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# **Engine Management Systems**

**Self Study Program**  
Course Number 841003

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Volkswagen of America, Inc.  
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Always check Technical Bulletins and the Volkswagen Worldwide Repair Information System for information that may supersede any information included in this booklet.

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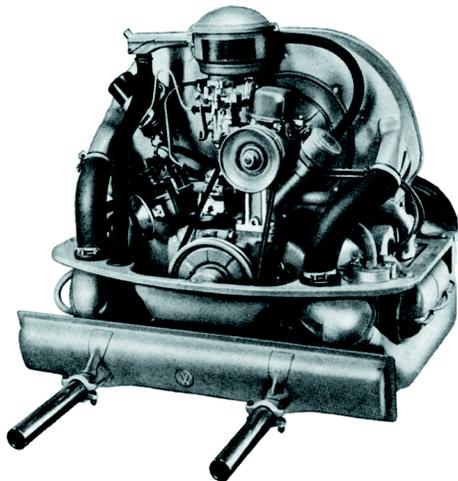
## Introduction

The origins of Volkswagen engine development can be traced back to a 1912 horizontally-opposed air-cooled overhead valve aircraft engine designed and built by Dr. Ferdinand Porsche in Austria. This great-grandfather of the air-cooled Volkswagen engine shared the same operating principles as the most modern 5 valve per cylinder water-cooled automotive engine.

Both engines are four-stroke reciprocating internal combustion engines and, although a direct comparison cannot be made, the basic operating principles remain the same.

Technology moved the four-stroke engine from magnetos and carburetors, to ignition coils, points, distributors, mechanical fuel injection, hydraulic fuel injection, electronic ignition, electronic fuel injection, and finally to the combined fuel and ignition control of the most modern Motronic engine management systems.

Motronic engine management systems use electronics to precisely monitor and control every aspect of engine operation, thereby improving efficiency, power, and driveability, while at the same time reducing fuel consumption and tailpipe emissions.



**Air-cooled Beetle engine as used from 1963 through 1965.**

<b>Displacement:</b>	1192 cc (72.7 cid)
<b>Compression ratio:</b>	7.0:1
<b>Maximum torque:</b>	82 Nm (61 LbFt) @ 2400 rpm (65 LbFt @ 2400 rpm SAE)
<b>Maximum power:</b>	34 PS @ 3600 rpm (41.5 bph @ 3900 rpm SAE)
<b>Engine management:</b>	Solex 28 PICT carburetor Bosch/VW ignition distributor
<b>Fuel requirement:</b>	76 octane leaded regular gasoline

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**Turbo-charged and intercooled New Beetle engine with 5 valves per cylinder as installed from the 1999 model year.**

<b>Displacement:</b>	1781 cc (108.6 cid)
<b>Compression ratio:</b>	9.5:1
<b>Maximum torque:</b>	210 Nm @ 1750 rpm (155 LbFt @ 1750 rpm)
<b>Maximum power:</b>	110 Kw @ 5800 rpm (150 hp @ 5800 rpm)
<b>Engine management:</b>	Bosch Motronic ME 7.5.1 OBD II
<b>Fuel requirement:</b>	87 AKI unleaded (minimum) 91 AKI unleaded (best perf.)

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# Introduction

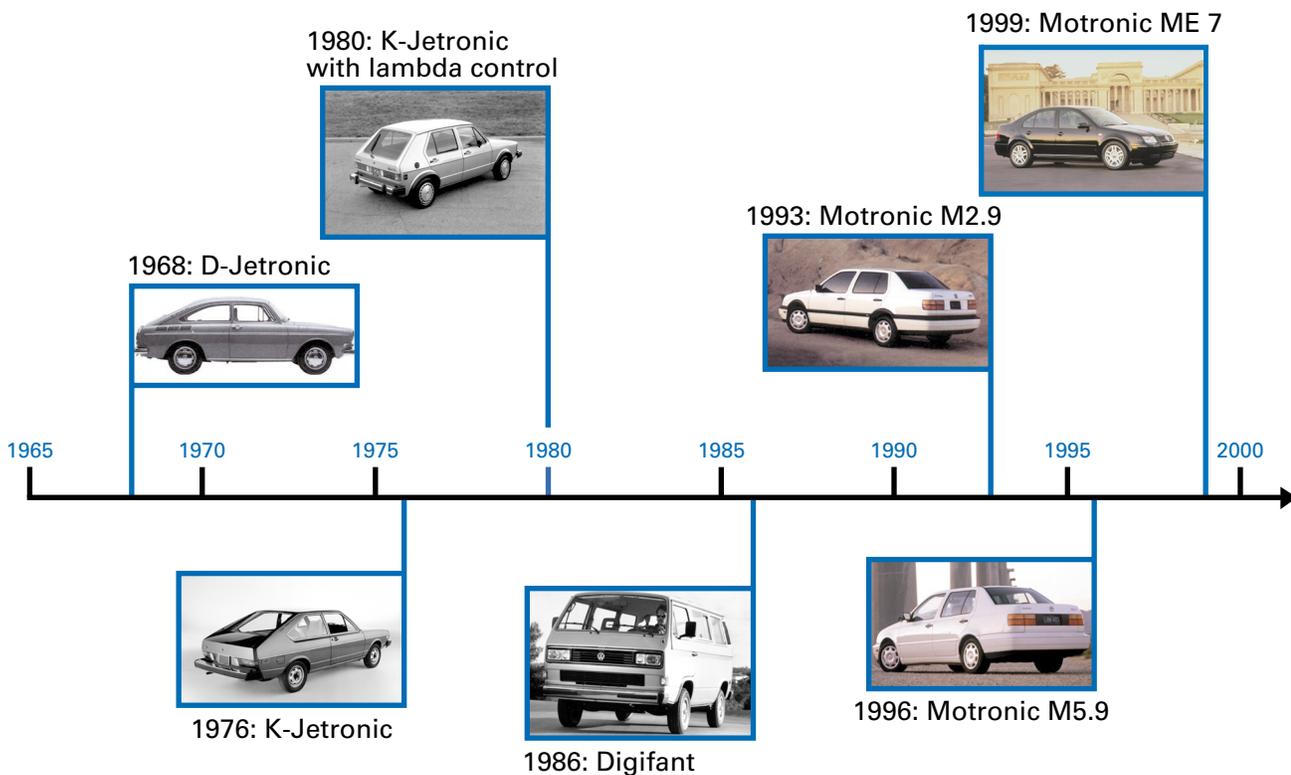
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Motronic engine management systems control engine operation so precisely that it is no longer possible to identify a separate emissions system. All functions previously identified as emissions system functions are now components of Motronic engine management.

The intent of this program is to provide information that will yield a greater understanding of engine management systems commonly in use, and the progression leading to the newest Motronic ME 7 systems.

## Course goals

- Review principles of engine operation
- Explain the progression of engine management systems used by Volkswagen
- Provide an in-depth understanding of both previous engine management systems, and the state-of-the-art engine management systems in use today



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# Principles of engine operation

## Principles of engine operation

### Basic four-stroke principle

An internal combustion engine requires the proper ratios of air and fuel, combined with a properly timed spark for efficient combustion.

Operation of most automotive engines is described in two upward and two downward movements of the piston, called strokes. These four strokes occur during two revolutions of the crankshaft and one revolution of the camshaft. The complete process of cyclic external spark ignition resulting in internal combustion is called the "Otto cycle."

All four-stroke engines operate in the same manner, regardless of the number of cylinders, although an engine with multiple cylinders has more firing pulses, resulting in a smoother running engine.

### Intake stroke (1)

The first phase of engine operation begins with the intake valve opening and the piston moving down into the cylinder. This draws air and atomized fuel into the cylinder.

### Compression stroke (2)

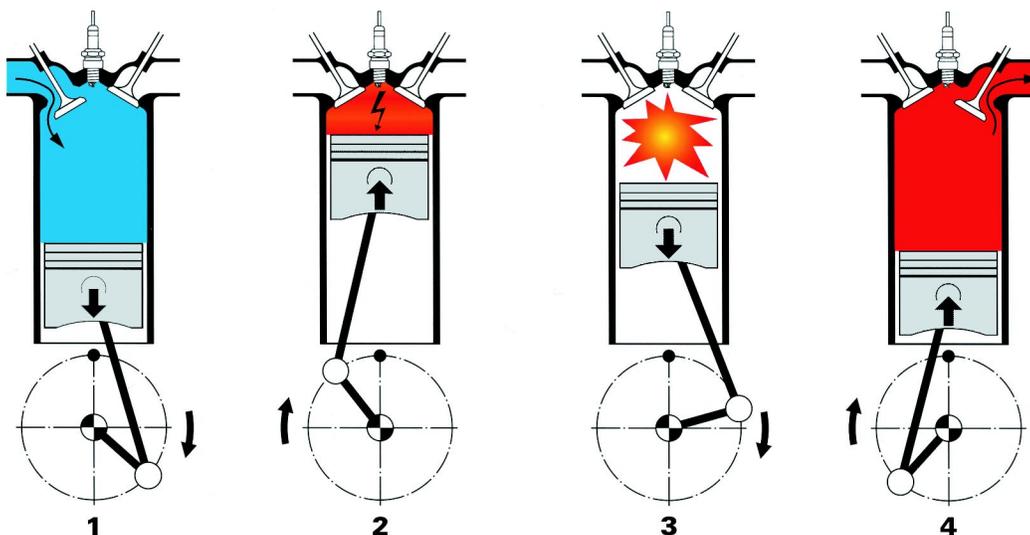
Operation continues with the piston at the bottom of its stroke, and the intake valve closing. The piston moves up in the cylinder, compressing the air/fuel mixture. Near the end of the stroke the air/fuel mixture is ignited by the ignition system.

### Combustion (power) stroke (3)

As the air/fuel mixture burns it expands, creating pressure within the cylinder, pushing the piston down. This provides the motion which turns the crankshaft.

### Exhaust stroke (4)

The exhaust valve opens near the end of the power stroke and the piston moves up. The burned gases are pushed up and out the exhaust port, and the cycle is repeated.



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# Principles of engine operation

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## Mechanical systems

Several support systems are required to make the combustion process occur continuously. The valvetrain operates the valves, the lubrication system supplies the oil, the cooling system removes heat, and the electrical system supplies the voltage. The engine management system delivers fuel and spark to match the air demands of the engine.

Because of heat and drag, the thermal efficiency of a typical gasoline engine is around 25% (approximately one fourth of the heat energy of the fuel is converted into usable engine power).

## Mechanical integrity

The mechanical condition of the cylinder directly influences the combustion process.

Conditions within the combustion chamber can also be influenced by other factors, including:

- Camshaft timing
- Oil pressure
- Restrictions in the intake or exhaust paths

The following diagnostic tests are used to check cylinder condition:

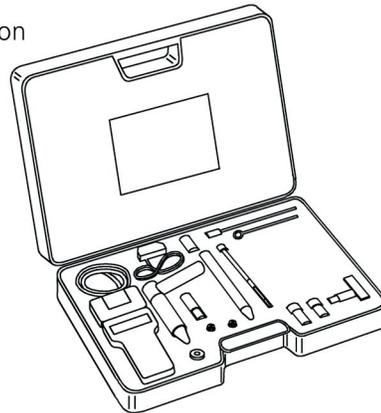
### • Compression test:

This test can be useful in evaluating condition of the piston rings, head gasket and valve sealing ability when used in conjunction with other diagnostic tests.

A compression test requires the removal of all the spark plugs. A pressure gauge is then threaded into the spark plug hole. The engine is cranked while applying Wide Open Throttle (WOT) until the pressure stops increasing. Pressure gauge readings are then compared to factory specifications.

To ensure the accuracy of the test, the engine should be at normal operating temperature.

VAG 1763  
Compression  
test kit



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# Principles of engine operation

## • Cylinder leakdown test

A cylinder leakdown test is especially useful to identify sources of cylinder leakage. As an example, a hissing sound heard at the tailpipe while the test is being performed indicates possible leaking exhaust valves.

A cylinder leakdown test also requires the removal of the spark plugs, but necessitates that the crankshaft be turned so that the piston is at the top of the compression stroke (Top Dead Center or TDC) with both valves closed. A measured amount of compressed air is applied the cylinder through the spark plug hole using a leakdown tester. The pressure of the air in the cylinder is compared to the pressure being applied. A "percentage of leakage reading" is given by the gauge. The reading is compared to adjacent cylinders to determine cylinder condition.

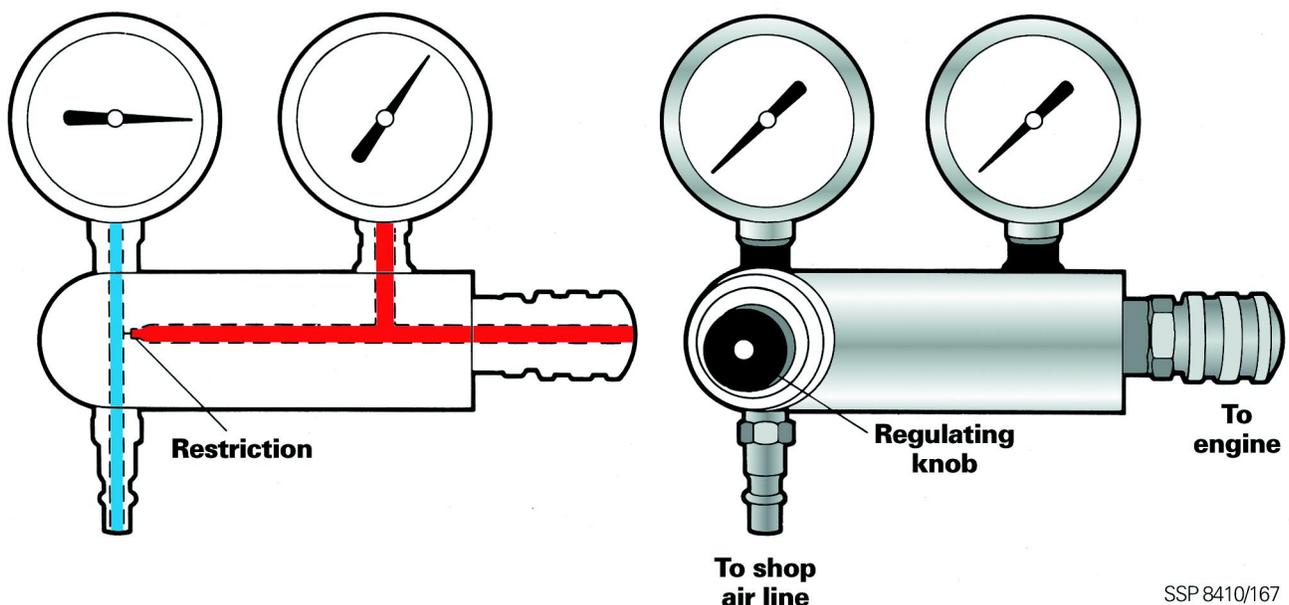
As in the compression test, the engine should be at normal operating temperature to ensure the accuracy of the test.

## Summary

For any combustion process to occur, proper air/fuel mixture and a source of ignition are required. For an internal combustion engine to operate, the air/fuel mixture must be compressed, and the spark must occur at the proper time to create the combustion that is the motive force used to drive the piston.

The mechanical systems must all work together to draw the combustible mixture into the cylinder, to compress it, to extract maximum power from combustion and to expel what remains after the combustion process. These systems work together to provide the support necessary to keep the engine running.

**Cylinder leakdown tester**



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# Principles of engine operation

## Gasoline properties

For the engine management system to allow the engine to operate at peak efficiency and power, the octane rating of the gasoline must be within factory specifications as outlined in the owner's manual.

Octane is a relative measure showing the gasoline's ability to resist self-ignition due to heat and pressure within the cylinder. Self ignition of the fuel is known as knocking (detonation) or pinging (pre-ignition).

- Pinging:  
When the air/fuel mixture ignites before the spark occurs.
- Knock:  
When a pressure wave from spark igniting the fuel creates a secondary combustion, causing the two pressure waves to collide.

Gasoline with higher octane numbers resist temperature and pressure better, and therefore have less tendency to self-ignite.

Several methods of measuring octane are used worldwide. These include the following:

- Research Octane Number (RON); tests resistance to knock at lower engine speeds.
- Motor Octane Number (MON); tests resistance to knock at higher engine speeds.

In an effort to simplify a confusing array of octane numbers, the United States Government enacted legislation requiring the posting of a number on the dispensing pump reflecting the minimum octane number as determined by the Cost of Living Council (CLC).

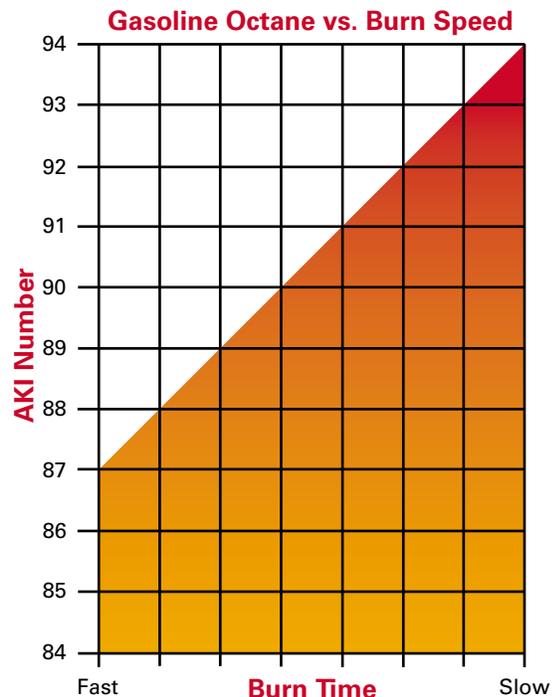
The CLC number is derived from both the RON and the MON as follows:

$$\frac{\text{RON} + \text{MON}}{2} = \text{CLC}$$

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The CLC number was later changed to the Anti-Knock Index (AKI) number. Gasolines identified as "regular" generally have an AKI number of around 87, while gasolines identified as "premium" generally have an AKI number around 92.

AKI numbers apply to gasoline that is freshly pumped. Gasoline that is exposed to the air for extended periods of time undergoes a decrease in AKI number due to evaporation and oxidation.



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# Principles of engine operation

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Modern pump gasoline contains a wide variety of additives to help obtain optimal engine and fuel system operation. The additive package added to the base gasoline will include at least the following:

- Anti-aging additives
- Intake contamination inhibitors (detergents)
- Corrosion inhibitors
- Icing protection
- Anti-knock additives

Different concentrations of additives, along with other blending considerations, are used according to market and seasonal demands.

All Volkswagen Owner's Manuals list recommended fuel grade specifications, along with notes on the use of fuels containing methanol, ethanol and MTBE (methyl tertiary butyl ether).

- Octane must be between 87 AKI and 93 AKI, but exact requirements depend on model and year.
- MTBE is blended with gasoline and sold in some areas of the country as oxygenated fuel to help reduce tailpipe emissions. This fuel can be used as long as specific percentage requirements are maintained and octane minimums are met.
- Methanol and ethanol are types of alcohol commonly mixed with gasoline. Fuel with these additives can be used as long as specific percentage requirements are maintained and octane minimums are met. These requirements vary from year to year.

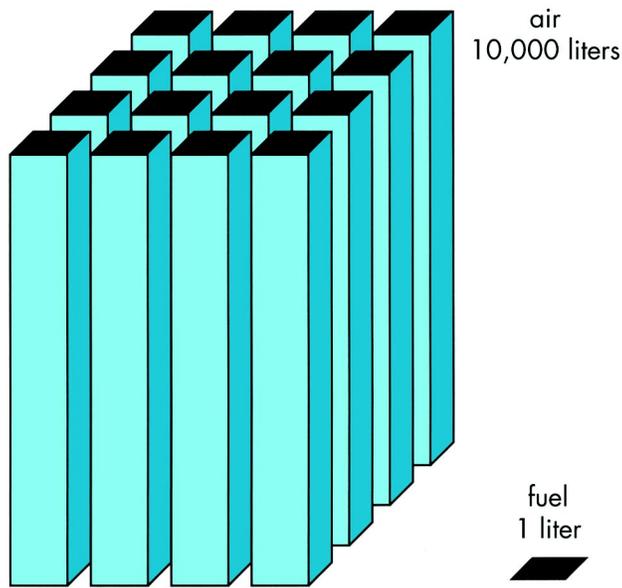
The combustion process is dependent on the correct grade and quality of gasoline. If gasoline sits for an extended period of time, the octane can evaporate from the fuel, creating a varnished residue. This can restrict injector flow and fuel pump/fuel line performance. This can lead to hard starting, reduced performance and no code driveability complaints.

**Note:**

*MTBE has been identified by the Government as a possible carcinogen and is being phased out in automotive use.*

# Principles of engine operation

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Air required for proper combustion of 1 liter of gasoline.

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## **Definition:**

A **rich** mixture contains more fuel than air in relation to the stoichiometric ratio.

A **lean** mixture contains more air than fuel in relation to the stoichiometric ratio.

## **Air/fuel mixture formation**

The function of the fuel system is to deliver the correct air/fuel mixture to the engine.

The optimal air/fuel ratio for complete combustion is 14.7 parts air to 1 part fuel by mass. This is referred to as the **stoichiometric ratio**.

Mixture corrections must be made as required to satisfy the differing engine demands encountered under any given driving condition.

Engine operating conditions include:

- **Idle:**  
For a smooth and efficient idle, the air/fuel mixture must be 14.7:1 (stoichiometric ratio).
- **Part throttle:**  
Most automotive engines spend the largest part of their operational life running at part throttle and fuel delivery is calibrated to yield minimum consumption (maximum economy).
- **Full throttle:**  
Mixtures containing a higher proportion of fuel (richer) provide more power at the expense of economy.
- **Transition:**  
Both gradual and sudden changes in engine speed and load require instantaneous mixture correction. Transition from open to closed throttle plate tends to give a higher proportion of fuel, whereas transition from closed to open tends to give a higher proportion of air.
- **Cold start:**  
During cold start and warm-up phases of engine operation, the fuel condenses on the cold cylinders, creating a lean condition, resulting in incomplete combustion. To counteract this, the fuel mixture is enriched.

# Principles of engine operation

The fuel system must be able to quickly respond to and satisfy these widely varying operating conditions.

The air/fuel mixture is referred to by the Greek letter  $\lambda$  (Lambda), and is generally referencing the air factor in the ratio. Listed below are several common  $\lambda$  operating ranges:

- $\lambda = 1$ : mixture is optimum (stoichiometric).
- $\lambda < 1$ : mixture is rich (lacking air) typically in the range  $\lambda = 0.85$  to  $0.95$ .
- $\lambda > 1$ : mixture has an excess of air; a lean mixture typically in the range  $\lambda = 1.05$  to  $1.30$ .
- $\lambda > 1.30$ : mixture has too much air to support consistent combustion.

On an engine at normal operating temperature, it is important to maintain  $\lambda = 1$ . This allows for optimal catalytic converter operation (although in actual practice,  $\lambda$  factors between  $0.9$  and  $1.1$  provide the best engine operation).

Because of the importance of the fuel mixture under a variety of operating conditions, the air/fuel mixture must be adapted constantly. In modern fuel systems, a feedback loop using oxygen sensors for the primary input is used for this adaptation.

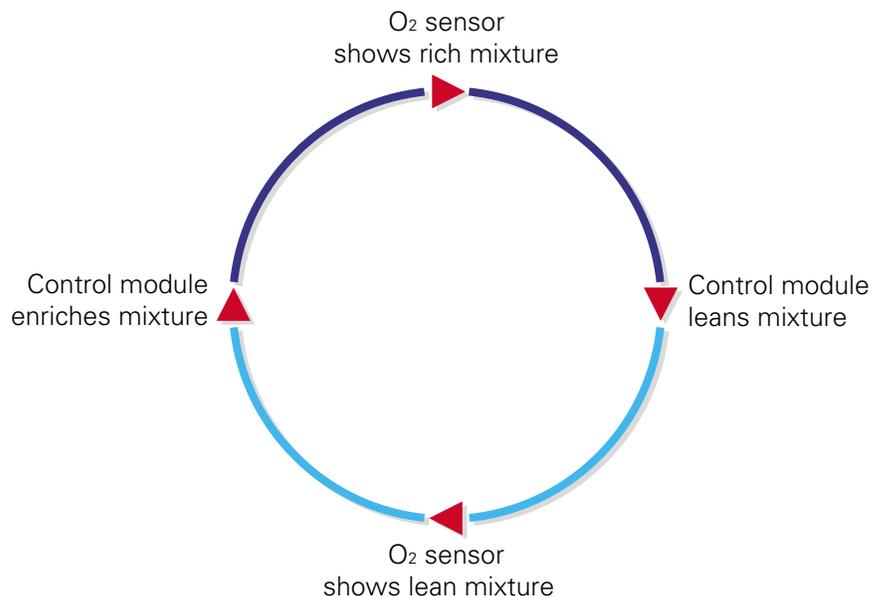
The period of time after an engine start when the oxygen sensor is not at operating temperature, and therefore not used, is called **open loop operation**. This condition can occur after either a cold or warm start. Conversely, engine operation with a valid oxygen sensor signal is called **closed loop operation**.

For more information on open loop operation and closed loop operation, please refer to the glossary.

## **Note:**

*For more information regarding oxygen sensor function, refer to the Motronic M2.9 component overview.*

## Closed Loop Operation



# Principles of engine operation

## Fuel system, overview

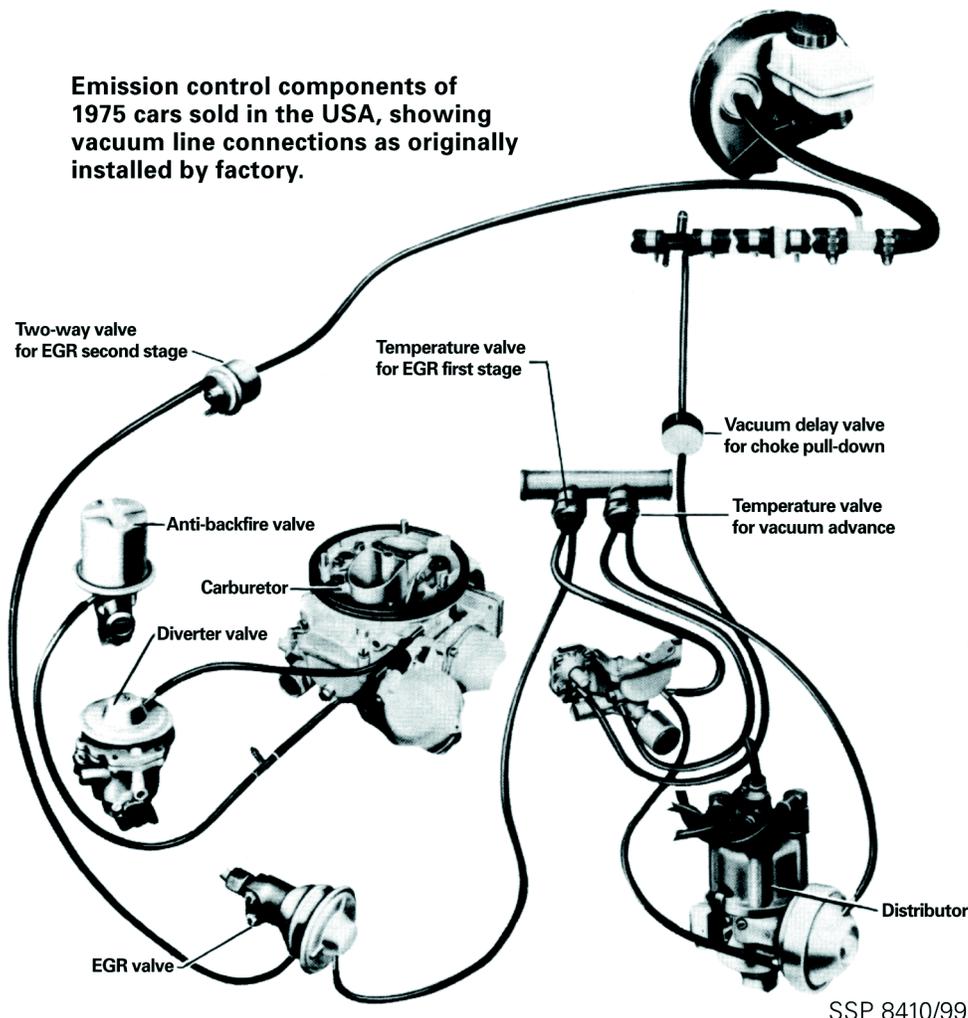
The fuel system is made up of numerous individual components. The purpose of these components is to insure delivery of the correct air/fuel mixture formation to the engine at the correct time.

Components such as fuel pumps and carburetors represented the state-of-the-art technology in early systems, but mechanical limitations prevented further development.

Although advantages of these systems include simplicity and relatively low cost, disadvantages are frequent maintenance, poor emissions, relative inefficiency, and the inability to be self-diagnosing.

Due to limited interaction between individual components, control of fuel delivery was not precise enough to meet modern standards.

The advent of solid-state electronics allowed improvements in many fuel system areas. Sensors were able to provide information on current engine operating conditions. A central control unit would then process the data, make the calculations, and signal the appropriate actuators that would, in turn, run the engine. This level of control far exceeded the abilities of a carburetor and its related mechanical systems, and led to widespread use of fuel injection.







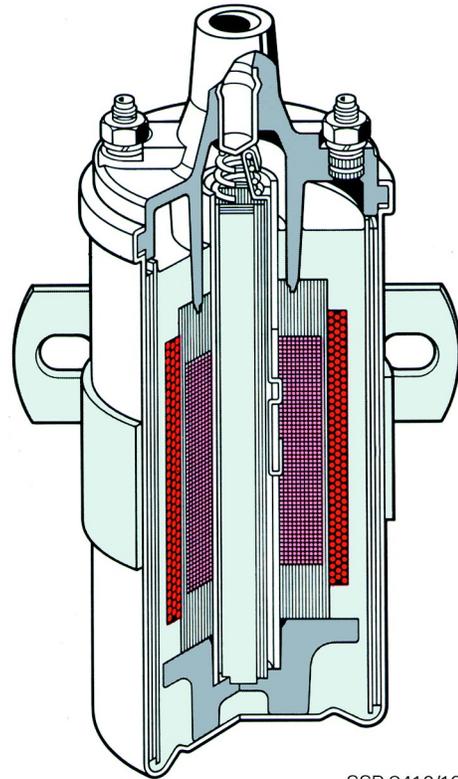
# Principles of engine operation

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Simply stated, the ignition coil is a step-up transformer switched on and off by the trigger unit.

The high voltage generated by the ignition coil is distributed to each spark plug in the proper order through the distributor cap as the distributor shaft turns. At the spark plug, the high voltage causes an electrical spark to arc from the center electrode to the Ground electrode and spark plug threads.

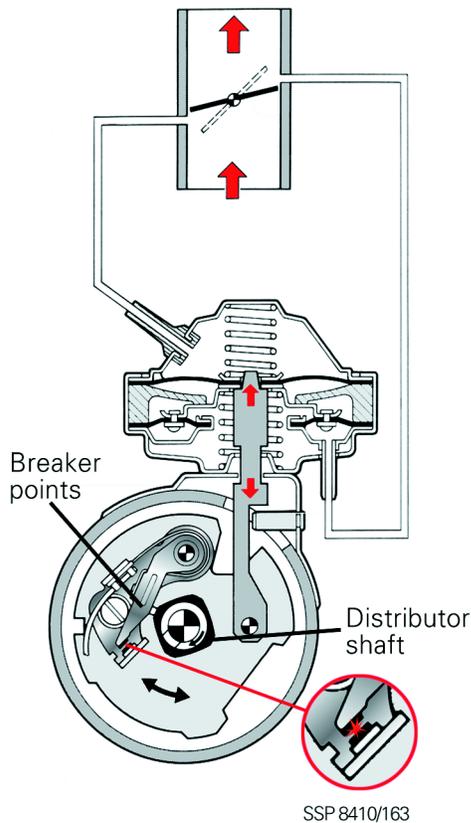
The period of time that the negative side of the coil is grounded (points remain closed) is referred to as **dwell**. Dwell is the length of time the primary winding can generate a magnetic field. The longer the dwell time, the stronger the magnetic field. This results in a higher secondary voltage (stronger spark).



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# Principles of engine operation

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In a **breaker point style ignition system**, the ignition points are mounted to a movable mechanism in the distributor called the breaker plate. They are switched on and off by the action of a rubbing block working against lobes of a cam on the distributor shaft. The distributor shaft turns at the same speed as the camshaft ( $1/2$  crankshaft speed). A condenser (also called a capacitor), is connected in parallel with the ignition points, and acts as a filter to prevent point arcing.

The inherent drawback to the breaker points system is mechanical wear (requiring periodic maintenance). To eliminate this, the **solid state ignition system** was developed. By replacing the ignition points with a Hall sender, more consistent and reliable ignition system performance was attained.

The **Hall sender** is a solid-state, semi-conduc-

# Principles of engine operation

tor device mounted in the distributor housing. A rotating trigger wheel is passed between a magnet and a Hall-effect transistor (see Glossary). Windows in the trigger wheel allow the Hall-effect transistor to be exposed to the magnetic field causing current to flow through the transistor. When a shutter wheel vane blocks the magnetic field to the Hall-effect transistor, current flow stops.

Operating voltage is supplied by either an igni-

tion control module or the engine control module. Through these control modules, the Hall sender switches off the ignition coil when current flows (exposed) and on when there is no current flow (blocked).

Advantages include:

- High speed switching
- No mechanical wear
- No maintenance

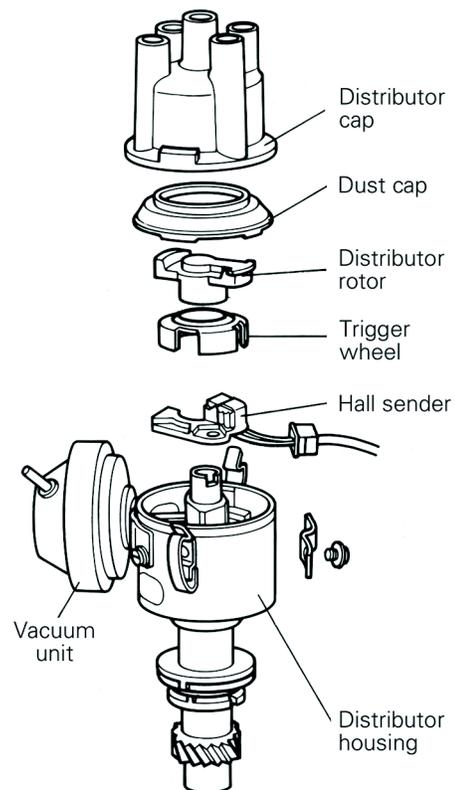
The accompanying table highlights the performance advantages.

Advantages of Hall Sensor vs. Breaker Point Ignition

	Hall-effect ignition	Breaker point ignition
Available voltage	25,000 volts	18,000 volts
Primary current capacity	7.5 amps	3.5 amps
Secondary coil energy	80 mWs	30 mWs
Spark duration at plug	3.4 ms	3.2 ms

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Newer engine management systems take the Hall signal a step further, and combine it with computer control to provide even more precise spark control.



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# Principles of engine operation

## Ignition advance

It takes approximately 2 milliseconds (0.002 seconds) from the start of mixture ignition to complete combustion. This time remains consistent for all engine speeds, but the time available for the process to occur is reduced as engine speed increases (the piston is moving faster). For this reason, spark must be generated sooner.

The process of starting the ignition spark sooner in the cycle is called ignition advance. Ignition advance must be adjusted to account for wide variations in engine operating conditions, with primary concern given to engine speed and engine load.

At idle, the start of combustion can occur near the top of the compression stroke. This allows maximum combustion pressure to push the piston down during the power stroke.

As engine speed increases, the spark must be generated sooner, so that maximum cylinder pressure will continue to occur as the piston starts down on the power stroke.

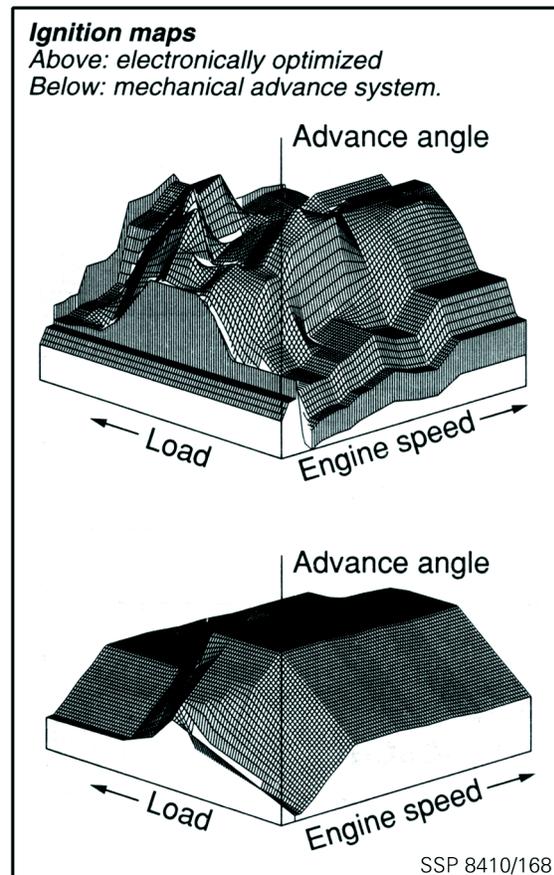
In the basic ignition system described previously, the cam which operates the breaker points is connected to a mechanism where centrifugal fly-weights move the cam's position in relation to points position in the distributor.

This allows the spark timing to change with engine speed. The faster the engine speed, the sooner the spark occurs.

The breaker plate is also attached to a vacuum diaphragm. This allows the spark timing to change in relation to an engine vacuum signal that changes with engine load.

### **Note:**

*Spark ignition engines produce the greatest power, and are the most efficient, when ignition occurs just before the point of detonation.*



## Spark plugs

Spark plugs represent the end component in the ignition system. They must endure the high temperatures and pressures of the combustion chamber for millions of ignition operating cycles without failure.

An important characteristic of any spark plug is its ability to dissipate heat. Classifications exist for hot or cold or anywhere in between.

A **cold** spark plug is a one that transfers the heat from the combustion process rapidly through the threads to the head and cooling system.

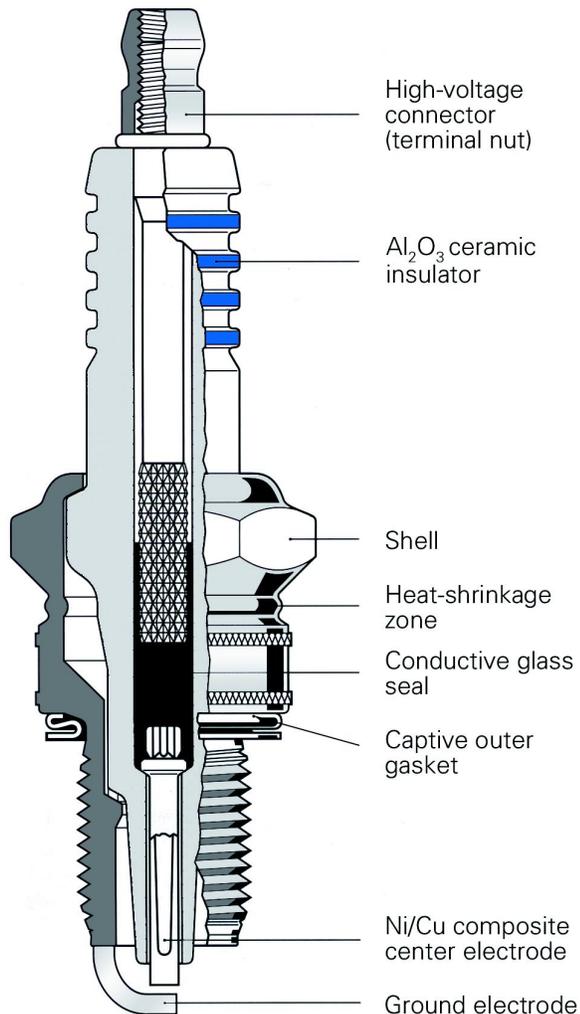
A **hot** spark plug is a one that transfers the heat from the combustion process slowly through the threads to the head and cooling system.

Different engine types require spark plugs with different physical characteristics, as well as electrical characteristics, and are supplied by several different manufacturers. Since spark plug characteristics are specified for each particular engine type by the factory, it is advisable to stay within these recommendations.

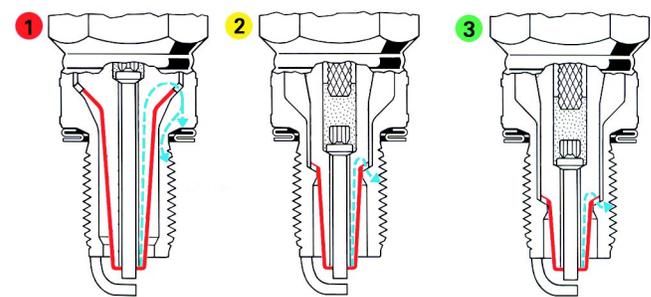
For the heat transfer process to the cylinder head to be effective, the spark plug must be properly torqued into a cold cylinder head (refer to VESIS).

### Note:

*To ensure the integrity of the ground through the threads, anti-seize or similar products should never be applied to the spark plug before installation.*



- 1 Spark plug with high heat-range code number ("hot plug"). Large insulator nose area absorbs much heat, low heat dissipation.
- 2 Spark plug with medium heat-range code number. Insulator nose area smaller than in "hot plug". Lower heat absorption, better heat dissipation.
- 3 Spark plug with low heat-range code number ("cold plug"). Smaller insulator nose area absorbs little heat. Very good heat dissipation through short thermal conduction path.



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# Principles of engine operation

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## Emissions system, overview

Air quality has been an environmental concern for many years. Pollution from numerous sources, combined with atmospheric conditions, resulted in the degradation of air quality in many of the industrialized areas of the world. The State of California recognized that automobile emissions contributed significantly to the rising levels of pollution, and enacted legislation to establish air quality standards for motor vehicles. Other states continue to adopt California emissions standards.

The first emissions requirement was to control crankcase emissions through Positive Crankcase Ventilation (PCV). The 1963 Type I Beetle engine pictured on page 1 shows compliance with this requirement. This is the first Volkswagen emission controlled engine.

Federal and state clean air legislation continued to be passed with California leading the rest of the nation. In an effort to reduce exhaust emissions, various parts of the fuel and ignition systems were modified.

New systems were added and existing systems were modified to reduce tailpipe and crankcase emissions. Systems were also added to reduce emissions from the fuel tank and vent system.

A basic emissions system may have the following components:

- Throttle positioners and dashpots
- Exhaust gas recirculation
- Oxidation catalytic converters
- Oxygen sensors
- Secondary air injection
- Intake air pre-heating
- Evaporative emissions (fuel tank)
- Crankcase emissions

# Principles of engine operation

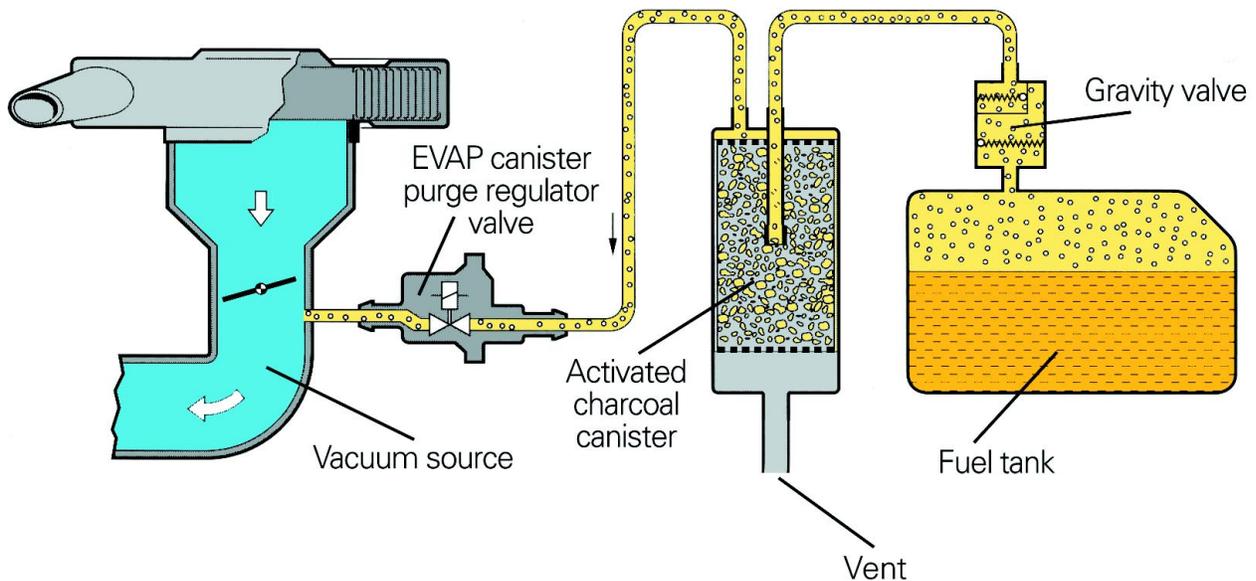
It was soon clear that a more advanced means of managing fuel, air and ignition was needed to meet the changing Federal and State emissions requirements and fuel economy standards. Excellent driveability, performance and economy had to be maintained, and at the same time ensuring low exhaust emissions.

Testing indicated that fuel vapor escaping into the atmosphere contained more hydrocarbons than the exhaust emissions of the vehicle. As a result, the Evaporative Emissions (EVAP) return system was added to minimize the amount of fuel vapor released.

Vapors are stored in a charcoal canister, and then passed along via the EVAP canister purge regulator valve to the engine to be consumed in the combustion process.

Current Motronic engine management systems also use a Leak Detection Pump (LDP) to pressurize the evaporative return system to insure the integrity of the system (checks for leaks). Fuel vapors that escape to the atmosphere are reduced to a minimum. Systems after 1998 include On Board Refueling Vapor Recovery (ORVR) systems to control fuel vapor emissions during refueling.

All of these efforts are contributing to the reduction of harmful pollutants that escape into the atmosphere. For more information see SSP 841903, *EVAP Systems, Operation and Diagnosis*.



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# Principles of engine operation

## Three-way Catalytic Converter, overview

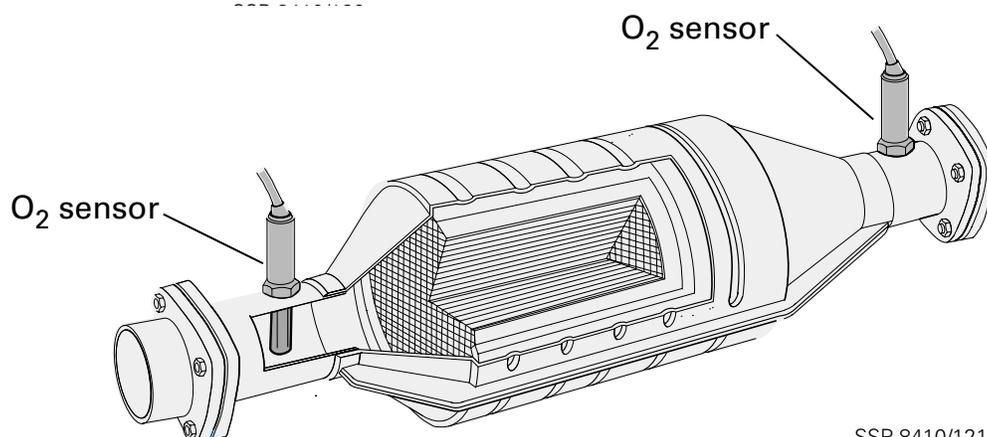
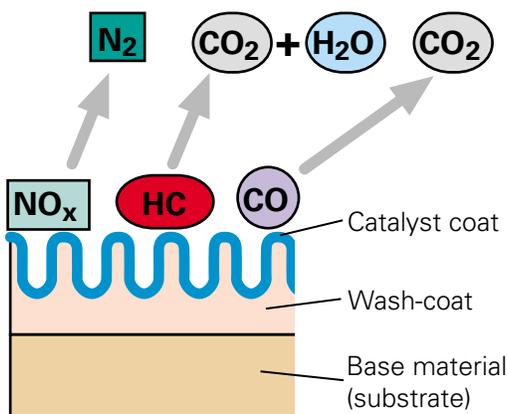
The catalytic converter is a major component in exhaust emission control “downstream” of the combustion process. Development and common usage of this device began with open-loop versions of carburetor and fuel injection systems in the 1970s. Closed loop engine management systems required by current legislation in the United States and Canada insure that almost all internal combustion engines are equipped with this important component.

A catalyst, by chemical definition, is any substance that promotes, accelerates, or initiates a chemical reaction without being consumed in the reaction itself. In the case of the automotive catalytic converter, the active catalyzing agents are platinum, rhodium, and/or palladium.

For maximum efficiency, the internal surface area exposed to the exhaust flow must be as large as possible. For that reason, the catalyzing agents are deposited by evaporation onto a ceramic or metallic sub-structure called a monolith. The monolith is a long-channel honey-comb shaped structure with a large surface area contained in a high temperature steel housing. The surface area is increased even more through a process where a “wash-coat” is applied. Other types of converters are used by other automotive manufacturers, but all Volkswagens use the ceramic or metallic monolith design.

Catalytic converters operate most efficiently at high temperatures and are usually placed in the exhaust stream as close to the engine as possible.

A modern three-way catalytic converter is so named because it takes the three major automotive pollutants and reduces and oxidizes them into relatively harmless substances that do not contribute to air pollution.



SSP 8410/121

## Catalytic Converter Operation

The three-way catalytic converter takes the major exhaust pollutants of:

- $\text{NO}_x$  (nitrous oxides- several)
- HC (hydrocarbons)
- CO (carbon monoxide)

and breaks them down into their component chemicals through a two-part process.

The first part of the operating process is the catalytic reduction of the  $\text{NO}_x$  component.

This phase reduces the nitrous oxides to their basic elements of nitrogen and oxygen. Since the air we breath is roughly 78% nitrogen, this is an acceptable result. The liberated oxygen is roughly 21% of the air and it too, is acceptable. However, the oxygen remains in the converter where it is used for the oxidation part of the process.

The second part of the operating process is the catalytic oxidation of the HC and CO components. This phase combines the oxygen from the previous phase with the oxygen already contained in the monolith to produce water and carbon dioxide. Both of these compounds are essentially harmless.

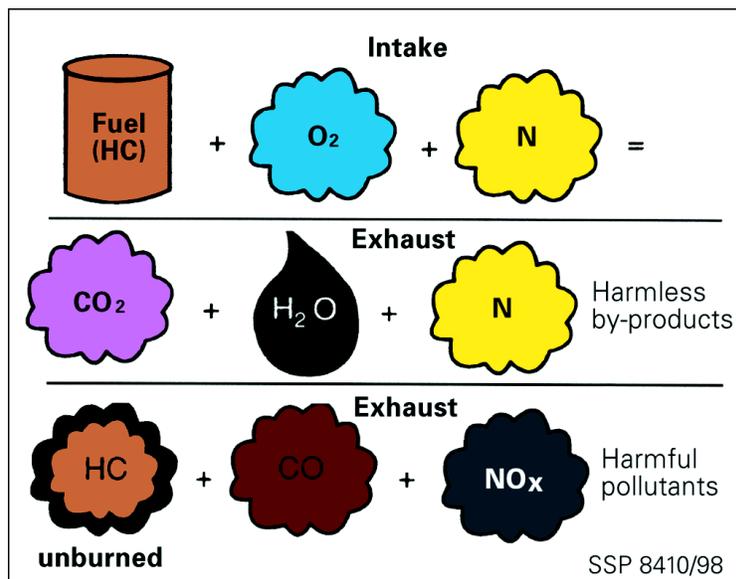
The output from a normally operating three-way catalytic converter consists primarily of:

- $\text{N}_2$  (nitrogen)
- $\text{CO}_2$  (carbon dioxide)
- $\text{H}_2\text{O}$  (water)

The reduction process is most efficient in a low  $\text{O}_2$  environment, and the oxidation process is most efficient in a high  $\text{O}_2$  environment.

It is the job of the engine management system to regulate the exhaust gas mixture to obtain the optimum environment for the reduction and oxidation process to occur. For maximum efficiency within the converter, lambda ( $\lambda$ ) must be at 0.99 or 1.00 for both reactions. This operating range is referred to as the lambda ( $\lambda$ ) window.

The data required for this closed-loop control process is provided by the oxygen sensors (illustration SSP 8410/121 on previous page). Oxygen sensor functionality varies by engine management system. Please refer to the appropriate chapter for system specific oxygen sensor information.



# Principles of engine operation

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## On Board Diagnostics

On Board Diagnostic (OBD) capability allows the Engine Control Module (ECM) to recognize faults that could indicate a problem with a component or associated wiring. When a fault is recognized, a Diagnostic Trouble Code (DTC) will be stored in DTC memory.

Current federal regulations require that any fault that affects exhaust emissions, or the monitoring of exhaust emissions, sets a Diagnostic Trouble Code (DTC), and illuminates a Malfunction Indicator Light (MIL) to alert the operator of an emissions related failure.

## Engine Control Module (ECM) fault recognition

Volkswagen engine management systems have the ability to diagnose and identify several different component failure conditions, including:

- Short circuit to Battery Positive (B+)
- Open circuit/Short circuit to Ground

Systems complying with OBD II regulations also identify implausible signals. An implausible signal is a reading that is considered out of range for operating conditions. This is covered in the OBD II section of this SSP.

ECM inputs (sensors) and outputs (actuators) are powered in one of two ways:

- The ECM supplies a ground signal and the B+ is supplied from the fuse/relay panel.
- The ECM provides a reference voltage and monitors the voltage drop across the sensor's resistance (e.g. engine coolant temperature sensor).

# Principles of engine operation

## Component Ground controlled via ECM

The following examples illustrate a solenoid valve in a circuit that receives a constant 12 Volt source from the fuse/relay panel with component Ground controlled via the ECM.

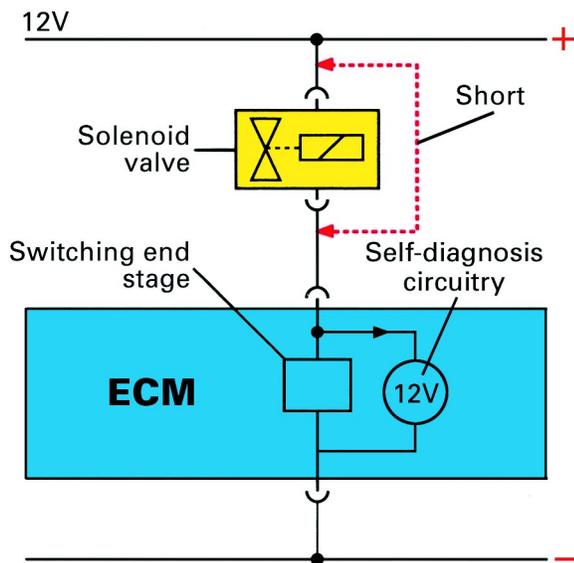
Normal operation of the component is checked by the self diagnosis circuitry in the ECM. The ECM monitors the voltage drop. This will change from 12V when the solenoid is in-active (open circuit voltage) to approximately 0V when the solenoid is active (voltage drops across the consumer). If the self-diagnosis circuitry does not see the correct voltage drops during operation of the component, the appropriate DTC is stored.

## Short circuit to B+

If a short circuit exists in the wiring harness, harness connector, or in the component itself, the input to the ECM is a constant positive voltage. The ECM recognizes this as an abnormal condition, and a DTC is stored.

Scan tool display:

- Short circuit to positive (B+)



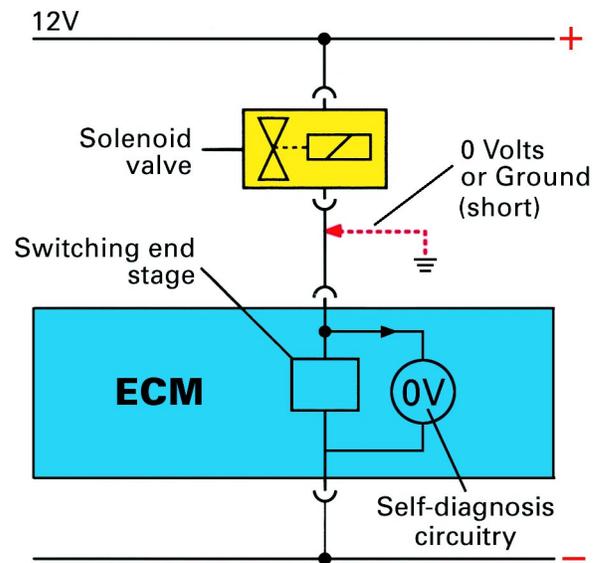
SSP 8410/112

## Open circuit/Short circuit to Ground

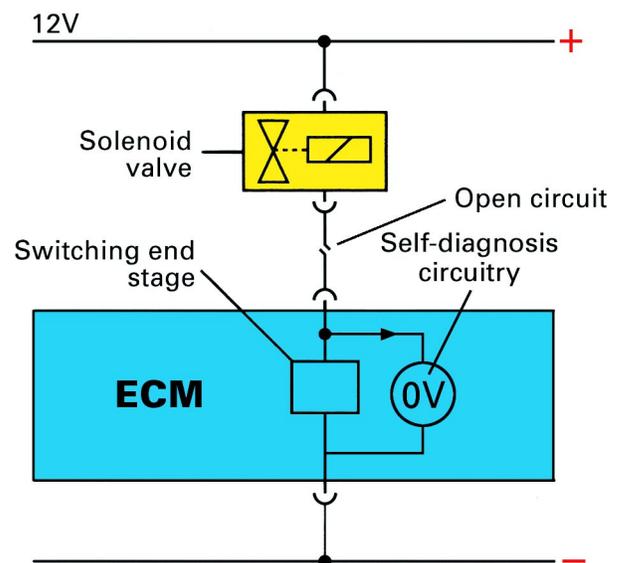
If an open or short circuit exists in the wiring harness, harness connector, or in the component itself, the input to the ECM is a constant Ground (0 Volts). The ECM recognizes this as an abnormal condition, and a DTC is stored. To determine the exact failure, additional testing is required.

Scan tool display:

- Open circuit/ Short circuit to Ground



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# Principles of engine operation

## Component power (B+) controlled via ECM

The following examples illustrate a temperature sensor in a circuit that receives a constant 5 Volt reference source from the ECM. It also can receive a Ground from a variety of sources for signal accuracy. In this type of circuit, as the temperature changes the resistance changes, resulting in a varying voltage drop across the sensor.

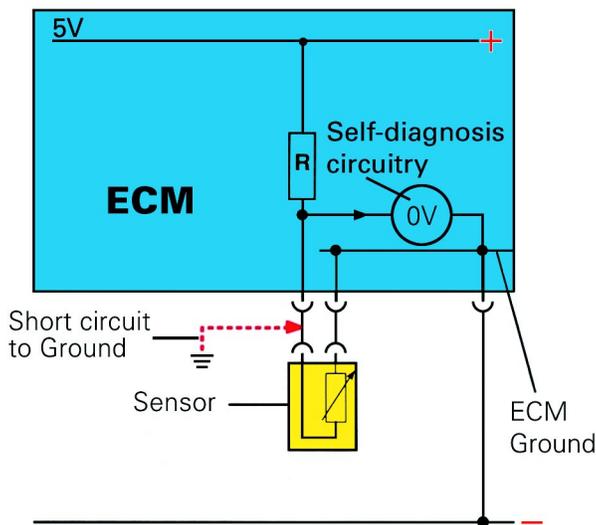
During normal operation the self diagnosis circuitry monitors the 5V reference and the voltage drop across the component. The ECM "watches" for a valid signal, which varies by component, but will not equal either 0 or 5 Volts. If Battery +, Ground or the 5V reference is seen by the ECM, an appropriate DTC is set.

### Short circuit to Ground

A break in the wiring harness insulation short circuits the 5 Volt output to Ground. The input to the ECM is a constant Ground (0 Volts). The ECM recognizes this as an abnormal condition, and a DTC is stored.

Scan tool display:

- Short circuit to Ground



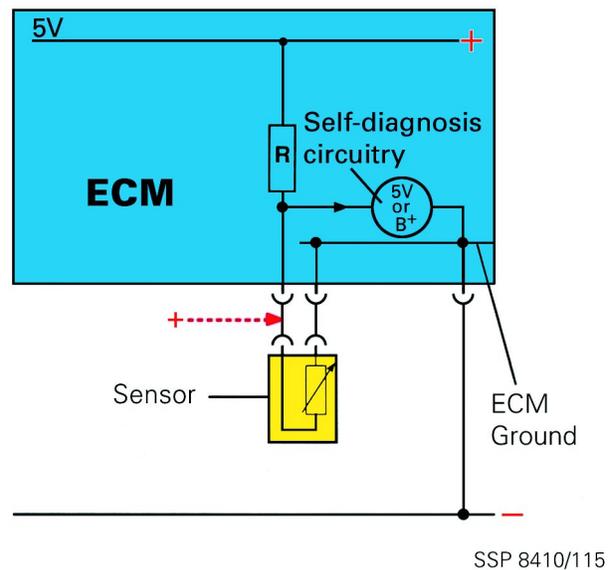
SSP 8410/114

## Open circuit/Short circuit to B+

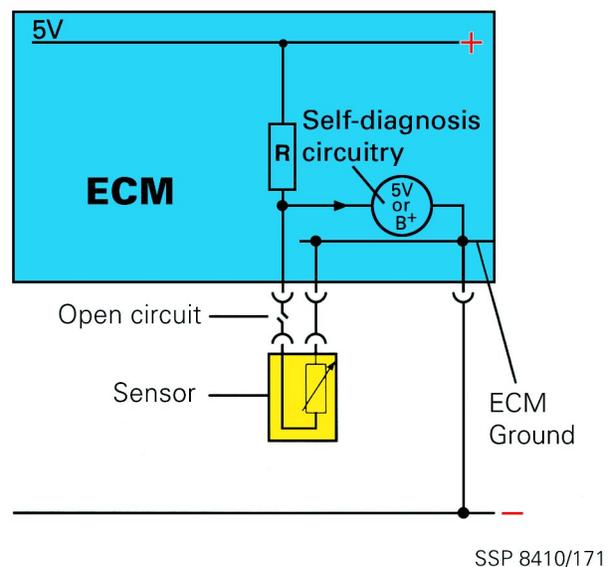
If an open or short circuit exists in the wiring harness, harness connector, or in the component itself, the input to the ECM is a constant 5 Volts. The ECM recognizes this as an abnormal condition, and a DTC is stored.

Scan tool display:

- Open circuit/ Short circuit to B+



SSP 8410/115



SSP 8410/171

# Principles of engine operation - Review

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## Review

1. Technician A says that Motronic engine management systems can identify short circuits to positive with some system components.

Technician B says that Motronic engine management systems can identify short circuits to Ground with some system components.

Which Technician is correct?

- a. Technician A only
- b. Technician B only
- c. Both Technician A and Technician B
- d. Neither Technician A nor Technician B

2. Which of the following is **NOT** an operating requirement for efficient operation of the Three Way Catalyst?

- a. High operating temperature.
- b. Lambda ( $\lambda$ ) window of 0.99 to 1.00.
- c. Gasoline without lead or lead compounds.
- d. Gasoline with a minimum octane of 87 AKI.

3. In the four-stroke gasoline engine, the camshaft turns at what speed in relation to the crankshaft?

- a. Twice crankshaft
- b. Same as crankshaft
- c.  $\frac{1}{4}$  crankshaft
- d.  $\frac{1}{2}$  crankshaft

4. Which of the following components is **NOT** a component of gasoline's ability to pre-ignite?

- a. Research octane number
- b. Motor octane number
- c. Cetane
- d. Anti-knock index

5. Which of the following is **NOT** a component failure condition recognizable by the scan tool?

- a. Short circuit to positive
- b. Short circuit to neutral
- c. Short circuit to Ground
- d. Open circuit

6. Technician A says that the ignition coil is part of both the primary and the secondary sides of the ignition system.

Technician B says that the distributor rotor is part of the primary side of the ignition system.

Which Technician is correct?

- a. Technician A only
- b. Technician B only
- c. Both Technician A and Technician B
- d. Neither Technician A nor Technician B

7. Which of the listed exhaust by-products is **NOT** harmful to the atmosphere?

- a. Hydrocarbons (HC)
- b. Oxygen ( $O_2$ )
- c. Carbon monoxide (CO)
- d. Oxides of Nitrogen ( $NO_x$ )



## K-Jetronic/CIS

In 1976, Volkswagen introduced Bosch K-Jetronic, or CIS, fuel injection on the Dasher model. This early hydro-mechanical fuel system provided efficient and consistent running characteristics.

Continuous Injection System (CIS) operates by controlling fuel flow rates and variable pressures to the fuel injector. As the name implies, the fuel injectors are constantly injecting fuel. When the intake valve is closed, the fuel is stored in the intake port. Opening the valve allows the stored fuel to be pulled into the cylinder.

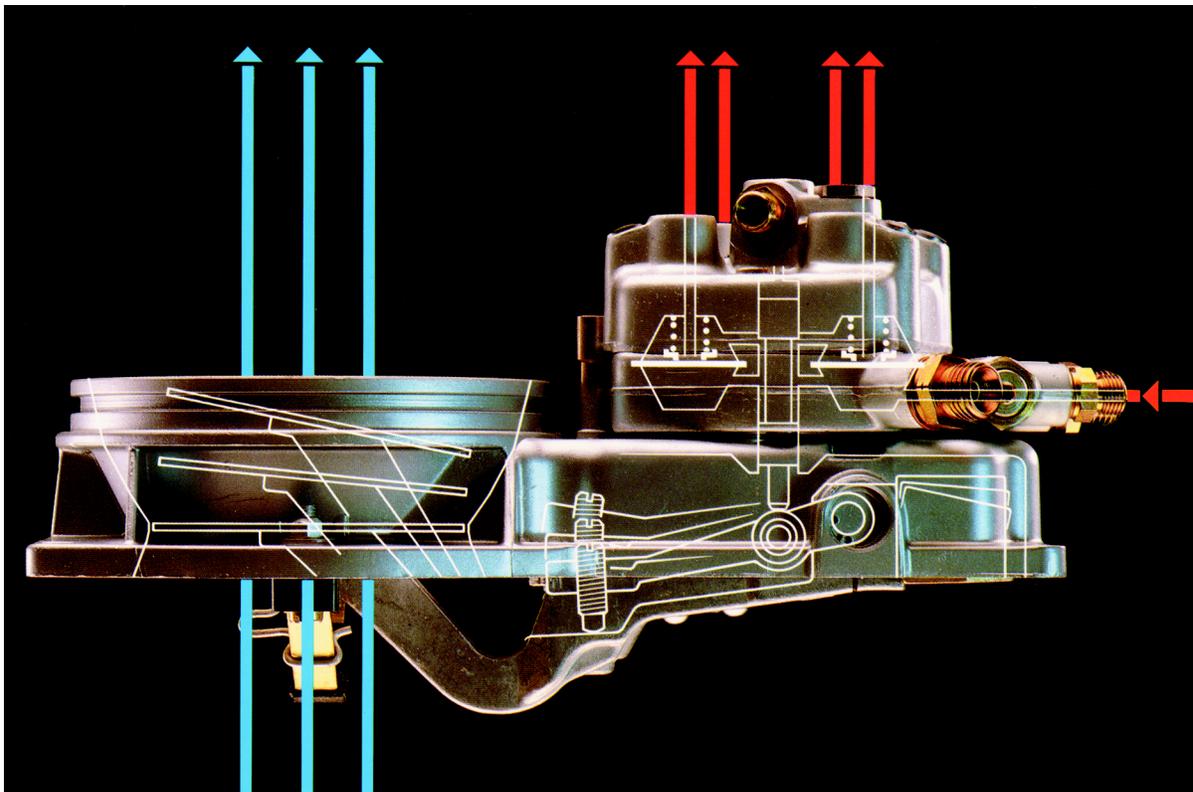
Fuel for the injectors is provided by the fuel distributor. This component is directly linked to the air flow sensor. Any increase in airflow provides a proportional increase in fuel flow to the injectors.

Fuel pressure is controlled by a control pressure regulator, or warm-up regulator.

The control pressure regulator supplies pressure to the top of the control plunger, and depending on how much pressure is applied, will create a resistance for the plunger to rise, affecting the fuel mixture.

### **Example:**

*On a cold start, control pressure is 0.5 bar. As a result, there is little resistance for the plunger to rise with movement of the air flow sensor. As operating temperature rises, control pressure increases to 3.7 bar, hence there is greater resistance, resulting in a leaner fuel mixture.*



SSP 8410/201

# K-Jetronic

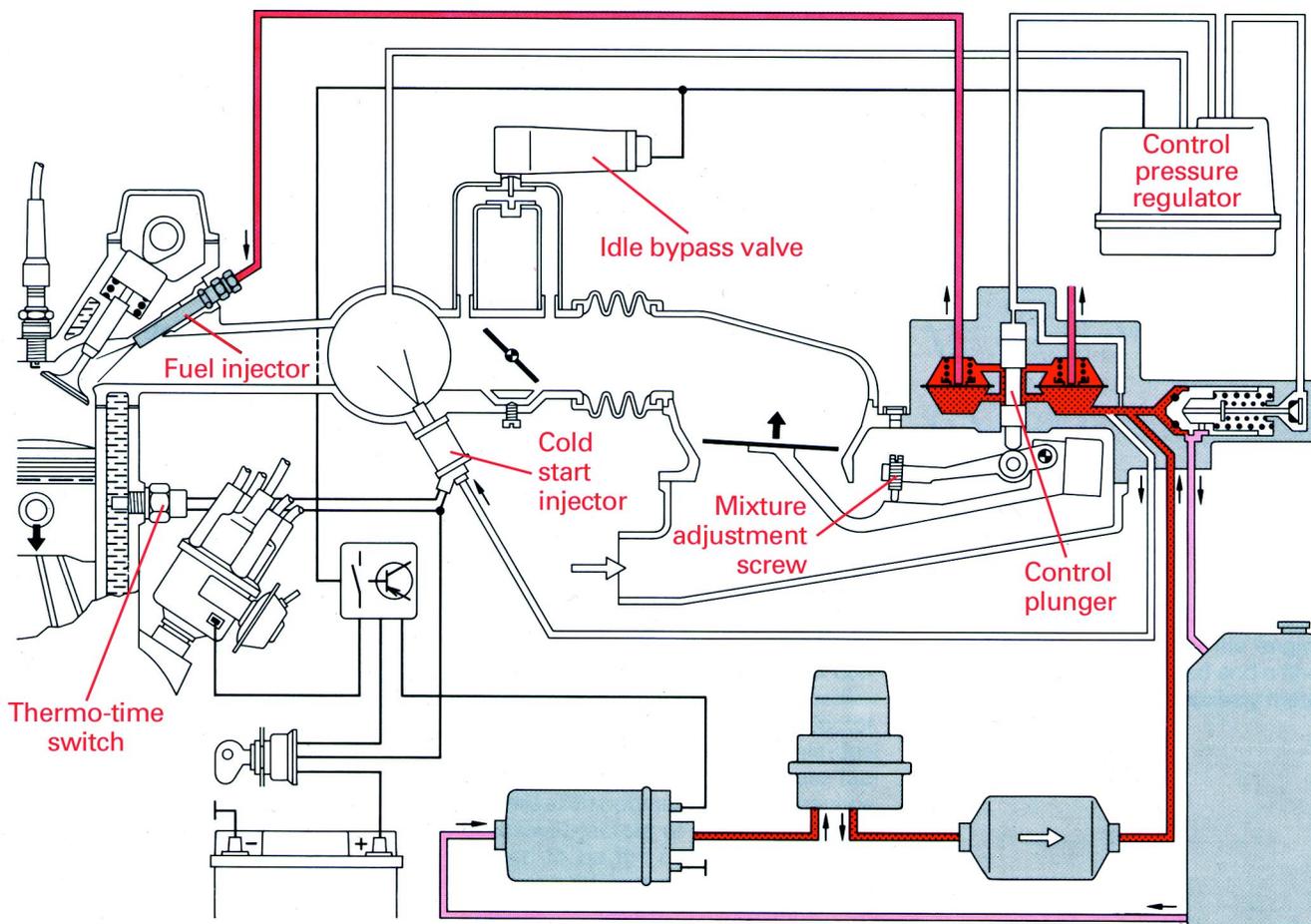
Baseline air/fuel mixture is accomplished by adjusting the rest position of the control plunger. The design of the system is such that the fuel mixture will scale according to this baseline setting.

Cold start enrichment is handled by a separate electrically operated fuel injector mounted in the intake manifold. Power is provided via Terminal 50 from the ignition switch. The Ground is completed through a Thermo-time switch mounted in the cylinder head.

The Thermo-time switch has a bi-metallic strip that is heated by 12 Volts also supplied by Terminal 50. Heating the strip causes it to flex

and open the circuit. This "timer" circuit allows for a temperature sensitive quantity of fuel to be injected during cranking of the engine. If coolant temperature is above roughly 35° C, the heat of the engine will not allow the cold start injector to operate.

Additional airflow during cold running is handled by an auxiliary air bypass valve. A heated bi-metallic strip opens a passage in the valve. This allows a controlled excess of air during the warm-up period of the engine. As the engine enters warm running, the passage is closed and idle air quantity defaults to a bypass channel in the throttle valve housing.



SSP 8410/202

## K-Jetronic with Lambda control

In 1980, CIS fuel injection was modified to better meet exhaust emission standards.

The addition of an oxygen sensor allowed the fuel system to adapt to running conditions. This provided more consistent running characteristics, as well as minimizing the amount of adjustment necessary to the system.

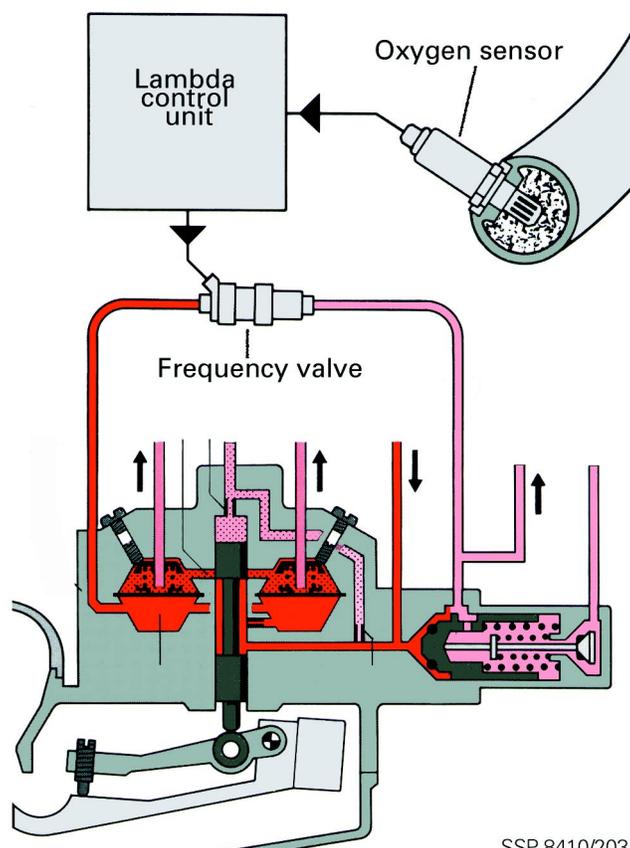
The control unit is able to adjust fuel trim by continually modifying the differential pressure between the upper and lower chambers of the fuel distributor. A solenoid valve (frequency valve) is installed inline between the system pressure from the lower chamber and the control pressure in the lower chamber.

After the engine has reached operating temperature it enters closed loop operation (see Glossary). The control unit pulses the frequency valve with a varying duty cycle, thus varying the differential pressure.

The baseline air/fuel mixture is no longer set by means of sampling pre-catalyst exhaust gases. A test connector is provided to test the duty cycle of the valve. During closed loop operation the duty cycle should fluctuate between 45%-55%. The fluctuations follow the voltage output of the oxygen sensor.

The Lambda control unit receives input from the oxygen sensor, as well as an idle and full throttle switch.

This system was the beginning of today's adaptive engine management systems.



SSP 8410/203

# K-Jetronic

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## KE-Jetronic/CIS-E

For the 1985 model year, Volkswagen expanded the capabilities of the CIS fuel injection system. New features include:

- Warm-up regulator replaced with electrically operated solenoid valve
- Electrically heated oxygen sensor (allows for faster closed loop operation)
- Air flow sensor potentiometer (more accurate control of Lambda)
- Altitude sensor (varies fuel trim with barometric pressure)
- Idle stabilizer valve (more stable idle characteristics)

The major change for the CIS-E system is the replacement of the control pressure regulator with a Differential Pressure Regulator (DPR). This electro-mechanical valve receives a varying amperage from the CIS-E control unit; as amperage is increased control pressure is decreased. This increases fuel flow to the injectors.

This change allowed for more accurate control of the fuel trim, as well as decreased maintenance.

## KE-Motronic/CIS-E Motronic

For the 1990 model year, the 16-valve 2.0 liter engine received the last change to the K-Jetronic system.

CIS-E Motronic integrated fuel and ignition timing in one common control unit, as well as the following features:

- Oxygen sensor control with adaptive learning
- Dual map ignition control with cylinder selective knock control
- EVAP purge control
- Permanent fault memory with self diagnosis

For more information regarding knock control, and **adaptive learning** (refer to Glossary).

## Digifant System Overview

### System description

Digifant Engine Management was first introduced on the 1986 2.1 liter Volkswagen Vanagon engine. This system combined digital fuel control as used in the earlier Digi-Jet systems with a new digital ignition system. Digifant as used in Golf and Jetta models simplified several functions and added knock sensor control to the ignition system. Other versions of Digifant appeared on the Fox, Corrado, and Eurovan in both the United States and Canada.

Fuel injection control is digital electronic. It is based on the measurement engine load (Air Flow sensor), and on engine speed (Hall sender). These primary signals are compared to a map, or table of values, stored in the Engine Control Module (ECM) memory.

The amount of fuel is controlled by the injector opening time (duration). This value is taken from a program in the ECM that has 16 points for load and 16 points for speed. These 256 primary values are then modified by coolant temperature, intake air temperature, oxygen content of the exhaust, battery voltage and throttle position to provide 65,000 possible injector duration points.



SSP 8410/97

# Digifant

The fuel injectors are wired in parallel, and are supplied with constant system voltage. The ECM switches the Ground on and off to control duration. All injectors operate at the same time each crankshaft revolution; two complete revolutions being needed for each cylinder to receive the correct amount of fuel for each combustion cycle.

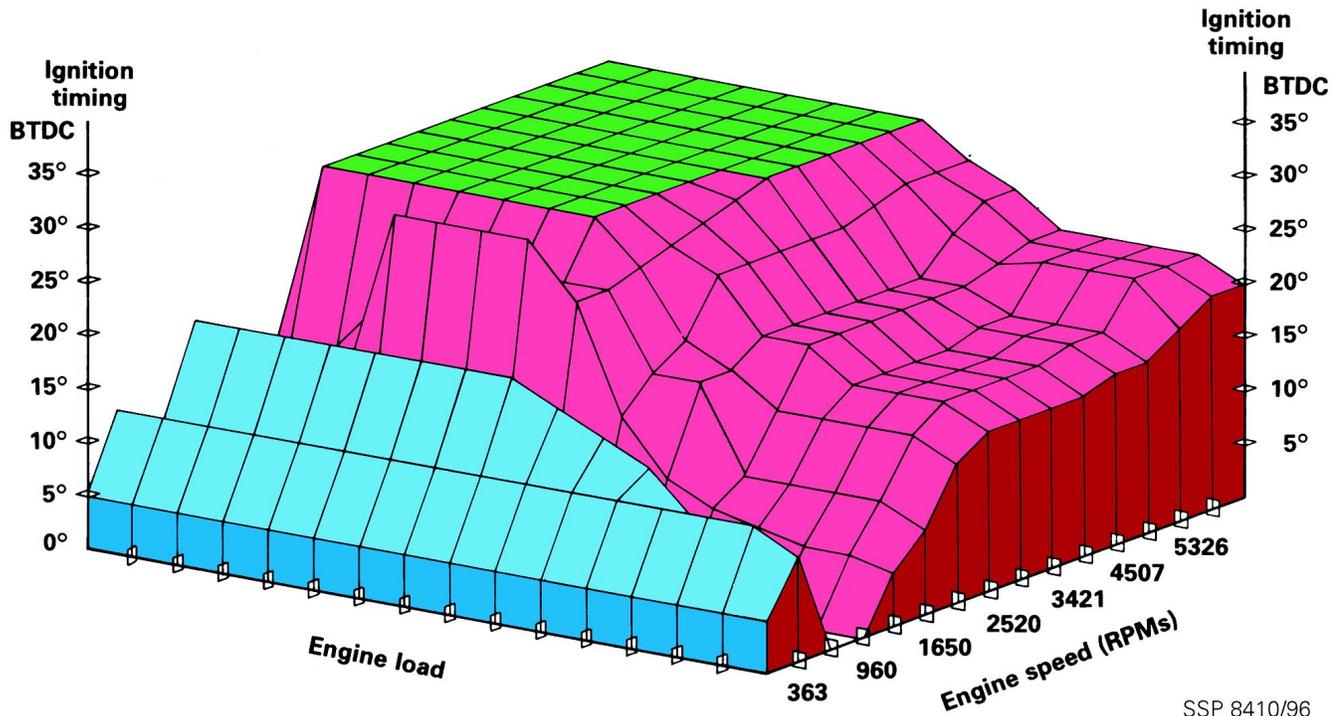
Ignition control is also digital electronic. The sensors that supply the engine load and engine speed signals for injector duration provide information about the basic ignition timing point. The signal sent to the Hall control unit is derived from a program in the ECM that is similar to the injector duration program.

There are 16 points available for load and 16 points for speed. The resulting 256 single operational points are modified by coolant temperature signals and cylinder selective knock control (where applicable) to achieve the optimal ignition point.

Knock control is used to allow the ignition timing to continually approach the point of detonation. This point is where the engine will produce the most power, as well as the highest efficiency. For more information on knock control function refer to the appropriate section in Motronic M2.9.

Additional functions of the ECM include operation of the fuel pump by closing the Ground for the fuel pump relay, and control of idle speed by a throttle plate bypass valve. The idle air control valve (previously known as an idle air stabilizer valve), receives a changing milliamp signal that varies the strength of an electro-magnet pulling open the bypass valve.

Idle speed stabilization is enhanced by a process known as Idle Speed Control (ISC). This function (previously known as Digital Idle Stabilization), allows the ECM to modify ignition timing at idle to further improve idle quality.



## Inputs/Outputs - Digifant II

The 25-pin electronic control unit used in the Golf and Jetta receives inputs from the following sources:

- Hall sending unit (engine speed)
- Air flow sensor (engine load)
- Coolant temperature sensor
- Intake air temperature sensor
- Oxygen sensor
- Throttle position switches
- Knock sensor

Additional signals used as inputs are:

- Air conditioner (compressor on)
- Battery voltage
- Starter signal

The anti-lock brake system, 3-speed automatic transmission and vehicle speed sensor are not linked to this system.

Outputs controlling engine operation include signals to the following:

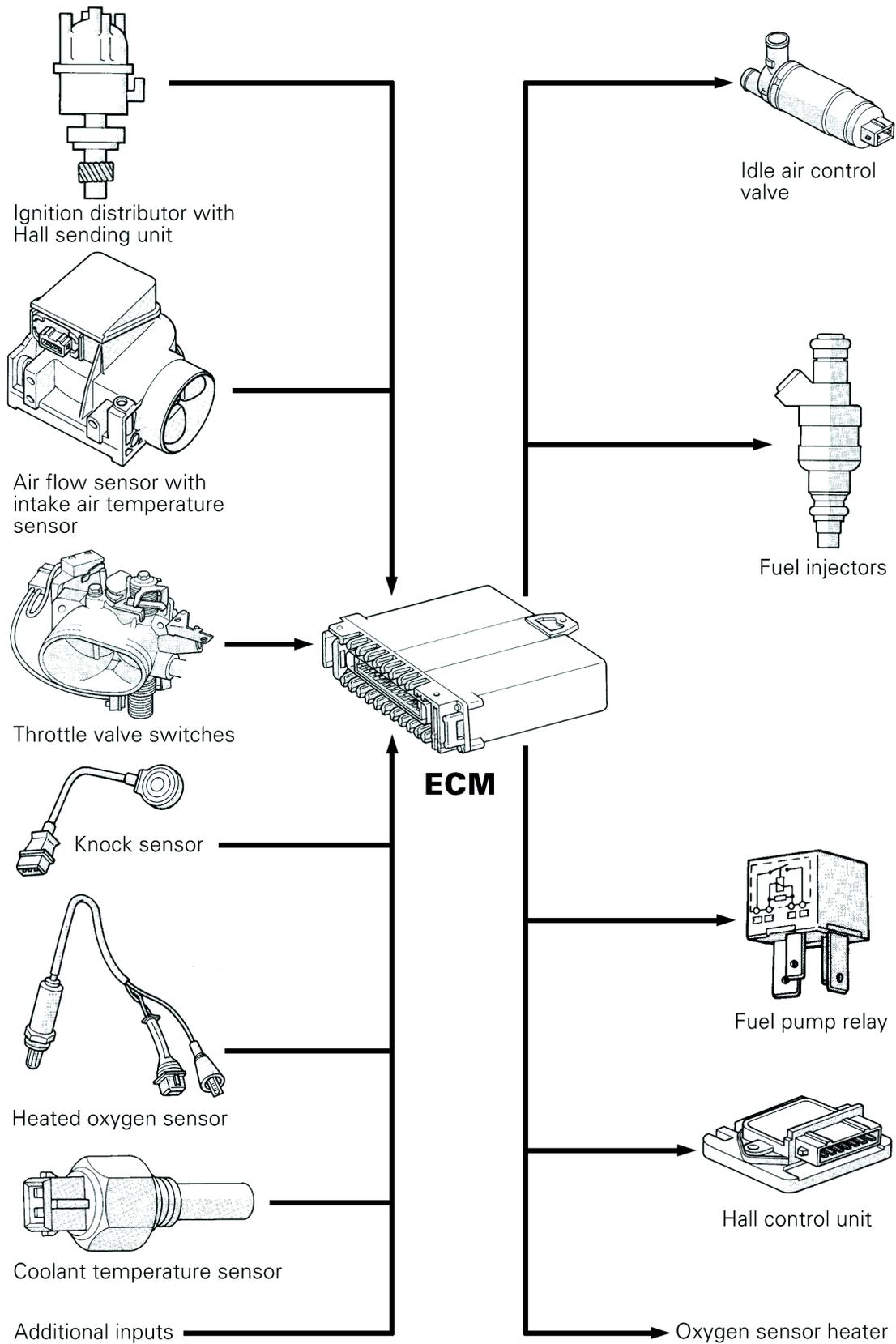
- Fuel injectors
- Idle air control valve
- Hall control unit
- Fuel pump relay
- Oxygen sensor heater

## Additional systems

The evaporative emission system is controlled by a vacuum operated mechanical carbon canister control valve.

Fuel pressure is maintained by a vacuum operated mechanical fuel pressure regulator on the fuel injector rail assembly.

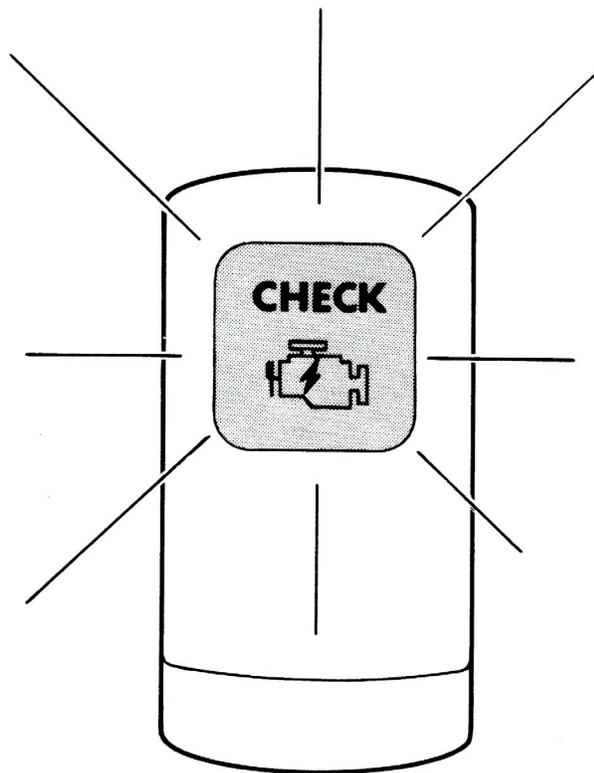
Inputs and outputs are shown in the following illustration. Digifant II as used on Golf and Jetta vehicles provides the basis for this chart.



SSP 8410/96a

## On Board Diagnostics

Golf, Jetta, and Vanagon Digifant systems have no On Board Diagnostic (OBD) capabilities, except for a limited number of 1987 to 1990 California Golfs and Jettas. These vehicles have blink code capability, with the capacity to store up to 5 Diagnostic Trouble Codes (DTCs). For the most part, diagnostic troubleshooting is done with the VAG 1598 and a digital multimeter. This system can also have carbon monoxide (CO), ignition timing and idle speed adjusted to baseline values.



SSP 8410/94

In 1991, California Golf, Jetta, Fox, Cabriolet and Corrado vehicles were equipped with expanded OBD capabilities. These latest Digifant versions have 38-pin ECMs with rapid data transfer and permanent DTC memory. All Eurovans with Digifant also have rapid data transfer and permanent DTC memory. These systems use a throttle plate potentiometer to track throttle position in place of the idle and full throttle switches used on earlier systems.

## Summary

Digifant is an engine management system designed originally to take advantage of the first generation of newly developed digital signal processing circuits. Production changes and updates were made to keep it current with the changing California and federal emissions requirements. Updates were also made to allow integration of other vehicle systems into the scope of engine operation.

Changes in circuit technology, design and processing speed along with evolving emissions standards, resulted in the development of new engine management systems. These new systems incorporated adaptive learning, enhanced and expanded diagnostics, and the ability to meet total vehicle emissions standards.

The table on the following page lists some of the major differences between versions of Digifant sold in California and the other states.

# Digifant

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Digifant Engine Management Components	United States and Canada					California Vehicles from m.y. 1991			
	Golf/Jetta	Corrado	Cabriolet	Vanagon	Fox	Golf/Jetta	Corrado	Cabriolet	Fox
25 pin ECU without Rapid Data	X	X	X	X	X				
38 pin ECU with Rapid Data						X	X	X	X
Knock sensor	X	X	X			X	X	X	
Idle air control valve	X	X	X	X <sup>**</sup>		X	X	X	
Idle speed boost valve					X				X
Throttle valve potentiometer						X	X	X	X
New ignition coil with power stage						X	X	X	X
Conventional ignition coil with separate switching unit	X	X <sup>*</sup>	X	X <sup>*</sup>	X				
Idle / full throttle switches	X	X	X	X	X				

\*Ignition switching unit inside Digifant ECU

\*\*With separate idle air control valve control module

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## Review

1. **Digifant engine management systems derive basic fuel injection quantity and ignition timing points from which two sensors?**

- a. Air flow sensor and coolant temperature sensor
- b. Knock sensor and camshaft position sensor
- c. Hall sender and coolant temperature sensor
- d. Hall sender and air flow sensor

2. **Technician A says that Digifant engine management systems use digital signal processing for fuel injection control.**

**Technician B says that Digifant engine management systems use analog signal processing for ignition control.**

**Which Technician is correct?**

- a. Technician A only
- b. Technician B only
- c. Both Technician A and Technician B
- d. Neither Technician A nor Technician B

3. **Which of the following items does *not* supply an input to the 25-pin Digifant control unit?**

- a. Transmission Control Module (TCM)
- b. Air conditioner system
- c. Battery voltage
- d. Starter

4. **Technician A says that the Digifant ECM operates the fuel injectors by controlling the ground signal.**

**Technician B says that the Digifant ECM operates the fuel pump relay by controlling the ground signal.**

**Which Technician is correct?**

- a. Technician A only
- b. Technician B only
- c. Both Technician A and Technician B
- d. Neither Technician A nor Technician B

5. **Digifant fuel injectors operate:**

- a. Sequentially every other crankshaft revolution.
- b. At the same time every other crankshaft revolution.
- c. Sequentially every crankshaft revolution.
- d. At the same time every crankshaft revolution

6. **Technician A says that all Digifant engine management systems use knock sensors.**

**Technician B says that all Digifant engine management systems use idle and full throttle switches.**

**Which Technician is correct?**

- a. Technician A only
- b. Technician B only
- c. Both Technician A and Technician B
- d. Neither Technician A or Technician B



## Motronic M2.9 Overview

### System description

Motronic Engine Management was first introduced in combination with the narrow angle (15°) 2.8 liter VR-6 engine in the 1992 Corrado SLC. The VR-6 with Motronic was later installed in the Passat GLX, Golf GTI, Jetta GLX and Eurovan. Motronic M2.9 engine management was also installed on Passat and Golf/Jetta 2.0 liter 4-cylinder 8-valve engines.

The Motronic Engine Management System combines all fuel, ignition and evaporative emissions system functions into a single electronic control unit. This electronic control unit is known as the Engine Control Module (ECM). The ECM governs all of the output devices responsible for running the engine, and operates other related system devices.

Engine-mounted sensors continuously gather operating data and send this information to the ECM. This data is converted and processed within the ECM for use in determining the engine's momentary operating conditions. This information is used as the basis for the ECM's output signals, and sent to the system actuators.

As on previous systems, engine management control is digital electronic, and is based on engine load and engine speed.



# Motronic M2.9 Overview

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## Functional overview

Motronic M2.9 uses engine speed and load as its primary inputs. An inductive sensor mounted on the cylinder block measures crankshaft speed, and provides the engine speed signal.

A Hall sender in the distributor provides camshaft position information to identify cylinder number one. This allows fuel injection to be sequential, and timed to the opening of the intake valve. This is different than previous systems, in which the injectors all fired at the same time.

Engine load information is received from the Mass Air Flow (MAF) sensor G70, which has no moving parts and is not adjustable.

All Volkswagen engine management systems with an oxygen sensor adapt to changing conditions while the engine is running. The ECM uses the oxygen sensor signal to determine the oxygen content of the exhaust gases. It then determines if the injector duration needs to be lengthened or shortened to achieve the optimum air/fuel ratio of 14.7: 1. This is referred to as **adaptation** (see Glossary).

When the ignition is switched off on Digifant equipped vehicles, all adaptations are erased. During the time before the oxygen sensor signal is reliable (at operating temperature), the ECM relies on baseline values from a calculation map. This air/fuel ratio may or may not reflect the current engine operating conditions because it always represents a basic setting.

Motronic M2.9 engine management systems take oxygen sensor adaptation to the next level. Values obtained during engine operation are stored, and used as the basis for engine operation on the next start. These stored values are said to be “learned” values and can change or adapt as often as needed. The process of storing and using learned values is called **adaptive learning** (see Glossary).

In addition to mixture adaptation, idle speed and ignition timing also adapt to changes in operating conditions (i.e. changes in altitude and small vacuum leaks). No periodic adjustments are required.

**Note:**

*If the battery is disconnected, or if power is interrupted to the ECM, all learned or adapted values will be erased.*

*The ECM will start from a baseline setting and relearn and adapt to operating conditions.*

With the VAG 1551/1552 or VAS 5051 connected and set to Basic Settings (function 04), the Motronic system can be made to adapt to current conditions in several minutes. When the Basic Settings function is selected the scan tool instructs the ECM to

- disable the A/C compressor
- disable the EVAP system
- stabilize ignition timing
- stabilize idle speed

Advantages of adaptive learning include:

- optimal fuel economy
- reduced emissions
- reduced maintenance
- improved driveability

**Note:**

*When diagnosing oxygen sensor adaptation faults, be sure to inspect the following:*

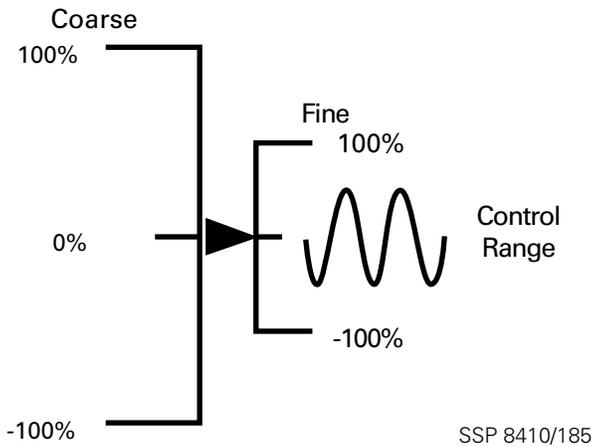
- *Exhaust system (allows outside air to mix with exhaust gases and affect oxygen sensor readings)*
- *Engine sealing (oil leaks can create false air leaks when the engine is running, causing un-metered air to enter the intake manifold)*
- *False air leaks (can include Idle Air Control (IAC) valve, or associated intake manifold)*

*Any of these systems, if not well sealed, can cause an inaccurate air/fuel mixture, resulting in poor driveability and possible adaptation faults.*

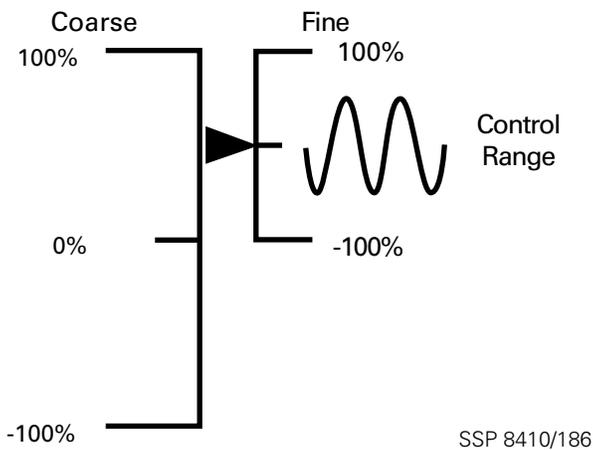
**Always check the basics first!**

# Motronic M2.9 Overview

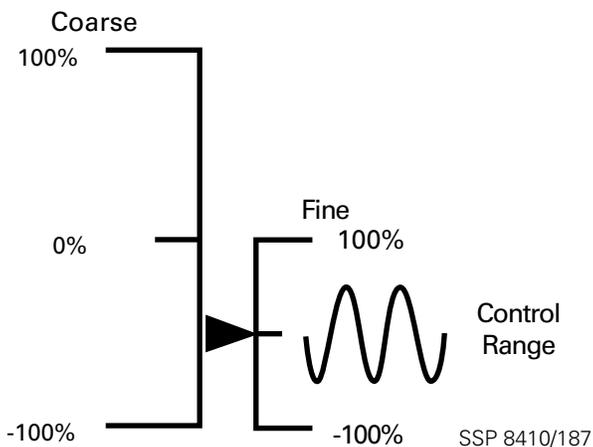
## System Adaptation - Balanced



## System Adaptation - Lean



## System Adaptation - Rich



The three illustrations show the normal window of operation for an engine management system, as well as a system that has adapted to a lean condition and a rich condition.

The layout of the illustrations shows the fine control range of the fuel system on the right, with its corresponding position in the coarse range on the left.

On the balanced system, the fuel trim is in the center of the graph. This means that the system has not adapted to any mechanical or component problems.

The second illustration shows the effect on the adaptation window from an excess of unburned Oxygen in the exhaust.

### **Example:**

*If a false air leak is introduced, the fuel system will register a lean running condition. The Motronic ECM will move the fine control range from 0% toward 100%, depending on the severity of the air leak. The system will adapt and the fine control window will continue to adjust short term fuel trim accordingly.*

The last illustration shows the system adapting to a rich running condition. This could be the result of excessive fuel pressure or faulty injectors, as examples.

Coarse control range is defined as Long term adaptation or learned value.

Fine control range is defined as Short term adaptation. Fuel adaptation is the control for both idle and part throttle conditions.

Idle adaptation is also referred to as:

- Additive

Part throttle adaptation is also referred to as:

- Multiplicative

*For definitions, refer to the Glossary.*

## Inputs/Outputs - Motronic M2.9

The 68-pin ECM used in Motronic M2.9 equipped vehicles receives signals from up to nine input sources. These include the following:

- Engine Speed (RPM) sensor G28
- Camshaft Position (CMP) sensor G40
- Mass Air Flow (MAF) sensor G70
- Engine Coolant Temperature (ECT) sensor G62
- Intake Air Temperature (IAT) sensor G42/G72
- Heated Oxygen Sensor (HO2S) G39
- Throttle Position (TP) sensor G69
- Knock Sensor(s) (KS) G61/G66
- EGR Temperature sensor G98

Additional signals used as inputs include:

- Air conditioner (compressor and/or system on)
- Battery voltage
- Speedometer Vehicle Speed Sensor (VSS) G22
- Transmission Control Module (TCM) J217

ECM output to actuators controlling engine operation include:

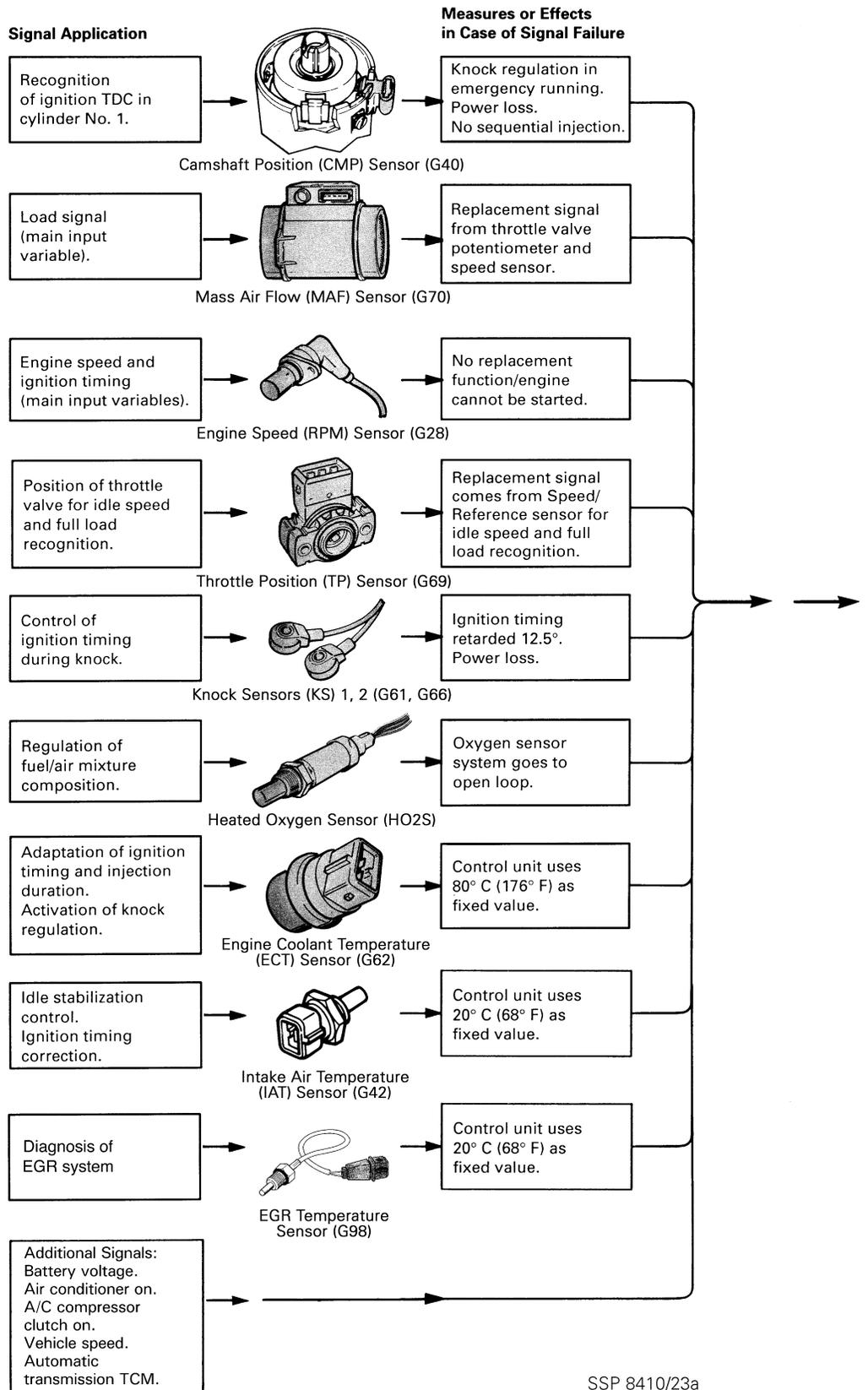
- Fuel injectors N30-N33,N83,N84
- Idle Air Control (IAC) valve N71
- Ignition Coil Power Output Stage N157
- Fuel Pump (FP) relay J17
- Heated Oxygen sensor (HO2S) control module J208.
- Heated Oxygen sensor (HO2S) relay J278
- EGR vacuum regulator solenoid valve N121/N18
- Evaporative Emissions (EVAP) Canister Purge Regulator Valve N80
- Secondary Air Injection (AIR) solenoid valve N112
- Secondary Air Injection (AIR) pump motor V101

Several other systems require input from the Motronic M2.9 system, or provide input to alter the engine management.

The Transmission Control Module (TCM) requires data corresponding to throttle position, engine load, and engine RPM for shift control. The TCM uses these inputs to control upshifts as well as downshifts according to driving conditions. The TCM also sends a shift "signal" to the ECM, the ECM retards ignition timing during the shift to help "soften" the shift.

Sensor inputs, other input signals, actuator signals and other output signals are shown in the illustration on the following pages. The illustration represents a composite view of components that are installed on several different engine types. Components listed may not be applicable to all engines.

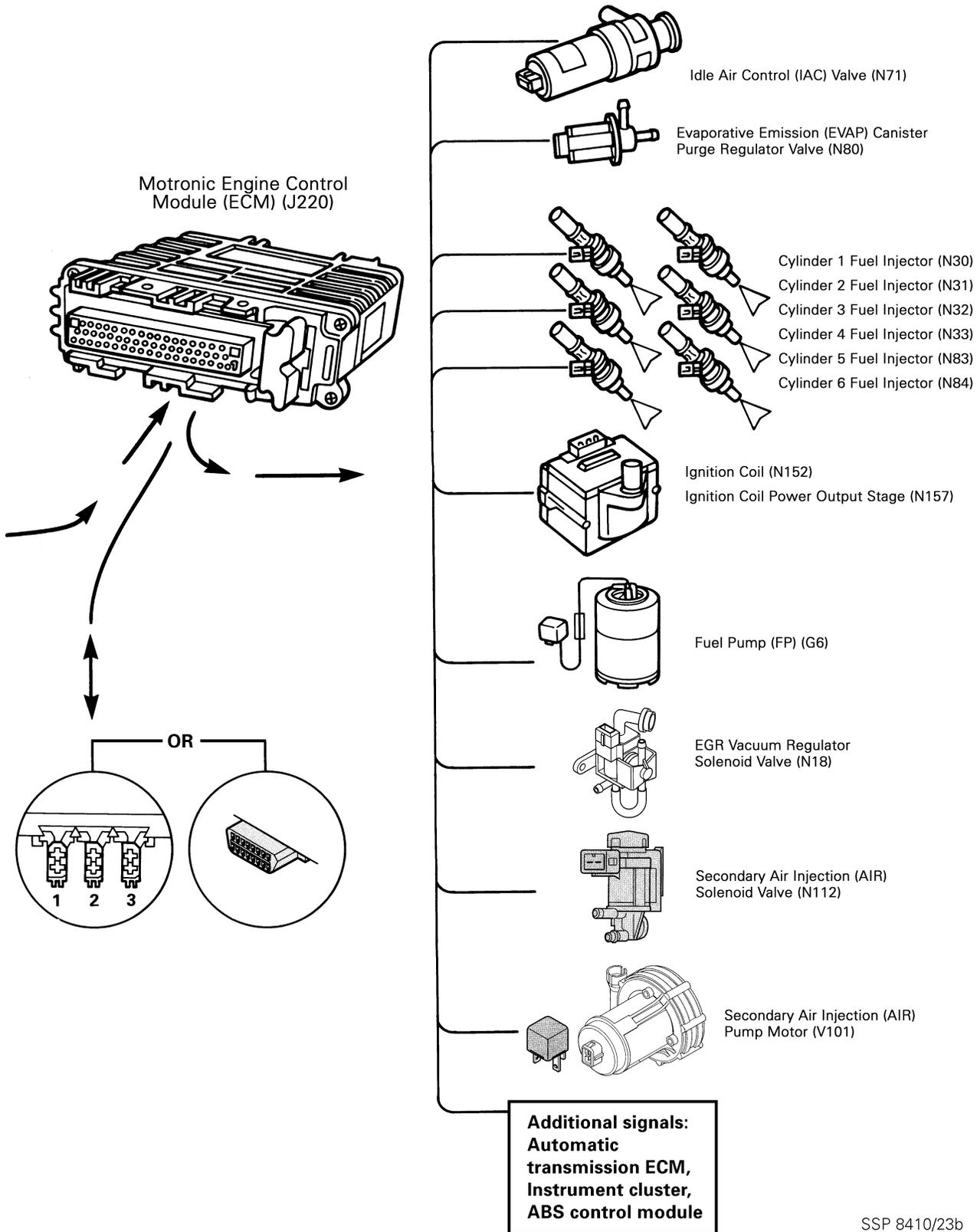
# Motronic M2.9 Overview



SSP 8410/23a

# Motronic M2.9 Overview

Motronic Engine Control Module (ECM) (J220)



SSP 8410/23b

# Motronic M2.9 Overview

## On-Board Diagnostics

Motronic M2.9 engine management systems comply with the On-Board Diagnostic standards for OBD I, including:

- Diagnostic Trouble Code (DTC) retrieval via blink code
- VAG 1551/1552 and VAS 5051 scan tool support for Rapid Data Transfer
- Diagnosis of open/short circuits for most sensors and actuators

Rapid data supported functions include:

- Retrieval and erasing of DTCs
- ECM identification and coding
- Viewing and setting of engine operating data
- Actuator function testing

## Signal usage

The following table summarizes the usage and function of Motronic M2.9 input signals found on early VR-6 engines.

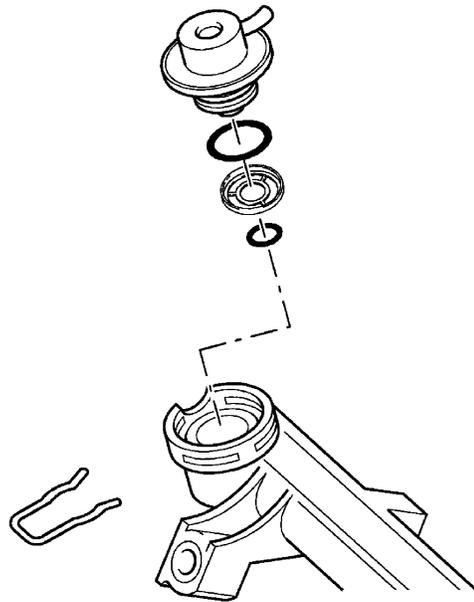
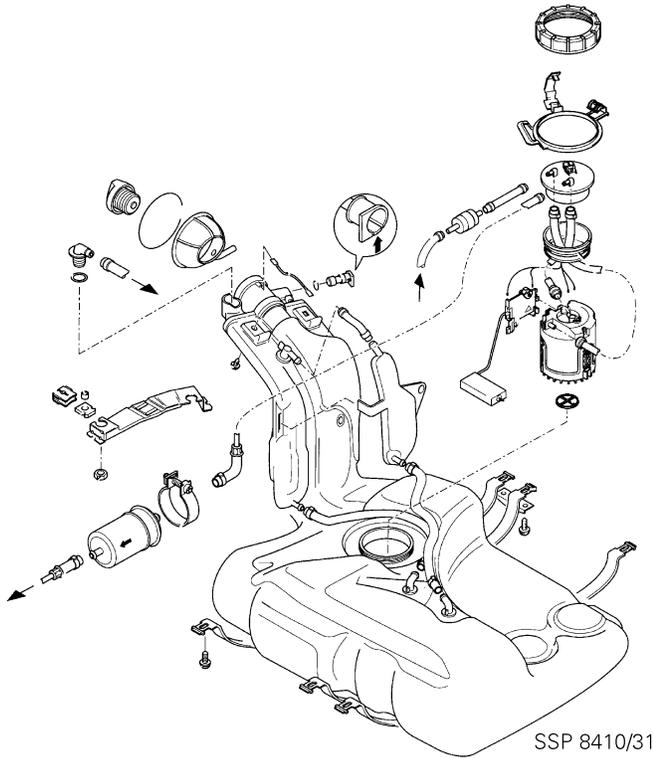
Functions	Input Signals												
	Ignition switch term. 15	Air volume	Engine speed	Throttle valve angle	Engine temperature	Battery voltage	Lambda probe	Air conditioner	Air conditioner compressor	Road speed	Hall sender	Knock sensor I	Knock sensor II
Start control			X		X								
After-start enrichment					X								
Warm-up enrichment					X								
Full load enrichment		X	X	X									
Acceleration enrichment		X	X		X								
Speed limit			X										
Deceleration fuel shut-off			X	X	X								
Battery voltage correction						X							
Oxygen sensor system		X	X	X	X		X						
Mixture adaptation		X	X		X		X						
Idle speed volumetric control		X	X	X	X			X	X	X			
Tank venting		X	X		X		X						
Ignition timing		X	X	X	X								
Dwell angle			X			X							
Idle speed stabilization			X	X									
Diagnosis		X	X	X	X		X			X	X	X	X
Sequential injection		X	X		X					X			
Knock control		X	X	X	X					X	X	X	
Burn-off signal for hot wire	X		X		X								
Fuel pump activation			X										

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# Motronic M2.9 Component Summary

## Motronic M2.9 Component Summary

### Fuel system components



### Fuel tank

Motronic equipped vehicles all use an injection molded plastic fuel tank located at the center-rear of the vehicle. The fuel tank assembly includes the filler neck and all of the fuel vent system. The fuel tank has an opening in the top large enough to allow placement of the fuel delivery unit within the tank. The delivery unit includes the fuel pump assembly, the fuel gauge sending unit, the fuel feed and return lines, and all the electrical connectors.

A large capacity fuel filter is mounted close to the tank in the fuel line feeding the engine.

### Fuel Pressure Regulator

The fuel pressure regulator is a diaphragm-type regulator attached to the fuel manifold on the return, or outlet side. Fuel pressure is regulated by controlling the fuel returned to the tank and is dependent on intake manifold pressure (engine load).

As intake manifold pressure changes, the pressure regulator will increase or decrease the system fuel pressure. This maintains a constant pressure difference between the injector outlet which is within the intake manifold and the injector inlet which is exposed to fuel pressure.

# Motronic M2.9 Component Summary

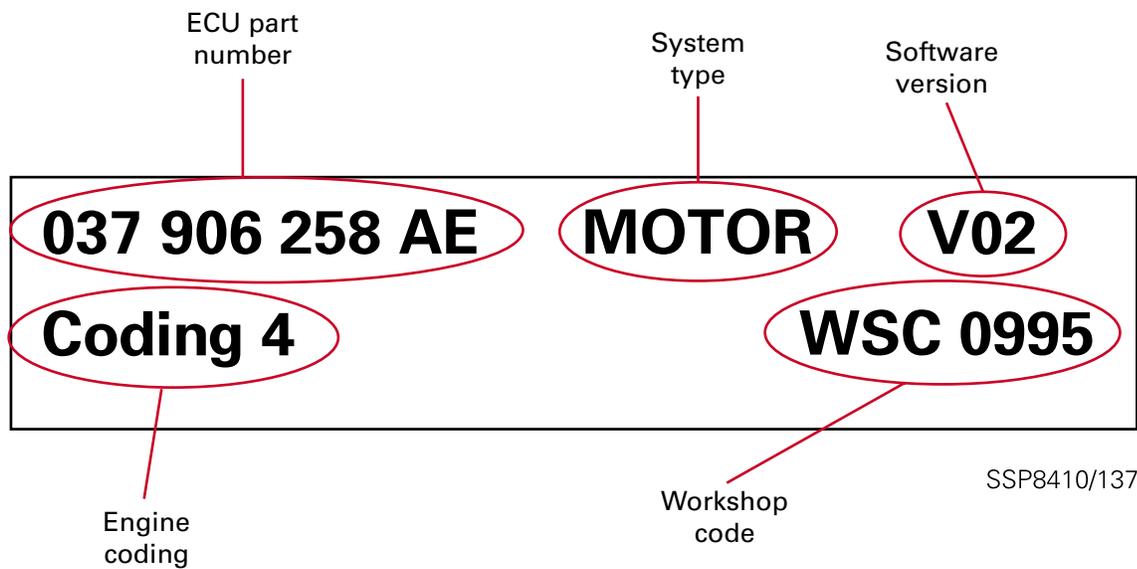
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## Engine Control Module (ECM) J220

The ECM must be supplied with the appropriate power sources and Grounds to function properly. Additionally, the ECM must “know” what equipment is installed in the vehicle. This process is known as **coding**, and must be performed whenever the ECM is replaced. New ECMs are generally shipped un-coded.

Coding memory is retained when the battery is disconnected. If a new ECM is installed without being coded, the engine may run poorly and the automatic transmission (if equipped) will not function properly. The ECM is electronically coded using the scan tool.

The ECM is equipped with rapid data transfer to facilitate communication with either the VAG 1551/VAG 1552 scan tools or the VAS 5051 Diagnostic Testing and Information System for retrieval of system and component malfunctions. System operating information can be viewed in real time as an aid in diagnosis.



# Motronic M2.9 Component Summary

## Input sensors

Motronic engine management systems rely on up to nine different input sensors for engine operating information. Different Motronic versions have variations of some sensors, but the signal usage and component operation remains essentially the same.

### Mass Air Flow (MAF) sensor G70

Two versions of the mass air flow sensor are used on Volkswagen Motronic engine management systems; hot wire and hot film.

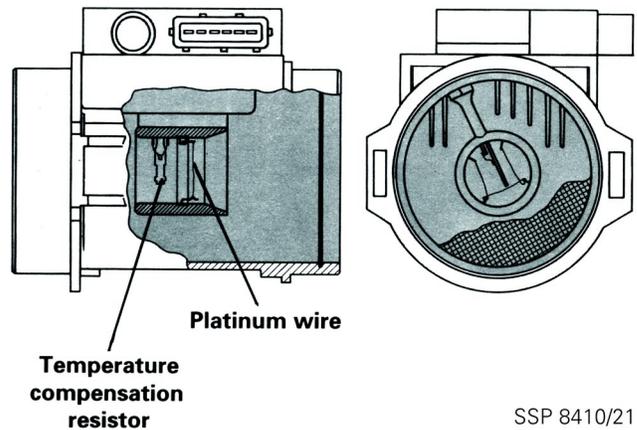
A **hot-wire mass air flow sensor** was used on VR-6 Motronic M2.9 engines from model years 1992 to 1994.

The mass air flow sensor is mounted to the air filter housing and measures air flow into the engine (which is an indication of engine load). A velocity stack is built into the air filter housing to shape and direct the incoming air charge, and a baffle reduces air turbulence and pulsing before measurement.

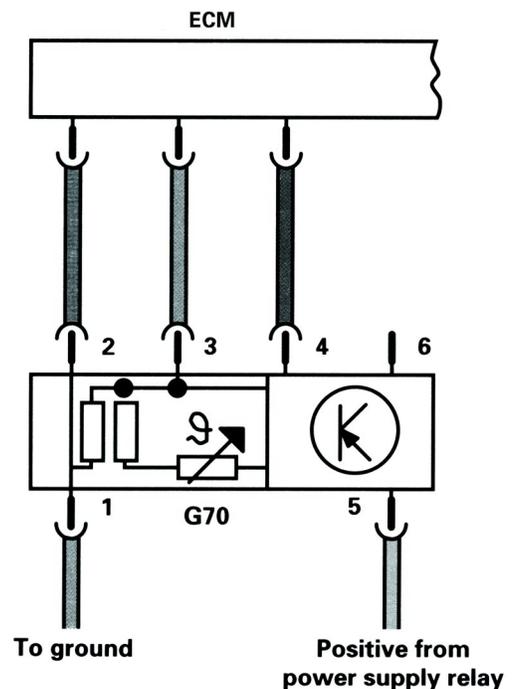
A thin electrically-heated, platinum hot-wire in the sensor is kept 180°C (356°F) above the air temperature as measured by the built-in thin-layer platinum air temperature sensor.

As air flow increases, the wires are cooled and the resistance of the sensors changes. Electrical current to the platinum hot-wire varies to maintain the constant temperature difference. The resulting current change is converted to a voltage signal, and is used by the ECM to calculate the mass of air taken in.

Dirt or other contamination on the platinum wire can cause inaccurate output signals. Because of this, the platinum wire is heated to approximately 1000°C (1832°F) for a period of one second each time the engine is switched off (after being run to operating temperature). This burns off any dirt or contamination.



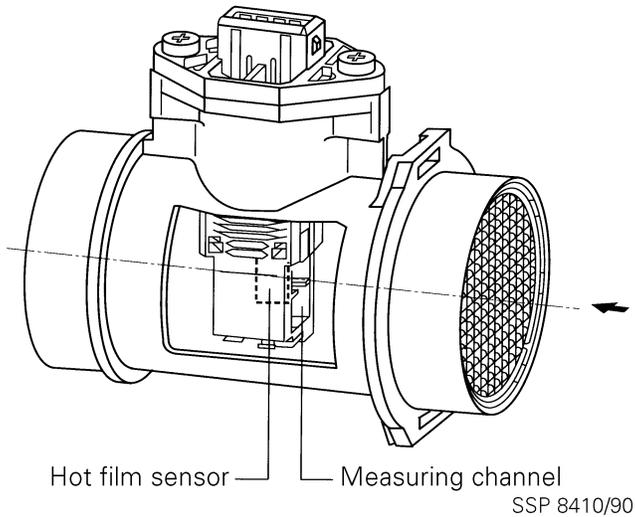
SSP 8410/21



SSP 8410/22

# Motronic M2.9 Component Summary

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A **hot film mass air flow sensor** was installed on Passat VR-6 Motronic M2.9 engines from model year 1995; Golf/Jetta VR-6 Motronic M2.9 engines from 1994; Golf/Jetta/Cabrio 4-cylinder M2.9 engines from 1993; and Passat 4-cylinder M2.9 engines from 1995. It is mounted in the same location as the hot-wire version.

The hot film mass air flow sensor uses a heated metallic film on a ceramic substrate instead of the hot-wire. The film is kept at a constant temperature above the intake air temperature by varying the current in much the same way as the hot-wire version.

This sensor differs from the hot-wire mass air flow sensor used earlier, because it does not require the "burn-off" phase to clean the sensor after the engine is switched off.

- Operation:

Air flows past the hot film and cools it. Current is supplied to maintain constant temperature. Changing current is converted to a signal used by the ECM to determine engine load.

- Substitute function:

If a fault develops with the signal from the mass air flow sensor, the signal from the throttle position sensor potentiometer is used as a substitute. Driveability is maintained and a fault or Diagnostic Trouble Code (DTC) is stored in the ECM.

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits and sets an appropriate DTC.

# Motronic M2.9 Component Summary

## Throttle Position (TP) sensor G69

The throttle position sensor is a potentiometer connected to the throttle valve shaft. The signal generated is used by the ECM to determine driver input.

Idle and full throttle switches are not incorporated into the throttle position sensor. These positions are recognized by the ECM from the appropriate voltage output of the potentiometer. Throttle position sensor signals are used by the ECM for determination of idle speed stabilization, idle air volume control, deceleration fuel shut-off, acceleration and full load enrichment.

Vehicles with electronically controlled automatic transmissions also require a throttle position sensor signal. This signal comes either from a second throttle position sensor or from the ECM, and is passed on to the Transmission Control Module (TCM).

- Operation:

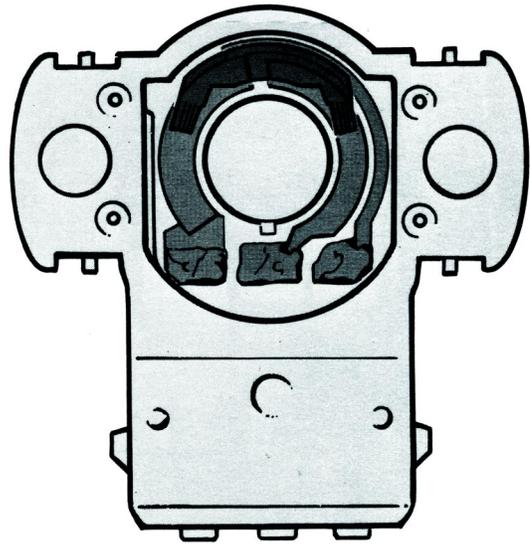
The ECM supplies a fixed voltage signal to the throttle position sensor. Movement of the throttle valve rotates a potentiometer, varying the resistance (voltage drop changes). The signal is then sent to the ECM.

- Substitute function:

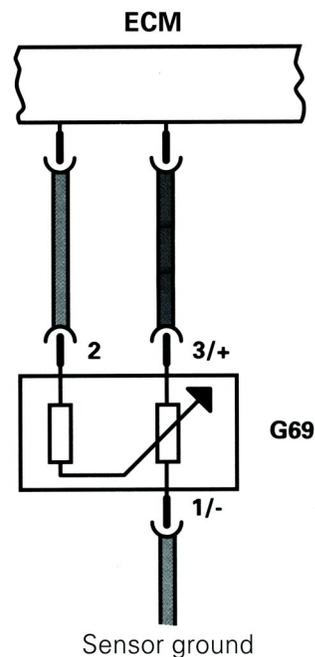
If a fault develops with the signal from the throttle position sensor, the signals from the mass air flow sensor and the engine speed (RPM) are used as a substitute. Driveability is maintained and a fault or Diagnostic Trouble Code (DTC) is stored in the ECM.

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits.

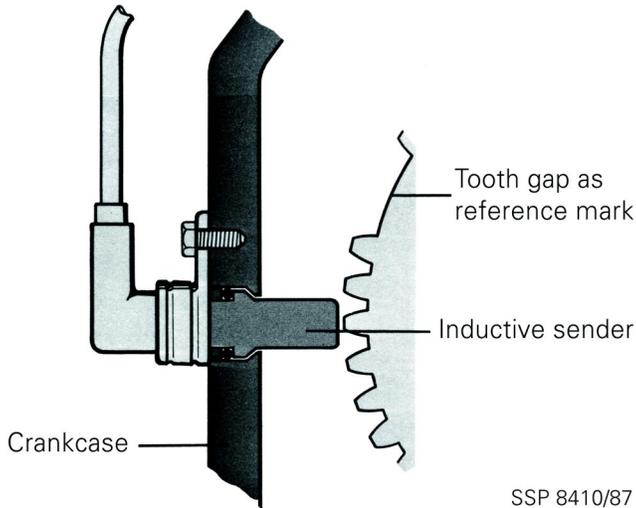


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# Motronic M2.9 Component Summary



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## Engine Speed (RPM) sensor G28

Engine speed and crankshaft position are registered by a single sensor located on the engine cylinder block. The sensor reads a toothed wheel mounted on the crankshaft through a hole in the lower part of the cylinder block.

The toothed wheel has space for 60 teeth. A two-tooth gap is used as a reference for crankshaft position.

The engine speed (RPM) sensor G28 signal is used for registration of engine speed. It is used in conjunction with the signal from the camshaft position sensor to identify cylinder number 1 for sequential fuel injection and cylinder selective knock control. The ECM also sends engine speed information from this sensor to all other systems that require it, such as the Transmission Control Module (TCM) and the instrument cluster.

- Operation:

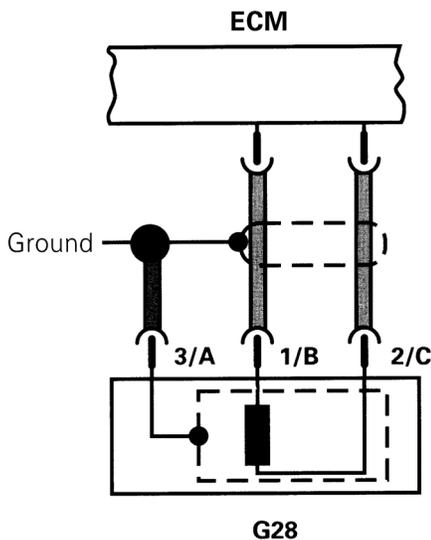
The Engine Speed (RPM) sensor G28 is an inductive sensor. The rotating sensor wheel causes an alternating current signal to be generated whose frequency varies with engine speed. The gap causes a slight variance in the pulses and identifies crankshaft position.

- Substitute function:

There is no substitute function for the speed/reference sensor. The engine will not start or run.

- On Board Diagnostic (OBD)

The ECM recognizes open circuits, and incorrect signals in this component and sets an appropriate DTC. This component will always show a DTC if the ECM fault memory is checked with the ignition on, but the engine not running. It will automatically erase itself when the engine starts.



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# Motronic M2.9 Component Summary

## Camshaft Position (CMP) sensor G40

Two major types of camshaft position sensors are used on Volkswagen Motronic engine management systems. The type is dependent upon whether or not the engine uses a distributor, or is distributor-less.

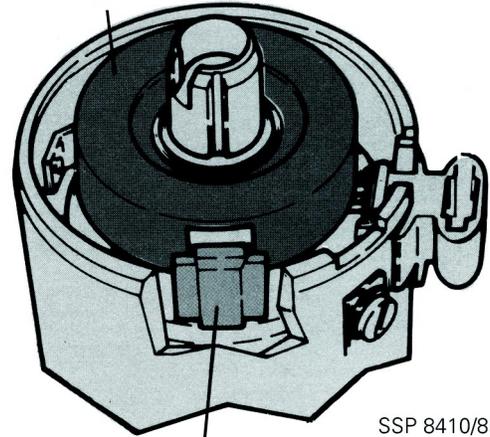
Engines that use distributors mount the Camshaft Position (CMP) sensor in the distributor housing. A shutter wheel with a single cut-out is attached to the distributor shaft.

Engines with distributor-less ignitions mount the camshaft position sensor to the end of the cylinder head where the shutter wheel is driven directly by the camshaft.

The camshaft position sensor is a **Hall sender** (see Glossary). It is housed in plastic to protect it from moisture, dirt, oil, and mechanical damage.

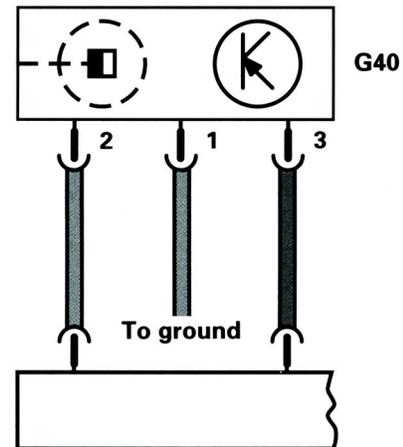
The camshaft position sensor signal is used along with the engine speed (RPM) sensor to identify cylinder number 1 for purposes of sequential fuel injection and knock regulation.

Shutter wheel



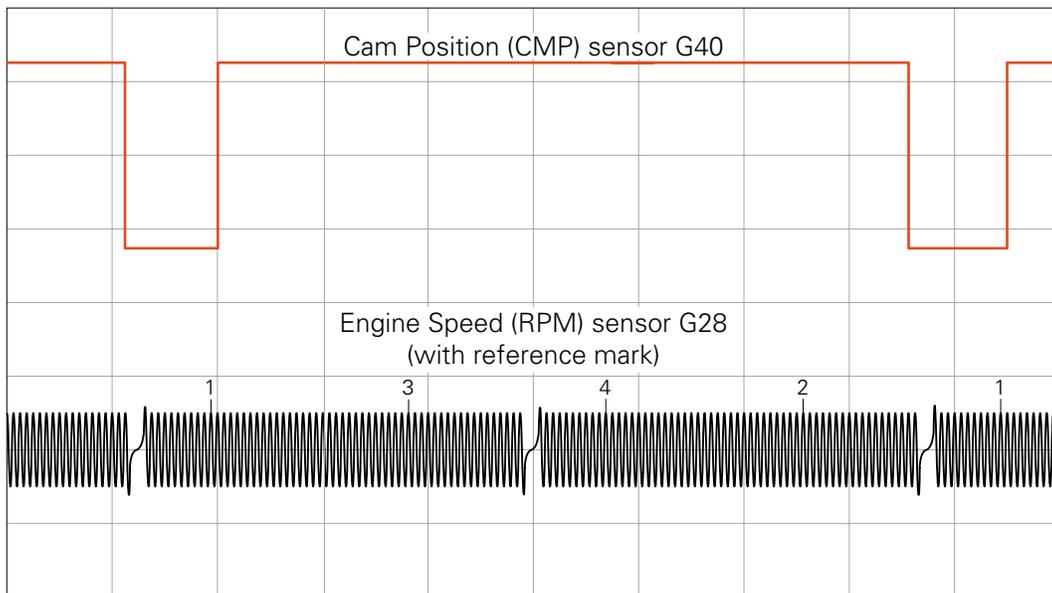
Hall module

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G40

SSP 8410/84



SSP 8410/182

# Motronic M2.9 Component Summary

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- Operation:

The ECM supplies a fixed voltage signal to the camshaft position sensor. An on/off voltage signal is generated and returned to the ECM when the rotating shutter wheel interrupts the magnetic field generated by the Hall effect semiconductor. One signal is generated for every two crankshaft revolutions.

**Note:**

*It is important for the ECM to receive the Camshaft Position (CMP) sensor signal in phase with the Engine Speed (RPM) sensor signal. If not, the ECM will record an open/short circuit to Battery + DTC, despite the fact that the sensors are working correctly.*

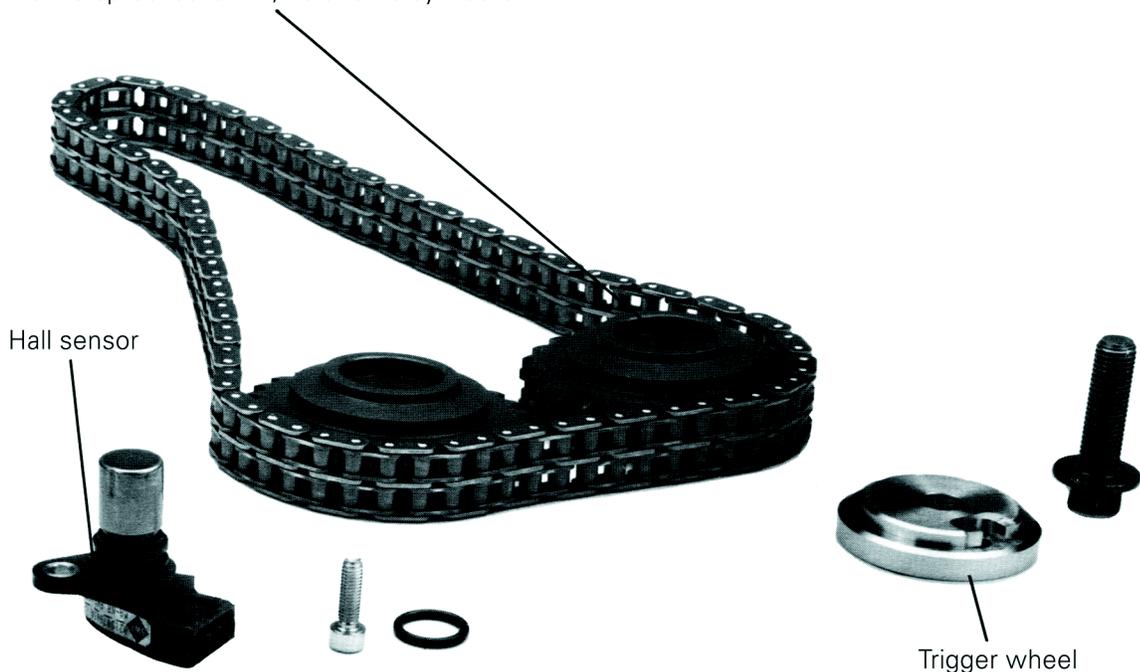
- Substitute function:

There is no substitute function for the camshaft position. If a fault develops with the signal from the camshaft position sensor, the ECM will revert to non-sequential injection and retarded, non-cylinder selective knock control. Engine output is reduced, and a fault or Diagnostic Trouble Code (DTC) is stored in the ECM.

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits.

Cam drive sprocket for #1, #3 and #5 cylinders



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# Motronic M2.9 Component Summary

## Knock Sensor (KS) I G61 and Knock Sensor (KS) II G66

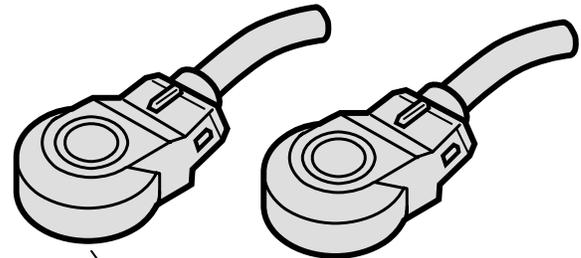
A knock sensor is a piezo-electric device that works like a sensitive microphone to detect vibrations in an engine. Since certain types of vibrations are associated with engine knock, a knock sensor provides a means for the ECM to monitor the combustion process. The purpose of the knock sensor is to keep combustion at the very edge of knock.

A single knock sensor monitors all cylinders on 4-cylinder engines and is centrally mounted on the lower front area of the cylinder block. Dual knock sensors are used on the VR-6-cylinder engines with sensor I responsible for cylinders 1, 3, and 5, and sensor II responsible for cylinders 2, 4, and 6. Knock sensor I is mounted to the rear of the cylinder block and knock sensor II is mounted to the front.

Knock sensors must be correctly torqued to the cylinder block in order to function properly. Correct torque pre-loads the sensor, allowing for proper operation.

When the knock sensor detects vibrations over and above a specified background level of noise, the individual cylinder is identified with the help of the camshaft position sensor. The ignition timing point for that particular cylinder is then retarded by a pre-determined amount until the knocking is eliminated.

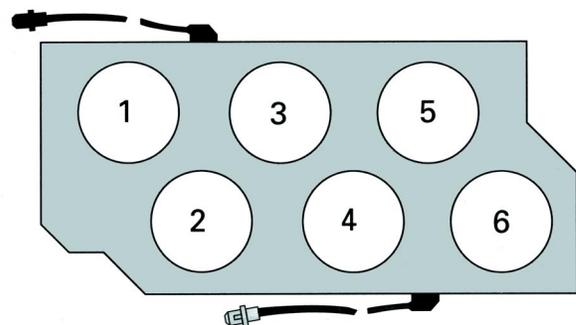
Once the knocking stops, the ECM advances the timing in smaller steps until it returns to the programmed point, or until it knocks again. If knocking re-occurs, the process is repeated.



Knock Sensors (G61, G66)

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Knock Sensor (KS) I G61



Knock Sensor (KS) II G66

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# Motronic M2.9 Component Summary

Differences between individual cylinder timing cannot exceed 12°. If the timing for an individual cylinder reaches 12° and it continues to knock, all remaining cylinders are retarded by 11° (even if they are not knocking), and a DTC is recorded.

Knock regulation does not occur until engine coolant temperature is above 40°C (104°F).

- Operation:

When subjected to engine vibration, the knock sensor generates its own continuous small voltage signal. The presence of knock changes the signal. The ECM identifies the change in signal voltage as engine knock.

- Substitute function:

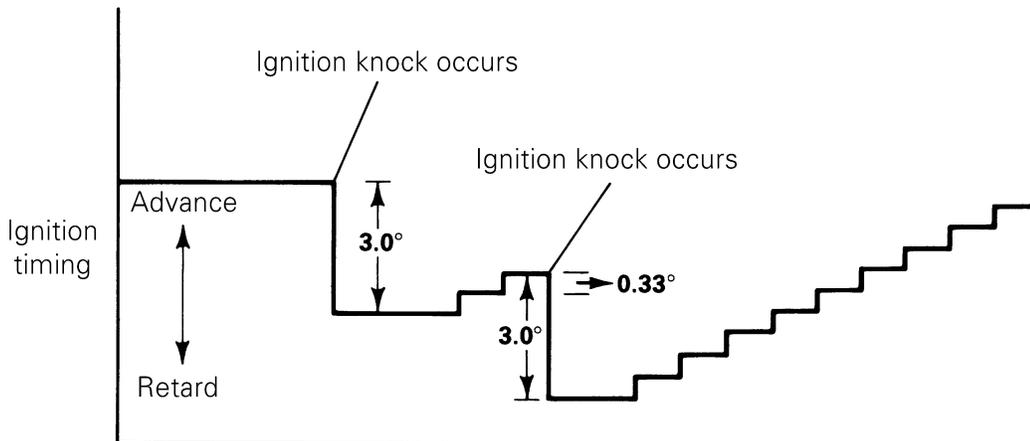
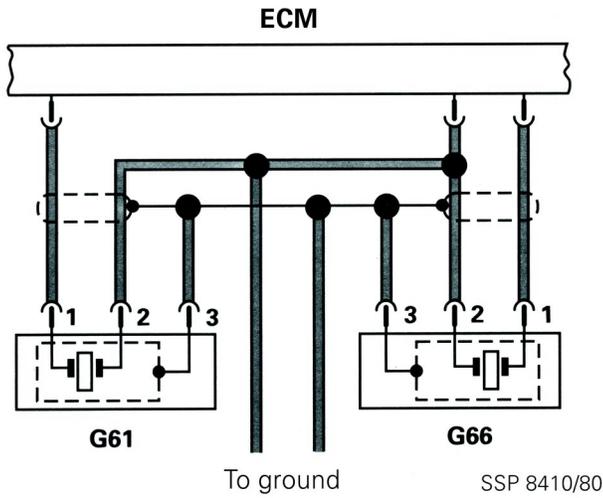
There is no substitute function. However, if a sensor fails, the timing of its assigned cylinders is retarded.

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits from the knock sensor(s) if no signal is received at coolant temperatures over 40°C (104°F).

**Note:**

*Knock Sensor mounting torque is critical for proper operation. Always refer to appropriate Service Information for latest specifications.*



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# Motronic M2.9 Component Summary

## Heated Oxygen Sensor (HO2S) G39

The heated oxygen sensor is constructed of the ceramic material zirconium dioxide and is stabilized with yttrium oxide. It is mounted in the exhaust stream close to the engine. The inner and outer surfaces of the ceramic material are coated with platinum. The outer platinum surface is exposed to the exhaust gas, while the inner surface is exposed to the outside air.

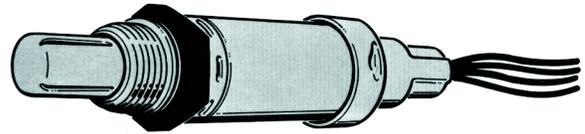
The difference in the amount of oxygen contacting the inner and the outer surfaces of the oxygen sensor creates an electrical pressure differential, resulting in the generation of a small voltage signal. This voltage falls within the range of 100 mV to 1000 mV. The exact voltage depends on the oxygen levels present in the exhaust gas and is a result of the air/fuel mixture.

Oxygen sensors in earlier systems were heated by exhaust gas. The oxygen sensor is now heated electrically to keep it at a constant operating temperature. The heater also insures that the sensor reaches operating temperature quickly and remains there.

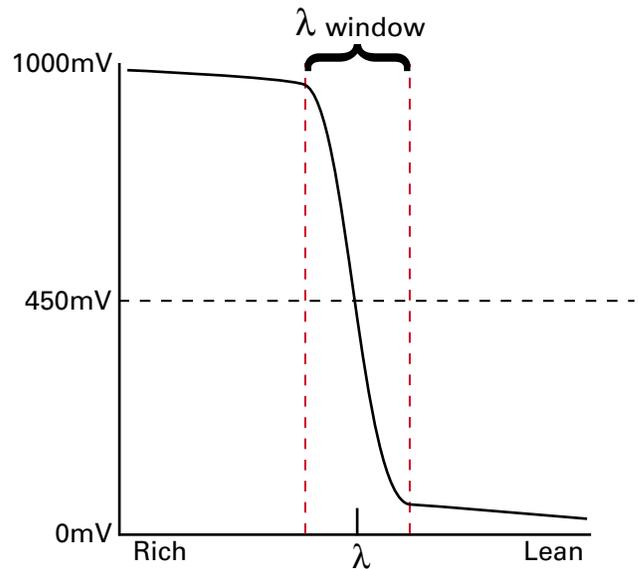
- Operation:

The base fuel injection opening time is modified according to the voltage signal from the oxygen sensor to maintain an air/fuel ratio of approximately 14.7:1. This mixture ratio is known as lambda ( $\lambda$ ). This optimal mixture of 14.7:1 is referred to as "lambda of 1 ( $\lambda=1$ )" and allows the three-way catalytic converter to operate at its maximum efficiency.

If the air/fuel mixture is lean (excess oxygen), the voltage signal sent to the ECM will be low (approximately 100 mV). This is because the voltage difference between the inner and outer surfaces of the ceramic material is low; low differences equate to low voltages.

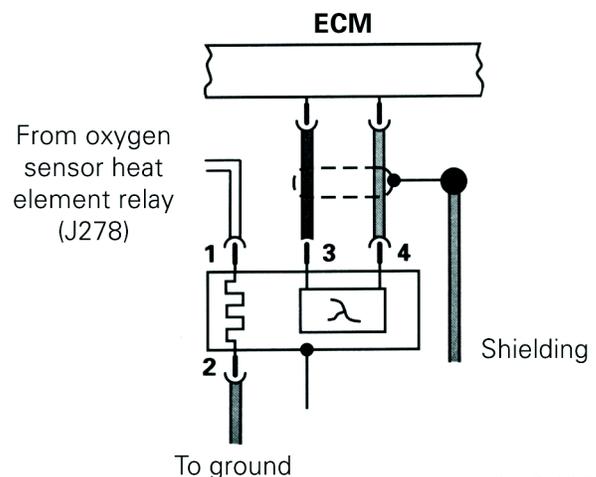


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### Electric circuit



SSP 8410/77

# Motronic M2.9 Component Summary

If the air/fuel mixture is rich (lacking oxygen), the voltage signal sent to the ECM will be high (approximately 900 mV). This is because the voltage difference between the inner and outer surfaces of the ceramic material is high; high differences equate to high voltages.

Oxygen sensors usually have four wires plus a separate grounded shield wire. The signal wire and a dedicated Ground wire are contained within the grounded shielding wire. Individual power and Ground wires are provided for the heating element. Additionally, the sensor is grounded when threaded into place.

The period of time after an engine start when the oxygen sensor is not at operating temperature, and therefore not used, is called **open loop operation**. This condition can occur after either a cold or warm start. Conversely, engine operation with a valid oxygen sensor signal is called **closed loop operation**.

As a result of the HO<sub>2</sub>S signal, the ECM lengthens the injector duration to richen the mixture, and shortens the duration to lean it out.

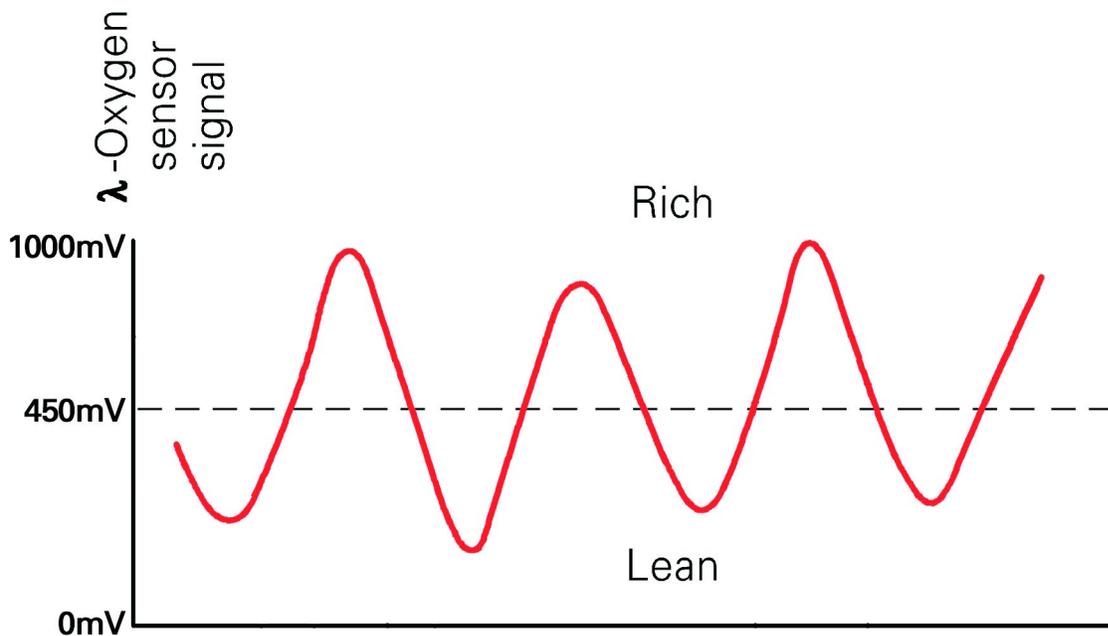
- Substitute function:

There is no direct substitute function for the oxygen sensor. If the sensor malfunctions, no oxygen sensor regulation will occur. The ECM will, however, revert to the base fuel injection opening time, allowing the engine to continue to run.

- On Board Diagnostic (OBD):

The ECM recognizes malfunctions in the oxygen sensor signal if no plausible signal is received within approximately five minutes after an engine start with coolant temperature over 40°C (104°F). It also recognizes open circuits and short circuits.

The ECM uses a correctly operating oxygen sensor to monitor faults with mixture control and other systems that influence mixture.



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# Motronic M2.9 Component Summary

## Engine Coolant Temperature (ECT) sensor G62

The engine coolant temperature sensor is an **NTC sensor** (see Glossary), mounted in the coolant flow near the cylinder head. As engine coolant temperature changes, the resistance of the sensor changes, providing the ECM with engine temperature data.

Coolant temperature sensor signal data is used as a correction factor for determining ignition timing, injector duration, and idle speed stabilization. In addition, several other systems or functions depend on coolant temperature sensor data for activation. These systems include:

- Knock sensor function
- Idle speed adaptation
- Oxygen sensor operation
- Fuel tank ventilation

For identification purposes, the coolant temperature sensor housing is usually blue in color, and is usually combined in the same housing as the Engine Coolant Temperature (ECT) sensor G2, which is used for the coolant gauge in the instrument cluster.

- Operation:

The ECM supplies a fixed reference voltage signal to the coolant temperature sensor and monitors the voltage drop caused by the resistance change.

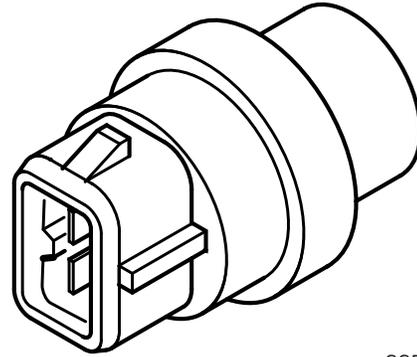
Increasing (warmer) temperatures cause the resistance to decrease; decreasing (colder) temperatures cause the resistance to increase.

- Substitute function:

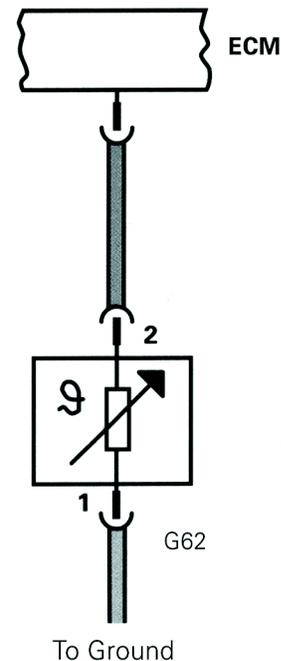
If a fault develops with the coolant temperature sensor, the ECM substitutes a value equivalent to 80°C (176°F).

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits.



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# Motronic M2.9 Component Summary

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## Intake Air Temperature (IAT) sensor G42 or G72

The intake air temperature sensor is also an NTC sensor (see Glossary), and is mounted in the intake manifold. As incoming air for combustion flows past the sensor, the resistance of the sensor changes, providing the ECM with air temperature data.

Intake air temperature sensor signal data is used as a correction factor for ignition timing and idle speed stabilization.

- Operation:

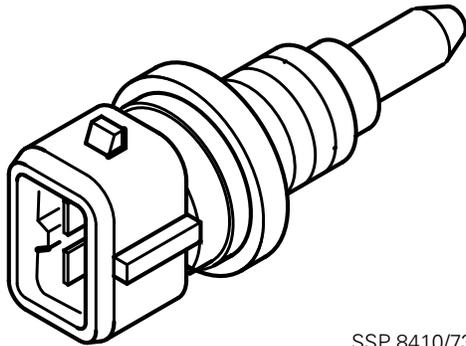
The ECM supplies a fixed reference voltage signal to the intake air temperature sensor and monitors the voltage drop caused by the resistance change. Increasing (warmer) temperatures cause the resistance to decrease; decreasing (colder) temperatures cause the resistance to increase.

- Substitute function:

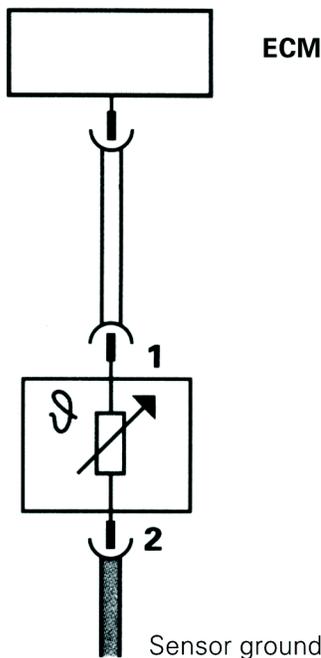
If a fault develops with the intake air temperature sensor, the ECM ignores the sensor and substitutes a value equivalent to 20°C (68°F) from memory.

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits.



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SSP 8410/72

# Motronic M2.9 Component Summary

## Exhaust Gas Recirculation (EGR) temperature sensor G98

Depending on the vehicle type and the marketing area, some vehicles are equipped with exhaust gas recirculation. The EGR system takes a small part of the non-combustible exhaust gas and injects it back into the intake tract to take up a small amount of space in the incoming air charge. The result is lower combustion temperatures and reduced oxides of Nitrogen (NO<sub>x</sub>).

The Exhaust Gas Recirculation (EGR) temperature sensor is an NTC sensor (see Glossary) mounted in the EGR valve. When the EGR is enabled by the ECM, the EGR valve opens, allowing the hot exhaust gases to flow past the temperature sensor. This raises the temperature substantially, changing the resistance of the sensor and providing the ECM with confirmation of EGR operation.

- Operation:

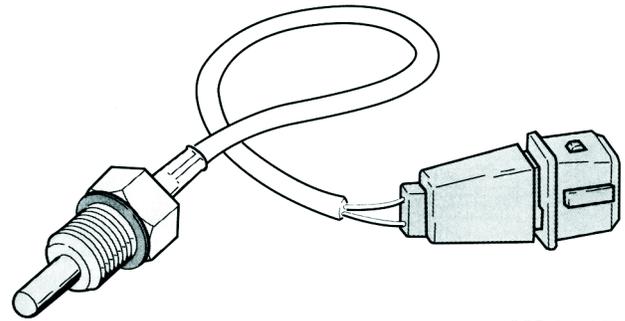
The ECM supplies a fixed reference voltage signal to the EGR temperature sensor and monitors the voltage drop caused by the resistance change. Increasing (hotter) temperatures cause the resistance to decrease; decreasing (cooler) temperatures cause the resistance to increase.

- Substitute function:

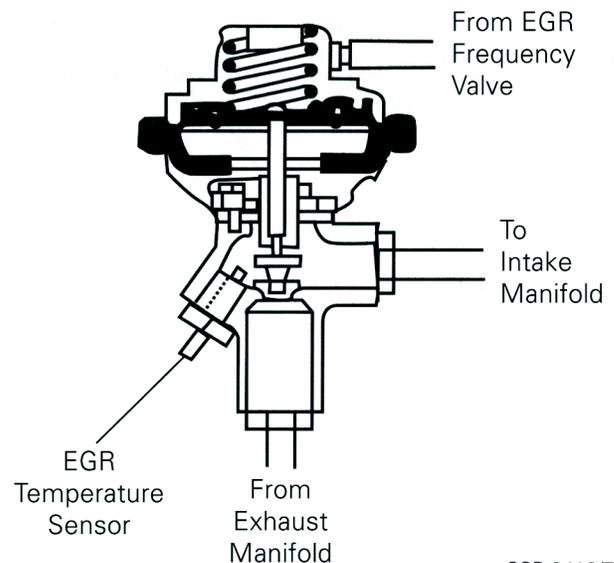
There is no substitute function.

- On Board Diagnostic (OBD):

The ECM recognizes short circuits.



SSP 8410/71



SSP 8410/70

# Motronic M2.9 Component Summary

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## Additional input signals

Several other signals are used by the ECM in much the same manner as input sensors. Depending on installed vehicle equipment, these additional signals may include:

- **Battery voltage:**

Aside from the voltage needed to actually operate the Motronic engine management system, the ECM monitors voltage to compensate for the quicker operation of some components due to higher or lower available operating voltage. Fuel injectors, for example, cycle slightly faster at 14.5 Volts than they do at 12 Volts or lower. This faster cycle time must be figured into the calculation of duration for accuracy.

- **Air conditioner “System ON” signal:**

The air conditioner system signal allows the ECM to be prepared for the additional load demands of the air conditioner on the engine.

- **Air conditioner compressor “Clutch ON” signal:**

The compressor “clutch on” signal prepares the ECM for a quick response to the sudden engine speed changes that occur when the compressor clutch is engaged, particularly at idle.

- **Vehicle speed sensor signal:**

The vehicle speed sensor signal originates from the instrument cluster and is used by the ECM to control the idle stabilizer during deceleration, and to limit vehicle top speed.

- **Automatic Transmission Control Module (TCM) signal:**

The TCM sends a signal to the ECM during shifting. This allows the ECM to retard ignition timing for smoother shifting.

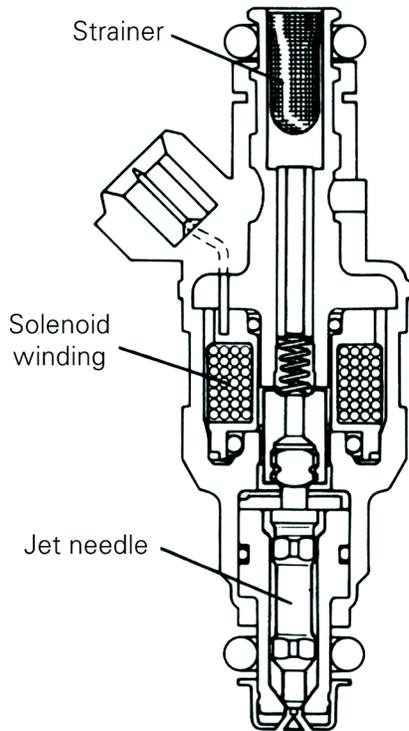
# Motronic M2.9 Component Summary

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## Actuators (outputs)

Motronic engine management systems rely on different actuators to run the engine and operate related systems. The type and number of actuators varies with the Motronic version, but the basic operation remains essentially the same for all versions.

**Cylinders 1 - 4 fuel injectors N30 - N33**  
**Cylinders 5 - 6 fuel injectors N83 - N84**



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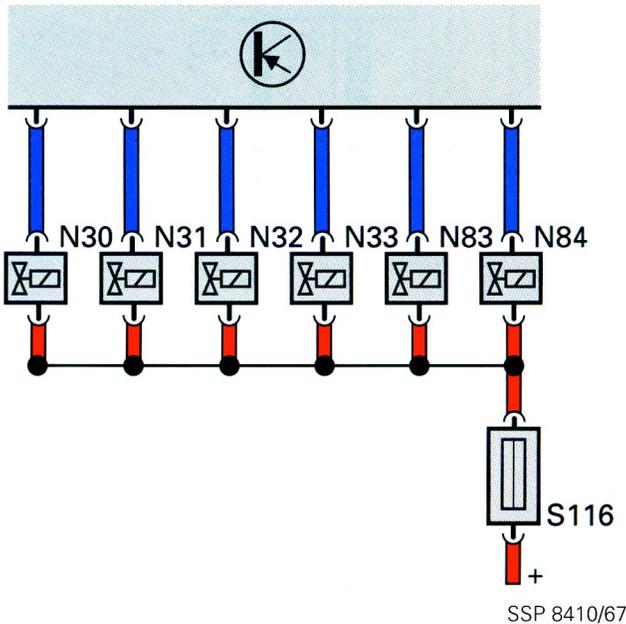
Motronic fuel injectors are electronically controlled **solenoid valves** (see Glossary).

Fuel injectors are attached to a common fuel rail with locking clips, and sealed at both ends by serviceable O-rings. The fuel rail doubles as a retaining bracket.

Fuel injector internal resistance specifications vary slightly depending on application, but typically are in the area of 15 Ohms. It should be noted that higher temperatures will cause resistance values to increase.

# Motronic M2.9 Component Summary

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- Operation:

The fuel injectors are supplied with constant system voltage by a supply relay, and are triggered in firing order sequence when the ECM supplies a Ground signal. When the injector opens, a fine spray of fuel is mixed with the incoming air flow. The volume or quantity of fuel is determined by the length of time that the ECM supplies the Ground signal. The longer the signal, the greater the fuel delivery. The time period is called **injector duration**.

Fuel injectors are switched off during certain phases of normal engine operation. When the engine is running at higher speeds with a closed throttle such as when "coasting," the ECM switches off the injectors to reduce emissions (deceleration fuel shut-off). Fuel injectors are also switched off at high engine speeds to limit maximum RPM.

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits. Additional diagnostic testing is available with the scan tool set in the output Diagnostic Test Mode (DTM).

# Motronic M2.9 Component Summary

## Ignition coil N152

### Power output stage N157

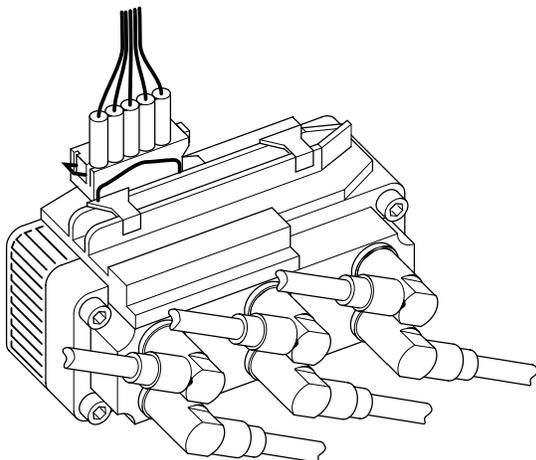
The ignition power output stage is mounted to the ignition coil and amplifies the low power signal from the ECM to a usable level. The ignition coil is a type of step-up transformer that takes the low primary voltage and raises it to the high secondary voltage level required by the spark plugs to ignite the mixture within the cylinder (see Ignition System Overview).

The combined ignition coil and power output stage is mounted to either the engine itself or the bulkhead. In some Motronic versions, the power output stage can be separated from the ignition coil for testing, but the power output stage and the ignition coil are only serviceable as a complete assembly.

- Operation:

The ignition system is triggered and the spark plugs fire when the ECM supplies a signal to the power output stage. This signal is primarily based on engine speed and load inputs.

Correction factors from other relevant input sensors allow the trigger signal generated to provide the correct ignition timing advance.



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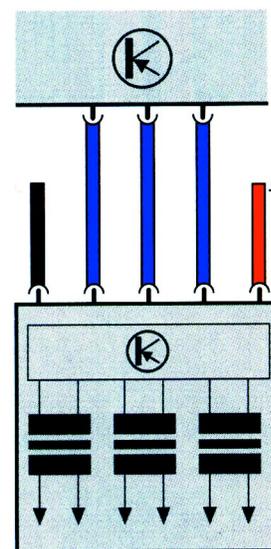
Additional ECM calculations include:

- dwell angle
- cylinder selective knock regulation
- Idle Speed Control (ISC) (see Glossary)

The power output stage and coil are supplied with power and Ground when the ignition is switched on. Systems with a distributor charge the ignition coil every time the spark plug fires. Systems without a distributor use multiple coils. The VR-6, for example, uses three double-ended coils with a spark plug attached to each end. At every firing pulse, when the magnetic field collapses, both spark plugs fire. The only cylinder to fire, however, is the one coming up on the compression stroke. The other spark occurs when the cylinder is not ready to be fired, and is considered to be a wasted spark. Since this spark does not ignite a combustible mixture, and is not under the severe heat and pressure of combustion, it causes no appreciable wear on the spark plug.

- On Board Diagnostic (OBD):

The ECM recognizes short circuits to Battery (+) positive.



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# Motronic M2.9 Component Summary

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## Fuel Pump (FP) relay J17

## Fuel Pump (FP) G6

Motronic engine management systems use a fuel tank-mounted two-stage electric fuel pump controlled by a signal from the ECM through the fuel pump relay. Mounting the pump within the fuel tank keeps the pump continuously cooled and lubricated by the circulating fuel. The fuel also provides sound absorption, resulting in quieter operation.

- Operation:

When the ECM determines that the appropriate conditions have been met, a Ground signal is sent to the fuel pump relay. This relay operates the two-stage electric fuel pump mounted in the fuel tank.

The two-stage fuel pump has a single electric motor driving two separate pumps on a common shaft.

- Stage One

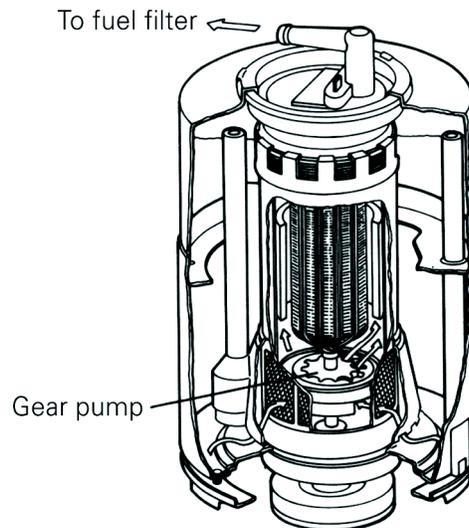
Fuel is drawn in through a screen at the bottom of the housing assembly by a vane-type pump. The screen provides coarse filtration, and the vane-type pump acts as a transfer pump. Its high volume design supplies fuel to the fuel accumulator which is within the pump housing.

- Stage Two

The gear-type pump draws fuel in from the bottom of the accumulator and through another screen. The fuel is then forced through the pump housing by the gear pump and out through the top of the fuel tank. It then flows through the external fuel filter and into tubes that carry it forward to the engine.

- On Board Diagnostic (OBD):

The ECM recognizes fuel pump relay short circuits to positive. Additional diagnostic testing is available using the scan tool set in the output Diagnostic Test Mode (DTM).



SSP 8410/18

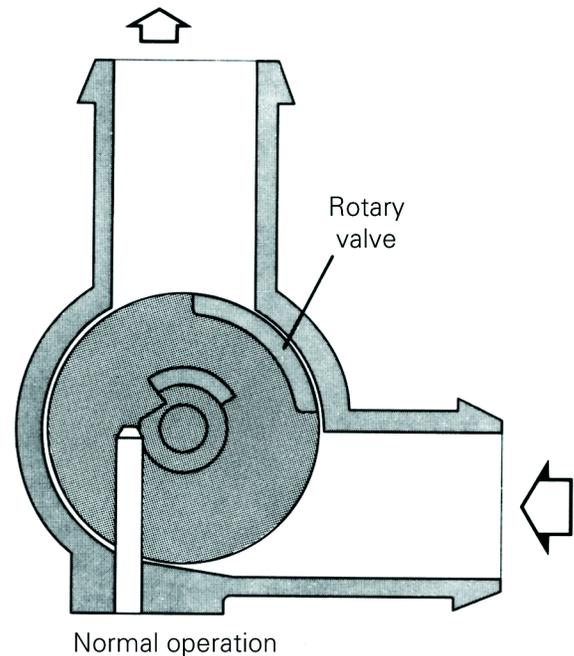
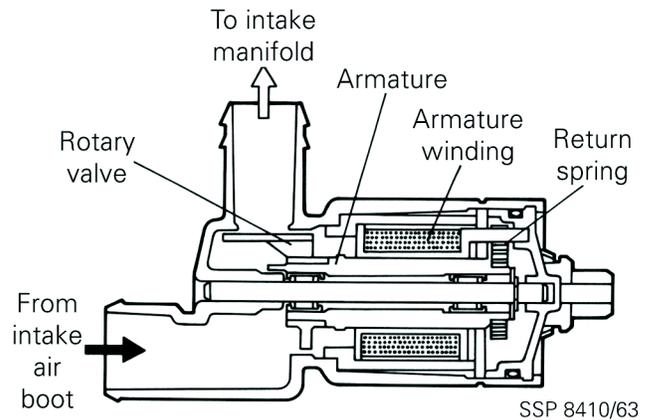
# Motronic M2.9 Component Summary

## Idle Air Control (IAC) valve N71

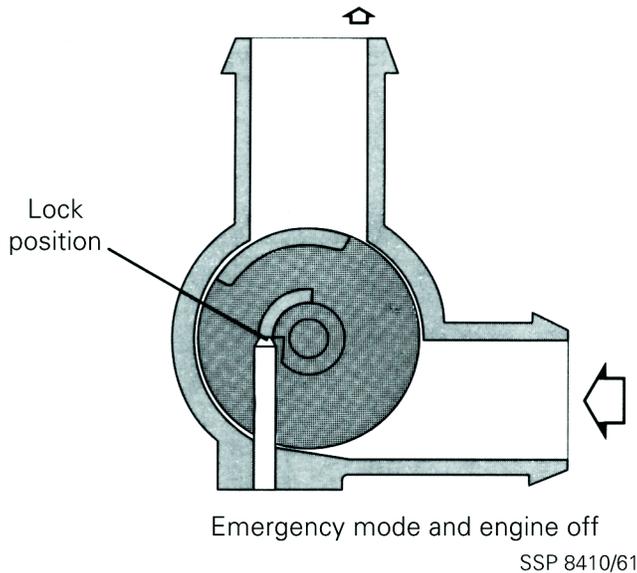
Engine idle speed is controlled by a rotary-valve idle stabilizer known as an idle air control valve. Because the valve varies the volume of air that is allowed to bypass the closed throttle valve, it is mounted near the throttle housing. Idle speed control (ISC) from the ignition system also helps to provide a smooth idle.

Load changes, such as those imposed by air conditioning, power steering, the generator, or a cold engine can cause the idle speed requirement to vary considerably. The idle air control valve opens or closes under the control of the ECM to maintain a constant idle speed regardless of temperature or load.

The ECM also controls the air flow during engine and vehicle deceleration to minimize emissions and reduce stalling tendencies. It does this by operating the idle air control valve as an **electronic dashpot** (see Glossary).



# Motronic M2.9 Component Summary



The idle air control valve is not adjustable.

- Operation:

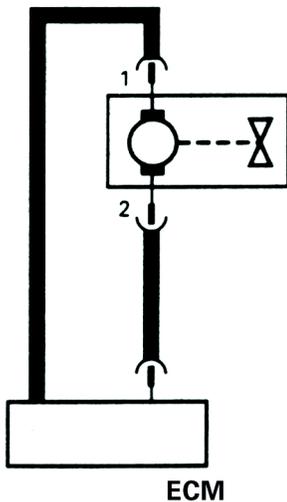
The idle air control valve housing mounts an electric motor with 90° of rotation. Attached to the motor shaft is a rotary valve and a return spring. When the ECM commands more throttle opening, more power is sent to the motor, opening the valve against spring tension. When less speed is required, the power is reduced. The valve closes against spring tension reducing the air flow and dropping the speed.

- Substitute function:

If a fault develops with the idle air control valve circuitry, the ECM output stages are shut off and the valve rotates to a fixed position allowing the engine to idle at a normal warm engine idle speed.

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits to Ground and Battery +, as well as adaptation limit reached/ exceeded and sets an appropriate DTC. Additional diagnostic testing is available using the scan tool in the output Diagnostic Test Mode (DTM).



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## Evaporative Emission (EVAP) canister purge regulator valve N80

The fuel tank ventilation system is designed to prevent fuel vapors from escaping directly to the atmosphere. Purging of fuel vapors from the fuel system is controlled by the ECM working via the evaporative emissions solenoid valve located near the engine air intake. Fuel vapors from the fuel tank are vented to the carbon canister for storage. When the engine is warm and above idle speed, the vapors are drawn into the intake manifold via the tank vent hose and the carbon canister.

- Operation:

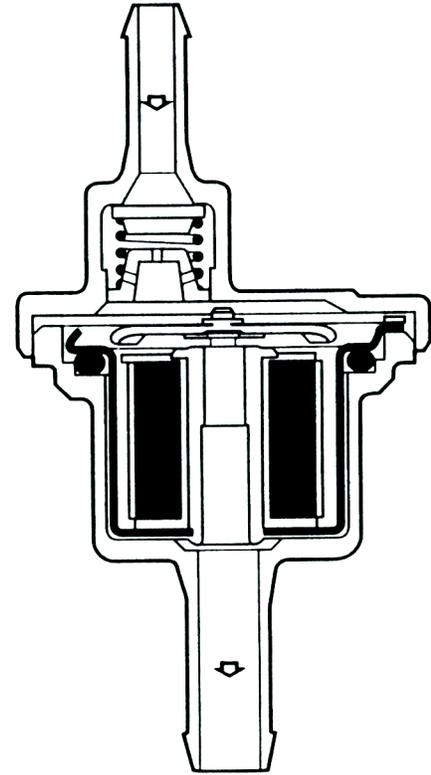
The ECM determines the duty cycle of the frequency valve to regulate the flow of the fuel vapors from the carbon canister to the engine.

A spring operated check valve inside the frequency valve closes when the engine is not running. This prevents fuel vapors from entering the intake manifold and causing an excessively rich mixture on a restart. When the engine is started, vacuum opens this valve.

When no current is supplied to the valve, it remains in the open position. The valve is closed (duty cycle = 100%) when the cold engine is started.

N80 begins to operate after oxygen sensor operation has begun. Depending on engine load and the oxygen sensor signal, the evaporative emissions solenoid valve will regulate the quantity of vapors entering the intake manifold from the carbon canister. The valve is completely open at full throttle, and completely closed during deceleration fuel shut-off.

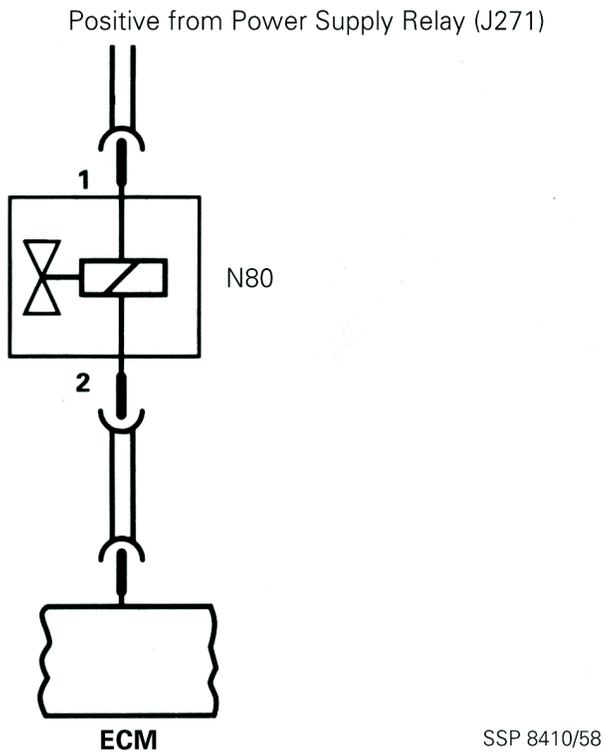
- Substitute function:



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# Motronic M2.9 Component Summary

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If power to the valve is interrupted, the valve remains fully open (as long as vacuum is applied to the check valve).

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits in this component and sets an appropriate Diagnostic Trouble Code (DTC). Additional diagnostic testing is available with the scan tool set in the output Diagnostic Test Mode (DTM).

# Motronic M2.9 Component Summary

## Exhaust Gas Recirculation (EGR) vacuum regulator solenoid valve N18

Exhaust Gas Recirculation (EGR) is the process by which a small amount of the spent combustion gas is re-injected into the intake air tract to be mixed with the fresh air/fuel charge and be reburned. Since there is very little combustibility left in the injected gas, it simply occupies space and reduces combustion chamber temperatures which, in turn, reduces harmful emissions of oxides of nitrogen ( $\text{NO}_x$ ).

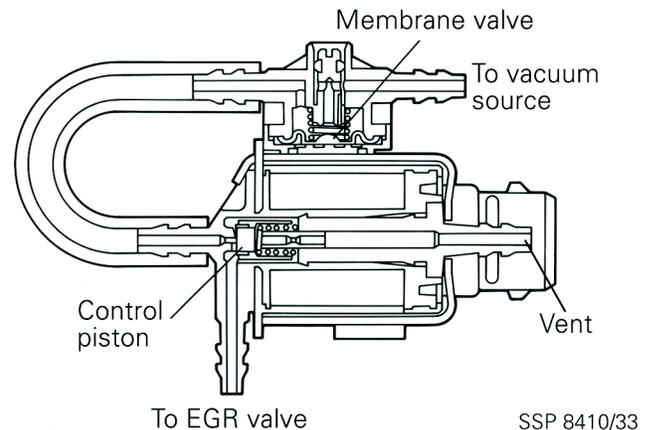
The EGR vacuum regulator solenoid valve is mounted on the rear of the intake manifold (close to the EGR valve) and regulates the amount of vacuum supplied to the EGR valve (which regulates the amount of EGR).

- Operation:

A controlling pressure (vacuum) is formed in the regulator valve from intake manifold pressure (vacuum) and atmospheric pressure. The atmospheric pressure is taken from a filtered air source.

The ECM operates the regulator valve by supplying an appropriate Ground signal. The regulator valve then controls the amount of vacuum supplied to the EGR valve diaphragm by cycling between the connection to the EGR valve and the atmospheric vent.

The actual amount of recirculated exhaust gas entering the engine is calculated by the ECM, and is dependent on engine speed and load conditions. The maximum vacuum supplied to the EGR valve is limited to approximately 200 mbar by a membrane valve within the solenoid valve.



# Motronic M2.9 Component Summary

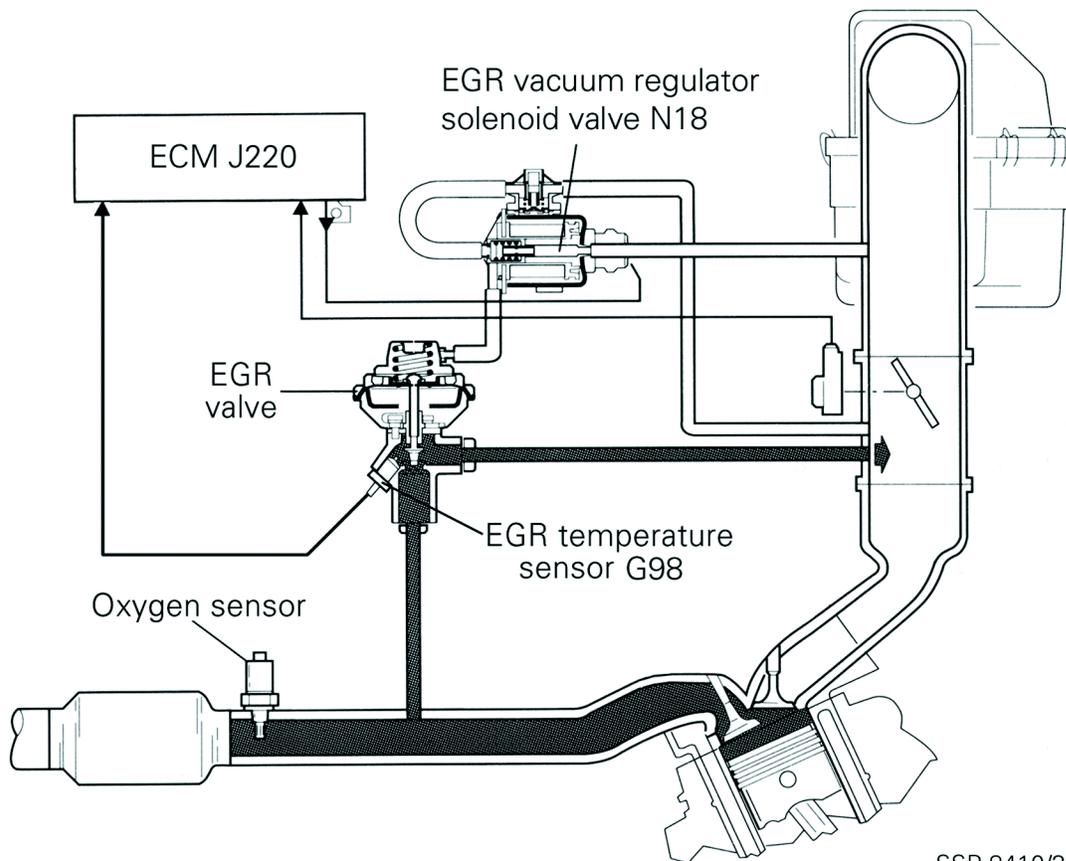
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- Substitute function:

There is no substitute function for the EGR vacuum regulator solenoid valve. If no vacuum is supplied to the EGR valve, it will remain in the closed or off position.

- On Board Diagnostic (OBD)

The ECM monitors the EGR solenoid valve for open circuits and short circuits. It also monitors EGR valve operation via the EGR temperature sensor. Additional diagnostic testing is available with the scan tool set in the output Diagnostic Test Mode (DTM).



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# Motronic M2.9 Component Summary

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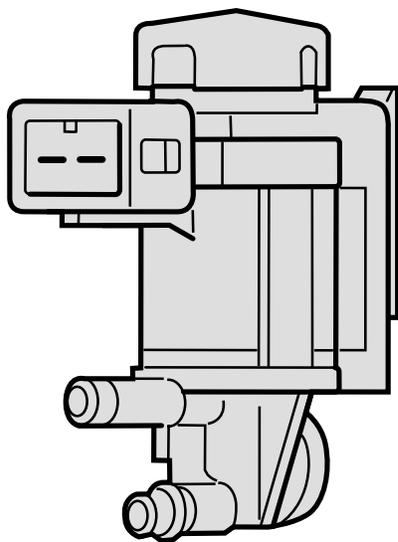
## Secondary Air Injection (AIR) solenoid valve N112 pump motor V101 pump relay J299

Most VR-6 engines and some 4-cylinder engines use an electrically operated air pump to reduce exhaust emissions during engine warm-up.

After a cold engine start, when the heated oxygen sensor signal is not accurate, the engine management system is in open loop mode. The secondary air injection system adds extra air into the exhaust stream just past the exhaust valves to aid in the afterburning of the combustion gases.

Advantages to this function include:

- Quicker warm-up for the three-way catalytic converter and heated oxygen sensor.
- Air/fuel ratios that make this process work most efficiently also improve driveability.
- Exhaust emissions are reduced.



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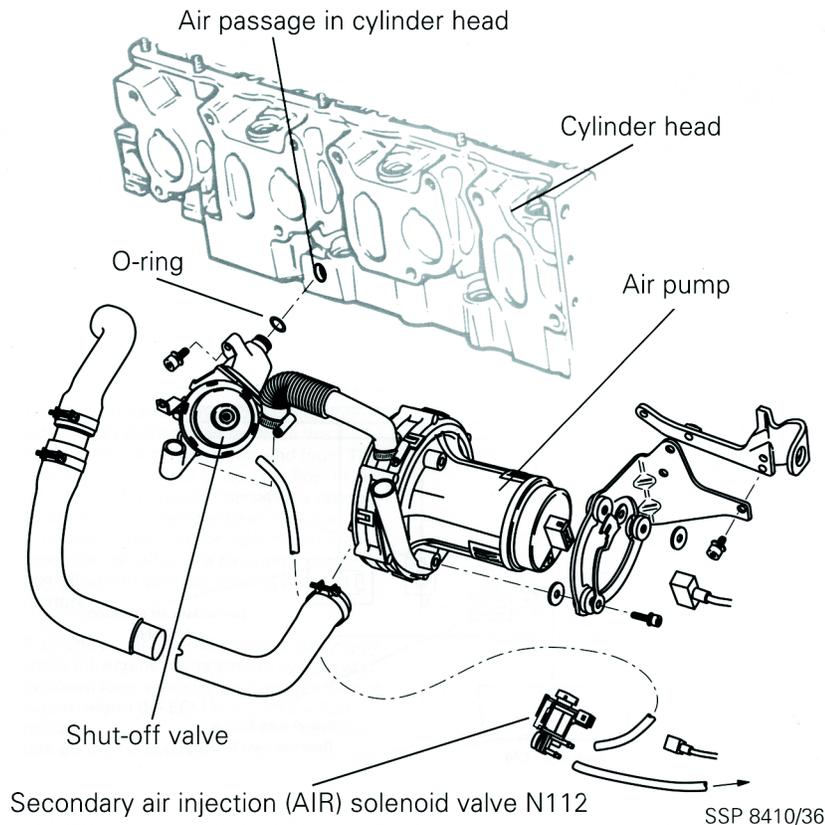
Secondary air injection system electrical components include an air pump, a solenoid valve, and a relay. A mechanical shut-off valve and connecting pipes complete the major system components.

- Operation:

When the engine is first started and the coolant temperature is between 15°C (59°F) and 35°C (95°), the ECM signals the relay which operates the secondary air injection pump and solenoid inlet valve. The air pump runs and the solenoid inlet valve opens. This sends vacuum to the shut-off valve, opening it. The pump then forces a calibrated amount of air into each exhaust port where it mixes with any unburned fuel to continue the combustion process. Operation continues for up to 65 seconds; the pump stops, and the shut-off valve closes. The additional heat generated by this process allows the three-way catalytic converter to reach operating temperature faster.

Approximately 15 seconds after the air pump switches off, the system will momentarily cycle on again, sending a blast of air past the oxygen sensor. The ECM anticipates the sudden change in the oxygen sensor signal that accompanies the system being switched on, and does not change the mixture. Rather, it uses this to confirm proper secondary air injection system operation to the ECM.

# Motronic M2.9 Component Summary

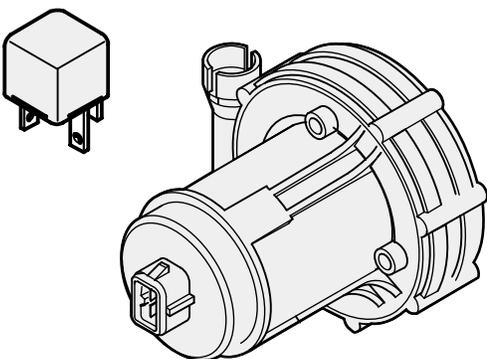


- Substitute function:

There is no substitute function for the secondary air injection system. If no vacuum is supplied to the shut-off valve, it will remain in the closed or off position.

- On Board Diagnostic (OBD)

The ECM recognizes short circuits to Battery +, and open and short circuits to Ground for both the Secondary Air Injection (AIR) relay and the Secondary Air Injection (AIR) solenoid valve. Additional diagnostic testing is available with the scan tool set in the output Diagnostic Test Mode (DTM).



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# Motronic M2.9 Component Summary

## Heated Oxygen Sensor (HO2S) Control Module J208 Heated Oxygen Sensor (HO2S) relay J278

The oxygen sensor heater helps to bring the oxygen sensor up to operating temperature quickly. The ECM controls the oxygen sensor heater through either a relay or a control module.

- Operation:

The ECM receives the appropriate input signals and when the engine is started, a signal is sent to the oxygen sensor heater relay or control module. This puts the engine management system into closed loop operation sooner.

- Substitute function:

There is no substitute function for a malfunctioning oxygen sensor heater control module.

- On Board Diagnostic (OBD)

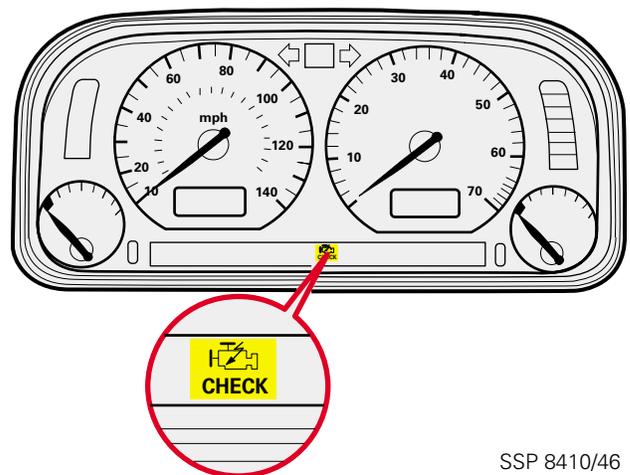
The ECM recognizes short circuits to positive and open and short circuits to Ground. Additional diagnostic testing is available with the scan tool set in the output Diagnostic Test Mode (DTM).

## Malfunction Indicator Light (MIL)

Motronic engine management systems are capable of sending a signal to a warning light if malfunctions occur with monitored components. The MIL is located within the instrument cluster.

- On Board Diagnostic (OBD)

The ECM recognizes short circuits to positive and open and short circuits to Ground with the MIL circuit.



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# Motronic M2.9 Component Summary

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## Additional output signals

The ECM generates several output signals that are used by other vehicle systems. These signals are derived from input sensors or internal ECM calculations, and usage varies with the equipment installed on the vehicle.

- **Engine speed signal:**

The ECM generates an engine speed or RPM signal that is sent to several other systems.

The instrument cluster uses the RPM signal for tachometer operation and dynamic oil pressure warning.

The Transmission Control Module (TCM) uses the RPM signal as a substitute function for a missing transmission vehicle speed sensor signal.

- **Engine load signal:**

The ECM generates a composite load signal used by the multi-function indicator (MFI) for miles-per-gallon calculations on vehicles equipped with the MFI.

The ECM monitors this function and recognizes short circuits to positive.

- **Throttle position:**

Early Motronic vehicles equipped with automatic transmissions used separate throttle position sensors for the engine and the transmission control modules. However, later versions use a single TPS, and pass the throttle opening information to the TCM through the ECM.

The ECM monitors this function and recognizes short circuits to Ground.

## Review

1. **Which of the following components does NOT receive an output signal from the Motronic M2.9 engine management system ECM?**
    - a. Idle air control valve (IAC)
    - b. Fuel injectors
    - c. Fuel pump relay
    - d. Intake air pre-heat servo
  2. **Technician A says that Motronic M2.9 engine management systems can adapt to variables such as small vacuum leaks and altitude. Technician B says that Motronic M2.9 engine management systems require periodic manual carbon monoxide (CO) adjustments. Which Technician is correct?**
    - a. Technician A only
    - b. Technician B only
    - c. Both Technician A and Technician B
    - d. Neither Technician A nor Technician B
  3. **Motronic M2.9 engine management systems store and use learned values. This process is called:**
    - a. Stoichiometric
    - b. Adaptive learning
    - c. Lambda
    - d. Default value retention
  4. **Technician A says that the Motronic M2.9 ECM retains learned values when the battery is disconnected. Technician B says that the Motronic M2.9 ECM combines all fuel and ignition functions, but uses a separate ECM for evaporative emissions and secondary air injection operation. Which Technician is correct?**
    - a. Technician A only
    - b. Technician B only
    - c. Both Technician A and Technician B
    - d. Neither Technician A nor Technician B
  5. **Motronic M2.9 fuel injectors operate:**
    - a. Sequentially
    - b. In groups of two
    - c. All at the same time
    - d. None of the above
  6. **Technician A says that all Motronic M2.9 engine management systems use exhaust gas recirculation. Technician B says that all Motronic M2.9 engine management systems use secondary air injection. Which Technician is correct?**
    - a. Technician A only
    - b. Technician B only
    - c. Both Technician A and Technician B
    - d. Neither Technician A nor Technician B
-

## Motronic M2.9 Review

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7. Which of the following statements is **NOT** applicable to the Motronic M2.9 engine management system?
- a. Fuel injection control is digital electronic.
  - b. All versions are capable of communicating with scan tools VAG 1551/1552 and VAS 5051.
  - c. The ECM can communicate with the TCM if the vehicle is equipped with an automatic transmission.
  - d. Ignition timing, idle speed and mixture adjustments should not be required until 30,000 miles (48,000 km).

## Mono-Motronic System Overview

### System Description

Beginning with the 1993 model year, Canadian base model Golf CLs were equipped with a 1.8 liter engine with Mono-Motronic Engine Management.

Mono-Motronic engine management combines familiar Digifant system elements with Motronic M2.9 system elements. Several new functions are combined with throttle-body fuel injection to complete the system.

Mono-Motronic engine management controls the following engine functions:

- Fuel injection quantity
- Ignition timing
- Fuel tank ventilation
- Idle speed stabilization

Fuel injection control is electronic. It is based on the quantity of air entering the throttle body as indicated by the throttle valve position sensor. The throttle valve position sensor's dual potentiometers provide the ECM with an indication of engine load conditions. Engine speed information is received from the camshaft position sensor (Hall sender in the ignition distributor) and corrected by coolant and intake air temperatures. A heated oxygen sensor provides feedback information to the ECM to modify the mixture as needed.

A single fuel injector (mono) is mounted in the throttle body housing, and supplies atomized fuel to the engine according to operating conditions specified by the ECM.



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# Mono-Motronic

Ignition control is also electronic. The signals for engine load and engine speed that are used to control the fuel injector duration also provide information for the basic ignition timing point. Corrections to the timing point are made from information supplied by the engine coolant temperature sensor, and a calculated signal is sent to the ignition coil power output stage from the ECM.

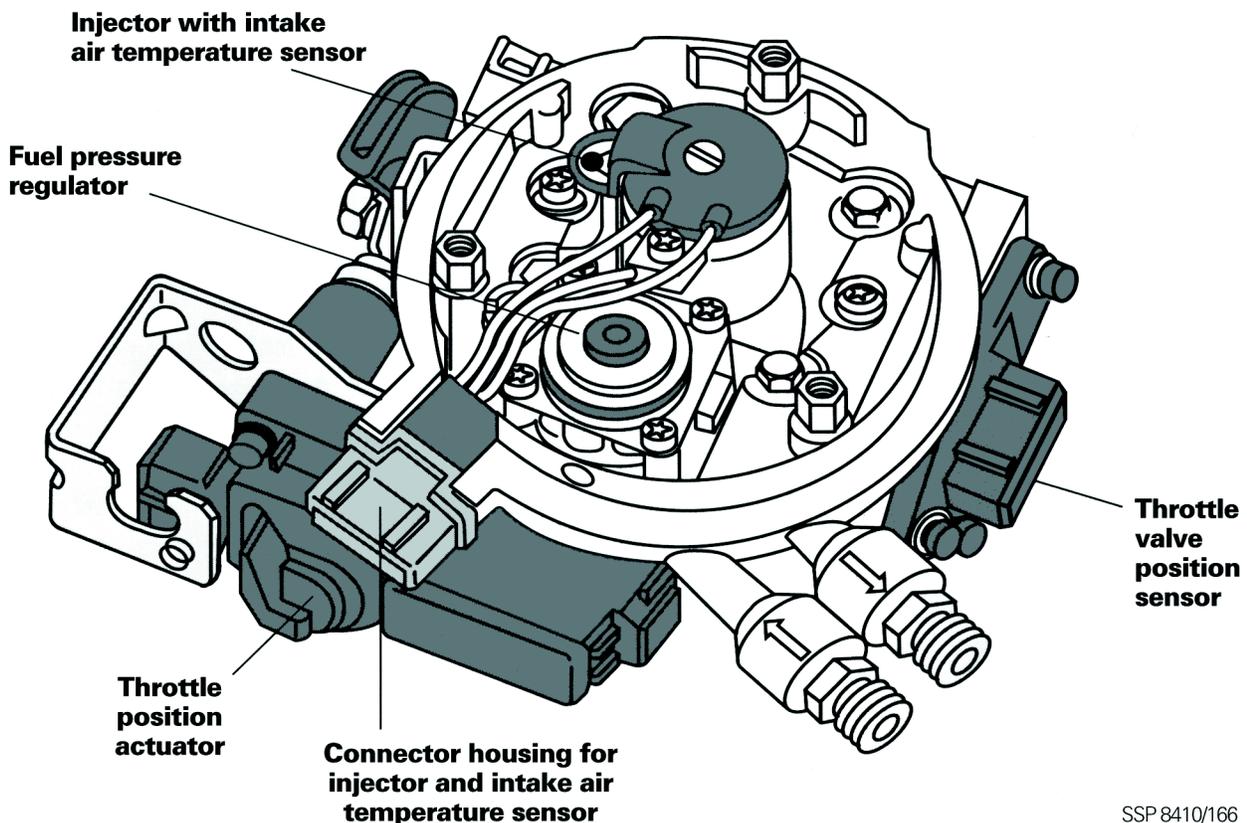
Fuel tank ventilation is accomplished through the use of an evaporative emissions frequency valve controlled by the ECM in the same manner as on Motronic M2.9.

Idle speed control on the Mono-Motronic system is by two methods; either one or both may function at the same time.

- A throttle position actuator connected to the throttle valve moves the valve to compensate for variations in idle speed brought about as the result of changes in engine loading.
- Idle speed stabilization is further accomplished by modification of the ignition timing point. Idle speed correction (ISC) is a function of the ECM and is capable of rapid response to engine speed changes brought about by sudden load changes. A sudden large load, such as a radiator cooling fan switching on, will cause a timing change and corresponding speed change within milliseconds.

Additional functions of the ECM include:

- Operation of the fuel pump through a ground signal sent to the fuel pump relay.



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## Inputs/Outputs

The 45-pin electronic control unit used in the Canadian Golf CL receives input signals from the following sources:

- Camshaft position sensor (Engine speed)
- Throttle position sensor (Engine load)
- Engine coolant temperature sensor
- Intake air temperature sensor
- Heated oxygen sensor
- Closed throttle position switch

Additional signals used as inputs are received from the following sources:

- Air conditioner
- Automatic transmission
- Vehicle speed sensor

Outputs or actuators controlling engine operation include signals to the following:

- Fuel injector (mono)
- Ignition coil power output stage
- Throttle position actuator
- Fuel pump relay
- Early fuel evaporation relay
- Evaporative emission canister purge regulator valve

Additional output signals are generated and include the following:

- Malfunction indicator lamp signal
- Engine speed (rpm) signal
- Automatic transmission TCM signals

## Additional Systems

Fuel is sent from the fuel tank to the throttle body by a 2-stage fuel delivery unit that is the same as Motronic M2.9 equipped vehicles.

Fuel pressure is maintained by a mechanical fuel pressure regulator in the throttle body assembly. Pressure is maintained at approximately 1 bar  $\pm$  0.2 bar during engine operation by regulation of the of fuel returned to the tank.

## On Board Diagnostics

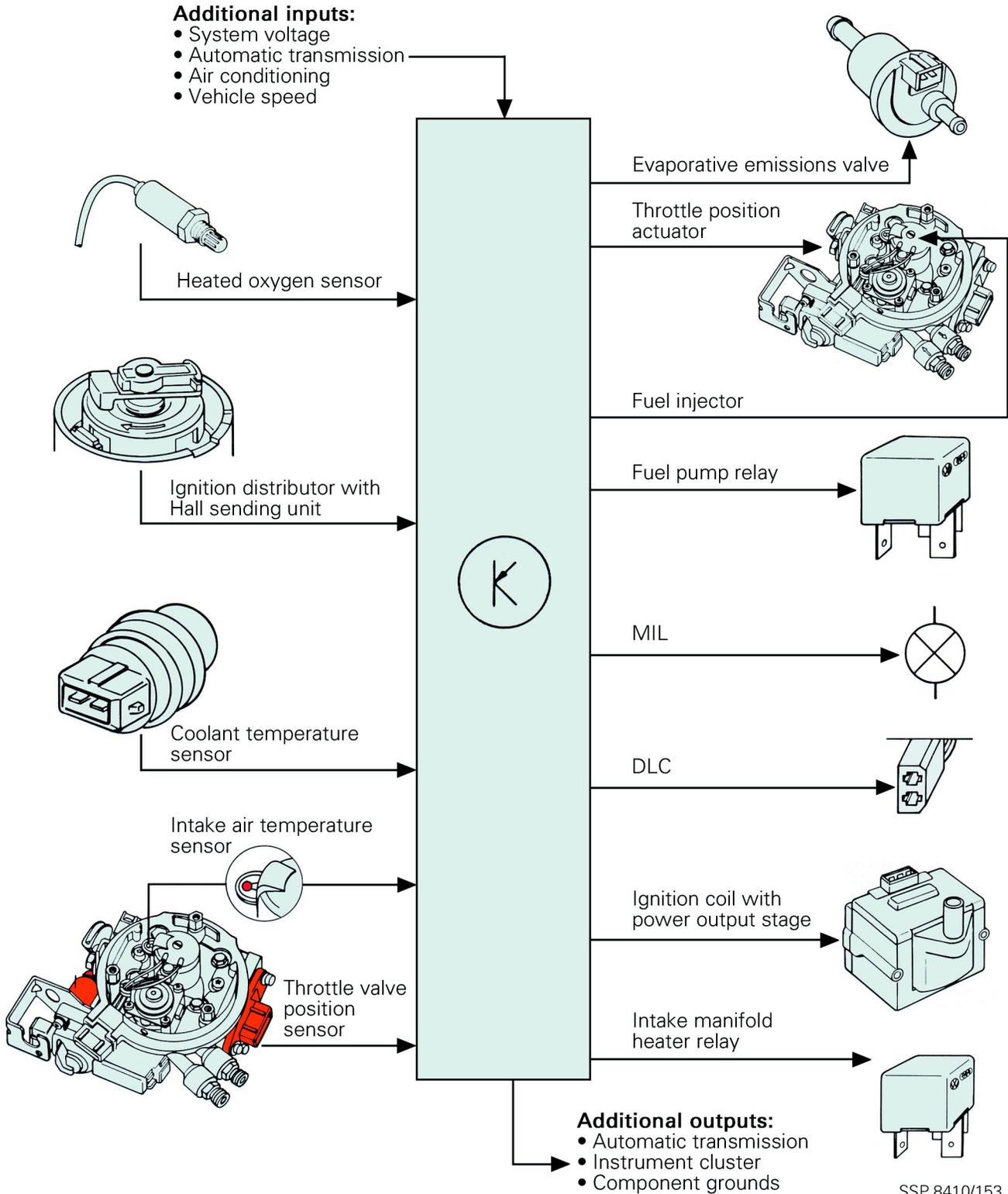
Mono-Motronic Golf CLs have On Board Diagnostic (OBD) capabilities through the use of Scan Tools VAG 1551/1552 and VAS 5051. Idle speed and carbon monoxide (CO) values are regulated by the ECM and are not adjustable. However, ignition timing can be adjusted to baseline values as needed. Information regarding On Board Diagnostics and engine checks/ adjustments are available in VESIS.

## Summary

Mono-Motronic is a basic engine management system designed originally to be used on smaller displacement engines. This was done to take advantage of newly developed signal processing circuits being introduced into the automotive marketplace that would eliminate the inefficiencies of a carburetor.

Sensor and other signal inputs, along with actuator and other signal outputs, are shown in the illustration on the following page.

# Mono-Motronic



## OBD II Overview

### Background

Pollution from the internal combustion engines in cars and trucks is a concern in the United States. California addressed these concerns when it enacted the first air quality standards for motor vehicles in 1961 for the 1963 model year. The California Air Resources Board (CARB) has led the effort to reduce all types of motor vehicle emissions nationwide. In addition to reducing vehicle emissions, CARB has been an innovator in related concepts such as standardized On Board Diagnostics (OBD) that help contribute to cleaner running engines.

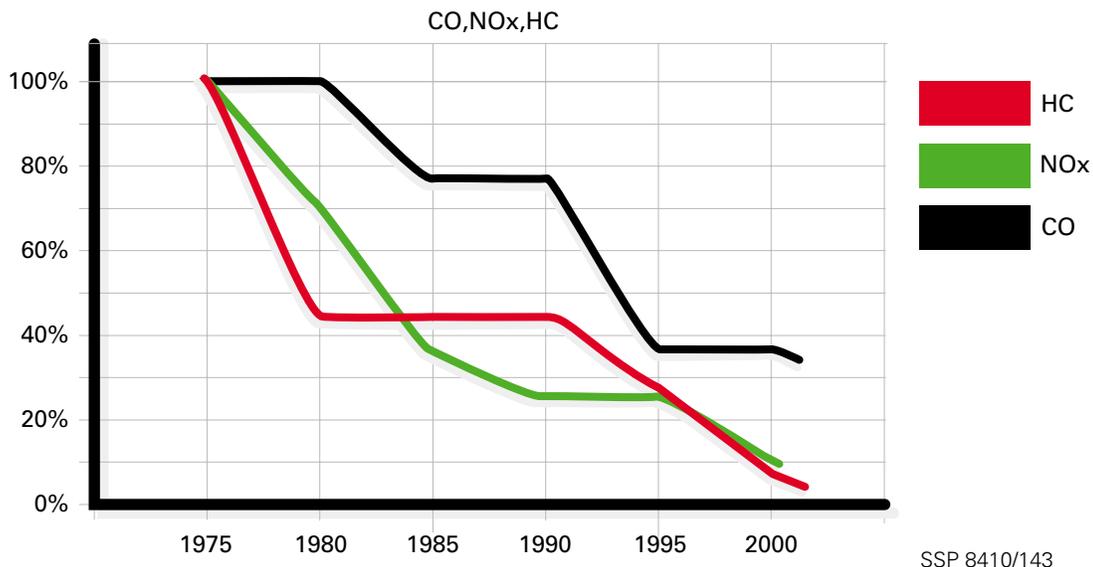
The United States Government is involved in air quality standards through the Environmental Protection Agency (EPA). The EPA works with the auto manufacturers, the Society of Automotive Engineers (SAE), and other agencies to regulate and enforce legislation dealing with air quality.

By the early 1980s, many vehicle manufacturers were using electronics and computers to manage fuel and ignition functions. Methods had been developed for these systems to diagnose problems with sensors and actuators. OBD-I refers to a requirement for vehicles sold in California, starting with the 1988 model year, to standardize these diagnostics.

The requirement stated that a partial or a complete malfunction that caused exhaust emissions to exceed a specified level would illuminate a Malfunction Indicator Light (MIL). An identification code is assigned to each malfunction.

As the graph shows, the major automotive pollutants of hydrocarbons (HC), carbon monoxide (CO), and nitrous oxides (NO<sub>x</sub>) have been dramatically reduced in California due to the effects of CARB-sponsored legislation.

Emissions reductions brought about as a result of OBD-I technology evolved into the next generation of on board diagnostics, OBD-II.



# OBD-II Overview

## OBD-II

Beginning with the 1996 model year, all Volkswagen passenger vehicles are equipped to meet the new OBD-II diagnostic standard. OBD-II is a refinement of the older OBD-I standard. These new standards encompass more than engine operating parameters alone. Additional engine management components, engine and fuel systems, and non-engine systems are monitored as part of the OBD-II system.

OBD-II standards include:

- Standardized diagnostic connection and location in the driver's area
- Standardized DTCs for all manufacturers
- Retrieval of DTCs by commercially available diagnostic equipment (generic scan tools)
- Retention of operating conditions present during a monitored malfunction
- Standards governing when and how a monitored malfunction must be displayed
- Standardized names for components and systems

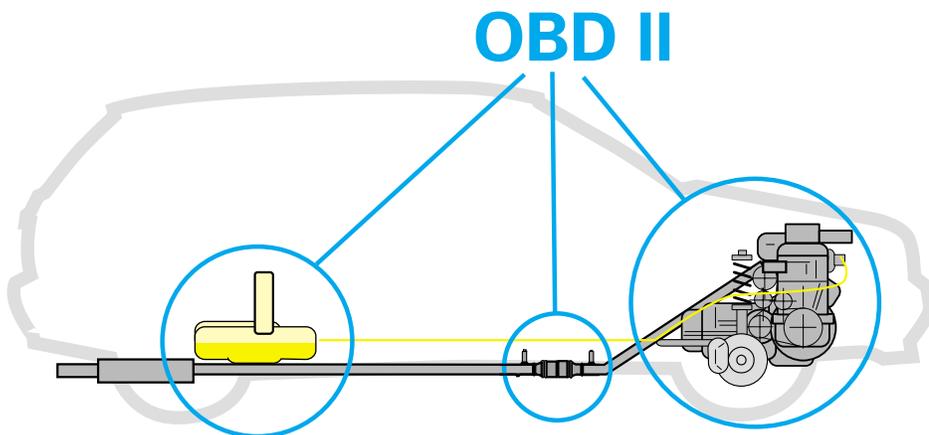
After establishing the set of standards as a framework, a set of objectives was developed to provide the basis for system operation.

The objectives include:

- Operational monitoring of all components that have an influencing effect on exhaust emissions
- Protection for the catalytic converter(s)
- Visual display within driver's view (malfunction indicator light) to signal malfunctions in emissions-relevant components
- On-board fault memory to store standardized error codes
- Diagnosis capability

With the objectives firmly established, a clear method of achieving them was designed into the engine management system and the ECM. The monitored components and systems include:

- Three-way catalytic converter
- Oxygen sensors
- Engine misfire detection
- Secondary air injection
- Exhaust gas recirculation
- Evaporative emissions control and system integrity
- Fuel distribution system
- All sensors, components, and inputs associated with the ECM
- Automatic transmission (emissions-related functions)



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## OBD-II Function

OBD-I systems verify the normal operation of sensors and actuators by measuring voltage drop at the component. This technique for confirmation of operation is known as a component monitor. This method can be used to determine short circuits to positive, short circuits to Ground, and open circuits.

OBD-II systems monitor inputs and outputs (sensors and actuators) in the same manner as OBD-I systems, but add comprehensive new processes that include:

- Plausibility of signals and components of emissions-related functions
- Monitors on functions not completely monitored previously
- Monitors on systems not monitored previously

Monitors, as used in this context, can take either of two forms:

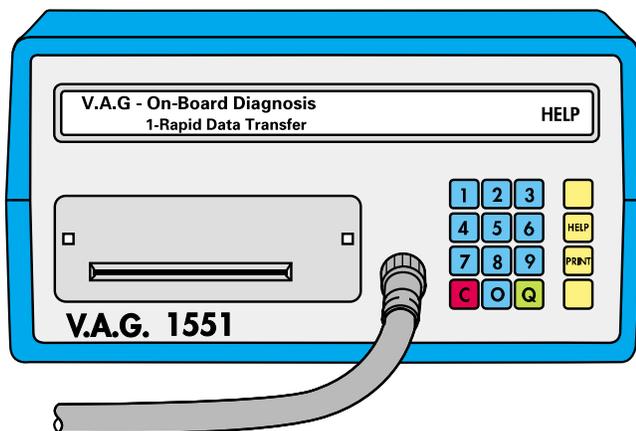
- **Component monitors:** the ECM looks at the operation of individual parts of the system.
- **System monitors:** the ECM operates a component (or multiple components) to verify system operation.

Legislation mandating OBD-II systems also requires that the vehicle manufacturer design the diagnostic system in a manner that permits retrieval of OBD data in a standard format using any available generic scan tool. OBD-II data can be retrieved through one of three data transfer protocols:

- ISO 9141 CARB
- SAE J1850 VPW
- SAE J1830 PWM

Scan tool access to the ECM on Volkswagen vehicles is through ISO 9141 CARB. A generic scan tool can be plugged into the Data Link Connector (DLC), and the required communication initiated with this protocol using the scan tool manufacturer's instructions. The VAG 1551/1552 and VAS 5051 can also operate as a generic scan tool using address word 33.

The OBD-II enabling legislation also allows vehicle manufacturers to supply additional data and functions above and beyond the required data. This is accomplished by means of a proprietary transfer mode which is part of ISO 9141.



VAG 1551 Scan Tool

SSP 8410/145

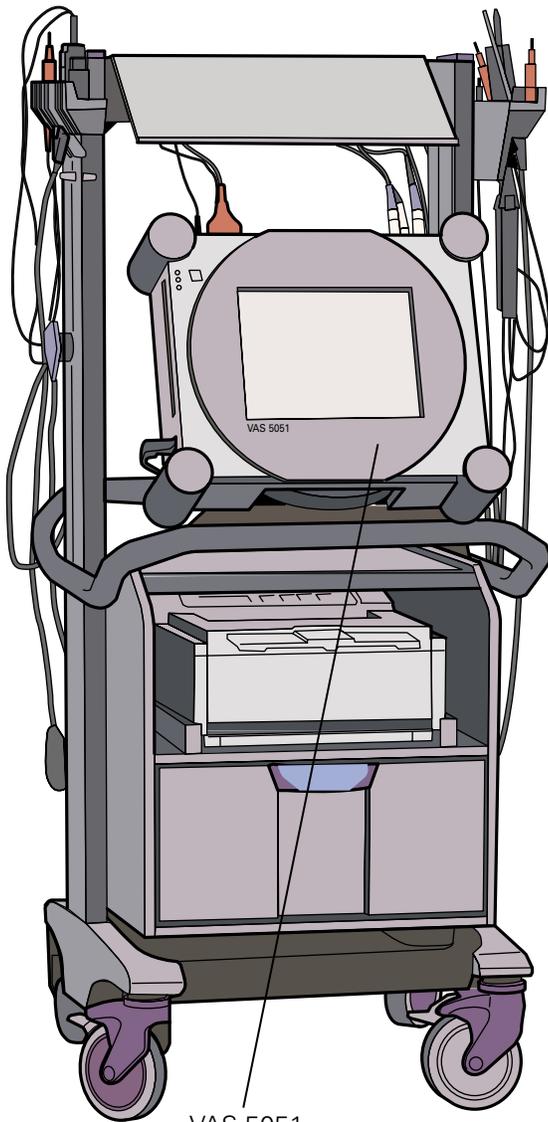


VAG 1552 Scan Tool

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# OBD-II Overview

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VAS 5051

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## **Address word 33**

Address word 33 gives access to the generic scan tool function of the 1551/1552 or 5051. This function allows for several expanded functions.

One of the most helpful is access to "Freeze Frame" data. This data documents exact operating conditions under which a DTC is stored. This can be useful in diagnosing intermittent faults.

The proprietary mode is accessed using address word 01. It can provide the same data as the generic mode, but in the more familiar Volkswagen scan tool formats. It also provides greatly expanded data and functionality, and is the preferred method of communication for Volkswagen technicians using the VAG 1551/1552 and VAS 5051.

## **Diagnostic Trouble Codes**

Diagnostic trouble codes are required by law to be structured in a manner that is consistent with SAE standard J2012. This standard uses a letter to designate the system, and four numbers to further identify and detail the malfunction. They are commonly referred to as "P-codes" and are used in addition to the familiar 5-digit VAG code.

First digit structure is as follows:

- Pxxxx for powertrain
- Bxxxx for body
- Cxxxx for chassis
- Uxxxx for future systems

Second digit structure is:

- P0xxx Government required codes
- P1xxx Manufacturer codes for additional emissions system function; not required but reported to the government

Third digit structure is:

- Px1xx measurement of air and fuel
- Px2xx measurement of air and fuel
- Px3xx ignition system
- Px4xx additional emission control
- Px5xx speed and idle regulation
- Px6xx computer and output signals
- Px7xx transmission

The fourth and fifth digits designate the individual components and systems.

For example, consider a camshaft position sensor (or related circuitry) that has a range or performance problem. This will generate the dual codes of P0341/16725 to be stored in DTC memory.

## Readiness Codes

OBD-II systems are required to generate a report concerning the operational status of up to 8 emission functions. This report is called the readiness code, and is viewable on both the generic scan tool and the VAG 1551/1552 and VAS 5051 scan tools.

The readiness code indicates whether a particular system or function passed the appropriate operational test and was found to be within specification (for the duration of the test). Malfunctions in the system that occur later and record a DTC will not change the readiness code. However, when the fault is repaired and the DTC is erased, the readiness will also be erased.

Accessing the OBD-II system with a scan tool allows access to data that can indicate if:

- a readiness code test is running
- there is a fault
- there is no fault

If the readiness code indicates that the diagnostics have not been performed, several methods can be used to confirm the required operation and set the codes.

Readiness codes can be useful for several reasons:

- During an emissions test, the readiness code can be used to confirm system function and may be required in some geographical areas.
- After emissions system repairs, proper operation can be confirmed by using the readiness code.

**Readiness code values**

Digit position								Diagnostic Function
1	2	3	4	5	6	7	8	
							0	Three Way Catalyst
							0	Catalyst Heating (always 0)
					0			Evaporative Emissions System (Fuel tank vent system)
				0				Secondary Air Injection System (always 0)
			0					Air Conditioning (no current diagnostic function-always 0)
		0						Oxygen Sensor
	0							Oxygen Sensor Heater
0								Exhaust Gas Recirculation - EGR (always 0)

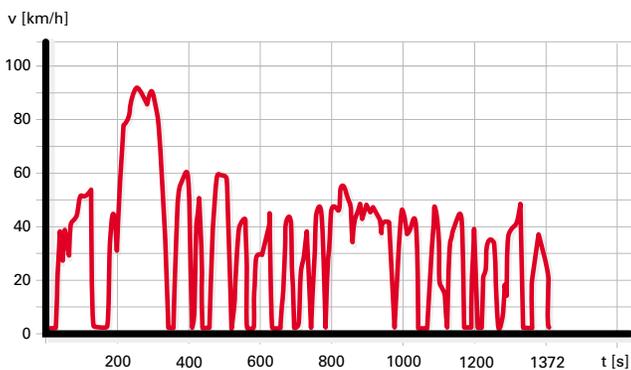
SSP 8410/29

# OBD-II Overview

## Setting readiness codes

Several methods exist for setting readiness codes. Some methods will not work with some systems, so the appropriate VESIS repair information must be consulted for the correct procedure.

The first method of setting the readiness code is by driving the vehicle in a prescribed manner called the Federal Test Procedure 72 (FTP72) driving cycle. This procedure, as shown in the accompanying illustration, requires that the vehicle be driven 7.5 miles (12.07 KM) over a period of 1372 seconds (22 minutes, 52 seconds) at a maximum speed of 56.67 m.p.h. (91.2 kph) from a cold start. This procedure allows all of the diagnostic procedures to run and if completed successfully, the readiness code will set. Carrying out this procedure can be difficult due to the time factor involved and the need for a cold start.



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The second method for setting readiness codes involves the use of scan tools VAG 1551/1552 or VAS 5051. In this instance, a road test, or "short trip," is used with the scan tool overriding some of the normal ECM programming to force diagnostics to run. This procedure is run following VESIS procedures specific for each vehicle and system. It considerably shortens the time required to set the readiness code.

The newest method of setting readiness codes allows the technician to use the appropriate scan tool, and set the code without the need to drive the vehicle. This procedure can only be used on the newer engine management systems where it has been programmed into the ECM. Specific VESIS procedures must be followed for each individual version.

```
Readinesscode
00000000 - Test complete
```

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## Summary

OBD-II systems are basically enhanced and expanded versions of OBD-I systems. Additional parts of the engine as well as other related systems and functions are included in the diagnostic structure. In practice, most of the changes are software changes to the ECM rather than major hardware changes. The new components simply provide more data to take advantage of the new computing power resulting in a dramatic reduction in total vehicle emissions.

## Motronic M5.9 Overview

### System Description

Motronic Engine Management Systems moved to the next level of development with model year 1996. This significant date marked the required compliance with On Board Diagnosis II (OBD-II) standards as mandated by the California Air Resources Board (CARB) and the United States government.

All Motronic M5.9 engine management systems comply with OBD-II standards. These standards apply to all passenger vehicles sold in the United States with different compliance levels being phased in over a period of several years.

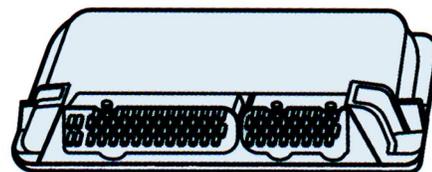
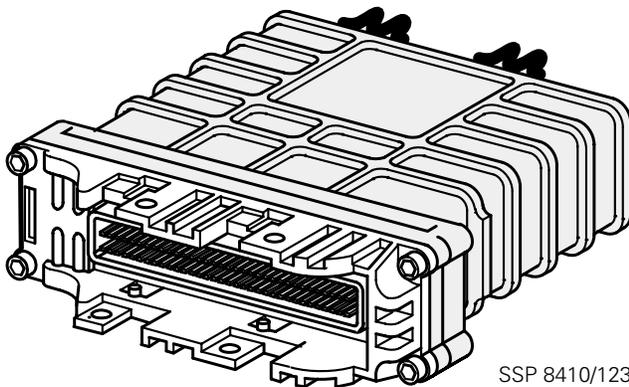
The Motronic M5.9 system also adds component and system monitors to the diagnostic capabilities.

Component monitors allow the Motronic ECM to check for plausible signals by cross checking against another component.

### **Example:**

*The Motronic ECM compares the Engine Coolant Temperature (ECT) sensor signal against a map based on the Intake Air Temperature (IAT) sensor signal at the time the engine was started.*

*If after a specified time the ECT signal is more than 20° C from the mapped point, the ECM believes this to be implausible for the running condition, and sets an appropriate DTC.*



# Motronic M5.9 Overview

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Motronic M5.9 systems operate with the same functionality as their predecessors, but add the second generation of diagnostic capabilities. The diagnostic system is integrated into the engine management system, and continuously monitors its own emissions-related components, as well as other vehicle systems that affect emissions. Furthermore, operation of some existing components has been modified and several new components have been added.

Enhancements over previous Motronic systems can include:

- Monitoring of three-way catalytic converter function
- Diagnosis of heated oxygen sensor response, voltage, and aging
- Diagnosis of oxygen sensor heating
- Diagnosis of fuel tank and venting system integrity
- Diagnosis of evaporative emissions flow
- Engine misfire detection
- Enhanced diagnostics for input and output components by checking function and signal plausibility in addition to open and short circuits
- Expanded and standardized DTC capabilities
- Status of emissions-related diagnostic routines (readiness code)

## Input/Outputs - Motronic M5.9

A 68-pin ECM receives inputs from sensors which are essentially the same as on Motronic M2.9 systems. These include the following sources:

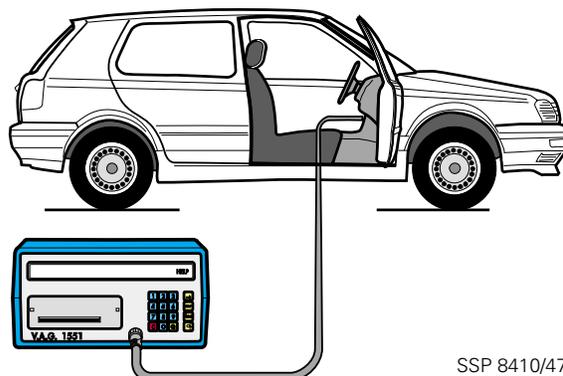
- Engine Speed (RPM) sensor G28
- Intake Air Temperature (IAT) sensor G72
- HO<sub>2</sub>S, B1S1 G39 (pre-catalyst)
- Engine Coolant Temperature (ECT) sensor G62
- Camshaft Position (CMP) sensor G40
- Mass Air Flow (MAF) sensor G70
- Knock Sensors (KS) G61 and G66
- EGR temperature sensor G98
- Signals received from the Speedometer Vehicle Speed Sensor (VSS) G22, A/C system, Transmission Control Module (TCM) J217, and electrical system voltage

Throttle position information formerly received from the throttle valve potentiometer G69 has been expanded and combined into the following new component:

- Throttle valve control module J338 with Throttle Position (TP) sensors G69 and G88, and Closed Throttle Position (CTP) switch F60

New sensors or signals added to the input side of the system include:

- HO<sub>2</sub>S, (G108) (post-catalyst)
- Leak Detection Pump (LDP) reed switch



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The outputs or actuators are essentially the same as on Motronic M2.9, and include the following:

- Evaporative Emission (EVAP) canister purge regulator valve N80
- Fuel injectors (N30 - N33, N83, N84)
- Ignition coil N152 with power output stage N157
- Fuel Pump (FP) relay J17 and Fuel Pump G
- EGR vacuum regulator solenoid valve N18
- Secondary Air Injection (AIR) pump relay J299 and Secondary Air Injection (AIR) pump V101
- Secondary Air Injection (AIR) solenoid valve N112
- Oxygen sensor heater relay J278
- Signals sent to the TCM J217, Instrument cluster

The IAC valve (idle stabilizer) has been eliminated and its function replaced by:

- Throttle valve positioner V60, which is part of the throttle valve control module J338.

New components or signals added to the output side of the system include:

- Evaporative Emission (EVAP) canister purge solenoid valve N115
- Fuel cut-off valve shut-off relay J335
- LDP vacuum solenoid switch

Adaptation of system variables occurs in Motronic M5.9 systems just as in earlier versions, and there are no mechanical engine settings or adjustments to be made. However, if the battery is disconnected, or if power is interrupted to the ECM, the learned or adapted values may be erased. DTCs and readiness codes may also be erased. The adapted value for the throttle valve control module J338 must be reset to avoid driveability problems.

### **Additional Systems**

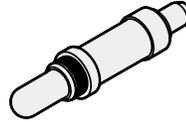
Fuel delivery from the tank is the same as the Motronic M2.9 versions, with pressure maintained by the manifold vacuum-operated fuel pressure regulator on the fuel injector rail assembly.

Sensor inputs, other input signals, actuator signals and other output signals are shown in the illustration on the following pages. The illustration represents components that are installed on several different engine types. Certain engines will not have some of the listed components.

# Motronic M5.9 Overview

## VR-6 system overview

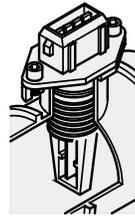
**Heated Oxygen Sensor (HO2S) (G39)**  
(Pre-CAT sensor)



**Heated Oxygen Sensor (HO2S) 2 (G108)**  
(Post-CAT sensor)



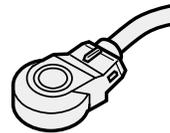
**Mass Air Flow (MAF) Sensor (G70)**



**EGR Temperature Sensor (G98)**



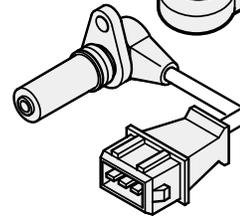
**Knock Sensor (KS) 1 (G61)**



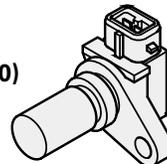
**Knock Sensor (KS) 2 (G66)**



**Engine Speed (RPM) Sensor (G28)**



**Camshaft Position (CMP) Sensor (G40)**  
integrated in distributor  
on the 2.0L



**Speedometer Vehicle Speed  
Sensor (VSS) (G22)**



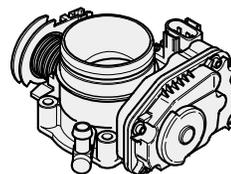
**Intake Air Temperature (IAT)  
Sensor (G72)**



**Engine Coolant Temperature  
(ECT) Sensor (G62)**

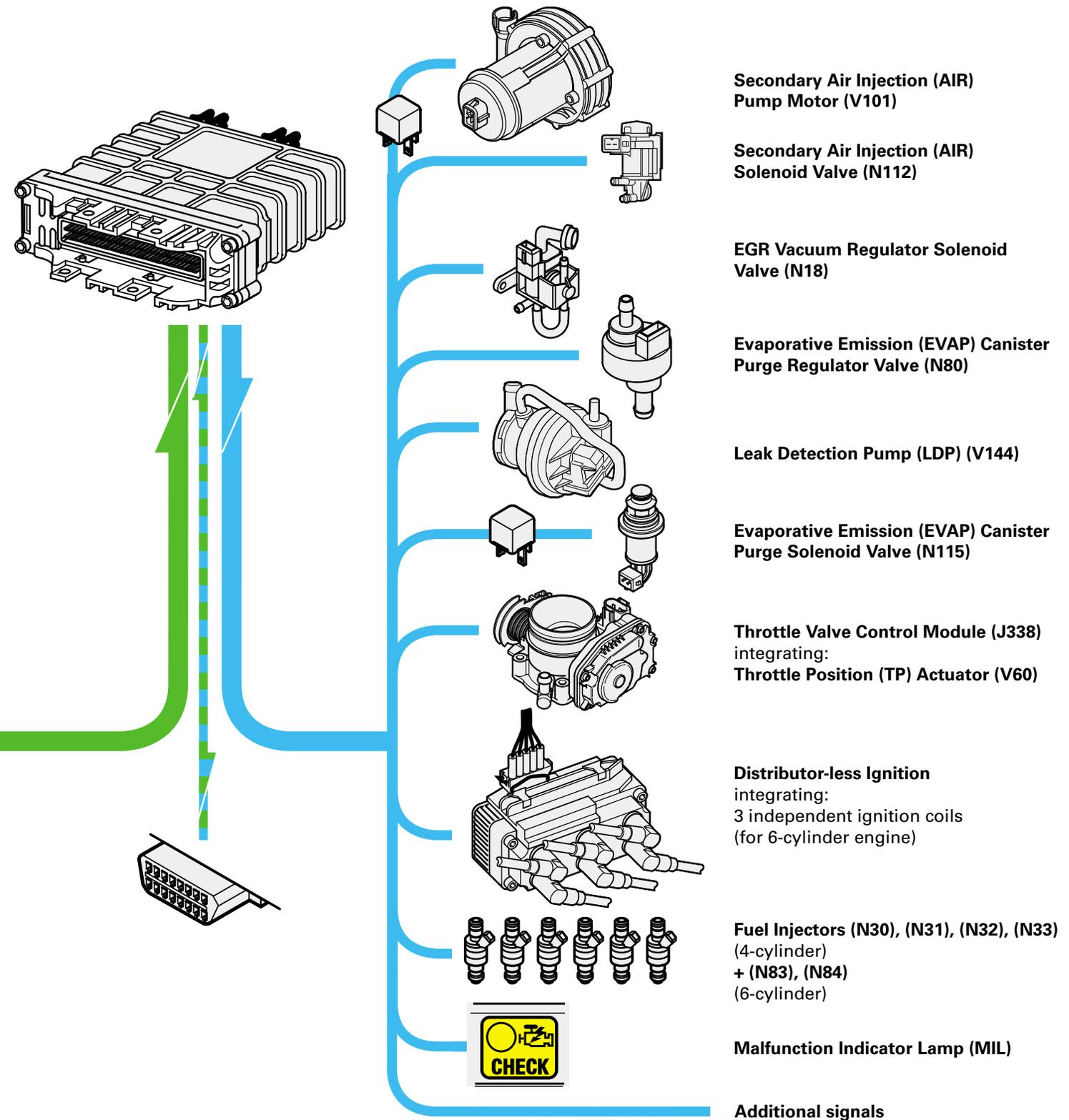


**Throttle Valve Control Module (J338)**  
integrating:  
**Throttle Position (TP) Sensor (G69)**  
**Throttle Position (TP) Sensor (G88)**  
**Closed Throttle Position (CPT)  
Switch (F60)**



**Additional signals**

# Motronic M5.9 Overview



# Motronic M5.9.2 Overview

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## Inputs/Outputs - Motronic M5.9.2

Motronic M5.9.2 is a slightly modified version of the earlier M5.9 system, with a new 80-pin ECM. The ECM accommodates new functions, input sensors and actuators. Enhancements improve starting and fuel economy, and reduce exhaust emissions.

On some models, cruise control is no longer a separate system; its functions are now integrated into the ECM on vehicles so equipped. On these vehicles, the cruise control inputs to the ECM can be monitored in measuring block values using the scan tool. The ECM is also now linked to the CAN-bus for communication with other systems (see SSP # 186, The CAN Data Bus).

Most of the input sensors used with this new system are the same as on the earlier versions. However, several sensors have been modified to enhance their performance or to adapt them to engine design changes. Changed or modified components on the input side of the system include:

- Mass Air flow (MAF) sensor G70
- Camshaft Position (CMP) sensor G40
- Planar oxygen sensors
- Barometric Pressure (BARO) sensor F96 (1.8T)
- Cruise control inputs (vehicles with cruise control)

New input signals include:

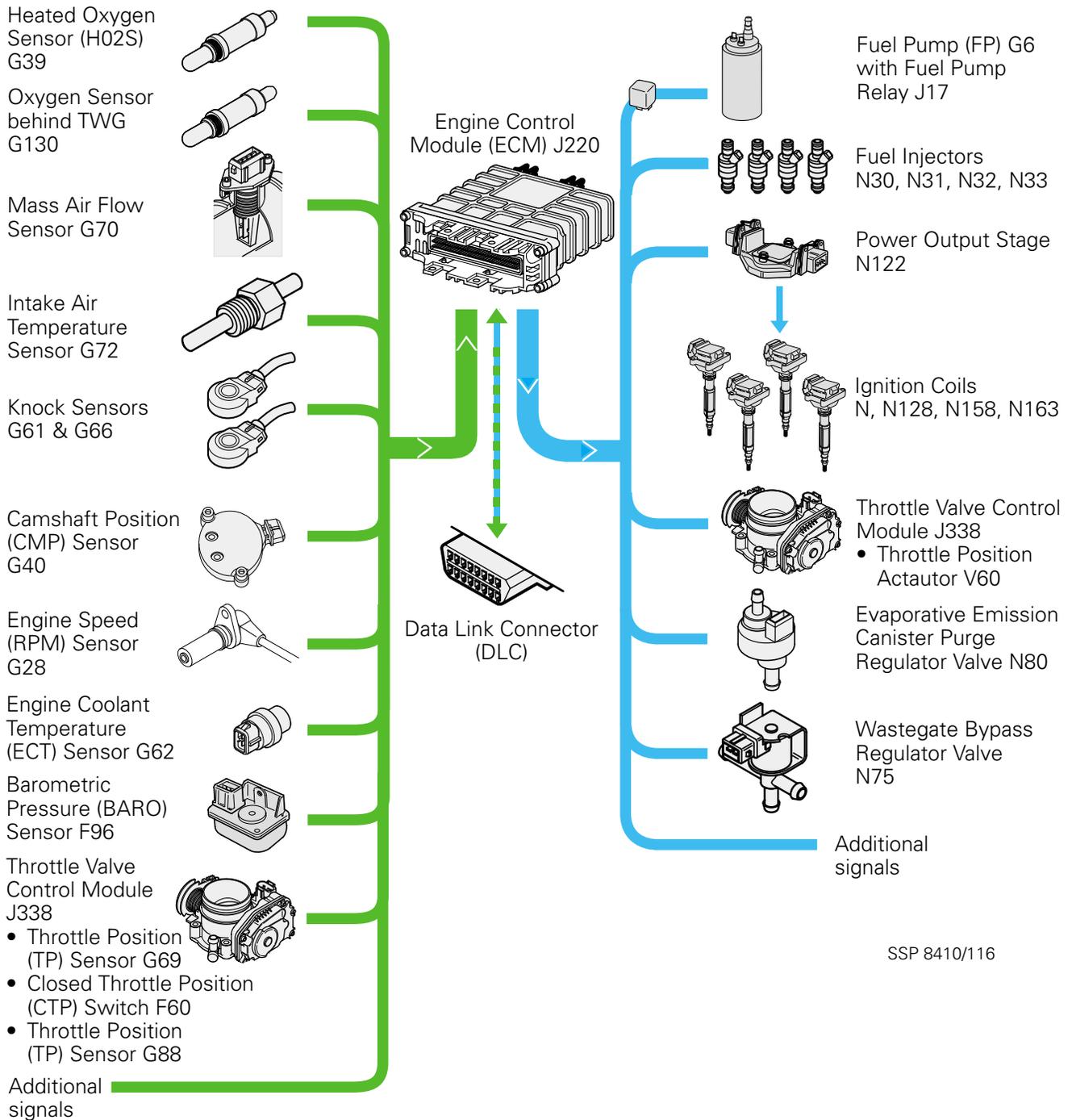
- Brake pedal position switch F47, (vehicles with cruise control)
- Clutch vacuum vent valve switch F36 (vehicles with cruise control)
- Cruise control switches E45 and E227, (vehicles with cruise control)
- Brake light switch F

Changes to the output side of Motronic M5.9.2 system include:

- Air-shrouded injectors
- Distributor-less ignition on 4-cylinder engines with either:
  - Separate power output stages and ignition coils for each cylinder
  - Or, two double-ended ignition coils and two power output stages
- Wastegate bypass regulator valve N75

Sensor inputs, other input signals, actuator signals and other output signals are shown in the illustration on the following page.

## 1.8 liter turbo, system overview



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# Motronic M5.9 Component Differences

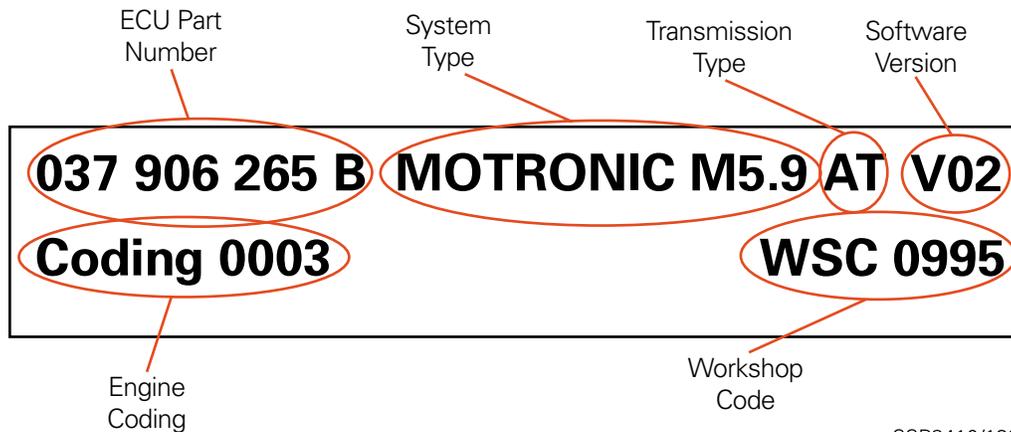
## Motronic M5.9 Component Differences

### Engine Control Module J220

The Motronic M5.9 ECM combines all of the functionality of the M2.9 ECM, with additional functions and enhanced diagnostics.

Enhanced diagnostics include full OBD-II support in the generic scan tool mode, and expanded diagnostics in the proprietary VAG 1551/1552 mode or VAS 5051 (as previously noted).

The ECM also interfaces with the Malfunction Indicator Lamp (MIL) to emphasize malfunctions by signaling with either a flashing or a continuously illuminated MIL.



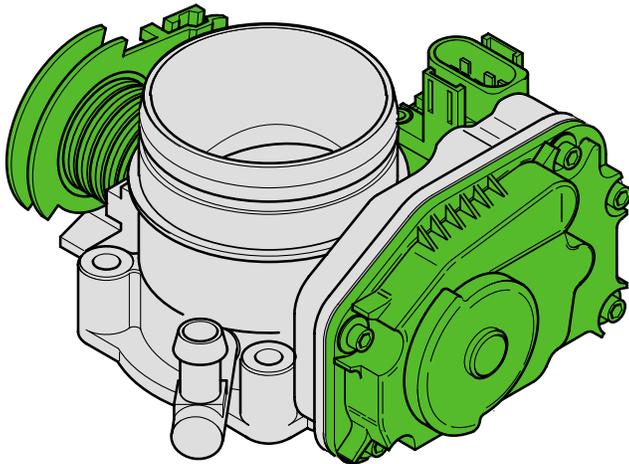
SSP8410/138

# Motronic M5.9 Component Differences

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## Combined Sensors/Actuators

Motronic M5.9 engine management systems use input sensors for engine operating data, and output actuators for engine control in much the same way as those found on the Motronic M2.9 systems. Most of these sensors and actuators are the same as those found on the earlier system, but several new components combine both sensors and actuators (inputs/outputs). These new combined sensor/actuator components are detailed in this section.



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### Throttle valve control module J338

The throttle valve control module J338 is a new component with three input sensors and one actuator. It replaces throttle position sensor G69, and Idle Air Control (IAC) valve N71.

Within the sealed housing are the following components:

- Throttle Position (TP) sensor G69
- Closed Throttle Position (CTP) switch F60
- Throttle Position (TP) sensor G88
- Throttle Position (TP) actuator V60

### Throttle Position (TP) sensor G69

The new throttle valve control module retains the function of the previously used Throttle Position (TP) sensor G69.

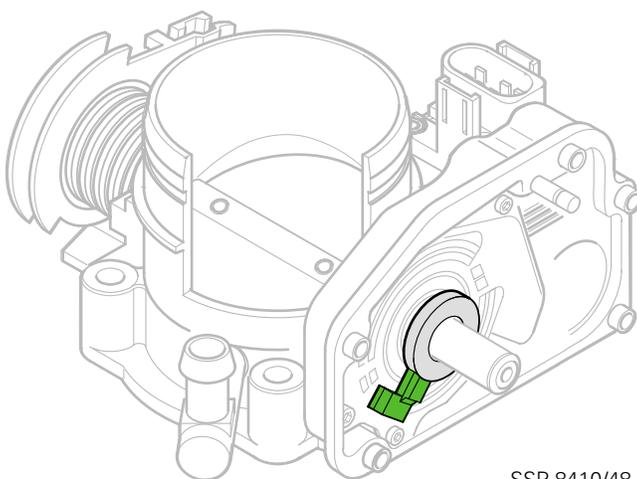
G69 sends information to the ECM regarding the position of the throttle plate throughout the full range of travel.

- Operation:

The ECM supplies a fixed voltage signal of 5 Volts to the TP sensor. Movement of the throttle valve changes the voltage, which is returned to the ECM.

- On Board Diagnostic (OBD):

The ECM recognizes circuit malfunctions now referred to as high and low inputs, the ECM also uses the Mass Air Flow (MAF) sensor signal to check for a plausible TP signal.



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# Motronic M5.9 Component Differences

## Closed Throttle Position (CTP) switch F60

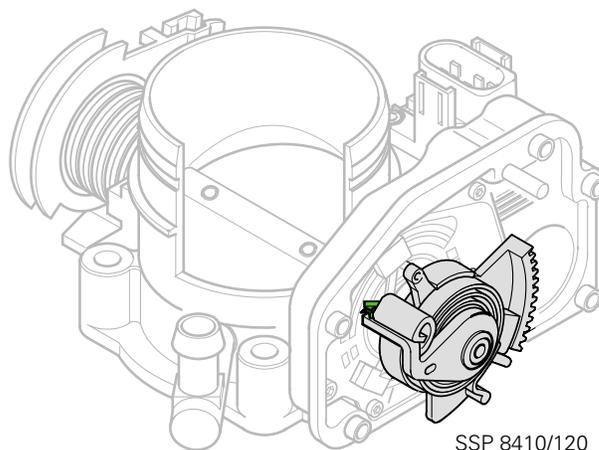
New, and included within the throttle valve control module housing, is a Closed Throttle Position (CTP) switch F60. This on/off switch is used to identify the closed throttle position for idle control functions.

- Operation:

The ECM supplies a fixed voltage signal to the CTP switch. Movement of the throttle valve switches the signal to a common ground.

- On Board Diagnostic (OBD):

The ECM recognizes open circuit and short circuit to Ground.



## Throttle Position (TP) sensor G88

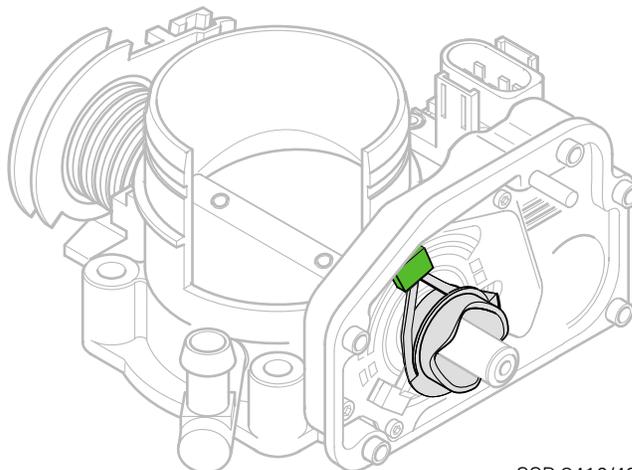
Also new and included within the throttle valve control module housing is a second throttle position sensor, G88. This TPS provides feedback data for the Throttle Position (TP) actuator V60, and the throttle stop position.

- Operation:

The ECM supplies a fixed voltage signal of approximately 5 Volts to the TPS. Movement of the throttle valve by the throttle position actuator changes the voltage which is returned to the ECM.

- On Board Diagnostic (OBD):

The ECM recognizes high and low inputs. Operation of G88 is cross checked against G69 for plausible inputs.



# Motronic M5.9 Component Differences

## Throttle position actuator V60

The throttle valve control module is fitted with the Throttle Position (TP) actuator V60, which replaces the Idle Air Control (IAC) valve used previously.

The new throttle position actuator incorporates an electric servo motor connected to the throttle plate that controls air flow when the engine is idling. Idle speed compensation is made electronically to adjust for changes in engine temperature and load within pre-programmed limits. This is accomplished by moving the mechanical throttle stop, along with G88.

The throttle position actuator also functions as the throttle dashpot, holding the throttle valve partially open on deceleration for emissions purposes.

The position of V60 is monitored by the Throttle Position (TP) sensor G88.

Idle speed variations due to component aging, wear, and false air leaks are identified by the system and compensations are made. Newly learned limits are retained by the ECM as adapted values.

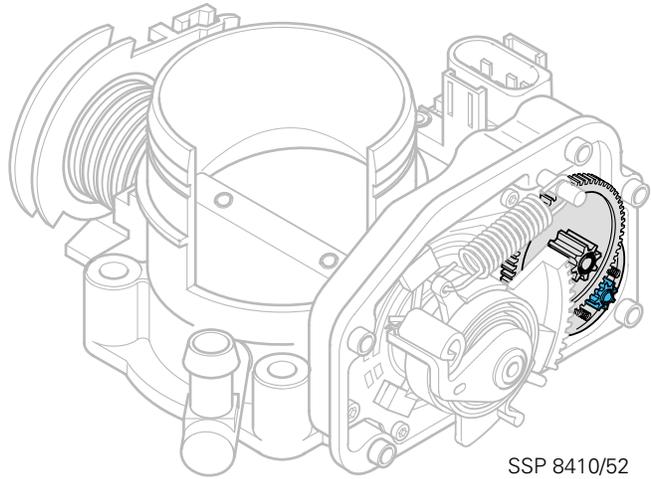
Since idle speed is electronically controlled, no external adjustments are required.

- Operation:

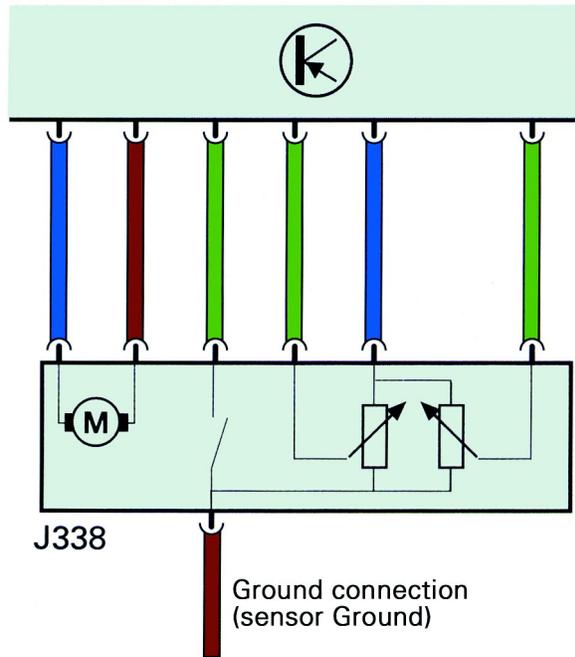
The ECM supplies a varying signal to the throttle position actuator. Movement of the throttle valve by the throttle position actuator changes the position of the throttle plate, which changes engine speed.

- On Board Diagnostic (OBD):

The ECM recognizes Short circuit to Battery +/Short circuit to Ground, as well as idle speed adaptation faults (including low voltage and adaptation limits exceeded).



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SSP 8410/53

**Note:**

Throttle Valve Control module J338 has no user serviceable components. If any internal components fail, the assembly must be replaced.

# Motronic M5.9 Component Differences

## Leak Detection Pump (LDP) V144

To confirm evaporative emission system integrity, a vacuum-operated diaphragm-type leak detection pump is used to slightly pressurize the fuel tank, and related components of the evaporative emissions system.

### Solenoid valve and reed switch, Leak Detection Pump (LDP) V144

The leak detection pump incorporates two new electrical components:

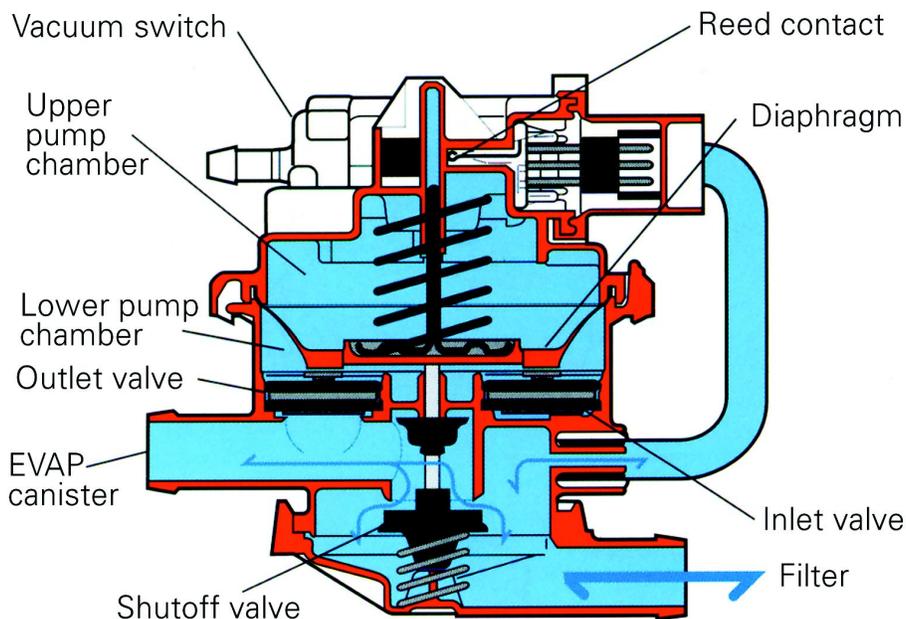
- a vacuum solenoid switch controlled by the ECM
- a reed switch operated by the pump diaphragm

On signal from the ECM, the solenoid valve allows engine vacuum to enter the upper pump chamber. This allows atmospheric pressure to work on a diaphragm in the pump, which generates a small amount of pressure that is pumped into the tank and lines.

As the LDP pressurizes the fuel tank, filler neck and related evaporative components, a reed switch closes when the pressure reaches a pre-determined point. As pressure falls or is maintained, the reed switch opens or closes, signaling the ECM of the appropriate condition.

- Operation:  
The ECM supplies a signal to the solenoid valve. Movement of the LDP diaphragm opens or closes the reed switch.
- On Board Diagnostic (OBD):  
The ECM recognizes short circuits and open circuits. It also recognizes several other types of malfunctions based on the frequency of operation of the reed switch.

The LDP system can identify and differentiate between small leaks in the evaporative system (possible pinhole leak in a hose), or a large leak (caused by a missing gas cap). See EVAP Emissions SSP and video #841903.



SSP 8410/51

# Motronic M5.9 Component Differences

## Input sensors

Motronic M5.9 engine management systems rely on input sensors for engine operating data in much the same way as those found on Motronic M2.9 versions. Most of these sensors and input signals are the same as those on the earlier system. Aside from the combined sensor/actuators of the throttle valve control module and the leak detection pump, the major additional sensor is the post-catalyst heated oxygen sensor.

### Heated Oxygen Sensor (HO2S) G39

### Heated Oxygen Sensor (HO2S) 2 G108

A second oxygen sensor is added to the Motronic M5.9 system to monitor the function of the three-way catalytic converter. Positioned at the converter outlet, the post-cat heated oxygen sensor monitors oxygen levels after the catalyst to determine proper converter operation. Oxygen is consumed during the catalytic process, and levels should therefore be low. Since the atmospheric oxygen levels are high and converter outlet oxygen levels are low, sensor voltage will be high due to the large difference in levels.

To avoid the possibility of incorrectly connecting post-CAT and pre-CAT connectors, different connector designs and colors are used.

G39 and G108 differ from the Oxygen sensors used previously by Volkswagen. This new sensor design no longer obtains the Ground from the mounting threads. The ground is now provided by the Motronic ECM and is stepped roughly 350 mV above battery Ground. The ECM uses this to check for plausible signals.

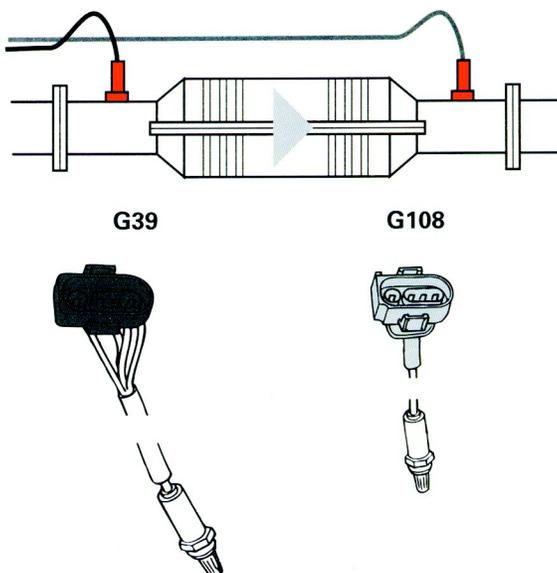
The ground for the Oxygen sensor heater is closed by the Motronic ECM, and is pulsed to bring the temperature of the heater element to operating levels. Pulsing the heater reduces the risk of cracking the porcelain heating element.

The ECM monitors heater function by measuring the voltage drop across the heater. The resistance changes with temperature. The ECM is capable of recording a fault for open circuit only.

The post catalytic sensor is also used for the adaptation of long term fuel trim.

#### **Note:**

*Post-catalyst oxygen sensor failures may set a DTC for the pre-catalyst sensor showing adaptation faults.*



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## Motronic M5.9 Component Differences

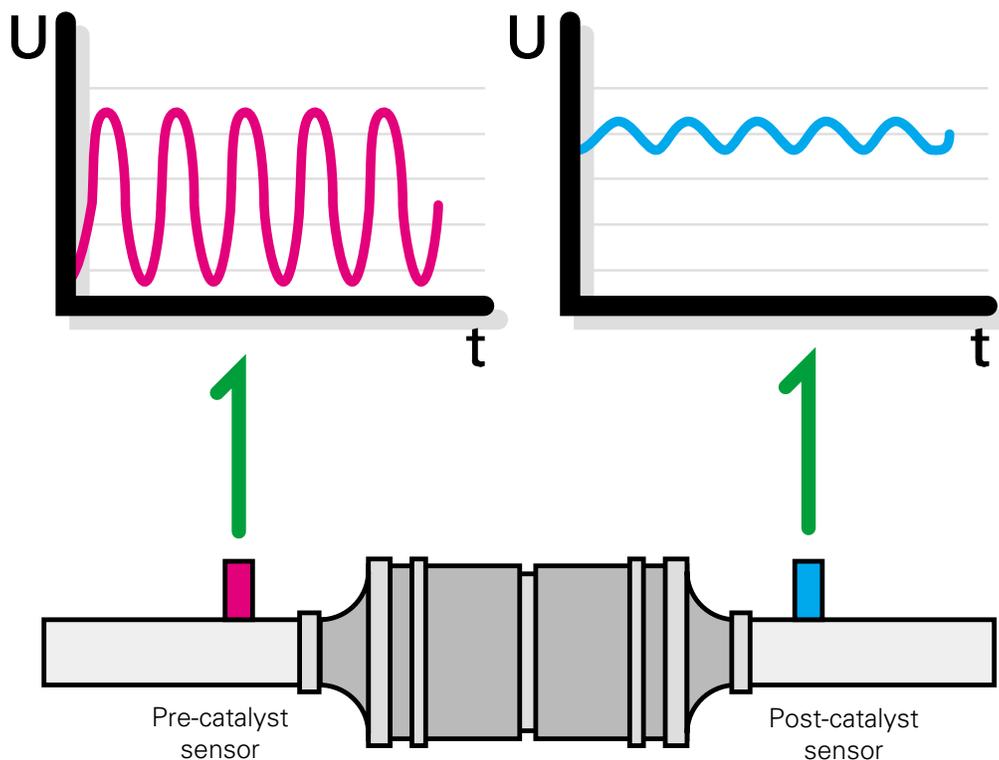
A comparison of the voltage signals between the pre-catalyst HO2S G39 and the post-catalyst HO2S 2 G108 shows the differences in functionality.

- Operation:

In a normally operating system, the voltage of the pre-catalyst sensor varies in response to normal engine operating parameters the same as on earlier systems. As the oxygen levels in the converter decrease after oxidation, the post-catalyst sensor reflects the reduced levels by generating a higher voltage. This is due to the greater difference in oxygen level between the outside air sample and the converter sample.

- On Board Diagnostic (OBD):

The ECM recognizes numerous malfunctions for both G39 and G108, including low and high voltages, slow response, no activity, and heater circuit malfunctions, in addition to signaling lean and rich running conditions that may be outside the adaptation window.



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# Motronic M5.9 Component Differences

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## Actuators (outputs)

Motronic M5.9 engine management systems rely on different actuators to run the engine and operate related systems in much the same way as those found on Motronic M2.9 versions. As in the case of the input sensors, most of the actuators and output signals are the same as those on the earlier system. Aside from the combined sensor/actuators of the throttle valve control module and the leak detection pump, the major additional actuators are the Evaporative Emission (EVAP) canister purge solenoid valve N115, and fuel cut-off valve shut-off relay.

### **Evaporative Emission (EVAP) canister purge solenoid valve N115** **Fuel cut-off valve shut-off relay J335** **(Golf/Jetta/Cabrio only)**

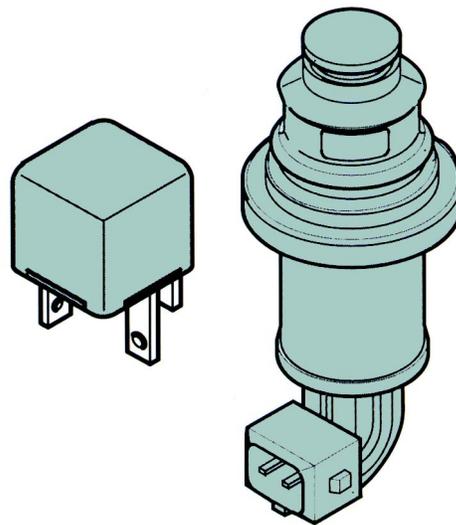
The Evaporative Emission (EVAP) canister purge solenoid valve N115 is mounted in the lower section of the evaporative emissions canister.

On vehicles where the carbon canister is mounted a distance away from the Leak Detection Pump (LDP), this valve is used to seal the carbon canister during leak testing.

When N115 is not in the diagnosis mode, it is normally open to allow the carbon canister to vent.

The fuel cut-off valve shut-off relay J335 is a time delay relay that closes N115 for 10 seconds with each leak detection pump stroke at the command of the ECM.

- Operation:  
The ECM closes the valve by way of the fuel cut-off valve shut-off relay J335 during the Leak Detection Pump (LDP) diagnosis cycle. This closes the evaporative emissions canister vent, sealing the system for diagnosis.
- On Board Diagnostic (OBD):  
The valve and relay are not diagnosed directly by the ECM. Failures may show as DTCs for EVAP Emissions system (leak detected).



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# Motronic M5.9 Component Differences

## Evaporative Emission (EVAP) canister purge regulator valve N80

The Evaporative Emissions (EVAP) canister purge regulator valve N80 is a **solenoid valve** (see Glossary) that allows fuel vapors stored in the charcoal canister to be admitted into the intake manifold to be consumed in the combustion process.

- Operation:

N80 is normally closed (no current flow). The ECM uses a variable duty cycle to control when exactly to admit the fuel vapor into the engine. During LDP operation, N80 operates as a check valve to monitor system integrity.

- On Board Diagnostic:

The ECM is capable of recognizing Open circuit, Short circuit to Battery Positive, and Short circuit to Ground.

## Malfunction Indicator Light (MIL)

The malfunction indicator light in the instrument cluster has a new operating mode for the OBD-II compliant Motronic M5.9 system.

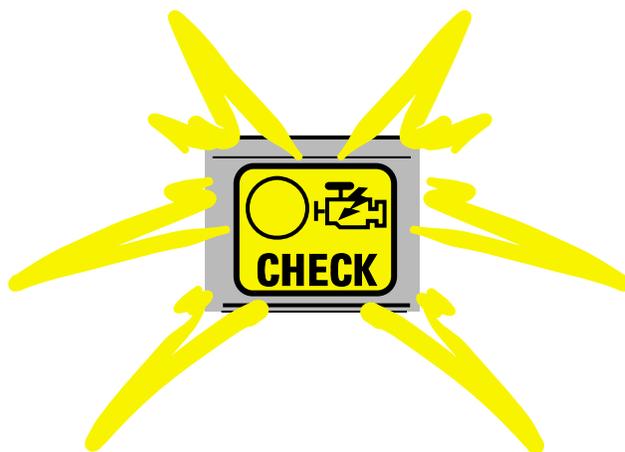
- Operation:

If the ECM detects an emissions-related malfunction, the driver is made aware of this fact by continuous illumination of the MIL.

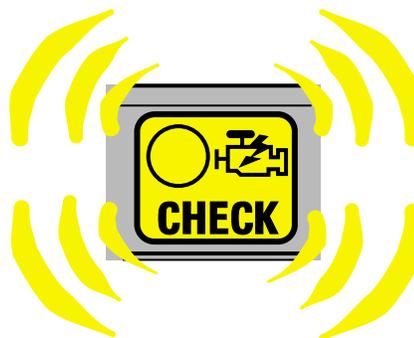
Certain conditions, such as engine misfiring, can lead to damage of the three-way catalytic converter, and must be immediately called to the driver's attention. In this situation, the MIL will flash (blink) at the rate of approximately 1 flash per second as long as the malfunction continues to damage the three-way catalytic converter.

- On Board Diagnostic:

The ECM recognizes open circuits and short circuits in the MIL circuit.



Lamp continuously on



Lamp flashing once per second



# Motronic M5.9.2 Component Differences

## Motronic M5.9.2 Component Differences

### Engine Control Module J220

The Motronic M5.9.2 Engine Management System is a further development of the M5.9 version of the system. Several new functions, input sensors, and actuators have been added to the 80-pin ECM.

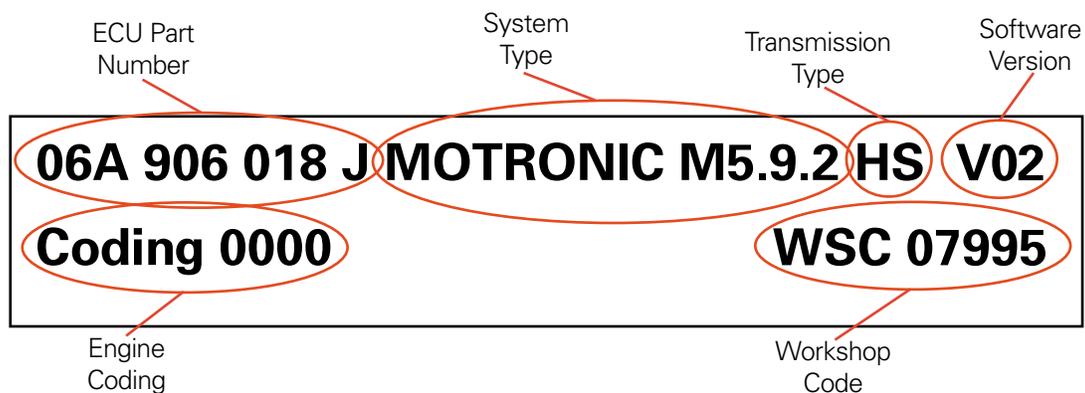
Data transfer between the ECM and other powertrain systems has been enhanced through the use of a Controller Area Network. This high-speed network, called the CAN data bus, links all of the powertrain control modules in a given vehicle to allow data sharing. Engine speed, fuel consumption, throttle valve position, engine intervention, and upshift/downshift data are transferred between the Motronic, transmission, and ABS/EDL control modules for the purpose of improved performance for all involved systems.

The powertrain CAN data bus links the appropriate control modules with a pair of specially twisted wires used solely for data transfer. Each control module can send, receive and process digital data through the twisted pair of wires. Depending on vehicle equipment, other systems will have their own separate CAN data bus systems.

It should be noted that Motronic M5.9.2 is installed on three different engine types:

- 2.0 liter 4-cylinder engine used in Golf, Jetta and New Beetle with the A4 platform starting with the 1998 model year
- 1.8 liter 5-valve 4-cylinder turbocharged engine used in the Passat for the 1998 and 1999 model year
- 2.8 liter 5-valve V6 engine used in the Passat for the 1998 and 1999 model year

Due to the wide variety of engine types, not all changes are found on all engines.



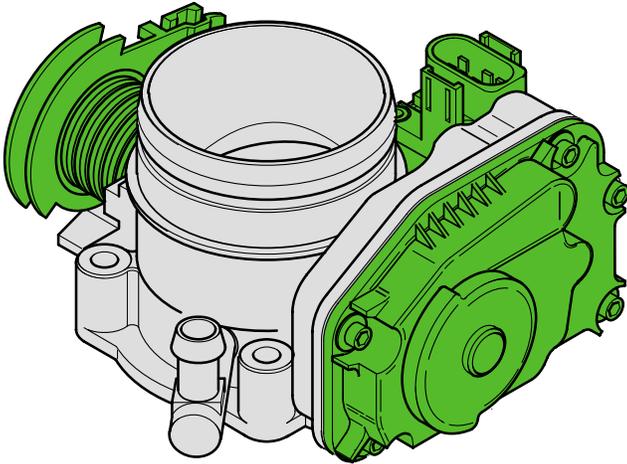
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# Motronic M5.9.2 Component Differences

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## Input Sensors

Most of the input sensors and signals are the same as those on the earlier M5.9 as shown in the Motronic overview illustration. Differences between the M5.9.2 and M5.9 version are summarized in this section.

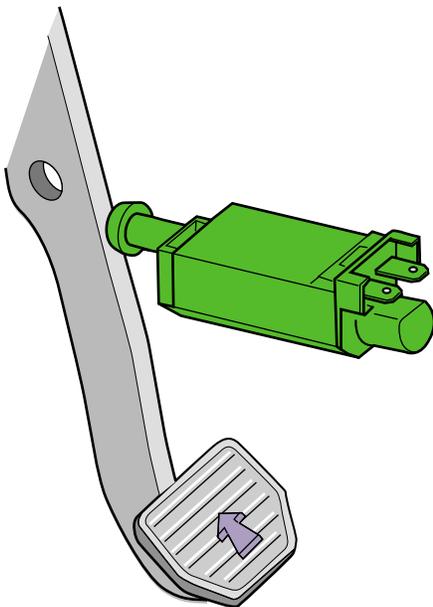


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## Throttle Valve Control Module J338

Cruise control is standard equipment on most vehicles equipped with Motronic M5.9.2. Some vehicles continue to use a separate vacuum-operated system as in the past. On Golf, Jetta, and New Beetles, the Motronic ECM operates the Throttle Valve Control Module J338 for the cruise control function.

- Operation:  
The operating range of J338 has been increased to accommodate the additional throttle opening required by the ECM during cruise control operation.
- On Board Diagnostic:  
The ECM recognizes incorrect/improbable signals from the cruise control switches.



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## Brake Light Switch F

With cruise control functions integrated into the Motronic system, the ECM must know the brake pedal position. On some models, brake light switch F is integral with brake pedal switch F47.

- Operation:  
The current brake light switch F is now an ECM input.
- Function:  
On Board Diagnostic:  
The ECM monitors operation.

# Motronic M5.9.2 Component Differences

## Clutch Vacuum Vent Valve Switch F36

With cruise control functions integrated into the Motronic system, the ECM must also know the clutch pedal position on manual transmission-equipped vehicles.

- Operation:  
The Clutch Vacuum Vent Valve Switch F36 is used to electrically signal clutch pedal position to the ECM. There is no vacuum function for this switch, although the older designation of “vacuum vent valve” is retained.
- On Board Diagnostic:  
The ECM does not monitor this component.

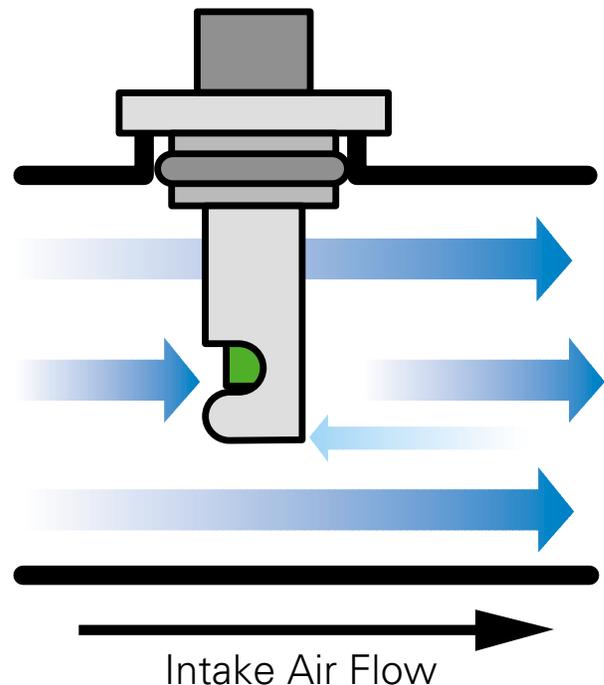
Vehicles with manual transmissions continue to use Clutch Pedal Position (CPP) switch F194 and Locking relay for starter (clutch pedal switch) J434. These components, however, are not linked to the Motronic ECM.

## Mass Air Flow (MAF) Sensor G70

Some versions of Motronic M5.9.2 use a MAF Sensor with several new functions to allow more precise mixture control and improve overall sensor performance.

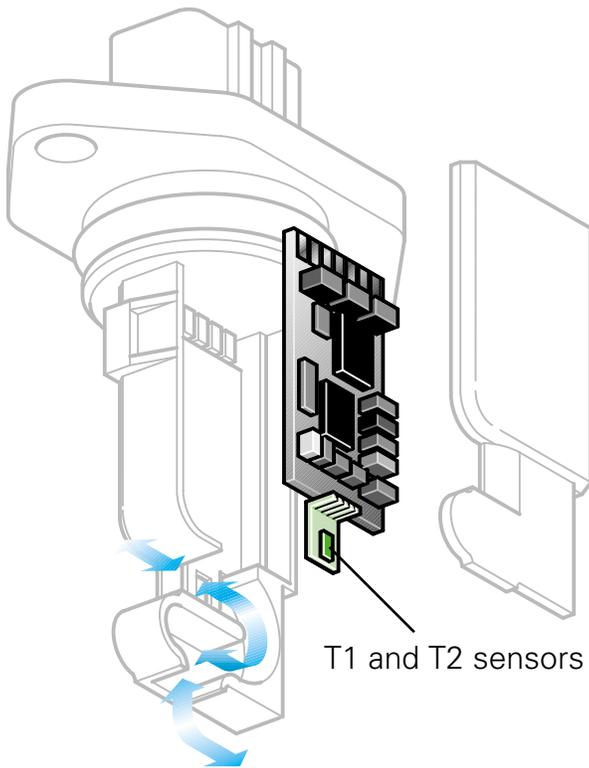
The sensor elements are encased in a glass membrane for better protection against contamination from oil vapor, dirt, and moisture that may be present in the intake air flow.

The new MAF sensor incorporates a feature to cancel the effects of normal intake air turbulence caused by the shape of the manifolds and the opening and closing of the valves. Under some circumstances, previous sensors would measure this reflected air pulse a second time. The ECM could not detect this reverse flow, and the resulting fuel delivery would be greater than required for the actual air flow.

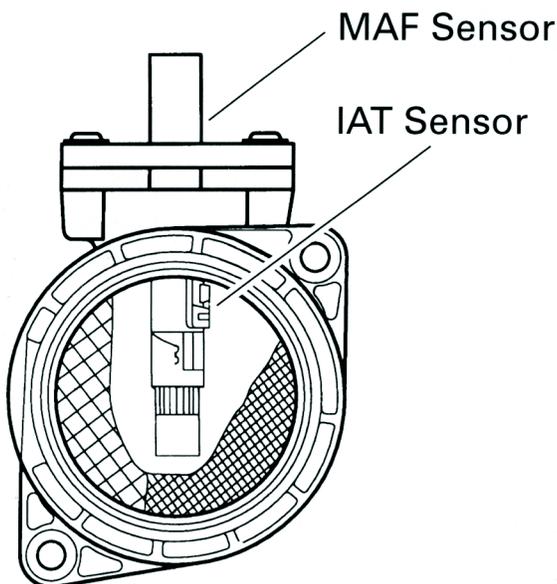


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## Motronic M5.9.2 Component Differences



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Reverse flow detection allows incoming air to be measured just once through the coordination of the air flow sensing element and two new temperature sensors.

The air flow sensing element is positioned in the intake passage in such a way that normal air pulsations coming from the opposite direction are less likely to be re-measured.

On some models (2.0 Liter), the Intake Air Temperature (IAT) sensor G72 has been moved from its previous location in the intake manifold. The sensor's new location is integrated into the side of the MAF, where it is exposed to the intake air flow.

- Operation:  
Two temperature sensors,  $T_1$  and  $T_2$ , are mounted together with a common heating element near the air flow sensor. The heating element warms both sensors equally when there is no air flow. As air flows over sensors  $T_1$  and  $T_2$  when the engine runs, they are cooled at different rates.  $T_2$ , which is slightly downstream in the air flow, is cooled less because of the warming effect of the  $T_1$  sensor.  $T_1$  is upstream of the heating element. Any reverse air flow causes the cooling of  $T_1$  and  $T_2$  to be reversed. The ECM senses this difference and factors in the appropriate correction to cancel out the effects of the reverse flow.
- On Board Diagnostic:  
The ECM recognizes low input and high input MAF sensor malfunctions, and low input and high input IAT sensor malfunctions (where applicable).

# Motronic M5.9.2 Component Differences

## Camshaft Position (CMP) Sensor G40 Camshaft Position (CMP) Sensor 2 G163

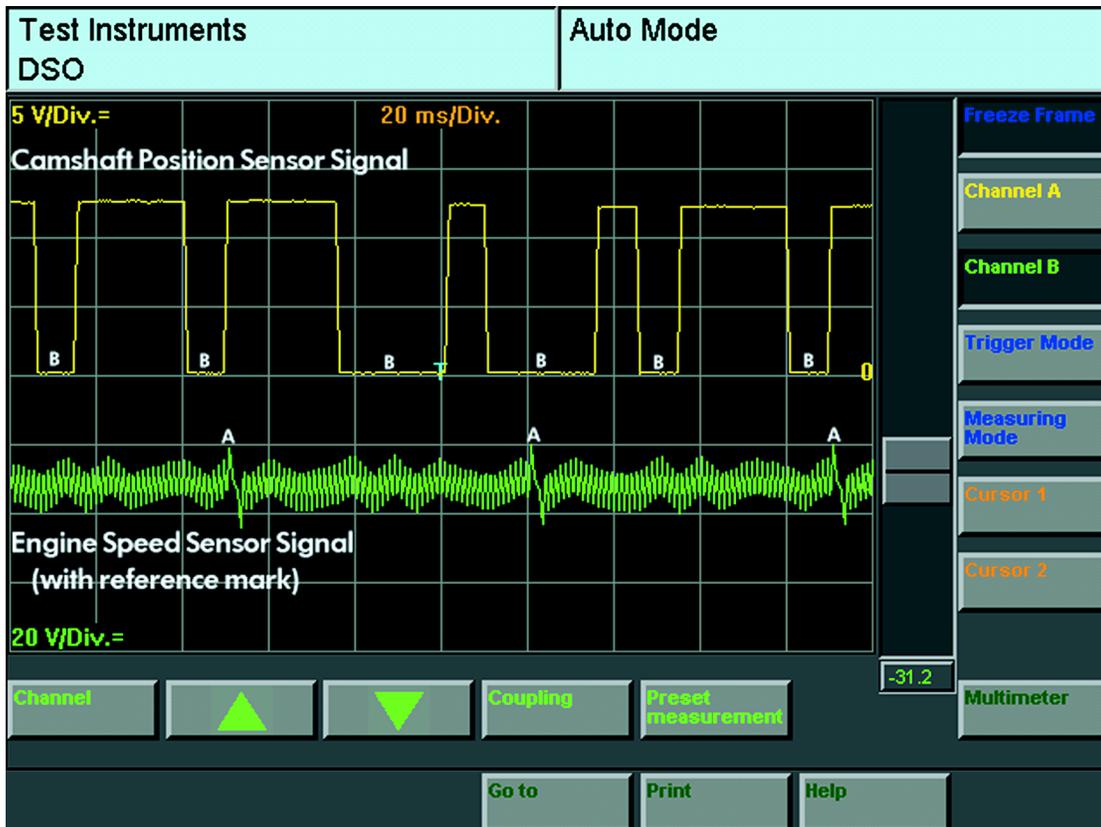
All versions of Motronic M5.9.2 use distributor-less ignition systems with camshaft position sensors.

Passat 1.8T engines use a trigger wheel attached to the forward end of the intake camshaft.

- Operation:  
This trigger wheel has a single window and is keyed to the camshaft. The ECM coordinates this signal with the Engine Speed (RPM) sensor G28 signal to identify cylinder number one for ignition and injection purposes.
- On Board Diagnostic:  
The ECM recognizes open circuits and short circuits.

Golf, Jetta, and New Beetles use a trigger wheel attached to the toothed belt sprocket for the camshaft.

- Operation:  
The trigger wheel has four slots or windows. Cylinders one and three use windows that are 25° wide and cylinders four and two use windows 65° wide. A distinctive impulse pattern is generated by this un-even spacing every 90° of camshaft rotation. This allows the ECM to identify the correct fuel injection and ignition sequence for every 180° of crankshaft rotation resulting in improved starting and reduced cold-start emissions.
- On Board Diagnostics:  
The ECM recognizes implausible signals and no signal malfunctions.



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# Motronic M5.9.2 Component Differences

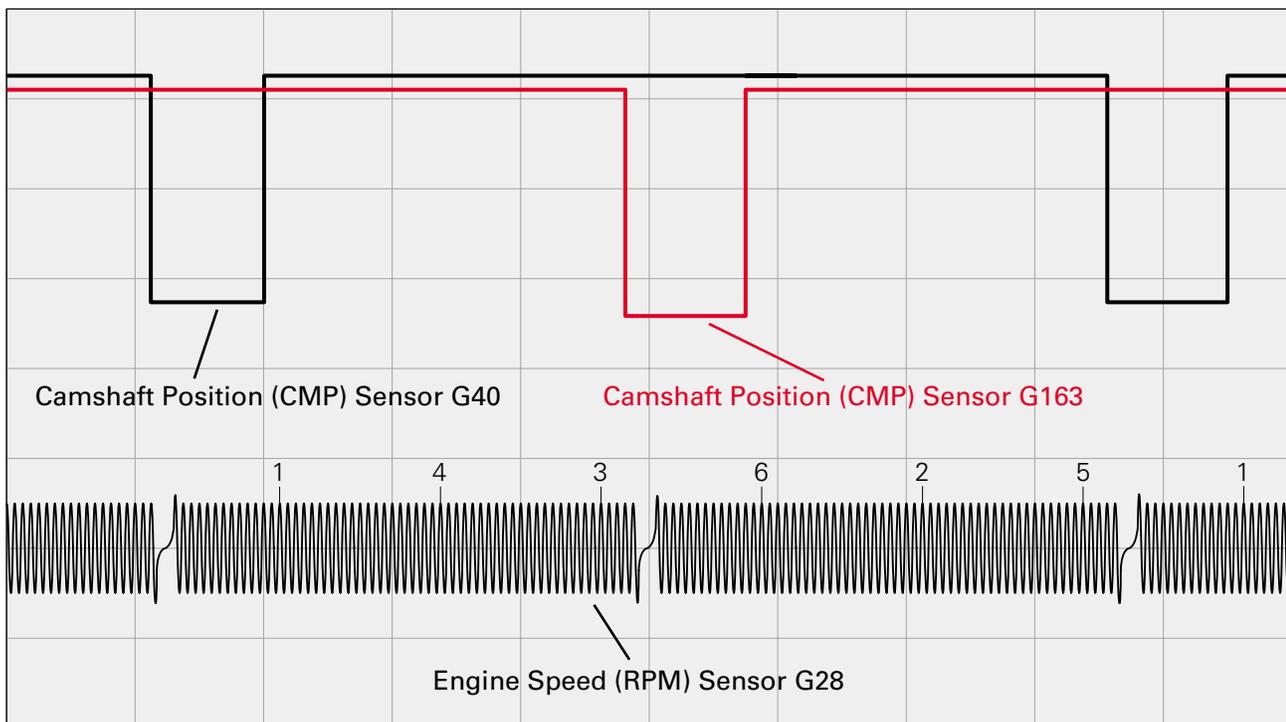
Passat 2.8 liter V-6 engines use 2 camshaft position sensors, which are also used to monitor the function of the valves -1- and -2-for Camshaft adjustment.

- Operation:

The trigger wheel for cylinder bank one (cylinders one, two, and three) is on the passenger's side of the engine, and is attached to the intake camshaft in the same way as the 1.8T engine. The camshaft position sensor for cylinder bank 1 is G163 and is identified as CMP 2. The trigger wheel for cylinder bank two (cylinders four, five, and six) is on the driver's side of the engine and is attached to the intake camshaft in the same manner as the trigger wheel for cylinder bank 1. Due to conflict with the camshaft adjuster for cylinder bank 2, the CMP is mounted at the rear of the engine. The camshaft position sensor for cylinder bank 2 is designated G40 and is identified as CMP 1.

- On Board Diagnostic:

The ECM recognizes Short circuit to Ground/Open circuit as well as Short circuit to Battery +. The ECM also uses the CMP to diagnose mechanical problems involving camshaft positioning and timing.



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# Motronic M5.9.2 Component Differences

## Heated Oxygen Sensors

- HO2S G39
- HO2S 2 G108
- O2S Behind Three Way Catalytic Converter (TWC) G130
- O2S 2 Behind Three Way Catalytic Converter (TWC) G131

### Note:

*The alpha-numeric designations for oxygen sensors vary slightly depending on vehicle and engine type. Always consult VESIS when diagnosing malfunctions.*

Some applications of Motronic M5.9.2 engine management systems use new heated oxygen sensors with planar technology. Planar technology is a further development of the older thimble or finger-type (LSH) heated oxygen sensor, and refers to new methods of internal construction.

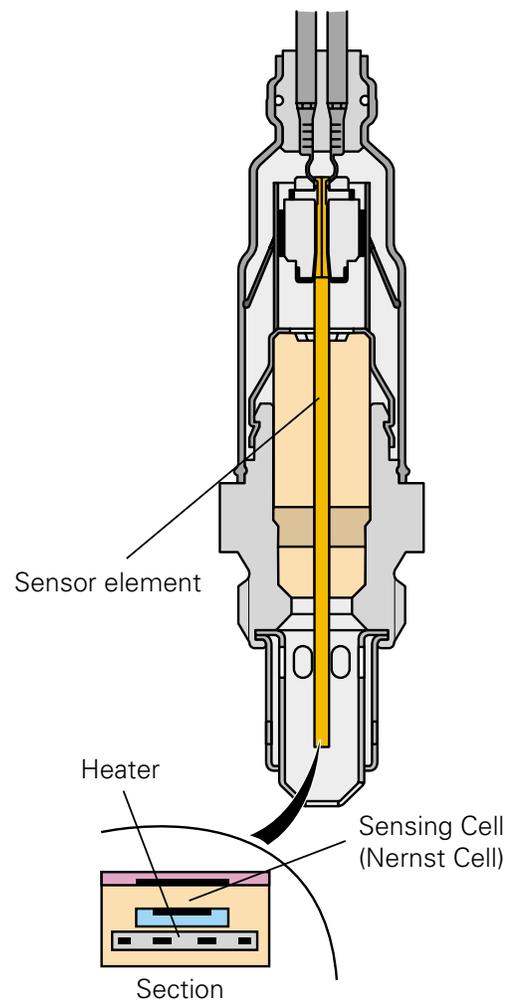
Planar construction takes advantage of newly developed layering processes that allow thin sheets, or ribbons, of the zirconium dioxide ( $ZrO_2$ ) sensing material to be stacked with other sensing elements and a flat heating element. This flat or planar construction has several advantages:

- Smaller, less complicated sensor design
- Lower heater current requirements (from approximately 72 Watts to 28 Watts)
- Shorter warm-up time, fast on-line time (operational as soon as 10 seconds after engine start-up)
- Quicker response time
- Greater stability over time
- Readily adaptable to more complex designs and functions

## Planar heated oxygen sensors

(Bosch LSF 4.7)

- Operation:  
The LSF 4.7 series oxygen sensor is similar in operation to the older finger-style heated oxygen sensors, but incorporates all the benefits of the new technology.
- On Board Diagnostic:  
The ECM recognizes open circuits and short circuits to the sensor and the heating element, as well as a full range of OBD-II performance DTCs.



# Motronic M5.9.2 Component Differences

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## Actuators (outputs)

Motronic M5.9.2 actuators are essentially the same as those found on M5.9. Not all changes are found on all engines. A summary of the differences between M5.9 and M5.9.2 is detailed in this section, along with variations within M5.9.2.

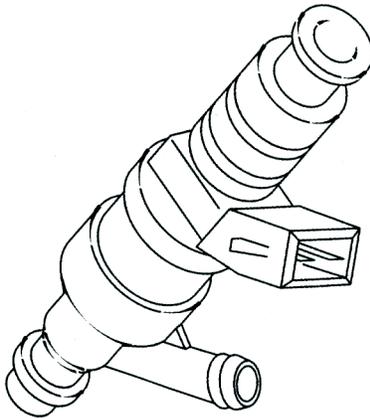
### Air-shrouded Fuel Injectors

**Cylinder 1 Fuel Injector N30**

**Cylinder 2 Fuel Injector N31**

**Cylinder 3 Fuel Injector N32**

**Cylinder 4 Fuel Injector N33**



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Golf, Jetta, and New Beetle versions of Motronic M5.9.2 use air-shrouded fuel injectors to help atomize fuel more effectively.

- **Operation:**  
Low pressure air (vacuum) is drawn in from the measured air flow of the MAF sensor and directed past each fuel injector tip. The additional air mixes more thoroughly with the fuel, resulting in more efficient combustion. This reduces exhaust emissions, especially at the low flow rates of an idling engine, and also improves idle quality. Air for this function is supplied by a line from the intake air duct feeding a manifold near the fuel rail. Short hoses connect the manifold to fittings at the discharge end of the fuel injector.
- **On Board Diagnostics:**  
Electrical operation and On Board Diagnostics of air-shrouded injectors are unchanged from previous versions.

# Motronic M5.9.2 Component Differences

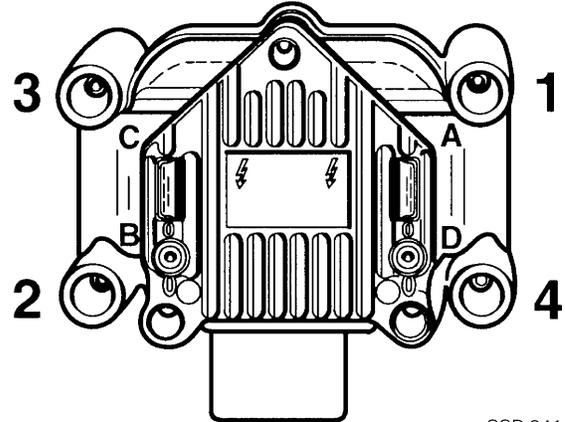
## Distributor-less Ignition

### Ignition Coil and Power Output Stage N122

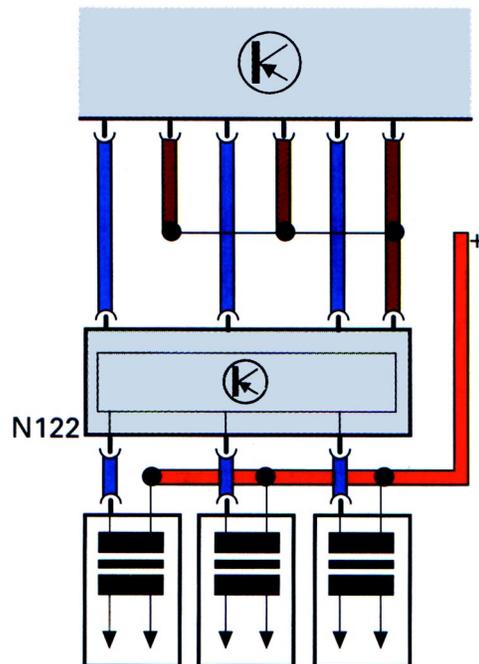
Distributor-less ignition is used on all Motronic M5.9.2 engines. The type used on 2.0 liter 4-cylinder and 2.8 liter V6 engines is similar to the type found on M2.9 versions of the VR-6 engine.

- Operation:  
Principles of operation are the same as the earlier distributor-less ignition systems. The primary difference is only the configuration and location of the components.
- On Board Diagnostics:  
Malfunctions in these components are not recognized by the ECM.

Ignition Coil N122 incorporates an integral power output stage. This is shown in the accompanying wiring diagram section of a 2.8 liter V6 engine.



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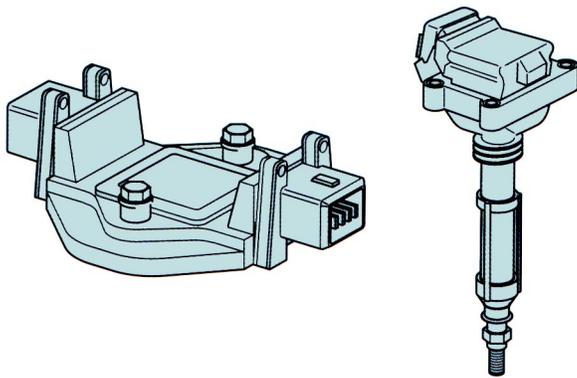


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## Motronic M5.9.2 Component Differences

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**Ignition Coil N**  
**Ignition Coil 2 N128**  
**Ignition Coil 3 N158**  
**Ignition Coil 4 N163**  
**Power Output Stage N122**



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The distributor-less ignition used on the 1.8 liter turbocharged 4-cylinder engine differs slightly from the other M5.9.2 versions. Each cylinder has an ignition coil mounted directly above the spark plug on the cylinder head (valve) cover (N, N128, N158, and N163). A short suppressor/connector links the two components. A Power Output Stage N122, with four separate outputs, is mounted in the air cleaner housing. This mounting location allows the aluminum heat sink to be cooled by the incoming air moving in the housing.

- **Operation:**  
The operation of this system is otherwise conventional. A small signal is sent to the power output stage from the ECM at the appropriate time. The power output stage amplifies the signal to the level required by the individual ignition coils, which then sends it to the spark plug via the short connector.
- **On Board Diagnostics:**  
Malfunctions in these components are not recognized by the ECM.

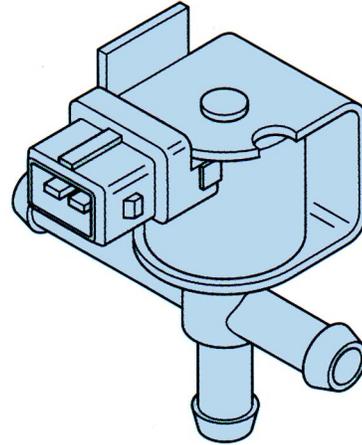
Ignition coil removal is easily accomplished for access to the spark plugs.

# Motronic M5.9.2 Component Differences

## Wastegate Bypass Regulator Valve N75

The turbocharger on the 1.8 liter engine uses a wastegate controlled by the ECM to regulate boost pressure. The wastegate valve allows exhaust gas to bypass the turbine wheel when engine turbocharger pressure is supplied to the wastegate servo.

- Operation:  
The pressure to operate the servo is regulated by the Wastegate Bypass Regulator Valve N75. The ECM calculates the correct level of boost pressure and supplies a signal to the valve. The valve allows the appropriate pressure to the wastegate servo for boost control. When wastegate operation is not required, the valve closes off the servo to the pressure side and then vents the pressure trapped in the line back into the turbocharger inlet thereby closing the wastegate. The ECM supplied signal is a duty cycle to allow for continuous regulation.
- On Board Diagnostics:  
The ECM recognizes open circuits and short circuits. Additional diagnostic testing is available with the scan tool set in the output Diagnostic Test Mode (DTM).

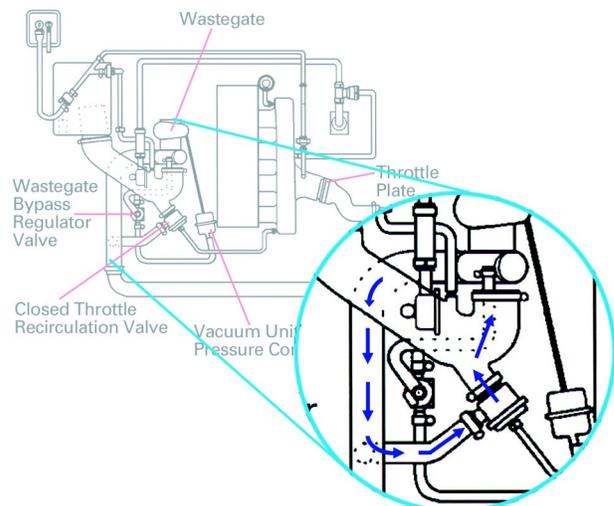


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## Charge pressure recirculation valve

In addition to N75, turbocharged engines also use a manifold vacuum actuated recirculation valve during deceleration and shifts to minimize compressor stall (refer to graphic at right).

When the throttle is closed at higher engine speeds (deceleration), the manifold vacuum will overcome the spring pressure in the valve. This opens a passage that allows the pressurized air charge to be recirculated to the inlet side of the turbocharger. This reduces compressor stall, allowing for smoother operation of the turbocharger, and reduces turbo "lag."

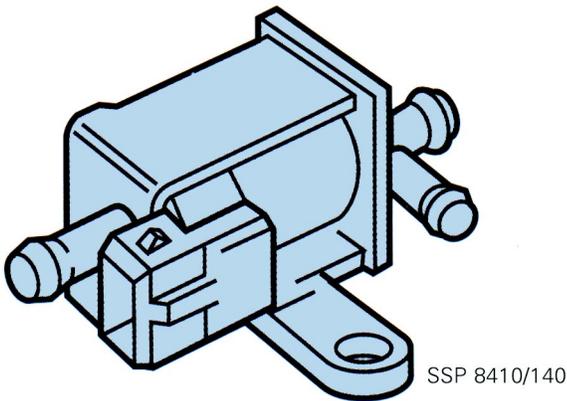


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# Motronic M5.9.2 Component Differences

## Intake Manifold Change-Over Valve N156

The 2.8 liter 5V V6 used in the Passat has an intake manifold with two sets of intake runners of different lengths. At lower engine speeds the length of the intake runner is lengthened to produce a ram effect. At higher RPMs intake charge velocity rises and a shorter runner length is needed for optimal cylinder filling. This design feature allows for accurate tuning of the intake air path for optimum low RPM and high RPM operation. This air routing intake manifold design is known as a dual path intake manifold.

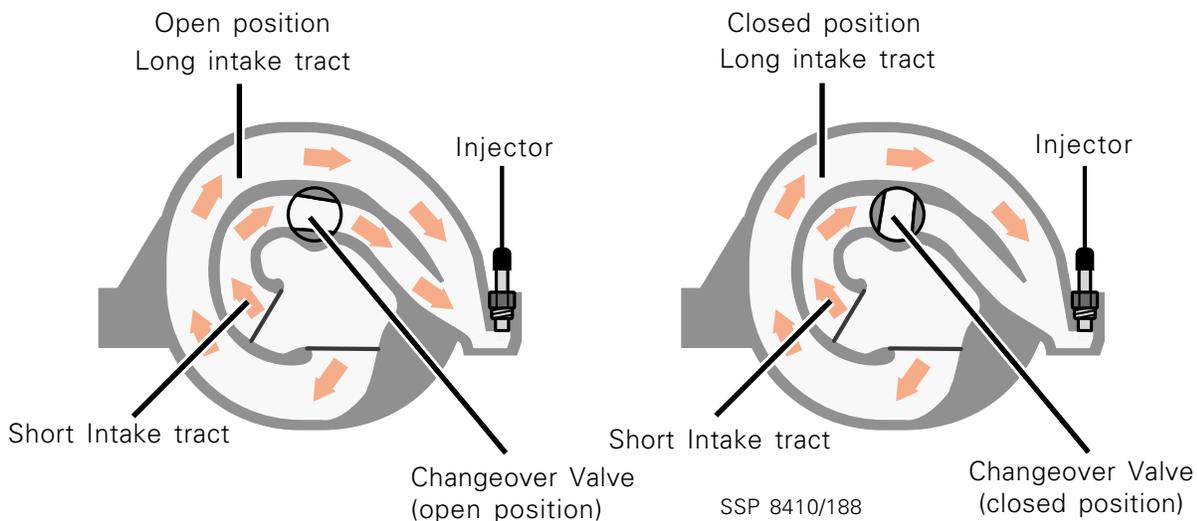


The “Ram effect” is based on the principle that air moving through a longer but smaller diameter column will cause the velocity to rise. This quickly moving mass of air continues to fill the cylinder after the piston has reached Bottom Dead Center (BDC). As engine speed and intake air velocity increase, the narrow diameter of the intake tube restricts airflow. As a result a larger, shorter tube is used at higher engine RPMs.

- Operation:  
The intake manifold change-over valve receives a command from the ECM at 4500 RPM. It then supplies manifold vacuum to the change-over servo which, in turn, moves the rotary valve from the low speed position to the high speed position. When the engine speed drops, the change-over valve closes off the vacuum to the servo and vents the trapped vacuum.
- On Board Diagnostics:  
The ECM recognizes open circuits and short circuits. Additional diagnostic testing is available with the scan tool set in the output Diagnostic Test Mode (DTM).

**Note:**

*The ECM has no way of diagnosing rotary valve position.*



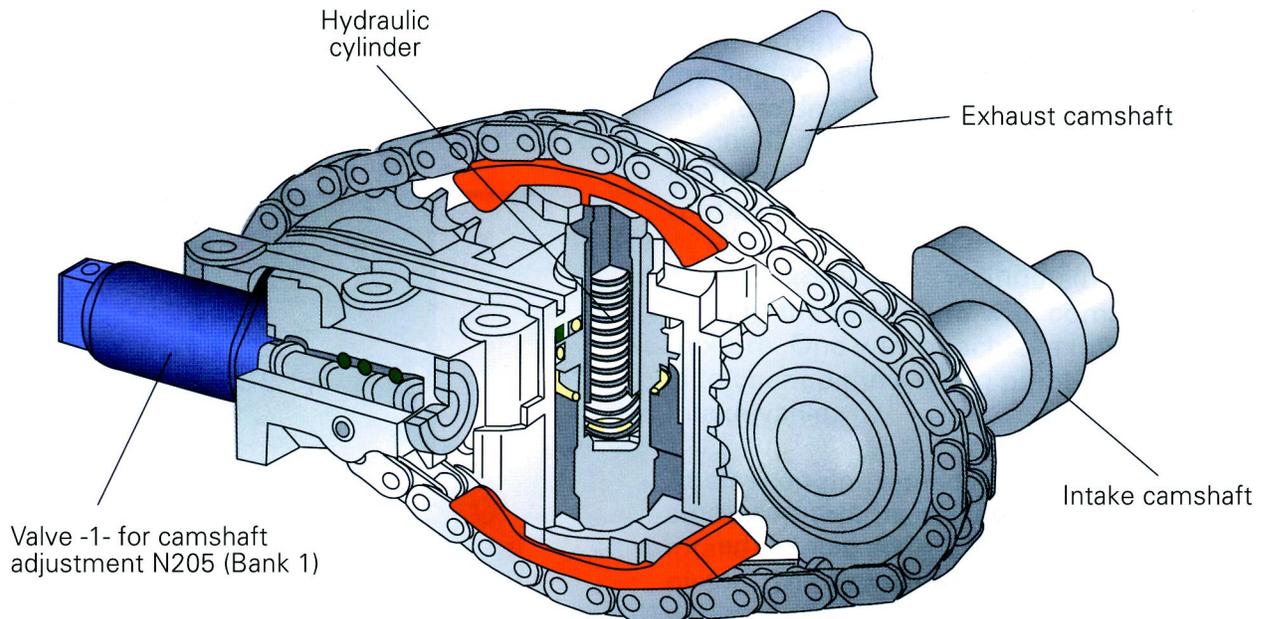
## Motronic M5.9.2 Component Differences

**Valve -1- for camshaft adjustment N205**

**Valve -2- for camshaft adjustment N208**

The 2.8 liter 5V V6 used in the Passat is equipped with variable camshaft geometry to help achieve optimum low RPM torque while still delivering maximum high RPM power and minimum exhaust emissions.

On the V6 with four cams, the exhaust cams are driven by the crankshaft by a toothed belt. The intake cams are driven by sprockets and short chains running from the exhaust camshafts. The position of the exhaust camshafts relative to the crankshaft remains constant during engine operation, but the position of the intake cams relative to the exhaust cams (and, therefore, the crankshaft) can be changed.



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## Motronic M5.9.2 Component Differences

- Operation:

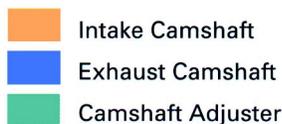
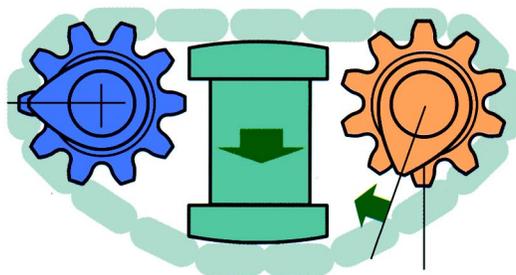
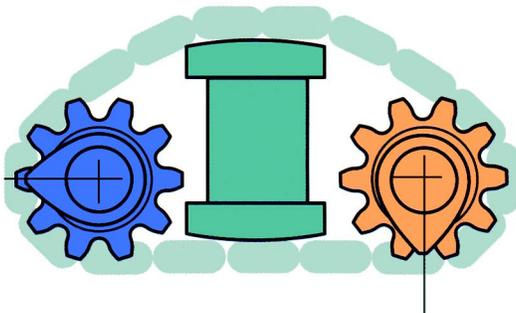
Each cylinder bank has a camshaft adjuster to keep the drive chains properly tensioned. Working with each tensioner is a solenoid valve that uses engine oil pressure to effectively move the slack side of the chain from one side of its travel to the other. By changing position of the slack side of the chain, the intake camshaft position changes relative to the exhaust camshaft without changing overall chain tension. The adjusters change cam timing  $22^\circ$  in relation to the crankshaft ( $11^\circ$  of camshaft rotation).

Valves 1 and 2 for camshaft adjustment receive commands from the ECM at the appropriate time and allow high pressure engine oil to enter the hydraulic cylinder in each adjuster. Oil pressure causes the hydraulic cylinder to move the slack side of the chain to the "pull" side which effectively advances the intake camshaft and enhances mid-range torque.

The process is reversed at idle for emissions reasons, and at higher engine speeds to take better advantage of the high air velocity of the dual path manifold.

- On Board Diagnostic:

The ECM recognizes malfunctions with valve -1- and valve -2- for camshaft adjustment. The ECM is able to monitor position of the cams with the Camshaft Position (CMP) sensors. Any change from one bank to the other will set an appropriate DTC. Additional diagnostic testing is available with the scan tool set in the output Diagnostic Test Mode (DTM). Camshaft position can be monitored with the scan tool by viewing measuring value blocks 091 and 092.



SSP 8410/135

## Review

1. **Technician A says that the Motronic M5.9 engine management system is an enhanced version of Motronic M2.9.**

**Technician B says that the Motronic M5.9 engine management system complies with OBD-II standards.**

**Which Technician is correct?**

- a. Technician A only
- b. Technician B only
- c. Both Technician A and Technician B
- d. Neither Technician A nor Technician B

2. **Which of the following is NOT an advantage of the air shrouded fuel injectors used in some versions of Motronic M5.9.2?**

- a. Improvement in idle quality
- b. Reduction in idle emissions
- c. More efficient combustion
- d. Faster electrical response than previous injector versions

3. **Technician A says that the ignition coils used on the 1.8 liter turbocharged 4-cylinder Motronic M5.9.2 engine use integrated power output stages.**

**Technician B says that the ignition coils must be removed on the 1.8 liter turbocharged 4-cylinder Motronic M5.9.2 engine to gain access to the spark plugs.**

**Which Technician is correct?**

- a. Technician A only
- b. Technician B only
- c. Both Technician A and Technician B
- d. Neither Technician A nor Technician B

4. **Technician A says that the pre-catalyst heated oxygen sensor monitors combustion efficiency.**

**Technician B says that the post-catalyst heated oxygen sensor monitors three-way catalytic converter efficiency.**

**Which Technician is correct?**

- a. Technician A only
- b. Technician B only
- c. Both Technician A and Technician B
- d. Neither Technician A nor Technician B

# Review

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5. **Golfs, Jettas and New Beetles equipped with Motronic M5.9.2 use a trigger wheel attached to the toothed belt sprocket for the camshaft. Which statement best describes the trigger wheel configuration?**

- a. Four windows, two 65° wide and two 25° wide
- b. Four equally spaced windows
- c. Six windows, three 65° wide and three 25° wide
- d. Six equally spaced windows

6. **Which of the following statements about the mass air flow sensor with reverse flow detection in Motronic M5.9.2 is NOT true:**

- a. Reverse flow detection allows incoming air to be measured just once.
- b. The intake air temperature sensor is now built into the mass air flow sensor housing.
- c. Two electrically heated pressure sensors within the mass air flow sensor housing help to determine reverse flow.
- d. Two electrically heated temperature sensors within the mass air flow sensor housing help to determine reverse flow.

7. **Technician A says that the Motronic M5.9.2 system can have cruise control as an ECM function.**

**Technician B says that the Motronic M2.9 system can have cruise control as an ECM function.**

**Which Technician is correct?**

- a. Technician A only
- b. Technician B only
- c. Both Technician A and Technician B
- d. Neither Technician A nor Technician B

8. **Motronic M5.9 evaporative emissions leak detection pumps are:**

- a. Operated by an electric motor.
- b. Operated by pressure from the secondary air injection pump.
- c. Operated by pressure from the fuel pump.
- d. Operated by engine vacuum.

9. **The Motronic M5.9 ECM will cause the malfunction indicator light to flash under which of the following circumstances?**

- a. Engine misfiring.
- b. Open circuit in the engine coolant temperature sensor.
- c. Leak detection pump records a large or a small leak.
- d. Engine speed (RPM) at maximum governed limit.

## Motronic ME 7

The newest generation of engine management systems is the Bosch™ Motronic ME 7. This new system was implemented on the VR-6 engine for the 1999 model year, and model year 2000 for the 2.8 liter 5V V6 and the 1.8 liter 5V turbo.

Motronic ME 7 departs from previous engine management systems in that all subsystems are processed in a sub-processor responsible for all functions of engine performance. Earlier systems used separate sub-processors for functions such as ignition, fuel, or emissions.

The main concept of ME 7 is that the previous way of viewing inputs and outputs has been done away with. This new system is a **torque based system**.

Motronic ME 7 is continually monitoring inputs from both external sources, like driver input, and transmission control, as well as internal requests such as cruise control, and idle speed. The Motronic ECM interprets these inputs as torque demands, then controls actuators accordingly to produce the required torque for the given demand.

The ECM designates signals along two pathways. This separation of how actuators are handled allows the ECM to better utilize the resources at its disposal.

This new way of viewing inputs as torque demands is a key factor in the functionality of the Motronic ME 7 system.

## Pathways

The Motronic ECM coordinates torque demands via two separate pathways.

- The **charge air path** controls all charge influencing components, such as throttle valve angle and wastegate actuation.
- The **crankshaft synchronous path** controls all interactions that occur at the same time with the operating cycle of the engine, such as ignition and injector timing and duration.

The crank synchronous path is particularly well suited to meeting short term torque demands, usually having a torque reducing effect.

The charge air path is suited to fulfilling long term torque demands; this path is primarily used for a required torque increase.

*For more information on the ME 7 system, refer to the Volkswagen ME 7 SSP #842003.*

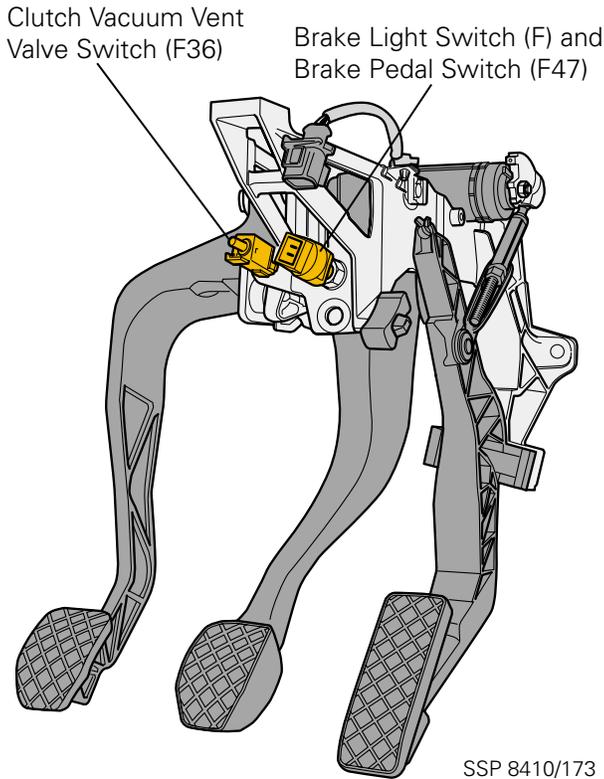
## Components of Motronic ME 7

Motronic ME 7 has brought on several changes or additions in components to both engine management and other related systems.

The changes include:

- Electronic throttle control
- Cruise control
- Charge air pressure sensor G31
- Integration of Barometric Pressure (BARO) sensor F96 as a component of the Motronic ECM J220
- Recirculating Valve for Turbocharger N249

# Motronic ME 7

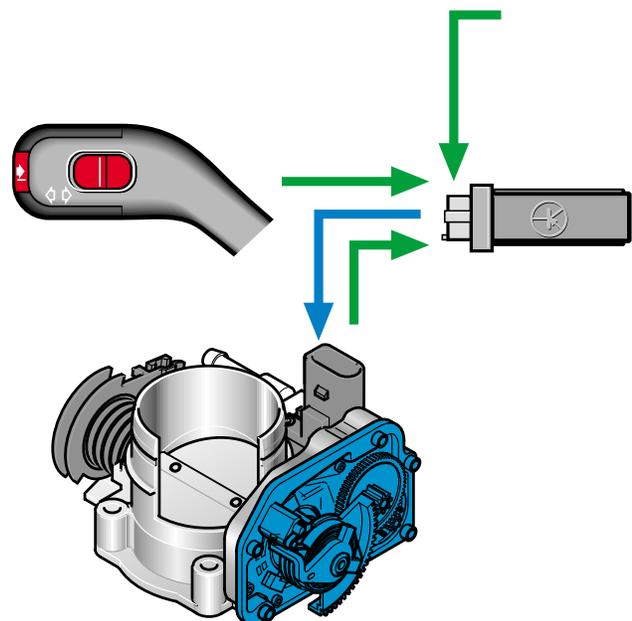


## Cruise control

Cruise control is no longer handled by a separate vacuum sub-system. The addition of electronic throttle control has enabled the Motronic ECM J220 to handle this function.

The Motronic ECM is able to control throttle valve angle in the same manner as the vacuum pump used previously. This allows for a more accurate transition of throttle as well as a more stable speed.

Similar to M5.9.2 systems, the Brake vacuum vent valve switch F47 and brake switch F are combined in a single housing. This dual function switch is entirely electric. One side controls normal brake light function, and the second side provides information to the Motronic ECM regarding the application of brakes to disengage cruise control.



## Charge air pressure sensor G31

Previous Motronic M5.9.2 controlled charge pressure via a calculation map, derived from engine speed, throttle valve angle and engine load (MAF).

In ME 7, the sensor is mounted in the intake tract between the charge air cooler and the Throttle Valve Control Module J338.

- Operation:

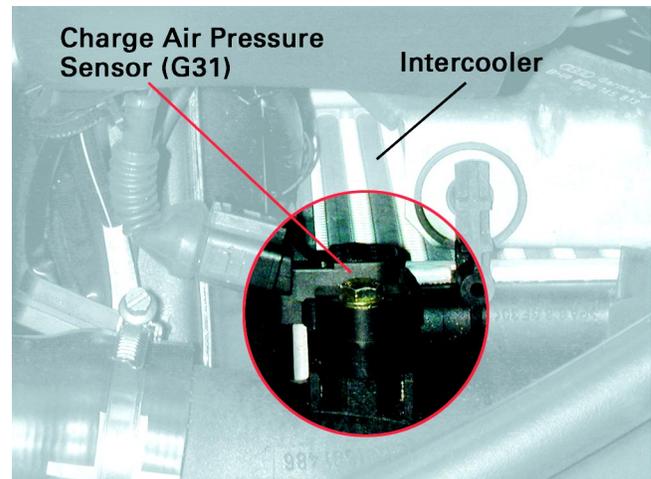
Charge Air Pressure sensor G31 is a piezo-electro sensor. Operation is via a 5V reference from the Motronic ECM, with a varying resistance to indicate manifold absolute pressure. Atmospheric pressure provides a signal of approximately 2.5V. Range of operation for the ECM to recognize a plausible signal is 0.14V - 4.88V.

- Substitute function:

If Charge Air Pressure sensor G31 fails, charge pressure will be controlled by a calculation map based on engine speed and load. Power output will also be reduced.

- On Board Diagnostic:

The ECM recognizes short circuit to Battery +, short circuit to Ground, as well as implausible signals. The ECM cross checks the Charge Air Pressure sensor against the BARO sensor. If a difference of 200 mbar is seen, a code for implausible signal is set.



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# Motronic ME 7

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## Barometric Pressure (BARO) sensor F96

The Barometric Pressure (BARO) sensor F96 is no longer a separate component. The BARO sensor is now mounted internally within the Motronic ECM J220.

The BARO sensor is used in conjunction with the Charge Air Pressure sensor G31 for charge pressure control.

In higher elevations charge pressure is reduced to prevent overspinning the turbocharger.

The BARO sensor is also used for fuel mixture control, leaning out the short term fuel trim with increasing altitudes.

- Substitute function:

If the BARO sensor fails, boost is limited to a safe level, and power levels are reduced. Cold running fuel adaptation will no longer take place.

- On Board Diagnostic:

The ECM recognizes implausible signals, as well as short circuit to Battery + and Ground. The fault will display "Control unit defective."

## Recirculating Valve for Turbocharger N249

Previous Motronic M5.9.2 systems used a charge pressure recirculating valve operated by intake manifold vacuum. The key to its functionality was a fully closed throttle valve allowing full engine vacuum to operate the valve.

Electronic throttle control may not allow for this under certain operating conditions. The throttle valve may be held partially open for emissions purposes.

Recirculating Valve for Turbocharger N249 is used to provide vacuum to the recirculating valve using vacuum from a reservoir mounted under the front wheelhousing liner. This allows the Motronic ECM to more accurately control the turbocharger's performance during throttle transition.

- Operation:

N249 is a solenoid valve (see Glossary) similar in design to others used in the engine management system. Power is supplied via the fuel pump relay and the Ground is switched by the Motronic ECM.

- Substitute function:

The system is designed so that if N249 fails, the recirculating valve will continue to function by manifold vacuum.

- On Board Diagnostic:

The ECM recognizes short to Battery + and short circuit to Ground.

## Heated Oxygen Sensors (HO2S) G39/G108

### Broadband planar heated oxygen sensors (Bosch LSU 4.7)

The Bosch LSU series pre-catalyst oxygen sensors as used on the Motronic ME 7 vehicles are a new design. Post-catalyst sensors are the LSF as described in the M5.9.2 chapter. Advantages of this new 6 wire sensor include:

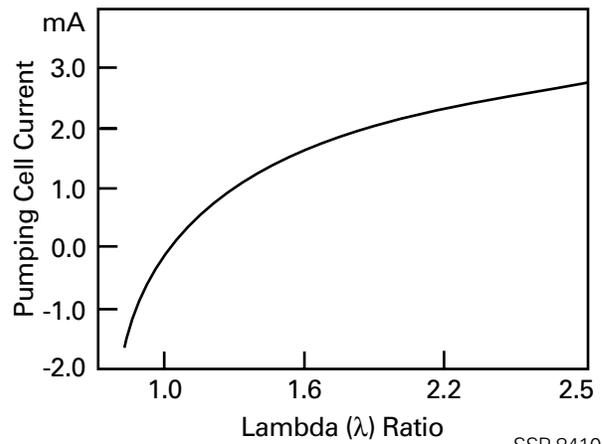
- Faster response time
- More accurate control of Lambda
- Ability to maintain closed loop under broader conditions

The LSU sensor is designated as a broadband sensor due to its ability to accurately measure larger changes in exhaust mixture. The way the sensor functions is similar in concept to a hot film Mass Air Flow (MAF) sensor. The new design is able to track mixture changes nearly twice as far in the lean direction. This allows the Motronic ECM to stay in closed loop during fuel cutoff during deceleration, and allows for more accurate mixture control during transitional changes.

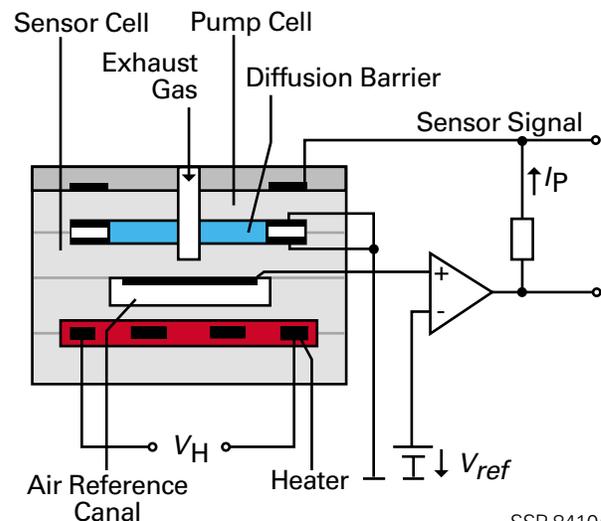
#### • Operation:

The LSU series wideband oxygen sensor operates differently from other types of heated oxygen sensors. Within the housing is a pumping cell and a sensing cell (**Nernst Cell**, see Glossary). The ECM regulates the pumping cell, controlling the volume of exhaust gas passed across the sensing cell. The ECM maintains  $\lambda=1$  at the sensing cell, by changing the current through the pumping cell. The changing milliamperere signal to the pumping cell is converted and interpreted by the operating electronics in the ECM to an oxygen level value for further processing.

- On Board Diagnostic:  
The ECM recognizes open circuits and short circuits to the sensor elements and signals, as well as the heating element. It also recognizes adaptation and range/performance faults.



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SSP 8410/197

# Motronic ME 7

## Electronic throttle control

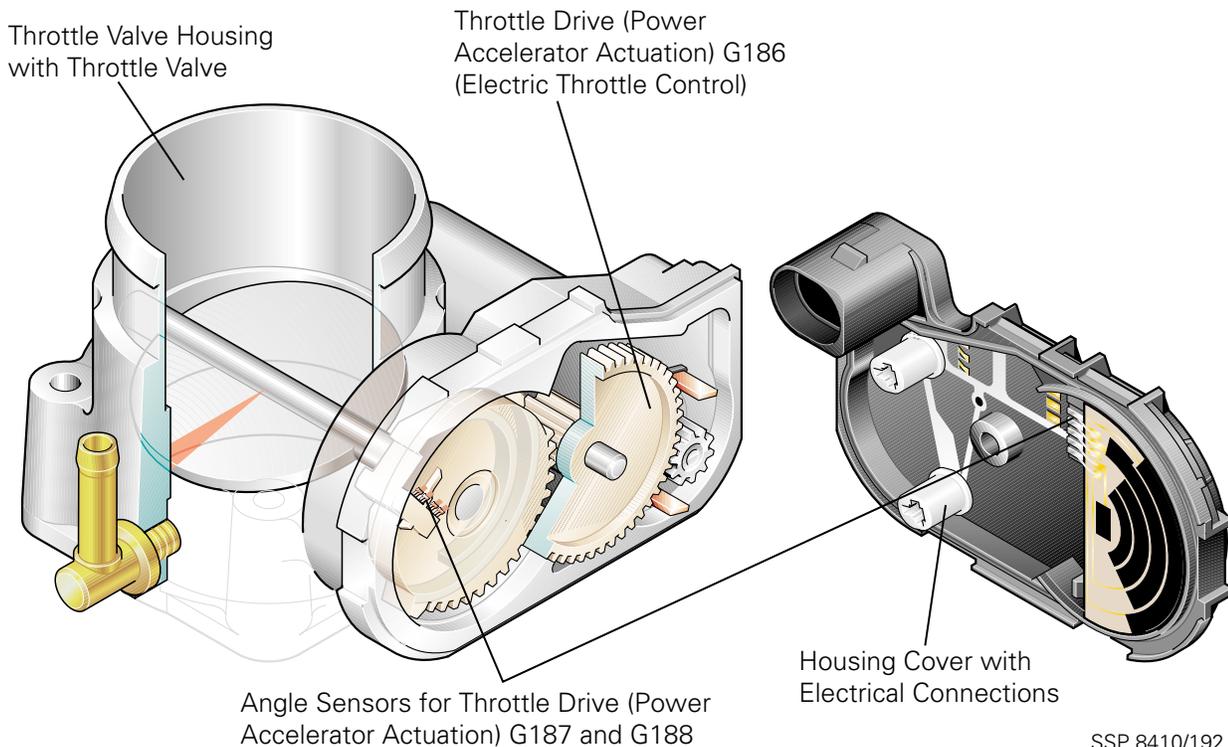
The ME 7 engine management system utilizes electronic throttle control. This enables the Motronic ECM to control the intake charge volume and velocity for optimization of engine torque.

The throttle valve control module has been modified from the M5.9 system to allow the Motronic ECM to drive the throttle valve under all running conditions. This new system no longer makes use of a mechanical link between the accelerator pedal and the throttle valve housing.

The Motronic ECM J220 positions the throttle valve according to torque demands, allowing the ECM to control throttle angle. This is a key factor in torque management.

The throttle valve control module allows the throttle valve angle to be optimized for maximum intake velocity.

Extensive safety measures have been implemented in the hardware and the software. Dual sensors are used for continual self checking of signal plausibility. A safety module is integrated in the Motronic ECM to monitor the functional processor for proper operation.



## Throttle valve control module J338

The throttle valve control module combines the following components:

- Throttle drive (power accelerator activation) G186
- Angle sensor for throttle drive G187
- Angle sensor for throttle drive G188

The throttle valve control module is controlled by the Motronic ECM J220, and regulates the required air charge to produce the required torque.

- Operation:

The two angle sensors for the throttle drive (G187 and G188) are opposite in resistance, and are used for continuous cross checking by the Motronic ECM. The angle sensors are provided with a 5V reference voltage by the Motronic ECM. The ECM reads the voltage drop across the dual potentiometers and uses this to monitor throttle valve angle.

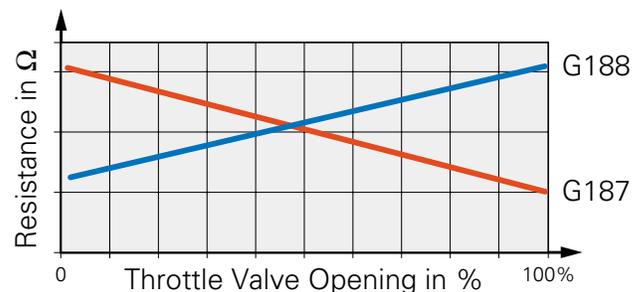
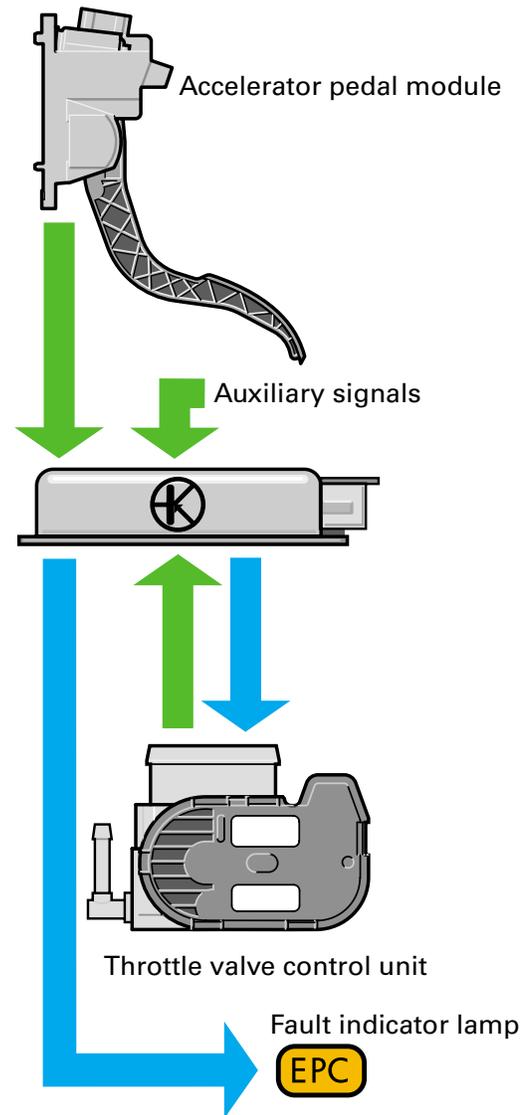
The Throttle drive is an electric motor that operates the throttle valve by way of a set of reduction gears. Its position is continually monitored by angle sensors G187 and G188.

- Substitute function:

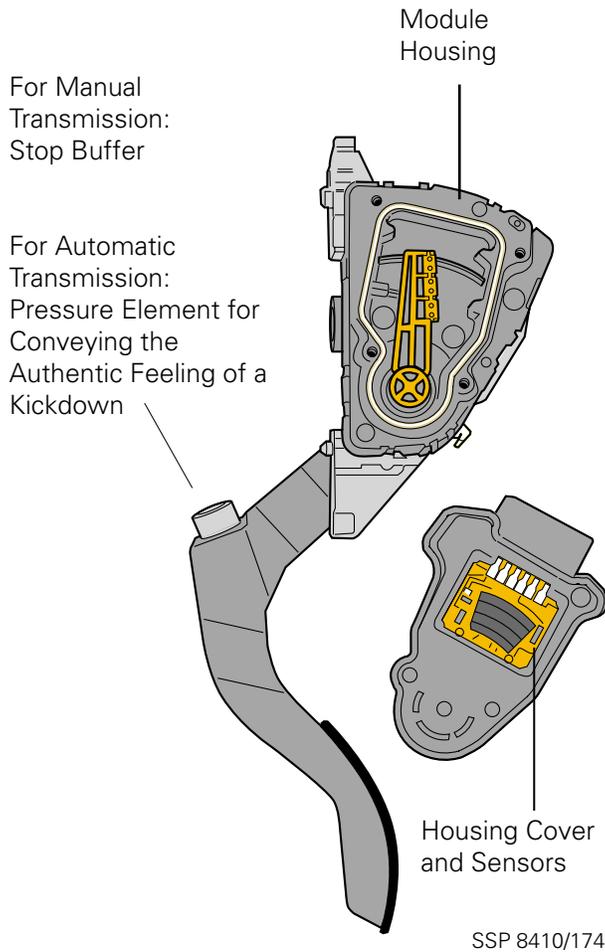
In the case of a component failure the Motronic ECM will initiate an "Emergency running mode," and allows only limited vehicle operation. There is no substitute function for the throttle drive.

- On Board Diagnostic:

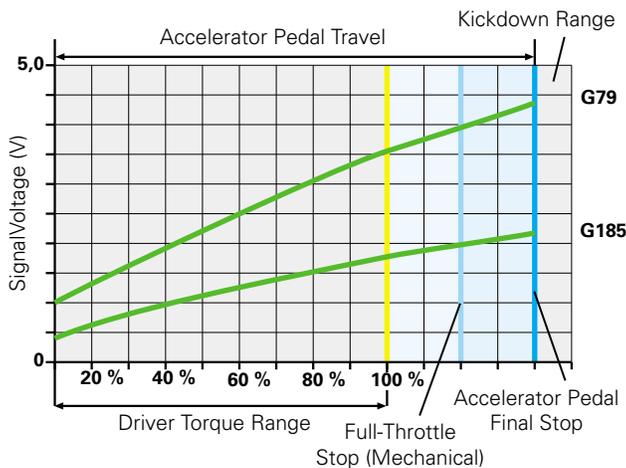
The Motronic ECM is able to recognize range/performance faults, as well as signal range checks for the angle sensors. The throttle drive is monitored for range of operation and idle adaptation faults.



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SSP 8410/174



SSP 8410/175

## Accelerator pedal module

The accelerator pedal module is comprised of the accelerator pedal and the accelerator position sensors as one assembly.

The components of the accelerator pedal module are:

- Throttle Position (TP) sensor G79
- Throttle position (TP) sensor G185

The redundant throttle position sensors are linear to each other on different scales. Like the throttle drive sensors, the duplicate sensors are for self-diagnosis.

- Operation:

The sensors provide an analog signal to the ECM referencing accelerator position. The kickdown function is also incorporated into the module.

There is no longer a separate switch for the automatic transmission kickdown. When the normal voltage limits of the sensors are exceeded, the Motronic ECM recognizes this and interprets this as a kickdown. This signal is passed on to the Transmission Control Module (TCM) by way of the CAN data bus.

- Substitute function:

If one of the TP sensors fail, the ECM relies on the redundant sensor. If both TP sensors fail, an Emergency Running Mode is initiated.

- On Board Diagnostic:

The ECM recognizes range/performance failures, as well as signal plausibility checks.

### Note:

For more information regarding electronic throttle control function, refer to Volkswagen ME 7 SSP #842003.

## Fault light for power accelerator activation K132

A separate indicator light is used for the **E**lec-  
tronic **P**ower **C**ontrol system.

Malfunctions in either the electronic accelera-  
tor system or associated sensors are  
detected by self-diagnosis, and indicated by  
the separate EPC fault light.

For example, a fault in the Mass Air Flow  
(MAF) sensor G70 will trigger the EPC light  
due to its usage by the Motronic ECM for an  
engine load signal. The Motronic ECM uses  
this signal for checking signal plausibility of  
other inputs. At the same time, an entry is  
made in the fault memory.

- Operation:

When the ignition is switched on, K132 is  
illuminated for three seconds. If there are  
no faults in the system the light will go  
out.

K132 is activated by the Motronic ECM  
providing a Ground for the light.

- Substitute function:

There is no substitute function for K132.

- On Board Diagnosis:

The ECM recognizes Short circuit to Bat-  
tery +/-Ground, as well as Open circuit.



SSP 8410/200

# Review

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## Review

- 1. The ME 7 system is referred to as:**
  - e. A "torque based engine management system"
  - f. A "horsepower based engine management system"
  - g. A "crank synchronous system"
  - h. A "charge path optimization system"
- 2. Component changes for the ME 7 system include:**
  - a. Engine Speed (RPM) sensor G28
  - b. Camshaft Position (CMP) sensor G40/G163
  - c. Throttle valve control module J338
  - d. Post catalyst oxygen sensor(s)
- 3. The resistance curves for throttle angle drive sensors G187 and G188 are:**
  - a. Opposite
  - b. Linear, on different scales
  - c. Identical
  - d. Flat, with no change
- 4. The throttle valve control module performs what function?**
  - a. Regulates air charge to produce necessary torque demanded by engine
  - b. EGR regulation
  - c. Accelerator pump function
  - d. Transfers an analog signal to the ECM which corresponds to accelerator pedal position.
- 5. Which of the following components is not used in the charge air pressure system?**
  - a. Charge air pressure sensor G31
  - b. Vehicle Speed Sensor (VSS) G54
  - c. Wastegate by-pass regulator valve N75
  - d. Motronic Engine Control Module (ECM) J220

## Level one course preparation

To be better prepared for the Level One Instructor Led Course, and ultimately, to enable you to succeed in the shop, you are encouraged to utilize the following "tools."

### Critical Thinking Skills

The key to successful, timely problem diagnosis, and ultimately customer satisfaction, involves "critical thinking." Getting good information from service advisors, and diagnosing and solving customer problems is a skill that must be mastered to achieve success.

The four steps to getting good information from service advisors are:

- 1. Focus the discussion on the symptom description.**
- 2. Ask questions that clarify what, when, where and how often.**
  - Use open ended questions to expand discussion.
  - Use closed ended questions to prompt for specifics.
- 3. Summarize your understanding and get agreement.**
- 4. Explain what you will do to proceed and get acknowledgment.**

The five steps to diagnosing and solving customer problems are:

- 1. Describe the problem.**
  - List known symptoms.
  - Avoid opinions or disguised solutions.
- 2. Verify and analyze.**
  - Try to duplicate the problem.
  - List possible causes.
- 3. Locate the problem.**
  - Select probable causes.
  - Prioritize tasks.
  - Identify the problem.
- 4. Repair the problem.**
  - Determine the specific cause.
  - Perform the repair.
- 5. Conduct a quality check.**
  - Recheck for proper operation and reassembly.
  - Check for cleanliness and appearance.

# Technician's Reference

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## Volkswagen Electronic Service Information System (VESIS) navigation

Throughout the Level One Instructor Led Course the technician is required to successfully navigate through VESIS to diagnose problems, locate components and obtain the latest information pertaining to the subject at hand.

As a technician, you know how important it is to have the proper tools to complete a job in a timely manner. With VESIS, you have fast and simple access to the all the latest repair information. Advantages include:

- a single source for all Repair Information, including Technical Bulletins, Service Circulars, Component Locations and Suggested Repair Times (SRT).
- frequent updates ensure information is always current.
- simple access to information, as well as hyperlinked cross references, reduce the time spent tracking down procedures and specifications.

Becoming familiar with VESIS will allow you to spend less time searching for information, and more time using the information.

If you have questions regarding the functionality or setup of VESIS, software support is available from 9:00 AM to 6:00 PM, Monday through Thursday, and 9:00 AM to 5:00 PM, Friday (Eastern Standard Time). The toll-free number is:

- **800-423-1617**

## Volkswagen HELP line/Tech-tip line

Eventually even the most experienced technicians come across a problem that proves extremely difficult to resolve. Volkswagen has created a HELP line to give the technician support during these times. This line connects the technician with technical specialists who will work together with the technician to resolve the problem. Hours of operation are eastern time. Phone numbers and times are:

- **800-678-2389 English/French** Monday through Friday, 9:00 AM to 7:00 PM Eastern time
- **800-403-4710 English** FAX
- **514-331-0477 French** FAX

Occasionally the specialists are busy, and the caller will be put on hold. During this time, Volkswagen plays various recorded "Tech-tips." These tips can include anything from "basics" to the latest problems/solutions being experienced in the field, and can be very useful.

The following information should be recorded and available before you call the Tech Hotline:

- Dealer number (i.e. 401-424).
- Ownership Technical Specialist (OTS) name.
- Repair Order (RO) number.
- Vehicle Identification Number (VIN).
- Production date (from door post label).
- Mileage.
- Engine type and code.
- Transmission type and code.
- Driveline (front wheel drive or 4-Motion).
- Complete VAG 1551/VAS 5051 printout.
- Service history (if possible).

## Diagnostic and Special Tools

Before attending the Level One Instructor Led Course, be sure you are familiar with all the Diagnostic equipment and Special Tools in your dealership. The following is a list of some of the tools you will be using in class:

- VAS 5051 Vehicle Diagnostic, Testing and Information System, including the Digital Storage Oscilloscope (DSO)
- VAG 1598 pin-out box
- VW 1318 fuel pressure gauges with adapters
- Multimeter (Fluke 83 or equivalent)
- VAG 1594 wiring harness connector test kit
- Leak-down tester
- Compression tester

## Review questions

1. **In your dealership, locate the tools listed. Are these tools in good working order and readily available?**
2. **Where are the wiring diagrams and Technical Bulletins stored in your dealership?**
3. **Where is the service literature (including microfiche) stored in your dealership?**
4. **What is the phone number for the Volkswagen Help line?**

## Suggested reading and reference

There are many resources available for further reading, study, and reference including Self Study Program books published by Volkswagen of America. Listed below are several that contain Fuel System and/or Engine Management System information:

- **EVAP Systems, Operation and Diagnosis**  
published 11/99, order 841303
- **The CAN Data Bus**  
published 03/99, order WSP 521 419 00
- **The New Volkswagen 2.8 Liter V6 Engine**  
published 12/98, order 821803
- **The New 1999 Volkswagen Golf and Jetta**  
published 11/98, order 893803
- **Service Training SSP for the 1998 New Beetle**  
published 02/98, order 891803
- **The 1998 Volkswagen Passat**  
published 08/97, order WSP 521 416 00
- **The New Volkswagen Eurovan with the VR-6 Engine**  
published 06/98, order WSP 521 414 00
- **On Board Diagnosis II**  
published 12/95, order WSP 521 413 00
- **The New Volkswagen Passat**  
published 10/94, order WSP 521 409 00
- **The New Volkswagen Cabrio**  
published 03/94, order WSP 521 408 00
- **1994 Model Change Information**  
published 12/93, order WSP 521 407 00
- **1993 Model Change Information**  
published 11/92, order WSP 521 406 00
- **The New Golf III, GTI, Jetta III**  
published 05/93, order WSP 521 405 00
- **1992 Model Change Information**  
published 12/91, order WSP 521 404 00

# Technician's Reference

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- **The New Volkswagen VR-6 with Motronic Engine Management System**  
published 12/91, order WSP 521 402 00
- **The New Eurovan**  
published 08/92, order WSP 521 401 00
- **1991 Model Change Information**  
published 12/90, order WSP 521 400 00
- **1990 Model Change Information**  
published 11/89, order WSP 521 206 00
- **The New Volkswagen Passat**  
published 10/89, order WSP 521 203 00
- **The New Volkswagen Corrado**  
published 08/89, order WSP 521 202 00
- **Digifant I & Digifant II - Pro Training**  
published 12/88, order WSP 521 194 00
- **1988 Product Change**  
published 09/87, order WSP 521 150 00
- **Digifant II Engine Management System**  
published 02/88, order WSP 521 149 00
- **Vanagon/Type II Fuel Systems - Pro Training**  
published 03/87, order WSP 521 148 00
- **The New Volkswagen Fox**  
published 08/86, order WSP 521 143 00
- **Scirocco 16V**  
published 05/86, order WSP 521 141 00
- **CIS-Electronic Fuel Injection, 2nd Edition**  
published 06/86, order WSP 521 140 00
- **1986 Vanagon and Vanagon Synchro**  
published 10/85, order WSP 521 133 00
- **1986 Model Change Information**  
published 10/85, order WSP 521 132 00
- **Service Advisor Technical Reference Guide**  
published 04/87, order WSP 521 131 00
- **Quantum Synchro**  
published 08/85, order WSP 521 129 00

- **The New Golf, Jetta and GTI**  
published 1984, order WSP 521 123 00
- **The 1984 Volkswagens**  
published 1983, order WSP 521 118 00
- **Water-Cooled Vanagon**  
published 1983, order WSP 521 112 00
- **Solving Driveability Complaints (Digifant I & II, CIS-E)**  
published 03/93, order WSP 521 101 00
- **The 1983 Rabbits**  
published 1982, order W42 003 855 1

Many of these titles are available from Dymont Distribution at 800-544-8021. Some titles are no longer in print, but may still be available at the Dealer since all titles were originally sent to the Dealer body.

Several other excellent sources of reference are:

- **Bosch Fuel Injection & Engine Management**  
by Charles O. Probst, SAE, ISBN 0-8376-0300-5
- **Bosch Automotive Handbook**  
ISBN 0-8376-0333-1
- **Bosch Automotive Electric/Electronic Systems**  
ISBN 0-8376-0467-2
- **Volkswagen Inspection/Maintenance (I/M) Emission Test Handbook 1980>1997**  
ISBN 0-8376-0394-3, VW part number LPV 800 901

The above titles can be ordered from book-sellers everywhere including Robert Bentley Publishers, 800-423-4595.

## Glossary

**Adaptation:** The ability of an engine management system to continuously modify operating parameters to account for changing operating conditions. For example, an oxygen sensor continuously adjusts or corrects the mixture formation to account for small vacuum leaks, or a knock sensor modifies ignition timing to account for gasoline AKI variances.

**Adaptive learning:** The ability of an engine management system to continuously modify operating parameters (fine control range) to account for changing operating conditions (i.e. mechanical) and the ability to adjust to long term changes by moving the control window within a larger range (coarse control range).

**Additive:** The effects of the fault (e.g. unmetered air) will reduce as engine speed increases. The injector duration will be modified by a fixed amount for additive learned values. This amount is **not** dependent upon the basic injection duration.

**Barometric pressure sensor:** A piezo-electric device used for measuring pressure. A piezo-crystal structure similar to that found in a knock sensor is connected to and sealed within a small diaphragm chamber. An outer chamber surrounds the diaphragm and is connected to the intake tract by a small hose or left open to the atmosphere. Changing pressure conditions act on the diaphragm and, in turn, the crystal. A small voltage signal is generated in relation to air pressure changes. Barometric pressure sensors with sensing elements left open to the atmosphere measure changes in air pressure such as those associated with changes in altitude. Sensors with elements connected to the intake tract measure manifold pressure changes. Barometric pressure sensors can be either a separate component or built into the ECM.

**CARB:** California Air Resources Board. Created after the Clean Air Act of 1970 to implement more stringent clean air standards.

**Closed loop:** A period of engine operation when the ECM is receiving and responding to information supplied by the oxygen sensor. Loop operation refers to the ECM's action in response to reaction or feedback supplied by the oxygen sensor.

**Dashpot:** A mechanical dampening device mounted near the throttle plate. The purpose of the dashpot is to slowly close the throttle, preventing stalling and reducing emissions. Dampening action is accomplished by a spring or a pneumatic diaphragm. Also known as a throttle positioner on some older engines.

**Duty cycle:** As applied to engine management systems, a duty cycle (or duty factor) is the period of time when a component is switched on or activated. It is usually expressed as a percentage, such as "a duty cycle of 60%." Since many automotive components have only two states, on or off, a duty cycle allows accurate control of a function, over a period of time, under conditions that are not always completely on or completely off. For example, the ECM pulses the Ground to the EGR vacuum regulator solenoid valve, switching it on for 10 ms and off for 10 ms continuously, yielding a 50% duty cycle. This effectively operates it at one-half of the flow capacity, even though it does not open half way.

# Glossary

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**Hall sensor:** A magnetically switched, solid state integrated circuit sensor. When the Hall effect transistor is exposed to a magnetic field, it allows current to flow through the transistor to Ground, completing a circuit. When the magnetic field is not present current flow stops. Trigger wheels are often used to pass between the magnet and the transistor. Other applications attach the magnet to a rotating component. When the magnet passes the hall sensor current flow is enabled. Unlike Inductive sensors, Hall sensors require a power source to operate.

**I/M 240:** (Inspection and Maintenance) A 240 second test period defined in the Federal Test Procedure (FTP), in which a vehicle is tested on a dynamometer under varying engine loads. The test measures the level of emissions of HC, NOx and CO.

**Implausible signal:** A term used in OBD-I and OBD-II to denote particular types of signal malfunctions. Generally; a signal that falls outside the range of expected values, but is not an open circuit or a short circuit. For example, an ECM sends a 5 Volt reference signal to a sensor and expects a returned signal (voltage drop) of between 0.5 Volts and 4.5 Volts in normal operation. If the ECM "sees" a signal of 4.75 Volts, it is not within the expected range (0.5 to 4.5 Volts), nor is it a short circuit (0 Volts) or an open circuit (5.0 Volts). It is in an area of undefined or implausible signals.

**Inductive pickup:** Generally, a magnet wrapped with wire. A rotating trigger wheel of ferrous metal causes an alternating current signal to be generated. The signal frequency generated varies with the speed of the trigger wheel. The trigger wheel can have a gap which causes a variation in the pulses and identifies a given position. Commonly used for ABS wheel speed sensors and engine RPM and reference sensors.

**ISO:** International Standards Organization

**LSH oxygen sensor (Lambda Sonde Heizung)** (Lambda Sensor Heated): Designation given to Bosch™ heated oxygen sensors of the "thimble" or "finger" type of construction where the center electrode is of a circular design. Commonly used in both pre-catalyst and post-catalyst positions.

**LSF 4.7 oxygen sensor (Lambda Sonde Finger)** (Lambda Sensor Finger): Designation given to Bosch™ heated oxygen sensors using planar (flat) technology but with operation similar to the older finger-style heated oxygen sensors. Commonly used in both pre-catalyst and post-catalyst positions.

**LSU 4.7 oxygen sensor (Lambda Sonde Universal)** (Lambda Sensor Universal): Designation given to Bosch™ universal or wideband heated oxygen sensors using planar (flat) technology and new methods of signal generation. These six-wire heated oxygen sensors operate by using an internal ion pump to supply a measuring cell. The sensor signal is derived from the strength of the signal sent to the ion pump. Used in the pre-catalyst position of some systems.

**Multiplicative:** The effects of the fault (e.g. faulty injector) will increase with engine speed (RPM). A multiplicative learned value is a proportional change to the injector duration. This change is dependant on the basic injector duration.

**NTC sensor:** **N**egative **T**emperature **C**oefficient; a temperature sensing component in which the electrical resistance decreases as the temperature increases.

**Nernst Cell:** An electro-chemical (Voltaic) cell based on mathematical equations first devised by Walther Hermann Nernst (1864-1941). The equation predicts the flow of gaseous ions and the resulting voltage at very high temperatures. Used as a measuring cell in oxygen sensors.

**Open loop:** A period of engine operation when the ECM is either not receiving or not responding to information supplied by the oxygen sensor. Generally, an engine management system is in open loop after start-up (hot or cold), because the oxygen sensor is not up to proper operating temperature. In this situation, the ECM is instructed to run the engine with pre-programmed values until it recognizes a valid oxygen sensor signal. An engine management system can also be in open loop during hard acceleration where the ECM is programmed to slightly enrich the mixture. In this situation, the ECM is receiving valid signal information, but is programmed to temporarily disregard it. If an engine management system receives no signal, such as in the case of a disconnected or open circuited oxygen sensor, the ECM is programmed to run on pre-programmed internal values. Open loop operation, in this context, refers to the ECM's lack of response to feedback supplied by the oxygen sensor or the lack of a signal, thereby breaking the feedback loop.

**Range/Performance malfunction:** An OBD-II term used to denote particular types of malfunctions that do not seem to be possible under normal operating circumstances. An example of a Range/Performance malfunction is a throttle position sensor that has a low voltage at a engine speed with high rpm and a high mass air flow. High engine speed and high flow through the mass air flow sensor generally equate to high throttle position voltage, so this situation should not occur and will set a DTC as appropriate.

**Solenoid valve:** An electrically switched electro-magnetic valve. Usually consists of a coil of wire through which an electric current is passed. The resulting magnetic field opens a valve, allowing passage of a gas or liquid.

**Solid State:** An electronic device or circuit using transistors and similar components. Does not use vacuum tubes.

**Stoichiometric:** 14.7:1. Theoretical optimum air/fuel ratio for operating a spark ignition gasoline engine.

**ϑ - Greek symbol theta:** This symbol is placed in or near a component illustration to denote the influence of temperature on the component. Commonly used in wiring diagrams to identify temperature sensors and circuit breakers.

**λ - Greek letter lambda:** This symbol denotes the air factor in the air/fuel mixture of an internal combustion engine. A λ value of 1 ( $\lambda = 1$ ) indicates **Stoichiometric**.

# Glossary

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**< - Mathematical symbol:** This symbol denotes "less than." The text " $\lambda < 1$ " is read as "lambda is less than 1."

**> - Mathematical symbol:** This symbol denotes "greater than." The text " $\lambda > 1$ " is read as "lambda is greater than 1."

## **Volkswagen Engine Management Systems Teletest**

The test accompanying this course, #841003, has been prepared and shipped as a separate document. Please refer to your copy of that document and follow the testing instructions to complete the Teletest.

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