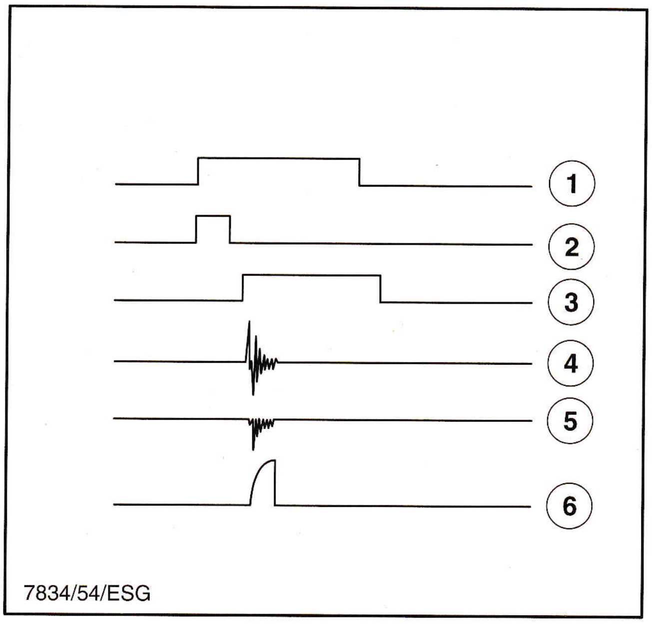
Knock sensor (KS)

- The installed position of the knock sensor (KS) on the cylinder block is extremely important. It must be such that the reception of knock signals is maximised and the reception of other noise signals is minimized.
- The linear knock sensing system works with one or two broad band knock sensors with a frequency of 6 to 22 kHz. Here, the strength (or energy) of the KS signal is checked within two crankshaft windows.



1 Knock sensor (KS)
2 KS installed position

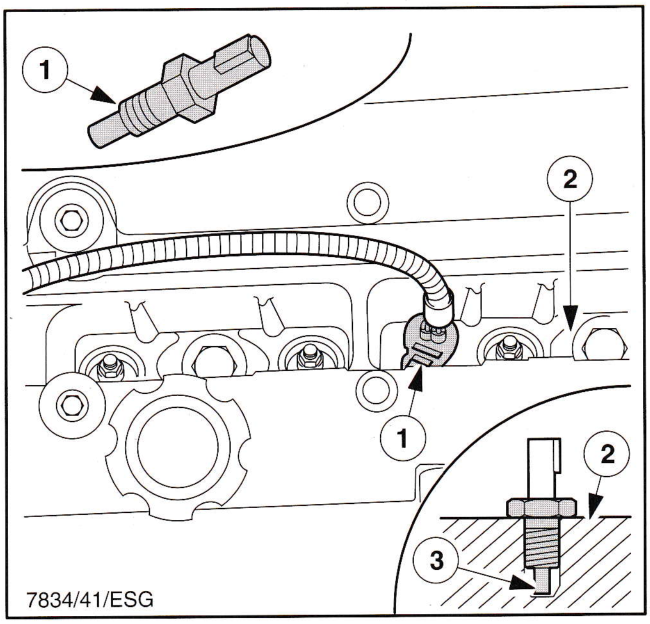
- In the **knock window** KS signals are checked in a crankshaft angular range in which detonation is expected.
- The **noise window** is used to determine the background noise level of the engine in which **no** detonation is expected.
- Detonating combustion is indicated when the ratio of "detonations/background noise" exceeds a certain limit (knock signals are stronger than noise signals).
- The KS signals passed to the analogue input signal adapting unit of the PCM (refer to pages 46 and 48) which carries out the signal correction, integration and analogue/digital conversion.
- Then, depending on the engine operating condition, the spark angle is retarded by 0,25 degrees/second for example for the corresponding cylinder.



1 PIP
2 Noise window
3 Knock window
4 KS sensor signal
5 Filtered KS signal
6 Integrated KS signal

Cylinder head temperature (CHT) sensor

- In some engines the cylinder head temperature (CHT) sensor supersedes the ECT sensor and the temperature sensor for the temperature gauge in the instrument cluster.
- The CHT sensor is screwed into the cylinder head and measures the temperature of the material instead of the temperature of the engine coolant.
- This ensures a more accurate temperature measurement if the engine is overheating (for example due to loss of coolant).
- Once the CHT sensor has been removed, a new sensor must always be fitted and tightened exactly to the specified torque. Otherwise it is possible that the sensor may be damaged (for example due to deformation of the sensor tip).
- The CHT sensor is a thermistor, namely a negative temperature coefficient (NTC) resistor).

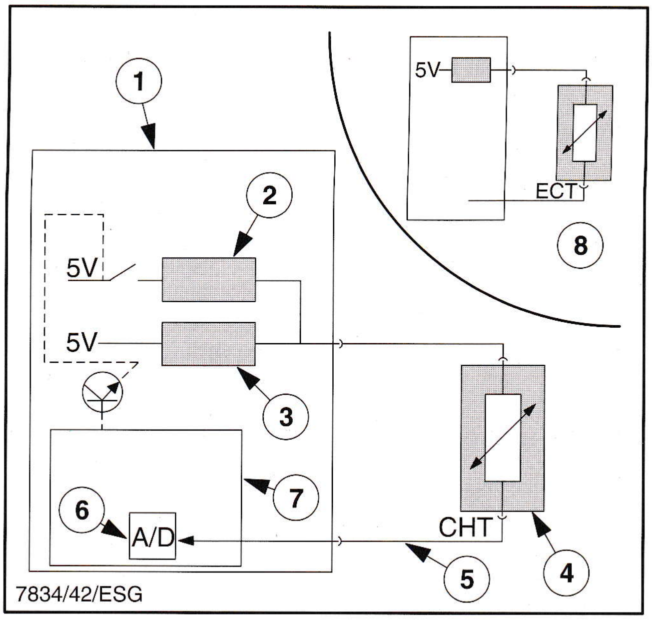


Installed position of the CHT sensor

1 CHT sensor
2 Cylinder head
3 Sensor tip

Cylinder head temperature (CHT) sensor (continued)

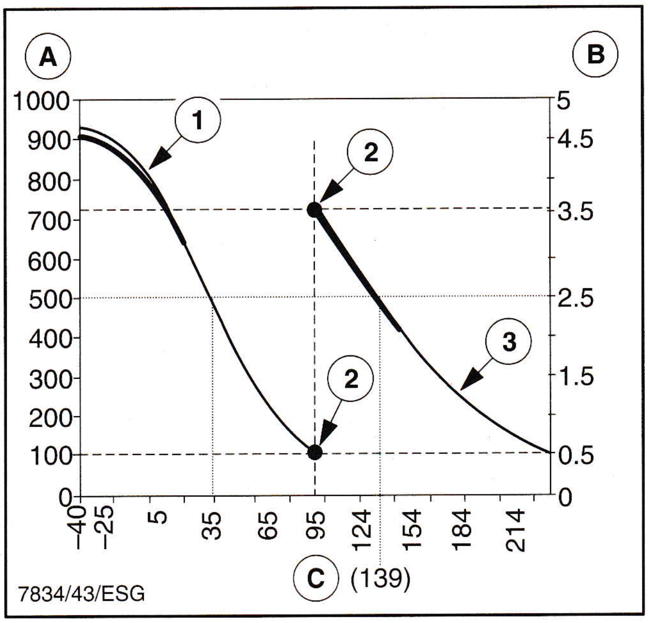
- The sensor is supplied with a voltage of 5 volts by the EEC V PCM.
- The output signal is an analogue voltage signal which is inversely proportional to the temperature of the material and proportional to the resistance.
- The voltage signal is digitized in the analogue/digital converter and passed on in the form of digital values (counts) to the microprocessor which translates the corresponding temperature values.



1 EEC V PCM
2 Second resistor (“pull up” resistor)
3 First resistor
4 CHT sensor (NTC)
5 Sensor output signal
6 Analogue/digital converter
7 Microprocessor
8 ECT sensor comparison

Cylinder head temperature (CHT) sensor (continued)

- The resolution of the CHT sensor is not sufficient at high temperatures to adequately cover the entire temperature range from – 40°C to 214°C. Therefore, the temperature characteristic is shifted by incorporating a resistor.
- The first characteristic extends from a material temperature of – 40°C to approximately 95°C. A transistor in the PCM then brings in a second "pull up" resistor to expand the sensor signal function. This second characteristic extends from a material temperature of approximately 95°C to 214°C.
- Example: a sensor output voltage of 2.5V (= 500 counts) can mean a material temperature of both 35°C and 139°C (refer to the graph) depending on which characteristic the voltage value is applied to. When the "pull-up" resistor is switched in, the microprocessor applies the digital value "500 counts" to the second characteristic. This means that the material temperature is in the higher temperature range (in this case 139°C).



A Counts
B Voltage (volts)
C Material sensor temperature
1 First characteristic
2 Switching point of "pull-up" resistor
3 Second characteristic

CHT signal use

- Fuel metering
- Idle air control (IAC)
- Spark angle calculation
- Evaporative emission (EVAP) system
- Cooling fan control
- Actuation of the temperature gauge and powertrain warning indicator (engine overheating safety function) in the instrument cluster by means of the SCP data bus.

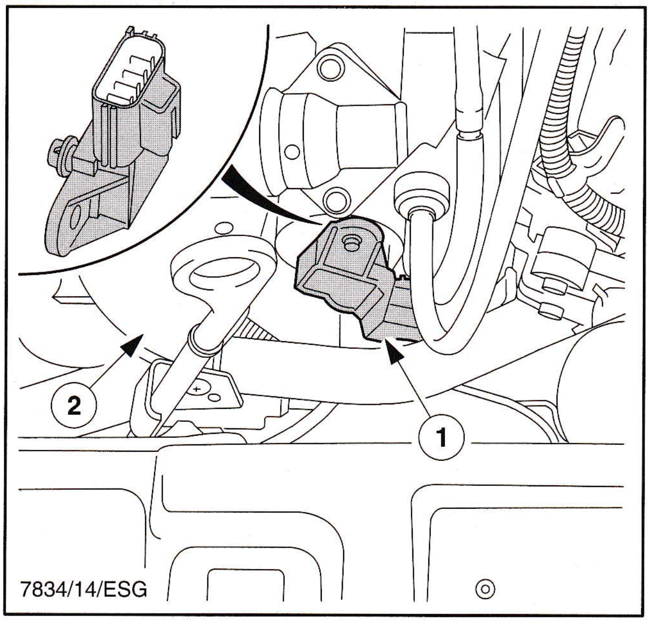
Temperature and manifold absolute pressure T-MAP sensor

- On some engines the manifold absolute pressure (MAP) sensor with the integrated intake air temperature (IAT) sensor (**T-MAP = T**emperature and **M**anifold **A**bsolute **P**ressure) takes the place of the mass air flow (MAF) sensor (refer to "speed density" in Lesson 2).

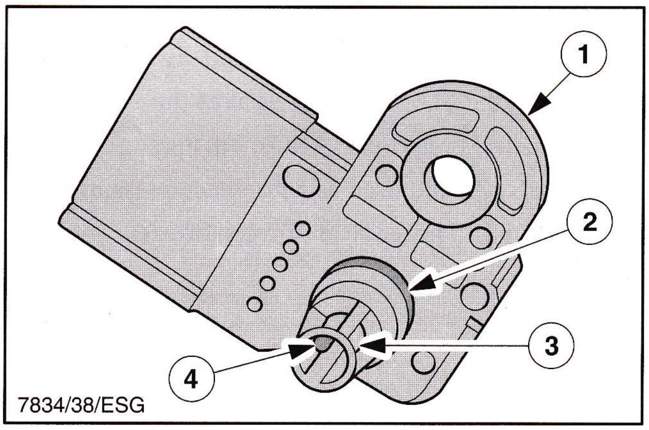
- The T-MAP sensor is able to measure the absolute intake manifold pressure to 115 kPa and the temperature of the intake air flowing through.

- The sensor is mounted directly on the intake manifold and sealed against atmospheric pressure (externally) with an O-ring seal. The opening for measuring the intake manifold pressure and the intake air temperature (IAT) sensor element project into the intake manifold.

- When the T-MAP sensor is fitted, it is important to make sure that the sensor is seated correctly in the intake manifold to prevent air leaking into the intake manifold from the outside.



Installed position of the T-MAP sensor
(1.25L Zetec–SE in Fiesta shown)
1 T-MAP sensor
2 Intake manifold



1 T-MAP sensor
2 O-ring
3 Pressure measuring opening
4 IAT sensor element

Temperature and manifold absolute pressure (T-MAP) sensor (continued)

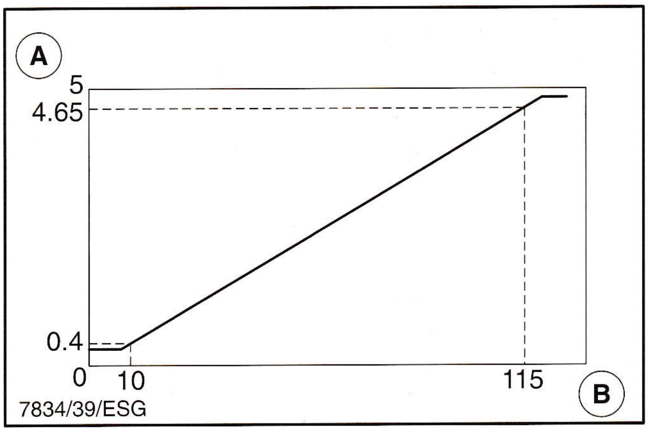
- The T-MAP sensor housing contains a piezo-pressure sensor element (MAP sensor) and the electronic circuits for signal amplification and temperature equalisation.

- The IAT sensor element is a hot wire (NTC) resistor. As a result of a special coating process, the MAP and IAT sensor elements are resistant to vapours and moisture in the intake manifold.

- The T-MAP sensor receives a reference voltage of 5 volts from the EEC V PCM.

- The output signal of the MAP sensor is an analogue voltage signal which changes in proportion to the prevailing manifold absolute pressure (MAP): A high manifold absolute pressure (wide open throttle) means a high voltage and a low manifold absolute pressure (closed throttle) means a low voltage.

- With the ignition switched on and a wide open throttle, the MAP sensor measures the barometric pressure (BARO). This is stored in the KAM and used as a reference pressure for the manifold pressure at different loads.



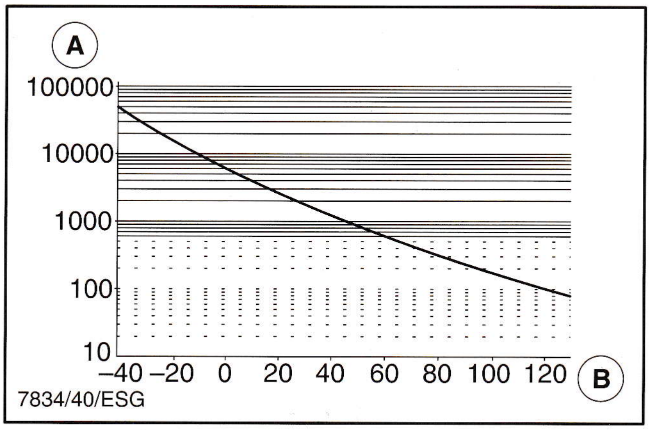
Analogue output signal of the T-MAP sensor

A Voltage (volts)

B Manifold absolute pressure (kPa)

Temperature and manifold absolute pressure (T-MAP) sensor (continued)

- The IAT sensor element also sends an analogue voltage signal to the PCM. The temperature range (falling temperature characteristic) of the IAT sensor extends from – 40°C (nominal resistance approx. 48 kΩ) to 130°C (nominal resistance inately 85 Ω).
- At an intake air temperature of 20°C the nominal resistance is 2.5 kΩ +/– 5%.
- The analogue voltage signals are digitized in the analogue/digital convertor and passed on to the microprocessor in the form of digital values (counts).



Characteristic of IAT sensor element

A Resistance (Ω)

B Intake air temperature (°C)

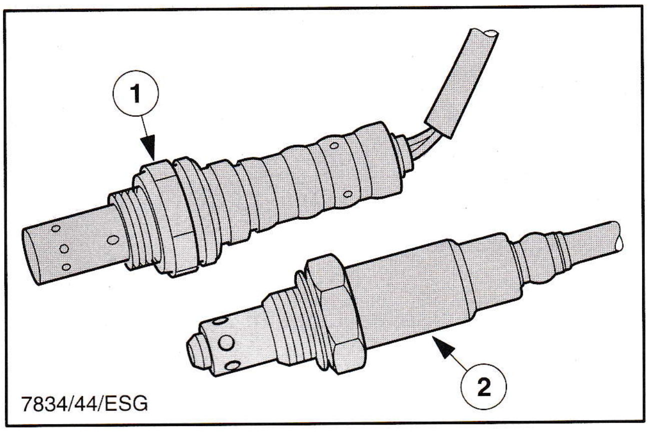
T-MAP signal use

- Air mass calculation
- Fuel metering
- Spark angle calculation
- Idle air control (IAC)

Heated oxygen sensors (HO2S)

Additional information

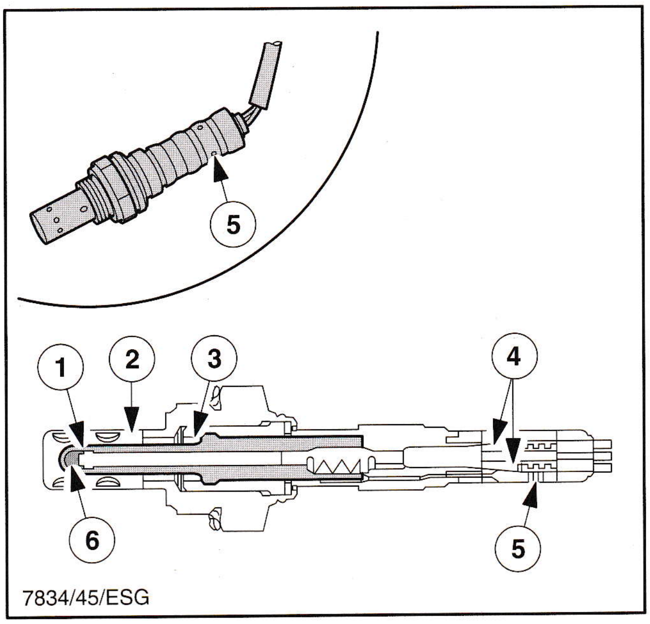
- At present, two types of heated oxygen sesors are used:
  - **NTK Heated oxygen sensor** (Ka, Fiesta, Escort and Mondeo, all engines. Focus Zetec-E and Focus Zetec–SE from 2001 MY onwards).
  - **Bosch planar heated oxygen sensor**: (Puma: 1.7 Zetec–SE–VCT, Focus Zetec–SE, 2000 MY. Scorpio, Galaxy and Transit: all engines).



1 NTK heated oxygen sensor
2 Planar heated oxygen sensor (Bosch LSF4)

NTK heated oxygen sensor (HO2S)

- The NTK heated oxygen sensor is a conventional, 4-pole, thimble-shaped heated oxygen sensor.
- The sensor is exposed to the air through 4 openings at the upper end of the protective sleeve. On the inside of the protective sleeve there is Goretex material which allows exterior air through but prevents moisture entering.
- The sensor heater can reach its normal operating temperature of 350°C in 10 seconds, depending on actuation.

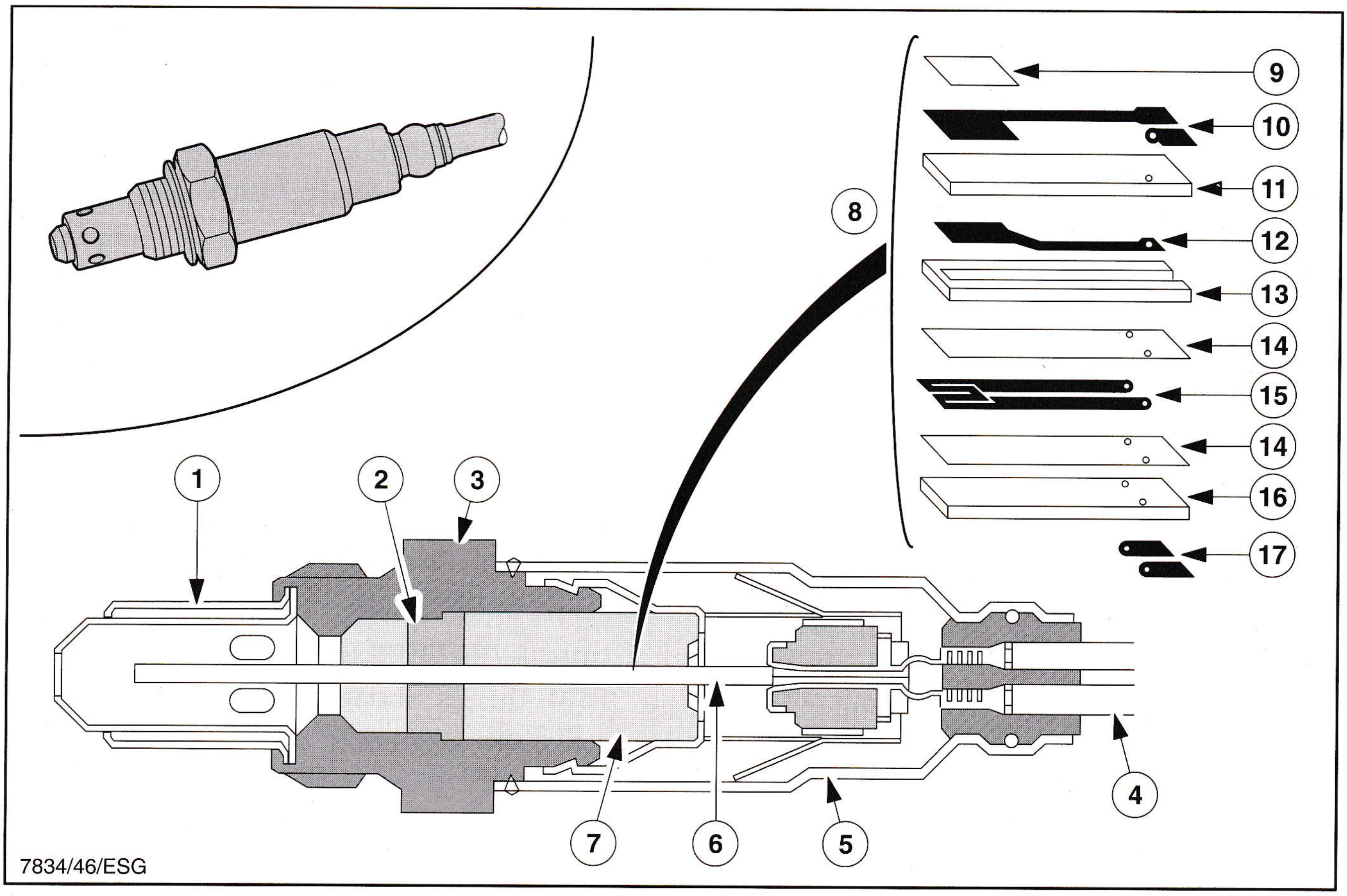


1 Sensor ceramic material
2 Protective tube
3 Seal
4 Goretex material
5 Air openings in protective sleeve
6 Reference air chamber (exterior air)

Heated oxygen sensors (HO2S) (continued)

Bosch planar heated oxygen sensor (HO2S)

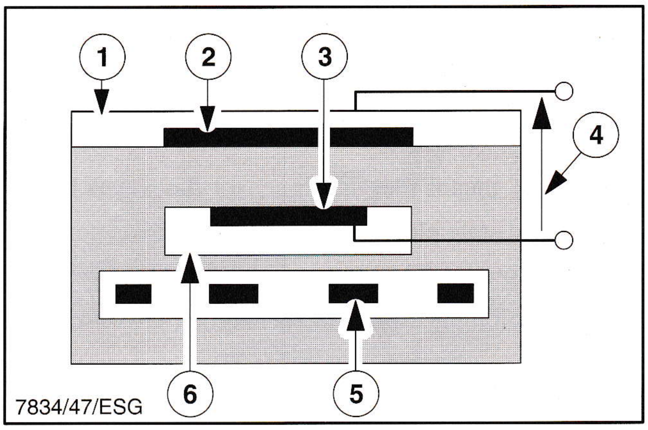
- The planar heated oxygen sensor is a development of the pencil-shaped heated oxygen sensor.
- "Planar" means that in this sensor flat sheets form the solid state electrolyte in contrast to the pencil-shaped sensor. The planar sensor element is shaped like an elongated plate of rectangular cross-section.
- The individual operating layers are produced by screen printing.
- The laminating (coating) of the different printed sheets makes it possible to integrate a heating element in the sensor element.
- A ceramic sealing package holds the planar sensor element in the sensor housing. The double-walled protective tube protects the sensor element particularly effectively against excessive thermal and mechanical loads.



1 Double-walled protective tube
2 Ceramic sealing package
3 Sensor housing
4 Connecting cable
5 Protective sleeve
6 Planar sensor element
7 Ceramic supporting tube
8 Operating layers
9 Porous protective layer
10 External electrode (+)
11 Sensor sheet
12 Internal electrode (–)
13 Reference air duct sheet
14 Insulating layer
15 Heating element
16 Heating element sheet
17 Connecting contacts

Heated oxygen sensors (HO2S) (continued)

Bosch planar heated oxygen sensor (HO2S)



- Layers of the planar sensor:

1 Exhaust gas area
2 External electrode (+)
3 Internal electrode (–)
4 Sensor voltage (volts)
5 Heating element
6 Reference air duct

- Particular features of the planar sensor:
  - rapid actuation of lambda control,
  - stable control characteristic,
  - minimal heating power requirement,
  - exposure to air through connecting cable,
  - compact size and low weight.

- The sensor heater reaches its operating temperature of 350°C in 10 seconds.

Charateristic shift downward (CSD)

(NTK and planar heated oxygen sensors)

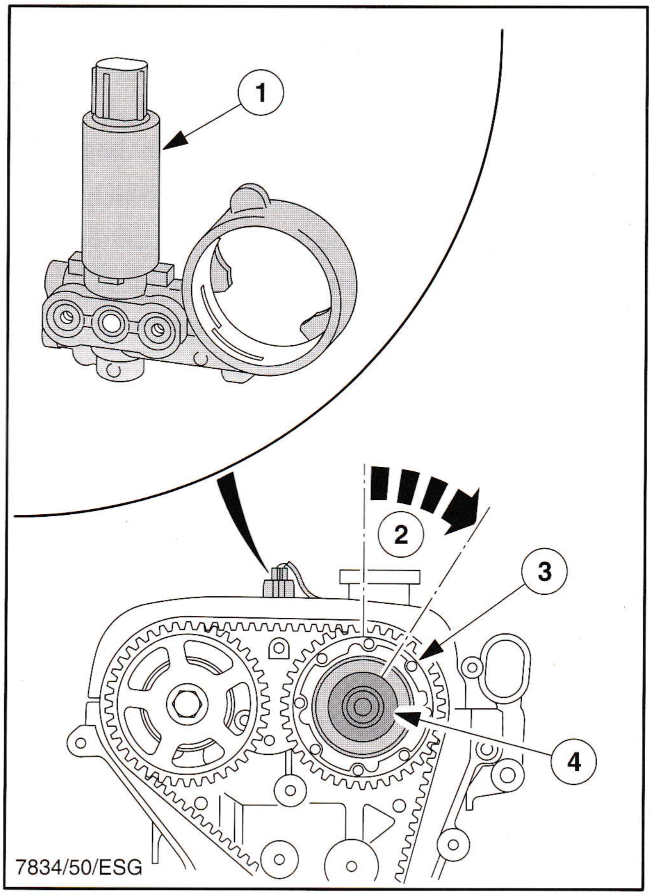
- The characteristic shift downwards (**CSD**) is used to identify a faulty HO2S. A deviation is caused by contamination in the reference air chamber or reference air duct in the HO2S (for example due to ingress of water, exhaust gas or fuel). The measured sensor output voltage is then less than 0 volts, which means that it is negative.

- Causes of contamination can be:
  - cracked HO2S material or leakage past the seal,
  - entry of water due to a faulty housing, connector or cable insulation.

- An HO2S output voltage of less than 0 volts, caused by the CSD, is detected by the EEC V PCM. The EEC strategy then reacts with appropriate adjustments.

Solenoid valve of VCT adjusting unit

- The solenoid valve controls the oil pressure in the variable camshaft timing (VCT) adjusting unit according to the actual engine operating state in order to achieve the required camshaft adjustment angle.
- It is actuated variably by the EEC V PCM by pulse width modulation (PWM) signal.
- The EEC V PCM recognizes three engine operating states to determine the required camshaft position:
  - idle (low engine speed and closed throttle), based on the intake air temperature (IAT) and engine coolant temperature (ECT) or cylinder head temperature (CHT);
  - part throttle and wide open throttle, based on engine load, engine speed and throttle position (TP);
  - malfunction: if the PCM detects a fault in the system, the solenoid valve is no longer supplied with current; the VCT adjusting unit returns to its initial position in which camshaft adjustment is prevented.



1 Solenoid valve
2 Camshaft adjustment angle
3 Camshaft timing pulley
4 Camshaft adjusting unit

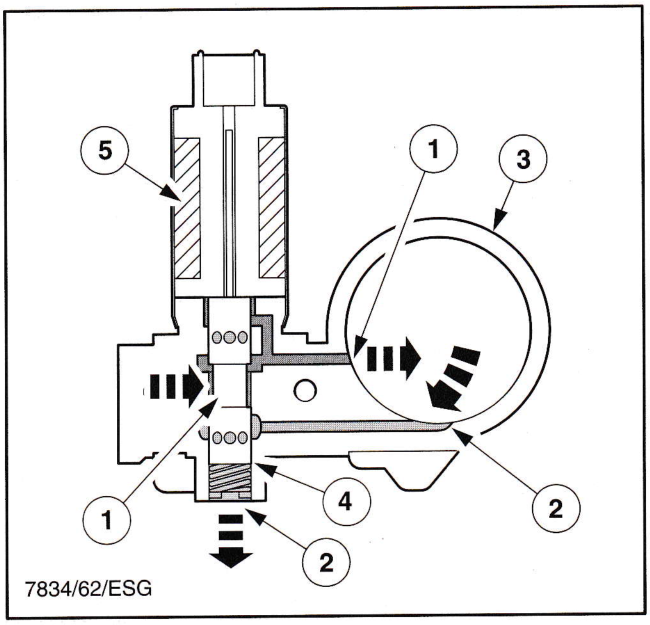
- When the engine is started, the solenoid valve keeps the VCT adjusting unit in its initial position until the engine oil pressure has built up sufficiently.
- To avoid a malfunction of the VCT adjusting unit at insufficient exterior and engine oil temperatures, this is activated by the PCM through the solenoid valve with a delay.
- The PCM obtains the information required for this from the ECT or CHT sensor and the IAT sensor.

Solenoid valve of VCT adjusting unit (continued)

- The EEC V PCM determines the position of the camshaft in relation to the crankshaft from the signals from the CKP and CMP sensors. A feedback control system establishes the duty cycle of the solenoid valve (times for which the PWM signal is switched on and off) according to the engine operating state, and determines the required control current (0 to 1 amp) for the coil of the solenoid valve.

Solenoid valve end position 1 (retarded position)

- The duty cycle of the **PWM signal is 0%**, this means that the solenoid valve is currentless.
- The spring holds the control piston in **end position 1**.

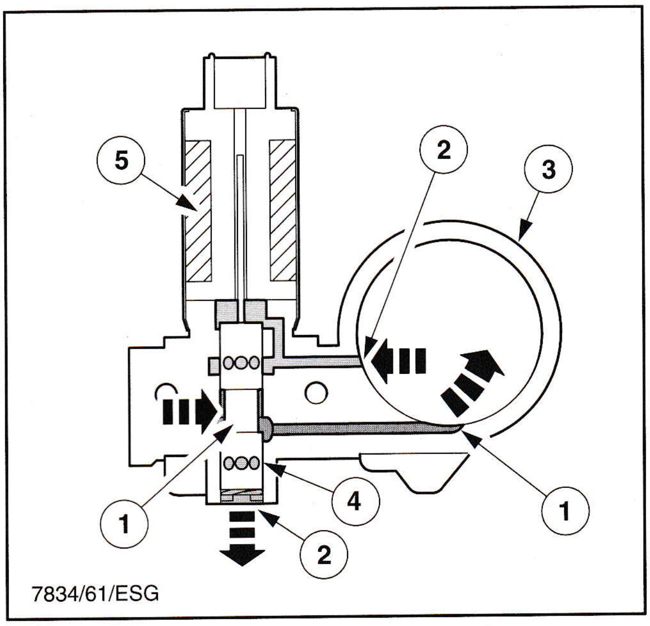


Solenoid valve end position 1

1 Oil under pressure
2 Returning oil
3 Oil flange
4 Control piston
5 Solenoid

Solenoid valve end position 2 (advanced position)

- The duty cycle of the **PWM signal is 100%**. A current of 1 amp flows through the coil of the solenoid valve.
- The thrust pin connected to the magnet core moves the control piston against the force of the spring to the **end position 2**.



Solenoid valve end position 2

Find the correct answer or fill in the gaps.

1. **Which of the following statements is correct?**

☐ a) The FEEPROM of the EEC V PCM is a read-only memory the contents of which can only be read by the CPU.
☐ b) The contents of the FEEPROM can only be erased and reprogrammed during a drive cycle.
☐ c) If the engine calibration is changed, the FEEPROM can be reprogrammed electronically with the aid of WDS.
☐ d) If the engine calibration is changed, the FEEPROM may only be reprogrammed by the manufacturer.

2. **How are the analogue sensor input signals digitised in the EEC V PCM?**

☐ a) The analogue signals are converted into digital values (counts) in an analogue/digital converter and passed onto the CPU.
☐ b) The analogue signals are stored as digital values in an analogue/digital converter and passed on if necessary.
☐ c) The analogue signals pass directly into the CPU and are digitized there.
☐ d) The analogue signals are passed on by the CPU direct to the control bus and digitized there.

3. **Which statement is true for the software EDIS?**

☐ a) The incoming analogue CKP signal is digitised in the integrated EDIS module and passed to the microprocessor in the form of a PIP signal.
☐ b) PIP is no longer an input signal and must be produced in the PCM software. It is no longer displayed.
☐ c) PIP is no longer an input signal and must be produced in the PCM software. However, it is still displayed.
☐ d) The PIP signal is eliminated completely.

4. **What does "voltage offset" mean and what does it produce?**

☐ a) The voltage induced by a sensor is boosted to obtain a constant voltage value.
☐ b) The output voltage of a sensor fluctuating about the 0 V level is shifted so that a voltage drop is prevented.
☐ c) The output voltage of a sensor fluctuating about the 0 V level is reduced so as not to exceed certain voltage limits.
☐ d) The output voltage of a sensor fluctuating about the 0 V level is boosted to a higher voltage level (for example 1.5 V) to make the system less sensitive to voltage fluctuations.

5. **The knock sensor (KS) informs the EEC V PCM of detonating combustion when**

☐ a) the engine is overheating.

☐ b) the ratio of "knocking noise/background noise" reaches a certain limit (knock signals equal to noise signals).

☐ c) the ratio of "knocking noise/background noise" exceeds a certain limit (knock signals stronger than noise signals).

☐ d) the engine is running at less than the required speed.

6. **The cylinder head temperature (CHT) sensor**

☐ a) supersedes the ECT sensor and measures the temperature of the coolant in the cylinder head.

☐ b) supersedes the ECT sensor and the temperature sensor for the temperature gauge. It measures the temperature of the material instead of the temperature of the coolant.

☐ c) supersedes the ECT sensor and measures the coolant temperature and material temperature of the cylinder block.

☐ d) is installed in addition to the ECT sensor to allow more accurate temperature measurement.

7. **The output signal of the T-MAP sensor is**

an analogue ...., which changes .... at the prevailing ....
.... A .... intake manifold pressure (closed-
................) means a ....voltage. A high ....
(.................. throttle) means a .... voltage.

8. **The solenoid valve of the variable camshaft timing (VCT) adjusting unit**

☐ a) is switched on at a specific throttle setting.

☐ b) continuously adjusts the camshaft in the "advance" direction on the basis of the PWM signal received from the PCM at part throttle.

☐ c) adjusts the camshaft in the "advance" or "retard" direction according to the particular engine operating conditions dependent on the PWM signal received and its duty cycle.

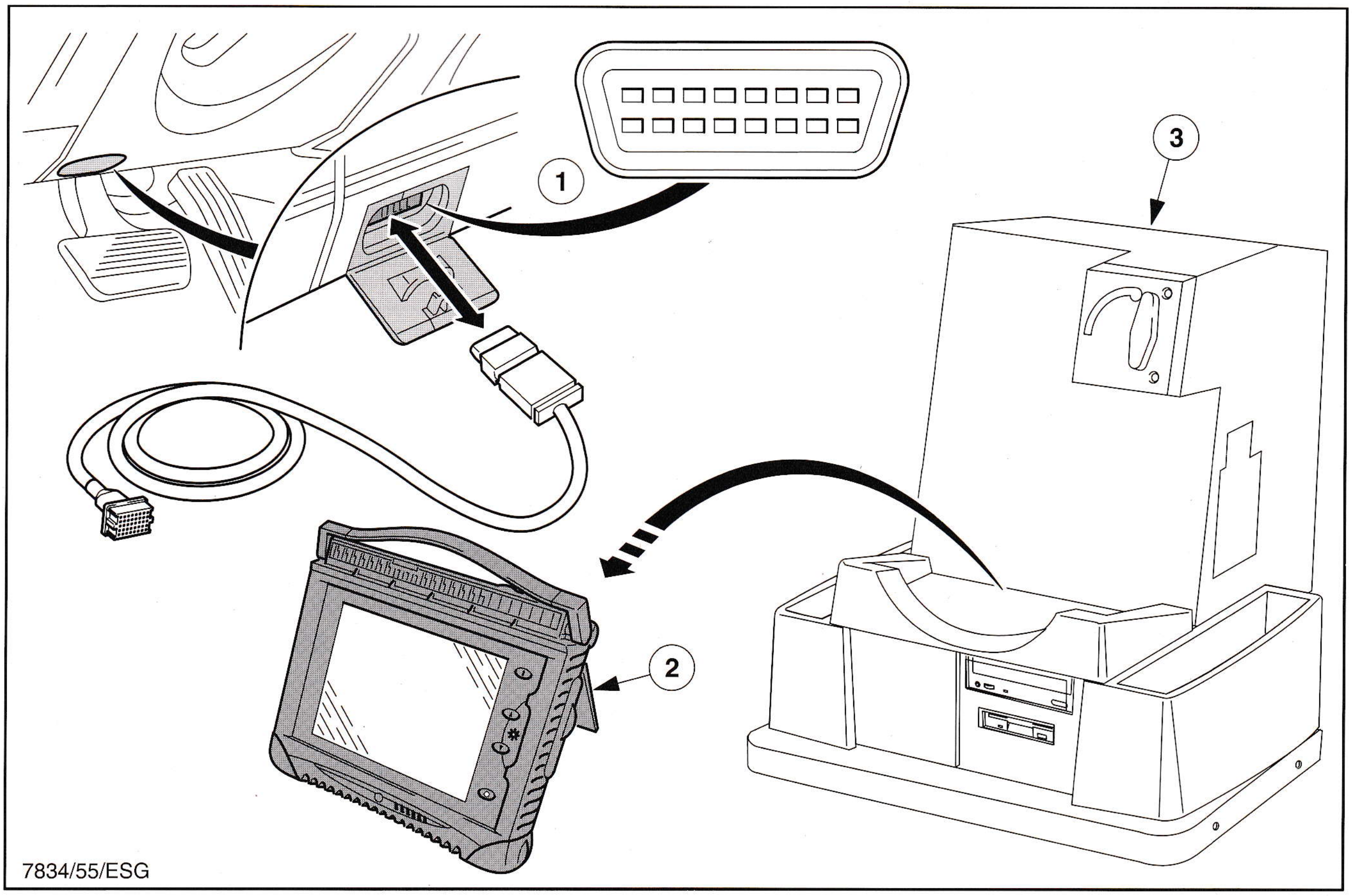
☐ d) has the function of adjusting the camshaft when the duty cycle of the incoming PWM signal is 50%.

Objectives

On completing this lesson, you will be able to:

- explain what "octane adjustments" is
- explain what is understood by a tyre size/axle ratio (TAR)
- explain in broad terms the function of failure mode effects management (FMEM)
- carry out vehicle diagnostics

Data link connector (DLC) and diagnostic equipment



1 Data link connector (DLC)
2 Portable WDS test unit (PTU)
3 Docking station with CD-ROM and disc drive

Reference: Training publication TN1012010S "Worldwide Diagnostic System (WDS)", CG 7843/S.

Octane adjustment

- The formerly customary octane adjustment (for example by disconnecting part of the plug with a bridging cable by hand) is no longer possible on current vehicles with the EEC V engine management system. This is also no longer necessary since the EEC V PCM can be electronically reprogrammed for any octane adjustment.
- In production the PCM in vehicles built in Europe is programmed to operate the engine on 95 octane. The ignition strategy takes account of this in determining the favourable base spark angle in all engine operating conditions.
- In service octane adjustment can be carried out with the aid of WDS by reprogramming (SCP flash reprogramming). A typical reason for such an adjustment would only be if the vehicle was being driven in a country with different fuel standards (lower octane rating).

Tyre size/axle ratio (TAR)

- The tyre size/axle ratio (**TAR**) of the particular model variant is stored in the EEC V PCM (currently still dependent on the type of engine).
- A change in the tyre size must be communicated to the PCM. Therefore, in service it is possible to carry out reprogramming (SCP flash reprogramming) with WDS.
- The PCM calculates the appropriate new parameters for the speedometer, trip computer and speed control system from the new TAR (ratio of the new tyre size to the existing axle ratio).

Failure mode effects management (FMEM)

- With earlier EEC IV systems a substitute value was always called up in the event of a fault to take the place of the faulty signal. A faulty ECT sensor was given for example the fixed signal value of 70°C corresponding roughly to the normal operating temperature of a warm engine. Consequently, this engine did not have normal running characteristics when cold.

- With the current EEC system a special software is used called failure mode effects management (FMEM) strategy, the function of which is to guarantee normal running characteristics of the vehicle as far as possible in spite of faulty sensors.

- If a fault is registered while the engine is running, the FMEM then applies an alternative vehicle strategy. **The FMEM action is always dependent on the nature of the fault discovered.**

- The EEC V PCM now contains comprehensive FMEM strategies, for example for some sensors and for the primary side of the EI coil and for all the EOBD monitoring systems with the exception of the catalytic converter.

- In the following, FMEM strategies of the EEC V engine management system are explained **with reference to a few examples**. All the monitoring systems are described in training publication TC3043027S "European On–board Diagnostics - EOBD", CG 7856/S.

FMEM strategies for a faulty engine coolant temperature (ECT) sensor

- As all the engines are equipped with either the ECT or the CHT sensor, a similar FMEM strategy can be applied for both sensors.

- The FMEM strategy for the ECT sensor is described in the following.

- The analogue/digital converter is interrogated by the microprocessor of the PCM and the counts (resulting from the analogue input signal of the ECT sensor) are converted into degrees Fahrenheit (°F). This value is then used to check whether the ECT sensor input signal lies outside specific limits or whether other causes of faults are present.

- If the value is ok, this is assumed to be the correct engine coolant temperature (ECT). The ECT sensor input signal is checked continuously.

- If the value is not ok, the EEC V PCM uses the last "correct value", namely the last "ok value" before the occurrence of the "not ok state" as the engine coolant temperature (ECT) value. Only if the fault is present long enough (specified time), is a fault code stored in the KAM and the FMEM activated as follows:

  – during engine starting (engine cranking) the IAT, CHT or transmission fluid temperature (**TFT**) are used as a substitute value for the engine coolant temperature (ECT);

  – while the engine is running a value calculated by the EEC V PCM is used.

Failure mode effects management (FMEM) (continued)

FMEM strategies with a faulty engine coolant temperature (ECT) sensor

- In every case, among other things the activation of the air conditioning system is prevented, the engine fan or fans are switched to operate continuously and the EGR system, when fitted, is switched off.

- The ECT value can be read out with the WDS as follows:

  - Start the data logger.
  - Select the "ECT" or "CHT" option.

Example of ECT:

- There is the option of looking either at the ECT voltage value (volts) or the ECT temperature (C°).
  Voltage: shows a modified form consisting of counts from which the PCM input voltage can be established.
  Temperature: shows the engine coolant temperature (ECT) value.
- If there is a fault in the system (for example if the connector of the ECT sensor has been disconnected), the voltage differs, which means that the counts no longer match. The FMEM is started.
- The temperature value (ECT) indicated in the WDS is then the FMEM value, namely the **substitute value calculated** by the PCM for the current fault.

NOTE: It could be assumed that the indicated FMEM value (for example 90°C) is the actual engine coolant temperature (ECT). Therefore, in every case the voltage value of the engine coolant temperature (ECT) should also be used for comparison (table showing ratio of voltage/temperature).

EI–FMEM strategies

NOTE: This strategy does not apply to software EDIS!

- If a malfunction occurs on the primary side of the EI coil or coils or there is a fault in the cable system between the EI-ICM and the EI coil or coils, this is registered in the PCM during the continuous self-test.

- The affected EI system ignition coil and hence also the affected cylinders are identified by the different ignition diagnostic monitor (IDM) signal from the EI-ICM to the PCM. When this is a fault which occurs continuously, an FMEM comes into operation.

- The following FMEM strategies can be applied:

  - Deactivation of the fuel injectors of the cylinders which are receiving no ignition spark (two fuel injectors per ignition coil).
  - The system switches to the open loop and a spark angle adjustment is made.
  - The EGR system (if equipped) and the air conditioning are switched off to reduce the engine load.

Find the correct answer or fill in the gaps.

1. **What is meant by "octane adjustment"?**

☐ a) Restriction of the engine speed by the PCM when using fuel of inferior quality.
☐ b) Advancing the most favourable base spark angle by reprogramming the EEC V PCM.
☐ c) Retarding the most favourable base spark angle by reprogramming the EEC V PCM.
☐ d) Retarding the spark angle at part throttle.

2. **The tyre size/axle ratio (TAR)**

☐ a) is contained in a specification table in the Technical Information System (TIS) with the aid of which corresponding adjustments can be made.
☐ b) is stored in the EEC V PCM and can be reprogrammed in service if the tyre size is changed.
☐ c) is stored in the EEC V PCM and must always be reprogrammed by the manufacturer if the tyre size is changed.
☐ d) is calculated anew whenever the engine is started, and stored in the KAM.

3. **What is the function of "failure mode effects management"?**

☐ a) To guarantee the normal running characteristics of the vehicle in spite of faulty sensors and actuators.
☐ b) To guarantee the normal running characteristics of the vehicle in spite of faulty actuators.
☐ c) To guarantee the normal running characteristics of the vehicle in spite of faulty sensors.
☐ d) To monitor and if necessary switch off the actuators.

List of abbreviations

The abbreviations conform to standard SAE J1930 with the exception of those marked with an asterisk (*).

ABS*	Anti-lock Brake System
A/C	Air Conditioning
ACCS*	Air Conditioning Cycle Switch
AIR	Secondary Air Injection
BARO*	Barometric Pressure
BDL*	Border Line Detonation
BPP	Brake Pedal Position
CHT*	Cylinder Head Temperature
CKP	Crankshaft Position
CMP	Camshaft Position
CO*	Carbon Monoxide
CPP	Clutch Pedal Position
CPU*	Central Processing Unit
CSD*	Characteristic Shift Downward
CT*	Closed Throttle
DLC	Data Link Connector
ECT	Engine Coolant Temperature
EDIS*	Electronic Distributorless Ignition System
EEC*	Electronic Engine Control
EEPROM	Electronically Erasable Programmable Read Only Memory
EGR	Exhaust Gas Recirculation
EI	Electronic Ignition
EOBD*	European On–Board Diagnostics
EPC*	Electronic Pressure Control

The abbreviations conform to standard SAE J1930 with the exception of those marked with an asterisk * (continued).

ESP* Electronic Pressure Control

EVAP Evaporative Emission

FEEPROM* Flash Electronically Erasable Programable Read Only Memory

FLI* Fuel Level Input

FMEM* Failure Mode Effects Management

FP Fuel Pump

HC* Hydrocarbons

HO2S Heated Oxygen Sensor

IAC Idle Air Control

IAT Intake Air Temperature

ICM Ignition Control Module

IFS Inertia Fuel Shutoff

IMRC Intake Manifold Runner Control

I/O Input/Output

IPATS* Integrated Passive Anti–Theft System

KAM* Keep Alive Memory

KS Knock Sensor

LOS Limited Operation Strategie

LTFT* Long Term Fuel Trim

MAF Mass Air Flow

MAP Manifold Absolute Pressure

MBT* Maximum Brake Torque

MFI Multiport Fuel Injection

MIL Malfunction Indicator Lamp

List of abbreviations

The abbreviations conform to standard SAE J1930 with the exception of those marked with an asterisk * (continued).

NOx*	Oxides of Nitrogen
NTC	Negative Temperature Coefficient
OSS	Output Shaft Speed
PAIR	Pulsed Secondary Air Injection
PATS*	Passive Anti-Theft System
PCM	Powertrain Control Module
PIP	Profile Ignition Pickup
PNP	Park Neutral Position
PSP	Power Steering Pressure
PT*	Part Throttle
PTU*	Portable Test Unit
PWM	Pulse Width Modulation
RAM	Random Access Memory
ROM	Read Only Memory
SAW	Spark Advance Word (Signal)
SCP*	Standard Corporate Protocol
SFI	Sequential Multiport Fuel Injection
SFTC*	Spark Fuel Traction Control
SPK*	Spark (spark angle)
SPK-ABS*	Spark – Absolute Maximum
SPK-FLEX*	Spark – Flexible limit
STFT*	Short Term Fuel Trim
TAR*	Tyre Size Axle Ratio
TDC*	Top Dead Center

The abbreviations conform to standard SAE J1930 with the exception of those marked with an asterisk * (continued).

TFT* Transmission Fluid Temperature

TIS Technical Information System

T-MAP Temperature and Manifold Absolute Pressure

TP Throttle Position

TWC Three Way Catalytic Converter

V batt* Battery Voltage

VCT* Variable Camshaft Timing

VMV* Vapour Management Valve

VSS Vehicle Speed Sensor

WDS* World-wide Diagnostic System

WOT Wide Open Throttle

Answers to the test questions

Lesson 1 – General

1. c)

2. b)

3. c)

4. d)

5. a)

Lesson 2 – ECC V fundamentals

1. c)

2. b)

3. d)

4. c)

5. c)

6. b)

7. a)

8. b)

9. c)

Lesson 3 – Components

1. c)

2. a)

3. b)

4. d)

5. c)

6. b)

7. An analogue **voltage signal** which changes **proportionally** to the prevailing **absolute manifold pressure**. **A low** manifold absolute pressure (closed **throttle**) means a **low** voltage. A high **manifold absolute pressure** (**wide** open throttle) means a **high** voltage.

8. c)

Lesson 4 – Diagnostics

1. c)

2. b)

3. c)