

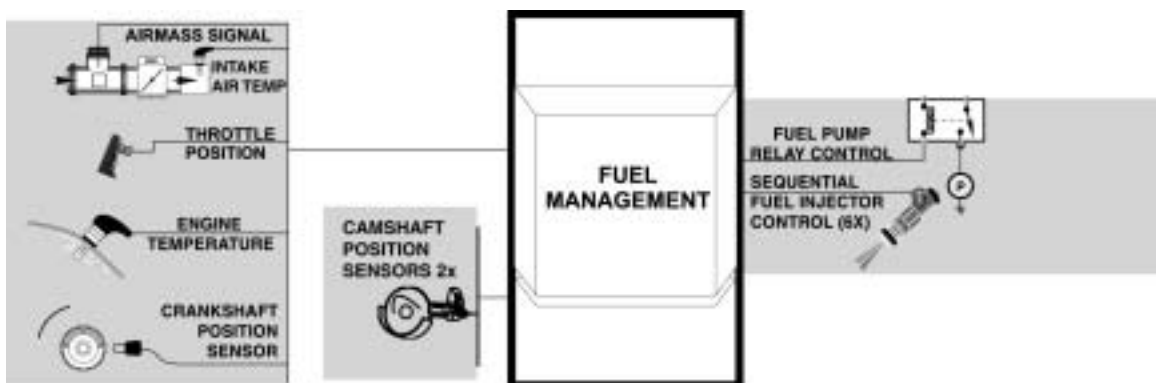
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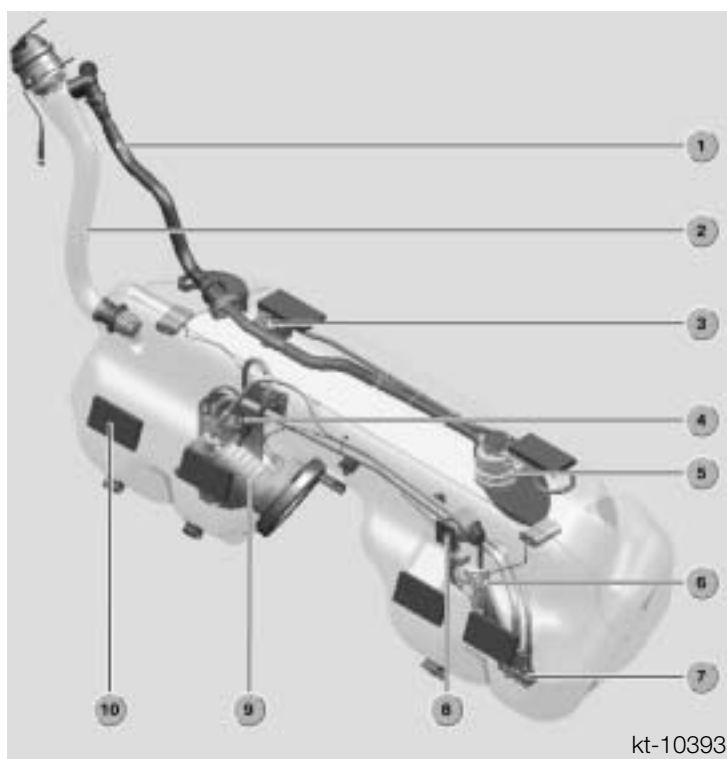
## Fuel Management



**Fuel Tank:** The fuel tank is made of high density polyethylene (reduced weight) which is manufactured to meet safety requirements.

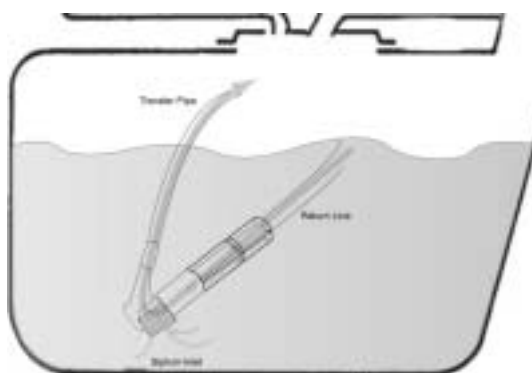
A mid-chassis mounted “saddle” type tank is used providing a tunnel for the driveshaft but creates two separate lower chambers.

1. Ventilation line
2. Filler tube
3. Operating vent valve
4. Fuel pump assembly
5. Filling vent valve
6. Left fuel level sensor
7. Left syphon jet
8. Overpressure protection valve
9. Fuel filter and fuel pressure regulator
10. Anti-chafing pads (foam cushion)



A syphon jet is required with this type of tank to transfer fuel from the left side, linked to the fuel return line. As fuel moves through the return, the syphon jet creates a low pressure (suction) to pick up fuel from the left side of the tank and transfer it to the right side at the fuel pick up.

*The fuel tank capacity is 55 liters (14.5 gallons). This includes a reserve capacity of 8 liters (2 gal.).*



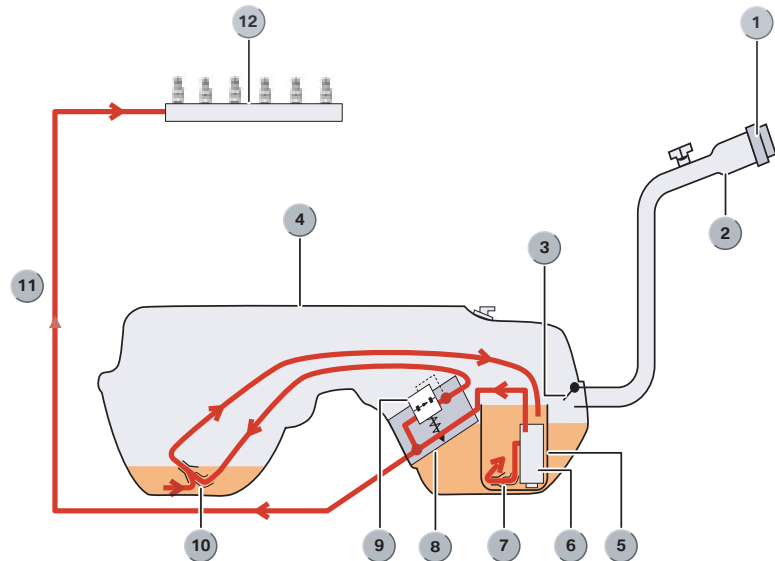
Detailed View of Syphon Jet

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*The E85 fuel tank design represents the next step in reducing the potential evaporative emissions. This design reduces the number of external connections and openings by increasing the amount of “in tank” or integral components. The fuel system is divided into two subsystems: fuel supply and fuel ventilation (evaporative containment and control - refer to Emissions Management section).*

## MS45 Fuel Supply:

1. Filler cap and tank grounding
2. Filler tube
3. Slosh baffle (anti-spitback valve)
4. Fuel tank
5. Baffle chamber with right fuel level sensor
6. Electric fuel pump (EKP)
7. Right syphon jet
8. **Service access cap with fuel filter**
9. Fuel pressure regulator (3.5 bar)
10. Left syphon jet
11. Fuel supply line
12. Injection rail



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When the fuel pump is energized, it supplies fuel from the pickup area in the baffle chamber through the fuel filter to the fuel pressure regulator. The fuel supply pressure is controlled by the **3.5 Bar fuel pressure regulator** (integrated in the fuel filter assembly). The regulator is influenced by internal fuel pressure and not intake manifold vacuum. The fuel exits the fuel pressure regulator supplying the fuel rail and the injectors. The fuel rail distributes an even supply of fuel to all of the injectors, and also serves as a volume reservoir.

The fuel is supplied through a Non Return Fuel Rail System. The fuel return line is located on the filter/regulator assembly which directs the unused fuel back through the fuel tank. The fuel tank hydrocarbons are reduced by returning the fuel from this point (lower temperatures) instead of from the fuel rail.

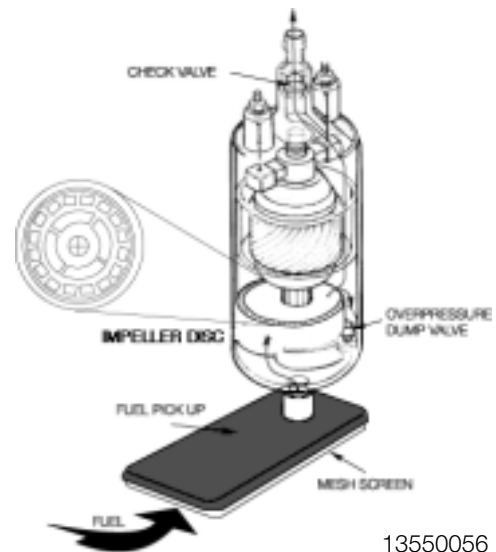
As fuel moves through the return, the syphon jet creates a low pressure (suction) to pick up fuel from the left side of the tank and transfer it to the right side at the fuel pick up. A second syphon jet is mounted through the baffle chamber to draw as much fuel as possible from the right side of the tank into the baffle chamber (critical for low fuel or reserve situations).

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

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

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

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



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**Fuel Supply Components:** The fuel is transferred from the fuel pump to the fuel filter. The fuel filter “traps” contaminants before they reach the fuel injectors and should be replaced at the specified interval. The large filter size also serves as a volume reservoir (dampening fuel pump pulsations).

**Fuel Pressure Regulator:** The Fuel Pressure Regulator maintains a constant pressure for the fuel injectors. The fuel pressure is set to **3.5 bar** by internal spring tension on the restriction valve. The fuel pressure regulator is not influenced by vacuum.

The ECM determines the fuel quantity compensation for manifold vacuum changes. This is based on throttle position, HFM and load for precise compensation.

When the restriction valve opens, unused fuel returns from the regulator/filter assembly back through the fuel tank to the left side syphon jet.

**Siemens Fuel Injectors:** The Fuel Injectors are electronically controlled solenoid valves that provide precise metered and atomized fuel into the engine intake ports. The Fuel Injector Valve consists of:

1. Fuel Strainer
2. Electrical Connector
3. Solenoid Winding
4. Closing Spring
5. Solenoid Armature
6. Needle Valve
7. Pintle

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

A Fuel Injector is faulty (mechanical or electrical), it can produce the following complaints:

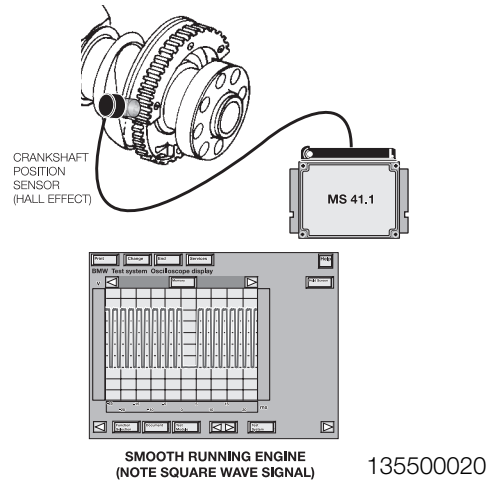
- Malfunction Indicator Light
- Excessive Tailpipe smoke (leaking)
- Engine Hydrolock (leaking)
- Misfire/Rough Idle (Leaking or Blocked)
- Long Crank Time (Leaking)
- Oxygen Sensor/Mixture/Injector Related Fault Code



**Crankshaft Position/RPM Sensor (Hall Effect):** This sensor provides the crankshaft position and engine speed (RPM) signal to the ECM for fuel pump and Injector operation.

A Hall sensor is mounted on the left side at the rear of the engine block. The impulse wheel is mounted on the crankshaft inside the crankcase, at the rear main bearing support. The impulse wheel contains 58 teeth with a gap of two missing teeth.

The Hall sensor is supplied with voltage from the ECM. A digital square wave signal is produced by the sensor as the teeth of the impulse wheel pass by. The “gap” allows the ECM to establish crankshaft position.



The crankshaft position sensor is monitored as part of OBD II requirements for Misfire Detection. If this input is faulty, the ECM will operate the engine (limited driveability) from the Camshaft Sensor input. A fault with this input will produce the following complaints:

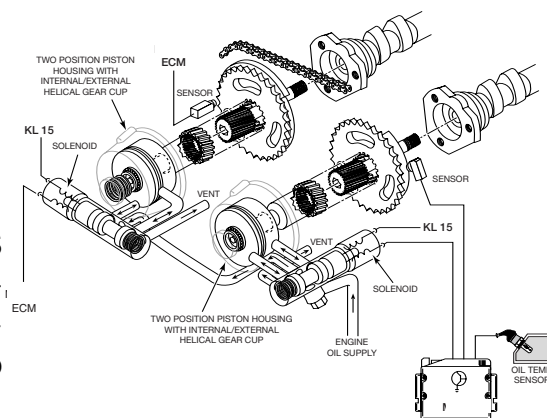
- Hard Starting/Long Crank Time
- “Malfunction Indicator Light”
- Driveability/Misfire/Engine Stalling

## Camshaft Sensors - Intake and Exhaust Camshafts

The "static" Hall sensors are used so that the camshaft positions are recognized once ignition is on (KL15) before the engine is started. The function of the intake cam sensor is:

- Cylinder “work cycle” for injection timing
- Synchronization
- Engine speed sensor (if crankshaft speed sensor fails)
- VANOS position control of the intake cam

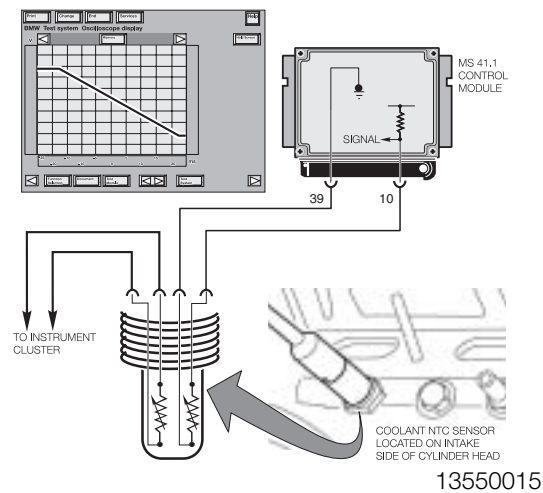
The exhaust cam sensor is used for VANOS position control of the exhaust cam. If these sensors fail there are no substitute values, the system will operate in the failsafe mode with no VANOS adjustment. The engine will still operate, but torque reduction will be noticeable.



NOTE: Use caution on repairs as not to bend the impulse wheels.

**Engine Coolant Temperature:** The Engine Coolant Temperature is provided to the ECM from an NTC type sensor located in the coolant jacket of the cylinder head (left rear). The sensor contains two NTC elements, the other sensor is used for the instrument cluster temperature gauge.

The ECM determines the correct air/fuel mixture required for the engine temperature by monitoring an applied voltage to the sensor (5v). This voltage will vary (0-5v) as coolant temperature changes the resistance value.



If the Coolant Temperature Sensor input is faulty, a fault code will be set the ECM will assume a substitute value (80° C) to maintain engine operation.

**Throttle Position:** For details about the sensor, refer to the Air Management section. As the throttle is opened, the ECM will increase the volume of fuel injected into the engine. As the throttle plate is closed, the ECM activates fuel shut off if the rpm is above idle speed (coasting).

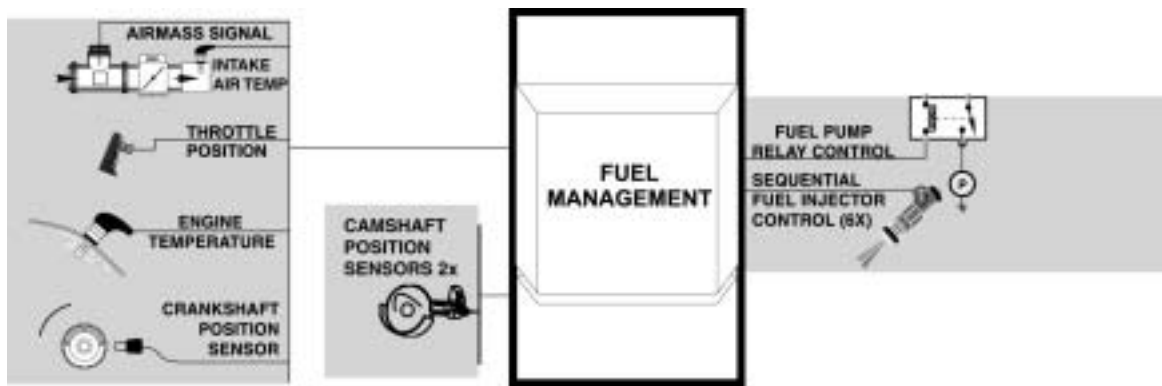
**Hot-Film Air Mass Meter (HFM):** The air volume input signal is used by the ECM to determine the amount of fuel to be injected for correct air/fuel ratio. For details about the sensor, refer to the Air Management section.

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

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

## Principle of Operation

Fuel Management delivers fuel from the tank to the intake ports of the engine. To accomplish this, **fuel supply** must be available to the fuel injectors. Then the fuel must be **inject-ed** in the precise amount and at the correct time. The ECM does not directly monitor fuel supply, although it does control fuel supply. **The Fuel Pump** supplies fuel when it receives operating voltage from the Engine Control Module Relay supplying the Fuel Pump Relay. The ECM controls and monitors **fuel injection**.

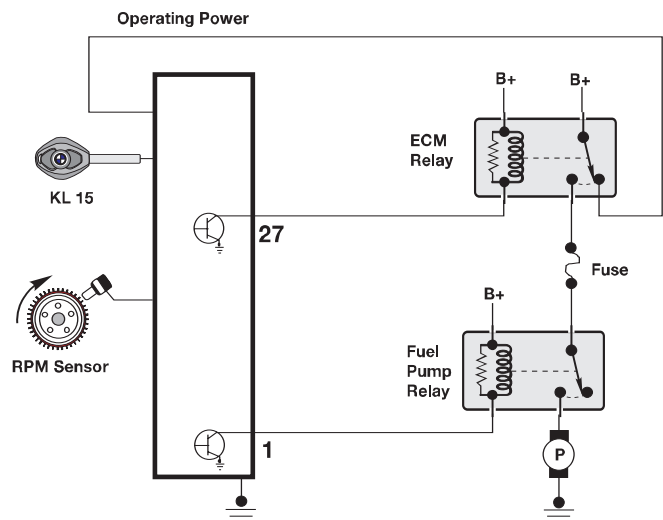


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**The Fuel Pump** will be activated when the ignition (KL15) is switched “on” and the ECM supplies a ground circuit to activate the Fuel Pump Relay. The Fuel Pump Relay supplies operating power to the in-tank mounted fuel pump. This is a momentary activation to “pressurize” (prime) the fuel system.

The ECM then requires an engine speed signal from the Crankshaft Position/RPM Sensor to maintain continuous Fuel Pump Relay activation.

If the engine RPM signal is not present, the ECM will deactivate the Fuel Pump Relay.



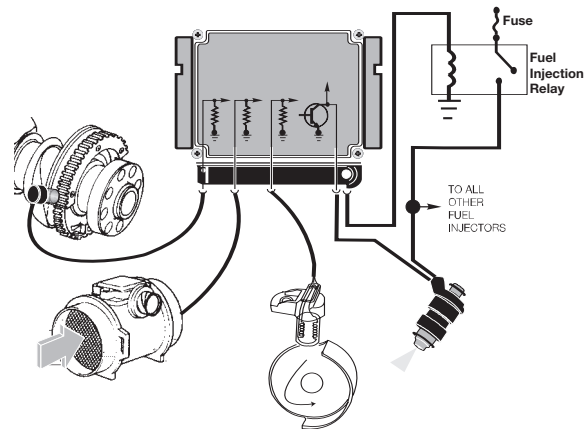
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**The Fuel Injectors** will be opened by the ECM to inject pressurized fuel into the intake ports. The Fuel Injectors receive voltage from the Engine Control Module Relay. The ECM controls the opening by activating the ground circuits for the Solenoid Windings. The ECM will vary the duration (in milli-seconds) of “opening” time to regulate the air/fuel ratio.



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

The ECM is programmed to activate the Final Stage output transistors once for every two revolutions of the crankshaft in two groups (Semi-Sequential Injection).

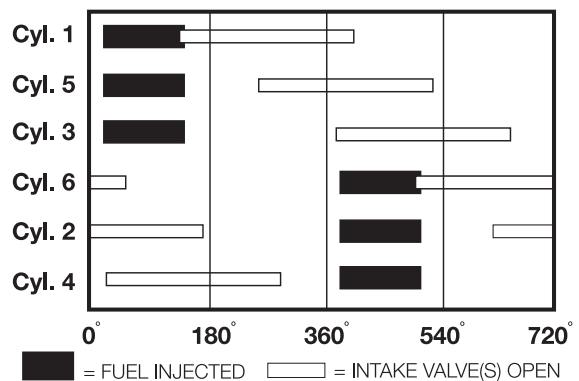


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The injectors are opened in two groups for every complete “working cycle” of the engine. This delivers the fuel charge for cylinders 1,5,3 during one revolution of the crankshaft and cylinders 6,2,4 during the second revolution of the crankshaft. This process enhances fuel atomization during start up.

During start up, the ECM recognizes the Camshaft Position (Cylinder ID) input. The camshaft position is referenced to the crankshaft position. It then switches the injection to Full Sequential. This process “times” the injection closer to the intake valve opening for increased efficiency.

### Semi-Sequential Injection

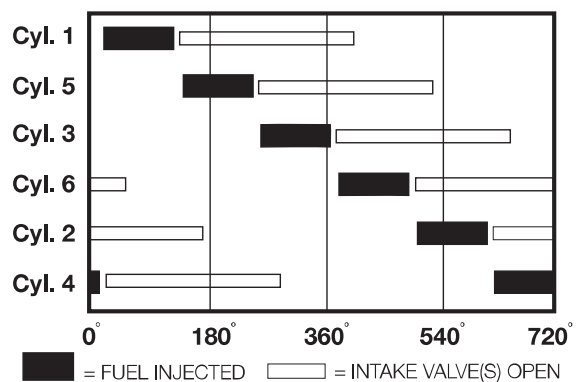


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When activated, each injector delivers the full fuel charge at separate times during each engine working cycle.

If this input is faulty, the ECM will activate the injectors in Parallel to maintain engine operation and set a fault code.

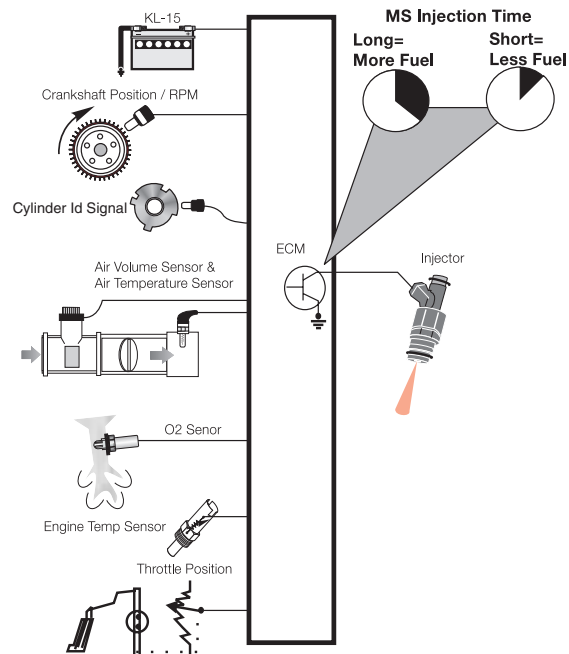
### Full Sequential Injection



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

- Battery Voltage
  - Throttle Position
  - Air Flow Volume/Mass
  - Air Temperature
  - Crankshaft Position/RPM
  - Camshaft Position (Cylinder ID)
  - Engine Coolant
  - Oxygen Sensor
- (Detailed in Emissions)



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

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

During cranking, additional fuel is injected (in Semi-Sequential) for the first few crankshaft revolutions. After the first few crankshaft revolutions, the injected quantity is metered down as the engine comes up to speed. When the engine speed approaches idle rpm, the ECM recognizes the Camshaft Position and switches to Full Sequential injection.

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

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

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

The Hot-Film Air Mass (HFM) signal provides the measured amount of intake air volume/mass. This input is used by the ECM to determine the amount of fuel to be injected to “balance” the air/fuel ratio.

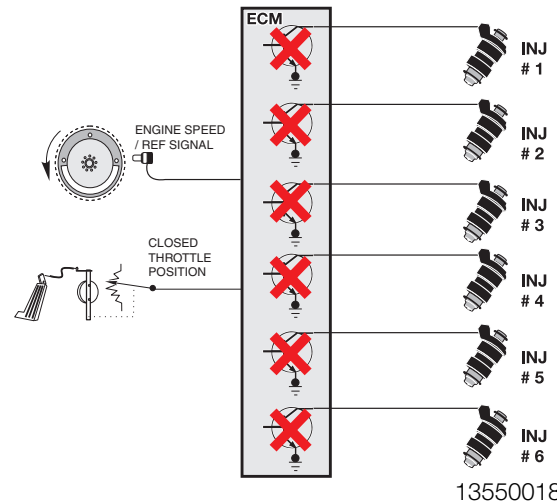
The Air Temperature Signal allows the ECM to make an additional calculation of air density. The varying voltage input from the NTC sensor indicates the larger proportion of oxygen found in cold air, as compared to less oxygen found in warmer air. The ECM will adjust the amount of injected fuel because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

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

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

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

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



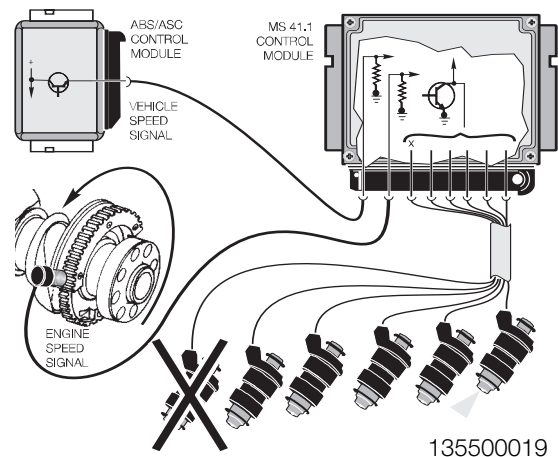
When the engine rpm approaches idle speed, the injection ms value is increased (cut-in) to prevent the engine from stalling. The cut-in rpm is dependent upon the engine temperature and the rate of deceleration. This function can be observed as displayed on the Fuel Economy (MPG) gauge.

The ECM 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. **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 ECM selectively deactivating the injectors (regardless of engine rpm).

This limitation is based on the vehicle dimensions, specifications and installed tires (speed rating).

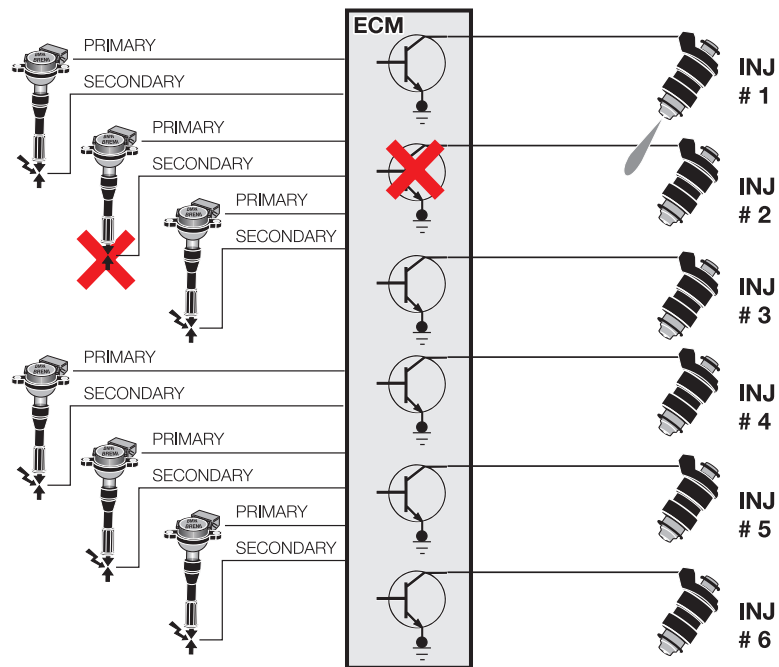


The ECM will also protect the Catalytic Converter by deactivating the injectors.

If the ECM 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 MS45 system, there are six individual injector circuits resulting in deactivation of one or multiples. This will limit engine power, but protect the Catalytic Converter.



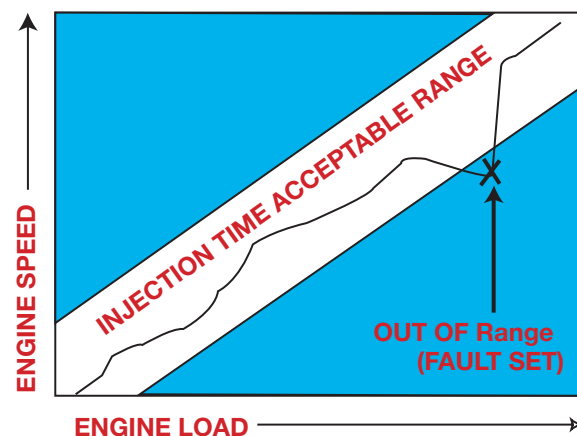
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**Fuel Injection Control Monitoring** is performed by the ECM for OBD II requirements. Faults with the fuel injectors and/or control circuits will be stored in memory. This monitoring includes:

- Closed Loop Operation
- Oxygen Sensor Feedback

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

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



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## Workshop Hints

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

- Observe relevant safety legislation pertaining to your area.
- Ensure adequate ventilation.
- Use exhaust extraction system where applicable (alleviate fumes).
- DO NOT OPERATE THE FUEL PUMP unless it is properly installed in the fuel tank and is submersed in the fuel (fuel lubricates the pump).
- 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.
- BMW 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.

## Fuel

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

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

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

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## Fuel Supply

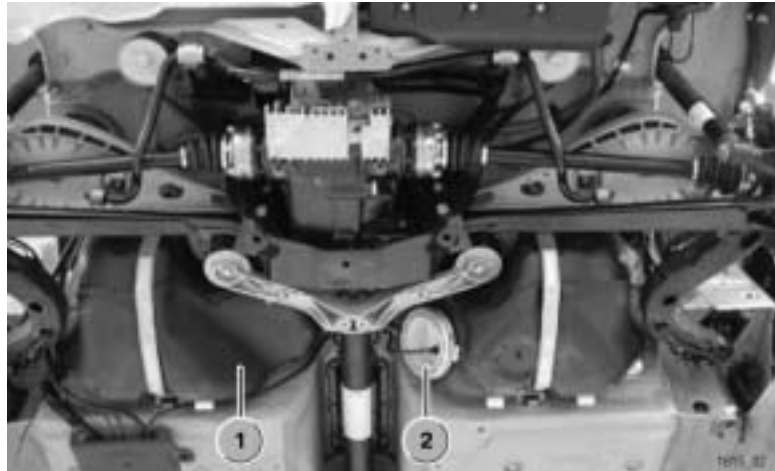
The fuel supply hardware should be visually inspected for damage that can affect pick-up, transfer, pressure and return. Please refer to the Repair Instructions for details on fuel supply hardware.

### Fuel Filter, Pressure Regulator, Pump and Sending Unit Access

*Caution! The fuel tank must be drained first before removing the Service access cap to perform any repair attempts.*

*Consult the Repair Instructions for additional details and updated information.*

1. Fuel tank
2. Service access cap



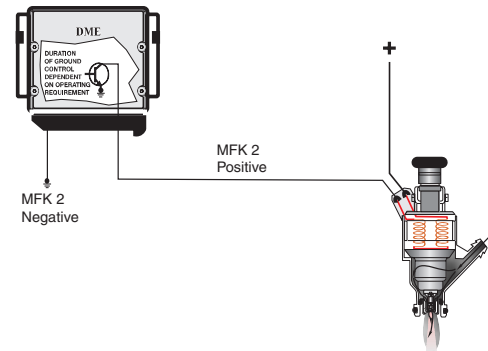
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The fuel filter, fuel pressure regulator, electric fuel pump, right fuel level sensor and syphon jet are accessed through the “Service access cap”. Remove the single 6 pin electrical connector (2 pins for the fuel pump, 2 for each level sensor - left/right). Remove the fuel supply line by releasing the “quick” release coupling.

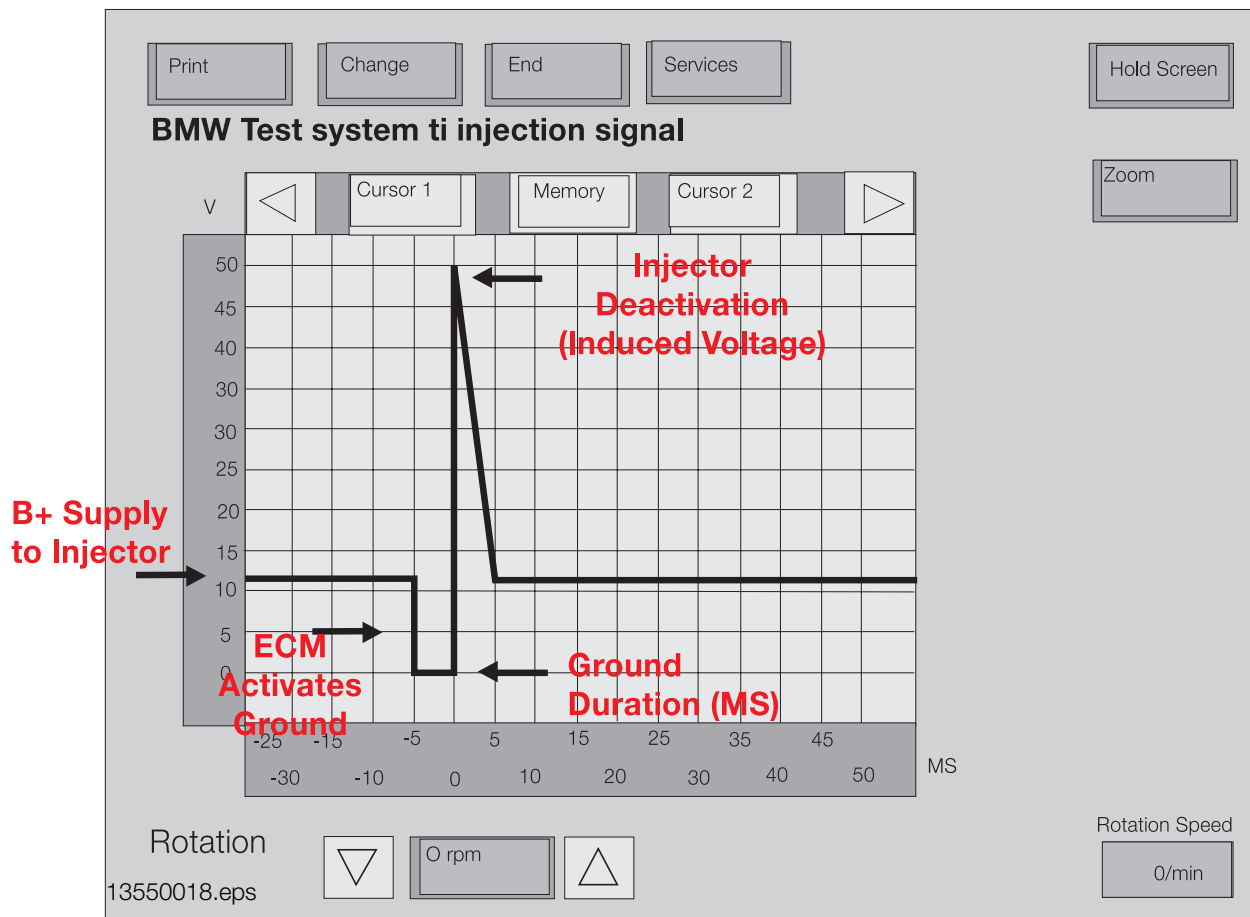
The fuel tank is secured by two straps to the body.

The Fuel Injectors should also be tested using the DISplus/GT1 for:

- Resistance
- Power Supply
- Status Display - Fuel Injection Signal
- ECM Final Stage transistor activation. This test functions is found under the oscilloscope Preset list - "Ti Injection Signal". Install the Universal Adapter, Diagnostic cable, MFK 2 negative lead to ECM ground and MFK 2 positive lead to the ground activation circuit for the injector. This test is performed with the engine cranking or running.



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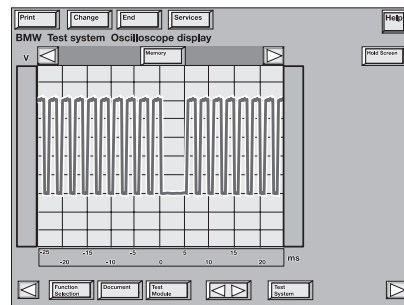
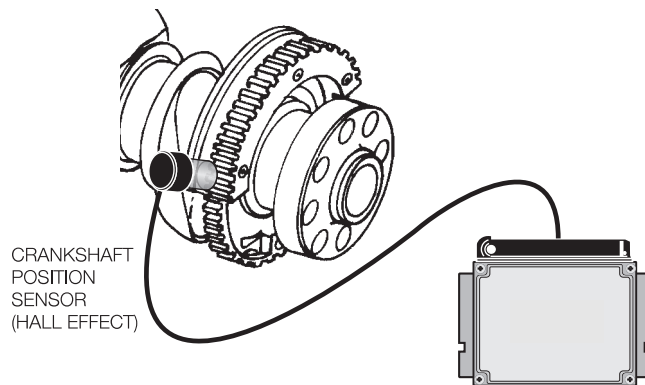




## Crankshaft Position/RPM Sensor

This sensor should be tested using the DISplus/GT1 for:

- Power Supply
- DC Voltage
- Status Display
- Oscilloscope Display found under Preset Measurements - "Engine Speed Sensor Signal"



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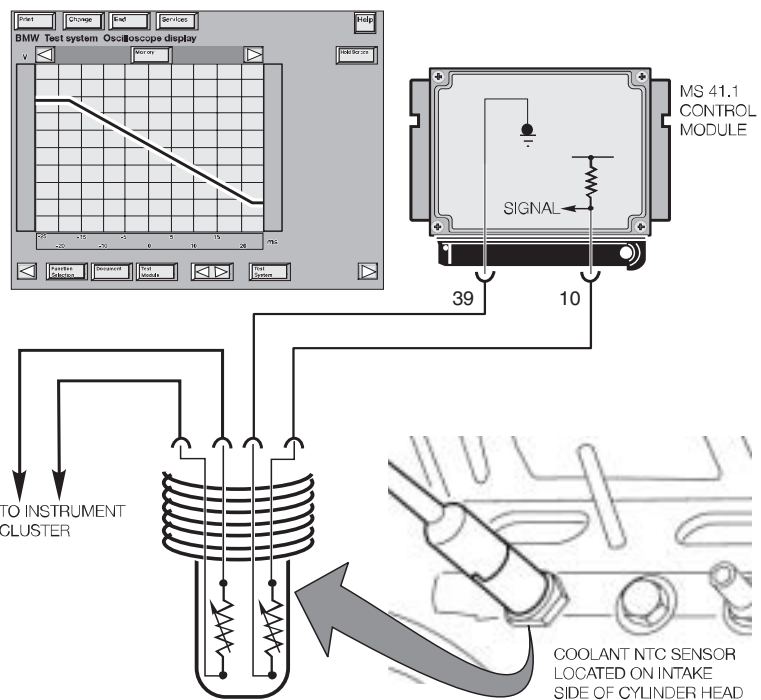
## Engine Coolant Temperature

NTC sensors decrease in resistance as the temperature rises and vice versa. The ECM monitors the sensor voltage which varies as temperature changes the resistance value. For example, as temperature rises:

- Resistance through the sensor decreases
- Voltage drop of the sensor decreases
- Input signal voltage also decreases (5-0v)

The Sensor should be tested using:

- DISplus/GT1 Multimeter degrees C (dependent on engine temperature).
- DISplus/GT1 Multimeter ECM input 2.250K ohms at 20° C Temp. Gauge input 6.7 k ohms at 20° C Temperature. Gauge input 6.7 K ohms at 20° C.



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## Tools and Equipment

The DISplus/GT1 as well as a reputable hand held multimeter can be used when testing inputs/components.

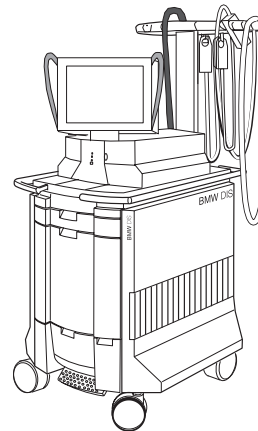
It is best to make the checks at the ECM connection, this method includes testing the wiring harness.

The correct Universal Adapter for the MS45 application should be used (#90 88 6 121 300). This will ensure the pin connectors and the harness will not be damaged.

When installing the Universal Adapter to the ECM (located below the windshield on the passenger side of the engine compartment), make sure the ignition is switched off.

**NOTE for MS45:** Allow at least 3 minutes to elapse after the key was set to the "OFF" position before disconnecting the ECM/ TCM.

*This will allow sufficient time to complete the DM TL test. Voltage may be present (up to 3 minutes) causing damage to the ECM/TCM if they are disconnected during this time period (arcing).*



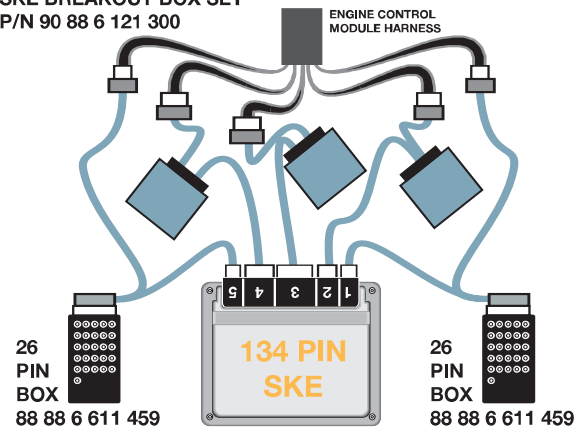
DISplus



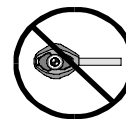
GT-1

16550019

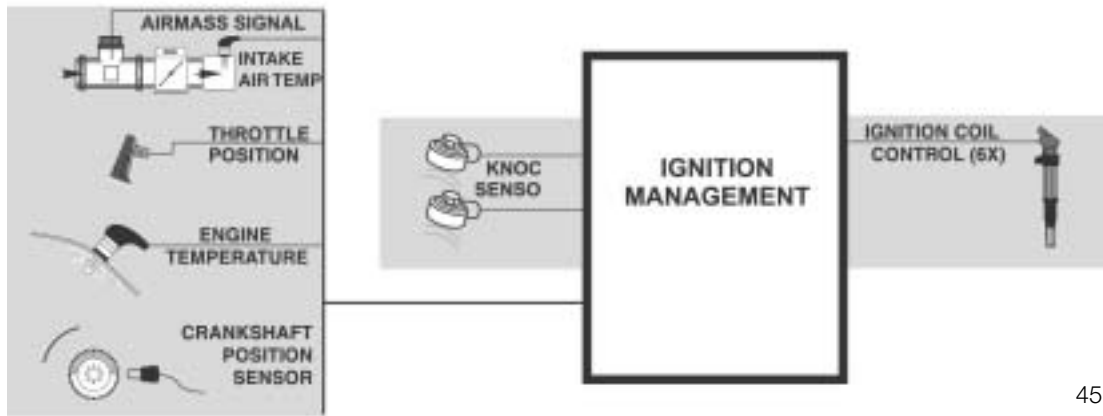
**SKE BREAKOUT BOX SET**  
P/N 90 88 6 121 300



16550020



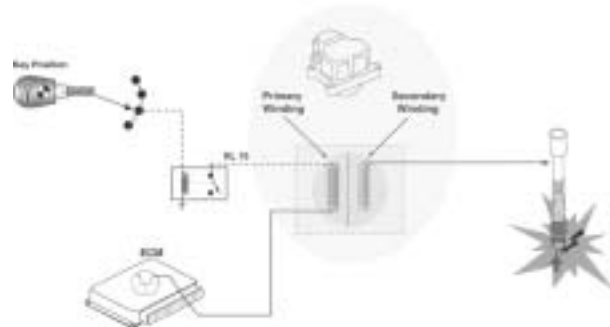
## Ignition Management



45-02-05

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

1. Coil Assembly
  - Primary Winding
  - Secondary Winding
2. Boot Connector
3. Spark Plug
4. ECM Final Stage Transistor



16550021

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.

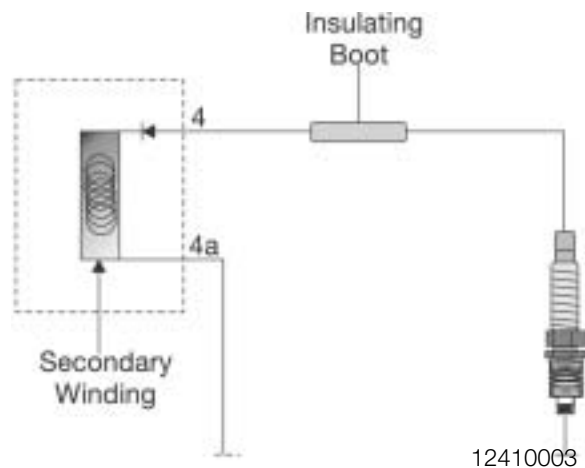
The MS45 primary winding receives battery voltage from the ECM Main Relay which is activated by the ignition switch KL15 (Emission Optimized). The ECM provides a ground path for the primary coil (Terminal 1) by activating a Final Stage transistor. The length of time that current flows through the primary winding is the “dwell” which allows the coil to “saturate” or build up a magnetic field.

After this storage process, the ECM will interrupt the primary circuit at the point of ignition by deactivating the Final Stage transistor. The magnetic field built up within the primary winding collapses and induces the ignition voltage in the secondary winding.

The high voltage generated in the secondary winding is discharged through Coil Terminal 4 to the spark plug (insulated by the boot connector). The primary and secondary windings are un-coupled, therefore, the secondary winding requires a ground supply (Coil Terminal 4a).

There is an individual ignition circuit and coil for each cylinder on the MS45 system. The six individual ignition coils are integrated with the insulated connector (boot). The assemblies are mounted on top of the cylinder head cover.

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

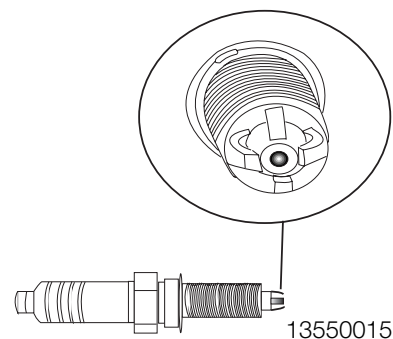


**Spark Plugs:** The spark plugs introduce the ignition energy into the combustion chamber. The high voltage “arcs” across the air gap in the spark plug from the positive electrode to the negative electrode. This creates a spark which ignites the combustible air/fuel mixture.

The spark plugs are located in the center of the combustion area (on the top of the cylinder head) which is the most suitable point for igniting the compressed air/fuel mixture.

**Note:** High Performance Platinum Spark Plugs are approved for use.

- NGK BKR6EQUP (quad electrode, non adjustable gap)



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

- “Malfunction Indicator Light” With Mixture Related Fault Codes
- Poor Engine Performance
- No Start/Hard Starting
- Excessive Exhaust Emissions/Black Smoke

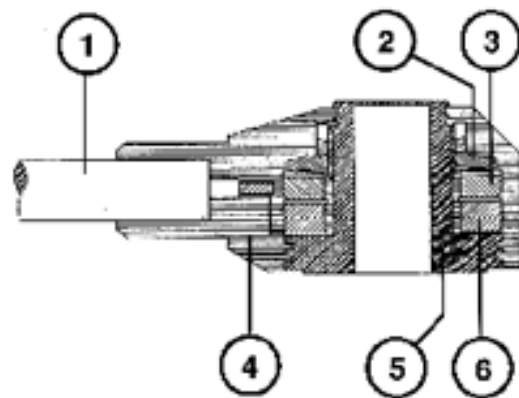
The *ignition* is monitored by the ECM via the secondary ignition feedback circuit and Crankshaft Position/RPM Sensor. If a Misfire fault is present, the “Malfunction Indicator Light” will illuminate when the OBD II criteria is achieved and the ECM will deactivate the corresponding fuel injector for that cylinder. Engine operation will still be possible.

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

- High Compression Ratio
- Poor Quality Fuel (Octane Rating)
- High Level of Cylinder Filling
- Maximum Timing Advance Curve
- High Intake Air and Engine Temperature
- Carbon Build-Up (Combustion Chamber)

The Knock Sensor consists of:

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

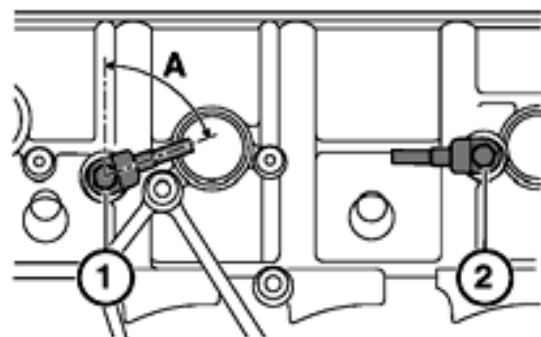


13550005

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

There are two Knock Sensors bolted to the engine block on the intake manifold side, (1) between cylinders 1 - 3 and (2) between cylinders 4 - 6. If the signal value exceeds the threshold, the ECM identifies the “knock” and retards the ignition timing for that cylinder.

If a fault is detected with the sensor(s), the ECM deactivates Knock Control. The “Malfunction Indicator Light” will be illuminated when the OBD II criteria is achieved, the ignition timing will be set to a conservative basic setting and a fault will be stored.

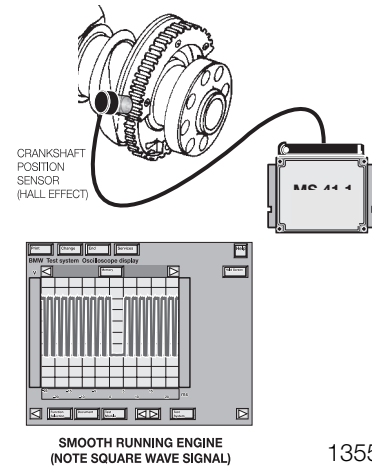


13550001

**Crankshaft Position/RPM Sensor:** This sensor provides the crankshaft position and engine speed (RPM) signal to the ECM for ignition activation and correct timing. This input is also monitored for Misfire Detection. For details about the sensor, refer to the Fuel Management section.

A fault with this input will produce the following complaints:

- No Start
- Intermittent Misfire/Driveability
- Engine Stalling



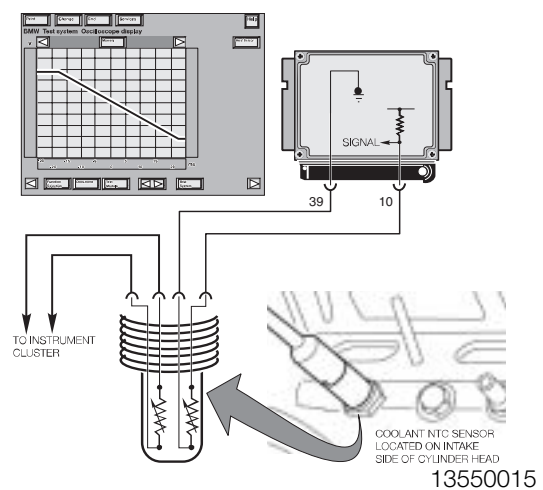
**Camshaft Position Sensors (Cylinder Identification):** The cylinder ID sensor input allows the ECM to determine camshaft position in relation to crankshaft position. It is used by the ECM to establish the “working cycle” of the engine for precise ignition timing. For details about the sensor, refer to the Fuel Management section.

If the ECM detects a fault with the Cylinder ID Sensor, the “Malfunction Indicator Light” will be illuminated when the OBD II criteria is achieved and the system will still operate precise single ignition based on the Crankshaft Position/RPM Sensor.

If the signal is impaired during a restart, the ECM will activate “*double ignition*”. The ignition coils will be activated on both the compression and exhaust strokes to maintain engine operation.

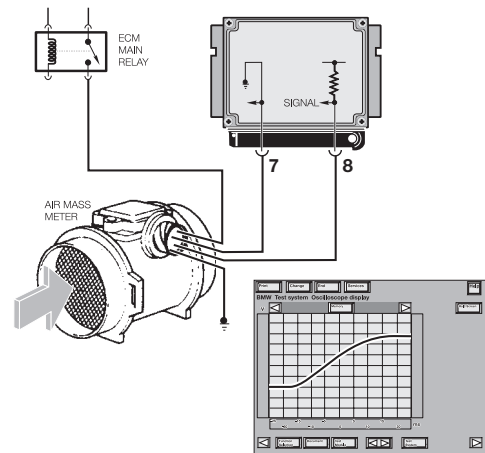
**Engine Coolant Temperature:** The ECM determines the correct ignition timing required for the engine temperature. For details about the sensor, refer to the Fuel Management section. This sensor is located in the coolant jacket of the cylinder head (left rear).

If the Coolant Temperature Sensor input is faulty, the “Malfunction Indicator Light” will be illuminated when the OBD II criteria is achieved and the ECM will assume a substitute value (80° C) to maintain engine operation. The ignition timing will be set to a conservative basic setting.



**Hot-Film Air Mass Meter:** This input is used by the ECM to determine the amount of ignition timing advance based on the amount of intake air volume. For details about the sensor, refer to the Air Management section.

If this input is defective, a fault code will be set and the “Malfunction Indicator Light” will illuminate when the OBD II criteria is achieved. The ECM will maintain engine operation based on throttle position and the Engine Speed Sensor, and the ignition timing will be set to a conservative basic setting.



13550004

**Throttle Position:** This provides the ECM with accelerator pedal position and rate of movement. As the accelerator pedal is depressed the ECM will advance the ignition timing. The “full throttle” position indicates maximum acceleration to the ECM, the ignition will be advanced for maximum torque. For details about the sensor, refer to the Air Management section.

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

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

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

**Notes:**

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## Principle of Operation

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



45-02-05

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

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

- Battery Voltage
- Accelerator Pedal Position
- Air Flow Volume
- Air Temperature
- Engine Coolant
- Crankshaft Position / RPM
- Camshaft Positions (Cylinder ID)
- Knock Sensors

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

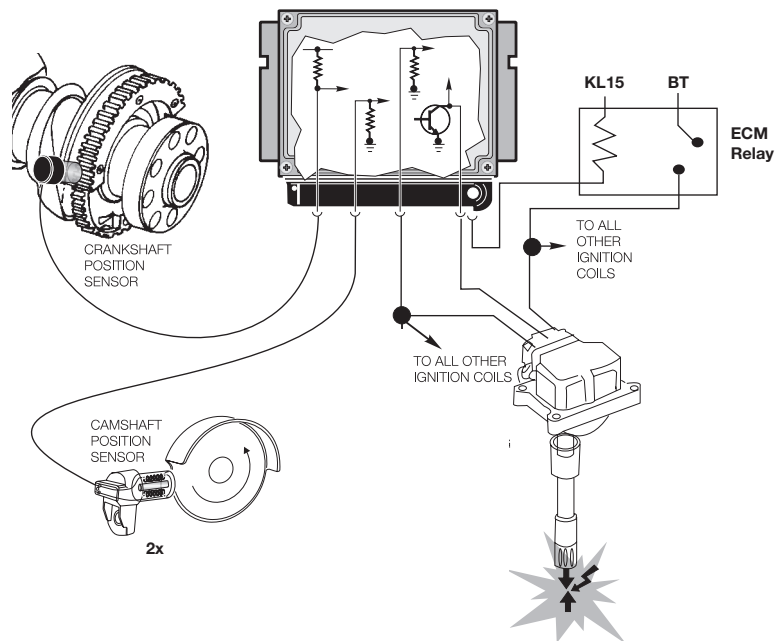
The Crankshaft Position/RPM signals the ECM to start ignition in firing order (1-5-3-6-2-4) as well as providing information about the engine operation. This input is used in combination with other inputs to determine engine load which advances/retards the ignition timing. Without this input, the ECM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



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

When starting a warm engine, the rpm is higher which results in slightly advanced timing.

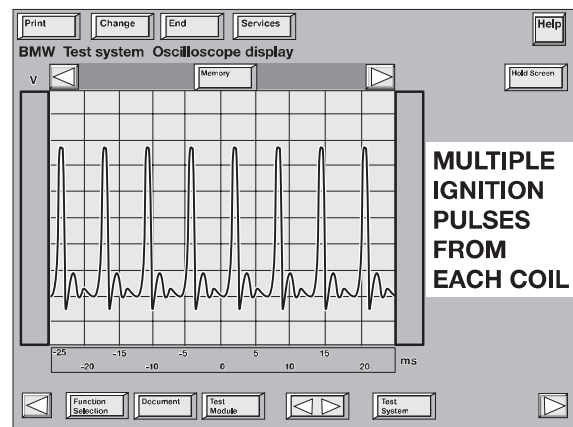
If the engine coolant and intake air temperature is hot, the ignition timing will not be advanced reducing starter motor “load”.



12550010

**Multiple Ignition Pulses** ensure good spark quality during engine start up. The ECM will activate the ignition coils 9 times (voltage dependent) per 720° of crankshaft revolution.

The ignition timing will be progressively advanced assisting the engine in coming up to speed. As the engine speed approaches idle rpm, the timing remains slightly advanced to boost torque. When the engine is at idle speed, minimum timing advance is required. This will allow faster engine and catalyst warm up.



12550011

The multiple pulsing switches to single pulse when:

- Engine Speed >1350 RPM (varied with engine temperature)

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

## MS45 Emission Optimized - Ignition Key Off

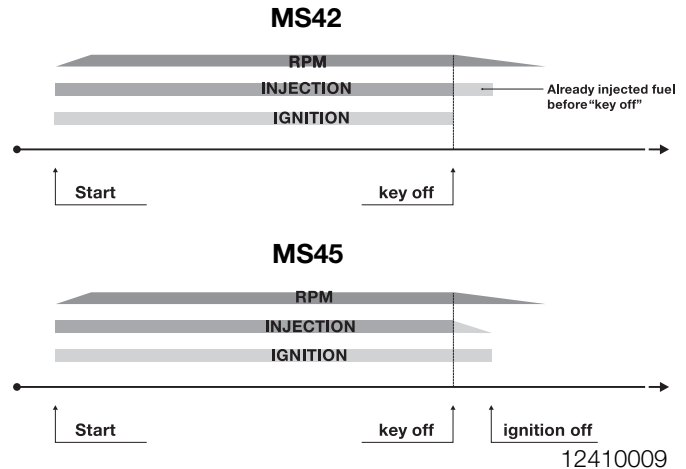
“Emission Optimized Ignition Key Off” is a programmed feature of the MS45 ECM.

After the ECM detects KL15 is switched “off”, the ignition stays active (ECM Relay/voltage supply) for two more individual coil firings.

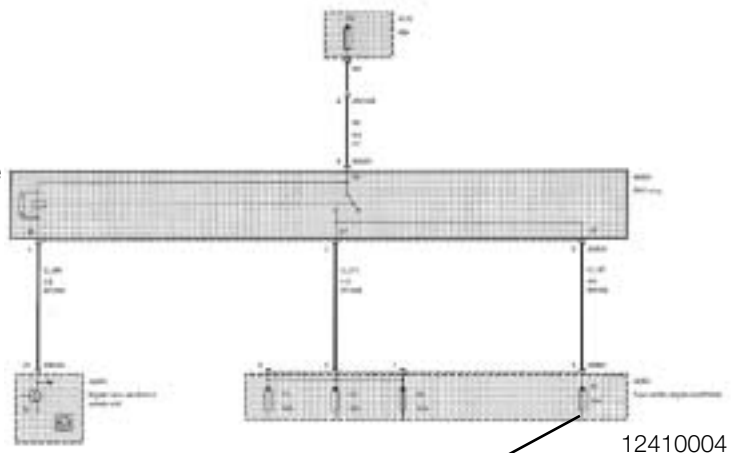
This means that just two cylinders are fired - not two revolutions.

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

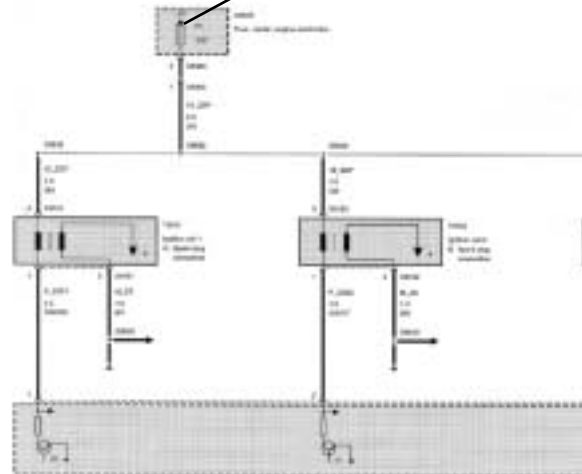
### EMISSION OPTIMIZED IGNITION KEY OFF



When **KL15** is switched “off” the ECM operating voltage is removed.



The ECM will maintain a ground to the Engine Control Module Relay for a few seconds to maintain ignition coil activation.



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The HFM signal represents the amount of intake air volume. This input is used by the ECM to determine the amount of timing advance to properly combust the air/fuel mixture.

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

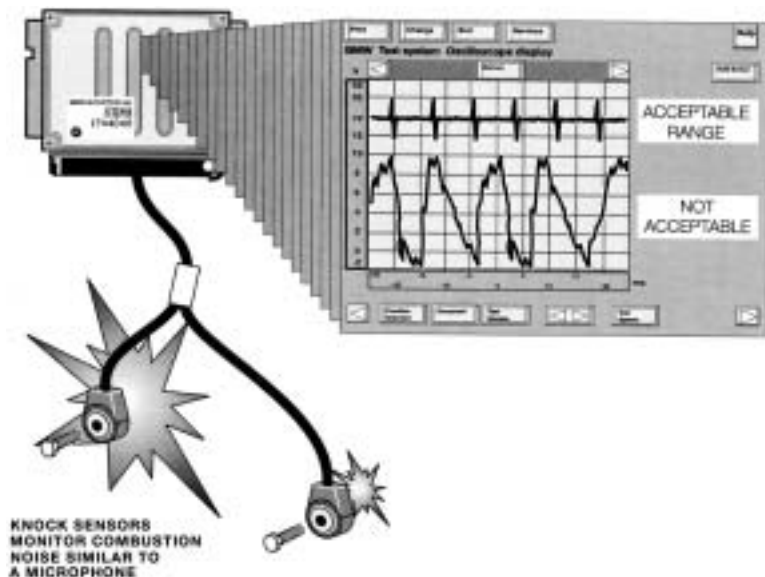
As the throttle is closed, the ECM decreases the ignition timing if the rpm is above idle speed (coasting). This feature lowers the engine torque for deceleration. When the engine rpm approaches idle speed, the timing is slightly advanced to prevent the engine from stalling. The amount of advance is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

**Knock Control** allows the ECM to further advance the ignition timing under load for increased torque. This system uses two Knock Sensors located between cylinders 1,2,3 and between cylinders 4,5,6. Knock Control is only in affect when the engine temperature is greater than 35 °C and there is a load on the engine. This will disregard false signals while idling or from a cold engine.

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

If the signal value exceeds the threshold, the ECM identifies the “knock” and retards the ignition timing (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.



13550010

If a fault is detected with the Knock Sensor(s) or circuits, the ECM 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.

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## Workshop Hints

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

- Observe relevant safety legislation pertaining to your area
- Always wear adequate protection clothing including eye protection
- Use caution when working around a HOT engine compartment
- Always consult the REPAIR INSTRUCTIONS on the specific model you are working on before attempting a repair.
- Always SWITCH OFF THE IGNITION (KL 15) before working on the ignition system.
- Use only BMW approved test leads.
- NEVER TOUCH COMPONENTS CONDUCTING CURRENT with the engine running.
- Do not connect suppression devices or a “test light” to terminal 1 of the ignition coils.
- Terminal 1 from the ignition coil to the ECM (High Voltage approximately 350 V)

### **HIGH VOLTAGE - DANGER!**

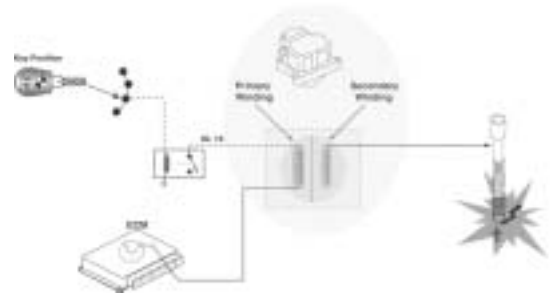
**Caution!** Hazardous voltages occur at:

- Ignition Leads
- Spark Plug Connector
- Spark Plug
- Ignition Coil (High Voltage at terminal 4 is approximately 40 KV)
- Terminal 1 from the ignition coil to the ECM (High Voltage approximately 350V)

## Ignition System Diagnosis

A fault survey should first be performed using the DISplus/GT1 to determine if there is a fault in the primary ignition or secondary ignition. If there is a fault in the primary ignition, testing should include:

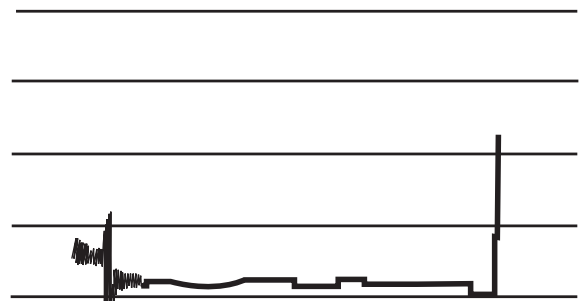
- Power Supply at the coil (KL 15)
- Resistance of the harness and ignition coil primary winding
  - using the Universal Adapter with the ECM disconnected



16550021

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

Install the Universal Adapter, Diagnostic cable, MFK 2 negative lead to ECM ground and MFK 2 positive lead to the ground activation circuit for Terminal 1 of the ignition coil. This test is performed with the engine cranking/running.



13550017

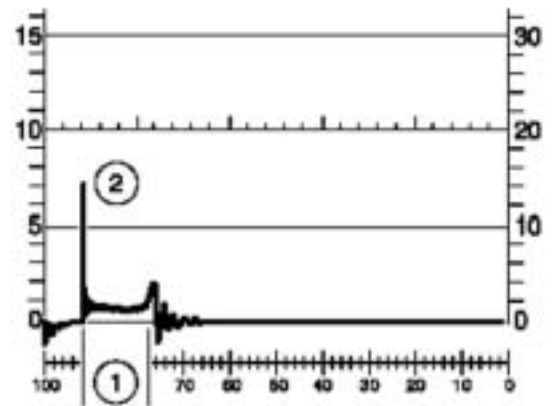
If there is a fault in the secondary ignition, testing should include:

- Primary Ignition
- Evaluation of Secondary Oscilloscope Patterns

**The Following are Examples of Secondary Oscilloscope Patterns** (consult Repair Instructions for ignition pattern variations per coil manufacturer):

This is a normal pattern for one ignition circuit with the engine at idle speed.

- Normal Combustion Period
- Normal Ignition Voltage Peak

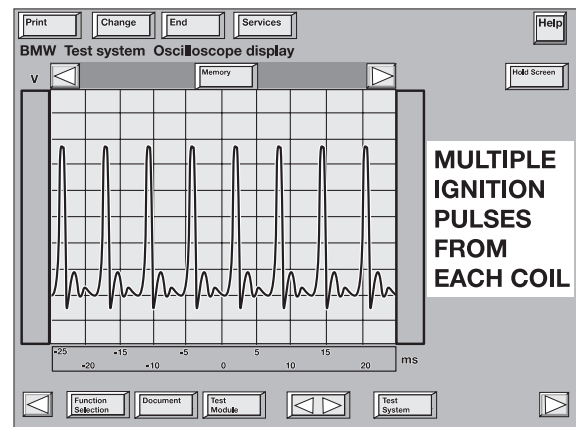


07550001

**Multiple Ignition Pulses** ensure good spark quality during engine start up. The ECM will activate the ignition coils 9 times per 720° of crankshaft revolution.

This is a normal pattern for one ignition circuit when:

1. Normal Combustion Period
2. Normal Ignition Voltage Peak



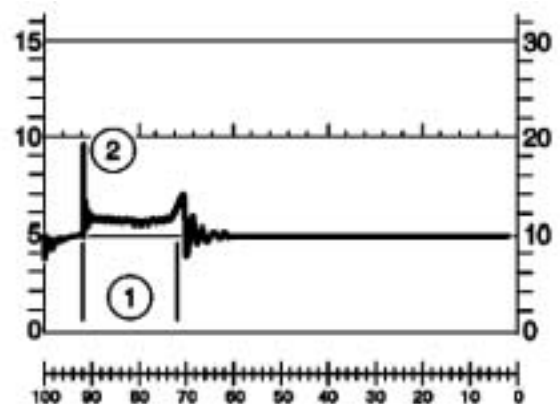
12550011

Long Spark Period (1) with Low Ignition Voltage Peak (2). If Spark Period is Fluctuating:

- Indicates Low Compression
- Contamination on Spark Plug or Defective Spark Plug

Short Spark Period (1) with High Ignition Voltage Peak (2).

- Defective Ignition Connector or Resistive Adaptive Boot



07550002

## Evaluation of Ignition Voltage Peaks at Idle Speed (Multiple Cylinders Displayed).

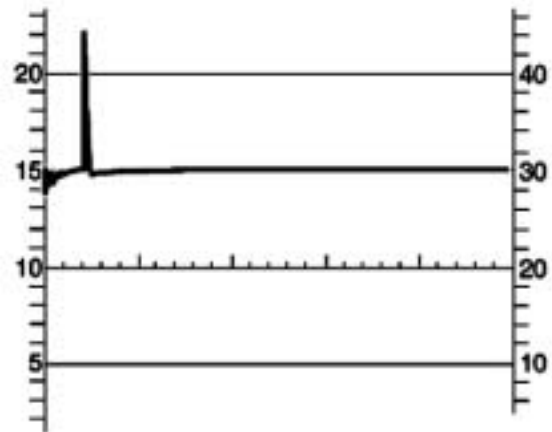
1. Normal Attenuation (Voltage Reduction) Process
2. Shorten Attenuation Process (arrow)-Defective Ignition Coil
3. Absence of Attenuation (arrow )-Defective Ignition Coil



07550004

## No Sparking Voltage Line (Single Cylinder Displayed)

- Defective Ignition Coil



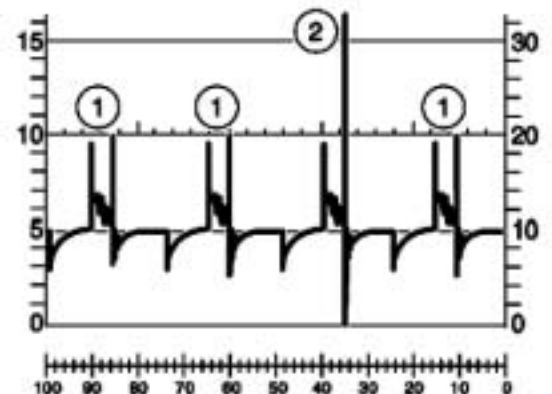
07550005

## Evaluation of Ignition Voltage Peaks under Sudden Loads (Multiple Cylinders Displayed).

- Defective Ignition Coil

Decaying Process is considerably Higher than Ignition Voltage Peak (2):

- Lean Mixture
- Defective Fuel Injector
- Low Compression



07550006

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

In Summary,

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

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

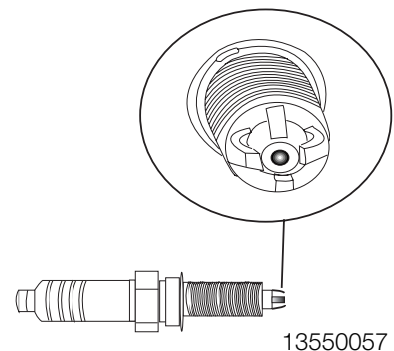
If the Secondary Ignition **Voltage is Too Low (Low Resistance for Ignition):**

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

## Spark Plugs

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

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

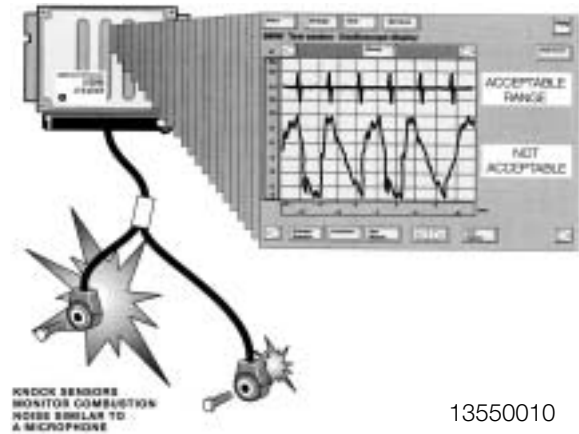




## Knock Sensors

The Knock Sensors should be tested using the DIS/GT1 for:

- Fault Codes
- Status Display - Knock Control  
(active / not active)
- Oscilloscope Display (Low DC Voltage -mV setting)



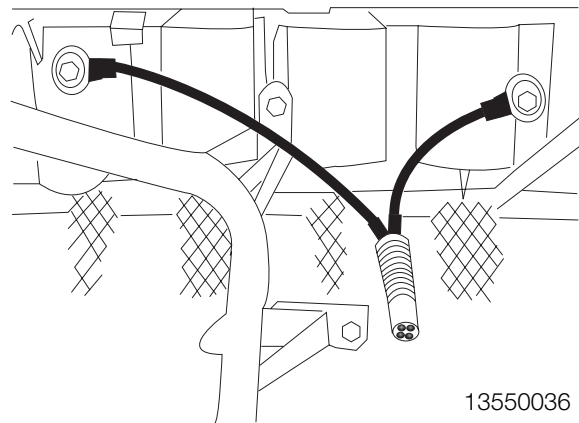
13550010

When installing Knock Sensors:

***DO NOT MIX THE LOCATIONS*** or Engine Damage will result! The Knock Sensors use a combined connection to the engine harness. The Knock Sensor with the shorter cable is for cylinders 4 - 6.

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

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



13550036

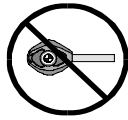
## Tools and Equipment

The DISplus/GT1 as well as a reputable hand held multimeter can be used when testing inputs/components.

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

The correct Universal Adapter for the MS45 application should be used (#90 88 6 121 300). This will ensure the pin connectors and the harness will not be damaged.

When installing the Universal Adapter to the ECM, make sure the ignition is switched off.

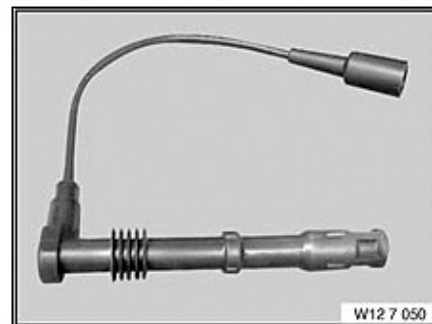
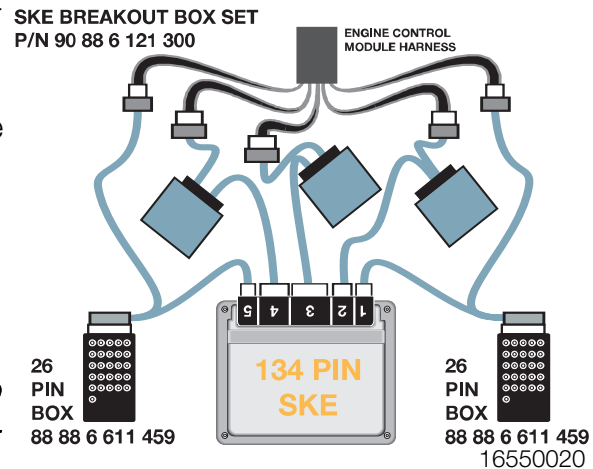
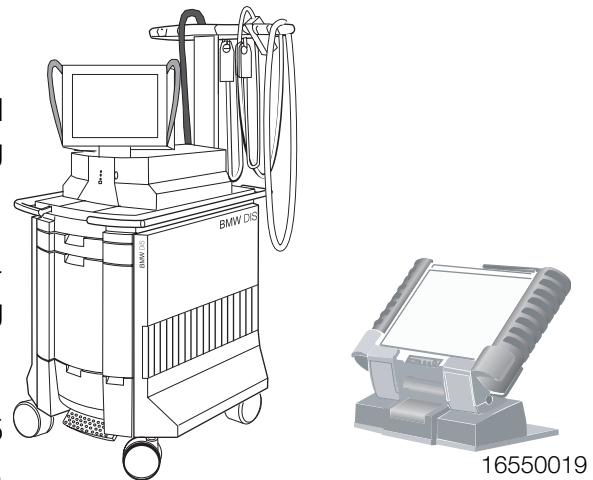


**NOTE for MS45:** Allow at least 3 minutes to elapse after the key was set to the "OFF" position before disconnecting the ECM/ TCM.

*This will allow sufficient time to complete the DM TL test. Voltage may be present (up to 3 minutes) causing damage to the ECM/TCM if they are disconnected during this time period (arcing).*

When Testing the Secondary Ignition System, use Special Tool (Secondary Voltage Test Cable) #90 88 6 127 050. This provides a clamping surface for the DISplus primary and secondary ignition adapter clamps. Refer to the HELP button for additional (on screen) connections.

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

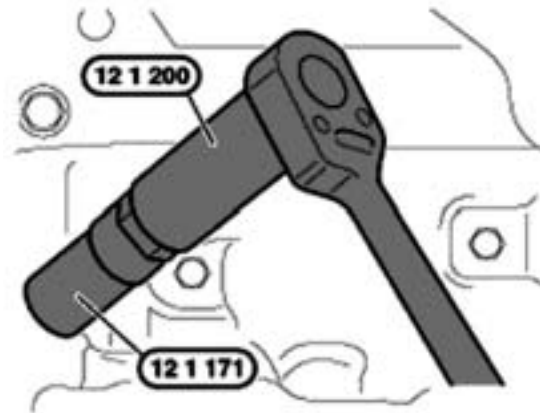


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The Spark Plugs should be properly installed and torqued using the following Special Tools:

- 12 1 200 Torque Adapter
- 12 1 171 Spark Plug Socket

**NOTE: NEVER USE AIR TOOLS FOR REM-OVAL OR INSTALLATION!**



13550020