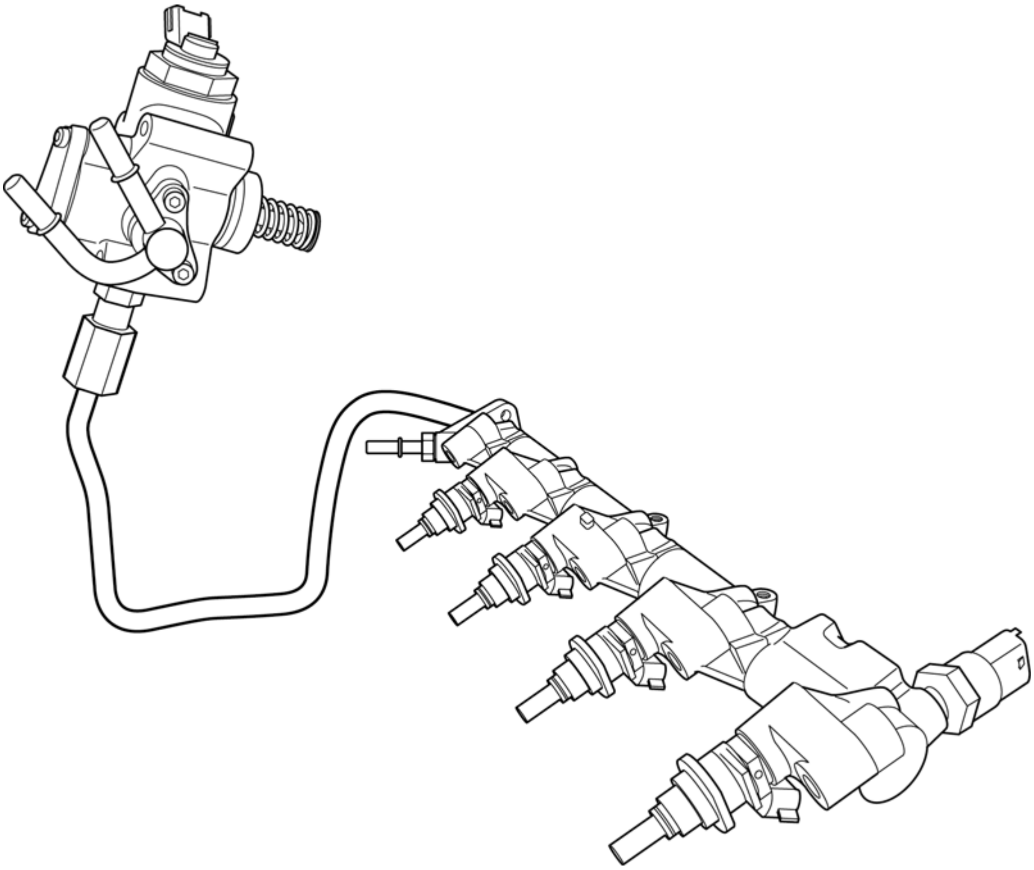
Training Manual

Advanced Petrol Engine Management

CT-L3003



Introduction

- Ever stricter exhaust and noise emission regulations, and the demand for high power output and low fuel consumption impose increasing demands on the engine management system of the petrol engine. In order to fulfill these requirements the combustion process is improved continuously.
- This course is a theoretical and practical guide to gain general and Mazda specific knowledge about direct injection systems, including their components, operation and diagnosis. In addition, the course provides comprehensive information about the on-board diagnostic system (incl. EOBD), the engine mechanical system and the diagnostic process.
- While the manifold injection systems used on Mazda vehicles have already been covered by the course “Basic Petrol Engine Management” (CT-L2004), this course describes the more complex direct injection system employed on the Mazda3 MPS and Mazda6 MPS with 2.3 MZR DISI Turbo engine.
- Anyone associated with the diagnosis and repair of petrol engine management systems must have the knowledge to deliver a “Fix it right first time” repair. Therefore, the Mazda Masters development and qualification path provides the following training courses required for diagnosing and repairing petrol engine management systems:
  - Basic Petrol Engine Management CT-L2004
  - Advanced Petrol Engine Management CT-L3003
- The ranking of this course within the Mazda Masters educational system is Level 3 - ‘Mazda Master Technician’. It is intended for technicians who have experience in maintaining and repairing Mazda vehicles, and who are familiar with the features and the operation of the various manifold injection systems.

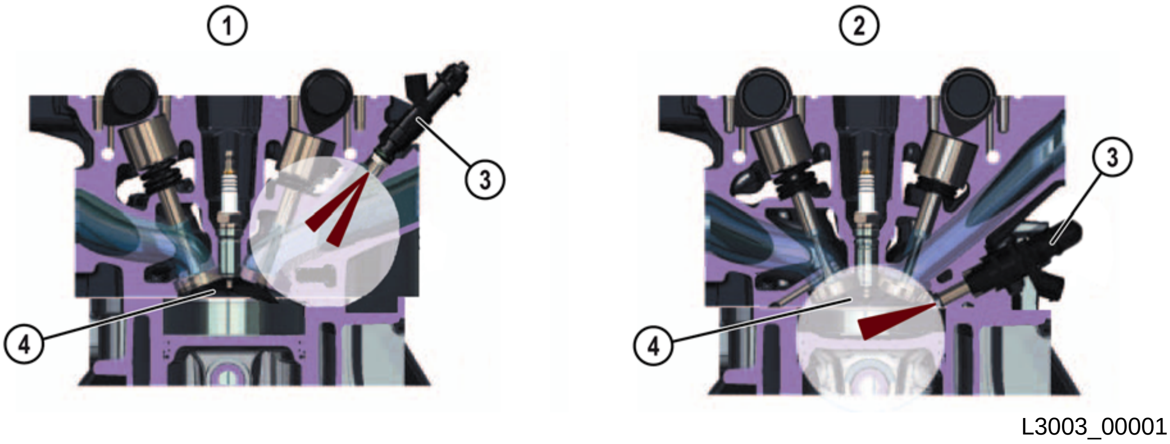
Fundamentals

Turbocharged Engine with Direct Injection

- In comparison to a naturally aspirated engine with the same power output the 2.3 MZR **DISI** (**D**irect **I**njection **S**park **I**gnition) Turbo engine has a considerably smaller displacement, achieving the following advantages:
  - Reduced pumping loss due to less volume swept during each working cycle
  - Reduced heat transfer to the cylinder wall due to its smaller surface area
  - Reduced friction loss due to the smaller size of the moving parts (piston, piston rings, connecting rod etc.)

- These measures result in lower fuel consumption, especially at part load. In addition, the engine is more compact and lightweight, improving handling of the vehicle.
- In order to increase the engine torque and hence the power output across the entire engine speed range, the charging efficiency is increased with the aid of a turbocharger. However, turbochargers have serious disadvantages in terms of exhaust emissions and fuel consumption.
- Basically, in a turbocharged engine it takes longer until the catalytic converter reaches its operating temperature, i.e. the exhaust emissions immediately after engine start are higher than on a naturally aspirated engine. This is due to the fact that the turbocharger absorbs large amounts of exhaust heat, reducing the exhaust gas temperature.
- At the same time, there is an adverse effect on the thermal efficiency due to the low compression ratio of the turbocharged engine, i.e. the fuel consumption is higher compared with a naturally aspirated engine. However, it is impracticable to set a high compression ratio, since the higher temperature in the combustion chamber of the turbocharged engine can easily lead to engine knocking.

- The adoption of direct injection is the solution to these problems of the turbocharged engine. Through the injection of a finely atomized fuel spray directly into the combustion chamber a homogeneous air/fuel mixture forms in the vicinity of the spark plug, ensuring stable combustion. This allows the ignition timing to be retarded, enabling a high exhaust gas temperature even with a turbocharger installed. As a result, the catalytic converter reaches its operating temperature faster, achieving low exhaust emissions immediately after engine start.
- Furthermore, direct injection improves the internal cooling effect in the combustion chamber, since the fuel evaporates solely in the cylinder (and not already in the intake port as on a turbocharged engine with manifold injection). In this way, engine knocking is prevented even with a turbocharger installed. As a result, the compression ratio can be set as high as for a naturally aspirated engine, reducing the fuel consumption.



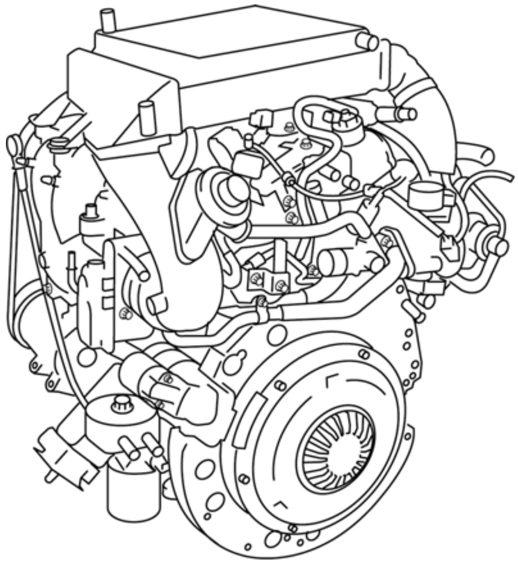
1	2.3 MZR engine	3	Injector
2	2.3 MZR DISI Turbo engine	4	Spark plug

Notes:

Mazda Direct Injection System

Features

- The Mazda3 and Mazda6 with L3T engine are equipped with the Mazda direct injection system. This system has the following features:
  - Turbocharger with charge-air cooler
  - Returnless fuel system with high-pressure pump
  - Distributorless ignition system with direct ignition coils



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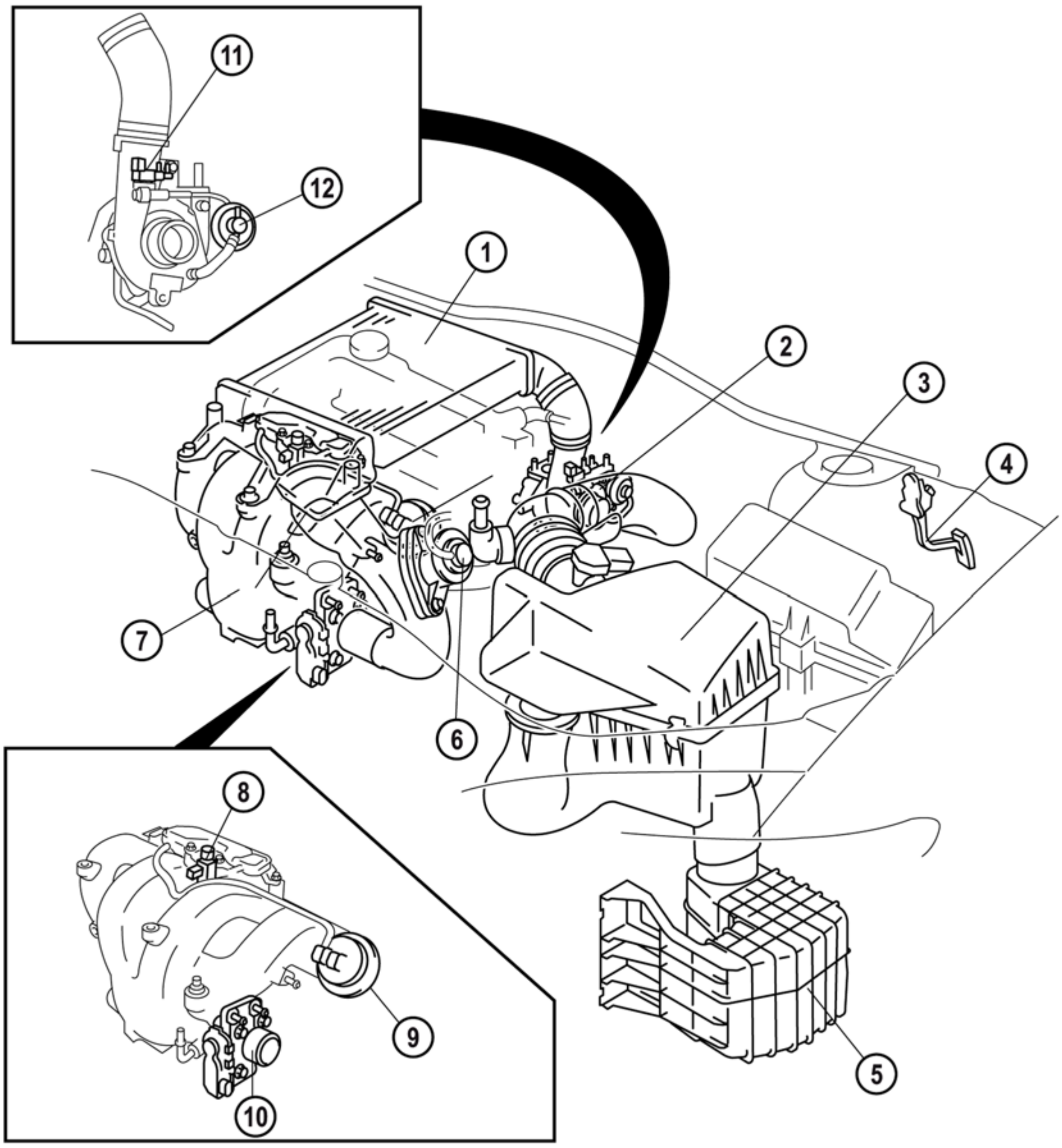
NOTE: Some of the components of the Mazda direct injection system are very similar in design and operation to those of the Mazda manifold injection system. Therefore, this section only describes the components which are new or operate in a different way to those of the Mazda manifold injection system.

Intake-air System

Features

- The intake-air system of the Mazda direct injection system has the following features:
  - Hot wire-type mass air flow sensor with integrated intake air temperature sensor (similar to that of the Mazda manifold injection system)
  - Turbocharger with fixed geometry turbine and boost pressure control valve with pressure actuator
  - Charge-air cooler
  - Charge-air bypass valve
  - Electronic throttle valve with hall-type accelerator pedal position sensor for Mazda6 MPS (similar to that of the Mazda manifold injection system)
  - Electronic throttle valve with inductive-type accelerator pedal position sensor for Mazda3 MPS
  - Manifold absolute pressure sensor with integrated intake air temperature sensor (similar to that of the Mazda manifold injection system)
  - No variable intake-air system
  - No variable tumble control system
  - Variable swirl control system

Parts Location



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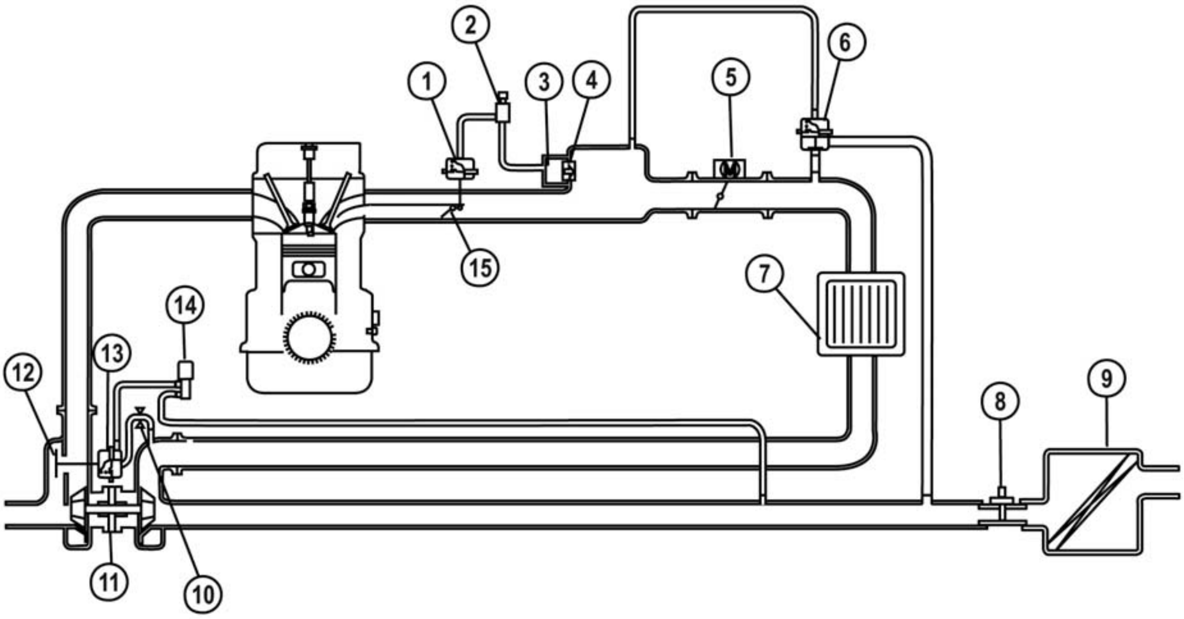
Mazda6 MPS

1	Charge –air-cooler	7	Intake manifold
2	Turbocharger	8	VSC solenoid valve
3	Air cleaner	9	VSC vacuum actuator
4	Accelerator pedal	10	Electronic throttle valve
5	Resonance chamber	11	VBC solenoid valve
6	Charge-air bypass valve	12	VBC pressure actuator

System Overview



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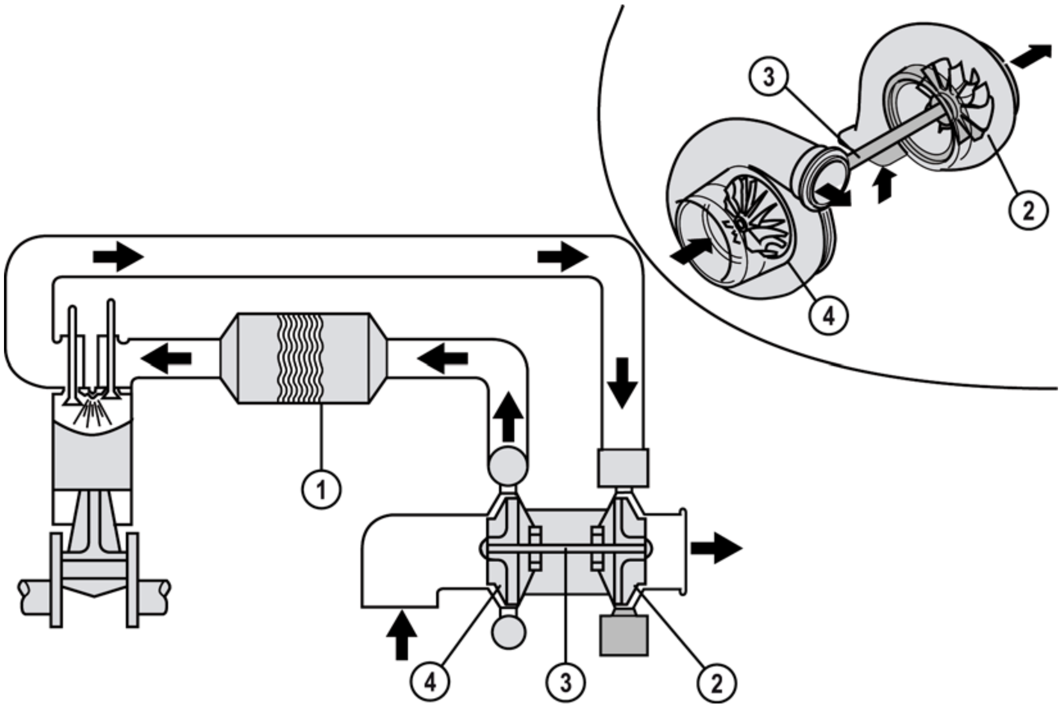
1	VSC vacuum actuator	9	Air cleaner
2	VSC solenoid valve	10	Flow limiter
3	Vacuum chamber	11	Turbocharger
4	One-way valve	12	Boost pressure control valve
5	Electronic throttle valve	13	VBC pressure actuator
6	Charge-air bypass valve	14	VBC solenoid valve
7	Charge-air cooler	15	VSC shutter valves
8	MAF/IAT sensor		

Turbocharger

- The turbocharger improves the charging efficiency of the engine, so that the torque and hence the power output of the engine are increased accordingly. The exhaust gases flowing out of the cylinder drive a turbine, which is connected to a compressor by means of the turbine shaft. The compressor forces the intake air into the cylinders at a pressure of up to 120 kPa (depending on the engine load).
- During engine operation the turbine shaft turns at a speed of up to 200,000 min^{-1}. Additionally it has to withstand a high thermal load due to the high exhaust gas temperature of approx. 1000 °C. Only hydrodynamic bearings can cope with these operating conditions. In order to lubricate the hydrodynamic bearings the turbocharger is connected to the lubrication system of the engine. In addition, the turbocharger housing is cooled by the engine cooling system.

NOTE: The extremely high rotational speeds of the turbine shaft subject its bearings to a certain amount of wear. As a result, engine oil can escape from a faulty bearing and get into the intake-air system, contaminating its components (such as charge-air cooler etc.). In addition, the oil burns in the engine, which can lead to damage to the engine components (such as contamination of the spark plugs, HO2S, TWC etc.).



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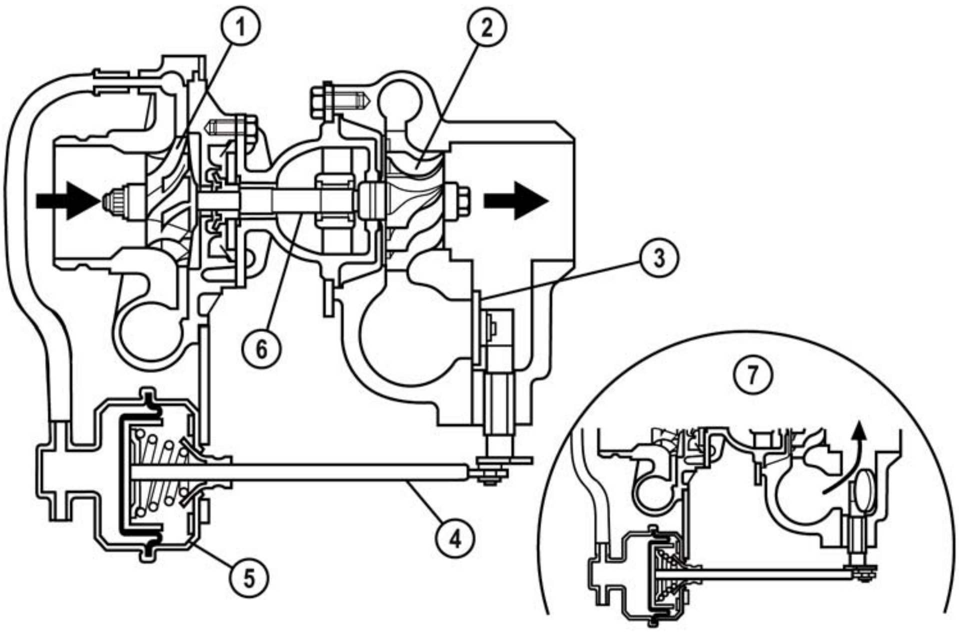
1	Charge-air cooler	3	Turbine shaft
2	Turbine	4	Compressor

- Since the turbine and compressor wheel have the same rotational speed, the boost pressure created by the turbocharger depends on the exhaust-gas flow, which in turn depends on the engine speed. As a result, the boost pressure rises with increasing engine speed.
- The turbocharger features a **FGT** (**F**ixed **G**eometry **T**urbine) and controls the boost pressure via a boost pressure control valve (also termed as wastegate). The boost pressure control valve is driven by a pressure actuator, which is connected to the compressor housing by means of a hose.
- When the boost pressure exceeds a pre-set value, the boost pressure control valve opens and the surplus exhaust gas is ducted past the turbine. In this way, the exhaust-gas flow through the turbine is limited, preventing a further increase in boost pressure.



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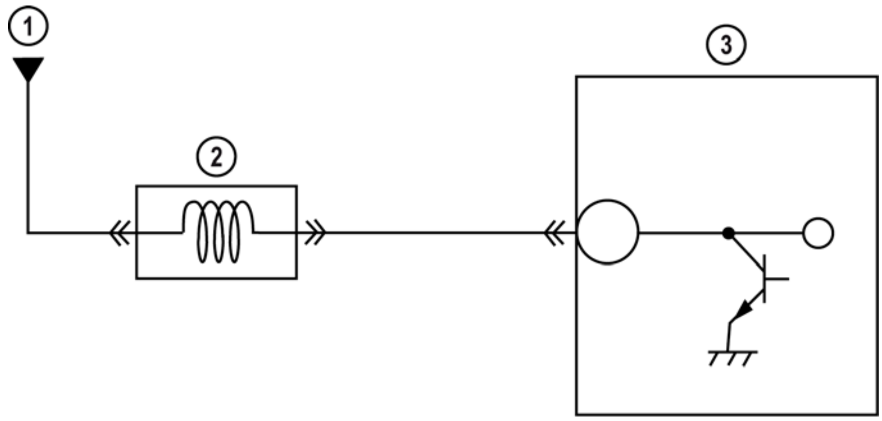
1	Compressor	5	VBC pressure actuator
2	Turbine	6	Turbine shaft
3	Boost pressure control valve	7	Boost pressure control valve open
4	Push rod		

- In order to increase the boost pressure temporarily under certain operating conditions, the operation of the boost pressure control valve is controlled by the PCM via the **VBC** (**V**ariable **B**oost **C**ontrol) solenoid valve (also termed as wastegate control solenoid valve). The VBC solenoid valve opens or closes a connection between pressure actuator and intake pipe (upstream of the turbocharger).
- The pressure applied to the pressure actuator of the boost pressure control valve and hence the position of the valve varies depending on the current flowing through the coil of the VBC solenoid valve, which in turn depends on the duty signal from the PCM.



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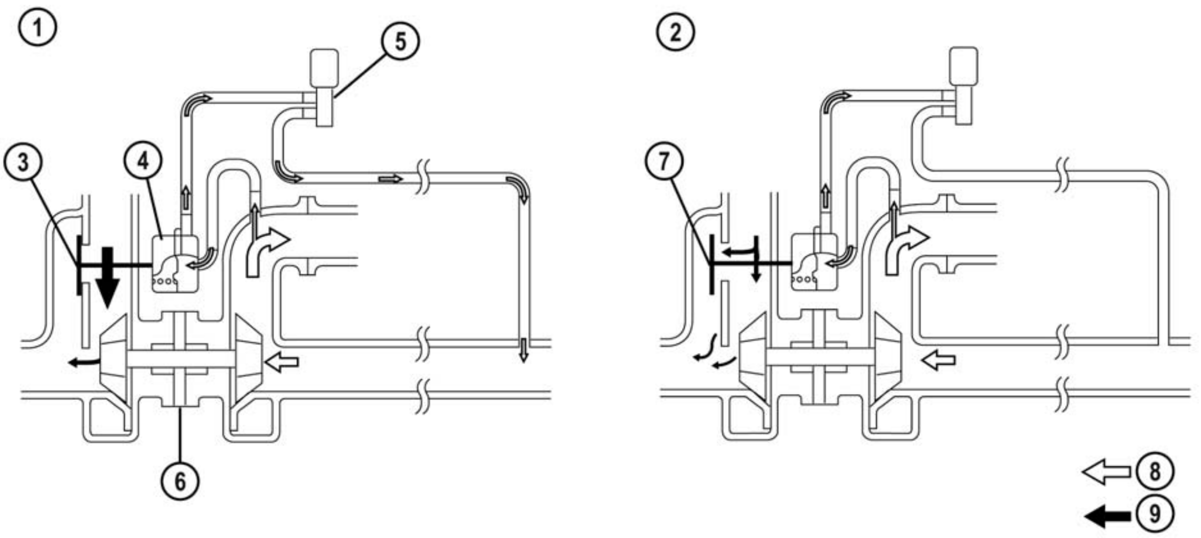
1 From PCM control relay
2 VBC solenoid valve
3 PCM

- When the accelerator pedal position is above 18.75 % and the engine speed is below 7000 min^{-1} (depending on the model), the PCM activates the VBC solenoid valve, opening the connection between pressure actuator and intake pipe. As a result, the pressure applied to the pressure actuator falls below the pre-set value, so that the boost pressure control valve does not open. This allows a temporary increase in boost pressure.
- In any other condition than above the PCM deactivates the VBC solenoid valve, closing the connection between pressure actuator and intake pipe. As a result, the pressure applied to the pressure actuator exceeds the pre-set value, so that the boost pressure control valve opens. This prevents a further increase in boost pressure.

NOTE: In case of an open circuit the VBC solenoid valve adopts in the closed position in which the pressure applied to the boost pressure actuator exceeds the pre-set value and the boost pressure control valve opens. This fail-safe strategy is also applied when there is an open circuit at the MAP sensor.



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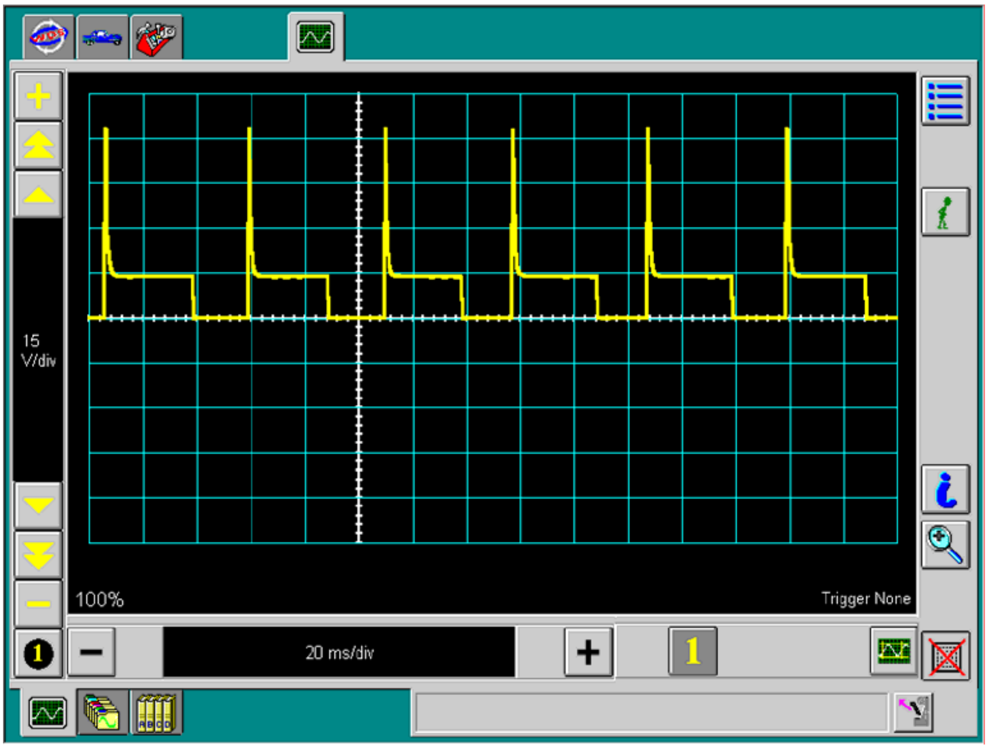
1	VBC solenoid valve energized	6	Turbocharger
2	VBC solenoid valve de-energized	7	Boost pressure control valve open
3	Boost pressure control valve closed	8	Intake-air flow
4	VBC pressure actuator	9	Exhaust-gas flow
5	VBC solenoid valve		

- The PCM controls the VBC solenoid valve by a duty signal 0 V/12 V. The boost pressure is proportional to the duty ratio, i.e. the larger the duty ratio the higher the boost pressure.



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Strategy of the Boost Pressure Control

- The boost pressure control varies the boost pressure according to the operating conditions of the engine. The PCM processes the incoming information, calculates from it the target boost pressure and controls the boost pressure control valve accordingly. The main parameters for calculating the boost pressure are:
  - Mass airflow
  - Engine speed
  - Throttle position

- The PCM continuously monitors the boost pressure via the MAP sensor signal. In order to protect the engine against overheating in case of a malfunction, the PCM reduces the injection amount.

Diagnostics

- The turbocharger can be checked as following:
  - Monitoring the boost pressure via the PID **MAP** (Press/Volt)
  - Monitoring the charge-air temperature via the PIDs **BAT** (Temp)/ **BAT_V** (Volt)
  - Checking the turbocharger
  - Monitoring/Activating the VBC solenoid valve via the PID **WGC#** (Per)
  - Checking the voltage signal at the VBC solenoid valve
  - Checking the resistance of the VBC solenoid valve
  - Checking the function of the boost pressure control valve

Checking the turbocharger

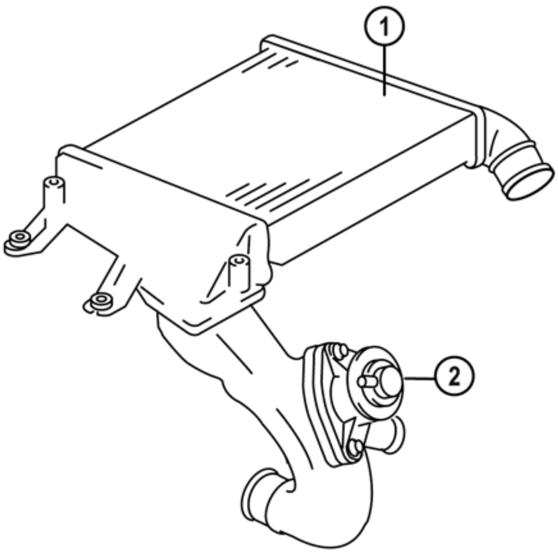
- Turn the turbine shaft in the normal direction of rotation. If scraping noises are heard, this indicates a faulty turbocharger (the compressor wheel and/or the turbine wheel is scraping on the housing). In addition, a visual check must be made for missing or damaged turbine and compressor blades.

Checking the function of the boost pressure control valve

- Pinch the hose from the compressor housing to the pressure actuator using a hose clamp. Then disconnect the hose coming from the VBC solenoid valve at the pressure actuator, connect a hand-operated pressure pump to the VBC pressure actuator and apply pressure. Check, whether the boost pressure control valve opens at a certain pressure, and closes when the system is vented.

Charge-air Cooler

- The charge-air cooler (also termed as intercooler) improves the charging efficiency of the turbocharged engine, so that torque and hence power output are increased accordingly. When the intake air is compressed in the turbocharger, not only the pressure but also the temperature of the air rises. As a result, the density of the charge air decreases, leading to a larger volume and hence to a lower cylinder charge. In order to compensate this effect the charge air is cooled accordingly.
- In addition, cooling the charge air lowers the temperature in the combustion chamber, preventing engine knocking.



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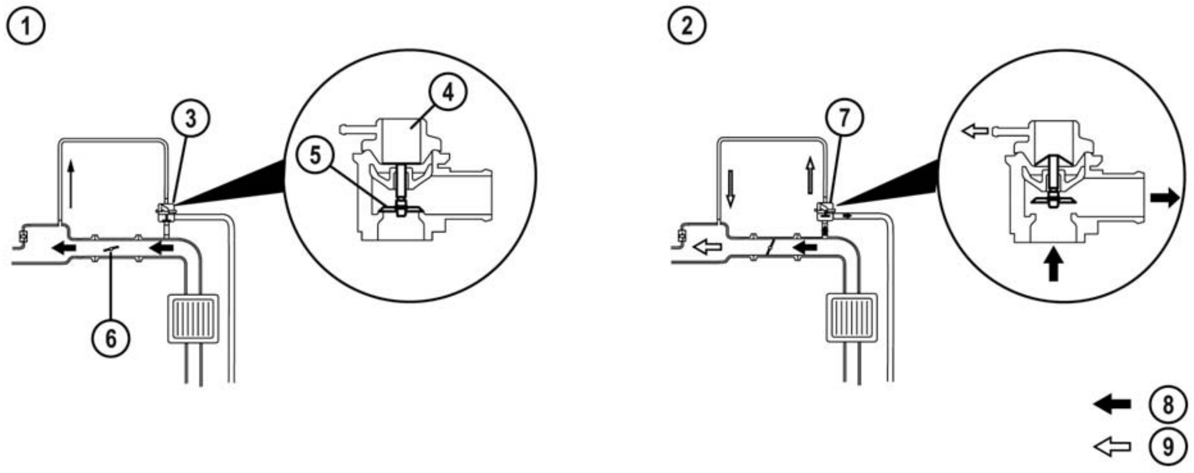
1	Charge-air cooler	2	Charge-air bypass valve

Charge-air Bypass Valve

- The charge-air bypass valve protects the turbocharger's compressor wheel against pressure waves. These pressure waves occur when the throttle valve closes suddenly, but the compressor wheel is still rotating very fast and pumping air at the closed throttle valve.
- The charge-air bypass valve is located in the intake pipe between charge-air cooler and electronic throttle valve, and is driven by a vacuum actuator.
- When the throttle valve is closed or partly open (at idle or at part load) there is a vacuum in the intake manifold. As a result, the charge-air bypass valve opens and the surplus air is returned to the intake pipe upstream of the turbocharger. In this way, the air pumped at the closed throttle valve does not flow backwards to the compressor, allowing the compressor wheel to rotate freely.



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1	Throttle valve open
2	Throttle valve closed
3	Charge-air bypass valve closed
4	Vacuum actuator
5	Valve
6	Throttle valve
7	Charge-air bypass valve open
8	Atmosphere pressure or excess pressure
9	Vacuum

Diagnostics

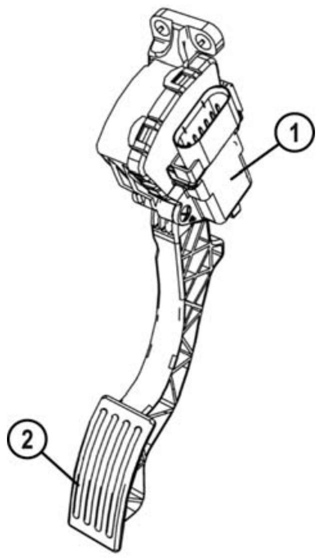
- The charge-air bypass valve can be checked as following:
  - Checking the function of the charge-air bypass valve

Checking the function of the charge-air bypass valve

- Remove the charge-air bypass valve from the intake pipe, connect a hand-operated vacuum pump to the vacuum actuator and apply vacuum. Check, whether the valve moves easily, and returns to the parked position when the system is vented.

Accelerator Pedal Position Sensor

- The Mazda3 MPS is equipped with an inductive-type APP sensor. For safety reasons the APP sensor features two inductive sensors, each consisting of a stator element with excitation and receiver coils, and a rotor element joint to the accelerator pedal.



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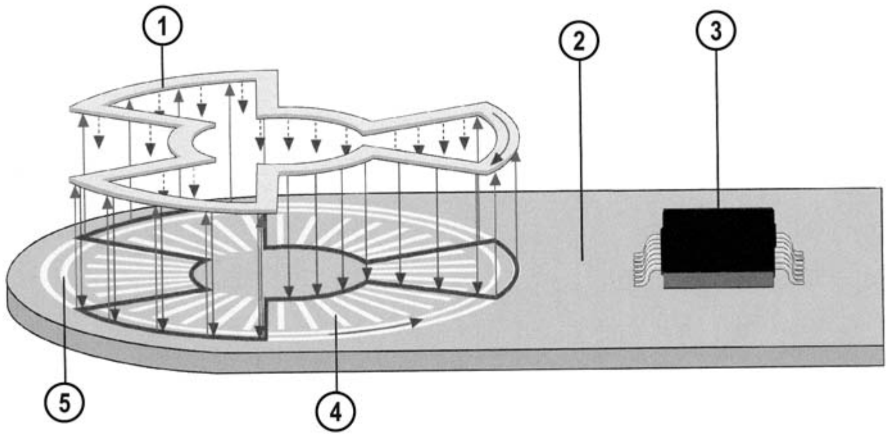
1	APP sensor	2	Accelerator pedal

- Alternating current passing through the excitation coils creates an electromagnetic field, which acts on the rotor and hence on the receiver coils. In this way, a voltage is induced in the receiver coils, which changes depending on the angular position of the rotor. As a result, the position of the accelerator pedal can be detected wear-free.

NOTE: If one inductive sensor fails, the PCM uses the signal from the other inductive sensor to detect the driver's acceleration demand. As a result, the vehicle can be driven without major restrictions. If the APP sensor fails completely, the PCM deactivates the DC motor of the electronic throttle valve. As a result, the throttle valve is maintained slightly open by the spring-loaded stop, so that the engine speed is fixed at approx. 1500 min^{-1}.



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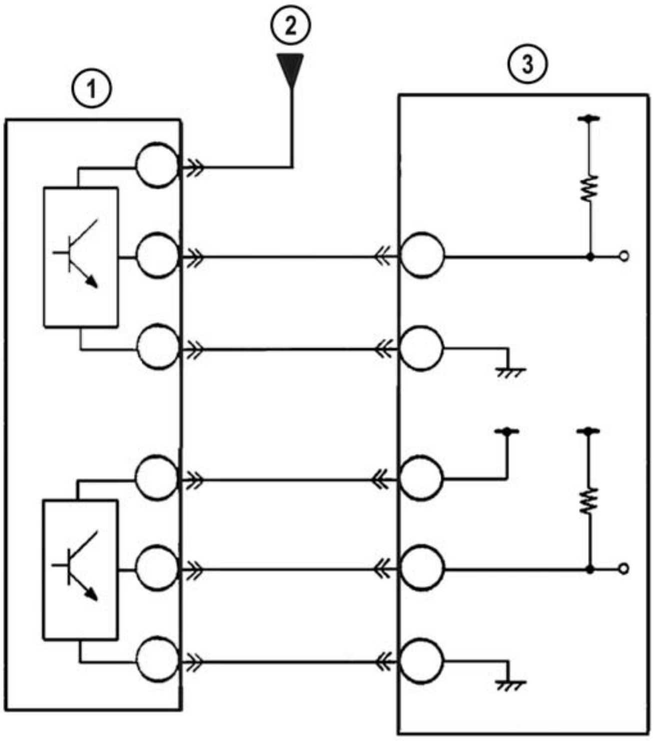
1	Rotor	4	Receiver coil
2	Printed circuit board	5	Excitation coil
3	Evaluation electronics		



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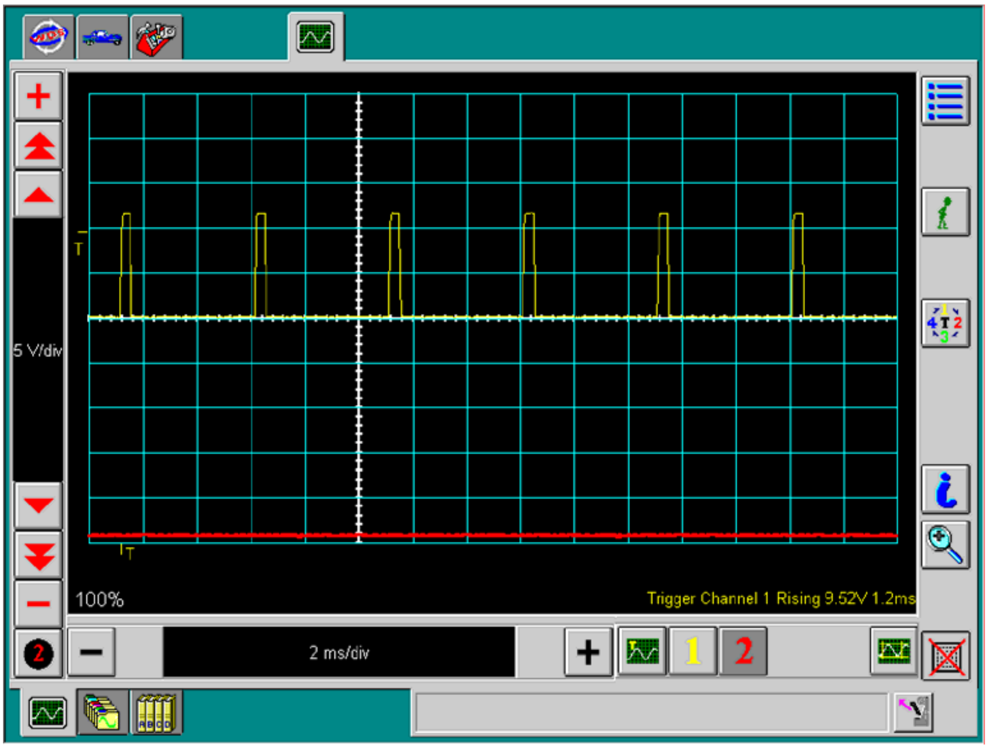
1 APP sensor
2 From PCM control relay
3 PCM

- One inductive sensor transmits a digital voltage signal 0 V/12 V to the PCM. The frequency of the signal is proportional to the accelerator pedal position, i.e. the more the accelerator pedal is pressed the higher the frequency.
- The other inductive sensor supplies the PCM with an analogue voltage signal between 0…5 V. The output voltage is proportional to the accelerator pedal position, i.e. the more the accelerator pedal is pressed the higher the voltage. The PCM permanently compares the signals of both sensors to monitor the APP sensor for failure.



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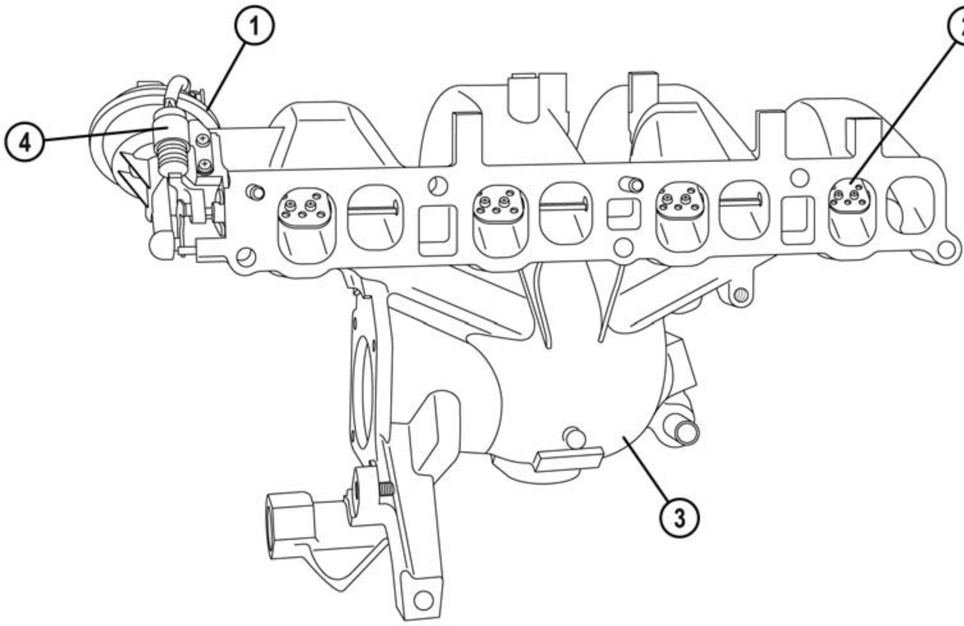
Diagnostics

- The electronic throttle valve can be checked as following:
  - Monitoring the engine speed via the PID **RPM** (Rpm)
  - Monitoring the desired engine speed via the PID **ARPMDES** (Rpm)
  - Checking the voltage at the drive-by-wire relay
  - Checking the resistance of the drive-by-wire relay
  - Monitoring the actual and desired position of the DC motor via the PIDs **ETC_ACT** (Angl) and **ETC_DSD** (Per/Angl)
  - Checking the voltage signal at the DC motor
  - Checking the resistance of the DC motor
  - Monitoring the TP sensor signals via the PIDs **TP1/TP2** (Per/Volt) and **TP REL** (Per)
  - Monitoring the closed throttle position via the PID **IVS** (Mode)
  - Monitoring the learned value for the fully closed throttle position via the PID **TPCT** (Volt)
  - Checking the voltage signals of the TP sensor
  - Monitoring the APP sensor signals via the PIDs **APP1/APP2** (Per/Volt) and **APP** (Per)
  - Checking the voltage signals of the APP sensor

Variable Swirl Control System

- The **VSC** (**V**ariable **S**wirl **C**ontrol) system is integrated in the intake manifold and reduces the exhaust emissions of the cold engine. The VSC shutter valves are driven by a vacuum actuator, and open or close one of the two intake ports per cylinder.



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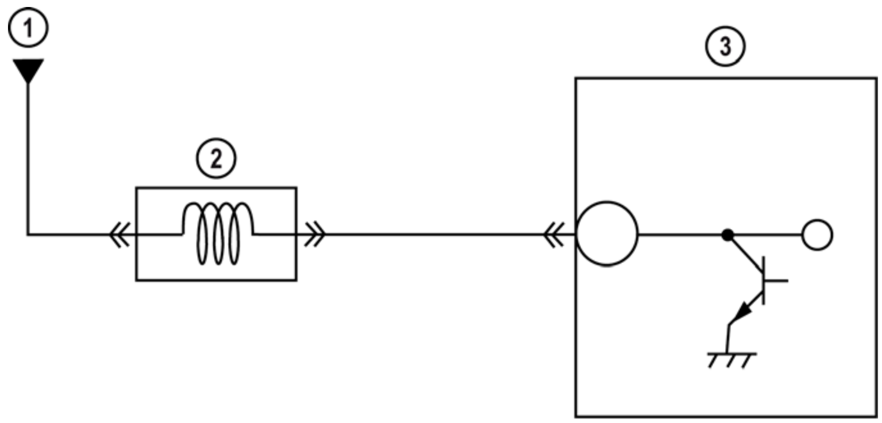
1	VSC vacúum actuator	3	Intake manifold
2	VSC shutter valves	4	VSC position switch

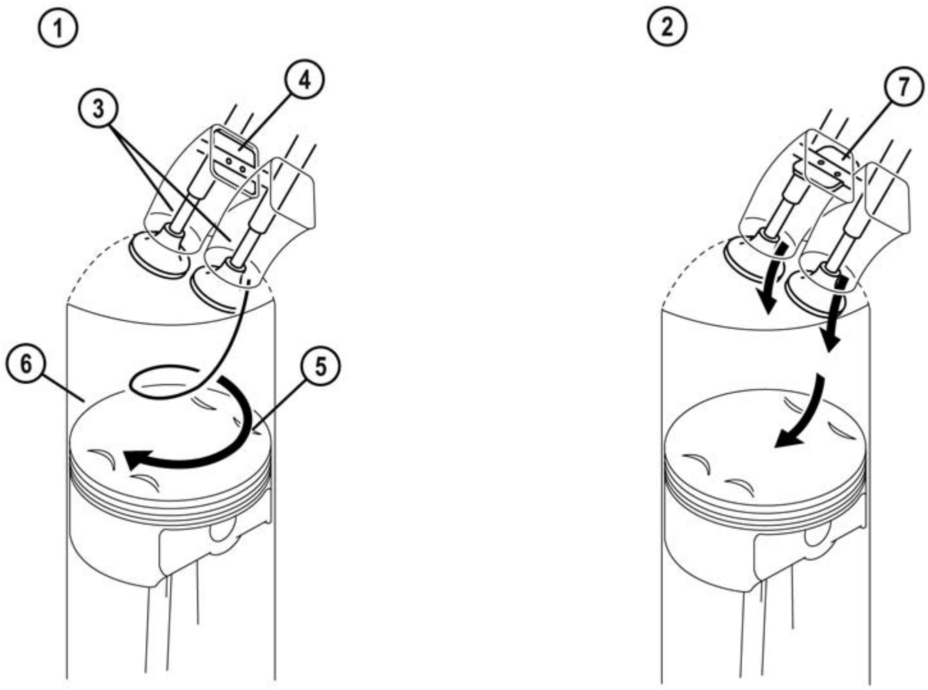
- The position of the VSC shutter valves is controlled by the PCM, which activates the VSC solenoid valve by an ON/OFF signal.



1 From PCM control relay
2 VSC solenoid valve
3 PCM

- When the engine speed is less than 3250 min^{-1} (depending on the model), the engine coolant temperature is less than 60 °C and the throttle opening angle is below a certain value (light engine load), the PCM energizes the VSC solenoid valve, applying vacuum to the vacuum actuator. As a result, the VSC shutter valves close the second intake port of each cylinder, so that the intake air is induced in the cylinder only via one intake port. Thus, the flow speed of the air entering the cylinder is increased, resulting in a strong swirl and a good mixture of the injected fuel with the air. This improves the combustion process and hence the exhaust emissions.
- In any other condition than above the PCM de-energizes the VSC solenoid valve, applying atmosphere pressure to the vacuum actuator. As a result, the VSC shutter valves open the second intake port of each cylinder, so that the intake air is induced into the cylinder via both intake ports. Thus, the intake air is induced in the cylinder without throttling, resulting in a high air throughput and a good cylinder charge. This ensures, that the engine delivers the required power output.

NOTE: In case of an open circuit the VSC shutter valves adopt in the open position in which no swirl is produced.



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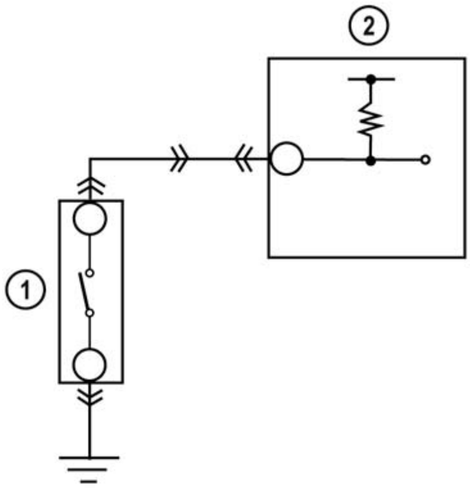
1 VSC solenoid valve energized
2 VSC solenoid valve de-energized
3 Intake port
4 VSC shutter valve closed
5 Air swirl
6 Cylinder
7 VSC shutter valve open

VSC Position Switch

- The VSC position switch is located at the VSC vacuum actuator and detects the position of the VSC shutter valves. When the VSC shutter valves are open, the switch closes and supplies the PCM with a voltage signal of 0 V.
- The signal of the VSC position switch serves to detect a malfunction of the VSC system (such as VSC shutter valves stuck closed etc.).



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1 VSC position switch
2 PCM

Diagnostics

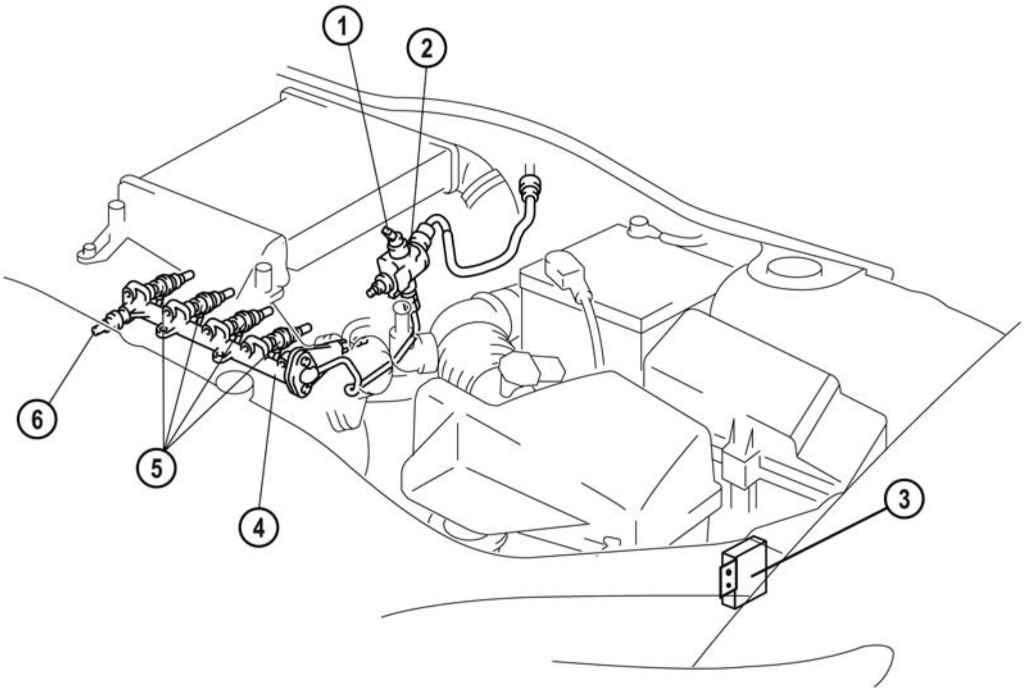
- The VSC system can be checked as following:
  - Monitoring/Activating the VSC shutter valves via the PID **IMRC#** (Mode)
  - Checking the voltage at the VSC solenoid valve
  - Checking the resistance of the VSC solenoid valve
  - Checking the function of the VSC shutter valves
  - Checking the voltage of the VSC position switch
  - Checking the resistance of the VSC position switch

Checking the function of the VSC shutter valves

- Connect a hand-operated vacuum pump to the VSC vacuum actuator and apply vacuum. Check, whether the adjusting linkage moves easily, and returns to the parked position when the system is vented.

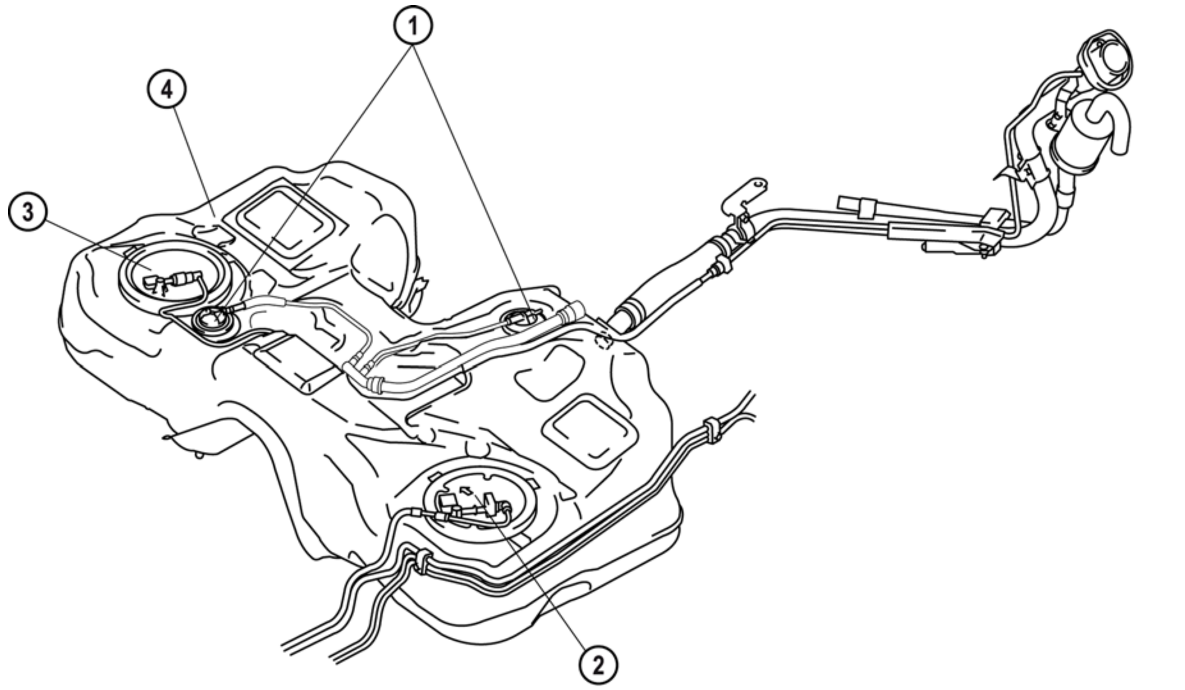
Fuel System

Parts Location



Mazda6 MPS (engine compartment side)

1	Spill control solenoid	4	Fuel rail
2	High-pressure pump	5	Fuel injector
3	Ballast resistor	6	Fuel pressure sensor



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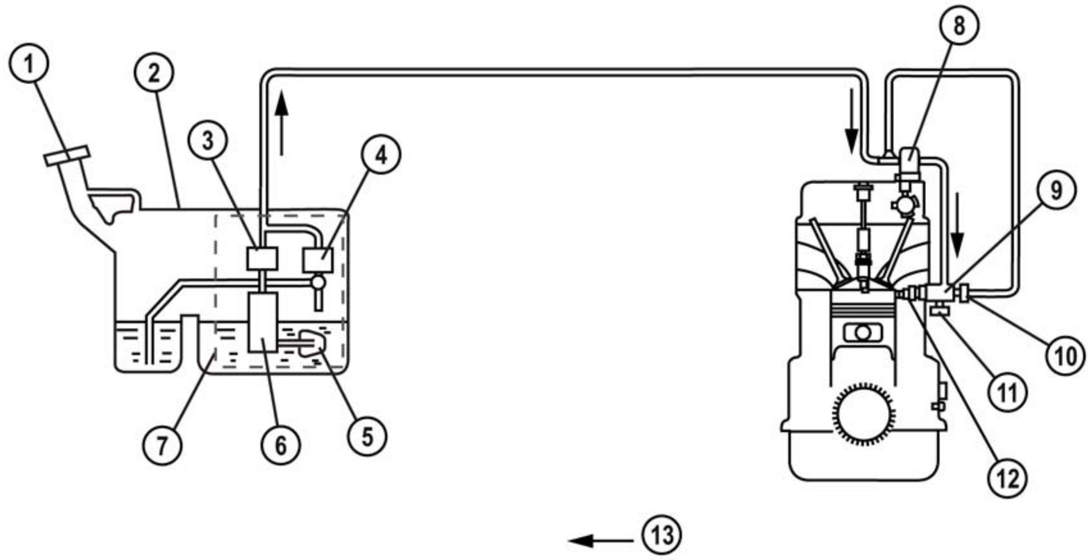
Mazda6 MPS (fuel tank side)

1	Rollover valve	3	Fuel tank unit
2	Fuel pump unit	4	Fuel tank

System Overview



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Mazda6 MPS

1	Fuel-filler cap	8	High-pressure pump
2	Fuel tank	9	Fuel rail
3	Fuel filter (high-pressure)	10	Pressure limiter valve
4	Pressure regulator	11	Fuel pressure sensor
5	Filter screen	12	Fuel injectors
6	Fuel pump	13	Fuel flow
7	Fuel pump unit		

NOTE: To ensure proper function of the engine only unleaded petrol with a maximum lead proportion of 5 mg/L and a maximum sulphur proportion of 150 ppm according to standard DIN EN 228 must be used. Although the L3T engine is designed to use petrol with 98 RON premium specification, it will also run with 95 RON petrol, resulting in a reduced power output. Do NOT use petrol with less than 95 RON, since this can cause severe knocking and hence serious engine damage.

NOTE: Mixing of any additives (e.g. fuel system cleaner) to the petrol other than those specified by Mazda is strictly forbidden, since this can lead to damage of the engine components (such as contamination of the spark plugs, HO2S, TWC etc.).

Directives for Working on Petrol Direct Injection Systems

- The work on petrol direct injection systems must be carried out by skilled professional personnel, who are familiar with the safety regulations and who take special measures to ensure that these are followed. The relevant rules and directives must be observed, especially regarding:
  - Directives of the responsible health authorities
  - Accident prevention
  - Environment protection

Preparatory Work

- Before working on a petrol direct injection system the following preparatory work must be done:
  - The working area must be clean and dust free.
  - The workers must wear clean clothing.
  - Parts which are in for repair must be stored in a dust free environment.
  - Always observe the tightening torques for the high-pressure line and utilise a torque wrench that is controlled regularly.

NOTE: The use of fuel additives for cleaning or metal coating of the fuel system is forbidden.

Safety Instructions

- In consideration of the high pressure (max. 12 MPa) in the petrol direct injection system, the following instructions must be observed:
  - Absolute prohibition of smoking in the immediate vicinity of the fuel system while working on it.
  - No work to be carried out in the immediate vicinity of open flames or sparks.
  - No work to be carried out on the fuel system when the engine is running.
  - Do not open the fuel system unless the fuel pressure has been released using a special procedure (refer to the section “Low-pressure System, Diagnostics”).
  - Always stay outside of the range of a possible fuel jet when the engine is running, since this can cause serious injuries.
  - Do not position the hands in the area of a suspected leak in the high-pressure system when the engine is running.

Low-pressure System

Features

- The low-pressure system has the following features:
  - Returnless, demand-controlled fuel system
  - Fuel pump unit (incorporating main fuel gauge sender unit, swirl pot with main and sub-jet pump, fuel filter, fuel pump and pressure regulator) and fuel tank unit (incorporating sub-fuel gauge sender unit and filter screen) for Mazda6 MPS
  - Fuel pump unit incorporating fuel gauge sender unit, swirl pot with jet pump, fuel filter, fuel pump and pressure regulator for Mazda3 MPS (similar to that of the Mazda manifold injection system)

Fuel Tank Unit

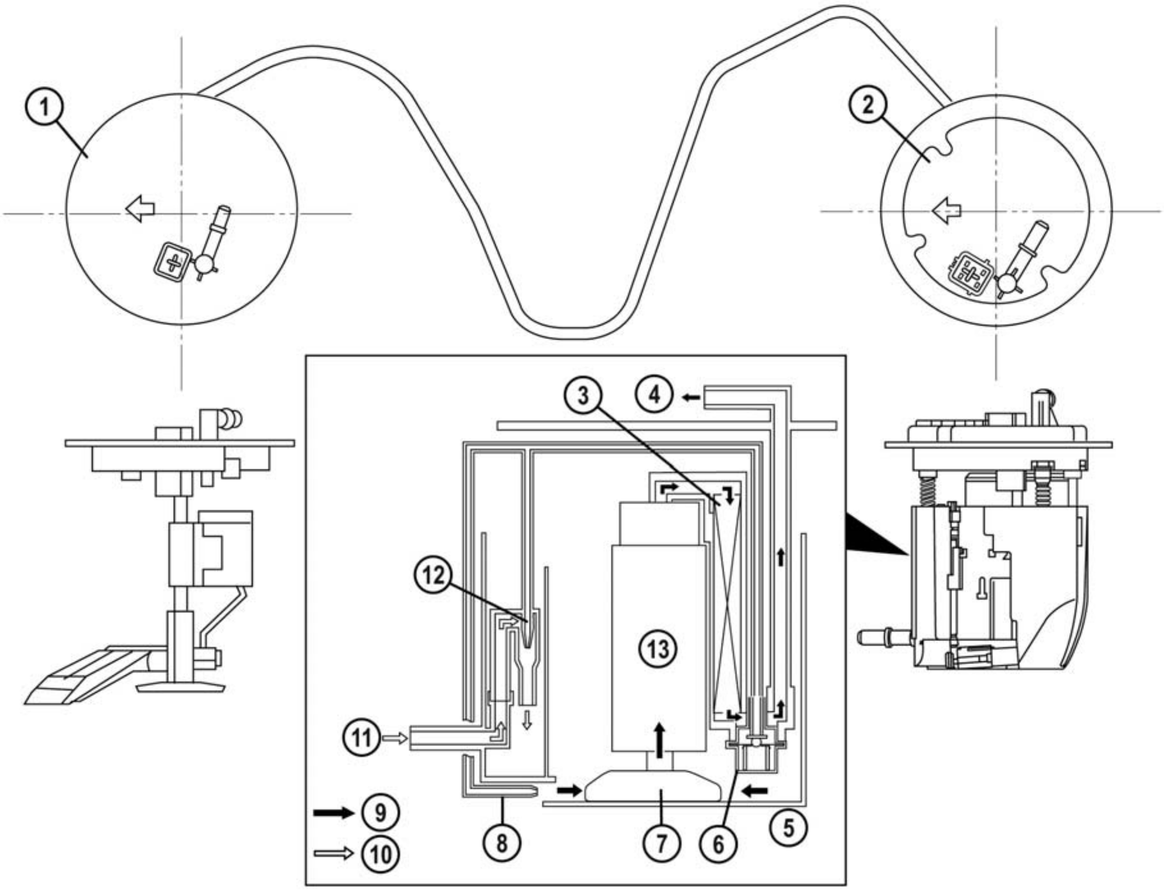
- Due to the saddle-shaped fuel tank divided into main and sub-tank, the Mazda6 MPS features a fuel tank unit in addition to the fuel pump unit.
- The fuel tank unit is located in the sub-tank and incorporates the sub-fuel gauge sender unit and the filter screen.

Fuel Pump Unit

- Vehicles with Mazda direct injection system feature a returnless, demand-controlled fuel system. The system varies the fuel amount delivered to the high-pressure pump and hence the fuel pressure in the low-pressure system depending on the operating conditions, improving reliability.
- On the Mazda6 MPS the fuel pump unit is located in the main tank and incorporates the main fuel gauge sender unit, swirl pot with main and sub-jet pump, fuel filter, fuel pump and pressure regulator.
- On the Mazda3 MPS the fuel pump unit is located in the fuel tank and incorporates the fuel gauge sender unit, swirl pot with jet pump, fuel filter, fuel pump and pressure regulator.

Swirl Pot

- On the Mazda6 MPS the swirl pot features a main jet pump and a sub-jet pump, which are connected in parallel. The main jet pump transfers fuel from the main tank to the swirl pot, and the sub-jet pump from the sub-tank to the swirl pot. Both jet pumps operate on the venturi effect, i.e. the returning fuel from the pressure regulator flows through the jet pump and sucks additional fuel into the swirl pot.



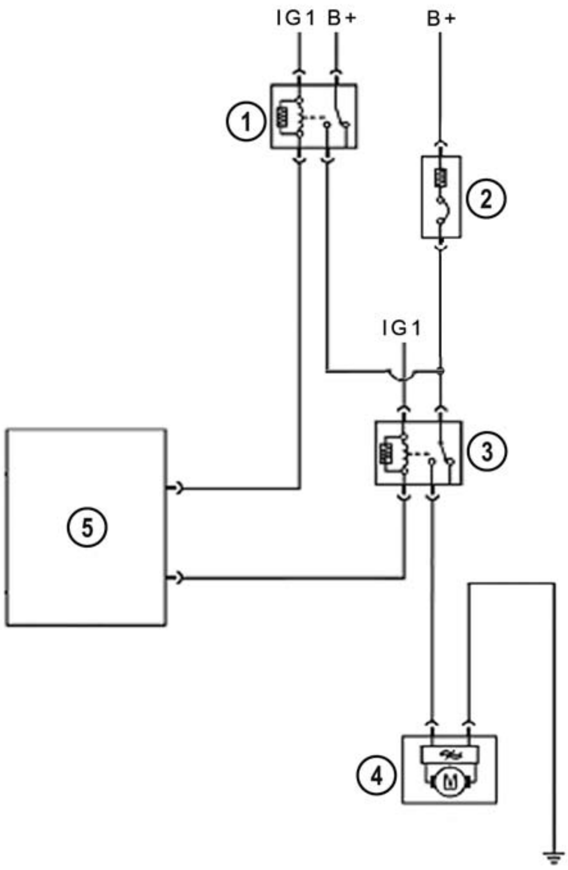
L3003_01027

Mazda6 MPS

1	Fuel tank unit	8	Main jet pump
2	Fuel pump unit	9	Feed fuel flow
3	Fuel filter	10	Flow of transferred fuel
4	To high-pressure pump	11	From fuel tank unit
5	Swirl pot	12	Sub-jet pump
6	Pressure regulator	13	Fuel pump
7	Filter screen		

Fuel Pump

- The fuel pump is controlled by the PCM via the fuel pump relay, the fuel pump speed control relay and the ballast resistor (the latter one is located under the air cleaner housing).



L3003_01028

1 Fuel pump speed control relay
2 Ballast resistor
3 Fuel pump relay
4 Fuel pump motor
5 PCM

- When the ignition is switched on the PCM energizes the fuel pump relay for 1 s to build up pressure in the fuel feed line, improving engine start.
- During cranking, a short time after hot start or when the engine speed is high the PCM energizes both the fuel pump relay and the fuel pump speed control relay, switching the power supply directly to the fuel pump motor. As a result, battery voltage is supplied to the fuel pump motor, so that the fuel pump operates at high speed. Thus, the fuel amount delivered to the high-pressure pump and hence the fuel pressure in the low-pressure system is high.
- In any other condition than above the PCM energizes solely the fuel pump relay, switching the power supply to the fuel pump motor via the ballast resistor. Due to the voltage drop at the ballast resistor the voltage supplied to the fuel pump motor is reduced, so that the fuel pump operates at low speed. Thus, the fuel amount delivered to the high-pressure pump and hence the fuel pressure in the low-pressure system is low.
- In this way, the fuel pump relay and the fuel pump speed control relay vary the pressure in the fuel feed line between 380…480 kPa (depending on the operating conditions) while the engine is running.

Diagnostics

- The low-pressure system can be checked as following:
  - Monitoring / Activating the fuel pump relay and the fuel pump speed control relay via the PID **FP#** (Mode)
  - Checking the voltage at the fuel pump relay/fuel pump speed control relay
  - Checking the resistance of the fuel pump relay/fuel pump speed control relay
  - Checking the voltage at the fuel pump motor
  - Checking the resistance of the fuel pump motor
  - Checking the resistance of the ballast resistor
  - Releasing the fuel pressure
  - Checking the fuel pressure
  - Checking the fuel hold pressure
  - Checking the fuel delivery amount

Releasing the fuel pressure

- Start the engine, remove the fuel pump relay (to switch off the fuel pump) and wait until the engine stalls. Then crank the engine several times until the fuel pressure is released.

Checking the fuel pressure

- Connect the PVT (with the aid of the FHA and the SST GV2323) between fuel feed line and high-pressure pump. Then select the PID **FP#** (Mode) in the M-MDS Datalogger and set the PID to “ON” (to switch on the fuel pump). Check the fuel pressure using the WDS Digital Multimeter. If the fuel pressure is above the specification (refer to the workshop manual), the fuel pump unit might be faulty (e.g. blocked pressure regulator).
- If the fuel pressure is below the specification, this could be caused by a restriction in the fuel feed line, faulty fuel pump unit (e.g. blocked fuel filter, faulty fuel pump or leaking pressure regulator) or a leaking injector. In order to rule out a faulty fuel pump unit, pinch the fuel line from the SST to the high-pressure pump while repeating the test. If the fuel pressure is now within specification, an injector might be leaking.

NOTE: This test should only be performed, if the diagnostic check revealed that the fuel feed line itself is leak-free.

Checking the fuel hold pressure

- Connect the PVT (with the aid of the FHA and the SST GV2323) between fuel feed line and high-pressure pump. Then select the PID **FP#** (Mode) in the M-MDS Datalogger and set the PID for 10 s to “ON” (to switch on the fuel pump). Then set the PID to “OFF” again and check the fuel hold pressure after 5 min using the WDS Digital Multimeter.
- If the fuel hold pressure is below the specification, this could be caused by a faulty fuel pump unit (e.g. leaking fuel pump or leaking pressure regulator) or a leaking injector. In order to rule out a faulty fuel pump unit, pinch the fuel line from the SST to the high-pressure pump while repeating the test. If the fuel hold pressure is now within specification, an injector might be leaking.

NOTE: This test should only be performed, if the diagnostic check revealed that the fuel feed line itself is leak-free.

Checking the fuel delivery amount

- Disconnect the fuel feed line at the high-pressure pump and connect the SST GV2323 to the line. The other end of the SST must go to a measuring container. Then select the PID **FP#** (Mode) in the M-MDS Datalogger, set the PID for 10 s to “ON” (to switch on the fuel pump) and measure the amount of fuel delivered during this time.
- If the fuel amount is far below the reference value, this could be caused by a faulty fuel pump speed control relay or a faulty fuel pump unit (e.g. blocked fuel filter or faulty fuel pump). In order to rule out a faulty fuel pump speed control relay, measure the voltage at the fuel pump motor while repeating the test. If the voltage is approx. 12 V, the fuel pump unit might be faulty.

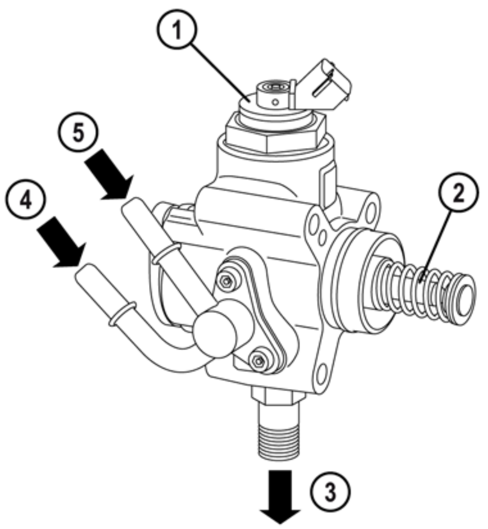
High-pressure System

Features

- The high-pressure system has the following features:
  - High-pressure pump
  - High-pressure line
  - Fuel rail with pressure limiter valve

High-pressure Pump

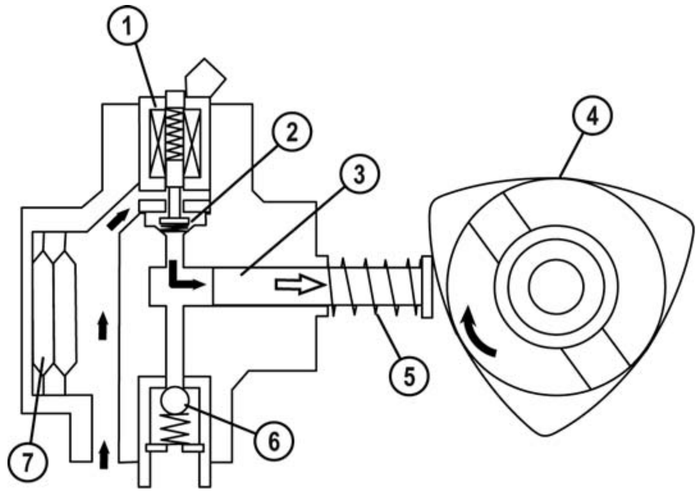
- The high-pressure pump produces the high pressure and delivers the fuel to the fuel rail. It is located at the cylinder head and consists of the plunger, inlet valve, outlet valve, spill control solenoid and pulsation damper.



L3003_01040

1	Spill control solenoid	4	From fuel tank
2	Plunger	5	From pressure limiter valve
3	To fuel rail		

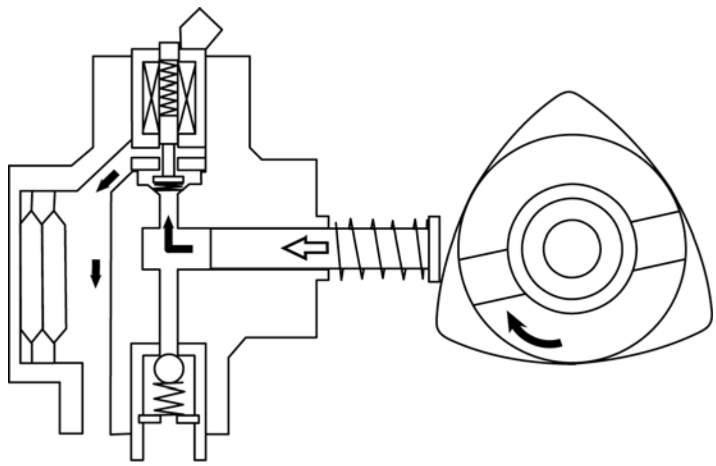
- The spring-loaded plunger of the high-pressure pump is driven by a trochoid-shaped cam on the camshaft, which turns with half the engine speed.
- When the plunger moves from TDC to BDC, fuel flows through the open inlet valve into the high-pressure chamber (filling phase).



L3003_01043

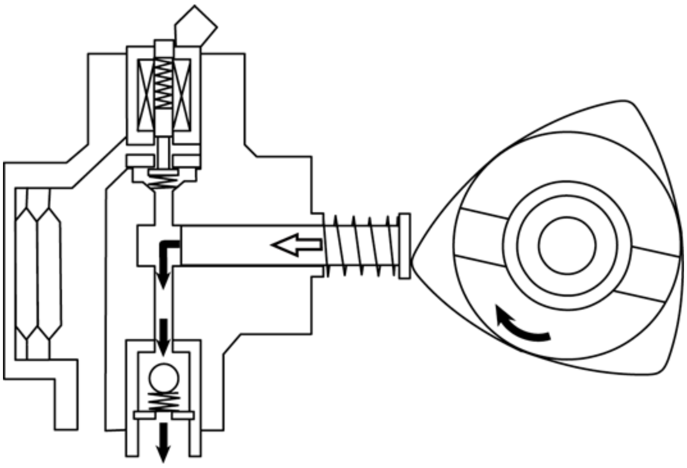
1	Spill control solenoid	5	Spring
2	Inlet valve	6	Outlet valve
3	Plunger	7	Pulsation damper
4	Camshaft with trochoid-shaped cam		

- When the plunger moves from BDC to TDC (working stroke) and the spill control solenoid holds the inlet valve open, the fuel in the high-pressure chamber is returned to the suction side of the pump (spilling phase).



L3003_01044

- As soon as the spill control solenoid releases the inlet valve, the valve closes and fuel is compressed in the high-pressure chamber (start of high-pressure phase). When the pressure in the high-pressure chamber rises, the outlet valve opens and the fuel is forced through the high-pressure line to the fuel rail. The working stroke is completed as soon as the pressure in the high-pressure chamber is lower than the pressure in the high-pressure line and the outlet valve closes (end of high-pressure phase).



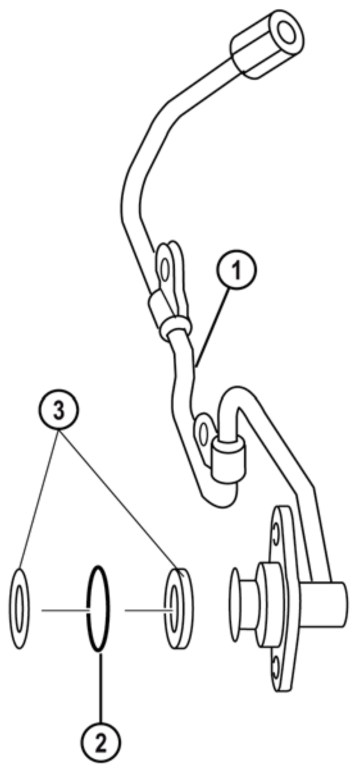
L3003_01045

- In addition, the high-pressure pump is equipped with a pulsation damper, which is located on the suction side of the pump and consists of two damping chambers made of sheet metal. If the pressure on the suction side has reached the target value, the damping chambers become deformed, enlarging the volume available for the fuel. As a result, the surplus fuel is absorbed when pressure peaks occur and is also released when the pressure drops, so that the pressure fluctuations resulting from the delivery characteristics of the pump are damped.
- Since the high-pressure pump is not equipped with a return line to the fuel tank that allows to release the fuel pressure, the fuel might be under high pressure even if the engine is not running. For this reason, the fuel pressure must always be released before the fuel system is opened.

High-pressure Line

- The high-pressure line connects the high-pressure pump to the fuel rail. To avoid pressure fluctuations and vibration fractures, it is made of thick-walled seamless steel tube with large bending radii.

NOTE: When removing the high-pressure line it must always be replaced, since the O-ring and the plastic washers are not available as separate spare parts.



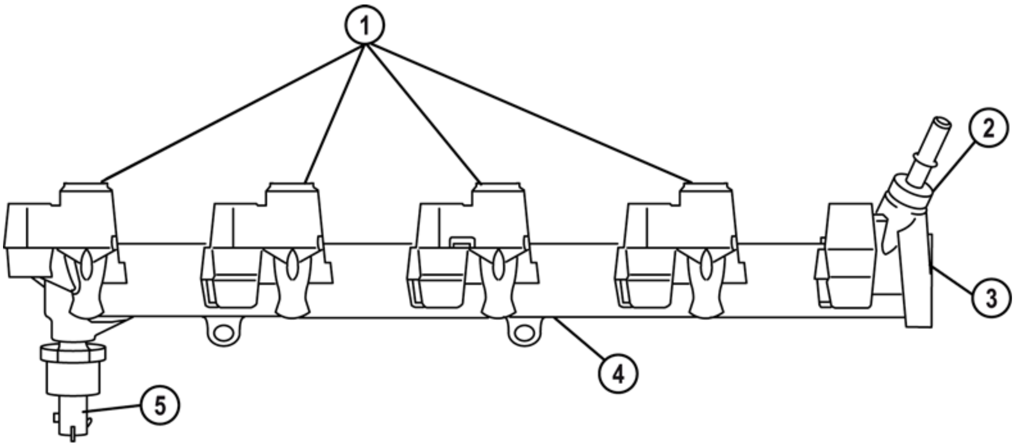
L3003_01030

1	High-pressure line	3	Plastic washer
2	O-ring		

Fuel Rail

- The fuel rail stores the fuel at constant high pressure between 3…12 MPa (depending on the operating conditions). The working strokes of the high-pressure pump, and the opening and closing of the injectors produce pressure fluctuations in the high-pressure system. Therefore, the fuel rail is designed in a way that it has sufficient volume to restrict the pressure fluctuations to a minimum. On the other hand, the volume of the fuel rail is small enough to build up the fuel pressure required for rapid starting in the shortest possible time.

NOTE: When re-installing the fuel rail always replace the O-rings and/or plastic washers between fuel rail and injectors, and between injectors and cylinder head.

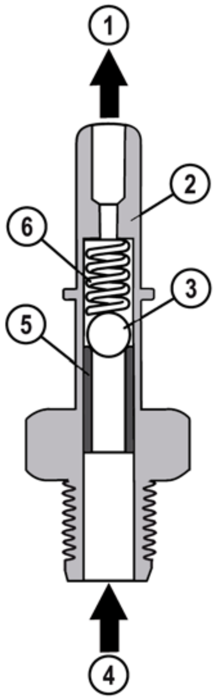


L3003_01029

1 To injector
2 Pressure limiter valve
3 From high-pressure pump
4 Fuel rail
5 Fuel pressure sensor

Pressure Limiter Valve

- The pressure limiter valve protects the high-pressure system against excessive pressure in case of a malfunction. The valve is located on the fuel rail and contains a spring-loaded ball valve. If the pressure in the fuel rail exceeds the maximum permissible level of 13 MPa, the valve opens and the surplus fuel is returned to the suction side of the high-pressure pump.



L3003_01048

1	To high-pressure pump	4	From fuel rail
2	Valve body	5	Valve seat
3	Valve ball	6	Spring

Fuel Pressure Control

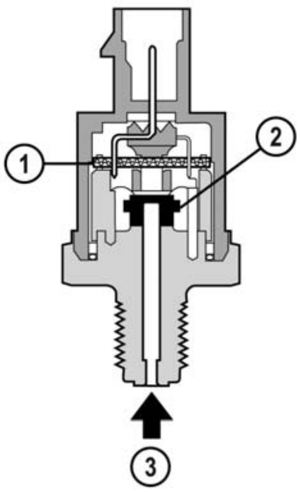
Features

- The fuel pressure control has the following features:
  - Fuel pressure sensor
  - Spill control solenoid

Fuel Pressure Sensor

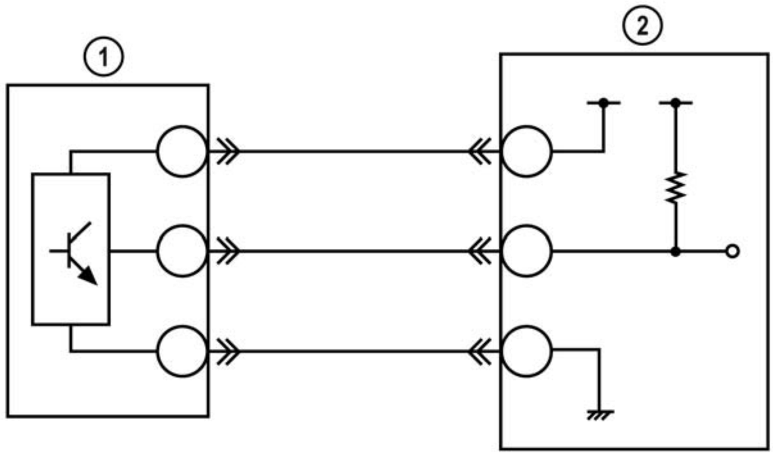
- The fuel pressure sensor is located on the fuel rail and detects the fuel pressure in the rail. It consists of a steel diaphragm with integrated strain gauges. The electrical resistance of the strain gauges varies, when their shape changes due to exposure to pressure.

NOTE: When removing the fuel pressure sensor it must always be replaced as well as the fuel rail, since the sealing cones of sensor and rail become deformed during installation.



L3003_01031

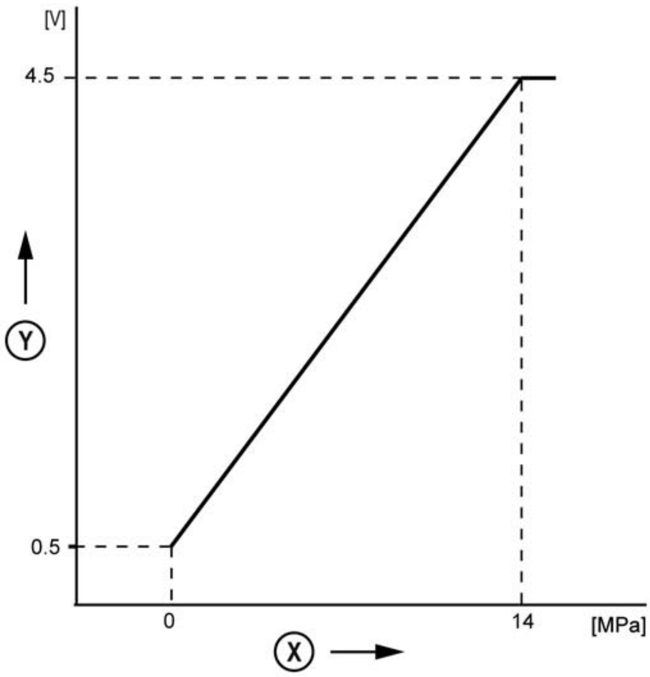
1 Evaluation electronics
2 Steel diaphragm with integrated strain gauges
3 From fuel rail



L3003_01053

1	Fuel pressure sensor	2	PCM

- The fuel pressure sensor supplies the PCM with an analogue voltage signal between 0…5 V. The output voltage is proportional to the fuel pressure, i.e. the higher the fuel pressure the higher the output voltage.



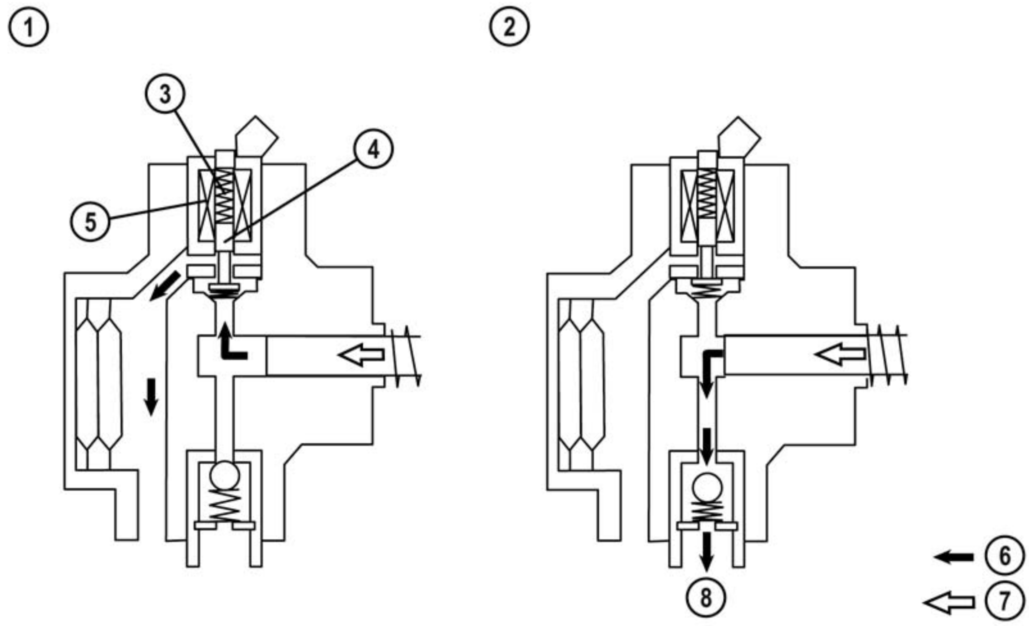
L3003_01050

X	Fuel pressure	Y	Output voltage

Spill Control Solenoid

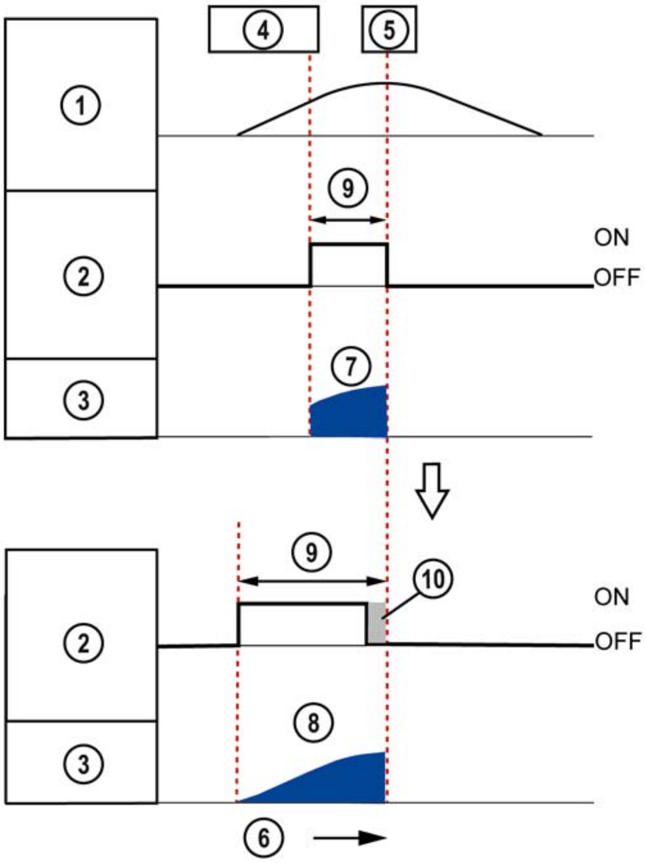
- The spill control solenoid controls the high-pressure phase duration of the pump and hence the fuel amount delivered to the fuel rail. As a result, the fuel pressure in the rail varies depending on the operating conditions. The spill control solenoid consists of a coil and a spring-loaded armature.
- When the spill control solenoid is de-energized during the working stroke of the pump, the armature holds the inlet valve open. As a result, the spilling phase starts, i.e. fuel is returned to the suction side of the pump.
- When the spill control solenoid is energized during the working stroke of the pump, the armature releases the inlet valve. As a result, the valve closes and the high-pressure phase starts, i.e. fuel is delivered to the fuel rail.

NOTE: In case of an open circuit the spill control solenoid holds the inlet valve open, i.e. no high pressure is produced anymore. As a result, the fuel supplied by the fuel pump suffices to open the outlet valve of the high-pressure pump and flows into the fuel rail, so that the engine continues to run with a fuel pressure of approx. 450…540 kPa. Since the PCM increases the opening time of the injectors to keep the injection amount constant, the engine exhibits a severe bucking during acceleration. This fail-safe strategy is also applied when there is an open circuit at the fuel pressure sensor.



1 Spill control solenoid de-energized
2 Spill control solenoid energized
3 Spring
4 Armature
5 Coil
6 Fuel flow
7 Plunger movement
8 To fuel rail

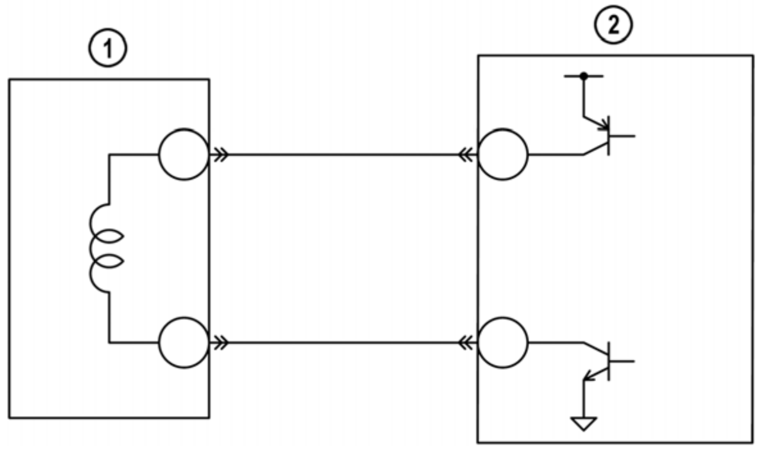
- The energization time of the spill control solenoid determines the duration of the high-pressure phase, varying the fuel pressure from zero to maximum.
- However, the energization time is restricted to minimize the power loss in the spill control solenoid, preventing it from overheating. For this reason, the PCM de-energizes the solenoid before the end of the working stroke when maximum fuel pressure is required. Due to the high pressure at the end of the working stroke the inlet valve remains closed, so that the high-pressure phase continues.



L3003_01047

1	Cam lift	6	Cam angle
2	Energization state of the spill control solenoid	7	Small delivery amount
3	Injection amount	8	Large delivery amount
4	Start of fuel delivery	9	Inlet valve closed
5	End of fuel delivery	10	Inlet valve closed although spill control solenoid is OFF

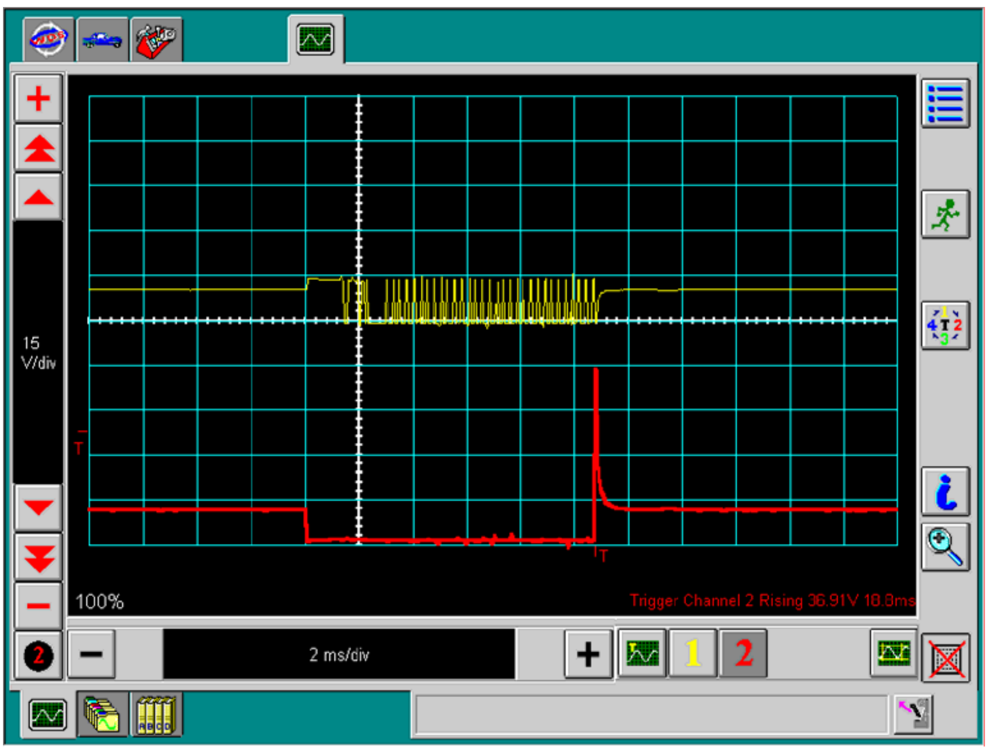
- The energization of the spill control solenoid and hence the duration of the high-pressure phase varies depending on the duty signal from the PCM.



L3003_01052

1	Spill control solenoid	2	PCM

- The PCM controls the spill control solenoid by a duty signal 0 V/12 V. The duration of the high-pressure phase is proportional to the duty ratio, i.e. the larger the duty ratio the higher the fuel pressure.



L3003_01056

Strategy of the Fuel Pressure Control

- The fuel pressure control varies the fuel pressure according to the operating conditions of the engine. The PCM processes the incoming information, calculates from it the target fuel pressure and controls the spill control solenoid accordingly. The main parameters for calculating the fuel pressure are:
  - Mass airflow
  - Engine speed
  - Engine coolant temperature
- Generally, the fuel pressure is increased with rising engine speed, since the time available for the injection process becomes shorter.

Diagnostics

- The components of the fuel pressure control can be checked as following:
  - Monitoring the fuel pressure via the PIDs **FUEL_PRES** (Press)/ **FUEL_PRES_V** (Volt)
  - Checking the voltage of the fuel pressure sensor
  - Monitoring the spill control solenoid via the PID **FP_HI_PRES** (Mode)
  - Checking the voltage signal of the spill control solenoid
  - Checking the resistance of the spill control solenoid

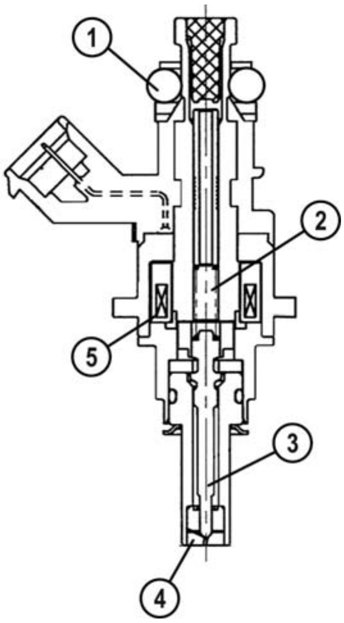
Injection Control

Features

- The injection control has the following features:
  - Injectors driven by an injector driver module (Mazda6 MPS)
  - Injectors driven by the PCM (Mazda3 MPS)

Injector

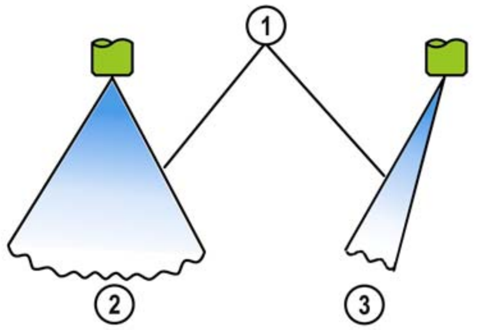
- The electrically actuated fuel injectors control the injection amount and the injection timing according to the operating conditions. The injectors consist of a coil, spring and valve needle.



L3003_01034

1	O-ring	4	Injection orifice plate
2	Spring	5	Coil
3	Valve needle		

- When the coil is de-energized, the injector is closed by the spring force acting on the valve needle.
- When the coil is energized, the magnetic force exceeds the spring force acting on the valve needle and the injector opens.
- The injectors are equipped with an injection orifice plate with one spray hole, which ensures optimum atomization of the fuel.



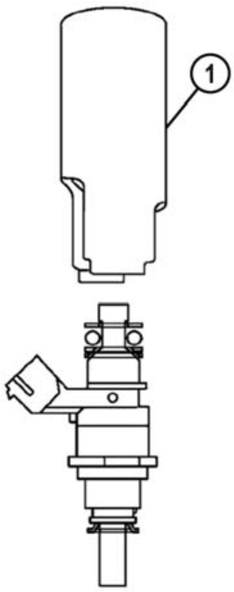
L3003_01035

1	Fuel jet
2	Front view
3	Side view

- In case the injectors stick in the cylinder head due to carbon accumulation, they can be removed using the SST 49G013101.

NOTE: When removing the injectors care must be taken not to damage the injector connector. In addition, it might be necessary to cut the tab of the oil separator to remove injector no.3 (refer to the workshop manual for details).

NOTE: Do NOT apply grease to the injectors or to the injector bore in the cylinder head during installation, since this causes the injectors to stick.

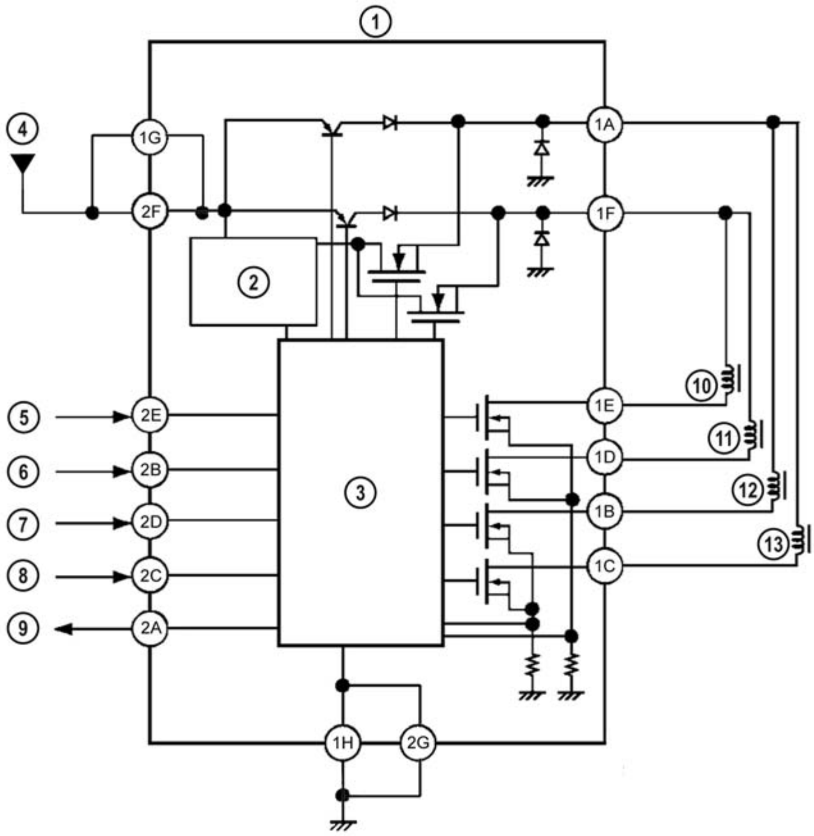


L3003_01036

1 SST 49G013101

Injector Driver Module

- The Mazda6 MPS is equipped with an **IDM** (**I**njector **D**river **M**odule), which is located under the battery tray and drives the injectors according to the control signals from the PCM. It has a high-voltage generator inside, which amplifies the battery voltage into a high voltage of approx. 100 V and stores it in a capacitor. A control circuit outputs the high voltage to the injectors as a drive signal.
- The PCM also controls the power supply of the IDM via the IDM relay.

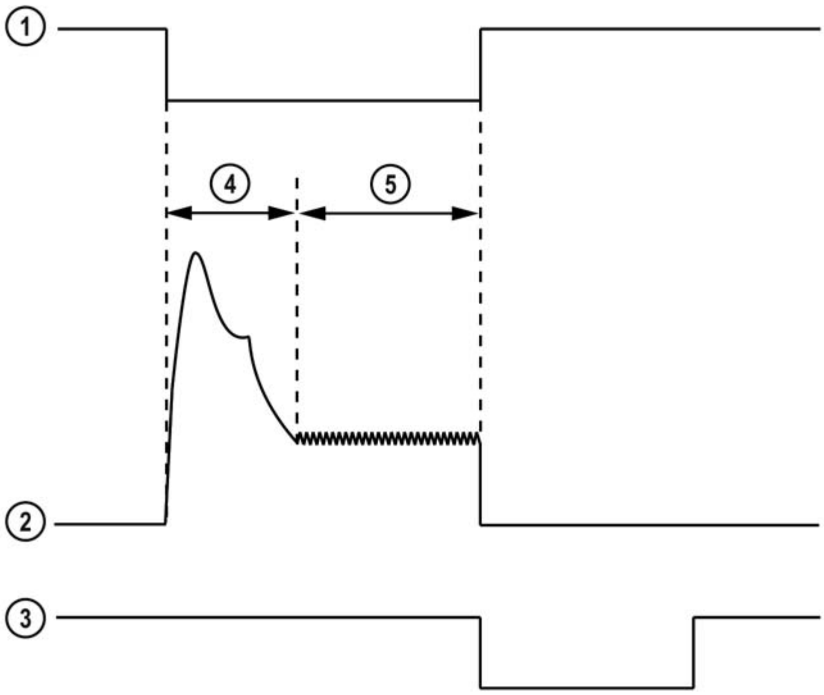


L3003_01037

Mazda6 MPS

1	IDM	8	Control signal for injector no 3
2	High-voltage generator	9	Feedback signal
3	Control circuit	10	Injector no.1
4	From IDM relay	11	Injector no.4
5	Control signal for injector no 1	12	Injector no.2
6	Control signal for injector no.4	13	Injector no.3
7	Control signal for injector no.2		

- The energization of the injector coil and hence the opening time of the injector varies depending on the drive signal from the IDM, which in turn depends on the control signal from the PCM.
- The IDM actuates the injectors in three phases. When the control signal for a certain injector is input from the PCM to the IDM, the IDM energizes the injector in question with a high voltage of approx. 100 V (pull-up phase). Due to the high pull-up current (approx. 10 A) the injector opens rapidly.
- In the holding phase the IDM reduces the actuating voltage to 12 V, resulting in a lower holding current (approx. 7 A). As a result, the power loss in the IDM and in the injector is minimized, preventing overheating of these components.
- In the turn-off phase, the IDM cuts off the actuating voltage to close the injector.
- The PCM controls the IDM by a duty signal 0 V/10 V. The opening time of the injectors is proportional to the duty ratio, i.e. the larger the duty ratio the higher the injection amount. In addition, the IDM sends a feedback signal 0 V/5 V to the PCM to facilitate failure detection.

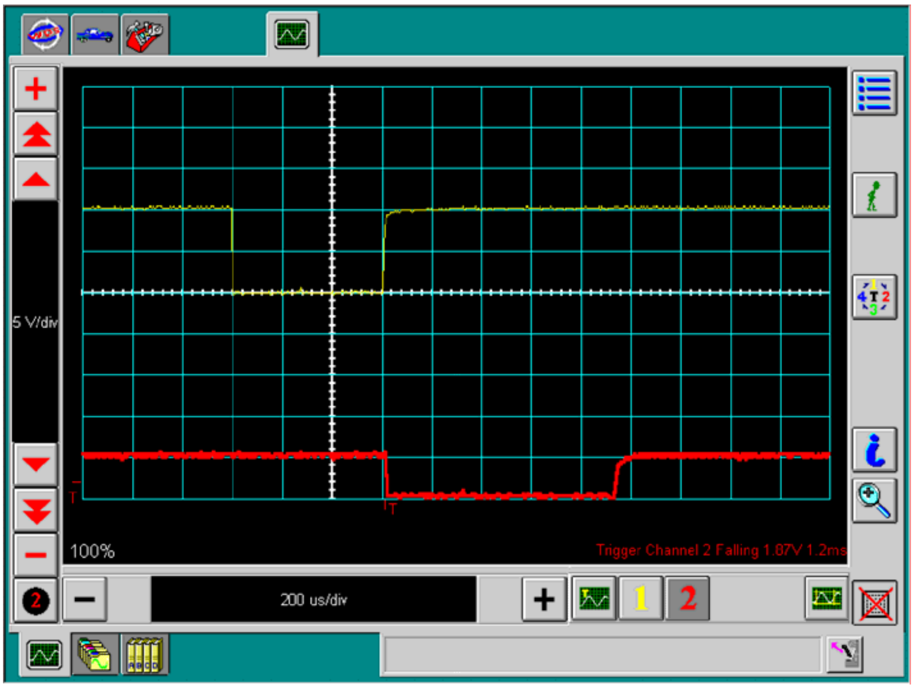


L3003_01051

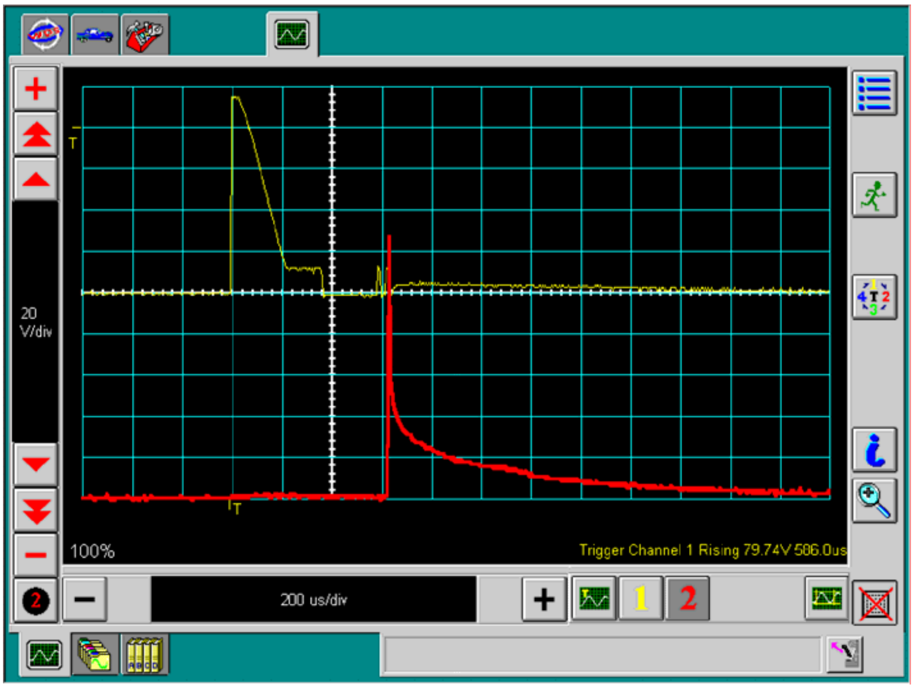
1	Injector control signal	4	Pull-up phase
2	Injector drive current	5	Holding phase
3	Feedback signal		

- The injectors no.1 and no.4, and the injectors no. 2 and no.3 are connected in parallel, i.e. two injectors each feature the same IDM terminal for the positive voltage supply.

NOTE: In case of an open circuit the IDM cuts off the negative voltage supply for the injector in question, so that the engine continues to run on three cylinders.

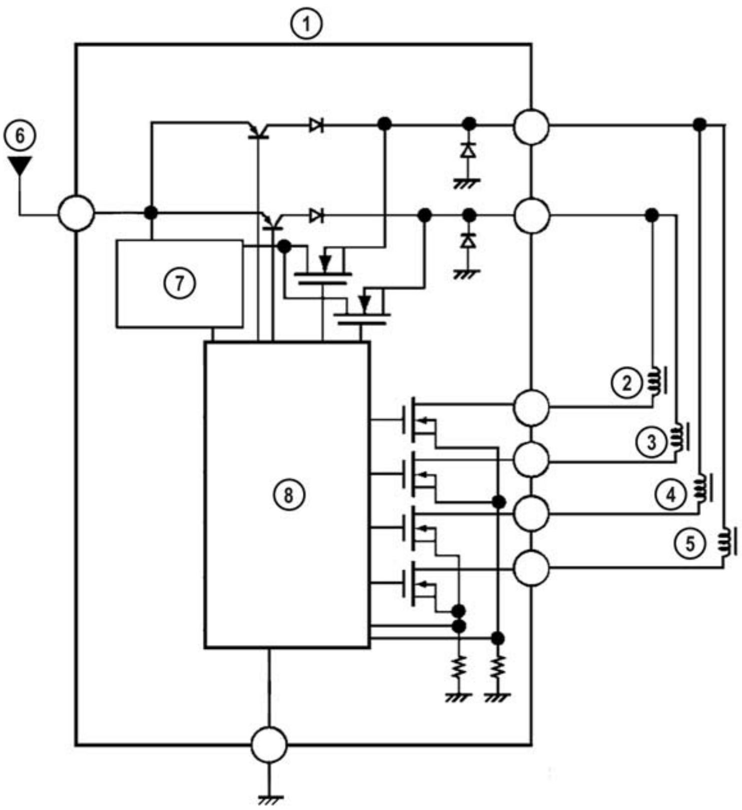


L3003_01057



L3003_01058

- On the Mazda3 MPS the IDM has been cancelled, i.e. the injectors are directly driven by the PCM. The module has a high-voltage generator inside, which amplifies the battery voltage into a high voltage of approx. 70 V and stores it in a capacitor. A control circuit outputs the high voltage to the injectors as a drive signal.

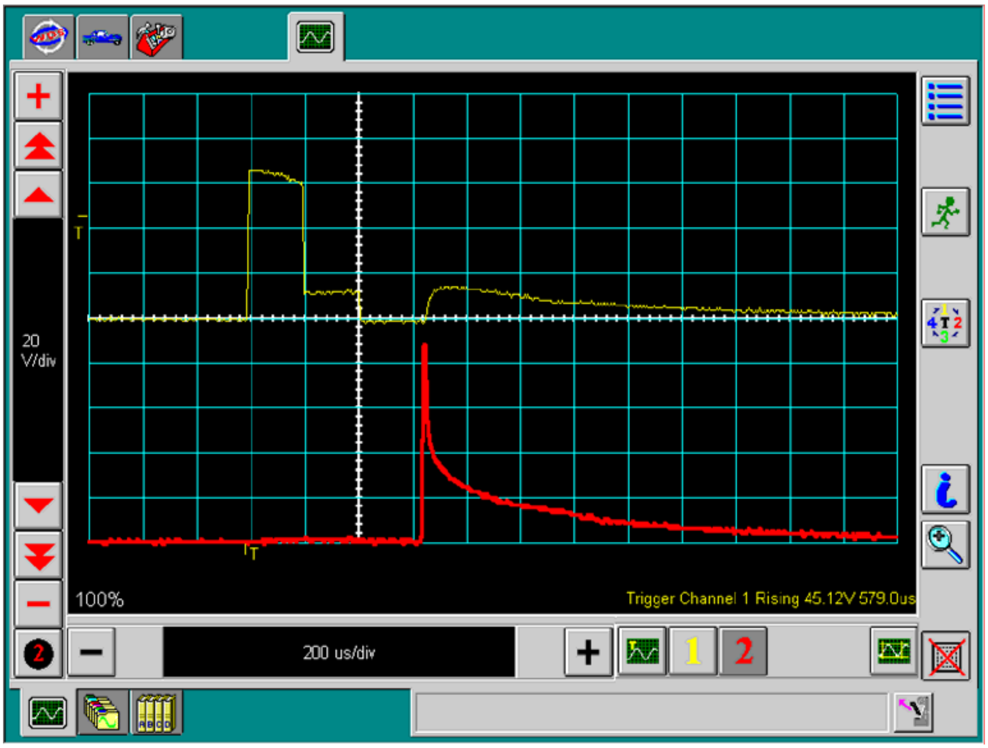


L3003_01038

Mazda3 MPS

1	PCM	5	Injector no.3
2	Injector no.1	6	From PCM control relay
3	Injector no.4	7	High-voltage generator
4	Injector no.2	8	Control circuit

- The operation of the injection control is similar to that of the Mazda6 MPS.



L3003_01059

Diagnostics

- The components of the injection control can be checked as following:
  - Monitoring the injector opening time via the PID **FUELPW** (Time)
  - Varying the injector opening time via the PID **FUELPW1#** (Per)
  - Monitoring the fuel injection amount via the PID **FIA** (Num)
  - Checking the voltage at the IDM relay (only Mazda6 MPS)
  - Checking the resistance of the IDM relay (only Mazda6 MPS)
  - Checking the control signals at the IDM (only Mazda6 MPS)
  - Checking the feedback signal at the PCM (only Mazda6 MPS)
  - Checking the voltage signals of the injectors
  - Checking the resistance of the injectors
  - Checking the function of the injectors

Checking the function of the injectors

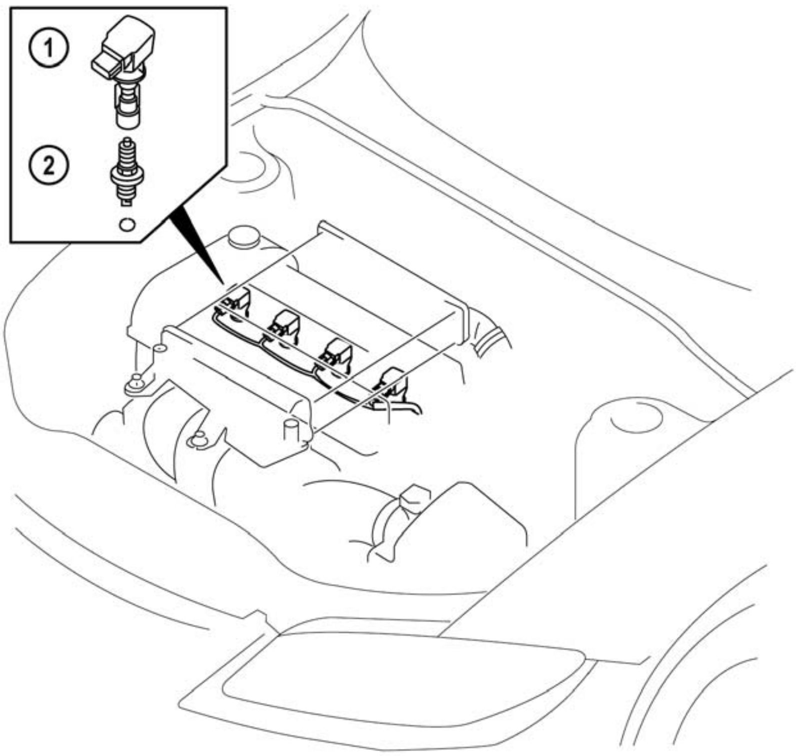
- Select the PIDs **INJ_1#**, **INJ_2#**, **INJ_3#** and **INJ_4#** (Mode) in the M-MDS Datalogger and start the engine. Then set the PID INJ_1# to "OFF" (to disable the corresponding injector) and check, whether the engine speed drops (and if so, how much it drops). Repeat this procedure for all injectors and note the values.
- If the drop in engine speed at a certain cylinder is lower than on the other cylinders, the injector, ignition system or base engine might be faulty. In order to rule out a faulty ignition system, check the secondary voltage of the direct ignition coils using the WDS Ignition Test. In order to rule out a faulty base engine, check the compression of the engine.

Ignition System

Features

- The ignition system of the Mazda direct injection system has the following features:
  - Distributorless ignition system
  - Direct ignition coils with integrated power transistor (similar to those of the Mazda manifold injection system)
  - Spark plugs
  - Knock sensor (similar to that of the Mazda manifold injection system)

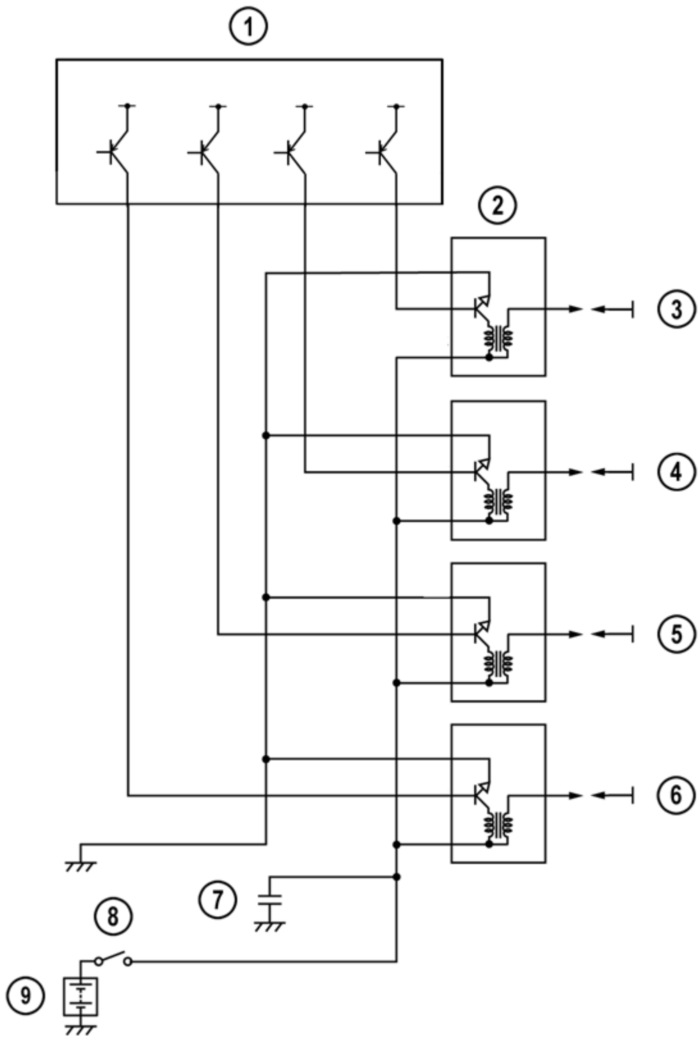
Parts Location



L3003_01049

1 Ignition coil
2 Spark plug

Wiring Diagram

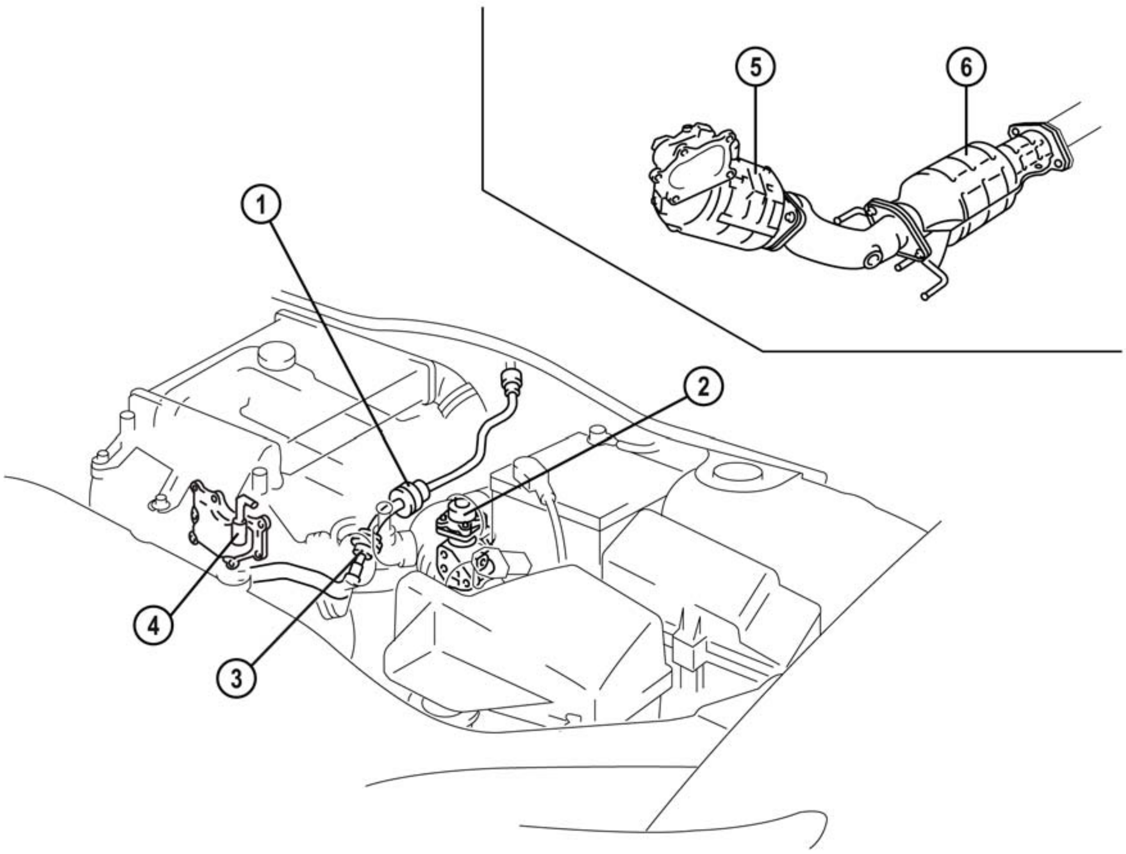


L3003_01018

1	PCM	6	Cylinder no.4
2	Direct ignition coil	7	Capacitor
3	Cylinder no.1	8	Ignition switch
4	Cylinder no.2	9	Battery
5	Cylinder no.3		

Emission System

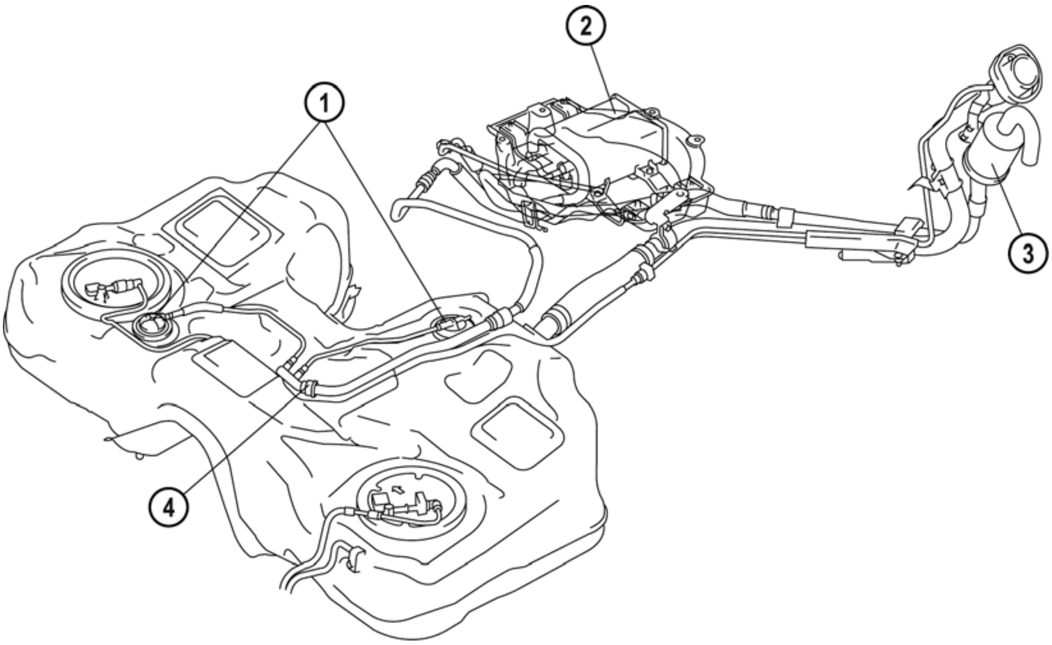
Parts Location



L3003_01019

Mazda6 MPS (engine compartment side)

1	Purge control valve	4	PCV valve
2	EGR valve	5	Warm-up TWC
3	One-way valve	6	TWC

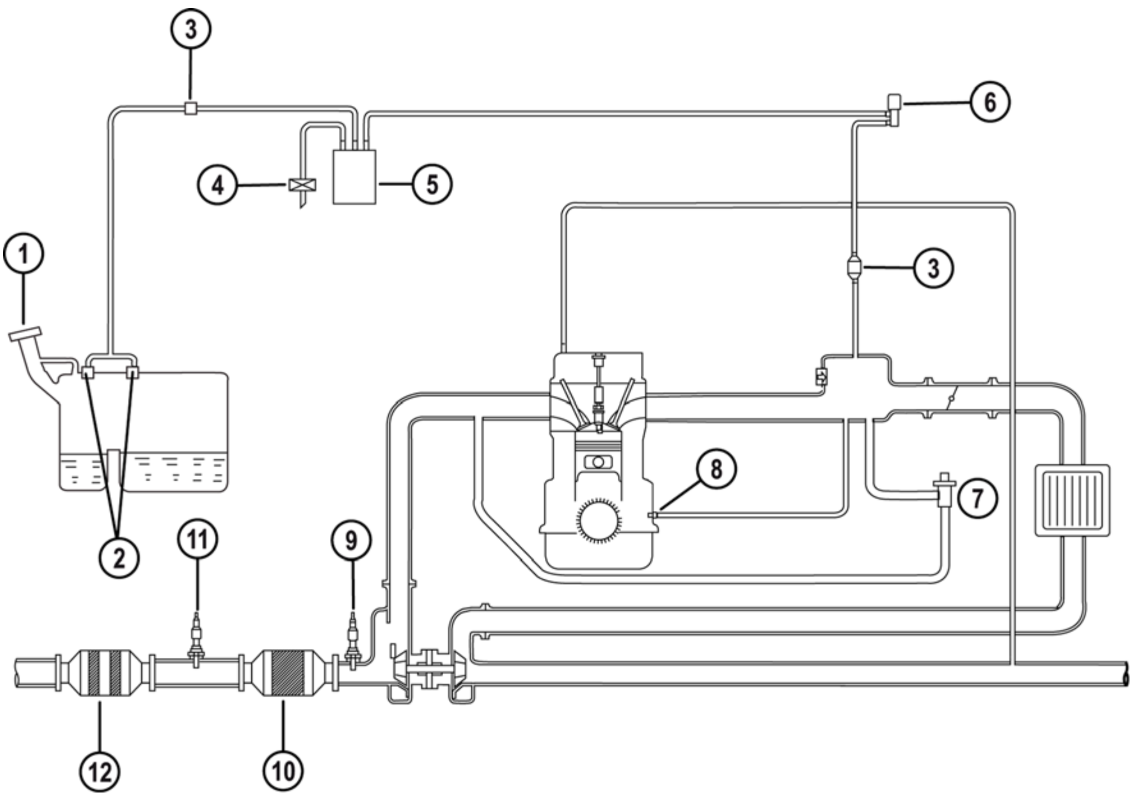


L3003_01020

Mazda6 MPS (fuel tank side)

1	Rollover valve	3	Air filter
2	Charcoal canister	4	One-way valve

System Overview



L3003_01021

1	Fuel-filler cap	7	EGR valve
2	Rollover valve	8	PCV valve
3	One-way valve	9	Upstream HO2S
4	Air filter	10	Warm-up TWC
5	Charcoal canister	11	Downstream HO2S
6	Purge control valve	12	TWC

Exhaust System

Features

- The exhaust system of the Mazda direct injection system has the following features:
  - Warm-up three-way catalytic converter (similar to that of the Mazda manifold injection system)
  - Three-way catalytic converter (similar to that of the Mazda manifold injection system)
  - Linear-type oxygen sensor with heater upstream of the catalytic converter (similar to that of the Mazda manifold injection system)
  - Jump-type oxygen sensor with heater downstream of the catalytic converter (similar to that of the Mazda manifold injection system)

Exhaust Gas Recirculation System

Features

- The exhaust gas recirculation system of the Mazda direct injection system has the following features:
  - EGR valve with stepper motor (similar to that of the Mazda manifold injection system)

Evaporative Emissions Control System

Features

- The evaporative emissions control system of the Mazda direct injection system has the following features:
  - Charcoal canister (similar to that of the Mazda manifold injection system)
  - Purge control valve (similar to that of the Mazda manifold injection system)

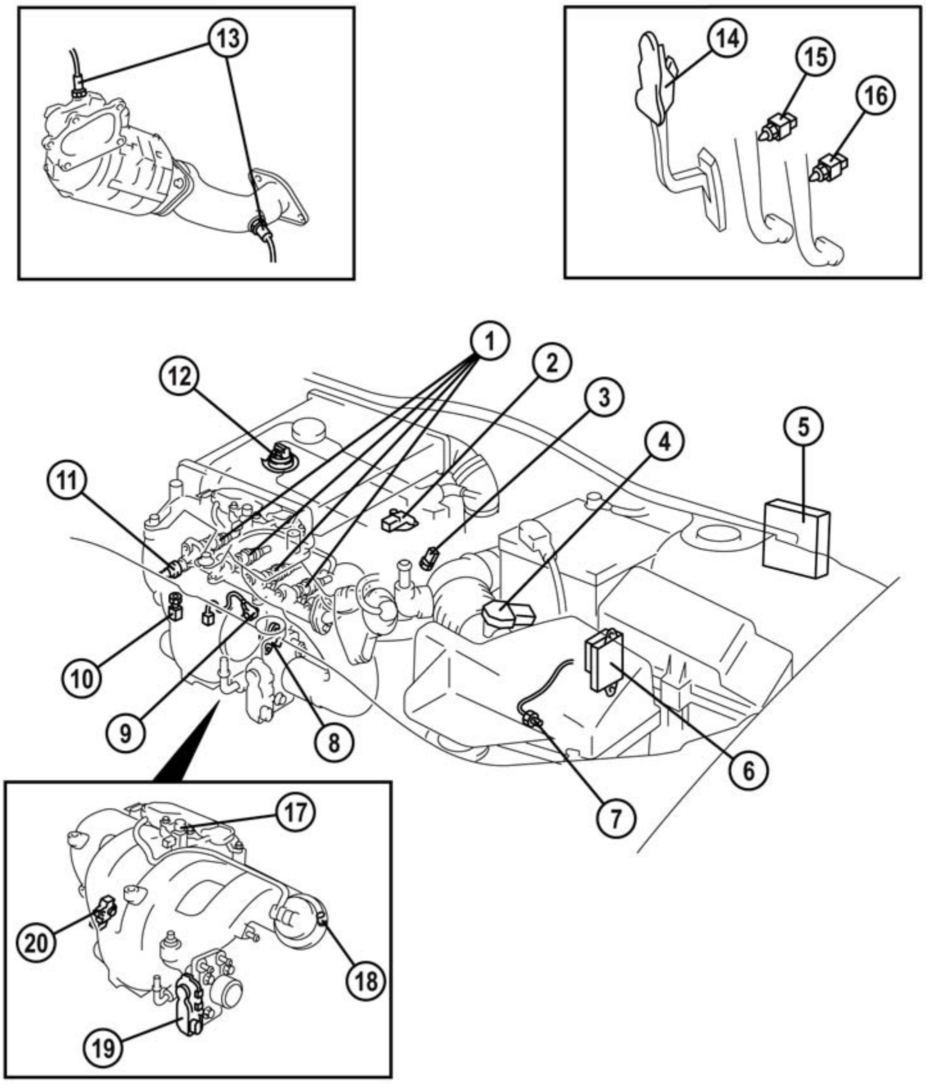
Positive Crankcase Ventilation System

Features

- The positive crankcase ventilation system of the Mazda direct injection system has the following features:
  - Positive crankcase ventilation valve with oil separator (similar to that of the Mazda manifold injection system)

Control System

Parts Location

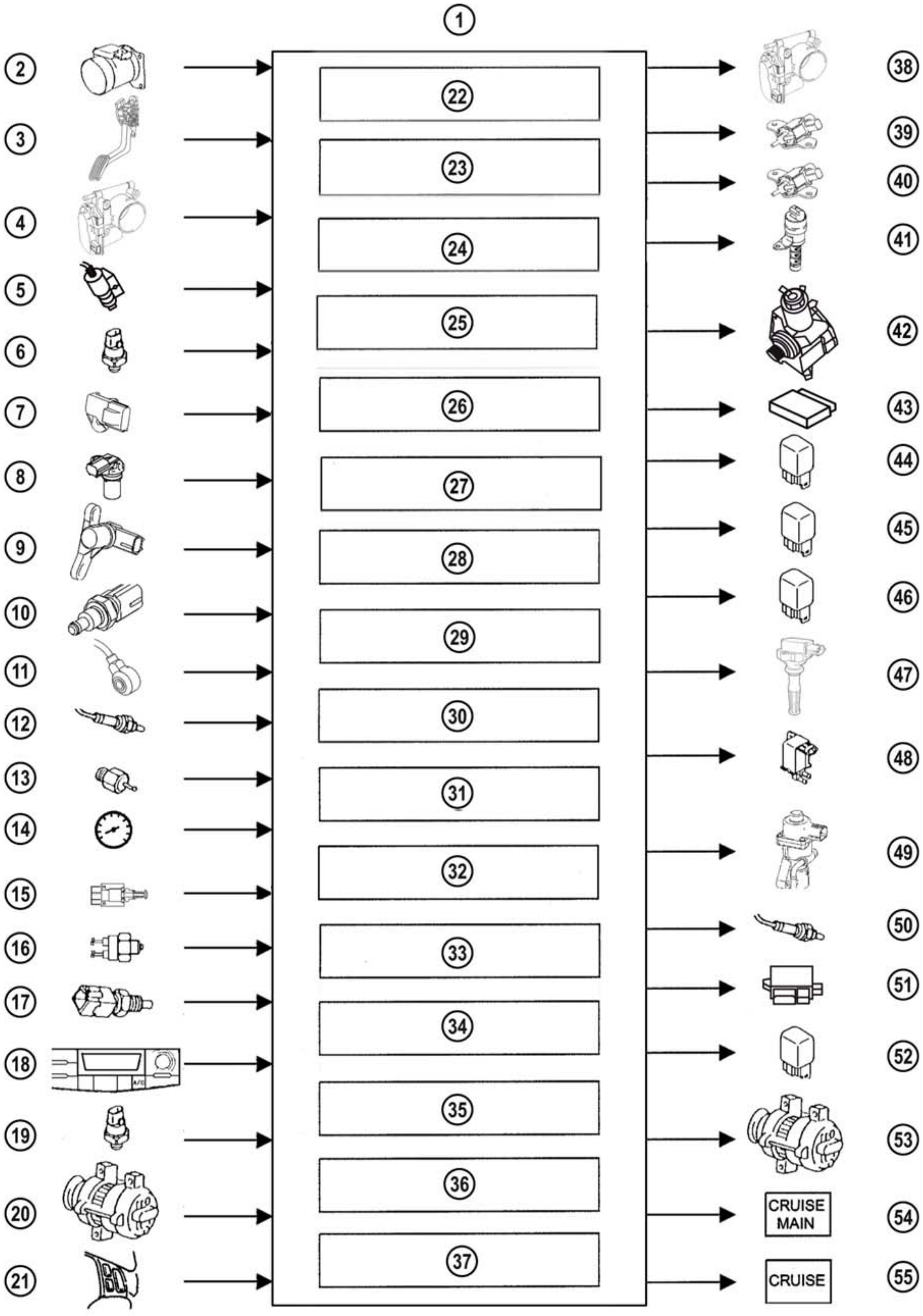


L3003_01022

Mazda6 MPS

1 Fuel injector
2 Camshaft position sensor
3 Engine coolant temperature sensor
4 MAF/IAT sensor
5 PCM
6 IDM
7 Park/Neutral position switch
8 Crankshaft position sensor
9 KS
10 Power steering pressure switch
11 Fuel pressure sensor
12 Oil control valve
13 HO2S incl. heater (upstream, downstream)
14 APP sensor
15 Brake switch
16 Clutch pedal position switch
17 VSC solenoid valve
18 VSC position switch
19 Electronic throttle valve
20 MAP/IAT sensor

Block Diagram



L3003_01041

1	PCM (incl. barometric pressure sensor)	29	Ignition control
2	MAF/IAT sensor	30	HO2S heater control
3	APP sensor	31	EGR control
4	TP sensor	32	Evaporative purge control
5	VSC position switch	33	Electrical fan control
6	Fuel pressure sensor	34	A/C compressor control
7	MAP/IAT sensor	35	Generator control
8	Camshaft position sensor	36	Cruise control
9	Crankshaft position sensor	37	Immobilizer control
10	Engine coolant temperature sensor	38	Electronic throttle DC motor
11	KS	39	VSC solenoid valve
12	HO2S (upstream, downstream)	40	VBC solenoid valve
13	Power steering pressure switch	41	Oil control valve
14	Vehicle speed sensor	42	Spill control solenoid
15	Clutch pedal position switch	43	IDM
16	Park/Neutral position switch	44	PCM control relay
17	Brake switch	45	Drive-by-wire relay
18	A/C switch	46	Fuel pump relay and fuel pump speed control relay
19	Refrigerant pressure switch	47	Direct ignition coils
20	Generator (stator coil)	48	Purge control valve
21	Cruise control switches	49	EGR stepper motor
22	Electronic throttle control	50	HO2S heater (upstream, downstream)
23	VSC control	51	Fan control module
24	VBC control	52	A/C relay
25	Variable valve timing control	53	Generator (field coil)
26	Fuel pump control	54	Cruise main indicator light
27	Fuel pressure control	55	Cruise indicator light
28	Injection control		

Relationship Chart

Device		Control Item															
		Electronic throttle control	VSC control	VBC control	Variable valve timing control	Fuel pump control	Fuel pressure control	Injection control	Ignition control	HO2S heater control	EGR control	Evaporative purge control	Electrical fan control	A/C compressor control	Generator control	Cruise control	Immobilizer control
Input	MAF/IAT sensor	X	X	X	X	X	X	X	X	X	X	X	X		X		
	APP sensor no.1, no.2	X	X		X			X	X		X	X	X	X			
	TP sensor no.1, no.2	X		X				X	X		X			X			
	MAP/IAT sensor	X		X				X	X			X					
	BARO sensor (built into PCM)	X		X				X				X	X				
	Engine coolant temperature sensor	X	X		X	X	X	X	X	X	X	X	X	X	X		
	Crankshaft position sensor	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Camshaft position sensor	X			X		X	X	X								
	VSC position switch		X														
	Fuel pressure sensor	X				X	X	X									
	KS								X								
	HO2S (upstream, downstream)							X				X					
	Clutch pedal position switch	X		X				X	X		X	X		X		X	
	Park/Neutral position switch	X		X				X	X		X	X		X		X	
	Brake switch	X						X	X							X	
	Power steering pressure switch	X															
	A/C switch	X						X	X				X	X			
	Refrigerant pressure switch	X						X	X				X	X			
	Battery			X	X	X	X	X	X	X	X	X	X		X		
	Generator (stator coil)	X													X		
	Vehicle speed sensor	X						X	X		X	X	X		X	X	
	Cruise control switches															X	

X: Applicable

L3003_T01001a

Device		Control Item															
		Electronic throttle control	VSC control	VBC control	Variable valve timing control	Fuel pump control	Fuel pressure control	Injection control	Ignition control	HO2S heater control	EGR control	Evaporative purge control	Electrical fan control	A/C compressor control	Generator control	Cruise control	Immobilizer control
Output	Drive-by-wire relay	X															
	Electronic throttle DC motor	X														X	
	VSC solenoid valve		X														
	VBC solenoid valve			X													
	Oil control valve				X												
	Fuel pump relay					X											
	Fuel pump speed control relay					X											
	Spill control solenoid						X										
	IDM relay							X									
	IDM							X									
	Direct ignition coils								X								
	HO2S heater (upstream, downstream)									X							
	EGR stepper motor										X						
	Purge control valve											X					
	Cooling fan relay												X				
	Fan control module												X				
	A/C relay													X			
	Generator (field coil)														X		
	Cruise main indicator light															X	
	Cruise indicator light															X	
	Starter relay																X

X: Applicable

L3003_T01001b

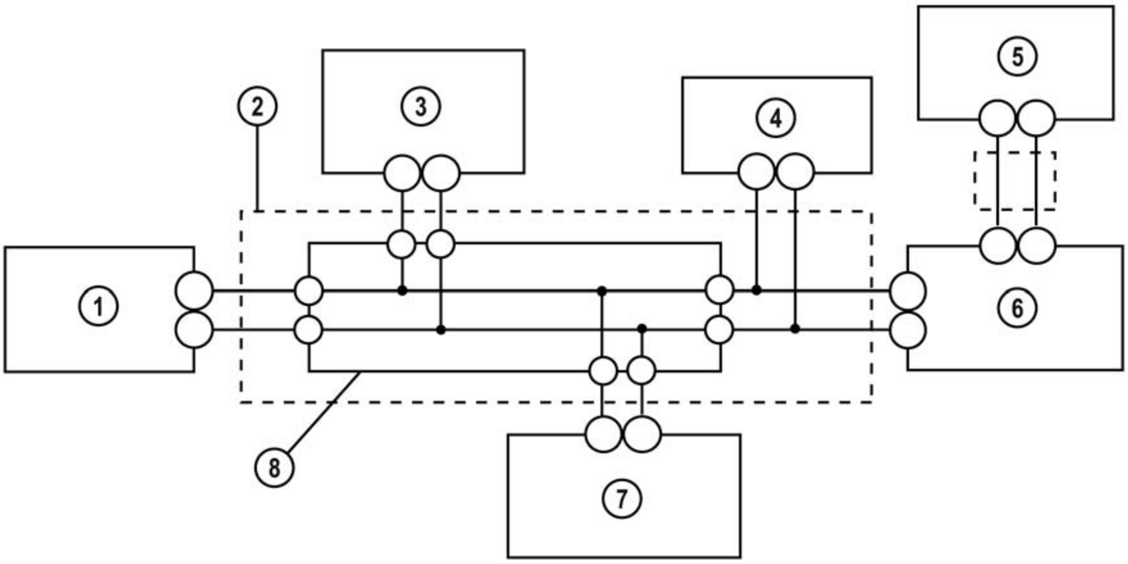
Powertrain Control Module

Features

- The powertrain control module of the Mazda direct injection system has the following features:
  - Read-only memory (similar to that of the Mazda manifold injection system)
  - Random access memory with keep-alive power supply (similar to that of the Mazda manifold injection system)
  - Variant configuration (similar to that of the Mazda manifold injection system)
  - Controller area network with high-speed bus

Controller Area Network

- The PCM communicates with other modules (e.g. DSC module, instrument cluster) through the **CAN** (**C**ontroller **A**rea **N**etwork) bus in order to transmit engine-related data. The following illustration shows the high-speed CAN bus of the Mazda6 MPS.



L3003_01024

1	PCM	5	Information display
2	CAN bus	6	Instrument cluster
3	DSC HU/CM	7	4WD control module
4	DLC	8	BCM

NOTE: For diagnosis on the controller area network refer to the workshop manual (section 09 – Control System).

- The following table describes the engine-related data that are transmitted via the high-speed CAN bus of the Mazda6 MPS.

Signal	Multiplex module				
	PCM	**DSC HU/CM**	**4WD control module**	**Instrument cluster**	**Information display**
Engine torque	OUT	IN	–	–	–
Torque reduction inhibit	OUT	IN	–	–	–
Engine speed	OUT	IN	IN	IN	–
Vehicle speed	OUT	–	–	IN	–
	–			OUT	IN
Accelerator pedal position	OUT	IN	IN	–	–
Throttle position	OUT	IN	IN	–	–
Neutral determination	OUT	–	IN	–	–
Gear ratio	OUT	IN	–	–	–
Engine coolant temperature	OUT	–	–	IN	–
Transaxle specifications	OUT	IN	–	–	–
Travelled distance	OUT	–	–	IN	–
Fuel injection amount	OUT	–	–	IN	–
MIL on request	OUT	–	–	IN	–
Generator warning light on request	OUT	–	–	IN	–
Engine specifications	OUT	IN	–	–	–
Tire circumference	OUT	IN	–	–	–
Cruise main indicator light on request	OUT	–	–	IN	–
Cruise indicator light on request	OUT	–	–	IN	–
Brake pedal position	OUT	IN	IN	–	–
Torque reduction request	IN	OUT	–	–	–
Brake system configuration (EBD/ABS/TCS/DSC)	IN	OUT	IN	IN	–
Brake system status (EBD/ABS/TCS/DSC)	IN	OUT	IN	IN	–
Wheel speed (LF, RF, LR, RR)	IN	OUT	IN	–	–
Back-up light switch condition	–	OUT	IN	–	–
Brake fluid pressure	–	OUT	IN	–	–
Steering wheel angle	–	OUT	IN	–	–
Yaw rate	–	OUT	IN	–	–
Lateral acceleration	–	OUT	IN	–	–
Desired coupling torque	–	OUT	IN	–	–
Actual coupling torque	–	IN	OUT	–	–
4WD warning light on request	–	–	OUT	IN	–
Brake fluid level	–	IN	–	OUT	–
Fuel tank level	IN	–	–	OUT	–

IN: Input (receives signal)
OUT: Output (sends signal)

L3003_T01002

Sensors

Features

- The sensors of the Mazda direct injection system have the following features:
  - Magneto resistive-type crankshaft and camshaft position sensor (similar to that of the Mazda manifold injection system)
  - Engine coolant temperature sensor (similar to that of the Mazda manifold injection system)
  - Barometric pressure sensor integrated in the PCM (similar to that of the Mazda manifold injection system)
  - Clutch pedal position and park/neutral position switch (similar to that of the Mazda manifold injection system)
  - Power steering pressure switch (similar to that of the Mazda manifold injection system)
  - Triple-type refrigerant pressure switch with medium-pressure contact (similar to that of the Mazda manifold injection system)

Actuators

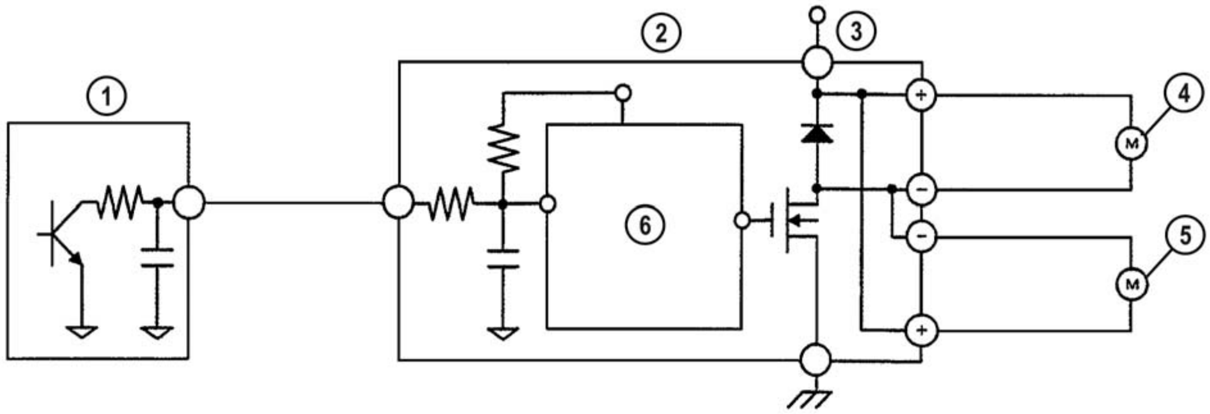
Features

- The actuators of the Mazda direct injection system have the following features:
  - Variable valve timing system (similar to that of the Mazda manifold injection system)
  - Electrical fan with fan control module
  - A/C compressor (similar to that of the Mazda manifold injection system)
  - Smart charging system (similar to that of the Mazda manifold injection system)
  - Cruise control system (similar to that of the Mazda manifold injection system)
  - Immobilizer system with immobilizer module integrated in the PCM, instrument cluster or keyless control module (depending on model and grade)

Electrical Fan

- The Mazda3 MPS and Mazda6 MPS are equipped with a fan control module for the cooling fan(s) to reduce fan noise and electrical power consumption. The module is located on the radiator cowling and varies the fan speed infinitely variable depending on the engine coolant temperature and the A/C load (derived from the refrigerant pressure switch).
- On the Mazda6 MPS the PCM also controls the power supply of the fan control module via the cooling fan relay.
- The current flowing through the stator coil of the cooling fan motor(s) and hence the fan speed varies depending on the duty signal from the fan control module, which in turn depends on the duty signal from the PCM.

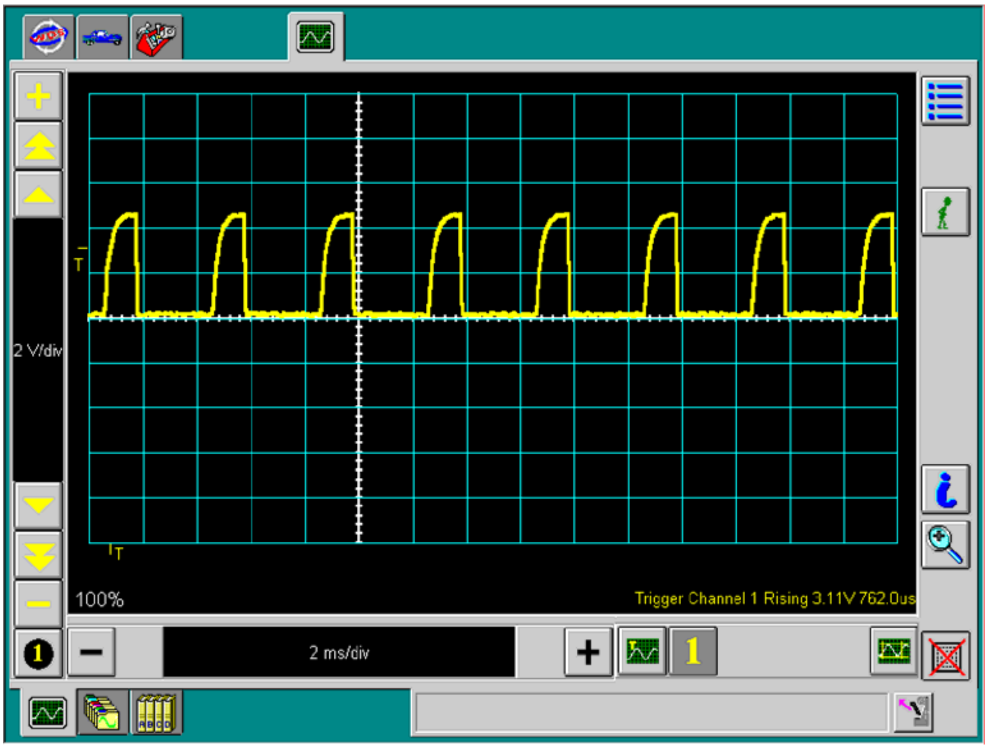
NOTE: In case of an open circuit in the cable between PCM and fan control module, the duty ratio outputted from the fan control module is fixed at 100 % and the cooling fans operate at maximum speed.



L3003_01023

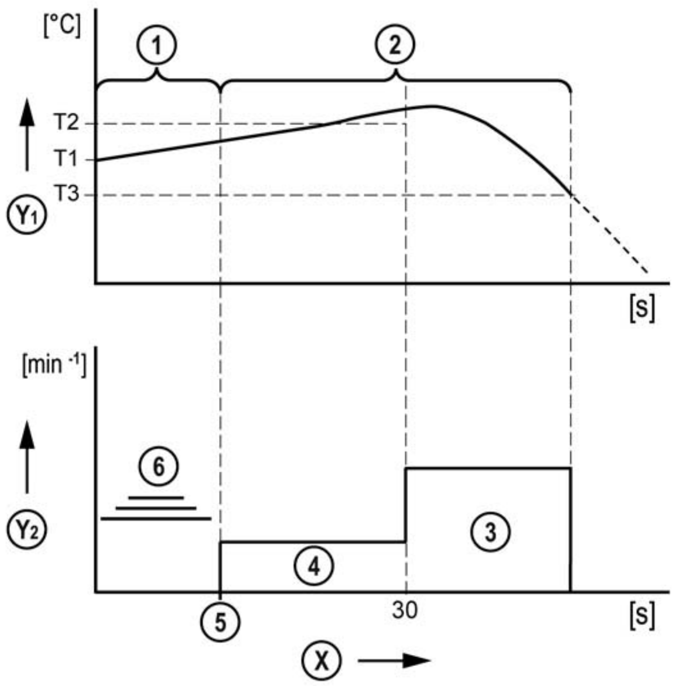
1	PCM	4	Main fan motor
2	Fan control module	5	Additional fan motor (only Mazda6 MPS)
3	Power supply	6	Control circuit

- The PCM controls the fan control module by a duty signal (the voltage level differs depending on the model). The speed of the cooling fan motor(s) is proportional to the duty ratio, i.e. the larger the duty ratio the higher the fan speed.



L3003_01060

- In addition, the Mazda3 MPS and Mazda6 MPS are equipped with an after-cooling function to prevent engine damage due to heat accumulation in the engine compartment. If the engine coolant temperature exceeds the pre-set value T1 when the engine is shut off or the ignition is switched off, the PCM controls the fan control module with a small duty ratio until the temperature falls below the pre-set value T3.
- In case the engine coolant temperature rises further and exceeds the pre-set value T2 after 30 s from when the after-cooling function has started, the PCM controls the fan control module with a large duty ratio until the temperature falls below the pre-set value T3.



L3003_01042

X	Time	Y_1	Engine coolant temperature
Y_2	Cooling fan speed	4	Low fan speed
1	Cooling fan control during engine operation	5	Engine shut-off or ignition off
2	Cooling fan control after engine shut-off	6	Fan speed during engine operation
3	High fan speed		

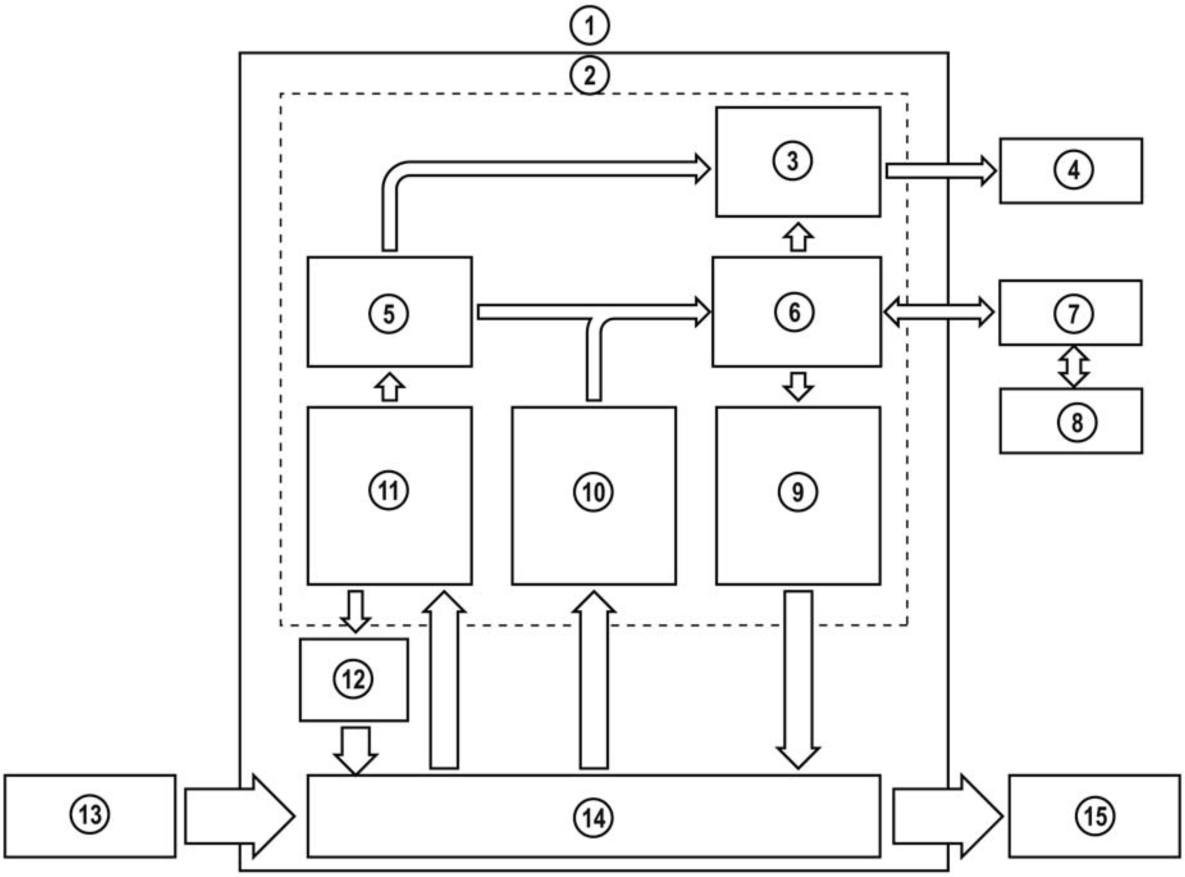
Diagnostics

- The function of the electrical fan can be checked as following:
  - Checking the voltage at the cooling fan relay
  - Checking the resistance of the cooling fan relay
  - Monitoring / Activating the fan control module via the PID **FAN_DUTY#** (Per/Mode)
  - Checking the voltage signal to the fan control module
  - Checking the voltage signal at the cooling fan motor(s)
  - Checking the resistance of the cooling fan motor(s)

On-board Diagnostic System

General

- The **OBD** (**O**n-**B**oard **D**iagnostic) system is integrated in the PCM and checks the overall engine management system for malfunctions. If a malfunction is detected, a corresponding diagnostic trouble code is stored in the fault memory. Then the malfunction indicator light is illuminated in order to alert the driver to the malfunction. A serial interface allows access to the engine-related diagnostic information using M-MDS, providing the basis for an efficient diagnosis and repair.



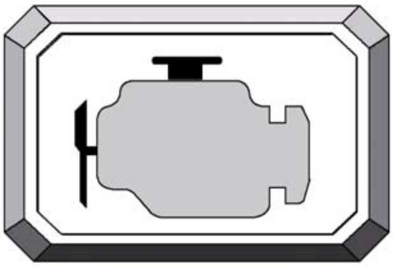
L3003_02001

1	PCM	9	Simulation test function
2	OBD system	10	PID monitor function
3	MIL driver	11	Fault detection function
4	Malfunction indicator light	12	Fail-safe function
5	Fault memory	13	Sensors
6	Serial interface	14	Engine management system
7	Data link connector	15	Actuators
8	M-MDS		

Malfunction Indicator Light

- The **MIL** (**M**alfunction **I**ndicator **L**ight) is located in the instrument cluster and serves to alert the driver to a malfunction in the engine management system. During normal operation the MIL illuminates when the ignition is on and is extinguished when the engine has started.
- If the MIL stays on after engine start or comes up continuously during driving, then the OBD system has detected a fault causing increased exhaust emissions.
- If the MIL starts to flash after engine start or during driving, then the OBD system has detected severe misfire causing irreversible damage to the TWC.

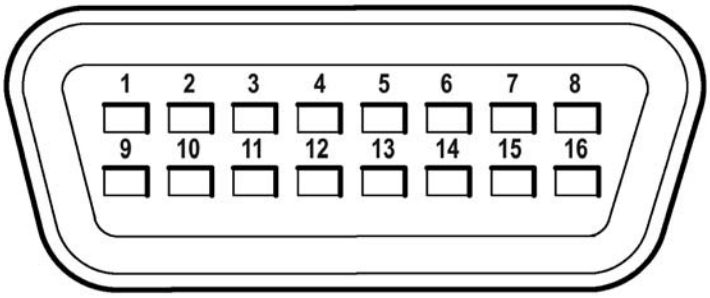
NOTE: If the MIL does not illuminate when the ignition is on, or stays on or flashes after engine start but no fault is stored in the PCM memory, this indicates a malfunction in the MIL control circuit.



L3003_02002

Data Link Connector

- The **DLC** (**D**ata **L**ink **C**onnector) is the interface between the OBD system and M-MDS, and allows access to the engine-related diagnostic information.
- All EOBD vehicles are equipped with a 16-pin DLC (also termed as DLC-2) in the passenger compartment (near the steering column). The connector and the data communication protocols are standardized, i.e. the engine-related diagnostic information can also be accessed using a generic scan tool.

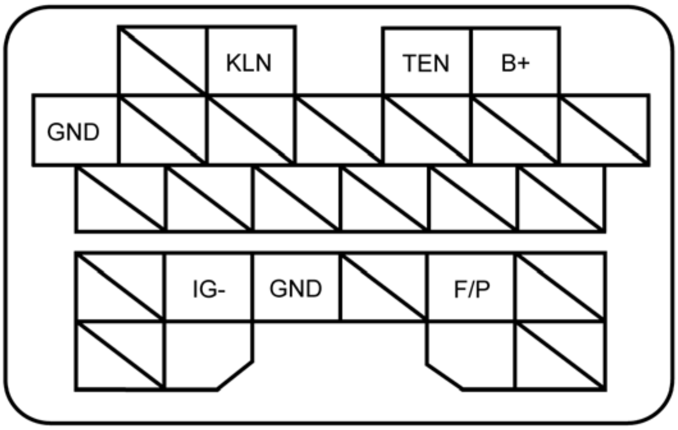


L3003_02003

Terminal	Description
4	Ground
5	Ground
6	HS-CAN High
7	KLN
14	HS-CAN Low
16	Battery power supply

L2003_T02008

- Some Mazda vehicles are additionally equipped with a 17-pin DLC (also termed as DLC-1) in the engine compartment (near the left suspension strut). The connector is not standardized, i.e. the engine-related diagnostic information can only be accessed using M-MDS.
- Furthermore, the 17-pin DLC features eight additional pins, which allow to retrieve an engine speed signal or to activate the fuel pump.



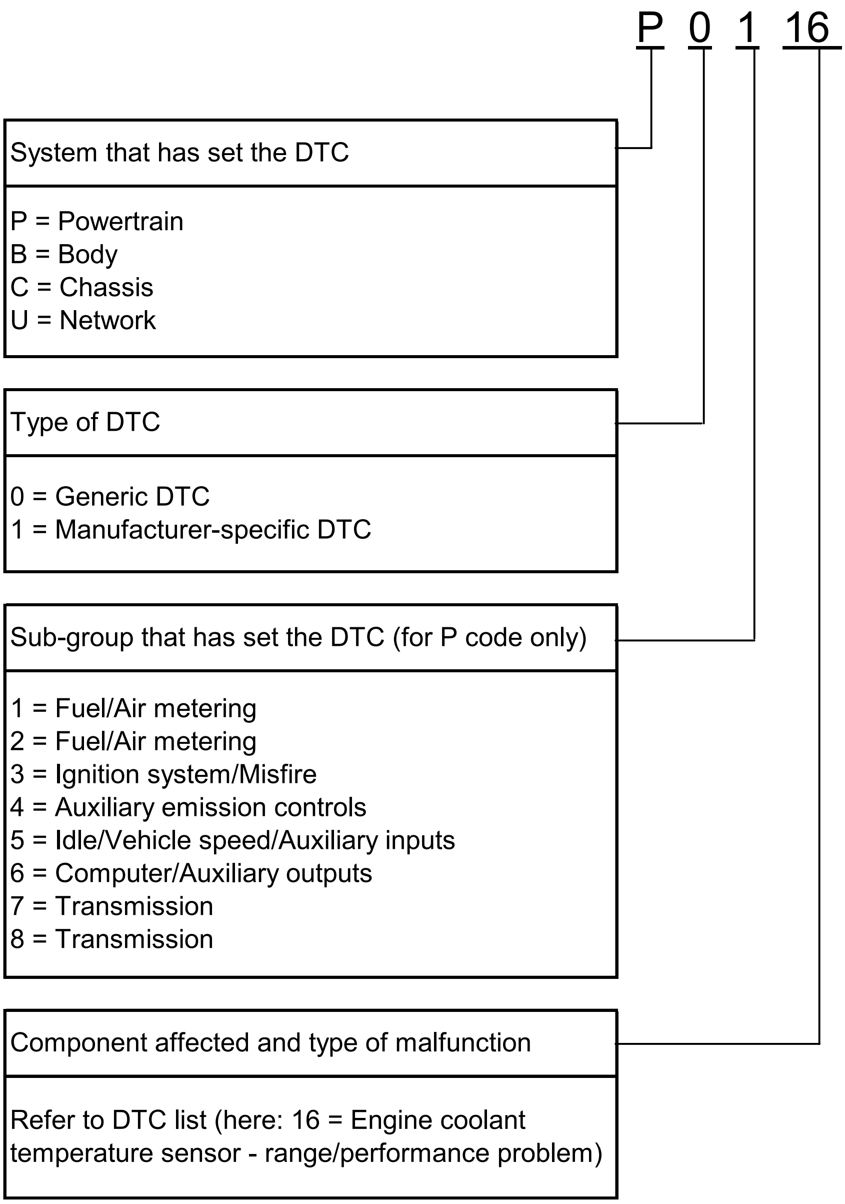
L3003_02004

Terminal	Description
KLN	Serial interface
TEN	Triggering for engine tune-up
B+	Ignition power supply
GND	Ground
IG-	Engine speed signal
F/P	Activating the fuel pump

L2003_T02009

Diagnostic Trouble Codes

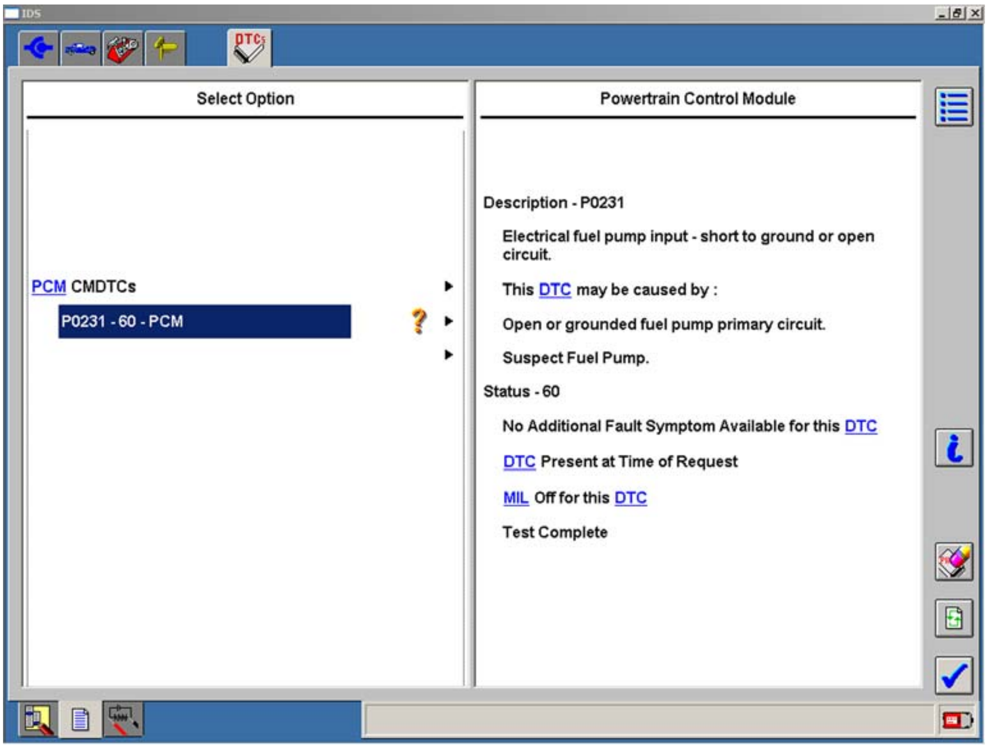
- After a fault has been detected a corresponding **DTC** (**D**iagnostic **T**rouble **C**ode) is stored in the PCM memory and can be read out using M-MDS. A DTC is defined as a 5-digit alphanumerical code (e.g. P0116) containing the information shown below.



L3003_T02001

DTC Status

- When reading out **CMDTC**s (**C**ontinuous **M**emory **DTC**s) on a vehicle with HS-CAN bus, the M-MDS additionally displays a status information behind each DTC (e.g. P0231-**60**). A corresponding description for the DTC status can be found on the right-hand side of the M-MDS screen.



L3003_02023

- The DTC status is defined as a two-digit numerical or alphanumerical code. The first digit indicates, whether the fault is present at the time of DTC read-out and whether the MIL is on for this fault. The second digit provides information about the fault symptom (e.g. signal above or below threshold, no signal etc.). The following status information is used:

DTC Status	Description
2x	DTC not present, MIL OFF
6x	DTC present, MIL OFF
7x	DTC present, MIL OFF
Ax	DTC not present, MIL ON
Ex	DTC present, MIL ON
FF	No status available

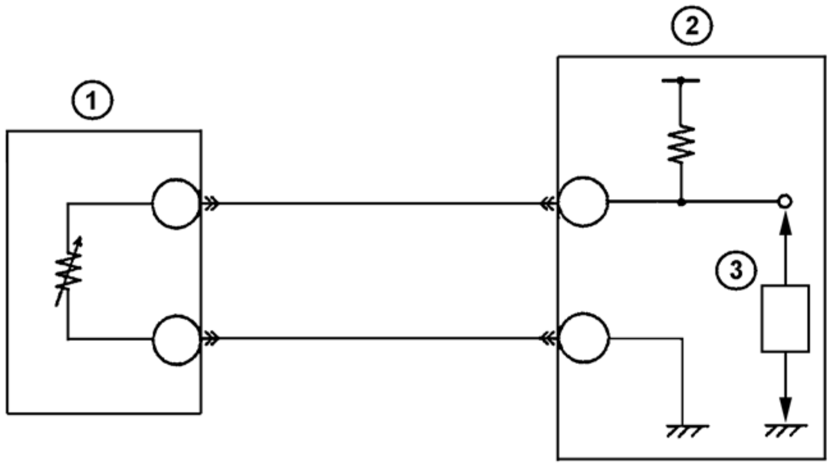
L2003_T02010

Fault Detection Function

- The fault detection function is integrated in the PCM and monitors the sensors, actuators and PCM-internal components for malfunctions. Different monitoring strategies are used depending on the component concerned.

Monitoring Strategy for Sensors

- The sensors of the engine management system are monitored for electrical faults, range faults and plausibility faults. Therefore, the fault detection function measures the signal voltage of the sensors.

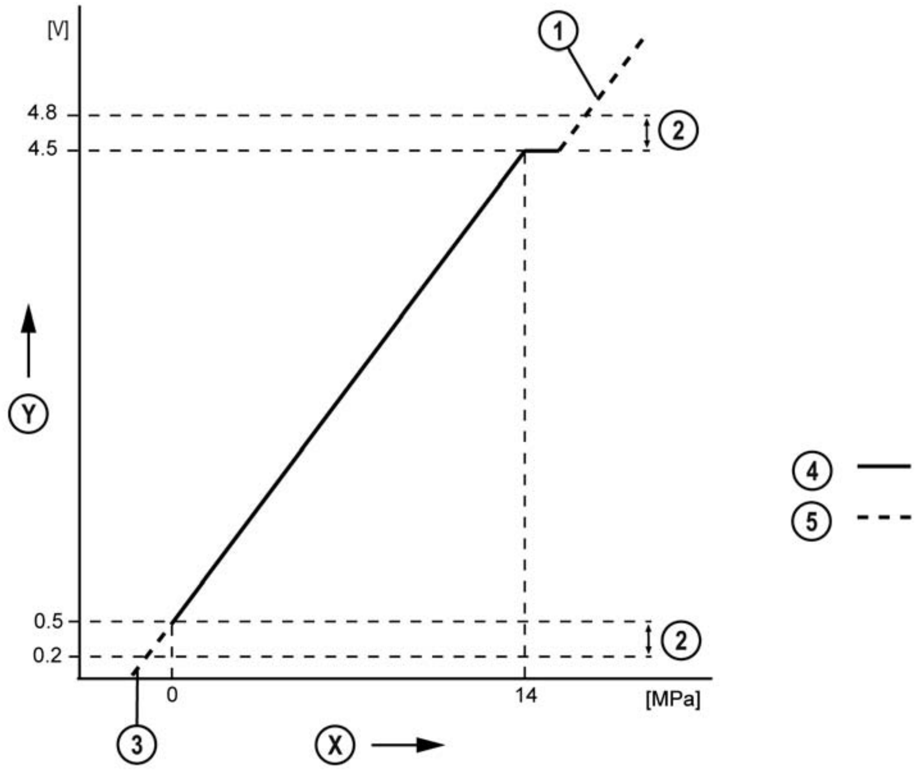


L3003_02006

1	Sensor	3	Voltage detection circuit
2	PCM		

Electrical Faults

- In order to detect electrical faults the fault detection function continuously compares the signal voltage measured to the limits for open circuit and short circuit to ground. If the signal voltage exceeds the upper limit (e.g. more than 4.8 V), the fault detection function determines that an open circuit exists. If the signal voltage measured exceeds the lower limit (e.g. less than 0.2 V), then this indicates a short circuit to ground.



L3003_02033

X	Physical parameter (here: pressure)	Y	Output voltage
1	Open circuit	4	Correct signal
2	Range fault	5	Faulty signal
3	Short circuit to ground		

Range Faults

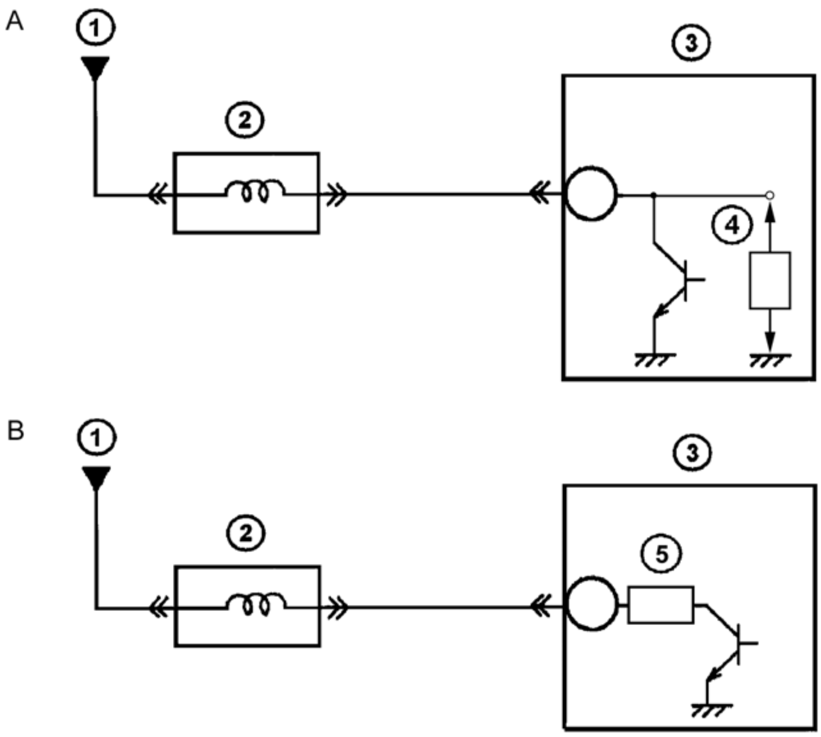
- In order to detect range faults the fault detection function continuously compares the signal voltage measured to the measuring range of the sensor. If the signal voltage exceeds the specified range (e.g. less than 0.5 V or more than 4.5 V), the fault detection function determines that a range fault exists.

Plausibility Faults

- In order to detect plausibility faults the fault detection function compares the signal voltage measured to other parameters of the engine management system by means of logical aspects. These parameters are derived from the momentary operating conditions of the engine and define an expected range for the sensor signals.
- If the signal voltage exceeds this range (e.g. the difference between the mass air flow detected by the MAF sensor and the mass air flow derived from the TP sensor signal is too high), the fault detection function determines that a plausibility fault exists.

Monitoring Strategy for Actuators

- The actuators of the engine management system are monitored for electrical faults and functional faults. Therefore, the fault detection function measures the control voltage or the control current of the actuators.

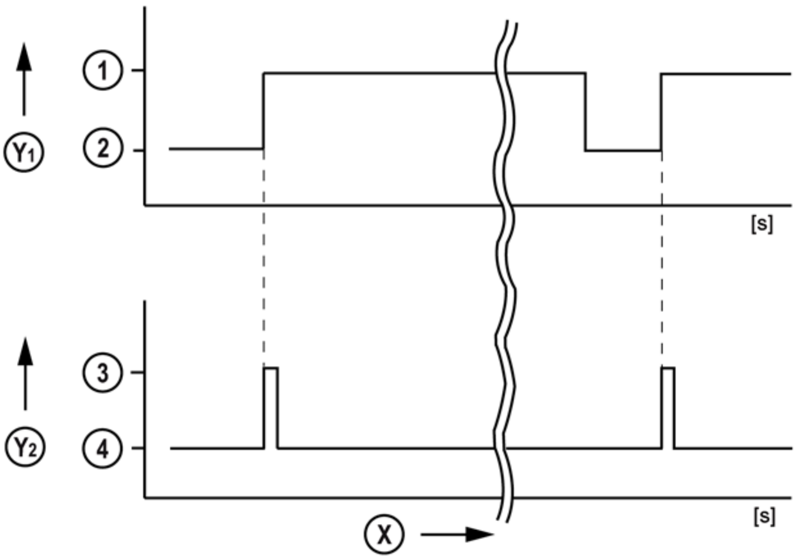


L3003_02008

A	Monitoring the control voltage of the actuator	B	Monitoring the control current of the actuator
1	From PCM control relay	4	Voltage detection circuit
2	Actuator	5	Current detection circuit
3	PCM		

Electrical Faults

- In order to detect electrical faults the fault detection function energizes the actuator in question for a short time (e.g. after switching the ignition on or during engine start) and compares the control voltage/control current measured to the limits for faulty control circuit, open circuit and short circuit to ground.
- If the control voltage measured exceeds the upper limit (e.g. more than 8 V) when the actuator is energized, the fault detection function determines that the control circuit is faulty. If the control voltage measured exceeds the lower limit (e.g. less than 8 V) when the actuator is de-energized, then this indicates an open circuit or a short circuit to ground.
- If the control current measured exceeds the lower limit (e.g. less than 1 A) when the actuator is energized, the fault detection function determines that the control circuit is faulty, or that there is an open circuit or a short circuit to ground.



L3003_02009

X	Time	Y_1	Ignition switch status
Y_2	Actuator status	3	Actuator energized
1	Ignition ON or engine start	4	Actuator de-energized
2	Ignition OFF		

Functional Faults

- In order to detect functional faults the fault detection function monitors other parameters of the engine management system by means of logical aspects, when the actuator in question is activated. These parameters are derived from the momentary operating conditions of the engine and show the reaction of the system that is influenced by the actuator.
- If the reaction of the system does not correspond to the control signals output to the actuator (e.g. the engine speed detected by the CKP sensor does not increase when the IAC valve is opened), the fault detection function determines that a functional fault exists.

Monitoring Strategy for PCM

- The components of the PCM (e.g. FEEPROM, RAM) are monitored for functional integrity by the PCM-internal hardware and software. Many of the diagnostic routines for the PCM are performed when the ignition is switched on or when the engine is running. Other routines that require a considerable amount of processor capacity (e.g. diagnostic routines for the FEEPROM) are carried out during the power-latch phase of the PCM. This prevents the diagnostic routines from interfering with other PCM operations.

Fail-safe Function

- The fail-safe function is integrated in the PCM and ensures the drivability of the vehicle during the occurrence of a fault. Different fail-safe strategies are used for sensors and actuators.

Fail-safe Strategy for Sensors

- If a fault is detected on a sensor for which fail-safe data is stored in the PCM, the fail-safe function reverts to a constant substitute value for engine control. In order to prevent any further damage the fail-safe function will always use a “safe” substitute value. As a result, the vehicle can be driven without major restrictions.
- If e.g. the ECT sensor is faulty, the PCM uses the engine coolant temperature of the cold engine (e.g. -40 °C) for engine control to ensure that the engine operates properly even at low ambient temperatures. In addition, the cooling fan is activated continuously to prevent the engine from overheating.

NOTE: If the fail-safe function uses a constant substitute value due to a faulty sensor, this value is also displayed when monitoring the calculated value (e.g. temperature, pressure etc.) of the corresponding PID using M-MDS. In order to prevent mis-diagnosis the voltage value of the PID concerned should be monitored as well. If e.g. an open circuit exists on the ECT sensor, the PID **ECT (Temp)** displays a value of -40 °C (substitute value) but the PID **ECT (Volt)** indicates a value of 4.6 V (open circuit).

- If a fault is detected on a sensor for which no fail-safe data is stored in the PCM, the fail-safe function initiates a limp home mode. As a result, the vehicle can be driven either with reduced driving comfort or with limited power output (depending on the sensor affected).

Fail-safe Strategy for Actuators

- If a fault is detected on an actuator, the fail-safe function deactivates the corresponding control circuit and initiates a limp home mode. As a result, the vehicle can be driven either with reduced driving comfort or with limited power output (depending on the actuator affected).

NOTE: The fail-safe function might also deactivate the control circuit of an actuator, if an input signal required for control of the actuator in question is faulty. In order to rule out a faulty actuator, perform a simulation test using M-MDS. If the actuator can be controlled via M-MDS, check the relevant input signals for malfunctions.

European On-board Diagnostics

General

- The European Union is introducing progressively stricter emissions legislation to achieve a long-lasting reduction in air pollution from vehicle emissions. As part of this legislation, all new petrol passenger vehicles requiring type approval from January 1st 2000 must be equipped with the **EOBD** (**E**uropean **O**n-**B**oard **D**iagnostics) to monitor exhaust emissions. In addition, all petrol passenger vehicles first registered from January 1st 2001 must meet the EOBD regulations.
- The EOBD system uses no additional sensors or actuators to measure the pollutants in the exhaust gas. It is integrated in the PCM and generally uses the existing sensors and actuators of the engine management system plus special software. These check the emission-relevant systems and components while the vehicle is traveling, and calculate the exhaust emissions accordingly.
- If any changes that significantly deteriorate exhaust emissions are detected, the MIL is illuminated continuously. This is to alert the driver to the fact that the vehicle is potentially producing more emissions than it should, and the cause should be investigated as soon as reasonably practicable.
- However, if severe misfire that causes irreversible damage to the TWC is detected, the MIL flashes. In this case, the driver should reduce the vehicle speed immediately and have the vehicle checked as soon as possible.

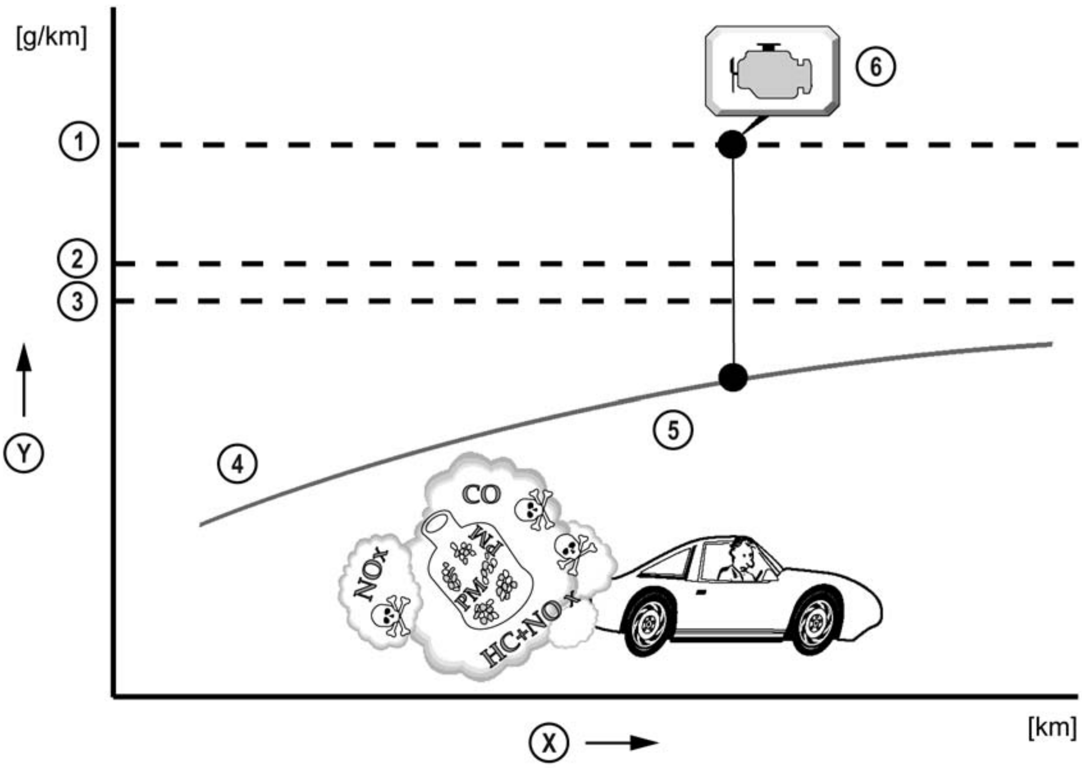
NOTE: If the MIL continues to flash after the vehicle speed has been reduced, heavy acceleration should be avoided to prevent the TWC from being damaged.

Type Approval and Testing

- According to the EOBD regulations the operation of the EOBD system must be guaranteed over the entire life of the vehicle. To obtain type approval for the European market, a vehicle must comply with the specified exhaust emission limits for at least 80,000 km (vehicles with Euro 3 emission standard) / 100,000 km (vehicles with Euro 4 emission standard) or five years (whichever comes first).
- Compliance of mass production vehicles with the specified exhaust emission limits will be monitored in future by the authorities. Therefore, vehicles with various mileages will undergo random testing. If these checks reveal that the specified limits are exceeded systematically, the vehicle manufacturer will be held responsible. This may lead to costly recalls or restrictions to the type approval.

- The exhaust emission limits used by the EOBD system to activate the MIL are always slightly higher than the limits of the Euro 3 emission standard. As a result, minimal overshooting of the Euro 3 limits still does not lead to an activation of the MIL.

	CO (g/km)	**HC (g/km)**	**NO_X (g/km)**
Euro 3	2.3	0.2	0.15
Euro 4	1.0	0.1	0.08
EOBD	3.2	0.4	0.6



L3003_02010

X	Mileage	Y	Exhaust emissions
1	Exhaust emission limits of EOBD	4	Actual exhaust emissions of the vehicle
2	Exhaust emission limits of Euro 3 emission standard	5	Emission relevant fault
3	Exhaust emission limits of Euro 4 emission standard	6	MIL activated

Definitions

- The following definitions are important to understand the operation of the EOBD system.

Drive Cycle

- According to the EOBD regulations a drive cycle consists of engine start-up, engine operation where a malfunction would be detected if present, and engine shut off.

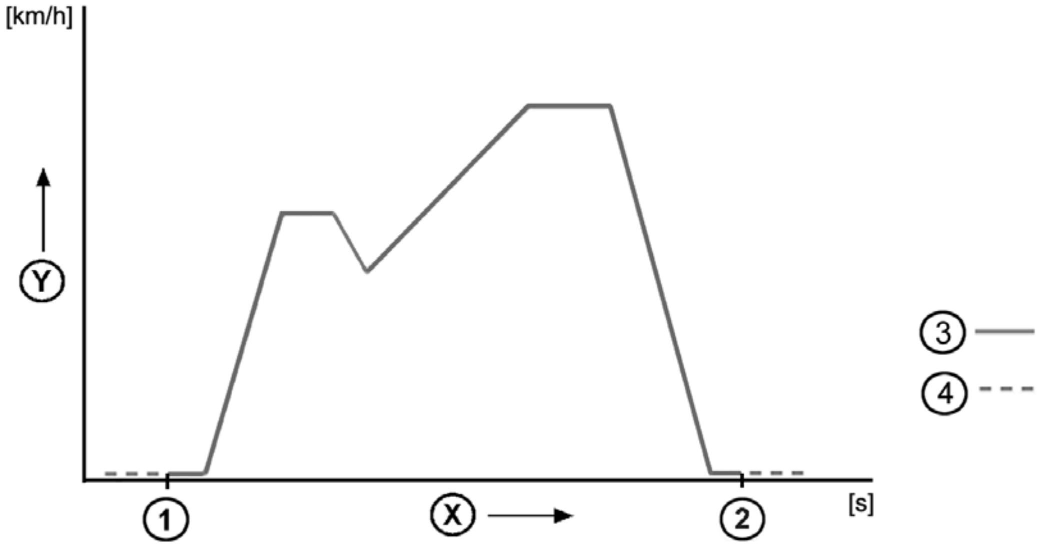
NOTE: A drive cycle starts when the engine exits from the "Engine Start" state and is completed when the ignition is switched off and the power latch phase of the PCM has ended. However, if the ignition is switched back on during the power latch phase the drive cycle is not completed.

Warm-up Cycle

- According to the EOBD regulations a warm-up cycle consists of engine start-up and sufficient engine operation, so that the engine coolant temperature has risen at least 22 °C from engine starting and reaches a minimum temperature of 70 °C.

Monitors

- The so called monitors are diagnostic routines carried out by the PCM in order to detect malfunctions of the emission-relevant systems and components. On Mazda petrol engines continuous and non-continuous monitors are used.
- Continuous monitors operate permanently, i.e. the correct function of a system/ component is checked permanently during a drive cycle.

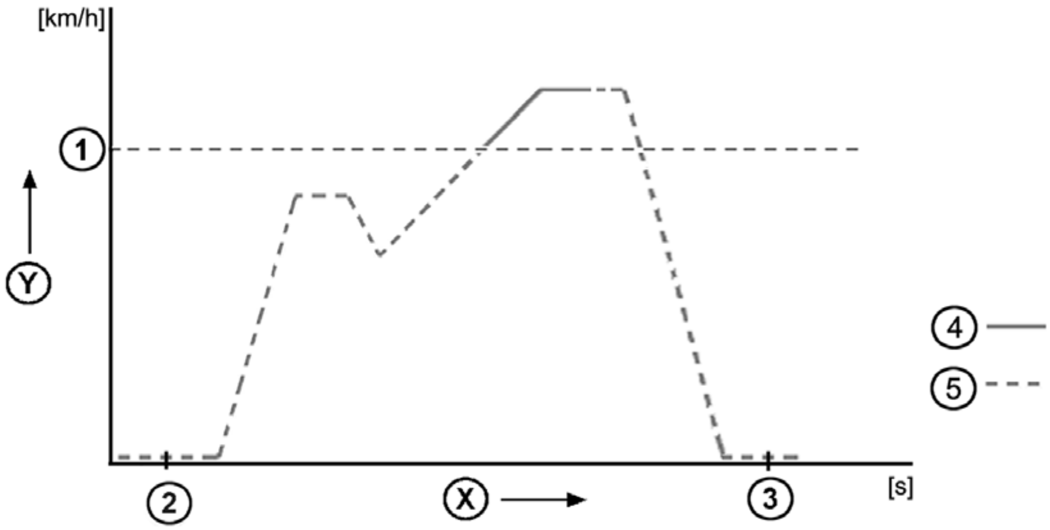


L3003_02011

X	Time	Y	Vehicle speed
1	Engine start	3	Monitor operative
2	Engine shut-off	4	Monitor inoperative

- The continuous monitors are activated after engine start and operate until the engine is shut off.

- Non-continuous monitors operate intermittently, i.e. the correct function of a system/ component is checked only once during a drive cycle, when suitable engine operating conditions exist.



L3003_02012

X	Time	Y	Vehicle speed
1	Vehicle speed when the monitoring conditions are met	4	Monitor operative
2	Engine start	5	Monitor inoperative
3	Engine shut-off		

- The non-continuous monitor is activated as soon as the operating conditions required for monitoring (also termed as monitoring conditions) exist, and the respective tests are carried out in a certain order. If the required operating conditions are no longer met during the monitoring phase, monitoring is stopped and the data collected so far is frozen. After regaining the operating conditions during the same drive cycle, monitoring is continued. In case the operating conditions are not met again during the same drive cycle, monitoring starts anew during the next drive cycle.
- When monitoring is completed and no fault has occurred, the monitor is deactivated. As a result, a fault occurring in the system/component after the monitor has been deactivated will only be detected during the next drive cycle.
- If a fault is detected during the monitoring phase, the system/component concerned and the monitor are switched off until the next drive cycle starts. In case the fault also affects the operation of other monitors, these are switched off as well. In this way, storage of subsequent faults is prevented.

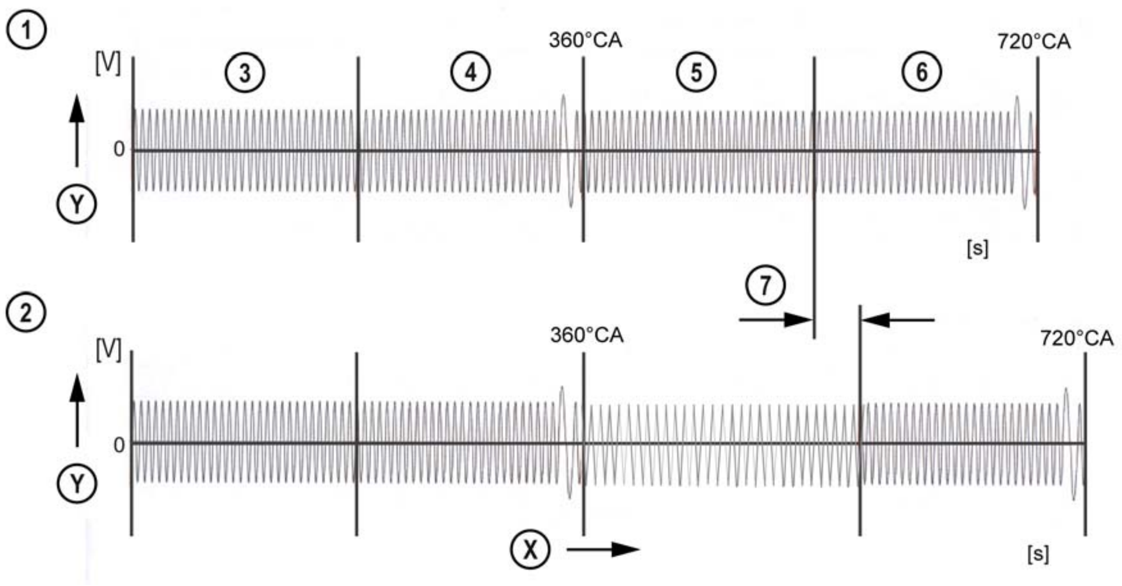
- The EOBD system of Mazda petrol engines comprises the following monitors:
  - Comprehensive component monitor
  - Misfire monitor
  - Fuel system monitor
  - HO2S monitor
  - HO2S heater monitor
  - TWC monitor
  - EGR system monitor (depending on the vehicle type)

Comprehensive Component Monitor

- The **CCM** (**C**omprehensive **C**omponent **M**onitor) continuously checks the emission-relevant sensors and actuators for electrical faults, range faults, plausibility faults and functional faults. If an emission-relevant component fails, this is recognized by the monitor and a fault is stored in the PCM memory.
- The CCM only monitors those emission-relevant sensors and actuators, which are not checked by another monitor. In addition, the monitor checks components that are used by the EOBD system, but have no influence on the exhaust emissions.

Misfire Monitor

- The misfire monitor continuously checks, whether the acceleration of the crankshaft during the working stroke of each cylinder is above a certain limit. The acceleration of the crankshaft depends on the amount of torque produced by each cylinder. A misfiring cylinder reduces the amount of torque produced and hence the acceleration of the crankshaft.
- The misfire monitor compares the crankshaft acceleration during the working stroke of each cylinder (detected via the CKP sensor signal by additionally using the CMP sensor signal) to the average value of the crankshaft accelerations of the other cylinders during two crankshaft revolutions to determine, if any of the cylinders is not producing the expected amount of torque. Crankshaft accelerations that deviate too much from the average value of the other cylinders indicate a misfiring cylinder.



L3003_02030

X	Time	Y	Output voltage
1	Normal CKP sensor signal	5	Working stroke of cylinder no.4
2	CKP sensor signal when misfire occurs	6	Working stroke of cylinder no.2
3	Working stroke of cylinder no.1	7	Time deviation due to misfire at cylinder no.4
4	Working stroke of cylinder no.3		

- If misfire is detected, the PCM counts the number of misfires over 200 and 1000 crankshaft revolutions, and calculates the total misfire rate and the misfire rate for each cylinder:

  Misfire rate = No. of misfires / No. of working strokes

- E.g. a total misfire rate of 25 % means that one cylinder in a 4-cylinder engine misfires completely.

- If the misfire rate over 200 crankshaft revolutions exceeds the limit (typical values range from 40 % at idle to as low as 5 % at high engine speed and load) and the TWC has reached its operating temperature (calculated by the PCM), this is classified as a severe misfire causing irreversible damage to the TWC.
- If the misfire rate over 1000 crankshaft revolutions exceeds the limit (typically 1…3 % regardless of engine speed and load), this is classified as a minor misfire causing increased exhaust emissions only.
- If a cylinder misfires and subsequently the misfire rate over 200 or 1000 crankshaft revolutions exceeds the limit, this is recognized by the monitor and a fault is stored in the PCM memory.

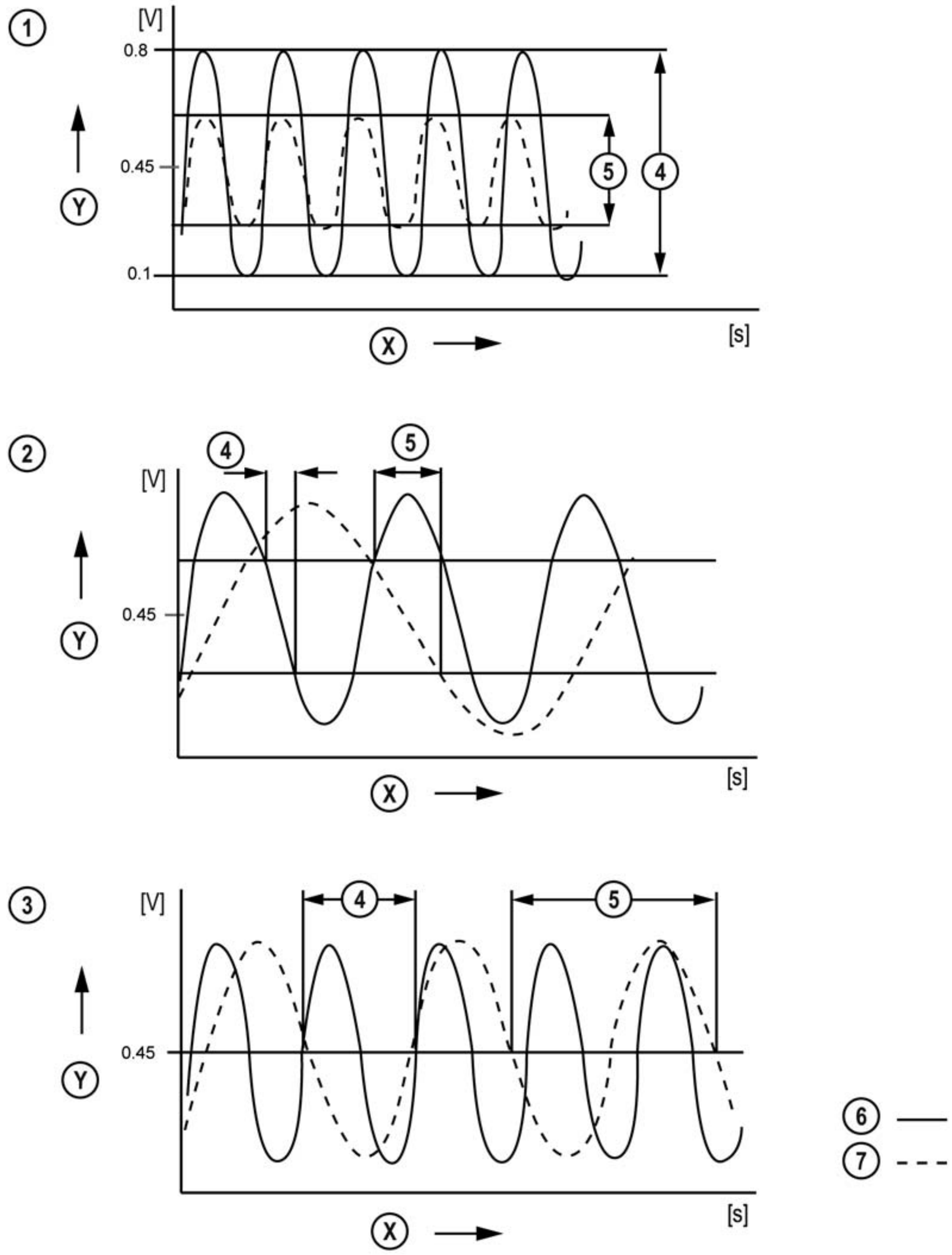
NOTE: The Tribute F/L features a special strategy to protect the TWC against damage in case of severe misfire. If such a misfire is detected, the PCM cuts off the fuel injection at the cylinder in question. As a result, no unburnt fuel is induced into the TWC and burnt there, preventing the catalytic converter from being damaged.

Fuel System Monitor

- The fuel system monitor continuously checks, whether the short-term and long-term fuel trim values of the fuel system are within a certain range. If a fuel system-related component fails and subsequently the correction factors of the short-term and long-term fuel trim exceed the rich or lean limit (typically ± 25 %) for more than a specified duration, this is recognized by the monitor and a fault is stored in the PCM memory.

HO2S Monitor

- The HO2S monitor intermittently checks the upstream and downstream HO2S for range faults and plausibility faults. In addition, the monitor checks the upstream HO2S for dynamic faults. Therefore, the PCM uniformly varies the air/fuel ratio around $\lambda = 1$, and monitors the response time and period duration of the HO2S signal. If the HO2S fails, this is recognized by the monitor and a fault is stored in the PCM memory.



L3003_02031

X	Time	Y	Output voltage
1	Amplitude of HO2S signal	5	Aged HO2S
2	Response time of HO2S signal	6	Correct signal
3	Period duration of HO2S signal	7	Faulty signal
4	New HO2S		

HO2S Heater Monitor

- The HO2S heater monitor intermittently checks the heater element of the upstream and downstream HO2S for electrical faults. On vehicles with linear-type HO2S the monitor additionally checks the heater element for functional faults by monitoring the HO2S signal a short time after engine start. If the HO2S heater fails, this is recognized by the monitor and a fault is stored in the PCM memory.

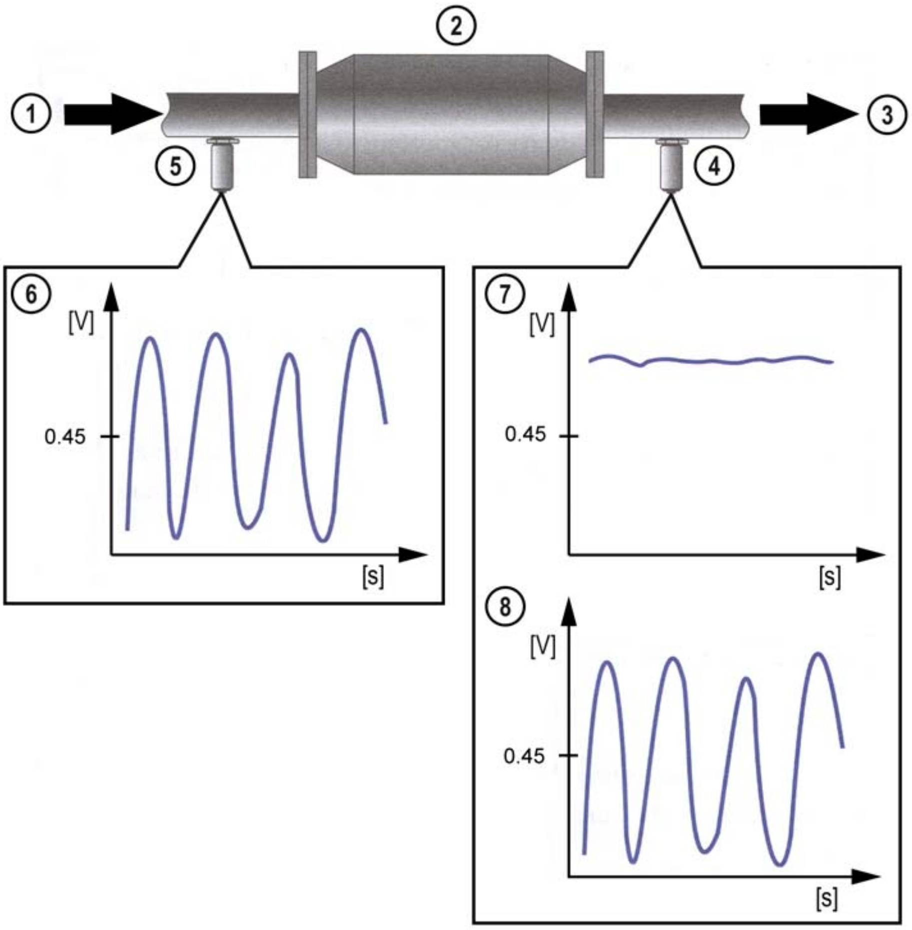
TWC Monitor

- The TWC monitor intermittently checks, whether the conversion rate of the TWC is above a certain limit. The conversion rate depends on the ability of the active catalytic coating to store oxygen. Contamination or ageing of the active catalytic coating reduces this ability and hence the conversion rate of the TWC.
- The TWC monitor compares the oxygen concentration in the exhaust gas downstream of the TWC (detected via the downstream HO2S) to that upstream of the TWC (detected via the upstream HO2S) to determine the oxygen storage capacity of the TWC. The PCM counts the number of switches between rich and lean cycles at the downstream and upstream HO2S, and calculates the switch ratio:

  Switch ratio = No. of switches at downstream HO2S / No. of switches at upstream HO2S

- A low switch ratio of 0 means that there are no switches at the downstream HO2S, i.e. the oxygen concentration downstream of the TWC is low. As a result, the oxygen storage capacity of the TWC is high and consequently the conversion rate is good.
- A high switch ratio of 1 means that the number of switches at the downstream HO2S is equivalent to the number of switches at the upstream HO2S, i.e. the oxygen concentration downstream of the TWC is equivalent to that upstream of the TWC. As a result, the oxygen storage capacity of the TWC is low and consequently the conversion rate is bad (e.g. active catalytic coating completely ineffective or hole in the ceramic carrier).
- If the TWC fails and subsequently the switch ratio exceeds a certain limit (typically 0.75), this is recognized by the monitor and a fault is stored in the PCM memory.

NOTE: On vehicles with two catalytic converters arranged in series only the upstream TWC (warm-up TWC) is monitored.

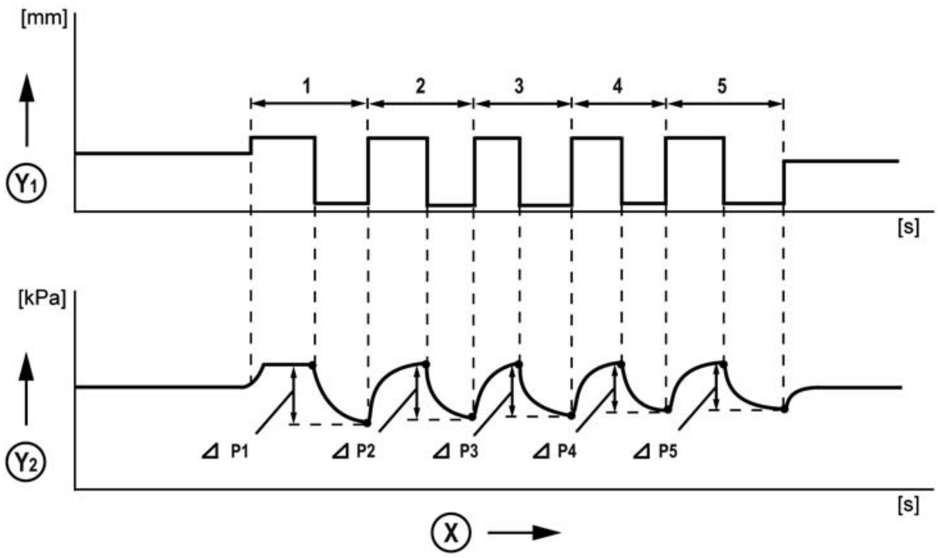


L3003_02032

1 From exhaust manifold
2 TWC
3 To tailpipe
4 Downstream HO2S
5 Upstream HO2S
6 Signal of the upstream HO2S
7 Normal signal of the downstream HO2S
8 Signal of the downstream HO2S when the TWC is aged

EGR System Monitor

- The Tribute F/L features an EGR system monitor, which intermittently checks the components of the EGR system for electrical faults and functional faults. The monitoring strategy for functional faults varies depending on the engine type.
- On the Tribute F/L with L3 engine (equipped with stepper motor-controlled EGR valve) the EGR system is checked for functional faults by monitoring the pressure changes in the intake manifold (derived from the MAP sensor signal) when opening and closing the EGR valve several times.



L3003_02034

X	Time	Y_1	EGR valve lift
Y_2	Manifold absolute pressure		

- On the Tribute F/L with AJ engine (equipped with vacuum-controlled EGR valve) the EGR system is checked for functional faults by monitoring the EGR rate in the EGR pipe (derived from the EGR differential pressure sensor signal).
- If an EGR system-related component fails, this is recognized by the monitor and a fault is stored in the PCM memory.

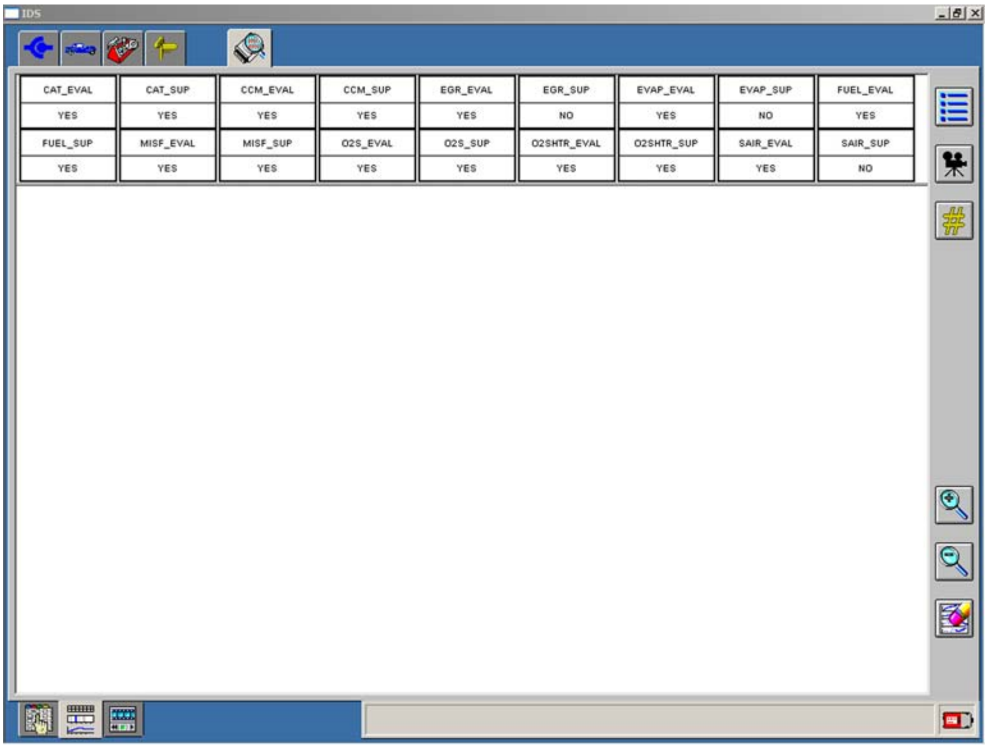
NOTE: On all other current Mazda vehicles (equipped with stepper motor-controlled EGR valve) the EGR system is solely monitored for electrical faults via the CCM.

Temporary Disablement of Monitors

- According to the EOBD regulations temporary disablement of individual monitors is permitted under certain conditions to prevent mis-diagnosis and hence incorrect malfunction indication by the EOBD system. The monitors can be disabled during:
  - Vehicle operation with a fuel tank level below 20 %
  - Vehicle operation at elevations over 2500 m above sea level
  - Engine start at ambient temperatures below -7 °C

Monitor Status

- The monitor status provides information about the monitors supported by the EOBD system and their completion status.



L3003_02024

- The monitors supported by the EOBD system can be checked with the aid of the PIDs with the ending "_SUP". If e.g. the PID **EGR_SUP** is set to "YES", the EGR system monitor is supported. Monitors that are set to "NO" are generally not supported and can be disregarded.
- The completion status of the monitors can be checked with the aid of the PIDs with the ending "_EVAL". If e.g. the PID **EGR_EVAL** is set to "YES", the tests of the EGR system monitor have been completed.

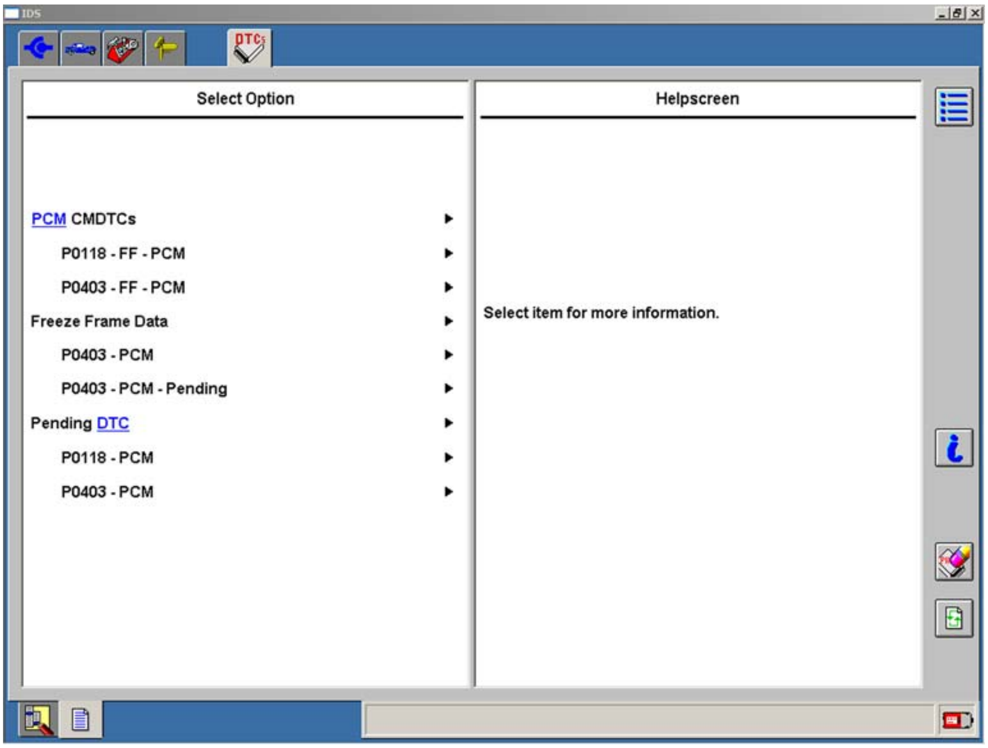
NOTE: For monitors that are not supported by the EOBD system the PIDs with the ending "_EVAL" are automatically set to "YES“. If e.g. the evaporative system monitor is not supported on Mazda petrol engines, the PID **EVAP_SUP** is set to "NO" and the PID **EVAP_EVAL** is set to "YES". This is to prevent technicians from mis-interpreting that the tests of this monitor have not been completed yet.

- CCM, misfire monitor and fuel system monitor run continuously and therefore always display "YES“ for the completion status. The intermittently operating HO2S, HO2S heater, TWC and EGR system monitors only display "YES", if the respective tests have been completed at least once.
- For non-continuous monitors the completion status is reset to "NO" when clearing the DTCs with M-MDS. Then the OBD drive mode must be performed, so that these monitors can carry out their tests.
- If "NO" is displayed for a non-continuous monitor, the following reasons should be considered:
  - No monitoring has been performed since the vehicle was manufactured.
  - No monitoring has been performed since the fault memory was last cleared.
  - A fault has been detected during monitoring.

- The monitor status and other EOBD-related PIDs can be checked with M-MDS via the option **Toolbox→Powertrain→OBD Test Modes→Mode 1 Powertrain Data**.

MIL Activation and Fault Storage

- The conditions for MIL activation and fault storage largely depend on the vehicle type. Generally the MIL only comes on when a fault is stored in the PCM memory as a confirmed fault. If the fault does not reoccur during three drive cycles, the MIL is extinguished in the fourth drive cycle. However, the fault remains stored in the PCM memory. Faults that no longer occur are automatically cleared from the PCM memory after 40 warm-up cycles.
- In addition, the MIL is extinguished when the related fault is cleared with M-MDS.



L3003_02025

- If the MIL illuminates or flashes, the customer is not legally obliged to do anything, but the fault that caused the MIL to illuminate continuously or to flash may result in the vehicle failing a regular emission test. However, the customer is advised to take the vehicle to an authorized Mazda workshop as soon as possible.
- In addition, the EOBD system records the distance traveled since the MIL was activated. Thus a check can be made on how long a customer took to have an emission-relevant fault repaired. This may become important in warranty issues and therefore should be noted on the repair order.

- The distance traveled since activation of the MIL can be checked with the aid of the PID **MIL_DIS** (Meter), which can be called up with M-MDS via the option **Toolbox→ Powertrain→OBD Test Modes→Mode 1 Powertrain Data**.
- On all current Mazda vehicles with Z-type or L-type engines the MIL is activated either after one drive cycle or after two drive cycles. In addition, on the Tribute F/L the MIL is generally activated after two drive cycles.
- MIL activation after one drive cycle is used for faults for which fail-safe data is stored in the PCM. If such a fault comes up, the PCM reverts to the fail-safe data (e.g. substitute value) for engine control. As a result, a fault occurring for the first time is stored in the PCM memory directly as a confirmed fault (MIL DTC). Consequently, the MIL is illuminated.

	DC		DC	DC	DC	DC		DC	DC		WUC	DC
	1	Monitoring conditions not met	2	1	1	2	Monitoring conditions not met	3	1		40	1
Fault	**Yes**	**Yes**	**Yes**	**Yes**	**No**	→	→	→	→	→	→	→
MIL DTC	**Stored**	→	**Stored**	→	→	→	→	→	→	→	→	**Erased**
MIL	**ON**	→	**ON**	→	→	→	→	→	**OFF**	→	→	→

DC: Drive cycle
WUC: Warm-up cycle

L3003_T02002

- MIL activation after two drive cycles is used for faults for which no fail-safe data is stored in the PCM. If such a fault comes up, the PCM initiates a limp home mode (e.g. engine speed limitation). As a result, a fault occurring for the first time is stored in the PCM memory as a presumed fault (pending DTC), but the MIL is not illuminated. If the fault is not confirmed during the second drive cycle, the PCM judges that the system/ component has returned to normal operation or that the fault was detected due to mis-diagnosis, and deletes the presumed fault.
- Presumed faults related to minor misfire or the fuel system are only deleted, if they are not confirmed during a second drive cycle that meets all of the following conditions:
  - Engine speed within ± 375 min^{-1} of that during the first drive cycle
  - Engine load within ± 20 % of that during the first drive cycle
  - Engine warm-up status same as that during the first drive cycle (i.e. engine coolant temperature either below 70 °C (cold engine) or 70 °C or above (warm engine))

	DC 1	Monitoring conditions not met	DC 2	DC 1	DC 1	DC 2	Monitoring conditions not met	DC 3	DC 1		WUC 40	DC 1
Fault	**Yes**	**Yes**	**No**	→								
Pending DTC	**Stored**	→	**Stored**	**Erased**	→							
MIL DTC	**No**	→	**No**	→								
MIL	**OFF**	→	**OFF**	→								

DC: Drive cycle
WUC: Warm-up cycle

L3003_T02003

- However, if such a fault is confirmed during the second drive cycle, the PCM judges that the system/component has failed, and stores a confirmed fault in addition to the presumed fault. As a result, the MIL is illuminated.

	DC 1	Monitoring conditions not met	DC 2	DC 1	DC 1	DC 2	Monitoring conditions not met	DC 3	DC 1		WUC 40	DC 1
Fault	**Yes**	**Yes**	**Yes**	**Yes**	**No**	→						
Pending DTC	**Stored**	→	**Stored**	→		**Erased**	→					
MIL DTC	**No**	→	**Stored**	→								**Erased**
MIL	**OFF**	→	**ON**	→					**OFF**	→		

DC: Drive cycle
WUC: Warm-up cycle

L3003_T02004

- On the Mazda2 with MZI engine the MIL is generally activated after three drive cycles. As a result, a fault occurring for the first time is stored in the PCM memory as a presumed fault, but the MIL is not illuminated. If the fault is not confirmed during the second drive cycle, the PCM judges that the system/component has returned to normal operation or that the fault was detected due to mis-diagnosis, and deletes the presumed fault (also refer to MIL activation after two drive cycles).
- However, if such a fault is confirmed during the second and the third drive cycle, the PCM judges that the system/component has failed, and stores a confirmed fault in addition to the presumed fault in the third drive cycle. As a result, the MIL is illuminated.

	DC 1	Monitoring conditions not met	DC 2	DC 3	DC 1	DC 1	DC 2	Monitoring conditions not met	DC 3	DC 1		WUC 40	DC 1
Fault	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	→	→	→	→	→	→	→
Pending DTC	**Stored**	→	→	**Stored**	→	→	**Erased**	→	→	→	→	→	→
MIL DTC	**No**	→	→	**Stored**	→	→	→	→	→	→	→	→	**Erased**
MIL	**OFF**	→	→	**ON**	→	→	→	→	→	**OFF**	→	→	→

DC: Drive cycle
WUC: Warm-up cycle

L3003_T02005

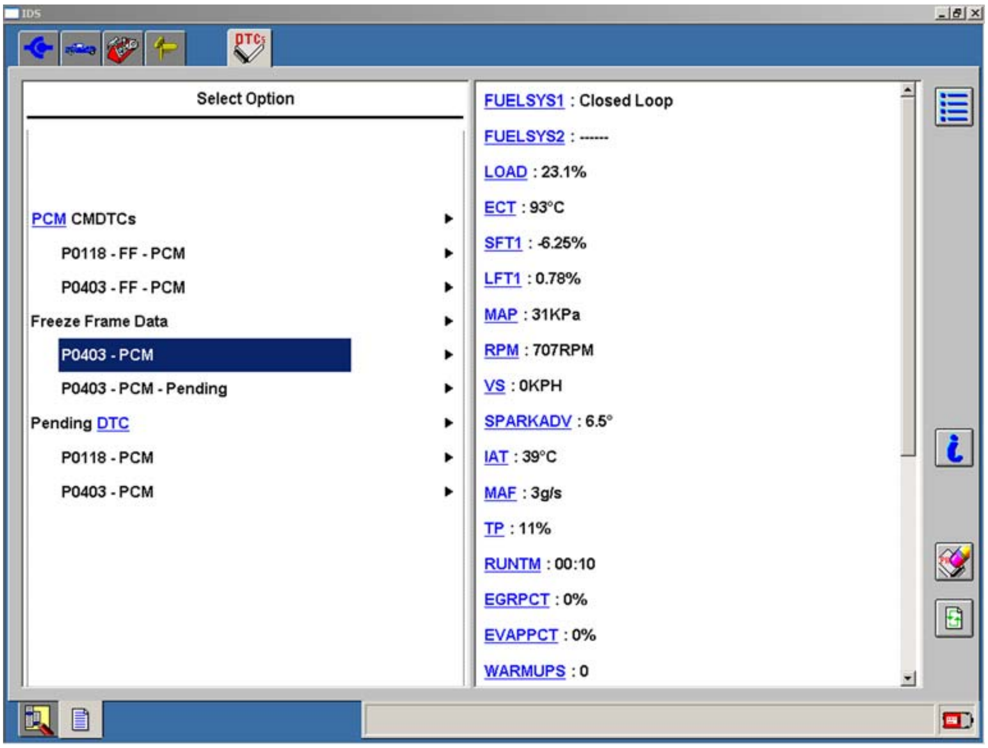
- Independent from the vehicle type the MIL is activated immediately during the first drive cycle, if severe misfire causing irreversible damage to the TWC is detected. In this case, a confirmed fault is stored in the PCM memory and the MIL flashes.
- The pending DTCs and the MIL DTCs can be read out and cleared with M-MDS via the option **Toolbox→Selftest→Modules→PCM→Retrieve CMDTCs**.

NOTE: When the DTCs are cleared, the freeze frame data, diagnostic monitoring test results and distance traveled since activation of the MIL are cleared as well. In addition, the completion status of the non-continuous monitors is reset.

NOTE: On the Mazda2 and Tribute F/L the DTC P1000 (OBD system readiness test not complete) comes up after the PCM memory has been cleared. This fault code indicates that not all monitors have completed their tests. The fault code does not mean that a fault has been found in a system/component, and can therefore not be cleared with M-MDS. Once the OBD drive mode has been performed and all monitors have completed their tests, the DTC P1000 is cleared automatically.

Freeze Frame Data

- The **FFD** (**F**reeze **F**rame **D**ata) is a snapshot of the engine operating conditions at the occurrence of the first fault. This data is stored in the PCM memory and will not be overwritten, even if a confirmed fault is stored in addition to a presumed fault. The only exception are faults related to misfire or the fuel system, since these have a higher priority. If such a fault is stored in the PCM memory, its FFD will overwrite any old data, unless the previous FFD are also related to misfire or the fuel system.



L3003_02026

- The FFD is very helpful when diagnosing the potential causes of a malfunction. In addition, a concern can be reproduced easier by driving the vehicle under the same conditions as indicated by the FFD.
- According to the EOBD regulations the following data must be stored in the PCM memory when the first fault is detected:

FFD	Description
ECT	Engine coolant temperature
FRP	Fuel rail pressure
FUELSYS1/2	Fuel system status (right bank/left bank)
LFT1/2	Long-term fuel trim (right bank/left bank)
LOAD	Calculated engine load
MAP	Manifold absolute pressure
RPM	Engine speed
SFT1/2	Short-term fuel trim (right bank/left bank)
VS	Vehicle speed

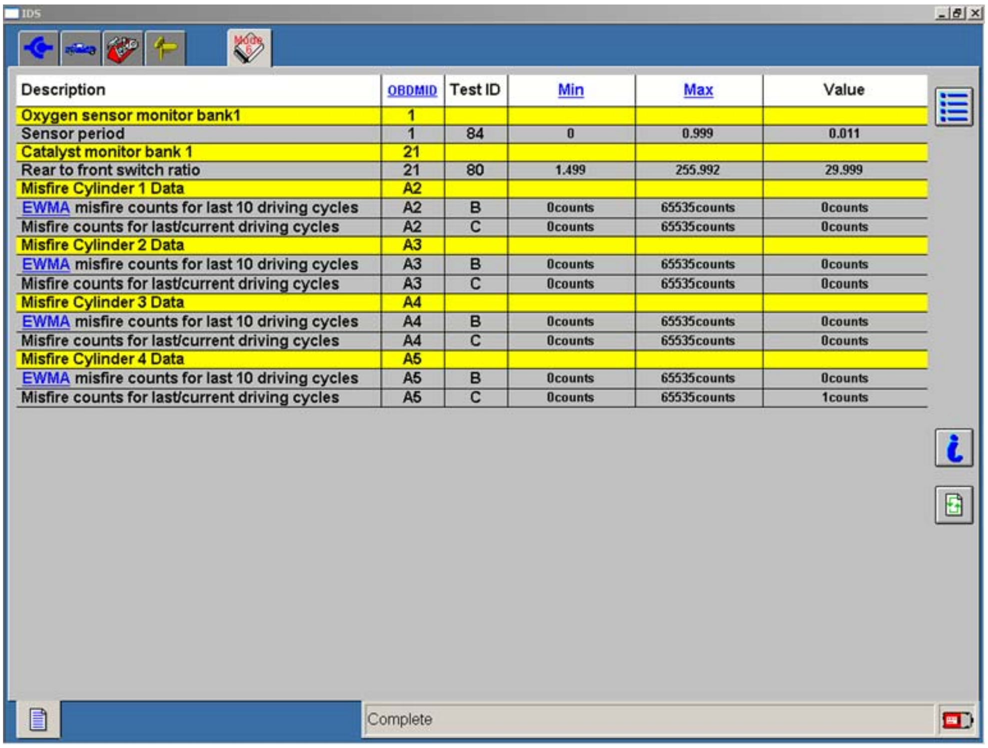
L2003_T02011

- The FFD can be read out with M-MDS via the option **Toolbox→Selftest→Modules→ PCM→Retrieve CMDTCs**.

NOTE: Depending on the vehicle type FFD for a pending DTC is only displayed by M-MDS, if the fault in question is also stored as a confirmed fault in the PCM memory.

Diagnostic Monitoring Test Results

- The **DMTR** (**D**iagnostic **M**onitoring **T**est **R**esults) are the numerical results from the last tests performed by certain monitors. This data is stored in the PCM memory and will only be overwritten whenever a monitor has completed its tests again. The data consists of a description of the corresponding test, the **OBDMID** (**OBD M**onitor **Id**entification), test ID, minimum/maximum limit and test result.



Description	OBDMID	Test ID	Min	Max	Value
Oxygen sensor monitor bank1	1				
Sensor period	1	84	0	0.999	0.011
Catalyst monitor bank 1	21				
Rear to front switch ratio	21	80	1.499	255.992	29.999
Misfire Cylinder 1 Data	A2				
EWMA misfire counts for last 10 driving cycles	A2	B	0counts	65535counts	0counts
Misfire counts for last/current driving cycles	A2	C	0counts	65535counts	0counts
Misfire Cylinder 2 Data	A3				
EWMA misfire counts for last 10 driving cycles	A3	B	0counts	65535counts	0counts
Misfire counts for last/current driving cycles	A3	C	0counts	65535counts	0counts
Misfire Cylinder 3 Data	A4				
EWMA misfire counts for last 10 driving cycles	A4	B	0counts	65535counts	0counts
Misfire counts for last/current driving cycles	A4	C	0counts	65535counts	0counts
Misfire Cylinder 4 Data	A5				
EWMA misfire counts for last 10 driving cycles	A5	B	0counts	65535counts	0counts
Misfire counts for last/current driving cycles	A5	C	0counts	65535counts	1counts

L3003_02027

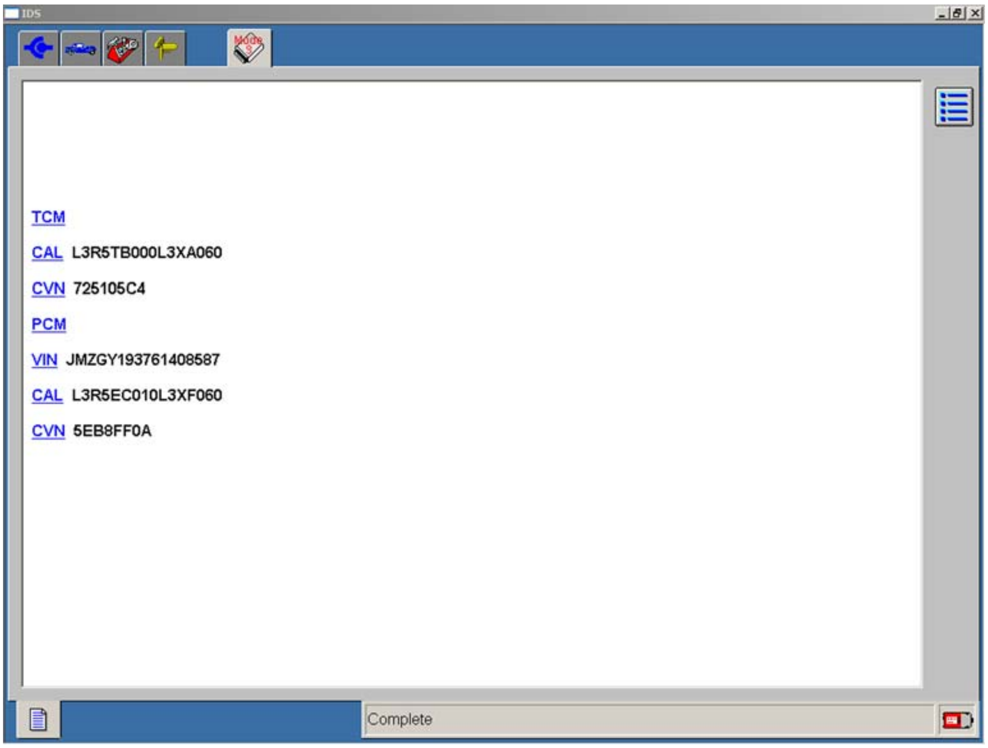
- The DMTR provide additional information, whether monitoring of a component/system has been completed and whether the component/system is okay. Therefore, the test results of the monitor in question must be compared to the respective minimum/ maximum limit:
  - If the DMTR and the minimum/maximum limit indicate the initial values (e.g. 0), monitoring has not been performed at all or has not been completed yet. The completion status of the corresponding monitor is consequently set to “NO”. In this case, the OBD drive mode required for the monitor in question must be repeated.
  - If the DMTR indicate a value which is outside the limits, monitoring is completed and the component/system in question is faulty. The completion status of the corresponding monitor is consequently set to “NO”, and a pending DTC or MIL DTC is stored in the PCM memory.
  - If the DMTR indicate a value which is within the limits, monitoring is completed and the component/system in question is okay. The completion status of the corresponding monitor is consequently set to “YES”.

- The DMTR can be read out with M-MDS via the option **Toolbox→Powertrain→ OBD Test Modes→Mode 6 On-board Test Results**.

NOTE: The DMTR displayed by M-MDS are not updated even when the data stored in the PCM memory changes. For this reason, the Repeat button must be pressed to update the M-MDS display.

Tamper Protection

- According to the EOBD regulations the PCM/TCM must have a write-protection for any reprogrammable computer code to prevent tampering (such as unauthorized reprogramming etc.).
- The **CALID** (**CAL**ibration **Id**entification) identifies the specific calibration and is defined as a 16-digit alphanumerical code providing information about calibration name, type of vehicle, release date, release engineer and version number. The **CVN** (**C**alibration **V**erification **N**umber) serves to verify whether the correct software is stored in the PCM/TCM and is similar to an encrypted checksum. CALID and CVN will be tracked for all initial releases, running changes and field fixes of the PCM/TCM software.



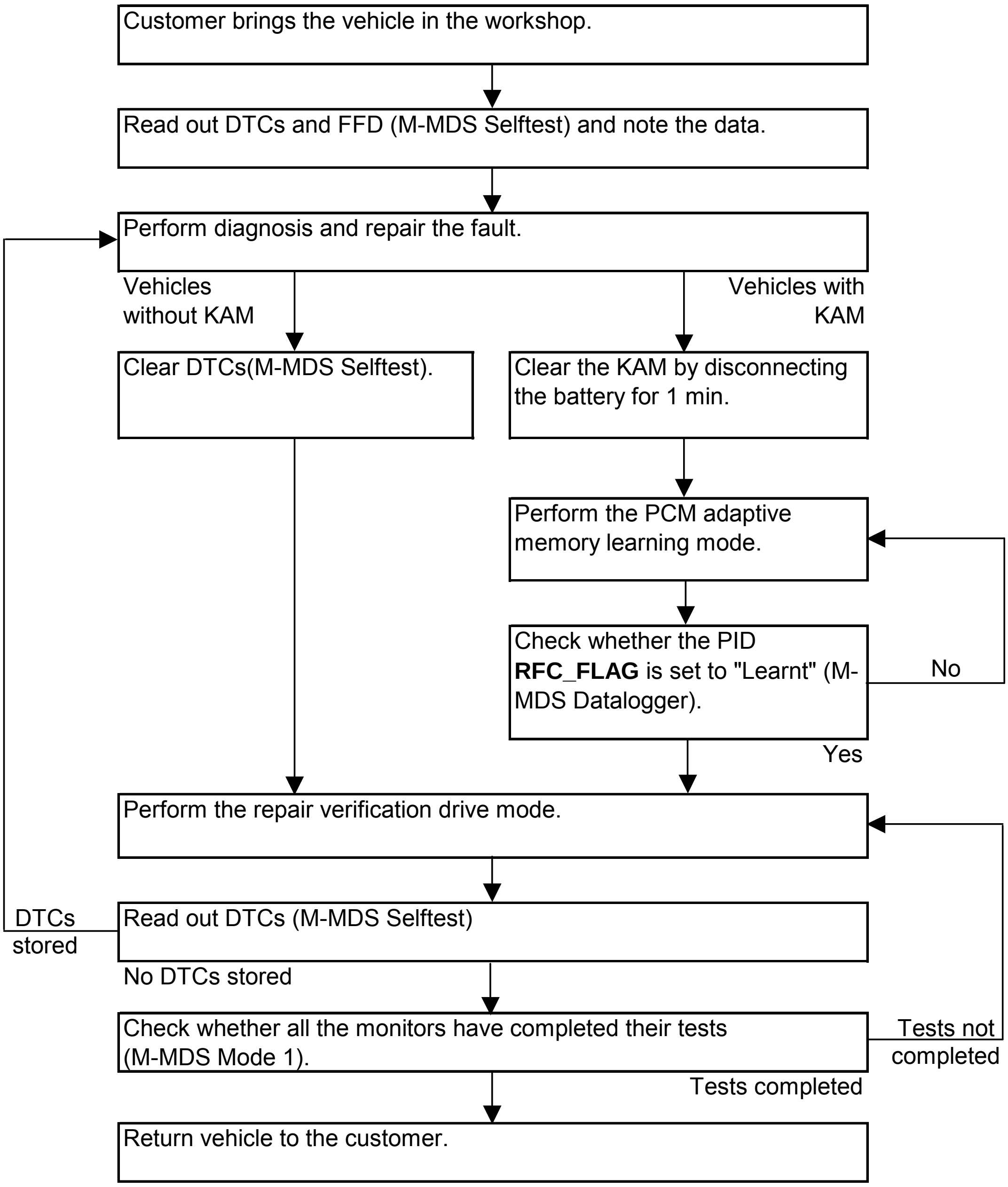
L3003_02028

- The CALID, CVN and VIN can be read out with M-MDS via the option **Toolbox→ Powertrain→OBD Test Modes→Mode 9 Vehicle Information**.

Diagnostics

- When performing diagnosis and repair of EOBD-related concerns the basic procedure shown below should be followed.

NOTE: Failure to follow this procedure will make it extremely difficult to properly diagnose and repair EOBD-related concerns.



L3003_T02006

OBD Drive Mode

- The OBD drive mode consists of the PCM adaptive memory learning mode and the repair verification drive mode, and serves to verify that the vehicle is in order after performing any EOBD-related repairs.

PCM Adaptive Memory Learning Mode

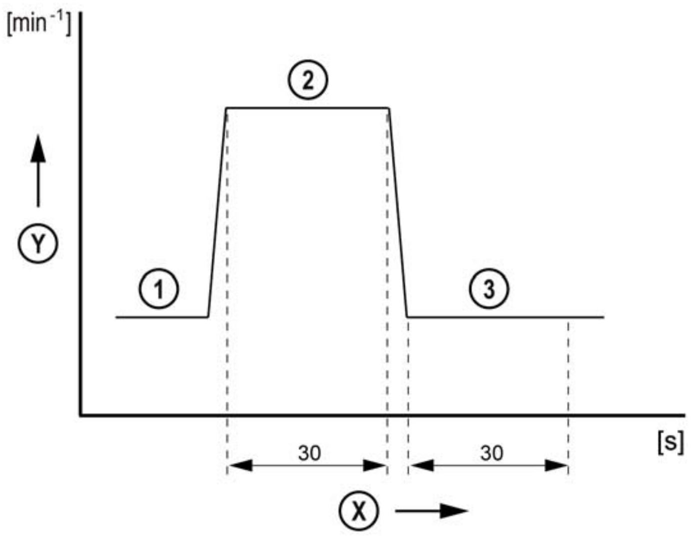
- The PCM adaptive memory learning mode allows the engine management system to establish the permanent correction factors of the long-term fuel trim. The PCM uses these values for the air/fuel ratio control and for the OBD monitors.
- If the PCM adaptive memory learning mode is not performed, most monitors will never run. For this reason, it is absolutely necessary to conduct the learning mode prior to the repair verification drive mode.
- On all current Mazda vehicles except for the Mazda2 the permanent correction factors for the long-term fuel trim are logged in the KAM. Since the Mazda2 features no KAM, the correction factors are logged in the FEEPROM.

NOTE: After performing EOBD-related repairs the permanent correction factors of the long-term fuel trim should be reset by disconnecting the battery for 1 min. Hereafter, the PCM adaptive memory learning mode must be performed, allowing the PCM to re-establish the correction factors.

NOTE: On the Mazda2 and Tribute F/L the PCM adaptive memory learning mode is not available.

- E.g. the PCM adaptive memory learning mode for Mazda3 BK and Mazda6 GG/GY with 2.0 MZR engine must be performed as following:
  1. Bring the engine to normal operating temperature and verify that all accessory loads (A/C, headlights, blower motor, rear window defroster) are off.
  2. Make sure that ignition timing and idle speed are within specification.
  3. Increase the engine speed according to the learning mode indicated in the figure. Hereafter, let the engine idle for more than 30 s after the cooling fan has stopped.
  4. Confirm that the PCM adaptive memory learning mode has been performed successfully by checking the PID **RFC_FLAG** (Mode), which can be called up with M-MDS via the option **Toolbox→Datalogger→Modules→PCM**. If the PID is set to "Learnt", the learning mode has been performed successfully. Otherwise repeat the PCM adaptive memory learning mode.

NOTE: Depending on the vehicle type the PID **RFC_FLAG** may not be available.



L3003_02017

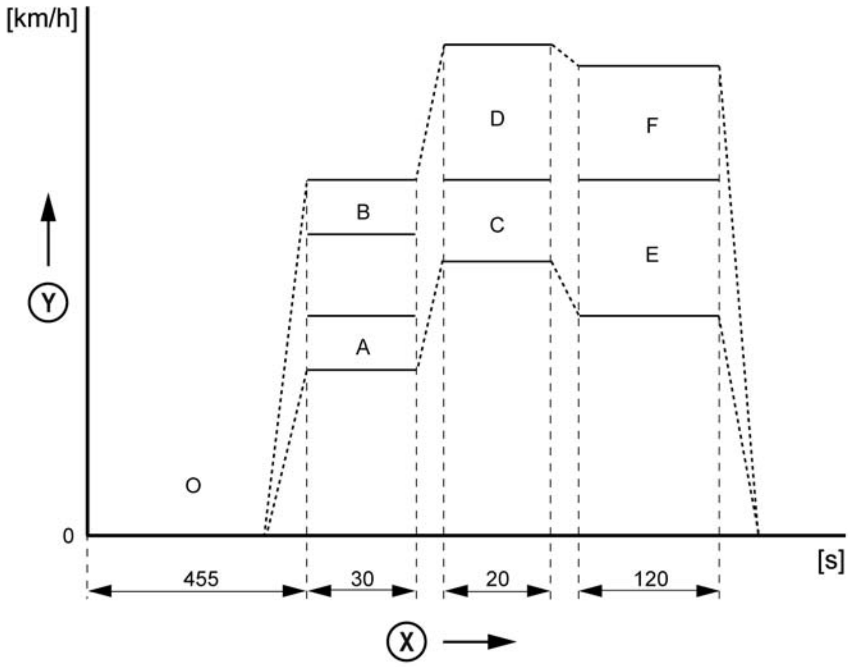
X	Time	Y	Engine speed
1	Idle	3	Idle with cooling fan OFF
2	2800…3200 min^{-1}		

Repair Verification Drive Mode

- The repair verification drive mode is designed in a way that all the monitors can conduct and complete their tests in a logical order and hence in the fastest possible way.

NOTE: The tests of the monitors can be completed faster if the accelerator pedal is moved smoothly when accelerating or decelerating. In addition, the fuel tank level should be above 20 % as otherwise the misfire monitor, fuel system monitor, HO2S monitor and TWC monitor might be disabled, preventing other monitors from running.

- E.g. the repair verification drive mode for the Mazda3 BK with 2.0 MZR engine and MTX must be performed as following:
  1. Confirm that the PID **RFC_FLAG** is set to “Learnt”. If the PID is set to “Not Learnt”, perform the PCM adaptive memory learning mode prior to the repair verification drive mode.
  2. Bring the engine to normal operating temperature and verify that all accessory loads (A/C, headlights, blower motor, rear window defroster) are off.
  3. Drive the vehicle according to the drive mode indicated in the figure. First drive in zone O, then A or B, followed by C or D and finally E or F. The driving conditions before driving at constant vehicle speed are not specified.
  4. Confirm that the repair verification drive mode has been performed successfully by checking the completion status of the monitors. If all PIDs with the ending “_EVAL” are set to “YES”, the drive mode has been performed successfully. Otherwise repeat the repair verification drive mode.



L3003_02018

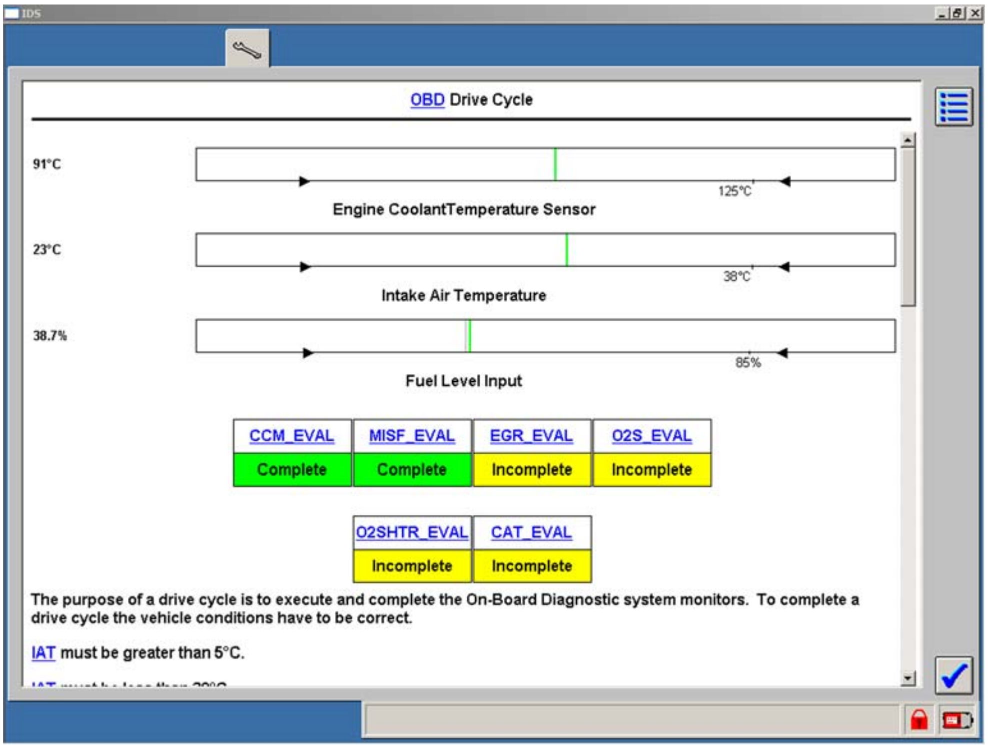
X Time

Y Vehicle speed

Zone	Shift Position	Vehicle Speed (km/h)
O	Neutral	0
A	2nd gear	40...50
B	3rd gear	65...75
C	2nd gear	60...75
D	3rd gear	75...100
E	4th gear	50...75
F	5th gear	70...95

L2003_T02007

- On the Tribute F/L the instructions for the repair verification drive mode can be found in M-MDS. In addition, the M-MDS allows the user to check the current operating conditions and the status of the individual monitors.



L3003_02029

- The instructions for the repair verification drive mode can be accessed with M-MDS via the option **Toolbox→Powertrain→OBD Test Modes→OBD Drive Cycle**.

Notes:

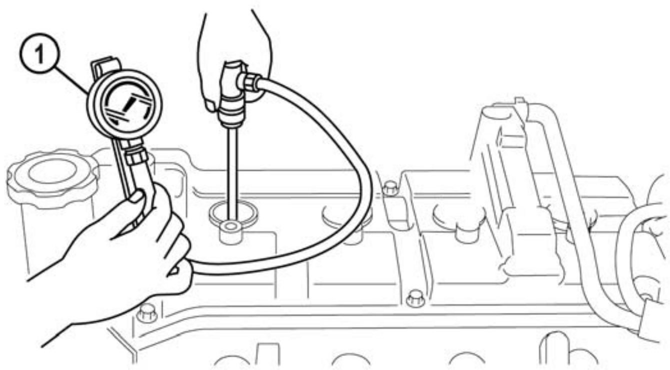
Engine Mechanical System

General

- While the various sub-systems of the Mazda petrol engine management systems (such as intake-air system, fuel system, ignition system, emission system and control system) have already been covered in the course “Basic Petrol Engine Management” and in the preceding sections, this section describes the engine mechanical system.
- The following parameters of the engine mechanical system can affect the running of a petrol engine:
  - Compression pressure
  - Valve timing
  - Valve clearance

Compression Pressure

- A sufficiently high compression pressure ensures that the air/fuel mixture burns completely in the combustion chamber.
- Insufficient compression pressure can occur due to worn piston rings, worn valves or a leaking cylinder head gasket. This can lead to poor engine power and increased exhaust emissions.

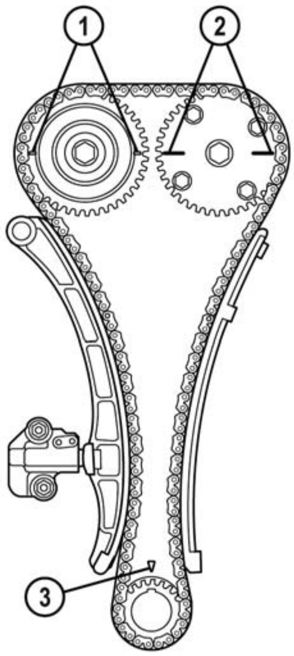


L3003_02019

1 Compression pressure tester

Valve Timing

- The correct valve timing ensures that the valves open and close at the right time to provide a good cylinder charge and optimum compression pressure.
- Incorrect valve timing can occur, if the camshaft sprockets are not aligned correctly or if the timing belt has jumped over. On engines with variable valve timing a faulty camshaft actuator can also cause incorrect valve timing. This can lead to misfire, poor engine power, increased exhaust emissions, or engine damage due to contact between the piston and the valves (the latter one depending on the engine type).

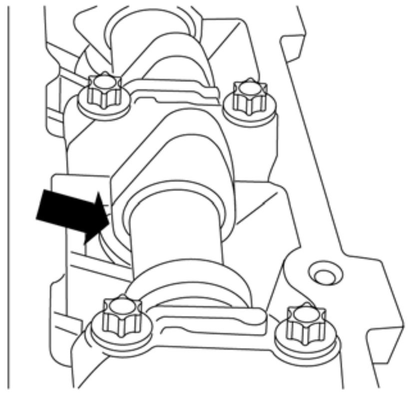


L3003_02020

1 Timing mark for exhaust camshaft
2 Timing mark for intake camshaft
3 Timing mark for crankshaft

Valve Clearance

- The correct valve clearance ensures that the valves open wide enough to provide a good cylinder charge and at the same time close fully to ensure an optimum compression pressure.
- Incorrect valve clearance can occur due to wear and thermal overloading of the valves. On engines with hydraulic valve clearance compensation, faulty hydraulic lash adjusters can also cause incorrect valve clearance. This can lead to poor engine power, noises from the valve gear, or burnt valves due to insufficient heat transfer to the cylinder head.



L3003_02021

Diagnostics

- The engine mechanical system can be checked as following:
  - Checking the compression pressure
  - Checking the pressure loss
  - Checking the valve timing
  - Checking the valve clearance

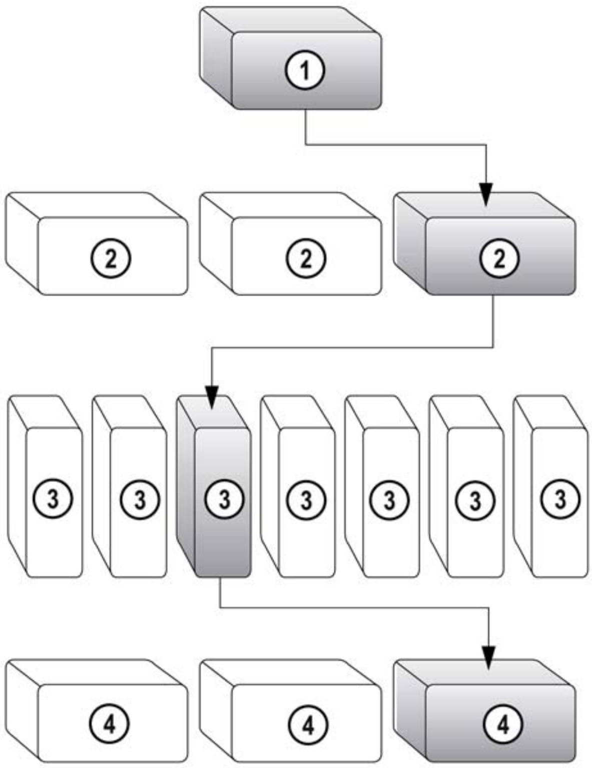
Checking the pressure loss

- If the compression pressure of a cylinder is found to be too low, the pressure loss test can be used to locate the leak in the combustion chamber and to establish which components are faulty. The principle of the pressure loss test is that the combustion chamber is pressurized with compressed air and the loss of pressure arising due to the leak is indicated by flowing noises. For this, the piston must be in TDC position and the valves closed. Then a compressed air hose is connected with a suitable adapter to the spark plug opening of the cylinder concerned.
- If the compressed air is escaping at a valve, flowing noises will be audible in the intake-air or exhaust system. Loss of pressure past the piston rings into the crankcase can be identified by flowing noises from the oil filler opening. Flowing noises in another cylinder or bubbling in the cooling system indicates a leaking cylinder head gasket.

Diagnostic Process

General

- Diagnosis requires comprehensive knowledge of the system operation. As with all diagnosis, a technician must use symptoms and clues to determine the cause of a customer concern. The following diagnostic process provides you with a logical method for rectifying customer concerns:
  1. Confirm the symptom of the customer concern.
  2. Determine which system of the vehicle could be causing the symptom.
  3. Once you identify the particular system, determine which component(s) within that system could be the cause for the symptom.
  4. After determining the faulty component(s) you should always try to identify the cause of the failure. In some cases components just wear out. However, in other cases something else than the failed component is responsible for the problem.



L3003_02022

1	Symptom	3	Components
2	Systems	4	Causes

- For example, a customer's car is brought in the workshop with a "No start" concern, i.e. the symptom is that the engine will not start. During diagnosis you find that the fuel pressure in the fuel rail is too low. Therefore, you determine that the fuel system is the cause for the problem. By performing diagnostic routines, you determine that the fuel pump is the faulty component. Further investigation shows that contamination in the fuel tank is the cause of the component failure.

Basic Checks for Troubleshooting

- When performing troubleshooting on a petrol engine the following basic checks should be made before moving on to more complex electrical checks.

NOTE: If the customer concern is "No start" or "Hard start", spray "Start Pilot" into the intake-air duct while cranking the engine. If the engine starts, the fuel system might be faulty. If the engine does not start, then this indicates a fault in the ignition system or engine mechanical system.

Engine Mechanical System

- Check the compression and if necessary the pressure loss.
- Check the valve timing.
- Check the valve clearance.
- Check the engine oil for contamination (e.g. by engine coolant).
- Check the engine coolant for contamination (e.g. by engine oil).

Intake-air System

- Check the condition of the air cleaner.
- Check the intake-air system for leakage (incl. O-rings of the injectors) or oil ingress.
- Check the adjustment of the accelerator cable (only mechanical throttle valve).
- Check the function of the electronic throttle valve.
- Check the function of the idle air control valve (only mechanical throttle valve).
- Check the idle speed.
- Check the turbocharger (only 2.3 MZR DISI Turbo engine).
- Check the function of the boost pressure control valve (only 2.3 MZR DISI Turbo engine).

Fuel System

- Check whether the fuel tank contains sufficient petrol.
- Check the petrol for contamination (e.g. by particles, water, diesel fuel).
- Check the fuel system for leakage.
- Check the fuel lines for leakage or kinks.
- Check the function of the fuel tank ventilation.
- Check the function of the fuel pump.
- Check the fuel pressure.

Ignition System

- Check the condition of the spark plugs.
- Check condition and resistance of the high-tension leads.
- Check the ignition voltage.
- Check the ignition timing.

Emission System

- Check the exhaust system for leakage.
- Check the catalytic converter for blockage.
- Check the function of the EGR system.
- Check the function of the evaporative emissions control system.
- Check the function of the positive crankcase ventilation system.

Control System

- Check the function of the fuses and relays.
- Check the condition of the electrical connections incl. ground connections.
- Check the condition of the battery.
- Check the condition of the starter motor.
- Check the function of the variable valve timing system.

Notes:

ABS	**A**nti-**l**ock **B**rake **S**ystem
A/C	**A**ir **C**onditioning
APP	**A**ccelerator **P**edal **P**osition
BARO	**Baro**metric Pressure
BCM	**B**ody **C**ontrol **M**odule
BDC	**B**ottom **D**ead **C**enter
CALID	**Cal**ibration **Id**entification
CAN	**C**ontroller **A**rea **N**etwork
CCM	**C**omprehensive **C**omponent **M**onitor
CKP	**C**ran**k**shaft **P**osition
CMDTC	**C**ontinuous **M**emory **DTC**
CMP	**Cam**shaft **P**osition
CO	**C**arbon Mon**o**xide
CVN	**C**alibration **V**erification **N**umber
DC	**D**irect **C**urrent
DISI	**D**irect **I**njection **S**park **I**gnition
DLC	**D**ata **L**ink **C**onnector
DMTR	**D**iagnostic **M**onitoring **T**est **R**esults
DSC	**D**ynamic **S**tability **C**ontrol
DTC	**D**iagnostic **T**rouble **C**ode
EBD	**El**ectronic **B**rakeforce **D**istribution
ECT	**E**ngine **C**oolant **T**emperature
EGR	**E**xhaust **G**as **R**ecirculation
EOBD	**E**uropean **O**n-**B**oard **D**iagnostics
FFD	**F**reeze **F**rame **D**ata
FGT	**F**ixed **G**eometry **T**urbine
FHA	**F**uel **H**ose **A**dapter

HC	**H**ydro **C**arbon
HO2S	**H**eated **O_2** **S**ensor
HU/CM	**H**ydraulic **U**nit/**C**ontrol **M**odule
IAC	**I**dle **A**ir **C**ontrol
IAT	**I**ntake **A**ir **T**emperature
IDM	**I**njector **D**river **M**odule
KS	**K**nock **S**ensor
MAF	**M**ass **A**ir **F**low
MAP	**M**anifold **A**bsolute **P**ressure
MIL	**M**alfunction **I**ndicator **L**ight
M-MDS	**M**azda **M**odular **D**iagnostic **S**ystem
MTX	**M**anual **T**ransa**x**le
NO_x	**O**xides of **N**itrogen
OBD	**O**n-**B**oard **D**iagnostics
OBDMID	**OBD** **M**onitor **Id**entification
PCM	**P**owertrain **C**ontrol **M**odule
PCV	**P**ositive **C**rankcase **V**entilation
PID	**P**arameter **Id**entification
PVT	**P**ressure/**V**acuum **T**ransducer
SST	**S**pecial **S**ervice **T**ool
TCM	**T**ransmission **C**ontrol **M**odule
TCS	**T**raction **C**ontrol **S**ystem
TDC	**T**op **D**ead **C**enter
TP	**T**hrottle **P**osition
TWC	**T**hree-**W**ay **C**atalytic Converter
VBC	**V**ariable **B**oost **C**ontrol
VIN	**V**ehicle **I**dentification **N**umber

VSC **V**ariable **S**wirl **C**ontrol

WDS **W**orldwide **D**iagnostic **S**ystem

4WD **4-W**heel **D**rive

Notes: