Reference Manual

E46 M
COMPLETE VEHICLE

Technical Training

Table of Contents

Subject **Page**

COMPLETE VEHICLE

Model: E46 M3
Production Date: 01/2001

Objectives of the Module

After completing this module, you will be able to:

- Identify the differences on the E46 M3 from other production vehicles.
- List the Bus Systems used on the E46 M3.
- Describe the Sports Seat operation.
- Describe the Driveline and Running Gear used in the E46 M3.

E46 M3 Complete Vehicle

Introduction

The E46 M3 is the third generation of the M3 replacing the E36 M3.

In comparison to its predecessor, the high engine performance and dynamic driving characteristics is expressed in its sport-oriented design.

The E46 M3 is a high performance automobile which assumes the leading position in its class.

The E46 M3 is a high performance coupe based on the new E46/2 body.

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System Components

The vehicle is fitted with an in-line 6-cylinder 3246 ccm engine (S54B32) which is used worldwide. The 4-valve induction engine with high pressure VANOS outputs 333 bhp at 7900 rpm. The maximum engine speed is 8000 rpm. The engine develops its maximum torque of 355 Nm at 4900 rpm. The engine management system is the MS S54. The drive train is reinforced to satisfy the engine's increased horsepower and torque.

The running gear of the E46/2 production vehicle and that of the E36 M3 form the basis of the E46 M3 running gear. In addition to the running gear which was specifically adapted to the M3, the vehicle also features: special wheels, Teves MK 20 dynamic drive control system, a variable locking M-differential and high performance brakes.

The design of the E46 M3 makes it capable for everyday driving, economic operation, and high performance while meeting environmental requirements.

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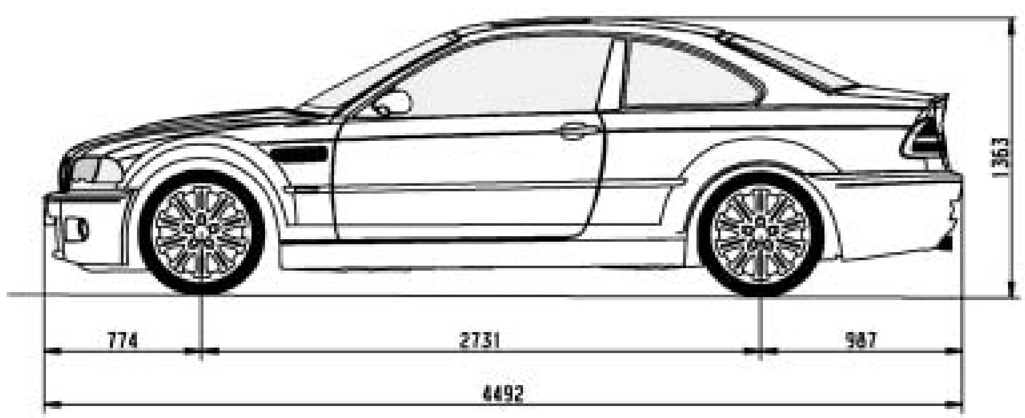
E46 M3 Technical Data

Vehicle Dimensions

The overall length of the E46 M3 measures 4 mm longer than the E46 coupe (license plate bracket).

Compared to the E46/2 production vehicle, the track width on the front and rear axle of the E46 M3 have been increased considerably (track width: front axle +37 mm, rear axle +47mm). The new wider side panels enhance the sports character of the E46 M3.

E46 M3 Side View
(vehicle heights: 1372 mm Unloaded, 1363 mm loaded position)



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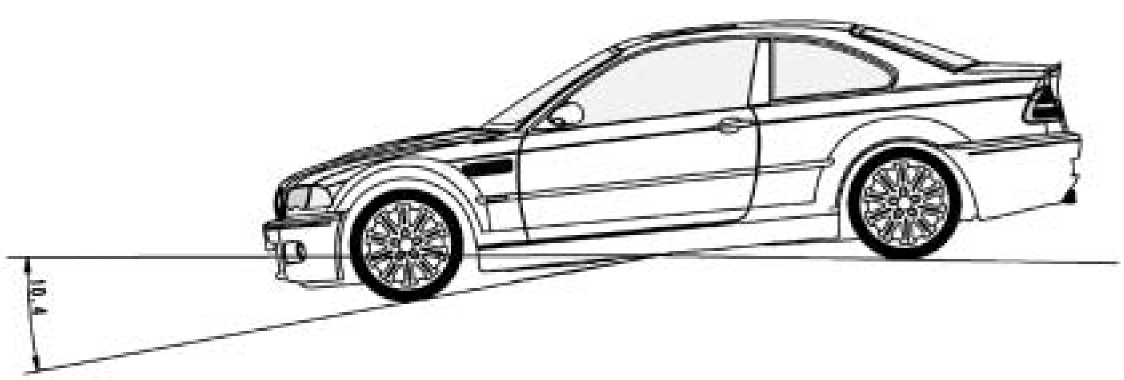
E46 Technical Data (Approach Angle)



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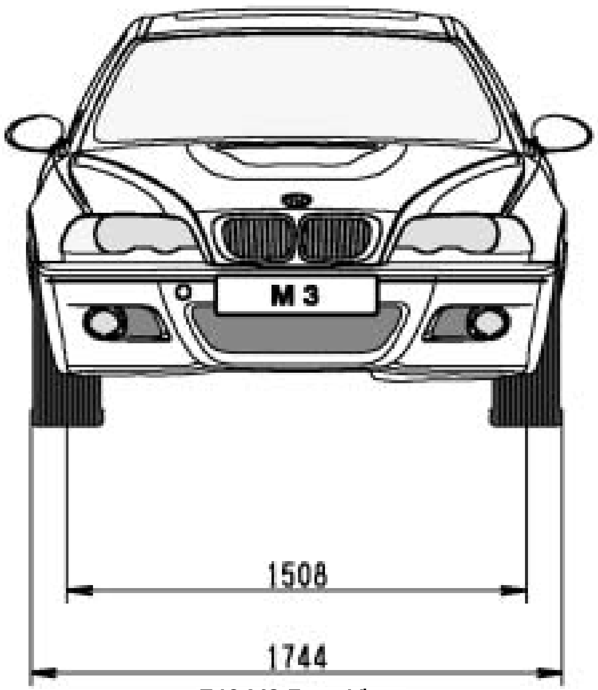
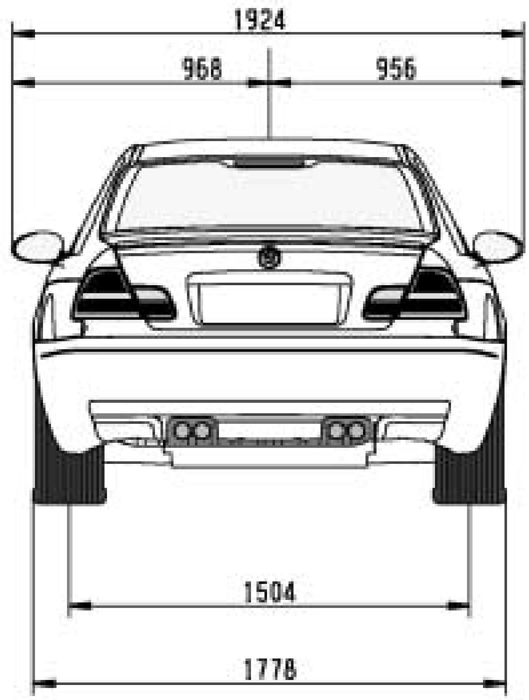
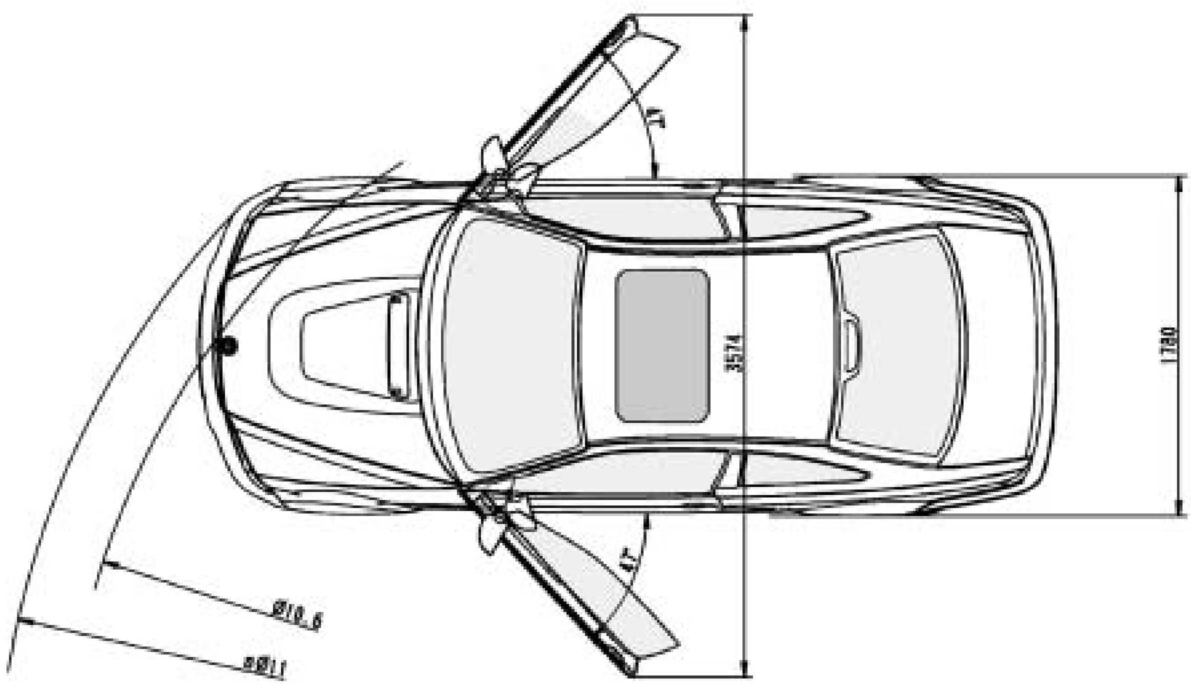


00410003.bmp **E46 M3 Front View**



00410004.bmp **E46 M3 Rear View**



00410005.bmp **E46 M3 Top View**

E46 M3 Specifications Table

	E46 M3	E36 M3
Body Version	Coupe	Coupe
Doors / Seating	2/5	2/5
Vehicle Length	4492 mm	4432 mm
Vehicle Width	1780 mm	1709 mm
Vehicle Height,Unladen	1372 mm	1336 mm
Wheelbase	2731 mm	2700 mm
Turning Radius	11.0m (36.1ft)	
Luggage Compartment Volume	410 L	291 L
Fuel Tank Capacity	63 L	62 L
Curb Weight, DIN	1495 kg	1441
Gross Vehicle Weight Rating	2000 kg	
Permissible Front Axle Load	970 kg	
Permissible Rear Axle Load	1140 kg	
Roof Load	75 kg	

	E46 M3	E36 M3
Engine Type In-line, 6-cylinder, 4-valve	S54B32	S52B32
Engine Management	MS S54	MS 41.2
Engine Size	3246 ccm	3152 ccm
Stroke	91.0 mm	89.6 mm
Bore	87.0 mm	86.4 mm
Torque	355 Nm/4900 rpm	320 Nm/3800 rpm
Engine Output	333 bhp/7900 rpm	240 bhp/6000 rpm
Max. Engine Speed	8000 rpm	6800 rpm
Compression Ratio	11.5 : 1	10.5 : 1
Fuel Grade	Premium Unleaded	Premium Unleaded
Engine Oil Change Capacity With Oil Filter	5.5 L	6.5 L

E46 M3 Specifications Table

	E46 M3	E36 M3
Running Gear		
Gearbox Designation *	SG 6, Getrag D, S65420G	S5D ZF 310Z
Gear ratio, 1st gear	4.227	4.20
Gear ratio, 2nd gear	2.528	2.49
Gear ratio, 3rd gear	1.669	1.67
Gear ratio, 4th Gear	1.226	1.24
Gear ratio, 5th gear	1.00	1.00
Gear ratio, 6th gear	0.828	-
Gear ratio, reverse gear	3.746	4.13
Oil Capacity	1.9 L	1.2 L
Rear Axle Differential Gear Ratio	3.64	3.23
Oil Change Capacity	1.1 L	1.1 L
Type of Steering	Rack and Pinion Power Steering	

***Note:** Refer to SMG II section for transmission specifications.

Miscellaneous	E46 M3
Aerodynamic Drag CD	0.33
Top Speed	155mph (governed)
Battery (V/Ah/A)	12/70/570 in luggage compartment
Alternator	70/120 Valeo
Washer Fluid (Reservoir fitted On Front Right Behind Front Apron)	5.3L

E46 M3 Body

Changes Compared to E46/2

The increase in engine output, torque, dynamic driving characteristics and sport design of the E46 M3 places more demand requirements on the individual components in the body. Visual, functional as well as technical features of the E46 M3 body have been modified in order to satisfy all these requirements. The individual changes contribute to increasing the E46 M3 body rigidity.

The visual differences of the E46 M3 as compared to the E46/2 in the body area include widening of the front and rear side panels, a modified aluminum hood as well as front and rear bumper covers.

The increased body rigidity is achieved by the use of additional gusset plates and weld points. Both functional and technical modifications have been made to the side frame structures, front and rear wheel arches, reinforcement in the C-pillar area as well as the luggage compartment floor.

The body of the E46 M3 corresponds to that of the E46/2 but with the following Changes:

1.	**Floor Assembly / Luggage Compartment Floor**
2.	**Side Frame / Wheel Arches**
3.	**Front / Rear Side Panels**
4.	**Hood / Fuel Filler Flap**
5.	**Front Bumper**
6.	**Rear Bumper**
7.	**C-Pillar Reinforced**
8.	**Spring Strut Tower**
9.	**Rear Axle Mounts**

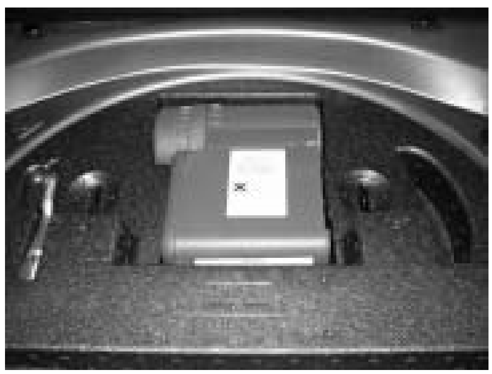
Floor Assembly / Luggage Compartment Floor

The basic structure of the E46 M3 floor assembly corresponds to that of the E46/2 but with M3-specific modifications.

The luggage compartment floor has been modified in order to accommodate the larger rear silencer: The M-mobility system is mounted in a foam moulding in the luggage compartment floor.

The retaining fixtures for the large volume rear silencer are located on the outer ends of the under body.

E46 M3 foam moulding of M-mobility system in spare wheel well.



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E46 M3 M-mobility Air Pump

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Side Frame/Wheel Arches

Due to the larger tire sizes, the side frame structures of the E46 M3 are modified in the area of the wheel cutouts. The front and rear wheel arches have been modified for the larger tire sizes and track widths. The inner side section has also been modified as compared to the E46/2.

The C-pillar area features additional reinforcement.

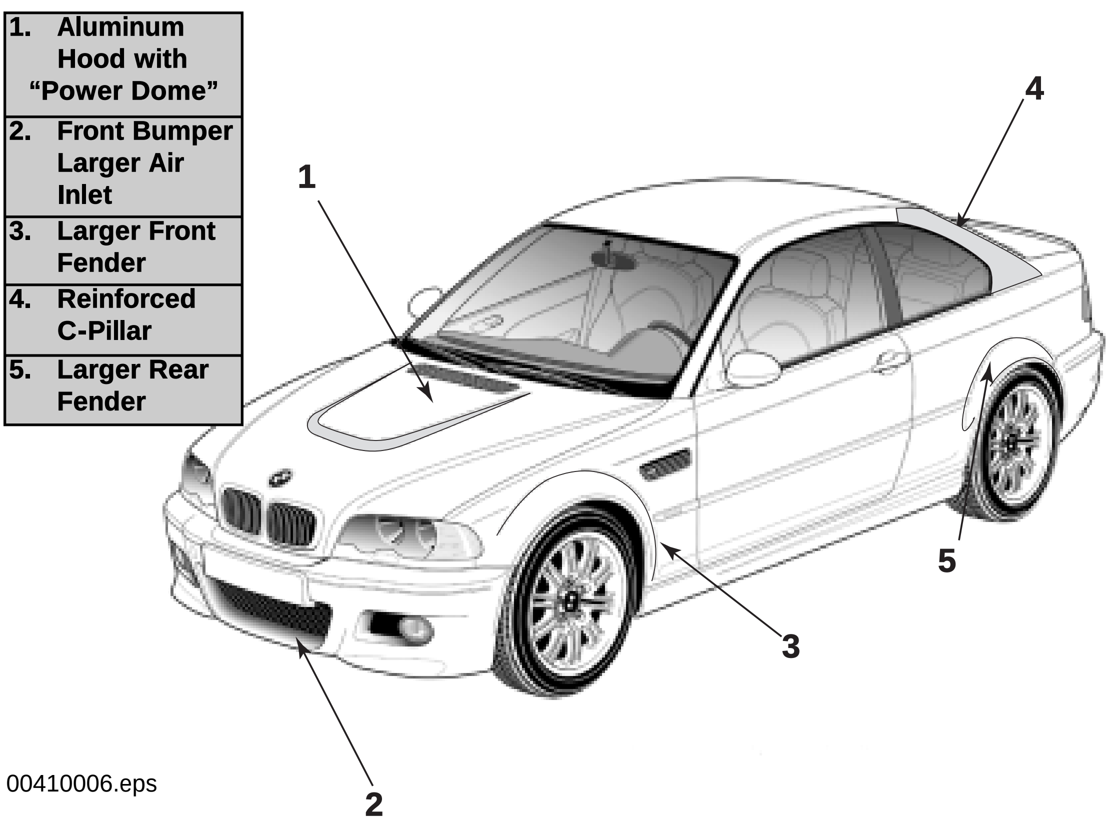
The hole pattern of the front spring strut towers and rear shock absorber mounts is the same as on the standard parts.

Side Panels

The design of the front and rear side panels lends the E46 a sport appearance.

The front fenders have been formed corresponding to the tire sizes and track width. The fender side grill represents an M-GmbH development.

The rear quarter panels have also been formed corresponding to the tire sizes and track width.



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Hood

The hood of the M3 is made of aluminum. The “power dome” is an elevated section in the center of the hood which accents the sports-oriented character of the vehicle. The hood consists of the outer skin panel, an inner panel and the front inner panel. A reinforcement plate is integrated at the rear left and right for mounting the hinges.

The gas struts for opening and closing the hood have been modified to the weight of the M3 hood. The hood latch is the same as that of the E46/2 production vehicle.

Front Bumper

The front bumper cladding is aerodynamically designed.

The air inlets for brake cooling next to the fog lights are closed off. The air inlet next to the left fog light is used for engine air intake.

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Rear Bumper

The cladding for the rear bumper is also modified with painted PDC sensors. The PDC setting has been modified due to the changed positions of the PDC sensors in the rear bumper.


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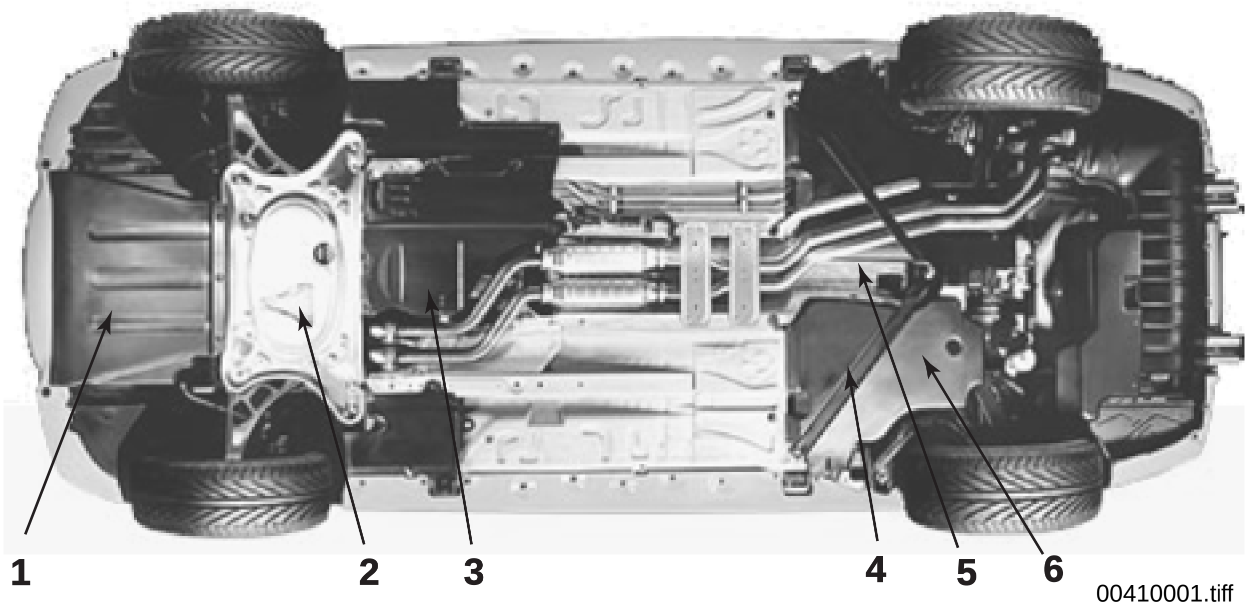
Fuel Filler Flap

The fuel filler flap is new and has been modified to the shape of the rear quarter panel.

Underbody Panels



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Index	Designation
1.	Engine Bottom Panel (provides negative lift at the front axle)
2.	Thrust Zone (reinforces the front axle area and provides specific cooling for the transmission)
3.	Transmission Panel (provides additional cooling for the transmission)
4.	V-Strut (connects the rear axle carrier to the body and reinforces the rear axle area)
5.	Propeller shaft panel with opening at the rear constant-velocity joints (heat guard and cooling of constant-velocity joint to rear axle differential output flange)
6.	Rear Filler panel

E46 M3 Interior/Vehicle Trim

The E46/2 serves as the basis for the Interior/Vehicle trim of the E46 M3.

The cockpit contains an M-Multifunction Sports Steering Wheel and specially designed seats.

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The interior trim and upholstery of the E46 M3 corresponds to that of the E46/2 but with the following changes:

1.	**M emblems, M trim fittings**
2.	**Inside and outside mirrors (M mirror)**
3.	**Interior trim panels and finishes**
4.	**Front seats (M Sport Seat)**
5.	**Rear Seats**

E46 Trim and Accessories

1.	**Multifunction Sports Steering Wheel (MFL II)**	**M-sport steering wheel with button pad for cruise control (right). Button pad for multimedia (left) functions same as E46 series**
2.	**Electric Seat Adjustment for Driver and Passenger (M-sport seat)**	**Electric seats optional**
3.	**Seat Heating**	**Driver and passenger same as E46**
4.	**Seat/mirror adjustment Including lumbar support**	
5.	**Windshield anti-glare strip**	
6.	**Heat-Insulated Windshield**	**Same as E46**

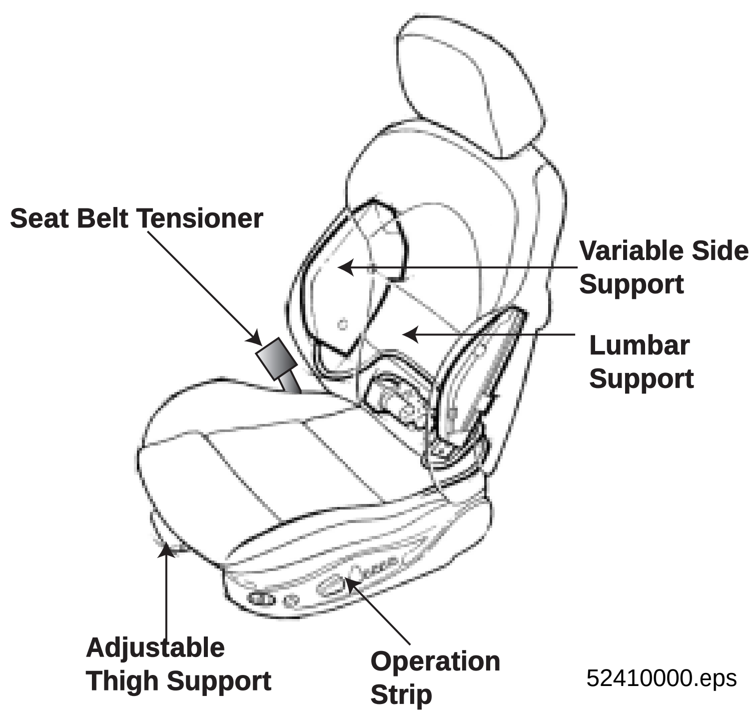
E46 M3 Sports Seats

The M3 is equipped with sport seats as standard equipment. The seat is manufactured by Lear. The E46/2 sport seats serve as the basis for the M3 sport seats.

The sport seats are mechanical or electrical depending on the accessory package.

For the first time, a variable side support is offered as an option. Air cushions fitted in the left and right side upholstery can be inflated or deflated to adapt to the body shape of the driver.

In addition, a pneumatic lumbar support is fitted as in the E46/2.



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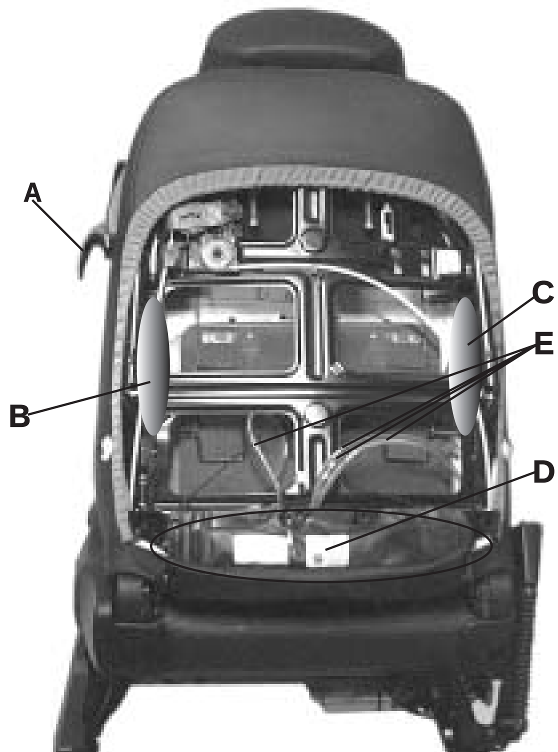
Seat Design

The air supply system of the M3 sport seat can be seen when the back panel is removed.



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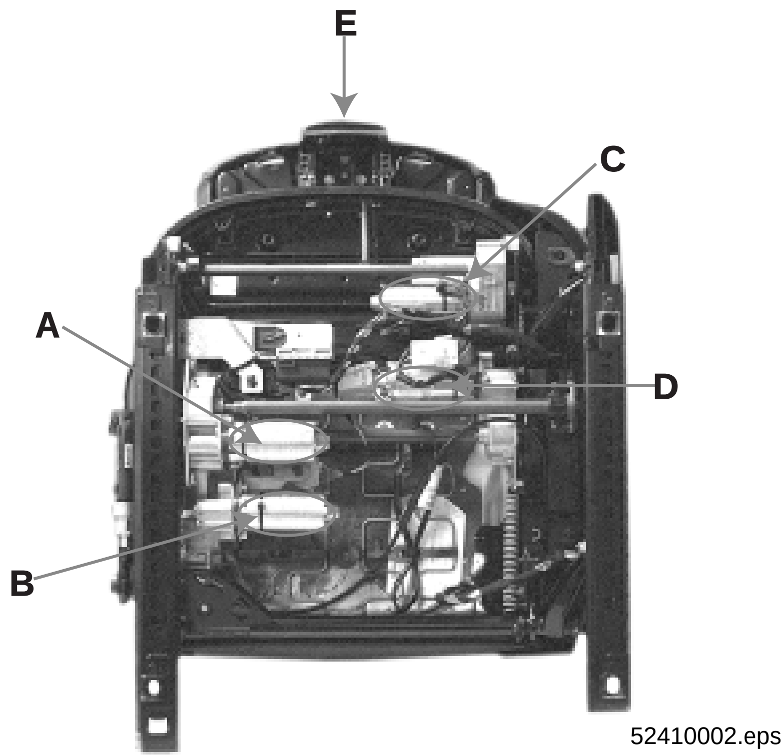
Index	Description
A.	Adjustment mechanism for easy-entry function
B.	Position of air cushion for left side support
C.	Position of air cushion for right side support
D.	The pump unit for the lumbar support and side support upholstery is located in a plastic sleeve. The pump unit can be replaced.
E.	Air Supply Lines



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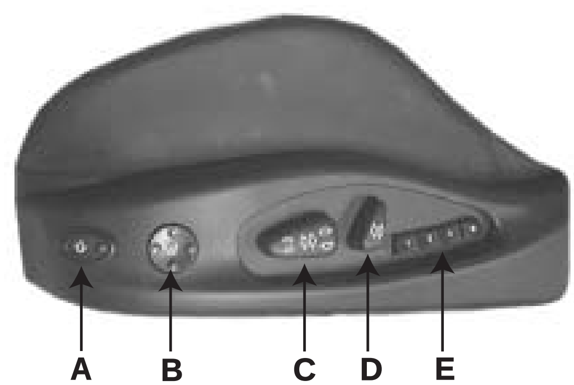
A.	**Motor for seat forward / backward adjustment**
B.	**Motor for seat backrest angle adjustment**
C.	**Motor for seat angle adjustment**
D.	**Motor for seat height adjustment**
E.	**Mechanical adjustment for thigh support**

Seat Functions

A.	**Adjustment switch for variable side support cushions**
B.	**Adjustment switch for lumbar support (for space reasons, the electronics of switch A are integrated in switch B). Switch A is M-specific.**
C.	**Seat adjustment switch (same as E46/2)**
D.	**Backrest adjustment (same as E46/2)**
E.	**Seat memory switch (driver's side only)**



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E46 M3 General M Equipment

Aero Outside Mirror

The E46 M3 Aero mirrors can be “manually” folded up for additional clearance in tight spaces.


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The driver can adjust the outside mirrors by the switch on the handle in the door trim panel. The mirror memory control unit is located in the front of the door behind the door panel.

The mirror adjustment and mirror heating functions correspond to those of the E46/2.

M-Multifunctional Sports Steering Wheel (MFL II)

The MFL in the E46 M3 is a BMW M development. The assembly and operation of the buttons for audio communication and cruise control function as in the E46/2.


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Cockpit

Characteristic M styling elements in the E46 M3:

Sports steering wheel, instrument cluster, gearshift lever and center switching console.

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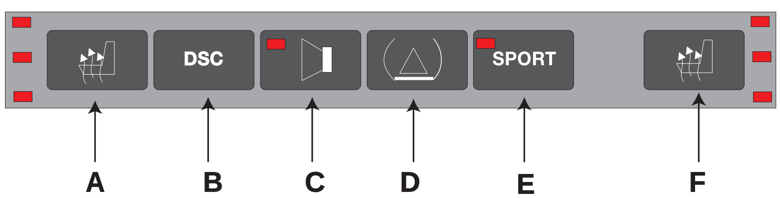

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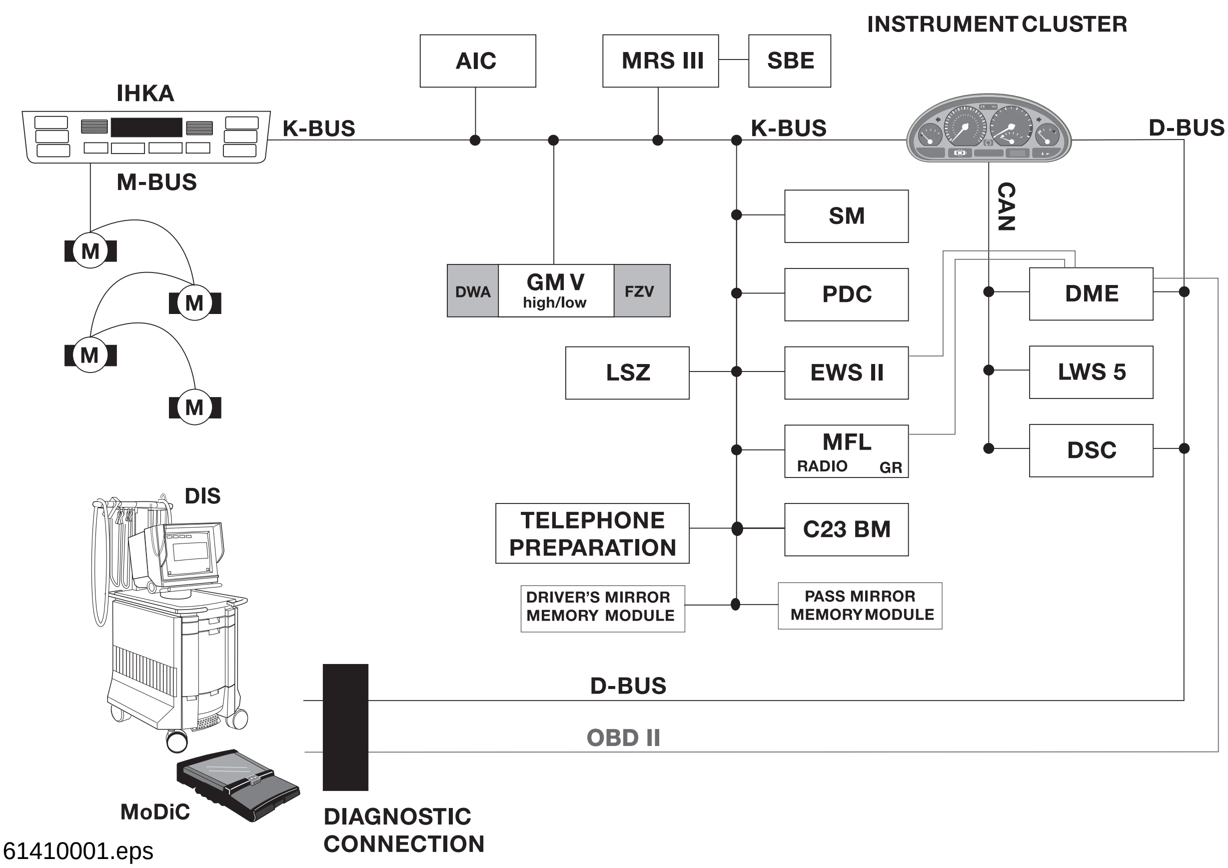
A.	**Driver Seat Heater Switch**
B.	**Dynamic Stability Control**
C.	**Hi-Fi System Switch**
D.	**Tire Pressure Warning System**
E.	**Sport Switch (throttle opening characteristics)**
F.	**Passenger Seat Heater Switch**

Central Body Electronics

The Body Electronic Systems of the E46 M3 are carried over from the E46 Coupe and Sedan models. The Driver Information System and Central Body Electronic System (ZKE V) continue to be used as the primary body electronic systems.

The M3 uses the "K"- Bus as the Primary communication link between body electronic control modules. The "D" - Bus is used as the diagnostic interface from the diagnostic equipment to the instrument cluster. The "CAN" Bus is used as the communication link between all power train systems. Finally, the "M" - Bus is used for IHKA operation of the flap control stepper motors.

E46 M3 Bus Systems



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Instrument Cluster

The instrument cluster in the E46 M3 is similar to the cluster used in the coupes and it is the main source for information display. Information about the status of different operating systems in the vehicle is displayed through the gauges, LCD display, warning LEDs and Gong. Switches are also integrated in the instrument cluster to reset the trip mileage, perform BC functions and to change over some units of measurement e.g. degrees F to degrees C.

Additional to the E46 M3 Cluster is the use of an engine oil temperature gauge which replaces the fuel economy gauge below the tachometer.

The tachometer incorporates the cold engine warning LEDs that were introduced with the E39 M5. Starting at 4000 RPM, orange LEDs are illuminated with a cold engine start up. The LEDs will go out, in 500 RPM increments, as the engine warms up. The MS S54 engine control system monitors the engine oil temperature and signals the instrument cluster over the CAN line for operation of the oil temperature gauge and illumination of the LEDs.

Central Body Electronics (ZKE)

The following functions **are directly** controlled by the General Module (GM V):

- Windshield wiping/washing with optional Rain Sensor Interface
- Central locking with power trunk release
- FZV Keyless Entry
- Power window control
- Car Memory/Key Memory Capabilities
- Interior lighting
- DWA alarm system (optional)
- Consumer cut-off/sleep mode

The following functions are included as body electrical systems but are **not directly** controlled by the GM V:

- Rain Sensor
- Sunroof operation (Sunroof Control module on K Bus).
- Driver's seat electrical adjustment with memory (Seat Memory control module on K Bus)
- Passenger seat electrical adjustment (no control module - switch controlled)
- Mirror Memory - adjustment/heating (also includes windshield washer jet heating switch controlled)

Review Questions

1. What is the engine designation for the E46 M3? ____________________________

2. What body components have changed for the E46 M3 as compared to the E46/2?

   _____________________ _____________________
   _____________________ _____________________
   _____________________ _____________________
   _____________________ _____________________
   ____

3. What function does the “Sport Switch” have? ________________________________

4. List the Bus systems used on the E46 M3.

   ___________ ___________ ___________ __________

5. What new feature can be found in the E46 M3 Sports Seat? ___________________
   ____

Table of Contents

Subject **Page**

M ENGINES

Model: E46 M3, E46 M3 Convertible, M roadster, M coupé

Engine: S54B32

Production Date: 2001 MY to Present

Objectives of The Module

After Completing this module, you will be able to:

- Perform a valve adjustment.
- Identify camshaft markings and correct “timing”.
- Explain the VANOS operation.
- Identify piston markings for correct installation.
- Explain the oil flow circuit.
- Understand the oil pump operation.
- Identify the crankcase ventilation components.
- Explain the coolant circuit flow.
- Distinguish the differences between the intake and exhaust valves.
- Identify the intake air system components.
- Identify the S54 fuel injectors and ignition coils.

S54B32 Engine

Purpose of The System

The S54B32 engine is an in-line 6 cylinder power plant. This 3246 ccm displacement engine is used worldwide. The engine designation is:

S 54 B 32

Sport Engine — Engine Designation — Gasoline Powered — Displacement in Liters

The S54 engine design provides:

1.	**Everyday Driveability**	5.	**Economic Operation**
2.	**Reduction in Weight of Engine Components**	6.	**Increased Output (to previous M3)**
3.	**Environmental Comparability**	7.	**High Performance**
4.	**Greater Speed Range**	8.	**EDR (Electronic Throttle)**

The S54B32 is a 4-valve per cylinder dual VANOS naturally aspirated engine with high torque and high-rev concepts. High torque is developed by a large volume engine at low engine rpm and a long total gear ratio. High-rev is achieved with a small displacement "lightweight" (internal components) engine and short total gear ratio. This powertrain provides the best of both worlds by using a 3.2 Liter in-line 6 cylinder configuration coupled to a 6 speed manual transmission.

Power Output for the E46 M3:

1. 333 hp at 7900 rpm
2. 355 Nm of Torque at 4900 rpm

Power Output for the M roadster and M coupe:

1. 315 hp at 7900 rpm
2. 340 Nm of Torque at 4900 rpm

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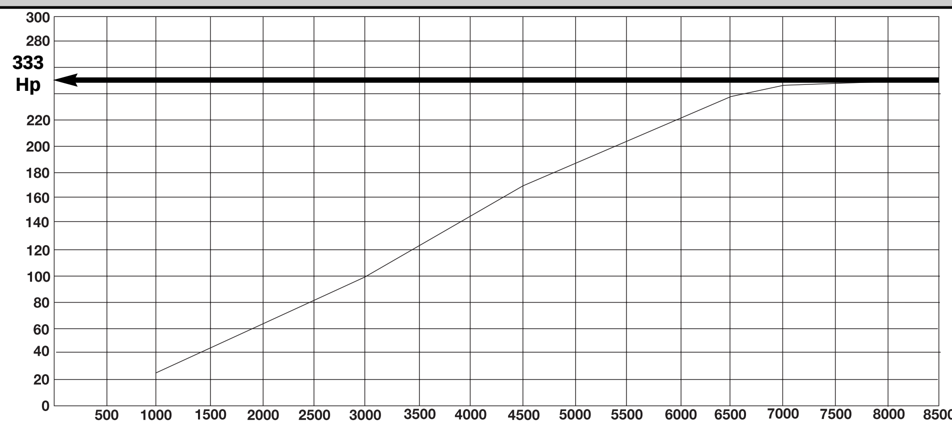
Technical Data

Engine Management	**MS S54**
Effective Displacement (CCM) Design / Valve Per Cylinder	**3246 in-line 6 / 4**
Bore / Stroke (mm)	**87 / 91**
Maximum Engine RPM	**8000**
Power Output (bhp/rpm) M3 / M roadster - M coupe	**333 / 315 bhp @ 7900 rpm**
Weight-to-Power Ratio (DIN) kg per KW-kg per bhp	**5.93kg/kw-4.36kg / bhp**
US Torque (Nm/rpm) M3 / M roadster - M coupe	**355 / 340 Nm @ 4900 rpm**
Compression Ratio	**11.5 : 1**
Fuel	**Premium Unleaded**
Valve Diameter	
Intake / Exhaust (mm)	**35 / 30.5**
Stem - Intake / Exhaust (mm)	**6.0 / 6.0**
Valve Lift	
Intake / Exhaust (mm)	**12 / 12**
Valve Clearance (Adjustment < 35º C Engine Temperature)	
Intake (mm)	**0.18 - 0.23**
Exhaust (mm)	**0.28 - 0.33**
Camshaft Spread Angle	
Intake (degrees)	**70 - 130**
Exhaust (degrees)	**83 - 128**
US Emission Compliance	**LEV**

M3 Hp Shown



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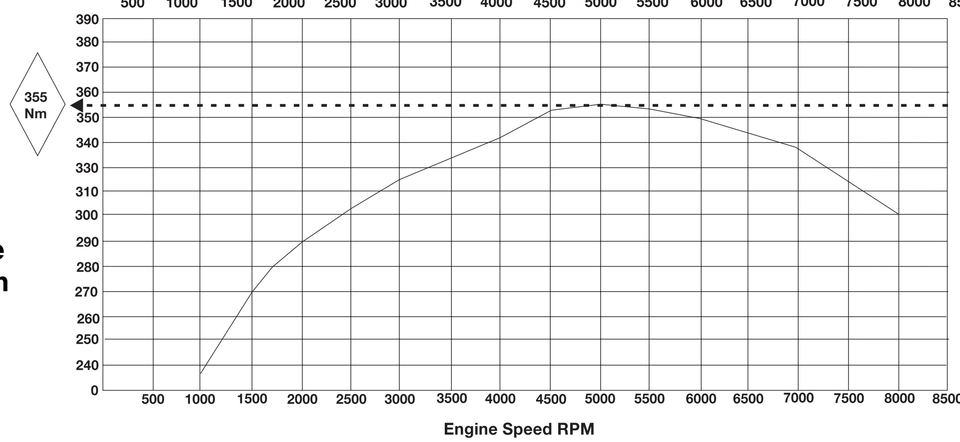
M3 Torque Shown



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System Components

Engine Block: The S54 engine block is cast iron in order to absorb the high forces produced by the crankshaft (combustion pressure and high engine rpm).

The engine block has cast provisions for 3 Knock Sensors and and the Crankshaft Position/RPM Sensor (on the intake side).

The cylinder bores are 87 mm in diameter and are spaced 91 mm on center.

The "bare" block weighs approximately 105 lbs. (48 kg).

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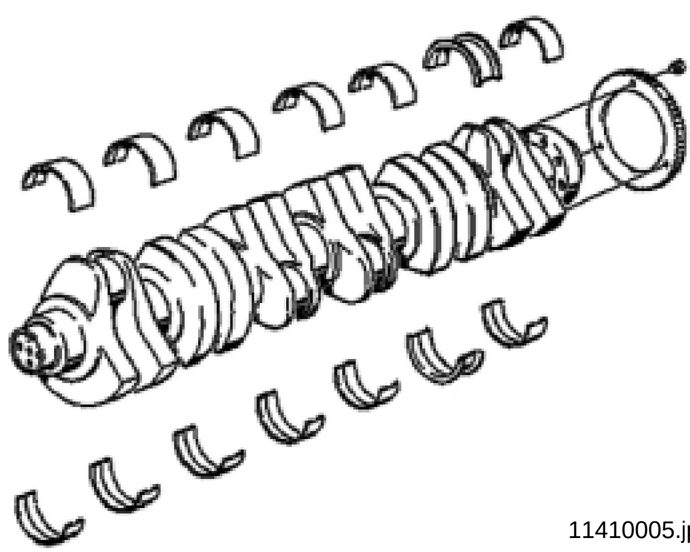
Crankshaft and Bearings: The S54 crankshaft is forged steel with 12 counterweights and a 91 mm stroke. The crankshaft is supported by 7 (60 mm diameter) main bearings with 49 mm diameter connecting rod journals.

The "thrust" bearing is a multi-piece shell assembled as a unit and is located on the number 6 main journal of the crankshaft.

Bearing Clearance:

1. Main 0.02 - 0.05 mm
2. Thrust (end play) 0.08 - 0.16 mm



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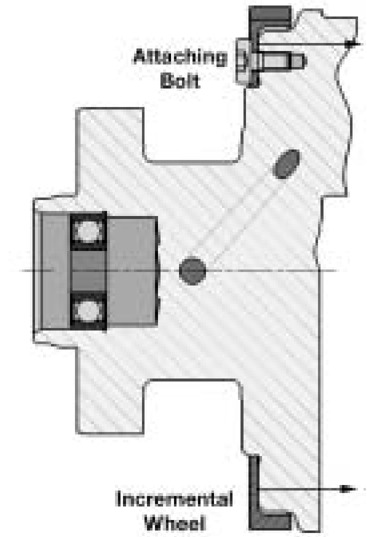
The impulse wheel is bolted to the number 6 connecting rod journal counterweight.

The S54 impulse wheel is bolted directly to the crankshaft providing accurate:

1.	**Crankshaft Position - Reference**
2.	**Engine RPM**
3.	**Smooth Running Measurement**
4.	**Misfire Detection**



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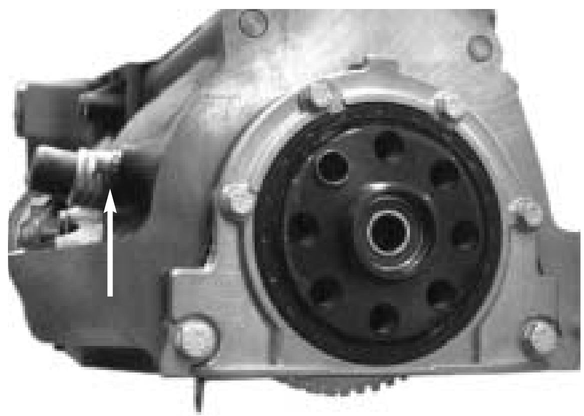
The Crankshaft Position/RPM Sensor is mounted on the rear of the engine block (below the intake manifold).

The sensor protrudes through the engine block (arrow) to scan the impulse wheel gear teeth.

The cast sensor mounting is shown from the rear view of the engine.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The torsional vibration damper is specifically designed for the higher engine rpm.

The damper is secured by 4 bolts which must be angle torqued (refer to Repair Instructions and Technical Data).

Note the installation location for the crankshaft position locating tool (arrow).


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Connecting Rods and Bearings: The S54 uses reinforced forged steel "cracked" connecting rods:

1. Length = 139 mm
2. Small End (Integrated Bushing) Diameter = 21 mm
3. Large End Diameter = 49 mm

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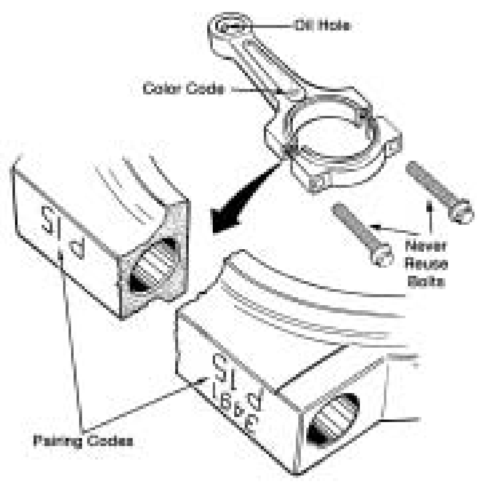
The "cracked" connecting rod refers to the cap which is split off leaving rough surfaces on both the cap and the rod.

Centering of the cap on the rod is carried out through the structure of the split which eliminates the alignment sleeves. Pairing codes are stamped into the rod to ensure proper installation of the cap.



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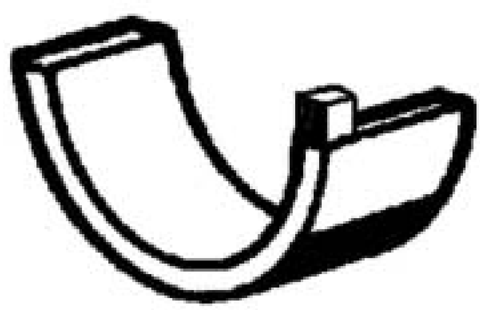
The S54 connecting rods are weight-optimized (+/- 4 grams). Only one set of connecting rods (the same weight class) is available to maintain balance.

The connecting rod bolts must be angle torqued (refer to Repair Instructions and Technical Data). ***The bolts can not be replaced separately***, if damaged; the connecting rod must be replaced (supplied with new bolts).

The S54 connecting rod bearings use end mounted locating tabs.



11410010.bmp

Notes: ______________________________________

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Pistons and Piston Rings: The S54 uses graphite coated cast aluminum (full slipper skirt) pistons with valve recesses.

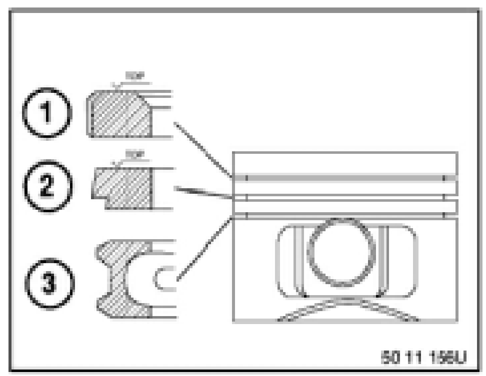
The piston diameter is 86.965 mm, weighs approximately 470 grams with a compression ratio of 11.5:1.

Install the pistons with the arrow pointing towards the front of the engine.

11410065.eps

Piston Rings:

1. Compression Ring 1 = 1.2 mm Height
2. Compression Ring 2 = Stepped Face 1.5 mm Height
3. Oil Control Ring = Beveled, Spring Loaded 2 mm Height



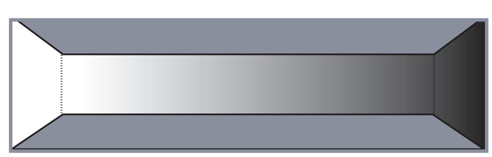
A Special Tool (ring compressor) is required to install the pistons.

The pistons are cooled by oil spray nozzles that are bolted into the crankcase.

The nozzles are “tapped” into the main oil gallery and delivers a constant oil spray to the underside of the pistons.

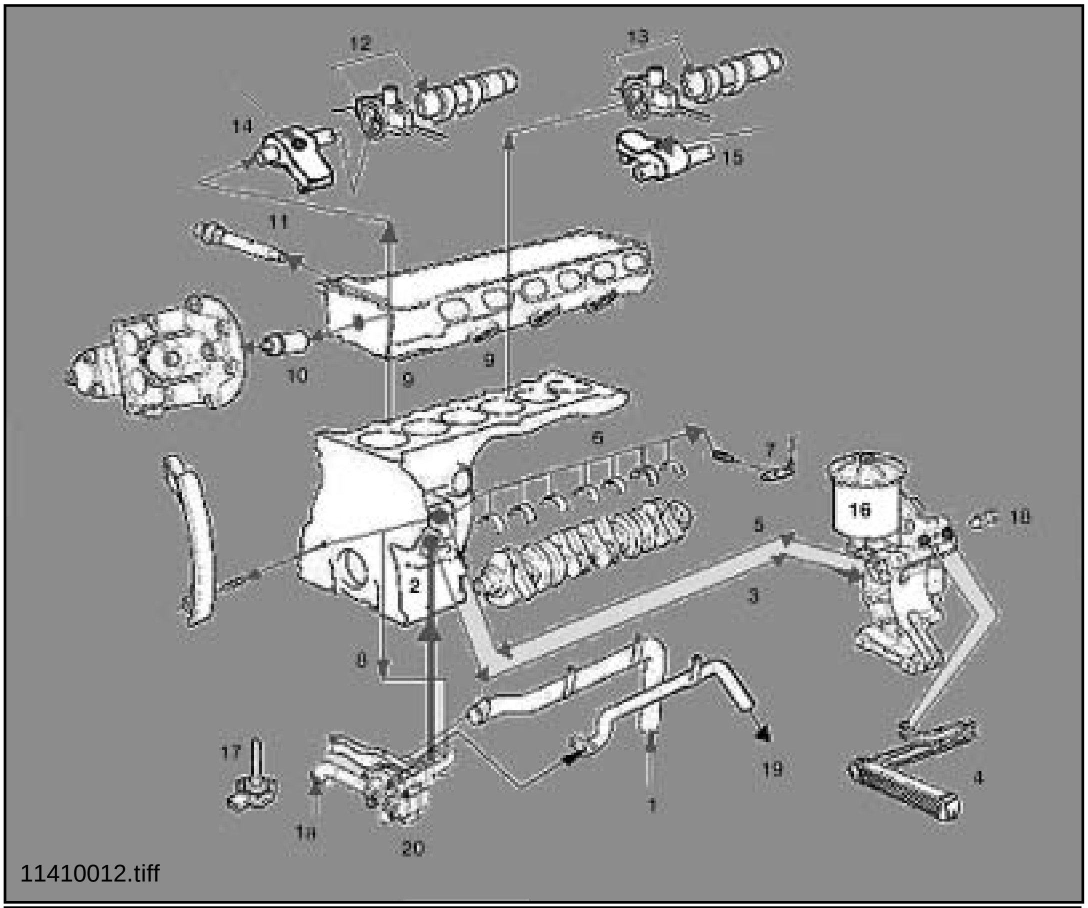
11410011.bmp

The wrist pins are 21 mm in diameter and have tapered ends (inside diameter) for weight reduction.



11410066.eps

Oil Circuit Flow:



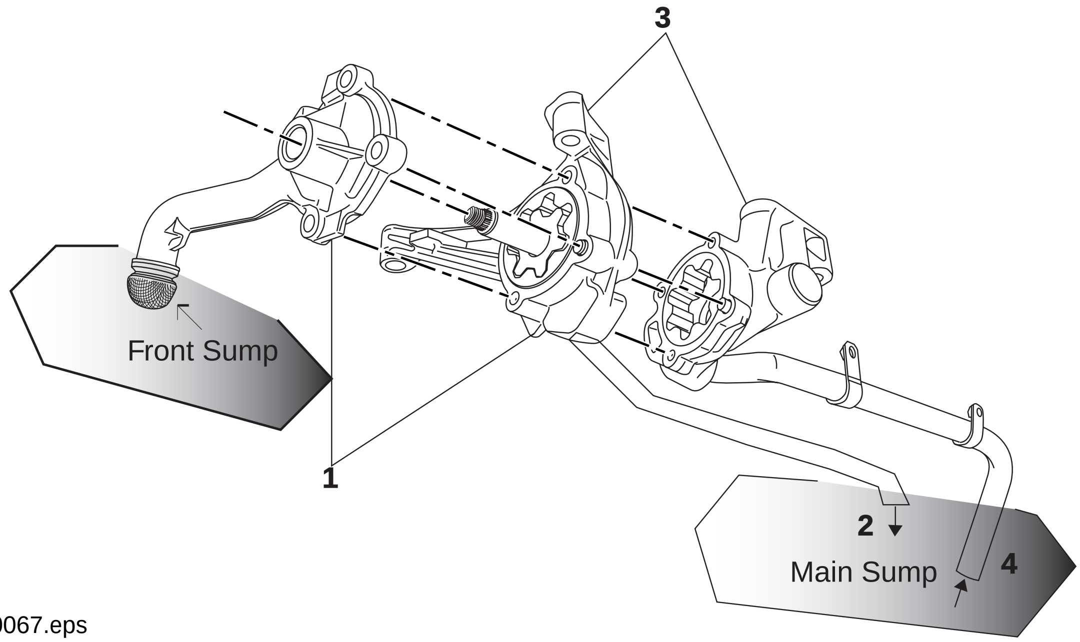
1.	Oil Pump Intake (rear of pan)	17.	Thermal Oil Level Sensor
1a.	Oil Pump Intake (front of Pan)	18.	Oil Pressure Switch
2.	Supply to Block	19.	Oil Return Flow Line
3.	Supply to Oil Filter / Cooler	20.	Oil Pump (two stage)
4.	Oil Cooler (flow controlled by 95mº C thermostat in oil filter housing)		
5.	Filtered Oil Return to Main Gallery		
6.	Main Oil Gallery (crankshaft, connecting rods, spray nozzles)		
7.	Spray Nozzles for Pistons		
8.	Oil Pressure Control (back to valve in Pump)		
9.	Supply to Cylinder Head		
10.	Supply to VANOS Pressure Reducer Valve		
11.	Supply to Timing Chain Tensioner		
12.	Exhaust Camshaft Bearings		
13.	Intake Camshaft Bearings		
14.	Exhaust Valve Finger with Oil Collector Hole		
15.	Intake Valve Finger with Oil Collector Hole		
16.	Oil Filter Housing		

The recommended oil for the S54 is CASTROL TWS MOTORSPORT SAE 10W-60 or CASTROL FORMULA RS 10W-60 SYNTHETIC OIL - PN 07 51 0 009 420 (refer to SIB # 00 02 00 and 11 06 01). Oil Capacity: Refer to Technical Data or the Oil Capacity Chart found in the Service Information Bulletin.

Oil Pump: The S54 oil pump is two stage, supply and scavenge. The pump is driven by the crankshaft with a single row chain.

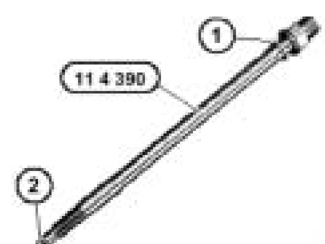
The oil pump has two separate chambers, the scavenge chamber (1) draws oil from the pickup at the front of the oil pan. The oil is transferred from the pump through a small pipe to the main sump at the rear of the oil pan (2).

The supply chamber (3) draws oil from the main sump through a large pipe (4) to supply oil to the main gallery. The main gallery circuit returns to the pump housing which contains the oil pressure control piston.



11410067.eps

The oil pressure is tested at the oil filter housing using the Special Tool #90 88 6 114 390 (adapting retainer bolt and pressure gauge as shown in the Repair Instructions).



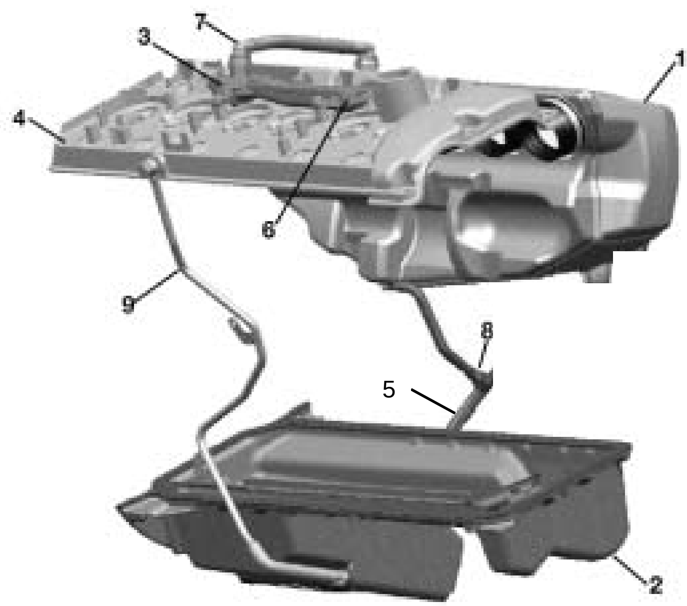
11410016-1

The adapter retainer bolt replaces the oil filter housing cover retaining bolt and provides an adapter fitting for the oil pressure gauge.

11410016.tiff

Crankcase Ventilation: The S54 features a non-pressurized sealed crankcase ventilation system for the blow-by vapors.

1. Intake Manifold	
2. Oil Pan	
3. Oil Separator (Labyrinth)	
4. Cylinder Head Cover	
5. Drainback Tube	
6. Crankcase Vapor Inlet	
7. Crankcase Vapor Outlet (To Intake Manifold)	
8. Condensate Return to Oil Pan (With Check Valve)	
9. Condensate Return To Oil Pan	



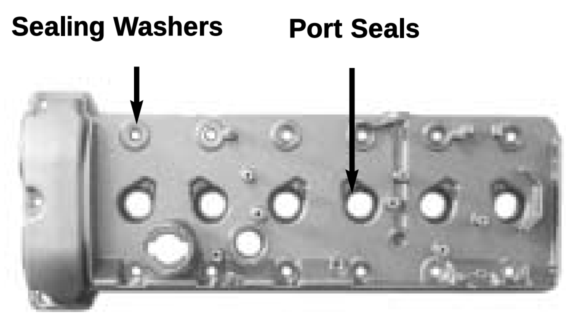
11410013.jpg

The crankcase blow-by vapors are "purged" by intake manifold vacuum. The vapors are drawn from the cylinder head cover (4) through the inlet of the Oil Separator (6). The Labyrinth (3) separates the oil from the vapors, and the condensate (oil) returns to the oil pan through the return line (9). The vapors exit the Oil Separator through the outlet hose (7) to the intake manifold to be inducted into the combustion chambers.

When the engine is running, intake manifold vacuum will close the Check Valve in the return line (8). When the engine is not running, the Check Valve will open. This allows any condensation (oil) that have collected in the intake manifold to drain back to the oil pan through the dipstick tube.

The cylinder head cover is sealed by a perimeter seal, spark plug port seals and sealing washers under the retaining bolts.

These individual seals must all be properly installed to prevent oil and vacuum leaks.



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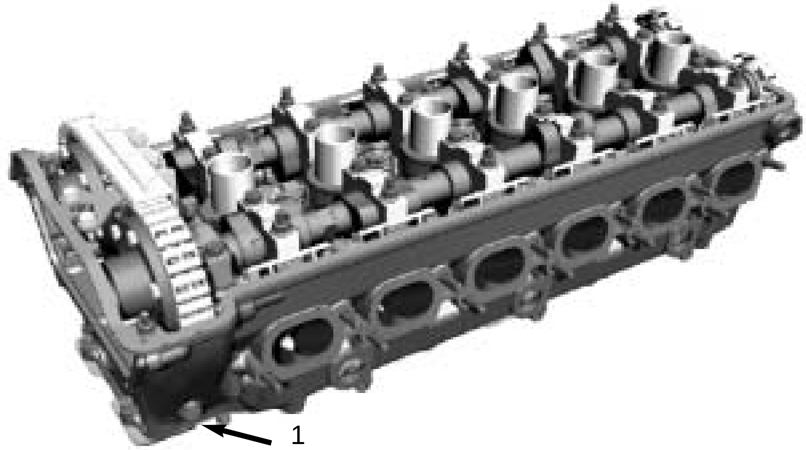
Cylinder Head: The S54 features an aluminum cross-flow cylinder head designed as a single component that houses the camshafts and valve train.



11410018.tiff

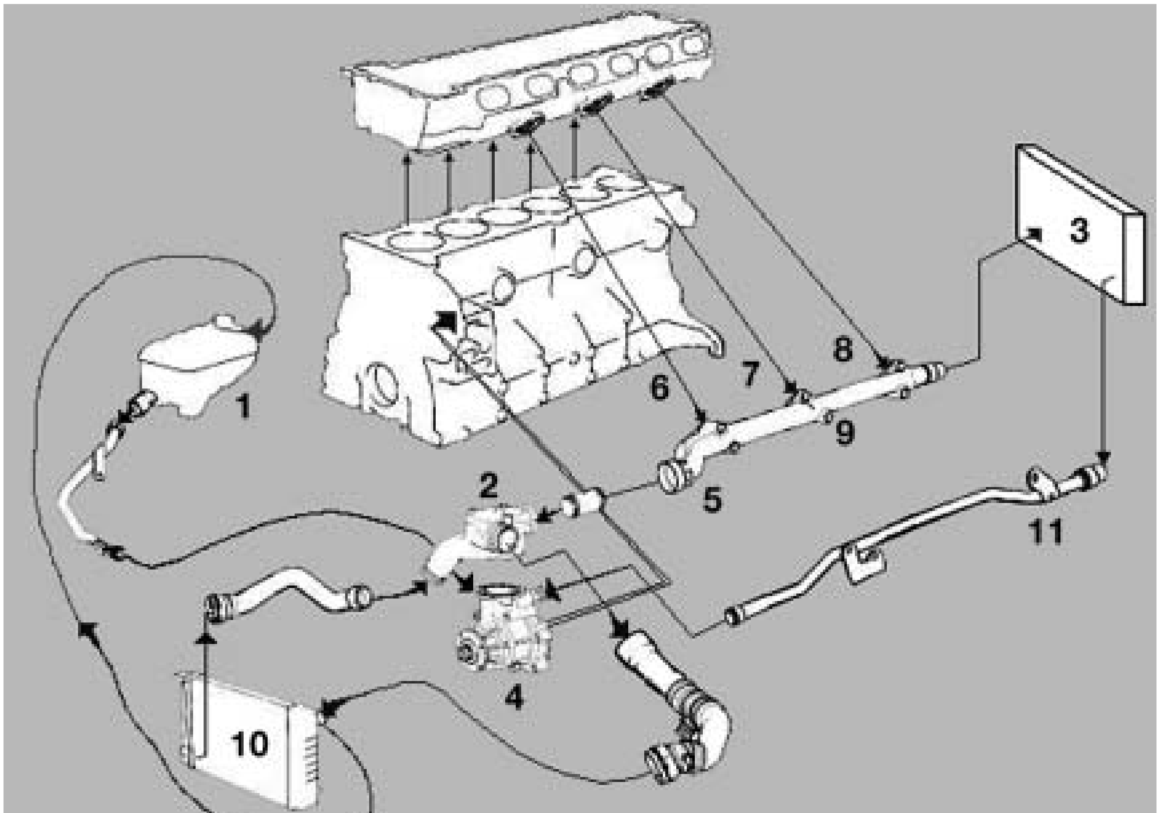
11410015.jpg

The combustion chamber reveals the 4 valve per cylinder arrangement and the optimized (flow enhanced) intake and exhaust ports. The spark plugs are centrally located in the combustion area for the most effective power and reduced emission outputs.

To remove the cylinder head, the camshafts must first be removed to access the cylinder head bolts (refer to the Repair Instructions). ***The timing chain guide rail bolt must also be removed (upper picture #1) and the special sealing washer must be replaced.***

To pressure test the cylinder head, a Special Tool (Pressure Tester Adapter Kit) is required. ***Cylinder head machining is not permitted.***

Coolant Circuit Flow:



11410019.jpg

1.	**Coolant Reservoir (2 bar system)**
2.	**Thermostat Housing (80º C thermostat)**
3.	**Heater Core**
4.	**Water Pump**
5.	**Coolant Temperature Sensor**
6,7,8	**Coolant Outlet (from cross-flow cylinder head)**
9.	**Coolant Return Pipe**
10.	**Radiator**
11.	**Coolant Return Line (from heater core)**

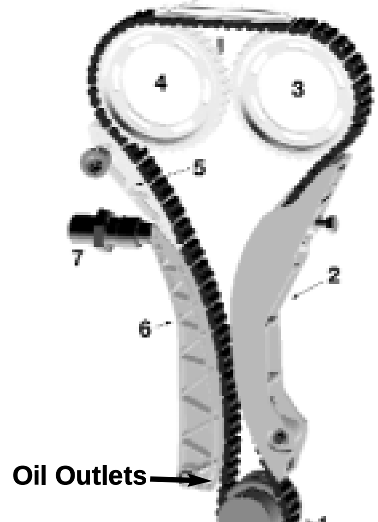
The S54 uses a high efficiency water pump (4) to enhance the Cross Flow cylinder head design.

The cross-flow design ensures even temperature distribution through out the cylinder head. The coolant flows from the engine block on the exhaust side into the cylinder head.

The coolant flows through (across) the cylinder head and exits at the intake side through three outlets (6,7,8). The coolant is routed through the Return Pipe (9) to the thermostat housing (2).

Camshaft Drive: The camshafts are driven by the crankshaft using a double-roller timing chain.

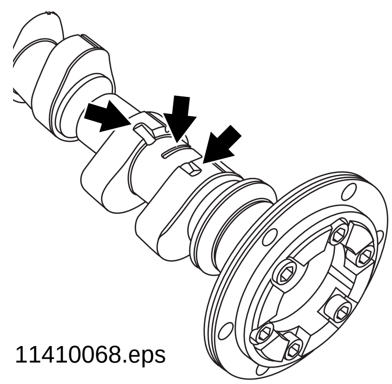
1.	**Crankshaft Sprocket**
2.	**Aluminum Guide Rail**
3.	**Intake Camshaft Sprocket**
4.	**Exhaust Camshaft Sprocket**
5.	**Short Tension Rail**
6.	**Long Tension Rail (with 3 Lubrication Holes)**
7.	**Hydraulic Tensioner**



11410014.eps

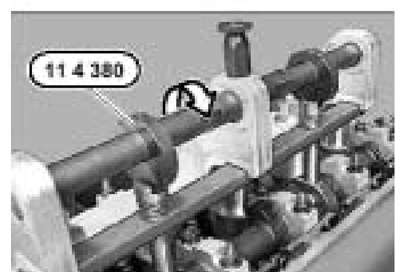
The chain is routed from the crankshaft over a guide rail to the intake and exhaust camshaft sprockets. A two piece hydraulically tensioned guide rail lubricates (three oil outlets provided) and "self adjusts" the chain.

Camshafts: The S54 cast iron overhead camshafts are hollow and are strengthened by heat treating the journals and cam lobes. The duration and lift (12 mm) of the lobes are the same on both camshafts.


11410068.eps

The camshafts are not interchangeable, therefore they should be marked before disassembly.

The camshaft lobes have oil grooves (shown by arrows to the right) that provide lubrication from the camshaft journals to the lobes and the valve fingers.



11410014.tiff

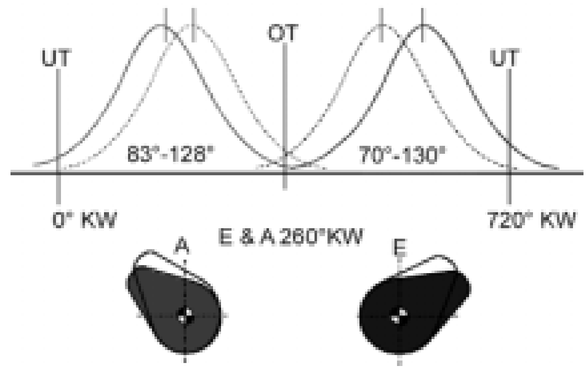
The camshafts must be removed and installed with the press fixture (Special Tool #90 88 6 114 380 as shown in the Repair Instructions).

11410013.tiff

The camshafts are "timed" with the bridged location tool (pinned into camshaft as shown in the Repair Instructions).

The VANOS enhanced camshaft spread angles are:

Intake (E) 70° - 130°	
Exhaust (A) 83° – 128°	

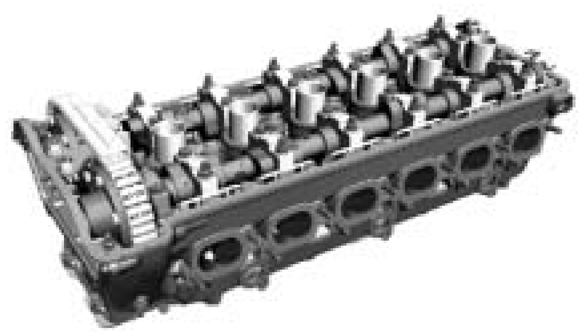


11410021.bmp

The camshafts are supported by 7 bearing journals machined into the cylinder head.

The bearing journal caps are location specific. The markings are:

1.	**E=Intake Side Number 2 - 7**
2.	**A=Exhaust Side Number 2 - 7**

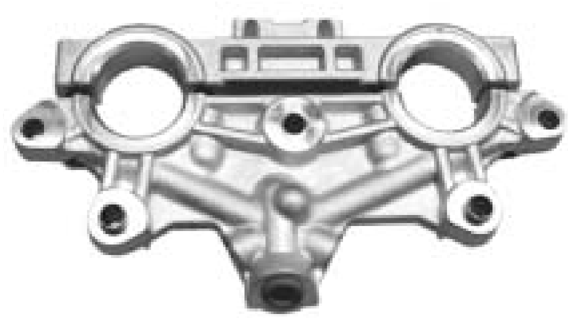


11410018.jpg

The first camshaft bearing journal also serves as the thrust bearing (unmarked).

This two-piece bearing flange is forged to support VANOS axial loads.

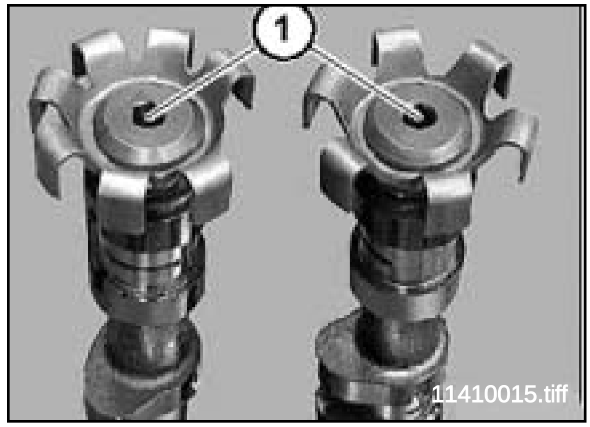
The thrust bearing flange is bolted to the face of the cylinder head. ***This component is not separately available because the journals are machined with the cylinder head.***



11410021.jpg

An impulse wheel is mounted on the end of each camshaft for position detection. The impulse wheels are secured by a removable bolt (1).

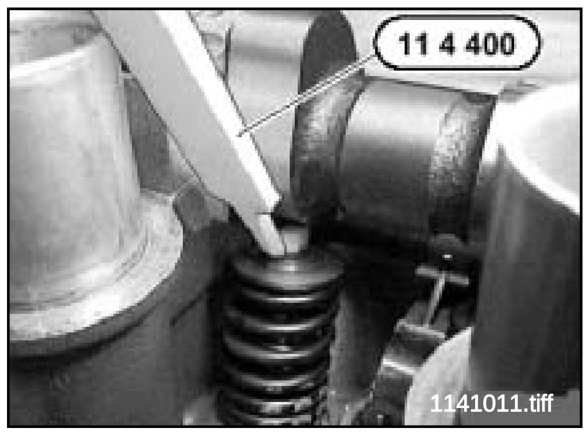
The intake camshaft impulse wheel has 6 lugs and the exhaust camshaft impulse wheel has 7 lugs (with gap).



Valve Train: The camshaft lobe actuates the valve finger (rocker arm) which rotates on a finger (rocker) shaft. The valve finger is secured by a spring clip and contacts the valve clearance shim (9 mm diameter) to open the valve.

The adjustable valve clearance set by various shim thickness is:

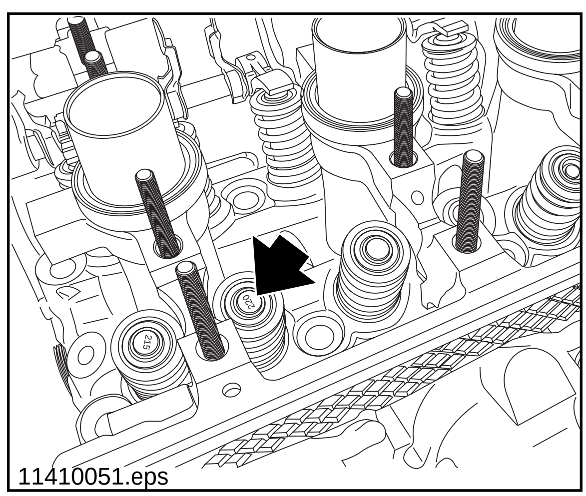
1.	**Intake 0.18 - 0.23mm**
2.	**Exhaust 0.28-0.33mm**
*****	**Set With Engine Temperature < 35^{o} C**



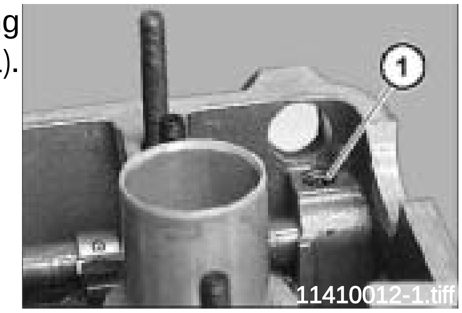
Two feeler gages and a holder with a magnetic tip (Special Tools) are required to adjust the valve clearance. The cam lobe must be rotated away from the valve finger for maximum clearance.

To access the valve clearance shim, remove the finger securing clip. Slide the finger away from the valve spring to expose the shim. Use the magnetic tip holder to extract the shim.

The shims (shown by the arrow to the right) are available in sizes from 1.72 to 2.52 mm at 0.04 mm increments.



The finger (rocker) shafts are secured with locating bolts (one per side) at the back of the cylinder head (1).



11410012-1.tiff

Remove the threaded access bolts (1) from the rear face of the cylinder head and push the shafts through.

11410012-2.tiff

Both finger shafts are hollow, the exhaust shaft is unique because it supplies oil to the camshaft bearing journals.

The exhaust shaft receives oil from the main oil gallery through the transfer hole (arrow).

The intake camshaft is lubricated directly from the main oil gallery.

11410026.tiff

The valve fingers are identical but must be marked for location when previously used.

Lubrication for the slide contact is provided from the camshafts (lobe grooves) and an inlet hole (arrow) allows lubrication for the finger pivot journal.

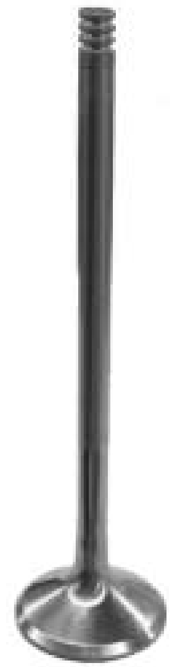
11410027.jpg

Valves and Valve Springs: The intake and exhaust valves are lightweight in design to reduce reciprocating mass. The valve diameter is:

1.	**Intake 35 mm**
2.	**Exhaust 30.5 mm**
3.	**Stem-Intake / Exhaust 6.0 mm**

The exhaust valve stems are sodium filled to enhance cooling.

CAUTION! Consult the Repair Instructions before performing any repairs and for proper disposal of sodium filled valves.



11410028.tiff

The valve spring assembly consists of two progressive tensioned valve springs.

The springs are marked for correct installation due to progressive tensioning ***(paint stripes facing down towards cylinder head).***

11410030.tiff

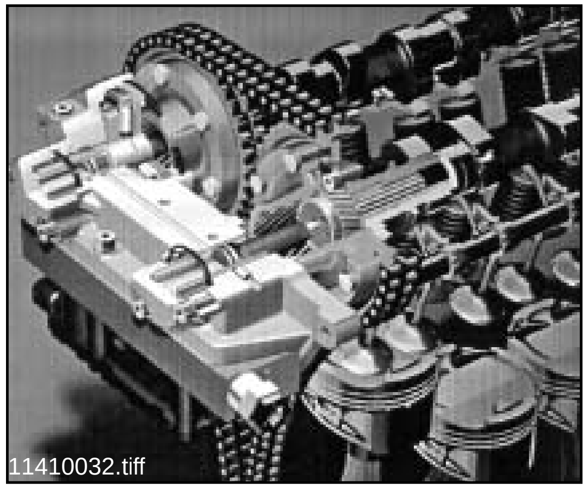
Notes: ______________________________________

VANOS

Performance, torque, idle characteristics and exhaust emissions reduction are improved by variable camshaft timing (VANOS).

The S54 engine uses double VANOS to adjust the spread angles of the intake and exhaust camshafts.

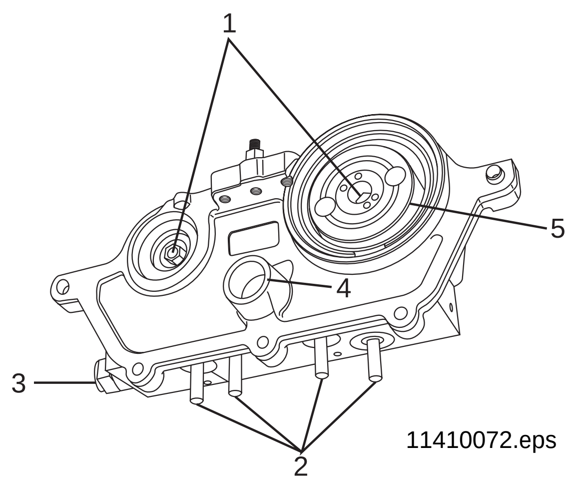
This system uses a high pressure (100 Bar) control system that ensures responsive and accurate camshaft adjustments to meet the high performance requirements of the M Engines.


11410032.tiff

The VANOS unit is mounted directly on the front of the cylinder head.

The VANOS unit contains the hydraulically actuated mechanical drives (1), the electronically controlled oil pressure regulating solenoids (2) and the 100 Bar pressure regulating valve (3).

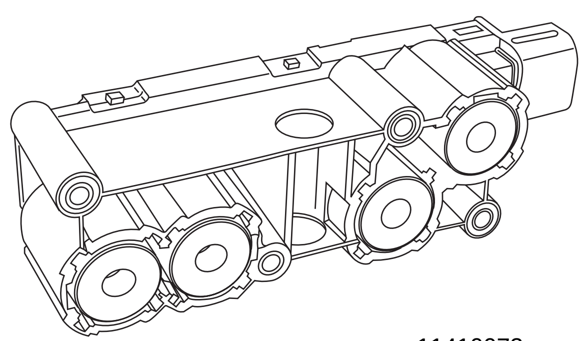
The back view of the VANOS unit shows the inlet oil supply pressure reducing valve (4) and the radial piston high pressure output pump driven by the exhaust camshaft (5).



11410072.eps

The VANOS solenoid electrical assembly (removed from the VANOS unit) contains four solenoids.

Two solenoids are required for each adjusting piston circuit, one for advancing and one for retarding the camshaft timing. The solenoids are controlled by the ECM.

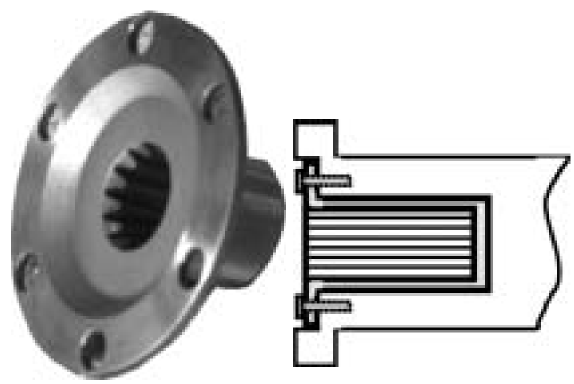

11410073.eps

The adjustment shafts contain two sets of splines that engage with:

1.	**Camshaft Sleeves (Straight Splines)**
2.	**Chain Driven Sprocket (Helical Splines)**

11410037.jpg

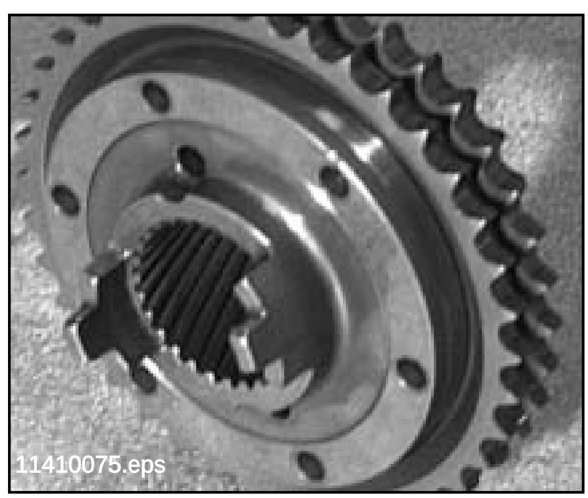
The camshaft sleeves are bolted to the end of the camshafts and engage with the straight spline of the adjustment shaft shown above.



11410074.eps

The chain driven sprocket and spacer sleeve assembly is shown to the right (one assembly per camshaft). The sprocket engages with the helical splines of the adjustment shaft shown above.

The exhaust camshaft sprocket assembly has two drive “lugs” that must be aligned with the radial piston oil pump during installation.



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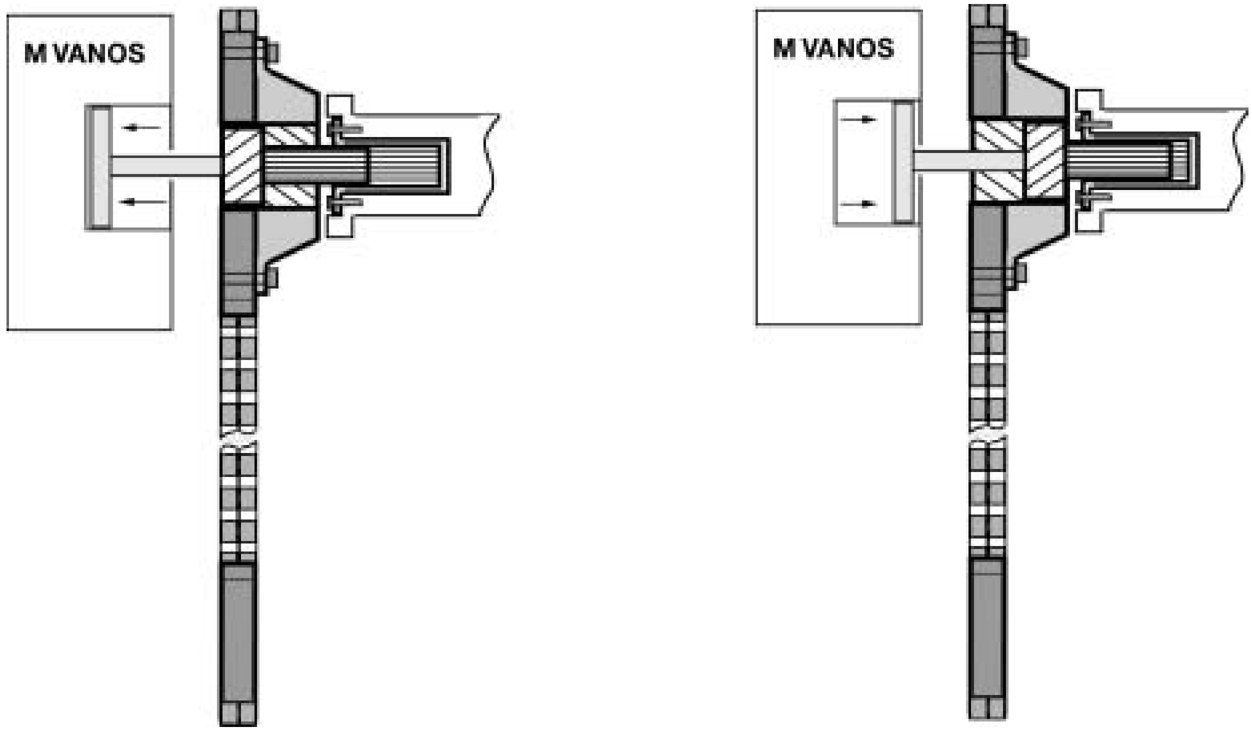


11410039.bmp

VANOS mechanical operation is dependent on oil pressure applied to position the control pistons. The double VANOS camshafts are infinitely adjustable within the mechanical travel limits of the drive gears.

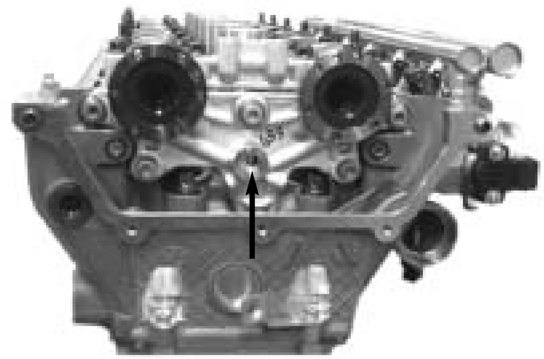
When oil pressure is applied to the control piston, the piston moves causing the splined adjustment shaft to move. The straight splines slide within the camshaft sleeve. The helical splines rotate the camshaft drive sprocket changing the position in relation to the camshaft position which advances/retards the camshaft timing.

The total adjustment range of the intake camshaft is 60º.
The total adjustment range of the exhaust camshaft is 45º

The “default” mechanical stop position without VANOS influence is:

Intake Camshaft = Retarded (130º spread angle)
Exhaust Camshaft = Advance (83º spread angle)

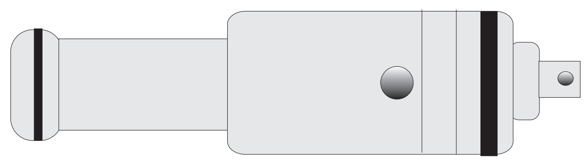
Oil is supplied from the main gallery through the front of cylinder head (arrow) to the inlet pressure reducing valve.



11410042.tiff

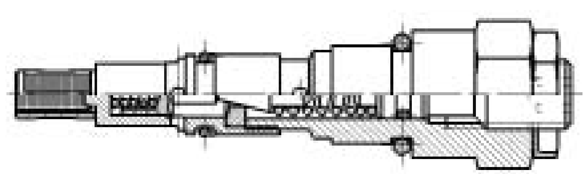
Pressure Reducing Valve: The pressure reducing valve supplies oil to the radial piston high pressure oil pump. It is located between the cylinder head and the VANOS unit.

The valve ensures the oil pressure supply to the VANOS pump is 0.5 Bar regardless of the varying pressure from the main oil pressure gallery. The pressure reducing valve is pressed into the VANOS unit and secured by an “o-ring”.



11410080.eps

100 Bar Pressure Regulating Valve: The 100 Bar pressure regulating valve is mounted in the VANOS unit. This valve regulates the pressure produced by the radial piston high pressure oil pump.

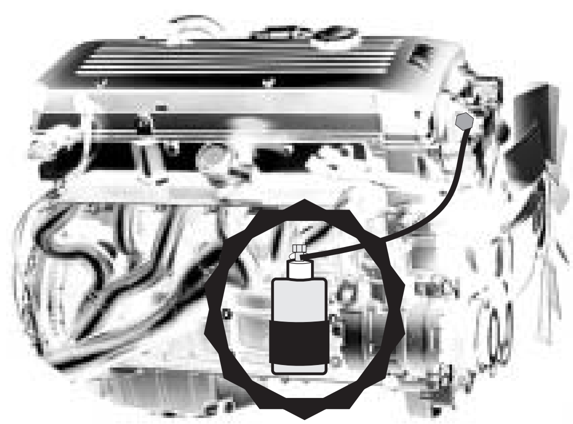


11410002.eps

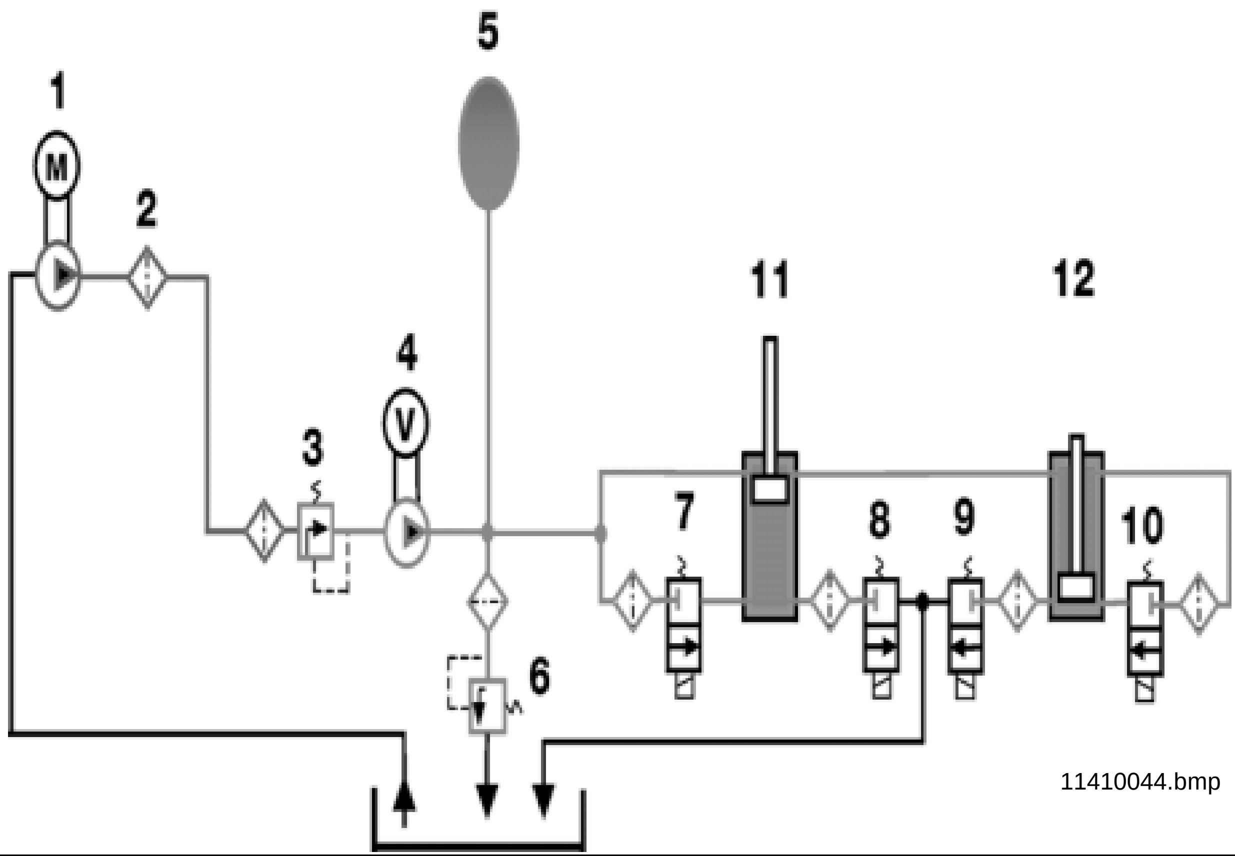
Note: The 100 Bar pressure regulating valve is not adjustable.

VANOS Accumulator: The VANOS accumulator ensures that there is a sufficient volume of oil under pressure to adjust the camshafts under all engine operating conditions.

The accumulator is Nitrogen charged and is located on the exhaust side of the engine behind the A/C compressor. It is connected to the VANOS unit by a high pressure line.



11410076.eps



1.	Engine Oil Pump	7.	Exhaust Camshaft Inlet Solenoid Valve
2.	Engine Oil Filter	8.	Exhaust Camshaft Outlet Solenoid Valve
3.	Pressure Reducing Valve (0.5 Bar)	9.	Intake Camshaft Outlet Solenoid Valve
4.	VANOS Oil Pump	10.	Intake Camshaft Inlet Solenoid Valve
5.	VANOS Accumulator	11.	Exhaust Camshaft Control Piston (Advance)
6.	100 Bar Pressure Regulating Valve	12.	Intake Camshaft Control Piston (Retard)

VANOS system hydraulic operation:

- When the engine starts, oil from the main engine oil pump is fed under pressure to the pressure reducing valve.
- The oil pressure is dropped to approximately 0.5 Bar and fed to the radial piston high pressure oil pump.
- The pump is driven by the exhaust camshaft and the 100 bar pressure is built up by the pressure regulating valve. The volume of pressurized oil is stored in the accumulator supplying both adjustment pistons. Both pistons are held in the default position by the high pressure oil.

- At the same time the high pressure oil is available at the inlet solenoids of both adjustment pistons.

- VANOS adjustment is carried out by the ECM pulsing the inlet and outlet solenoids to allow pressurized oil to the back side of the adjustment pistons. The surface area on this side of the piston is larger so that the oil pressure is greater and the adjustment piston will move causing the valve timing to change.

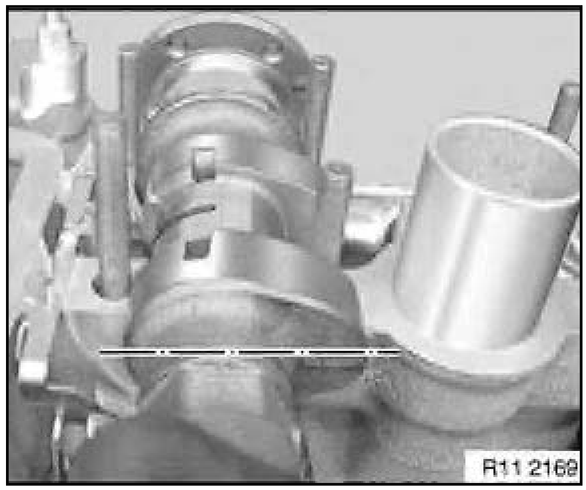
- The piston is connected to the adjustment shaft. As the piston moves, the shaft turns the helical splines varying the camshaft sprocket position in relation to the camshafts.

CAUTION! The VANOS system is under high pressure (100 Bar). Consult the Repair Instructions before performing any repairs.

Workshop Hints

When installing the intake camshaft, a visual "sight" is the cam lobes on cylinder number 1 should be pointing horizontally inwards (as shown on the right).

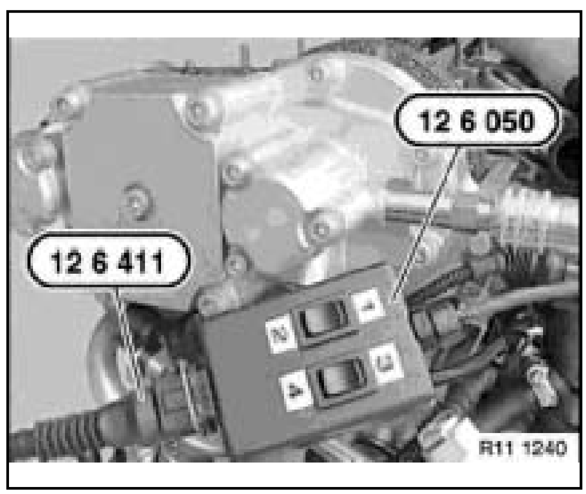
When installing the exhaust camshaft, the cam lobes for cylinder number 1 should be pointing horizontally inwards (refer to Repair Instructions for detailed graphics).



The VANOS function test can be performed by using Special Tools:

#90 88 6 126 411
#90 88 6 126 050
Regulated Compressed Air (2-8 bar)

Refer to the Repair Instructions for the VANOS function test procedures.



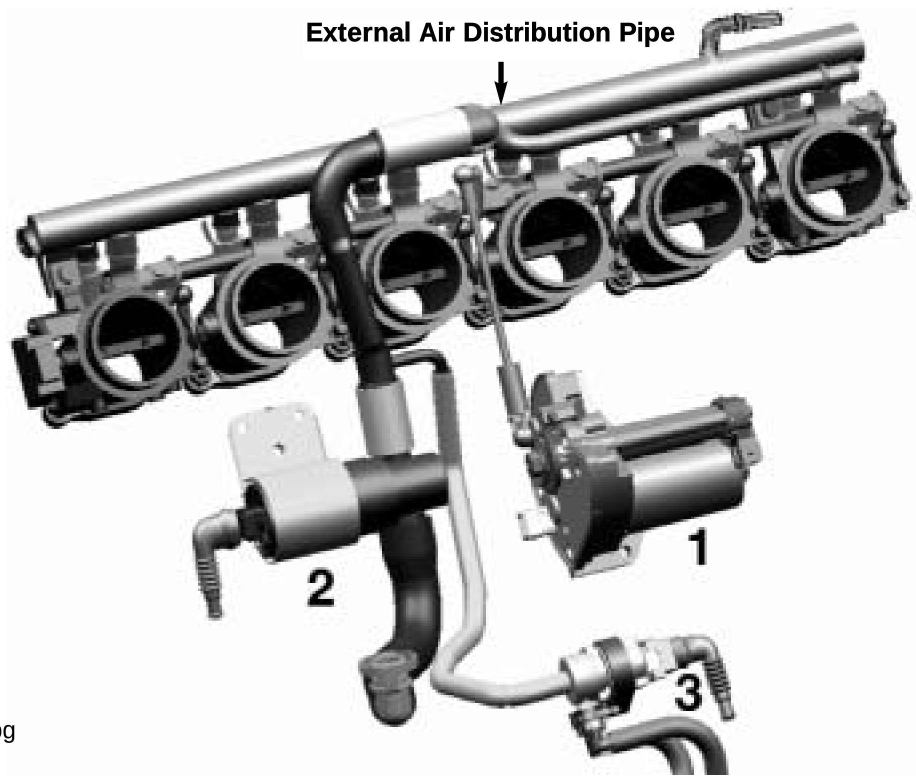
Intake Air Plenum: The intake air plenum is designed for maximum volume required for the S54 engine. The air filter housing and intake manifold are different on the M roadster and M coupé as compared with the M3 due to the under hood dimensions.

The flow characteristics of the one-piece plastic shell is enhanced by internal “funnel” cones to direct the intake air to the throttle housings.

The plenum is attached to the throttle housings by rubber sleeves. A Special Tool (clamp pliers) is required to secure the one-time use clamps.

E46 M3 Shown

11410043.jpg



11410044.jpg

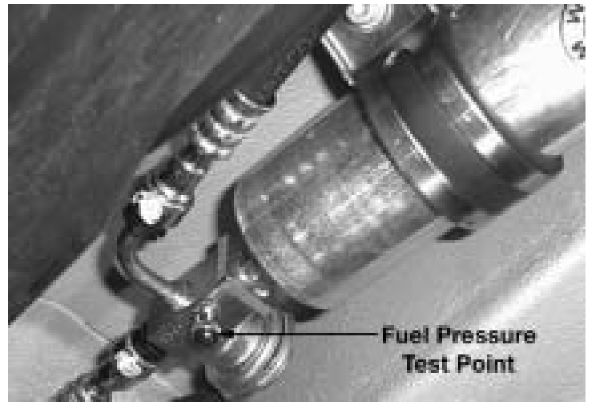
Intake Air System: The S54 uses six individual throttle housings operated by an EDR actuator (1 electronic throttle control). For low engine speed (low load) and idling, intake air is provided by an idle air actuator (2). The valve regulates air flow through an external air distribution pipe to the individual throttle housings. Fuel tank vapor intake is regulated by the Evaporative Emission Valve (3).

Refer to the Repair Instructions for the procedure to adjust and synchronize the throttle housings.

Fuel Supply: The fuel is supplied through a Non Return Fuel Rail System. This system is used on the S54 for LEV compliancy.

The fuel supply pressure is controlled by the 5 Bar fuel pressure regulator integrated in the fuel filter assembly. The regulator is influenced by engine vacuum via a hose connected to the external air distribution pipe. The fuel exits the fuel pressure regulator supplying the fuel rail and the injectors. The E46 M3 fuel filter assembly is located under the left front floor area (next to the frame rail).

E46 M3 Shown



11410045.tiff

The fuel return line is located on the filter/regulator assembly which directs the unused fuel back to the fuel tank. The fuel tank hydrocarbons are reduced by returning the fuel from this point instead of from the fuel rail.

11410045.tiff

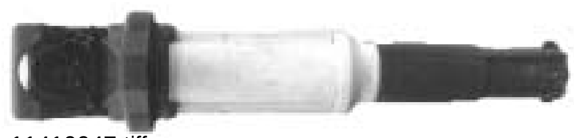
The S54 uses Bosch (4 hole plate) fuel injectors. The ECM controls the fuel injectors to regulate the air/fuel mixture.

The injector identification markings are:

1.	**BMW Number**
2.	**Fuel Injector Code**
3.	**Manufacturing Date (week 06 year 2000)**
4.	**B+ Voltage Connection**

11410046.tiff

Ignition Coils: The S54 uses “pencil type” ignition coils manufactured by Bremi. The six individual ignition coils are integrated with the spark plug connector (boot).



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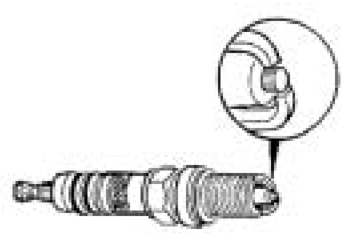
The coils are removed by lifting the swivel latch connector retainer to release the wiring harness, apply a slight twist and lift the assembly upwards.

NGK DCPR8EKP dual electrode spark plugs are used.



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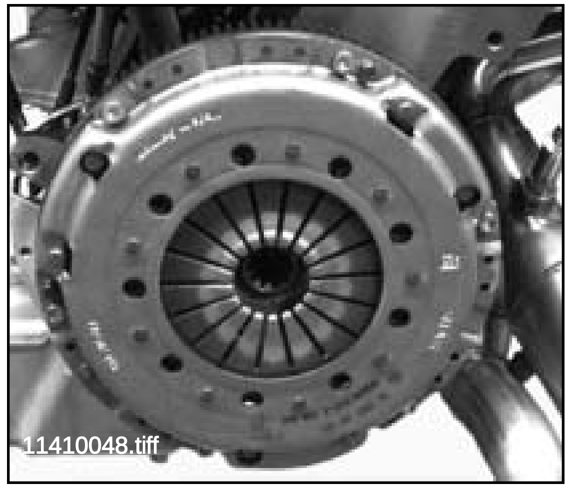
Clutch Assembly: The S54 clutch assembly is specially designed to transfer the high torque to the driveline and dampen vibrations throughout the rpm range.

The clutch assembly consists of:

Hydraulically Dampened Dual-Mass Flywheel
Diaphragm Type Pressure Plate and Drive Disk



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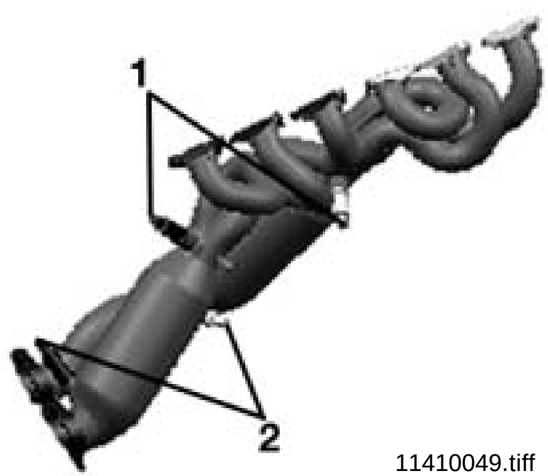
Exhaust System: The US S54 uses two high performance stainless steel exhaust manifolds. The catalytic converters are integral with each exhaust manifold.

Each exhaust manifold/catalyst contains a pre (1) and post (2) oxygen sensor. The sensors require a Special Tool (crescent wrench with swivel adapter) for removal.



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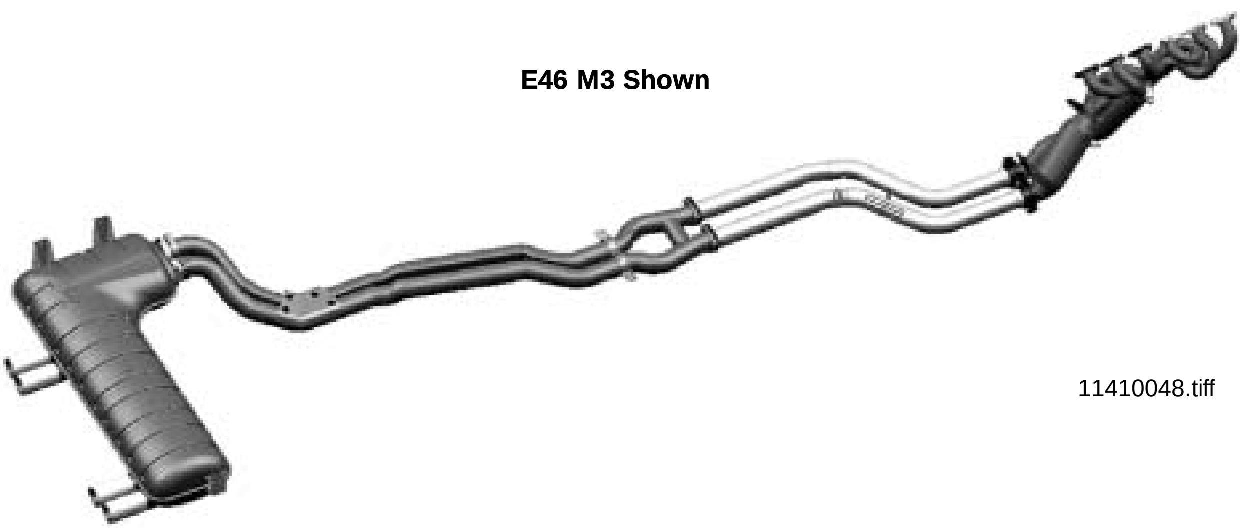
The E46 M3 exhaust system is a dual channel up to the muffler. By using the M-mobility kit, additional clearance is provided for the 40 liter half-shell muffler with four outlets. The M roadster and M coupe have separate dual mufflers

E46 M3 Shown



11410048.tiff

Review Questions

1. What is the valve clearance and at what temperature should it be checked?

   Intake __________ Exhaust __________ Engine Temperature _________

2. The crankshaft mounted impulse wheel on the S54 provides:

   ________________ _________________ _________________ ________________

3. What does the term “cracked” connecting rod mean?

   ____
   ____
   ____

4. What is the function(s) of the oil pumps on the S54?

   ______________________________ ______________________________

5. Regarding the Crankcase Ventilation System, what is the purpose of the Check Valve in the oil return line from the intake manifold?

   ____
   ____
   ____

6. When installing the camshafts, they should be installed based on what visual sight?

   ____
   ____

7. What is unique about the exhaust finger (rocker) shaft?

   ____

8. What are the two differences between the intake and exhaust valves?

   _______________________________ __________________________________

9. What must be “aligned” with the radial piston high pressure pump when installing the VANOS unit? ____

10. Where is the fuel pressure tested on the E46 M3 and what is the nominal pressure?

    ____
    ____

Table of Contents

Subject **Page**

MS S54

Model: E46 M3, E46 M3 Convertible, M roadster, M coupé

Production Date: 01/2001

Manufacturer: Siemens

Pin Connector: 134 Pins - 5 Modular Connectors

Objectives of the Module

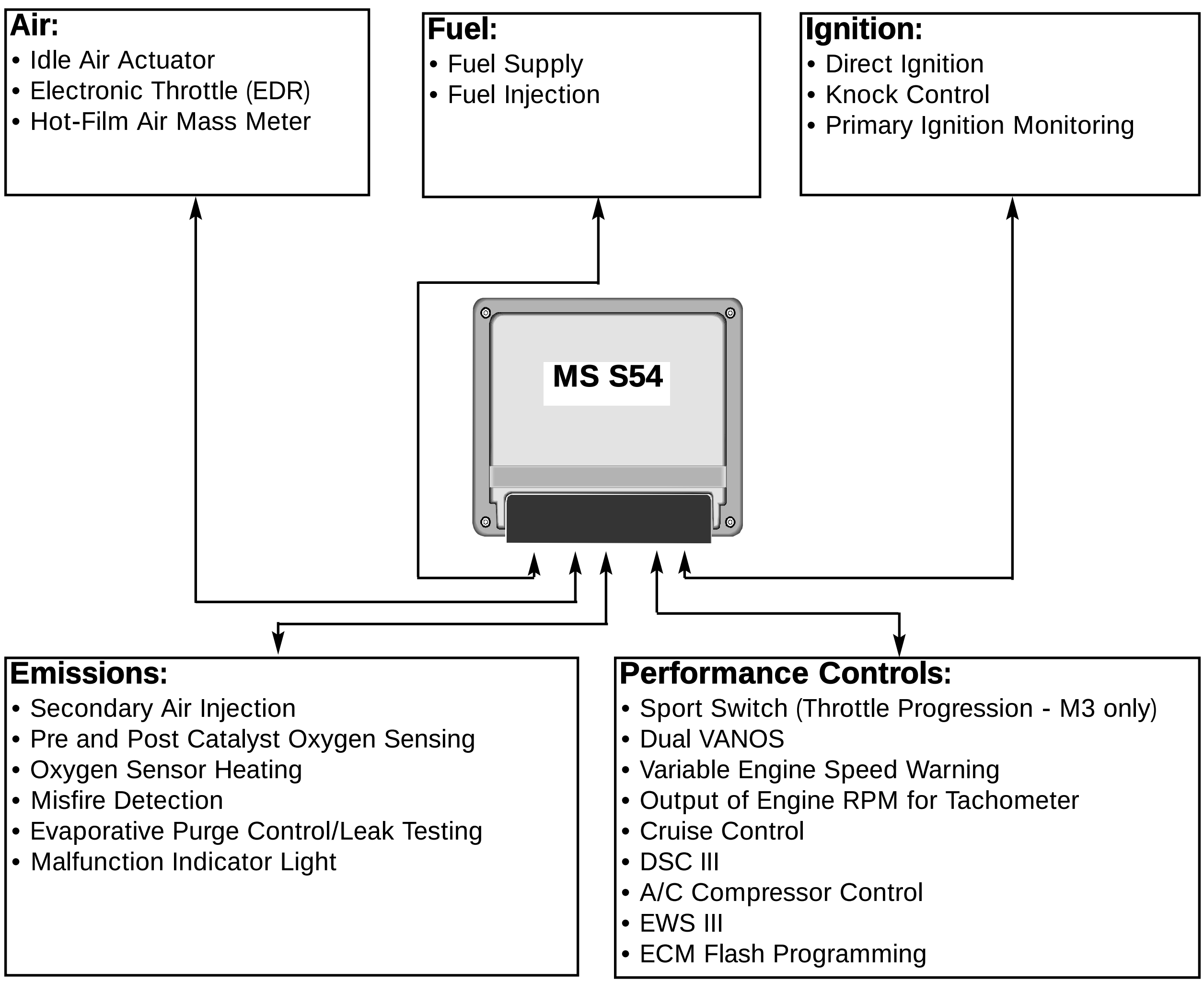
After completing this module, you will be able to:

- Describe the Power Supply for the Fuel Injectors and Ignition Coils.
- Understand the EDR and Idle Air Actuator Operation.
- Name the Component Location of the Fuel Supply System.
- List the Inputs Required for Fuel Injector Operation.
- Describe Emission Optimized Function.
- Name the Two Types of Emissions the ECM Controls.
- Explain Why Two Sensors are used to Monitor Throttle Movement.
- Describe the Dual Input from the Accelerator Pedal.
- Locate the Diagnostic Socket.

MS S54

Purpose of the System

The MS S54 system manages the following functions:



System Components

MS S54 Engine Control Module: The MS S54 ECM features a single printed circuit board with two 32-bit microprocessors.

The task of the first processor is to control:

- Engine Load
- Electronic Throttle (EDR)
- Idle actuator
- Ignition
- Knock Control

The task of the second processor is to control:

- Air/Fuel Mixture
- Emission Control
- Misfire Detection
- Evaporative Leak Detection

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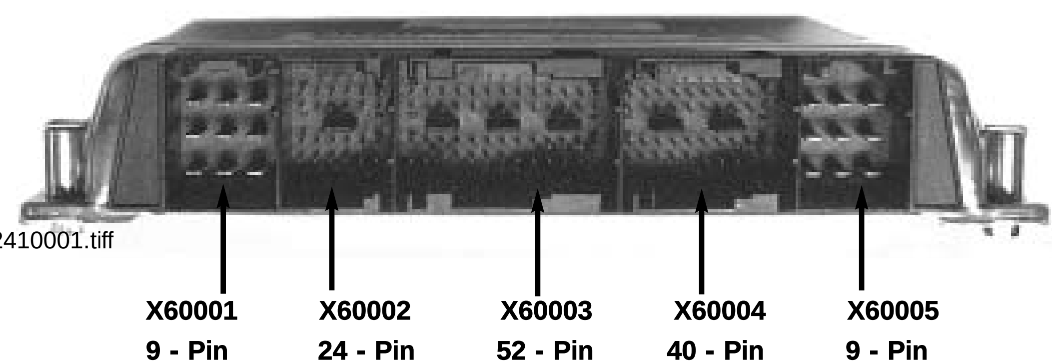

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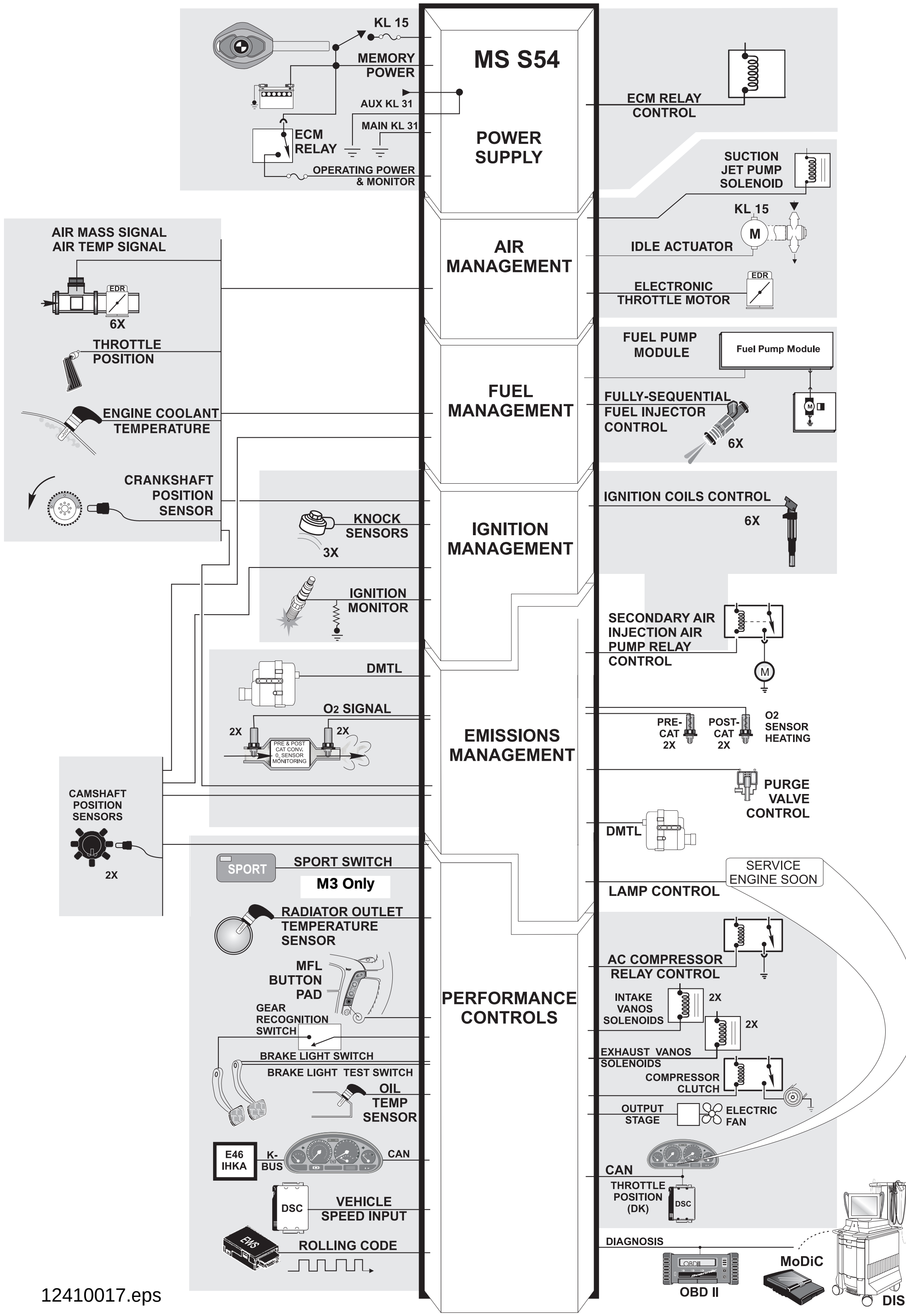
The 134 pin MS S54 Engine Control Module is manufactured by Siemens to BMW M specifications. The ECM is the SKE (standard shell construction) housing and uses 5 modular connectors. For testing, use the Universal Adapter Set (break-out box) Special Tool: # 90 88 6 121 300.

MS S54 ECM Inputs - Processing - Outputs



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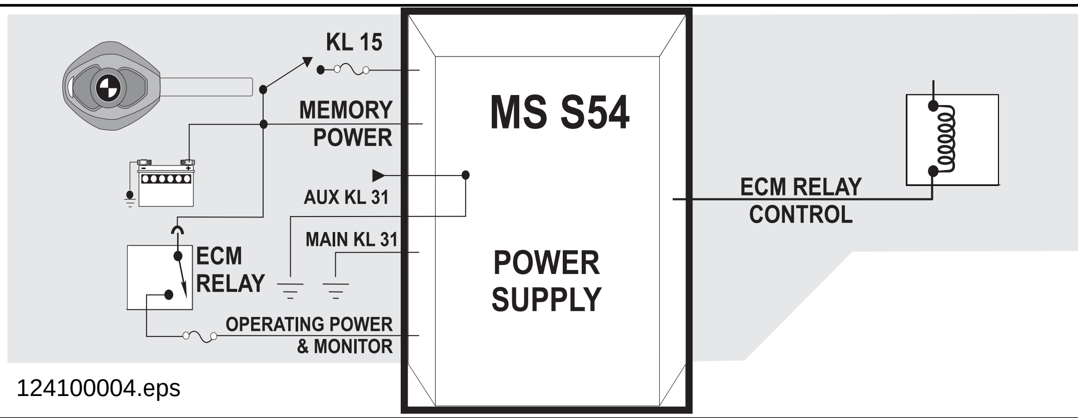
Power Supply

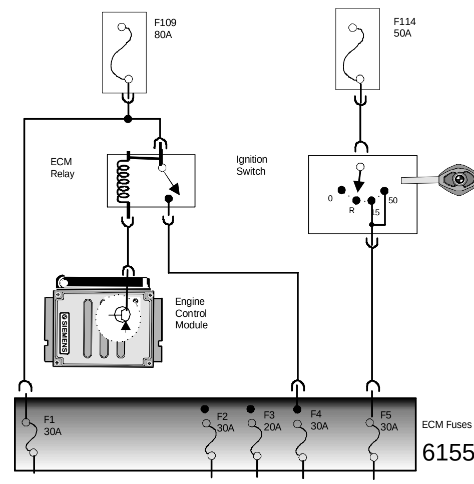


124100004.eps

KL30 - Battery Voltage: B+ is the main supply of operating voltage to the ECM.

Power Supplies: The power supplies (KL15 and ECM Relay) are fused to the MS S54 ECM. The fuses are housed in the Engine Fuse Block located in the Electronics Box.

KL15 - Ignition Switch: When the ignition is switched "on" the ECM is informed that the eng-gine is about to be started. KL15 (fused) supplies voltage to the Engine Control Module Relay and the Fuel Injector Relay. Switching KL15 "off" removes the ECM operating voltage.



61550004

Engine Control Module Relay: The ECM Relay provides the operating voltage for:

1.	**ECM**	**6.**	**Ignition Coils**
2.	**Fuel Injector Relay**	**7.**	**DMTL**
3.	**Idle Air Actuator**	**8.**	**Camshaft Sensor**
4.	**Evaporative Emission Valve**	**9.**	**Hot Film Air Mass**
5.	**Fuel Pump Relay**	**10.**	**Oxygen Sensor Heaters**

Ground: Multiple ground paths are necessary to complete current flow through the ECM. The ECM ground pin numbers are:

Connector X60001	**Connector X60004**	**Connector X60005**
Pin 4 - Ground for ECM	**Pin 5 - Ground for ECM**	**Pin 5 - Ground for ECM**
Pin 5 - Ground for ECM		
Pin 6 - Ground for ECM		

Principle of Operation

Battery Voltage is monitored by the ECM for fluctuations. It will adjust the output functions to compensate for a lower (6v) and higher (14v) voltage value. For example, the ECM will:

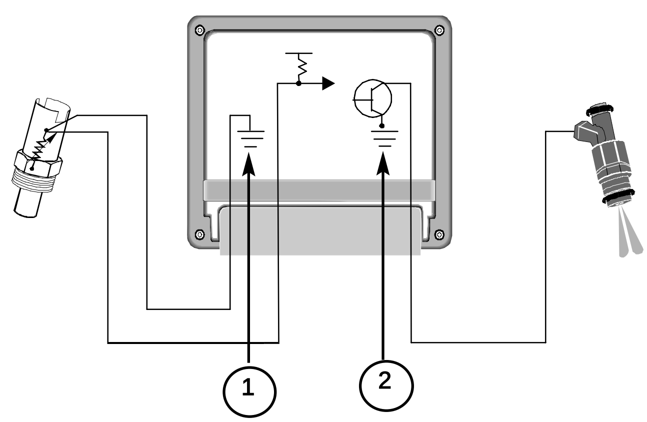
- Modify pulse width duration of fuel injection.
- Modify dwell time of ignition.

When **KL15** is switched "on" the ECM is ready for engine management. The ECM will activate ground to energize the Engine Control Module Relay. The Engine Control Module Relay supplies operating voltage to the ECM and the previously mentioned operating components. Five seconds after the ignition is switched on and the voltage at the KL15 input is >9 volts, the ECM compares the voltage to the ECM Relay supplied voltage. If the voltage difference between the two terminals is greater than 3 volts, a fault code will be set.

When **KL15** is switched "off" the ECM operating voltage is removed. The ECM will maintain a ground to the Engine Control Module Relay for a few seconds to maintain ignition coil activation (Emission Optimized - introduced in 2000 MY).

Ground is required to complete the current path through the ECM. The ECM also:

- Internally links a constant ground (1) to the engine sensors.
- Switches ground (2) to activate components.



61420002.eps

Workshop Hints

Power Supply - Testing

Inadequate power and ground supply can result in:

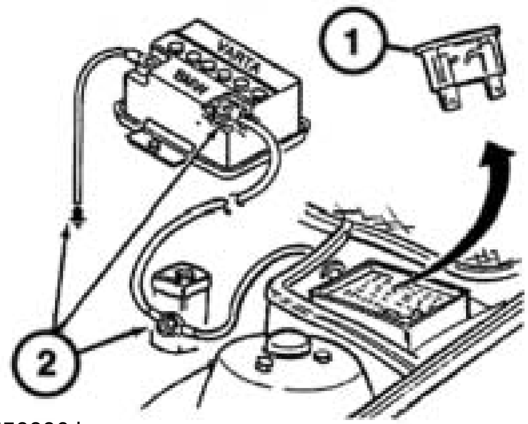
1.	**No Start**
2.	**Hard Starting (Long Crank Times)**
3.	**Inaccurate Diagnostic Status or ECM (Not Found)**
4.	**Intermittent / Constant "Malfunction Indicator Light"**
5.	**Intermittent/Constant Driveability Problems**

Electronics Box - ECM and Fuses

12410003.tiff

Power supply including **fuses** should be tested for:

1.	**Visual (1) Blown Fuse**
2.	**Available Voltage (2)**
3.	**Voltage Drop (Dynamic Resistance) (2)**
4.	**Resistance of Cables and Wires (2)**



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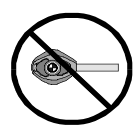
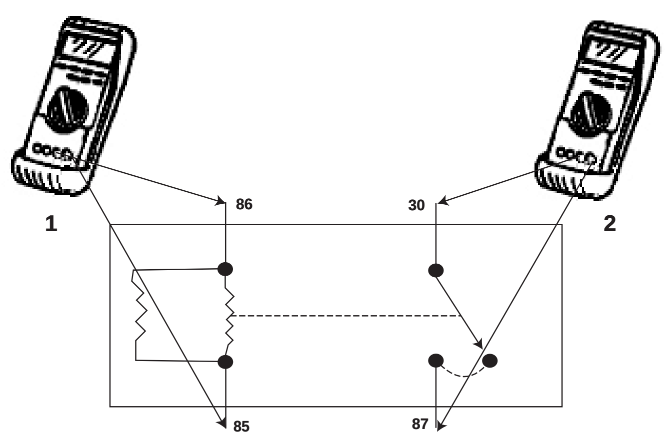
The ignition (KL15) must be switched off when removing or installing the ECM connector to prevent voltage spikes (arcing) that can damage the Control Module!



The Engine Control Module **Relay** (located in the Electronics Box) should be tested for:

1.	**Battery Voltage and Switched Ground (1)**
2.	**Resistance (1)**
3.	**Battery Voltage and Voltage Drop (2)**



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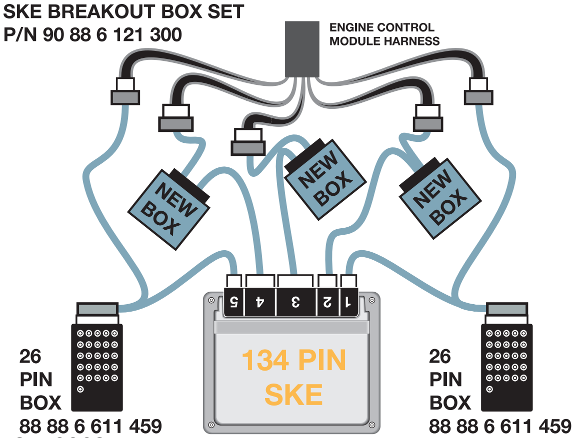
Tools and Equipment

Power Supply

When testing power supply to an ECM, the DISplus/MoDIC multimeter function as well as a reputable hand held multimeter can be used.

It is best to make the checks at the ECM connection, this method includes testing the wiring harness.

The correct Universal Adapter for the MS S54 application should be used (#90 88 6 121 300). This will ensure the pin connectors and the harness will not be damaged.



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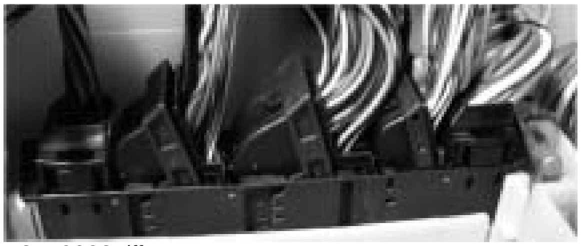
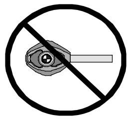
When installing the Universal Adapter to the ECM (located in the Electronics Box in engine compartment), ***make sure the ignition is switched off.***

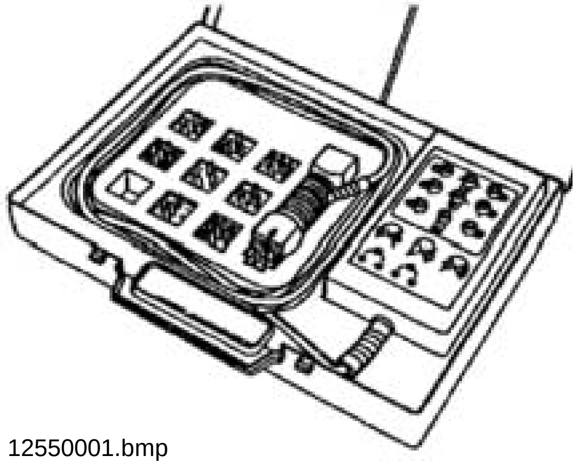

12410002.tiff



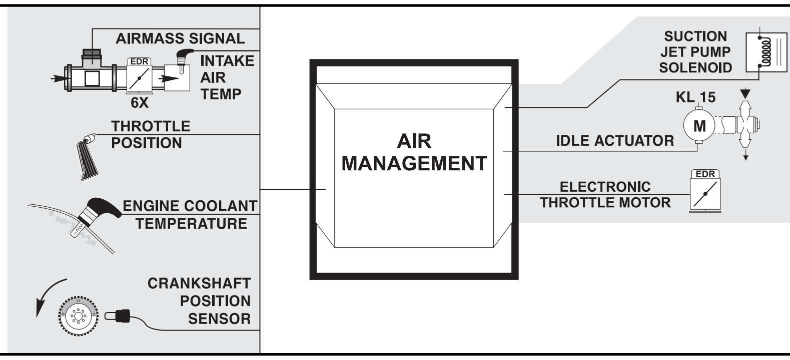
The Engine Control Module **Relay** should be tested using the relay test kit (P/N 88 88 6 613 010) shown on the right.

This kit allows testing of relays from a remote position.

Always consult the ETM for proper relay connections.


12550001.bmp

Air Management



12410008.eps

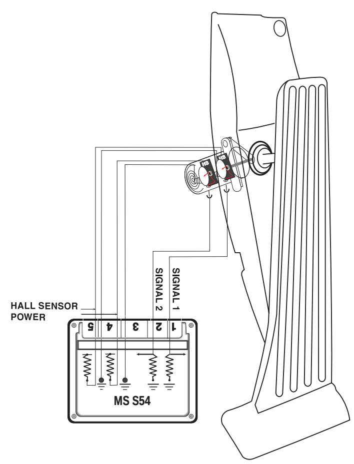
Throttle Valves: The mechanical throttle valves regulate the intake air flow and are operated by an Electronic Throttle Actuator (1 EDR).

11410057.tiff

The throttle valves are an assembly of six individual throttle housings linked by a common shaft. The throttle opening depends on engine rpm and load (1000 kg/h maximum air flow).

Refer to the Repair Instructions for throttle adjustments.

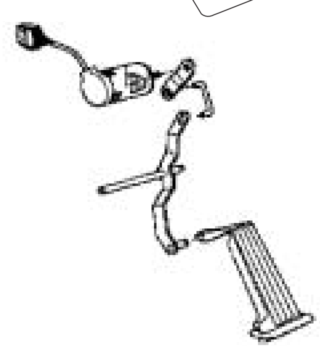
Accelerator Pedal Position (PWG): The accelerator pedal module (E46 M3) provides two variable voltage signals to the ECM that represents accelerator pedal position and rate of movement. The ECM will activate the EDR and Idle Air actuator based on the request.



13410065.eps

Dual Hall sensors are integral in the accelerator pedal module. The ECM compares the two values for plausibility.

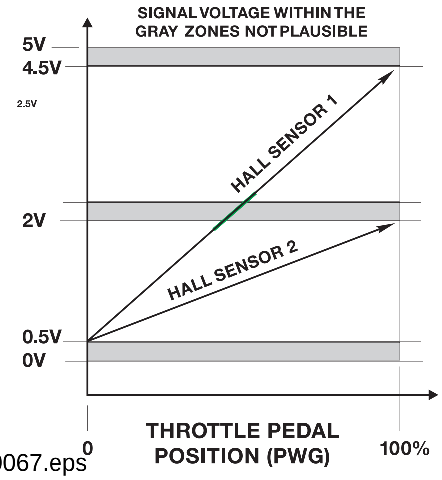
The M roadster and M coupe use a remote mounted PWG. This type uses twin potentiometers to produce the same input signals (voltage) as the Hall sensors.



The ECM provides voltage (5v) and ground for the Hall sensors. As the accelerator pedal is moved from rest to full throttle, the sensors produce a variable voltage signal.

Hall sensor 1(request) = 0.5 to 4.5 volts
Hall sensor 2 (plausibility) = 0.5 to 2.0 volts

If the signals are not plausible, the ECM will use the lower of the two signals as the request input. The throttle response will be slower and the maximum throttle response will be reduced.



13410067.eps

The potentiometer PWG produces the same voltage signals to the ECM.

Electronic Throttle Actuator (EDR): The EDR is specifically designed for the S54 engine. This allows one actuator to operate all six throttles via a common linkage.

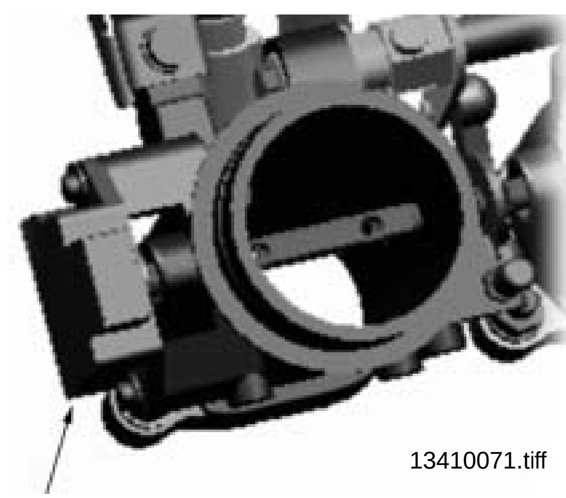
The ECM provides the operating voltage and ground to the EDR for opening and closing the throttles. The ECM monitors a feedback potentiometer located on the actuator shaft (arrow) for actuator position/plausibility (closed 4.5v - full open 0.5v).


13410069.tiff

There is a return spring fitted to the actuator lever end that assists in closing the throttles.

Throttle Valve Position: A potentiometer is fitted to the end of the throttle shaft (arrow) that allows the ECM to monitor throttle position.

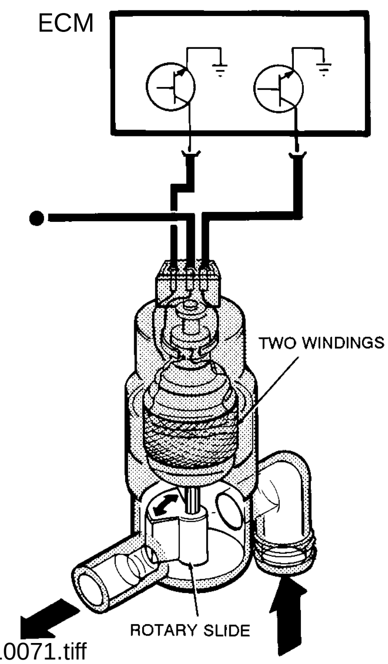
This signal is used by the ECM for a position/plausibility check (closed 0.5v - full open 4.5v).


13410071.tiff

Idle Air Actuator: The Idle Air Actuator is a two-coil rotary actuator (ZWD5). The S54 features a second air supply system that functions independent of the throttle valve control system (EDR). This actuator regulates air by-passing the throttle valves to control low engine speed.

The valve is supplied with operating voltage from the ECM Relay. The ECM is equipped with two final stage transistors which will alternate positioning of the actuator. The final stages are "pulsed" simultaneously by the ECM which provides ground paths for the actuator. The duty cycle of each circuit is varied to achieve the required idle RPM.

The valve (2) regulates air flow through an external air distribution pipe to the individual throttle housings. The inducted air is shared between the idle actuator and throttle valves depending on the engine load. The maximum air flow of the idle air actuator (80 kg/h) permits emergency operation of the vehicle (limp-home mode).



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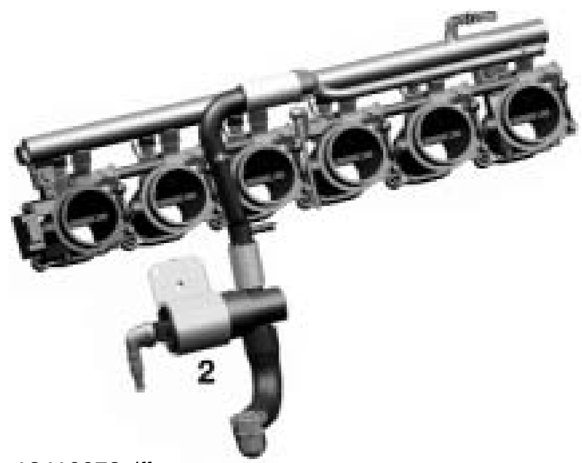

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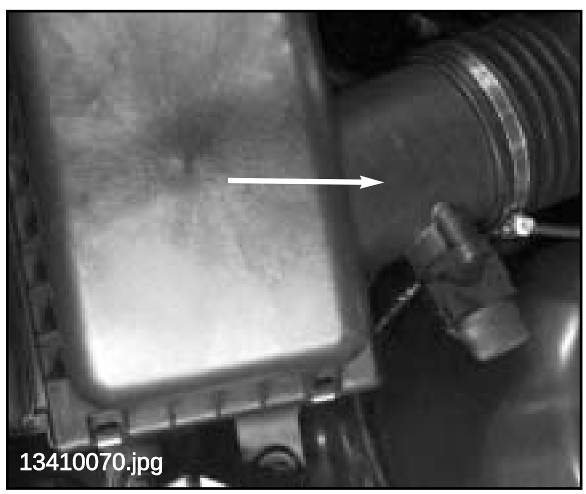
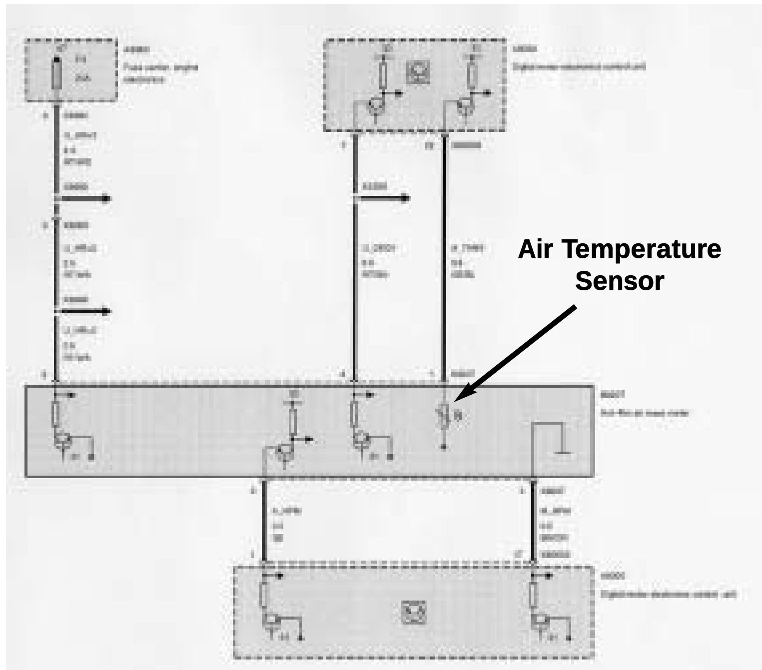
Hot-Film Air Mass Meter (HFM): The air volume input signal is produced electronically by the HFM which uses a heated metal film in the air flow stream. The HFM housing is integral with the air filter upper housing (one-piece).

The ECM Relay provides the operating voltage. As air flows through the HFM, the film is cooled changing the resistance which affects current flow (voltage drop) through the circuit as the resistance changes. The ECM monitors this change regulating the amount of fuel injected.

If these components/circuits are defective, a fault code will be set and the "Malfunction Indicator Light" will be illuminated when the OBD II criteria is achieved.


13410070.jpg

Air Temperature Signal: The HFM contains an integral air temperature sensor. This is a Negative Temperature Coefficient (NTC) type sensor. This signal is needed by the ECM to correct the air volume input for changes in the intake air temperature (air density) affecting the amount of fuel injected, ignition timing ***and Secondary Air Injection activation.***



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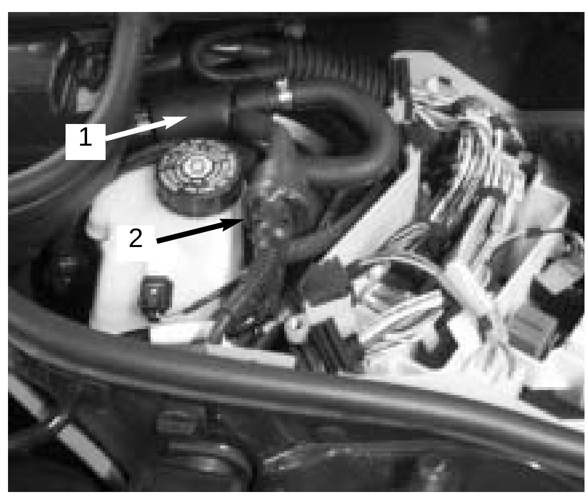
The ECM provides the power supply to this component. The sensor decreases in resistance as the temperature rises and vice versa. The ECM monitors an applied voltage to the sensor that will vary as air temperature changes the resistance value.

If this input is defective, a fault code will be set and the “Malfunction Indicator Light” will be illuminated when the OBD II criteria is achieved. The ECM will operate the engine using the Engine Coolant Sensor input as a back up.

Suction Jet Pump: The ECM regulates the Suction Jet Pump (1) to provide sufficient vacuum for the brake booster under all operating conditions. The ECM controls the Suction Jet Pump Solenoid (2) to allow vacuum flow through.

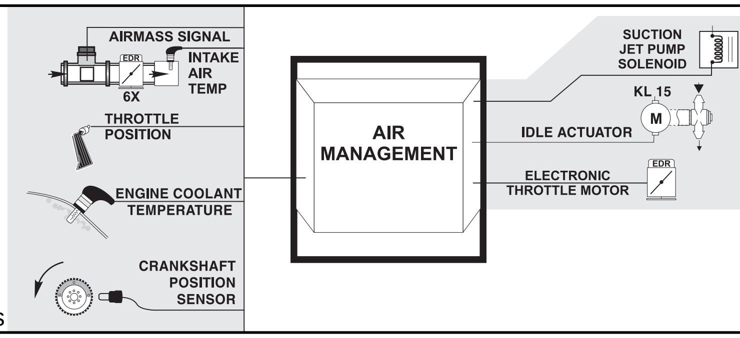


Additional vacuum compensation is applied to the brake booster when the circuit is “deactivated” (solenoid sprung open).

Vacuum enhancement is limited to the brake booster when the control circuit is “activated” (solenoid powered closed).

Principle of Operation

Air flow into the engine is regulated by the Throttle Valves and/or the Idle Air Actuator. Both of these air "passages" are necessary for smooth engine operation from idle to full load. On the MS S54 system, the Throttle Valve and the Idle Air Actuator are **electrically controlled**. All of the ECM monitoring, processing and output functions are a result of regulated air flow.

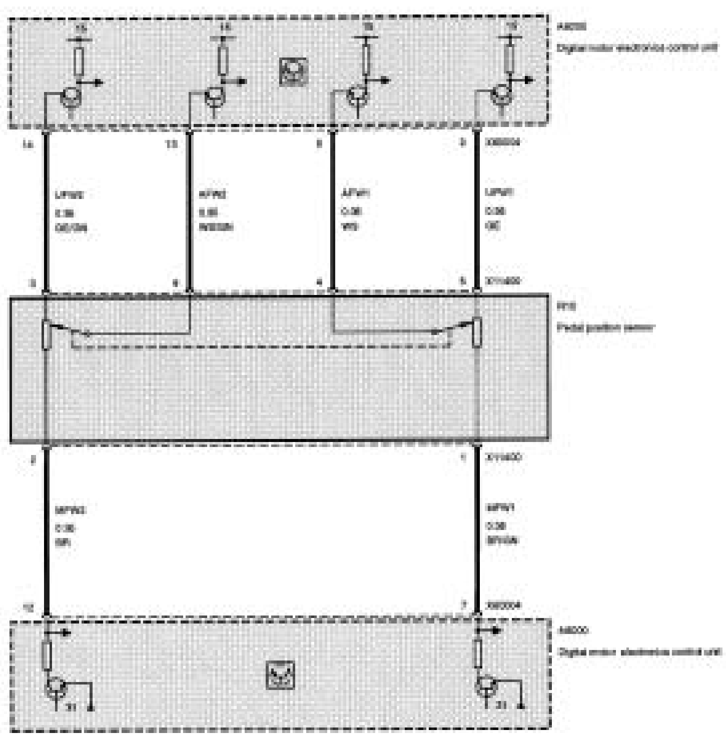


12410008.eps

The Accelerator Pedal Position (M3 PWG) is monitored by the ECM for pedal angle position and rate of movement. As the accelerator is moved, a rising voltage signal from the Hall sensors requests acceleration and at what rate. The ECM will increase the volume of fuel injected into the engine, advance the ignition timing and open the Throttle Valves and/or Idle Air Actuator. The "full throttle" position indicates maximum acceleration to the ECM, and in addition to the functions just mentioned, this will have an effect on the air conditioning compressor (covered in Performance Controls).

As the accelerator pedal is released (integral springs), a decrease in voltage signals the ECM to activate fuel shut off if the rpm is above idle speed (coasting). The Throttle Valves will be closed and Idle Air Actuator Valve will open to maintain idle speed.

The ECM monitors the engine idle speed in addition to the accelerator pedal position and throttle position voltage. If the voltage values have changed (mechanical wear of throttle plates or linkage), the ECM will adjust the Idle Air Actuator to maintain the correct idle speed.


12410001.bmp

The pedal position sensor consists of two separate Hall sensors with different voltage characteristics and independent ground and voltage supply. Sensing of the accelerator pedal position is redundant. The pedal position sensor is monitored by checking each individual sensor channel and comparing the two pedal values. Monitoring is active as soon as the sensors receive their voltage supply (KL15). The ECM decides what operating mode the pedal position sensor is to assume.

Mode 0 = Pedal position sensor fully operable
Mode 1 = Failure of one pedal position sensor (maximum engine speed is limited)
Mode 2 = Failure of both pedal position sensors (engine speed limited to 1500 rpm)

The potentiometers/Hall sensors are non-adjustable because the ECM "learns" the throttle angle voltage at idle speed. If the throttle housing/accelerator pedal module is replaced, the **ADAPTATIONS MUST BE CLEARED and ADAPTATION PROCEDURE MUST BE PERFORMED** using the DISplus/MoDIC. **If this is not performed, the vehicle will not start, or run in "fail-safe" mode.**

If this input is defective, a fault code will be stored and the "Malfunction Indicator and/or EML" Light will be illuminated. Limited engine operation will be possible.

The Idle Air Actuator is controlled by the ECM modulating the ground signals (PWM at 100 Hz) to the valve. By varying the duty cycle applied to the windings, the valve can be progressively opened, or held steady to maintain the idle speed. The ECM controls the Idle Air Actuator to supply the necessary air to maintain idle speed. When acceleration is requested and the engine load is low (<15%), the actuator will also supply the required air.

There are additional factors that influence the ECM in regulating idle speed:

- The RPM sensor input allows the ECM to monitor engine speed because of loads that cause idle fluctuations due to drag on the engine: power steering, thick oil (frictional forces), etc.

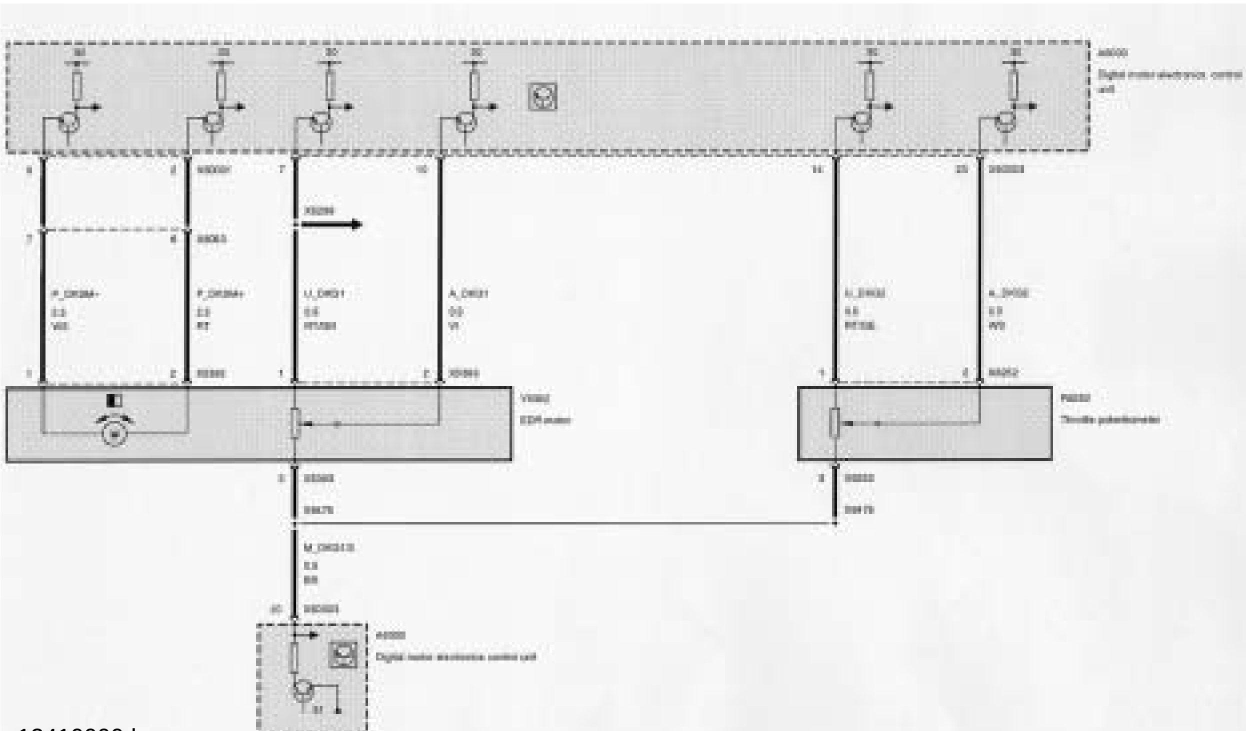
- Cold engine temperature (coolant NTC) provides higher idle speed to raise temperature sooner.

- Vehicle speed informs ECM when the vehicle is stationary and requires idle maintenance.

- A/C on request from the climate control system (arming the ECM) and compressor engage (stabilize idle speed) acknowledgment.

The Electronic Throttle Actuator (EDR) is operated by the ECM for opening and closing based on the accelerator pedal position, DSC intervention and cruise control functions. For exclusive control, the ECM supplies the voltage and ground for operation. The system requires approx. 110 milliseconds in order to fully open the closed throttle valves.

When the EDR is operated, the ECM monitors a feedback potentiometer located on the actuator shaft for position/plausibility. As the EDR opens the Throttle Valves to accelerate the engine, the position is also monitored by a feedback potentiometer located on the end of the throttle shaft on the number 1 throttle housing. These two sensors operate inversely (voltage values) with throttle actuation.



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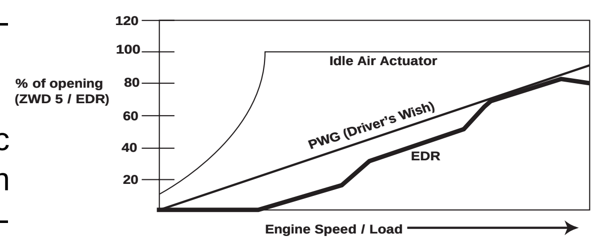
The EDR actuator will "open" the throttle valves for acceleration when the engine load is >15%. There is a transition during acceleration when the Idle Air Actuator will also be open providing additional air for initial acceleration torque.



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With the Idle Actuator System and Electronic Throttle Control (EDR), the S54 is equipped with two independent air systems. The ECM is therefore capable of dividing the air volume of the engine between the idle actuator and/or throttle valves corresponding to the load status.

Pre-drive Check

The pre-drive check has following tasks:

- Zero point adaptation of the throttle potentiometers.
- Checking freedom of movement of the throttle valves and electronic accelerator pedal control circuit.
- Checking the safety cutout and the return springs of the electronic accelerator pedal and throttle valves.

This check is conducted every time KL15 is activated. The full load adaptation stop is learned in a new ECM the first time KL15 is recognized.

The pre-drive check is conducted in 3 phases:

- Phase 1: The throttle valves are closed by the EDR actuator. The position of the throttle potetiometer on the EDR is determined.
- Phase 2: The throttle valves are opened 3% by the EDR actuator. The position of the throttle potentiometer on the throttle valve shaft is determined.
- Phase 3: The throttle valves are opened by approx. 20%. The EDR actuator is switched off. The throttle valves are closed by spring force (a mechanical clicking sound can be heard while the throttle valves are closing).

Post Drive Check

- Post Drive Check: 10 seconds after KL15 is switched “OFF" the EDR actuator is opened 102% in order to carry out renewed full load adaptation. Adaptation during the post drive check is only carried out when the engine is turned off before reaching the operating temperature.

EDR Safety Concept - Emergency Running Programs

The safety concept of the throttle valve control system achieves a slow transition to an emergency running (limp-home) program that can still be managed by the driver.

A basic differentiation is made between PWG emergency operation with a PWG sensor and PWG emergency operation without a PWG sensor. There is a total of 4 emergency operation (limp-home) program stages.

In the event of a PWG sensor failing, the system switches to a PWG emergency operation characteristic curve with lower setpoints. "Engine Emergency Program" is indicated to the driver by the EML warning lamp in the instrument cluster.

Stage 1 (Emergency Operation with a Throttle Position Sensor)

The emergency program stage 1 includes limiting the torque and the EDR setpoint. Based on the current engine torque, the maximum torque is limited in the emergency operation stage. The EDR actuator is limited by reducing the pulse duty factor. The plausibility of the throttle position sensors are checked based on the load signal from the hot-film air mass meter. The measured air mass must not exceed a defined limit. This limit is above the value that can be achieved with the idle air actuator.

Stage 2 (Emergency Operation via Idle Air Actuator)

The transition to emergency program stage 2 greatly depends on the type of fault. For example, if there is a defect in EDR actuator operation, the throttle valves are sprung closed without ECM influence.

In the event of implausible signals from the throttle position Hall sensors 1 and 2, immediate deactivation of the EDR actuator may be necessary under certain circumstances.

In cases where feedback of the actual position is still available and the set position can still be controlled, the ECM closes the throttle valves. The EDR actuator is then switched off and engine speed and road speed limitation activated.

Stage 3 (Emergency Operation with Open Throttle Valves)

The stage 3 emergency operation program is activated when the actual throttle position exceeds the set throttle position for a defined period of time despite power being applied to the EDR actuator, the throttle valves cannot be closed. The ECM reduces the amount of fuel injected (fade out) and retards the ignition timing to limit engine torque. If it is necessary to further reduce the torque, individual fuel injectors are deactivated one cylinder at the time.

Stage 4 (Emergency Operation with Internal ECM Fault)

The stage 4 emergency operation program is always activated when an internal ECM fault is detected. In this case, the characteristics of the throttle valve control (EDR) are not predictable, therefore the ECM reduces the amount of fuel injected (fade out) and retards the ignition timing to limit engine torque. If it is necessary to further reduce the torque, individual fuel injectors are deactivated one cylinder at the time.

Emergency Operation Functions

Engine torque limitation In the emergency programs stage 1 - 4 is restricted to a value specified by the emergency operation (limp-home) program.

Stage	Engine Speed RPM	Road Speed km/h	Torque Nm
1	7600 rpm	240 km/h	320 Nm
2	4000 rpm	80 Km/H	250 Nm
3	2750 rpm	50 km/h	200 Nm
4	2750 rpm	50 km/h	200 Nm

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In the relevant emergency programs, the MS S54 limits the engine characteristics to the values indicated in the table. In emergency programs 3 and 4, in addition to the engine emergency program being indicated in the instrument cluster (EML), ***all warning elements in the tachometer are activated.***

The Hot-Film Air Mass Meter (HFM) varies voltage monitored by the ECM representing the measured amount of intake air volume. This input is used by the ECM to determine the amount of fuel to be injected.

The heated surface of the hot-film in the intake air stream is regulated by the ECM to a constant temperature of 180º above ambient air temperature. The incoming air cools the film and the ECM monitors the changing resistance which affects current flow through the circuit. The hot-film does not require a “clean burn”, it is self cleaning due to the high operating temperature for normal operation.

If this input is defective, a fault code will be set and the “Malfunction Indicator Light” will illuminate when the OBD II criteria is achieved. The ECM will maintain engine operation based on the Throttle Position Sensors and Crankshaft Position/Engine Speed Sensor.

The Air Temperature signal allows the ECM to make a calculation of air density. The varying voltage input from the NTC sensor indicates the larger proportion of oxygen found in cold air, as compared to less oxygen found in warmer air. The ECM will adjust the amount of injected fuel because the quality of combustion depends on oxygen sensing ratio.

The ignition timimg is also affected by air temperature. If the intake air is hot the ECM retards the base igniton timing to reduce the risk of detonation. If the intake air is cooler, the base ignition timing will be advanced. The ECM uses this input as a determining factor for Secondary Air Injection activation (covered in the Emissions section).

If this input is defective, a fault code will be set and the “Malfunction Indicator Light” will illuminate when the OBD II criteria is achieved. The ECM will maintain engine operation based on the HFM and Engine Coolant Temperature sensor.

The Suction Jet Pump is regulated by the ECM to provide sufficient vacuum for the brake booster under all operating conditions. The ECM controls the Suction Jet Pump Solenoid to allow vacuum flow through.

The additional vacuum compensation is activated by the ECM when the idle air actuator is regulated for:

- A/C compressor “on”
- Vehicle in gear and the clutch is released (driving under load)
- Engine in warm-up phase <70º C

Additional vacuum compensation is applied to the brake booster when the circuit is “deactivated” (Solenoid sprung open). Vacuum enhancement is limited to the brake booster when the control circuit is “activated” (Solenoid powered closed).

Workshop Hints

Air Management

Unmetered air leaks can be misleading when diagnosing faults causing “Malfunction Indicator Light”/driveability complaints. Refer to S.I. # 11 03 92 (3500) for testing intake vacuum leaks.

Crankcase Ventilation System

A fault in this system can often “mislead” diagnosis. This type of fault can produce:

• Mixture/misfire defect codes

• Whistling noises

• Performance/driveability complaints

Please refer to the following Service Information Bulletins for details on the ***Crankcase Ventilation System:***

• Crankcase Ventilation System Check S.I. #11 05 98

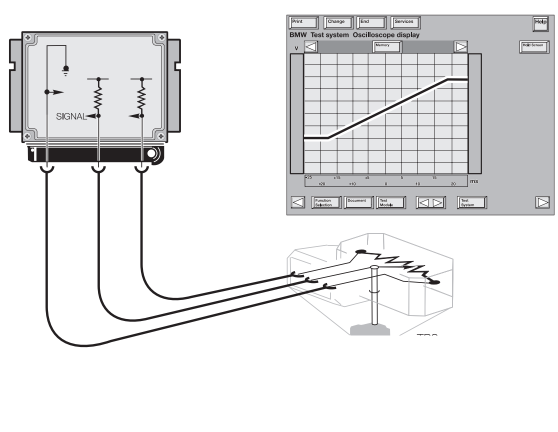
Throttle Position Sensors - Testing

The Throttle Position Sensors (potetiometers) can be tested with the following methods:

• DISplus Status Page (approx. 0.5v to 4.5v)

• DISplus Oscilloscope - Select from the Preset Measurements which requires taking the measurement with the ECM and Universal Adapter connected to the circuit (as shown on the right).

• Resistance check of the entire circuit, using the Universal Adapter with the ECM disconnected.



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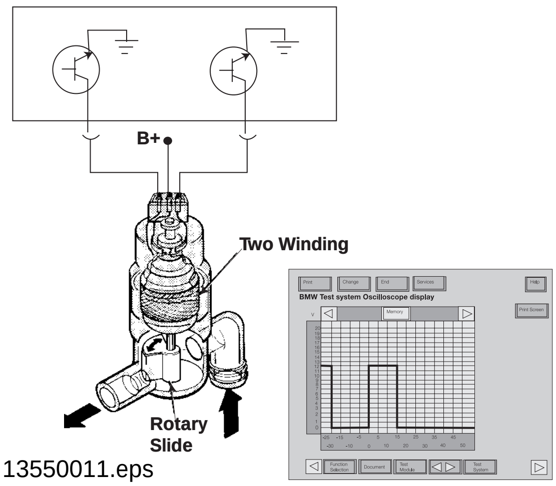
Idle Air Actuator - Testing

- The Idle Air Actuator and idle air circuit (passage ways) should be checked for physical obstructions.
- The resistance of the valve winding should be checked.
- The ECM output and Idle Speed Control Valve operation can be tested by “Component Activation” on the DISplus/MoDIC.
- The Pulse Width Modulated ground output from the ECM can be tested using the DISplus/MoDIC Oscilloscope.
- Consult Technical Data for specified idle speed.



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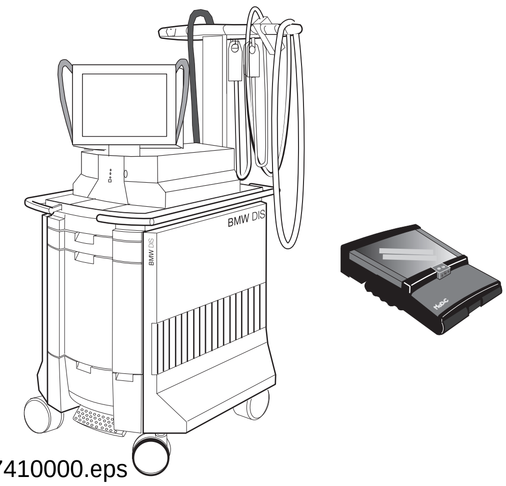
Tools and Equipment

The DISplus/MoDIC as well as a reputable hand held multimeter can be used when testing inputs/components.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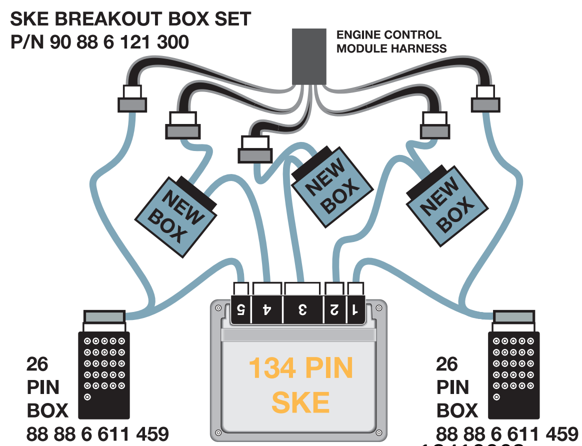
It is best to make the checks at the ECM connection, this method includes testing the wiring harness.

The correct Universal Adapter for the MS S54 application should be used (#90 88 6 121 300). This will ensure the pin connectors and the harness will not be damaged.



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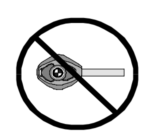
When installing the Universal Adapter to the ECM (located in the Electronics Box in the engine compartment), ***make sure the ignition is switched off.***



The Slack Tube Manometer Test Tool (#99 00 0 001 410) should be used to troubleshoot crankcase ventilation valves.

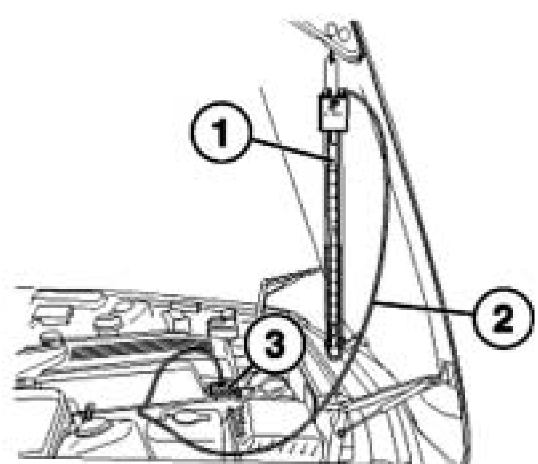


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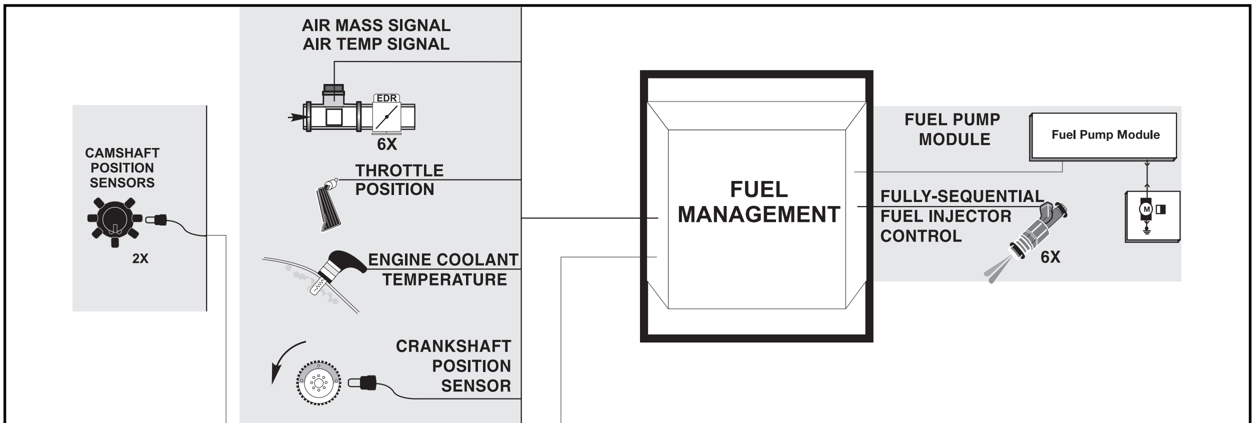
Table of Contents

Subject **Page**

Fuel Management



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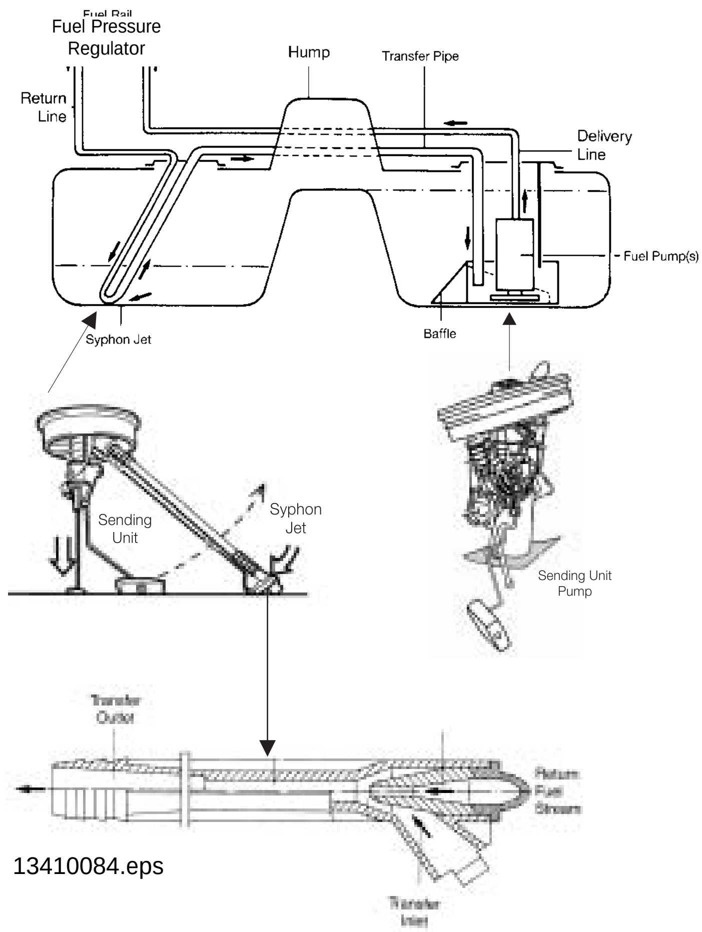
Fuel Tank: The fuel tank is made of high density polyethylene (reduced weight) which is manufactured to meet safety requirements. The baffling has been modified for the E46 M3 fuel pump pickup in the right hand side of the fuel tank to maintain fuel supply during aggressive cornering.

A “saddle” type tank is used which provides a tunnel for the driveshaft but creates two separate low spots in the tank. A Syphon jet is required with this type of tank to transfer fuel from the left side, linked to the fuel return line.

As fuel moves through the return, the siphon jet creates a low pressure (suction) to pick up fuel from the left side of the tank and transfer it to the right side at the fuel pick up.

The Z3 uses a conventional type fuel tank that is mounted between the seats and the luggage compartment. The Z3 has a single sending unit that (with the fuel pump) is accessed from behind the passenger seat.



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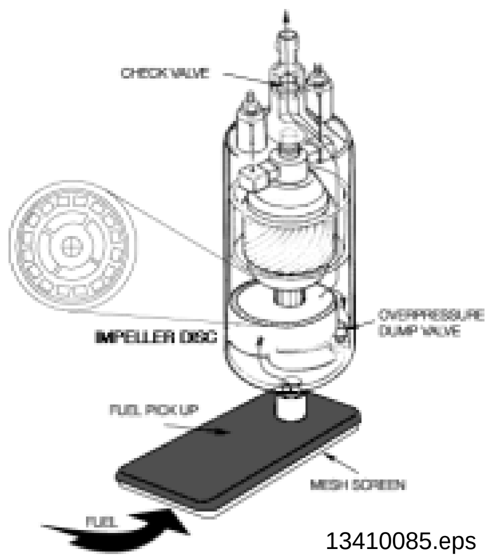
Fuel Pump: The electric fuel pump supplies constant fuel volume to the injection system. This system uses a single submersible (in the fuel tank) high volume pump. The inlet is protected by a mesh screen.

When the fuel pump is powered, the armature will rotate the impeller disc creating low pressure at the inlet. The fuel will be drawn into the inlet and passed through the fuel pump housing (around the armature). The fuel lubricates and cools the internals of the pump motor.



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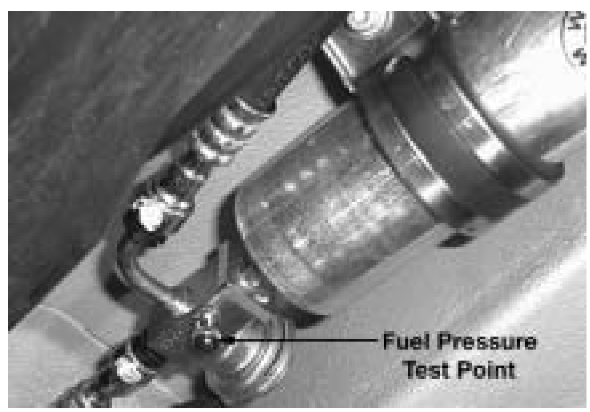
The fuel will exit through a non-return check valve to supply the injection system. The non-return check valve is opened by fuel exiting the pump and will close when the pump is deactivated. This maintains a "prime" of fuel in the filter, lines, hoses and fuel rail.

The pump contains an internal overpressure relief valve that will open (reducing internal pressure) if there is a restriction in the fuel supply hardware.

Fuel Supply: The fuel is supplied through a Non Return Fuel Rail System. This system is used on the S54 for LEV compliancy.



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The fuel supply pressure is controlled by the 5 Bar fuel pressure regulator integrated in the fuel filter assembly. The regulator is influenced by engine vacuum via a hose connected to the idle air distribution pipe. The fuel exits the fuel pressure regulator supplying the fuel rail and the injectors. The fuel filter assembly is located under the left front floor area (next to the frame rail).

The fuel return line is located on the filter/regulator assembly which directs the unused fuel back to the fuel tank. The fuel tank hydrocarbons are reduced by returning the fuel from this point instead of from the fuel rail.


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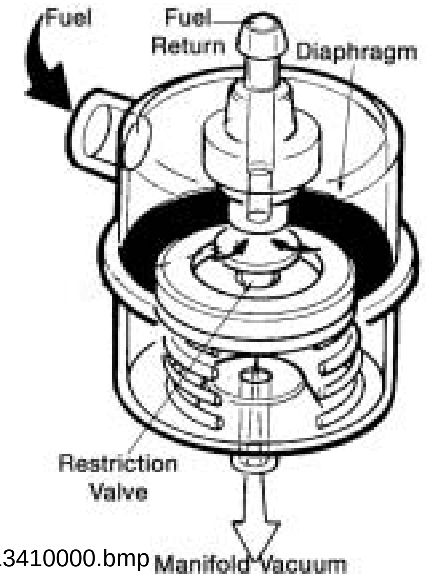
Fuel Pressure Regulator: The Fuel Pressure Regulator maintains a constant “pressure differential" for the fuel injectors.

The fuel pressure is set to 5.0 Bar (+/- 0.2) by internal spring tension on the restriction valve.

The vacuum chamber is sealed off by a diaphragm which is connected by a hose to the idle air distribution pipe (vacuum). Intake manifold vacuum regulates the fuel pressure by assisting to compress the spring (lowering fuel pressure).

When the restriction valve opens, unused fuel returns back to the fuel tank.



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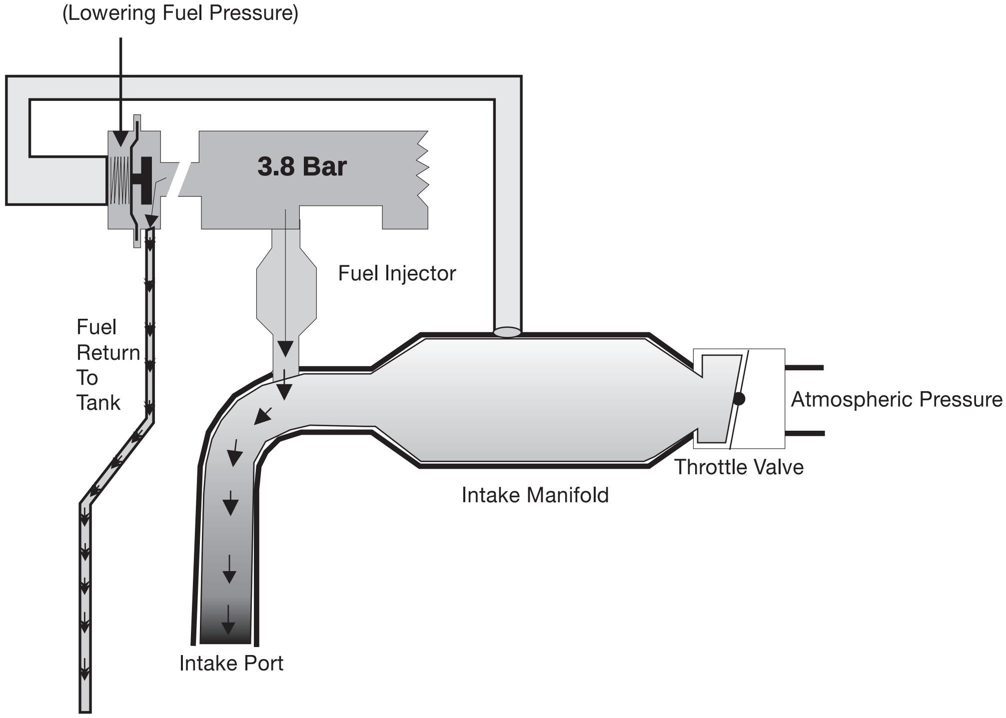
Examples of “pressure differential” are:

• At low to part throttle, intake manifold vacuum is available at the tip of the fuel injectors to enhance fuel “flow through”. Vacuum is also applied to the fuel pressure regulator vacuum chamber, causing the diaphragm to compress the spring which opens the restriction valve. This lowers the fuel pressure available to the fuel injectors.



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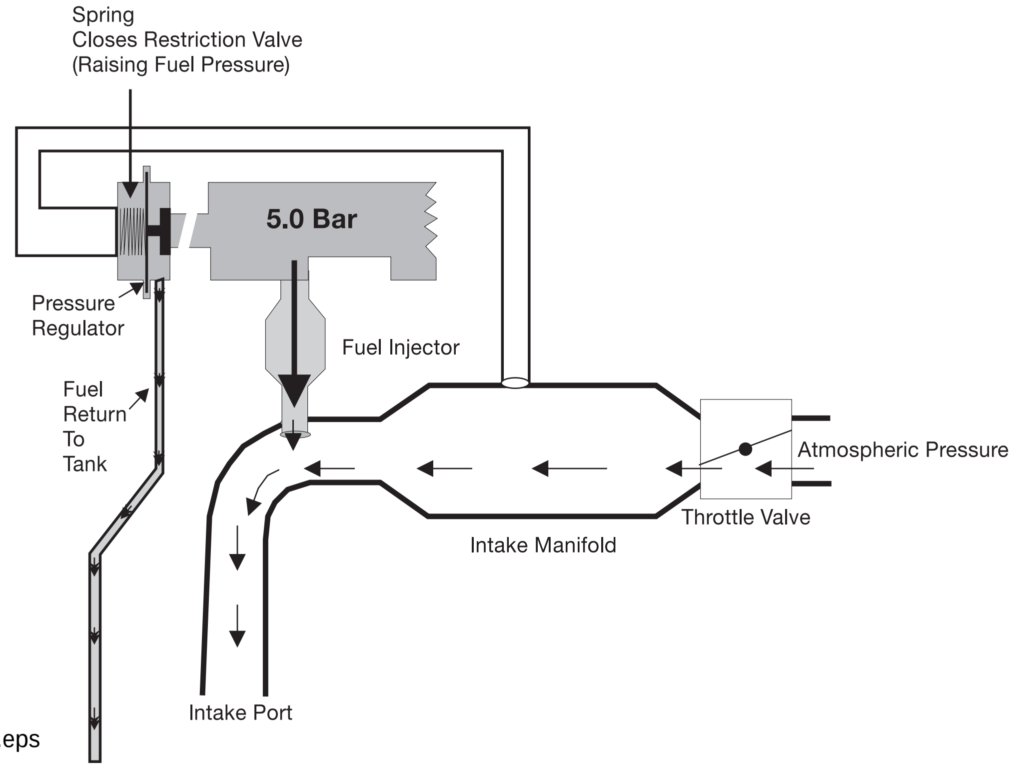
- Wide open throttle depletes intake manifold vacuum at the tip of the fuel injectors and in the fuel pressure regulator vacuum chamber. The spring closes the restriction valve to raise fuel pressure available to the fuel injectors. This maintains pressure differential (fuel flow through) for the fuel injectors.



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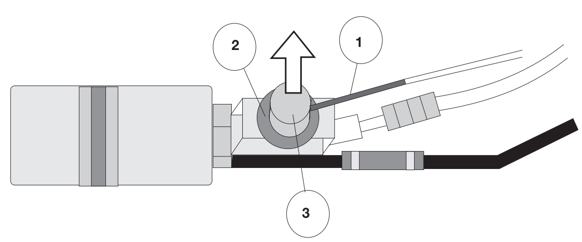
By maintaining constant Fuel Pressure Differential through vacuum sensing (engine load), the ECM can then regulate volume and mixture by the length of time the injectors are open (duration).

The Fuel Pressure Regulator is mounted on the fuel filter assembly.

1.	**Vacuum Hose**
2.	**Retaining Ring**
3.	**5 Bar Fuel Pressure Regulator**



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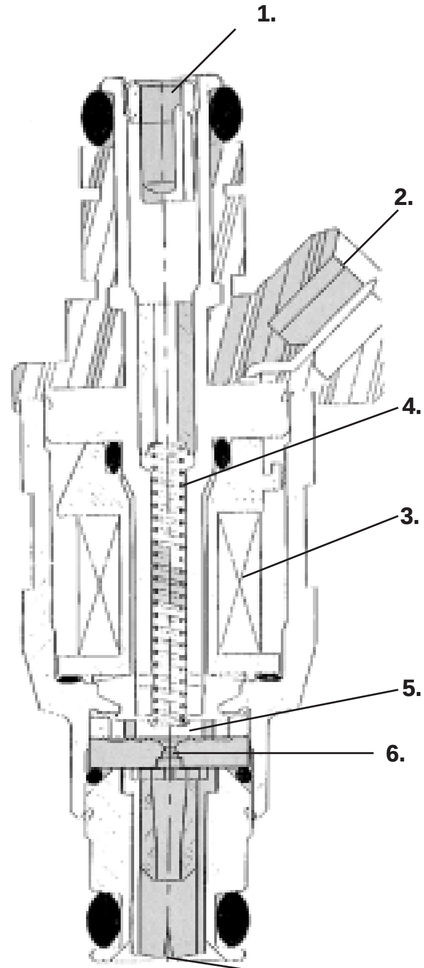
Bosch Fuel Injectors (4 Hole Plate Type): The Fuel Injectors are electronically controlled solenoid valves that provide precisely metered and atomized fuel into the engine intake ports. The Fuel Injector Valve consists of:

1.	**Fuel Strainer**
2.	**Electronic Connector**
3.	**Solenoid Winding**
4.	**Closing Spring**
5.	**Plate Valve**
6.	**Outlet Orifice**
7.	**4 Hole Channeling**



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Fuel is supplied from the fuel rail to the injector body. The fuel is channeled through the injector body to the plate valve and seat.

Without electrical current, the plate valve is sprung closed against the seat.

The Fuel Injectors receive voltage from the Fuel Injector Relay. The ECM activates current flow through the injector solenoid creating a magnetic field that pulls the plate valve “up” off of its seat.

The pressurized fuel flows through the outlet orifice into the channeling. The channel “fans out” the fuel spray into four angled spray patterns which helps to atomize the fuel.

When the ECM deactivates current flow, the plate valve is sprung closed against the seat and fuel flow through the injector is stopped.

The length of time that the ECM activates the injectors is very brief, the duration is in milli-seconds (ms). This affects the mount of fuel volume flowing through the Fuel Injectors. The ECM will vary the length of time (ms) to regulate the air/fuel ratio (mixture).


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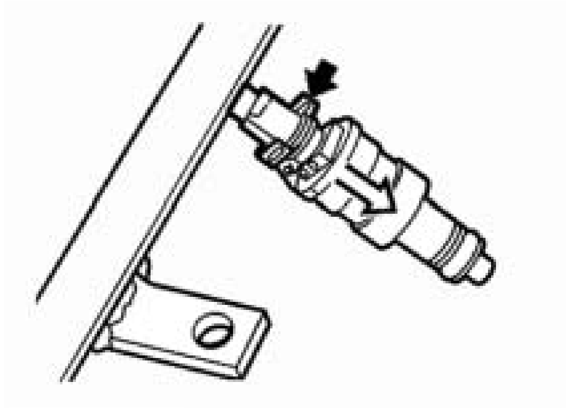
1.	**BMW Number**
2.	**Fuel Injector Code**
3.	**Mfg Date (week 06 year 2000)**
4.	**B+ Voltage Connection**

The Fuel Injectors are mounted in rubber "o-rings" between the fuel rail and the intake manifold to insulate them from heat and vibration.

This insulation also reduces the injector noise from being transmitted through the engine compartment.

The Fuel Injectors are held to the fuel rail by securing clips (arrow).



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If a Fuel Injector is faulty (mechanical/electrical), it can produce the following complaints:

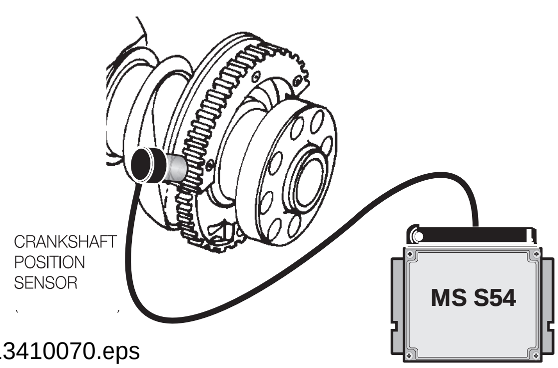
1.	**"Engine EMISSION" Light**	**4.**	**Excessive Tailpipe Smoke (leaking)**
2.	**Long Crank Time (Leaking)**	**5.**	**Misfire/Rough Idle (leaking/blocked)**
3.	**Oxygen Sensor/Mixture/Injector Related Fault Codes**	**6.**	**Engine Hydrolock (leaking)**

Crankshaft Position/RPM Sensor: This sensor provides the crankshaft position and engine speed (RPM) signal to the ECM for Fuel Pump and Injector operation. This is an inductive pulse type sensor mounted on the left side at the rear of the engine block. The impulse wheel is mounted on the crankshaft inside the crankcase, at the rear main bearing support. The impulse wheel contains 58 teeth with a gap of two missing teeth. The ECM provides the power supply to this component.

The rotation of the impulse wheel generates an A/C voltage signal in the sensor where-by each tooth of the wheel produces one pulse. The ECM counts the pulses and determines engine rpm.

The gap of two missing teeth provides a reference point that the ECM recognizes as crankshaft position.

The crankshaft position sensor is monitored as part of OBD II requirements for Misfire Detection.



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Camshaft Position Sensors (Hall Effect): The ECM uses the signal from the camshaft sensors to set up the triggering of the ignition coils, correct timing of fully sequential fuel injection, and VANOS operation. The ECM Relay supplies voltage to the Hall elements and the ECM supplies the ground. The power flow through the Hall elements is the basis for the sensors output to the ECM.

As the camshaft rotates, the leading edge of the impulse wheel approaches the sensor tip creating a magnetic field with the permanent magnet in the sensor.

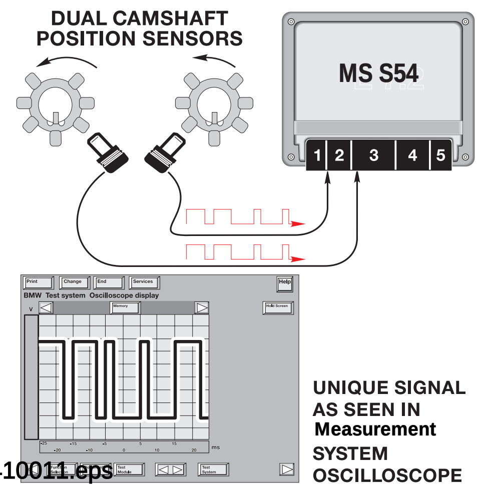
The attraction causes the magnetic field to penetrate through the Hall element. The magnetic field affects the power flow in the element causing the input signal to go high. As the impulse wheel passes by the sensor, the signal goes low.

The repetitive high/low creates a square wave signal that the ECM uses to recognize the camshaft position.

The “active” Hall sensors supply a signal representative of camshaft position even before the engine is running. The ECM determines an approximate location of the camshaft position (high or low signal) prior to engine start up optimizing cold start injection (reduced emissions).

An impulse wheel is mounted on the end of each camshaft for position detection. The intake camshaft impulse wheel has 6 lugs and the exhaust camshaft impulse wheel has 7 lugs. The sensors are mounted on each side at the back of the cylinder head.

If the ECM detects a fault with this type of sensor (shown on the right), the “Malfunction Indicator Light” will be illuminated and the system will maintain engine operation based on the Crankshaft Position/RPM Sensor. Torque reduction will be noticed due to “default” VANOS position.



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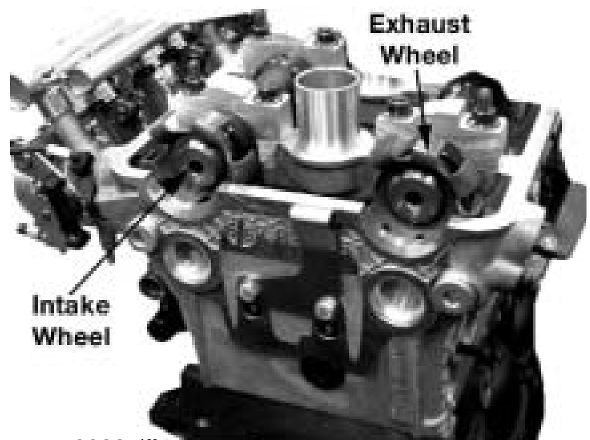

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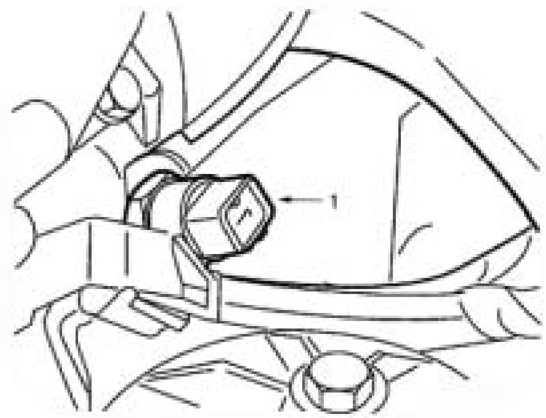
Engine Coolant Temperature: The Engine Coolant Temperature is provided to the ECM from a Negative Temperature Coefficient (NTC) type sensor. The ECM determines the correct fuel mixture and base ignition timing required for the engine temperature.

The dual sensor (ECM/Temp Gage) is located in the coolant return pipe (arrow).

The sensor decreases in resistance as the temperature rises and vice verse. The ECM monitors an applied voltage to the sensor (5v). This voltage will vary (0-5v) as coolant temperature changes the resistance value.

If the Coolant Temperature Sensor input is faulty, the "Malfunction Indicator Light" will be illuminated and the ECM will use the oil temperature sensor as an alternate.



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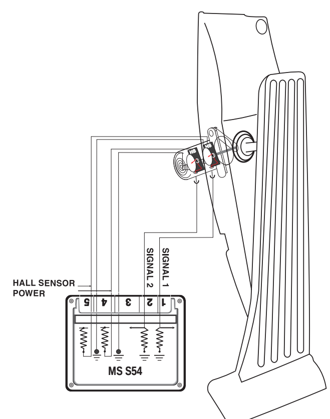
Accelerator Pedal Position (PWG):
As the accelerator pedal is actuated, the ECM will increase the volume of fuel injected into the engine. As the accelerator pedal is released, the ECM activates fuel shut off if the rpm is above idle speed (coasting).

For details about the sensor, refer to the Air Management section.



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Hot-Film Air Mass Meter (HFM): The air volume input signal is used by the ECM to determine the amount of fuel to be injected for correct air/fuel ratio.

For details about the sensor, refer to the Air Management section.


13410070.jpg

Air Temperature: This signal allows the ECM to make a calculation of air density. For details about the sensor, refer to the Air Management section.

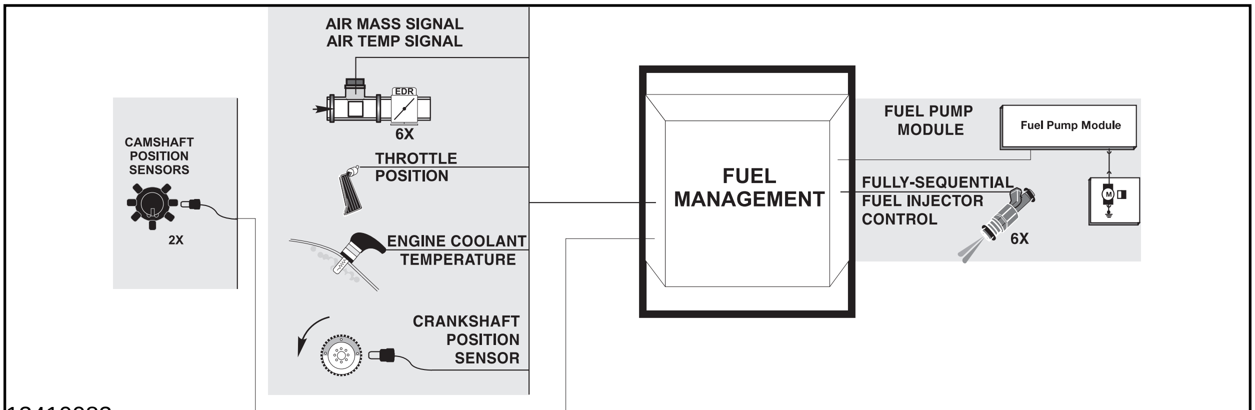
The varying voltage input from the NTC sensor indicates the larger proportion of oxygen found in cold air, as compared to less oxygen found in warmer air. The ECM will adjust the amount of injected fuel because the quality of combustion depends on oxygen sensing ratio.

If a fault is present in this circuit, the ECM will operate on a substitute value.

Notes: ___

Principle of Operation

Fuel Management delivers fuel from the tank to the intake ports of the engine. To accomplish this, **fuel supply** must be available to the fuel injectors. Then the fuel must be **injected** in the precise amount and at the correct time. The ECM does not directly monitor fuel supply, although it does control it. The ECM controls and monitors **fuel injection.**



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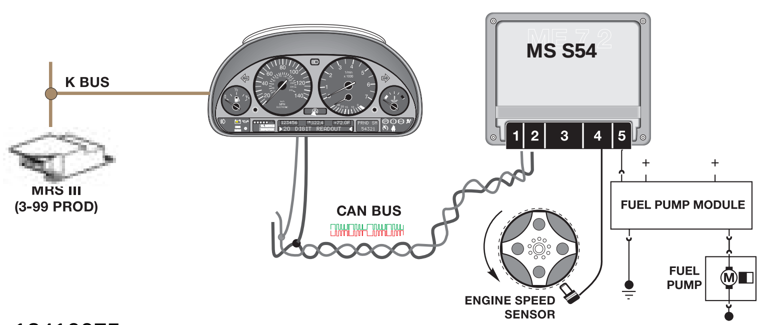
The Fuel Pump supplies fuel when it receives operating voltage from the Fuel Pump Module. The ECM Relay supplies voltage to the Fuel Pump Module (M3 -located in the trunk, above right wheel well).

The ECM controls the activation of the fuel pump module. After the ignition is switched ON, the ECM provides voltage for the fuel pump module and the voltage is maintained (pulse width modulated) with the presence of the engine speed signal.



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A high output fuel pump is utilized to match the fuel supply demands of the S54 engine (5 Bar). The ECM will cycle the voltage signal (0 - 120 Hz) to the fuel pump module. The fuel pump module will cycle the voltage to the pump (to reduce the speed). The fuel pump will operate at low speed during idle and part load. The pump will run at full speed during start-up (approx. 20 seconds) and full load.

The power to the fuel pump module will be switched off in the event of an airbag activation. The MRS lll control module will signal the ECM over K-bus and CAN bus for this purpose.

The Fuel Injectors will be opened by the ECM to inject pressurized fuel into the intake ports. The ECM Relay supplies voltage to the Fuel Injector Relay, the Fuel Injector Relay supplies operating voltage to the injectors. The ECM controls the opening by activating the ground circuit for the Solenoid Windings. The ECM will vary the duration (in milli-seconds) of "opening" time to regulate the air/fuel ratio.

The ECM has six Final Stage output transistors that switch ground to the six injector solenoids. The Injector "triggering" is first established from the Crankshaft Position/RPM Sensor.

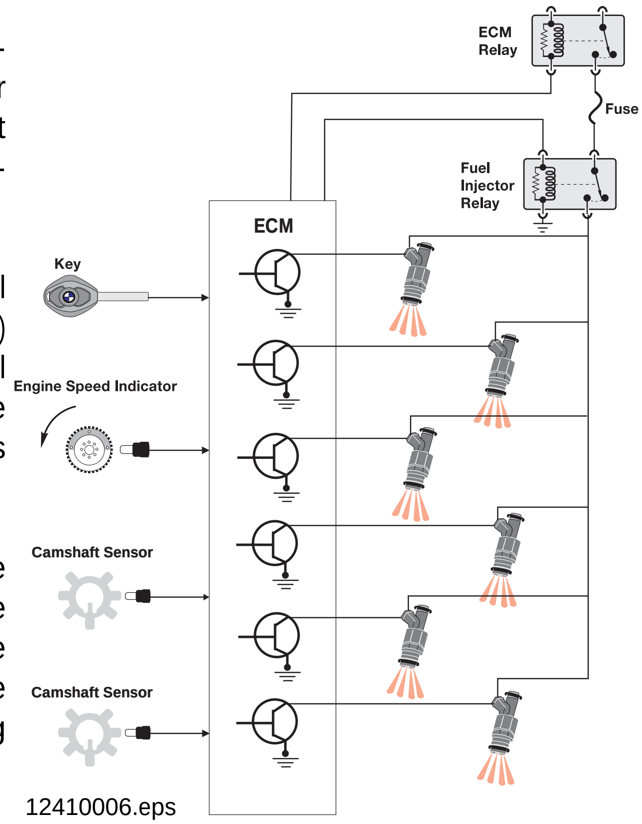
The ECM is programmed to activate the Final Stage output transistors once (per cylinder) for every working cycle of the engine (Full Sequential Injection). The ECM calculates the total milli-second time to open the injectors and triggers them independently.

During start up, the ECM recognizes the Camshaft Position (Cylinder ID) inputs. The camshaft positions are referenced to the crankshaft position. This process "times" the injection closer to the intake valve opening for increased efficiency.

When activated, each injector delivers the full fuel charge at separate times for each cylinder working cycle.

The Camshaft Position input is monitored by the ECM during start up. There will be an effect on injector timing if this input is missing when the engine is started.

When KL15 is switched "off", the ECM discontinues voltage to the Fuel Injector Relay and deactivates the six Final Stage transistors to discontinue fuel injection.



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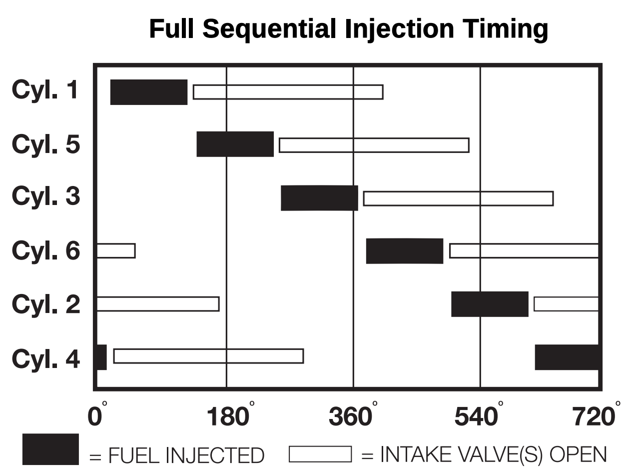

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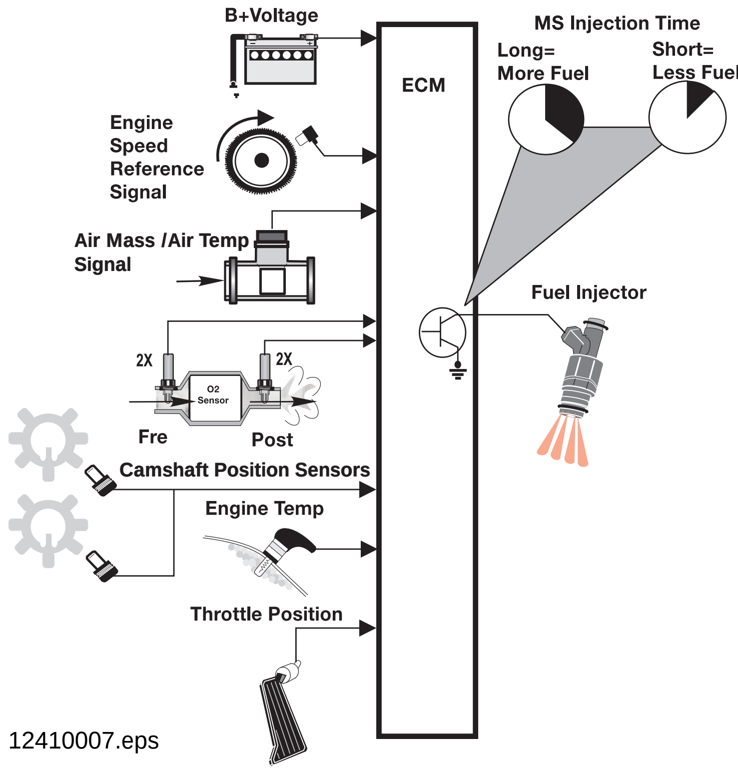
The Injector "open" Time to maintain engine operation after it has been started is determined by the ECM (programming). The ECM will calculate the injector timing based on a combination of the following inputs:

1.	Battery Voltage
2.	Accelerator Pedal Sensor
3.	Air Flow Volume / Mass
4.	Air Temperature
5.	Crankshaft Position / RPM
6.	Camshaft Position (Cylinder ID)
7.	Engine Coolant Temperature
8.	Oxygen Sensor (details in Emissions Management)



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The injection ms value will be regulated based on battery voltage. When cranking, the voltage is low and the ECM will increase the ms value to compensate for injector "lag time". When the engine is running and the battery voltage is higher, the ECM will decrease the injection ms value due to faster injector reaction time.

Cold starting requires additional fuel to compensate for poor mixture and the loss of fuel as it condenses onto cold intake ports, valves and cylinder walls. The cold start fuel quantity is determined by the ECM based on the Engine Coolant Temperature Sensor input during start up.

During cranking, additional fuel is injected for the first few crankshaft revolutions. The ECM recognizes the Camshaft Positions and precisely times the Full Sequential Injection. After the first few crankshaft revolutions, the injected quantity is metered down as the engine comes up to speed.

When the engine is cold, optimum fuel metering is not possible due to poor air/fuel mixing and an enriched mixture is required. The Coolant Temperature input allows the ECM to adjust the injection ms value to compensate during warm up and minimize the the injected fuel at engine operating temperature.

When the engine is at idle, minimum injection is required. Additional fuel will be added if the ECM observes low engine rpm and increasing throttle / air volume inputs (acceleration enrichment). As the accelerator pedal is actuated, the ECM monitors acceleration and rate of movement. The ECM will increase the volume of fuel injected into the engine by increasing the injection ms value. The “full throttle” position indicates maximum acceleration and the ECM will add more fuel (full load enrichment).

As the accelerator pedal is released, the ECM decreases the injection ms value (fuel shut off) if the rpm is above idle speed (coasting). This feature decreases fuel consumption and lowers emissions. When the engine rpm approaches idle speed, the injection ms value is increased (cut-in) to prevent the engine from stalling. The cut-in rpm is dependent upon the engine temperature and the rate of deceleration.

The HFM signal provides the measured amount of intake air volume. This input is used by the ECM to determine the amount of fuel to be injected to “balance” the air / fuel ratio.

The Air Temperature Signal allows the ECM to make a calculation of air density. The varying voltage input from the NTC sensor indicates the larger proportion of oxygen found in cold air, as compared to less oxygen found in warmer air. The ECM will adjust the amount of injected fuel because the quality of combustion depends on oxygen sensing ratio (details in Emissions).

The Crankshaft Position/RPM signals the ECM to start injection as well as providing information about the engine operation. This input is used in combination with other inputs to determine engine load which increases / decreases the injection ms value. ***Without this input, the ECM will not activate the injectors.***

When KL15 is switched “off”, the ECM discontinues voltage to the Fuel Injector Relay and deactivates the six Final Stage transistors to cease fuel injection.

Notes: ____

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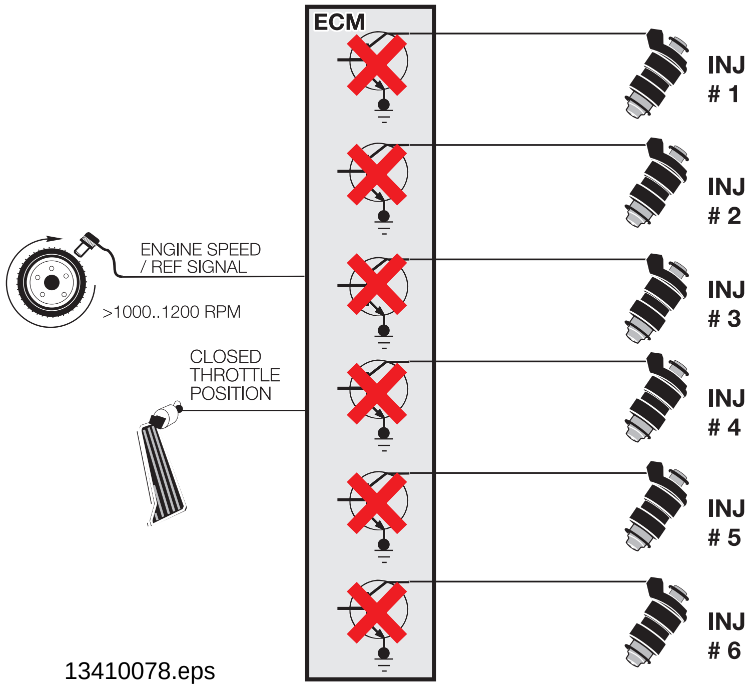
Injection "Reduction" Time is required to control fuel economy, emissions, engine and vehicle speed limitation. The ECM will "trim" back or deactivate the fuel injection as necessary while maintaining optimum engine operation.



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As the throttle is closed during deceleration, the ECM decreases the injection ms value (fuel shut off) if the rpm is above idle speed (coasting). This feature decreases fuel consumption and lowers emissions.

When the engine rpm approaches idle speed, the injection ms value is increased (cut-in) to prevent the engine from stalling. The cut-in rpm is dependent upon the engine temperature and the rate of deceleration.

The ECM will deactivate the injectors to control maximum engine rpm (regardless of vehicle speed). When the engine speed reaches 8000 rpm, the injectors will be deactivated to protect the engine from over-rev. As the engine speed drops below 8000 rpm, injector activation will be resumed. ***This feature does not protect the engine from a forced over-rev such as improperly downshifting a manual transmission equipped vehicle (driver error).***


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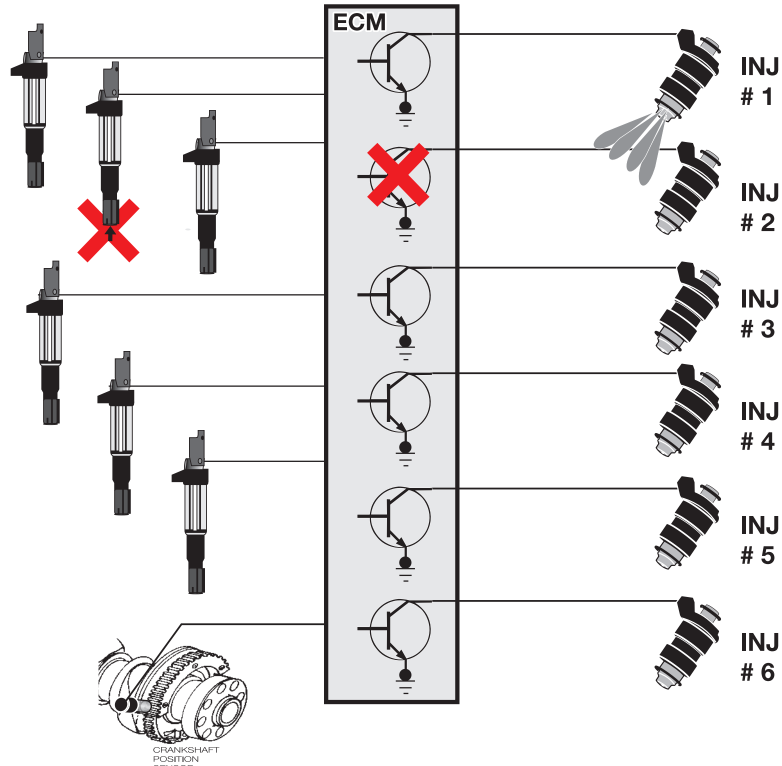
Maximum vehicle speed is limited by the ECM reducing the injection ms value (regardless of engine rpm). This limitation is based on the vehicle dimensions, specifications and installed tires (speed rating).

The ECM will also protect the Catalytic Converters by deactivating the injectors.

If the ECM detects a "Misfire" (ignition, injection or combustion), it will selectively deactivate the Final Stage output transistor for that cylinder(s). On the MS S54 system, there are six individual injector circuits resulting in deactivation of one or multiples. This will limit engine power, but protect the Catalytic Converters.



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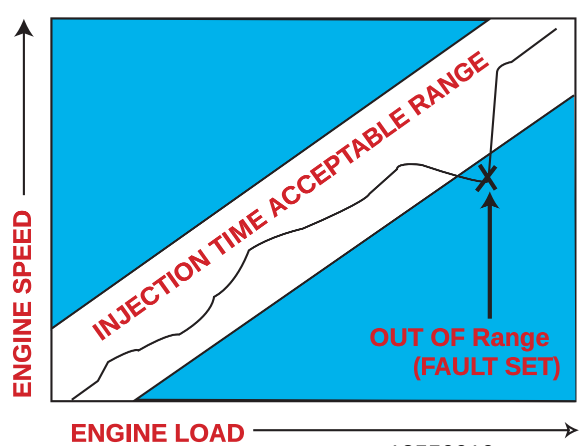
Fuel Injection Control Monitoring is performed by the ECM for OBD II requirements. Faults with the fuel injectors and/or control circuits will be stored in memory. This monitoring includes:

- Closed Loop Operation
- Oxygen Sensor Feedback

These additional corrections are factored into the calculated injection time. If the correction factor exceeds set limits a fault will be stored in memory.

When the criteria for OBD II monitoring is achieved, the "Malfunction Indicator Light" will be illuminated.



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Workshop Hints

Before any service work is performed on any fuel system related component, always adhere to the following:

- Observe relevant safety legislation pertaining to your area.
- Ensure adequate ventilation
- Use exhaust extraction system where applicable (alleviate fumes).
- **DO NOT OPERATE THE FUEL PUMP** unless it is properly installed in the fuel tank and is submersed in the fuel (fuel lubricates the pump).
- **DO NOT SMOKE** while performing fuel system repairs.
- Always wear adequate protective clothing including eye protection.
- Use caution when working around a **HOT** engine compartment.
- BMW does not recommend any **UNAUTHORIZED MODIFICATIONS** to the fuel system. The fuel systems are designed to comply with strict federal safety and emissions regulations. In the concern of product liability, it is unauthorized to sell or perform modifications to customer vehicles, particularly in safety related areas.
- Always consult the **REPAIR INSTRUCTIONS** on the specific model you are working on before attempting a repair.

Fuel

Fuel quality should always be considered when diagnosing a driveability complaint. ***The type of fuel, proper AKI rating, impurities and moisture are not factored by the ECM.***

Please refer to the Owner’s Manual and following Service Information Bulletins regarding fuel:

- Gasoline Fuel Quality S.I. #13 01 88 (1564)
- Gasoline Additive S.I. #13 04 88 (1591)

Fuel Supply

The fuel supply hardware should be visually inspected for damage that can affect pick- up, transfer, pressure and return.

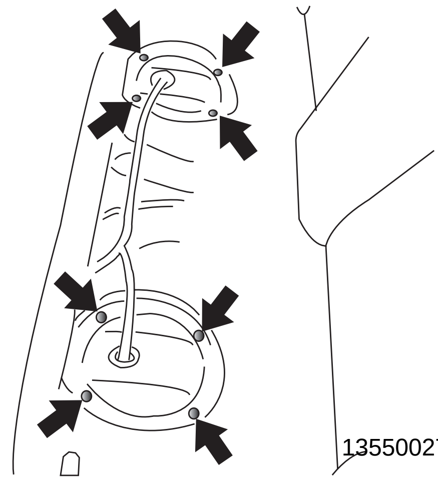
Please refer to the Repair Instructions and Service Information Bulletins details on fuel supply hardware.

Fuel Pump and Sending Unit Access

All BMW vehicles have access plates to service the fuel pump and sending unit(s) without removing the fuel tank.

The E46 M3 access plates are located under the rear seat.

The “saddle” type fuel tank (under rear seat) has two access plates.



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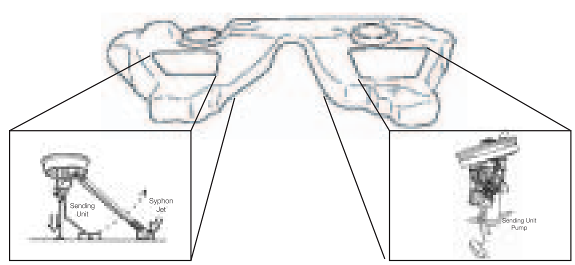
The passenger side allows access to the fuel pump / sending unit.

The driver side accesses the sending unit / syphon jet.



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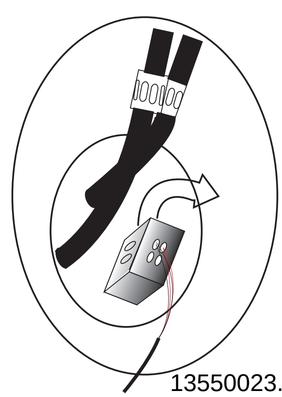
The M roadster and M coupé have a single access plate located behind the passenger seat.



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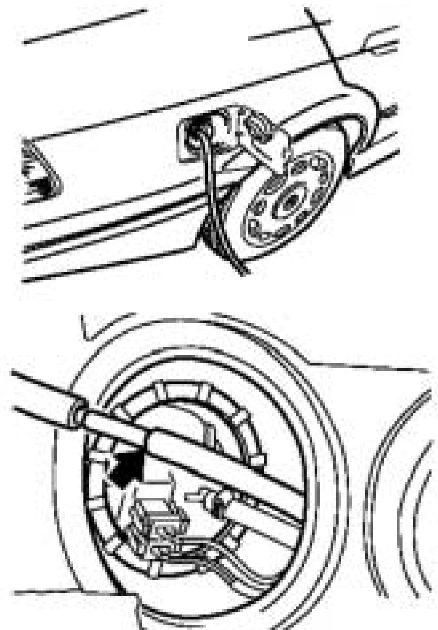
Draining the Fuel Tank

In order to remove the fuel tank it must be drained first to avoid fuel spills and handling excessive weight. In some cases depending on the fuel tank dimensions (vehicle specific), it is also necessary to drain the fuel tank to replace the sending units and/or fuel pump.

CAUTION: In some vehicles, the sending units/fuel pump is mounted lower than the top of the fuel tank. A fuel spill will be encountered if the fuel is not drained.

NOTE: Consult the BMW Service Workshop Equipment for the proper evacuation equipment. The saddle type tank requires an additional step to drain the fuel from the driver side. The evacuation equipment should be attached to the tank compensating hose (arrow) to drain out the remaining fuel.



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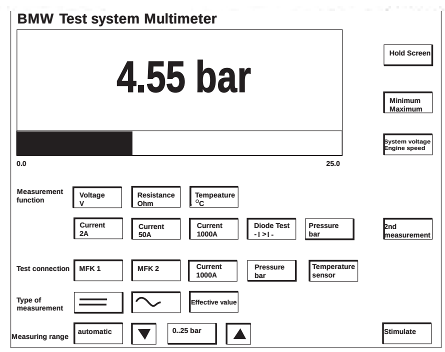
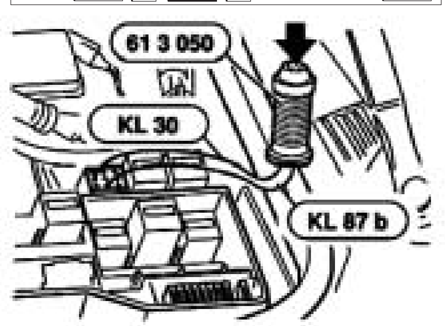
Fuel Pump / Pressure Regulator - Testing

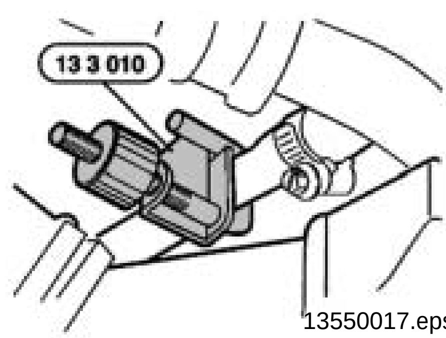
The fuel pump should be tested for delivery pressure and volume. **Caution** when disconnecting fuel hoses because there is the possibility of residual fuel pressure! Install the fuel pressure adapter and DISplus pressure sensing lead to the fuel pressure fitting ****DISplus starts with atmospheric pressure as the base.***



Remove the fuel pump relay/module (M roadster/ coupé located in the Electronics Box, E46 M3 located in the trunk, above right wheel well - see relay testing in the power supply section). Connect the Relay Bypass Switch to pin 87b and 30 of the relay socket. This will activate the fuel pump without running the engine.



If the 5 bar (*+ atmosphere DISplus base starting point) fuel pressure is not achieved or bleed off is more than 0.5 bar, refer to **13 31 of the Repair instructions** for further diagnosis. The Fuel Hose Clamp Tool can be used to isolate bleed off from the pump (non-return check valve) or the pressure regulator (restriction valve). Also verify power supply to the fuel pump.



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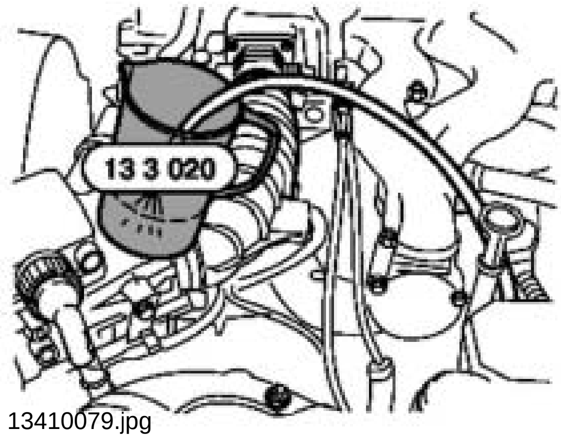
Fuel volume must be tested to verify:

1.	**Fuel Pump Output**
2.	**Restriction are not present in the pump, lines/hoses and fuel filter.**



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Fuel Injectors

When inspecting the fuel injectors, consider the following:

1.	**O-rings should be replaced, lubricate with Vaseline or SAE 90 gear oil for installation.**
2.	**Verify the code number.**
3.	**Color code injector housing**

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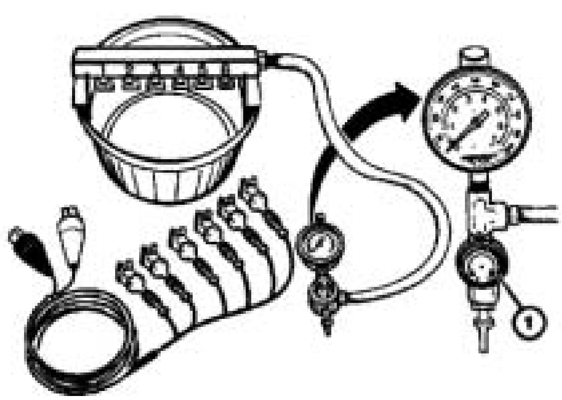
Fuel injectors can leak which bleeds off fuel pressure and increases emissions. The injectors can be tested using the Fuel Injector Leakage Tester.

The fuel injectors can be cleaned, refer to Service Information Bulletin S.I. #04 07 86.



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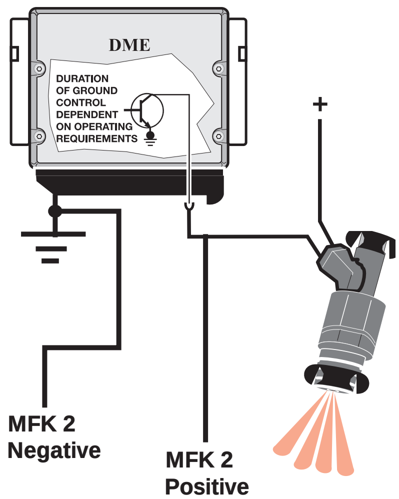
The Fuel Injectors should also be tested using the DISplus/MoDIC for:

1.	**Resistance**
2.	**Power Supply**
3.	**Status Display- Fuel Injection Signal**
4.	**ECM Final Stage transistor activation. This test function is found under the Oscilloscope Preset list-"Ti Injection Signal" Install the 88 pin adapter, Diagnostic cable MFK 2 positive lead to the ground activation circuit for the injector. This test is performed with the engine running.**



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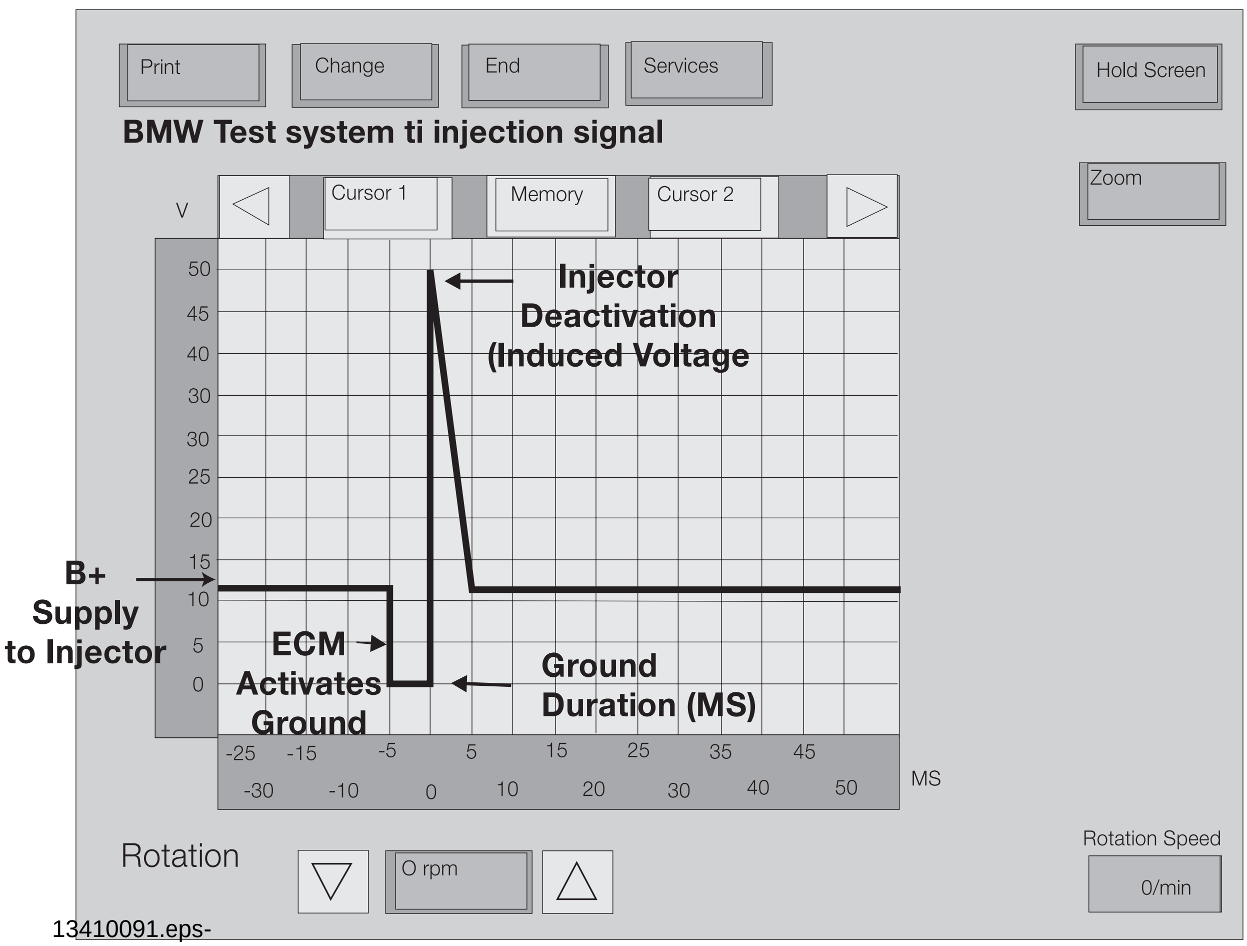

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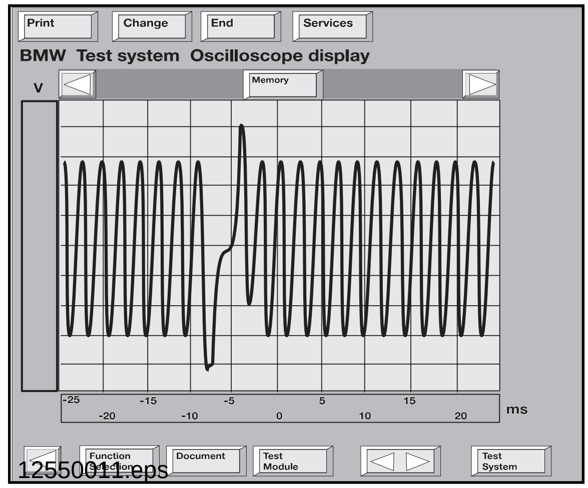
Crankshaft Position/RPM Sensor

This sensor should be tested using the DISplus/MoDIC for:

1.	**Power Supply**
2.	**AC Voltage**
3.	**Status Display**
4.	**Oscilloscope Display Found Under Preset List “Rotation Speed Sensor Signal”**



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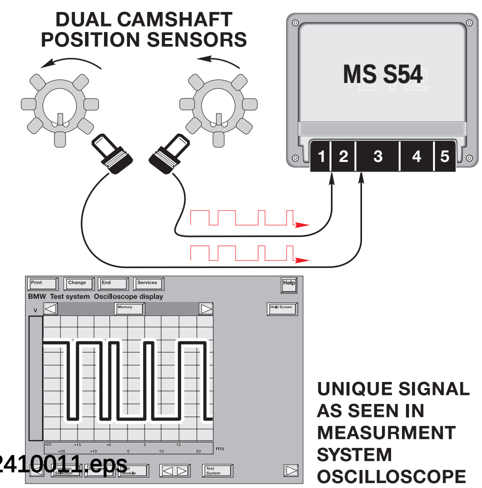
Camshaft Position Sensor (Cylinder ID)

This sensor should be tested using the DISplus/MoDic for:

1.	**Power Supply**
2.	**DC Voltage**
3.	**Status Display**
4.	**Oscilloscope Display Found Under Preset List “Rotation**



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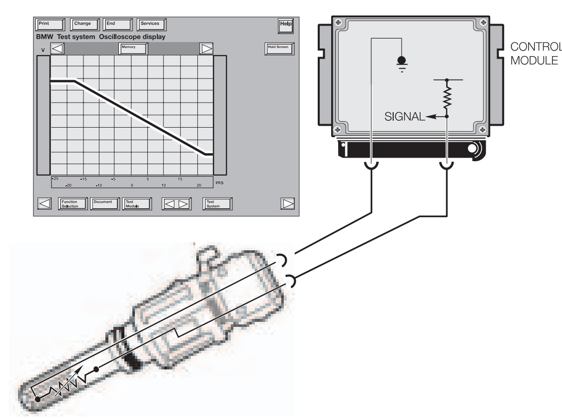
Engine Coolant Temperature

This Sensor should be tested using:

1.	**DISplus/Modic Status Page - Degrees C (dependent on engine temperature)**
2.	**DISplus/Modic Multimeter - Resistance**



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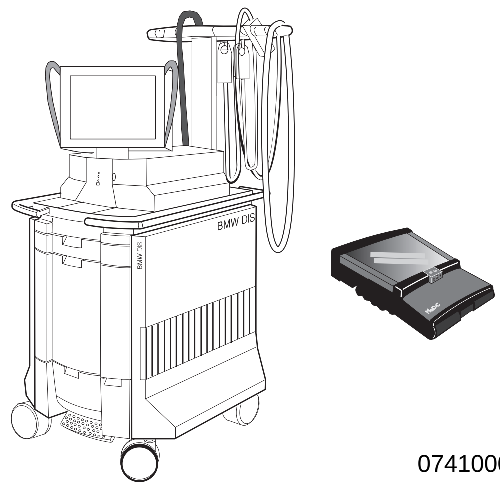
Tools and Equipment

The DISplus/Modic as well as a reputable hand held multimeter can be used when testing inputs/components.

It is best to make the checks at the ECM connection, this method includes testing the wiring harness.



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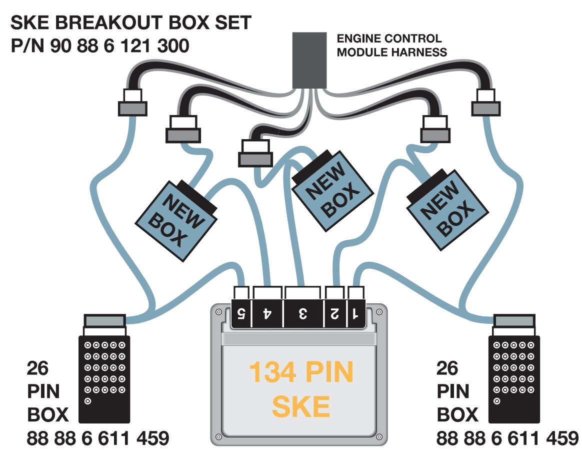
The correct Universal Adapter for the MS S54 application should be used (#90 88 6 121 300). This will ensure the pin connectors and the harness will not be damaged.



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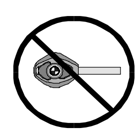
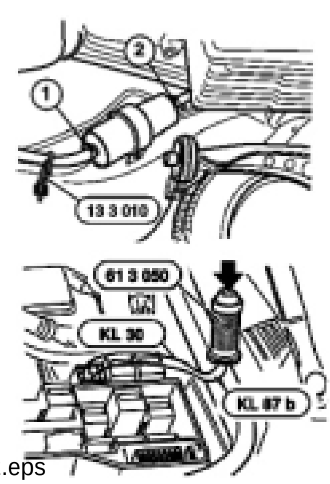
When installing the Universal Adapter to the ECM (located in the Electronics Box in the engine compartment), ***make sure the ignition is switched off.***



The Fuel Hose Clamp Tool (#13 3 010) can be used for isolating pressure faults. In addition, fuel loss can be reduced when changing the fuel filter while loosening clamps (1 and 2).

The Relay Bypass Switch (#61 3 050) must be used especially **when fuel vapors are present!** The switch eliminates the risk of electrical arcing.



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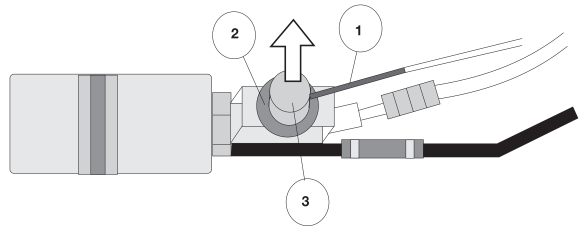
When testing fuel pressure, the DISplus is equipped with a pressure measuring function, found in Measurement testing can be used.

A threaded fitting provides a test point at the fuel pressure regulator. This threaded adapter fitting allows Adapter #13 5 220 to be coupled to the DIS Pressure Adapter.

Caution! Residual fuel pressure may be present.



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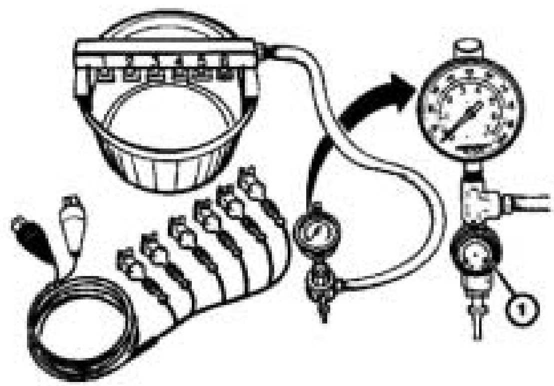
When testing the fuel injectors for leakage, use Special Tool #88 88 5 000 362. Leak testing the fuel injectors is one of the diagnostic steps listed in “Long Cranking Times” S.I. #13 08 90 (3096).

This tool pressurizes the injectors with air and the injector tips are submersed in water. If air bubbles are present, this indicates the leaking injector(s).



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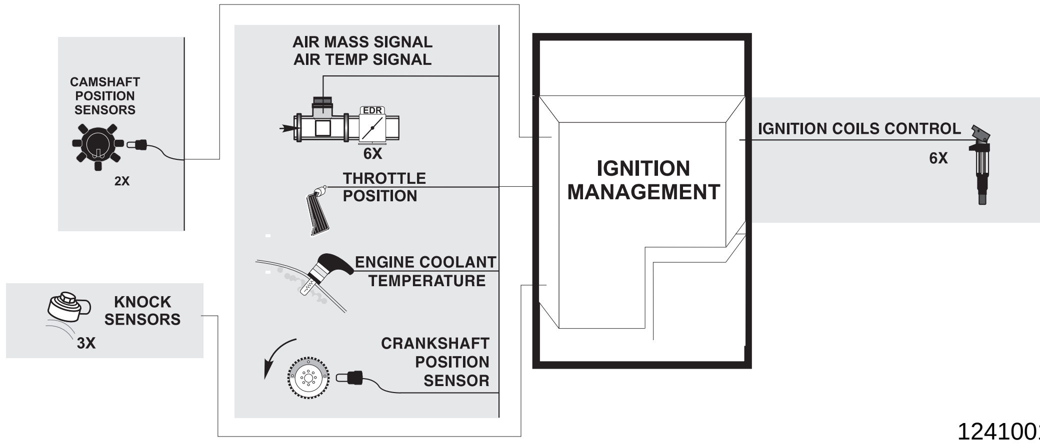
Ignition Management



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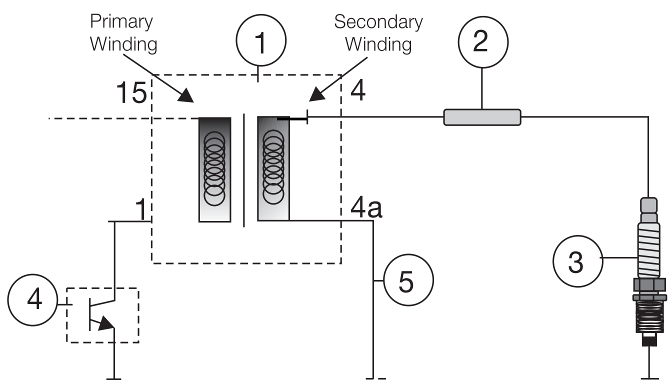
Ignition Coils: The high voltage supply required to ignite the mixture in the combustion chambers is determined by the stored energy in the ignition coils. The stored energy contributes to the ignition duration, ignition current and rate of high voltage increase. The Coil circuit including primary and secondary components consists of:

1.	**Coil Assembly** **- Primary Winding** **- Secondary Winding**
2.	**Insulator Boot**
3.	**Spark Plug**
4.	**ECM Final Stage Transistor**
5.	**Secondary Coil Ground**



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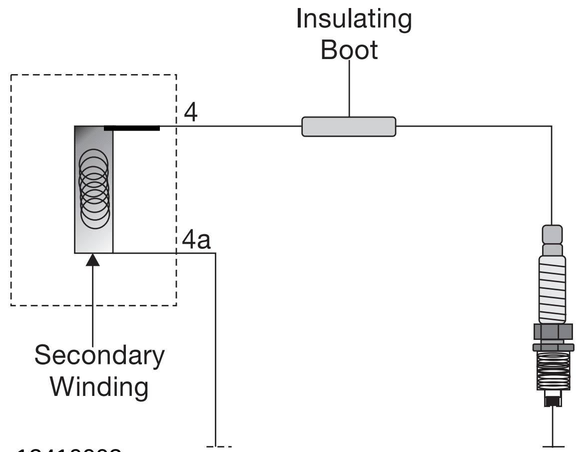
The Coil Assembly contains two copper windings insulated from each other. One winding is the primary winding, formed by a few turns of thick wire. The secondary winding is formed by a great many turns of thin wire.

The primary winding receives battery voltage from the ECM Relay (Coil Terminal 15). The ECM provides a ground path for the primary coil (Coil Terminal 1) by activating a Final Stage transistor. The length of time that current flows through the primary winding is the “dwell” which allows the coil to “saturate” or build up a magnetic field. After this storage process, the ECM will interrupt the primary circuit at the point of ignition by deactivating the Final Stage transistor. The magnetic field built up within the primary winding collapses and induces the ignition voltage in the secondary winding.

The high voltage generated in the secondary winding is discharged through Coil Terminal 4 to the spark plug (insulated by the boot connector).



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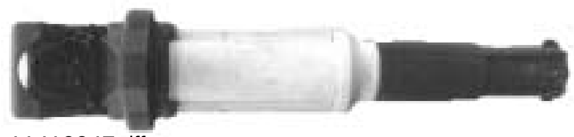
The primary and secondary windings are uncoupled, therefore, the secondary winding requires a ground supply (Coil Terminal 4a).

There is an individual ignition circuit and coil for each cylinder on the MS S54 system. The S54 uses "pencil type" ignition coils manufactured by Bremi. The six individual ignition coils are integrated with the insulated connector (boot).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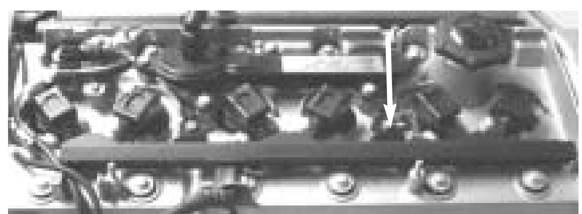
The coils are removed by lifting the swivel latch connector retainer to release the wiring harness, apply a slight twist and lift the assembly upwards.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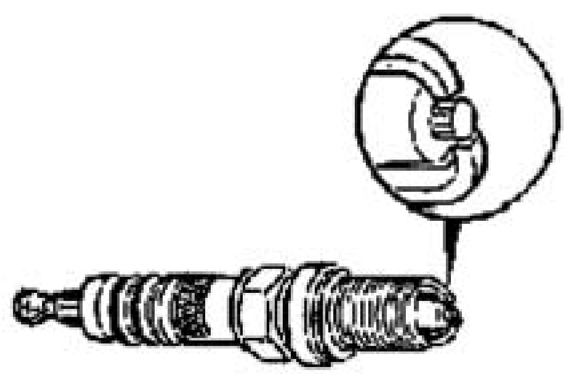
The primary ignition cables are routed on the top of the cylinder head cover. A suppression capacitor is installed on the secondary ignition ground circuit (arrow).

Spark Plugs: The spark plugs introduce the ignition energy into the combustion chamber. The high voltage "arcs" across the air gap in the spark plug from the positive electrode to the negative electrodes. This creates a spark which ignites the combustible air/fuel mixture.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The spark plugs are located in the center of the combustion area (on the top of the cylinder head) which is the most suitable point for igniting the compressed air/fuel mixture.

The correct spark plugs for the S54 are NGK DCPR8EKP dual electrode (non-adjustable gap).

Faults with the Ignition Output Components are monitored by the ECM. If there are faults with the ignition coil(s) output, and/or spark plugs, the following complaints could be encountered:

1.	“Service Engine Soon” Light with Mixture Related and / or Misfire Fault Codes
2.	Poor Engine Performance
3.	Engine Misfire
4.	No Start/Hard Starting
5.	Excessive Exhaust Emission/Black Smoke

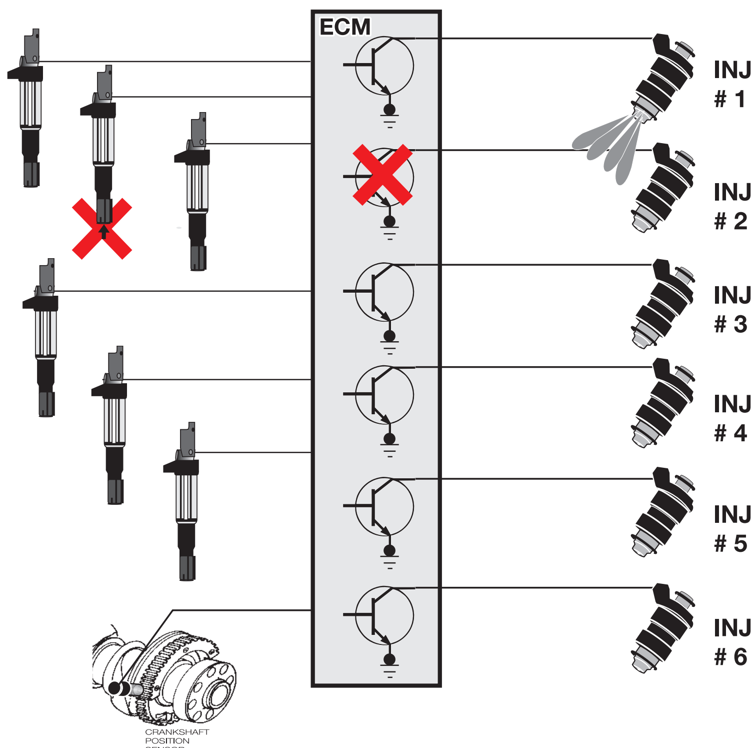
The Ignition Output Components must be individually tested (see Workshop Hints).

The **primary ignition** circuits are monitored by the ECM.

If a fault is present, the “Malfunction Indicator Light” will illuminate and the ECM will deactivate the corresponding fuel injector for that cylinder. Engine operation will still be possible.

The **secondary ignition** is monitored by the ECM via the Crankshaft Position/RPM Sensor.

If a Misfire fault is present, the “Malfunction Indicator Light” will illuminate and the ECM will deactivate the corresponding fuel injector for that cylinder. Engine operation will still be possible.



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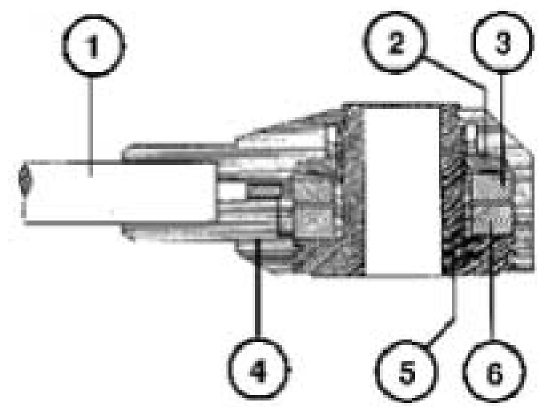
Knock Sensors: are required to prevent detonation (pinging) from damaging the engine. The Knock Sensor is a piezoelectric conductor-sound microphone. The ECM will retard the ignition timing (cylinder selective) based on the input of these sensors. Detonation can occur due to:

1.	**High Compression Ratio**	**4.**	**Maximum Timing Advance Curve**
2.	**Poor Quality Fuel (Octane Rating)**	**5.**	**High Intake Air and Engine Temperatures**
3.	**High Level of Cylinder Filling**	**6.**	**Carbon Build-Up (Combustion Chamber)**

The Knock Sensor consists of:

1.	**Shielded Wire**
2.	**Cup Spring**
3.	**Seismic Mass**
4.	**Housing**
5.	**Inner Sleeve**
6.	**Piezo-Ceramic Element**



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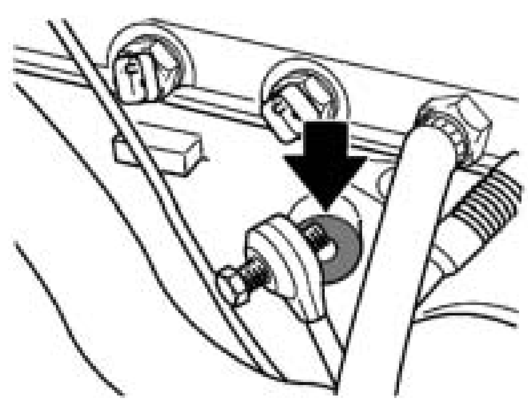
A piezo-ceramic ring is clamped between a seismic mass and the sensor body. When the seismic mass senses vibration (flexing), it exerts a force on the piezo-ceramic element. Opposed electrical charges build up on the upper and lower ceramic surfaces which generates a voltage signal. The acoustic vibrations are converted into electrical signals. These low voltage signals are transmitted to the ECM for processing.

There are three Knock Sensors bolted to the engine block between cylinders 1 & 2, 3 & 4 and 5 &6. If the signal value exceeds the threshold, the ECM identifies the "knock" and retards the ignition timing for that cylinder.

If a fault is detected with the sensor(s), the ECM deactivates Knock Control and the "Malfunction Indicator Light" will be illuminated. The ignition timing will be set to a conservative basic setting based on intake air temperature and a fault will be stored.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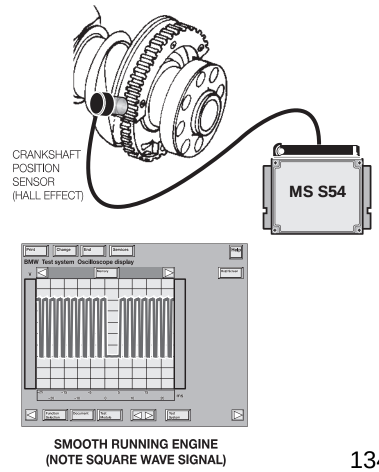
Crankshaft Position/RPM Sensor: This sensor provides the crankshaft position and engine speed (RPM) signal to the ECM for ignition activation and correct timing. This input is also monitored for Misfire Detection. For details about the sensor, refer to the Fuel Management section.

A fault with this input will produce the following complaints:

1.	**No Start**
2.	**Intermittent Misfire/Driveability**
3.	**Engine Stalling**



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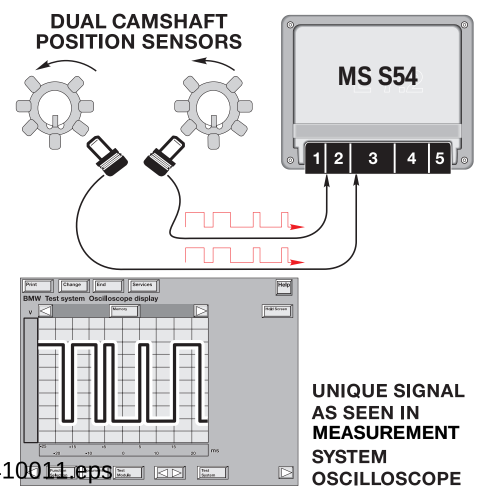
Camshaft Position Sensor (Cylinder Identification): The camshaft sensors (Hall type) inputs allows the ECM to determine camshaft positions in relation to crankshaft position. It is used by the ECM to establish the "working cycle" of the engine for precise ignition timing. For details about the sensor, refer to the Fuel Management section.

If the ECM detects a fault with the Camshaft Sensors, the "Malfunction Indicator Light" will be illuminated and the ignition will still operate based on the Crankshaft Position/RPM Sensor.



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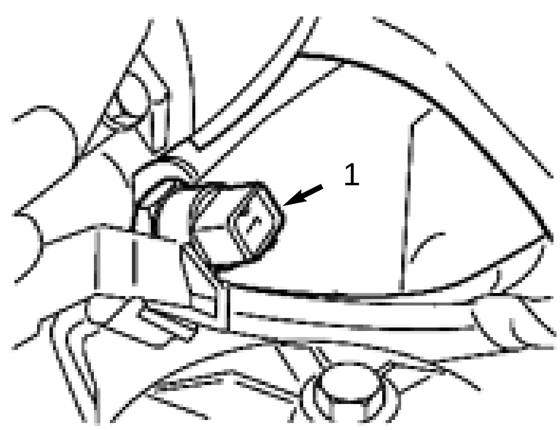
Engine Coolant Temperature: The ECM determines the correct ignition timing required for the engine temperature. For details about the sensor, refer to the Fuel Management section. This sensor is located in the coolant return pipe on the cylinder head (1).

If the Coolant Temperature Sensor input is faulty, the "Malfunction Indicator Light" will be illuminated and the ECM will use the oil temperature sensor as an alternate. The ignition timing will be set to a conservative basic setting.



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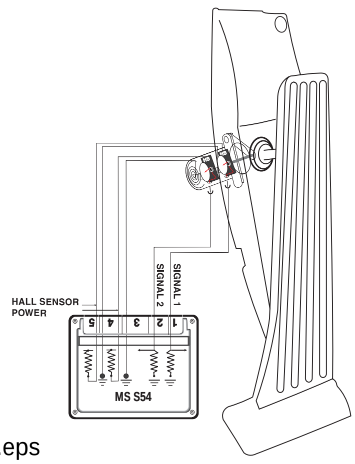
Accelerator Pedal Position (PWG): As the accelerator pedal is actuated, the ECM will advance the ignition timing. The “full throttle” position indicates maximum acceleration to the ECM, the ignition will be advanced for maximum torque.

For details about the sensor, refer to the Air Management section.



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Hot-Film Air Mass Meter (HFM): The air volume input signal is used by the ECM to determine the amount of ignition timing advance.

For details about the sensor, refer to the Air Management section.

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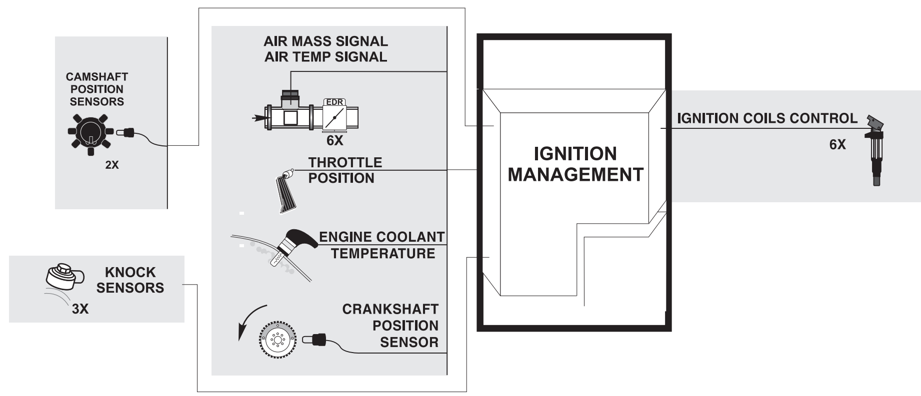
Air Temperature: This signal allows the ECM to make a calculation of air density. The sensor is located in the HFM. For details about the sensor, refer to the Air Management section.

The ECM will adjust the ignition timing based on air temperature. If the intake air is hot the ECM retards the ignition timing to reduce the risk of detonation. If the intake air is cooler, the ignition timing will be advanced.

If this input is defective, a fault code will be set and the “Malfunction Indicator Light” will illuminate. The ignition timing will be set to a conservative basic setting.

Principle of Operation

Ignition Management provides ignition to the combustion chambers with the required voltage at the correct time. Based on the combination of inputs, the ECM calculates and controls the **ignition timing** and **secondary output voltage** by regulating the activation and dwell of the **primary ignition circuit.** The ECM controls and monitors the primary ignition circuit as well as the secondary ignition output (Misfire Detection).



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The ECM has a very “broad” range of ignition timing. This is possible by using a Direct Ignition System, or sometimes referred to as “Static Ignition System”. Reliability is also increased by having separate individual ignition circuits.

The Ignition Control is determined by the ECM (load dependent). The ECM will calculate the engine “load” based on a combination of the following inputs:

1. Battery Voltage	**4. Accelerator Pedal Position**	**7. Knock Sensor**
2. Air Temperature	**5. Engine Coolant**	**8. Air Flow Volume**
3. Camshaft Position (Cylinder ID)	**6. Crankshaft Position/RPM**	

The dwell time will be regulated based on battery voltage. When cranking, the voltage is low and the ECM will increase the dwell to compensate for saturation “lag time”. When the engine is running and the battery voltage is higher, the ECM will decrease the dwell due to a faster saturation time.

The Crankshaft Position/RPM signals the ECM to start ignition in firing order (1-5-3-6-2-4) as well as providing information about the engine operation. This input is used in combination with other inputs to determine engine load which advances/retards the ignition timing. Without this input, the ECM will not activate the ignition.

Cold start is determined by the ECM based on the engine coolant temperature and rpm during start up. A cold engine will crank over slower than a warm engine, the ignition timing will range between top dead center to slightly retarded providing optimum starting.

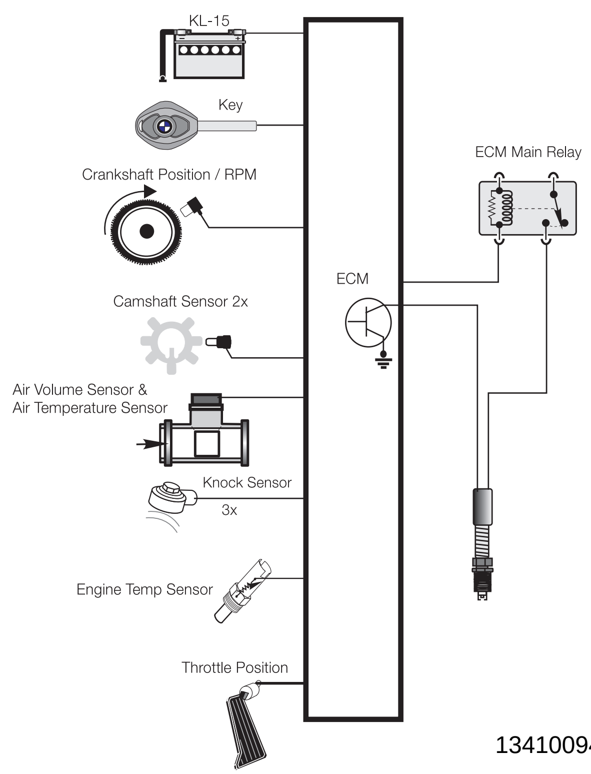
When starting a warm engine, the rpm is higher which results in slightly advanced timing. If the engine coolant and intake air temperature is hot, the ignition timing will not be advanced reducing starter motor “load”.

During cranking, the ECM recognizes the Camshaft Position (compression stroke) and activates a single ignition per cylinder. The ignition timing will be progressively advanced assisting the engine in coming up to speed.

As the engine speed approaches idle rpm, the timing remains slightly advanced to boost torque.

When the engine is at idle speed, minimum timing advance is required. This will allow faster engine and catalyst warm up.

The timing will be advanced when the ECM observes low engine rpm and increasing accelerator/air volume inputs (acceleration torque). As the throttle is opened, the ECM advances the timing based on engine acceleration and at what rate. The ECM will fully advance timing for the “full throttle” position indicating maximum acceleration (torque).



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The Air Flow Volume signal provides the measured amount of intake air volume. This input is used by the ECM to determine the amount of timing advance to properly combust the air/fuel mixture.

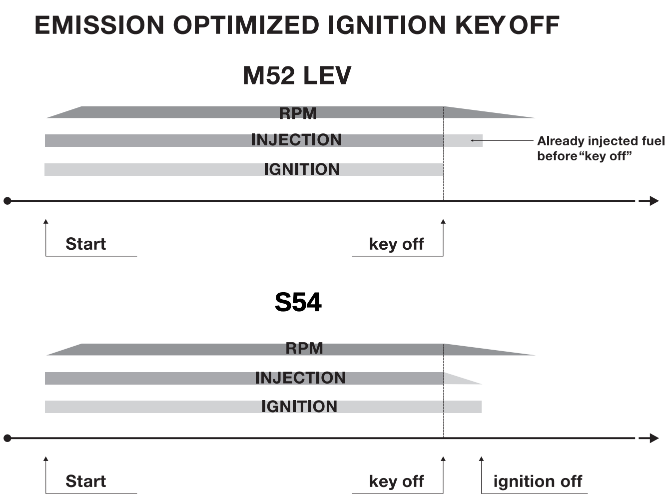
The Air Temperature Signal assists the ECM in reducing the risk of detonation (ping). If the intake air is hot the ECM retards the ignition timing. If the intake air is cooler, the ignition timing will be advanced.

As the throttle is closed, the ECM decreases the ignition timing if the rpm is above idle speed (coasting). This feature lowers the engine torque for deceleration. When the engine rpm approaches idle speed, the timing is slightly advanced to prevent the engine from stalling. The amount of advance is dependent upon the engine temperature and the rate of deceleration.

EMISSION OPTIMIZED - IGNITION KEY OFF

“Emission Optimized Ignition Key Off” is a programmed feature of the MS 54 ECM. After the ECM detects KL 15 is switched “off”, the ignition stays active (ECM Relay/voltage supply) for two more individual coil firings. This means that just two cylinders are fired - not two revolutions.

This feature allows residual fuel injected into the cylinders, as the ignition key is switched off, to be combusted as the engine runs down.



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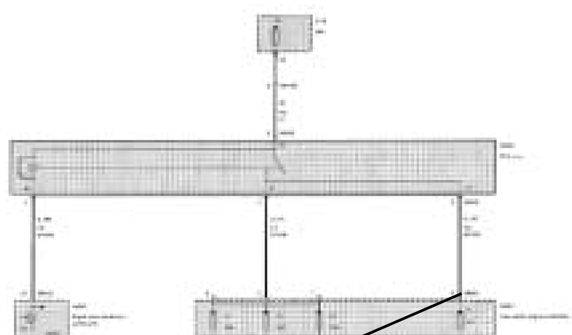
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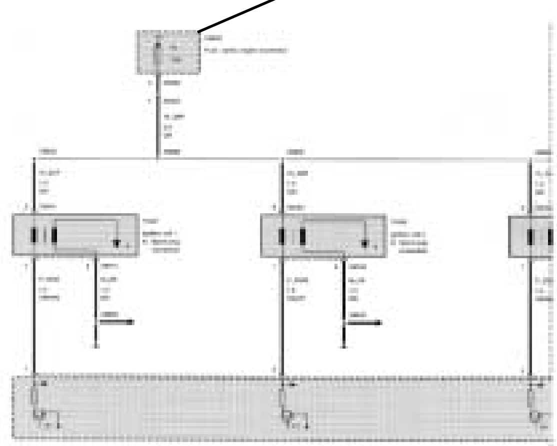
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When **KL15** is switched “off” the ECM operating voltage is removed. The ECM will maintain a ground to the Engine Control Module Relay for a few seconds to maintain ignition coil activation.

Knock Control

The use of Knock Control allows the ECM to further advance the ignition timing under load for increased torque. This system uses three Knock Sensors located between cylinders 1 & 2, cylinders 3 & 4 and cylinders 5 & 6.

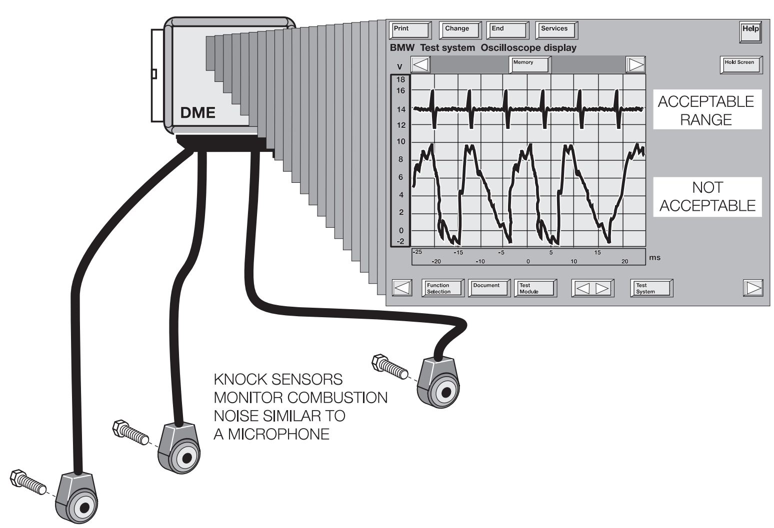
Knock Control is only in affect when the engine temperature is greater than 35 ºC and there is a load on the engine. This will disregard false signals while idling or from a cold engine.

Based on the firing order, the ECM monitors the Knock Sensors after each ignition for a normal (low) signal.

If the signal value exceeds the threshold, the ECM identifies the “knock” and retards the ignition timing (3º) for that cylinder the next time it is fired.

This process is repeated in 3º increments until the knock ceases. The ignition timing will be advanced again in increments right up to the knock limit and maintain the timing at that point.

If a fault is detected with the Knock Sensor(s) or circuits, the ECM deactivates Knock Control. The “Malfunction Indicator Light” will be illuminated, the ignition timing will be set to a conservative basic setting (to reduce the risk of detonation) and a fault will be stored.



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Workshop Hints

Before any service work is performed on any ignition system related component, always adhere to the following:

- Observe relevant safety legislation pertaining to your area.
- Always wear adequate protective clothing including eye protection.
- Use caution when working around a **HOT** engine compartment.
- Always consult the **REPAIR INSTRUCTIONS** on the specific model you are working on before attempting a repair.
- Always **switch off the ignition (KL15)** before working on the ignition system.
- Use only BMW approved test leads.
- **Never touch components conducting current** with the engine running!
- Do not connect suppression devices or a "test light" to terminal 1 of the ignition coils.
- Terminal 1 of the ignition coil must not be connected to Ground or B+.
- Never run the engine with a secondary ignition component disconnected.

HIGH VOLTAGE - DANGER!

Caution! Hazardous voltages occur at:

- Ignition Leads
- Spark Plug Connector
- Spark Plug
- Ignition Coil (High Voltage at terminal 4 is approximately 30 KV)
- Terminal 1 from the ignition coil to the ECM (High Voltage approximately 350 V)

Ignition System Diagnosis

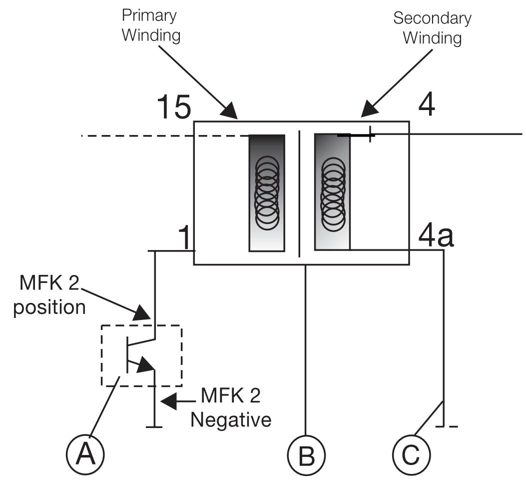
A fault survey should first be performed using the DISplus/MoDIC to determine if there is a fault in the primary ignition or secondary ignition.

If there is a fault in the primary ignition, testing should include:

- Power Supply at the Coil (KL15)

- Resistance of the harness and ignition coil primary winding (terminal 15 to 1 approx. 0.8 ohms) - using the 134 Pin Adapter Set with the ECM disconnected.

A.	**ECM Primary Circuit Final Stage Transistor**
B.	**Ignition Coil (one of four)**
C.	**Secondary Coil Ground**



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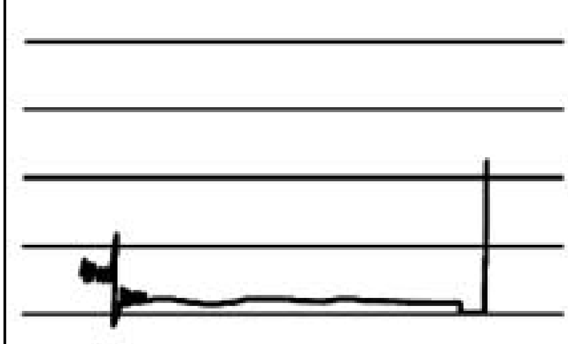
- ECM Final Stage transistor activation. This test function is found under the Oscilloscope Preset list - “Ignition Signal Primary” (normal Terminal 1 Signal shown on the right).

  Install the 134 Pin Adapter Set, Diagnostic cable, MFK 2 negative lead to ECM ground and MFK 2 positive lead to the ground activation circuit for Terminal 1 of the ignition coil. This test is performed with the engine running.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If there is a fault in the secondary ignition, testing should include:

- Primary Ignition
- Evaluation of Secondary Oscilloscope Patterns

The Repair Instructions should be consulted for additional Oscilloscope Patterns under various engine speeds.

In Summary,

If the Secondary Ignition **Voltage is Too High (Excessive Resistance for Ignition) :**

- Spark Plug Gap is to Large (Worn or Burned)
- Incorrect Heat Range Spark Plug
- Compression is too High (Carbon, etc.)
- Lean Mixture (Vacuum Leak, etc.)
- Interruption in the Secondary Ignition Cable, Connector, or Resistive Adapter Boot

If the Secondary Ignition **Voltage is Too Low (Low Resistance for Ignition):**

- Spark Plug Gap is Too Small (Mishandled on Installation)
- Incorrect Heat Range Spark Plug
- Compression is Too Low
- Voltage Leak in the Secondary Ignition Cable, Connector, or Resistive Boot to Ground

Spark Plugs

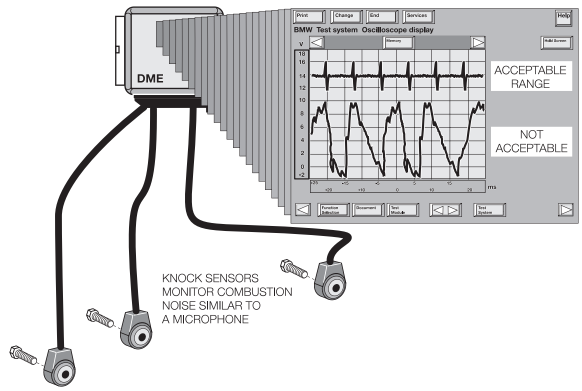
The Spark Plugs should be inspected for the proper type, gap and replaced at the specified intervals.

Refer to the Service Information Bulletin S.I. #12 01 99 for the proper type and a visual of the spark plug (showing effects of combustion, fouling, etc.)

Knock Sensors

The Knock Sensors should be tested using the DISplus/MoDIC for:

1.	**Fault Codes**
2.	**Status Display** **-Knock Control (active/not active)**
3.	**Oscilloscope Display** **(Low DC Voltage-mV Setting)**



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When installing Knock Sensors:

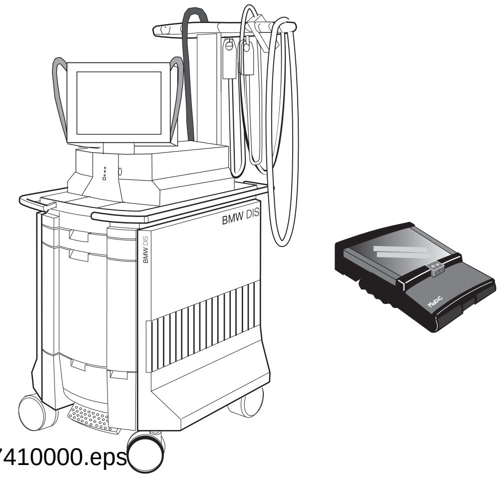
DO NOT MIX THE CONNECTORS: Engine Damage will result! - the connector is critical to sensor location.

Do Not Over Tighten attaching bolt! - Piezo ceramic will be cracked. Torque to 20 nm.

Do Not Under Tighten attaching bolt, a loose sensor can vibrate producing a similar signal to a knock.

Tools and Equipment

The DISplus/MoDIC as well as a reputable hand held multimeter can be used when testing inputs/components. It is best to make the checks at the ECM connection, this method includes testing the wiring harness.



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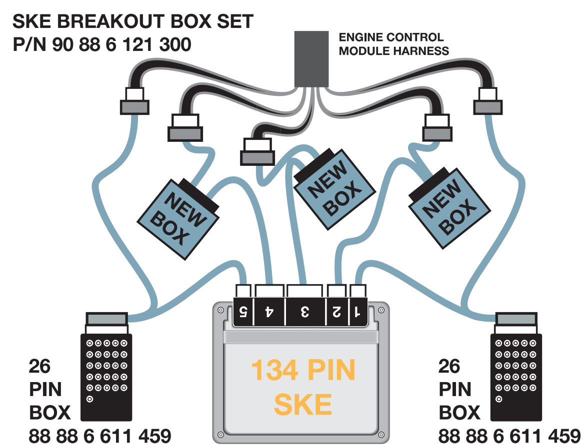
The correct Universal Adapter for the MS S54 application should be used (#90 88 6 121 300). This will ensure the pin connectors and the harness will not be damaged.



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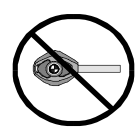
When installing the Universal Adapter to the ECM (located in the Electronics Box in the engine compartment), ***make sure the ignition is switched off.***



When Testing the Secondary Ignition System, use the High Tension clip of the DISplus. Refer to the HELP button for additional (on screen) connections.

Caution! Observe Safety Precautions, High Voltage is Present with the Engine Running

The Spark Plugs should be properly installed and torqued using the following Special Tools:

- 12 1 200 Torque Adapter (prevents over tightening)
- 12 1 171 Spark Plug Socket

13410012.bmp

NOTE: NEVER USE AIR TOOLS FOR REMOVAL OR INSTALLATION!

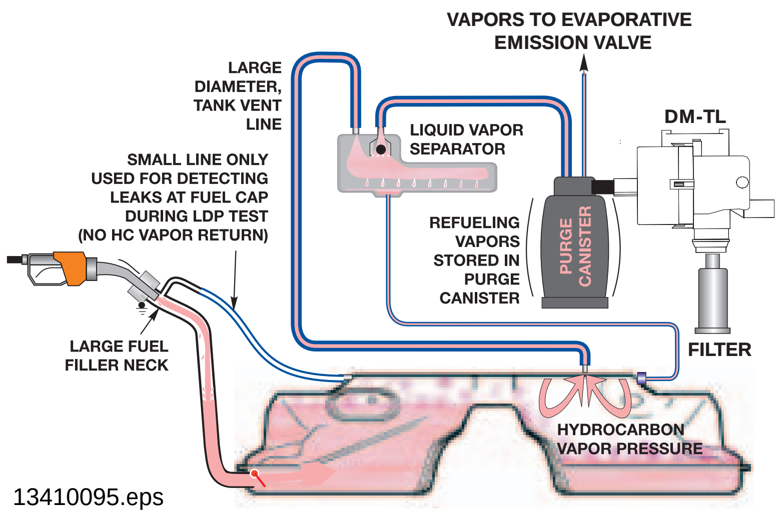
Table of Contents

Subject **Page**

Emissions Management

Evaporative Emissions: The control of the evaporative fuel vapors (Hydrocarbons) from the fuel tank is important for the overall reduction in vehicle emissions.

The evaporative system has been combined with the ventilation of the fuel tank, which allows the tank to breath (equalization). The overall operation provides:



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- An inlet vent, to an otherwise "sealed" fuel tank, for the entry of air to replace the fuel consumed during engine operation.
- An outlet vent with a storage canister to "trap and hold" fuel vapors that are produced by the expansion/evaporation of fuel in the tank, when the vehicle is stationary.

The canister is then "purged" using the engine vacuum to draw the fuel vapors into the combustion chamber. This "cleans" the canister allowing for additional storage. Like any other form of combustible fuel, the introduction of these vapors on a running engine must be controlled. The ECM controls the Evaporative Emission Valve which regulates purging of evaporative vapors.

ON-BOARD REFUELING VAPOR RECOVERY (ORVR)

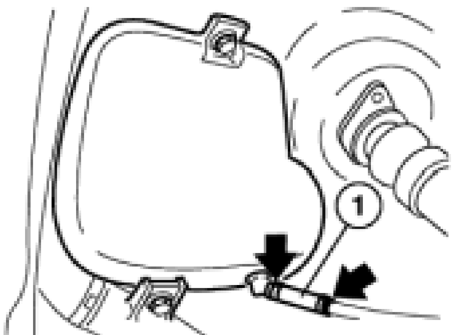
The ORVR system recovers and stores hydrocarbon fuel vapor that was previously released during refueling. Non ORVR vehicles vent fuel vapors from the tank venting line back to the filler neck and in many states reclaimed by a vacuum receiver on the filling station's fuel pump nozzle.

When refueling, the pressure of the fuel entering the tank forces the hydrocarbon vapors through the tank vent line to the liquid/ vapor separator, through the rollover valve and into the charcoal canister.

The HC is stored in the charcoal canister, and the system can then "breath" through the DM TL and the air filter.

Liquid/Vapor Separator: Fuel vapors are routed from the fuel tank filler neck through a hose to the Liquid/Vapor Separator (located in the right rear wheel well behind the trim).

The vapors cool when exiting the fuel tank, the condensates separate and drain back to the fuel tank through a return hose (1). The remaining vapors exit the Liquid/ Vapor Separator to the Active Carbon Canister.



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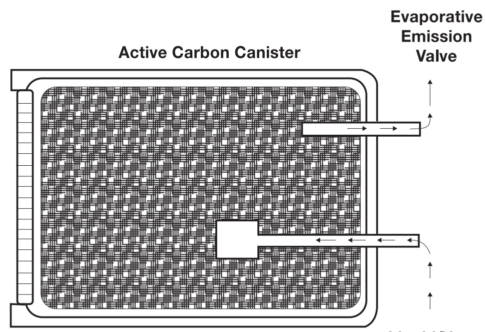
Active Carbon Canister: As the fuel vapors enter the canister, they will be absorbed by the active carbon. The remaining air will be vented to the atmosphere through the end of the canister (passing through the DMTL and filter) allowing the fuel tank to “breath”.



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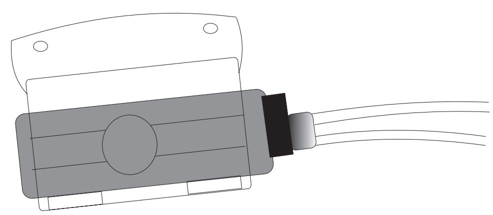
When the engine is running, the canister is then "purged" using intake manifold vacuum to draw fresh air through the canister which extracts the hydrocarbon vapors into the combustion chamber. This cleans the canister for additional storage. The Active Carbon Canister is located under the luggage compartment floor with the DM TL Pump.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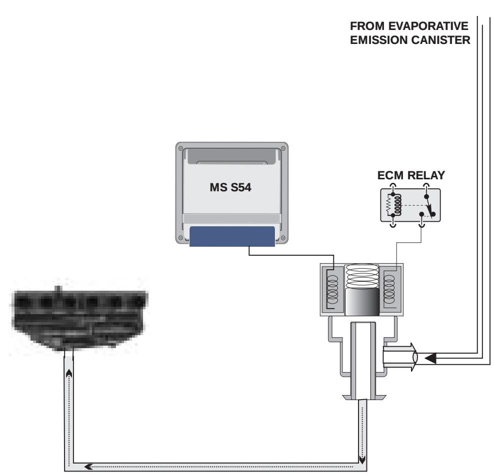
Evaporative Emission Valve: This ECM controlled solenoid valve (located under the intake manifold) regulates the purge flow from the Active Carbon Canister through the idle air distribution pipe into the intake manifold .

The ECM Relay provides operating voltage, and the ECM controls the valve by regulating the ground circuit. The valve is powered open and closed by an internal spring.

If the Evaporative Emission Valve circuit is defective, a fault code will be set and the “Malfunction Indicator Light” will be illuminated. If the valve is “mechanically” defective, a driveability complaint could be encountered and a mixture related fault code will be set.



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DMTL (Diagnosis Module - Evaporative Leakage Detection): This component ensures accurate fuel system leak detection for leaks as small as 1.0 mm (.040”) by slightly pressurizing the fuel tank and evaporative components. The DM TL pump contains an integral DC motor which is activated directly by the ECM. The ECM monitors the pump motor operating current as the measurement for detecting leaks.

The pump also contains an ECM controlled change over valve that is energized closed during a Leak Diagnosis test. The change over valve is open during all other periods of operation allowing the fuel system to “breath” through the inlet filter. The DM TL is located under the luggage compartment floor with the Active Carbon Canister.

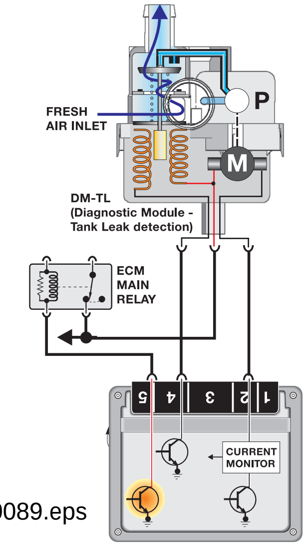
1. In its inactive state, filtered fresh air enters the evaporative system through the sprung open valve of the DM TL.

2. When the DME activates the DM TL for leak testing, it first activates only the pump motor. This pumps air through a restricted orifice (1.0 mm) which causes the electric motor to draw a specific amperage value. This value is equivalent to the size of the restricted.

3. The solenoid valve is then energized which seals the evaporative system and directs the pump output to pressurize the evaporative system.

- A large leak is detected in the evaporative system if the amperage value is not achieved.
- A small leak is detected if the same reference amper age is achieved.
- The system is sealed if the amperage value is higher than the reference amperage.

1



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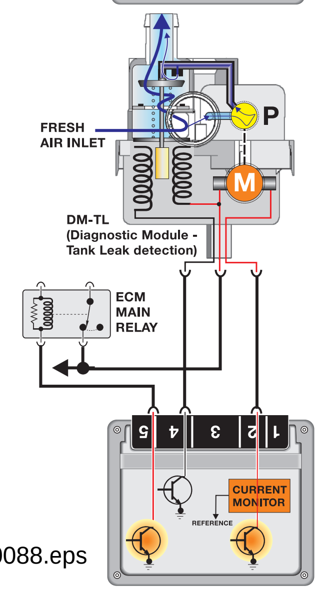

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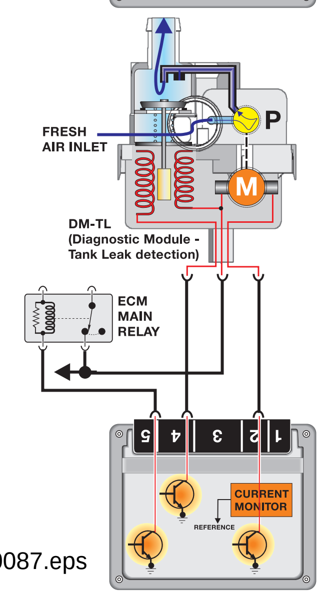

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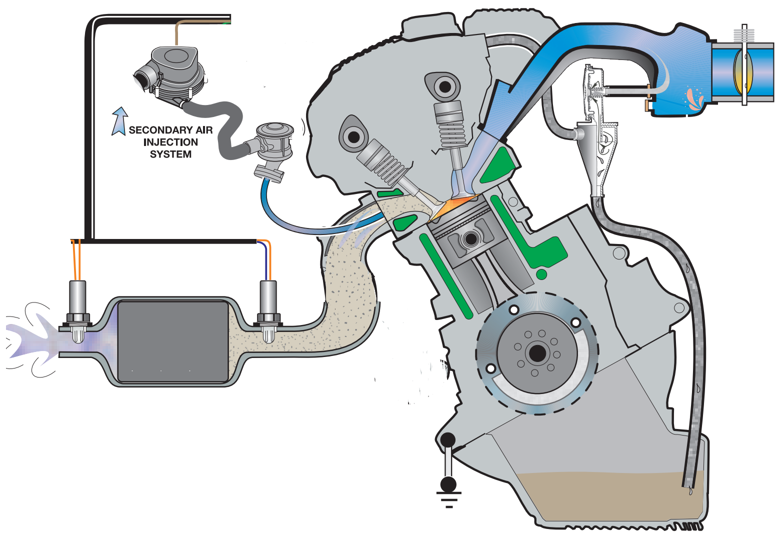
Exhaust Emissions: The combustion process of a gasoline powered engine produces Carbon Monoxide (CO), Hydrocarbons (HC) and Oxides of Nitrogen (NOx).

- Carbon Monoxide is a product of incomplete combustion under conditions of air deficiency. CO emissions are strongly dependent on the air/fuel ratio.

- Hydrocarbons are also a product of incomplete combustion which results in unburned fuel. HC emissions are dependent on air/fuel ratio and the ignition of the mixture.



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- Oxides of Nitrogen are a product of peak combustion temperature (and temperature duration). NOx emissions are dependent on internal cylinder temperatures affected by the air/fuel ratio and ignition of the mixture.

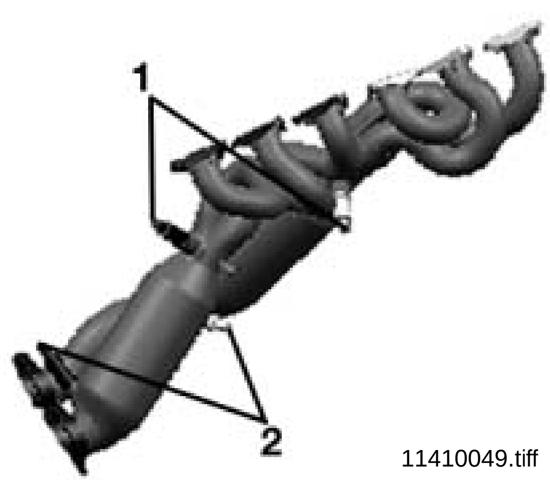
Control of exhaust emissions is accomplished by the engine and engine management design as well as after-treatment.

- The ECM manages exhaust emissions by controlling the air/fuel ratio and ignition.

- The Catalytic Converter further reduces exhaust emissions leaving the engine.

Bosch LSH 25 Oxygen Sensors: The pre-cat oxygen sensors (1) measure the residual oxygen content of the exhaust gas. The sensors produces a low voltage (0-1000 mV) proportional to the oxygen content that allows the ECM to monitor the air/fuel ratio.

If necessary, the ECM will “correct” the air/fuel ratio by regulating the ms injection time. The sensor is mounted in the hot exhaust stream directly in front of the catalytic converter.



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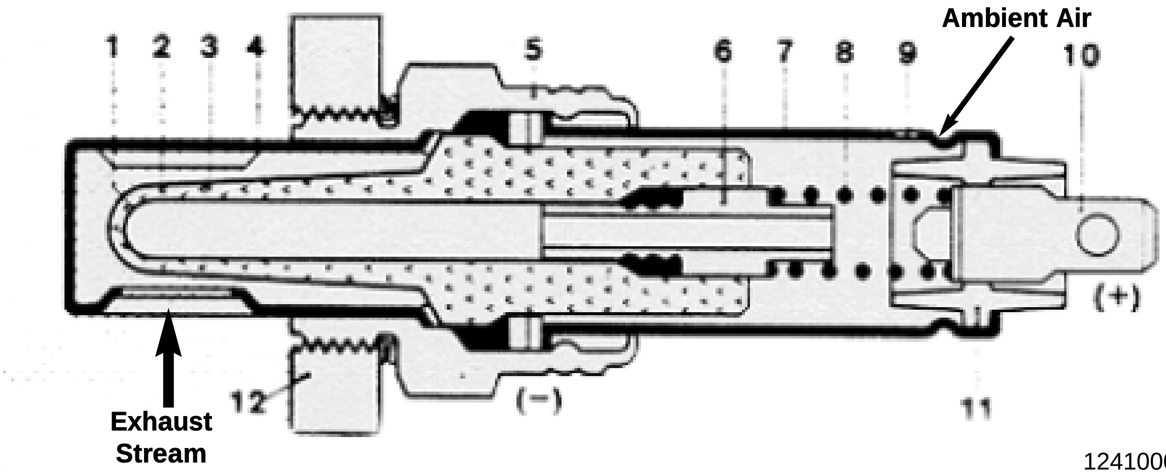

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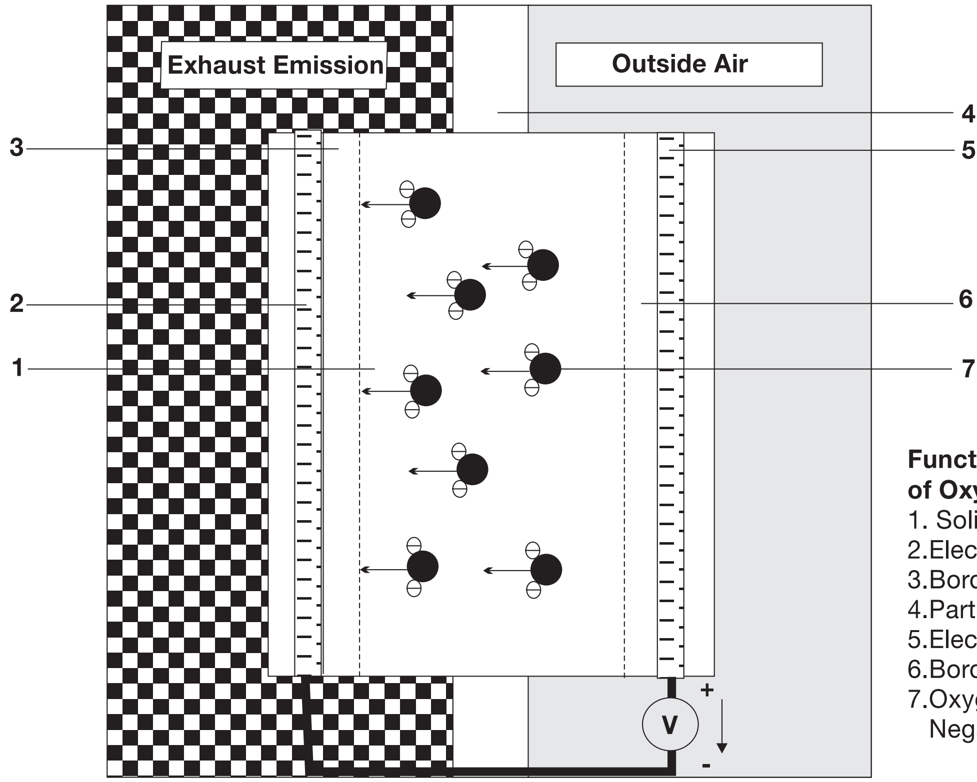
1. Electrode (+)	7. External Body (Ventilated)
2. Electrode (-)	8. Contact Spring
3. Porous Ceramic Coating (encasing electrolyte)	9. Vent Opening
4. Protective Metal Cage (Ventilated)	10. Output Lead
5. Casing	11. Insulator
6. Contact Sleeve	12. Exhaust Pipe Wall

The “tip” of the sensor contains a microporous platinum coating (electrodes) which conduct current. The platinum electrodes are separated by solid electrolyte which conducts oxygen ions.

The platinum conductors are covered with a highly porous ceramic coating and the entire tip is encased in a ventilated metal “cage”. This assembly is submersed in the exhaust stream. The sensor body (external) has a small vent opening in the housing that allows ambient air to enter the inside of the tip.

The ambient air contains a constant level of oxygen content (21%) and the exhaust stream has a much lower oxygen content. The oxygen ions (which contain small electrical charges) are “purged” through the solid electrolyte by the hot exhaust gas flow. The electrical charges (low voltage) are conducted by the platinum electrodes to the sensor signal wire that is monitored by the ECM.



Functional Layout of Oxygen Sensor

1. Solid Electrolyte
2. Electrode Exhaust Side
3. Border Zone Exhaust Side.
4. Partition Wall (Exhaust Pipe)
5. Electrode, Air Side
6. Border Zone, Air Side
7. Oxygen Ion With Double Negative.

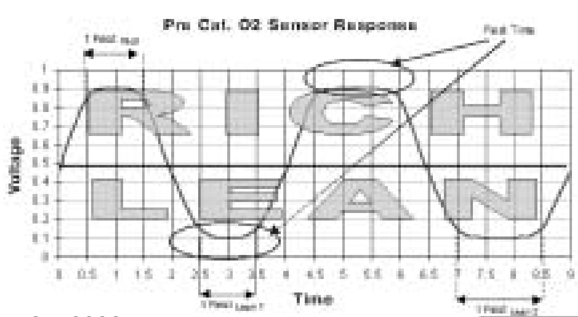
18410000.eps

If the exhaust has a lower oxygen content (rich mixture), there will be a large ion “migration” through the sensor generating a higher voltage (950 mV).

If the exhaust has a higher oxygen content (lean mixture), there will be a small ion “migration” through the sensor generating a lower voltage (080 mV).

This voltage signal is constantly changing due to combustion variations and normal exhaust pulsations.

The ECM monitors the length of time the sensors are operating in the lean, rich and rest conditions. The evaluation period of the sensors is over a predefined number of oscillation cycles.



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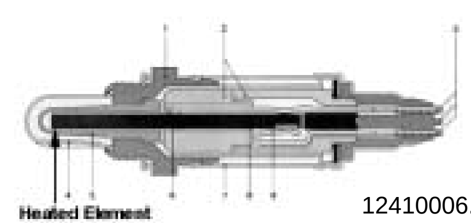
This conductivity is efficient when the oxygen sensor is hot (250º - 300º C). For this reason, the sensor contains a heating element. This “heated” sensor reduces warm up time, and retains the heat during low engine speed when the exhaust temperature is cooler.



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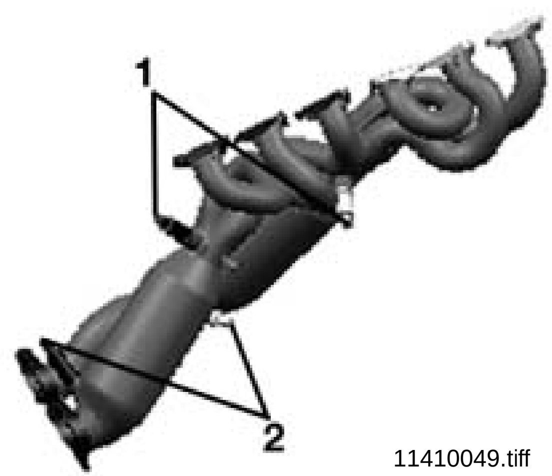
Catalytic Converter Monitoring: The efficiency of catalyst operation is determined by evaluating the oxygen storage capability of the catalytic converters using the pre and post oxygen sensor signals.

A properly operating catalyst consumes or stores most of the O2 (oxygen) that is present in the exhaust gas (input to catalyst). The gases that flow into the catalyst are converted from CO, HC and NOx to CO2, H2O and N2 respectively.

In order to determine if the catalysts are working correctly, post catalyst oxygen sensors (2) are installed to monitor exhaust gas content exiting the catalysts.



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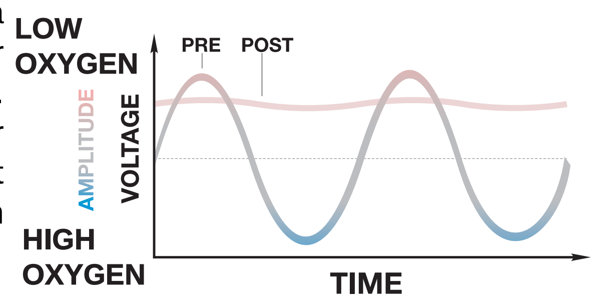
The signal of the post cat. O2 sensor is evaluated over the course of several pre cat. O2 sensor oscillations. During the evaluation period, the signal of the post cat. sensor must remain within a relatively constant voltage range (700 - 800 mV).

The post cat. O2 voltage remains high with a very slight fluctuation. This indicates a further lack of oxygen when compared to the pre cat. sensor. If this signal decreased in voltage and/or increased in fluctuation, a fault code will be set for Catalyst Efficiency and the “Malfunction Indicator Light” will illuminate.



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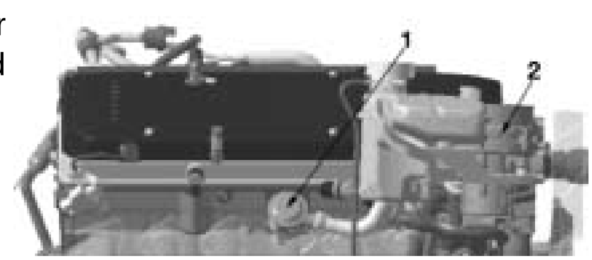
Secondary Air Injection: In order to reduce HC and CO emissions during engine warm up, an electric Air Pump (2) and Air Injection Valve (1) direct fresh air through an internal channel in the cylinder head into the exhaust ports. The Air Injection Valve is opened by air pressure and closed by an internal spring.



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Secondary Air injection also provides:

- Reduction in catalyst warm-up time
- Accelerated hydrocarbon Oxidation

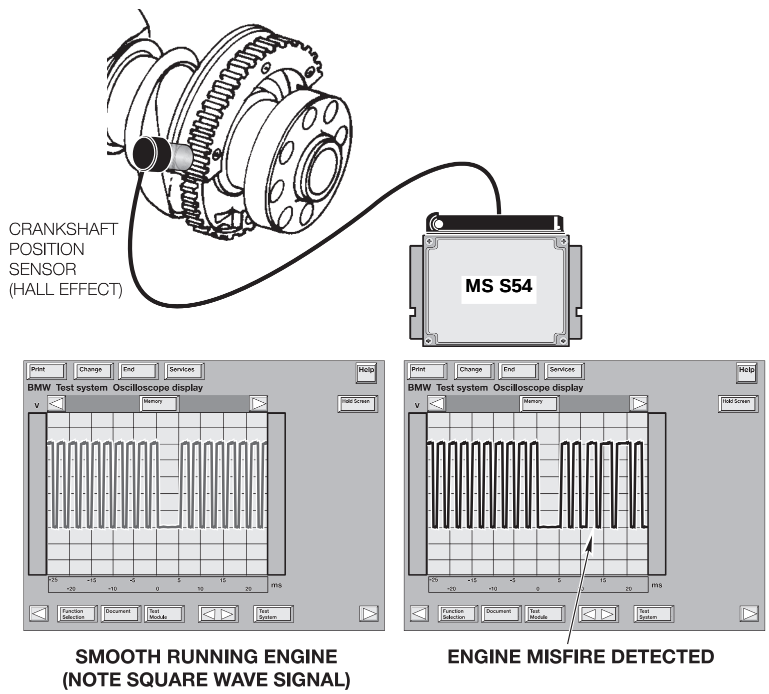
Misfire Detection: As part of the OBD II regulations the ECM must determine misfire and also identify the specific cylinder(s), the severity of the misfire and whether it is emissions relevant or catalyst damaging based on monitoring crankshaft acceleration.

In order to accomplish these tasks the ECM monitors the crankshaft for acceleration by the impulse wheel segments of cylinder specific firing order. The misfire/engine roughness calculation is derived from the differences in the period duration of individual increment gear segments.

Each segment period consist of an angular range of 90° crank angle that starts 54° before Top Dead Center.

If the expected period duration is greater than the permissible value a misfire fault for the particular cylinder is stored in the fault memory of the ECM.

Depending on the level of misfire rate measured the ECM will illuminate the “Malfunction Indicator Light”, deactivate the specific fuel injector to the particular cylinder and switch lambda operation to open-loop.



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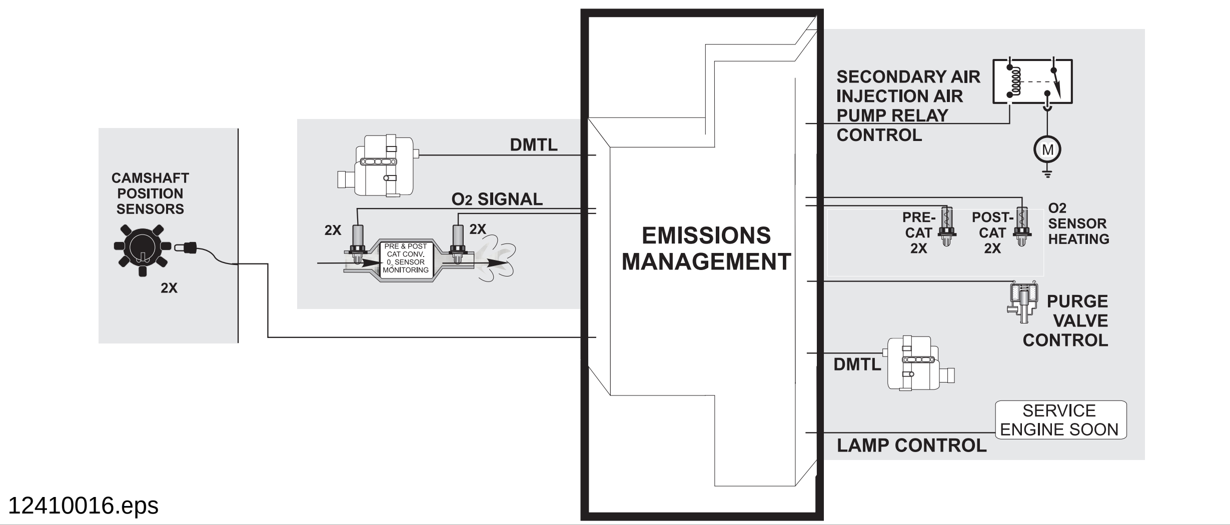
In order to eliminate misfire faults that can occur as a result of varying flywheel tolerances (manufacturing process) an internal adaptation of the flywheel is made. The adaptation is made during periods of decel fuel cut-off in order to avoid any rotational irregularities which the engine can cause during combustion. This adaptation is used to correct segment duration periods prior to evaluation for a misfire event.

If the sensor wheel adaptation has not been completed the misfire thresholds are limited to engine speed dependent values only and misfire detection is less sensitive. The crankshaft sensor adaptation is stored internally and is not displayed via DISplus or MoDIC. If the adaptation limit is exceeded a fault will be set.

Principle of Operation

Emissions Management controls evaporative and exhaust emissions. The ECM monitors the fuel storage system for **evaporative leakage** and controls the **purging** of evaporative fuel. The ECM monitors and controls the exhaust emissions by regulating the **combustible mixture** and after treating by injecting **fresh air** into the exhaust system. The catalytic converter further breaks down remaining combustible exhaust gases and is monitored by the ECM for **catalyst efficiency**.



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The Evaporative Leakage Detection is performed on the fuel storage system by the DM TL pump which contains an integral DC motor that is activated by the ECM. The ECM monitors the pump motor operating current as the measurement for detecting leaks.

The pump also contains an ECM controlled change over valve that is energized closed during a Leak Diagnosis test. The ECM only initiates a leak diagnosis test every second time the criteria are met. The criteria is as follows:

- Engine **OFF** with ignition switched **OFF**.
- ECM still in active state or what is known as “follow up mode” (ECM Relay energized, ECM and components online for extended period after key off).
- Prior to Engine/Ignition switch OFF condition, vehicle must have been driven for a minimum of 20 minutes.
- Prior to minimum 20 minute drive, the vehicle must have been OFF for a minimum of 5 hours.

- Fuel Tank Capacity must be between **15 and 85%** (safe approximation between 1/4 - 3/4 of a tank).

- Ambient Air Temperature between **-7^oC & 35^oC** (20^oF & 95^oF)

- Altitude **< 2500m** (8,202 feet).

- Battery Voltage between **11.5 and 14.5 Volts**

When these criteria are satisfied every second time, the ECM will start the Fuel System Leak Diagnosis Test. The test will typically be carried out once a day ie:, once after driving to work in the morning, when driving home in the evening, the criteria are once again met but the test is not initiated. The following morning, the test will run again.

PHASE 1 - REFERENCE MEASUREMENT

The ECM activates the pump motor. The pump pulls air from the filtered air inlet and passes it through a precise 1.0 mm reference orifice in the pump assembly.

The ECM simultaneously monitors the pump motor current flow. The motor current raises quickly and levels off (stabilizes) due to the orifice restriction. The ECM stores the stabilized amperage value in memory. The stored amperage value is the electrical equivalent of a 1.0 mm (0.040") leak.

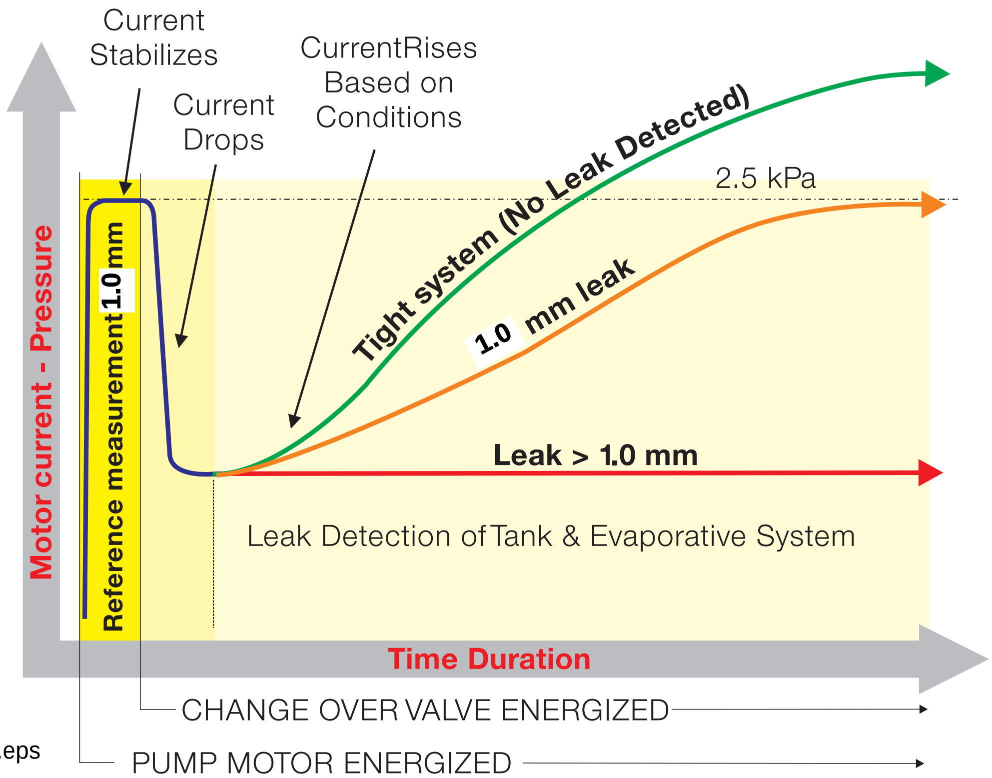
PHASE 2 - LEAK DETECTION

The ECM energizes the Change Over Valve allowing the pressurized air to enter the fuel system through the Charcoal Canister. The ECM monitors the current flow and compares it with the stored reference measurement over a duration of time.

Once the test is concluded, the ECM stops the pump motor and immediately de-energizes the change over valve. This allows the stored pressure to vent thorough the charcoal canister trapping hydrocarbon vapor and venting air to atmosphere through the filter.

TEST RESULTS

The time duration varies between 45 & 270 seconds depending on the resulting leak diagnosis test results (developed tank pressure "amperage" / within a specific time period). However the chart below depicts the logic used to determine fuel system leaks.



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If the ECM detects a leak, a fault will be stored and the "Malfunction Indicator Light" will be illuminated. Depending on the amperage measurement detected by the ECM, the fault code displayed will be "small leak" or "large leak".

If the vehicle was refueled and the filler cap was not properly installed, the **"Check Filler Cap"** message will be displayed.

The ECM detects refueling from a change in the fuel tank sending unit level via the Instrument Cluster. Upon a restart and driving the vehicle, the leakage test will be performed. If the ECM detects leakage, the **"Check Filler Cap"** light will illuminate in the lower left corner of the instrument cluster.

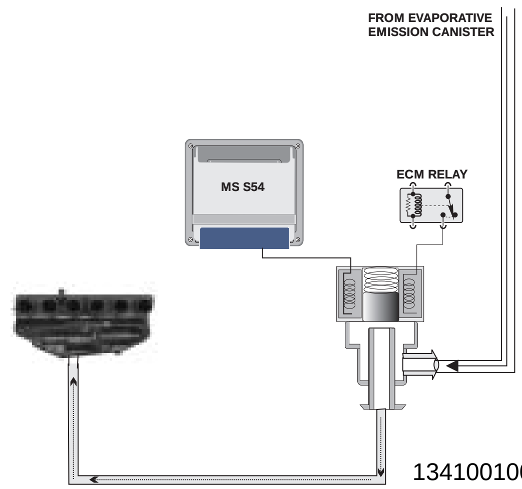
62410002.

If the filler cap is installed and there is no leakage present the next time the leakage test is performed, the "Malfunction Indicator Light" will not be illuminated.

Evaporative Emission Purging is regulated by the ECM controlling the Evaporative Emission Valve. The Evaporative Emission Valve is a solenoid that regulates purge flow from the Active Carbon Canister into the intake manifold. The ECM Relay provides operating voltage, and the ECM controls the valve by regulating the ground circuit. The valve is powered open and closed by an internal spring.

The "purging" process takes place when:

- Oxygen Sensor Control is active
- Engine Coolant Temperature is >60º C
- Engine Load is present



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The Evaporative Emission Valve is opened in stages to moderate the purging.

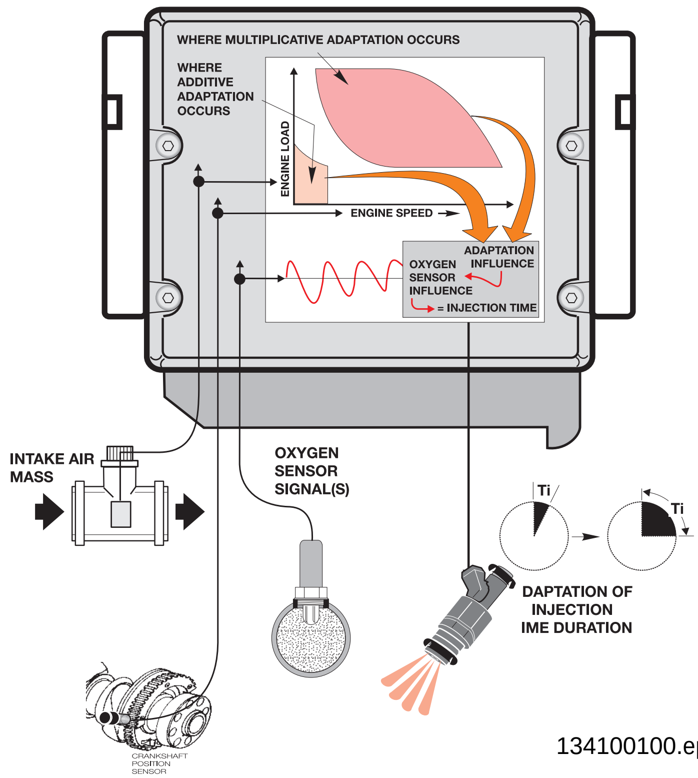
- Stage 1 opens the valve for 10 ms (milli-seconds) and then closes for 150 ms.
- The stages continue with increasing opening times (up to 16 stages) until the valve is completely open.
- The valve now starts to close in 16 stages in reverse order
- This staged process takes 6 minutes to complete. The function is inactive for 1 minute then starts the process all over again.
- During the purging process the valve is completely opened during full throttle operation and is completely closed during deceleration fuel cutoff.

Evaporative Purge System Flow Check is performed by the ECM when the oxygen sensor control and purging is active. When the Evaporative Emission Valve is open the ECM detects a rich/lean shift as monitored by the oxygen sensors indicating the valve is functioning properly.

If the ECM does not detect a rich/lean shift, a second step is performed when the vehicle is stationary and the engine is at idle speed. The ECM opens and close the valve (abruptly) several times and monitors the engine rpm for changes. If there are no changes, a fault code will be set.

Fuel System Monitoring is an OBD II requirement which monitors the calculated injection time (ti) in relation to engine speed, load, and the pre catalytic converter oxygen sensor(s) signals as a result of the residual oxygen in the exhaust stream.

The ECM uses the pre catalyst oxygen sensor signals as a correction factor for adjusting and optimizing the mixture pilot control under all engine operating conditions.



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Adaptation Values are stored by the ECM In order to maintain an "ideal" air/fuel ratio. The ECM is capable of adapting to various environmental conditions encountered while the vehicle is in operation (changes in altitude, humidity, ambient temperature, fuel quality, etc.).

The adaptation can only make slight corrections and can not compensate for large changes which may be encountered as a result of incorrect airflow or incorrect fuel supply to the engine.

Within the areas of adjustable adaption, the ECM modifies the injection rate under two areas of engine operation:

- During idle and low load mid range engine speeds **(Additive Adaptation)**,

- During operation under a normal to higher load when at higher engine speeds **(Multiplicative Adaptation)**.

These values indicate how the ECM is compensating for a less than ideal initial air/fuel ratio.

NOTE: If the adaptation value is greater than "0.0 ms" the ECM is trying to richen the mixture. If the adaptation value is less then "0.0 ms the ECM is trying to lean-out the mixture.

Catalyst Monitoring is performed by the ECM under oxygen sensor closed loop operation. The changing air/fuel ratio in the exhaust gas results in lambda oscillations at the pre-catalyst sensors. These oscillations are dampened by the oxygen storage activity of the catalysts and are reflected at the post catalyst sensors as a fairly stable signal (indicating oxygen has been consumed). Conditions for Catalyst Monitoring:

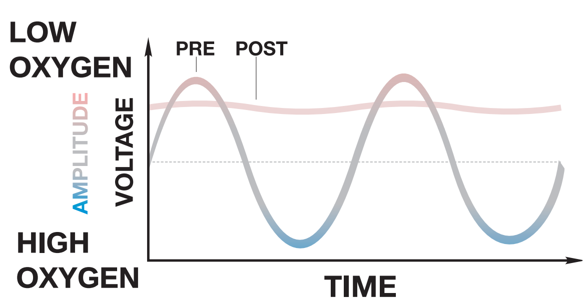
Requirements	**Status/Condition**
• Closed loop operation	YES
• Engine coolant temperature	Operating Temp.
• Vehicle road speed	3 - 50 MPH (5 to 80 km/h)
• Catalyst temperature (calculated)*	350°C to 650°C
• Throttle angle deviation	Steady throttle
• Engine speed deviation	Steady/stable engine speed
• Average lambda value deviation	Steady/stable load

* Catalyst temperature is an internally calculated value that is a function of load/air mass and time.

Note: The catalyst efficiency is monitored once per trip while the vehicle is in closed loop operation.

As part of the monitoring process, the pre and post O2 sensor signals are evaluated by the ECM to determine the length of time each sensor is operating in the rich and lean range.

If the catalyst is defective the post O2 sensor signal will reflect the pre O2 sensor signal (minus a phase shift/time delay), since the catalyst is no longer able to store oxygen.



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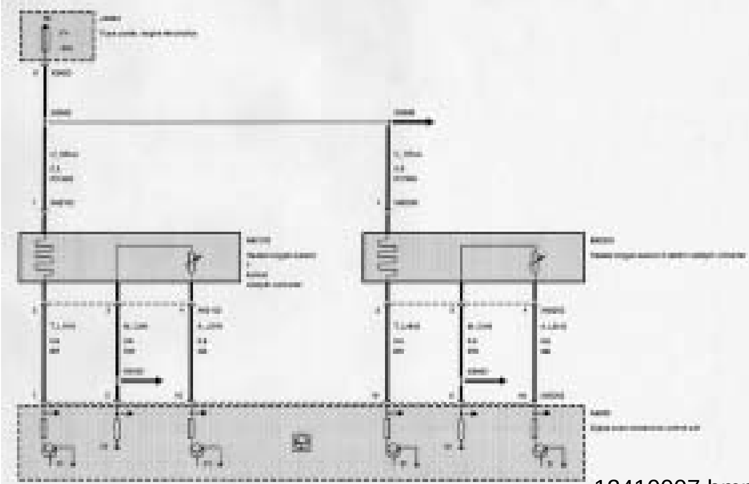
The catalyst monitoring process is stopped once the predetermined number of cycles are completed, until the engine is shut-off and started again. After completing the next "customer driving cycle" whereby the specific conditions are met and a fault is again set, the "Malfunction Indicator Light" will be illuminated.

Oxygen Sensor Heating is controlled by the ECM to reduces warm up time and retain heat during low engine speed when the exhaust temperature is cooler.

Voltage is supplied from the ECM Relay and the ground circuit is provided by the ECM in pulse width modulation. By pulsing the ground circuit, the oxygen sensor heaters are gradually brought up to temperature. Each oxygen sensor has an individual circuit provided by the ECM.



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During full throttle operation electrical heating is not required and is deactivated by the ECM.

Oxygen Sensor Heater Monitoring is part of the OBD II requirements requiring all oxygen sensors to be monitored separately for electrical integrity and heater operation. The heater function is monitored continuously while the vehicle is in closed loop operation, during activation by the ECM. An improperly/non operating heater will not allow the sensor signal to reach its predefined maximum and minimum thresholds which can:

- Result in delayed closed loop operation causing an impact on emission levels.
- Result in increased emission levels while in closed loop operation.

As part of the monitoring function for heater current and voltage, the circuit is also checked for an open, short to ground and short to B+ depending on the values of the current or voltage being monitored.

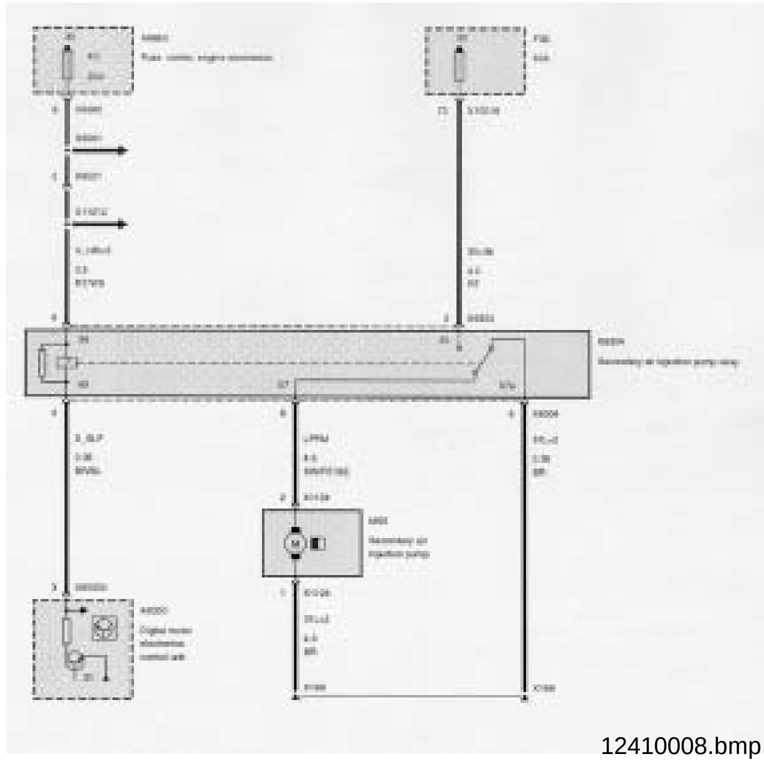
The ECM measures both sensor heater current and the heater voltage in order to calculate the sensor heater resistance and power. If the power of the heater is not within a specified range, a fault will be set. The next time the heater circuit is monitored and a fault is again present the “Malfunction Indicator Light” will be illuminated.

Secondary Air Injection is required to reduce HC and CO emissions while the engine is warming up. Immediately following a cold engine start (-10 to 40°C) fresh air/oxygen is injected directly into the exhaust stream.

The temperature signal is provided to the ECM by the Air Temperature Sensor in the HFM.

The ECM provides a ground circuit to activate the Secondary Air Injection Pump Relay. The relay supplies voltage to the Secondary Air Injection Pump.

The single speed pump runs for approximately 90 seconds after engine start up.



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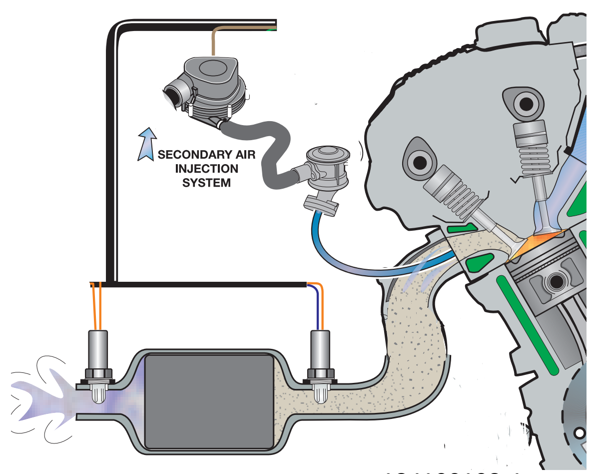
* Below -10º C the pump is activated briefly to “blow out” any accumulated moisture.

Secondary Air Injection Monitoring is performed by the ECM via the use of the pre-catalyst oxygen sensors. Once the air pump is active and is air injected into the exhaust system the oxygen sensor signals will indict a lean condition.

If the oxygen sensor signals do not change within a predefined time a fault will be set and identify the faulty bank(s). After completing the next cold start and a fault is again present the “Malfunction Indicator Light” will be illuminated.



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Misfire Detection is part of the OBD II regulations the ECM must determine misfire and also identify the specific cylinder(s), the severity of the misfire and whether it is emissions relevant or catalyst damaging based on monitoring crankshaft acceleration.

Emission Increase:

- Within an interval of 1000 crankshaft revolutions, the ECM adds the the detected misfire events for each cylinder. If the sum of all cylinder misfire incidents exceeds the predeter mined value, a fault code will be stored.

- If more than one cylinder is misfiring, all misfiring cylinders will be specified and the indi vidual fault codes for all misfiring cylinders and for multiple cylinder will be stored.

Catalyst Damage:

- Within an interval of 200 crankshaft revolutions the detected number of misfiring events is calculated for each cylinder. The ECM monitors this based on load/rpm. If the sum of cylinder misfire incidents exceeds a predetermined value, a fault code is stored and the "Malfunction Indicator Light" will be illuminated.

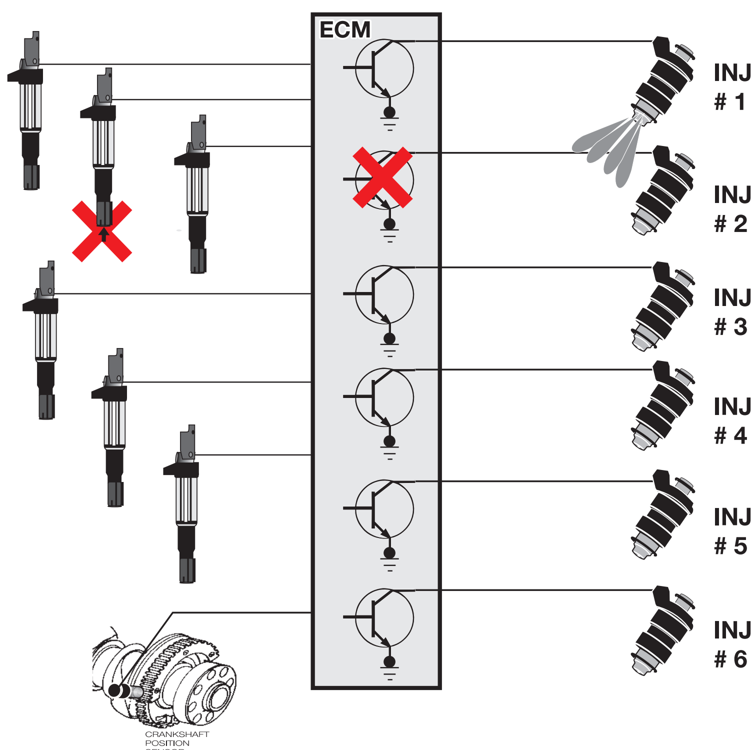
If the cylinder misfire count exceeds the predetermined threshold the ECM will take the following measures:

- The oxygen sensor control will be switched to open loop.

- The cylinder selective fault code is stored.

- If more than one cylinder is mis firing the fault code for all indi vidual cylinders and for multiple cylinders will be stored.

- The fuel injector to the respec tive cylinder(s) is deactivated.

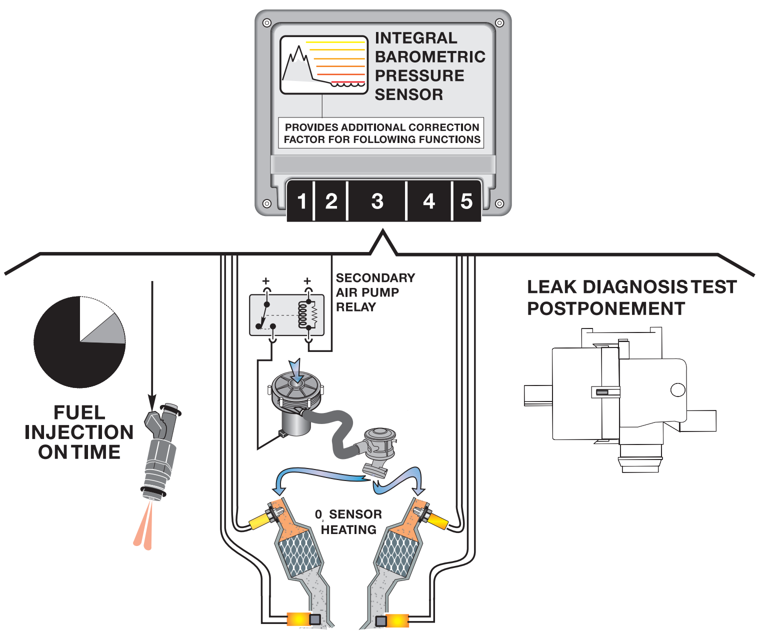


The Integrated Ambient Barometric Pressure Sensor of the MS S54 is part of the ECM and is not serviceable. The internal sensor is supplied with 5 volts. In return it provides a linear voltage of approx. 2.4 to 4.5 volts representative of barometric pressure (altitude).

The MS S54 monitors barometric pressure for the following reasons:

- The barometric pressure signal along with calculated air mass provides an additional correction factor to further refine injection "on" time.

- Provides a base value to calculate the air mass being injected into the exhaust system by the Secondary Air Injection System. This correction factor alters the secondary air injection "on" time, optimizing the necessary air flow into the exhaust system.



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E46 M3 Diagnostic Socket: For model year 2001 the E46 will eliminate the 20 pin diagnostic connector from the engine compartment. The 16 pin OBD II connector located inside the vehicle will be the only diagnosis port. The 16 pin OBD II connector has been in all BMWs since 1996 to comply with OBD regulations requiring a standardized diagnostic port.


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Previously before 2001, only emissions relevant data could be extracted from the OBD connector because it did not provide access to TXD (D-bus). The TXD line is connected to pin 8 of the OBD II connector on vehicles without the 20 pin diagnostic connector.

The cap to the OBD II connector contains a bridge that bridges KL 30 to TXD and TXD II. This is to protect the diagnostic circuit integrity and prevent erroneous faults from being logged.

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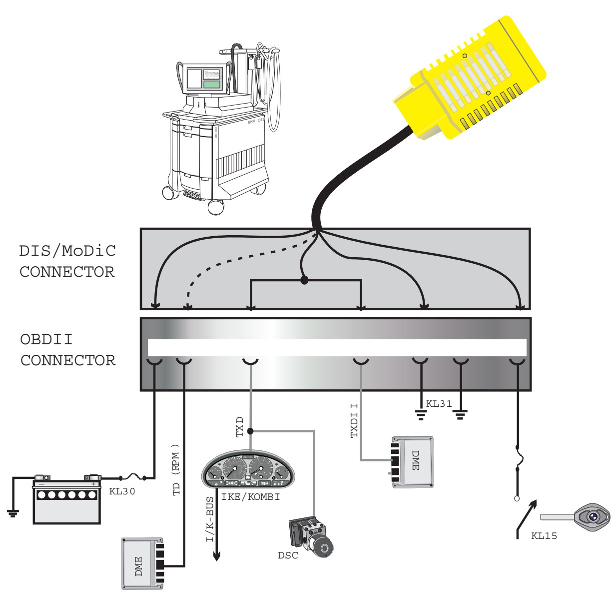
The OBD II connector is located in the drivers footwell to the left of the steering column.

Special tool 61 4 300 is used to connect to the 20 pin diagnostic lead of the DIS until the introduction of the DISplus.

Diagnostics via the OBD II Connector



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Workshop Hints

Before any service work is performed on any fuel system related component, always adhere to the following:

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- Observe relevant safety legislation pertaining to your area.
- Ensure adequate ventilation
- Use exhaust extraction system where applicable (alleviate fumes).
- **DO NOT SMOKE** while performing fuel system repairs.
- Always wear adequate protective clothing including eye protection.
- Use caution when working around a **HOT** engine compartment.
- BMW does not recommend any **UNAUTHORIZED MODIFICATIONS** to the fuel system. The fuel systems are designed to comply with strict federal safety and emissions regulations. In the concern of product liability, it is unauthorized to sell or perform modifications to customer vehicles, particularly in safety related areas.
- Always consult the **REPAIR INSTRUCTIONS** on the specific model you are working on before attempting a repair.

Checking Fuel Tank and Ventilation System for Leak-Tightness

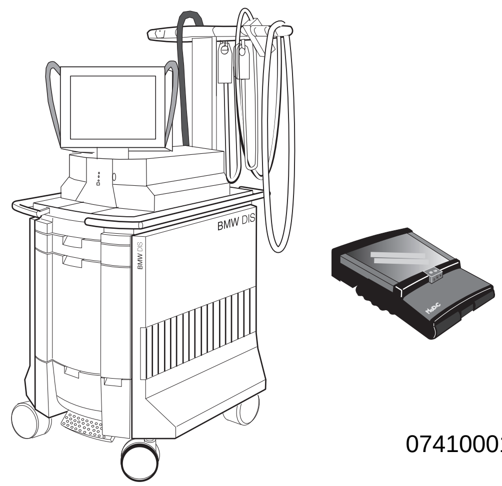
Refer to the Repair Information Section 16 00 100 for procedures on testing the fuel tank/ventilation system.

Refer to Service Information Bulletins SI # 04 06 97 and # 04 01 98 for the special tools and adapters to perform the Evaporative Leakage Diagnosis Test.

Tools and Equipment

The DISplus/Modic as well as a reputable hand held multimeter can be used when testing inputs/components.

It is best to make the checks at the ECM connection, this method includes testing the wiring harness.



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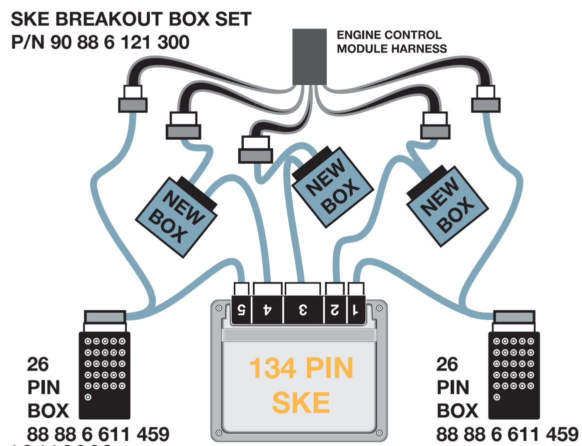
The correct Universal Adapter for the MS S54 application should be used (#90 88 6 121 300). This will ensure the pin connectors and the harness will not be damaged.



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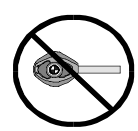
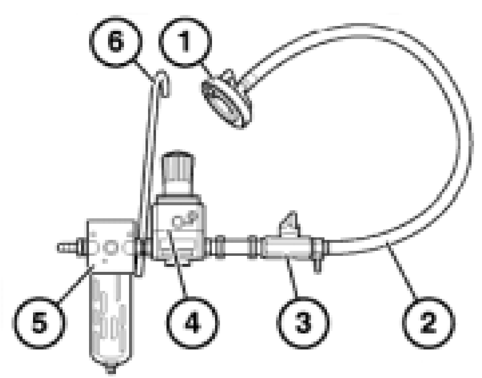
When installing the Universal Adapter to the ECM (located in the Electronics Box in the engine compartment), ***make sure the ignition is switched off.***



When checking the fuel tank and ventilation system for leak-tightness use Special Tool Set #90 88 6 161 150 which includes all of the pieces shown to the right.

This set is used in conjunction with shop supplied compressed air and the DISplus Multimeter function for reading the pressure bleed off.



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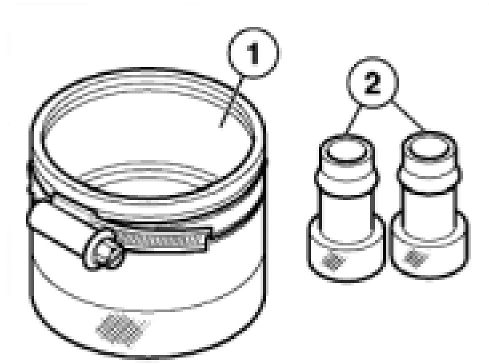
This Special Tool Set #90 88 6 161 160 will also be required to “cap off” the DM TL air filter and Evaporative Emission Valve hose when performing the Leakage Diagnosis Test.



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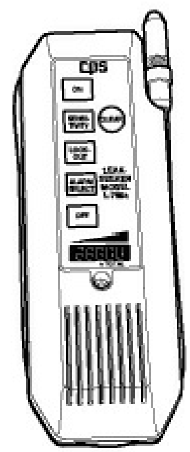
If the test indicates excessive bleed off a leak detector should be used (refer to Repair Instructions) to check for leaks at:

- Fuel Filler Cap and Filler Neck
- Fuel Tank Ventilation Lines
- Evaporative Emission Valve
- Fuel Tank and Fuel Sending Unit
- Liquid/Vapor Separator



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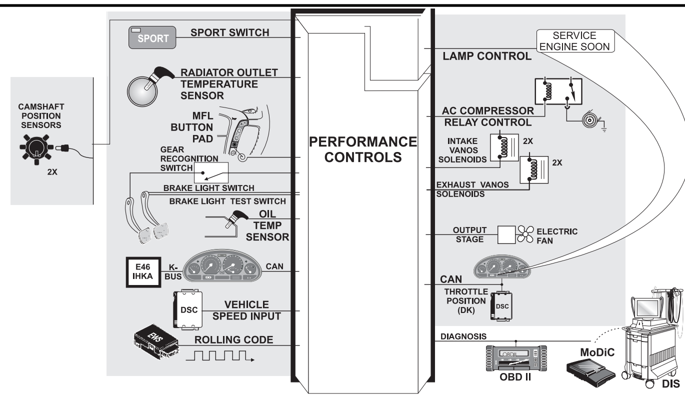
Performance Controls



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Sport Switch: The MS S54 ECM contains two different throttle progression program curves (Sport and Normal). The sport program is selected by pressing the Sport switch located in the center console switch panel.

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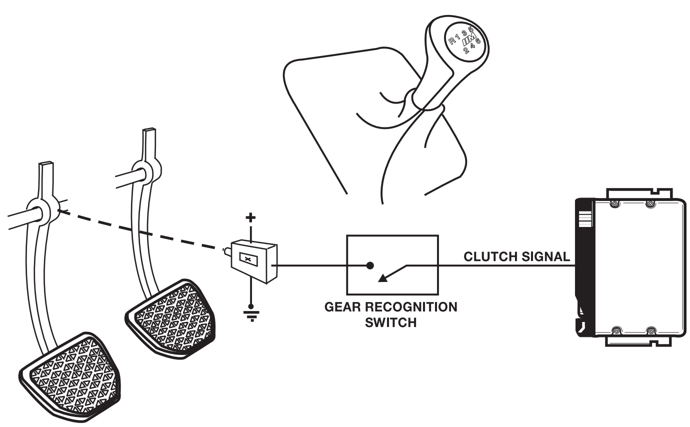
The switch provides a ground signal (input) to the ECM when pressed. The MS S54 activates the sport characteristics for the EDR throttle control. This provides an increase in throttle opening and response time over the non-sport position.

Power Transmission Switch: The power transmission switch (circuit) consists of two switches in series. The circuit includes a clutch switch and a gear selector switch on the transmission. The functions of the power transmission switch are as follows:

- Cutout for cruise control operation
- Enable condition for idle control

The switches provide a high signal for the MS S54 when the clutch is disengaged and the transmission is in gear. If either the clutch is engaged or the transmission is in neutral, the cruise control will be disengaged.



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Cruise Control: As with other electronic throttle systems, the MS S54 ECM takes over the function of cruise control. Throttle activation is provided by the MS S54 electronic control of the EDR Actuator and monitoring of the feedback potentiometers.

All driver requested cruise control function requests are provided to the MS S54 from the MFL ll control module in the steering wheel over a single FGR data lead.

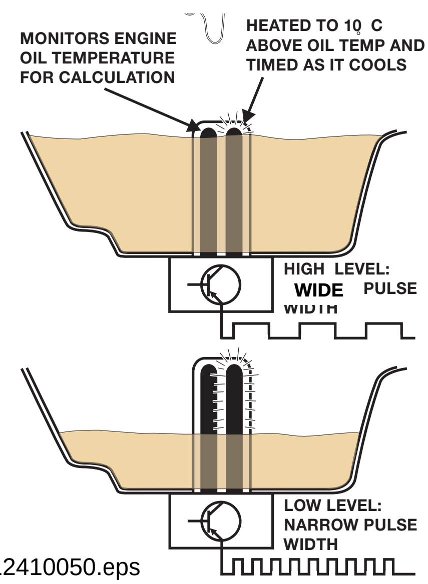
31410001.jpg

Oil Temperature/Level Sensor: The electronic level sensor is located in the engine sump mounted to the engine oil pan. The probe of the level sensor contains two temperature sensing elements.

- One senses the engine oil temperature.
- The other is heated to 10º C above the temperature of the engine and then is allowed to cool.

The length of time it takes to cool the heated element is how the sensor determines the engine oil level. When the oil level is high it covers a larger portion of the probe submersed in the oil sump. The engine oil around the probe absorbs the heat of the heated element quicker than if the level is low.

The microprocessor in the base of the sensor produces a pulse width modulated signal proportional to the oil level. The pulse width increases with a decreased level of oil.



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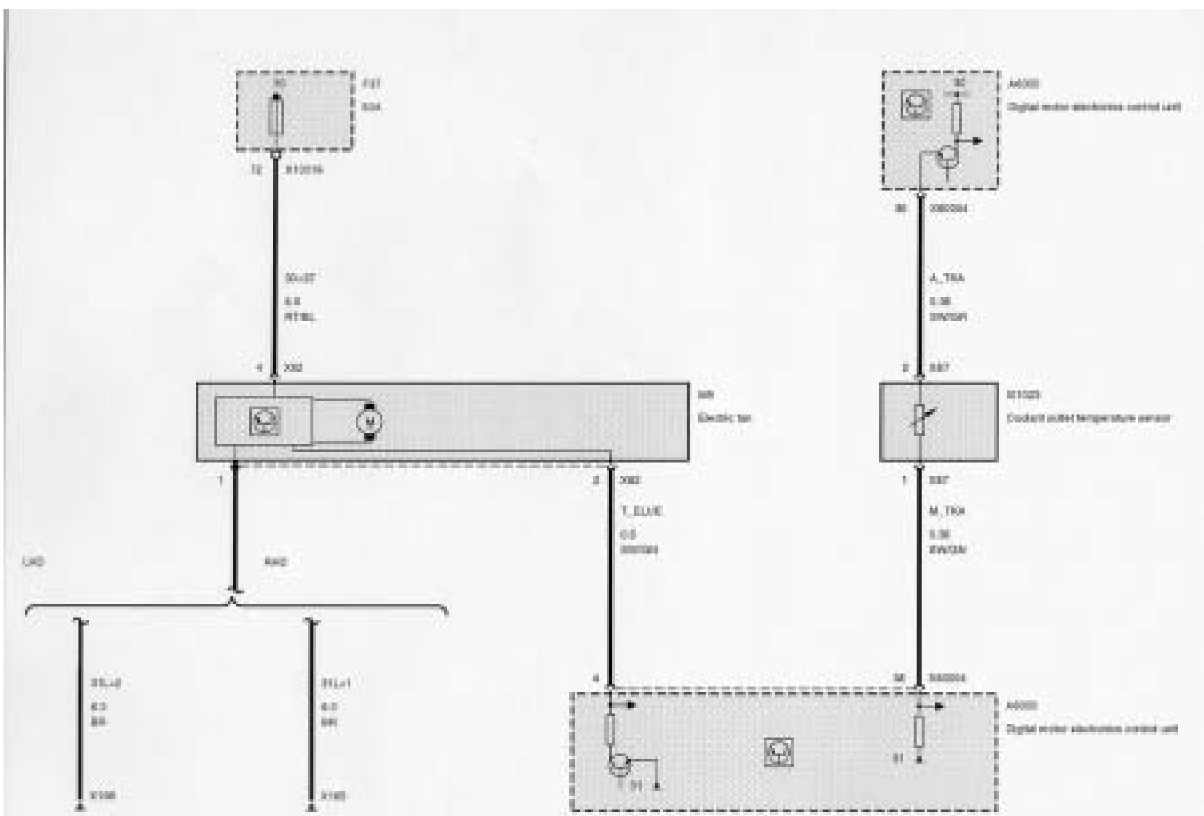
Based on the oil temperature, the visual warning LEDs in the tachometer will illuminate at cold engine start up and slowly be extinguished as the oil temperature increases. One amber and the red LEDs always stay illuminated reminding the driver of maximum rpm zone.

The oil temp sensor also serves as a vital input for VANOS operation, varying the solenoid control based on oil temperature (reaction time of camshaft movement). In the event of a fault the engine coolant temperature is used as a substitute value.

Electric Cooling Fan: The electric cooling fan is controlled by the ECM. The ECM uses a remote power output final stage (mounted on the fan housing). The power output stage receives power from a 50 amp fuse. The electric fan is controlled by a pulse width modulated signal from the ECM.

The fan is activated based on the ECM calculation of:

- Coolant outlet temperature (monitored by the Radiator Outlet Temperature Sensor)
- Calculated (by the ECM) catalyst temperature
- Vehicle speed
- Battery voltage
- Air Conditioning refrigerant pressure (calculated by IHKA and sent via the K-Bus to the ECM)



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Workshop Hints

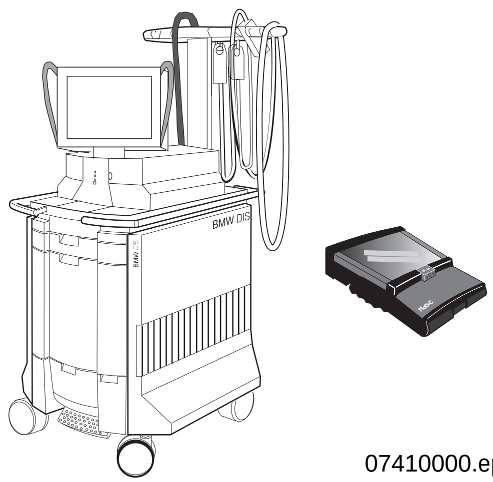
IMPORTANT!

From December 2001production, M3 and M roadster/coupé vehicles with S54 engines are delivered to the centers with the engine speed electronically limited to 5500 rpm as a transportation protection feature.

During the pre-delivery inspection the engine speed limiter function has to be disabled using DISplus or MoDIC loaded with CD28.0 or higher. ***Refer to SI 12 01 02 for additional details.***

Procedure

- Perform a **"short test"** on the ECM (DME) only
- Select **"Control Units Functions"** path
- Select **"Digital Motor Electronics DME"**
- Select **"Acknowledge Handover Inspection"**
- Select **"Activate"**
- The display will show **"off: terminate"**



07410000.eps

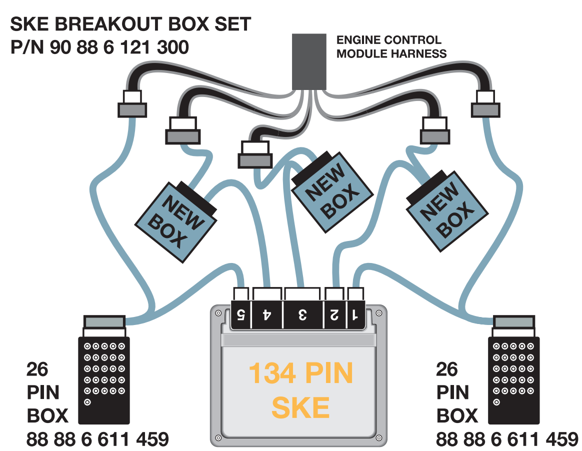
Tools and Equipment

The DISplus/MoDIC as well as a reputable hand held multimeter can be used when testing inputs/components.

It is best to make the checks at the ECM connection, this method includes testing the wiring harness.

The correct Universal Adapter for the MS S54 application should be used (#90 88 6 121 300). This will ensure the pin connectors and the harness will not be damaged.

When installing the Universal Adapter to the ECM (located in the Electronics Box in the engine compartment), ***make sure the ignition is switched off.***



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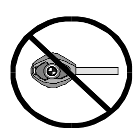

Review Questions

1. Describe the Power Supply for the Fuel Injectors and Ignition Coils:_______________
____
____
____
____

2. Name the Components of the Fuel Supply System:
_______________ _______________ _______________
_______________ _______________ _______________

3. List the inputs required fpr Fuel Injector operation:
_______________ _______________ _______________
_______________ _______________ _______________

4. Describe the Emission Optimized Function:___________________________________
____
____
____

5. Name two types of Emissions the ECM controls:_____________ _____________

6. What two sensors are used to monitor throttle movement?
_____________________ _____________________

7. Why are there two inputs from the Accelerator Module?________________________
____
____

8. Where is the Diagnostic Socket located? ____________________________________

9. How many speeds will the Secondary Air Injection Pump run at?_________________

10. What is the Repair Instruction (number) for the procedure to perform a Leakage Diagnosis Test?____

11. How is the secondary ignition monitored for misfire?__________________________
____
____

TABLE OF CONTENTS

RUNNING GEAR

Model: E46 M3
Production Date: 01/2001

Objectives of the Module

After completing this module, you will be able to:

- Identify which suspension components are modified for the E46 M3.
- Explain what is unique about the Front Strut Upper Mount.
- Describe the operation of the M-differential Lock.

E46 M3 Running Gear and Suspension

Purpose of the System

A requirement in the development of the running gear for the E46 M3 was: "The running gear must be faster than the engine". The exceptional running gear and suspension of the E46/2 as well as the outstanding running gear of the M3 predecessor served as the basis for the E46 M3.

The combination of a very rigid 3 Series coupe body, lightweight aluminum axle components, 50/50 weight distribution and rear-wheel drive are ideal prerequisites for pure driving pleasure with the BMW E46 M3.

The development objectives of E46 M3 were to further improve the sports car handling characteristics as compared to the predecessor while retaining the outstanding driveability for everyday use.

In addition, by using the variable M-differential lock together with DSC III, it has been possible to avoid the restrictions in winter operation normally associated with sports cars.

00410000.tiff

System Components

Front Axle: The front axle of the E46 M3 is designed as a single-joint spring strut front axle. The basic characteristics of the axle resemble those of the M3 predecessor.

The special feature of the E46 M3 front axle is the rigid link of the running gear components to the body.

The E46 M3 “specific” modified components are:

- Front axle mount
- Aluminum control arm frame
- Aluminum thrust zone
- Larger track width (1508 mm)
- Stabilizer bar
- Steering (track rod length changed)
- Steering knuckle
- Wheel bearings
- Front axle carrier
- Modified elastokinematics (rubber mounts and joints)


31410001.tiff

Mount: The spring and damper are insulated from each other. This arrangement improves the feel of the road surface conditions through the steering wheel.

Additional damping (rubber) has been inserted between the spring and damper mounting.

The geometric layout (offset center) of the front axle mount makes it possible to increase the caster angle.


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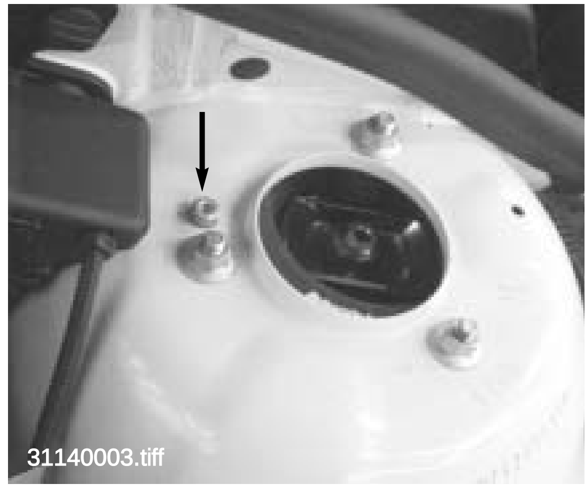
The offset mount center can be seen at the right.

A locating bolt (arrow) can be removed and the upper mount bolt holes in the strut tower are slotted to allow the mount to be re-positioned ***for minimum camber adjustment.***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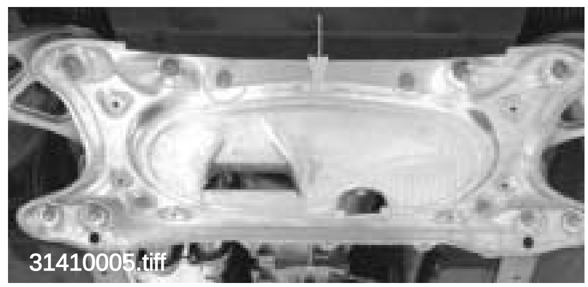
Thrust Zone: The rigid connection of the suspension components to the body is further assisted by the transversely rigid thrust zone.

The thrust zone is made of aluminum and is bolted to the control arm joints, front axle carrier and the rear control arm mounts.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Aluminum Control Arm: The forged aluminum control arm of the E46 M3 front axle is a specific development of BMW M.

Compared to the control arm of the E36 M3, the weight has been reduced by 40%. Its design incorporates specific deformation characteristics.


37410007.tiff

Suspension and Damping: The spring rate of the front springs on the E46 M3 has been increased as compared to the E46/2.

The shock absorbers are twin-tube gas pressure dampers. The connection of the stabilizer support is new.

37410006.tiff

Stabilizer Bar: The front stabilizer bar is 26 mm in diameter. The stabilizer links have been adopted from the E46/2.

Wheel Carriers and Wheel Bearings: The wheel carriers on the M3 front axle are specific. The mount for the brake caliper has been modified compared to the E46/2. The wheel bearings have been modified for higher loads. A drive pin for the brake disc is located on the wheel hub.

31140006.tiff

Steering: The steering on the M3 is designed as a power-assisted rack and pinion steering system.

The steering pump produces a maximum pressure of 120 bar and has a delivery capacity of 11 L/min. The total gear ratio is 15.4 : 1. The steering has no hydraulic limit stops.

The turning circle is 11.0 m
The track circle is 10.6 m

The outer track rods of the rack and pinion steering are specific. They have been modified for the larger track width.

E46 M3 Rear Axle: The concept of the M3 rear axle originates from the E46/2. The characteristics of the central link axle has been adopted and modified from the E36 M3.

The track width of 1525 mm was achieved by modifying the rear rim offset.

The rear axle carrier was modified for accepting the differential and a modified rear stabilizer bar.

The lower control arm was adopted from the E46/2. To improve the wheel control, the outer joint is designed as a ball joint.

The upper control arm is aluminum. In order to improve the wheel control, the outer mount (as on the E36 M3) is designed as a ball joint.

The Semi-trailing arm is specific, the mounts on the body have been adopted from the E46/2. The linkage points of the control arms have been modified to increase the driving stability of the rear axle. The wheel bearing are the same as the E36 M3.

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Rear Axle Carrier with V-Strut: The rear axle carrier has been modified for the E46 M3. The rear body mounts have been specially modified to M3 requirements.

The mounting points for the rear axle differential are new (2 rear, 1 front). The stabilizer bar mounting is new.

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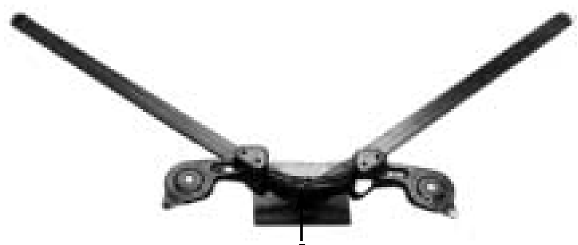
The V-strut is bolted to the body and rear axle assembly for additional rear axle reinforcement.

A reinforcement plate (A) is integrated in the V-strut. The plate deflects air flow towards the rear axle differential cover.



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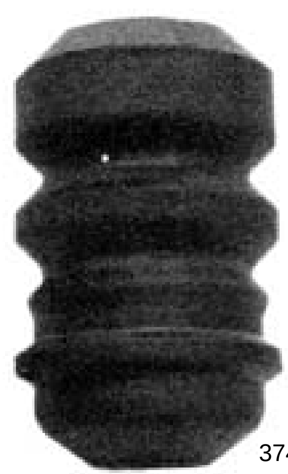
Suspension and Damping: The suspension and damping components have been tuned in line with sport characteristics.

The coil (barrel) springs on the rear axle are progressive rate. The tuning is M3-specific.

The shock absorbers are designed as twin tube gas pressure dampers. Compared to the E46/2, the diameter of the piston rod and the piston have been increased (piston 32mm, piston rod 15mm).

The auxiliary cushion on the rear axle shock absorber is new. It differs from the standard auxiliary cushion by an additional groove and the black coloring.



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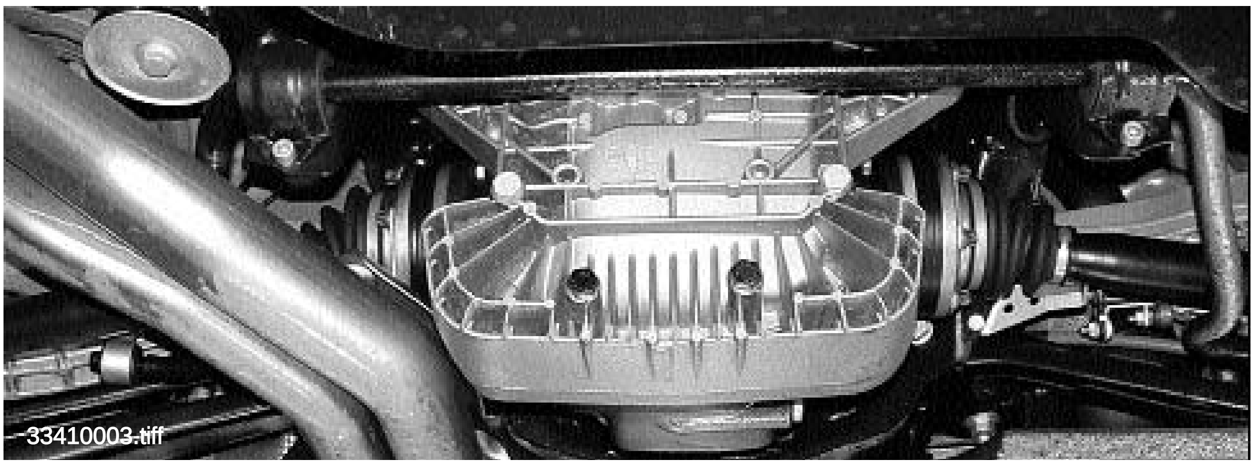
Stabilizer Bar: The rear axle stabilizer bar is specific. The diameter is 21.5 mm. The mounting on the rear axle carrier has been modified for the E46 M3.

E46 Rear Axle Differential: The rear axle differential is developed specifically for the E46 M3. The rear axle differential is designated “210” (ring gear diameter in mm).

The mounting points of the rear axle carrier for the differential have been modified compared to the E46/2.

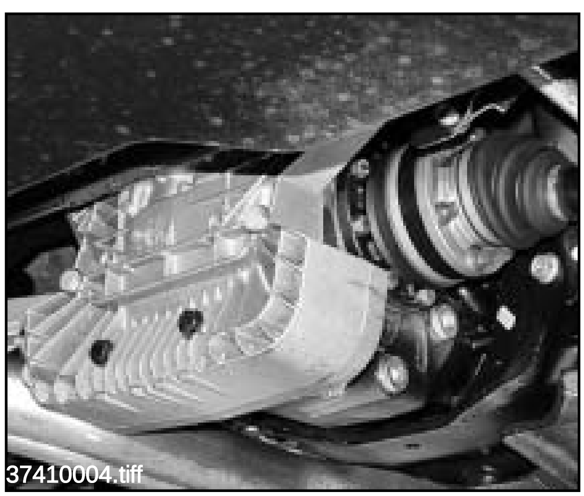
The rear axle differential is bolted to the rear axle carrier at two mounting points on the rear axle differential casing.

The rear axle carrier is connected to the body at the same points as the E46/2. For all BMW vehicles, this mounting arrangement is known as double-flexible rear axle mounting.



The housing of the rear axle differential is E46 M3 specific. The cover of the rear axle differential is made of pressure die cast aluminum. Special arranged cooling fins reduce the temperature of the oil in the differential.

The technical innovations of the variable M-differential lock developed by BMW M in cooperation with GKN Viscodrive GmbH is fitted in the E46 M3.



Variable M-differential Lock

To date, torque-sensing limited slip differentials with a constant basic locking torque have been used in M vehicles. The differential lock value for current M vehicles is 25%. However, if traction is very low, e.g. on snow, the advantages with this differential lock concept are limited due to the restricted support torque.

A variable differential lock is used for the first time in the E46 M3. Compared to the conventional torque-sensing differential lock, the variable M-differential lock is capable of providing traction advantages even under these extreme conditions.

When there is a speed difference between both wheels, a shear pump located on the ring gear side generates a pressure. A working piston transmits this controlled pressure on the basis of the differential speed of the drive wheels to the multi-disc clutches so that the drive torque is transmitted to the wheel with the most “grip”.

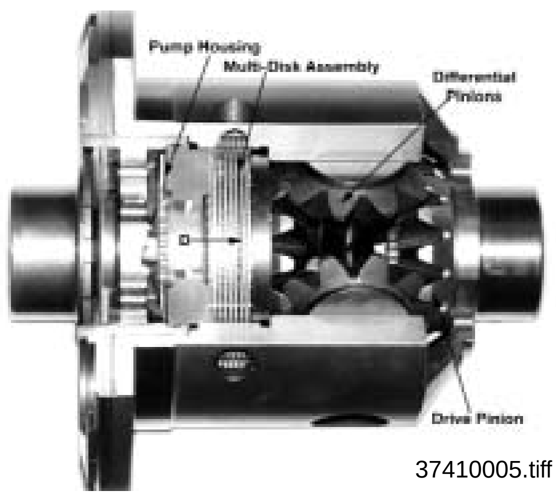
The pump pressure and locking power increase as the speed difference between the two wheels increase. If the differential speed between both wheels decreases, the pump pressure is also reduced and the locking power diminishes.

The Pump Unit: The pump unit is sealed (cannot be dismantled) and is filled with approx. 46 grams of high viscosity silicone oil.

As a result of the speed difference between the drive wheels, shear forces occur in the silicone oil in the pump unit between a channel filled with silicone oil and a pump disc located above it.

These shear forces generate a pressure that is dependent on the differential speed of the drive pinions.

The pressure is built up by a piston (max. 38 bar) that presses the multi-disc clutches together achieving a variable differential lock effect dependent on the differential speed.



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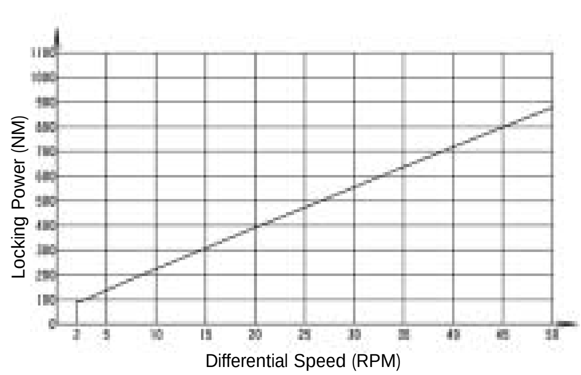
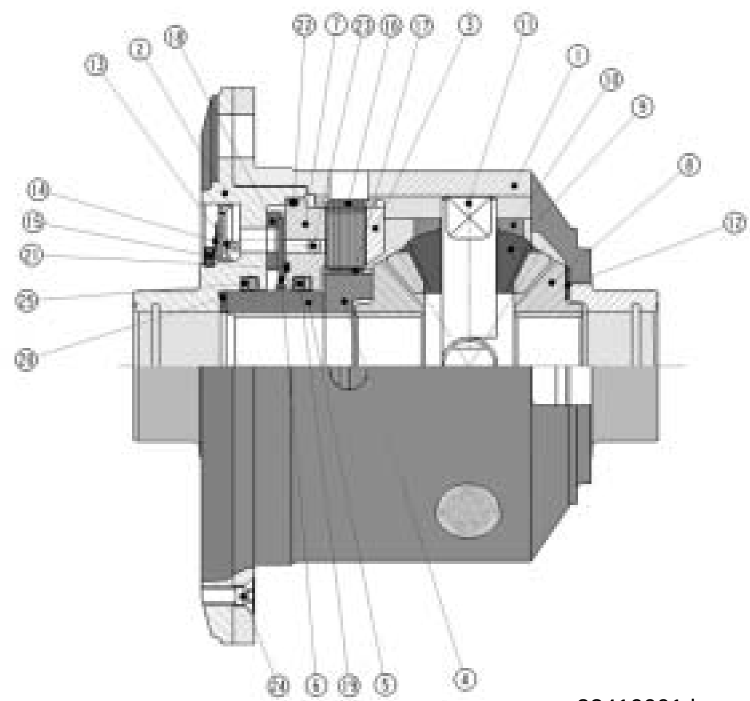


37410006.bmp

Description
1. Differential Case
2. Differential Cover
3. Differential Ring
4. Inner Disc Carrier
5. Displacement Disk Carrier
6. Displacement Disk
7. Pistons
8. Drive Pinion
9. Differential Bevel Pinion
10. Ball Disk
11. Differential Axle
12. Thrust Washer
13. Differential Piston
14. Disc Spring
15. Retaining Ring
16. Outer Friction Disc
17. Inner Friction Disc
18. Control Disc
19. Four-Lip Ring
20. Thrust Washer
21. O-Ring
22. O-Ring
23. Ball
24. Countersunk Screw
25. Support Ring



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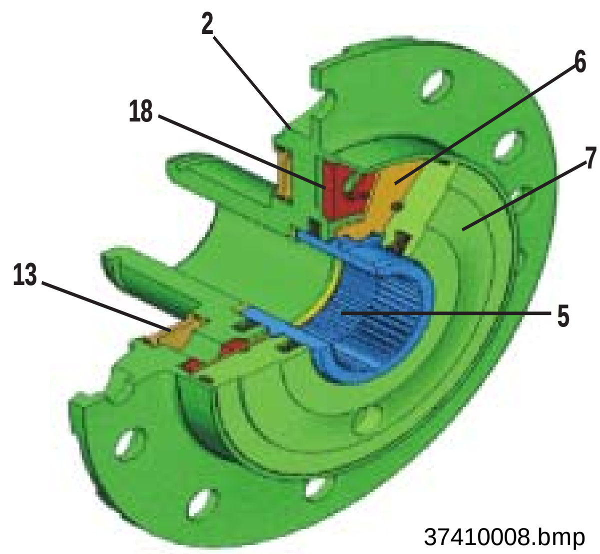
Sectional view of a shear pump unit is shown on the right.



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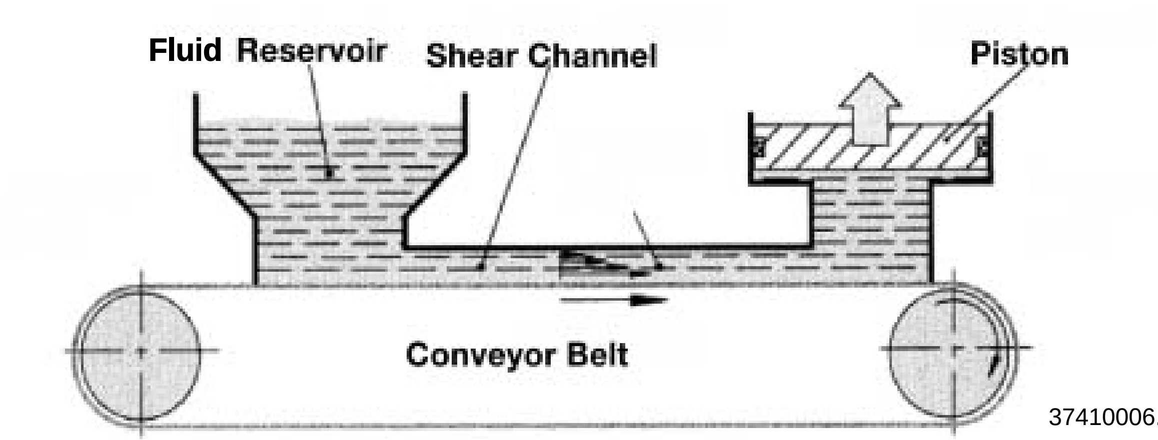
Principle of Operation

The conveyor belt model illustrates the functional principle of the shear pump. As the conveyor belt moves, the viscous friction in the laterally sealed shear channel conveys the fluid in the direction of movement.



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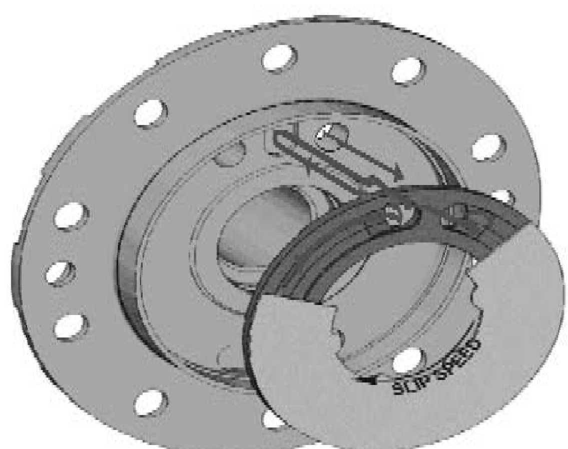
By transferring the operation principle to a rotary system, the conveyor belt becomes a displacement disc driven by the Hub. The shear channel is then a circular groove in the control disk. The control disk is located in the pump housing.

Transfer ports that are connected to outlet holes in the pump housing are provided at the ends of the shear channel.



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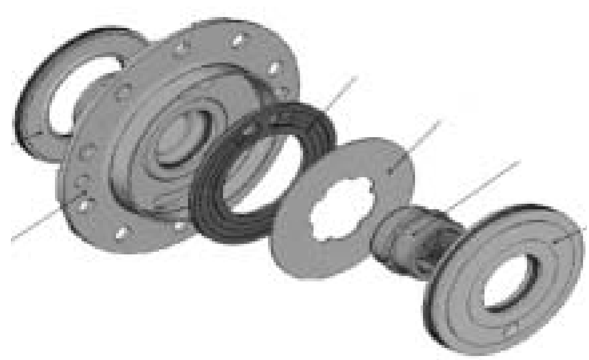
Silicone oil is conveyed through the outlet holes from the equalization chamber (fluid reservoir) into the pressure chamber. Piston exerts a pressure on the friction discs.

The arrows shown to the right represent the flow of silicone oil between the displacement disc and the control disc. The silicone oil is transferred from the reservoir on the outside of the pump housing to the pressure chamber between displacement discs and the piston.

The arrangement of the pump elements and specific routing of the silicone oil in a gap between the piston and displacement disc ensures the pressure generated acts on the piston.



33410008.html

E46 M3 Brakes: The E46 M3 is equipped with high performance brakes including floating calipers.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Front brake discs:

- 325 mm diameter
- 28 mm thick

Rear brake discs:

- 328 mm diameter
- 20 mm thick

The tandem (dual circuit) brake master cylinder is 2-stage.

The brake booster is a twin chamber (9”/10") vacuum assisted unit.

E46 M3 Wheels and Tires: 18" high performance tires were specially developed for the E46 M3.


36410000.tiff

The sizes are 225/45 ZR 18 on the front and 255/40 ZR 18 on the rear.

The newly styled 18" light alloy wheels for the E46 M3 are 8" wide on the front and 9" wide on the rear.

The extended hump (EH) of the wheels prevent the tire from slipping into the dropped center of the wheel in the event of pressure loss.


36410000.tiff

M-mobility System with RDW: The tire pressure warning system (RDW) is integrated in the Dynamic Stability Control (DSC III).

It triggers a warning when the tire inflation pressure has a loss of approx. 50%.

With the second generation M-mobility System (MMS), holes of up to 6 mm diameter can be sealed.


36410003.tiff

Dynamic Stability Control: One of the aims in the development of the E46 M3 was to improve traction and winter driving characteristics.

The E46 M3 uses the Teves MK 20 El DSC III system from the E46 production vehicle.

With software adaptation and logic expansion, the system is tuned to the variable M-differential lock.

Review Questions

1. What is unique about the Front Strut Upper Mount? ______________________
____
____

2. List the suspension components that are modified for the M3:

____________	____________	____________	____________
____________	____________	____________	____________
____________	____________	____________	____________
____________	____________	____________	____________
____________	____________	____________	____________

3. Concerning the M-differential Lock, what is the purpose of the Shear Pump?
____
____
____

4. What increases the Shear Pump Pressure?
____

5. How does “EH” affect a tire with low air pressure? ______________________
____

Table of Contents

SMG II

Initial Print Date:03/02 Revision Date:

SMG II

Model: E46 M3 SMG II

Production: Available 1/02 USA

Objectives:

After completion of this module you should be able to:

- Understand the SMG II operating modes.
- Recognize and locate the components of the SMG II.
- Understand operation of the SMG II
- Diagnose the SMG II.

Purpose of the System

SMG II

The SMG II combines the six-speed manual gearbox (S6S420G) of the E46 M3 with computer-controlled electrohydraulic clutch and gear change operation. The driver is provided with the accuracy of manual gear selection, the convenience of automated shifting and the speed and adaptability of driver-adjusted computer control.
Using technology developed for the BMW/Williams Formula 1 car, the SMG II with DRIVELOGIC adapts the speed, accuracy and control of the race cars electrohydraulic shifting to the M3.

1. Shift Lever
2. DRIVELOGIC Control
3. Shift Paddles
4. Missing Clutch Pedal

Shift Lever and Paddles 45-01-01

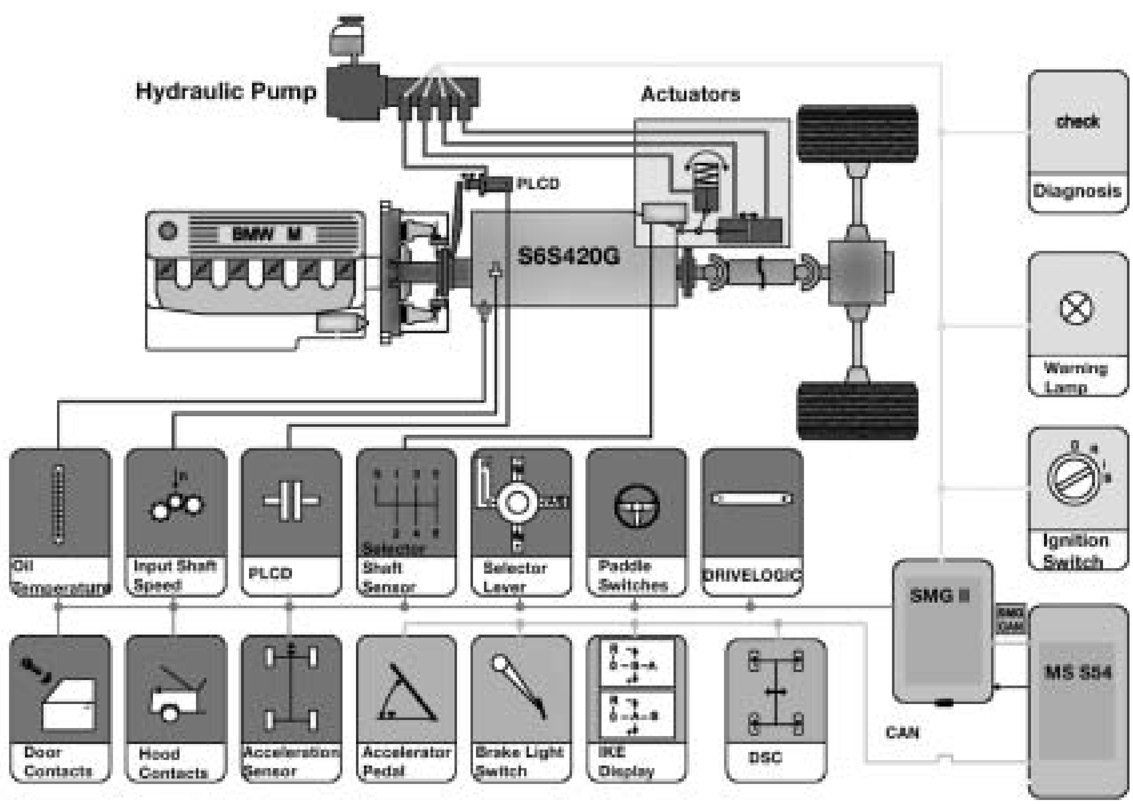
Features of the SMG II include:

- Two operating modes
  -Manual, shift lever or the steering wheel mounted paddle switches are used to make gear changes. (S-Mode)
  -Automatic, gear selection and shifting provided by the SMG II. (A-Mode)
- DRIVELOGIC control to adjust shift programs in the A mode or shift dynamics in the S Mode.
- Light weight and elimination of torque convertor when compared to an Automatic Transmission.
- Same basic 6 speed gear box design as Non-SMG II equipped M3.
- Elimination of clutch pedal.
- Adaptable based on engine torque and speed.

System Components

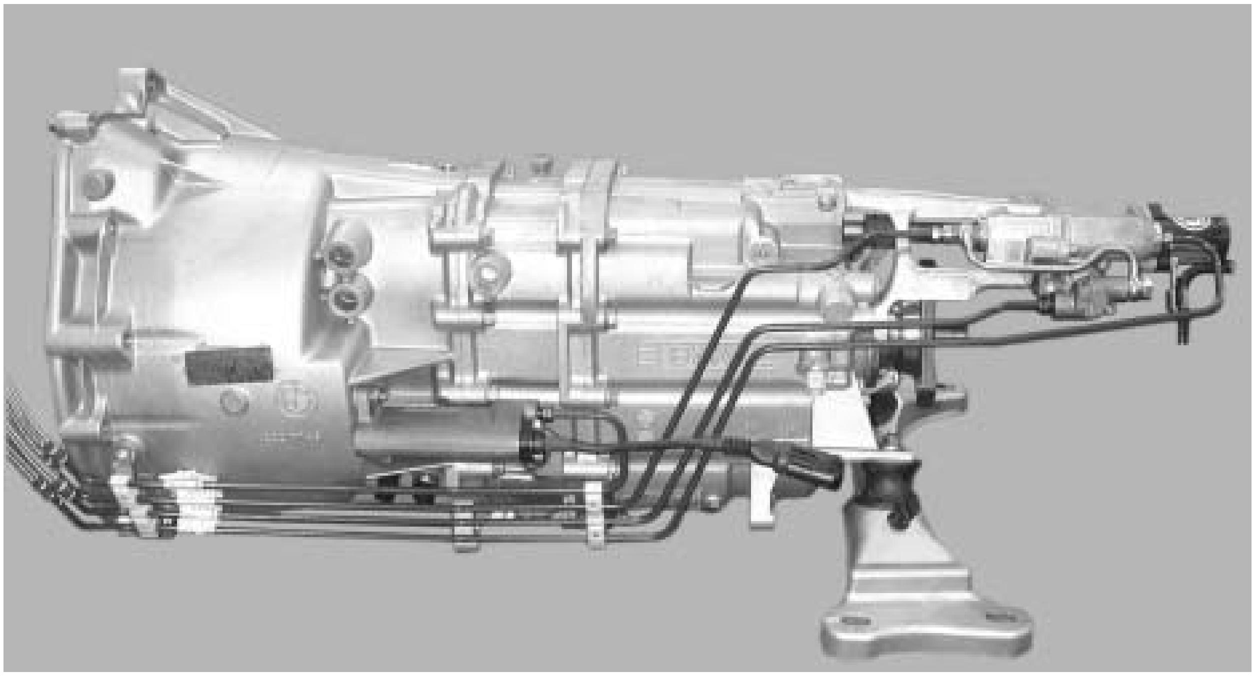
The SMG II system is consists of the following components:

- Basic Gearbox (S6S420G, Getrag type D)
- SMG II Control Unit (Siemens)
- SMG CAN Bus
- DME Control Unit (MSS54)
- Hydraulic unit and solenoids
- Gearbox Actuator
- Clutch Slave Cylinder with PLCD (Permanent Linear Contactless Displacement)
- Shift Lever Module with Shift Lock
- Steering Wheel Paddle mounted switches
- DRIVELOGIC Control
- Display in instrument cluster
- DSC control unit
- SAC dry single disc clutch



SMG II System Schematic 45-02-2A

Basic Gearbox



SMG II Manual Gearbox 45-01-03

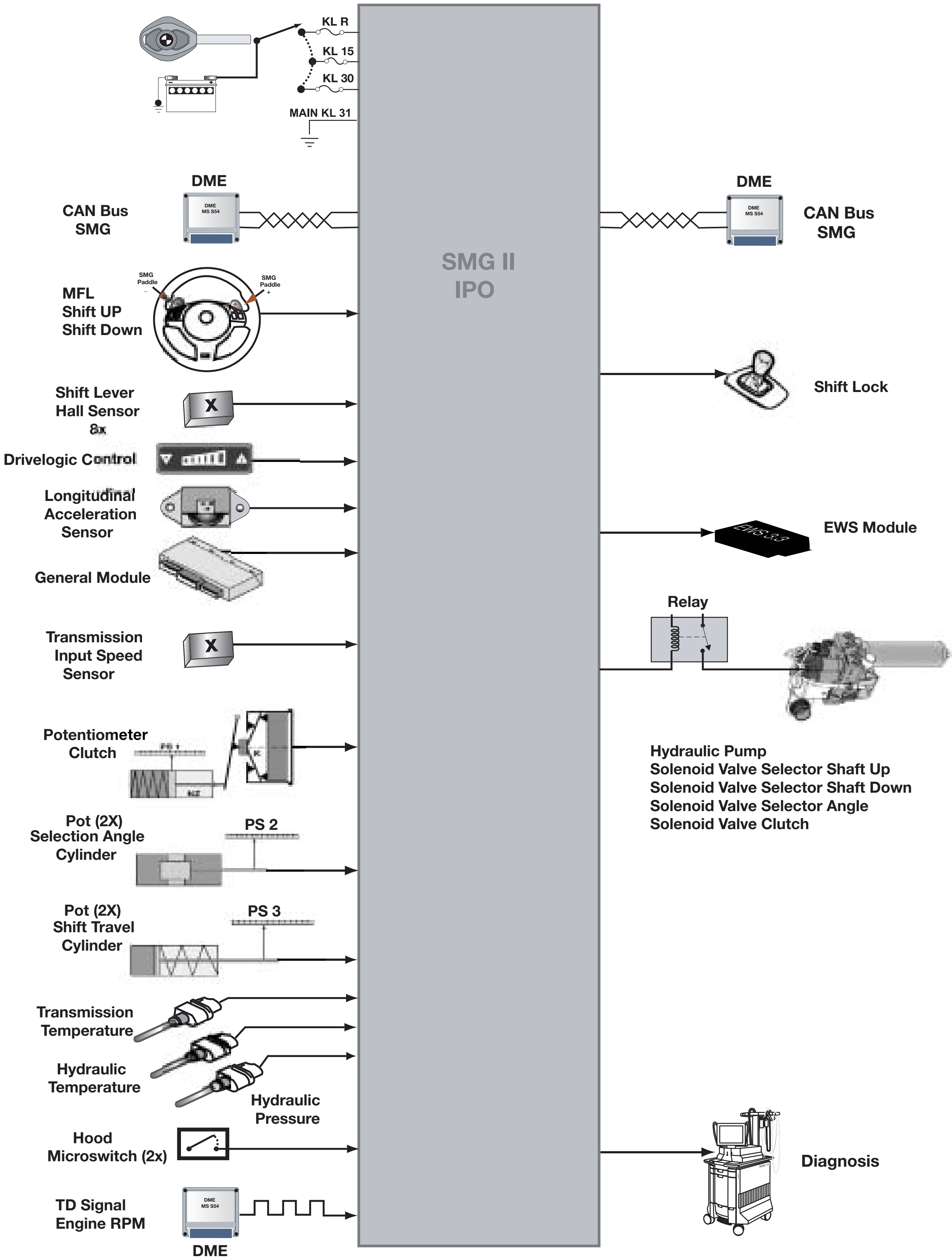
The standard basic gearbox (S6S420G), as used in the M3, is transformed into a sequential gearbox with the addition of a hydraulic unit and shift assembly, a special clutch slave cylinder and a new shift-lever module.

SMG II Control Unit

The SMG II Control Unit, installed in the E-Box next to the DME, is a single board module with SKE (134 pin) gray colored connectors. The unit contains protection against reverse polarity and overvoltage.

Communication with the DME is via a dedicated CAN bus (SMG II CAN Bus). Based on instructions received from the DME the SMG II control unit manages the clutch solenoid valve, the selector shaft up and down solenoids, and the selection angle solenoid. Safety functions and limp home capabilities are also part of the SMG II programming.

While the SMG II control unit receives many of the inputs and manages the control of the hydraulic system, the DME is responsible for and controls all gearshifts. Sensor inputs received by the SMG II control unit are relayed to the DME for processing and monitoring.


KL R
KL 15
KL 30
MAIN KL 31
DME
CAN Bus
SMG
MFL
Shift UP
Shift Down
SMG Paddle
Shift Lever
Hall Sensor
8x
Drivelogic Control
Longitudinal
Acceleration
Sensor
General Module
Transmission
Input Speed
Sensor
Potentiometer
Clutch
Pot (2X)
Selection Angle
Cylinder
PS 2
Pot (2X)
Shift Travel
Cylinder
PS 3
Transmission
Temperature
Hydraulic
Temperature
Hydraulic
Pressure
Hood
Microswitch (2x)
TD Signal
Engine RPM
DME
SMG II
IPO
DME
CAN Bus
SMG
Shift Lock
EWS Module
Relay
Hydraulic Pump
Solenoid Valve Selector Shaft Up
Solenoid Valve Selector Shaft Down
Solenoid Valve Selector Angle
Solenoid Valve Clutch
Diagnosis

SMG II Control Unit Inputs/Outputs

SMG CAN Bus

The SMG CAN Bus is the link for signal exchange between the DME and SMG II Control Unit. It allows the DME to issue command instructions for clutch and gearbox control as well as shift sequence and enables SMG II communication with the vehicle CAN BUS via the DME.

Signals exchanged via SMG CAN Bus:

Engine Speed	Engine Coolant Temp	Engine Oil Temp
Intake Air Temp	PWG	EDR Feedback Pots
Wheel Speed	Transverse Acceleration	Steering Angle
Cruise Status	Parking Brake	Door Contacts
Brake Light Switch	Key Memory	

Engine Speed

The engine speed signal is transmitted twice to the SMG II control unit. One signal arrives via the SMG CAN, the other arrives via a hard wire from the DME.

Engine Coolant Temp
Engine Oil Temp
Intake Air Temp

The signals are inputs directly into the DME and are shared with the SMG II control unit as the information is needed over the SMG II CAN.

PWG

The PWG signal is input into the DME and forwarded to the SMG II control unit. The information is used to calculate engine load.

EDR Feedback Pots

These potentiometers provide throttle position information that is useful during slip intervention.

Wheel Speed

Conditioned digital wheel speed information is received from the DSC control unit. The SMG II control unit uses data from all 4 wheels to detect vehicle speed and wheel slip in the A-Mode and during down shifts in all modes to detect drag torque induced wheel slip.

Transverse Acceleration

Transverse Acceleration data is transferred from the DSC control unit in the A-Mode so that up and down shifts may be prevented during high speed cornering. This sensor information is further evaluated for slip recognition purposes.

Steering Angle
This data from the steering angle sensor is sent via the CAN Bus for cornering and slip control information.

Cruise Status
The cruise mode is deactivated when a driver initiated shift is made in the S-Mode, during A-Mode operation, the cruise control setting is maintained.

Parking Brake
Information concerning parking brake application affects gear engagement and vehicle operation.

Door Contacts
The hall effect door position sensors integrated into the door latch mechanism signal the GM. This data is transferred via the K-Bus and CAN Bus for safety program initiation.

Brake Light Switch
Brake pedal status is transferred to the SMG II control unit via the DME. The signal is used for:

Unlocking the shift lock	Brake detection	Engine Starting
Downhill detection	Clutch Disengagement while stopped.	

Key Memory
At this time no functions for Car or Key Memory are provided for SMG II

SMG II Control Unit Inputs

MFL
Upshift and downshift signals from the paddle switches located on the steering wheel.

Shift lever
Located in the shift lever module, 8 hall sensors detect upshift and downshift requests and are also used for Selector Lever position indication (Forward, Reverse and Neutral). Signals from the hall sensors are also used to initiate mode changes from S-Mode to A-Mode and back.

DRIVELOGIC
The shift characteristics are activated by means of the switch located on the console just to the rear of the shift lever.

Longitudinal Acceleration
The signals from the Longitudinal Acceleration Sensor which is mounted under the passenger seat are used for uphill driving programs.

General Module
Load deactivation information (Sleep) is received by the SMG II Control Unit.

Clutch Position
Input from the PLCD providing exact clutch position.

Shift Position
The Position sensor provides two inputs (PS2 and PS3, each a dual pot) for position recognition of the main selector shaft in the transmission.

Gearbox RPM
A hall sensor is used to measure transmission input shaft speed.

Hydraulic Pressure
A Pressure transducer for monitoring hydraulic pressure sends pressure information to the SMG II Control Unit.

Temperature Sensors
Two NTC sensors are used for measuring Gearbox oil temperature and hydraulic fluid temperature.

Hood Contacts
Two Micro switches located in the hood latch mechanism provide a ground signal to the SMG II Control Unit when the hood is closed.

Engine Speed
Calculated engine speed received from DME via hardwire serves as redundant information with that received via the SMG CAN Bus.

SMG II Control Unit Outputs

Shift Lock Mechanism
The Shift Lock Mechanism locks the shift lever in position for parking and prevents unintended gear changes as part of the safety programming.

EWS
During the start-up operation, the SMG II Control Unit confirms shift lever position (0) and brake application and signals the EWS module which then allows starter engagement.

Hydraulic Unit
The Hydraulic Unit is energized through a relay controlled by the SMG II Control Unit. The operation of four (4) solenoid valves located in the hydraulic unit that are used to actuate the clutch and shift the transmission are also controlled by the SMG II.

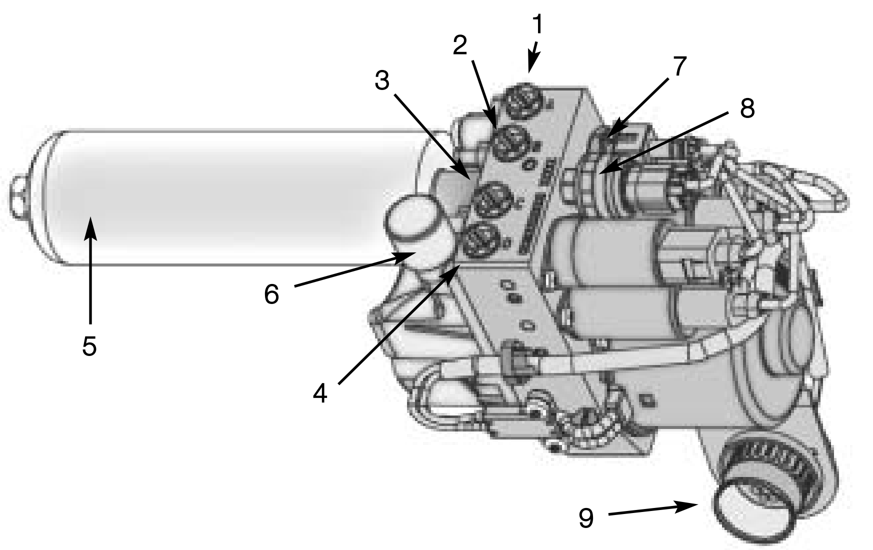
DME Control Unit MS S54

Programming in the MS S54 controls the shift sequence through the SMG II CAN Bus interface with the SMG II control unit.

Hydraulic Unit

The Hydraulic Unit generates the oil pressure and controls the shifts. It is mounted under the intake manifold in the area of the starter motor.
The hydraulic unit is filled with .45 L Pentosin CHF 11S fluid and operates at a working pressure of 45-80 Bar.
The hydraulic units consists of the following components:

- Aluminum Housing
- Electro-Hydraulic pump with filter
- 18 pin electrical connector
- Pressure accumulator and non-return valve
- Pressure relief valve
- Oil pressure sensor
- Oil temperature sensor
- Fluid Expansion tank
- Proportional directional valve for clutch control
- Proportional directional valve for selector shaft angle control
- Pressure control valve for shift travel cylinder actuation



1. Hydraulic Line for Shift Travel 1 Gears 1,3,5.
2. Hydraulic Line Slave Cylinder Clutch Control.
3. Hydraulic Line for Selector Angle Control Cylinder.
4. Hydraulic Line for Shift Travel 2 Gears 2,4,6.
5. Pressure Accumulator.
6. Supply Line from Hydraulic Tank.
7. Hydraulic Fluid Temp Sensor
8. Hydraulic Fluid Pressure Sensor.
9. X 5330 18 Pin connector.

SMG II Hydraulic Unit 45-01-5A

Hydraulic Pump

The Hydraulic Pump, installed in the Hydraulic unit, generates the pressure required to operate the clutch and perform gear changes.
The pump is a piston pump driven by an electric motor, actuated by the SMG control unit via a relay so that oil pressure is always between 45 and 80 bar. Power consumption of the electric motor is 20 amps.
When the fluid pressure in the hydraulic unit drops below 45 bar, the SMG II control unit activates the relay and supplies the electric motor with B+. At a hydraulic pressure of 80 bar, the SMG II control unit deactivates the relay.
To ensure there is sufficient pressure when the engine is started, the hydraulic pump is activated below an accumulator pressure of 45 bar when the door is opened or the vehicle is unlocked with the key or the remote.
In the event of a hydraulic system failure the gearbox warning lamp is turned on in the IKE and if hydraulic pressure fails to build, no further gearshifts are allowed. This allows the reserve pressure in the accumulator to be used to place the gearbox in the Neutral position when the vehicle comes to a stop.

Pressure Accumulator and Non-Return Valve

The Pressure Accumulator in the hydraulic unit ensures that pressure generated by the pump is stored in the system for a certain amount of time. The accumulator is divided into two chambers by a piston, with nitrogen at 39 bar filling one chamber and fluid delivered by the hydraulic pump filling the other chamber. The volume of the accumulator is 150ccm.
The Non-Return Valve at the pump outlet prevents the hydraulic oil pressure from dropping when the pump is not running.

Pressure Relief Valve

The Pressure Relief Valve opens if the hydraulic oil pressure reaches 100 bar, creating a circuit between the suction and pressure sides of the pump, thus preventing further increase in pressure.

Hydraulic Oil Pressure Sensor

Mounted on the hydraulic unit the Oil Pressure Sensor informs the SMG II control unit of the current hydraulic pressure. At 0 bar pressure a voltage signal of .5 volts is sent to the SMG II with the voltage increasing linearly to 4.58 volts at 100 bar of pressure.
Failure of the pressure sensor whether shorted or open will result in the hydraulic unit being activated for a fixed amount of time at predetermined intervals and after each gearshift to maintain system pressure.

Hydraulic Oil Temperature Sensor

Temperature of the hydraulic oil is monitored by the SMG II control unit via a NTC temperature sensor located in the hydraulic unit.

Hydraulic Fluid Expansion Tank

Hydraulic Fluid Expansion Tank Mounting

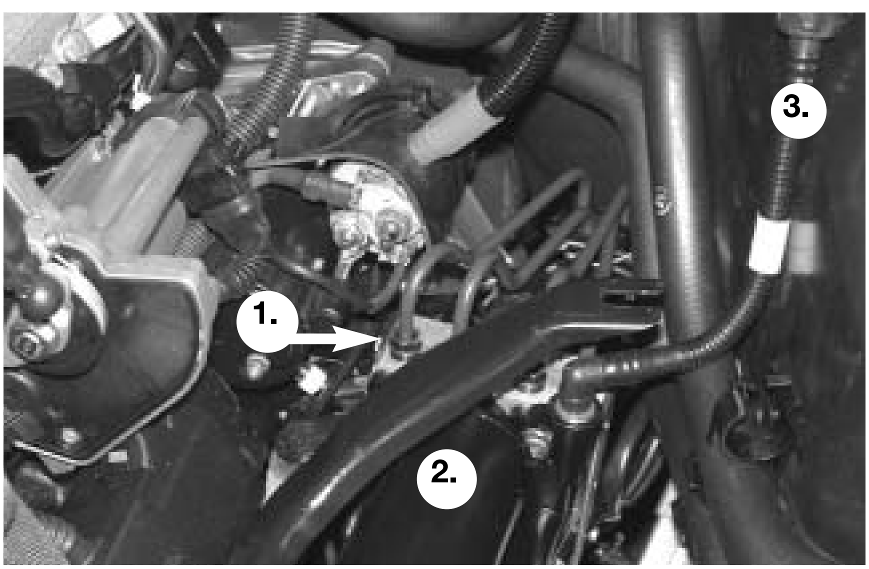
45-01-09

Hydraulic Fluid Expansion Tank Quick Release Coupling.

The Hydraulic Fluid Expansion Tank is mounted on the rear of the intake manifold and connected to the hydraulic unit via a plastic supply hose with a quick release coupling. A valve in the tank prevents oil loss when the supply hose is disconnected.

Solenoid Valves

Four solenoid valves are installed in the hydraulic unit. Two of the solenoid valves are designed as proportional directional valves (1- for clutch control and 1- for selection angle cylinder actuation). The other two solenoid valves are pressure control valves (both used for shift travel cylinder actuation).



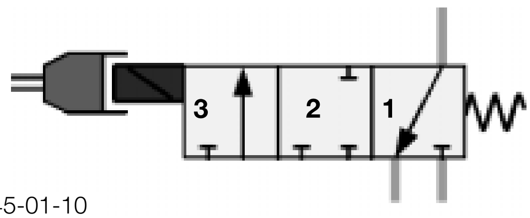
1. Hydraulic lines at solenoids
2. Accumulator
3. Supply Line from Expansion Tank

45-01-09

Hydraulic Unit in vehicle with intake manifold removed

Proportional Directional Valves

The two proportional directional valves have three positions: pressure reduction, pressure holding, pressure increase.



1. Pressure Reduction
2. Pressure Holding
3. Pressure Increase

45-01-10

Proportional Directional Control Valve

The proportional directional valves are set in the ***pressure reduction position*** when there is no gear shifting or clutch operation in progress. In this condition the two cylinders (clutch cylinder and selector angle cylinder) are connected to the expansion tank.

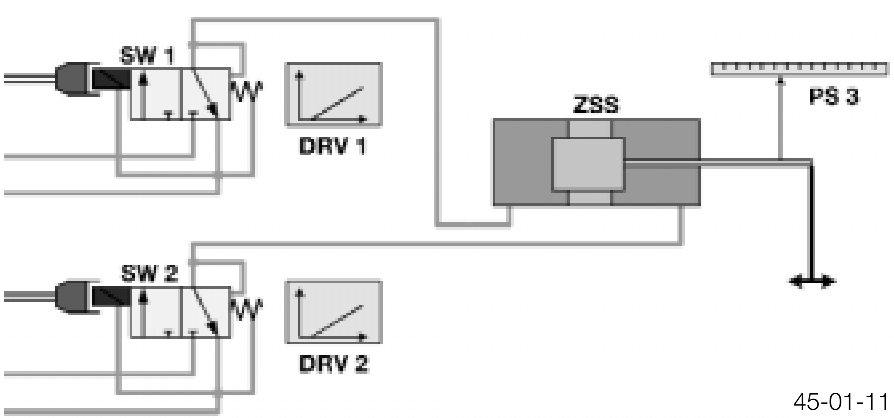
During clutch operation or main selector shaft rotation the valve is placed in the ***pressure increase position***. In this position the valve connects the cylinder to the hydraulic pressure accumulator. At this stage the solenoid will consume approximately 1.1 - 2 amps. The valve is fully open up to 2 amps.

When the clutch is to be disengaged or the main selector shaft is to remain in the activated position, the valve switches to the ***pressure holding position***. With the valve in this position the flow of hydraulic oil to the cylinder is interrupted and the piston of the activated cylinder remains in a pressurized mode.

Pressure Control Valve

The piston in the shift travel cylinder must be moved in both directions (in/out) by pressure. Two pressure control valves are required to achieve this movement.

With no current applied to the valves they are in the open position allowing connection of the cylinder chamber and the expansion tank. Applying current to one of the solenoids will cause hydraulic fluid to flow against the cylinder piston pushing it in one direction. Fluid from the other side of the piston will be forced through the second control valve into the expansion tank.



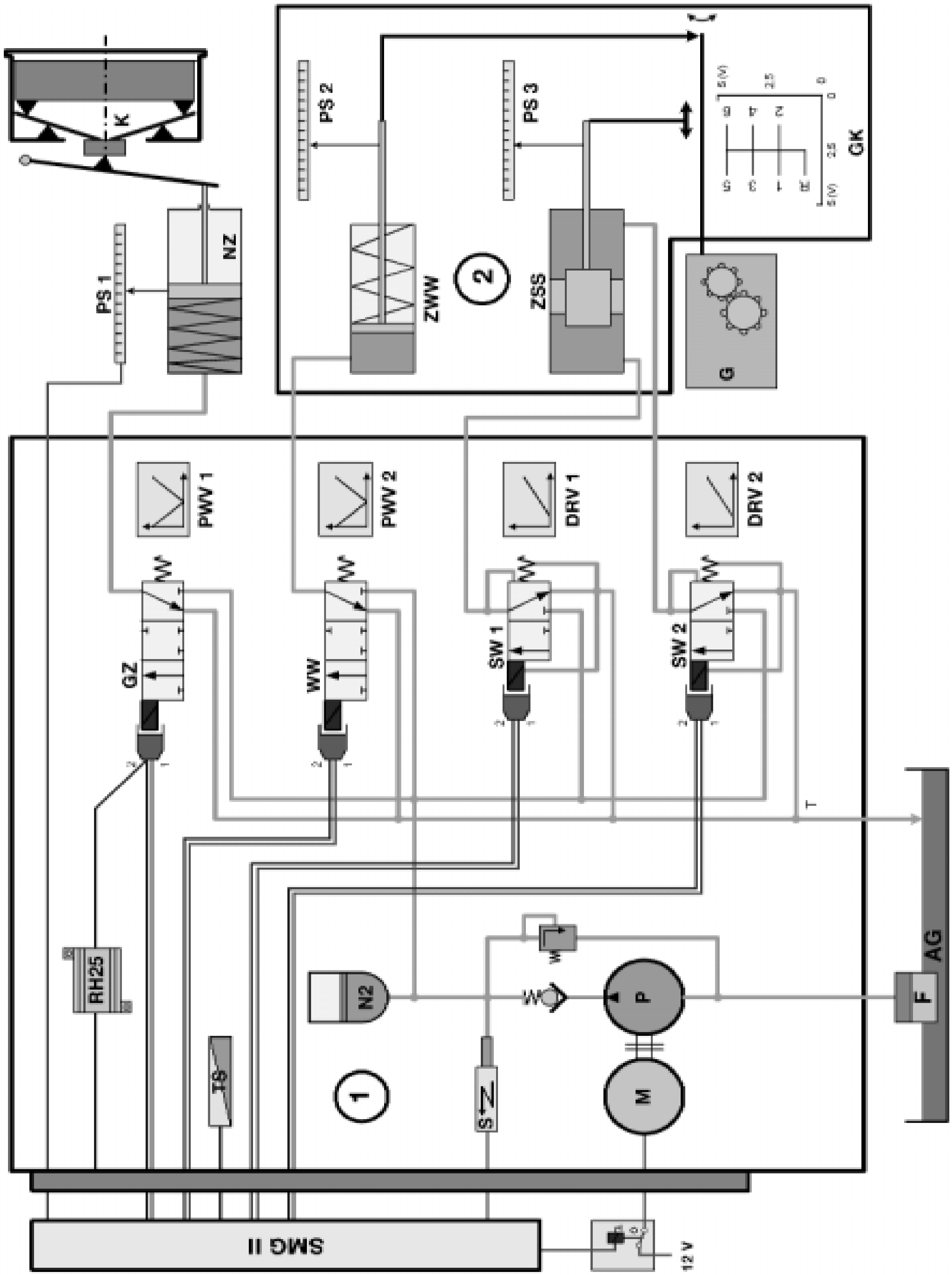
SW1 - DRV1
Pressure Control Valve

SW2 - DRV2
Pressure Control Valve

ZSS
Shift Travel Cylinder

PS3
Shift Travel Position Sensor

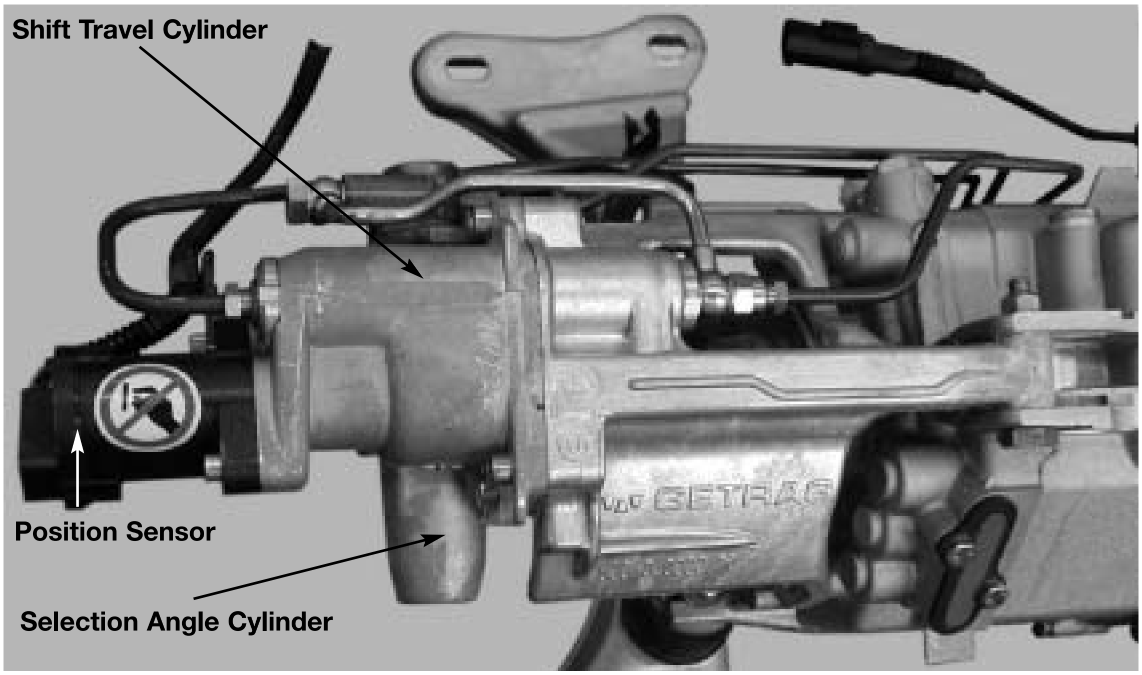
45-01-11


PS 1
NZ
K
PS 2
PS 3
ZWW
ZSS
2
G
GK
PWV 1
PWV 2
DRV 1
DRV 2
GZ
WW
SW 1
SW 2
T
AG
F
P
M
N2
1
RH25
TS
SMG II
12 V

Index	Designation/Function	Location
1	Electro-Hydraulic Control Unit	On Engine Under Intake Manifold
2	Gearbox Mounted Actuator	Top of Box at Rear
G	Manual Gearbox	Normal Position
K	SAC (Self Adjusting Clutch)	Normal Position
SMG II	SMG II Control Unit (134 Pin SKE)	E-Box next to DME (Grey colored Connectors)
R	Relay	
12v	12V Power Supply	
RH25	4.7 Ω Resistor	Internal in Hydraulic Control Unit
TS	Temperature Sensor	On Hydraulic Control Unit (See Page 9)
GZ PWV 1	Proportional Directional Control Valve and Solenoid for Clutch Control	In Hydraulic Control Unit
WW PWV2	Pressure control Valve and Solenoid for Selection Angle Control	In Hydraulic Control Unit
SW1 DRV1	Pressure control Valve and Solenoid for shift travel control	In Hydraulic Control Unit
SW2 DRV 2	Pressure control Valve and Solenoid for shift travel control	In Hydraulic Control Unit
N2	Hydraulic Accumulator 39 Bar	In Hydraulic Control Unit
S	Hydraulic Oil Pressure Sensor (0-100 Bar) (.4V=25 Bar, 2.9V=60 Bar, 3.7V=80 Bar, 4.5v=100 Bar)	On Hydraulic Control Unit (See Page 9)
RS	Non-return Valve	In Hydraulic Control Unit
DBV	Pressure Relief Valve	In Hydraulic Control Unit
M	12V Electric Motor	In Hydraulic Control Unit
P	Hydraulic Pump	In Hydraulic Control Unit
F	Fluid Intake Filter	
AG	Expansion Tank	Mounted on Intake Manifold
PS1	Position Sensor, Clutch	Mounted on slave Cylinder
NZ	Clutch slave Cylinder	Normal Position
PS2	Position Sensor, Selection Angle Cylinder	Mounted on Gearbox Actuator
ZWW	Selection Angle Cylinder	In Gearbox Actuator
PS3	Position Sensor, Shift travel Cylinder	In Gearbox Actuator
ZSS	Shift Travel Cylinder	In Gearbox Actuator
GK	Gear Detection	

Gearbox Actuator

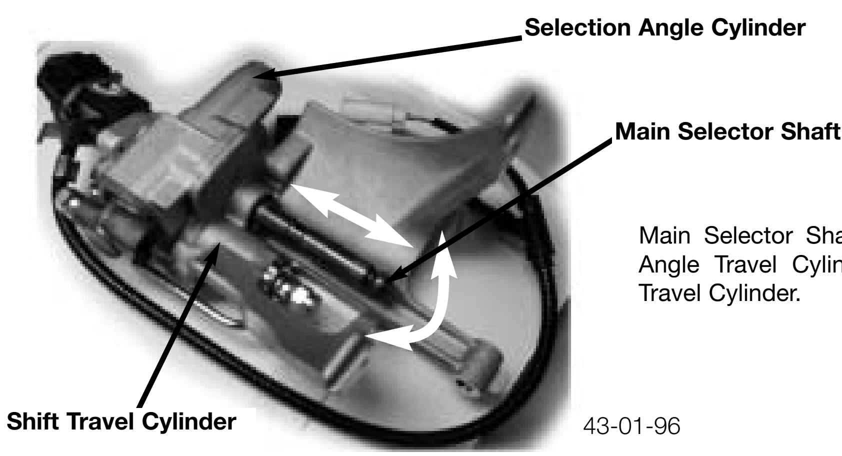
The Gearbox Actuator, manufactured by Getrag, is attached to the rear of the gearbox housing and performs the gear change movements.



SMG II Gear Box Actuator 45-01-15

The gearbox actuator consists of the following components:

- Gearbox Actuator Housing
- Main Selector Shaft
- Position Sensor

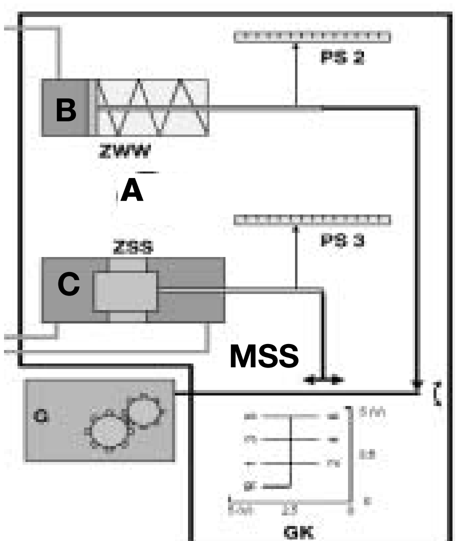


43-01-96

Main Selector Shaft (MSS) is rotated by Selection Angle Travel Cylinder and Moved In/Out by Shift Travel Cylinder.

Gear Actuation

When no gear is engaged the selector shaft is the the neutral position in the shift gate between 5th and 6th gears. The piston in the selection angle cylinder (B) is pushed against the stop by a spring. The shift travel cylinder is in the central position in cylinder C (pressure is equal on both sides).
With the selection of 1st gear, the piston in the selection angle cylinder (B) is charged with hydraulic fluid (Pressure increasing mode). The SMG II control unit is informed by the position sensor (PS2) when the piston and consequently the main selector shaft (MSS) has reached the point in the shift gate between 1st and 2nd gears. The piston is the selection angle cylinder is placed in the the pressure holding mode to maintain MSS position.
Shift Travel cylinder (C) is now activated via the control valves . One side of the piston in the cylinder is supplied with hydraulic fluid under pressure, the other side of the piston chamber is open to the expansion tank. The piston and with it the MSS is pushed in the appropriate position and a gear is engaged (Either 1st or 2nd). A redirection of fluid on the shift travel cylinder piston will cause the other gear to be engaged.



45-01-16

A Gearbox Actuator
B Selection Angle Cylinder with Position Sensor PS2
C Shift Travel Cylinder with Position Sensor PS 3
G Manual Gearbox
GK Position Sensor Voltage Matrix
MSS Main Selector Shaft

Position Sensor

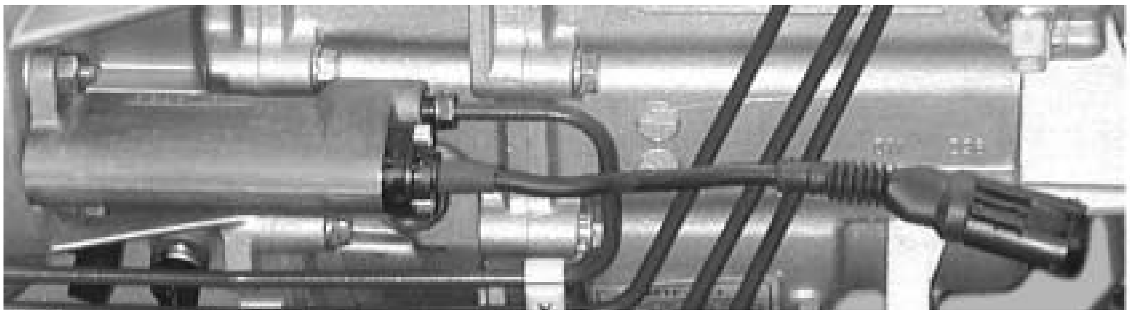
Position Sensor view from rear of Transmission

The Position Sensors (PS2,PS3) for Selection Angle and Shift travel are potentiometers and installed in a single housing.

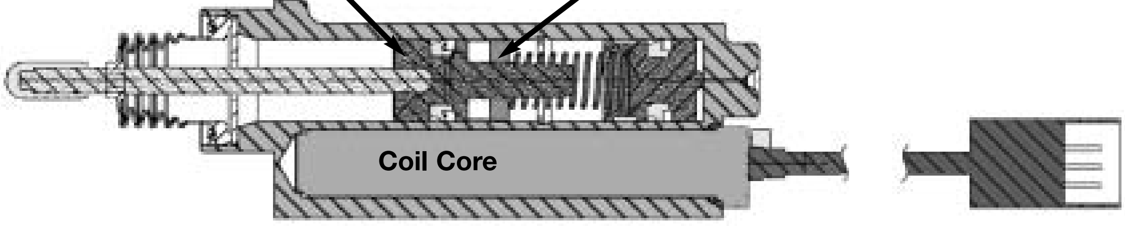
45-01-16

Clutch Slave Cylinder with PLCD

The Clutch Slave Cylinder is an innovative and new feature of the SMG II. The component consists of a slave cylinder with an integrated sensor housing. The sensor termed PLCD (Permanent Linear Contactless Displacement) measures clutch release travel.



SMG II Slave Cylinder with PLCD 43-01-22



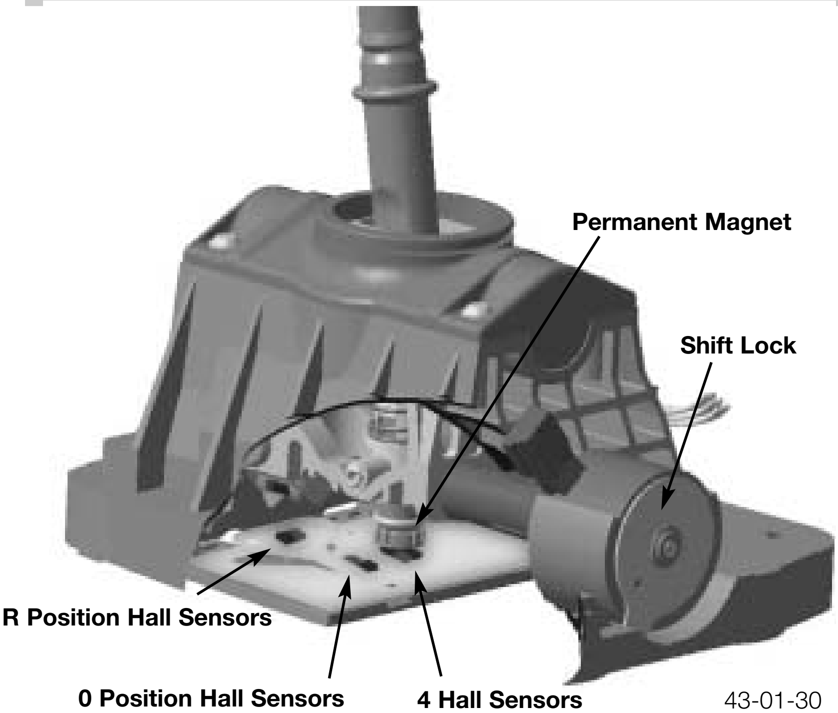
43-01-22

Shift Lever

Hall effect sensors are mounted in the Shift Lever Module to detect position and movement of the shift lever. A total of 8 hall sensors are used in the shift lever module with 4 sensors dedicated to +/- gear change requests and mode changes requests (A to S mode).
Two sensors are used for detection of the reverse gear position and two for detection of the neutral shift lever position.
The following shift lever positions are possible:

- Reverse (R)
- Idle-Speed (0) (Neutral)
- Forward/Sequential Mode (S-Mode)
- Change positions
  + for Upshifts
  - for Downshifts
- Mode Change (A/S Modes)

A spring loaded mechanism holds the shift lever in the forward, idle-speed and reverse positions.



Permanent Magnet
Located at bottom of shift lever

Shift Lock
Located towards front of shift module

4 Hall Sensors
Used for detection of +/- gear change requests and mode change requests

0 Position Hall Sensors
Used to detect idle-speed position (0)

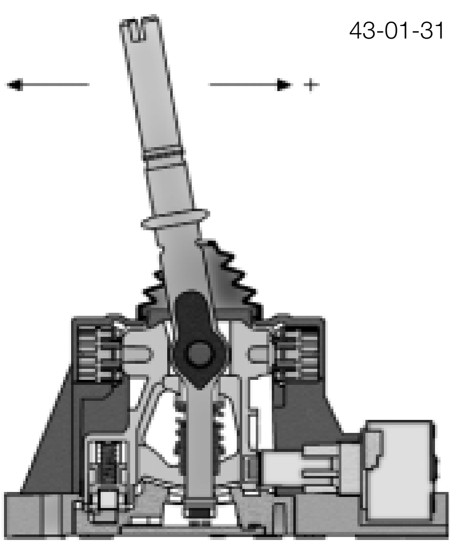
R Position Hall Sensors
Used to detect Reverse position (R)

SMG II Shift Lever Module

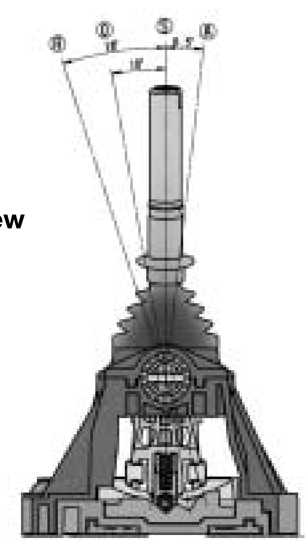
Upshifts and downshifts are made by moving the shift lever in the up or down direction from the spring latched forward position. Moving the shift lever back shifts the transmission up one gear, moving the lever forward shifts the transmission down one gear. The shift lever must be returned to the middle position to engage another upshift or downshift.

Moving the shift lever to the right while in the forward position changes the shift modes from A-Mode to S-Mode and back again.

Programming in the SMG II control unit will prevent impermissible downshift requests.



Side Cross Sectional View



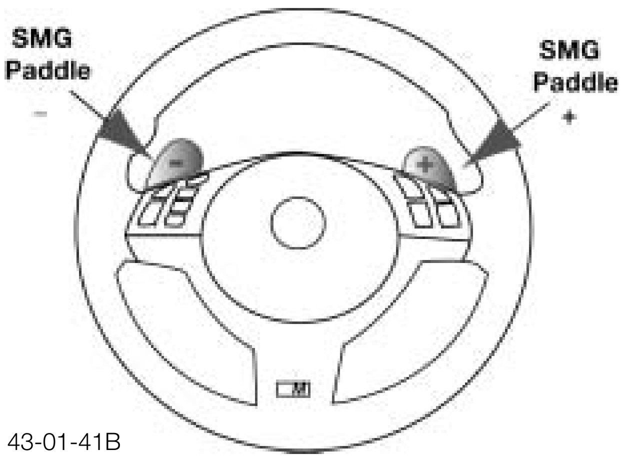
Rear Cross Sectional View

43-01-32

Shift Lock

The shift lock prevents unintended gear changes.
For safety reasons the brake pedal must be depressed before the shift lock is disengaged, allowing gear selection. Once a gear (either R or 1) has been engaged, shifting between R and 1 can be accomplished without stepping on the brake pedal for a time period of 2 seconds. When 2 seconds has elapsed, the shift lock will engage preventing shifting between R and 1 unless the brake pedal is depressed again.
The shift lock is energized in the unlocked position and rests in the lock position.

Steering Wheel Paddle Switches



43-01-41B

SMG Steering Mounted Paddle Switches
+ Request upshift
- Request downshift

The Steering Wheel Paddles Switches are hardwired to the SMG II control unit and are used to request upshift and downshifts. Pulling on the right side paddle will request the SMG II control to make a shift to a higher gear. Pulling the left side paddle request a shift to a lower gear.
Both paddles provide a momentary switched ground signal to the SMG II control unit.

DRIVELOGIC Control

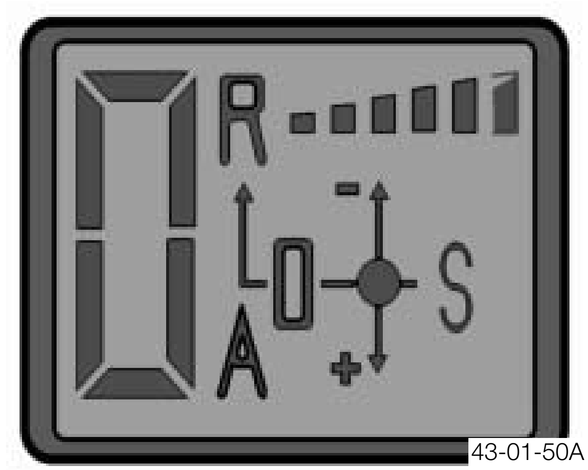
The DRIVELOGIC Control makes it possible for the driver to adapt the gearshift characteristics of the transmission to his own individual style with each driving mode (A-Mode, S-Mode).
The DRIVELOGIC Control Button is located on the center console just to the rear of the shifter. The button provides two inputs to the SMG II control unit. Both inputs are momentary switched grounds, one for program mode up and one for program mode down.
DRIVELOGIC Control provides selection of 5 programs in the A-Mode and 6 programs in the S-Mode. The individual programs differ as follows:

- A-Mode
  There are 5 automated gearshift programs from A1(Winter mode, vehicle starts off in 2nd gear) to A5 (Sport mode, a highly dynamic program).

- S-Mode
  There are 6 different sequential gearshift programs from S1 (Slow, relaxed shifts with soft clutch engagement) to S6 (Very fast shifts with quick clutch engagement, only accessible with DSC turned off).

43-01-98

SMG II Shifter and DRIVELOGIC Control



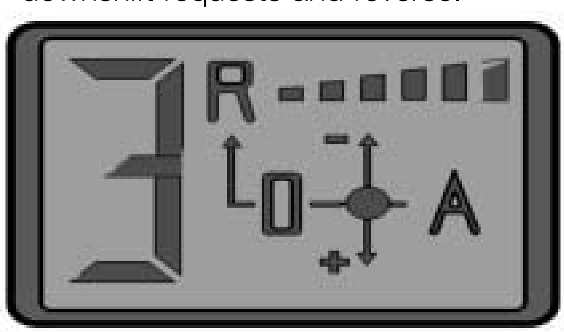
43-01-50A

SMG II Display Vehicle in A-Mode

SMG II Electronic Display Unit

Located in the instrument cluster just below the tachometer is the SMG II Electronic Display Unit. Information on the display is sent from the SMG II control unit to the instrument cluster via the MS S54 control unit.
The shift program, the gear engaged and the mode are indicated in the display.

- 0 Indicates vehicle is in idle-speed or neutral. This portion of the display changes dependent upon gear selected. Possible displays are: 0, 1, 2, 3, 4, 5, 6 or R.
- The bar graph indicates the drive program selected. The number of the bars lighted correspond to the program number (ie. 5 bars lighted means 5th program selected).
- The A next to the gear selected indicator shows the A-Mode is active. The A will disappear when the gear shift lever is moved to the right and S-Mode becomes active.
- The S next to the gate indicates the S-Mode is available. When S-Mode is active, and A will be displayed here.
- Gate Diagram in the display shows movement paths of the shift lever for upshift and downshift requests and reverse.



43-01-50B

SMG II display indicating:

3rd Gear
S-Mode
5th Program

Shift Lights

In S-Mode optimum shift points are indicated by LED's integrated into the tachometer. As the tachometer approaches redline a sequence of LED's illuminate on the face of the gauge. As the tach reaches the optimal shift point the final LED illuminates; this red LED indicates the optimal shift point.

Shift Lights

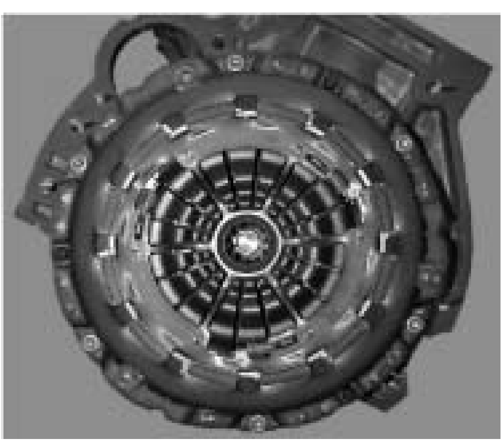
43-01-51

DSC Control Unit

Data concerning transverse acceleration and wheel speed (all 4 wheel speed sensors) is relayed to the SMG II control unit via the MS S54 control unit.
Unless specifically switched off Dynamic Stability Control remains in operation during all modes in A-Mode and in all S-Modes except program S6.
Regardless of the last setting, DSC is automatically activated whenever the car is started.

SAC Clutch

The SMG II operates with the SAC clutch used in the S54B32 manual gearbox.
The pressure force of the pressure plate over the driving disc onto the flywheel remains the same over the clutch's entire operating time.
The release force is likewise the same over the operating time.The shift quality in the SMG II thus remains the same.



Self Adjusting Clutch (SAC)

Workshop Hint
FC 68 Indicates discrepency between input and output speeds in relation to gear ingaged. Clutch is slipping.

43-01-97

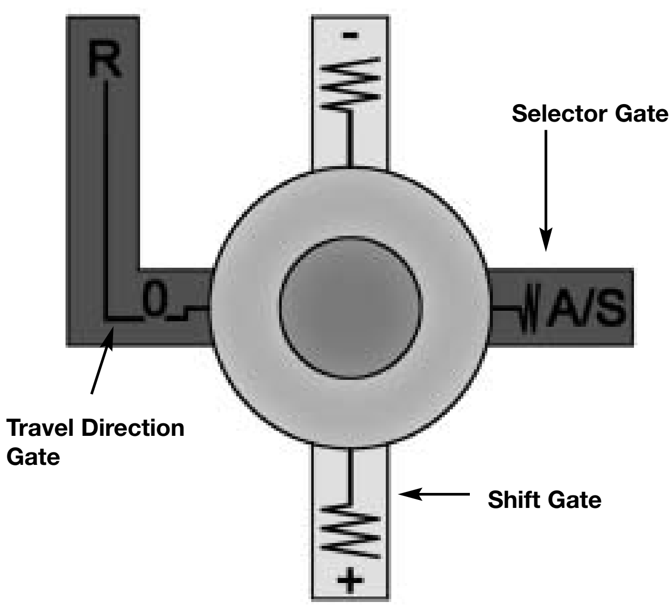
Principle of Operation

Engine Starting

Unlocking the car or opening the drivers door wakes up the GM which sends a wake up call to the SMG II control unit. Awoken the SMG II looks at hydraulic pressure stored in the accumulator. Pressure greater than 45 causes the SMG II to wait for starting initiation. Hydraulic pressure under 45 bar, causes the SMG II to energize the hydraulic pump relay, powering up the pump to build system pressure in anticipation of a start sequence.
Engine starting is only possible when the shift lever is in the 0 (idle-speed or neutral) position and the brake pedal is depressed. If a gear is selected before the key is turned to the start position of if the vehicle has been parked in gear, the shift lever must first be moved to the 0 position and the brake depressed.
Responsibility for starter operation remains with the EWS module. As the key is turned to the KL50 position, the EWS module waits for confirmation from the SMG II control unit that the shift lever position is 0 and that the brake pedal is depressed. The SMG II control unit is notified of KL50 and brake pedal position via the SMG CAN Bus by the MS S54. Receipt of notification of KL50 causes the SMG II control module to check shift lever and brake pedal position. Seeing shift lever position 0 and the brake pedal depressed, the SMG II momentarily supplies a switched ground signal to the EWS module to serve as a release to allow starter engagement. Upon receiving these confirmations the EWS module activates the starter.
The clutch is open (not engaged) during start-up operation.

Engaging A Gear

Once the engine is running the driver is able to engage the gear selection of choice through the shift lever.



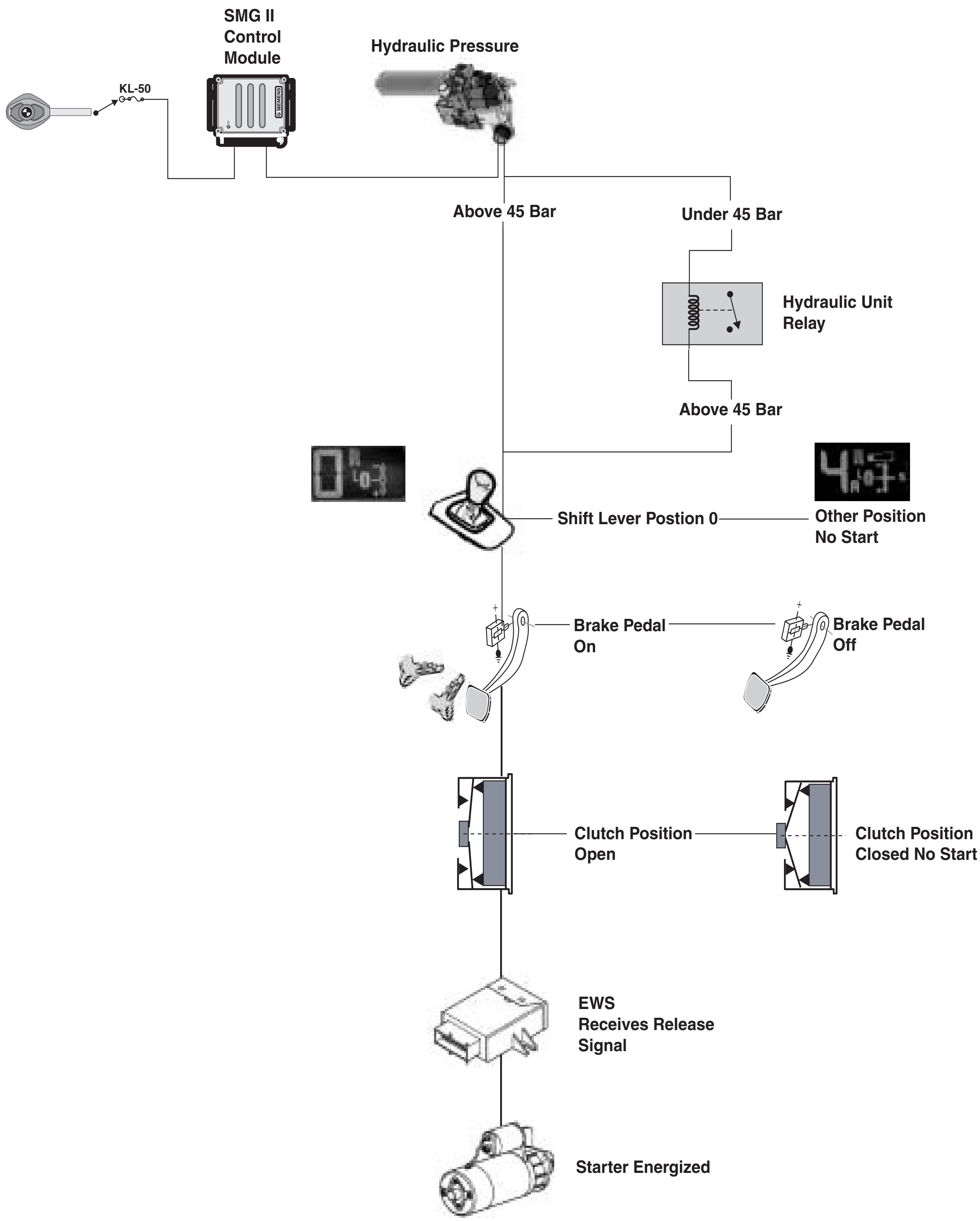
The shift lever may be moved in the following directions:

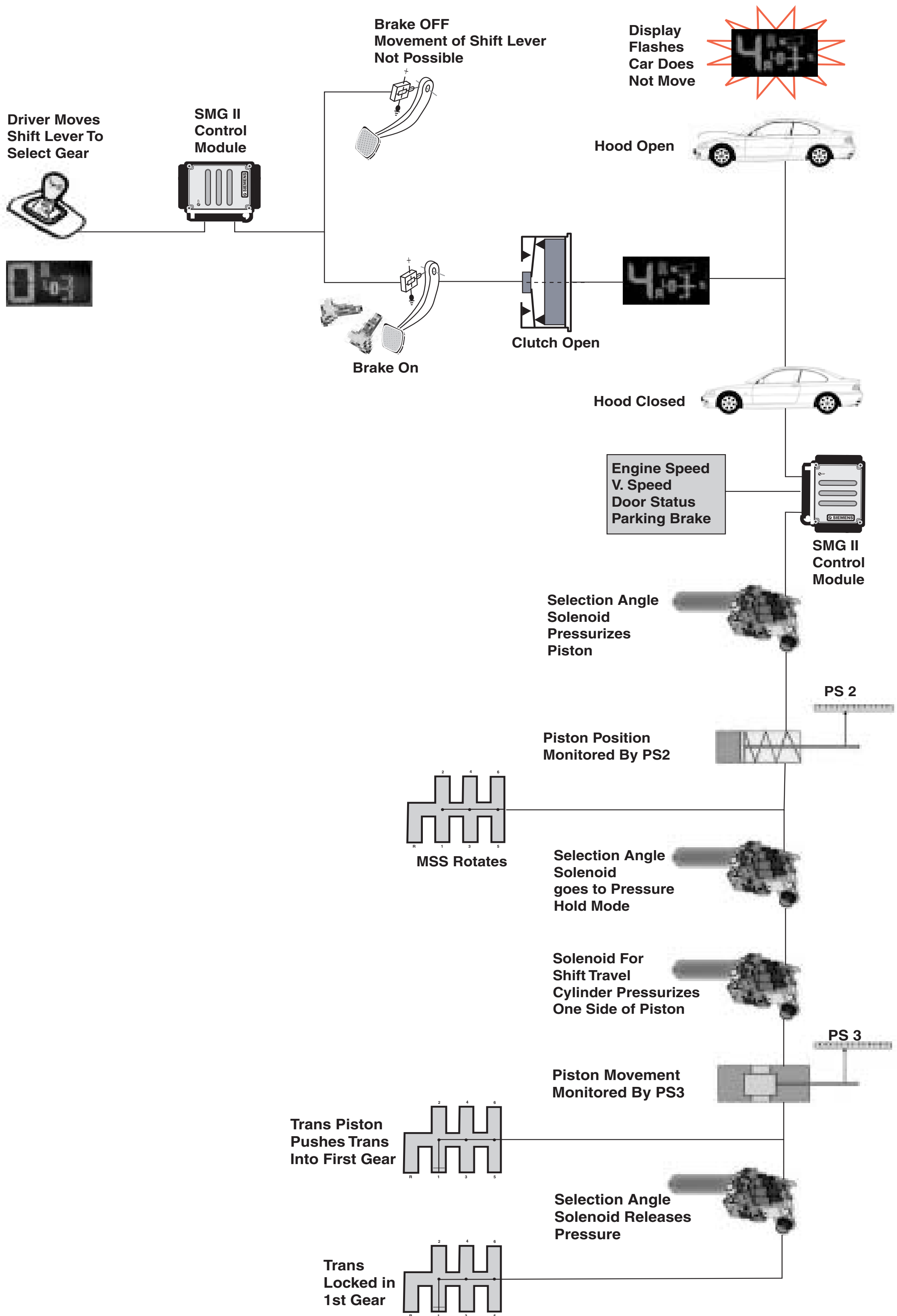
Travel Direction Gate for selecting direction of travel (Forward, Neutral (0) and Reverse).

Selector Gate for changing operating modes (A-S and S-A).

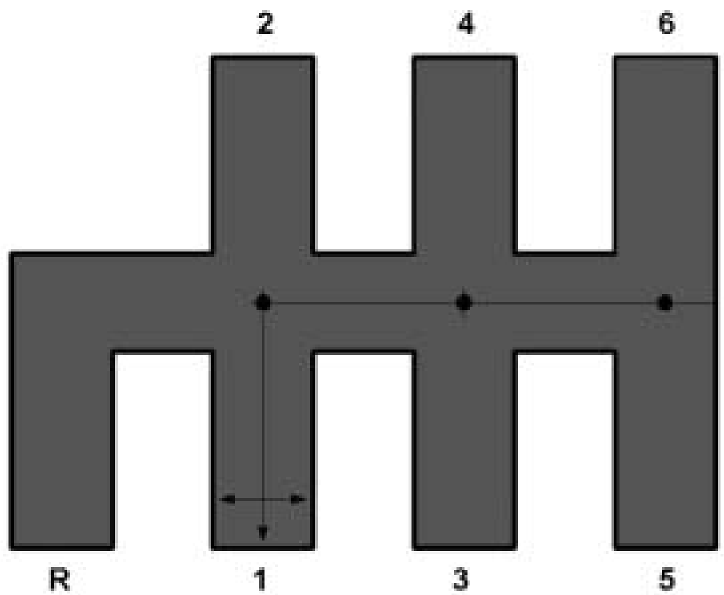
Shift Gate for selection of Specific forward gear (1-6).

43-01-70


SMG II
Control
Module
Hydraulic Pressure
KL-50
Above 45 Bar
Under 45 Bar
Hydraulic Unit
Relay
Above 45 Bar
Shift Lever Postion 0
Other Position
No Start
Brake Pedal
On
Brake Pedal
Off
Clutch Position
Open
Clutch Position
Closed No Start
EWS
Receives Release
Signal
Starter Energized


Driver Moves Shift Lever To Select Gear
SMG II Control Module
Brake OFF Movement of Shift Lever Not Possible
Display Flashes Car Does Not Move
Hood Open
Brake On
Clutch Open
Hood Closed
Engine Speed
V. Speed
Door Status
Parking Brake
SMG II Control Module
Selection Angle Solenoid Pressurizes Piston
PS 2
Piston Position Monitored By PS2
MSS Rotates
Selection Angle Solenoid goes to Pressure Hold Mode
Solenoid For Shift Travel Cylinder Pressurizes One Side of Piston
PS 3
Piston Movement Monitored By PS3
Trans Piston Pushes Trans Into First Gear
Selection Angle Solenoid Releases Pressure
Trans Locked in 1st Gear

Input from the hall effect switches in the gear shift lever is sent to the SMG II control unit. Status of the hood and brake pedal input is checked and the SMG II control unit looks at vehicle speed, engine speed, hand brake status and door position. With first gear requested and status of the inputs correct, the selection angle piston is pressurized until the main selector shaft reaches the shift gate between 1st and 2nd gears as indicated by the position sensor in the gearbox actuator assembly. The selection angle piston is then placed in pressure holding position and the shift travel cylinder is pressurized on one side by operation of the two shift valves in the hydraulic unit causing it to push the main selector shaft in the appropriate direction, engaging 1st gear.



Selection Angle cylinder rotates shift shaft into proper plane, then shift travel cylinder pushes the Main Selector Shaft in the proper direction to engage a gear.

43-02-90

First Gear Engaged

Engagement of the gear via the shift travel cylinder takes place in three phases with differing pressures.

- Phase 1 is the distance which must be covered from the central position of the shift gate to the synchronization point with the gear to be engaged occurs.
- Phase 2 is the engagement of the synchronizers.
- Phase 3 is the distance that the shifting sleeve must travel after engaging the synchromesh mechanism before passing over the teeth of the gear wheel.

In three phases, varying pressures applied to the piston to ensure that the gear shift takes place with maximum comfort under minimal material load conditions and minimal wear.

Pressure is now relieved on the selection angle piston and a spring in the selection angle cylinder forces the piston back until the main selector shift contacts the flank of the 1st gear gate. The transmission is now firmly in 1st gear.

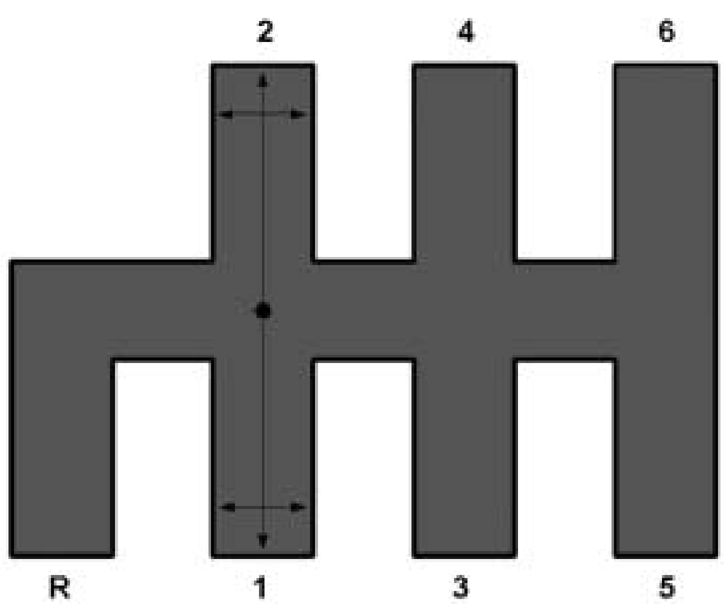
The number 1 is lighted in the shift display as communicated by the SMG II control unit to the DME and further passed on to the IKE via the CAN Bus. The SMG II control unit then looks at hood status and if closed allows clutch engagement. Hydraulic pressure to the clutch slave cylinder is controlled by a PWM signal to the Hydraulic Unit and based on engine speed, engine load, temperature, door contacts and inputs from the DSC.

Upshifts and Downshifts

The mechanical procedure for shifting whether up or down remains the same. The following sequence occurs during an upshift from 1st to 2nd.

- The selector angle cylinder is pressurized moving the MSS to an “unlocked” position in 1st gear. When the “unlocked” position is recognized by the Position Sensor, the selector angle cylinder is placed in the pressure holding mode.
- Pressure is applied to one side of the shift travel cylinder, causing the MSS shaft to move across the neutral gate into 2nd gear.
- 2nd Gear is engaged and the pressure on the selector angle cylinder is released, “locking” the transmission in 2nd gear.

All the upshifts and downshifts are made dependent on programming and mode selection.



43-02-91

Shift travel cylinder pushing the MSS from 1st gear position to 2nd gear.

Transmission is shifted from 1st to 2nd gear.

The forces required for shifting are strongly dependent on gearbox-fluid temperature. The fluid pressures acting on the pistons of the two shift cylinders are adapted according to fluid temperature.

Shifting Operation

Depending on the driving situation, distinctions are made between trailing-throttle upshifts, trailing-throttle downshifts, acceleration upshifts and acceleration downshifts. The complete shifting operation takes place in 3 phases.

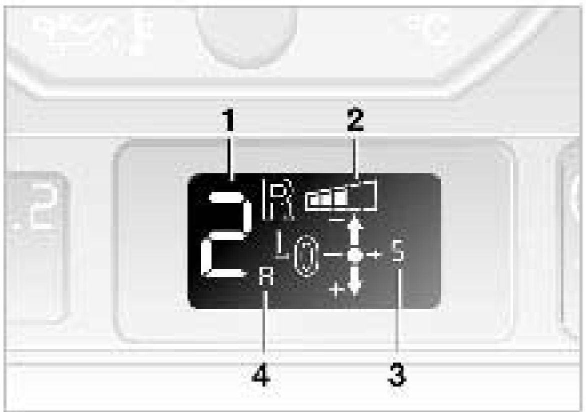
- Clutch disengagement
  The DME calculates engine torque in anticipation of a gear change. When a gear change is initiated, the speed at which the clutch is disengaged is based on this calculation. Engine torque (and rpm) is reduced as the clutch is being disengaged until a predetermined set point is reached where engine torque and clutch torque are approximately equal. The selector angle cylinder has begun to pressurize and the MSS reaches the neutral or "unlocked" position while still in gear. At this point the shift begins.
- Shift to Target Gear
  The quickness of the gearshift is defined by the SMG II control unit and influenced by the DME. Engine RPM drops off rapidly during the shift but engine torque remains relatively flat. When clutch disengagement confirmation is received by the SMG II the shift travel cylinder is pressurized on one side forcing the MSS into the neutral position in the gate (i.e. between first and second gears). Additional pressure is added causing the synchronization of the next gear and finally the MSS is driven to fully engage the gear. The pressure is then relieved from the selector angle cylinder.
- Clutch Engagement
  As soon as the target gear has been engaged fully the clutch begins to move at a speed determined beforehand by the DME. Engine RPM and torque begin to increase. The objective of the programming is to configure the meeting point of the engine and clutch torques as smoothly as possible by the engine management system.

Driving and Shift Programs

There are two drive programs for the SMG II: **A-Mode** for automated shifting and **S-Mode** for sequential shifting. Furthermore, the driver can use a DRIVELOGIC control in A/S mode to match the shift point characteristics as closely as possible to his driving style. For this purpose, 5 programs in A mode and 6 programs in S mode can be selected respectively. The individual programs differ as follows:

- **A-Mode**, automated
  There are five different automated shift programs, from A1(pulling away in 2nd gear) to A5 (sporty).
- **S-Mode**, sequential
  There are six different sequential shift programs, from S1(relaxed dynamic) to S5 (sporty) and, as a special function, S6 (super sporty).

In S mode, the 6th program can only be activated if the DSC function has been deactivated beforehand. The 6th program becomes active when the DRIVELOGIC control is operated.
Only in this program is it possible also to activate the acceleration boost. This ensures that the BMW E46 M3 receives the optimum propulsion. Naturally this places the highest load on the vehicle components affected and so increases wear.
The driver is shown which mode and which program has been selected by the SMG II display unit in the instrument cluster.



1. Gear Selected
2. Drive Program Selected
3. Shift Mode, A/S Mode
4. A Mode is active

43-02-93

SMG II Display in Instrument Cluster

A Mode

- Shift programs A1 to A5

If the driver has selected A mode using the selector lever, gearchanges are automated according to the road speed, the position of the accelerator pedal and the DRIVELOGIC control in the center console.
A mode is cancelled if the driver pulls one of the two shift switches on the steering wheel, moves the selector lever towards -/+ or activates S mode by briefly pressing the selector lever to the right.

Five shift programs (A1-A5) are available to the driver in A mode. The software for the five automated mode shift programs is stored in the SMG II control unit. The car drives in the winter driving program (A1) up to the sporty highly-dynamic program (A5).
Functions are also included to detect ambient conditions automatically and to influence the optimum gearselection.

Upshift suppression
Downshift suppression
Cornering
Uphill-driving detection
Downhill-driving detection
Braking retardation

A1 program (winter driving program)
On road surfaces with a low coefficient of friction, e.g. snow or black ice, it is possible to start off in 2nd gear by selecting the A1 program.

Upshift/downshift suppression
When driving, the driver may be forced to adapt the car's speed repeatedly to the flow of traffic by heavy braking and acceleration according to the traffic situation.

The rapid release of the accelerator pedal and rapid acceleration are detected by the SMG II control unit. If this exchange sequence takes place in short time intervals, the gearbox suppresses upshifting when the accelerator pedal is released and downshifting when it is depressed.

Upshifts to the economical gear only take place once the accelerator pedal has remained in the same position for a brief period.

Cornering
If the accelerator pedal is rapidly released before the car corners, an upshift does not take place, nor does an upshift take place while the car is cornering.

If an upshift were to occur while the car was cornering, the braking effect of the engine would be reduced or cancelled entirely, which in turn could reduce the car's rate of deceleration and it would be necessary to change back down to improve acceleration to accelerate out of the corner.

Cornering is detected by the SMG II control unit by means of the DSC lateral acceleration and steering angle detection.

Uphill-driving detection
Compared with driving on a level surface, tractive resistance during uphill driving increases by the component of the downgrade force. This requires increased engine power to maintain a constant speed. Increased engine power is achieved by having the throttle open at a slightly later stage. A downshift to a lower gear occurs to increase the engine speed depending on the road speed.

Assuming that the speed is to be kept constant, the throttle valve angle must now be reduced, which in turn would result in an upshift. The result would be damaging back-and-forth shifting if the gradient were to be negotiated at a constant speed.

Characteristic maps are stored in the control unit's software to suppress shifting of this type. The characteristic maps suppress back-and-forth shifting and provide the engine with the optimum traction force.

Downhill-driving detection

The rule of thumb that the same gear should be used for descending a gradient as for ascending the same gradient still applies.

This ensures that the engine's braking effect is exploited. The driver does not have to depress the brake pedal as frequently. This represents a clear improvement in comfort and takes the strain off the service brake.

This is made possible by the implementation of a downhill-driving detection function in the form of software. The control unit identifies that the vehicle speed is increasing in spite of overrun conditions and infers a downhill-driving scenario.

The logic circuit in the control unit begins by preventing a shift to the gear one higher.

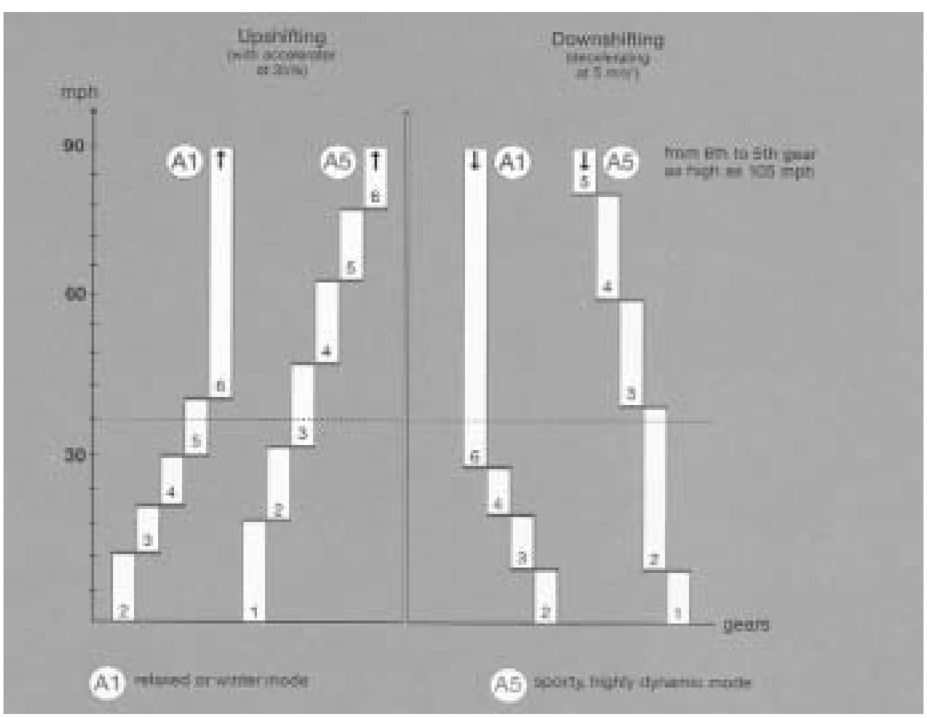
Nevertheless, if the vehicle speed increases in such a way that braking is required, a downshift takes place automatically to the gear one lower. This procedure can be repeated as many times until 1st gear is engaged.

The required data for downhill-driving detection are engine load, vehicle speed, longitudinal acceleration and service-brake condition.

Braking retardation

Because of the nature of an automatic transmission, releasing the accelerator pedal at medium or high driving speed results in an upshift. If the vehicle is then accelerated again, the accelerating performance is insufficient or a downshift must take place with more marked acceleration. In order to prevent this behavior, the braking-retardation signal is directed to the control unit.

Depending on the extent of braking retardation, a downshift to a lower gear is executed during the braking procedure. This ensures that the appropriate gear is engaged when the driver stops braking and starts accelerating.



SMG II Automated Shifting

43-02-96

S mode, sequential

Shift programs S1 to S5

The selector lever or the shift paddles on the motorsport multifunction steering wheel can be used to change gear in sequential mode (S mode). In principle all shift operations are executed.

There is no forced upshift when the maximum engine speed is reached. The driver is reminded visually by LEDs (shift lights) in the instrument cluster to make the necessary gearchange at full load before the engine's limit speed is reached.

It is possible to shift through several gears by multiple-touch operation. Gearshifting in the gearbox does not always have to take place sequentially. The driver can skip a gear by shifting very quickly.

If the driver changes down twice in rapid succession before the gearchange for the first shift command has time to complete, the gearchange is prevented in the gearbox and the gear selected by the second shift command is selected.

Downshifts which would cause the maximum engine speed to be exceeded are refused. If the driver forgets to change down as the car's speed decreases, a downshift is executed automatically when the road speed falls below a gear-dependent threshold stored in the control unit. This ensures perfect vehicle acceleration when the accelerator pedal is depressed.

Hill-climbing assistance

The SMG II is equipped with special software in order to facilitate driving off on an incline. On an ascending road, the vehicle would roll back when the brake pedal is released.

The driver can activate this function by pulling the shift switch (-) on the multifunction steering wheel for a period of 0.5 seconds while the vehicle is stationary and with the brake pedal pressed. The engine speed is increased in line with the gradient. When the brake is released, the clutch is moved to the biting point and so the car is held momentarily at the point of rolling back on an uphill gradient.

When the accelerator pedal is depressed, the clutch opens and the vehicle moves off in 1st gear. If the accelerator pedal is not pressed, the clutch opens again (after approx. 2 seconds) and the vehicle may roll back.

Note:
This mode is not for extended use. Vehicle will be held only for 2 seconds.
Holding vehicle on upgrade by holding slight pressure on accelerator pedal applies clutch.
Doing so will cause excessive wear on clutch and lead to failure.

Acceleration boost (S6)

To activate the acceleration boost, it is necessary for the DSC to be deactivated and the S6 shift program to be active. Only with this setting is it possible to perform a "racing start".

The shift lever must now be pushed forwards and the accelerator pedal depressed. The acceleration boost is performed once the shift lever has been released. Subsequent gear shifts must be initiated manually.

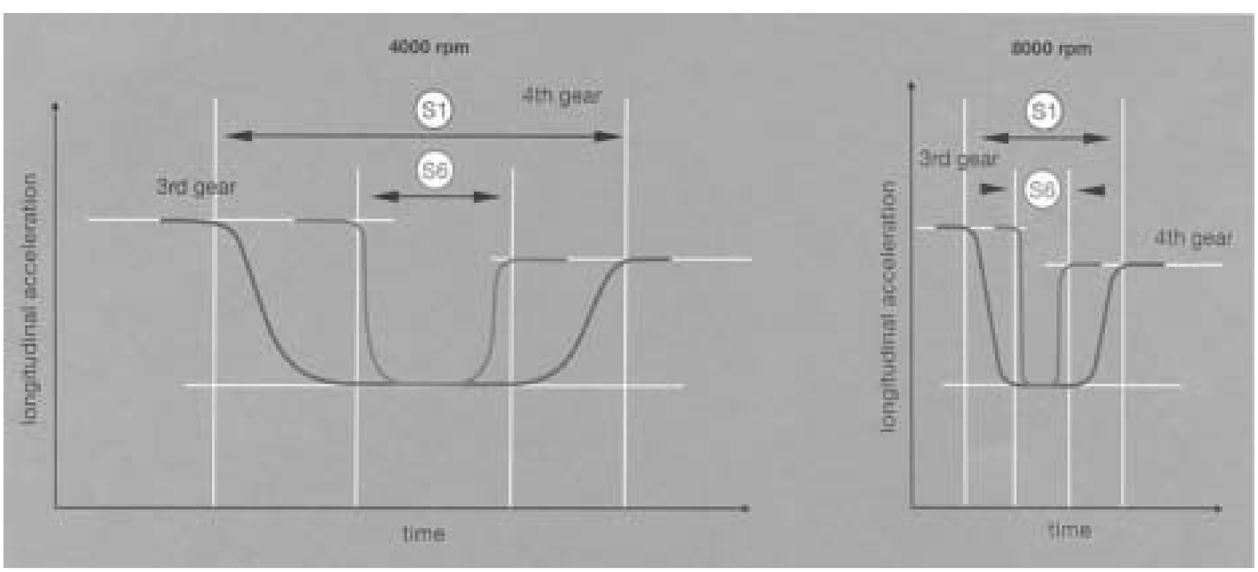
There are two modes included in the acceleration boost S6 position. The “racing start” and the “burnout” modes. The difference in the activation of these two modes is the rate at which the accelerator pedal is depressed.

Depressing the accelerator slowly to the floor activates the “racing start” mode. In this mode the clutch is pulsated at a high rate (up to 8 times a second) and the vehicle accelerates at the fastest speed possible without spinning the tires. The wheel speeds on the front and rear axles are compared with each other and the car pulls away according to the clutch biting point in order to achieve optimum propulsion.

Depressing the accelerator pedal very quickly to the floor activates “burnout” mode. This mode releases the clutch totally and completely when the shift lever is released. In this mode the rear tires are very likely to loose traction and the rear of the car to become unstable. Wheel speeds are ignored and the driver is in total control of wheel spin.

Note:

Both acceleration boost modes are hard on the clutch and driveline and continued use of these modes (particularly the “burnout” mode) may lead to clutch or driveline failure.



SMG II Shift Programs

43-02-95

Other Shift Functions

Slip Alert System

Under Slippery or inclement situations the SMG II can alter the clutch engagement and engine RPM to ensure the rear wheels never break traction. Functional in either sequential or automated mode, Slip Alert checks for tire slippage every 10 ms and also operates even with the DSC turned off.

Double Declutching

To prevent a fast downshift from upsetting the M3's composure in any way, the SMG II will automatically double clutch and raise engine speed on downshifts to guarantee that engine RPM and road speed are perfectly matched before the lower gear engages. The result is quicker, smoother downshifts with less wear on the clutch and less chance of upsetting the car's chassis.

Changing gears without altering the position of the accelerator pedal

The driver is not required to take his foot off the accelerator pedal during the shifting operation. This applies to both automatic and manual mode. The engine management system determines when a gearchange is necessary. All engine interventions, such as ignition timing intervention, cylinder fade-out and throttle adjustment are carried out automatically by the MS S54.
If an upshift to the gear one higher takes place, the engine speed must be lower after the shift operation. The speed is set by the ignition or the throttle.
If a downshift to the gear one lower takes place, the engine speed must be higher after completion of the shift operation. The speed is increased by means of a corresponding opening of the throttle.

Safety Functions

It is not necessary to disengage the gear to stop the car, regardless of whether the car is being driven in A mode or S mode.
If the SMG II control unit detects that the selector lever is in the idle-speed position and the engine speed is lower than the threshold set for a particular temperature, the clutch is automatically disengaged to prevent the engine from stalling.
If the driver takes no action, such as opening the driver's door or depressing the brake pedal, within a certain time of the car reaching a standstill with the engine running and a gear engaged, the gearbox is shifted to neutral. The last active gear is engaged once an appropriate action has been made.
If the driver's door is opened while the vehicle is at a standstill with the engine running and a driving position selected, the gear is disengaged after a preset time threshold if no action is taken within this time at the accelerator or brake pedal.

In this situation, the driver will be warned after a preset time by the gear indicator flashing and an acoustic signal of the need to disengage the gear. The warning remains, even after the gear has been disengaged. Regardless of the safety function, the shift display always flashes while the engine is running and the driver's door is open.
The safety function is terminated as soon as the selector lever is moved to the 0 position.

Hood Open

If the hood is opened while the car is at a standstill with the engine running and a gear engaged, or if the car's condition is unclear due to a system fault, the gear is disengaged. It is not possible to pull away and the gear indicator flashes when the hood is open, regardless of the safety function.

Shift Lock

A shift lock prevents an unintended gearchange.
It is possible to to only engage a gear with the brake applied, except that when shifting from Reverse to 1st or 1st to Reverse, shifting may be accomplished if the car is not moving for a time period of approximately 2 seconds.
The two seconds enable a rapid shift from position "R" to a forwards gear via position "0" without having to depress the footbrake.
The shift lock is activated by a magnet, which locks the selector lever at zero current in the "0" position.

Engine shutoff

If the key is turned to position 1 or 0 in the ignition while the selector lever is in the forwards or reverse position, a gear automatically remains engaged.
If the key is turned to position 1 or 0 in the ignition while the selector lever is in idle-speed position 0, a gong sounds and the gear indicator flashes in the SMG display as a reminder that the car has not been secured against rolling away.
The warning is silenced after approximately 10 seconds. If the selector lever is moved to the forwards or reverse position during this time, a gear is engaged automatically.

Emergency Acceleration

Emergency Acceleration is possible regardless of the shift mode (A-Mode or S-Mode) or the DRIVELOGIC position engaged.
Depressing the accelerator pedal quickly to the floor without the brake pedal depressed will engage emergency acceleration. The engine RPM will come up very quickly and the clutch will be pulsated to ensure maximum acceleration. Wheel spin will be limited even if DSC is switched off.
When this mode is activated subsequent shifts must be made manually.

SMG II Diagnosis

The SMG II control unit is fully diagnosable and can be checked using a DISplus Tester or GT1.
The first step involves the fault memory being read out. Malfunctions are communicated as part of the SMG II control unit's self-diagnosis. The second step involves appropriate operator prompting to facilitate diagnosis with simple measuring equipment using test modules. Repairs can be made once the fault in question has been found.
The diagnosis including self-diagnosis can only be carried out when the ignition (terminal 15) is switched on and there is a supply voltage of at least 10 volts. Erroneous fault entries may be recorded if the supply voltage drops below the threshold of approx. 10 volts.

Service functions

A test program (service functions) must be carried out upon completion of various types of work on the SMG system – see the following table. The test programs serve to implement test, initialize and adjustment functions.
The values determined are permanently stored in the non-volatile memory only after the test program has been success-fully completed.

Notes:

Function	Implementation	Conditions	Timeout
Initialize "0" Position in Accelerator Pedal	When replacing the control unit and/or the accelerator pedal module.	The accelerator pedal must be in position "0"	15 secs.
Initialize Idle Speed Position		The engine must be warm, the accelerator pedal must not be pressed and all loads must be switched off.	15 secs.
Initialize Clutch Engagement Point	When replacing the control unit, after work on hydraulic systems (valves, cables and actuator) if the system was opened and when replacing the clutch and hydraulic unit.	The gearbox must be in the position "0", the engine must be warm, the accelerator pedal must not be pressed and the gearbox input speed must be at zero at the start of the test routine.	30 secs.
Check hydraulic lines	When replacing the control unit, after work on hydraulic systems (valves, cables and actuator) if the system was opened and when replacing the clutch and hydraulic unit.	The engine must be off and the clutch must be disengaged.	
Bleeding	When replacing the control unit, after work on hydraulic systems (valves, cables and actuator) if the system was opened and when replacing the clutch and hydraulic unit.	The engine must be off and the clutch must be disengaged.	
Initialize Shift Module	When replacing the actuator, shift lever and components	The engine must be off and the clutch must be disengaged.	
Initialize Selector Angle Cylinder	When replacing the control unit and when replacing the hydraulic unit.	The engine must be off and the clutch must be disengaged.	
Gearbox adaptation	When replacing the control unit, gearbox, hydraulic unit and the gear recognition.	The engine must be off, the clutch must be disengaged and no brakes must be pressed.	

Review Questions

1. Which control unit is responsible for managing the control of the SMG II and which module make the shift decisions?

2. What is the purpose of the SMG CAN Bus?

3. Why is the data from the transverse acceleration sensor only evaluated during the A-Mode of SMG II operation?

4. Does the cruise control become deactivated during a gear shift in the A-Mode?

   How does this compare to cruise operation in the S-Mode?

5. Under what conditions will the hydraulic pump become energized when the engine is not running?

6. A customer complains that he can not access DRIVELOGIC Mode 6. What could the cause?

7. During engine start-up operation, the starter does not engage, what are the possible causes of this fault?

8. Why does the Selector angle cylinder have one electric solenoid at the Hydraulic Unit, and the Shift travel cylinder have two solenoids?

9. How is the Hill-Climbing Assistance feature activated?

10. A customer complains he hears the Hydraulic pump run sporadically, the car shifts normally, what could be the cause?

	Fault Type	Test Conditions	Fault Description	Ambient Conditions.	Warning Lamp	Measures	Normal Service
Gearbox Temp.	Fault sporadic, Fault currently present or Implausible value	Ignition On Battery >10 volts	Short-Circuit to ground, sensor supply or supply. **Or** open circuit **or** sensor fault	Mileage Voltage supply Ambient Temp. Gearbox Temp. Engine Temp. Hydraulic Temp.	Off	Calculate Gearbox Temp based on Engine Temp	Eliminate fault
Hydraulic Pressure Sensor	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10 volts **and** Good sensor voltage, **and** hydraulic pump inactive	Short-Circuit to ground, sensor supply or supply. **Or** open circuit **or** sensor fault	Mileage, Voltage supply, Ambient temp, Hydraulic temp, Sensor v supply, hydraulic pump status, current clutch solenoid	On	Hydraulic pump is switched on in fixed time intervals and with each shift for a fixed time	Eliminate fault, erase fault code
Hydraulic Pressure loss in system	Fault sporadic, Fault currently present, Invalid operation range	Ignition On, Battery >10V **and** Hydraulic pump fault free **and** hydraulic pressure sensor fault free	Pressure loss in system	Mileage Voltage supply Ambient Temp	On if hydraulic pressure <10 bar	During driving: Block gear change At standstill: Engage postion"0" so that vehicle can be towed	Eliminate fault, erase fault code
Hydraulic Pump	Fault sporadic, Fault currently present, Invalid operation range	Ignition On, Battery Voltage >10V **and** hydraulic pressure sensor trouble free	Short-circuit in hydraulic pump electric motor to ground, B+, or open circuit **or** no pressure increase with pump switched on **or** ON period of pump is outside tolerance	Mileage Voltage supply Ambient Temp. Hydraulic Temp. Status Hydraulic pump Current, solenoid valve, clutch	On	During driving: Continue driving for as long as possible (without changing gear). Disengage gear at lower limit pressure At Standstill: Disengage gear so that vehicle can be towed	Eliminate fault, erase fault code
Hood Contact While Driving	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery Voltage >10V, **and** driving speed >40km/h and <120KM/h	Different values detected by both hood contacts during driving	Mileage Voltage supply Ambient Temp Hood Switches Vehicle Speed	Off	Car can continued to be driven until next garage visit using input from good switch	Eliminate fault
Hood contact at standstill	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery Voltage >10V,	Different values detected by both hood contacts while vehicle is at standstill	Mileage Voltage supply Ambient Temp. Bonnet Contact Vehicle speed	Off Gear Indicator light will flash	Gear will not engage	Eliminate fault

	Fault Type	Test Conditions	Fault Description	Ambient Conditions.	Warning Lamp	Measures	Normal Service
Shift Lever	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V	Switch Positions not Plausible or complete malfunction of shift lever	Mileage, Voltage, Ambient Temp, Driving Direction, Shift-Lever Position, Digital inputs from shift lever, target gear	On with complete failure of shift lever, otherwise off		Eliminate fault
Position sensor, selection angle	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** sensor supply A trouble-free **and** sensor supply B trouble free	Short-circuit to ground, sensor supply or supply **or** open circuit **or** sensor faulty	Mileage Voltage supply, Ambient temperature Sensor supply A Sensor supply B Selection-angle position 1, Selection-angle Position 2	On	Failure of only one sensor Substitution by the other Sensor Failure of both sensors, Substitute program runs where manual operation is disabled. Gears R, 2, 5 and 6 can be shifted Gate position is approached under controlled conditions.	Eliminate fault
Position sensor, shift travel	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** sensor supply A trouble-free **and** sensor supply B trouble free	Short-circuit to ground, sensor supply or supply **or** open circuit **or** sensor faulty	Mileage Voltage supply Ambient temperature Sensor supply A Sensor supply B Shift-travel position1 Shift travel position2 Engaged gear Gearbox Status	On	Failure of only one sensor, Substitution by the other sensor Failure of both sensors Substitutes driving program runs where all gears can be shifted with loss of comfort. Gears can be engaged under controlled conditions.	Eliminate fault
Longitudinal acceleration	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** sensor supply A trouble-free	Short-circuit to ground, sensor supply or supply **or** open circuit **or** sensor faulty	Mileage Voltage supply Ambient temperature Sensor supply B Longitudinal Acceleration Vehicle speed Brake Signals	Off	Longitudinal acceleration = 0 g Moving off on incline possible in 2nd gear	After Fault is eliminated
Sensor voltage supply A	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V	V sensor supply/A < 4.5 V. V sensor supply/A > 5.5 V Impairment of longitudinal acceleration Signal, selection angle 1 Signal, shift travel 1	Mileage Voltage supply Ambient temperature	Off	Correction of: Longitudinal acceleration Signal, selection angle 1 Signal, shift travel	After Fault is eliminated

	Fault Type	Test Conditions	Fault Description	Ambient Conditions.	Warning Lamp	Measures	Normal Service
Sensor voltage supply B	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V	V sensor supply/B < 4.5 V. V sensor supply/B > 5.5 V Impairment of Gearbox Speed Hydraulic pressure Signal, selection angle 2 Signal, shift travel 2	Mileage Voltage supply Ambient temperature	On	Correction of: Gearbox speed Hydraulic pressure Signal, selection angle 2 Signal, shift travel 2	After Fault is eliminated
Gearbox input speed	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V additional checks for plausibility Clutch closed **and** **No faults in:** Clutch position sensor Clutch solenoid valve Engine speed sensor Rear wheel speed sensor Gear detection Gearbox speed sensor **and** Engine Running	Overspeed **or** Maximum gradient fault **or** if with clutch closed engine speed, gearbox input speed **or** gear input speed calculated from rear axle speed not plausible.	Mileage Voltage supply Ambient temperature	On	From gear ratio and gearbox output speed (rear axle speed) Use Engine speed	After Fault is eliminated
Engine speed (sensor)	Fault sporadic Fault currently present Implausible value	Ignition On, Battery >10V additional checks for plausibility Additional conditions for plausibility check clutch closed **and** clutch position sensor trouble-free **and** clutch solenoid valve trouble-free **and** rear wheel speeds trouble-free **and** engine running **and** CAN trouble-free	Overspeed **or** maximum gradient fault **or** if with clutch closed engine speed, gearbox speed **or** engine speed; engine speed from CAN	Mileage Voltage supply Ambient temperature	Off	Substitute value, engine speed, via CAN-bus	After Fault is eliminated

	Fault Type	Test Conditions	Fault Description	Ambient Conditions.	Warning Lamp	Measures	Normal Service
Engine speed (sensor and CAN)	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** engine running **and** CAN trouble-free	Engine speed from sensor **and** engine speed from CAN incorrect	Mileage Voltage supply Ambient temperature Gearbox input speed Engine speed Engine speed from CAN Clutch status	On	Engine speed can be partially substituted with clutch closed from gearbox speed	After Fault is eliminated
PLCD sensor for clutch position	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V	Hardware fault **or** sensor faulty	Mileage Voltage supply Ambient temperature	On	Open-loop instead of closed-loop clutch control	After Fault is eliminated
CAN incorrect value	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** no other fault message from CAN	DSC delivers an incorrectly identified value				
CAN-bus fault	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V	Telegram is no longer received (time-out) **or** bus fault (interruption)	Mileage Voltage supply Ambient temperature Info on CAN fault	On		After Fault is eliminated
Speed, rear left	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** driving speed > 40 km/h **and** brake not actuated **and** no wheel separation detected **and** no fault message via CAN	Speed, rear left > 320 km/h **or** speed change > 20 km/h per 10 ms **or** comparison with the other three wheel speeds produces an implausible value	Mileage Voltage supply U(batt.) Ambient temperature Speed, rear left Speed, rear right Speed, front left Speed, front right Clutch status Shifted gear Gearbox input speed	Off	Can be substituted: By rear right wheel speed **or** if rear right is also incorrect by front-axle speed **or** with engaged gear from gearbox input speed and gear ratio. The signal is supported until it is substituted in the event of a negative speed change.	After Fault is eliminated

	Fault Type	Test Conditions	Fault Description	Ambient Conditions.	Warning Lamp	Measures	Normal Service
Speed, rear right	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** driving speed > 40 km/h **and** brake not actuated and no wheel separation detected **and** no fault message via CAN	Speed, rear left > 320 km/h **or** speed change > 20 km/h per 10 ms **or** comparison with the other three wheel speeds produces an implausible value	Mileage Voltage supply U(batt.) Ambient temperature Speed, rear left Speed, rear right Speed, front left Speed, front right Clutch status Shifted gear Gearbox input speed	Off	Substituted By rear right wheel speed **or** if rear right is also incorrect by front-axle speed **or** with engaged gear from gearbox input speed and gear ratio. The signal is supported until it is substituted in the event of a negative speed change.	After Fault is eliminated
Speed, front left	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** driving speed > 40 km/h **and** brake not actuated **and** no wheel separation detected **and** no fault message via CAN	Speed, rear left > 320 km/h **or** speed change > 20 km/h per 10 ms **or** comparison with the other three wheel speeds produces an implausible value	Mileage Voltage supply Ambient temperature Speed, rear left Speed, rear right Speed, front left Speed, front right Clutch status Shifted gear Gearbox input speed	Off	Substituted By rear right wheel speed **or** if rear right is also incorrect by front-axle speed **or** with engaged gear from gearbox input speed and gear ratio. The signal is supported until it is substituted in the event of a negative speed change.	After Fault is eliminated
Speed, front right	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** driving speed > 40 km/h **and** brake not actuated **and** no wheel separation detected **and** no fault message via CAN	Speed, rear left > 320 km/h **or** speed change > 20 km/h per 10 ms **or** comparison with the other three wheel speeds produces an implausible value	Mileage Voltage supply Ambient temperature Speed, rear left Speed, rear right Speed, front left Speed, front right Clutch status Shifted gear Gearbox input speed	Off	Substituted By rear right wheel speed **or** if rear right is also incorrect by front-axle speed **or** with engaged gear from gearbox input speed and gear ratio. The signal is supported until it is substituted in the event of a negative speed change.	After Fault is eliminated
Speed (more than one signal)	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** driving speed > 40 km/h **and** brake not actuated **and** no wheel separation detected **and** no fault message via CAN	Two, three or four wheel speeds deliver an implausible value	Mileage Voltage supply Ambient temperature Speed, rear left Speed, rear right Speed, front left Speed, front right Clutch status Shifted gear Gearbox input speed	On	Can be substituted: With shifted gear from gearbox input speed and gear ratio	After Fault is eliminated

	Fault Type	Test Conditions	Fault Description	Ambient Conditions.	Warning Lamp	Measures	Normal Service
Service-brake signals via CAN	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** no fault message via CAN	Different values from both switches **or** at a speed > 45 km/h with accelerator pedal pressed the signals are active for longer than 1 min **or** with a vehicle deceleration > 0.4 g no signal active	Mileage Voltage supply Ambient temperature Brake signals Accelerator-pedal value Vehicle speed Longitudinal acceleration	Off	Ignore incorrect signal	After Fault is eliminated
Door contact via CAN	Fault sporadic, Fault currently present or Implausible value	Ignition On, Battery >10V **and** no fault message via CAN **and** vehicle speed trouble-free	Door contact active for longer than 10 seconds at a speed > 45 km/h	Mileage Voltage supply U(batt.) Ambient temperature Vehicle speed Door contact	On	Driving off only possible within 10 seconds of brake or shift-lever actuation	After Fault is eliminated
Shift lock	Fault sporadic Fault currently present Implausible value	Ignition On, Battery >10V	Short-circuit to ground **or** supply **or** open circuit **or** shift-lock magnet faulty	Mileage Voltage supply U(batt.) Ambient temperature Shift-lever position Shift-lock activation	On	During driving: Continue driving for as long as possible	After Fault is eliminated
Starter-motor enabling	Fault sporadic Fault currently present Short-circuit to ground Short-circuit to B+	Ignition On, Battery >10V	Short-circuit to ground or supply **or** open circuit **or** starter-relay enabling	Mileage Voltage supply Ambient temperature Starter-motor enabling	Off	Short-circuit to supply: Permanent starter-motor enabling All other fault types: Vehicle starting no longer possible	After Fault is eliminated
Hydraulic-pump relay	Fault sporadic Fault currently present Short-circuit to ground Short-circuit to B+ Open circuit Implausible value	Ignition On, Battery >10V **and** hydraulic pressure sensor trouble-free	Short-circuit to ground or supply **or** open circuit **or** hydraulic-pump relay faulty	Mileage Voltage supply Ambient temperature Hydraulic temperature Hydraulic pressure Status, hydraulic pump Current, solenoid valve, clutch	On	During driving: Continue driving for as long as possible (without changing gear). Disengage gear at lower limit pressure At standstill: Disengage gear so that vehicle can be towed	After Fault is eliminated

	Fault Type	Test Conditions	Fault Description	Ambient Conditions.	Warning Lamp	Measures	Normal Service
Reversing-light switch	Fault sporadic Fault currently present Implausible value	Ignition On, Battery >10V	Short-circuit to ground **or** supply **or** open circuit	Mileage Voltage supply Ambient temperature Activation, reversing-light switch Shift-lever position Driving direction	Off	Short-circuit to supply: Reversing light always lit All other faults: Reversing light never lit	After Fault is eliminated
Solenoid valve, shift travel up	Fault sporadic Fault currently present Short-circuit to ground Short-circuit to B+ Open circuit Implausible value	Ignition On, Battery >10V Additional conditions for plausibility check Shift-travel position sensor trouble-free **and** hydraulic pressure trouble-free	Short-circuit to ground or supply **or** open circuit **or** actual current = specified current **or** actual position = specified position **or** timeout during shifting of gears	Mileage, Voltage supply Ambient temperature Hydraulic pressure Actual current, shift travel up, Specified current, shift travel up Actual position, shift travel, Specified position, shift travel Actual position, selection angle Specified position, selection angle	On	Gearbox limp-home program No further gear shifts are permitted	After Fault is eliminated
Solenoid valve, shift travel down	Fault sporadic Fault currently present Short-circuit to ground Short-circuit to B+ Open circuit Implausible value	Ignition On, Battery >10V Additional conditions for plausibility check Shift-travel position sensor trouble-free **and** hydraulic pressure trouble-free	Short-circuit to ground or supply **or** open circuit **or** actual current = specified current **or** actual position = specified position **or** timeout during shifting of gears	Mileage, Voltage supply Ambient temperature Hydraulic pressure Actual current, shift travel up, Specified current, shift travel up Actual position, shift travel, Specified position, shift travel Actual position, selection angle Specified position, selection angle	On	Gearbox limp-home program No further gear shifts are permitted	After Fault is eliminated

	Fault Type	Test Conditions	Fault Description	Ambient Conditions.	Warning Lamp	Measures	Normal Service
Solenoid valve, selection angle	Fault sporadic Fault currently present Short-circuit to ground Short-circuit to B+, Open circuit Implausible value	Ignition On, Battery >10V Additional conditions for plausibility check Shift-travel position sensor trouble-free **and** hydraulic pressure trouble-free	Short-circuit to ground or supply **or** open circuit **or** actual current = specified current **or** actual position = specified position **or** timeout during shifting of gears	Mileage, Voltage supply Ambient temperature Hydraulic pressure Actual current, shift travel up, Specified current, shift travel up Actual position, shift travel, Specified position, shift travel Actual position, selection angle Specified position, selection angle	On	Gearbox limp-home program No further gear shifts are permitted	After Fault is eliminated
Solenoid valve, clutch	Fault sporadic Fault currently present Short-circuit to ground Short-circuit to B+, Open circuit Implausible value	Ignition On, Battery >10V Additional conditions for plausibility check position sensor trouble-free **and** hydraulic pressure trouble-free	Short-circuit to ground or supply **or** open circuit **or** actual current = specified current **or** actual position = specified position	Mileage, Voltage supply Ambient temperature Hydraulic pressure Actual current, clutch Specified current, clutch, Actual position, clutch Specified position, clutch Current gear	On	During driving: No further gear changes At standstill: Engage position "0"	After Fault is eliminated
Gearbox adaptation	Fault sporadic Fault currently present Implausible value	Ignition On, Battery >10V **and** gearbox adaptation started	Adaptation could not be properly carried out	Mileage ,Voltage supply Ambient temperature Fault message of adaptation ,Number of adaptation/test program Adaptation status in event of fault	On	The vehicle is only ready for operation under limited conditions, default values are used	After Fault is eliminated
Steering-angle-offset current adaptation	Fault sporadic Fault currently present Implausible value	Ignition On, Battery >10V and steering-angle-offset current adaptation started	Adaptation could not be properly carried out	Mileage, Voltage supply Ambient temperature Fault message of adaptation Number of adaptation/test program Adaptation status in event of fault	On	The vehicle is only ready for operation under limited conditions, default values are used	After Fault is eliminated

	Fault Type	Test Conditions	Fault Description	Ambient Conditions.	Warning Lamp	Measures	Normal Service
Clutch adaptation	Fault sporadic Fault currently present Implausible value	Ignition On, Battery >10V **and** clutch adaptation started	Adaptation could not be properly carried out	Mileage, Voltage supply Ambient temperature Fault message of adaptation ,Number of adaptation/test program Adaptation status in event of fault	On	The vehicle is only ready for operation under limited conditions, default values are used	After Fault is eliminated
Gear cannot be engaged	Fault sporadic Fault currently present Implausible value	Ignition On, Battery >10V	Gear cannot be engaged	Mileage, Voltage supply Ambient temperature Current gear, Desired gear, Shift position Selection-angle position Gearbox input speed Gearbox output speed	Off	Shifting to the relevant gear is not possible	After Fault is eliminated
Gear popping	Fault sporadic Fault currently present Implausible value	Ignition On, Battery >10V	Engaged gear pops out	Mileage, Voltage supply Ambient temperature Current gear, Desired gear, Shift position Selection-angle position Gearbox input speed Gearbox output speed	Off	Shifting to the relevant gear is not possible	After Fault is eliminated
Selection angle cannot be set	Fault sporadic Fault currently present Implausible value	Ignition On, Battery >10V	The requested selection-angle position cannot be set	Mileage, Voltage, supply Ambient temperature Current gear Desired gear Shift position Selection-angle position Gearbox input speed Gearbox output speed	On	During driving with gear engaged: Block gear change, i.e. continue driving for as long as possible At standstill: Engage position "0" so that vehicle can be towed	After Fault is eliminated