2002-07 GENINFO

Engine Management - Overview - MINI

MINI ENGINE MANAGEMENT

PURPOSE OF THE SYSTEM

The basic function of the Engine Management System is to produce smooth and efficient engine operation over varied driving conditions and engine loads. It also functions to monitor emissions systems and interfaces with other vehicle systems to enhance the driving experience.

The EMS2000 system manages the following functions:

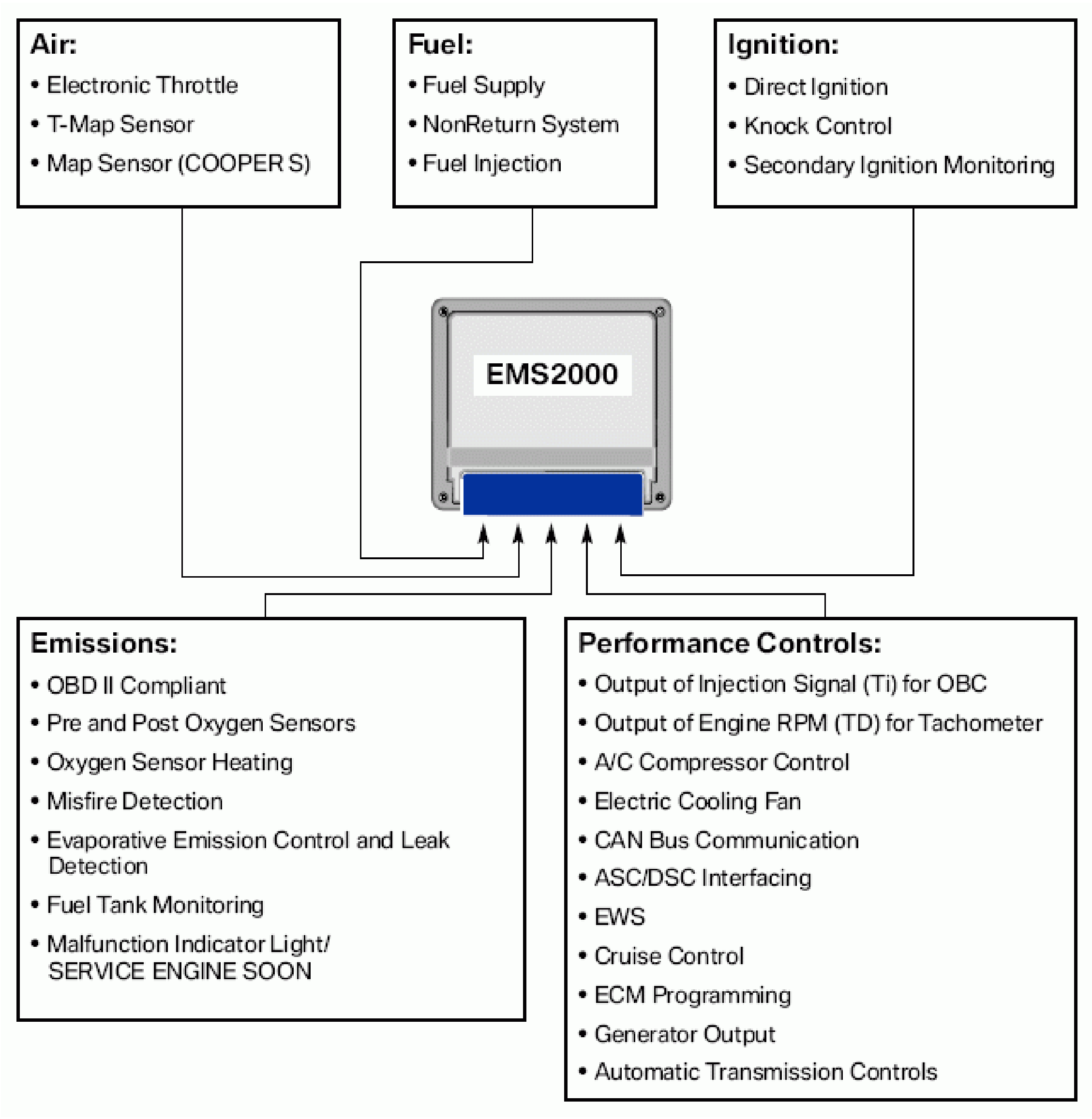


Fig. 1: EMS2000 System Function
Courtesy of BMW OF NORTH AMERICA, INC.

Inputs from sensors, switches and monitoring devices are received by the Engine Management system and processed. These inputs include the following:

- Ignition Switch
- Accelerator Pedal Sensor
- Coolant Temperature Sensor
- Knock Sensor
- O2 Sensors
- Transmission Speed Sensor
- EWS
- A/C Pressure Transducer
- Battery
- TMap Sensor
- EDR
- Crankshaft Sensor
- Brake Light Switch
- Oil Temp Sensor
- GIU
- IKE
- Main Relay
- Map Sensor (S Only)
- Camshaft Sensor
- LDP System
- Clutch Switch
- Generator
- ABS/DSC
- MFL

Using these inputs the Engine Management System makes operating decisions and outputs control signals to manage engine, transmission and emission operation. The outputs include:

- Main Relay
- Inertia Switch
- Ignition Coils
- O2 Sensor Heaters
- A/C Compressor
- IKE

- EDR
- Fuel Pump Relay
- LDP System
- Shift Interlock Relay
- Engine Cooling Fan
- EDR Warning LED
- Fuel Injectors
- Purge Valve
- GIU
- OBD II Plug

EMS2000 Control Module

The EMS2000 Control Unit is the center of the engine management system. It receives and processes all inputs and issues corresponding control commands.

The EMS2000 control unit is located on the left hand side compartment of the battery box (viewed from the drivers seat) next to the engine bay fuse box, on the MINI COOPER. On the MINI COOPER S it is located in a similar position to the left of the engine bay fuse box, mounted in a side compartment of the air box.

In addition to engine controls it has direct control over the following systems:

- Drive By Wire (DBW) throttle control
- Automatic Transmission (ECVT)
- Cruise control
- Air conditioning clutch relay
- Cooling fan relays

  The EMS2000 also has an interface with the following systems:

- Air Conditioning (IHKS/IHKA)
- Automatic Stability Control (ASC)
- Dynamic Stability Control (DSC)
- Immobilization (EWS)

Fig. 2: MINI Cooper EMS2000 Location
Courtesy of BMW OF NORTH AMERICA, INC.

Fig. 3: MINI Cooper S EMS2000 Location
Courtesy of BMW OF NORTH AMERICA, INC.

The EMS2000 connector is a single molding split into two housings.

- Engine Housing - 81 Pin

  Pins 1-5 : load terminals Pins 6-81 : signal terminals

- Vehicle Housing - 40 Pin

  Pins 114-121 : load terminals Pins 82-113 : signal terminals

MINI COOPER EMS2000 Connector

Fig. 4: MINI Cooper EMS2000 Connector
Courtesy of BMW OF NORTH AMERICA, INC.

EMS2000 receives its operating power from the battery through the Main Relay and Ignition Switch.

SYSTEM INPUTS

Power Supplies

KL30 is supplied through a fuse (F01) to provide memory. KL30 (F02) as provided by the Main Relay supplies operating power to the EMS2000.

Ignition Switch

When the ignition is switched on KL15 (F34) supplies wake up voltage to the EMS2000. The Main Relay is energized as long as KL15 is supplied.

Battery Voltage - KL 30

B+ is the main supply of operating voltage to the EMS2000. Battery Voltage is monitored by the EMS2000 for fluctuations. The EMS2000 will adjust the output functions to compensate for a lower (6v) and higher (14v) voltage value. Based on the available battery voltage the EMS2000 will adjust:

- Fuel injection pulse width
- Ignition system dwell

Main Relay

The Main Relay provides power for the EMS2000 and other system components. It has an additional function of protecting system components from reverse battery polarity. (Main Relay will not energize with reverse polarity.)

When the ignition switch is placed in the KL15 or KL50 positions, Fuse 34 is provided with power. Fuse 34 supplies the wake up or on signal to the EMS2000. Upon receipt of the "ON" signal EMS2000 supplies a ground signal from Pin 97 to the Main Relay. The ground signal energizes the Main Relay, supplying operating power to the following fuses:

- F02 - EMS2000, Fuel injectors, Crankshaft sensor, Ignition coils
- F03 - Camshaft sensor, O2 Heaters, Engine Cooling Fan, A/C Compressor Relay, Purge System
- F04 - Automatic Transmission controls
- F05 - Engine Coolant Fan

Workshop Hint

The Main Relay remains energized for 5 Minutes after the key is shut off. Before disconnecting connections to EMS2000, wait 5 minutes or remove Main Relay.

Workshop Hint

Always check current Wiring Diagrams for complete description of power supplies.

The Main Relay supplies power to the following components:

- EMS2000
- Ignition Coils
- Auxiliary Fan
- Fuel Injectors
- LDP
- ECVT/GIU
- Crankshaft Sensor
- Camshaft Sensor
- O2 Heaters

Main Relay Failure Symptoms

An open circuit in the Main Relay will result in no voltage to the EMS2000 and the other components as supplied by the Main Relay.

A permanently engaged Main Relay will result in an excessive closed current draw and will lead to a dead battery.

Main Relay activation is monitored by the EMS2000. Faults will be set if the main relay is energized and power is not received by the EMS2000.

Main Relay Testing

- Check Voltage Supply At Battery
- Test for Voltage at Fuse 34 (With key on)
- Check Voltage at KL 30 of Main Relay
- Check operation of Relay (Using relay adapter)

- Ground signal from EMS2000
- Voltage Drops across Relay (Relay Energized and Not Energized)

- Perform TEST PLAN on Power Supply

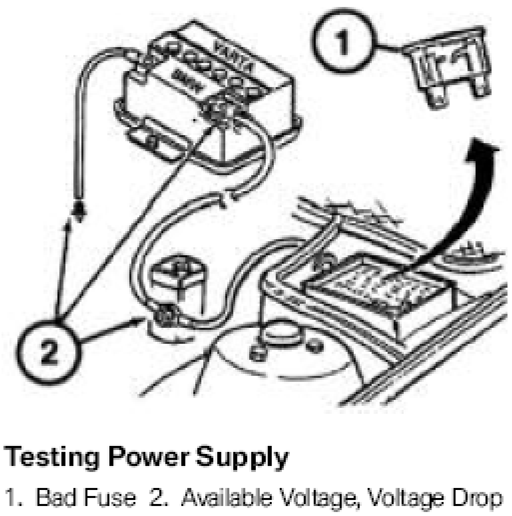


Fig. 5: Main Relay Testing Procedure
Courtesy of BMW OF NORTH AMERICA, INC.

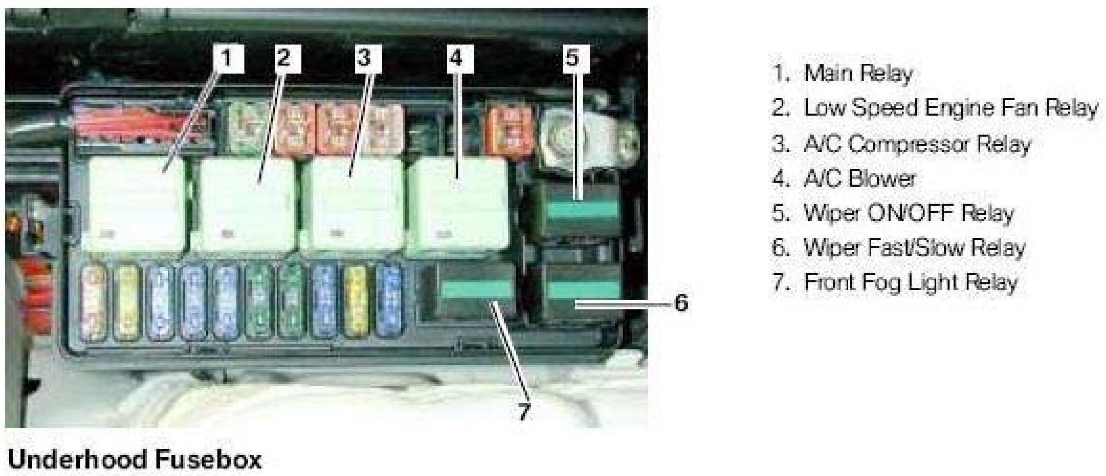


Fig. 6: Underhood Fusebox
Courtesy of BMW OF NORTH AMERICA, INC.

Special Tools

When testing the power supply of the EMS2000, the DISplus multimeter function or a hand held multimeter may be used. It is best to make the checks at the EMS2000 connection as this method tests the wiring harness. The correct V-Adapter Cables must be used to ensure the pin connectors and the harness will not be damaged.

V-Adapter Cables for the EMS2000 are:

- 40 Pin V-Adapter Cable P/N 12 7 240
- 81 Pin V-Adapter Cable P/N 12 7 250
- Breakout Box (BOB) P/N 61 4 390
- Breakout box (BOB) P/N 61 4 380

CAUTION: When installing the BOB and V-Adapter Cables to the EMS2000 make sure the ignition has been switched off for at least 5 minutes or remove the Main Relay.

Grounds

Multiple ground points are supplied to complete the current path through the EMS2000. Grounds are supplied as constants to sensors or as switched grounds to activate components.

Pins supplying ground to the EMS2000 are:

- X6000 - 61, 62, 80, and 81
- X6004 - 114 and 115

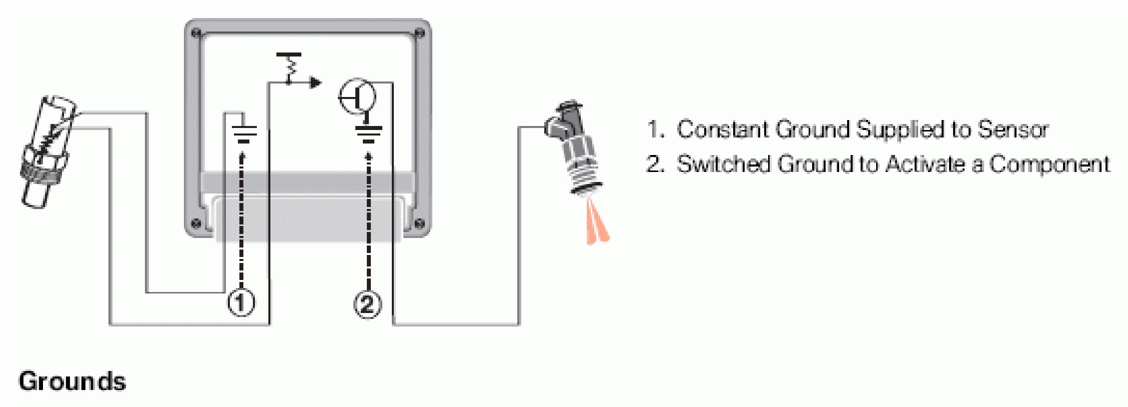
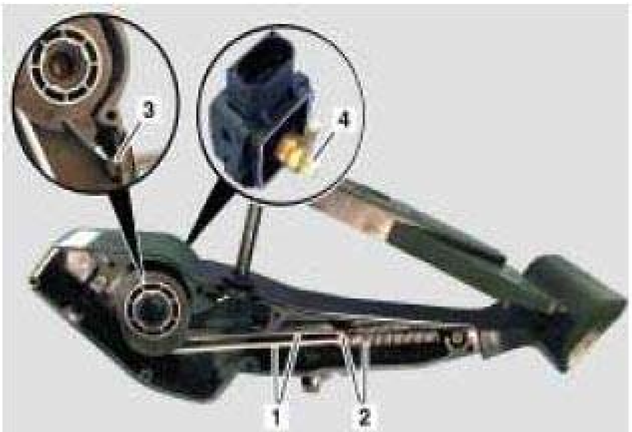


Fig. 7: Multiple Ground Points
Courtesy of BMW OF NORTH AMERICA, INC.

Accelerator Pedal Position Sensor (PWG)



1. Twin Cables
2. Return Springs
3. Ball Joint
4. Throttle lever for angle Hall sensors

Accelerator Pedal Position Sensor

Fig. 8: Accelerator Pedal Position Sensor (PWG)
Courtesy of BMW OF NORTH AMERICA, INC.

The Accelerator Pedal Position Sensor (PWG) is mounted in the passenger compartment, clipped to a bracket that is bolted to the floor. The PWG is monitored by the EMS2000 for input on pedal position as well as speed of change.

The Accelerator Pedal Position Sensor uses two angle Hall sensors with different voltage characteristics and independent power supplies to provide the drivers input request. The angle Hall sensors receive power (5v) and ground from the EMS2000. The PWG produces linear voltage signals as the pedal is pressed from the LL position (idle) to the VL position (full throttle).

The values for the two internal sensors are:

- Hall Sensor 1 - approximately 0.5 to 4.5 volts Driver Request
- Hall Sensor 2 - approximately 0.5 to 2.0 volts Plausibility Check

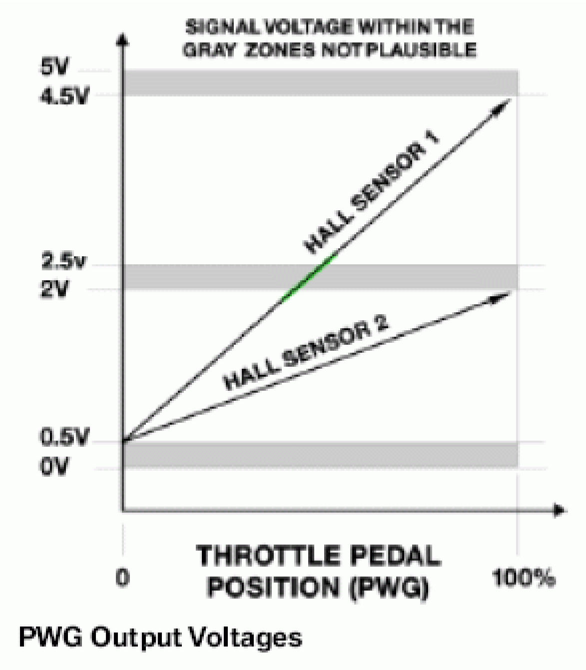


Fig. 9: PWG Output Voltages Graph
Courtesy of BMW OF NORTH AMERICA, INC.

The Accelerator Pedal Position (PWG) is monitored by the EMS2000 for pedal angle position and rate of movement. As the accelerator is moved, a rising voltage signal from the Hall sensors requests acceleration and rate. The ECM will increase the volume of fuel injected into the engine, advance the ignition timing and open the Throttle Valve.

The "full throttle" position (VL) indicates maximum acceleration to the ECM, and in addition effects air conditioning compressor activation.

As the accelerator pedal is released and returned to the rest position by integral springs, a decrease in voltage signals the EMS2000 to activate fuel shut off if the RPM is above idle speed (coasting). The Throttle Valve will be closed and will open enough to maintain idle speed.

EMS Adaptation for PWG

The EMS2000 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 plate or linkage), the ECM will adjust the throttle plate to maintain the correct idle speed.

The Hall sensors are non-adjustable because the EMS2000 "learns" the throttle angle voltage at idle speed.

NOTE: **If the throttle housing/accelerator pedal module is replaced, the adaptations must be cleared and adaptation procedure must be performed using the DISplus. If this is not performed, the vehicle will not start, or will run in "fail-safe" mode.**

PWG Failsafe

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

There are two failure modes of the PWG.

- Failure Mode 1 occurs with a defect in one of the hall effect pedal position sensors. Maximum engine speed will be limited.
- Failure Mode 2 occurs with a defect in both of the hall effect pedal position sensors. Engine speed is limited to approximately 1300 RPM and further reduced to 1000 RPM when the brake pedal is depressed.

Operation of the PWG can be fully diagnosed by an approved diagnostic computer (ex. GT1, DISplus).

Temperature - Manifold Absolute Pressure (T - MAP) Sensor

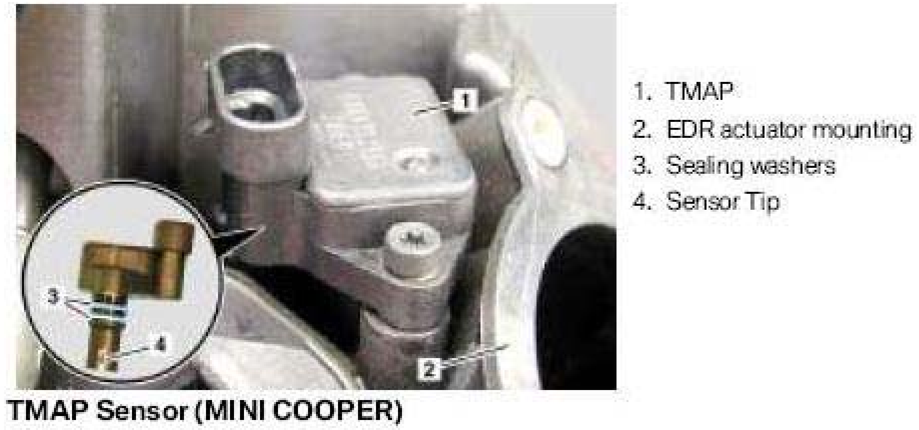


Fig. 10: TMAP Sensor (MINI Cooper)
Courtesy of BMW OF NORTH AMERICA, INC.

TMAP Sensor (MINI COOPER)

The TMAP (Temperature and Manifold Absolute Pressure) sensor contains a Manifold Absolute Pressure (MAP) Sensor and an Intake Air Temperature Sensor.

The Manifold Absolute Pressure Sensor is a Piezo-resistive pressure gauge that supplies an analog input to the EMS2000 corresponding to the absolute manifold pressure. The signal is used to determine the engine load. The engine load information is used for internal engine control via the EMS2000 (such as to control fuel delivery and ignition timing) and for traction control regulation.

The Manifold Absolute Pressure (MAP) sensor measures the changes in the intake manifold pressure which result from engine load (intake manifold vacuum) and RPM changes; and converts these into a voltage output. By monitoring the sensor output voltage, the EMS2000 knows the manifold pressure.

- At idle manifold pressure is lower (high vacuum) and output voltage will be about 1 to 2 volts.

- While at higher pressure or at Wide Open Throttle (lower vacuum) output voltage will be about 4 volts.

NOTE: This sensor has a maximum pressure range of 120 Kpa (17.40453psi).

Intake Air Temperature Sensor

The air intake temperature sensor is built into the TMap sensor. Air temperature information is used in conjunction with intake manifold pressure information as supplied by the MAP enabling the EMS2000 to calculate the volume of air being consumed by the engine. The sensor is a NTC type, supplied 5 volts by the EMS2000.

- A high voltage reading indicates high sensor resistance, or low temperature.
- A Low voltage reading indicates low sensor resistance or high temperature.

TMap Sensor (MINI COOPER S)

On the MINI COOPER S the pressure differential is measured across the supercharger to determine the manifold air density.

To measure this differential two sensors are fitted, one on either side of the supercharger.

A TMAP sensor is fitted on the intake manifold pressure side (after the supercharger) and has the same function as the TMAP on the MINI COOPER. The difference is that **this sensor has a maximum pressure range of 250 Kpa (36.25943psi)** .

Another TMAP sensor is fitted upstream of the supercharger and measures the pressure between the supercharger and throttle plate. This sensor is exactly the same part as the MINI COOPER TMAP but the temperature sensing capability is not utilized.

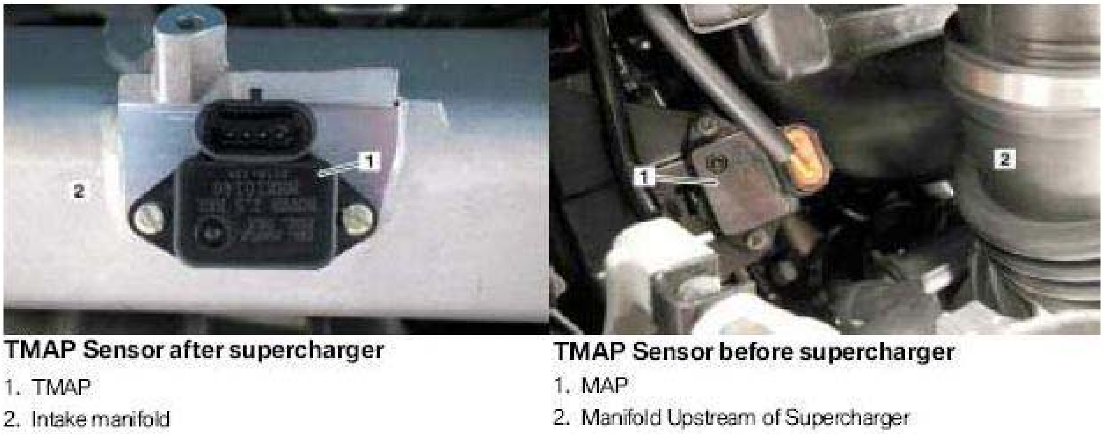


Fig. 11: TMap Sensor (MINI Cooper S)
Courtesy of BMW OF NORTH AMERICA, INC.

The TMAP sensor is located in the intake manifold where it is exposed to higher than atmospheric pressures as produced by the supercharger. The MAP sensor is located between the supercharger and the EDR, a location not effected by additional pressures from the supercharger.

The first job of the MAP sensor is the measurement of the barometric pressure. When the ignition key is placed in the "ON" position (Main Relay powered up), the sensor reads atmospheric pressure (High Voltage) because the pistons are not moving yet.

Second, it measures the absolute pressure in the intake manifold. Absolute pressure is barometric pressure minus the vacuum created by the pistons. So, if the barometer is reading 1.5 Bar at sea level and the manifold vacuum (gauge) is 1.0 Bar at idle, the manifold absolute pressure would be .5 Bar.

The EMS2000 compares the voltage from the TMAP sensor (ahead of the supercharger) to the voltage received from the TMAP (after the supercharger) and calculates air volume drawn into the engine.

- Voltage Reading of .6-1.5 volts indicates high vacuum condition (Idle or no load)
- Voltage Reading of 4 volts indicates low vacuum condition (Full Throttle)

TMap and MAP Sensors Failure Symptoms

- Engine difficult to start, stalls at idle and misfires.

TMap and MAP Sensor Testing

- Check status on DISplus status pages (0 - 5 volts) Ensure that voltage changes and does not remain constant at 0 or 5 volts
- Install BOB on EMS2000 check voltage at appropriate pins
- Check sensor for internal shorts
- Perform TEST PLAN

Intake Air Temp Sensor Failure Symptoms

- Problems with cold starting, poor driveability and an increase in emissions.
- Possible lack of power, particularly noticeable in hot ambient temperatures.

NOTE: With other possible failure modes the EMS2000 should ensure that the engine will limp home on a default value.

Intake Air Temp Sensor Testing

- Check status on DISplus status pages (0-5 volts). Ensure that voltage changes and does not remain constant at 0 or 5 volts.
- Check Sensor Resistance
- Perform TEST PLAN

Workshop Hint MAP and TMAP Sensors

- Voltage Reading of approx. 1-2 volts indicates high vacuum condition (Idle or no load)
- Voltage Reading of 4-4.8 volts indicates low vacuum condition (Full Throttle)

Workshop Hint Air Inlet Temp Sensor

- Workshop Hint MAP and TMAP Sensors Voltage Reading of 1 volt indicates warm air temperature
- Voltage Reading of 4 volts indicates cold air temperature

Notes:

Engine Coolant Temperature Sensor

The Engine Coolant Temperature Sensor is a Negative Temperature Coefficient thermistor sensor located in the coolant system. The sensor is located in the cylinder head next to the thermostat housing. It is accessed easier with the air box removed.

The Engine Coolant Temperature Sensor is a NTC type sensor. It is used to monitor the engine coolant temperature and has two wires both connected to the EMS2000. The signal is used for fuel control and ignition timing dependent on the engine temperature. The signal is also used to control the radiator fan speed as well as supplying a signal on the CAN-bus to drive the coolant temperature gauge in the instrument cluster.

A 5 volt reference signal is supplied to the coolant temp sensor by the EMS2000. High voltage readings at the EMS2000 indicate high sensor resistance, or low temperature. Low voltage readings indicate low sensor resistance or high temperature.

Engine Coolant Temp Sensor

1. Coolant Sensor
2. Thermostat Housing

Fig. 12: Engine Coolant Temperature Sensor
Courtesy of BMW OF NORTH AMERICA, INC.

COOLANT TEMPERATURE SENSOR RESISTANCE CHART

Coolant Temperature Sensor Resistance			
Temperature	Minimum Sensor	Typical Sensor	Maximum Sensor

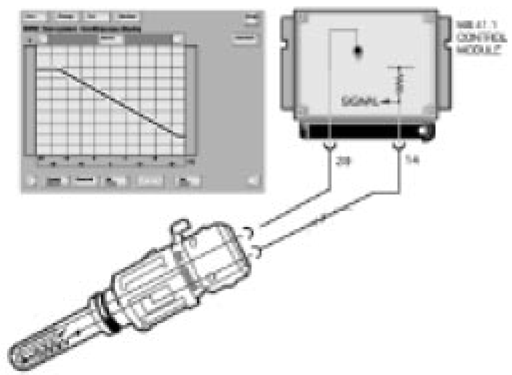
° Celsius	° Fahrenheit	Resistance (Kohms)	Resistance (Kohms)	Resistance (Kohms)
-40	-40	291.49	336.6	381.71
0	32	29.33	32.66	35.99
30	86	7.37	8.06	8.75
50	122	3.33	3.60	3.88
60	140	2.31	2.49	2.67
70	158	1.63	1.75	1.87
80	176	1.17	1.255	1.34
90	194	0.86	0.915	0.97
100	212	0.64	0.68	0.72
110	230	0.48	0.51	0.54
120	248	0.37	0.39	0.41
130	266	0.28	0.30	0.32
140	284	0.21	0.23	0.25
150	302	.017	0.185	0.20

Coolant Temperature Sensor Failure Symptoms

- The vehicle may be difficult to start, may run lean when the engine is cold or slightly rich when the engine is hot (default to 'emergency program' mode).
- Driveability of the vehicle will be affected.
- If the sensor output signal fails open, shorted to ground, shorted to 12V or shorted to 5V the EMS2000 will replace the temperature value with a default value.
- If the sensor ground is shorted to 12V or shorted to 5V, temperature gauge will go to full hot and engine cooling fan goes to high when fault is recognized.

Coolant Temperature Sensor Testing

- Check status on DISplus status pages (0 - 5volts) Ensure that voltage changes and does not remain constant at 0 or 5 volts
- Check Sensor Resistance
- Perform TEST PLAN



NTC type engine coolant temp sensor

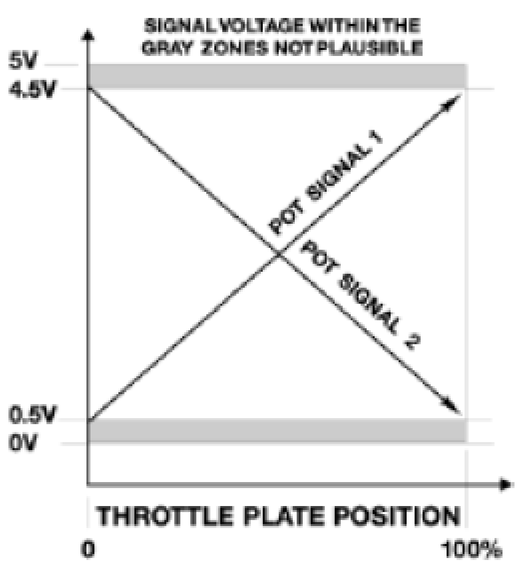
Fig. 13: Checking NTC Type Engine Coolant Temp Sensor
Courtesy of BMW OF NORTH AMERICA, INC.

EDR Throttle Position Feedback

The EDR throttle plate position is monitored by two integrated potentiometers. The potentiometers provide DC voltage feedback signals as input to the EMS2000 for throttle and idle control functions.

- Feedback potentiometer 1 provides a signal from 0.5V (LL) - 4.5V (VL),
- Feedback potentiometer 2 simultaneously provides a signal from 4.5V (LL) - 0.5V (VL).

Pot signal 1 is the primary signal, signal 2 is used as a plausibility cross-check through the total range of throttle plate movement.



EDR Feedback Potentiometer Voltages

Fig. 14: EDR Feedback Potentiometer Voltages Graph
Courtesy of BMW OF NORTH AMERICA, INC.

Failsafe

If there is an open or short in signal 1, signal 2 is used as a temporary substitute providing failsafe operation (faults stored).

If plausibility errors are detected between Pot 1 and Pot 2 one of two Emergency Modes is activated depending on severity of fault.

Emergency Mode 1

Emergency operation 1 limits the dynamic operation if one of the potentiometers fail. The engine can slowly reach maximum speed with limited power.

Emergency Mode 2

If another fault is encountered in addition to emergency mode 1 or if the plausibility is affected, emergency mode 2 is activated by the EMS2000. Emergency mode 2 is also be initiated by simultaneously pressing both the accelerator pedal and the brake pedal while in emergency mode 1 or if a fault is encountered in the brake light switch diagnosis.

NOTE: **When in emergency mode 2 operation mode, the engine runs very roughly. Throttle response is limited. This mode enables limp home functions.**

Additional Monitoring

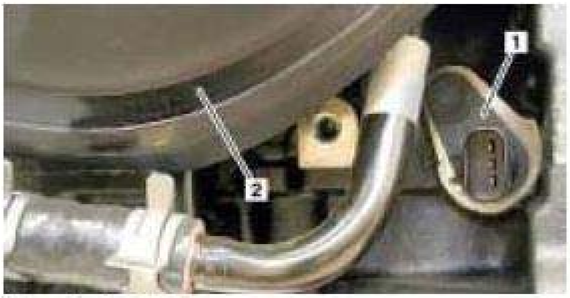
The EDR safety concept can detect a jammed or binding throttle valve as well as a broken link spring. This fault is detected by the EMS2000 monitoring of the feedback potentiometers from the EDR in relation to the pulse width modulation signal activating the EDR motor.

Crankshaft Sensor

The crankshaft sensor is a primary input to the EMS2000. It is used to determine the speed and position of the engine crankshaft. The sensor is a Hall Effect device. This provides a digital electrical signal that is created as the reluctor ring targets pass the sensor. The reluctor ring tooth pattern consists of 58 targets and a space of two missing teeth grouped together (6° tooth intervals). As the engine rotates the sensor output enables the EMS2000 to determine the crankshaft position and speed.

The missing teeth are essential for correct engine operation. They are used by the EMS2000 as an angular reference point. This information is used to determine:

- Fuel management
- Misfire detection
- RPM

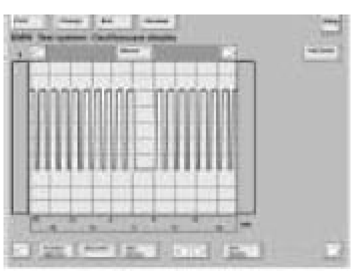


Crankshaft Sensor
1. Crankshaft sensor

Fig. 15: Crankshaft Sensor
Courtesy of BMW OF NORTH AMERICA, INC.

Crankshaft Tone Wheel
1. Tone Wheel
2. Attachment bolt
3. Missing teeth (gap)
4. Crankshaft

Fig. 16: Crankshaft tone Wheel
Courtesy of BMW OF NORTH AMERICA, INC.



Normal Crank Signal

Fig. 17: Normal Crank Signal Waveform
Courtesy of BMW OF NORTH AMERICA, INC.

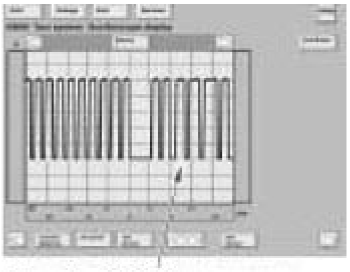


Fig. 18: Engine Misfire Waveform
Courtesy of BMW OF NORTH AMERICA, INC.

Diagnosis

During cranking the digital signal produced by the sensor is sent to the EMS2000. The EMS2000 expects to receive a signal of 58 targets and two missing targets. If this signal is received the EMS2000 will synchronize itself to the engine. (The EMS2000 knows crankshaft position.) In the event a faulty or improper signal is received the EMS2000 will not begin or allow injection or ignition.

There is no crankshaft back up facility on the EMS2000 because the camshaft sensor target only produces one pulse per revolution.

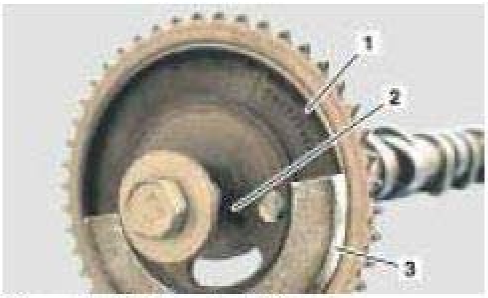
Camshaft Sensor

The signal from the camshaft sensor enables the EMS2000 to detect the position of the camshaft in relation to the position of the crankshaft. This allows the EMS2000 to synchronize the fuel injection and ignition spark.

The camshaft sensor is located in the front of the engine cylinder head just below the valve cover. The sensor reluctor ring is bolted to the front of the camshaft.

A digital signal is provided by the sensor in the range of 0-5 volts. The Hall Effect device produces one pulse for each revolution of the camshaft. The reluctor is of a half moon form with a single "tooth" that extends over 180° of the camshaft rotation.

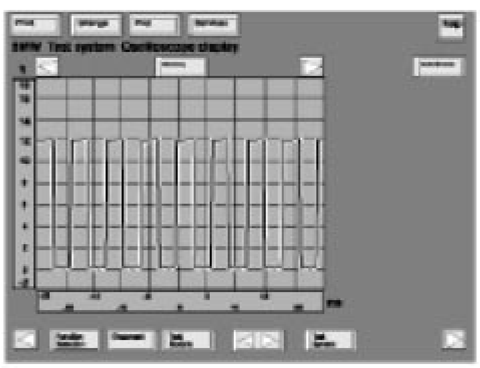
Fig. 19: Camshaft Sensor In Cylinder Head
Courtesy of BMW OF NORTH AMERICA, INC.



Camshaft Reluctor Ring

1. Camshaft Gear
2. Camshaft Gear Locating Pin
3. Reluctor "Tooth"

Fig. 20: Camshaft Reluctor Ring
Courtesy of BMW OF NORTH AMERICA, INC.



Scope Pattern for "Good" Camshaft Sensor

Fig. 21: Scope Pattern For "Good" Camshaft Sensor
Courtesy of BMW OF NORTH AMERICA, INC.

Diagnosis

Failure of the camshaft sensor will set a fault. Testing of the sensor is done through the test plan and the measurement system.

Camshaft sensor failure will cause the injection system to default into a semi-sequential mode.

NOTE:	**The EMS2000 can utilize the crankshaft sensor signal as a backup if the camshaft sensor fails.**

Knock Sensors

Knock Sensors are required to prevent detonation (pinging) from damaging the engine. The EMS2000 will retard the ignition timing (cylinder selective) based on the input of this sensor. Detonation occurs due to:

- High Compression Ratio
- Poor Quality Fuel
- High Level of Cylinder Filling
- Maximum Timing Advance Curve
- High Intake and Engine Temperatures
- Combustion Chamber Carbon Build-up

The knock sensor is a "Piezo-electric accelerometer" producing an output voltage proportional to mechanical vibration (knock) produced by the engine. Knock is caused by high-pressure waves of uncontrolled spontaneous combustion of gasses in the cylinder.

The EMS2000 receives a signal from the knock sensor, filters out any noise and calculates if the engine is knocking. During knock the crystal oscillation increases, the EMS2000 compares the signal received to known signal profiles in the memory.

From the camshaft and crankshaft signals supplying information regarding the position of the engine in it's cycle, the EMS2000 is able to determine which cylinder is knocking and will retard the ignition, on that particular cylinder until the knock is eliminated. It then gradually advances the ignition again towards the original setting until knock occurs again.

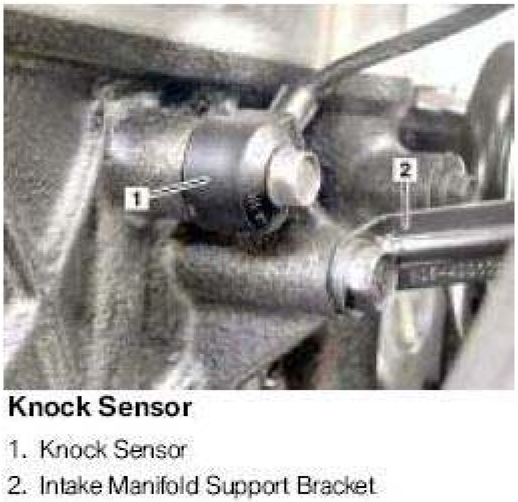


Fig. 22: Knock Sensor
Courtesy of BMW OF NORTH AMERICA, INC.

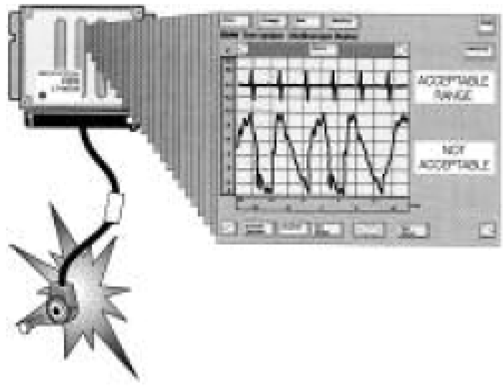


Fig. 23: Knock Sensor Scope Patterns
Courtesy of BMW OF NORTH AMERICA, INC.

Knock Sensor Fault Symptoms

- The EMS2000 will not be able to detect and correct for engine knock resulting in a "pinging" sound within the engine.
- The engine will lack power and fuel consumption will be affected.
- The knock strategy ensures that the engine defaults to a safe ignition value.

LDP System (Leak Diagnosis Pump) Reed Switch

Vapors containing Hydrocarbons form in the vehicles fuel tank and to prevent them from venting to atmosphere, legislation in the USA demands on-board monitoring of the fuel system sealing on all vehicles powered by an Internal Combustion engine. Beginning with Model Year 2000 these regulations were tightened, and call for detection of a 0.5 mm (0.02 inch) leak.

- The EVAP system used on the MINI will be the Siemens Leak Detection Pump (LDP). The LDP system is located above the right rear inner fender liner.

The LDP is an electrically/vacuum-actuated device that will pressurize the evaporative emission system for the purpose of detecting leaks and verifying canister purge valve integrity. It has an integrated Canister Vent Valve (CVV) that controls the atmospheric venting of the fuel vapor storage canister.

The LDP assembly is only replaceable as a complete unitized component, however, it is separate from the charcoal canister.

The upper chamber contains an integrated reed switch that produces a switched high/low voltage signal that is monitored by the EMS2000. The switch is opened by the magnetic interruption of the metal rod connected to the diaphragm when in the top dead center position. The repetitive up/down stroke is confirmation to the EMS2000 that the valve is functioning and the basis for determining if a leak is present in the system.

The EMS2000 monitors the length of time it takes for the reed switch to open, which is opposed by pressure under the diaphragm in the lower chamber. If this component or its circuits are defective, a fault code will be set and the "Malfunction Indicator Light" will illuminate when the OBD II criteria is achieved.

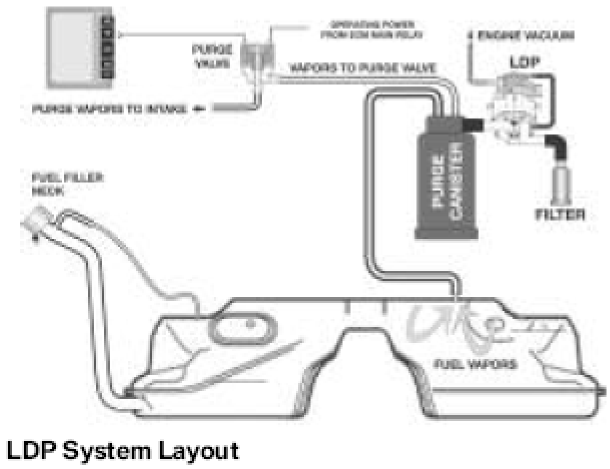


Fig. 24: LDP System Function Diagram
Courtesy of BMW OF NORTH AMERICA, INC.

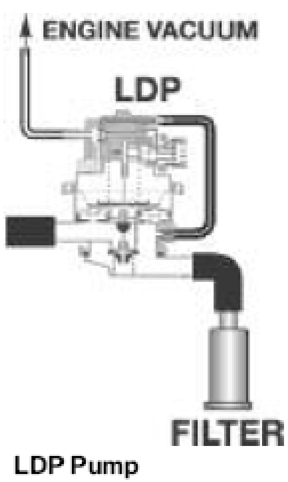


Fig. 25: LDP Pump Function Diagram
Courtesy of BMW OF NORTH AMERICA, INC.

O2 Sensors

The MINI COOPER and MINI COOPER S are equipped with two oxygen sensors. One is positioned upstream and the other downstream of the catalyst. The sensors are of a zirconium dioxide type and input a signal to the EMS2000 relative to the oxygen content within the exhaust gas. This enables the EMS2000 to provide closed loop operation and maintain strict control of the air/fuel ratio around stoichiometric (14.7:1). This allows the catalyst to work efficiently and reduce emissions of Carbon Monoxide (CO), Hydrocarbons (HC) and oxides of Nitrogen (NOx) to acceptable levels. The post catalyst sensor is used to monitor the catalyst performance.

The pre-cat oxygen sensor measure the residual oxygen content of the exhaust gas. The sensor produces a low voltage (0-1000 mV) proportional to the oxygen content that allows the EMS2000 to monitor the air/fuel ratio.

The sensor is mounted in the hot exhaust stream directly in front of the catalytic converter.

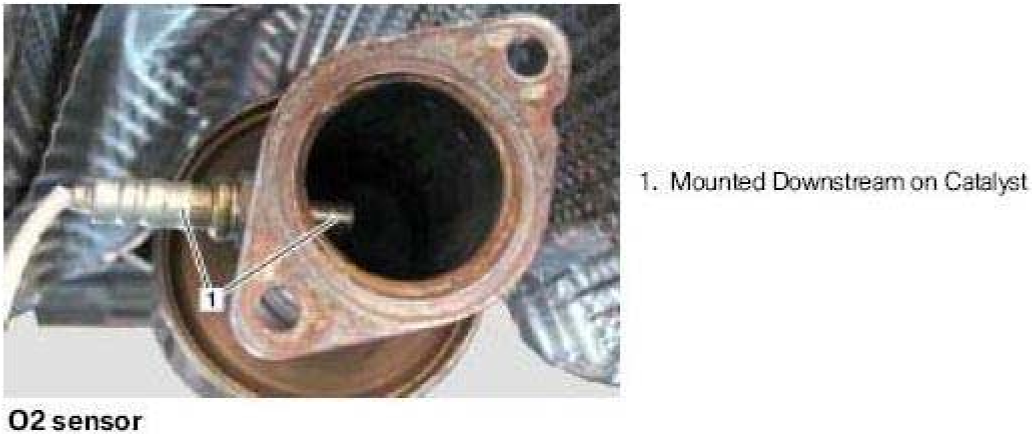


Fig. 26: O2 Sensor
Courtesy of BMW OF NORTH AMERICA, INC.

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 EMS2000.

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).

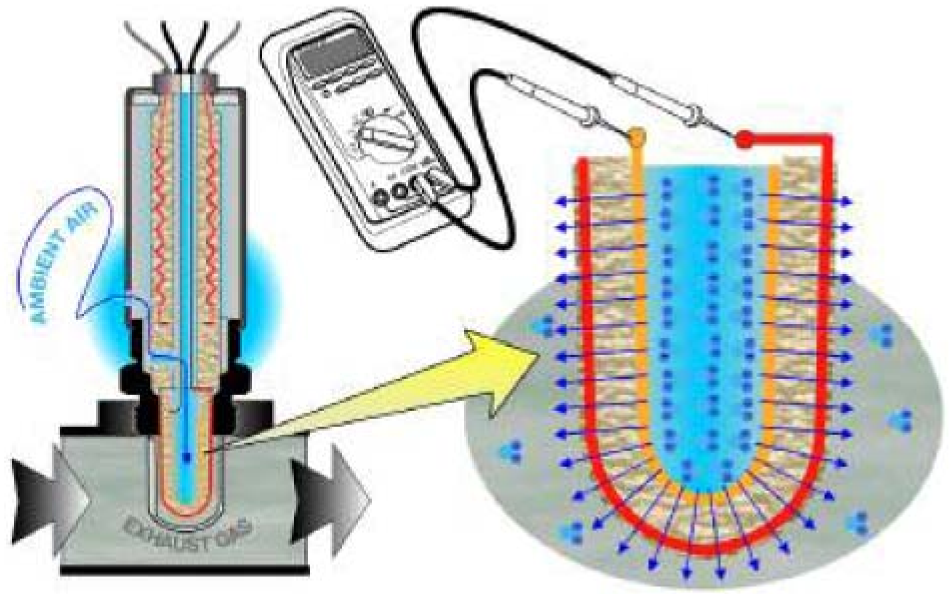


Fig. 27: O2 Sensor Operation
Courtesy of BMW OF NORTH AMERICA, INC.

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

The EMS2000 monitors the length of time the sensors are operating in the lean, rich (including the time of rise and fall) and rest conditions. The evaluation period of the sensors is over a predefined number of oscillation cycles.

This conductivity is efficient when the oxygen sensor is hot (250° - 300° 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.

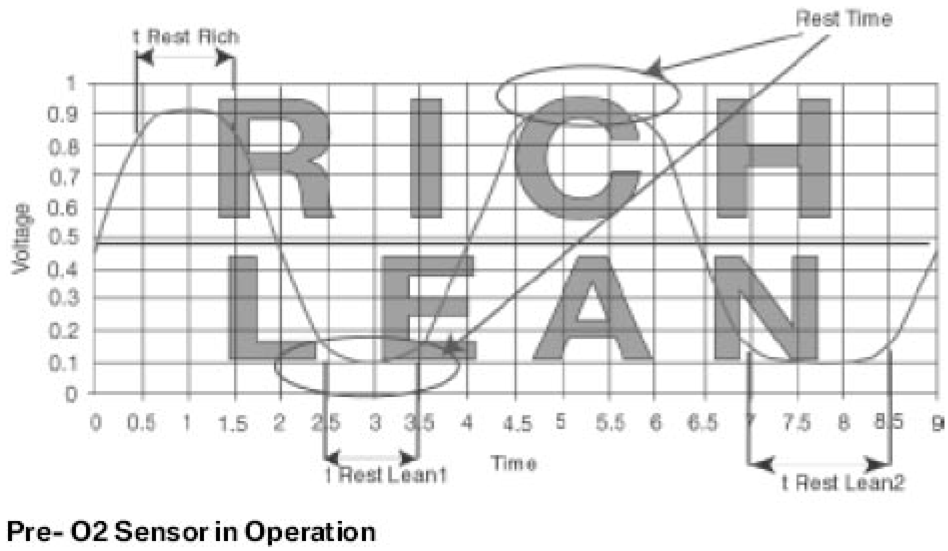


Fig. 28: O2 Sensor Graph
Courtesy of BMW OF NORTH AMERICA, INC.

The efficiency of catalyst operation is determined by evaluating the oxygen consumption of the catalytic converters using the pre and post oxygen sensor signals. A properly operating catalyst consumes 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 are installed to monitor exhaust gas content exiting the catalysts. 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 when the OBD II criteria is achieved.

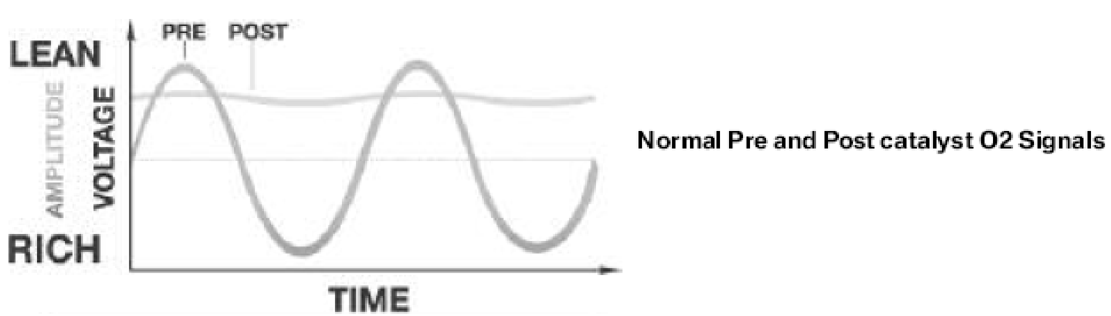


Fig. 29: Normal Pre And Post Catalyst O2 Signals
Courtesy of BMW OF NORTH AMERICA, INC.

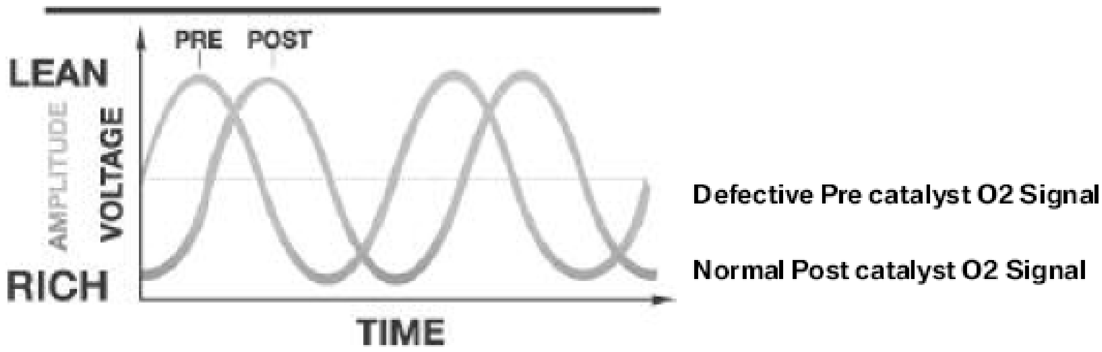


Fig. 30: Defective Pre Catalyst O2 Signal
Courtesy of BMW OF NORTH AMERICA, INC.

O2 Sensor Failure Symptom(s)

- If the upstream sensor fails it may result in poor performance and rough idle.
- Poor emissions control will cause the MIL to illuminate.
- As soon as the EMS2000 has detected an upstream oxygen sensor failure, it will default the fuel control to open loop operation.
- Slow response of sensor due to ageing or possible contaminated sensor tip.

Brake Light Switch

There are two separate Hall Effect brake-switch inputs into the EMS2000 to allow redundant integrity checking. The signal from the Main Brake switch is used in the control of both the Cruise Control and the Drive By Wire systems. If the brake is operated, the system shall suspend the cruise-mode, but shall retain any current valid target-speed in memory. The second switch is used in a safety plausibility check. If at any time the two brake signals are inconsistent, a fault condition is assumed and any accelerator demand will result in no throttle change and the engine will remain at its idle state.

Brake Light Switch Fault Symptoms

If the two brake signals are seen to be inconsistent at any time, a fault condition must be assumed. The accelerator pedal activation signal is set to zero, hence there will be no throttle demand and the engine will remain at idle. If this occurs while in a cruise active mode, the system shall suspend and will disable cruise for the remainder of that journey. The system will register a fault disallowing further operation.

Clutch Switch (Manual Transmission Models)

The clutch switch is a Hall Effect Device used on manual transmission derivatives to suspend the cruise-mode function when the clutch is operated. The device is a single channel version of the brake switch and the functionality is identical.

Transmission Secondary Speed Sensor (ECVT Models only)

The ECVT transmission has a dedicated secondary speed sensor located in the differential housing. This sensor is a Hall effect sensor and produces a pulse train of approximately 73,000 pulses per mile. The sensor allows for more precise calculation of transmission output speed that is used in the control strategy systems.

The secondary speed sensor is located so that the sensor tip is close to the crown wheel of the differential. By sensing the crown wheel, the signal is not affected by the different wheel speed signals when the vehicle is cornering.

Transmission Speed Sensor

1. Speed Sensor Mounted in ECVT

Fig. 31: Transmission Speed Sensor Location
Courtesy of BMW OF NORTH AMERICA, INC.

Transmission Speed Sensor

1. Speed Sensor
2. Speed Sensor Oil Seal

Fig. 32: Transmission Speed Sensor
Courtesy of BMW OF NORTH AMERICA, INC.

Transmission Oil Temperature Sensor (ECVT Models only)

The Transmission Oil Temperature Sensor is a two wire sensor and is located in the valve block area. The sensor continuously monitors the temperature of the oil. Should the oil temperature rise above preset parameters, the EMS2000 control unit will reduce the amount of slip within the clutch to reduce the oil temperature.

Generator

A dedicated output from the Generator is provided to the EMS2000 to determine electrical load on the engine. When electrical loads are switched on the generator will require more electrical energy, which will in turn create a greater load on the engine. The output is a PWM modulated signal.

If the PWM signal fails the engine may exhibit poor idle speed stability as the electrical loads are increased.

EWS

The EMS2000 communicates with the EWS system to provide immobilization of the vehicle. To start the engine, the correct key must be used which will transmit the correct code magnetically to the coil in the steering column. This code is then fed to the immobilization unit, which will transmit various codes to the EMS2000 to enable the engine to start.

The purpose of the immobilization system is to prevent the engine from starting if the information from the immobilizer module (EWS 3) is not recognized as the correct information.

A specific unidirectional single wire line supports communication between the EMS2000 and the EWS 3. To secure the system the information transmitted from the immobilizer is encrypted. To automatically protect the system there is a time limit, which represents the maximum duration of the communication between the EMS2000 and the EWS 3.

On the automatic transmission vehicle there is a park/neutral inhibit signal that the EWS 3 receives directly from the switch in the automatic transmission. The purpose of the switch is to ensure that the engine will only crank if the automatic transmission is in Neutral or Park.

Gearbox Interface Unit (GIU)

The main function of the GIU is to allow communication between the ECVT and the EMS2000. The GIU has the following functions:

- Conversion of inputs from the selector lever switches (and steering wheel switches if fitted) into a CAN instruction that is read by the EMS2000.
- Drive the LED's to display transmission mode.
- Conversion of the CAN instruction for the EMS2000 into electrical signals to drive the ratio control motor and clutch and secondary pressure solenoids.

ABS/ASC/DSC

The EMS2000 receives road speed signals from the ABS/ASC/DSC module for cruise functions (if equipped) and maximum vehicle speed limiting. Road speed signals arrives at the EMS2000 over the CAN BUS.

Requests for torque modification are also received from the ASC/DSC module over the CAN Bus. If either of the driven wheels loose traction the ASC/DSC control module will request a change in the torque output of the engine in order to regain traction. This occurs in either of the following situations:

- The wheels have broken traction due to excess torque being generated by the engine; the ASC Control Unit therefore requests a torque reduction from the engine.
- The wheels have broken traction due to excess engine braking when on low grip surface; the ASC Control Unit requests a torque increase from the engine under these circumstances. This is called the Engine Drag Torque Control (MSR) System.

Once traction has been regained then the brake or torque intervention will be removed allowing the engine to return to its appropriate torque output as determined by other inputs such as driver demand or cruise control. The requests for a torque increase or reduction are received from the ASC Control Unit via the vehicle CAN-bus.

A/C Pressure Transducer

The pressure transducer protects the refrigerant system from extremes of system pressure and in conjunction with the engine coolant temperature sensor, controls the speed of the engine coolant fan. The pressure transducer is fitted in the high pressure/temperature line of the refrigerant circuit on the AC pipe connecting the condenser and thermostatic expansion valve. It is installed in the left rear corner of the engine compartment, and is fitted to the pipe in a threaded coupling.

The transducer is connected through the vehicle harness to the EMS2000 where the signal is processed to calculate the pressure in the high pressure line.

Because the compressor is lubricated by oil suspended in the refrigerant, the EMS2000 prevents operation of the compressor unless there is a minimum refrigerant pressure, and thus refrigerant and oil, in the system.

When refrigerant pressure increases to a value that indicates additional condensing is required, the EMS2000 requests an increase in cooling fan speed.

The signal from the pressure transducer is a varying voltage type. Higher voltages indicate higher pressure, lower voltages lower pressure. Normal operating range is approximately 1.2 - 2.0 volts.

An open in the transducer circuit will cause the EMS to see maximum system pressure and disable the compressor from further operation.

Pressures in Bar are read from the sensor in the DISplus.

IKE

The IKE communicates with the EMS2000 over the CAN Bus. Information concerning Low Fuel Levels are passed to the EMS2000 for evaluation of misfires. The IKE also transfers requests for the A/C compressor from the IHKS/IHKA to the EMS2000. Any vehicle system not on the CAN Bus that communicates with the EMS2000 does so through the IKE.

MFL

Vehicles equipped with Cruise Control have single wire digital communication system between the MFL and the EMS2000. The MFL transmits requests for cruise operation to the EMS2000.

Notes:

EMS2000 CAN COMMUNICATION

The EMS200 control unit primarily communicates to other modules via bus communication. Very few signals are sent from one control unit to another via hard wired cables. Usually any extremely important signal is going to hardwired between modules. (ex. MRS control unit crash signal to EMS2000)

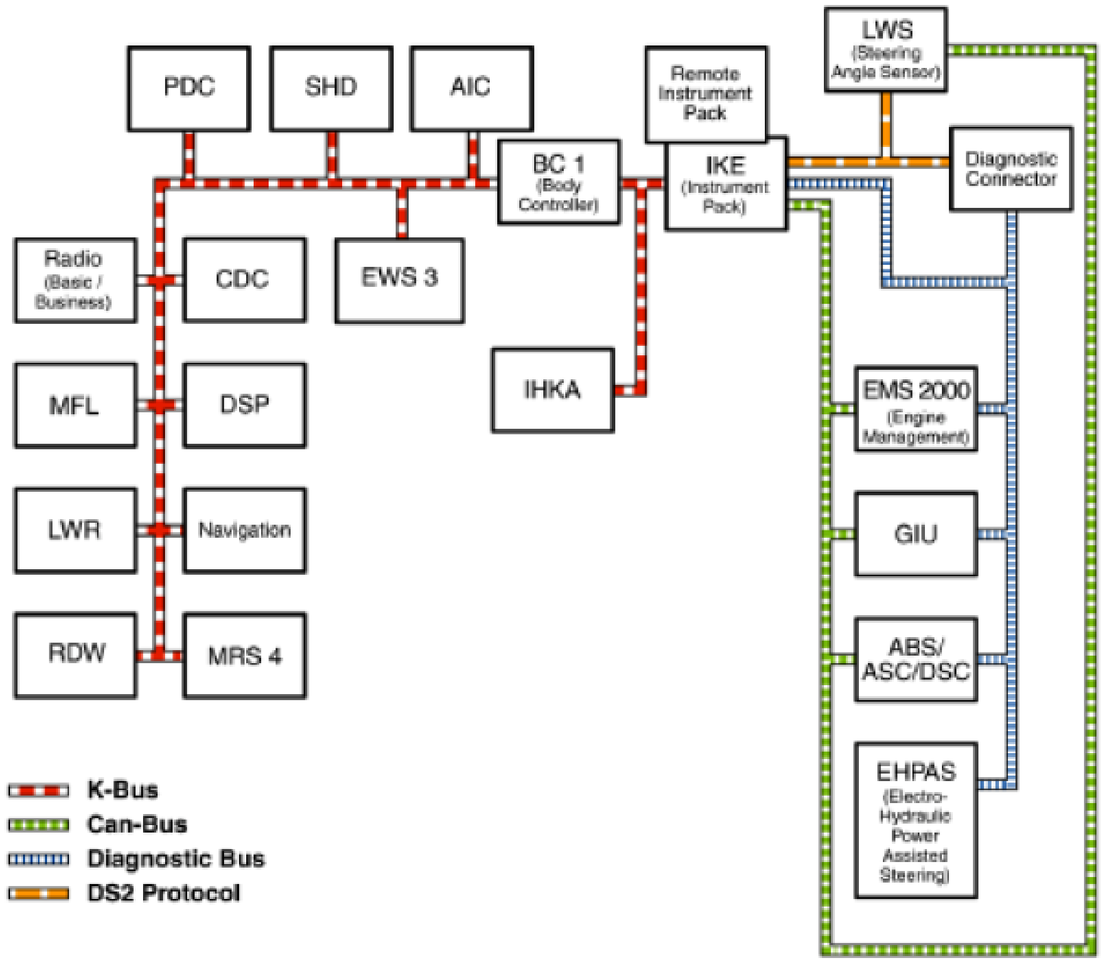


Fig. 33: EMS2000 CAN Communication Function
Courtesy of BMW OF NORTH AMERICA, INC.

SYSTEM OUTPUTS

Main Relay

Upon receiving the wake up signal from the ignition switch, KL15 supplying power to fuse 34, the EMS2000 provides a switched ground signal via Pin 97 to the Main Relay. This energizes the Main Relay, providing operating power to the EMS2000. Output of the Main Relay is monitored so that if the relay is energized and the power is not received by the EMS2000 a fault code is set.

EDR

An electronic throttle actuator (EDR) is used to adjust engine load based on throttle position requests received by the EMS2000 from the accelerator pedal position sensor. A DC-Motor electrically positions the throttle plate from idle to full load. The feedback of the position of the throttle plate and the position of the DC-Motor is achieved via 2 potentiometers, which are integrated in the throttle body.

- The MINI COOPER throttle body is 52 mm internal diameter.
- The MINI COOPER S throttle body is 57 mm internal diameter.

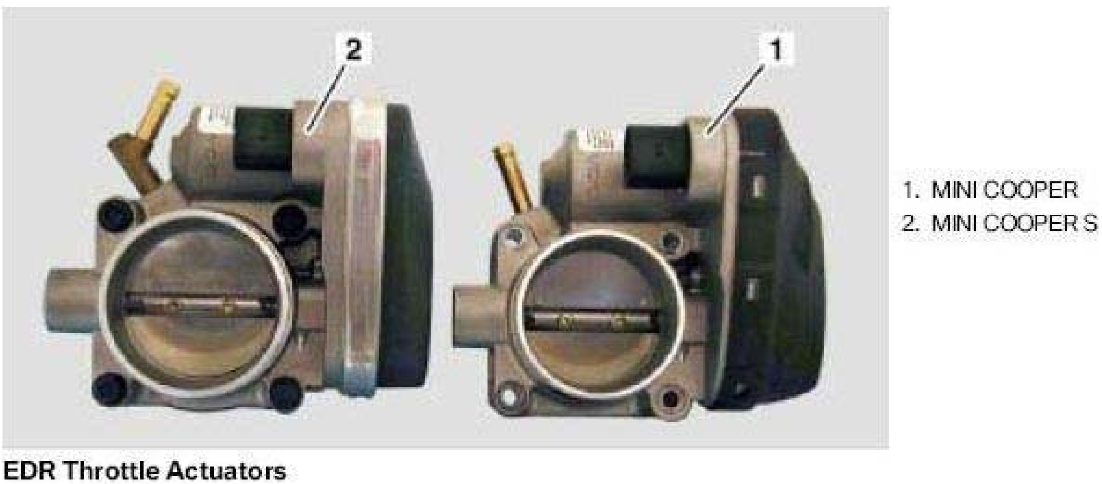


Fig. 34: EDR Throttle Actuators
Courtesy of BMW OF NORTH AMERICA, INC.

The EDR is operated by the EMS2000 for opening and closing of the throttle based on accelerator pedal position, DSC intervention and Cruise Control function. The EDR is a DC motor operating a gear driven throttle plate.

A variable duty cycle fixed frequency signal is sent to the EDR motor by the EMS2000. The EMS2000 switches polarity on the signal to the EDR motor at the rate of 600 Hz (600 times per second) to maintain throttle position. Position and movement of the throttle plates is confirmed through the dual feedback potentiometers control functions.

The EMS2000 also provides power and ground for the feed back potentiometers.

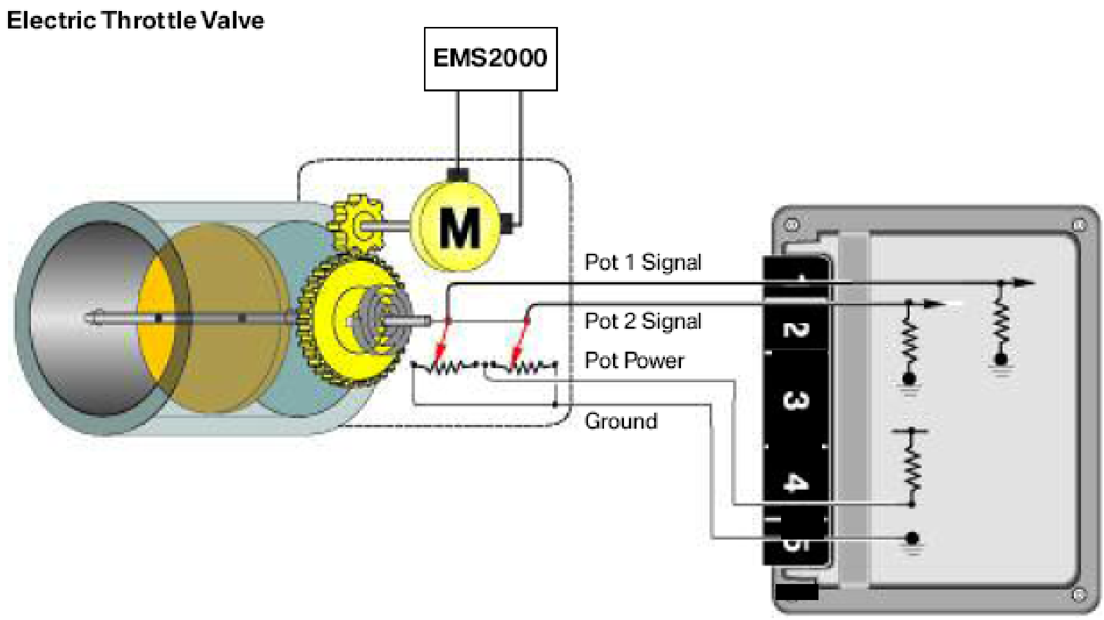


Fig. 35: Electric Throttle Valve Circuit Diagram
Courtesy of BMW OF NORTH AMERICA, INC.

Idle Speed Control

Idle Speed is controlled by the EMS2000 and EDR without the aid of an idle speed motor.

For smooth driveability of the vehicle, the engine speed should remain constant when at idle no matter what the varying loads may be on the engine. The driver should not detect a fluctuation in engine idle speed under the following conditions:

- Engine cold start (increase in idle speed setting).
- Switching of different electrical loads (e.g. headlights, HRW or HFS).
- Turning the steering wheel to full lock (increased load from the Electro Hydraulic Power Steering (EHPS pump)).
- Air Conditioning Compressor engagement.

When there is a rapid change in electrical power demand on the alternator ie. front and rear heated windshield on with air conditioning fully on, there will be a corresponding rapid increase in the mechanical loading that the alternator exerts upon the engine. This in turn will have a significant effect on the engine idle speed stability. There is a delay between the electrical demand being made on the alternator and the mechanical demand being made on the engine. During this period of time the alternator transmits a signal to the EMS2000 to inform the control unit of the change in electrical load. The signal is PWM and allows the EMS2000 to control the throttle demand at idle to prevent flares and dips in the engine speed due to alternator loading or unloading.

NOTE: The target idle speed setting for all MINI models is 750 rpm.

Idle Speed "Jack" Feature

As part of the vehicle power balancing strategy there is a feature to increase the engine idle speed to a set point when the EMS2000 system voltage reaches a certain threshold. The engine speed will remain at this point for a period of time before returning to the normal set point when the system voltage has recovered.

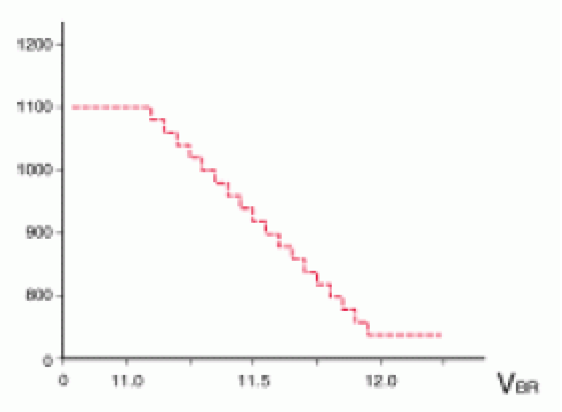


Fig. 36: Idle Speed Graph
Courtesy of BMW OF NORTH AMERICA, INC.

EML Warning LED

If the EMS2000 detects an engine safety related fault (but is not emissions related) in the EMS2000 itself, the EML warning light will illuminate in the IKE to show there is a fault with the drive by wire system. (This could be caused by a faulty throttle motor, gearbox or a sticking throttle flap.) The Warning Led is amber in color and is activated through a CAN Bus message to the IKE.

Fuel Pump Relay and Inertia Switch

The Fuel Pump Relay is a normally open contact relay used to control the fuel pump. The relay gets its B+ feed from the ignition switch through fuse 20 and is energized when the EMS2000 provides a ground on pin 105.

The pump is initially energized when the ignition is switched on to position 2. It will remain energized for a several seconds to pressurize the fuel system. The fuel pump relay will remain energized if the EMS2000 control unit detects the engine is running (RPM via crankshaft sensor). The relay is switched to off immediately if engine RPM is not detected or after ignition key Off is detected.

On early models an inertia switch is installed in the B+ line to the relay between the fuse and the fuel pump relay. In the event of an impact greater than 14G the switch will open interrupting power to the relay. The inertia switch has to be reset manually once it has been triggered.

As of 9/2002 production, vehicles utilize a crash signal from the MRS control unit to the EMS2000 control unit to control fuel pump shut off as oppose to the inertia switch.

Fig. 37: "A" Pillar Fusebox
Courtesy of BMW OF NORTH AMERICA, INC.

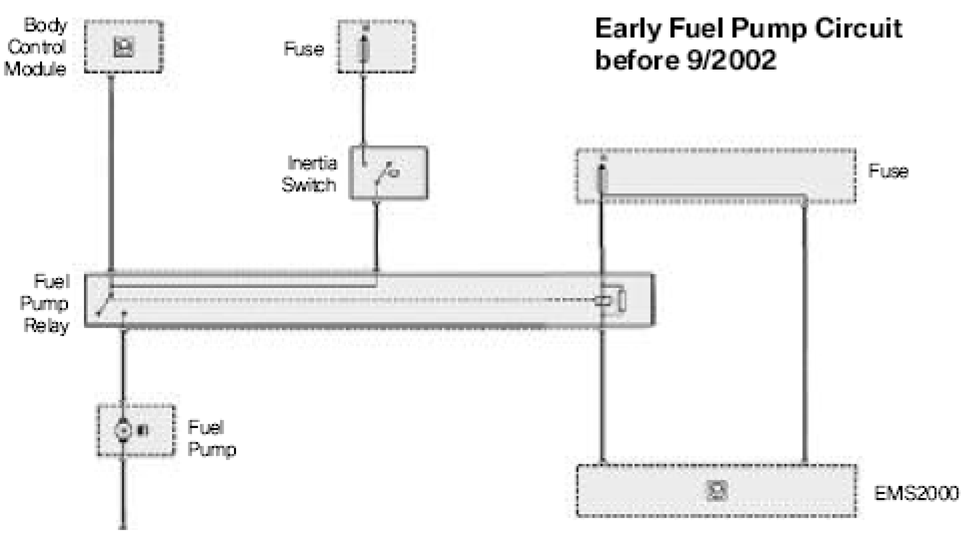


Fig. 38: Early Fuel Pump Circuit Diagram
Courtesy of BMW OF NORTH AMERICA, INC.

Fuel Injectors

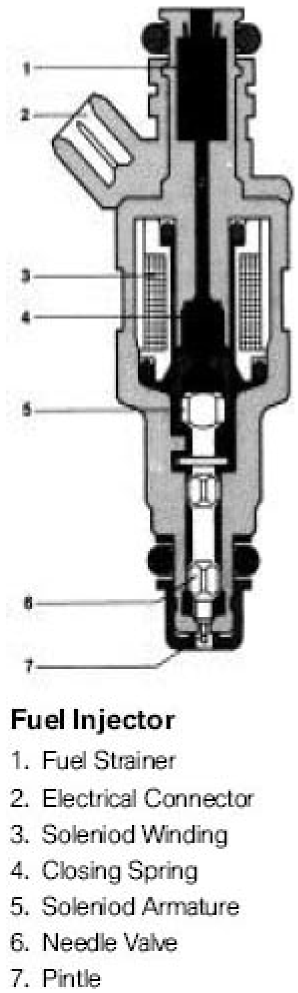


Fig. 39: Section View Of Fuel Injectors
Courtesy of BMW OF NORTH AMERICA, INC.

The Fuel Injectors are electronically controlled solenoid valves that provide precise metered and atomized fuel into the engine intake ports.

Fuel is supplied from the fuel rail to the injector body. The fuel is channeled through the injector body to the needle valve and seat at the tip of the injector. Without electrical current, the needle valve is sprung closed against the seat.

The Fuel Injectors receive voltage from the Main Relay. The EWS2000 activates ground, via a transistor, that allows current flow through the injector solenoid creating a magnetic field that pulls the needle "up" off of its seat. The pressurized fuel flows through the tip of the injector that is fitted with a directional angle "plate" with dual outlets. This "fans out" the spray into an angled patterns which helps to atomize the fuel.

When the EMS2000 turns off the transistor that supplies ground, the needle valve is sprung closed against the seat and fuel flow through the injector is stopped. The lower portion of the injector body is jacketed in metal.

The length of time that the EMS2000 activates the Fuel Injectors is very brief, the duration is usually represented in milli-seconds (ms). This affects the amount of fuel volume flowing through the Fuel Injectors. The EMS2000 will vary the length of time (ms) to regulate the air/fuel ratio (mixture).

Types of Fuel Injectors

There are two types of injectors used on the MINI.

- MINI COOPER uses an injector with 4 holes (Bosch).
- MINI COOPER S uses an injector with a higher flow rate having 2 holes (Siemens).

Injectors for both models are 62 mm in length and operate on a fuel pressure of 3.5 Bar. The electrical connectors are different for each type of injector preventing accidental installation of the wrong injector.

Fig. 40: Fuel Injectors
Courtesy of BMW OF NORTH AMERICA, INC.

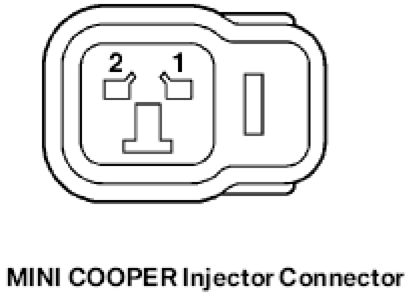


Fig. 41: MINI Cooper Injector Connector
Courtesy of BMW OF NORTH AMERICA, INC.

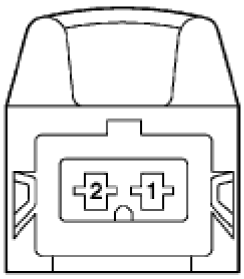


Fig. 42: MINI Cooper S Injector Connector
Courtesy of BMW OF NORTH AMERICA, INC.

Injector "ON" Time

Injector "ON" Time is the length of time in ms the injector is active and flowing fuel.

The injection ms value will be regulated based on:

- Battery Voltage
- Engine Load
- TMAP
- Camshaft Position
- Engine Coolant Temperature
- Fuel Shut off
- Crankshaft Position

Battery Voltage

When cranking, the voltage is low and the EMS2000 will increase the ms value to compensate for injector "lag time". When the engine is running and the battery voltage is higher, the EMS2000 will decrease the injection ms value due to faster injector reaction time.

Coolant Temperature

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 EMS2000 based on the Engine Coolant Temperature Sensor input during start up.

Engine Load

When the engine is at idle, minimum injection is required. Additional fuel will be added if the EMS observes low engine rpm and increasing throttle/air volume inputs (acceleration enrichment). As the throttle is opened, the EMS2000 recognizes acceleration and rate of movement. The EMS2000 will increase the volume by increasing the injection ms value. The "full throttle" position indicates maximum acceleration and the EMS2000 will add more fuel (full load enrichment).

As the throttle is closed, the EMS2000 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.

TMAP

The EMS2000 uses input from the TMap (and Map if COOPER S), the Engine Coolant Temperature Sensor and throttle position to calculate the volume of air consumed by the engine. This calculated measurement is used by the EMS2000 to determine the amount of fuel to be injected to "balance" the air/fuel ratio.

Crankshaft Position Sensor

The Crankshaft Position/RPM signals the EMS2000 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 in-put, the EMS2000 will not activate the injectors.

Camshaft Position Sensor

The Camshaft Position (Cylinder ID) affects the injection timing (Semi-Sequential/Full Sequential). To accomplish this, the EMS2000 contains four Final Stage output transistors that activate the injectors individually. The engine operates sufficiently on Semi- Sequential Injection (two groups of two), but more efficiently on Full Sequential Injection (four individual). If one of the fuel injector circuits is faulted, the engine can still operate on limited power from the remaining fuel injector circuits.

Injection "Reduction" Time

Reduction Time is required to control fuel economy, emissions, engine and vehicle speed limitation. The EMS2000 will "trim" back or deactivate the fuel injection as necessary while maintaining optimum engine operation.

As the throttle is closed during deceleration, the EMS2000 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.

Vehicle Speed Limiting

The EMS2000 will selectively deactivate injectors to control maximum engine rpm (regardless of vehicle speed). When the engine speed reaches 6500 rpm, the injectors will be individually deactivated as required to protect the engine from over-rev. As the engine speed drops below 6500 rpm, injector activation will be resumed.

NOTE: This feature does not protect the engine from a forced over-rev such as improperly downshifting a manual transmission equipped vehicle (driver error).

Maximum vehicle speed is also limited by the EMS2000 selectively deactivating the injectors (regardless of engine rpm). This limitation is based on the vehicle dimensions, specifications and installed tires (speed rating).

Catalytic Converter Protection

The EMS2000 will also protect the Catalytic Converter by deactivating the injectors. If the EMS2000 detects a "misfire" (ignition, injection or combustion) it can selectively deactivate the Final Stage output transistor for that cylinder(s).

The injector(s) will not open, preventing unburned fuel from entering the exhaust system.

On the EMS2000 system, there are four individual injector circuits resulting in deactivation of one or multiples. This will limit engine power, but protect the Catalytic Converter.

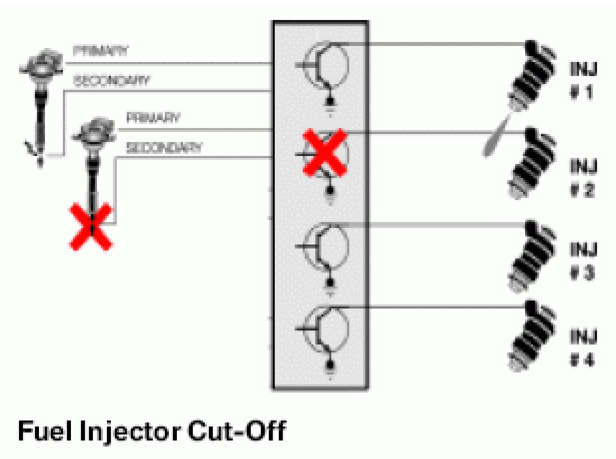


Fig. 43: Fuel Injector Cut-Off Function
Courtesy of BMW OF NORTH AMERICA, INC.

Fuel Injector Monitoring

Fuel Injection Control Monitoring is performed by the EMS2000 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.

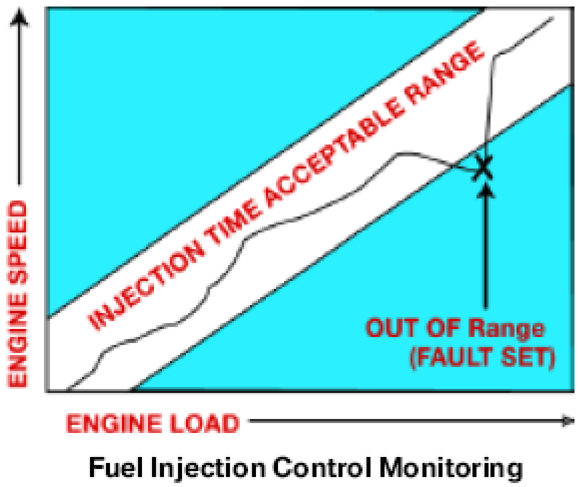


Fig. 44: Fuel Injection Control Monitoring
Courtesy of BMW OF NORTH AMERICA, INC.

Adaptation Values are stored by the EMS2000 in order to maintain an "ideal" air/fuel ratio. Within the areas of adjustable adaption, the EMS2000 modifies the injection rate under two areas of engine operation:

- During idle and low load mid range speeds. (Additive Adaptation)
- During operation under normal load to higher load at higher engine speeds. (Multiplicative Adaptation)

These values indicate how the EMS2000 is compensating for a less than ideal initial air/fuel ratio.

Additive Mixture Adaptation

- If the adaptation value is greater than "0.0ms" Additive or 0% Multiplicative, the EMS2000 is trying to richen the mixture.

Multiplicative Mixture Adaptation

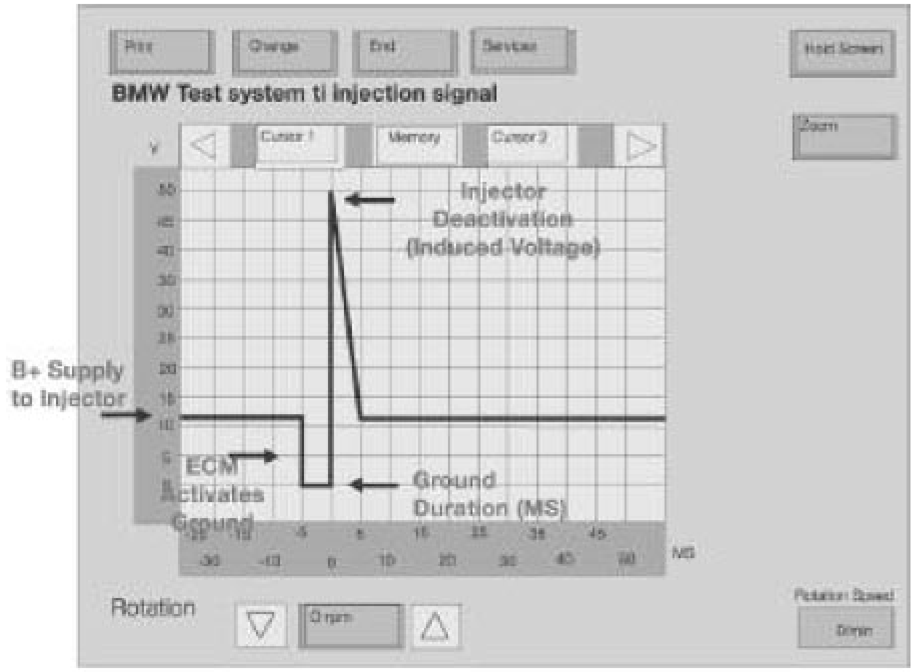
- If the adaptation value is less then "0.0ms" Additive or 0% Multiplicative, the EMS2000 is trying to lean-out the mixture.

Injector Testing

Fuel Injectors can leak and bleed off fuel pressure causing hard or long starting and increased emissions. Injectors are leak tested using the Fuel Injector Leakage Tester.

Injectors should also be tested using the DISplus for:

- Resistance (approximately 12W)
- Power Supply (B+ from Main Relay)
- Status Request - Fuel Injection Signal (approximately 3.0 ms - 5.0 ms)
- EMS2000 final stage activation (see graph)



"Good" Fuel Injector Scope Pattern

Fig. 45: "Good" Fuel Injector Scope Pattern
Courtesy of BMW OF NORTH AMERICA, INC.

NOTE:

- **Measurement is performed on the negative B- side of injector or trigger pin of EMS2000.**
- **Vehicle voltage is present when injector is not active.**
- **EMS2000 pulls voltage to ground causing injector to open.**
- **When EMS2000 releases ground, injector closes and a voltage spike is produced because of the collapsed coil winding of injector.**

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).
- Always wear adequate protection clothing including eye protection.
- Use caution when working around a hot engine compartment
- During fuel system repair that involves "sealing rings", always replace them with a new COPPER rings

only.

- MINI does not recommend any UNAUTHORIZED MODIFICATIONS to the fuel system. The fuel system 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 customers vehicles, particular in safety related areas.
- Always consult the Repair Instructions on the specific model you are working on before attempting a repair.

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:

- Coil Assembly
    - Primary Winding
    - Secondary Winding
- Resistor
- Spark Plug
- EMS2000 Final Stage Transistor

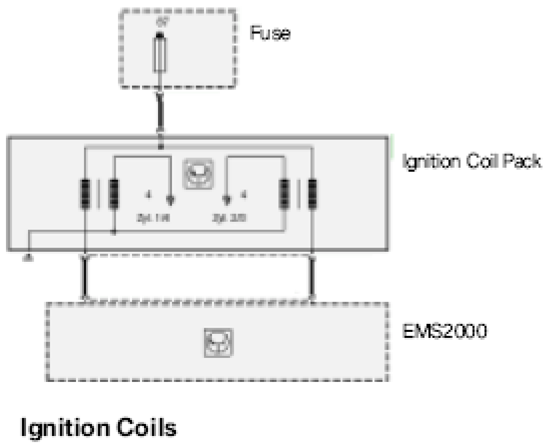


Fig. 46: Ignition Coils
Courtesy of BMW OF NORTH AMERICA, INC.

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 coil winding receives battery voltage from the Main Relay which is activated by the EMS2000. The EMS2000 provides a ground path for the primary 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 EMS2000 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 voltage generated in the secondary is capable of 40,000 volts (40kV). The high voltage is discharged through the secondary ignition spark plug connectors.

EMS2000 uses a dual output coil which provides voltage to fire two plugs "simultaneously". Spark delivered to one cylinder is wasted as the cylinder is on the exhaust stroke and two of the components of cylinder combustion are missing, fuel and compression. Little or no resistance to the spark movement is provided thus the voltage consumed during the waste spark firing is very low.

Spark delivered to the other cylinder provides the ignition for power generation. The cylinder is on the firing stroke, fuel is in the cylinder and cylinder pressures are high. The spark has a higher resistance and requires greater kV's to jump the plug gap.

Ignition Control

Ignition Control is determined by the EMS2000 (load dependent). The EMS2000 will calculate the engine "load" based on a combination of the following inputs:

- Battery Voltage
- Accelerator Pedal Position
- Calculated air volume and Mass
- Engine Coolant Temperature
- Crankshaft and Camshaft Position
- Knock sensors

The dwell time will be regulated based on battery voltage. When cranking, the voltage is low and the EMS2000 will increase the dwell to compensate for saturation "lag time". When the engine is running and the battery voltage is higher, the EMS2000 will decrease the dwell due to faster saturation time.

The Crankshaft Position/RPM signals the EMS2000 to start ignition in firing order (1-3-4-2) 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 EMS2000 will not activate the ignition.

Cold start is determined by the EMS2000 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". Based on the calculated air volume and mass the EMS2000 determines the proper amount of timing advance for the air/fuel mixture.

The EMS2000 monitors the Knock Sensors after each ignition for a normal (low) signal. If the signal value exceeds the threshold, the EMS2000 identifies the "knock" and retards the ignition timing (3°) for that cylinder the next time it is fired. This process is repeated in 3° increments until the knock ceases. The ignition timing will be advanced again in increments to just below the knock limit and maintain the timing at that point.

If a fault is detected with the Knock Sensor(s) or circuits, the EMS2000 deactivates Knock Control. The ignition timing will be set to a conservative basic setting (to reduce the risk of detonation) and a fault will be stored. The "Malfunction Indicator Light" will be illuminated when the OBD II criteria is achieved.

Waste Spark Ignition

The Waste Spark Theory of Ignition Systems is based on understanding basic electric circuits. Electricity always travels in a circuit. Electricity leaves the source, travels through conductors and a consumer and returns to the point of origin. The coil secondary winding is the source of spark for the spark plugs. The spark must return there in order for the circuit to be complete.

The plugs that fire simultaneously (1-4, and 2-3) are wired in series with the coil. Since the polarity of the coil windings is fixed, one spark plug fires in the forward direction, from the center to the outer electrode, the other plug always fires backwards or from the outer electrode to the center. The spark travels from the coil through the conductor to the spark plug, the energy remaining after the spark has jumped the gap, travels through the cylinder head, through the companion spark plug and back to the coil.

One of the spark plugs will be firing on exhaust and the other on compression. The cylinder firing on compression will consume 80-90% of the energy produced by the coil. The cylinder firing on exhaust will consume the balance.

On the MINI the secondary ignition for cylinders 1 and 4 are paired as are 2 and 3. Cylinders 3 and 4 fire in the conventional manner from the center electrode out to the outer electrode. Cylinders 1 and 2 fire from the outer electrode back to the center electrode.

Ignition Coil Testing

Ignition system faults may be diagnosed with the DISplus or GT1 if equipped with a Measurements Interface Box. Enter the test plan for ignition coil (a choice of four coils, 1, 2, 3, or 4 will be given). The oscilloscope will be pre-set during the test plan.

When measuring kV on cylinders 1 and 2, remember that the voltage is flowing from the outer electrode to the center and back to the coil. This will be indicated by negative voltage readings on the oscilloscope. kV's on cylinders 1 and 2. The voltage will be approximately 20% higher than on cylinders 3 and 4.

NOTE:

- **Secondary output in the 7- 9 kV range are normal during firing of the cylinder on the compression stroke and 3 - 5 kV for the cylinder on the wasted spark stroke.**
- **A defective coil will influence two cylinders, a defective plug wire only influences one cylinder.**

Purge System

Evaporative Emission Purging is regulated by the EMS2000 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 Main Relay provides operating voltage, and the EMS2000 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 (needed for feedback)
- Engine Coolant Temperature is >67° C(39°F)
- Engine Load is present

  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 EMS2000 when the oxygen sensor control and purging is active. When the Evaporative Emission Valve is open the EMS2000 detects a rich/lean shift as monitored by the oxygen sensors indicating the valve is functioning properly.

If the EMS2000 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 EMS2000 opens and closes the valve (abruptly) several times and monitors the engine rpm for changes. If there are no changes, a fault code will be set.

Fig. 47: Charcoal Canister
Courtesy of BMW OF NORTH AMERICA, INC.

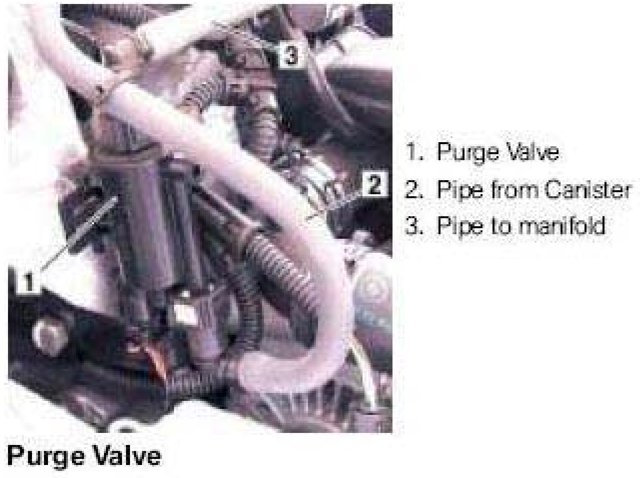


Fig. 48: Purge Valve
Courtesy of BMW OF NORTH AMERICA, INC.

O2 Sensor Heating

The oxygen sensor conductivity is efficient when it is heated 250° - 300° C (482 - 572°F). Because of this reason, the sensors contain heating elements. These "heated" sensors reduce warm up time, and retain the heat during low engine speed when the exhaust temperature is cooler. OBD II requires monitoring of the oxygen sensor heating function and heating elements for operation.

The two oxygen sensor heating circuits receive operating voltage from the Main Relay when KL15 is switched "ON". Each of the sensor heaters is controlled through separate final stage transistors.

The sensor heaters are controlled with a pulse width modulated ground during a cold engine startup. This allows the sensors to be brought gradually up to operating temperature. This helps reduce the possibility of thermal shock. The duty cycle is then varied to maintain the heating of the sensors.

When the engine is decelerating (closed throttle), the EMS2000 increases the duty cycle of the heating elements to compensate for the decreased exhaust temperature.

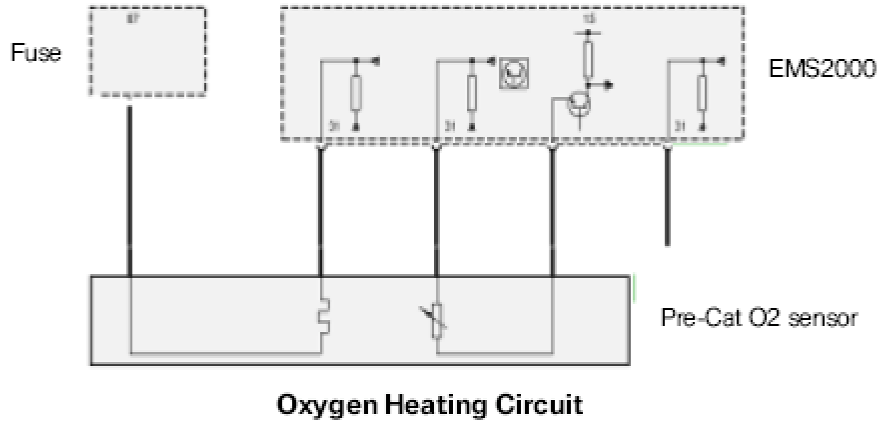


Fig. 49: Oxygen Heating Circuit Diagram
Courtesy of BMW OF NORTH AMERICA, INC.

Gearbox Interface Unit

All of the control methods associated with the transmission are run as part of the EMS2000 software. The EMS2000 receives inputs from the main sensors of this system, communicates with the gearbox interface unit (GIU) to control the transmission, accepts driver inputs and provides information to the driver via the instrument cluster.

The control of the transmission is integrated with the EMS2000 and a GIU enables this integration, acting as a slave/interpreter for the EMS2000.

All inputs and outputs of the ECVT control system pass through the EMS2000 and the GIU The EMS2000 monitors the speed of the transmission output shaft and communicates with the GIU to select the correct gear ratio to suit the current driving conditions. The GIU drives the park, reverse, neutral, drive and sport LED module to display the selected gear next to the gear selector lever and the EMS drives the instrument cluster display.

Shift Interlock Relay (ECVT Model Only)

This relay is used to drive the shiftlock system on automatic transmission equipped vehicles. The shiftlock system is a safety feature to prevent unexpected drive away of the vehicle by locking the gear lever in Park unless the brake pedal is depressed.

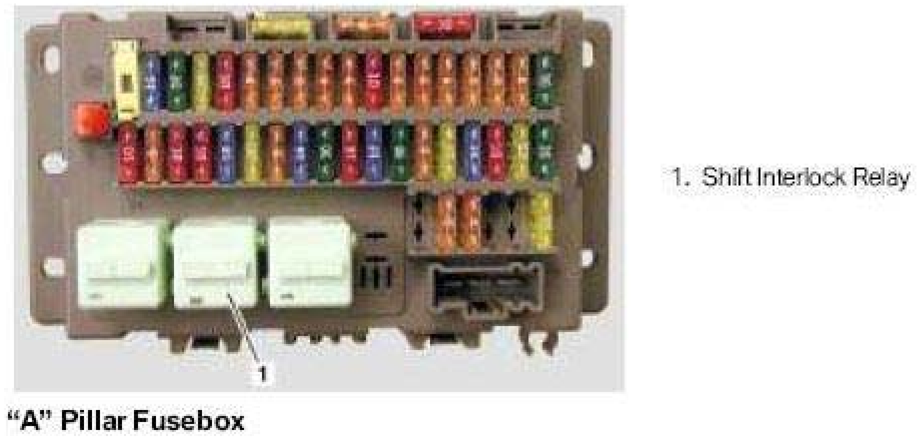


Fig. 50: "A" Pillar Fusebox
Courtesy of BMW OF NORTH AMERICA, INC.

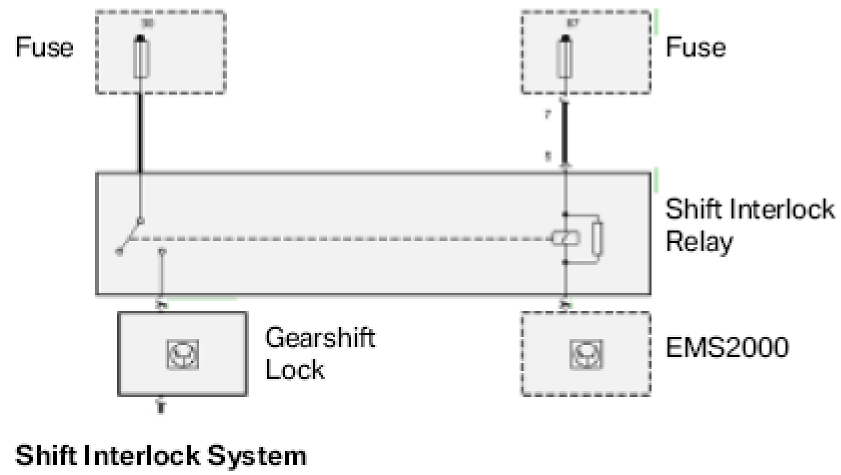


Fig. 51: Shift Interlock System Circuit Diagram
Courtesy of BMW OF NORTH AMERICA, INC.

Notes:

A/C Compressor Control

While the ignition is turned on, the BC1 outputs a compressor on/off request to the EMS2000 every 10 ± 0.1 seconds. When the ignition switch is first turned to position 2, the request is set to compressor off. When the engine is running and the AC switch is pressed, the BC1 illuminates the indicator LED in the switch and changes the request to compressor on.

When it detects the request has changed to compressor ON, the EMS2000 energizes the compressor clutch relay, located in the engine bay fusebox, to supply battery power to the compressor clutch.

After receiving a compressor ON request, the EMS2000 outputs a compressor clutch status message to the BC1 to advise if the request was granted or not. If the compressor ON request was granted, the BC1 keeps the indicator LED in the AC switch illuminated. If the compressor ON request was refused, the BC1 flashes the LED at 0.5 Hz and repeats the compressor ON request until it is granted or cancelled by:

- Pressing the AC switch again, which changes the request back to compressor OFF.
- Selecting the blower off, which changes the request back to compressor OFF.
- Selecting the ignition switch to 0.

Once the compressor ON request is granted the LED in the switch remains illuminated until the request is cancelled or the engine stops, even if one of the grant conditions no longer exists. If one of the grant conditions no longer exists, the EMS2000 de-energizes the compressor clutch relay, to disengage the compressor clutch, until the grant condition is restored.

Hard acceleration can cause the compressor clutch to be disengaged. After three occurrences in a single ignition cycle the EMS2000 disregards further hard acceleration occurrences and leaves the compressor clutch engaged. The air conditioning will be automatically suspended if:

- The engine speed is above 6016 rpm.
- The evaporator temperature falls below 2 °C - to prevent freezing.
- The coolant temperature goes above 118 °C - to protect the engine.
- The AC system pressure goes above 30 Bar to protect the system.
- The AC system pressure goes below 1.6 Bar - to protect the system.
- The accelerator pedal is fully depressed (continuous full pedal demand) for more than 5 seconds.
- The accelerator pedal is depressed rapidly (instantaneous full pedal demand) for more than 2 seconds.
- The engine speed is below 500 rpm (engine stall).

The system will revert back to normal operation once the reason for suspension has been removed.

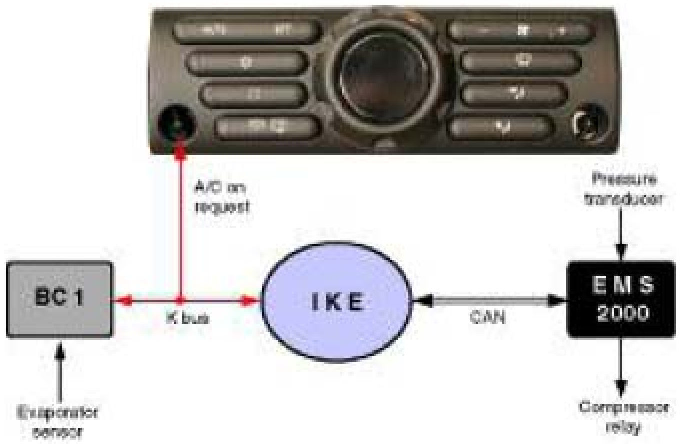


Fig. 52: A/C Compressor Control Function
Courtesy of BMW OF NORTH AMERICA, INC.

Engine Coolant Fan

The Engine Coolant Fan is controlled by the EMS2000 through a relay and relay pack at two different speeds, Low and High.

In addition to maintaining coolant temperature, the fan is used to cool the A/C refrigerant and where applicable, the ECVT gearbox oil.

The cooling fan operates on Low speed when the AC is switched on and the system pressure reaches 8 bar (116 psi). Should the AC system pressure rise above 18 bar (261psi), the fan will automatically run on High speed.

For the engine coolant system the fan operates on Low speed at 105°C (221°F). When the temperature drops to 101°C (214°F) the fan will switch off. High speed is switched on at 112°C (234°F) and will remain on until the system coolant temperature drops by 4°C (39°F) at which point the system will revert to Low speed fan.

The engine coolant fan is operated through two relays, a Low speed relay and a High speed relay. The Low speed relay is mounted in the engine compartment fusebox and is energized any time fan operation is needed (Both Low and High speed). The High speed relay is mounted on the fan housing in the relay pack. The relay pack contains the High speed relay and a voltage reducing resistor.

When Low speed fan operation is needed the EMS2000 energizes the Low speed relay. Voltage flows from the Low speed relay to the relay pack, through the voltage dropping resistor, enabling Low speed fan operation.

When High speed fan operation is needed, the EMS2000 energizes the High speed fan relay in the relay pack mounted on the fan housing. (The low speed relay remains energized). The fan is now run at full battery voltage and achieves high speed operation.

A diode is installed in the relay pack to prevent voltage feedback through the resistor.

NOTE: During cranking the AC compressor will be disengaged. The compressor request signal is sent via the CAN Bus from the IHKA or BC1 on a base system.

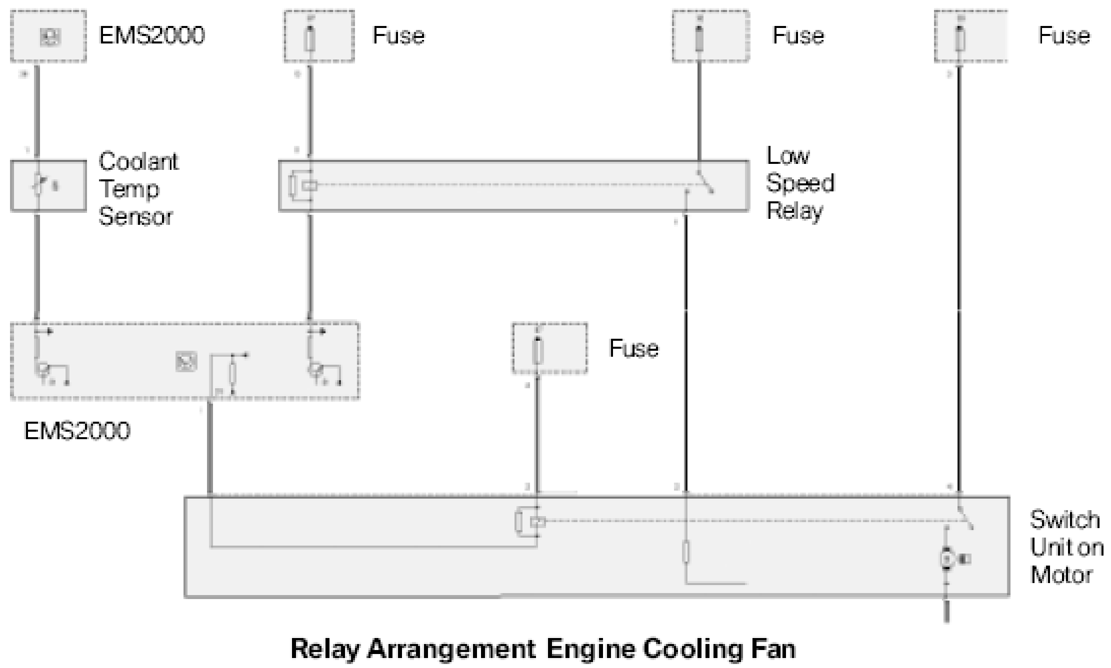


Fig. 53: Relay Arrangement Engine Cooling Fan Circuit Diagram
Courtesy of BMW OF NORTH AMERICA, INC.

IKE

The IKE communicates with the EMS2000 over the CAN Bus. Information concerning Low Fuel Levels are passed to the EMS2000 for evaluation of misfires. The IKE also transfers requests for the A/C compressor from the IHKS/IHKA to the EMS2000. Any vehicle system not on the CAN Bus that communicates with the EMS2000 does so through the IKE.

OBDII Plug

The OBDII connection to the EMS2000 is through the D-Bus. This allows communication with the DISplus and emission related powertrain components.

OBD Plug

Fig. 54: OBD Plug
Courtesy of BMW OF NORTH AMERICA, INC.

OBD Plug

Fig. 55: OBD Plug
Courtesy of BMW OF NORTH AMERICA, INC.

PRINCIPLE OF OPERATION

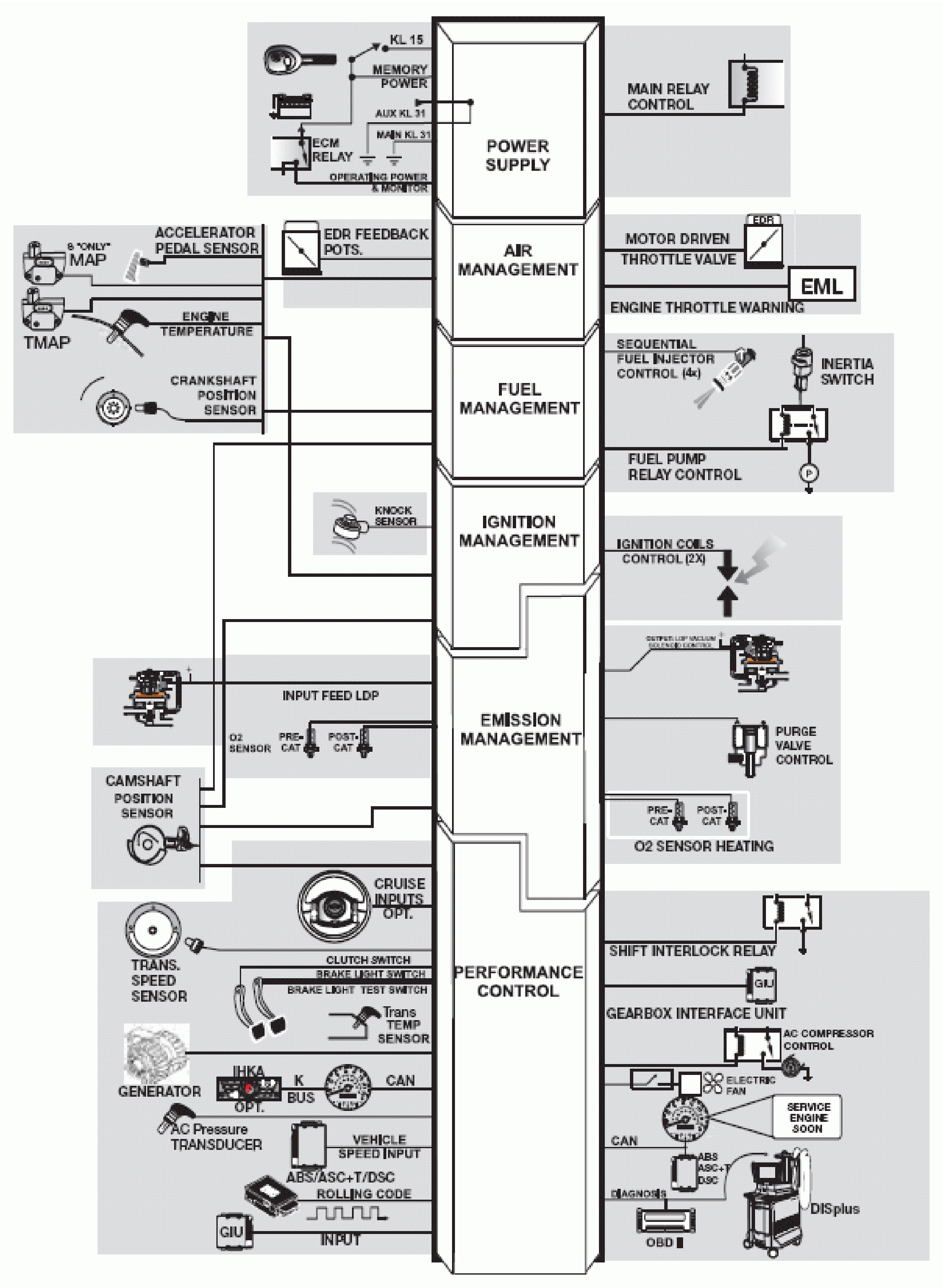


Fig. 56: Principle Of Operation
Courtesy of BMW OF NORTH AMERICA, INC.

Operation of the Engine Management System is broken into 6 subsystems. These subsystems are:

- Power Supply
- Air Management
- Fuel Management
- Ignition Management
- Emission Management
- Performance Management

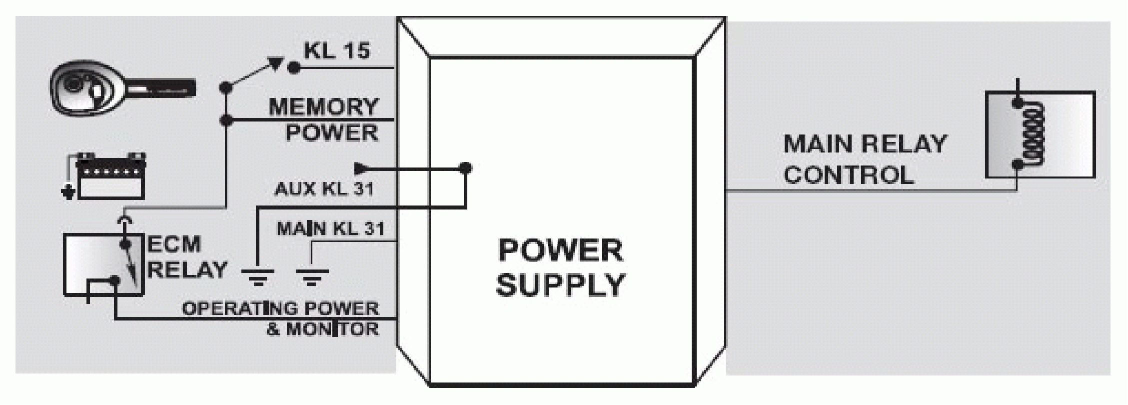


Fig. 57: Engine Management System Power Supply
Courtesy of BMW OF NORTH AMERICA, INC.

Power Supply

When the ignition switch is placed in the KL15 or KL50 positions, Fuse 34 is provided with power. Fuse 34 supplies the wake up or on signal to the EMS2000. Upon receipt of the "ON" signal EMS2000 supplies a ground signal on Pin 97 to the Main Relay. The ground signal energizes the Main Relay, supplying operating power to the following fuses:

- F02 - EMS2000, Fuel injectors, Crankshaft sensor, Ignition coils
- F03 - Camshaft sensor, O2 Heaters, Engine Fan, A/C Compressor Relay, Purge System
- F04 - Automatic Transmission controls
- F05 - Engine Coolant Fan

The engine is now ready to start.

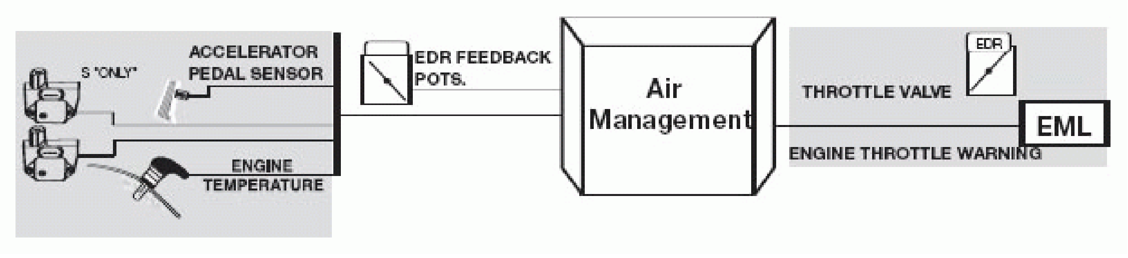


Fig. 58: Engine Management System Air Management
Courtesy of BMW OF NORTH AMERICA, INC.

Air Management

The EMS2000 sees engine cranking through the crank sensor. It checks the PWG and should see .5 volts on both inputs indicating request for idle. The feedback potentiometers are checked in the EDR to confirm throttle plate position. Signals of 0.5 volts from Pot 1 and 4.5 volts from Pot 2 indicate the throttle plate is in the LL or idle position.

With the engine now cranking the EMS2000 looks at inputs from the TMAP (and Map, if a COOPER S). TMAP volts drops from 4 volts toward the high vacuum voltage reading of 1 volt. A voltage of 5 volts or 0 volts puts the EMS2000 in Fault Mode. A fault is registered and air volume information is derived from a default map.

Intake air temperature is checked, 4 volts indicating a cold air, 1 volt or less hot air.

From the TMAP and Intake air temperature the intake air volume and density is calculated.

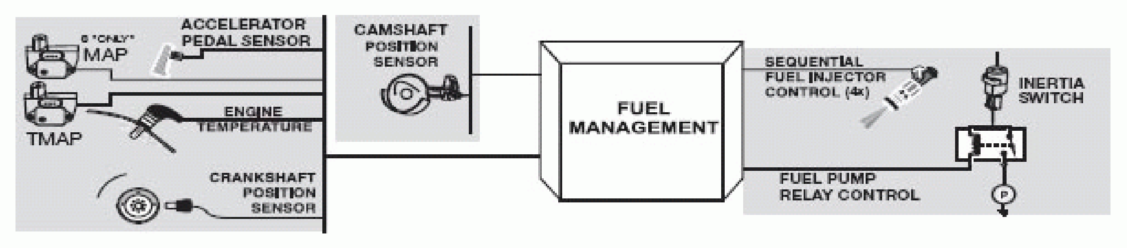


Fig. 59: Engine Management System Fuel Management
Courtesy of BMW OF NORTH AMERICA, INC.

Fuel Management

Seeing engine revolutions the EMS2000 provides a ground signal to the fuel pump relay. The fuel pump relay is on a fused circuit further protected by the inertia switch(<9/2002).

The fuel pump, mounted in the swirl pot of the left side of the blow molded saddle type fuel tank, picks up fuel through the life time fuel filter and passes it to the right side tank. In the right tank the fuel is passed through a pressure regulator where a fuel pressure of 3.5 bar is maintained. Excess fuel is returned from the right tank to the left tank through a syphon jet that also transfers fuel to the left tank.

Fig. 60: Saddle Type Fuel Tank
Courtesy of BMW OF NORTH AMERICA, INC.

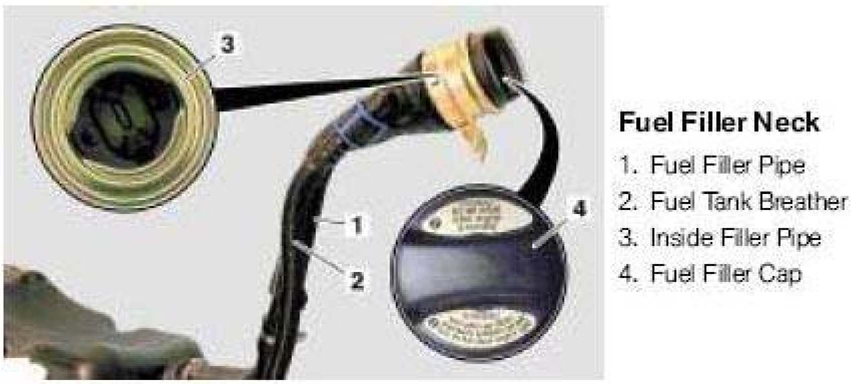


Fig. 61: Fuel Filler Neck
Courtesy of BMW OF NORTH AMERICA, INC.

Fuel at 3.5 bar is sent to the engine mounted fuel rail assembly. The fuel rail contains the pressure damper to smooth out fluctuations in fuel pressure during high load situations.

Based on the volume and density of the air, the engine load, engine rpm and temperature, the EMS2000 calculates the correct volume of fuel for injection.

Monitoring the crankshaft and camshaft sensors the EMS2000 decides upon the proper timing of the fully sequential injection. Failure of the camshaft sensor causes the EMS2000 to inject fuel on a semi-sequential basis (injectors are triggered every engine revolution). Failure of the crankshaft sensor causes cancellation of fuel injection.

Ignition Management

The firing cylinder has the proper air/fuel ratio, now ignition must be optimized for performance and emissions.

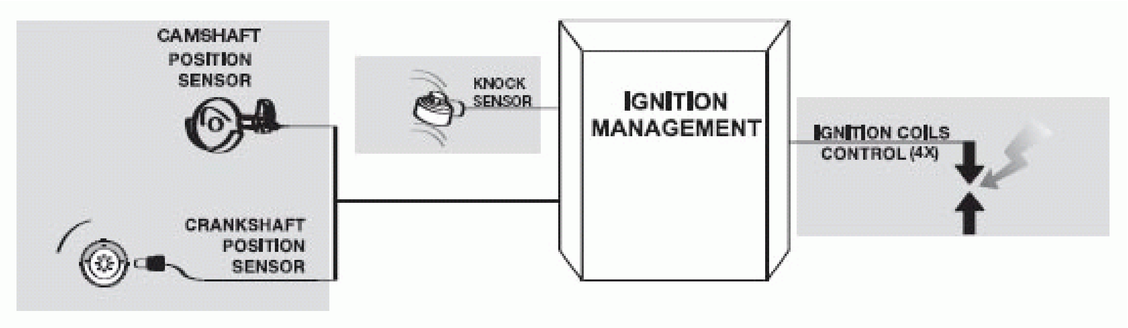


Fig. 62: Engine Management System GN T ON Management
Courtesy of BMW OF NORTH AMERICA, INC.

The EMS2000 again relying on previously analyzed sensor inputs, decides upon the correct time for ignition coil firing. As the engine approaches TDC, the EMS2000 grounds the appropriate output stage and fires the ignition coil, then listens through the knock sensor for variations in engine sound.

The spark plugs introduce the ignition energy into the combustion chamber. The high voltage "arcs" across the air gap in the spark plug. This creates a spark which ignites the air/fuel mixture.

Failure of the camshaft sensor has no effect on the ignition system as the coils are fired every revolution as a function of the waste spark system.

Failure of the crankshaft sensor causes immediate cut off of ignition.

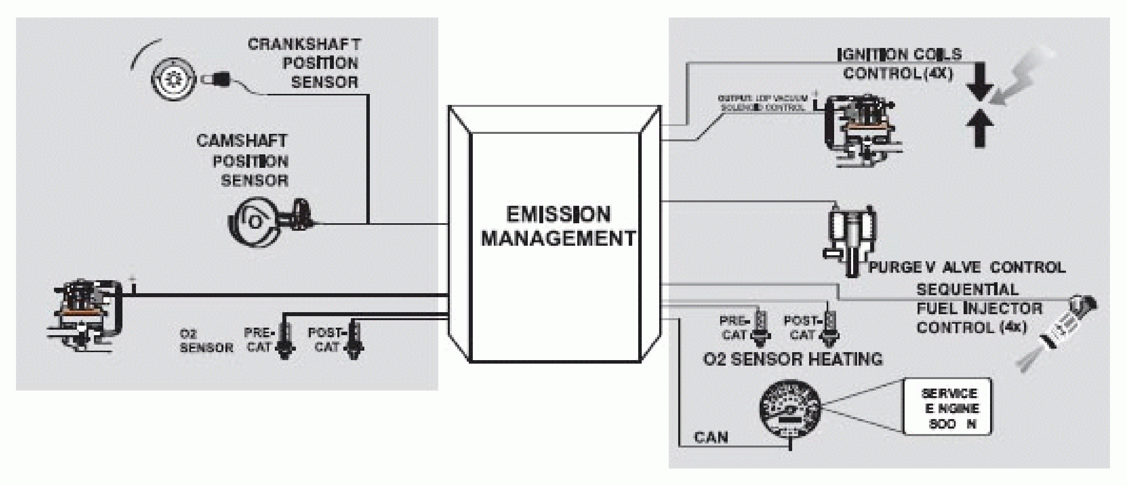


Fig. 63: Engine Management System EM SS ON Management
Courtesy of BMW OF NORTH AMERICA, INC.

Emission Management

As soon as the engine has started a pulse width modulated ground signal from the EMS2000 is supplied to the Oxygen Sensor Heaters. Duty cycle is increased to approximately 98% until the O2 sensors are fully heated. Afterwards the duty cycle is varied to maintain temperature of the sensors. During engine deceleration the duty cycle is increased to compensate for the decrease in exhaust temperatures.

Once heated fully the O2 sensors provide information about oxygen content in the exhaust. The EMS2000 makes trim adjustment to the injector on time based on the input from the pre - O2 sensor. The post O2 sensor is used for monitoring catalyst condition.

A high voltage reading from the pre - O2 sensor indicates a lack of oxygen in the exhaust or a rich mixture. The EMS2000 will reduce injector on time until the voltage reading drops at which time the on time will be increased again.

Catalytic Converter Monitoring

Catalyst Monitoring is performed by the EMS2000 under oxygen sensor closed loop operation. The changing air/fuel ratio in the exhaust gas results in lambda oscillations at the pre-catalyst sensor. These oscillations are dampened by the oxygen storage activity of the catalysts and are reflected at the post catalyst sensor as a fairly stable signal (indicating oxygen has been consumed). Conditions for Catalyst Monitoring:

CATALYTIC CONVERTER 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 a theoretical calculation performed by the EMS2000 that is a function of load/air mass and time.

As part of the monitoring process, the pre and post O2 sensor signals are evaluated by the EMS2000 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. 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.

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

LDP Operation

During every engine cold start the LDP solenoid is energized by the EMS2000. Engine manifold vacuum enters the upper chamber of the LDP to lift up the spring loaded diaphragm.

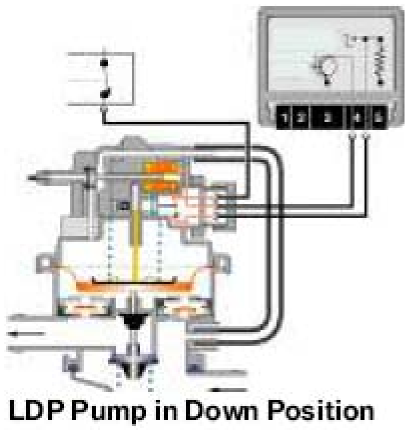


Fig. 64: LDP Pump In Down Position

Courtesy of BMW OF NORTH AMERICA, INC.

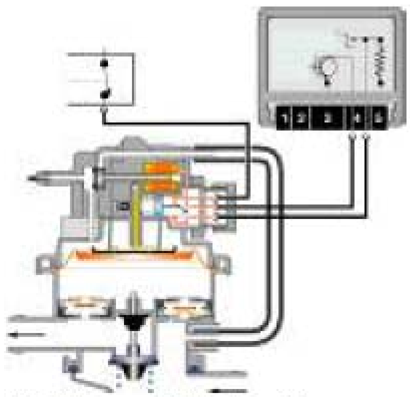


Fig. 65: LDP Pump In Up Position
Courtesy of BMW OF NORTH AMERICA, INC.

As the diaphragm is lifted it draws in ambient air through the filter and into the lower chamber of the LDP through the one way valve.

The solenoid is then de-energized, spring pressure closes the vacuum port blocking the engine vacuum and simultaneously opens the vent port to the balance tube which releases the captive vacuum in the upper chamber.

This allows the compressed spring to push the diaphragm down, starting the "limited down stroke". The air that was drawn into the lower chamber of the LDP during the upstroke is forced out of the lower chamber and into the fuel tank/evaporative system.

This electrically controlled repetitive up/down stroke is cycled repeatedly building up a total pressure of approximately +25mb in the evaporative system. After sufficient pressure has built up (LDP and its cycling is calibrated to the vehicle), the leak diagnosis begins.

The upper chamber contains an integrated reed switch that produces a switched high/ low voltage signal that is monitored by the EMS2000. The switch is opened by the magnetic interruption of the metal rod connected to the diaphragm when in the diaphragm is in the top dead center position.

The repetitive up/down stroke is confirmation to the EMS2000 that the valve is functioning. The EMS2000 also monitors the length of time it takes for the reed switch to open, which is opposed by pressure under the diaphragm in the lower chamber. The LDP is still cycled, but at a frequency that depends upon the rate of pressure loss in the lower chamber. If the pumping frequency is below parameters, there is no leak present. If the pumping frequency is above parameters, this indicates sufficient pressure can not build up in the lower chamber and evaporative system, indicating a leak.

The chart represents the diagnostic leak testing time frame in seconds. When the ignition is switched on, the EMS performs a "static check" of circuit integrity to the LDP pump including the reed switch.

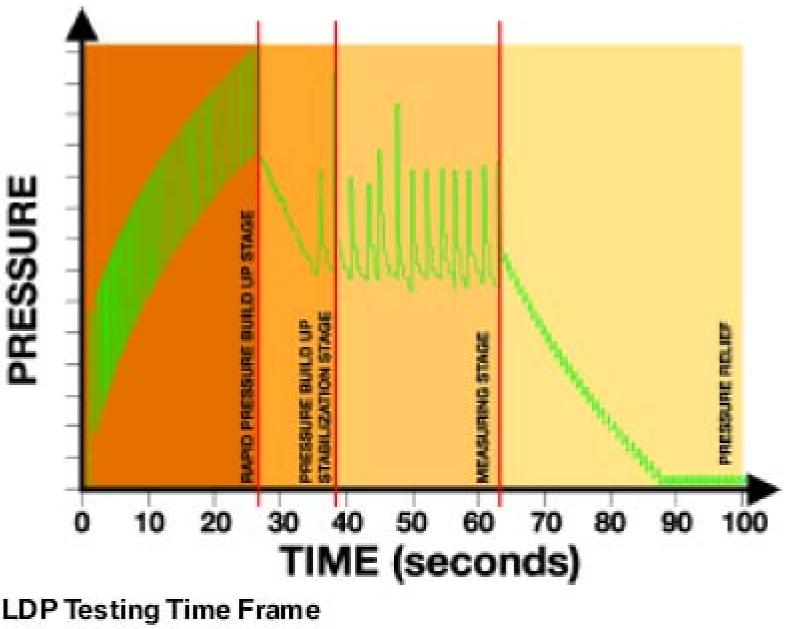


Fig. 66: LDP Testing Time Frame
Courtesy of BMW OF NORTH AMERICA, INC.

- On cold engine start up, the pump is rapidly activated for 27 seconds to pressurize the evaporative components.
- Once pressurized, the build up phase then continues from 27-38 seconds. The EMS2000 monitors the system through the reed switch to verify that pressure has stabilized.
- The measuring phase for leak diagnosis lasts from 38-63 seconds. The pump is activated but due to the pressure build up under the diaphragm, the pump moves slower. If the pump moves quickly, this indicates a lack of pressure or a leak.
- From 63-100 seconds the pump is deactivated, allowing full down stroke of the diaphragm and rod. At the extreme bottom of rod travel, the canister vent valve is pushed open relieving pressure and allowing normal purge operation when needed.

Evaporative Emission Purging

Evaporative Emission Purging is regulated by the EMS2000 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 EMS2000 Relay provides operating voltage, and the EMS2000 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 > 67°C (153°F)
- Engine Load is present

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 Monitoring

Evaporative Purge System Flow Check is performed by the EMS2000 when the oxygen sensor control and purging is active. When the Evaporative Emission Valve is open the EMS2000 detects a rich/lean shift as monitored by the oxygen sensors indicating the valve is functioning properly.

If the EMS2000 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 EMS2000 opens and closes the valve (abruptly) several times and monitors the engine rpm for changes. If there are no changes, a fault code will be set.

The purge valve will also be activated (opened) towards the end of the LDP test cycle. The EMS2000 has to see the reed switch frequency increase when the purge valve opens. If the frequency does not increase, the EMS2000 sets a fault for the purge system.

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 an ORVR equipped vehicle, the pressure of the fuel entering the tank forces the hydrocarbon vapor to the top of the fuel tank which is cool (The tank has an "integrated" liquid/ vapor separator). This causes the most of the vapor to condense and stay in the tank. The vapor that is not condensed is sent 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 LDP and the air filter. The vent line to the filler neck is smaller, but still necessary for checking the filler cap/neck during Evaporative Leak Testing.

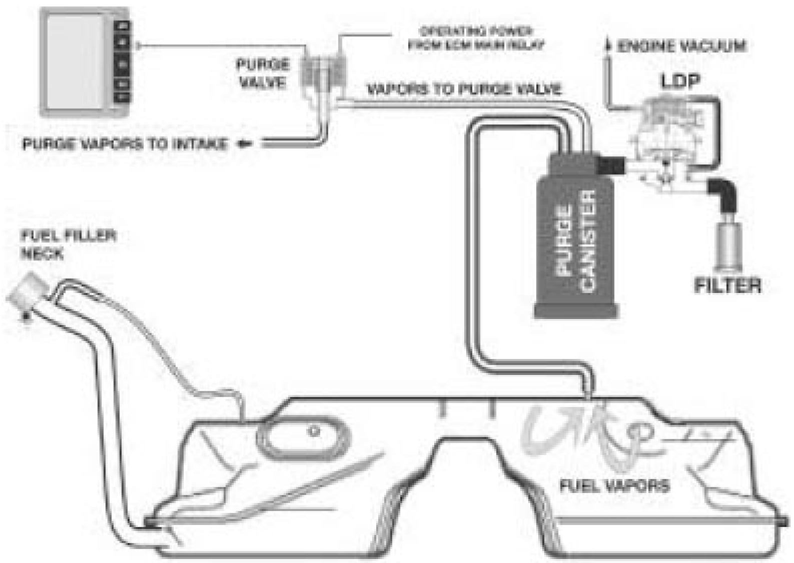


Fig. 67: ORVR System Connection Diagram
Courtesy of BMW OF NORTH AMERICA, INC.

Liquid/Vapor Separator (part of fuel tank)

Fuel vapors are routed from the fuel tank filler neck through a hose to the Liquid/Vapor Separator. The vapors cool when exiting the fuel tank, the condensates separate and drain back to the fuel tank through a return hose. The remaining vapors exit the Liquid/ Vapor Separator to the Active Carbon Canister.

Active Carbon Canister

As the hydrocarbon vapors enter the canister, they will be absorbed by the active carbon. The remaining air will be vented to the atmosphere through the LDP pump allowing the fuel tank to "breath". When the engine is running, the canister is then "purged" using intake manifold vacuum to draw air through the canister which extracts the hydrocarbon vapors into the combustion chamber.

NOTE: Fuel vapors do not escape into the atmosphere even though the system is "open" to the environment because the charcoal canister traps the hydrocarbon vapors from getting out.

Adaptation Values

Adaptation Values are stored by the EMS2000 in order to maintain an "ideal" air/fuel ratio.

The EMS2000 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 EMS2000 modifies the injection rate under two areas of engine operation:

- During idle and low load mid range speeds. (Additive Adaptation)
- During operation under normal load to higher load at higher engine speeds. (Multiplicative Adaptation)

  These values indicate how the EMS2000 is compensating for a less than ideal initial air/fuel ratio.

- If the adaptation value is greater than "0.0ms" Additive or 0% Multiplicative, the EMS2000 is trying to richen the mixture.
- If the adaptation value is less then "0.0ms" Additive or 0% Multiplicative, the EMS2000 is trying to lean-out the mixture.

Misfire Detection

As part of the OBD II regulations the EMS2000 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 EMS2000 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 180° 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 EMS2000.

Depending on the level of misfire rate measured the EMS2000 will illuminate the "Malfunction Indicator Light", deactivate the specific fuel injector to the particular cylinder and switch oxygen sensor control to open-loop.

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 the DISplus. If the adaptation limit is exceeded a fault will be set.

The EMS must also determine 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 EMS2000 adds the detected misfire events for each cylinder. If the sum of all cylinder misfire incidents exceeds the predetermined value, a fault code will be stored and the "Malfunction Indicator Light" will be illuminated.

- If more than one cylinder is misfiring, all misfiring cylinders will be specified and the individual fault codes for each misfiring cylinder, or multiple cylinders will be stored. The "Malfunction Indicator Light" will be illuminated.

Catalyst Damage

- Within an interval of 200 crankshaft revolutions the detected number of misfiring events is calculated for each cylinder. The EMS2000 monitors this based on load/rpm. If the sum of cylinder misfire incidents exceeds a predetermined value, a "Catalyst Damaging" fault code is stored and the "Malfunction Indicator Light" will be illuminated.

  If the cylinder misfire count exceeds the predetermined threshold the EMS2000 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 misfiring the fault code for all individual cylinders and for multiple cylinders will be stored.
- The fuel injector to the respective cylinder(s) is deactivated.

Malfunction Indicator Light

The "Malfunction Indicator Light" (MIL) will be illuminated under the following conditions:

- Upon the completion of the next consecutive driving cycle where the previously faulted system is monitored again and the emissions relevant fault is again present.
- Immediately if a "Catalyst Damaging" fault occurs (see **MISFIRE DETECTION**).

Fig. 68: Malfunction Indicator Light
Courtesy of BMW OF NORTH AMERICA, INC.

The illumination of the light is performed in accordance with the Federal Test Procedure (FTP) which requires the lamp to be illuminated when:

- A malfunction of a component that can affect the emission performance of the vehicle occurs and causes emissions to exceed 1.5 times the standards required by the (FTP).
- Manufacturer-defined specifications are exceeded.
- An implausible input signal is generated.
- Catalyst deterioration causes HC-emissions to exceed a limit equivalent to 1.5 times the standard (FTP).
- Misfire faults occur.
- A leak is detected in the evaporative system, or "purging" is defective.
- EMS2000 fails to enter closed-loop oxygen sensor control operation within a specified time interval.
- Engine control or automatic transmission control enters a "limp home" operating mode.
- Ignition is on (KL15) position before cranking = Bulb Check Function.

Within the BMW Group system the illumination of the Malfunction Indicator Light is performed in accordance with the regulations set forth in CARB mail-out 1968.1 and as demonstrated via the Federal Test Procedure (FTP). The following page provides several examples of when and how the Malfunction Indicator Light is illuminated based on the "customer drive cycle".

	DRIVE CYCLE # 1			DRIVE CYCLE # 2			DRIVE CYCLE # 3			DRIVE CYCLE # 4			DRIVE CYCLE # 5			* DRIVE CYCLE # 43		
TEXT NO.	FUNCTION CHECKED	FAULT CODE SET	MIL STATUS CHECK ENGINE	FUNCTION CHECKED	FAULT CODE SET	MIL STATUS CHECK ENGINE	FUNCTION CHECKED	FAULT CODE SET	MIL STATUS CHECK ENGINE	FUNCTION CHECKED	FAULT CODE SET	MIL STATUS CHECK ENGINE	FUNCTION CHECKED	FAULT CODE SET	MIL STATUS CHECK ENGINE	FUNCTION CHECKED	FAULT CODE ERASED	MIL STATUS CHECK ENGINE
1.	YES	YES	OFF															
2.	YES	YES	OFF	YES	YES	ON												
3.	YES	YES	OFF	NO	NO	OFF	YES	YES	ON									
4.	YES	YES	OFF	YES	NO	OFF	YES	NO	OFF	YES	YES	OFF	YES	YES	ON			
5.	YES	YES	OFF	YES	YES	ON	YES	NO	ON	YES	NO	ON	YES	NO	OFF			
6.	YES	YES	OFF	YES	YES	ON	YES	NO	ON	YES	NO	ON	YES	NO	OFF	YES	FAULT CODE ERASED	OFF

Fig. 69: Fault Code Chart
Courtesy of BMW OF NORTH AMERICA, INC.

1. A fault code is stored within the EMS2000 upon the first occurrence of a fault in the system being checked.
2. The "Malfunction Indicator Light" will not be illuminated until the completion of the second consecutive "customer driving cycle" where the previously faulted system is again monitored and a fault is still present or a catalyst damaging fault has occurred.
3. If the second drive cycle was not complete and the specific function was not checked as shown in the example, the EMS2000 counts the third drive cycle as the "next consecutive" drive cycle. The "Malfunction Indicator Light" is illuminated if the function is checked and the fault is still present.
4. If there is an intermittent fault present and does not cause a fault to be set through multiple drive cycles,

two complete consecutive drive cycles with the fault present are required for the "Malfunction Indicator Light" to be illuminated.

5. Once the "Malfunction Indicator Light" is illuminated it will remain illuminated unless the specific function has been checked without fault through three complete consecutive drive cycles.
6. The fault code will also be cleared from memory automatically if the specific function is checked through 40 consecutive drive cycles without the fault being detected or with the use of either the DISplus or Scan tool.

NOTE: In order to clear a catalyst damaging fault (see MISFIRE DETECTION) from memory, the condition must be evaluated for 80 consecutive cycles without the fault reoccurring.

With the use of a universal scan tool, connected to the "OBD" DLC an SAE standardized DTC can be obtained, along with the condition associated with the illumination of the "Malfunction Indicator Light". Using the GT1 or DISPlus a fault code and the conditions associated with its setting can be obtained prior to the illumination of the "Malfunction Indicator Light".

OBD II Drive Cycle's & Trips

- A "Drive cycle" consists of engine startup and engine shutoff.
- "Trip" is defined as vehicle operation (following an engine-off period) of duration and driving style so that all components and systems 2000 are monitored at least once by the diagnostic system except catalyst efficiency or evaporative system monitoring.

  This definition is subject to the limitations that the manufacturer-defined trip monitoring conditions are all monitored at least once during the first engine start portion of the Federal Test Procedure (FTP).

- Within this text the term "customer driving cycle" will be used and is defined as engine start-up, operation of vehicle (dependent upon customer drive style) and engine shut-off.

Federal Test Procedure (FTP)

The Federal Test Procedure (FTP) is a specific driving cycle that is utilized by the EPA to test light duty vehicle emissions. As part of the procedure for a vehicle manufacturer to obtain emission certification for a particular model/engine family the manufacturer must demonstrate that the vehicle(s) can pass the FTP defined driving cycle two consecutive times while monitoring various components/systems.

Some of the components/systems must be monitored either once per driving cycle or continuously. Systems and their components required to be monitored once within one driving cycle:

- Oxygen Sensors
- Catalyst Efficiency
- Evaporative Vapor Recovery System

  Due to the complexity involved in meeting the test criteria within the FTP defined driving cycle, all tests may not be completed within one "customer driving cycle". The test can be successfully completed within the FTP defined criteria, however customer driving styles may differ and therefore may not always monitor all involved components/systems in one "trip".

Components/systems required to be monitored continuously:

- Cylinder Misfire Detection
- Fuel system
- Oxygen Sensors
- All emissions related components/systems - EMS or EML (comprehensive component monitoring).

The graph shown below is an example of the driving cycle that is used by BMW to complete the FTP.

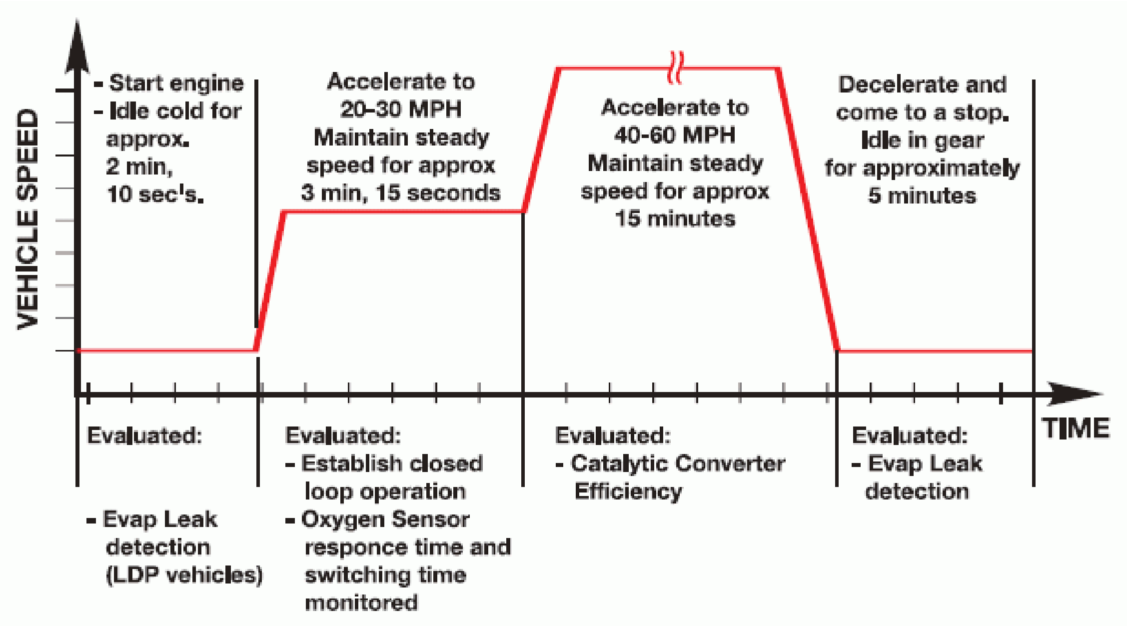


Fig. 70: Driving Cycle Pattern
Courtesy of BMW OF NORTH AMERICA, INC.

The diagnostic routine shown above will be discontinued whenever:

- Engine speed exceeds 3000 RPM
- Large fluctuations in throttle angle
- Road speed exceeds 60 MPH

NOTE: **The driving criteria shown can be completed within the FTP required approximately 11 miles in a controlled environment such as a dyno test or test track.**

Every time the vehicle is started a drive cycle resumes from where it left off. Depending on the customers driving habits, they might never reach a FTP.

A "customer driving cycle" may vary according to traffic patterns, route selection and distance traveled, which may not allow the "diagnostic trip" to be fully completed each time the vehicle is operated.

Readiness Flags

The Readiness Flags provide status of required emissions system monitoring. The systems available for readiness flag status are:

- Misfiring Stage A (A Catalyst Damaging Misfire)
- Misfiring Stage B1 (Sum of the Emission Increasing Misfires in the first 1000 Revs)
- Misfiring Stage B4 (Sum of the Emission Increasing Misfires 1000 Revs)
- Evap 1
- Evap 2
- Evap 3
- Evap 4
- Catalytic converter
- Oxygen Sensor Control
- Oxygen Sensor 1 (Pre-Cat)
- Oxygen Sensor 2 (Post-Cat)
- Complete System

Test Results are indicated by Test Completed or Not Completed.

A "Readiness Code" must be stored after any clearing of fault memory or disconnection of the EMS2000. A readiness code of "0" will be stored (see below) after a complete diagnostic check of all components/systems, that can turn on the "Malfunction Indicator Light" is performed.

The readiness code was established to prevent anyone with an emissions related fault and a "Malfunction Indicator Light" on from disconnecting the battery or clearing the fault memory to manipulate the results of the emissions test procedure (IM 240).

The complete readiness code is equal to "one" byte (eight bits). Every bit represents one complete test and is displayed by the scan tool, as required by CARB/EPA.

1 = EGR Monitoring (=0, N/A with MINI)

0 = Oxygen Sensor Heater Monitoring

1 = Oxygen Sensor Monitoring

1 = Air Conditioning (=0, N/A with MINI)

0 = Secondary Air Delivery Monitoring (N/A with MINI)

1 = Evaporative System Monitoring

1 = Catalyst Heating (=0, N/A with MINI at this time)

0 = Catalyst Efficiency Monitoring

Drive the car in such a manner that all tests listed above can be completed (refer to the). When the complete "readiness code" equals "0" then all tests have been completed and the system has established its "readiness".

OBD II Diagnostic Trouble Codes (DTC)

The Society of Automotive Engineers (SAE) established the Diagnostic Trouble Codes used for OBD II systems (SAE J2012). The DTC's are designed to be identified by their alpha/numeric structure. The SAE has designated the emission related DTC's to start with the letter "P" for Powertrain related systems, hence their nickname "P-code".

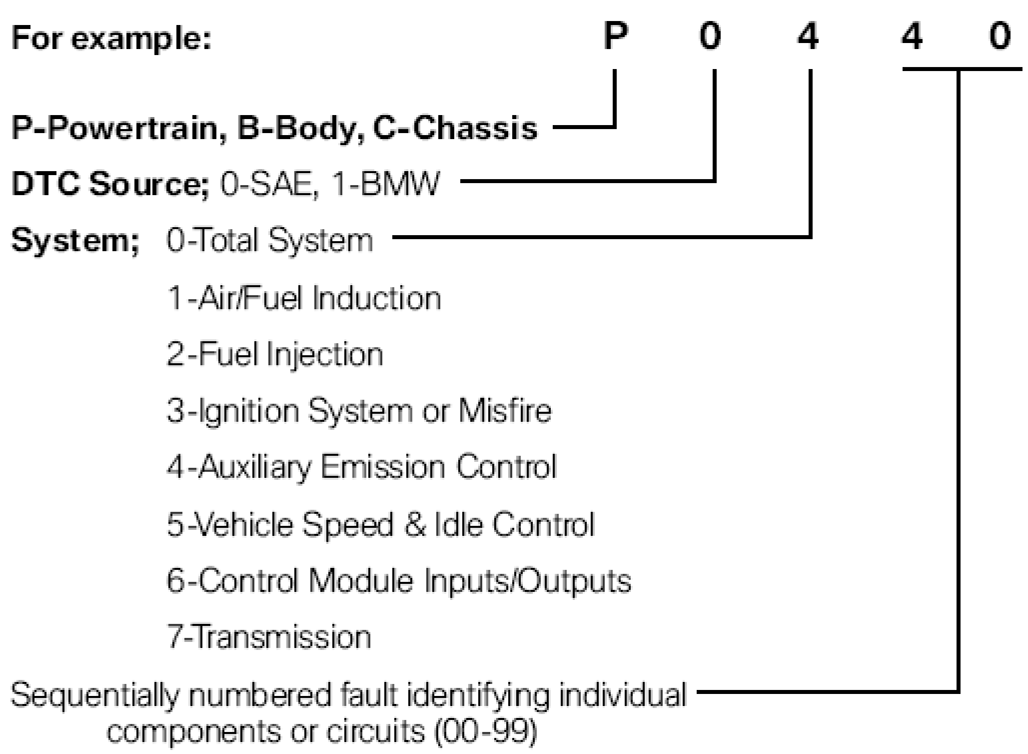


Fig. 71: OBD II Diagnostic Trouble Codes (DTC)
Courtesy of BMW OF NORTH AMERICA, INC.

- DTC's are stored whenever the "Malfunction Indicator Light" is illuminated.
- A requirement of CARB/EPA is providing universal diagnostic access to DTC's via a standardized Diagnostic Link Connector (DLC) using a standardized tester (scan tool).
- DTC's only provide one set of environmental operating conditions when a fault is stored. This single "Freeze Frame" or snapshot refers to a block of the vehicles environmental conditions for a specific time when the fault first occurred. The information which is stored is defined by SAE and is limited in scope.

This information may not even be specific to the type of fault.

BMWFault Code (DISplus)

- Engine control module codes are stored as soon they occur even before the "Malfunction Indicator Light" comes on.
- Engine control module codes are defined by MINI and Siemens Engineers to provide greater detail to fault specific information.
- Siemens systems - one set of four fault specific environmental conditions are stored with the first fault occurrence. This information can change and is specific to each fault code to aid in diagnosing. A maximum of ten different faults containing four environmental conditions can be stored.
- MINI codes also store and display a "time stamp" when the fault last occurred.
- A fault qualifier gives more specific detailed information about the type of fault (upper limit, lower limit, disconnection, plausibility, etc.).
- MINI Fault Codes will alert the Technician of the current fault status. He/she will be advised if the fault is actually still present, not currently present or intermittent. The fault specific information is stored and accessible through approved diagnostic equipment.
- MINI engine control module fault codes determine the diagnostic procedure or test plan output for BMW DISplus.

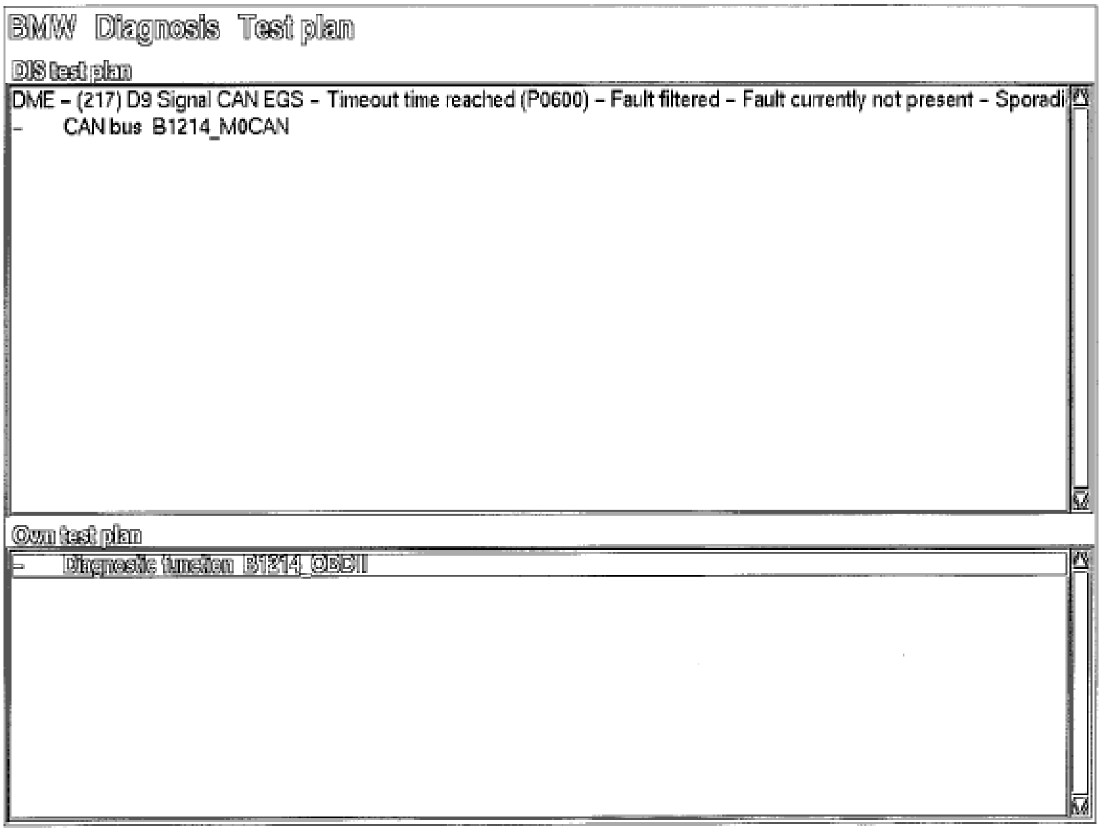


Fig. 72: BMW Fault Code (DISplus)
Courtesy of BMW OF NORTH AMERICA, INC.

Performance Controls

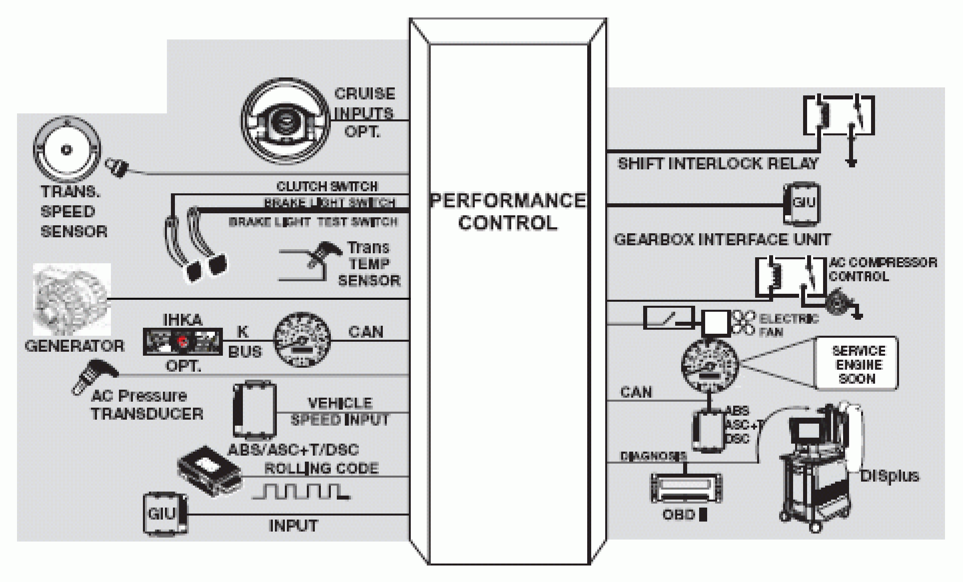


Fig. 73: Engine Management System Performance Controls
Courtesy of BMW OF NORTH AMERICA, INC.

EWS Interface

The EMS2000 communicates with the EWS module prior to releasing injection and ignition. Upon receiving the proper Rolling Code from EWS, EMS2000 allows the fuel injectors and ignition coils to operate.

Transmission Control (ECVT Only)

As the driver moves the shift selector lever from park the EMS2000 looks for a brake signal before releasing the shift interlock relay. Upon receiving a valid brake input the shift interlock relay is released and the gear shift lever is moved into a drive position.

The EMS2000 evaluates inputs from the crank sensor, the transmission temperature sensor and the transmission output speed sensor as well as the gear shift lever switches to make decisions for gear selection and programming. Instructions for gear control are passed from the EMS2000 through the GIU to the transmission.

A/C Compressor Control

A request from the IHKS/IHKA is passed via the K-Bus to the IKE and then over the CAN Bus to the EMS2000. The EMS2000 checks the signal from the A/C pressure transducer and if within range, activates the compressor relay. The EMS2000 signals the IHKS/IHKA that the compressor has been turned on.

As part of the compressor activation process, the EMS2000 slightly increases the idle speed to compensate for the increased engine load.

Torque Management

Internal combustion engines generate torque by being supplied with a correctly mixed quantity of fuel and air, which is ignited at a precisely calculated time. By varying the quantity of air/fuel and the timing of the spark, the torque output can be altered. However, altering the quantity of fuel relative to the airflow can adversely affect catalyst life, combustion chamber and piston temperatures.

Therefore, when the EMS2000 varies the torque in response to the demands of the previously mentioned systems, it achieves this by altering only the ignition timing and/or throttle position. Certain characteristics are involved in these two methods of torque alteration:

- **Ignition Timing** - Ignition Timing can be altered rapidly and gives an instant torque change however, because under normal circumstances the EMS2000 always ensures that the engine runs at peak efficiency.
- **Throttle Position -** By changing the Throttle Position (airflow) the engine torque can be increased or deceased. If airflow is increased or decreased the EMS2000 automatically maintains the correct fuel mixture by balancing the fuel input. Unlike the rapid torque change achieved by altering the ignition, changes in throttle position take longer to achieve torque variation. Each system can demand either a slow or fast torque variation.

Torque Control

The Engine Management System (EMS2000) has the ability to vary the torque output of the engine in response to demands from several systems. These demands can be divided into three categories:

- Engine running demands: torque variation is requested internally from within the EMS 2000 to support the following:
  - Idle Control
  - Catalyst 'light up' and overheat protection
  - Limp home control
- Powertrain and chassis demands: torque variation is requested externally from the following systems:
  - Dynamic stability control
  - Automatic Stability Control + Traction Control (ASC)
  - ECVT Automatic transmission
  - Cruise control
- Driver demand

  The EMS2000 is programmed to decide which of the torque variation demands is the most important and will then act upon that demand. This task is performed by the EMS2000 'Torque Manager' which performs two main functions:

- Torque selection: this function decides which of the torque demands shall be acted upon.
- Torque coordination: this function determines the ignition and throttle settings needed to produce the required torque.

Cruise Control

Cruise control functions are activated directly by the multifunction steering wheel to the EMS. The individual buttons are digitally encoded in the MFL switch and are input to the EMS2000 over a serial data wire. Cruise Control is integrated into the EMS2000 because of the MDK/EDK operation.

- The EMS2000 controls vehicle speed by activation of the Electronic Throttle Valve (EDR).
- The clutch switch disengages cruise control to prevent over-rev during gear changes.
- The brake light switch and the brake light test switch are input to the EMS2000 to disengage cruise control as well as fault recognition during engine operation.

Road speed is input to the EMS2000 for cruise control. The vehicle speed signal for normal engine operation is supplied from the DSC module (right rear wheel speed sensor). The road speed signal for cruise control is supplied from the DSC module. This is an average taken from both front wheel speed sensors, supplied via the CAN bus.

Engine Coolant Fan

Based on inputs from the Engine Coolant Temperature Sensor, and the A/C pressure transducer, the EMS2000 decides on the proper fan operation speed.

EMS2000 Programming

Programming of the EMS2000 is possible, however final instructions have not been specified at this time.

NOTE: **It is important that confirmation of programming procedures be done prior to attempting any programming. Failure to do this may result in a no start condition.**