HFM Gasoline Injection and Ignition System

A. General

The HFM gasoline injection and ignition system is a further development of the LH and EZL.

The basic system of the HFM electronic gasoline injection system is a rotorless, electronically controlled injection system.

The functions of fuel injection, ignition and idle speed control are combined in the HFM control unit (N3/4).

The abbreviation HFM means

HF = hot film

M = engine management

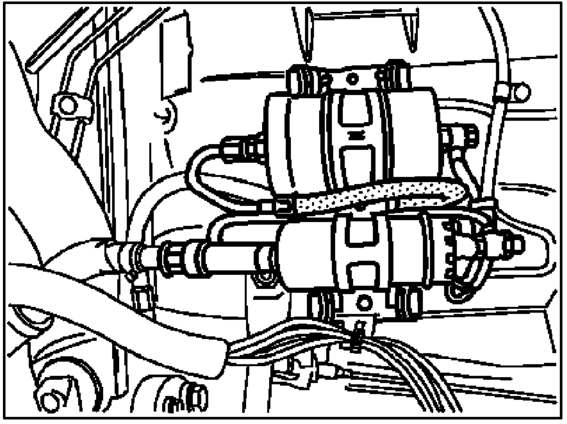
The principle features of the fuel injection and ignition system are:

, Hot film air mass sensor
, Electronically controlled injection valves
, Idle speed control actuator
, Distributorless high voltage distribution

B. Fuel supply

a) Fuel pump set

Depending on the vehicle model, the fuel pump set is equipped with one or two fuel pumps. If two pumps are fitted, these are connected in series at the fuel end. The pumps deliver the fuel from the fuel tank through a fuel filter into a fuel rail. The fuel pumps operate during the starting process and so long as the engine is running. For safety reasons, they are actuated for only about 1 second with the ignition "ON" (full running safeguard).



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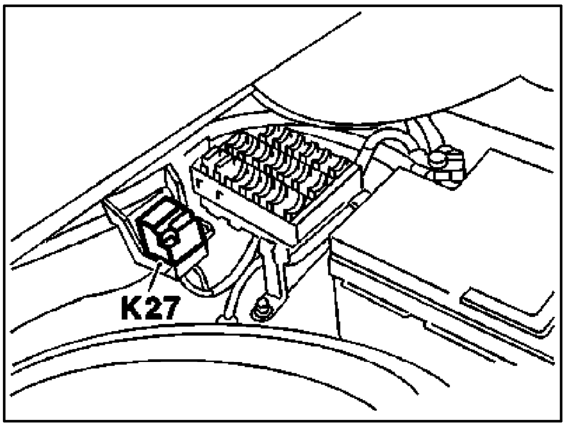
Shown on model 124

b) Actuation of fuel pump

The fuel pumps are actuated by the HFM control unit via the fuel pump relay (K27). The rpm recognition for the HFM control unit is provided by the TN signal or, if no TN signal is recognized, by the camshaft position sensor signal.



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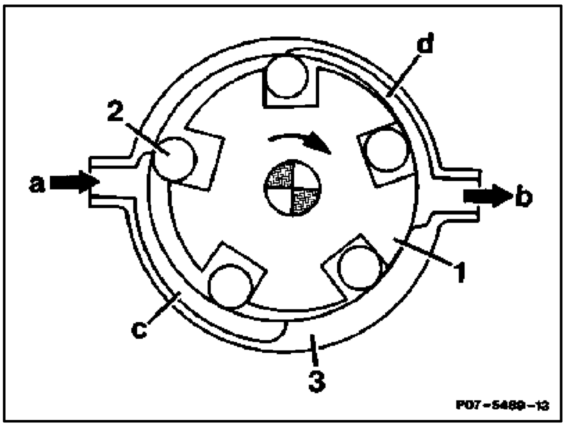
c) Operation of Bosch fuel pump

The fuel pump is a roller-cell pump and consists of the fuel pump housing with rotor ring (3), the rotor disk (1) and the rollers (2). As a result of the excentric positioning of the rotor disk (1) relative to the rotor ring (3), a volume change occurs between the rollers during each revolution, which produces the suction and pressure effect of the pump. The rollers are pushed to the outside as a result of the centrifugal force and act as a seal.



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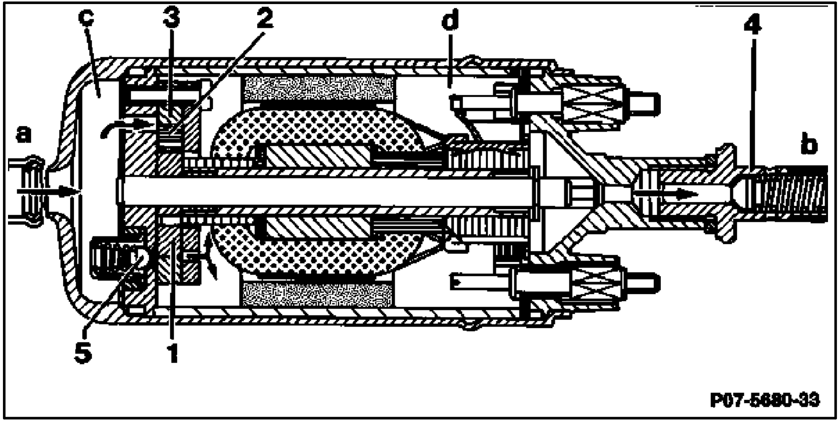
1	Rotor disk
2	Roller
3	Fuel pump housing with rotor ring
a	Suction side
b	Delivery side
c	Fuel pressureless
d	Fuel pressurized

1 Rotor disk
2 Roller
3 Fuel pump housing with rotor ring
4 Check valve
5 Pressure relief valve
a Suction side
b Delivery side
c Fuel pressureless
d Fuel pressurized



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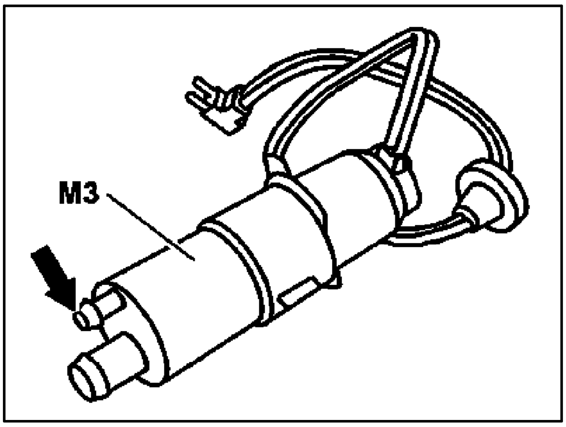
With its delivery of at least 90 l/h at 11.5 V (current consumption 6 to 10 A), the fuel pump supplies more fuel than the engine needs, as a result of which the engine is always supplied with cool fuel. The excess fuel flows back into the tank.

In the event of a pressurize to more than 8 bar (eg. as a result of constriction in the fuel feed or return pipe), a pressure relief valve opens and connects the suction and delivery ends within the fuel pump, which prevents a further rise in pressure.

When the engine is switched off, a check valve prevents the residual pressure being reduced through the fuel pump. This largely prevents the formation of vapor bubbles in the fuel injection system and improves warm starting characteristics. The check valve is located in the screw union and can be replaced separately.

Pierburg fuel pump

The fuel pump (M3) is a two-stage design. A side channel pump is located in the pump housing as a pre-stage and an internally geared pump as the main stage. The side channel pump supplies the fuel with a pre-pressure of 0.1 - 0.2 bar to the internally geared pump. The gas which is separated out in the side channel pump flows back through the vent connection (arrow) to the fuel tank.
The power consumption of the fuel pump (M3) is 8 - 12 A.



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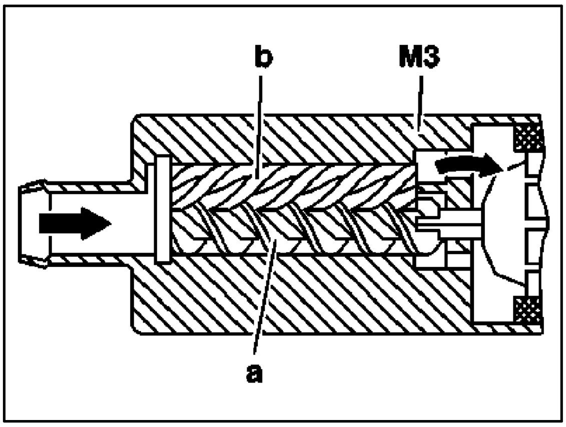
A screw spindle pump (M3) has been fitted as of June 1994. A drive spindle (a) and a driven spindle (b) are located in the fuel pump housing. These rotate in the opposite direction to each other and pump the fuel in the axial direction (arrow).
The current consumption is 5 to 9 A.



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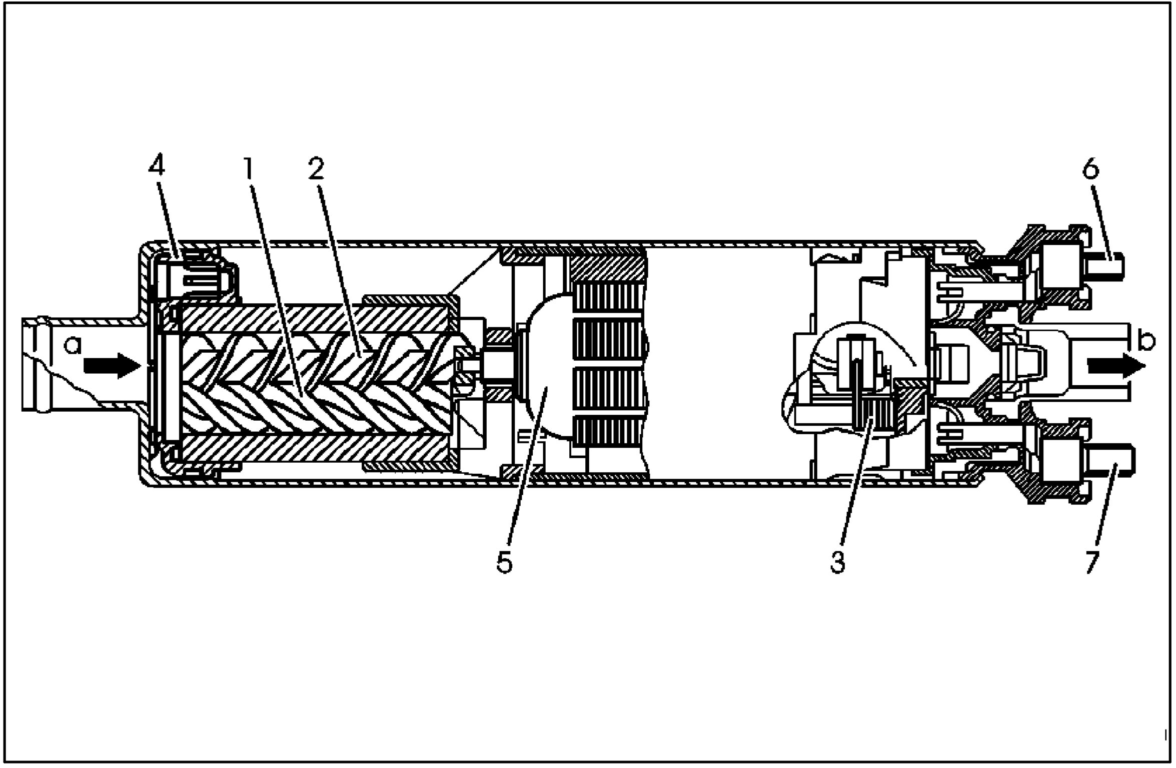

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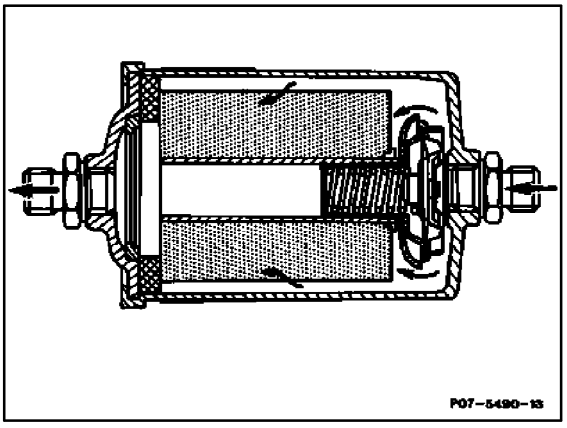
1 Driven spindle
2 Drive spindle
3 Brush spring
4 Valve plate
5 Electric motor
6 Positive terminal (M4 thread)
7 Negative terminal (M5 thread)
a Fuel inlet
b Fuel outlet

d) Fuel filter

The fuel filter is a micro-filter with a paper filter element.
A damper is installed on the fuel feed side in order to avoid fuel noises. The fuel flow direction is indicated by an arrow on the fuel filter housing.



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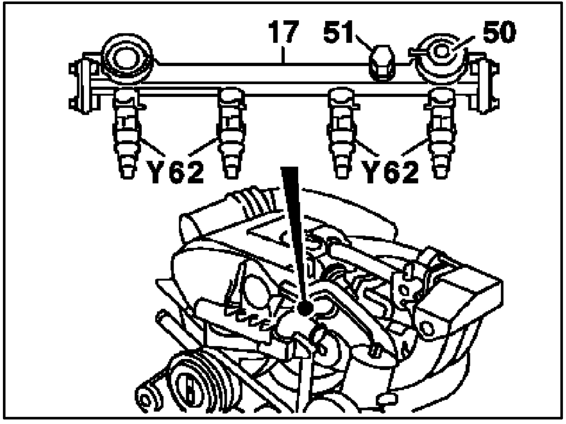
e) Fuel rail

The fuel passes through the fuel rail (17) to the injection valves (Y62). The diaphragm pressure regulator and the pressure test connection (51) are also integrated in the fuel rail.
The pressure test connection (51) with valve is used for testing the fuel pressure and also for releasing the fuel pressure during removal and installation operations.

Shown on engine 111



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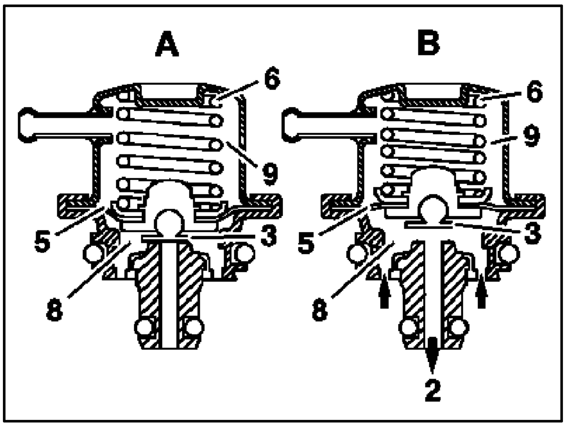
f) Diaphragm pressure regulator

The pressure regulator (50) is installed in the fuel return of the fuel rail (17). It is diaphragm-controlled overflow pressure regulator which regulates the fuel pressure between about 3.2 and 4.2 bar depending on the absolute pressure in the intake manifold. This control pressure cannot be altered.

Full load operation

At full load, no vacuum exists in the spring chamber (9), which is separated from the fuel chamber (8) by a diaphragm (5). If the set pressure is exceeded, the diaphragm (5) is forced against the compression spring (6). The valve (3) which is attached to the diaphragm opens the passage for the return flow (2) and the excess fuel flows back pressureless to the fuel tank.



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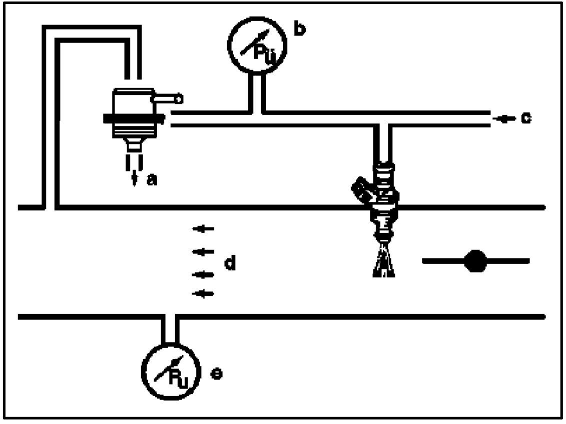
A Valve closed
B Valve open

Pressure ratio at fuel load
Difference in pressure between fuel pressure and intake manifold pressure is about **4.0 bar.**



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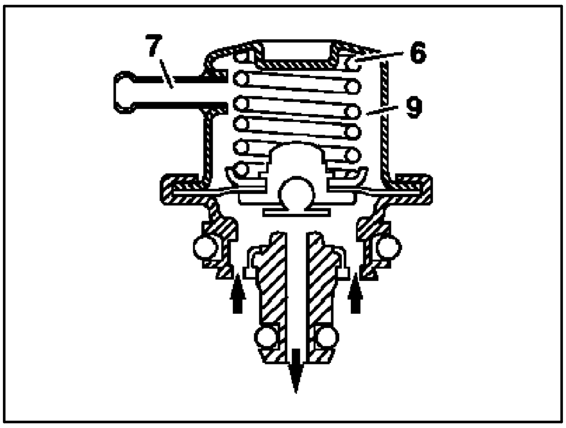
Schematic presentation
- a Fuel return to fuel tank
- b Fuel pressure about **4.0 bar**
- c Fuel feed from fuel pump
- d Intake manifold
- e Intake manifold pressure **0 bar**

Idle speed, part load operation
The spring chamber (9) is connected to the intake manifold by an intake pipe connection (7). The vacuum of the intake manifold acts via the diaphragm on the spring (6), as a result of which the fuel pressure is reduced by the intake manifold vacuum which exists at that moment. The result is that the fuel pressure in the fuel rail is dependent on the intake manifold pressure and the pressure drop through the fuel injection valves is identical no matter the position of the throttle valve. As a result, the quantity of fuel injected is determined solely by the opening time of the injection valves.



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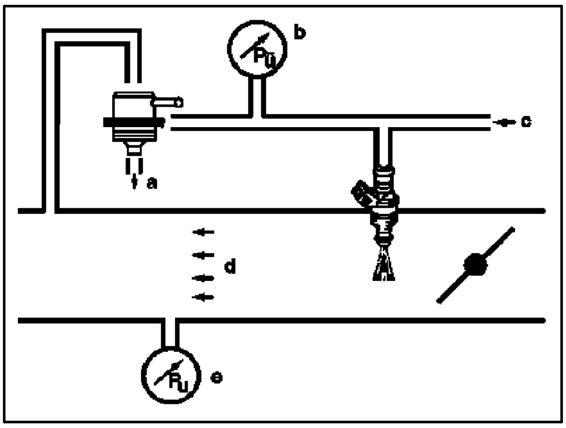
Pressure ratio at part load
Difference in pressure between fuel pressure and intake manifold pressure is about **3.4 bar.**



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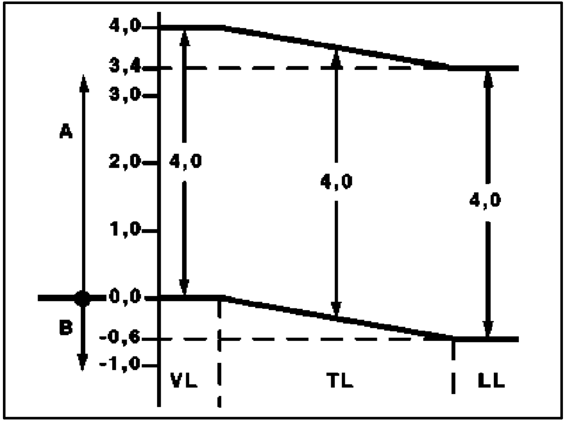
Schematic presentation
- a Fuel return to fuel tank
- b Fuel pressure approx. **4.0 bar**
- c Fuel feed from fuel pump
- d Intake manifold
- e Intake manifold vacuum **0.6 bar**

Diagram of fuel pressure

A Fuel pressure in bar
B Intake manifold vacuum in bar
LL Idle speed
TL Part load
VL Full load



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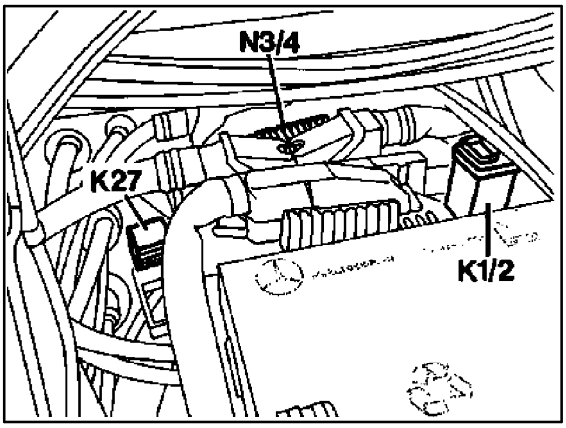
C. Functions in the HFM control unit

a) General

Located in the component compartment, it analyzes the data regarding the engine operating state which are supplied by the sensors, and controls essentially the fuel injection valves, the ignition coils and the actuator for idle speed control. Voltage is supplied by the overvoltage protection relay (K1/2).



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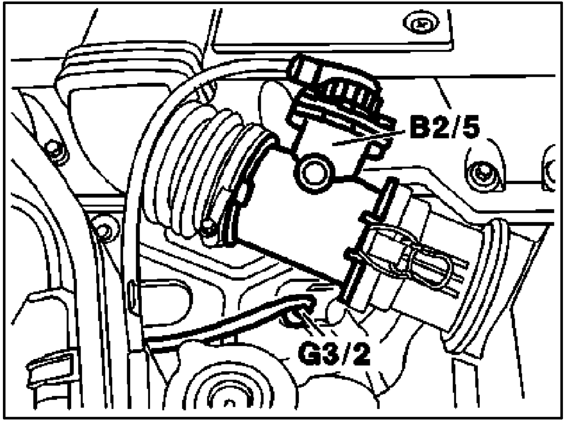
Base injection quantity

The map of the base injection quantity is controlled by the HFM control unit depending on the operating state of the following components:

, Engine speed
, Throttle valve position
, Air mass
, Position of resistance trimming plug
, CO potentiometer (without KAT)

b) Lambda control (KAT only)
The oxygen sensor (G3/2) measures the residual oxygen content (oxygen ions) in the exhaust gas. The oxygen sensor projects into the exhaust gas flow and produces a voltage depending on the oxygen content, which is signaled to the HFM control unit. This voltage in the case of a rich mixture is between 500 - 1000 mV, in the case of a lean mixture between 100 - 400 mV and at B= 1 around 450 mV.

The oxygen sensor signal is required for the lambda control.



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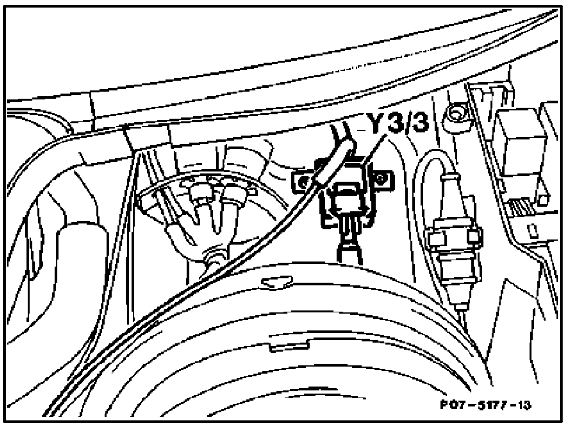
c) Transmission shiftpoint retard
The transmission shiftpoint retard is controlled by the HFM control unit through the shiftpoint retard switchover valve (Y3/3) to the shiftpoint retard vacuum element (see Function Diagram Group 14, Section A).
The HFM control unit requires the following information for this purpose:

- Coolant temperature
- Road speed signal
- Selector lever position
- Time after start



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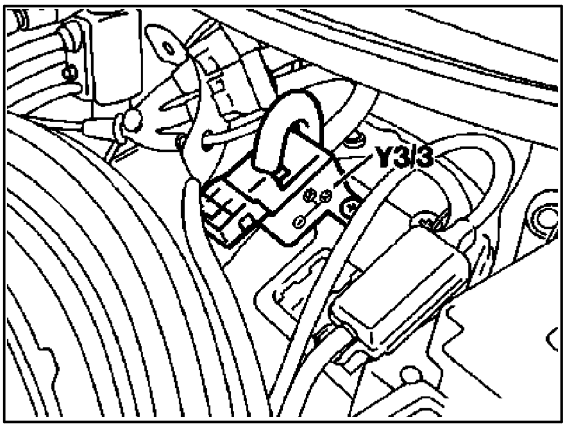
Shown on engine 111

Engine 104

Transmission shiftpoint retard 2 3
To enable the catalytic converter to reach its operating temperature more rapidly during the warming-up phase, the 2 3 idle throttle and part load shift in the automatic transmission is retarded for up to not more than 90 seconds after the engine is started at a coolant temperature between 0 and up to 50 °C. As a result, the engine revs up slightly more before the gearshift is performed. This shiftpoint retard is controlled by the HFM control unit through the shiftpoint retard switchover valve (Y3/3).



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Transmssion safeguard function 4 5/5 4

(with 5-speed automatic transmission only)

To protect the shift elements of the automatic transmission from excessive thermal stresses during gearshifts under load in the higher rev range, a transmission overload protection is integrated in the HFM control unit. The HFM is linked via the CAN databus to the 5-speed automatic transmission control unit (N5/1). As a result of the transmission overload protection function, ignition timing is retarded by the HFM control unit (N3/4) to 5° CA before TDC (reduced engine torque) during the 4 5 upshift for a period which is determined by the 5-speed automatic transmission control unit (N15/1).

As this retardation of ignition timing also improves gearshift smoothness during the shift phase, this measure is also used during a 5 4 full throttle downshift.

The HFM control unit processes the following information for this purpose:

- Engine speed
- Air mass
- Signal from transmission overload protection switch (S65)
- Signal from 5-speed automatic transmission control unit (N15/1)

Torque reduction (4-speed AG)

For the torque reduction function, the full load ignition angle is retarded by the HFM control unit in line with a map which is dependent on engine speed. The following pre-conditions must exist for this function:

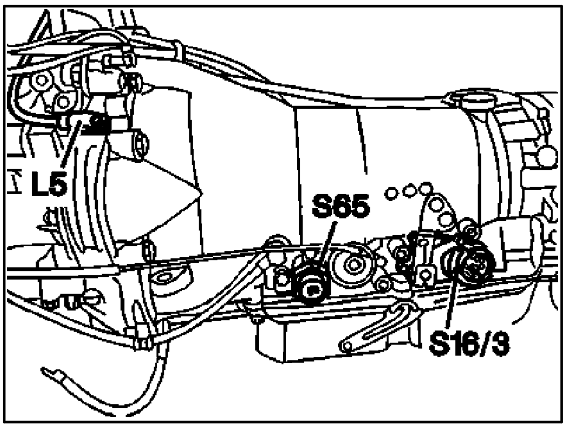
- Road speed <120 km/h
- Engine speed >3400 rpm
- Full load
- <1600 m above MSL

The HFM control unit processes the following information for this purpose:

- Engine speed
- Air mass
- Road speed signal
- Full load

Transmission overload recognition
(AG only)

The transmission overload protection switch (S65) is designed as a hydraulic pressure switch and is linked to the working pressure circuit of brake band "B1" of the automatic transmission. The switching function of the transmission overload protection switch (S65), brake band B1, is dependent on the working pressure which exists at "B1".



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Opening and closing of the transmission overload protection switch (S65), brake band B1, is recognized by the HFM control unit as a shift signal.

The shift signal is required for the following functions in the HFM control unit:

- Transmission safeguard function

Transmission overload protection

A transmission overload protection is integrated in the HFM control unit in order to protect the shift elements of the automatic transmission from excessive thermal stresses during load shifts at higher revs.

The HFM control unit processes the following information for this purpose:

- Signal from transmission overload protection switch (S65)
- Engine speed
- Air mass

As a result of the transmission overload protection function the ignition timing is retarded to 5° CA before TDC (reduced engine torque) for about 400 ms during
1 2 and 2 3 upshifts.

As this retardation of the ignition timing also improves the gearshift smoothness during the shifting phase, this measure is also used for 3 2 full throttle downshifts.

Emergency running mode transmission overload protection

If the HFM control unit does not receive a shift signal from the automatic transmission when the car is being driven, whether as a result of a fault at the transmission overload protection switch (S65), brake B1, or at the wiring, the HFM control unit switches into the emergency running mode. The transmission overload protection continues operating only to a restricted extent in the emergency running mode.

If no shift signal is sent by the automatic transmission, the HFM control unit recognizes the start of a gearshift as a result of a change in engine speed within a defined level.

When the transmission overload protection is operating in the emergency running mode, this may be noticable as a result of the temporary retardation of ignition timing at high speed.

⚠

In dealing with the complaint "Misfiring at high speed", it is then necessary to check the transmission overload protection switch (S65) and also the wiring.

Transmission shiftpoint retard 3 4

(KAT version only)

To enable the catalytic converter to reach its operating temperature more rapidly during the warming-up phase, the idle throttle and part load shifts in the automatic transmission are retarded for up to not more than 150 seconds after the engine is started at a coolant temperature between -40 °C and 100 °C. As a result, the engine revs faster until the gearshifts are performed. The 3 4 idle throttle shift is suppressed up to 55 km/h.

d) Variable camshaft timing (inlet camshaft)

Depending on engine speed and load, the inlet camshafts are advanced in order to achieve good engine torque over the entire engine speed range. An actuator is attached to each of the camshaft adjusters, which operates the control plunger for the hydraulic/mechanical adjustment. The actuators are operated by the HFM control unit. If the actuators are operated, the inlet camshafts are "advanced". The adjustment depends on engine speed and load. In selector lever positions P and N, the adjustment depends only on engine speed.

Example

Inlet camshaft adjustment (selector lever in drive position and moderate engine load)

Engine speed	Adjustment of camshaft
up to about 1200 rpm	retarded
from 1200 to 4300 rpm	advanced
4300 rpm or higher	retarded

Engine 104 governing top speed

The top speed is governed to about 250 km/h. If this speed is exceeded, a leaner mixture is produced and the inlet camshaft is "advanced".

Camshaft adjustment (selector lever in drive position and moderate engine load)

Engine speed	Adjustment of camshaft
up to about 1500 rpm	retarded
from 1500 to 4200 rpm	advanced
4200 rpm or higher	retarded

In selector lever position P/N the shiftpoint is advanced at 3000 rpm.

e) Fuel shutoff in the event of ignition faults (KAT only)

If ignition faults occur (50 ignitions in sequence) the injection valve of the cylinder(s) affected is shut off in order to protect the catalytic converter from overheating.

Once misfiring no longer exists, the fuel supply is activated again provided:

, 255 ignitions in sequence were in order

, car was in deceleration mode

, engine speed of about 2500 rpm was exceeded

The following faults are recognized by the primary current monitor in the HFM control unit:

, Ignition output stage in HFM control unit faulty

, Ignition coil faulty or open circuit in wiring

, Short circuit (also at high voltage end)

, Spark plug faulty

The HFM control unit processes the following information for this purpose:

, Primary voltage (combustion voltage, combustion time)

, Camshaft position ignition TDC cylinder 1

, Engine speed/Recognition of ignition circuit

Engine 104 safety fuel shutoff
(with EFP or TPM only)

The HFM control unit is linked for the safety fuel shutoff function to switching contacts in the EFP actuator (M16/1) and to the TPM actuator (M16/2), respectively. The switching contacts supply a positive signal to the HFM control unit when the engine is idling and also when driving.

If the throttle valve is opened further than specified by the position of the accelerator pedal as a result of the malfunction and if the car is not in the cruise control mode, a safety contact in the actuator switches a ground signal via the EFP control unit (N4/1) or the TPM control unit (N4/3), respectively, to the HFM control unit.

As a result, the fuel injection valves are shut off and are not activated again until engine speed is <1200 rpm.

f) Anti-jerk function (manual transmission only)

An anti-jerk function is integrated in the HFM control unit in order to suppress the tendency of cars fitted with manual transmission (MG) to jerk. After an engine load change, the sudden rise in engine speed is suppressed by retarding the ignition timing (depenpent on map load, rpm).

The HFM control unit processes the following information for this purpose:

, Engine speed

, Air mass

, Gear (1st gear/not 1st gear)

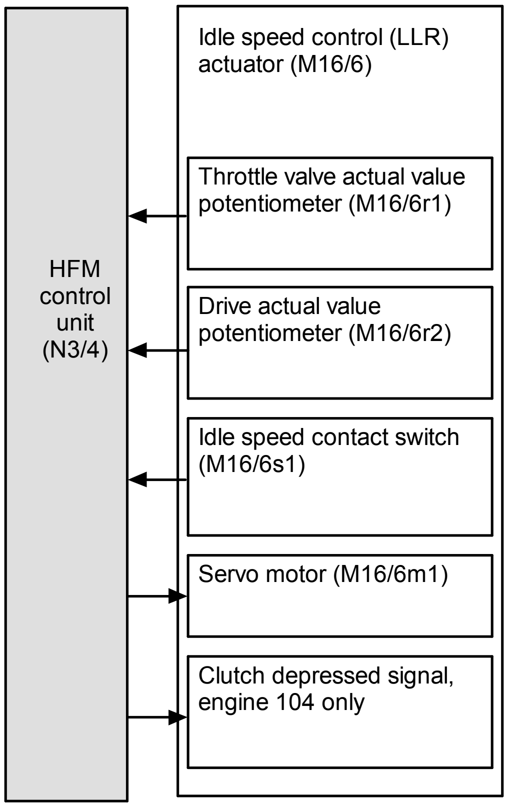
, Coolant temperature

g) Idle speed control

Idle speed is controlled by the HFM control unit and by the idle speed control actuator (M16/6). The idle speed control actuator (M16/6) comprises the throttle valve connection fitting with throttle valve actual value potentiometer (M16/6r1) for recognizing the throttle valve position, the drive actual value potentiometer (M16/6r2) for recognizing the servo motor position, the idle speed contact switch (M16/6s1) for recognizing idle speed, and the electric servo motor (M16/6m1) for correcting the throttle valve position.

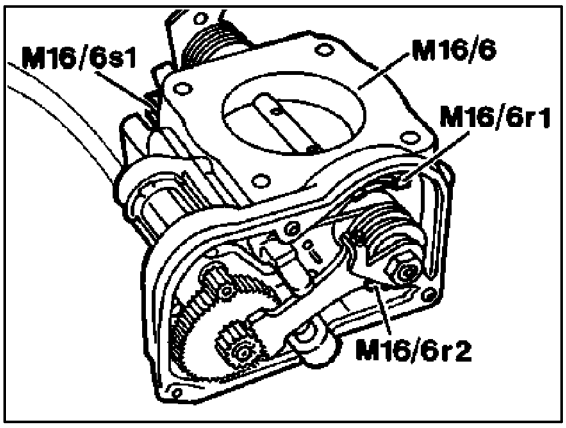
The HFM control unit processes the following information for idle speed control:

- Engine speed
- Coolant temperature
- Idle speed recognition
- Throttle valve position
- Idle speed servo motor position
- Road speed signal
- Selector lever position
- AC compressor cut-in signal
- Clutch depressed signal, engine 104 only



Function

When the ignition is switched on, the idle speed control is activated. Before the engine is started, the position of the throttle valve for idle speed is fixed by the servomotor (M16/6m1) as a function of the coolant temperature. The servo motor is actuated in this case with a frequency between 360 and 600 Hz. The throttle valve position is signaled by the throttle valve actual value potentiometer (M16/6r1).



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The HFM control unit compares actual and specified engine speed and determines the position of the throttle valve at that moment via the servo motor (M16/6m1). The adjustment range of the throttle valve for idle speed adjustment (ie. opening angle) is limited by the HFM control unit and is 0 to 10 %.

When the engine is idling and the idle speed contact switch (M16/6s1) is closed, 4 fixed ignition maps are set as a function of the coolant temperature (cold or warm) and the transmission (MG or AG). These are not influenced by the HFM resistance trimming plug.

If a difference in idling speed exists, the idle speed control is assisted by altering the ignition timing. The ignition timing can be advanced and retarded by up to 8°. Idle speed is continuously controlled as a function of the coolant temperature.

The idling speeds differ according to the selector lever position. These are determined by the HFM control unit.

Coolant temperature	MG, AG selector lever position P/N	AG selector lever in drive position
<0 °C	1000 7 50 rpm	800 7 50 rpm
0 °C to 30 °C	850 7 50 rpm	700 7 50 rpm
30 °C to 40 °C	800 7 50 rpm	650 7 50 rpm
>40 °C	750 7 50 rpm	600 7 50 rpm

Catalytic converter heating

The exhaust gas temperature is increased to enable the catalytic converter to reach its operating temperature more rapidly.

Each time the engine is started at a coolant temperature between about +15 °C up to +40 °C, ignition timing is continuously retarded by up to 8° when the engine is idling and selector lever in P or N for about 30 seconds, depending on the temperature, and idle speed is increased to 1150 7 100 rpm by the idle speed control.

The increase in idle speed is canceled as soon as a drive position is selected.

In the part load range, the ignition correction angle is scanned from a map in line with coolant temperature and load. The HFM control unit processes the following information for this purpose:

, Coolant temperature
, Engine speed/crankshaft position/ignition circuit recognition
, Air mass
, Ignition counter reading
, Idle speed recognition
, Selector lever position

Engine speed stabilization on engines with AC compressor

When the AC compressor cuts in, voltage exists at pin 11 of the HFM control unit. The HFM control unit processes the voltage level and actuates the servo motor (M16/6m1) in the idle speed control (LLR) actuator (M16/6). This increases the opening cross section of the throttle valve before the AC compressor cuts in so that idle speed is maintained at a practically constant level.

Throttle valve damping function

A damping function for the throttle valve is integrated in the HFM control unit.

If the throttle valve position is >8° opening angle, the throttle valve is closed again in the idle speed range only with a time lag if the accelerator is suddenly released.

The HFM control unit processes the following information for this purpose:

- Engine speed
- Coolant temperature
- Throttle valve position
- Road speed

Overheating or pinging protection

Ignition timing is retarded at an excessively high engine temperature as an overheating pinging protection.

The pinging protection correction is activated at a coolant temperature of 100 °C and is only effective under load.

The retardation of ignition timing is:

eg.:	100 °C	0° CA retarded
	105 °C	1.4° CA retarded
	120 °C	3.2° CA retarded

(The correction is dependent on engine load; the figures apply to full load.) The HFM control unit processes the following information for this purpose:

- Engine speed/crankshaft position/ignition circuit recognition
- Air mass
- Coolant temperature

⚠

The correction of the pinging protection and of the intake air are added together, ie. 120 °C coolant temperature and 50 °C intake air temperature produce a maximum retardation of 11° CA at full load.

Ignition timing support of idle speed control

If a variation in engine speed exists, the idle speed control is supported by altering the ignition timing.

The ignition timing can be advanced and retarded by up to 8°.

h) Intake air temperature correction

The ignition timing is corrected by the HFM control unit by being retarded as a function of intake air temperature and "load" (engine speed and air mass).

Ignition timing is retarded only at high engine loads and begins at an intake air temperature of 35 °C and achieves its maximum retardation at 65 °C.

Example:

35 °C 3.5° CA retarded

45 °C 6.3° CA retarded

65 °C 9.5° CA retarded

(The correction is dependent on engine load; the figures apply to full load.)

The HFM control unit processes the following information for this purpose:

- Intake air temperature
- Engine speed/crankshaft position/ignition circuit recognition
- Throttle valve position
- Air mass

i) Anti-knock control AKR

The ignition maps of the HFM injection system are designed for optimal engine output. Should knocking combustion occur under certain operating conditions, the anti-knock control integrated in the control unit recognizes the cylinder which is knocking and retards the ignition timing accordingly. Should knocking combustion occur for example as a result of fuel with low octane rating, the mechanical vibrations produced are converted in the knock sensor into electric signals and passed to the HFM control unit.

The HFM control unit processes the following information for this purpose:

- Knock sensor signals
- Camshaft position TDC cylinder 1
- Engine speed/crankshaft position/ignition circuit recognition
- Coolant temperature
- Intake air temperature

The HFM control unit compares these incoming signals with the specified values stored in the control unit. If differences exist, the ignition timing for the corresponding cylinder in which knocking combustion has occurred, is retarded by 3° CA immediately from the next ignition.

If the cylinder continues to knock, ignition timing is retarded by a further 3° CA. This retardation of ignition timing can be repeated if knocking combustion continues until a maximum retardation in line with coolant temperature is achieved (eg.: 10° CA at coolant temperature of 80 - 90 °C).
If knocking combustion no longer occurs, the ignition timing of the cylinder in question is advanced in stages of 0.35° CA until it is restored to the mapped value. Should one of the following components fail, a retarded ignition timing dependent on coolant temperature is activated for all the cylinders for safety reasons:

- Knock sensor
- Knock sensor analysis circuit of the anti-knock control in the HFM control unit
- Camshaft position sensor (L5/1)

j) Coding

The HFM control unit is provided with a variant coding as of 12/93 as a phased-in measure.

This can only be conducted with the hand-held tester (automatically and manualy).

The control unit has a code protection. When the code is entered, the number of the hand-held tester is also entered and stored. This makes it possible to determine the workshop in which coding was performed.

Before removing the control unit, determine the code number by reading it with the hand-held tester (menu point 6 variant coding).

After installing the control unit, the code number retrieved must be entered in the new control unit.

If it is not possible to retrieve the code number from the installed control unit, it is then necessary to determine the vehicle version and to refer to the Parts Microfilm Group 54 for the corresponding 9-digit code number and to enter this manually with the hand-held tester.

Pay attention to the following vehicle versions for coding:

- Vehicle model
- KAT
- Without KAT
- 5-speed manual transmission
- 4-speed automatic transmission
- 5-speed automatic transmission
- Tempomat cruise control
- ASR
- Controlled differential brake
- Nation version

Note

If the new control unit is not required, the code should be erased.

If a control unit is not coded, engine speed is governed to a maximum of 3200 rpm (emergency running mode). Automatic recognition of the vehicle version is not possible.

k) Diagnosis

The HFM control unit has a diagnosis facility and features a fault memory. The following distinctions are made in respect of recognizing and storing faults:

- Fault exists constantly
- Fault exists for longer than 2.5 seconds
- Loose contact faults which have occurred 5 times during a journey

In the event of the failure of a component, eg. coolant temperature sensor, the HFM control unit immediately switches to a substitute value or to an emergency running map.

This ensure that the operation of the fuel injection and ignition system as well as the idle speed control are retained. Faults which no longer occur, are automatically erased after 19 journeys. A journey is defined as follows:

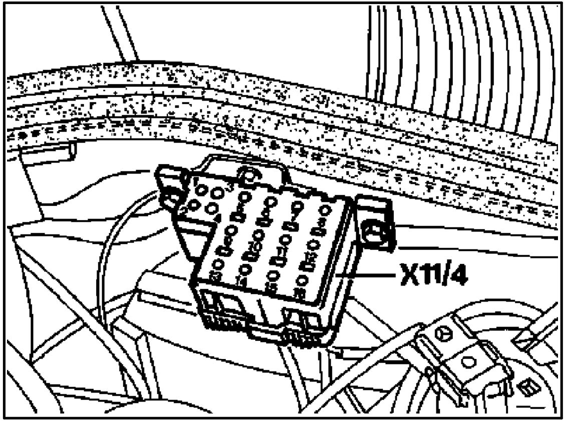
- Road speed >4 km/h
- Engine speed >700 rpm
- Engine switched off for 30 seconds

The faults are retained even after disconnecting the car battery.

The stored faults can be read and erased with the pulse counter of hand-held tester at the test coupling for diagnosis (X11/4), contact 8 (see Diagnosis Manual Engine Volume 2).

Note

Diagnosis by means of the on/off ratio display is discontinued.



P07-5447-13

Resetting and re-activating memory

Memory in the HFM control unit for the following functions:

, Automatic recognition of the vehicle version

, Automatic recognition of mechanical end stop of the closed throttle valve

, Self-adaptation of mixture formation

The memory must be reset and re-activated after replacing the HFM control unit or after installing the control unit from another car as a test.

Resetting and activating memory:

, Connect pulse counter (black cable contact 1, red cable contact 3, yellow cable contact 8)

, Read fault memory and erase, if necessary

, After the figure 1 appears, press start button of the pulse counter for between 6 and 8 seconds

, Switch off ignition and wait at least 2 seconds

, Switch on ignition and wait at least 10 seconds before starting the engine

I) Automatic recognition of mechanical end stop of closed throttle valve

It is necessary for the idle speed control function that the HFM control unit detects and stores the mechanical end stop of the closed throttle valve. The HFM control unit recognizes the throttle valve position in this case from the voltage signal at the potentiometer in the idle speed control actuator. After replacing the HFM control unit or the actuator, the position of the throttle valve must be re-detected and stored (see Resetting and re-activating memory of the HFM control unit).

m) Automatic recognition of vehicle version

The HFM control unit recognizes the following versions and stores them the first time the car is started:

- Manual/Automatic transmission
- KAT/without KAT
- Federal/California version
- KAT thermocouple (J)

This eliminates the need for a variety of control units.

After replacing the HFM control unit or installing it from another car as a test, it is necessary to erase the stored data and to re-activate recognition (see Resetting and re-activating memory of the HFM control unit). If re-activation is not performed, problems may occur with the fuel injection and ignition system and with the idle speed control.

n) Self-adaptation of mixture formation (with KAT)

The lambda control determines the injection time so exactly that the fuel-air ratio is always around lambda 1.0 (corresponds to 14.7 kg air to 1 kg fuel) in all operating states. If faults occur as a result of:

- unmetered air,
- wear or coking of the fuel injection valves,
- wear to the engine,
- contact resistance in the air mass sensor,
- faulty diaphragm pressure regulator,
- faulty purging switchover valve,

the HFM control unit automatically performs a correction of the mixture formation by altering the injection time. The correction parameters are constantly calculated and permanently stored provided the following conditions are met:

- Coolant temperature at engine start between 15 °C up to 95 °C
- Coolant temperature when driving between 80 °C up to 100 °C
- Intake air temperature between 0 °C up to 50 °C

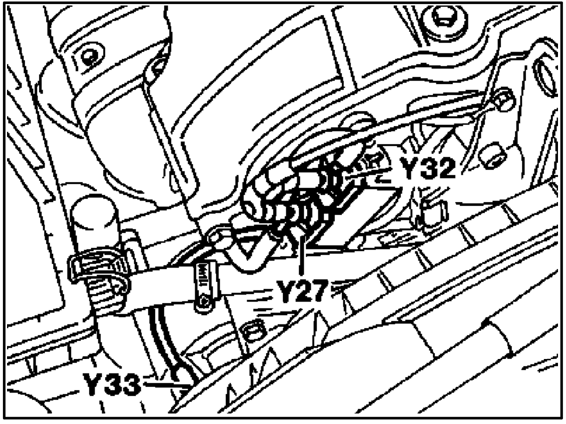
There are two ranges in which self-adaptation is performed, idle speed and at part load. The correction of toward a rich or lean mixture is in each case max. 25 %.

After repairs have been performed to the fuel injection system or to the engine, the HFM control unit automatically re-adapts after about 10 journeys. After a HFM control unit from another car has been installed as a test or after rectifying the faults stated, the self-adaptation must be reset (see Resetting and re-activating memory of the HFM control unit).

o) Exhaust gas recirculation engine 104 (USA J AUS only)

A map for the exhaust gas recirculation function is stored in the HFM control unit. The influencing parameters are engine load and engine speed. If the idle speed contact is open and the coolant temperature is greater than 48 °C, the ARF switchover valve (Y27) is actuated by the HFM control unit.
The HFM control unit processes the following information for this purpose:

- Engine speed
- Air mass
- Coolant temperature
- Idle speed recognition

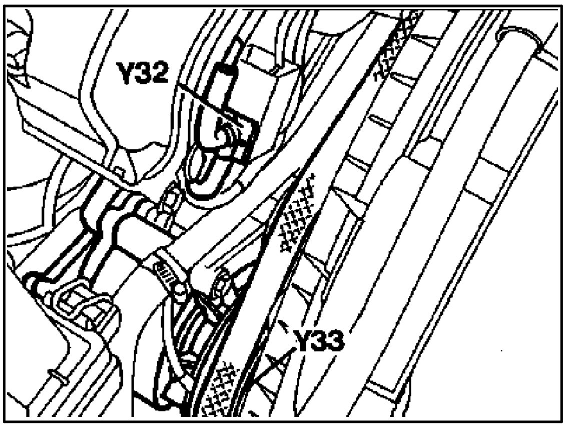


P07-5723-13

p) Air injection engine 104 (with KAT only, except AUS)

Air injection is controlled by the HFM control unit. The air pump electromagnetic coupling (Y33) and the air pump switchover valve (Y32) are actuated by the HFM control unit in line with the coolant temperature. Air injection is performed after the engine is started at a coolant temperature between +10 °C up to +40 °C. Air injection is switched off at full throttle or at an engine speed >3600 rpm. After the engine is started, the air pump is operated for not more than 120 seconds (so long as the lambda control is in the open-loop control mode).
The HFM control unit processes the following information for this purpose:

- Coolant temperature
- Engine speed
- Lambda control enabling



P07-5453-13

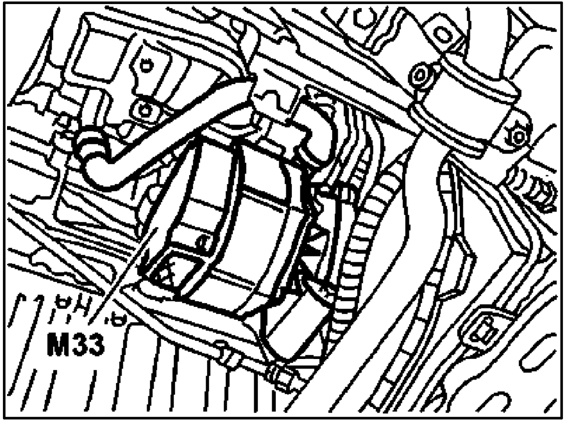
Note

As a result of the more rapid heating-up of the catalytic converter, the air pump is no longer fitted, with the exception of the following national versions:

CH S N A USA J FIN.

Electric air pump (M33) model 202
Located below the alternator. The current consumption is max. 35 A at 12 V and a back-pressure of 150 mbar.

The check valve (injected air) is no longer fitted. The function is performed by the shutoff valve.



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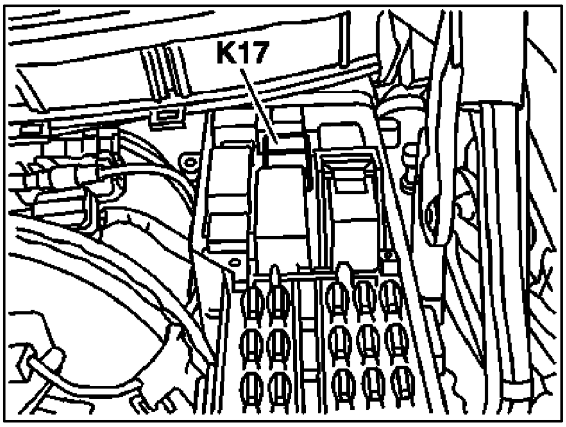
The electric air pump (M33) is actuated by the HFM control unit (N3/4) via the air injection relay (K17).



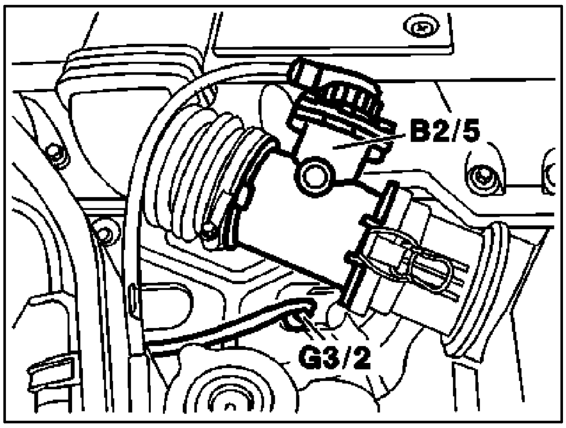
P07-6003-13

D. Mixture formation

a) Hot film air mass sensor

The air mass inducted is detected by a hot film air mass sensor (B2/5) which is located in the intake port between air cleaner and throttle valve.
The air mass is required by the HFM control unit for the following functions:

- Fuel injection
  - Base injection quantity
  - Warming-up enrichment
  - Acceleration enrichment
- Ignition
  - Ignition during warming-up
  - Ignition at full throttle
- Catalytic converter heating
- Lambda control
- Activated charcoal filter purging
- Camshaft adjustment
- Anti-jerk function (with MG only)
- Pinging protection
- Intake air temperature correction



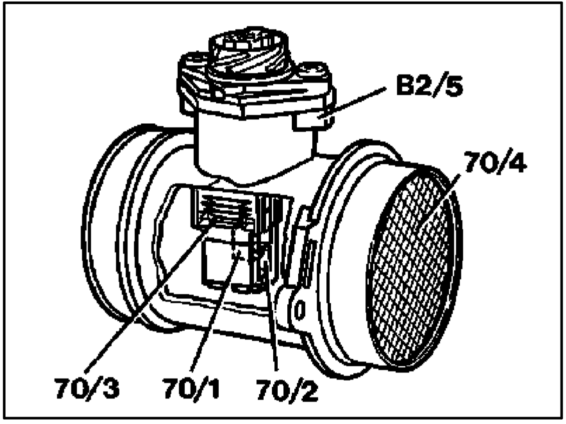
P07-5444-13

Design of air mass sensor

A hot film sensor (70/1) is mounted in the interior of the measuring passage. This sensor consists of a ceramic substrate onto which are fixed the following thick-film resistors.

- Heating resistor (R_H)
- Sensor resistor (R_S)
- Air temperature resistor (R_T)
- Compensation resistor (R_K)

A hybrid circuit and a power module are located downstream of the measuring channel (70/2) in the electronic housing. A heat sink is attached to the outside of the electronic housing (70/3).



P07-5437-13

The electronic housing with measuring channel is inserted in the connection housing. Turbulances are smoothed by the protective grille (70/4) so that a uniform flow of air flows around the hot film sensor.

Function of the air mass sensor

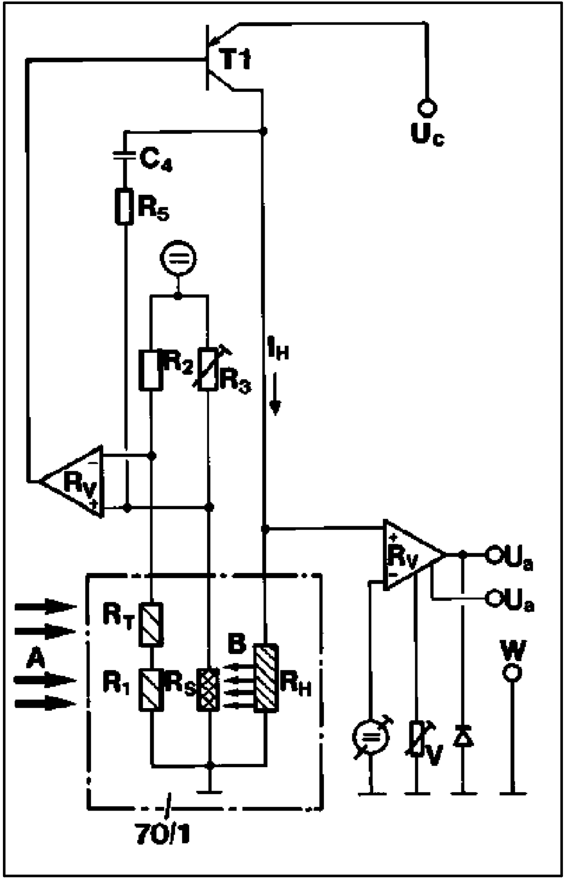
The hot film air mass sensor operates with a hot film sensor in the inducted air flow. The resistors (R_T), (R_1) and (R_S) and also (R_2) and (R_3) are combined to form a bridge circuit.

The heating resistor (R_H) is positioned outside of the bridge. The heating current which is required to maintain the heating resistor at a constant temperature determines the bridge voltage.

The heating resistor (R_H) and the sensor resistor (R_S) are temperature-dependent and reduce their resistance (NTC) as the temperature rises.

As the sensor resistor (R_S) is attached directly to the heating resistor (R_H), it adopts the latter's temperature.

In operation, such a high level of current (I_H) is supplied to the heating resistor that it heats up to about 160 °C above the momentary intake air temperature. When the air flow increases, the heating resistor is cooled down as a result of which its electrical resistance rises. The current (I_H) is adjusted in order to maintain the temperature at the heating resistor (R_H) at a constant level.



P07-5595-17

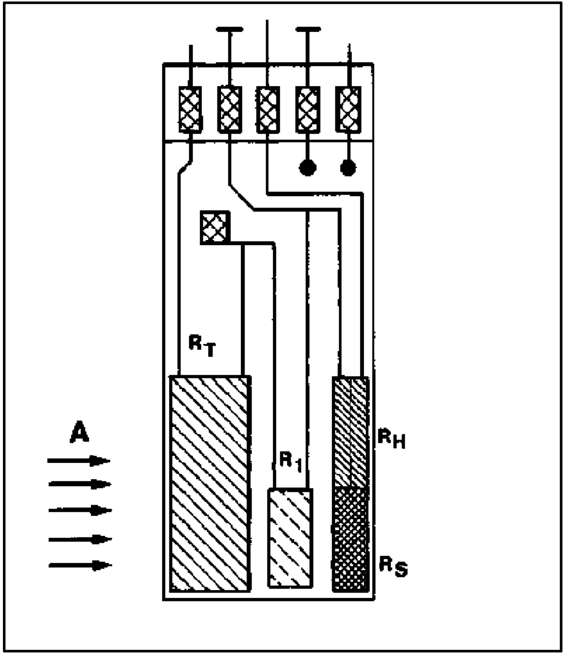
A	Intake air flow
B	Heat
C_4	Capacitor
R_H	Heating resistor
R_S	Sensor resistor
R_T	Air temperature resistor
R_V	Control amplifier
R_1	Trimming resistor
R_3	Trimming resistor
T_1	Transistor
U_a+	Measuring signal +
U_a -	Measuring signal -
U_C	Supply voltage
W	Ground
70/1	Hot film sensor

The momentary air temperature is detected by the air temperature resistor (R_T), which also alters its resistance in line with the temperature.
The control amplifier (R_V) compares the current flow of air temperature resistor (R_T) and sensor resistor (R_S) and then influences the current supply (I_H) to the heating resistor (R_H) accordingly in order to maintain the temperature difference of intake air temperature to heating resistor temperature at a constant 160 °C. This control to a constant temperature difference is performed within a few milliseconds.

At the test connection (U_A) a change in current is tapped as a voltage drop. Depending on the air mass, the heating current is between 250 and up to 800 mA. This voltage drop is the measured variable for the inducted air mass for the HFM control unit.

The hot film air mass sensor has no moving parts and causes only a slight flow resistance in the intake air passage.

The benefits of the hot film air mass sensor compared to the hot wire air mass sensor are:
, Elimination of cleaning process
, High resistance to vibrations



P07-5593-15

A Intake air flow
B Heat
R_H Heating resistor
R_S Sensor resistor
R_T Air temperature resistor
R_1 Trimming resistor

Emergency running properties

If a fault occurs in the hot film air mass sensor, the injection time is calculated from a map of the control unit using the throttle valve angle and the engine speed.

The throttle valve angle in this case is detected by the throttle valve actual value potentiometer (M16/6r1) in the idle speed control (LLR) actuator (M16/6) and passed to the HFM control unit.

b) Fuel injection valves

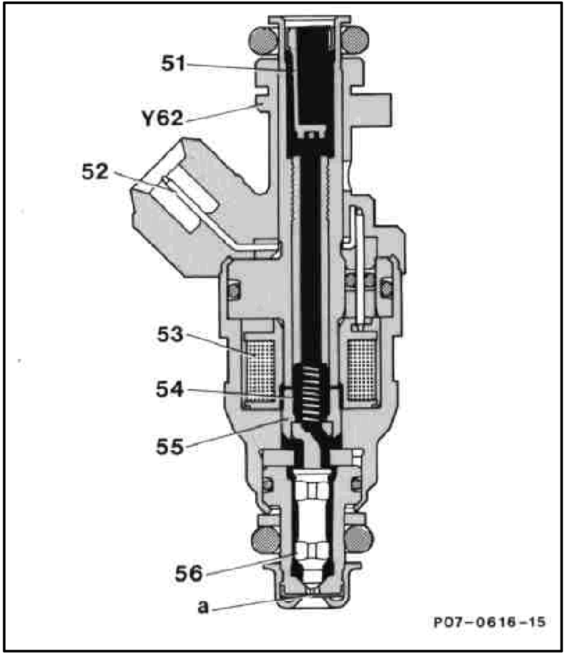
Injection is performed by electromagnetic injection valves (Y62). An injection valve is assigned to each cylinder and precisely meters the fuel which is injected into the intake manifold upstream of the inlet valve.

The injection valve consists of a valve body and the nozzle needle (56) with the mounted armature (55). The valve body contains the field winding (53) and the guide for the nozzle needle.

The fuel flows through a pre-filter (51) and a drilling in the armature to the calibrated outlet opening (a).

When the field winding is deenergized, the nozzle needle is pressed down onto its sealing seat by a coil spring (54).

When the field winding is excited, the nozzle needle is lifted about 0.1 mm off its seat and the fuel is able to flow through the 2 drillings (a) with + 0.2 mm. The opening and closing time of the valve is less than 1 ms.



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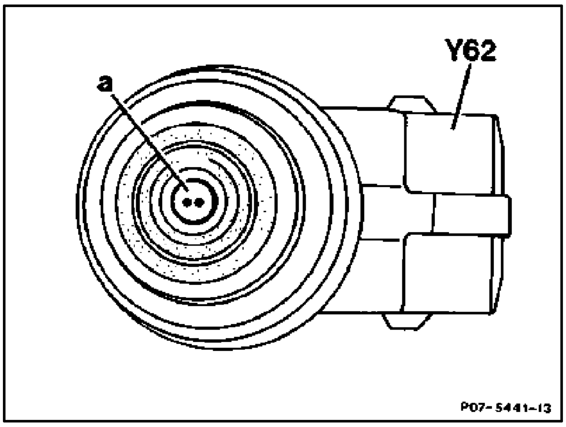
The arrangement of the drillings (a) causes 2 jets to form when the fuel flows out, which spray the finely atomized fuel onto both inlet valves.



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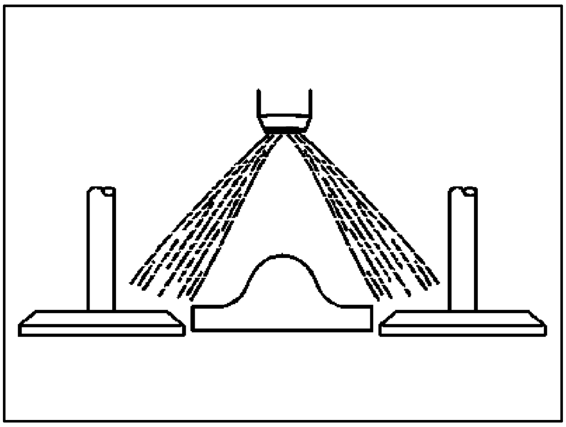

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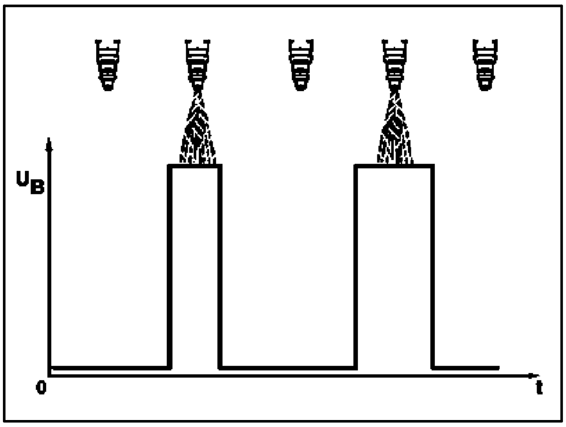
The fuel injection valves are connected directly to positive and are opened by the HFM control unit (N3/4) by means of ground pulses.

The fuel injection valves are actuated in line with the firing order (sequentially). Depending on engine load and speed, the fuel is injected more or less upstream and, when the inlet valves open, is inducted together with the air into the combustion chamber.

The control unit calculates the injection time in line with the operating state of the engine. The quantity of fuel injected is determined by the opening time of the fuel injection valves.



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U_B = Operating voltage
t = Time

c) Actuation of fuel metering in different operating states

Synchronization of injection sequence

The injection sequence has to be synchronized in order to ensure correct allocation of the moment of injection to the respective cylinder. The signal of the camshaft position sensor (L5/1) is required in this case for recognizing ignition TDC of cylinder 1.

Synchronization is performed during the first revolutions of the engine when it is started. The HFM control unit processes the following information for synchronizing the injection sequence:

- Engine speed/crankshaft position
- Camshaft position TDC cylinder 1

Start control

To facilitate starting the engine when cold, additional fuel has to be injected during the starting process, in line with the coolant temperature. The increased quantity of fuel injected is achieved by extending the injection time.

The start control begins with starting of the engine via terminal 50 and remains activated until a temperature- related engine speed is exceeded.

The quantity of fuel required for starting is calculated from the following factors irrespective of the air mass sensor with hot wire:

- Coolant temperature
- Camshaft speed (camshaft position sensor)
- Intake manifold pressure (EZL ignition control unit)
- Time during which engine was switched off

Post-start enrichment

After starting the engine from cold, it is necessary to enrich the mixture with additional fuel for a short time. The fuel which precipitates on the cylinder barrels is compensated for by the enrichment, and the engine turns smoothly. Post-start enrichment is dependent on:

- Coolant temperature at starting
- Time duration after start
- Selector lever position
- Position of resistance trimming plug

Warming-up enrichment

The precise quantity of fuel is metered to the engine in line with the coolant temperature. The injection time is appropriately extended for this purpose. Warming-up enrichment is dependent on:

- Coolant temperature during starting
- Intake air temperature
- Engine speed/engine load
- Idle speed/part load operation
- Position of resistance trimming plug

Acceleration enrichment

The injection valves are actuated with additional pulses during acceleration to achieve throttle response. Enrichment is dependent on:

- Coolant temperature
- Engine speed/engine load
- Speed of load change
- Position of resistance trimming plug

Full load enrichment

Full load enrichment is calculated by the HFM control unit above a throttle valve angle of 80°. The opening time of the fuel injection valves is extended.

Deceleration fuel shutoff

Deceleration fuel shutoff is dependent on:

- Engine speed
- Idle speed recognition
- Throttle valve position
- Coolant temperature
- Road speed signal

If deceleration fuel shut-off is activated, the injection valves are shut off and the throttle valve is positioned to an angle in line with engine speed.

The decel fuel shut-off function is operational if engine speed rises above 2100 rpm at a coolant temperature of >40 °C.
The HFM control unit recognizes "deceleration" below a speed-dependent throttle valve position or if the idle speed contact switch (M16/6s1) is closed.

The injection valves are shut off during deceleration above an engine speed of >2100 rpm.

The injection valves are opened again as soon as engine speed is <1700 rpm (with automatic transmission) or <1500 rpm (with manual transmission).

In order to prevent a sudden rise in engine torque when fuel injection recommences after deceleration fuel shutoff, the ignition timing is retarded briefly (see Function Ignition System 07.5-0035, Section A, Deceleration fuel shutoff).

Example

Change in engine speed when fuel injection valves shut off and re-actuated:
fuel injection valves shut off >1600 rpm,
fuel injection valves re-actuated <1200 rpm.

Limiting maximum engine speed

A leaner mixture is produced or fuel injection is shut off and ignition timing is retarded at the following engine speeds and operating states in order to protect the engine and the drive train. Engine speed is governed by the HFM control unit, which processes the following information for this purpose:

- Engine speed
- Selector lever position
- Road speed signal

Governing maximum engine speed

	Rpm threshold
Each 2nd injection valve in firing order off	>6200 rpm
All injection valves off	>6350 rpm
Each 2nd injection valve in firing order on 1)	<6325 rpm
All injection valves on	<6200 rpm

1) All injection valves are shut off

Engine 104

Brief governed speed for 3.5 seconds 6600+50 rpm,
then continuous governed speed 6400+50 rpm.

Torque converter protection

The torque converter is subjected to increased static internal pressure in selector lever positions P and N. For this reason, engine speed is governed to 4000 rpm when the selector lever is in positions P and N and vehicle speed is <5 km/h.

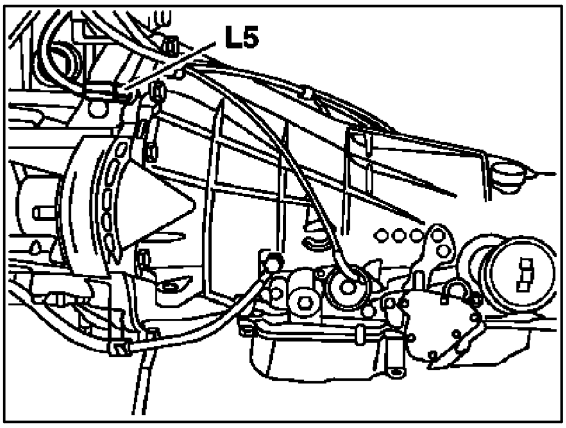
Drive train protection

Engine speed is governed for a period of 1 s to 3500 rpm if a drive position is engaged and vehicle speed is
<29 km/h in order to minimize the consequences of an "extreme start".

Engine speed of vehicles with a manual transmission is governed to 4000 rpm at a vehicle speed of <10 km/h.

a) Engine speed, crankshaft position, ignition circuit recognition

The information regarding engine speed, crankshaft position and ignition circuit 2 recognition for cylinders 2 and 3 is supplied by the crankshaft position sensor (L5) to the HFM control unit in the form of an alternating voltage.
An analog-digital converter converts the alternating voltage in the control unit into a square-wave signal (TN signal).



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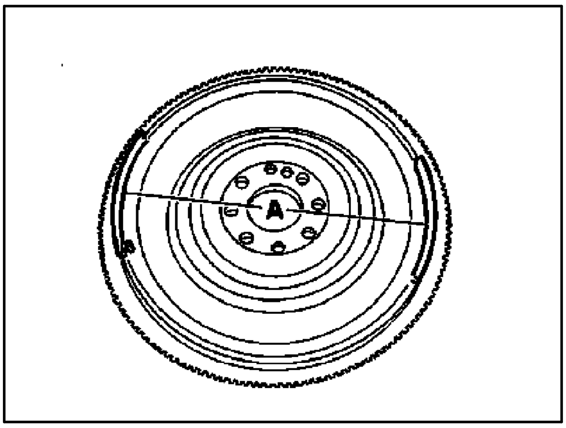
The engine speed is calculated over the period of half a crankshaft revolution.
The crankshaft position is detected from the voltage signals of the 1st and 2nd segment (A).



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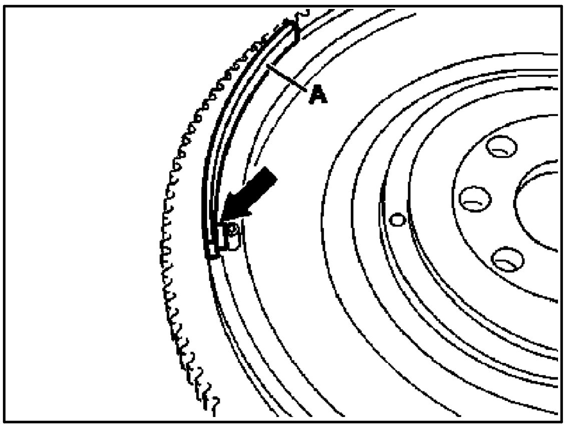
Ignition circuit 2 for cylinders 2 and 3 is recognized by the permanent magnet at the segment (A, arrow).



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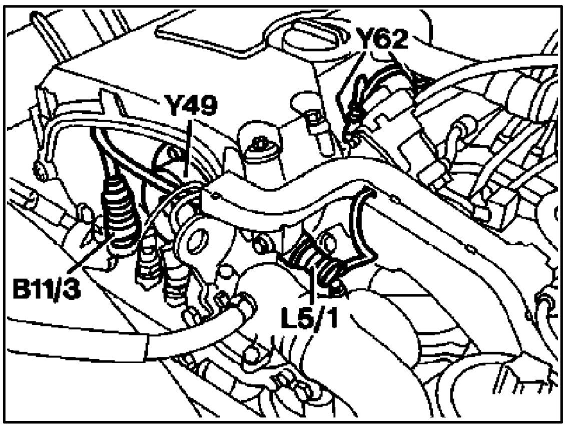
Engine speed, crankshaft position, ignition circuit recognition are required by the HFM control unit for the following functions:

- Fuel injection
  - Base injection quantity
  - Start control
  - Synchronization of injection sequence
  - Warming-up enrichment
  - Acceleration enrichment
  - Full load enrichment
  - Deceleration fuel shut-off
- Ignition
  - Ignition during starting
  - Ignition during warming-up
  - Ignition during idling
  - Ignition during full load
  - Ignition during deceleration fuel shut-off
- Idle speed control
- Catalytic converter heating
- Activated charcoal filter purging
- Camshaft adjustment
- Anti-jerk function (MG only)
- Anti-knock control AKR
- Partial intake manifold preheating
- Governing maximum engine speed

b) Camshaft position ignition TDC cylinder 1

The camshaft position sensor (L5/1) produces an alternating voltage signal for each camshaft revolution at 20° after TDC of cylinder 1. This is converted in the analog-digital converter into a square-wave signal and further processed in the HFM control unit.
The camshaft position TDC cylinder 1 is required by the HFM control unit for the following functions:

- Fuel injection
  - Synchronization of injection sequence
- Ignition
  - Ignition during starting
  - Fuel shutoff in the event of ignition faults
  - Anti-knock control



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c) Road speed signal

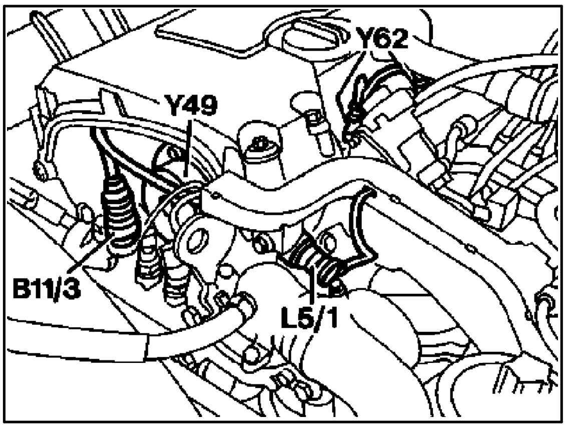
The road speed signal is supplied by the ABS control unit (N30) and corresponds to the wheel speed at the rear axle.

The road speed signal is required by the HFM control unit for the following functions:

- Fuel injection
  - Deceleration fuel shut-off
- Idle speed control
- Governing maximum engine speed
- Transmission shiftpoint retard (AG only)
- Governing maximum propeller shaft speed

d) Coolant temperature

The NTC coolant temperature sensor (B11/3) in the coolant circuit detects the coolant temperature and converts it into an electrical signal.
NTC = resistance with negative coefficient. The semi-conductor resistor reduces its electrical resistance as the temperature rises.



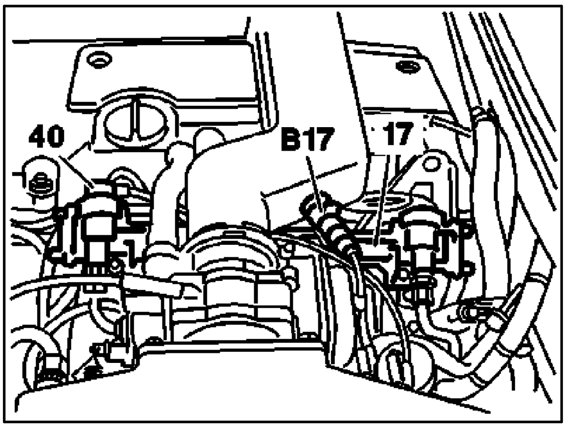
P07-5443-13A

This signal is required by the HFM control unit for the following functions:

- Fuel injection
  - Start control
  - Post-start enrichment
  - Warming-up enrichment
  - Acceleration enrichment
  - Deceleration fuel shut-off
- Ignition
  - Ignition during starting
  - Ignition during warming-up
  - Ignition during idling
  - Ignition during deceleration fuel shut-off

, Idle speed control
, Catalytic converter heating
, Activated charcoal filter purging
, Transmission shiftpoint retard
, Camshaft adjustment
, Pinging protection
, Anti-knock control AKR
, Partial intake manifold preheating

e) Intake air temperature
The intake air temperature sensor (B17) detects the intake air temperature in the intake air flow and converts it into electrical signals. These signals are processed in the HFM control unit and result in a correction of the injection time and of the ignition angle.
The intake air temperature sensor, like the coolant temperature sensor, is an NTC resistor.
The intake air temperature is required in the HFM control unit for the following functions:
, Fuel injection
  - Warming-up enrichment
, Ignition
  - Intake air temperature correction
, Activated charcoal filter purging



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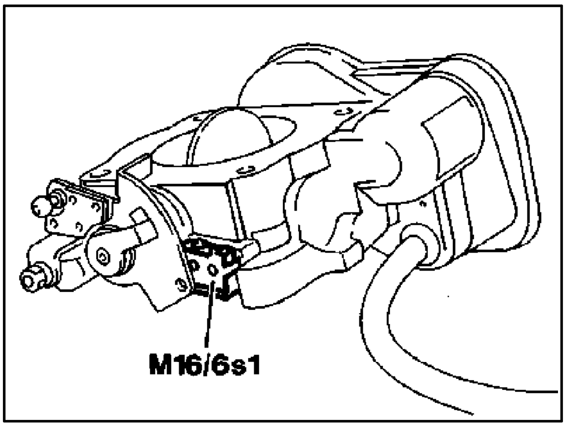
f) Idle speed recognition
The idle speed operating state is detected by the idle speed contact switch (M16/6s1) at the idle speed control (LLR) actuator (M16/6) and passed to the HFM control unit.
Idle speed recognition is required in the HFM control unit for the following functions:

, Fuel injection
  - Warming-up enrichment
  - Deceleration fuel shutoff
, Ignition
  - Ignition during idling
, Idle speed control
, Catalytic converter heating



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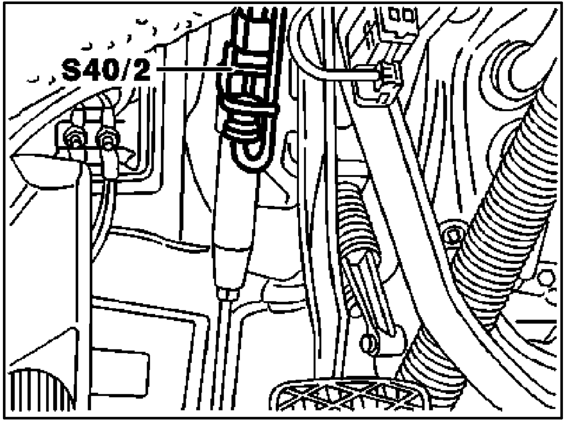
Engine 104
When the car is moving and the clutch depressed signal is transmitted, the HFM control unit is actuated by the clutch pedal switch (S40/2). The idle speed control is activated as a result (as for stationary vehicle).



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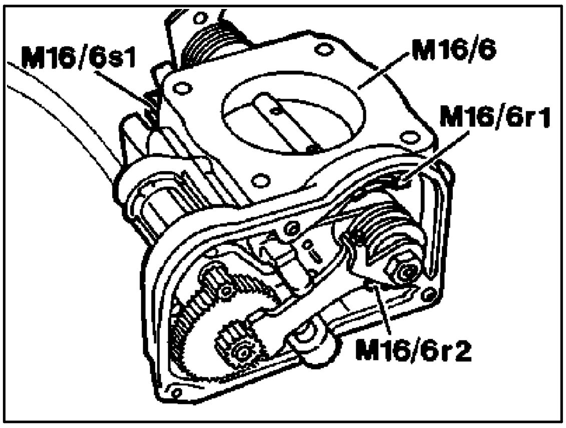
g) Throttle valve position

The throttle valve position is detected by the throttle valve actual value potentiometer (M16/6r1) in the idle speed control (LLR) actuator (M16/6) and passed to the HFM control unit.
The throttle valve position is required in the HFM control unit for the following functions:

- Fuel injection
  - Base injection quantity
  - Acceleration enrichment
  - Fuel load enrichment
  - Deceleration fuel shut-off
- Ignition
  - Ignition during full load

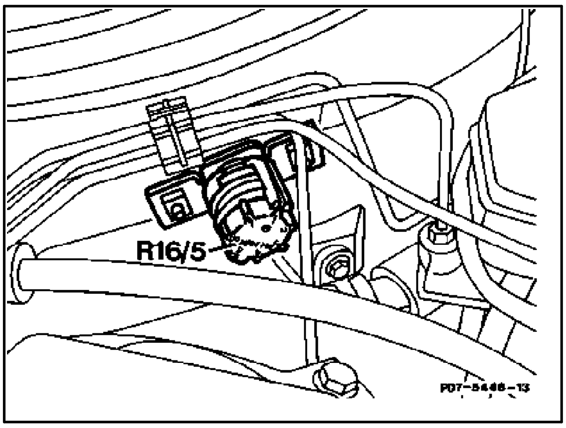


P07-5609-13

h) Adaptation of fuel injection and ignition maps with resistance trimming plug

All vehicles (except USA) are provided with a HFM resistance trimming plug (R16/5) for adapting various maps. A total of 7 adjustment positions are possible.
The HFM resistance trimming plug (R16/5) influences the following functions in the HFM control unit:

- Ignition
- Fuel injection
  - Base injection quantity
  - Post-start enrichment
  - Warming-up enrichment
  - Acceleration enrichment



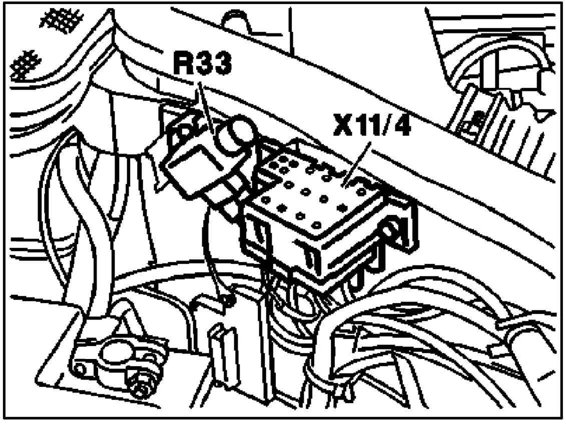
P07-5446-13

i) Idle speed CO correction (without KAT)

Vehicles **without KAT** are fitted with a CO potentiometer (R33) for setting the idle speed emissions level.

Turning to the left	**leaner**
Turning to the right	**richer**

Vehicles with KAT do not have any adjustment facility for the idle speed emissions level as mixture adaptation is performed by the lambda control.

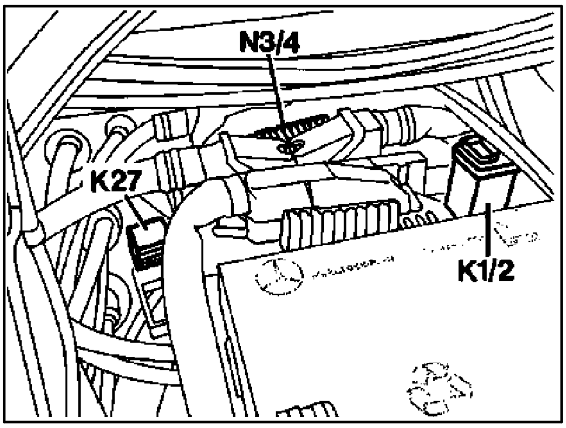


P07-5600-13

j) Battery voltage and voltage supply

The quantity of fuel injected is determined by the opening times of the fuel injection valves. These opening times are influenced by the battery voltage. The HFM control unit (N3/4) corrects the injection time in order to maintain a constant quantity of fuel injected even if the battery voltage varies.
For example:
lower battery voltage = longer opening time
higher battery voltage = shorter opening time

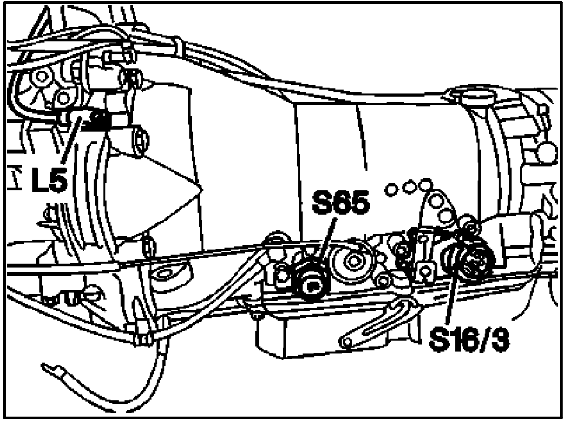
The voltage for the HFM control unit is supplied through the overvoltage protection relay (K1/2).



P07-5442-13A

k) Selector lever position (AG only)
The starter lockout switch (S16/3) is used for recognizing selector lever positions P/N and also 2/3 for the HFM control unit.
The selector lever position is required in the HFM control unit for the following functions:

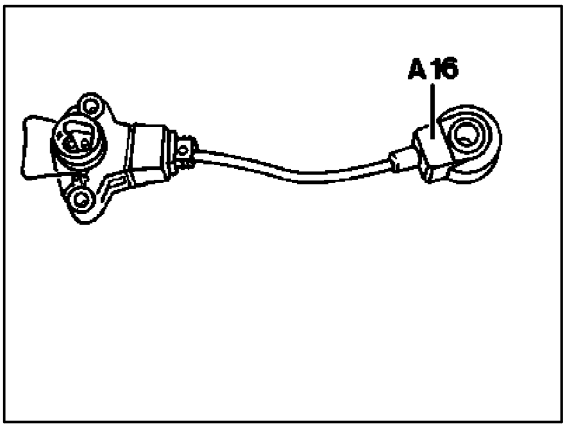
- Fuel injection
  - Post-start enrichment
- Catalytic converter heating
- Transmission shiftpoint retard
- Camshaft adjustment
- Governing maximum engine speed



P07-5694-13

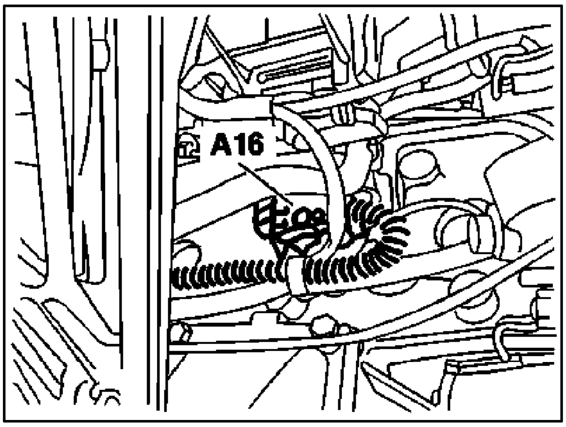
l) Knock sensor signals
A piezo-electric structure-borne sensor is used as the knock sensor (A16).
The vibrations of the engine block are transmitted to the piezo ceramic and passed in the form of an alternating voltage signal along a screened cable to the HFM control unit.

Note
Piezo effect = generation of voltage as a result of pressure on a certain ceramic



P07-5722-13

The knock sensor (A16) is attached to the engine block below the intake manifold. This fitting location was chosen in order to detect knocking combustion at all the cylinders.
The knock sensor signals are required for the anti-knock control (AKR).



P07-5692-13