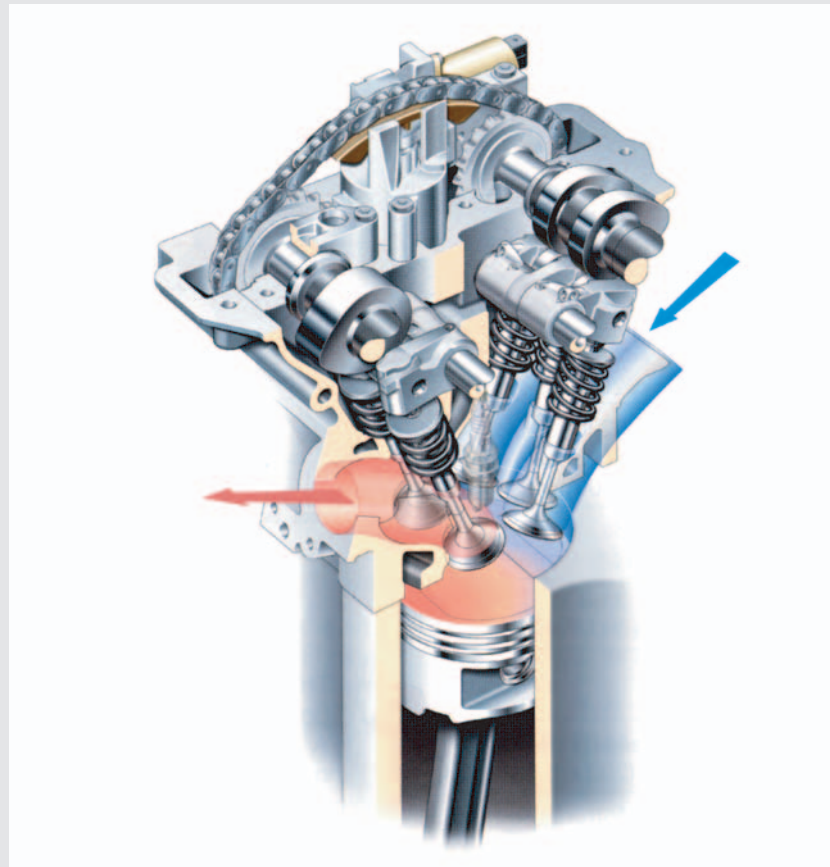


Engine Management Systems



Design and Function

Self-Study Program
Course Number 941003



Audi of America, Inc.
Service Training
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Course Number 941003

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Always check Technical Bulletins and the Audi Worldwide Repair Information System for information that may supersede any information included in this booklet.

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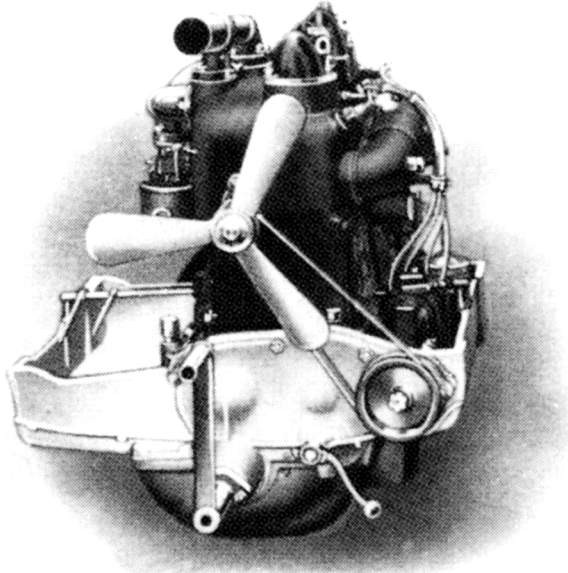
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Introduction

The origins of Audi engine development can be traced back to a 1913 4-cylinder liquid-cooled engine designed by August Horch (1868-1951) in Zwickau, Germany. This great-grandfather of the modern Audi 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.



Audi 14/35 engine as installed in the 1913 Type C Austrian Alpine Run car featuring three main bearings and a fixed cylinder head.

Displacement:	3560 cc (217.1 cid)
Compression ratio:	NA
Maximum torque:	NA
Maximum power:	35 hp @ 1800 rpm (40 hp competition version)
Engine management:	Spray-jet carburetor magneto ignition
Fuel requirement:	Gasoline

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 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.



Turbo-charged and intercooled TT engine with 5 valves per cylinder as installed from the 2000 model year.

Displacement:	1781 cc (108.6 cid)
Compression ratio:	9.5:1
Maximum torque:	235 Nm @ 1950-4700 rpm (173 LbFt @ 1950-4700 rpm)
Maximum power:	132 Kw @ 5500 rpm (180 hp @ 5500 rpm)
Engine management:	Bosch Motronic ME 7.5 OBD II
Fuel requirement:	87 AKI unleaded (minimum) 91 AKI unleaded (best perf.)

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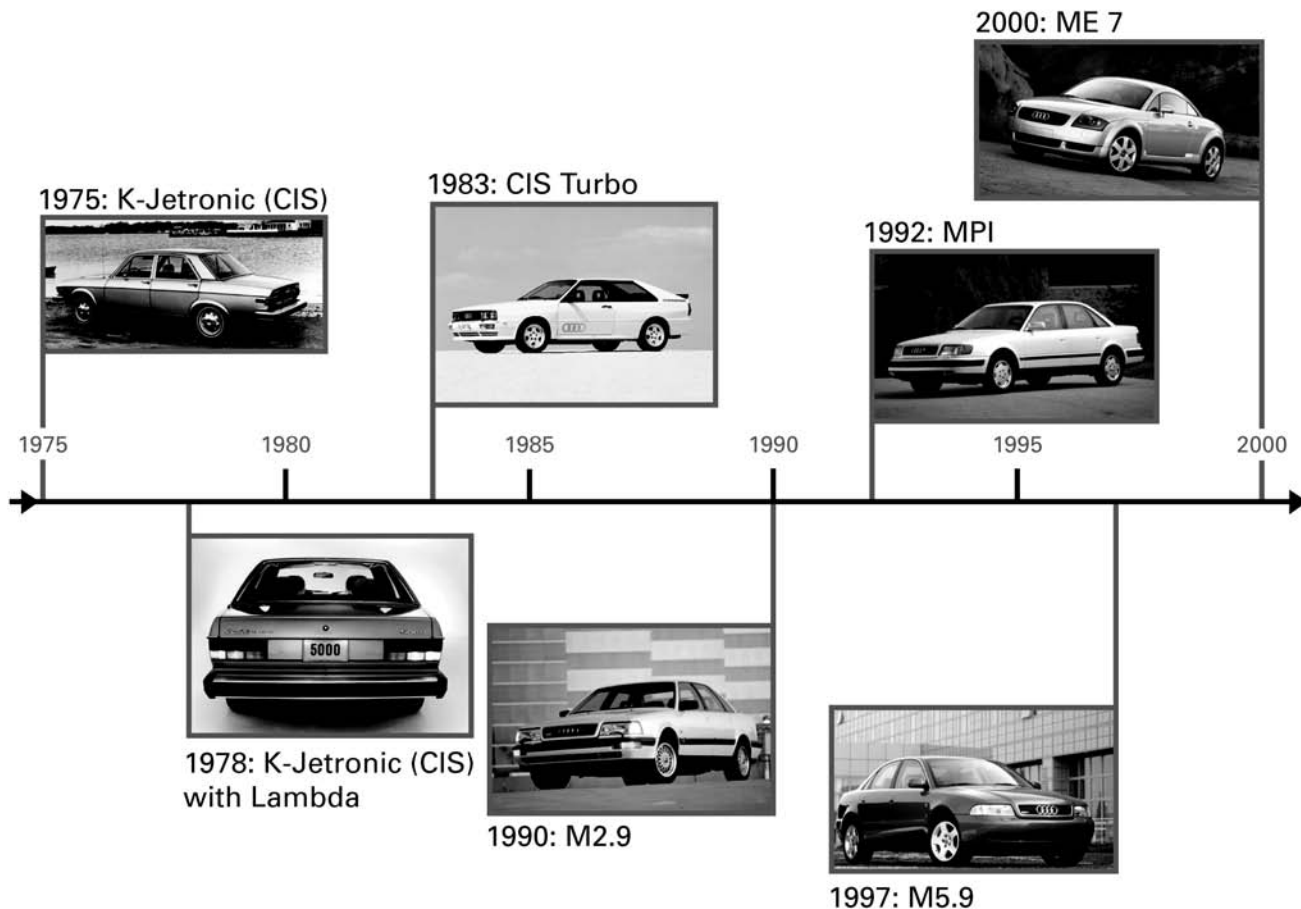
Introduction

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 system.

Course goals

- review principles of engine operation
- explain the progression of engine management systems used by Audi
- provide an in-depth understanding of both previous engine management systems and the state-of-the-art engine management systems in use today



SSP 9410/03

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)

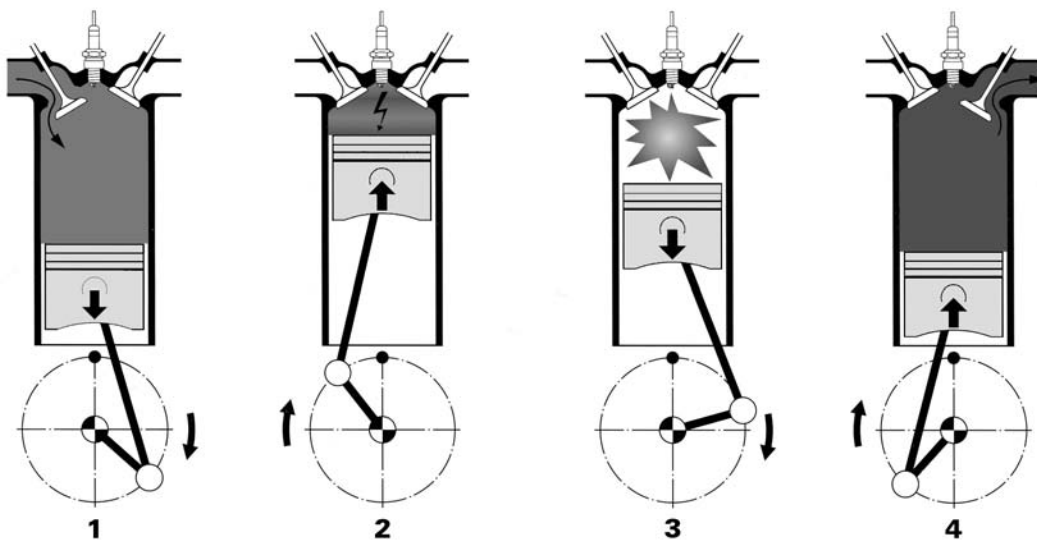
Operation continues with the piston at the bottom of its stroke, and the intake valve closing. The piston moves up in the cylinder, compressing the air/fuel mixture. Near the end of the stroke the air/fuel mixture is ignited by the ignition system.

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

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:

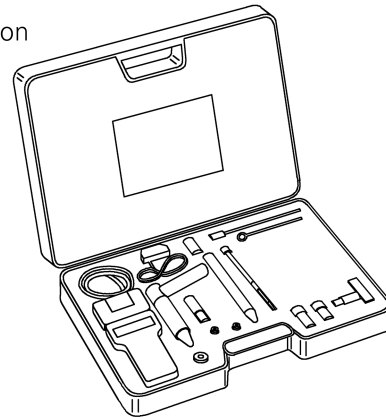
- **Compression test:**

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 for a specified number of pulses using the starter, while applying Wide Open Throttle (WOT). 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 to 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.

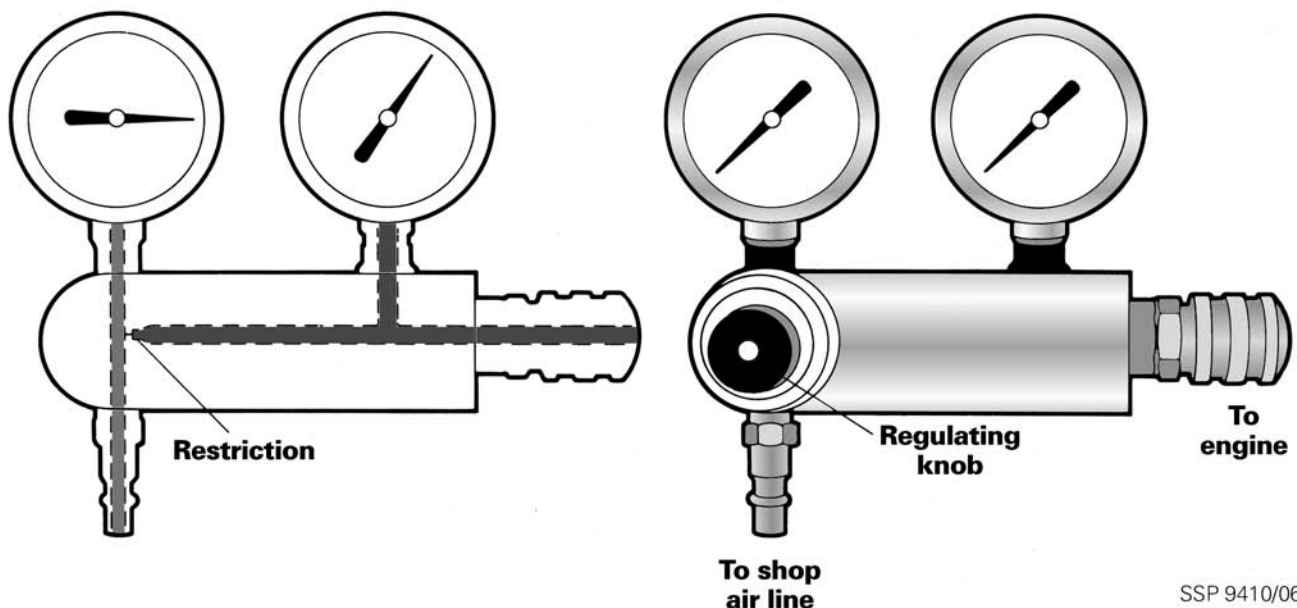
As in the compression test, the engine should be at normal operating temperature to ensure the accuracy of the test.

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 owners 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).

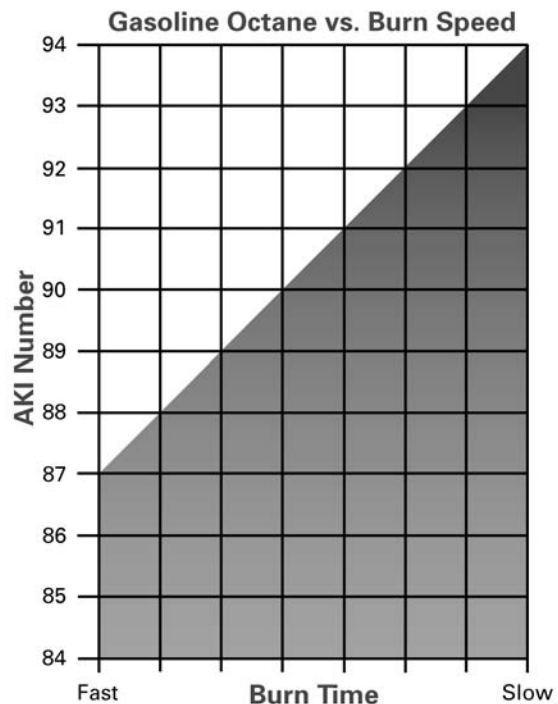
The CLC number is derived from both the RON and the MON as follows:

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

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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

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 Audi 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).

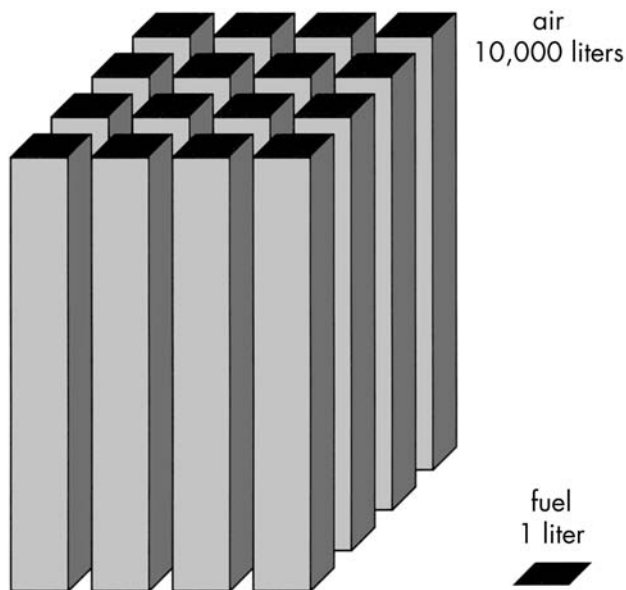
- Octane must be between 87 AKI and 93 AKI, but exact requirements depend on model and year.
- MTBE is blended with gasoline and sold in some areas of the country as oxygenated fuel to help reduce tailpipe emissions. This fuel can be used as long as specific percentage requirements are maintained and 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



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 volume. 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 λ (Lambda), and is generally referencing the air factor in the ratio. Listed below are several common λ 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, λ 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.

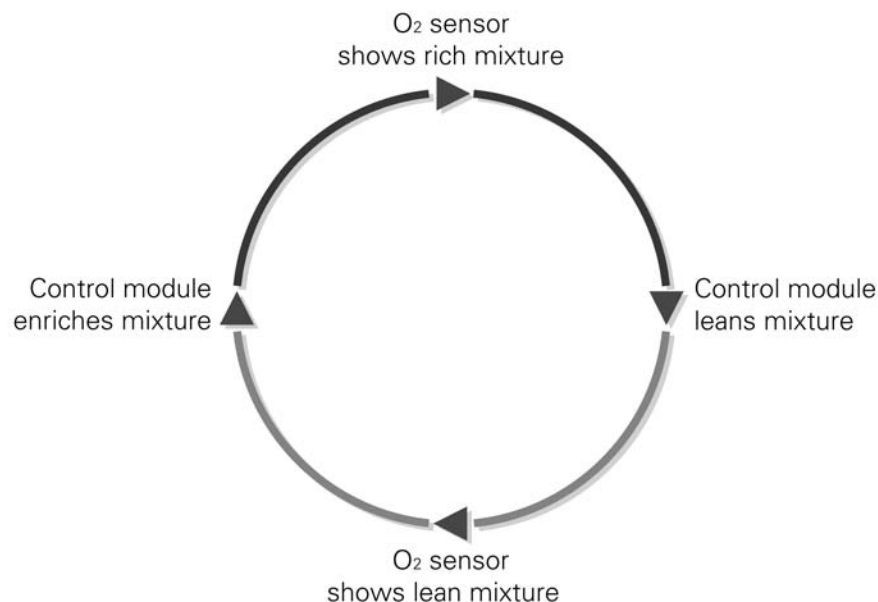
The period of time after an engine start when the oxygen sensor is not at operating temperature, and therefore not used, is called **open loop operation**. This condition can occur after either a cold or warm start. Conversely, engine operation with a valid oxygen sensor signal is called **closed loop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



SSP 9410/08

Principles of engine operation

Fuel system, overview

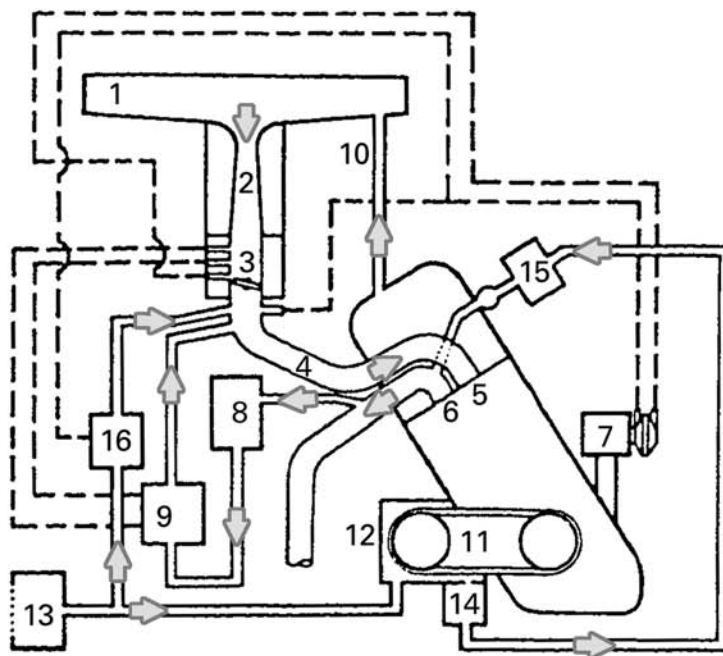
The fuel system is made up of numerous individual components. The purpose of these components is to insure delivery of the correct air/fuel mixture formation to the engine at the correct time.

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

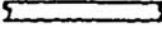

Although advantages of these systems include simplicity and relatively low cost, disadvantages are frequent maintenance, poor emissions, relative inefficiency, and the inability to be self-diagnosing.

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.



1. Air cleaner
2. Carburetor venturi
3. Carburetor throttle valve
4. Intake manifold
5. Cylinder head intake
6. Cylinder head exhaust
7. Double vacuum unit, distributor
8. Exhaust gas recirc. (EGR) filter
9. Exhaust gas recirc. (EGR) valve (double stage)
10. Engine block vent
11. Air pump belt
12. Air pump
13. Air pump filter
14. Pressure relief valve
15. Check valve
16. Anti-backfire (ABF) valve

Exhaust gas and air lines 
Vacuum hoses 

Emission Controls on Engines with an Air Pump (circa mid-70s)

SSP 9410/124

Evolution of Engine Management Systems

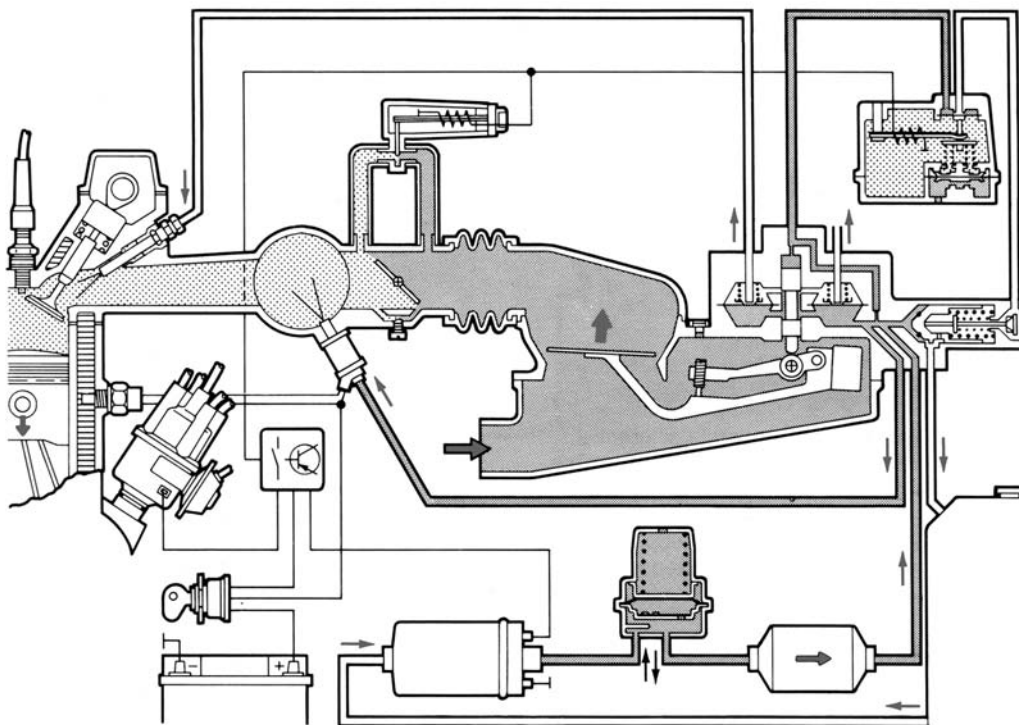
Modern technology created a new perspective in how fuel and ignition system management is viewed. Starting with the Fox and the 100LS in 1975, Audi began replacing carburetors with fuel injection. The Bosch™ K-Jetronic™ fuel injection system that was used seems very basic by today's standards, but it represented a giant technological leap forward at the time. Fuel delivery was by individual fuel injectors in a continuous flow with the fuel pump relay containing the only electronics in the system. The ignition continued to be handled by a breaker point distributor.

Advances in computer technology, combined with new circuit designs, allowed electronic control of the fuel and the ignition in later version of these systems.

Mixture control feedback through the use of oxygen sensors allows more precise metering of the fuel. Ignition system feedback through the use of knock sensors allows optimum spark timing. These feedback loops allowed engine operation to be continuously corrected to compensate for changing operating conditions.

Digital data processing and micro-processor technology made it possible to take extensive operating information from sensors and other input sources, and convert it to program-map-controlled fuel injection and ignition data.

Today, technology enables engine management systems to control not only emissions and driveability, but to constantly optimize engine torque as well.



Schematic Overview of the Bosch K-Jetronic Fuel Injection System used on the 1975 Audi Fox and 100LS

SSP 9410/15

Principles of engine operation

Ignition system, overview

The ignition system's function is to insure delivery of a correctly timed and sufficiently strong spark to ignite the air/fuel mixture.

Electrically, the ignition system components are divided into two categories by voltage level. Components using battery or low voltage are classified as **primary**, and include the following:

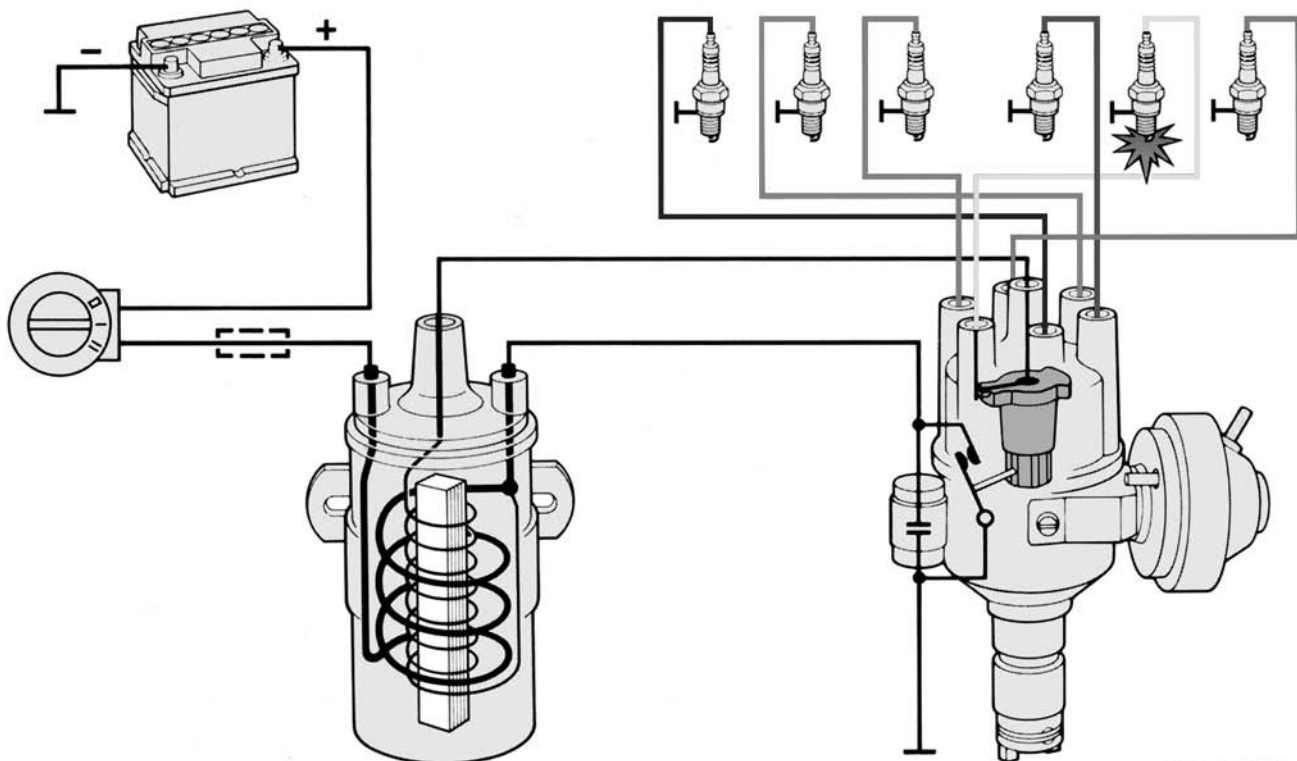
- Battery
- Coil
- Trigger (either breaker points or electronic)
- Electronic signal amplification and advance control

Components using high voltage are classified as **secondary**, and include the following:

- Spark plugs and wires
- Distributor cap, rotor
- Ignition coil (spark plug side)

System function

Refer to the basic coil ignition with breaker points graphic at the bottom of this page. When the ignition is switched on, battery voltage is supplied to the low voltage or primary side of the ignition coil. A strong magnetic field is developed in the primary windings. When the Ground side of the coil is open (by breaker points or electronically), the magnetic field around the primary windings collapses and induces a higher voltage in the secondary windings.



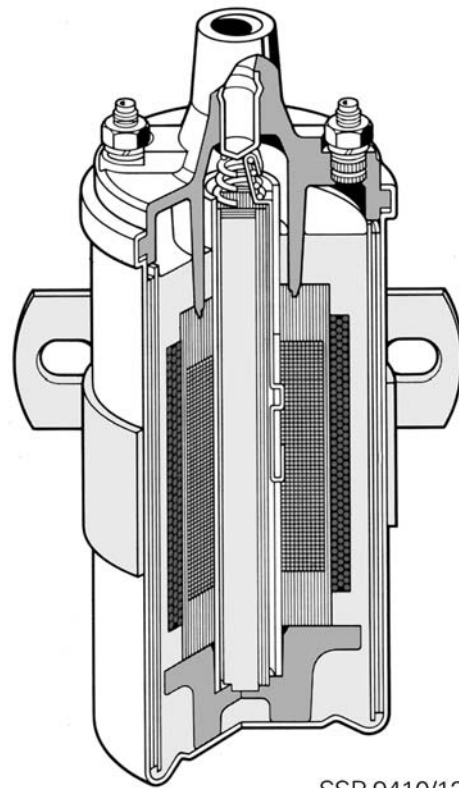
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Principles of engine operation

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.

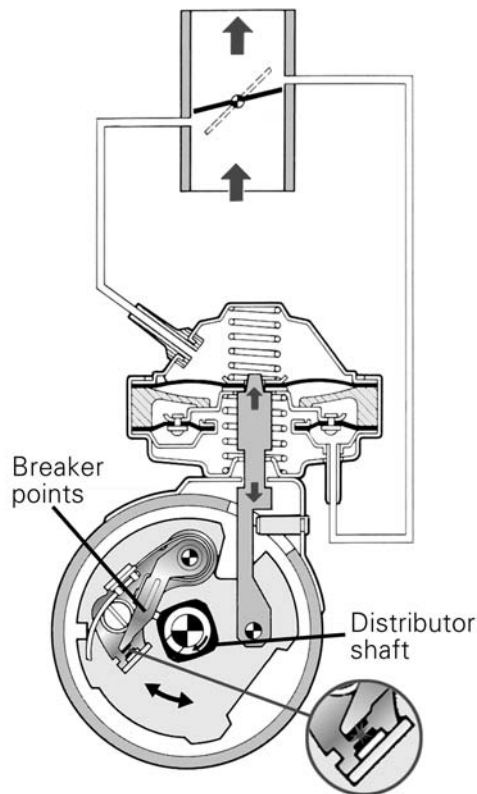
The period of time that the negative side of the coil is grounded (points remain closed) is referred to as **dwell**. Dwell is the length of time the primary winding can generate a magnetic field. The longer the dwell time, the stronger the magnetic field. This results in a higher secondary voltage (stronger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



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Principles of engine operation

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 ($\frac{1}{2}$ 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.



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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.

Principles of engine operation

The **Hall sender** is a solid-state, semi-conductor 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 ignition 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

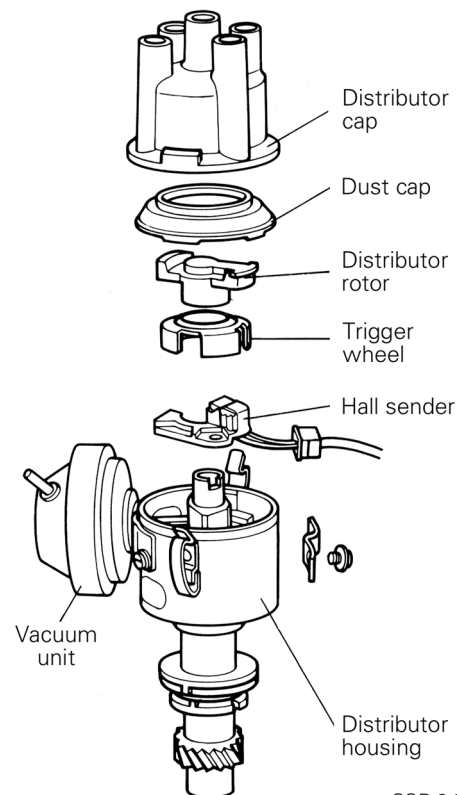
The accompanying table highlights the performance advantages.

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.



SSP 9410/11

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.

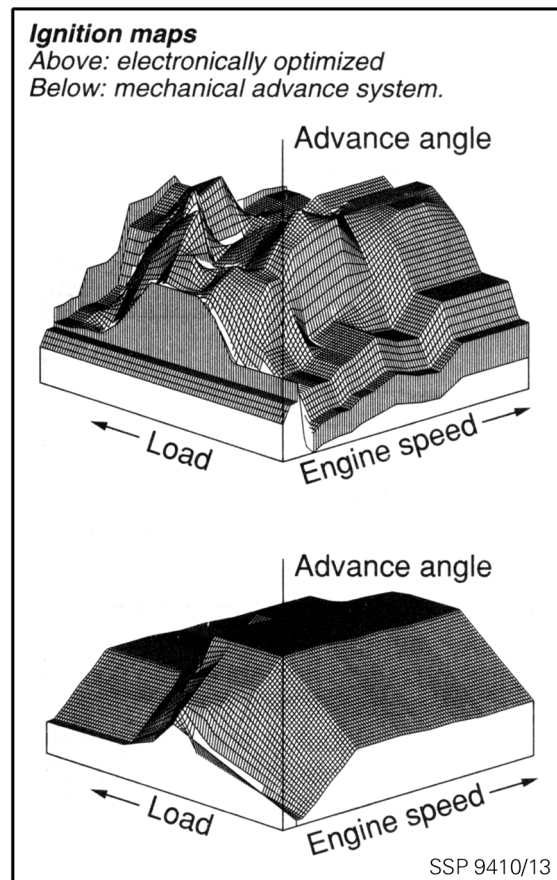
In the basic ignition system described previously, the cam which operates the breaker points is connected to a mechanism where centrifugal fly-weights move the cams position in relation to the points position in the distributor.

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. The electrode must get hot enough to burn off any carbon accumulation by the time the engine reaches operating temperature, but not hot enough to burn the insulator (or electrode). Classifications exist for hot, 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.

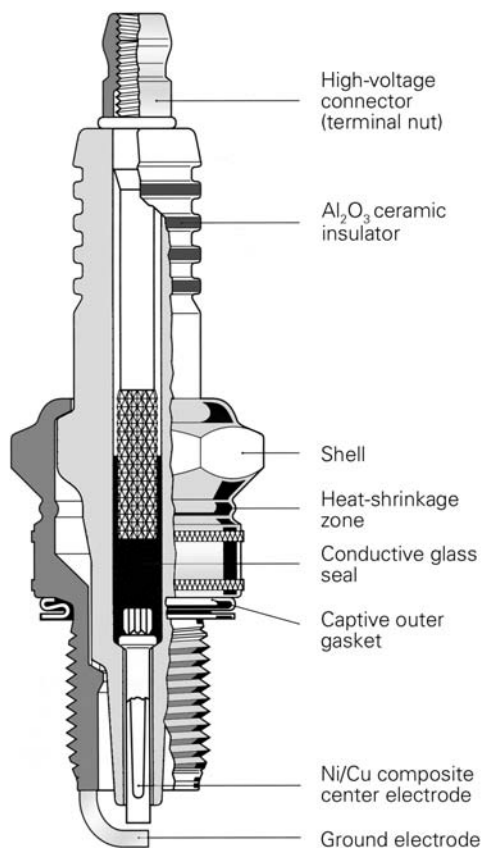
A **hot** spark plug is a one that transfers the heat from the combustion process slowly through the threads to the head and cooling system.

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 AESIS).

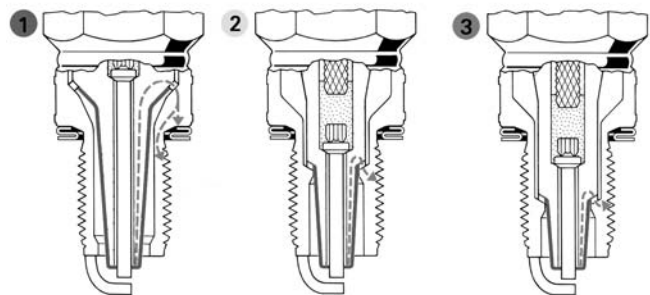
Note:

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.



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- 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.



— Heat-absorbing surface
--- Thermal conduction path

SSP 9410/17

Principles of engine operation

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.

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 has 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

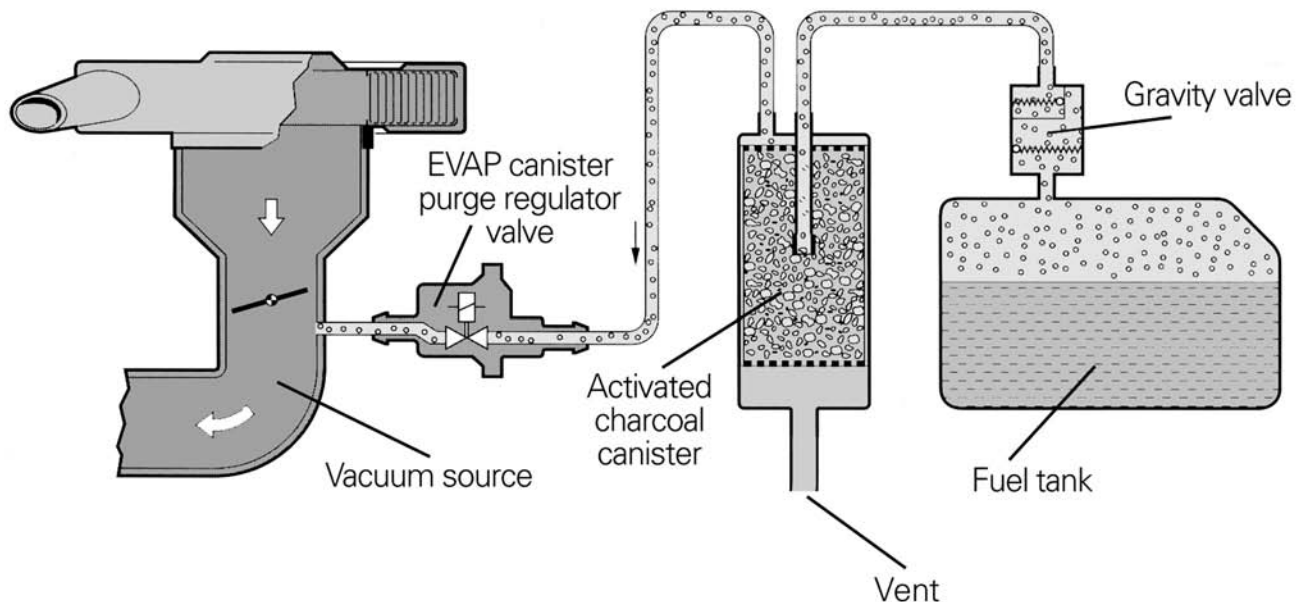
It was soon clear that a more advanced means of managing fuel, air and ignition was needed to meet the changing Federal and State emissions requirements and fuel economy standards. Excellent driveability, performance and economy had to be maintained, and at the same time ensuring low exhaust emissions.

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 941903, *EVAP Systems, Operation and Diagnosis*.



SSP 9410/122

Principles of engine operation

Three-way Catalytic Converter, overview

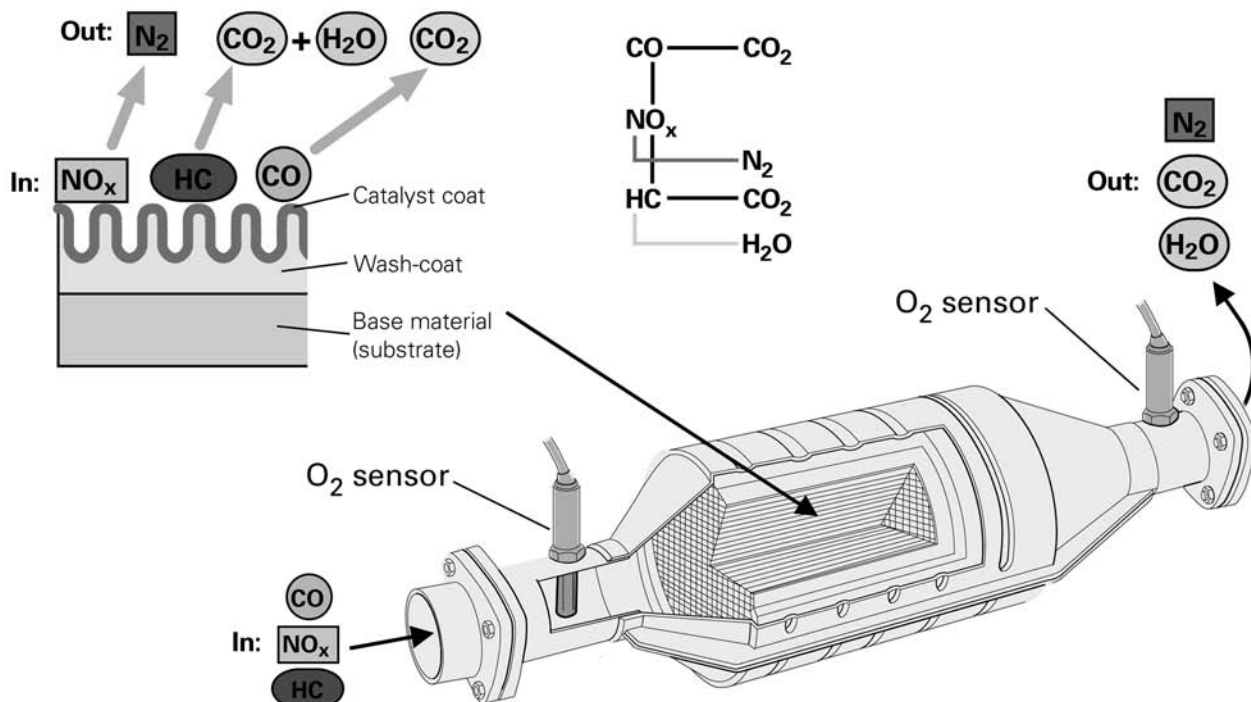
The catalytic converter is a major component in exhaust emission control "downstream" of the combustion process. Development and common usage of this device began with open-loop versions of carburetor and fuel injection systems in the 1970s. Closed loop engine management systems required by current legislation 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 noble metals 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 Audis 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.



Catalytic Converter Operation

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

- 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 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.

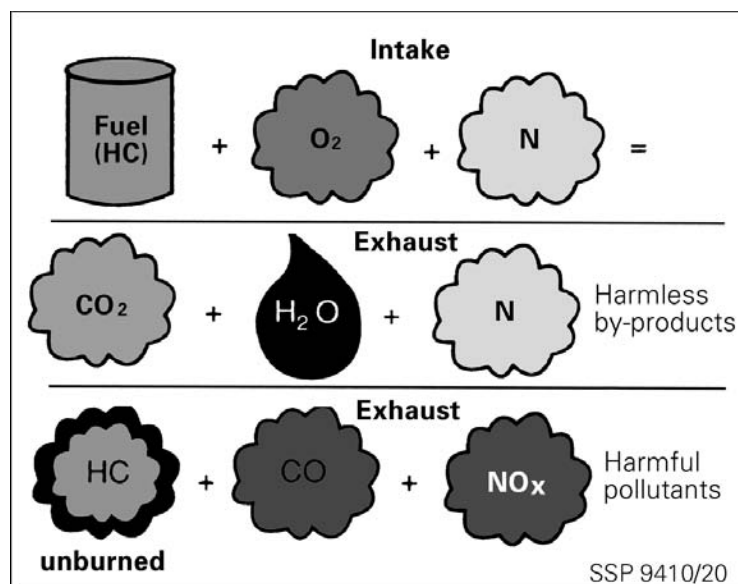
The output from a normally operating three-way catalytic converter consists primarily of:

- N_2 (nitrogen)
- CO_2 (carbon dioxide)
- H_2O (water)

The reduction process is most efficient in a low O_2 environment, and the oxidation process is most efficient in a high 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 (λ) must be at 0.99 or 1.00 for both reactions. This operating range is referred to as the lambda (λ) window.

The data required for this closed-loop control process is provided by the oxygen sensors (illustration 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

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 effects 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

Audi 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.

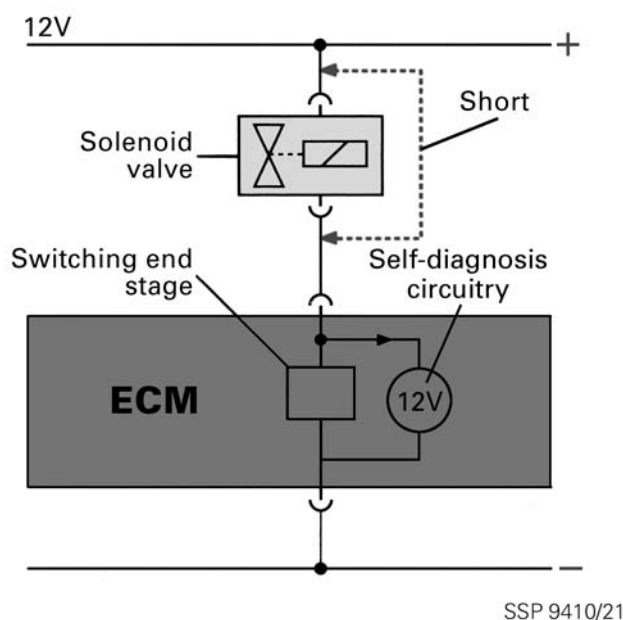
Normal operation of the component is checked by the self diagnosis circuitry in the ECM. The ECM monitors the voltage drop. This will change from 12V when the solenoid is in-active (open circuit voltage) to approximately 0V when the solenoid is active (voltage drops across the consumer). If self-diagnosis 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 the component, 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+)

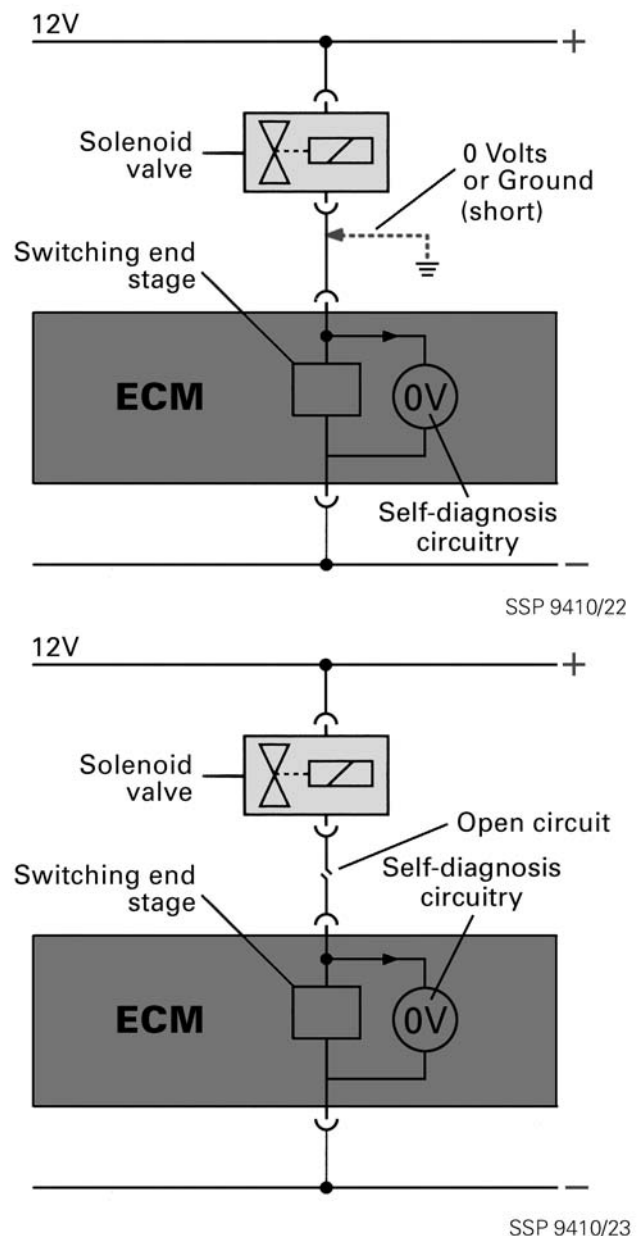


Open circuit/Short circuit to Ground

If an open or short circuit exists in the wiring harness, harness connector, or the component, 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



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.

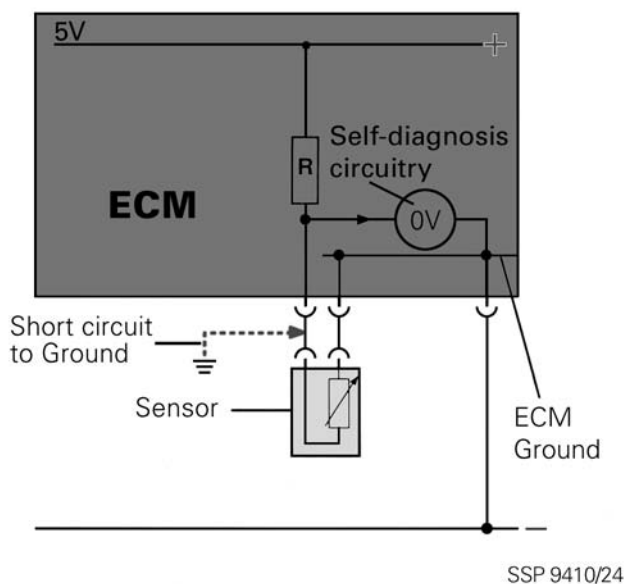
During normal operation the self diagnosis circuitry monitors the 5V reference and the voltage drop across the component. The ECM "watches" for a valid signal, which varies by component, but will not equal either 0 or 5 Volts. If Battery +, Ground or the 5V reference is seen by the ECM, an appropriate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

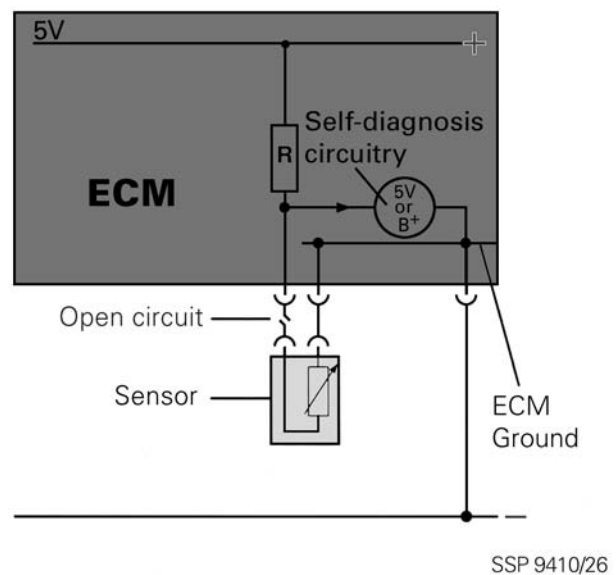
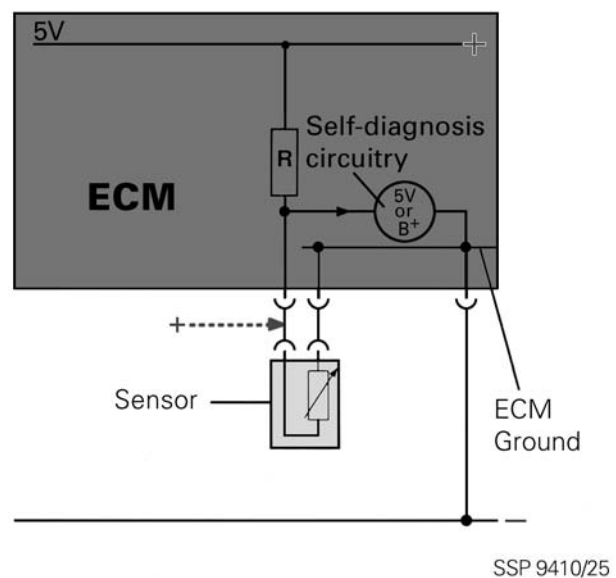


Open circuit/Short circuit to B+

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+



Principles of engine operation - Review

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 (λ) 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)

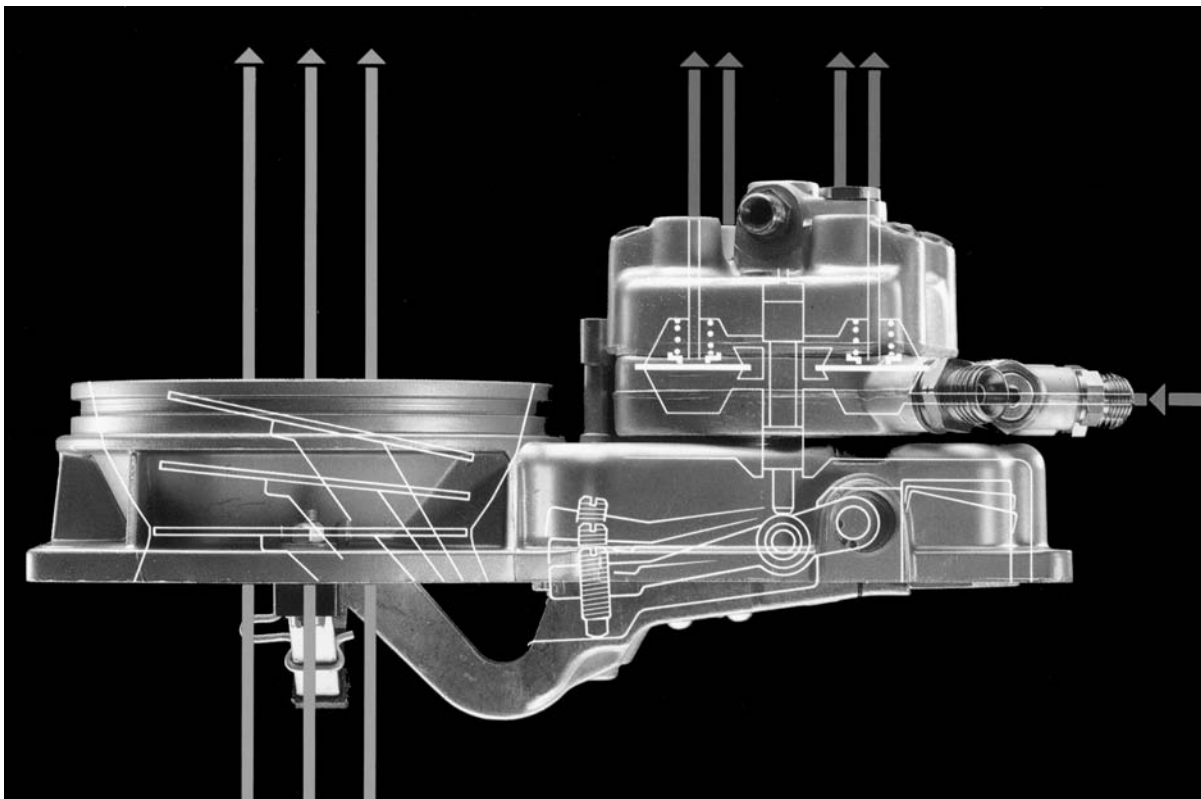
Continuous Injection Systems (CIS)

Continuous Injection System

In 1975, Audi introduced Bosch K-Jetronic™ fuel injection on the 100 LS model. This class of fuel injection system is characterized by the continuous flow of fuel from the fuel injectors and is more commonly known as CIS (Continuous Injection System).

Audi used several versions of this hydro-mechanical fuel system due to its efficient and consistent engine operation.

- **CIS:** Completely hydro-mechanical with the fuel pump relay being the only electronic component.
- **CIS-Lambda:** Similar in operation to CIS, but with an oxygen sensor providing feedback to an electronic control unit which continuously adjusts mixture.
- **CIS-E:** Electronic system with sensors providing engine operating data to an electronic control unit, and an oxygen sensor providing mixture feedback information. Idle speed is controlled electronically by a variable throttle bypass valve called an idle air control valve, or idle stabilizer.
- **CIS-E III:** An engine management system similar to CIS-E, but with electronic ignition and integrated knock regulation. Also features electronic fault recognition and memory.
- **CIS Turbo:** An engine management system combining the CIS lambda fuel system with electronic ignition and boost control. Later versions added knock sensors to the ignition system.
- **CIS-E Motronic:** An engine management system, similar to CIS-E III, but with adaptive mixture control.



Continuous Injection Systems (CIS)

CIS

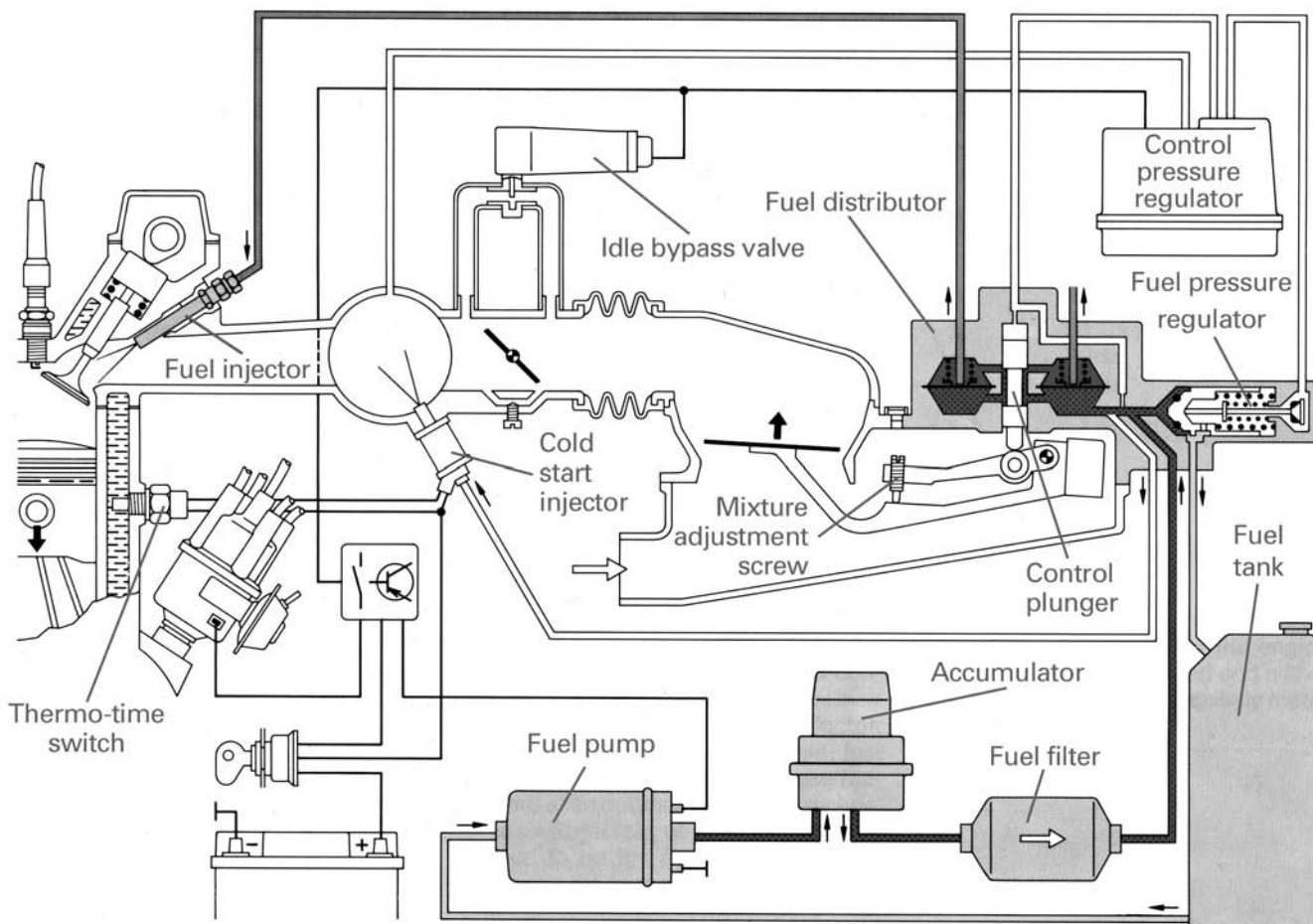
Continuous Injection System (CIS) operates by controlling fuel flow rates and variable pressures to the fuel injector. As the name implies, the fuel injectors are continuously injecting fuel. When the intake valve is closed, the fuel is stored in the intake port. Opening the valve allows the stored fuel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

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. Resistance is greater, resulting in a leaner fuel mixture.



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Continuous Injection Systems (CIS)

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 V also supplied by starter 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 approximately 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.

Since there are essentially no electronic controls to this system, there are no sensors or actuators.

Additional systems

Fuel is supplied to the CIS system by an externally mounted fuel pump with an accumulator and filter on the outlet side. Pressure is maintained by a fuel pressure regulating relief valve integral with the fuel distributor.

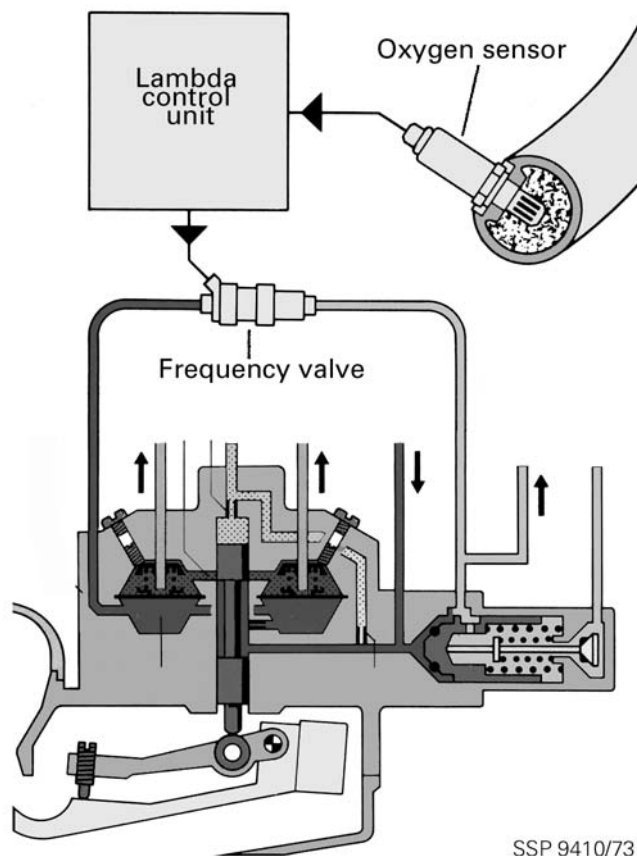
Continuous Injection Systems (CIS)

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 instantaneous 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 fuel return line. When lower chamber pressure drops, the diaphragm flexes downward, opening a larger fuel orifice.



Continuous Injection Systems (CIS)

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.

CIS with Lambda control was also available with a turbocharger on early 5000 models. The turbocharger added additional air to the engine which improved performance by making use of heat that would be otherwise wasted. A mechanical wastegate limited boost pressure, but fuel control remained essentially the same.

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

Inputs/Sensors

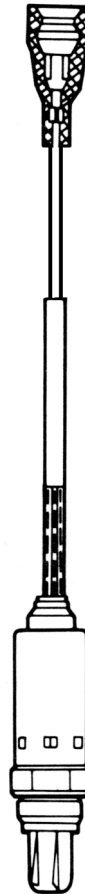
The addition of an Oxygen sensor control unit required a minimum number of input signals including:

- Oxygen sensor thermo-switch (to switch off oxygen sensor control on a cold engine)
- Oxygen sensor
- Full throttle enrichment switch

Outputs/Actuators

Only one output signal is generated:

- Oxygen sensor frequency valve



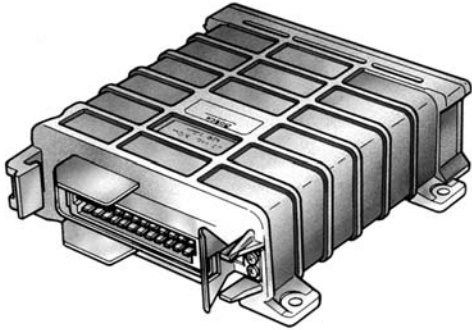
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Continuous Injection Systems (CIS)

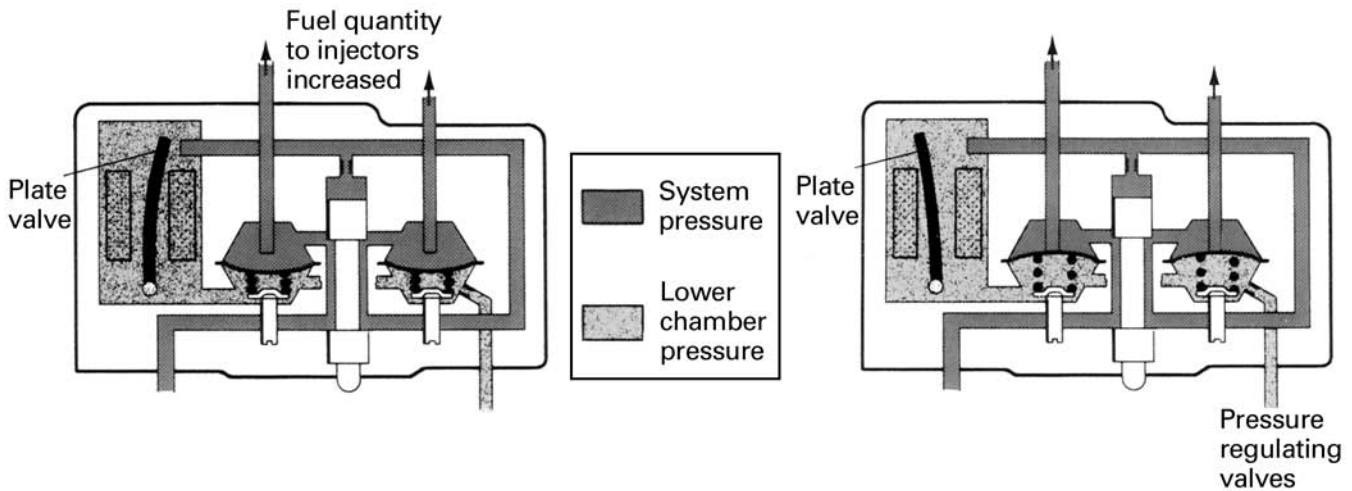
CIS-E

Beginning in 1984, Audi expanded the capabilities of the CIS fuel injection system. New features include:

- Control pressure regulator and frequency valve replaced by an Differential Pressure Regulator (DPR).
- 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).
- Fuel system pressure now regulated by an external fuel pressure regulator.



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Continuous Injection Systems (CIS)

The major difference between CIS-Lambda and CIS-E is the replacement of the control pressure regulator and frequency valve with an electro-hydraulic actuator. This actuator is more commonly called a Differential Pressure Regulator (DPR).

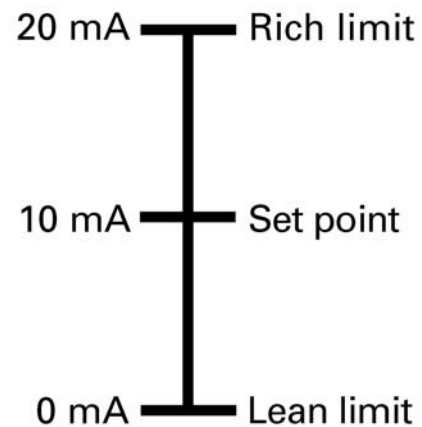
The differential pressure regulator receives a varying current signal from the CIS-E control unit. This energizes an electro-magnet, which deflects a valve plate to create a difference in the pressures between the upper and the lower chambers of the fuel distributor. As current is increased, the plate valves deflects more which restricts fuel flow to the upper chamber of the fuel distributor.

The reduction in fuel pressure in the lower chamber causes the pressure regulating valves at the fuel injector outlets to open further, increasing the quantity of fuel delivered to the injectors. This increases fuel pressure to the injectors and allows greater fuel flow for a given amount of sensor plate travel.

The operating range of the differential pressure regulator during oxygen sensor control is between 0 mA and +20 mA, allowing for more accurate control of the fuel trim, as well as decreased maintenance.

Continuous, variable control of idle speed is built into the CIS-E fuel injection system. This is accomplished by regulating the flow of air around the throttle valve by an electronically controlled bypass valve called an idle air control valve or idle stabilizer.

Compensation is made for differing engine load conditions such as those encountered with a cold engine or when the air conditioning is switched on. The idle air control valve replaces the function of the auxiliary air regulator.



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Continuous Injection Systems (CIS)

Inputs/Sensors

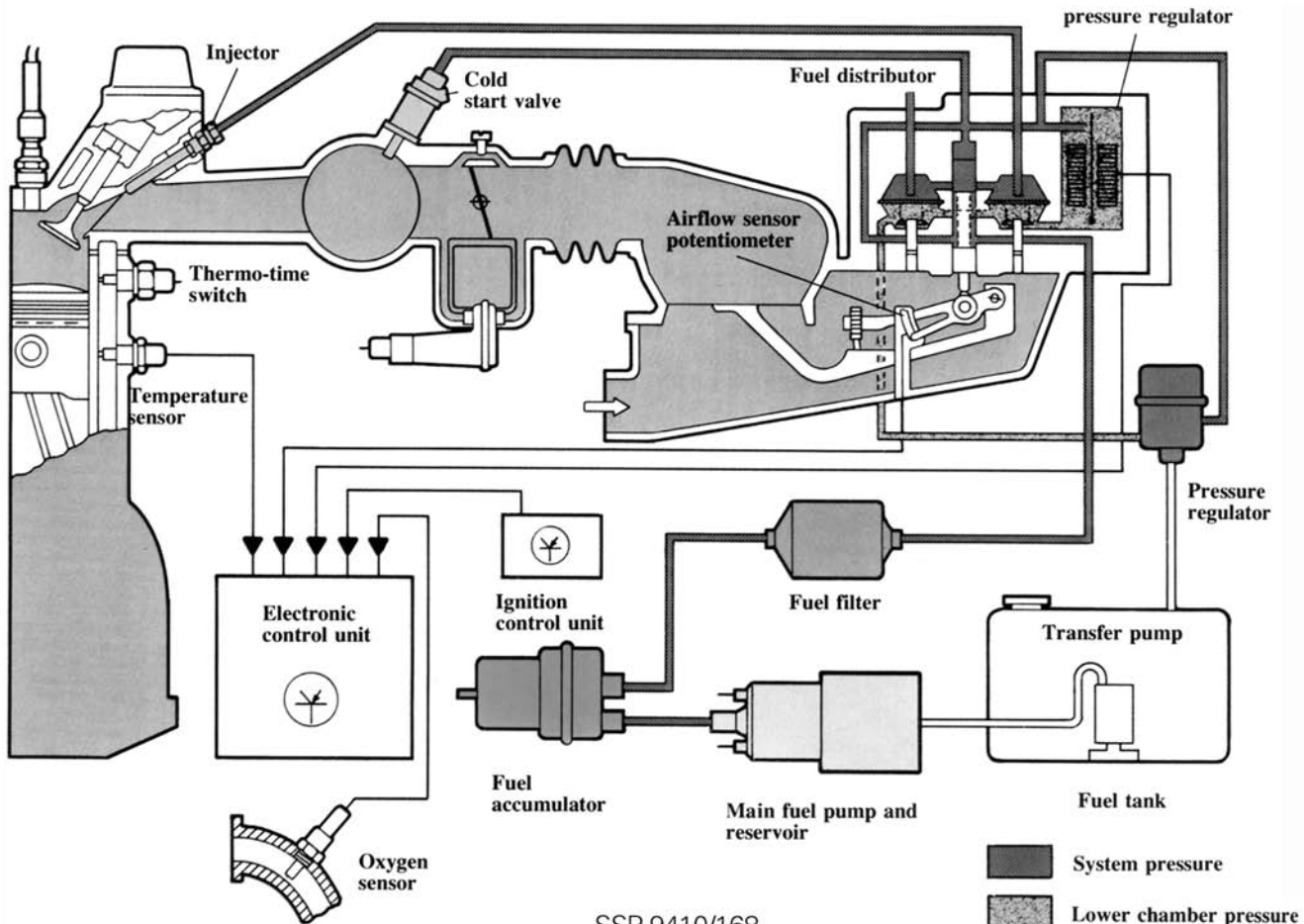
CIS-E fuel injection control units require several sensor inputs to calculate the current value required by the differential pressure regulator. These signals include:

- Engine coolant temperature sensor
- Airflow sensor potentiometer
- Oxygen sensor
- Engine RPM signal from ignition control unit
- Idle switch
- Full throttle enrichment switch

Outputs/Actuators

Output signals generated are:

- Differential pressure regulator
- Idle stabilizer



Continuous Injection Systems (CIS)

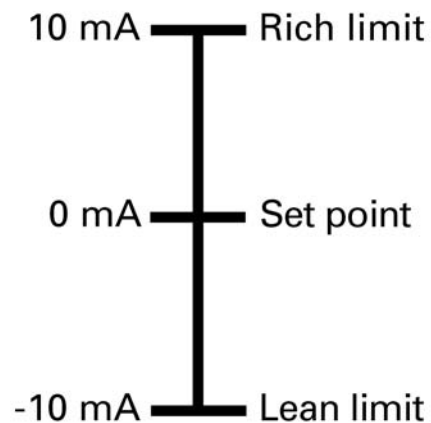
CIS-E III

Model year 1987 brought the next changes in CIS-based fuel injection systems.

CIS-E III added a separate knock sensor control unit with On Board Diagnosis through blink codes displayed in the instrument cluster.

The operating range of the differential pressure regulator during oxygen sensor control has been modified. The new range is between -10 mA and +10 mA with an adjusting point of 0 mA. This allows better engine operation in the event of an electrical failure and minimal ECM correction to a properly adjusted engine.

The addition of knock control allows the engine to operate at a higher level of efficiency. This is accomplished by optimizing the combustion process according to fuel grade.



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Inputs/Sensors

CIS-E III fuel injection and ignition control units require several sensor inputs to calculate the values required for engine operation. These inputs include signals from:

- Engine coolant temperature sensor
- Airflow sensor potentiometer
- Oxygen sensor
- Hall sender in the ignition distributor
- Knock sensor
- Altitude sensor
- Idle and full throttle switches

Continuous Injection Systems (CIS)

Outputs/Actuators

Output signals generated to operate the engine include:

- Differential pressure regulator signal
- Idle stabilizer signal
- Carbon canister shut-off valve signal
- Cold start valve signal
- Ignition signal to the power output stage
- Malfunction indicator light

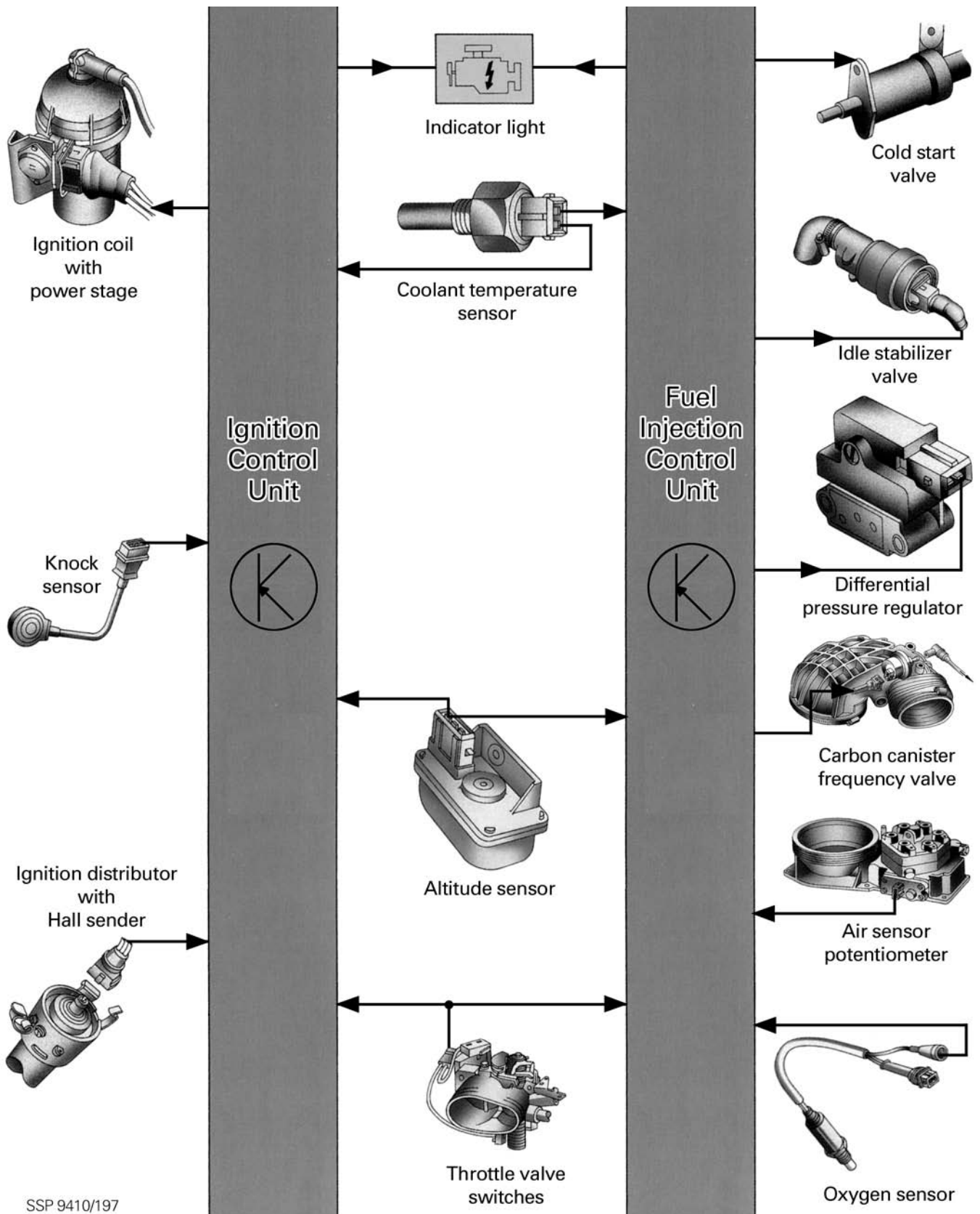
On Board Fault Memory

CIS-E III engine management systems have the ability to store information concerning certain component malfunctions in memory. Faults are stored in either the ignition control module or the fuel injection control module. Any malfunctions recorded will be erased when the ignition is switched off.

The system can recognize approximately 17 different 4-digit fault codes, and the fault memory can be accessed using scan tool VAG 1551. Model year 1988 vehicles require the use of adaptor VAG 1550/2 with system access through a connection to the fuel pump relay. Later vehicles access this data through the data link connector (DLC).

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

Continuous Injection Systems (CIS)



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Continuous Injection Systems (CIS)

CIS Turbo

1983 was a landmark year for Audi with the introduction of its first engine management system. CIS Turbo integrated both fuel injection and ignition timing into one control unit.

The early fuel/timing control unit, commonly referred to as the MAC-02, used inputs from the following sensors for engine control:

- Intake air temperature
- Engine coolant temperature
- Boost pressure transducer (integral with the fuel/timing control unit)
- Engine speed sensor
- Crankshaft position (reference) sensor
- Camshaft position (Hall sender in distributor)
- Oxygen sensor
- Idle/full throttle switches

The signals generated to operate the engine included outputs to the following:

- Ignition control unit
- Frequency valve
- Fuel pump relay

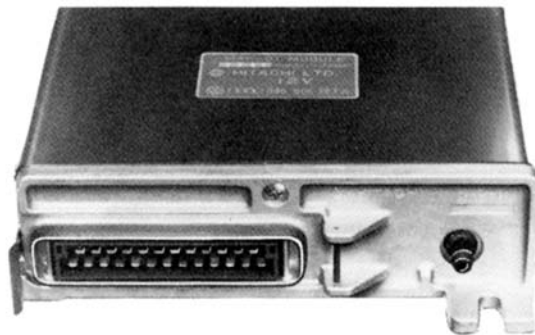
Ignition timing was controlled by a calculation map derived from engine RPM, boost pressure, and intake air temperature.

In 1986, several modifications were made with the addition of a new control unit known as the MAC-07. A new single knock sensor allowed optimized ignition timing, and minimized the possibility of engine knock under boost.

A wastegate frequency valve was also included giving more accurate control over total boost pressure. This component functioned at the command of the ECM by supplying boost pressure to the upper chamber of the wastegate. The pressure acting on the wastegate diaphragm controlled wastegate operation.

The final change to CIS Turbo was mid year 1989. The newest control unit, MAC-11, added a second knock sensor for even more accurate control of ignition timing.

On board diagnostics for this system were limited. Several fault indicators can be read through tachometer needle position on the instrument cluster on some models only.



Continuous Injection Systems (CIS)

CIS-E Motronic

With the introduction of the 4-cylinder Audi 80 and 90 models in the North American market, CIS fuel injection systems evolved into CIS-E Motronic engine management.

This system and its individual components are very similar to CIS-E III in operation, but combine fuel injection control and ignition control into a single electronic Engine Control Module (ECM).

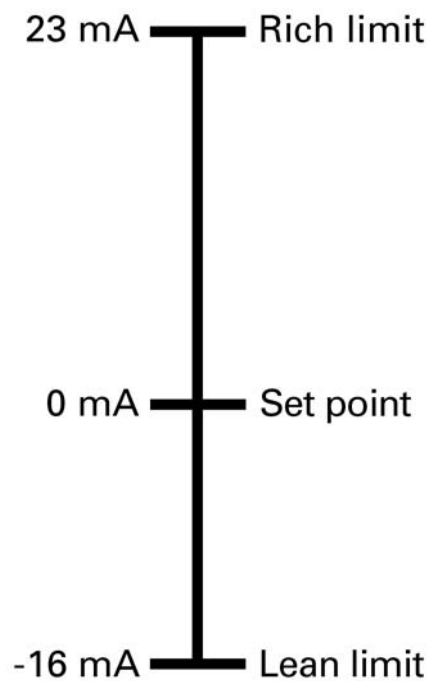
Located behind the air conditioner evaporator assembly, the 35-pin CIS-E Motronic ECM features encompass:

- Fuel injection control
- Ignition control by ECM map
- Individual cylinder selective knock regulation
- Oxygen sensor regulation with adaptive learning
- Idle speed control
- Fuel tank ventilation control
- Permanent fault memory via blink code

The operating range of the differential pressure regulator during oxygen sensor control has been expanded due to the adaptive learning capability (see Glossary). The rich adaptive limit is +23 mA, and the lean limit is -16 mA.

This new capability allows the engine management system to compensate for changes in the engine's operating conditions such as altitude changes, intake air leaks, or other deviations from normal running.

The adaptive learning capability necessitates new procedures when engine settings need to be adjusted, since engine idle speed is pre-programmed into the ECM and cannot be adjusted.



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Continuous Injection Systems (CIS)

Inputs/Sensors

CIS-E Motronic engine management receives operating inputs from the following sensors:

- Ignition distributor with Hall sender (engine RPM)
- Air sensor potentiometer (engine load)
- Idle and full throttle switches (throttle position)
- Coolant temperature
- Heated oxygen sensor
- Knock sensor

Additional input is received from the air conditioning system.

Actuators/Outputs

CIS-E Motronic engine management systems generate operating outputs to operate the following actuators:

- Differential pressure regulator
- Ignition coil power output stage
- Cold start valve
- Idle stabilizer
- Carbon canister frequency valve
- Carbon canister shut-off valve

An signal is also sent to the instrument cluster for tachometer, dynamic oil pressure, malfunction indicator light, and the Auto-Chek system.

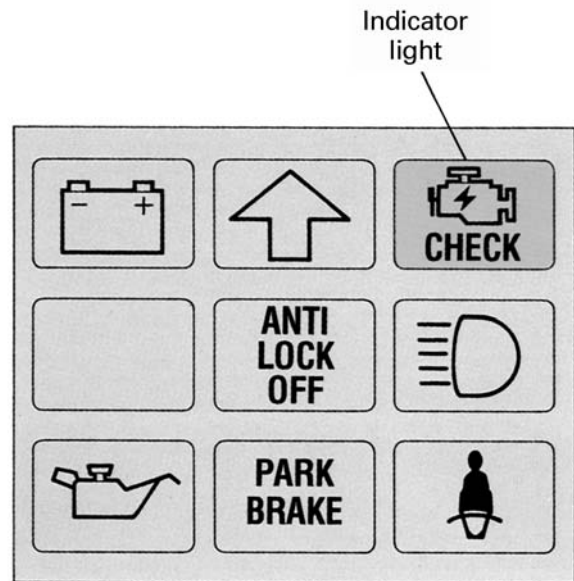
Continuous Injection Systems (CIS)

On Board Fault Memory

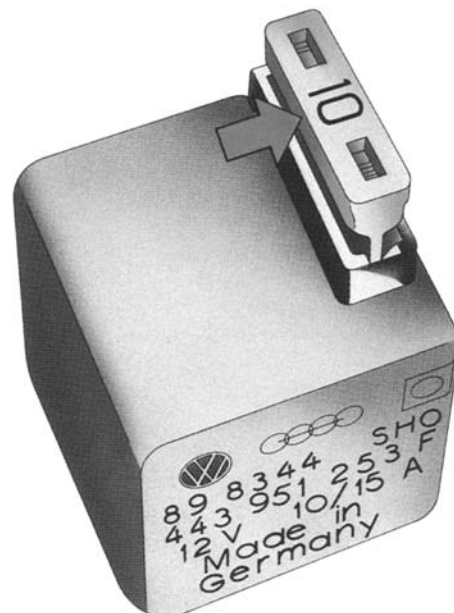
Permanent fault memory as applied to CIS-E Motronic means that any malfunctions recorded will be retained when the ignition is switched off. Checking and clearing the fault memory is generally done during maintenance, or if the malfunction indicator in the instrument cluster is illuminated.

The system can recognize up to 15 different 4-digit fault codes. The fault memory can be accessed using scan tool VAG 1551. Model year 1988 vehicles require the use of adaptor VAG 1550/2 with system access through a connection to the fuel pump relay. Later vehicles access this data through the data link connected (DLC).

Sensor inputs, actuator signals and other output signals of the 1988 - 1992 Audi 80, 2.0 liter, engine code 3A are shown in the illustration on the following page.

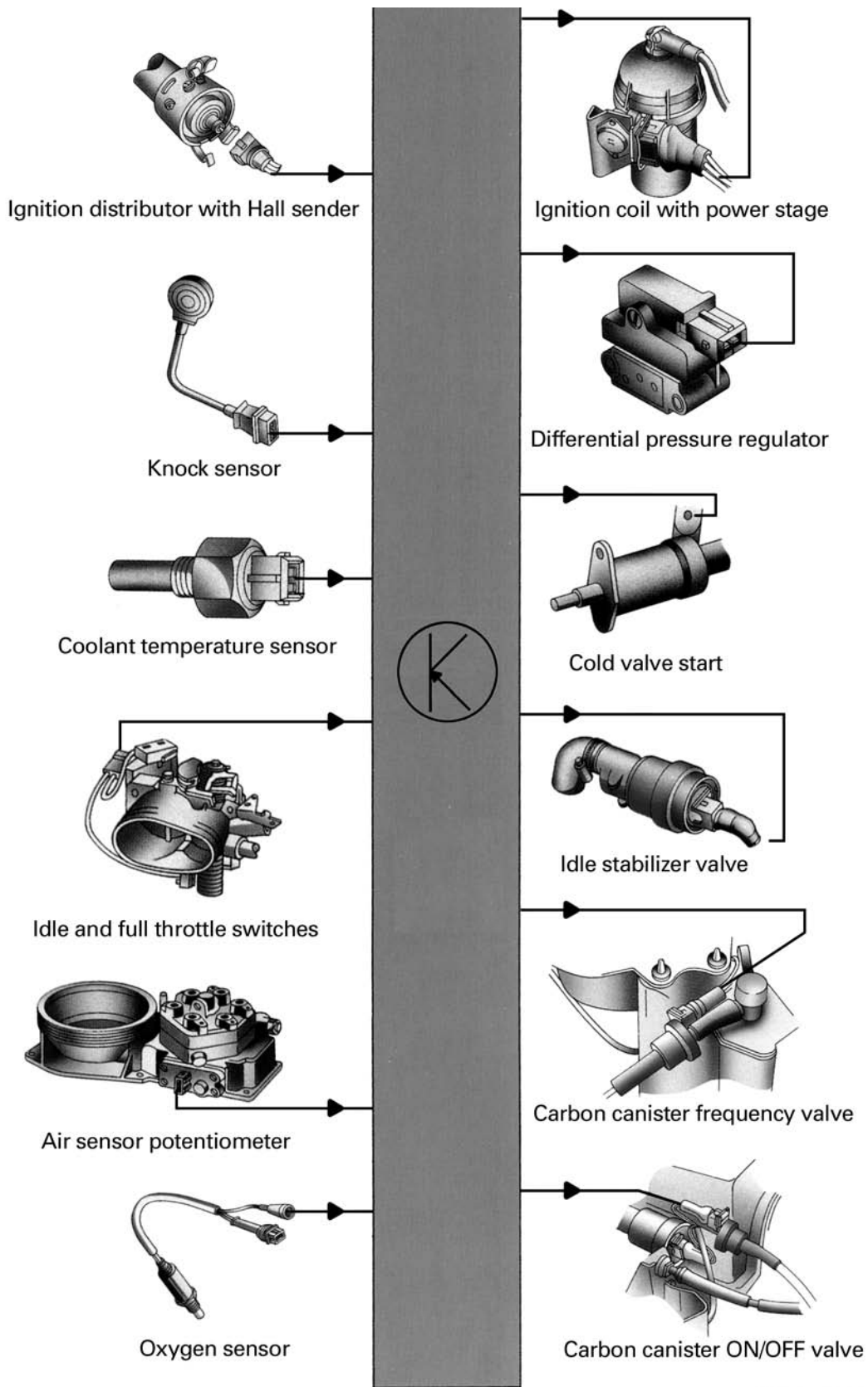


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Continuous Injection Systems (CIS)



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Motronic M2.3.2 Overview

System description

Audi first introduced Motronic Engine Management on the 1990 V8 Quattro with the all-aluminum 3.6 liter engine. For the 1993 model year, both the 20 Valve 5-cylinder 2.22 liter engine and the 4.2 liter V8 engine were equipped with Motronic M2.3.2.

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.



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Motronic M2.3.2 Overview

Functional overview

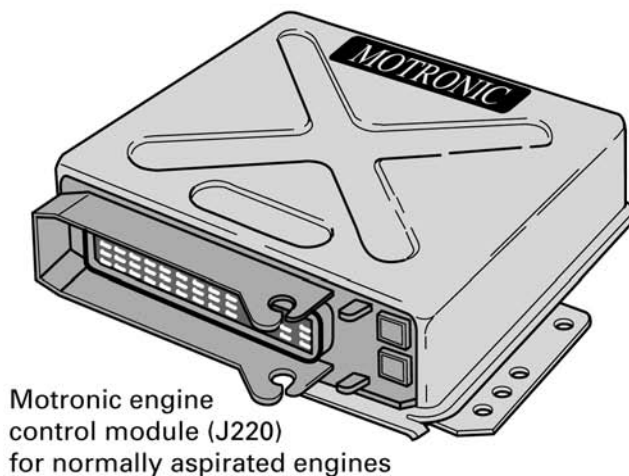
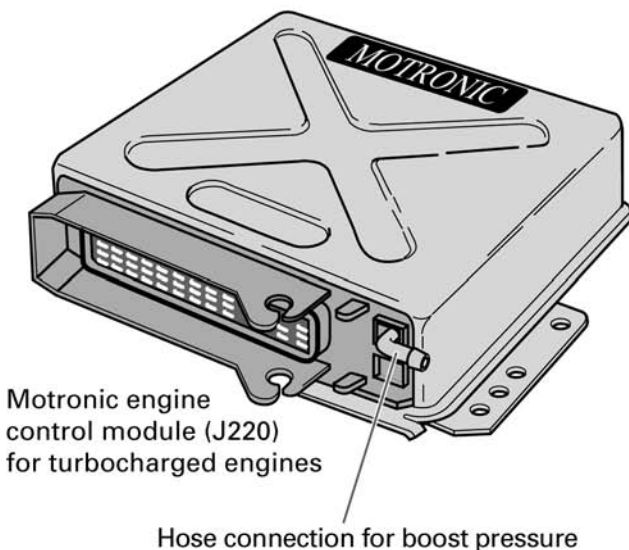
Motronic M2.3.2 uses engine speed and load as its primary inputs. An inductive sensor mounted on the cylinder block measures crankshaft speed at the flywheel, and provides the engine speed signal. A second induction sensor (mounted near the first) signals crankshaft position which provides a reference point.

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.

Engine load information is received from the Mass Air Flow (MAF) sensor G70, which has no moving parts.

All Audi engine management systems with oxygen sensor(s) 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 opening time or 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).

Motronic M2.3.2 engine management takes 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).



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Motronic M2.3.2 Overview

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).

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 signals the ECM to:

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

Motronic engine management systems consist of, and perform the following functions:

Sequential Fuel Injection

- Fuel injection via map control
- Starting enrichment
- Controlled ignition system
- After start enrichment
- Acceleration enrichment
- Fuel deceleration shut-off
- Maximum engine speed limitation
- Oxygen sensor control
- Vehicle speed limitation (130 m.p.h.)

Ignition timing via map control

- Dwell angle control
- Temperature correction
- Starting control
- Digital idle stabilization
- Selective cylinder knock control

Idle Air Control (IAC)

- Idle air volume via Map control
- Start control
- Correction for A/C switched on
- Correction for transmission in gear

Exhaust Gas Recirculation (EGR)

- EGR via map control
- On Board Diagnostic (California only)

Fuel Tank Ventilation

- Fuel tank ventilation via map control

Advantages of adaptive learning include:

- optimal fuel economy and driveability
- reduced emissions
- reduced maintenance
- Improved driveability

Note:

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

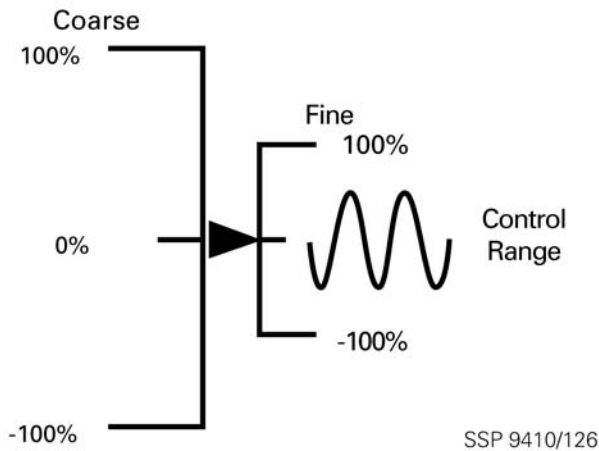
- *Exhaust system (allows outside air to mix with exhaust gases and affect oxygen sensor readings)*
- *Engine sealing (oil leaks can create false air leaks when the engine is running, causing un-metered air to enter the intake manifold)*
- *False air leaks (can include Idle Air Control (IAC) valve, or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

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

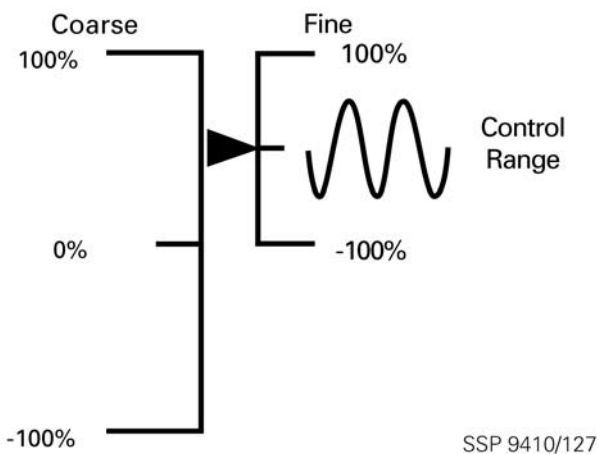
Always check the basics first!

Motronic M2.3.2 Overview

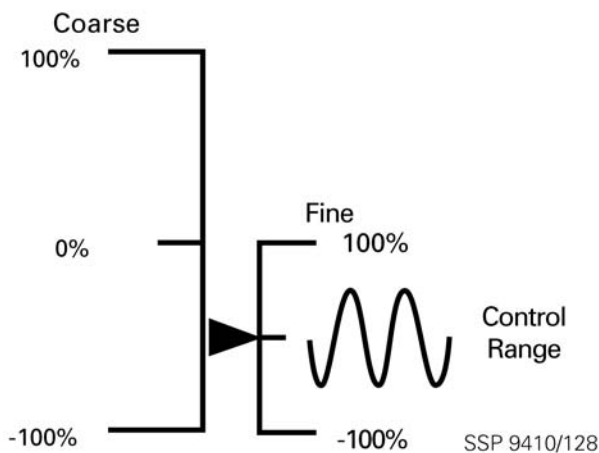
System Adaptation - Balanced



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, for example.

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 - 20 Valve Turbo Motronic M2.3.2

The 55-pin ECM used on 20-valve turbo M2.3.2 equipped vehicles receives signals from several input sources. These include the following:

- Engine Speed (RPM) sensor G28
- Crankshaft Position (CKP) sensor G4
- Camshaft Position (CMP) sensor G40
- Mass Air Flow (MAF) sensor G70
- Engine Coolant Temperature (ECT) sensor G62
- Intake Air Temperature (IAT) sensor G42
- Heated Oxygen Sensor (HO2S) G39
- Throttle Position (TP) sensor G69
- Closed Throttle Position (CTP) switch F60
- Knock Sensor(s) (KS) G61/G66
- Barometric Pressure (BARO) Sensor F96
- Manifold Absolute Pressure (MAP) Sensor G71 (component of Motronic ECM)

Additional signals used as inputs include:

- Air conditioner (compressor and/or system on)
- Battery voltage
- Speedometer Vehicle Speed Sensor (VSS)
- Electronic Engine Coolant Temperature (ECT) Thermal Switch F76

ECM output to actuators controlling engine operation include:

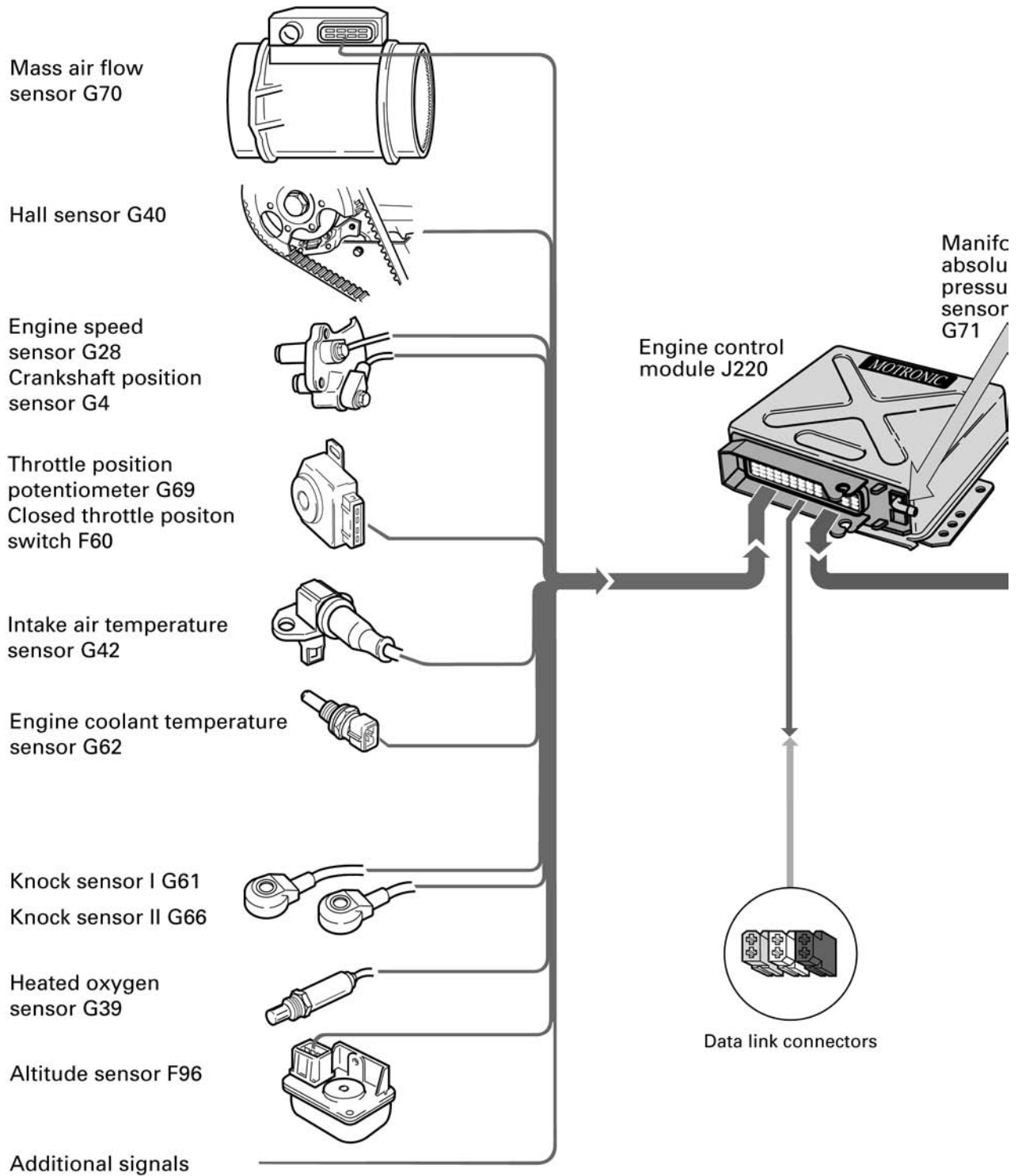
- Fuel injectors N30-N33, N83
- Idle Air Control (IAC) valve N71
- Ignition Coil Power Output Stages N122, N192
- Fuel Pump (FP) relay J17
- Evaporative Emissions (EVAP) Canister Purge Regulator Valve N80
- Wastegate Bypass Regulator Valve N75

Several other systems require input from the Motronic M2.3.2 system, or provide input to alter the engine management.

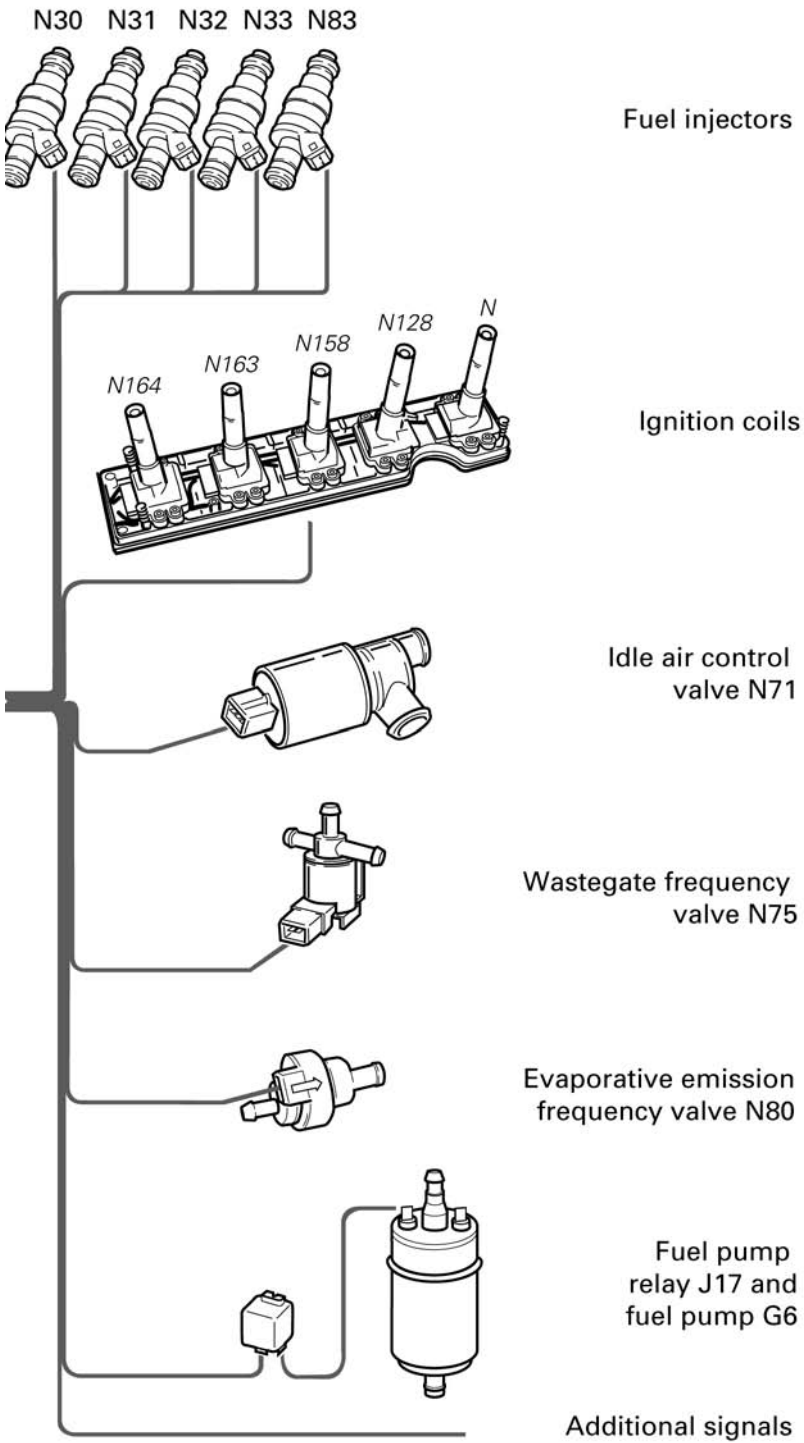
Sensor inputs, other input signals, actuator signals and other output signals on the 20 valve 2.22 liter turbo engine are shown in the illustration on the following pages.

Motronic M2.3.2 Overview

20 V 2.22 liter Turbo



Motronic M2.3.2 Overview



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Motronic M2.3.2 Overview

Notes:

Inputs/Outputs - 4.2 Liter V8 Motronic M2.3.2

The 55-pin ECM used on 4.2 Liter V8 M2.3.2 equipped vehicles receives signals from several input sources. These include the following:

- Engine Speed (RPM) sensor G28
- Crankshaft Position (CKP) sensor G4
- Camshaft Position (CMP) sensor G40
- Mass Air Flow (MAF) sensor G70
- Engine Coolant Temperature (ECT) sensor G62
- Intake Air Temperature (IAT) sensor G42
- Heated Oxygen Sensor (HO2S) G39
- Throttle Position (TP) sensor G69
- Closed Throttle Position (CTP) switch F60
- 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)
- Transmission Control Module (TCM) J217

ECM output to actuators controlling engine operation include:

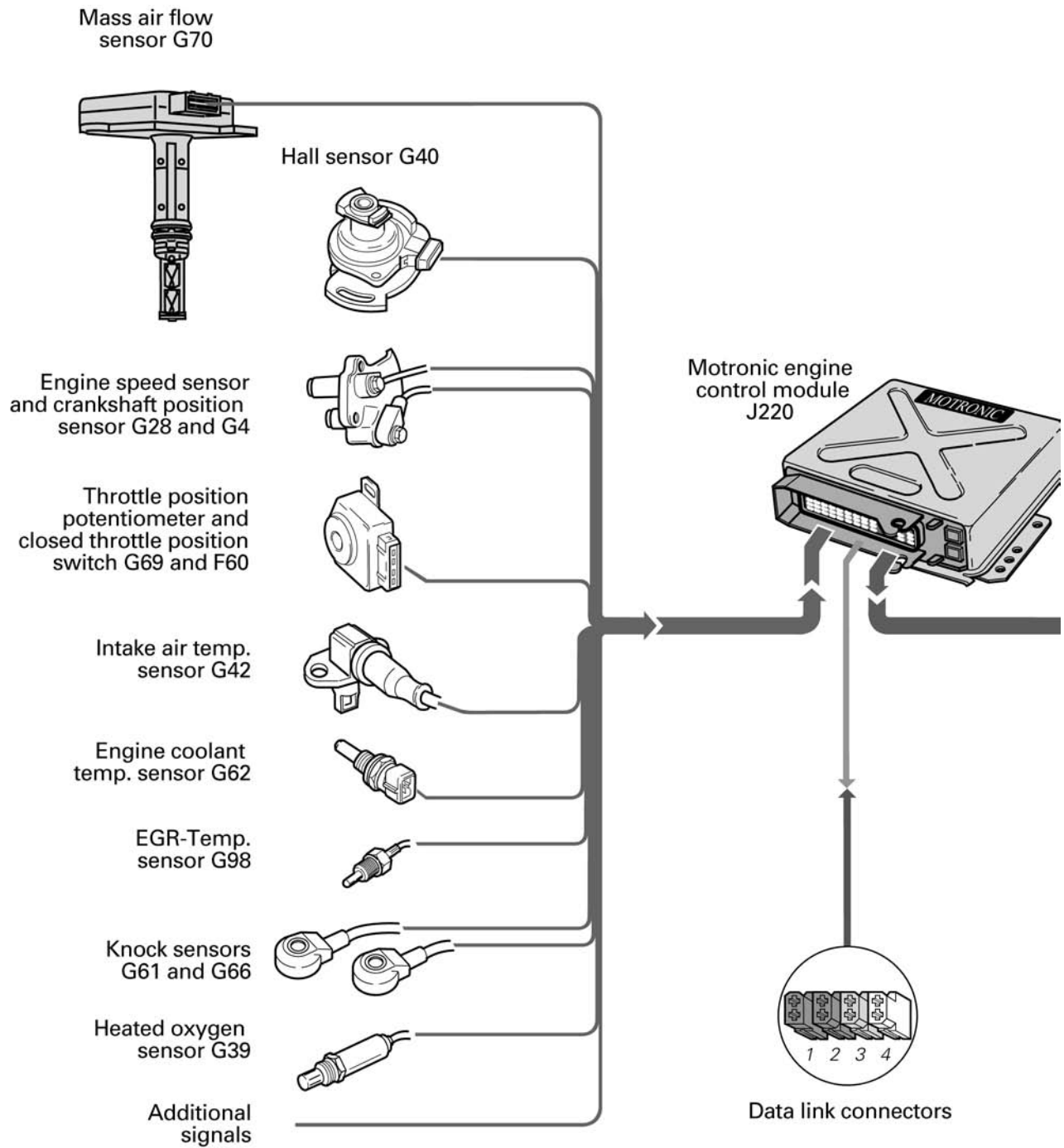
- Fuel injectors N30-N33, N83-N86
- Idle Air Control (IAC) valve N71
- Ignition Coil 1 with Power Output Stage N70
- Ignition Coil 2 with Power Output Stage N127
- Fuel Pump (FP) relay J17
- Evaporative Emissions (EVAP) Canister Purge Regulator Valve N80
- Heated Oxygen sensor (HO2S) control module J208
- EGR vacuum regulator solenoid valve N18

Several other systems require input from the Motronic M2.3.2 system, or provide input to alter the engine management.

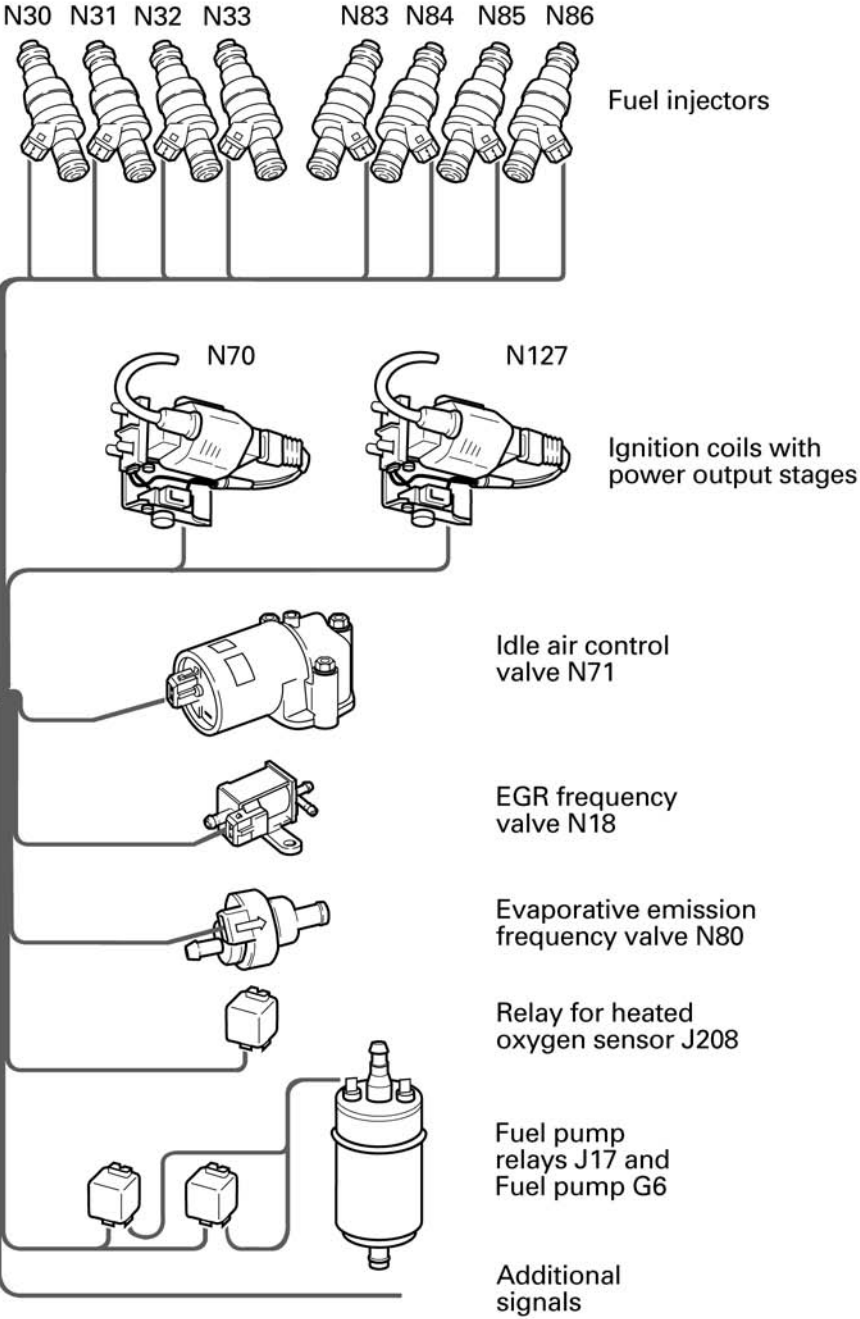
Sensor inputs, other input signals, actuator signals and other output signals on the 4.2 liter V8 are shown in the illustration on the following pages.

Motronic M2.3.2 Overview

4.2 liter V8



Motronic M2.3.2 Overview



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Motronic M2.3.2 Overview

On Board Diagnostics

Motronic M2.3.2 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

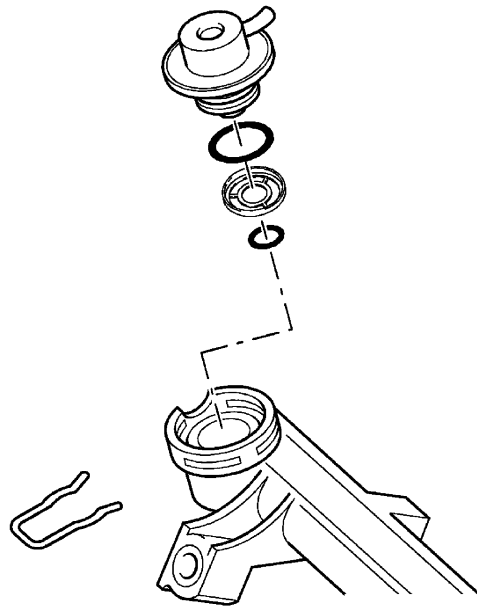
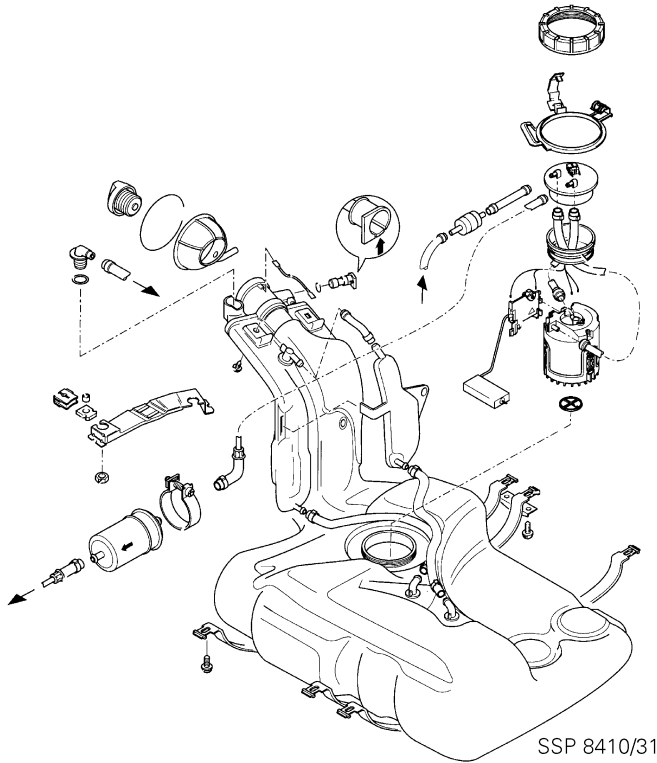
Rapid data supported functions include:

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

Motronic M2.3.2 Component Summary

Motronic M2.3.2 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.

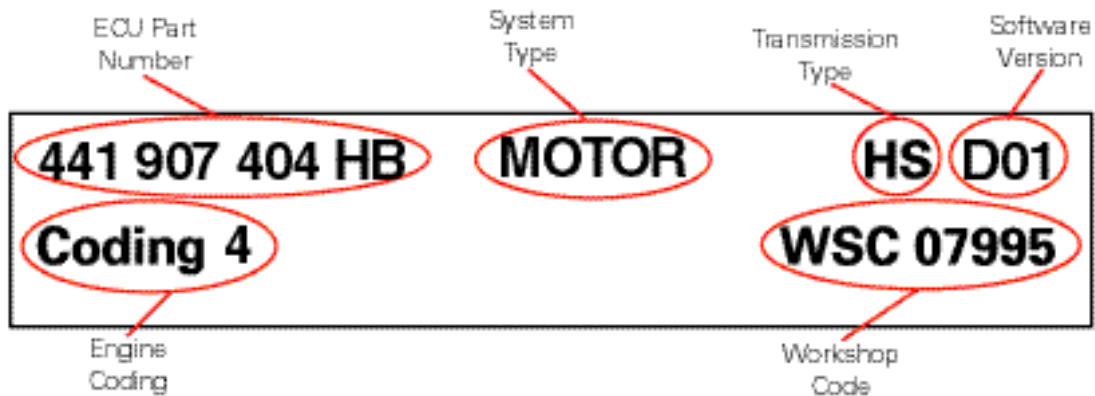
Motronic M2.3.2 Component Summary

Engine Control Module (ECM) J220

The 55-pin ECM must be supplied with the appropriate power sources and Grounds to function properly. Additionally, the ECM is coded with a vehicle speed limiter function.

If a new ECM is installed, the ECM must be coded. This is accomplished using a jumper harness connector which completes a Ground circuit in the ECM.

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.



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Motronic M2.3.2 Component Summary

Input sensors

Motronic engine management systems rely on 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

The **hot-wire 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.

- Operation:

Air flows past the hot wire 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.

Note:

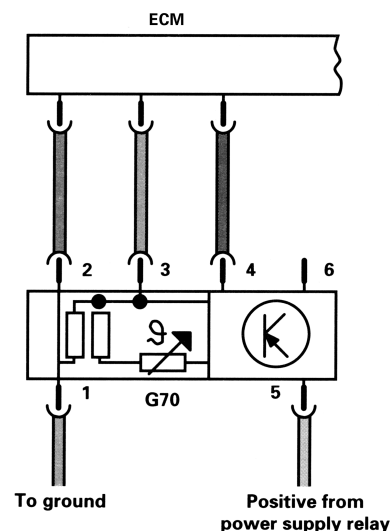
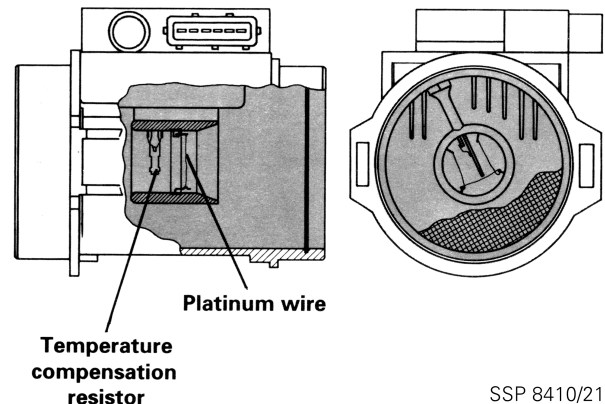
Wait 20 seconds after engine shutdown before removing connector from G70.

- 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.

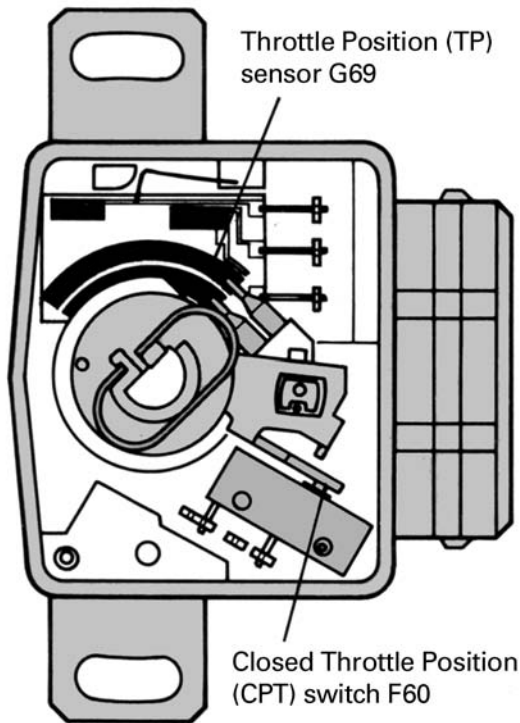
- On Board Diagnostic (OBD):

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



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Motronic M2.3.2 Component Summary



Throttle Position (TP) sensor G69, Closed Throttle Position (CTP) Switch F60

The throttle position sensor G69 is a potentiometer connected to the throttle valve shaft. The signal generated is used by the ECM to determine driver input.

The closed throttle position switch F60 is integral with G69, and is used to determine throttle position and boost regulation (turbocharged engines).

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. F60 operates by completing a Ground circuit to the Motronic ECM.

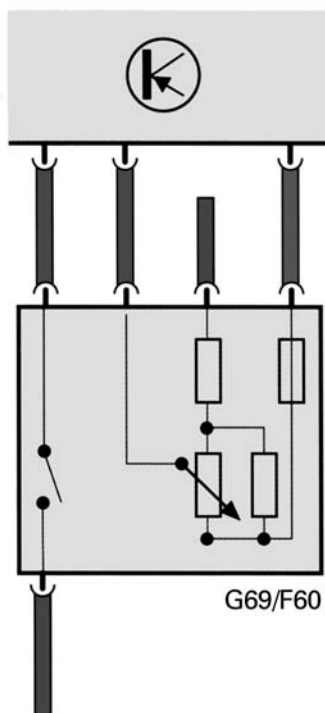
- Substitute function:

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.

Electrical Circuit



Motronic M2.3.2 Component Summary

Crankshaft Position (CKP) sensor G4

The Crankshaft Position (CKP) sensor is an **inductive pickup** (see Glossary). The sensor is located on the left side of the engine in the transmission bellhousing. The sensor is used to identify TDC number one cylinder.

A pin on the flywheel face (62° before TDC in the 20V turbo, 72° in the V8), is used as a reference point. The pin, along with the crankshaft sensor, generates one signal per crankshaft revolution.

The signals from the crankshaft sensor and the signal from the Camshaft Position (CMP) sensor G40 are used for authorization of sequential fuel injection and ignition timing.

- Substitute Function:

No substitute function for the crankshaft position sensor is available.

- On Board Diagnostic (OBD):

The Motronic ECM recognizes a missing signal after five seconds of cranking or engine operation, as well as Short to Battery + and Ground. Should the signal fail after the engine has been started, the engine will continue to run, based on the internally calculated cylinder signal after engine start.

If the Motronic ECM does not receive this signal, the engine will not start.

Motronic M2.3.2 Component Summary

Engine Speed (RPM) sensor G28

Engine speed is registered by a single sensor located on the transmission bellhousing. The sensor reads the teeth of the starter ring gear through a hole in the bell housing.

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:

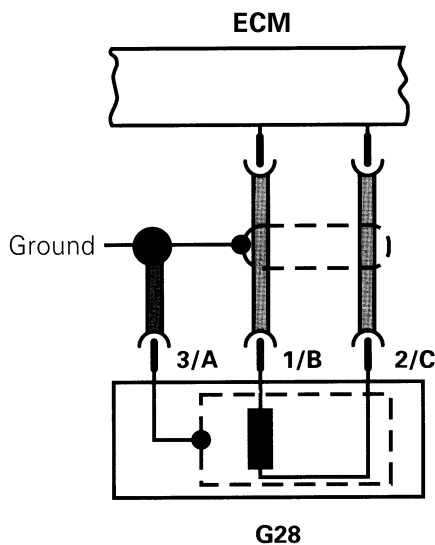
The Engine Speed (RPM) sensor G28 is an inductive sensor. The flywheel teeth cause an alternating current signal to be generated whose frequency varies with engine speed.

- 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 M2.3.2 Component Summary

Camshaft Position (CMP) sensor G40

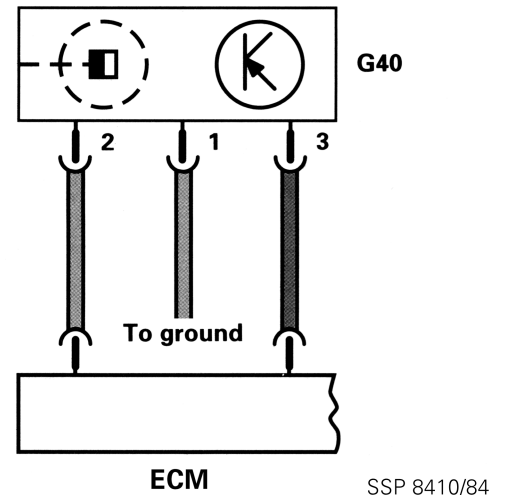
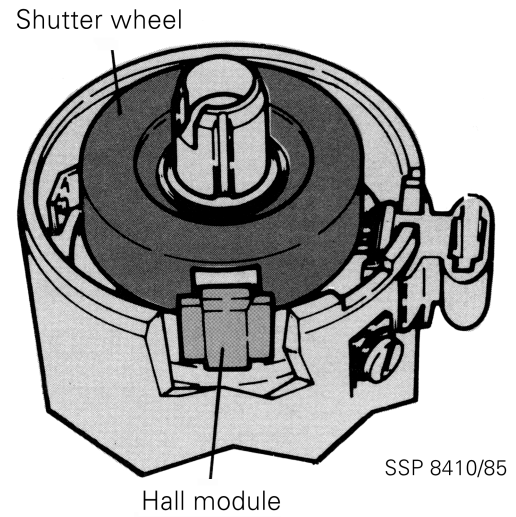
Two major types of camshaft position sensors are used on Audi Motronic engine management systems. The type is dependent upon whether or not the engine uses a distributor, or is distributor-less.

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.



Motronic M2.3.2 Component Summary

- 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.

Motronic M2.3.2 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.

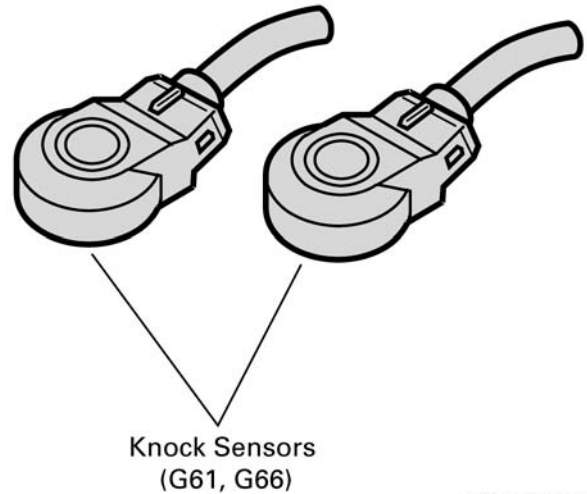
Dual knock sensors are used on the 5 cylinder engine, with sensor I responsible for cylinders 1 and 2, and sensor II responsible for cylinders 3, 4, and 5. Knock sensor I is mounted to the front of the cylinder block and knock sensor II is mounted to the rear.

Audi V8 engines also uses dual knock sensors, sensor 1 for cylinders 1 - 4 (bank 1), and sensor 2 for cylinders 5 - 8 (bank 2). The sensors are mounted on either side of the engine block below the exhaust manifolds.

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.



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Motronic M2.3.2 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:

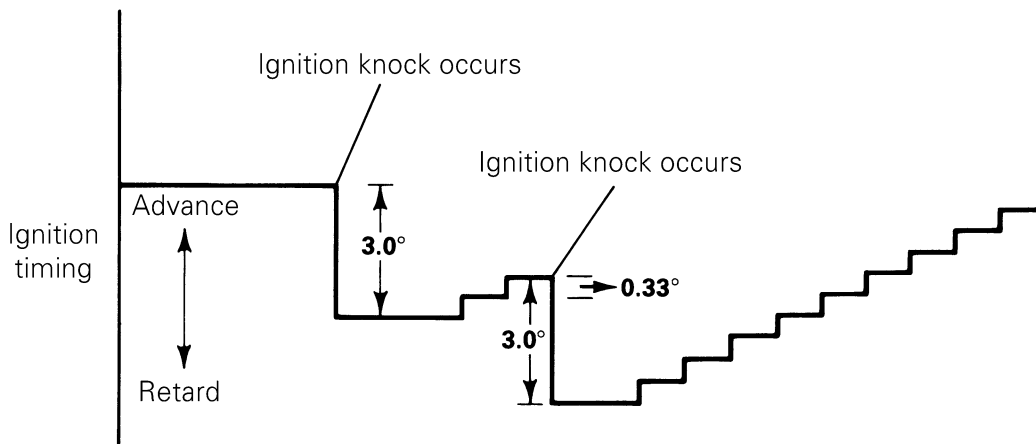
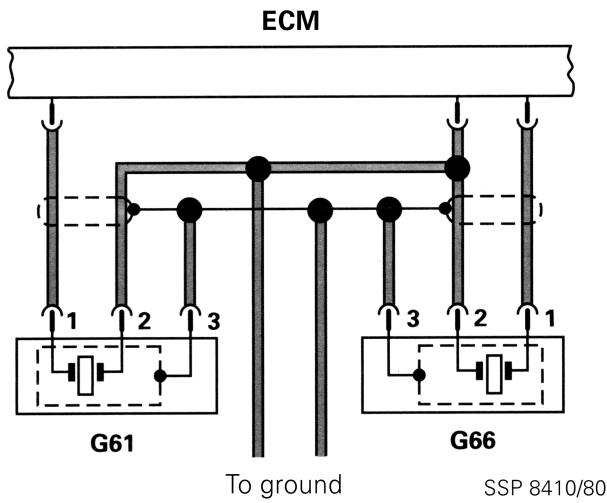
There is no substitute function. However, if a sensor fails, the timing of its assigned cylinders is retarded.

- 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.



Motronic M2.3.2 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.

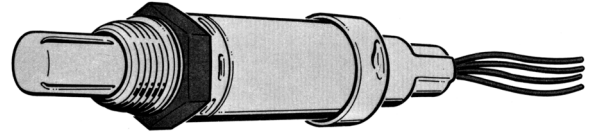
The difference in the amount of oxygen contacting the inner and the outer surfaces of the oxygen sensor creates an electrical pressure differential, resulting in the generation of a small voltage signal. This voltage falls within the range of 100 mV to 1000 mV. The exact voltage depends on the oxygen 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.

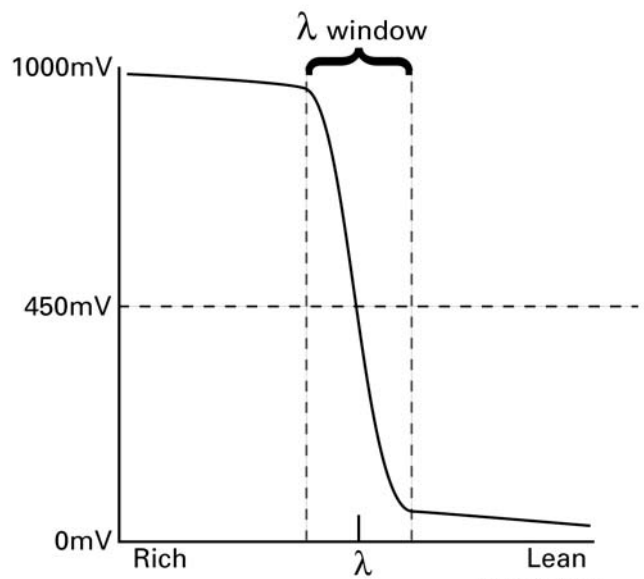
- Operation:

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 (λ). 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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Motronic M2.3.2 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.

The oxygen sensor has three wires. The oxygen sensor heating element receives ground and battery power, with the third wire being the sensor signal wire. The sensor is grounded through the mounting threads in the exhaust.

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 HO₂S signal, the ECM lengthens the injector duration to richen the mixture, and shortens the duration to lean it out.

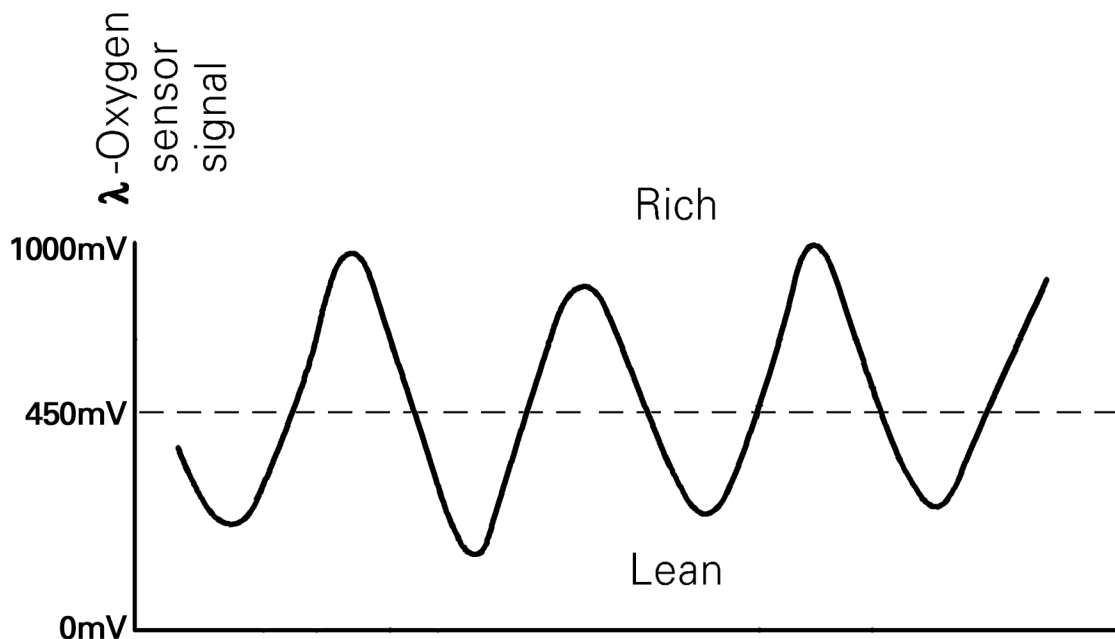
- Substitute function:

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 M2.3.2 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
- Operation:

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

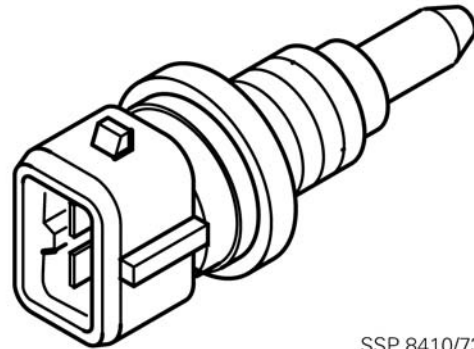
Increasing (warmer) temperatures cause the resistance to decrease; decreasing (colder) temperatures cause the resistance to increase.

- Substitute function:

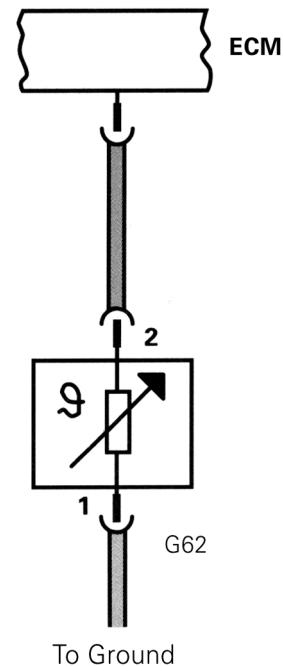
If a fault develops with the coolant temperature sensor, the ECM substitutes a value equivalent to 80°C (176°F).

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits.

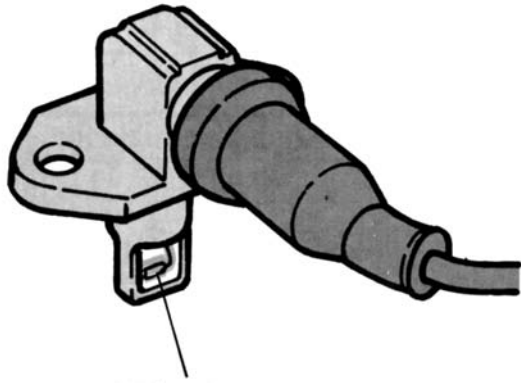


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Motronic M2.3.2 Component Summary



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Intake Air Temperature (IAT) sensor G42

The intake air temperature sensor is a **PTC 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.

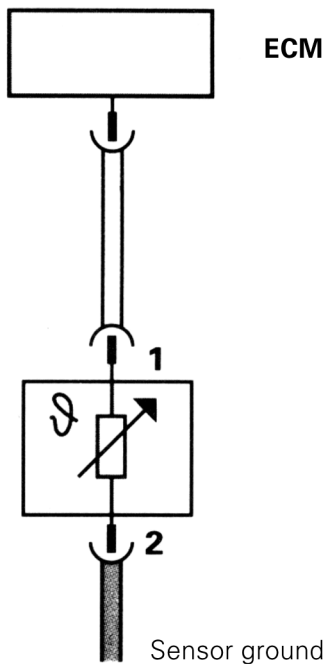
Decreasing (colder) temperatures cause the resistance to decrease; increasing (warmer) temperatures cause the resistance to increase.

- 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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Motronic M2.3.2 Component Summary

Barometric Pressure (BARO) Sensor F96 (5-cylinder)

Turbocharged engines are equipped with a pressure sensing device to signal the ECM with information referencing atmospheric pressure which varies from 14.7 psi at sea level to 12.3 psi or less in mountainous areas. It is located in the E-box (passenger-side floor), mounted next to the ECM.

The BARO signal is used to control turbo-charger boost pressure at higher altitudes where lower air pressure (density) can cause the turbo-charger to overspeed. The signal is also used to adjust the air/fuel mixture ratio at engine start-up to compensate for the decreased oxygen levels at higher altitudes.

- **Operation:**
The BARO sensor measuring chamber is open to the atmospheric. A piezo-electric crystal generates a signal that varies with the changing atmospheric air pressures.
- **On Board Diagnostic:**
The ECM recognizes Open circuits and Short circuits.

Manifold Absolute Pressure (MAP) sensor G71 (5-cylinder, component of ECM J220)

The MAP sensor operates in the same manner as the BARO sensor. The difference being, instead of referencing atmospheric pressure, a vacuum line is attached to the intake manifold. This signal is used to provide the Motronic ECM with information regarding boost pressure. This is used for pressure regulation.

Motronic M2.3.2 Component Summary

Exhaust Gas Recirculation (EGR) temperature sensor G98 (V8 only)

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_x).

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:

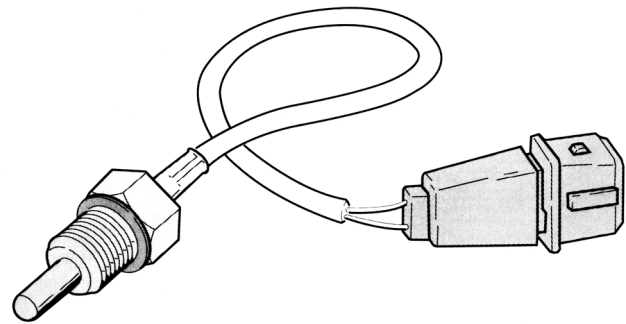
The ECM supplies a fixed reference voltage signal to the EGR temperature sensor and monitors the voltage drop caused by the resistance change. Increasing (hotter) temperatures cause the resistance to decrease; decreasing (cooler) temperatures cause the resistance to increase.

- Substitute function:

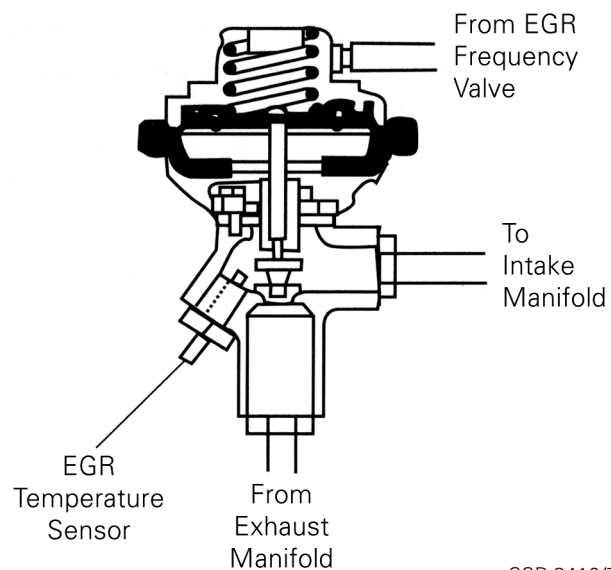
There is no substitute function.

- On Board Diagnostic (OBD):

The ECM recognizes short circuits.



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Motronic M2.3.2 Component Summary

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.

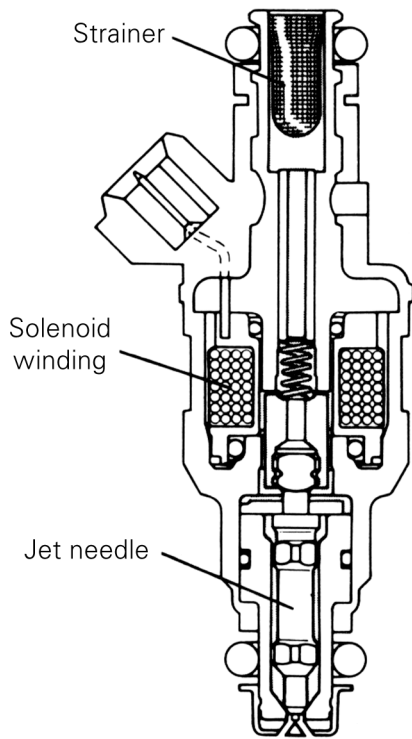
- **Automatic Transmission Control Module (TCM) signal:**

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

Motronic M2.3.2 Component Summary

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.



20 valve engine:

Cylinders 1 - 4 fuel injectors N30 - N33

Cylinder 5 fuel injector N83

V8 engine:

Cylinders 1 - 4 fuel injectors N30 - N33

Cylinders 5 - 8 fuel injectors N83 - N86

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.

- 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 M2.3.2 Component Summary

Power Output Stages N122 and N192, Ignition coils N, N128, N158, N163 and N164 (5-cylinder)

Ignition coil 1 with Power Output Stage N70, Ignition coil 2 with Power Output Stage N127 (V8)

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.

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 5-cylinder, for example, uses five spark plug mounted ignition coils. At every firing pulse, when the magnetic field collapses, the spark plug fires.

- **Substitute Function:**

There is no substitute function for the ignition coils or the power output stages.

- **On Board Diagnostic (OBD):**

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

Motronic M2.3.2 Component Summary

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

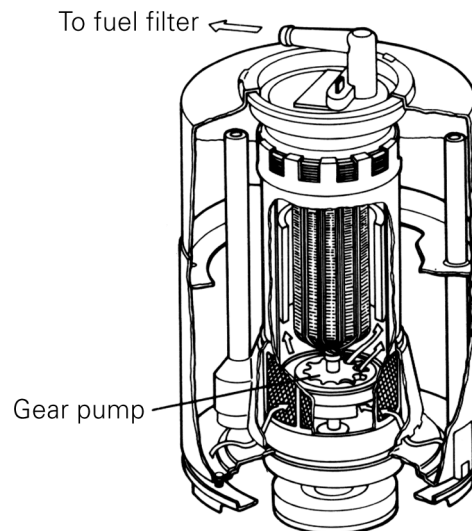
Fuel is drawn in through a screen at the bottom of the housing assembly by a vane-type pump. The screen provides coarse filtration, and the vane-type pump acts as a transfer pump. Its high volume design supplies fuel to the fuel accumulator which is within the pump housing.

- 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).



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Motronic M2.3.2 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).

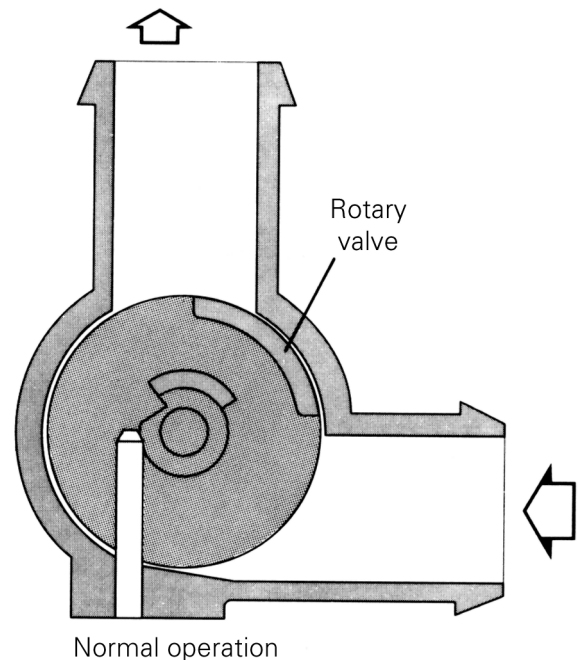
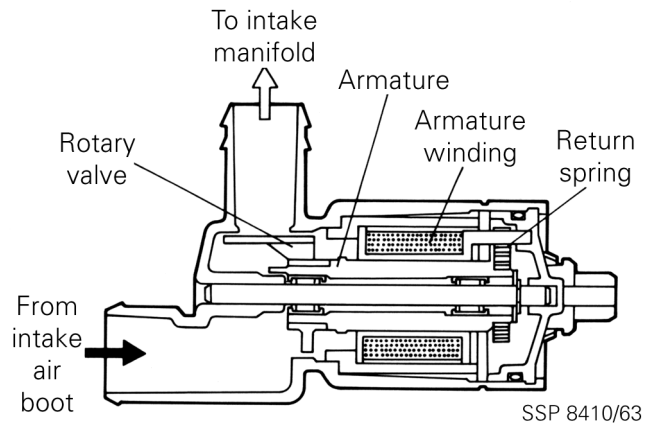
The idle air control valve is not adjustable.

- 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:

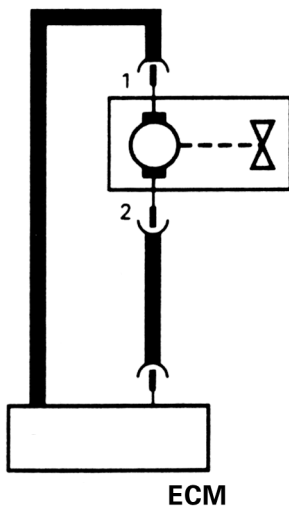
If a fault develops with the idle air control valve circuitry, the ECM output stages are shut off and the valve rotates to a fixed position allowing the engine to idle at a normal warm engine idle speed.



Motronic M2.3.2 Component Summary

- 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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Motronic M2.3.2 Component Summary

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.

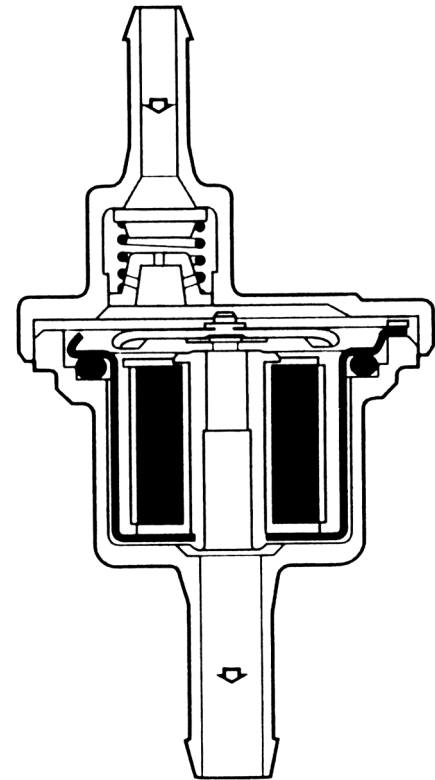
- Operation:

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.

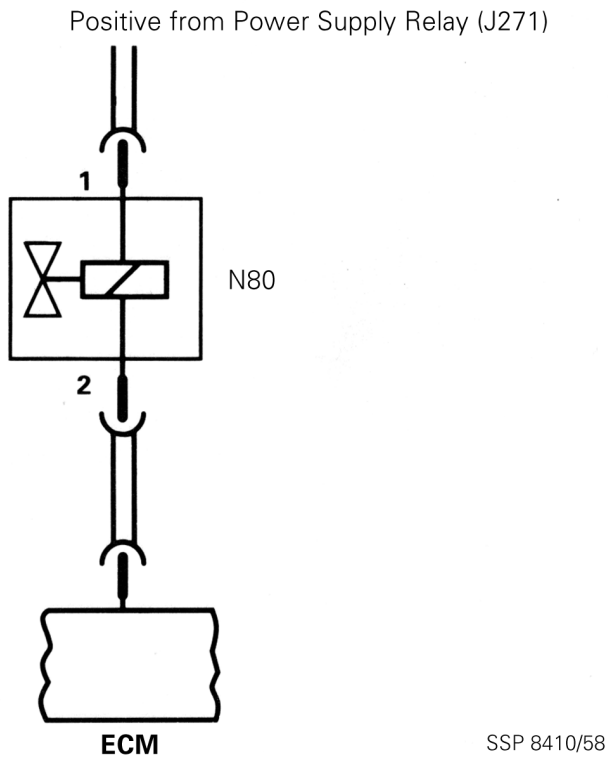
When no current is supplied to the valve, it remains in the open position. The valve is closed (duty cycle = 100%) when the cold engine is started.

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.



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Motronic M2.3.2 Component Summary



- Substitute function:
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 M2.3.2 Component Summary

Exhaust Gas Recirculation (EGR) vacuum regulator solenoid valve N18 (V8 only)

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 (NO_x).

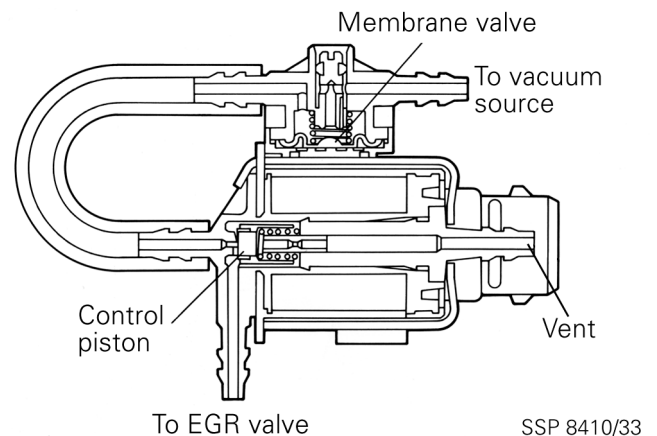
The EGR vacuum regulator solenoid valve is mounted on the rear of the intake manifold (close to the EGR valve) and regulates the amount of vacuum supplied to the EGR valve (which regulates the amount of EGR).

- 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.

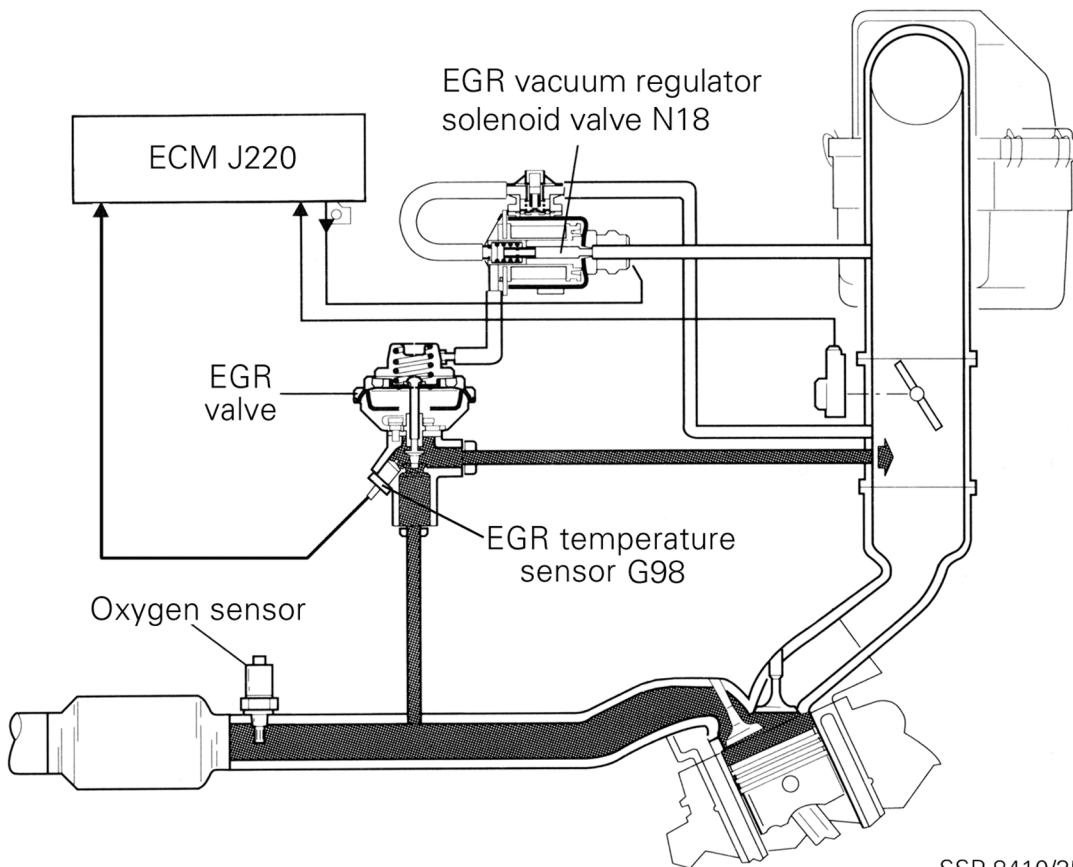


Motronic M2.3.2 Component Summary

- 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 M2.3.2 Component Summary

Heated Oxygen Sensor (HO2S) Control Module J208

The oxygen sensor heater helps to bring the oxygen sensor up to operating temperature quickly. The ECM controls the oxygen sensor heater through 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.

Motronic M2.3.2 Component Summary

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.

Motronic M2.3.2 Component Summary

Review

1. **Which of the following components does NOT receive an output signal from the Motronic M2.3.2 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 M2.3.2 engine management systems can adapt to variables such as small vacuum leaks and altitude. Technician B says that Motronic M2.3.2 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 M2.3.2 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 M2.3.2 ECM retains learned values when the battery is disconnected. Technician B says that the Motronic M2.3.2 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 M2.3.2 fuel injectors operate:**
 - a. Sequentially
 - b. In groups of two
 - c. All at the same time
 - d. None of the above

Motronic M2.3.2 Component Summary

6. Technician A says that all Motronic M2.3.2 engine management systems use exhaust gas recirculation.

Technician B says that all Motronic M2.3.2 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

7. Which of the following statements is **NOT** applicable to the Motronic M2.3.2 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).

MPI - Multi Port Fuel Injection system

System description

The MPI system is a multi port fuel injection system. The injection quantity and the ignition timing are continuously adjusted by control elements (actuators) on the basis of constantly evaluated signals from the transmitters (sensors).

The ECM J192 has four individual harness connectors with a total of 64 pin terminals, and is located in the electronics box in the passenger-side footwell.

The MPI system also has a permanent Diagnostic Trouble Code (DTC) memory used for On Board Diagnosis. The system can be tested using the VAG 1551 Scan Tool in "Rapid Data Transfer" mode.

The first MPI system was installed in the Audi quattro 90 and Audi Coupe. In 1992, the MPI system was installed on Audi 100 models (MMS 100), and continued through model year 1998 (Audi A6 Avant and Cabriolet). Functionality was continually improved, creating several different versions of the MPI system. These systems include:

- MMS 100/200
- MMS 300
- MMS 311
- MMS 400
- MMS 410
- MMS 411
- MMS 412



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MPI (MMS 100 - 300)

MMS 100/200 overview

In 1992, Audi began utilizing the MPI Multi port Fuel Injection System on their new 100 models equipped with the V6 2.8 liter 2 valve engine. This car replaced the previous 100 model and was the fourth generation of the large C class. The latest version of the Audi designed MPI Motor Management System (MMS100/200) was used in the V6 engine. It was similar to the system used on the Audi 90 quattro and Coupe quattro with the 20 valve engine, with the following changes:

- Distributorless ignition system
- New style Bosch fuel injectors
- Solenoid valve for the intake manifold change over valve
- EGR for 50 states
- Single valve for fuel tank ventilation

Inputs - MMS 100 - 300

The ECM receives inputs that are similar to previous Motronic systems, including the following:

- Mass Air Flow (MAF) sensor G70
- CO Potentiometer G74
- Crankshaft Position (CKP) sensor G4
- Engine Speed (RPM) sensor G28
- Camshaft Position (CMP) sensor G40
- Throttle Valve Potentiometer G69
- Idle switch F60
- Knock Sensors (KS) G61, G66
- Heated Oxygen Sensor (HO2S) G39 and G108
- Exhaust Gas Temperature sensor G98

Outputs - MMS 100 - 300

The ECM receives outputs that are similar to previous Motronic systems, including the following:

- Fuel Injectors N30 - 33, N83, N84
- Power output stage N122
- Ignition coils N, N128, N158
- Idle Air Control (IAC) N71
- EGR valve N18
- Evaporative Emissions (EVAP) canister purge regulator valve N80
- Intake Manifold change-over Valve N156
- Fuel Pump relay J17

On Board Diagnostic (OBD)

The ECM continuously monitors the systems input and output signals. If malfunctions occur, they are stored in the control units permanent Diagnostic Trouble Code (DTC) memory.

In addition, malfunctions will also be stored if the knock regulations or oxygen sensor control reach their control limits. On California models, the control unit also monitors the operation of the EGR system and will record malfunctions if they occur.

The MPI system expanded On Board Diagnostic is capable of the following:

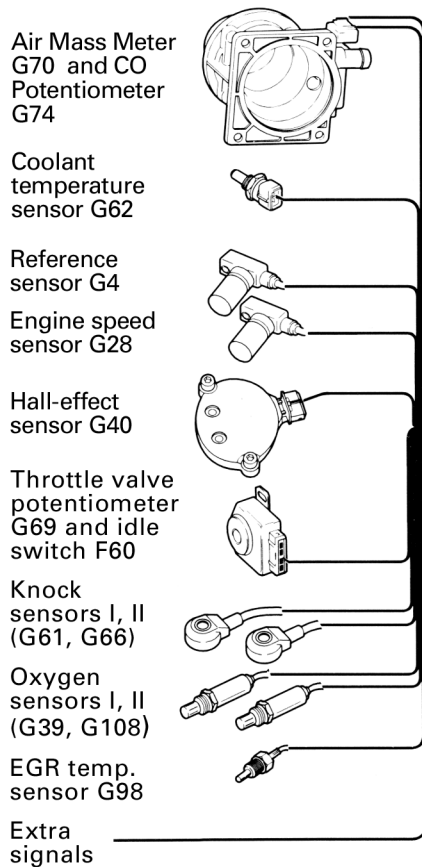
- Store and display malfunctions from the permanent DTC memory.
- Transmit information through VAG 1551 scan tool using "Rapid Data Mode."
- Generate output test signals via output Diagnostic Test Mode (DTM) of all actuators (Idle stabilizer valve, fuel injectors etc).

Fuel system

The MPI fuel delivery system operates the same as the Motronic system (see page 55 for more specific details).

MMS 100/200 System Components

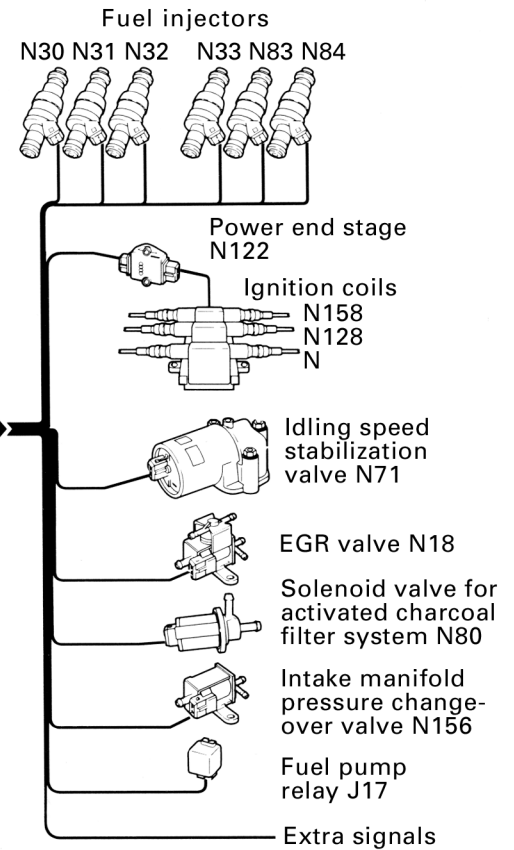
Inputs



MPI Control Unit J192

Diagnostic connectors

Actuators



SSP 9410/99

MPI (MMS 100 - 300) Component Differences

Input Sensors

The input sensors that differ from previous systems are detailed in this section.

ECM J192

The ECM J192 has four connectors, with a total of 64-pins. The individual harness connectors are attached to the ECM using locking tabs, which are released by squeezing the harness connector while gently pulling the connector from the ECM.

The ECM processes all inputs and calculates outputs for ignition timing and injector duration based on control maps.

The ECM has the following diagnostic capabilities:

- Read Individual Measuring Values (scan tool function 09)
- Rapid data transfer/Blink codes
- Individual component monitoring

Coding is accomplished using a coding connector as in the M2.3.2 system.

MPI (MMS 100 - 300) Component Differences

Mass Air Flow (MAF) Sensor G70

A hot-wire mass air flow sensor is used on the MMS 100/200 system. It is manufactured by Hitachi, and is digital (as opposed to the earlier Bosch sensors which were analog).

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.

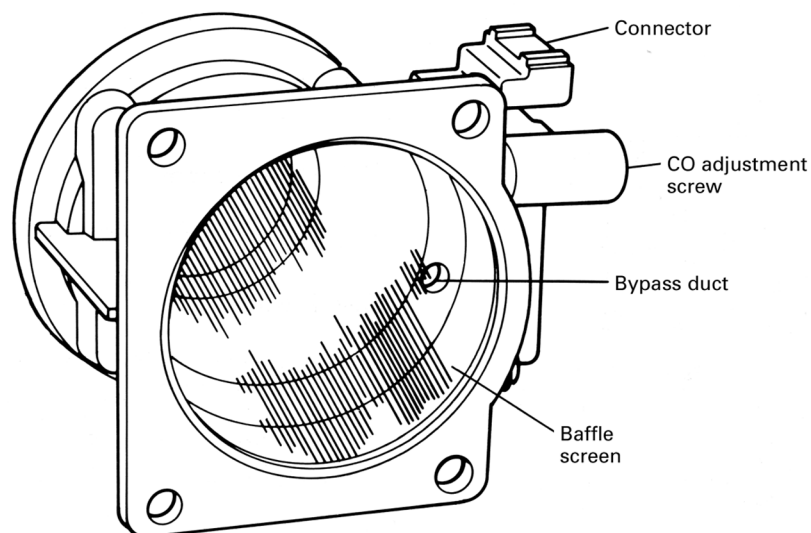
Dirt or other contamination on the platinum wire can cause inaccurate output signals. Because of this, the platinum wire is heated to approximately 1000°C (1832°F) for a period of one second each time the engine is switched off (after being run to operating temperature). This burns off any dirt or contamination.

- Substitute Function:

If a malfunction develops in the MAF sensor, the signals from the throttle potentiometer and Engine Speed (RPM) sensor are used as a substitute in order to maintain driveability.

- On Board Diagnostic (OBD):

The Engine control unit recognizes two fault conditions of the Mass Air Flow Sensor; Open and Short to Battery +.



SSP 9410/75

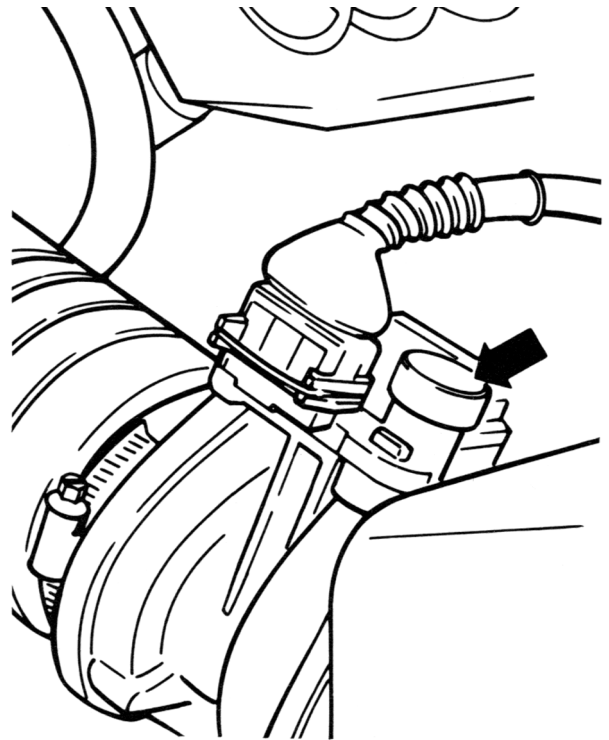
MPI (MMS 100 - 300) Component Differences

CO Fuel Trim (FT) Potentiometer G74

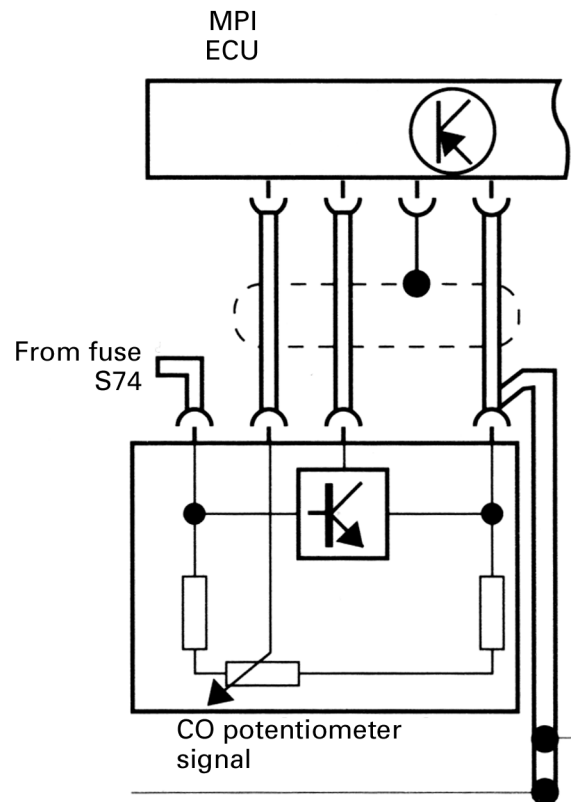
A Carbon Monoxide (CO) fuel trim potentiometer is installed in the MAF sensor housing. The CO potentiometer is used to adjust the idle injection quantity. The MAF Sensor G70 and the CO Fuel Trim (FT) Potentiometer G74 are supplied with battery voltage (terminal 15) by the Fuel Pump (FP) relay.

- Substitute Function:
No substitute function is available.
- On Board Diagnostic (OBD):

The ECM recognizes two failures of the CO potentiometer; Open and Short circuit to Battery +.



SSP 9410/76



SSP 9410/77

MPI (MMS 100 - 300) Component Differences

Engine Coolant Temperature (ECT) sensor G62

The coolant temperature sensor is located on the coolant pipe in back of the left cylinder head.

The coolant temperature is an NTC sensor (see Glossary). The coolant temperature information is used by the ECM as a correction factor for the following:

- Cold start enrichment
- Correction to injection and ignition timing for cold engine
- Idle speed control
- Deceleration fuel shut-off

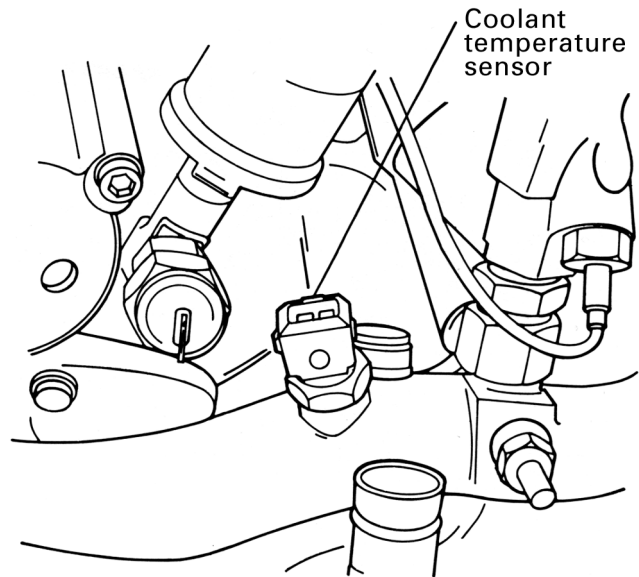
The engine coolant temperature sensor also is used to activate certain systems at a predetermined temperature such as, oxygen sensor control, knock control, and exhaust gas recirculation.

- Substitute Function:

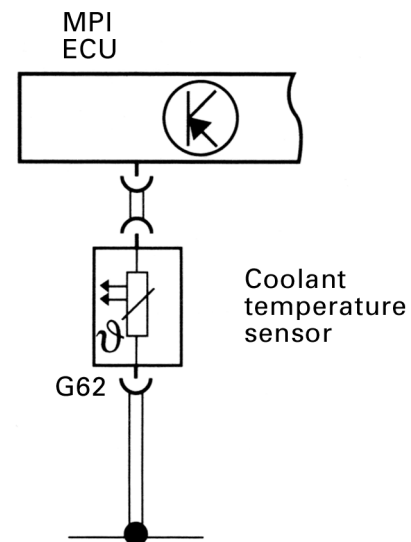
If the ECM detects a malfunction in the coolant temperature sensor or in the wiring, it assumes a temperature of 68°F (20°C) when the engine is first started. 18°F (10°C) is added per minute of engine operation until the maximum temperature of 185°F (85°C) is reached.

- On Board Diagnostic (OBD):

The MPI system recognizes Open circuit, Short circuit to Battery +/-Ground as well as implausible signals.



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SSP 9410/106

MPI (MMS 100 - 300) Component Differences

Engine Speed (RPM) Sensor G28

The engine speed sensor is an **inductive sensor** (see Glossary). The sensor is located on the rear, left side of the engine block. It senses the 135 teeth of the starter ring gear. The ECM receives one pulse for every tooth on the ring gear. This sine wave from the speed sensor is used by ECM to calculate the ignition firing point and injection point as determined by engine speed.

Note:

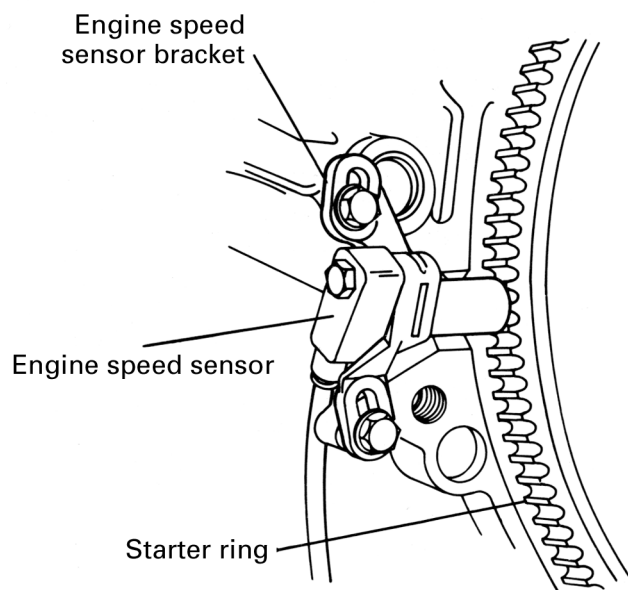
The engine speed sensor position is adjusted at the factory. Before removing the sensor bracket, mark the position of the bracket on the engine block.

- Substitute Function:

No substitute function for the engine speed sensor is available.

- On Board Diagnostic (OBD):

The ECM recognizes a missing signal after five seconds of cranking or engine operation. If the MPI does not receive a signal, the engine will not start.



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Crankshaft Position (CKP) Sensor G4

The Crankshaft Position (CKP) sensor is an **inductive pickup** (see Glossary). The sensor is located on the left side of the engine block. The sensor is used to identify TDC number three cylinder.

A notch, 62° before TDC in the counterweight of the crankshaft for number three cylinder, is used as a reference point. The notch, along with the crankshaft sensor, generates one signal per crankshaft revolution.

The signals from the crankshaft sensor and the signal from the Camshaft Position (CMP) sensor G40 are used for authorization of sequential fuel injection and ignition timing.

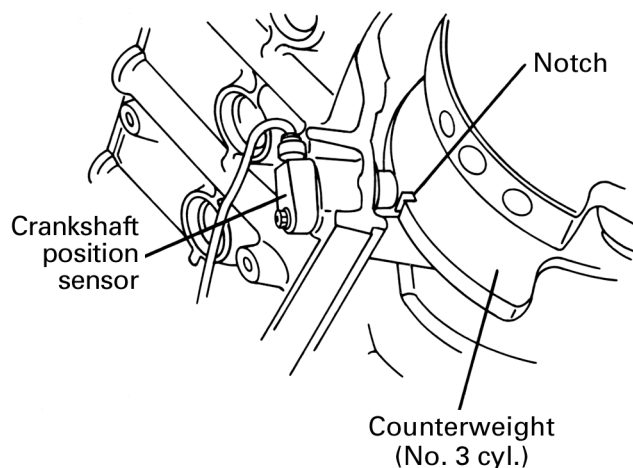
- Substitute Function:

No substitute function for the crankshaft position sensor is available.

- On Board Diagnostic (OBD):

The ECM recognizes a missing signal after five seconds of cranking or engine operation, as well as Short to Battery + and Ground.

If the MPI does not receive this signal, the engine will not start.



SSP 9410/78

MPI (MMS 100 - 300) Component Differences

Camshaft Position (CMP) Sensor G40

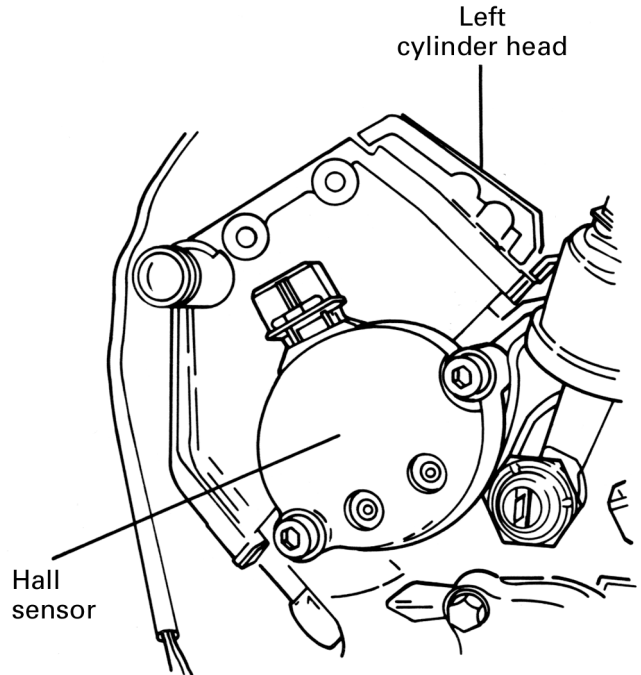
The CMP sensor is a **Hall sensor** (see Glossary). The sensor is located at the end of the camshaft on the left cylinder head.

The signal from the Camshaft Position (CMP) Sensor G40 along with Crankshaft Position (CKP) sensor are used during starting to identify TDC of cylinder number three.

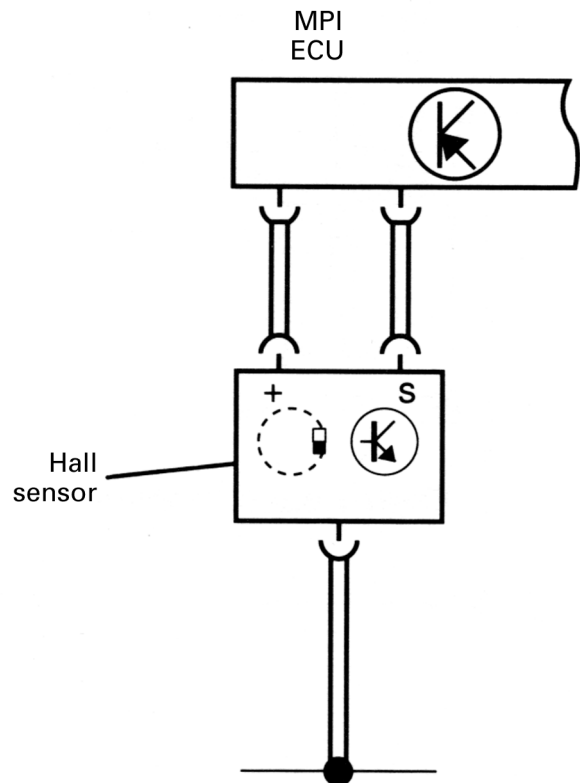
When starting the engine, the ECM triggers the ignition and sequential injection after receiving both signals.

- Substitute Function:
No substitute functions are available for the camshaft position sensor.
- On Board Diagnostic (OBD):
The ECM recognizes the following malfunctions. Open circuit and Short circuit to Ground/Battery +.

If the ECM does not receive the Hall signal the engine will not start.



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SSP 9410/83

MPI (MMS 100 - 300) Component Differences

Throttle Position (TP) Sensor G69

The throttle position sensor is a potentiometer connected to the throttle shaft. The ECM supplies a 5 Volt reference to the sensor and measures the voltage drop across the potentiometer as throttle valve angle changes. The TP sensor and Closed Throttle Position (CTP) Switch F60 are combined in a single housing, mounted on the throttle body.

The signal supplied to the ECM is used to determine the position of the throttle valve and the speed of throttle movement. This information is used for:

- Acceleration enrichment
- Full throttle enrichment

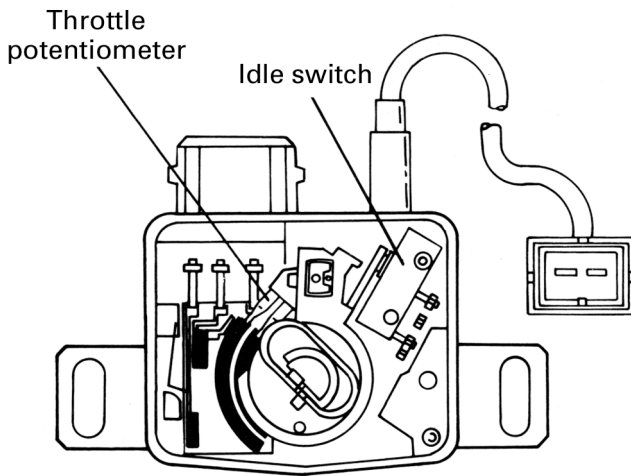
The throttle position sensor combined with the Engine Speed (RPM) sensor is also used as a substitute signal for Mass Air Flow (MAF) Sensor G70.

- Substitute Function:

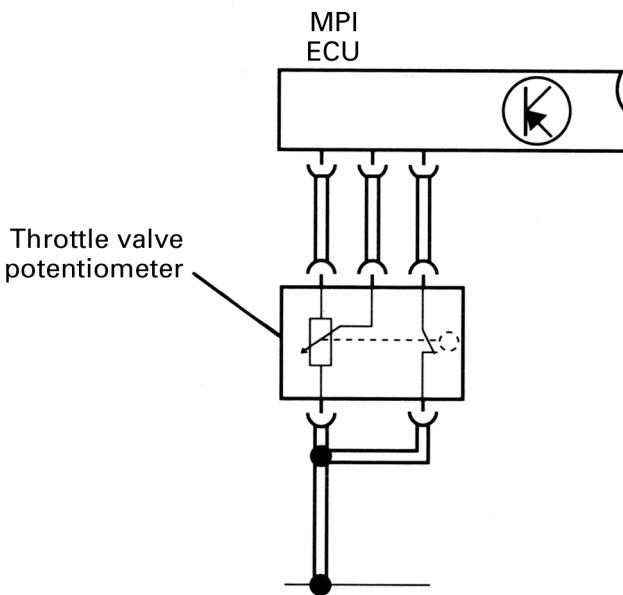
No substitute function is available for the throttle position sensor.

- On Board Diagnostic (OBD):

The ECM recognizes the following failures. Open circuit conditions of the throttle position sensor: Open/Short circuit to Ground, Implausible signals (checked against MAF signal).



SSP 9410/86



SSP 9410/87

MPI (MMS 100 - 300) Component Differences

Closed Throttle Position (CTP) Switch F60

The Closed Throttle Position (CTP) switch and the throttle position sensor are combined into a single housing on the bottom of the throttle housing.

The Closed Throttle Position (CTP) switch closes 1.5° before the primary throttle plate closes. When the switch is closed, a Ground signal is supplied to the ECM.

The ECM uses the CTP signal to activate the following functions:

- Idle stabilization
- Deceleration fuel shut off with engine warm and above 1500 RPM. Fuel supply is reactivated when engine speed falls below 1200 RPM.
- Special ignition map for deceleration

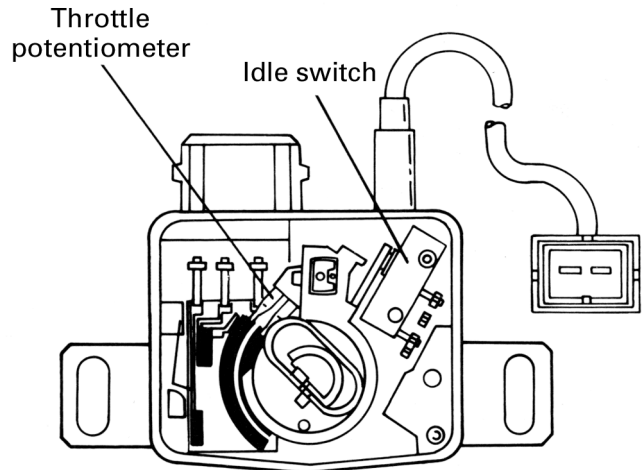
- Substitute Function:

No substitute function is available for the idle switch.

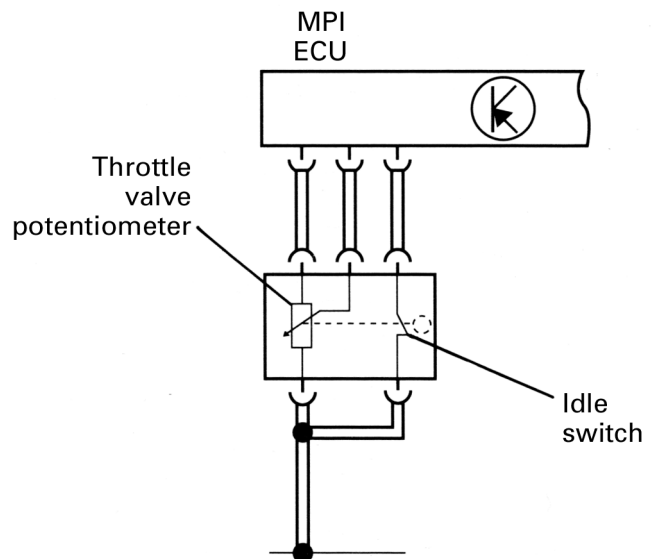
- On Board Diagnostic (OBD):

A short circuit to Ground is detected when the idle switch remains closed while the TP sensor signal varies.

If the idle switch is not operated once in ten minutes after the engine is started, and engine speed is above idle speed, and open circuit is detected.



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SSP 9410/85

MPI (MMS 100 - 300) Component Differences

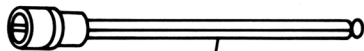
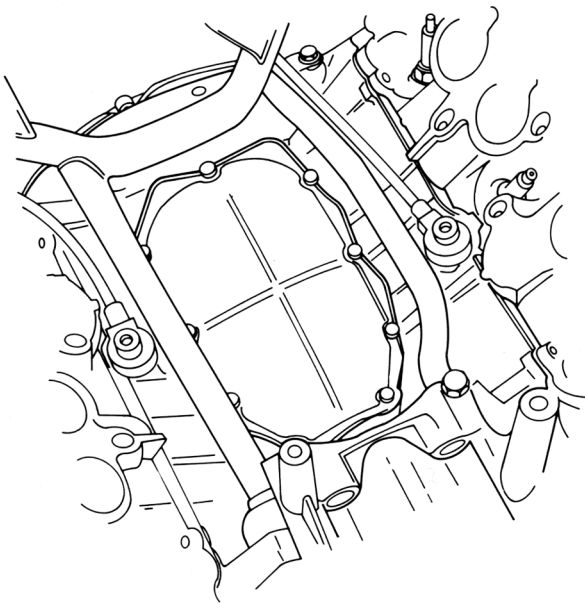
Knock Sensors (KS) I and II G61 and G66

On the Audi V6 engine, dual knock sensors are used. Dual sensors allow for more accurate control of cylinder selective knock control. When knock occurs, the ignition timing is retarded 3° per crankshaft rotation with a maximum retard of 12° . After knock has subsided, the ECM advances timing at a rate of 0.33° per revolution until knock occurs again.

Knock sensor I is located on the right cylinder bank under the manifold and monitors cylinders 1, 2 and 3.

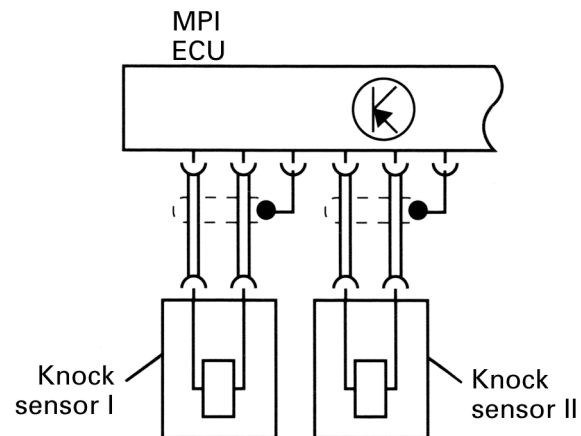
Knock sensor II is located on the left cylinder bank and monitors cylinder 4, 5 and 6.

The knock sensors can be removed by using a long 8 mm allen wrench (special tool 3247) without removing the intake manifold.



Special tool 3247

SSP 9410/89



SSP 9410/90

MPI (MMS 100 - 300) Component Differences

Oxygen Sensor heater (O2S) Z19/Z28

Heating elements are incorporated into the oxygen sensors to get the sensors to operating temperature as quickly as possible.

- Operation:

The heaters are provided Battery power from the Fuel Pump (FP) relay J17 and Grounded through a welded connection in the engine wiring harness. Power is provided at all times when the engine is running.

- Substitute Function:

There is no substitute function for the oxygen sensor heaters. The heating is provided by the exhaust gases. Closed loop operation may be delayed.

- On Board Diagnostic (OBD):

The ECM is incapable of diagnosing any faults with the oxygen sensor heaters.

MPI (MMS 100 - 300) Component Differences

Output Actuators

The output actuators that differ from previous systems are detailed in this section.

Fuel Injectors N30, N31, N32, N33, N83 and N84

The fuel injectors for the MPI system are 4-hole single stream injectors. The injectors are mounted in the intake manifold.

- Operation:

Battery voltage is supplied to the injectors from the Fuel Pump (FP) relay J17 via a 12 amp circuit breaker located in the electronic control box. A separate power output stage is provided in the ECM for each injector for sequential fuel injection.

The ECM controls the injectors by completing the Ground circuit for each injector.

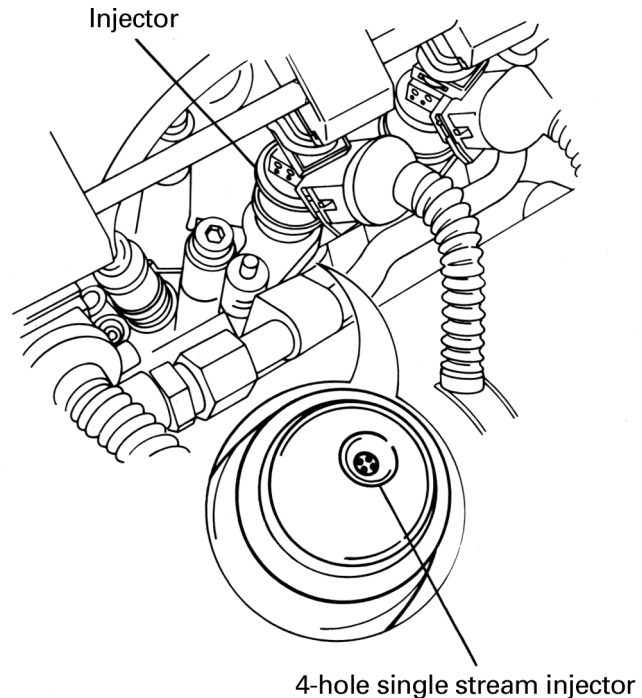
- Substitute Function:

In the event of a short circuit to B+, the injector that is affected will be switched off until the ignition is turned off. Full throttle enrichment and oxygen sensor control is switched off for the cylinder bank concerned.

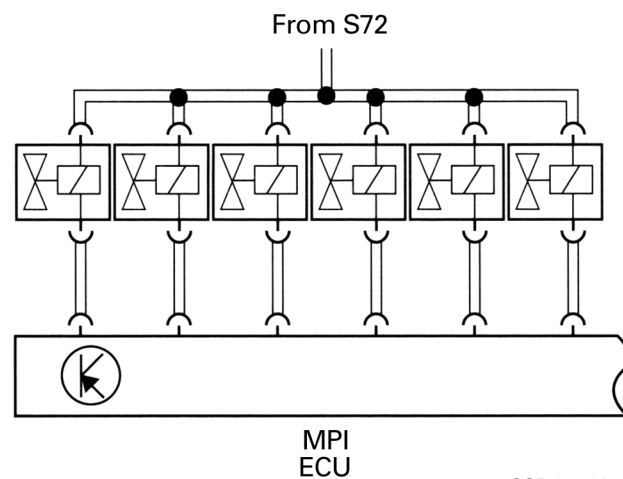
- On Board Diagnostic (OBD):

The ECM recognizes the following malfunctions;

Short circuit to Battery + and Open circuit/Short circuit to Ground.



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SSP 9410/144

MPI (MMS 100 - 300) Component Differences

Power Output Stage N122 and Ignition coils N, N128 and N158

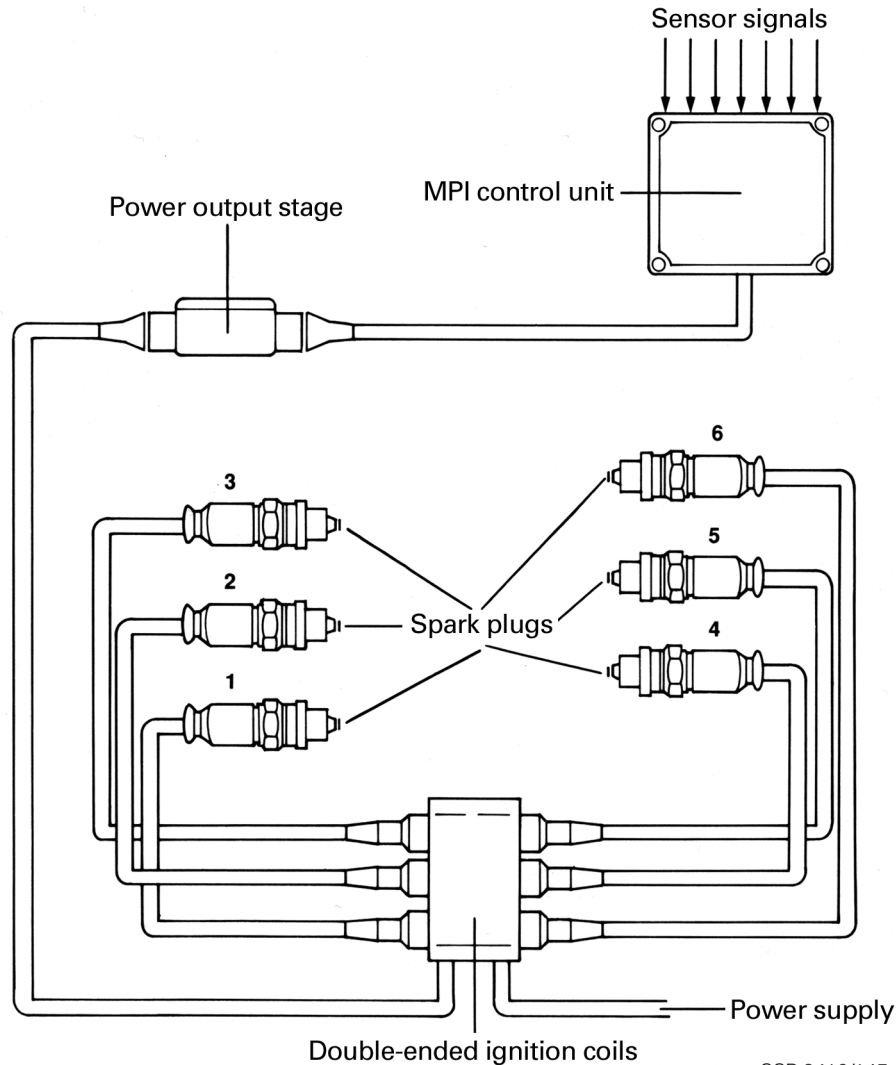
The ignition system for the V6 engine is distributorless. Since there are no moving parts, no noise is generated to interfere with the knock sensor system. The system is also easier to maintain, as no routine adjustments are necessary.

The ignition components of the MPI system consists of the following:

- Power output stage N122
- Three double-ended ignition coils N, N128, N158
- ECM J192

The ECM operates each double-ended ignition coil via the power output stage (power stage). The power stage is located on the bulkhead behind the engine.

When the ignition coil fires, spark is supplied to two cylinders at the same time. One plug fires during the compression stroke and ignites the fuel mixture, and at the same time the other plug fires during the exhaust stroke. This is known as a waste spark.



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MPI (MMS 100 - 300) Component Differences

The automatic Transmission Control Module (TCM) J217 provides an input to the ECM. The ECM responds by retarding the ignition timing point during gear changes. This reduces engine torque during a shift, resulting in smoother gear changes.

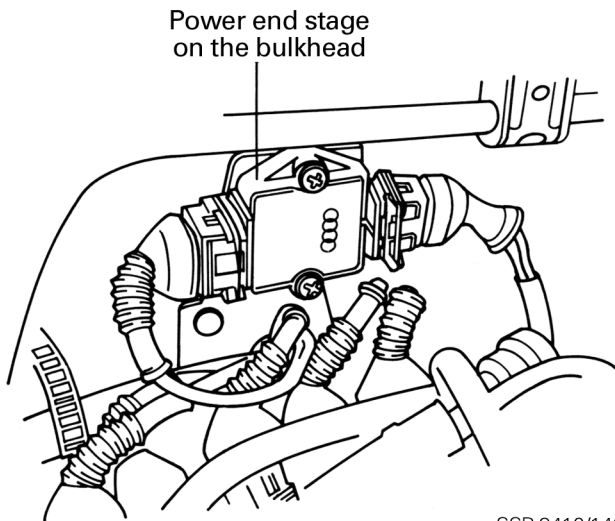
- Substitute Function:

There are no substitute functions for the ignition coils.

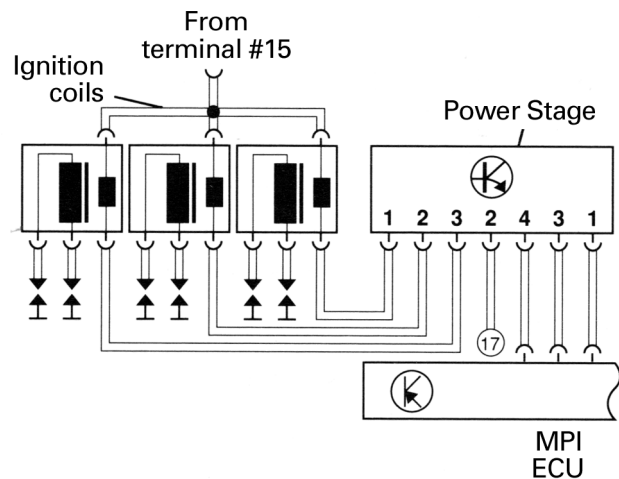
If an ignition coil, spark plug wire or spark plug should fail, the corresponding fuel injectors are switched off, as well as the oxygen sensor control and full throttle enrichment functions.

- On Board Diagnostic (OBD):

The ECM is capable of recognizing Short to Battery +/-Ground in the Power Output Stage. The ignition coils are not monitored by the ECM.



SSP 9410/146



SSP 9410/148

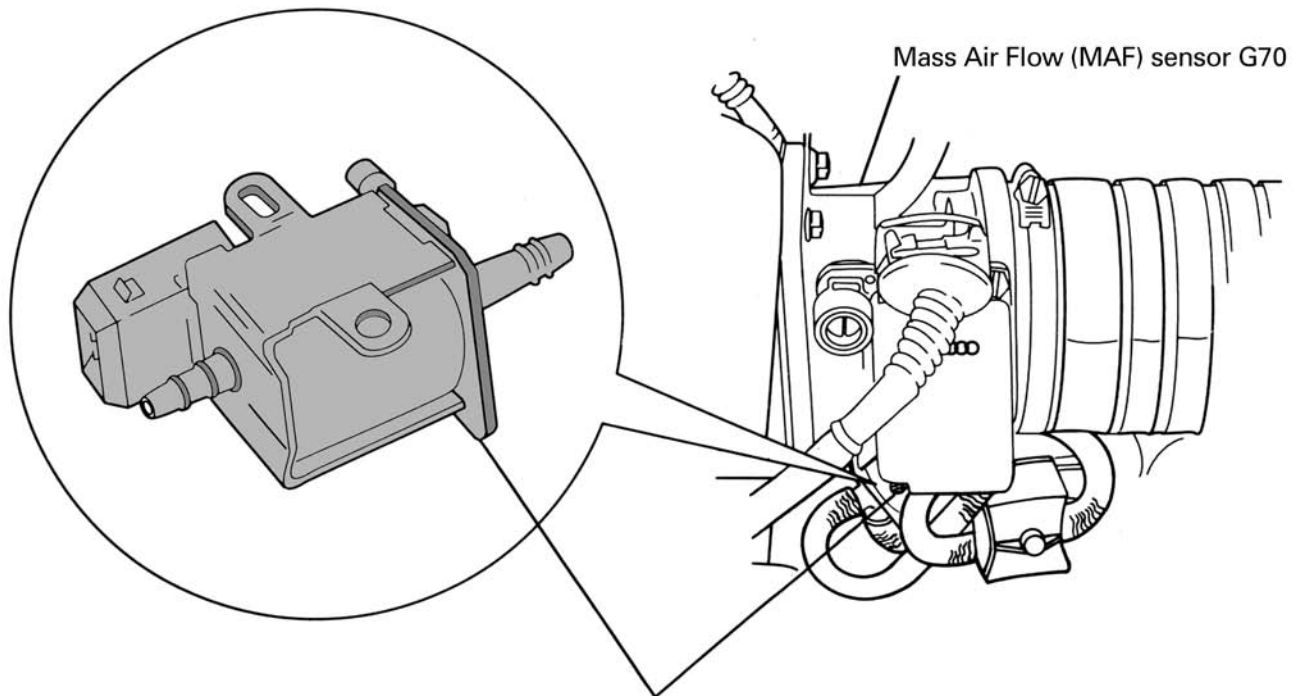
MPI (MMS 100 - 300) Component Differences

Intake Manifold Change-Over Valve N156

Control of the dual path intake manifold is handled by the ECM. The Intake Manifold Change-Over Valve N156 regulates a vacuum servo that allows use of either the short or long path in the intake manifold.

The valve is mounted under the MAF Sensor. N156 operates according to engine speed. Above 4100 RPM, the change-over valve opens the six flaps in the intake manifold.

- Operation:
The valve receives Battery power from the Fuel Pump (FP) relay J17. The ECM completes the Ground circuit.
- Substitute Function:
No substitute functions are available for the change-over valve. If the electrical circuit of the valve is faulty or the vacuum valve fails, the flaps remain closed.
- On Board Diagnostic (OBD):
The intake manifold change-over valve is not monitored. The valve can be checked electrically via the VAG 1551 scan tool using the output Diagnostic Test Mode (DTM).



Intake Manifold Change-Over Valve N156

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MPI (MMS 100 - 300) Component Differences

Idle Air Control (IAC) Valve N71

The Idle Air Control (IAC) valve is used to control engine idle speed. It regulates the flow of air to the engine when the throttle valve and idle switch are closed. The idle stabilizer valve is mounted on the throttle valve housing.

The idle air control system is adaptive. Therefore, idle speed adjustments are not necessary.

- Operation:

The idle air control valve is operated by a DC voltage duty cycle supplied by the ECM. The ECM regulates the idle speed with a warm engine between 700 - 800 RPM. The duty cycle will vary depending on engine load and engine conditions.

- Substitute Function:

If a malfunction in the circuit is recognized, both output stages in the ECM are shut off. The A/C compressor is switched off and the valve will rotate to a fixed opening position that allows the engine to idle.

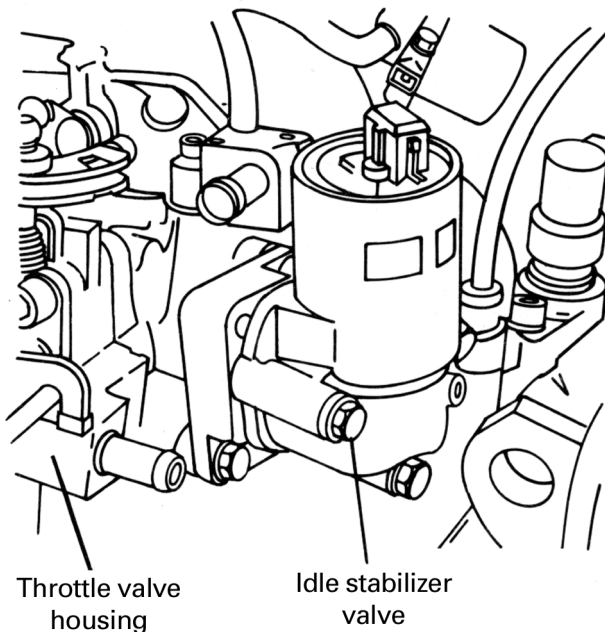
- On Board Diagnostic (OBD):

The ECM recognizes the following faults:

Short circuit to B+

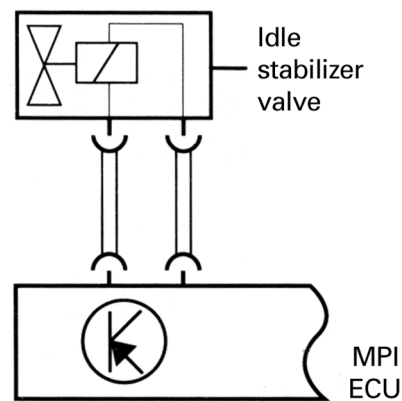
Open circuit/short circuit to Ground (GND)

Mechanical malfunction (valve inoperative)



SSP 9410/151

Electrical Circuit



SSP 9410/152

MPI (MMS 100 - 300) Component Differences

Fuel Pump (FP) relay J17

The fuel pump relay is located in the central electric panel under the drivers kneebar.

The fuel pump is operated by the ECM based on a valid Engine Speed (RPM) sensor signal. The fuel pump relay is often referred to as a "system relay" due to the fact that it provides Battery power to multiple engine management components, including:

- Fuel injectors
- Evaporative emissions frequency valve
- Manifold Absolute Pressure (MAP) valve
- EGR valve
- Oxygen sensor heating elements
- Intake Manifold change-over valve
- Mass Air Flow (MAF) sensor

Note:

If after checking DTC memory multiple DTC's are present for these components, a Fuel Pump relay failure is possible.

- Substitute Function:

No substitute function is available for the Fuel Pump relay. If the component or the associated wiring fails the engine cannot be run.
- On Board Diagnosis:

No faults are generated by the Fuel Pump relay, but components powered by the relay may set a fault for Open circuit if there is a failure.

MPI (MMS 100 - 300)

MMS 300/311 overview, system description and comparison

For the 1993 model year, the 2.8 Liter V6 in the Audi 90 and Audi 100 were modified.

These changes included:

- Modified MPI Engine Management System (MMS 300)
- Fully adaptive oxygen sensor control
- CO adjustment potentiometer removed
- Expanded diagnostic capability with the VAG 1551
- EGR temperature sensor relocated to the intake manifold EGR inlet
- Intake air pre-heat eliminated

The MPI system (MMS 300) was modified for increased capabilities. The ECM (software) is new, and the system has greater processing capability. A 16-bit microprocessor is used that can process up to twice the information as the previous 8-bit version. The systems memory capacity was also increased from 48K-byte to 60K-byte.

One control unit is used for all applications worldwide. After replacing an engine control unit, the new control unit needs to be coded using the VAG 1551 Scan Tool. ECM coding can greatly effect the operation of the system.

The revised MPI system on the 1993 Audi 90 and 100 models received new functions and capabilities. These additional functions can be tested using the 1551 scan tool.

Function 02: Check DTC memory

Several component changes allow for expanded diagnostic capability with the VAG 1551.

- Intake manifold change-over valve N156 is now monitored by the ECM
- The CO potentiometer diagnosis has been eliminated.
- Oxygen sensor control/learning monitored by ECM

Function 04: Basic Settings

Most of these new display groups show actual sensor values. When "Function 04" is selected, the A/C compressor, the digital idle stabilization, EVAP canister purge regulator valve and the EGR vacuum regulator solenoid valve are switched off. System learning or adapted values are not reset, however, the learning requirements displays are set to zero.

Function 07: Code Control Module

The control unit is coded to match the specific vehicle options in which it is installed.

This coding must be done whenever a new control unit is installed in a vehicle. The code should also be checked when any performance or running problems are encountered.

The following codes are for all Audi models with the revised MPI MMS 300 system.

- 003 = Vehicles with manual transmission
- 004 = Vehicles with 097 4-speed automatic transmission
- 005 = Vehicles with 01F/01K ZF 4-speed automatic transmission

Function 08: Read Measuring Value Block

The previous MMS 100/200 system made use of one measuring value block, 000. MMS 300 adds 20 more blocks, with access to four windows of information per block.

This expanded functionality allows for increased dynamic monitoring of sensor and actuator values while the engine is running.

Function 09: Read Individual Measuring value

Individual Measuring values have been taken away, and replaced by Measuring Value Blocks.

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.

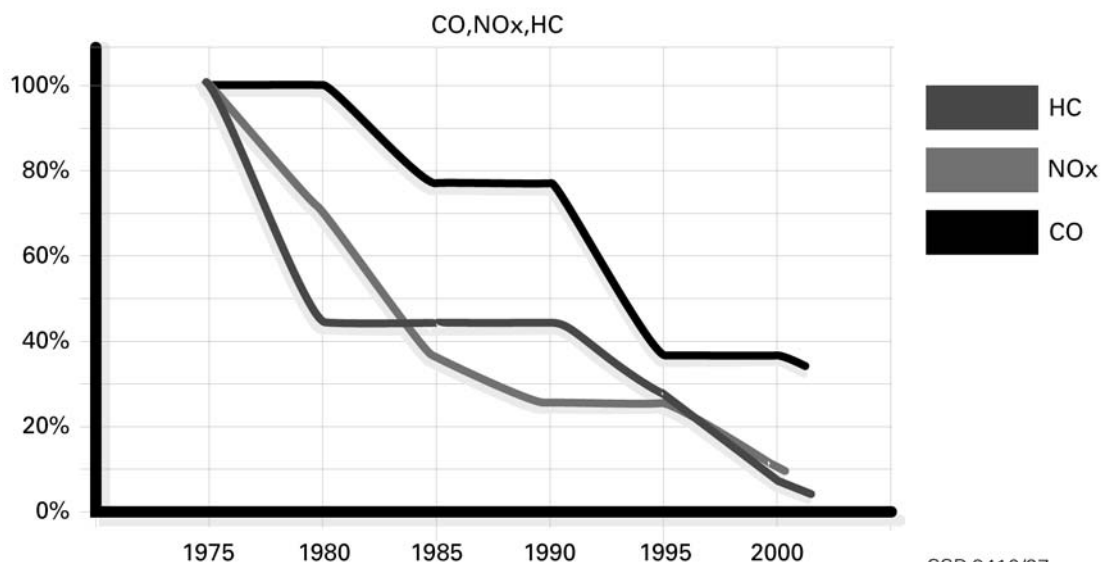
The United States Government is involved in air quality standards through the Environmental Protection Agency (EPA). The EPA works with the auto manufacturers, the Society of Automotive Engineers (SAE), and other agencies to regulate and enforce legislation dealing with air quality.

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 (hydrocarbons (HC), carbon monoxide (CO), and nitrous oxides (NOx)) 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.



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OBD-II Overview

OBD-II

Beginning with the 1996 model year, all Audi 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

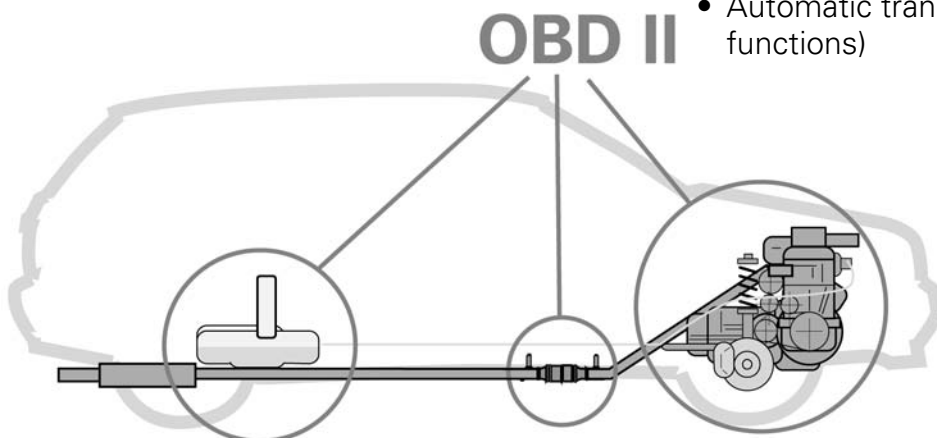
After establishing the set of standards as a framework, a set of objectives was developed to provide the basis for system operation.

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:

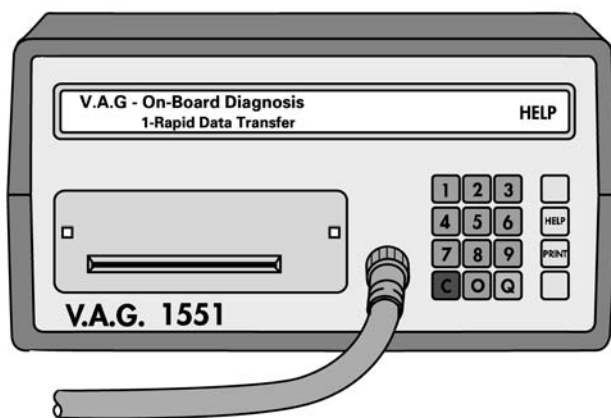
- **Component monitors:** the ECM looks at the operation of individual parts of the system.
- **System monitors:** the ECM operates a component (or multiple components) to verify system operation.

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 Audi 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 manufacturers 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

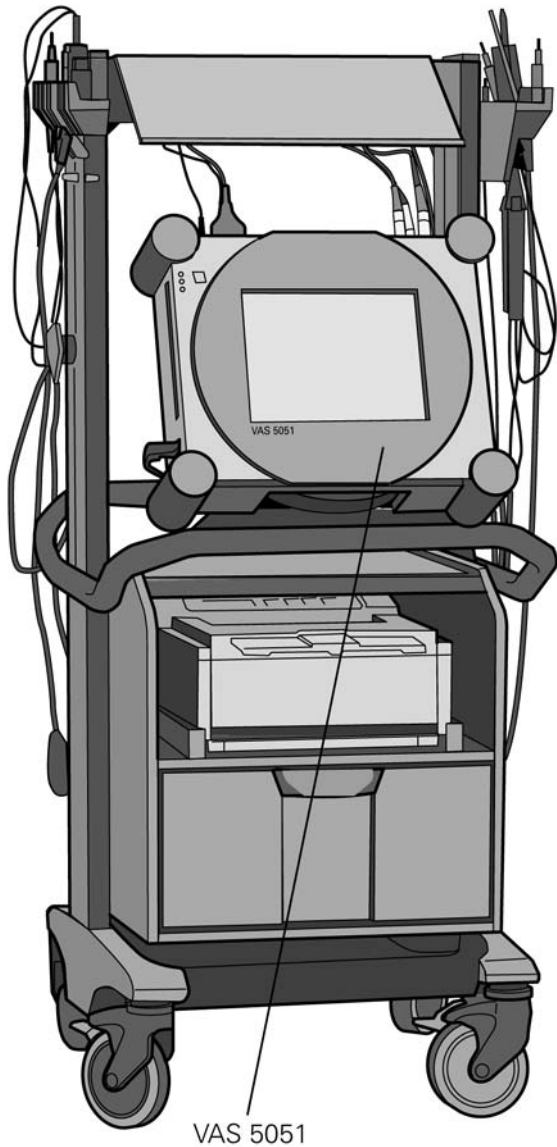
SSP 9410/29



VAG 1552 Scan Tool

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OBD-II Overview



VAS 5051

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The proprietary mode is accessed using address word 01. It can provide the same data as the generic mode, but in the more familiar Audi scan tool formats. It also provides greatly expanded data and functionality, and is the preferred method of communication for Audi 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 control module and output signals
- Px7xx transmission
- Px8xx transmission
- Px9xx control modules, input and output signals

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 of the repair 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)

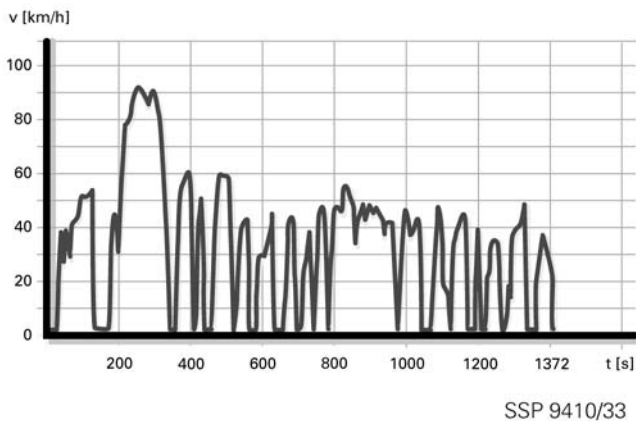
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OBD-II Overview

Setting readiness codes

Several methods exist for setting readiness codes. Some methods will not work with some systems, so the appropriate AESIS 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.



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 AESIS 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 driving the vehicle. This procedure can only be used on the newer engine management systems where it has been programmed into the ECM. Specific AESIS 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.

MMS 400/410/411 Overview

Beginning with m.y. 1996, Audi vehicles with the 2.8 Liter V6 are equipped with a new MPI Control Unit, part number 8A0 906 266 D (MMS 400). This new control unit complies with OBD II requirements as stated by the California Air Resources Board (CARB).

Additional components and features of the 2.8 Liter V6 with OBD II include:

- Heated Oxygen Sensors (HO2S) behind Three Way Catalytic Converters (TWC) G130 and G131
- Sensor for EVAP Canister G172
- New MPI Control Unit with 96 pins/5 individual harness connectors
- New 16-pin Data Link Connector (DLC) mounted in drivers compartment
- Diagnostics can be performed with the VAG 1551 Scan Tool using address word 01 or address word 33 (generic scan tool function), or with any generic Scan Tool.
- Secondary Air Injection (MMS 410/411)
- Leak Detection Pump (LDP) V144 (MMS 411)

With the OBD II system, address word 01 has several revised or expanded functions. In addition, address word 33 modes 1 through 5 are new. Also new were the Readiness Code, Calculated Load Values, and Mass Air Flow Rate, which were mandatory legal requirements of OBD II. The ECM can identify approximately 110 different malfunctions. For OBD II vehicles, malfunctions are also indicated via the Malfunction Indicator Light (MIL) in the instrument cluster.

Expanded MPI Control Unit diagnostic capabilities include:

- Readiness Code checking/setting
- Expanded access to Measuring Value Blocks
- Address word 33 (Generic Scan Tool) allowing use of freeze frame data.



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MPI (MMS 400 - 411)

Oxygen Sensor(s) (O2S) behind Three Way Catalyst (TWC) G130/G131

A major component of OBD II regulations requires post-catalyst oxygen sensors be installed on all vehicles. The purpose of these sensors is to monitor catalyst efficiency.

The MPI Control Unit accomplishes this function by monitoring the voltage output of the post-catalyst sensor and comparing it to a valid pre-catalyst signal. The resulting ratio is referred to as the amplitude ratio.

- Operation:

Operation of the post-catalyst sensor is similar to the pre-catalyst sensors.

The sensor Ground is no longer handled by the mounting in the exhaust pipe. The Ground is provided by the MPI Control Unit and is stepped roughly 450 mV. This stepped Ground is used to more accurately monitor the small voltage changes in the sensor.

The heating element is supplied Battery power by the Fuel Pump (FP) relay. The ground is a welded connection in the engine compartment wiring harness.

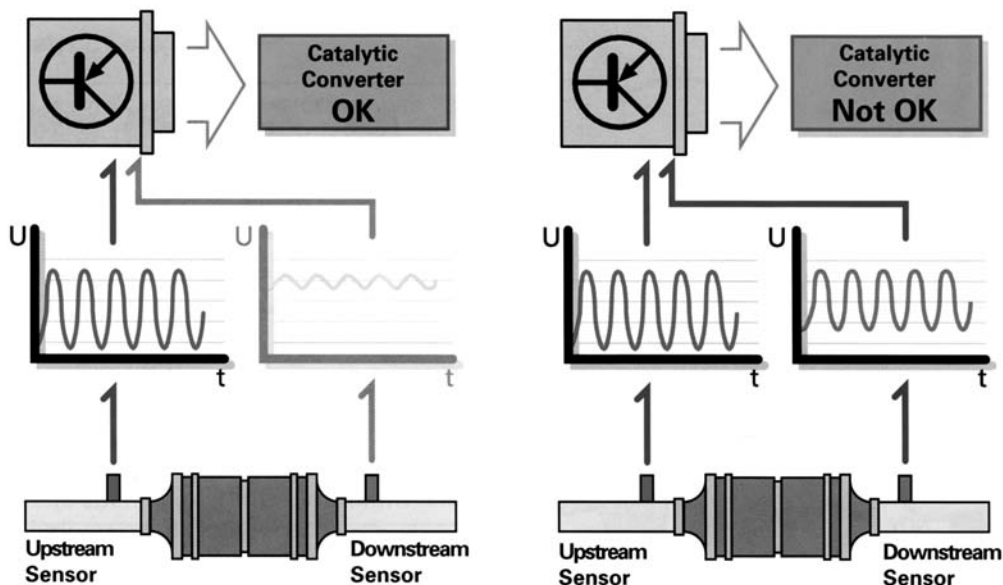
- Substitute Function:

There is no substitute function for the oxygen sensors. If the MPI Control Unit does not receive a valid signal from the sensors, lambda regulation is shut off and the control unit reverts to a backup running map.

- On Board Diagnostic:

The MPI control unit is able to recognize the following failures: Oxygen Sensor malfunction, Oxygen Sensor voltage too high, Fuel trim malfunction, Fuel trim too lean, Fuel trim too rich, and Voltage too low/air leak.

The sensor heaters are also monitored by the MPI Control Unit. The following faults are recognized: Heater circuit electrical malfunction and Heater circuit short to Battery +.



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Sensor for EVAP canister G172

The Sensor for EVAP canister G172 was added to the MPI system for the MMS 400 system.

The sensor is used as a cross check of the Evaporative Emissions (EVAP) system.

- Operation:

G172 is a piezo-electric pressure sensor. The MPI Control Unit provides a 5V reference voltage and a Ground. The sensor returns a varying voltage to the MPI Control Unit as an indication of the pressure in the EVAP canister.

As vapors accumulate in the EVAP canister, internal pressure increases. When the EVAP canister purge regulator valve N80 opens and vapors are drawn into the intake manifold pressure decreases. The Sensor for EVAP canister G172 recognizes this change in pressure. If there is a malfunction in the EVAP system the MPI Control Unit recognizes either a lack of change or a continual lack of pressure and sets an appropriate DTC.

- Substitute Function:

There is no substitute function for the Sensor for EVAP canister G172.

- On Board Diagnostic:

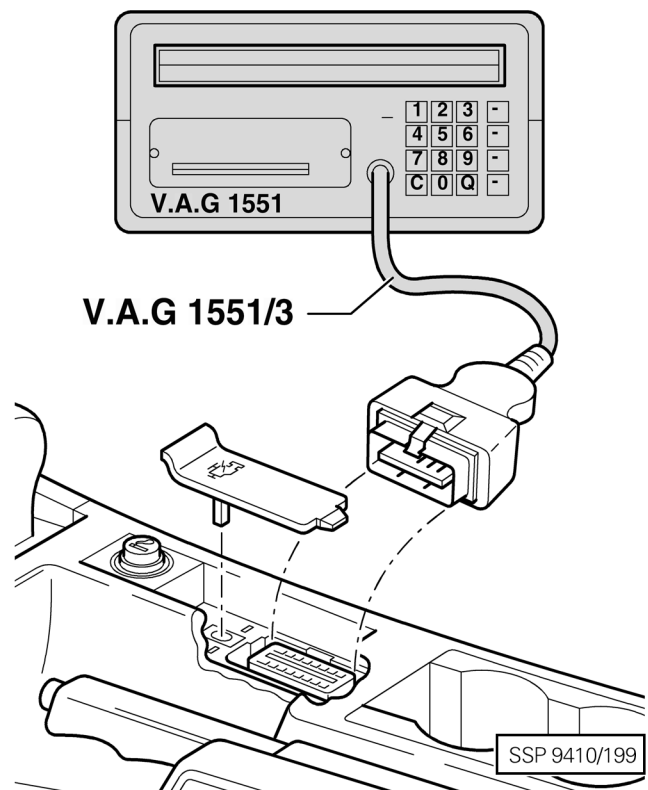
Not monitored by ECM.

Data Link Connector (DLC)

A newly designed Data Link Connector (DLC) is used on all OBD II compliant vehicles. Federal regulations require this connector to be mounted in the driver's compartment. Audi mounts this connector either in the center console, or under the drivers kneebar.

The connector is a 16-pin standardized design that allows any "generic" scan tool to be used for retrieval of DTCs under address word 33. This allows for checking readiness codes and limited sensor diagnostics without access to the VAG 1551 proprietary scan tool.

A new diagnostic cable is used (tool # VAG 1551/3) to connect to the scan tool.



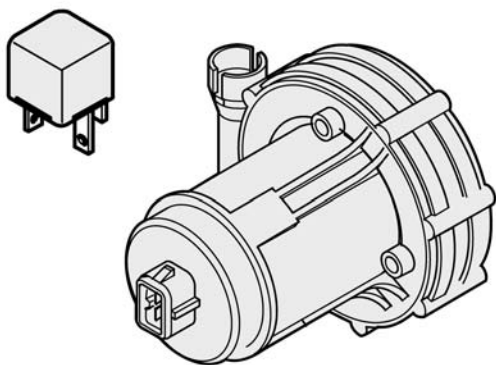
MPI (MMS 400 - 411)

Secondary Air Injection (AIR)

The Secondary Air Injection system is comprised of the following components:

- MPI Control Unit J192
- Secondary Air Injection (AIR) pump motor V101
- Combination valves
- Secondary Air Injection (AIR) pump relay J299
- Secondary Air Injection (AIR) solenoid valve N112

The AIR system is used to help minimize exhaust emissions during the cold running stage of the engine. The system functions by pumping a controlled amount of outside air into the exhaust manifolds. The air mixes with the unburned hydrocarbons in the exhaust to create a "secondary" combustion. This also helps to preheat the Three Way Catalytic converter to minimize exhaust emissions.



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- Operation:

The system operates by the Secondary Air Injection (AIR) pump motor via the (AIR) pump relay J299 triggered by the MPI Control Unit. This pumps outside air to the combination valves. At the same time the MPI control unit opens the combination valves by opening the AIR solenoid valve N112 and supplying vacuum to the combination valves.

This allows the pumped air to enter the exhaust manifold and combine with the unburned hydrocarbons. The MPI Control Unit monitors the pre-catalyst oxygen sensor signal to verify correct operation of the system.

- Substitute Function:

There is no substitute function for the Secondary Air Injection (AIR) system.

- On Board Diagnostic:

The MPI Control Unit is able to recognize the following malfunctions in the Secondary Air Injection (AIR) system:

AIR system low flow detected (banks 1 & 2), AIR system leak detected (banks 1 & 2), AIR system control module electrical malfunction, AIR solenoid valve Short to B+, AIR pump relay Short to B+, and AIR pump relay circuit electrical malfunction.

Leak Detection Pump (LDP) V144

Audi added Leak Detection Pump V144 to the 1997 A6 model equipped with the MMS 410 series system.

The purpose of the LDP system is to test the integrity of the Evaporative Emissions system for leaks. Fuel vapors are the leading contributor to hydrocarbons in the atmosphere today.

The LDP operates by pressurizing the fuel tank and EVAP system and then monitors the time for the EVAP system to leak down.

- Operation:

The LDP is engine vacuum driven pump. As the pump operates, a set of reed switches open and close. When the pressure in the EVAP system reaches 25 mbar, the pump stops running and the contacts stay open. The ECM now monitors the time until the contacts close.

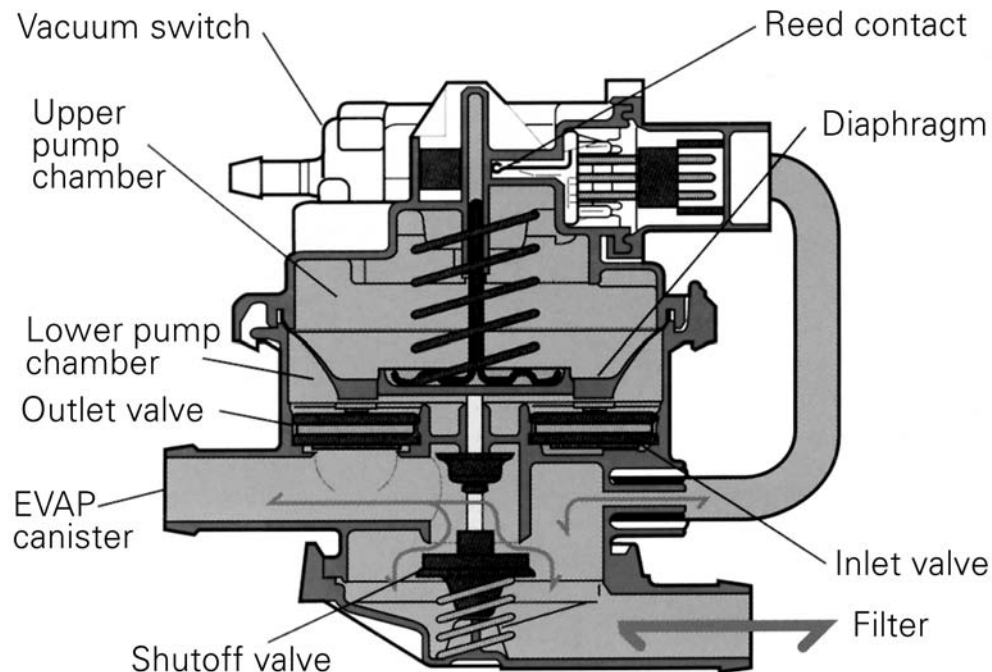
If the time for the EVAP system to leak down is from 0 to 1.15 seconds a DTC for a "Gross Leak" is set. If the time is between 1.15 and 3.3 seconds a DTC for a "Minor Leak" is stored.

- Substitute Function:

There is no substitute function for the LDP system.

- On Board Diagnostics:

The MPI Control Unit is able to recognize the following faults in the LDP system: Circuit malfunction, Short to B+, Open circuit and Insufficient vacuum.



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Motronic M5.4.2 Overview

System Description

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

Motronic M5.4.2 engine management was first used on the 3.6 and 4.2 liter engines equipping the Audi A8 (introduced to the North American market for model year 1997). This system complies with OBD-II standards that were first mandated for the 1996 model year. 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.

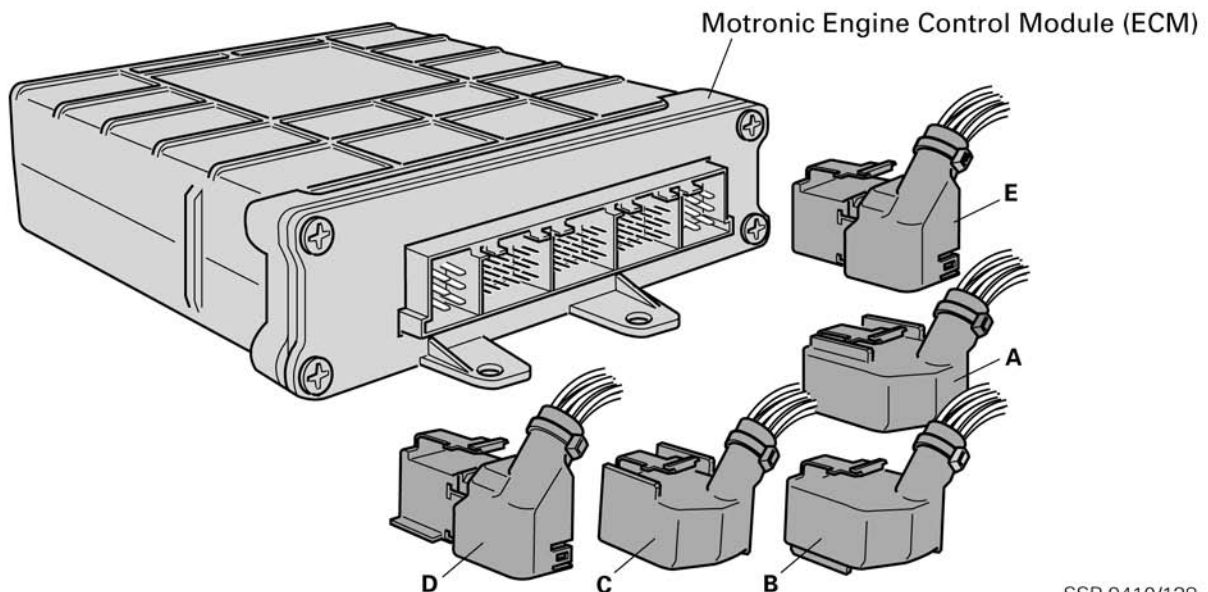
The Motronic M5.4.2 system adds component and system monitors to existing diagnostic capabilities found in earlier Motronic and MPI systems.

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 period of time, the ECT signal differs by more than 20°C from the mapped point, the ECM believes this to be implausible for the running condition and sets an appropriate DTC.



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Motronic M5.4.2 Overview

Motronic M5.4.2 systems operate with the same functionality as in previous systems, 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.

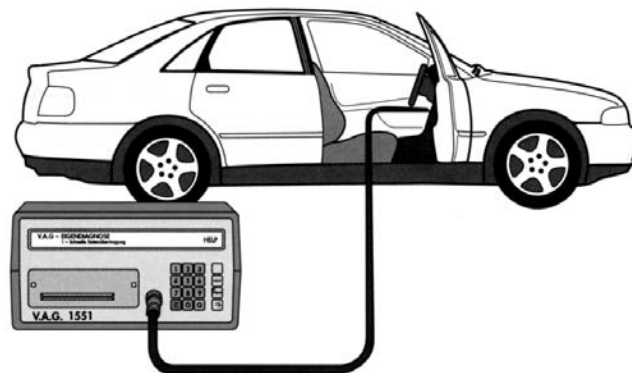
Enhancements over previous Motronic systems can include:

- 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 M5.4.2

The ECM receives inputs from sensors which are essentially the same as on other Motronic systems. These include the following sources:

- Engine Speed (RPM) sensor G28
- Intake Air Temperature (IAT) sensor G42
- HO2S, B1S1 G39 (pre-catalyst)
- HO2S, B1S2 G130 (post-catalyst)
- HO2S, B2S1 G108 (pre-catalyst)
- HO2S, B2S2 G131 (post-catalyst)
- Engine Coolant Temperature (ECT) sensor G62
- Camshaft Position (CMP) sensor G40
- Mass Air Flow (MAF) sensor G70
- Knock Sensors (KS) G61 and G66
- Throttle Position (TP) sensor, Closed Throttle Position (CTP) switch F60
- Leak Detection Pump (LDP) reed switch
- Signals received from the Transmission Range (TR) switch F125, instrument cluster, rear window defroster switch E15, A/C system, Transmission Control Module (TCM) J217, and electrical system voltage.



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The outputs or actuators are essentially the same as on other Motronic Systems, and include the following:

- Evaporative Emission (EVAP) canister purge regulator valve N80
- Fuel injectors N30 - N33, N83 - N86
- Air control valve for injectors N212
- Power Output Stages I & II, N122 & N192
- Fuel Pump (FP) relay J17
- Intake manifold change-over valve N156
- Idle Air Control (IAC) valve N71
- LDP vacuum solenoid switch
- Signals sent to the TCM J217, Instrument cluster, A/C system

Adaptation of system variables occurs in Motronic M5.4.2 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.

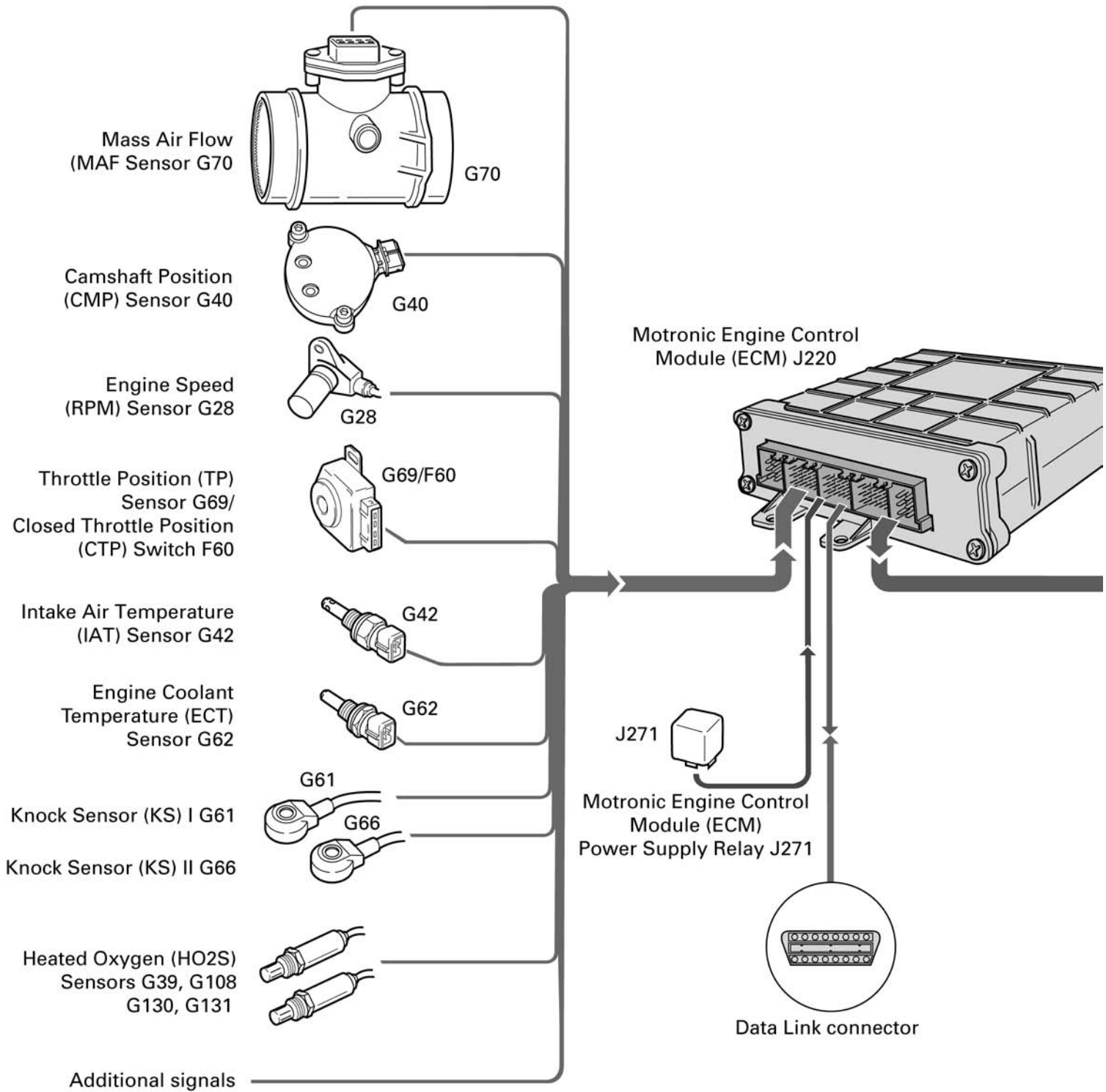
Additional Systems

Fuel delivery from the tank is the same as the Motronic M2.3.2 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.

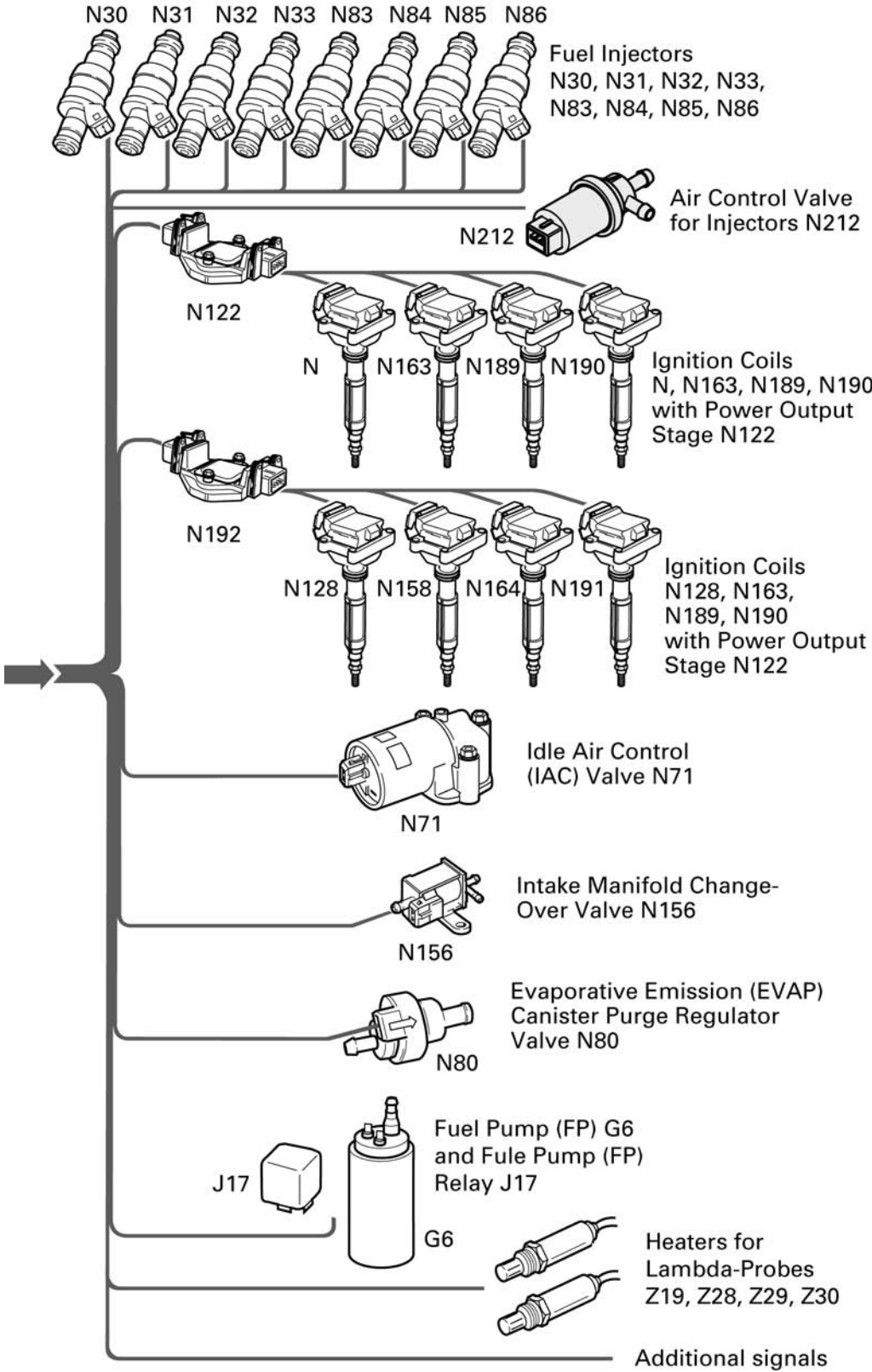
Motronic M5.4.2 Overview

A8 Motronic M5.4.2 system overview



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Motronic M5.4.2 Overview



Motronic M5.4.2 Component Differences

Motronic M5.4.2 Components

Engine Control Module J220

The Motronic M5.4.2 ECM combines all of the functionality of the M2.3.2 ECM, with additional functions and substantially enhanced diagnostics.

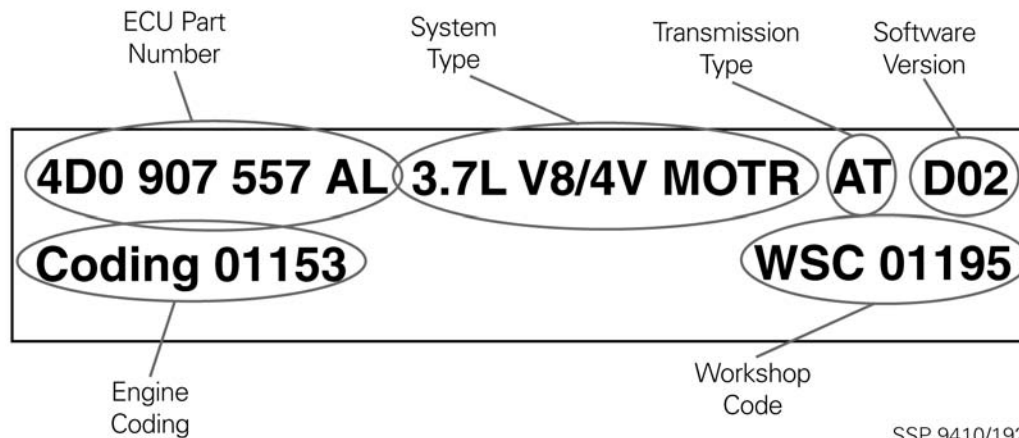
The ECM is equipped with rapid data transfer to facilitate communication with either the VAG 1551/VAG 1552 scan tools or the VAS 5051 Diagnostic Testing and Information System for retrieval of system and component malfunctions. System operating information can be viewed in real time as an aid in diagnosis.

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.

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 will not function properly. The ECM is electronically coded using the scan tool.



Motronic M5.4.2 Component Differences

Input Sensors

Motronic M5.4.2 engine management systems rely on input sensors for engine operating data in much the same way as on earlier Motronic and MPI systems. These input sensors are detailed in this section.

Mass Air Flow (MAF) sensor G70

A **hot film mass air flow sensor** is installed on both the 3.7 and 4.2 liter A8 engines using Motronic M5.4.2 from model year 1997.

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 on previous the hot-wire versions.

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

- Operation:

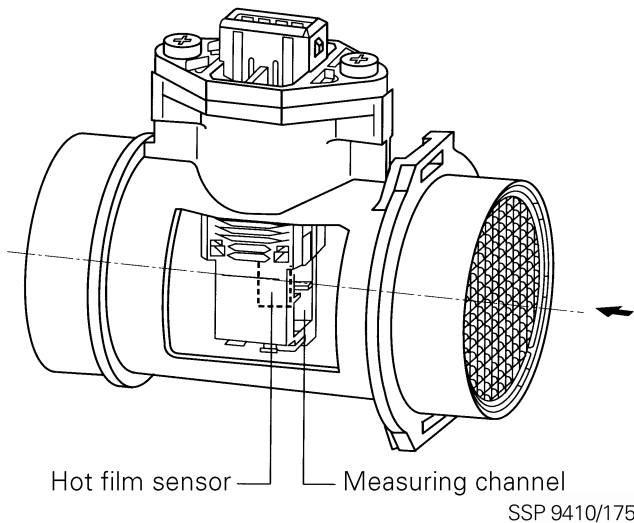
Air flows past the hot film and cools it. Current is supplied to maintain constant temperature. Changing current is converted to a signal used by the ECM to determine engine load.

- Substitute function:

If a fault develops with the signal from the mass air flow sensor, the signal from the throttle position sensor 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.

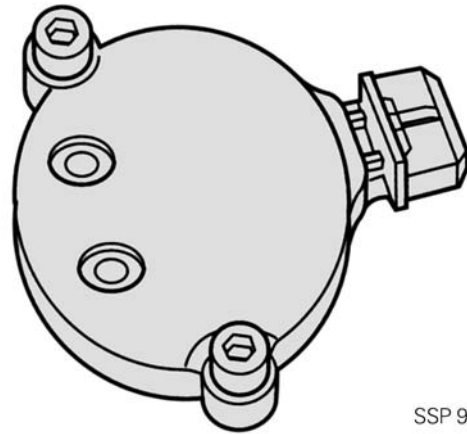


Motronic M5.4.2 Component Differences

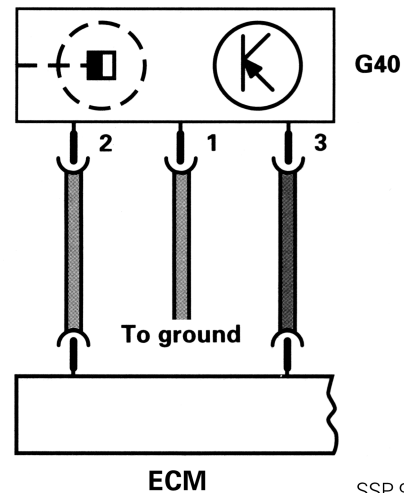
Camshaft Position (CMP) sensor G40

Motronic M5.4.2 uses a distributor-less ignition system with a single camshaft position sensor. A8 3.7 and 4.2 liter engines use a trigger wheel attached to the rear end of the driver's side (bank 2) exhaust 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.



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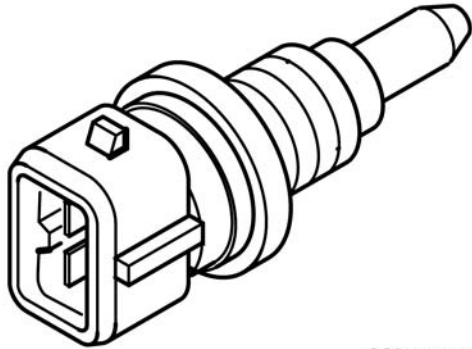
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Motronic M5.4.2 Component Differences

Intake Air Temperature (IAT) Sensor G42

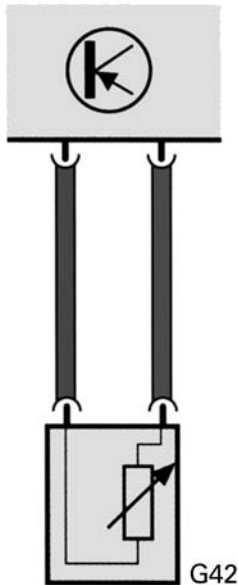
The intake air temperature sensor is an NTC sensor (see Glossary), and is mounted in the intake manifold. As incoming air for combustion flows past the sensor, the resistance of the sensor changes, providing the ECM with air temperature data.

Intake air temperature sensor signal data is used as a correction factor for cold starting, ignition timing and idle speed stabilization and is factored into the replacement signal for loss of the ECT signal.



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Electrical Circuit



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- 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 replacement value from memory.

- On Board Diagnostic (OBD):

The ECM recognizes open circuits and short circuits.

Motronic M5.4.2 Component Differences

Heated Oxygen Sensors (HO2S)

- HO2S G39
- HO2S 2 G108

Heated oxygen sensors are constructed of the ceramic material zirconium dioxide and are stabilized with yttrium oxide. 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.

- Operation, Pre-Catalyst HO2S:

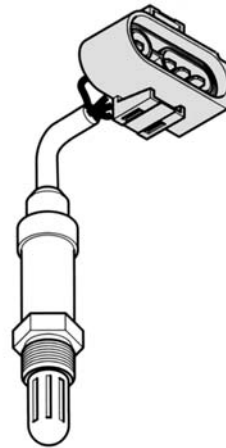
Operation is identical to previous Motronic systems, except for how the sensor is grounded.

Motronic M5.4.2 systems use a four-wire heated oxygen sensor. The heater element receives battery power from the fuel pump relay J17, and ground through a common sensor ground in the wiring harness.

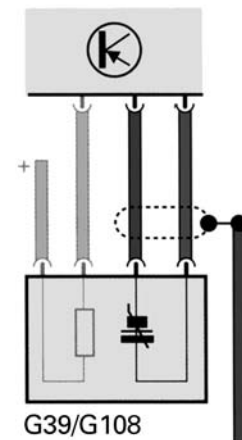
The ground for the oxygen sensor is no longer obtained through the mounting threads in the exhaust. The ECM provides a stepped ground of approximately 350 mV. This ensures an accurate signal to the ECM.

- 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.

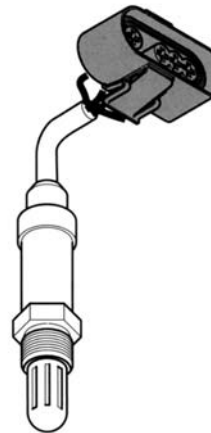


Electrical Circuit

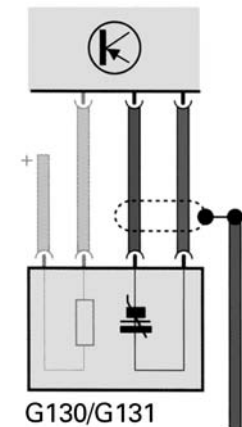


G39/G108

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Electrical Circuit



G130/G131

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Motronic M5.4.2 Component Differences

- On Board Diagnostic (OBD):

The ECM recognizes Range/Performance, as well as adaptation 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.

O2S Behind Three Way Catalytic Converter (TWC) G130

O2S 2 Behind Three Way Catalytic Converter (TWC) G131

A second set of oxygen sensors is added to the Motronic M5.4.2 system to monitor the function of the three-way catalytic converters. Positioned at the converter outlets, the post-catalyst or downstream heated oxygen sensors monitor oxygen levels after the catalyst to determine proper converter operation.

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

- Operation, Post-Catalyst HO2S:

Operation of the post-cat sensor is identical to MPI system post-cat, except that the heater element ground is provided by the ECM and pulsed to minimize the possibility of cracking the ceramic heater element.

The ECM uses the post-cat sensors to monitor long term fuel trim by observing trends in the sensor output. If post-cat oxygen content is consistently high, the system will adapt long-term fuel trim to enrich the mixture.

- Substitute function:

There is no direct substitute function for the post-catalyst oxygen sensor. If the sensor malfunctions, no TWC monitoring will occur.

- On Board Diagnostic (OBD):

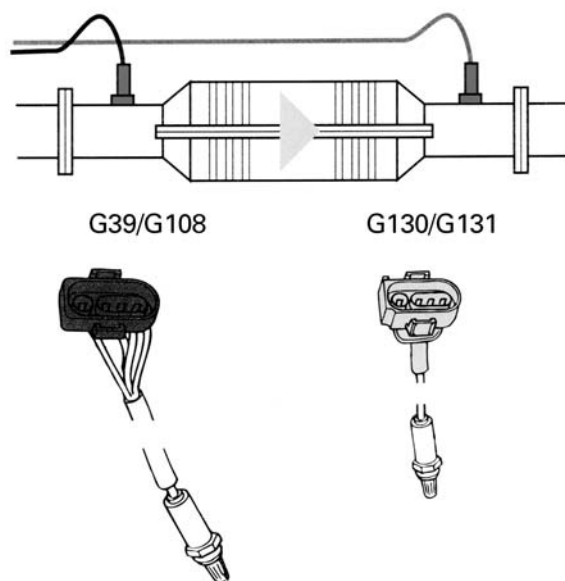
The ECM recognizes malfunctions in the post-catalyst oxygen sensor signal if no plausible signal is received within approximately five minutes after an engine start with coolant temperature over 40°C (104°F). It also recognizes open circuits and short circuits.

The ECM 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.

Note:

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

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



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Motronic M5.4.2 Component Differences

Actuators (outputs)

Motronic M5.4.2 engine management systems rely on different actuators to run the engine and operate related systems in much the same way as those found on earlier Motronic and MPI systems. These input sensors are detailed in this section.

Air-shrouded Fuel Injectors

Cylinder 1 Fuel Injector N30

Cylinder 2 Fuel Injector N31

Cylinder 3 Fuel Injector N32

Cylinder 4 Fuel Injector N33

Cylinder 5 Fuel Injector N83

Cylinder 6 Fuel Injector N84

Cylinder 7 Fuel Injector N85

Cylinder 8 Fuel Injector N86

Air Control Valve for Injectors N212

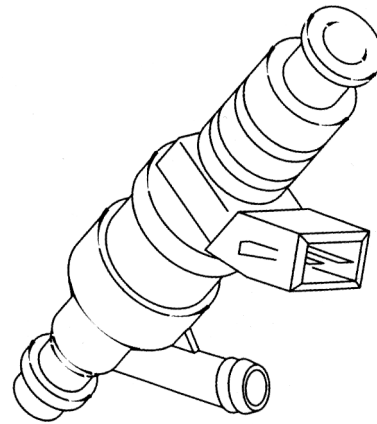
Motronic fuel injectors are electronically controlled **solenoid valves** (see Glossary).

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 12-20 Ohms. It should be noted that higher temperatures will cause resistance values to increase.

- Operation:

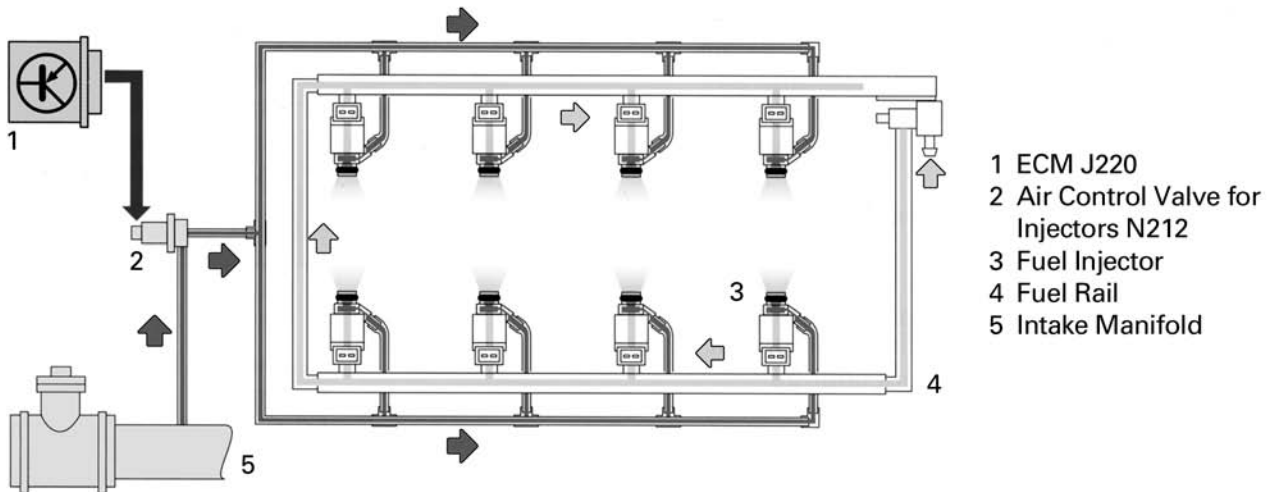
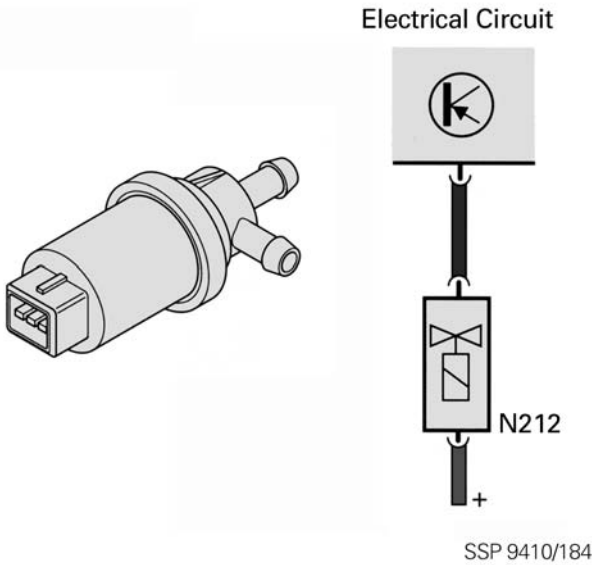
Operation is identical to previous engine management systems, except for the use of air-shrouded injectors. Both A8 engine versions of Motronic M5.4.2 use air-shrouded fuel injectors to help atomize fuel more effectively. The additional air mixes more thoroughly with the fuel, resulting in more efficient combustion. This reduces exhaust emissions, especially at the low flow rates of an idling engine, and also improves idle quality.



SSP 9410/161

Motronic M5.4.2 Component Differences

- 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).
- Operation:
Low pressure air (vacuum) is drawn in from the measured air flow of the MAF sensor and directed past each fuel injector tip. 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. Air flow is controlled by the ECM by the Air control valve for injectors, N212. Additional air is supplied to a cold engine at idle and to a warm engine at speeds higher than 1500 RPM.
- On Board Diagnostics:
The ECM recognizes electrical malfunctions and short circuits to positive.



SSP 9410/185

Motronic M5.4.2 Component Differences

Power Output Stage N122

Ignition Coil N

Ignition Coil 4 N163

Ignition Coil N189

Ignition Coil N190

Power Output Stage 2 N192

Ignition Coil 2 N128

Ignition Coil 3 N158

Ignition Coil 5 N164

Ignition Coil N191

The distributor-less ignition used on the 3.7 and 4.2 liter 8-cylinder engines differs from the MPI versions. Each cylinder has an ignition coil mounted directly above the spark plug on the cylinder head (valve) cover (N, N163, N189, and N190 and N192, N128, N158, N191). A short suppressor/connector links the two components. Power Output Stages, N122 and N192, with four separate outputs each, are mounted near the air cleaner 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 M5.4.2 Component Differences

Intake Manifold Change-Over Valve N156

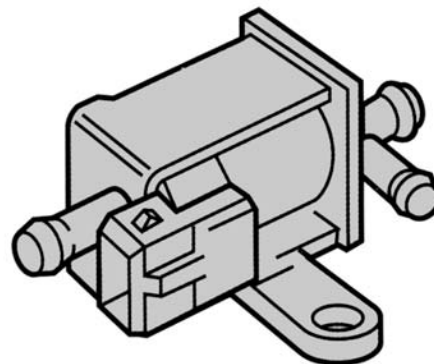
Both V8 engines used in the A8 have an intake manifold with two sets of different length intake runners. At lower engine speeds the length of the intake runner is lengthened to produce a ram effect. At higher RPM intake charge velocity rises and a shorter runner length is needed for optimal cylinder 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, or dual stage, 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 RPM.

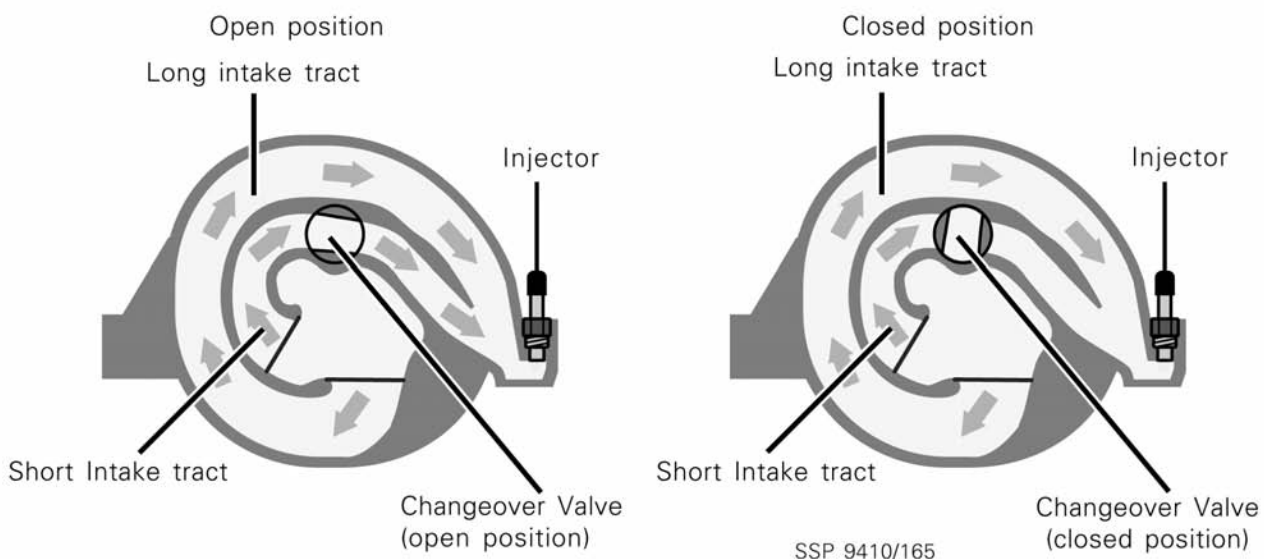
- Operation:
The intake manifold change-over valve receives a command from the ECM at 3950 RPM. It then supplies manifold vacuum to the change-over servo which, in turn, moves the rotary valve from the low speed position to the high speed position. When the engine speed drops, the change-over valve closes 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 determining rotary valve position.



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SSP 9410/165

Motronic M5.4.2 Component Differences

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 operating the evaporative emissions solenoid valve.

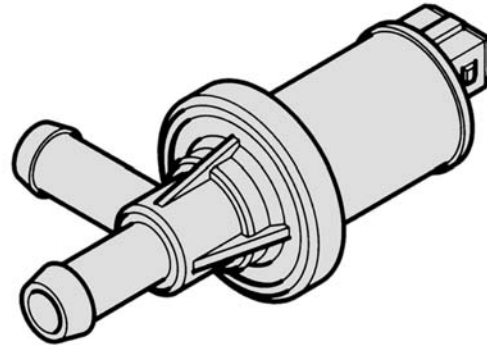
The Evaporative Emissions (EVAP) canister purge regulator valve N80 is a **solenoid valve** (see Glossary) that allows fuel vapors stored in the evaporative emissions (charcoal) canister to be admitted into the intake manifold to be consumed in the combustion process.

- Operation:

N80 is normally closed (no current flow). The ECM uses a duty cycle to precisely control the quantity and timing of fuel vapors admitted into the engine. This process begins after the HO2S is on line. During LDP operation, on vehicles so equipped, N80 operates as a check valve to monitor system integrity.

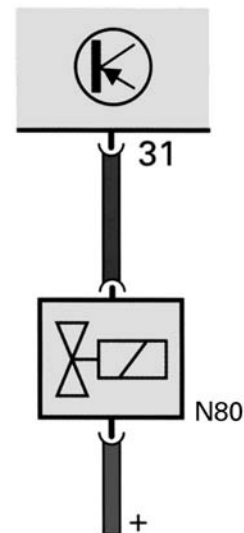
- On Board Diagnostic:

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



SSP 9410/189

Electrical Circuit



SSP 9410/190

Motronic M5.4.2 Component Differences

Malfunction Indicator Light (MIL)

The malfunction indicator light (MIL) in the instrument cluster has a new operating mode for the OBD-II compliant Motronic M5.4.2 system.

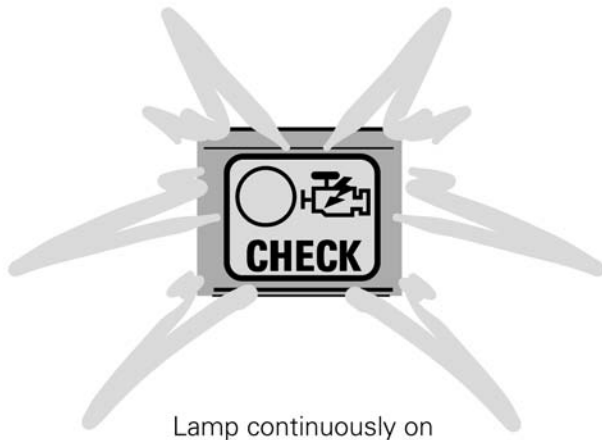
- Operation:

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.



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Motronic M5.4.2 Component Differences

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.

The fuel tank is contoured to fit against the underside of the vehicle for maximum safety. This allows for a nominal volume of approximately 90 liters (24 U.S. gallons). Due to the shape of the tank, 3 mechanical suction jet pumps supply fuel to the area of the fuel pump inlet. Dual fuel gauge sending units are also employed.

- 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

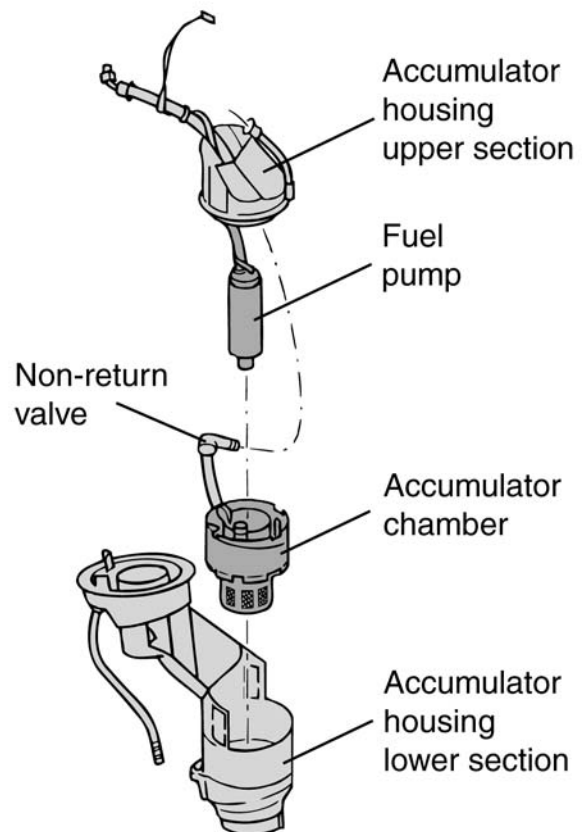
Fuel is drawn in through a screen at the bottom of the housing assembly by a vane-type pump. The screen provides coarse filtration, and the vane-type pump acts as a transfer pump. Its high volume design supplies fuel to the fuel accumulator which is within the pump housing.

- 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).



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Motronic M5.4.2 Component Differences

Leak Detection Pump (LDP) V144

Later versions of Motronic M5.4.2 use a pump 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:

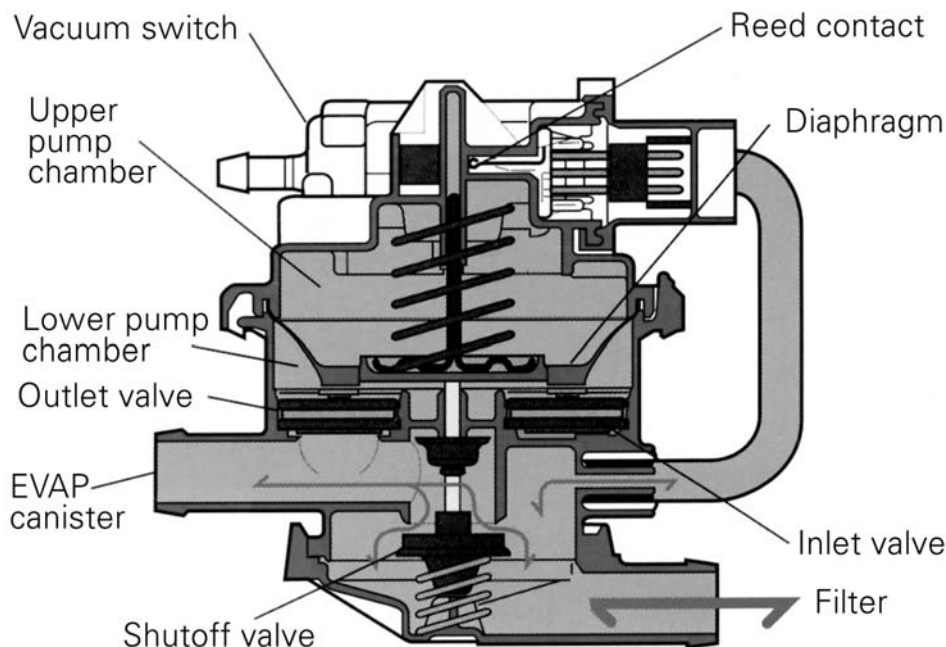
- a vacuum solenoid switch controlled by the ECM
- a reed switch operated by the pump diaphragm

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 #941903.



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Motronic M5.9.2 Overview

System Description

Motronic Engine Management Systems moved to the next level of development with the introduction of M5.9.2.

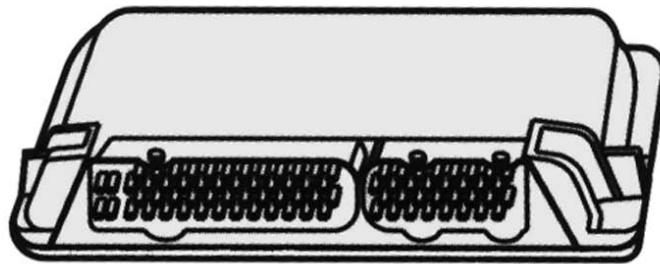
Motronic M5.9.2 is a modified version of the earlier M5.4.2 system, with a new 80-pin ECM. The ECM accommodates new functions, input sensors and actuators. Enhancements improve starting and fuel economy, and reduce exhaust emissions.

All Motronic 5.9.2 engine management systems comply with OBD-II standards which apply to all passenger vehicles sold in the United States.

Motronic M5.9.2 systems operate with the same functionality as their predecessors. Operation of some existing components has been modified, several components have been eliminated and several new components have been added.

Enhancements over previous Motronic systems can include:

- Diagnosis of fuel tank and venting system integrity
- Ability to control 4-cylinder and 6-cylinder engine with or without turbocharging.
- ECM linked to the CAN-bus for communication with other vehicle systems (see SSP # 971903, The CAN Data Bus).



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Motronic M5.9.2 Overview

Input/Outputs - Motronic M5.9.2

A 80-pin ECM receives input signals from sensors which are essentially the same as on Motronic M5.4.2 systems. These include the following sources:

- Engine Speed (RPM) sensor G28
- Intake Air Temperature (IAT) sensor G42
- Heated Oxygen Sensor (HO2S) B1S1 G39 (pre-catalyst)
- Heated Oxygen Sensor (HO2S) B2S1 G108 (post-catalyst)
- Heated Oxygen Sensor (HO2S) B1S2 G130 (pre-catalyst)
- Heated Oxygen Sensor (HO2S) B2S2 G131 (post-catalyst)
- Engine Coolant Temperature (ECT) sensor G62
- Camshaft Position (CMP) sensor G40
- Mass Air Flow (MAF) sensor G70
- Knock Sensors (KS) G61 and G66
- 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 previously received from the Throttle Position (TP) sensor G69, and Closed Throttle Position (CTP) switch F60, 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:

- Leak Detection Pump (LDP) V144, reed switch
- Camshaft Position (CMP) sensor 2 G163

The outputs or actuators are essentially the same as on Motronic M5.4.2, and include the following:

- Evaporative Emission (EVAP) canister purge regulator valve N80
- Fuel injectors N30 - N33, N83 - N86
- Air control valve for fuel injectors N212
- Intake Manifold Change-Over Valve N156
- Power output stage N122
- Fuel Pump (FP) relay J17 and Fuel Pump G
- Secondary Air Injection (AIR) pump relay J299 and Secondary Air Injection (AIR) pump V101
- Secondary Air Injection (AIR) solenoid valve N112
- Signals sent to the TCM J217, Instrument cluster

The IAC valve 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:

- Wastegate Bypass Regulator Valve N75
- Leak Detection Pump (LDP) V144, vacuum solenoid switch
- Valve -1- for camshaft adjustment N205
- Valve -2- for camshaft adjustment N208

Adaptation of system variables occurs in Motronic M5.9.2 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.

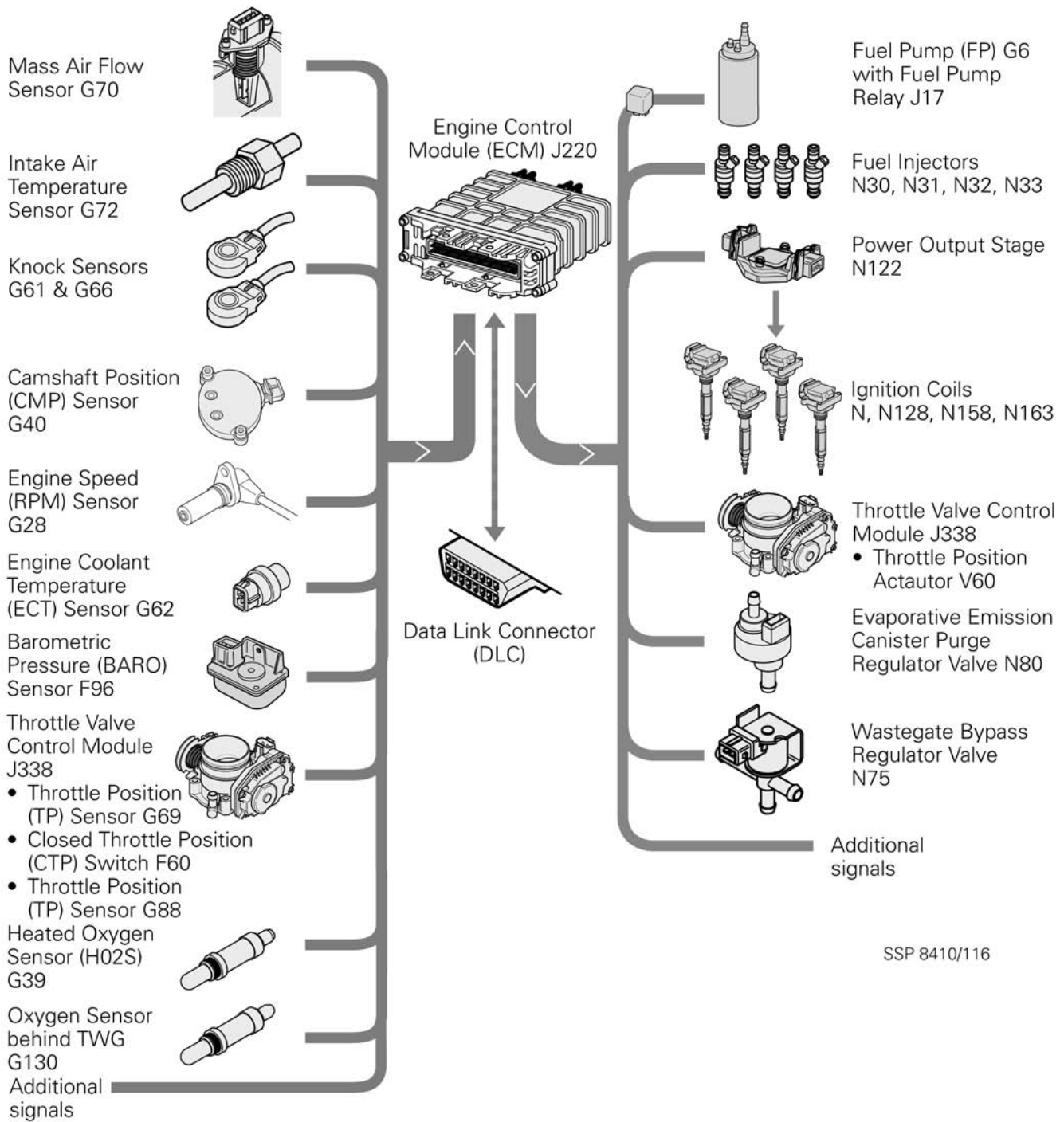
Additional Systems

Fuel delivery from the tank is the same as the Motronic M5.4.2 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 M5.9.2 Overview

1.8 liter turbo, system overview



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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 M5.4.2 version of the system. Several new functions, input sensors, and actuators have been added to the 80-pin ECM.

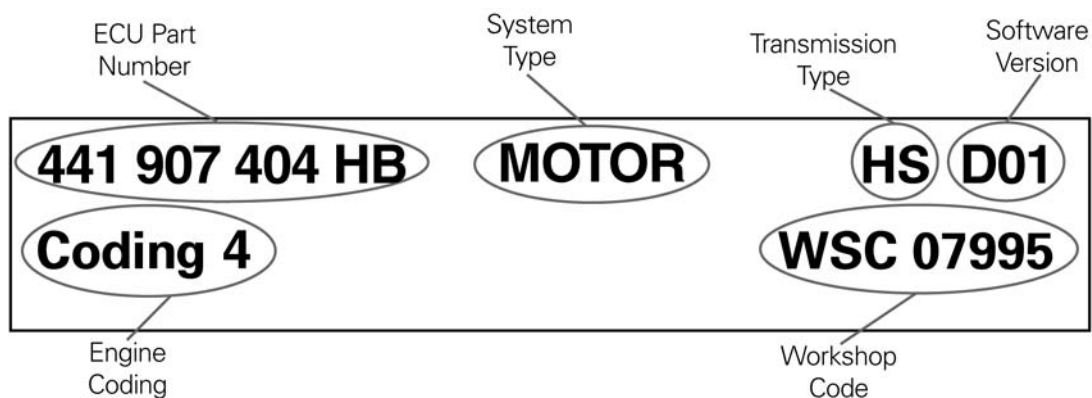
Data transfer between the ECM and other powertrain systems has been enhanced through the use of a Controller Area Network. This high-speed network, called the CAN data bus, links all of the powertrain control modules in a given vehicle to allow data sharing. Engine speed, fuel consumption, throttle valve 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 two different engine types:

- 1.8 liter 5-valve 4-cylinder turbocharged engine used in the A4 for the 1997 through 1999 model years
- 2.8 liter 5-valve V6 engine used in the A4 and the A6 for the 1998 and 1999 model years

Due to the differences in engine types, not all changes are found on both engines.

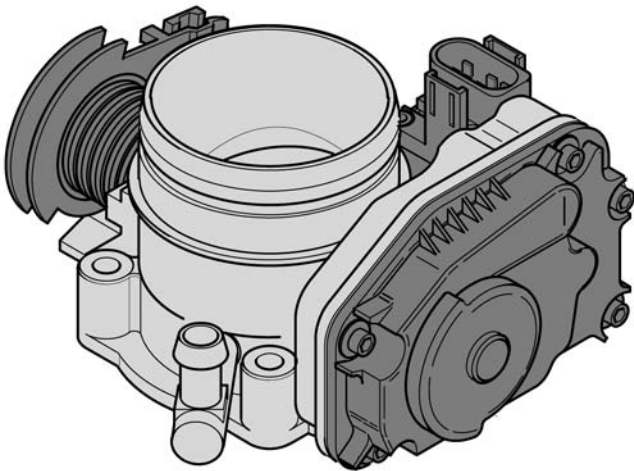


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Motronic M5.9.2 Component Differences

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.

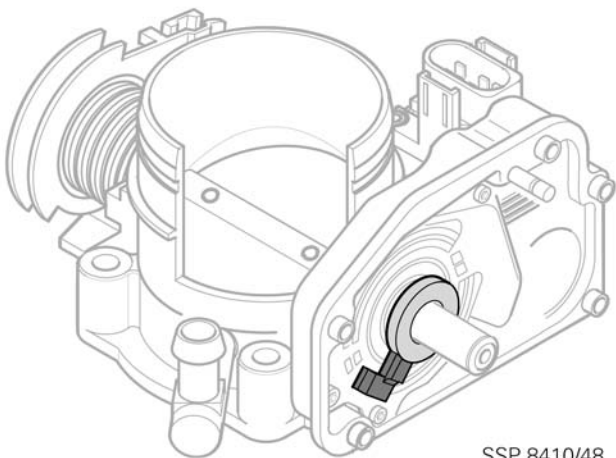
G69 sends information to the ECM regarding the position of the throttle plate throughout the full range of travel.

- 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 M5.9.2 Component Differences

Closed Throttle Position (CTP) switch F60

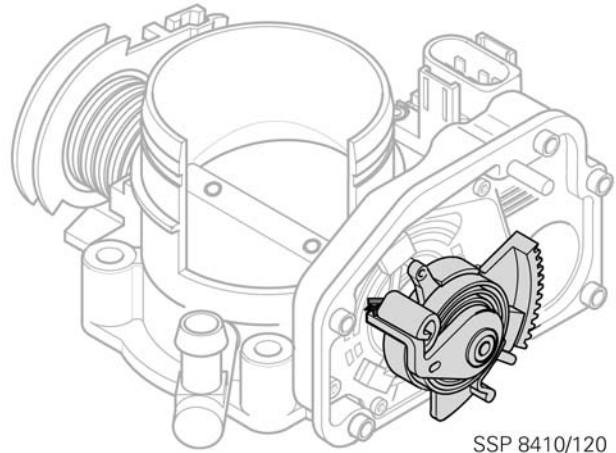
New, and included within the throttle valve control module housing, is a Closed Throttle Position (CTP) switch F60. This on/off switch is used to identify the closed throttle position for idle control functions.

- 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

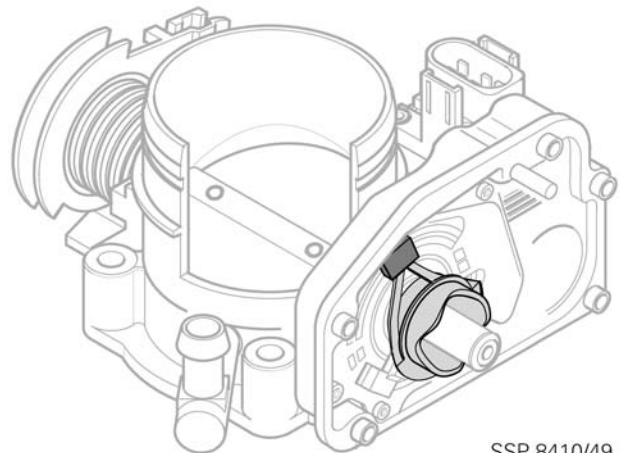
Also new and included within the throttle valve control module housing is a second throttle position sensor, G88. This TPS provides feedback data for the Throttle Position (TP) actuator V60, and the throttle stop position.

- Operation:

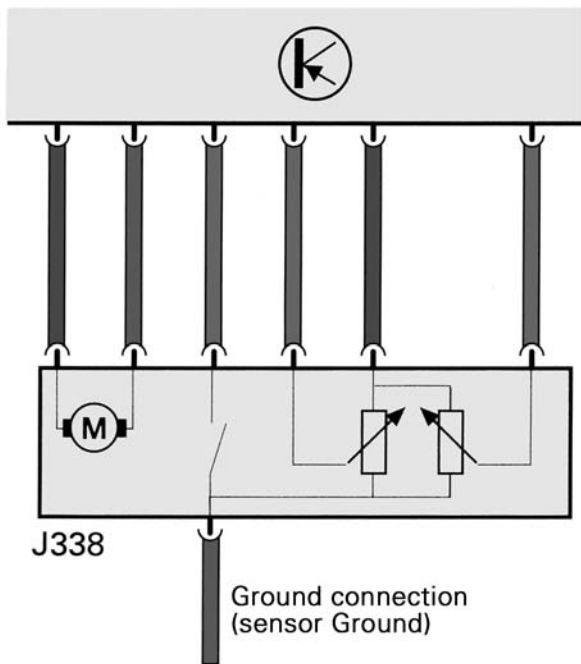
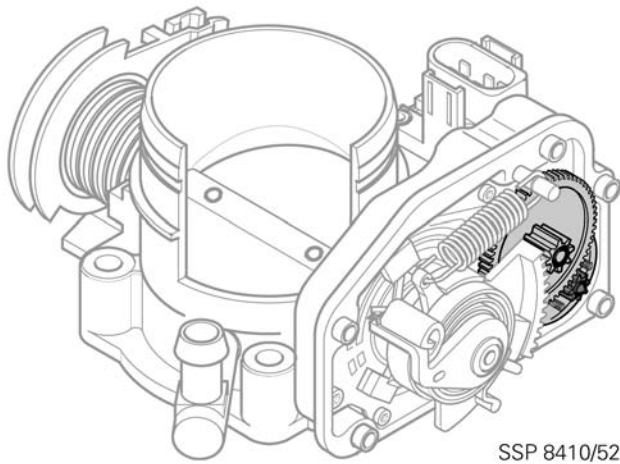
The ECM supplies a fixed voltage signal of approximately 5 Volts to the TPS. Movement of the throttle valve by the throttle position actuator changes the voltage which is returned to the ECM.

- On Board Diagnostic (OBD):

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



Motronic M5.9.2 Component Differences



Note:

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

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 Closed Throttle Position (CTP) switch F60.

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).

Motronic M5.9.2 Component Differences

Input Sensors

Most of the input sensors and signals are the same as those on the earlier M5.4.2 as shown in the Motronic overview illustration. Differences between the M5.9.2 and M5.4.2 versions are summarized in this section.

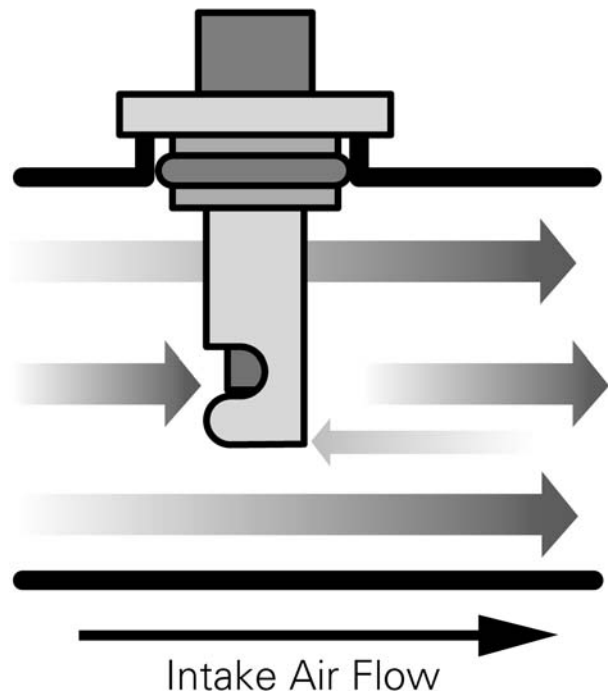
Mass Air Flow (MAF) Sensor G70

Motronic M5.9.2 uses a new MAF Sensor design 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.

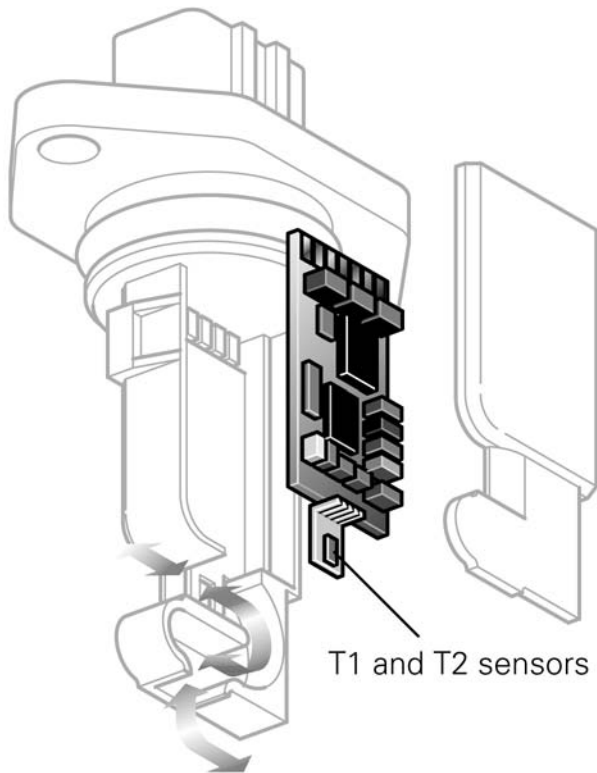
The new MAF sensor incorporates a feature to cancel the effects of normal intake air turbulence caused by the shape of the manifolds and the opening and closing of the valves. Under some circumstances, previous sensors would measure this reflected air pulse a second time. The ECM could not detect this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

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.

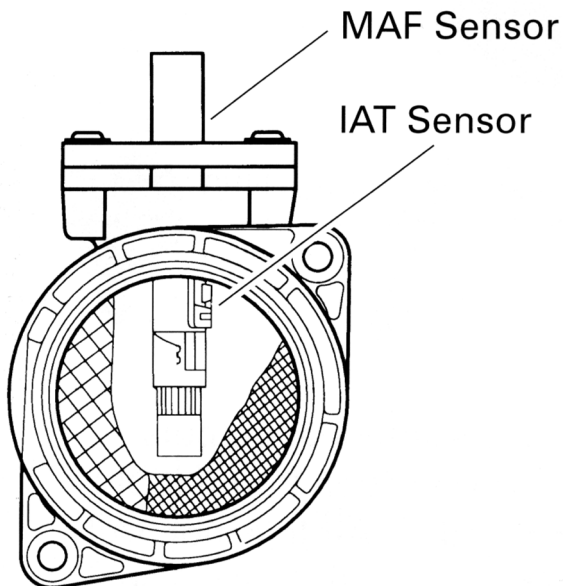


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Motronic M5.9.2 Component Differences



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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.

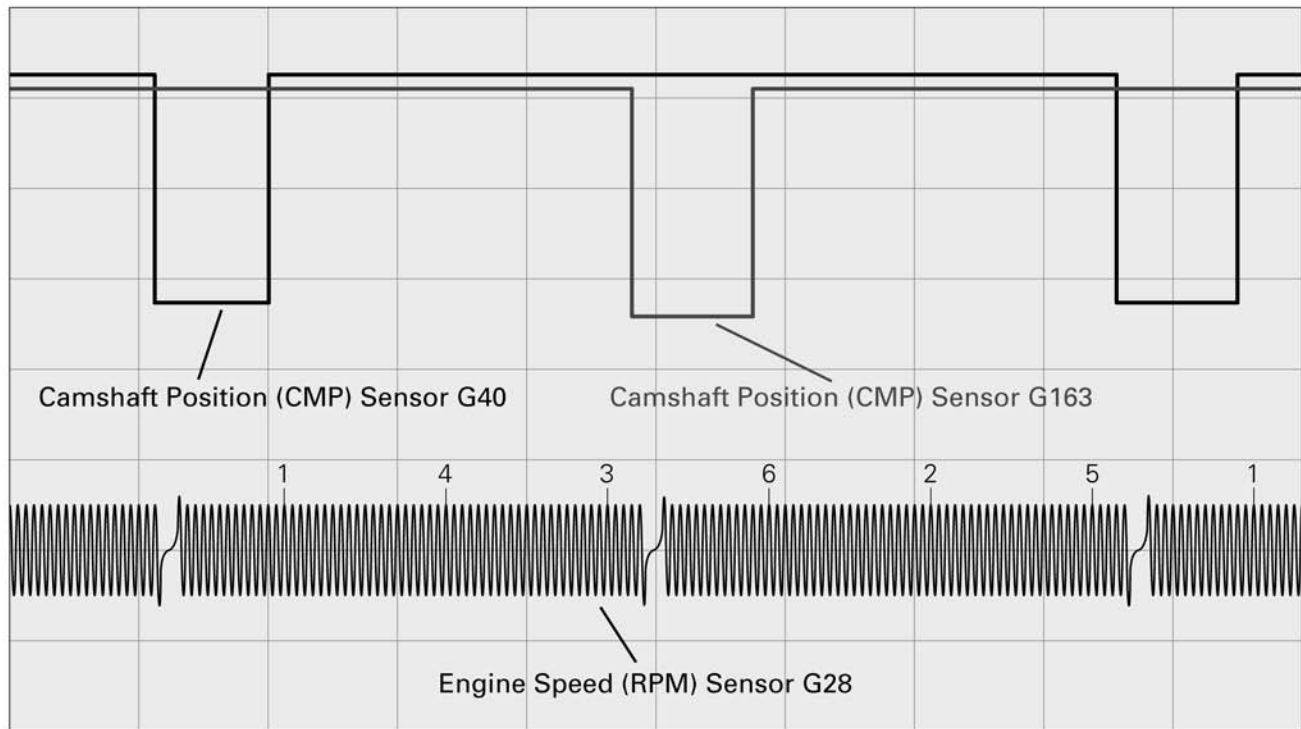
- **Operation:**
Two temperature sensors, T_1 and T_2 , are mounted together with a common heating element near the air flow sensor. The heating element warms both sensors equally when there is no air flow. As air flows over sensors T_1 and T_2 when the engine runs, they are cooled at different rates. 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

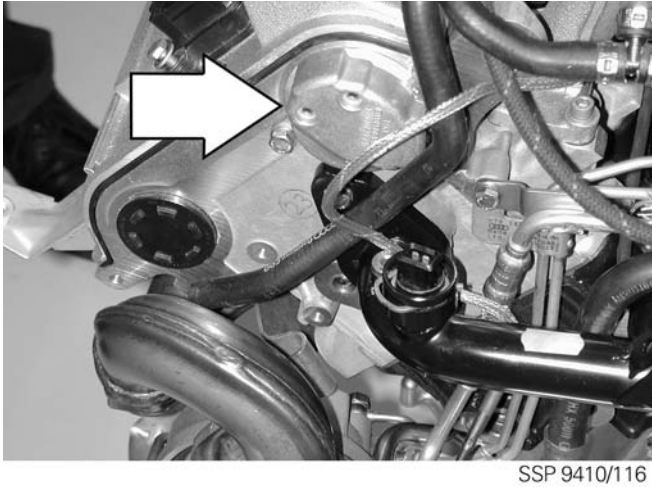
Both versions of Motronic M5.9.2 use distributor-less ignition systems with camshaft position sensors.

A4 and A6 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.



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Motronic M5.9.2 Component Differences

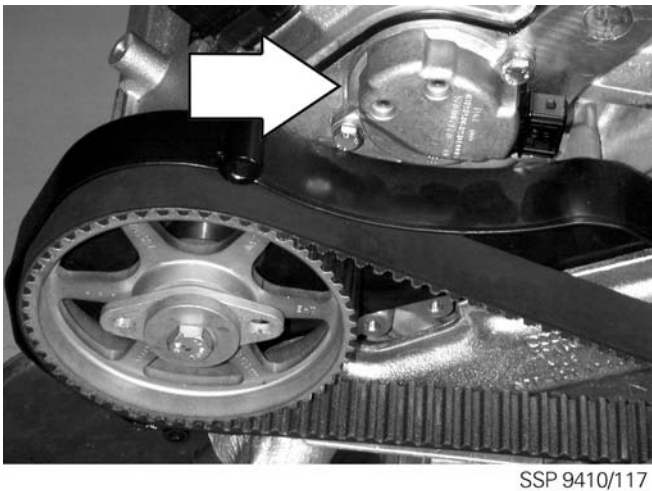


- Operation:

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.



A4 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.

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.

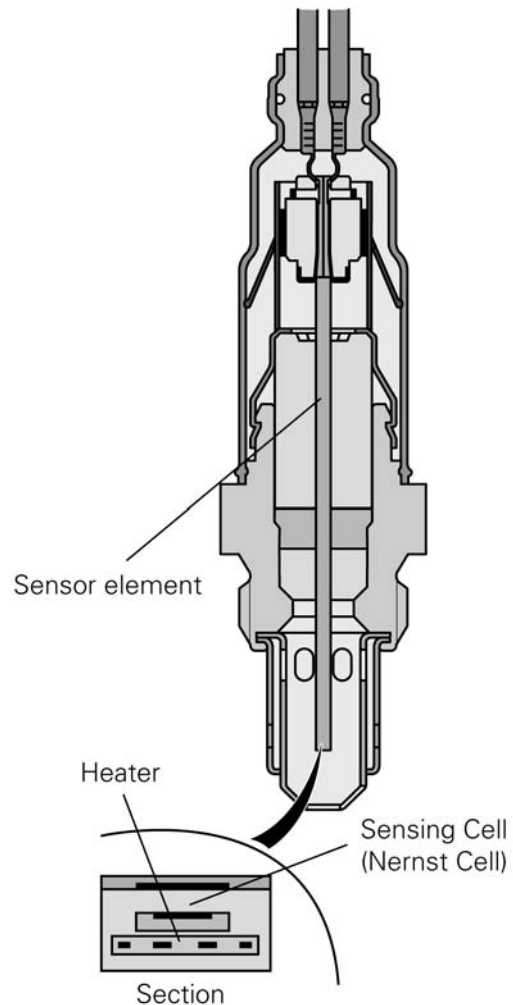
Planar construction takes advantage of newly developed layering processes that allow thin sheets, or ribbons, of the zirconium dioxide (ZrO_2) sensing material to be stacked with other sensing elements and a flat heating element. This flat or planar construction has several advantages:

- 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

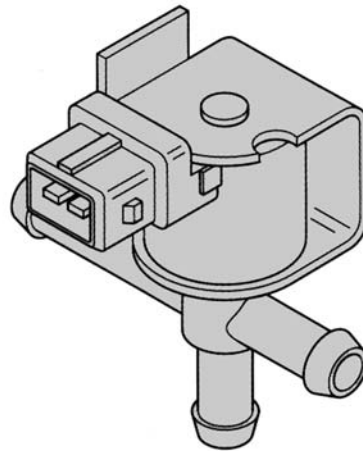
Actuators (outputs)

Motronic M5.9.2 actuators are essentially the same as those found on M5.4.2. Not all changes are found on both engines. A summary of the differences between M5.4.2 and M5.9.2 is detailed in this section, along with variations within M5.9.2.

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).



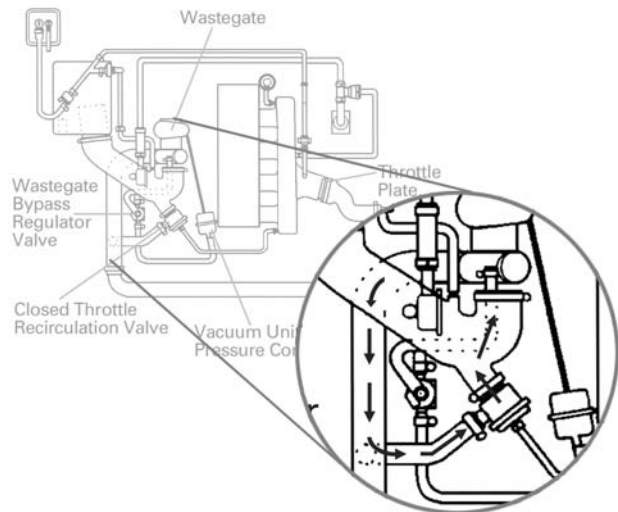
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Motronic M5.9.2 Component Differences

Charge pressure recirculation valve

In addition to the Wastegate Bypass Regulator Valve N75, turbocharged engines also use a mechanical manifold vacuum-actuated recirculation valve during deceleration and shifting. This valve minimizes compressor stall and the resulting turbocharger lag to significantly improve throttle response.

- Operation:
When the throttle valve is closed under engine load, manifold vacuum is applied to the recirculation valve diaphragm. This opens a passage allowing the pressurized air charge to be recirculated to the inlet side of the turbocharger rather than compressed against the closed throttle valve.
- On Board Diagnosis:
This component is a mechanical device and its operation is not monitored by the ECM.



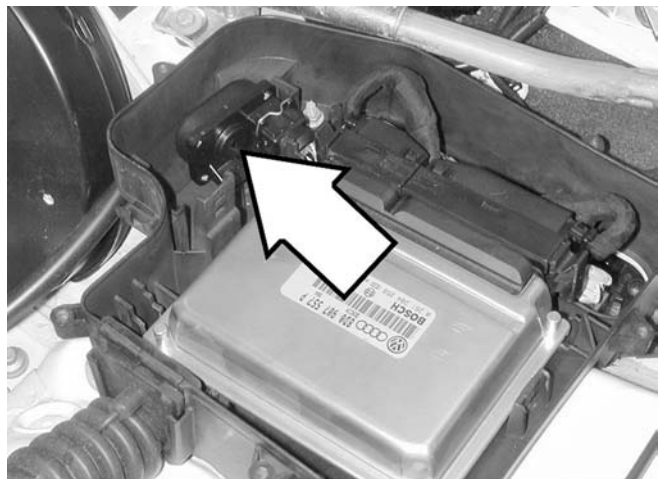
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Barometric Pressure (BARO) Sensor F96

The turbo-charged 1.8 Liter engine is equipped with a pressure sensing device to signal the ECM about atmospheric pressure which varies from 14.7 psi at sea level to 12.3 psi or less in mountainous areas. The BARO sensor is a separate component located near the ECM.

The BARO signal is used to control turbo-charger boost pressure at higher altitudes where lower air pressure (density) can cause the turbo-charger to overspeed. The signal is also used to adjust the air/fuel mixture ratio at engine start-up to compensate for the decreased oxygen levels at higher altitudes.

- Operation:
The BARO sensor measuring chamber is open to the atmospheric. A piezo-electric crystal generates a signal that varies with the changing atmospheric air pressures.
- On Board Diagnostic:
The ECM recognizes open circuits and short circuits.



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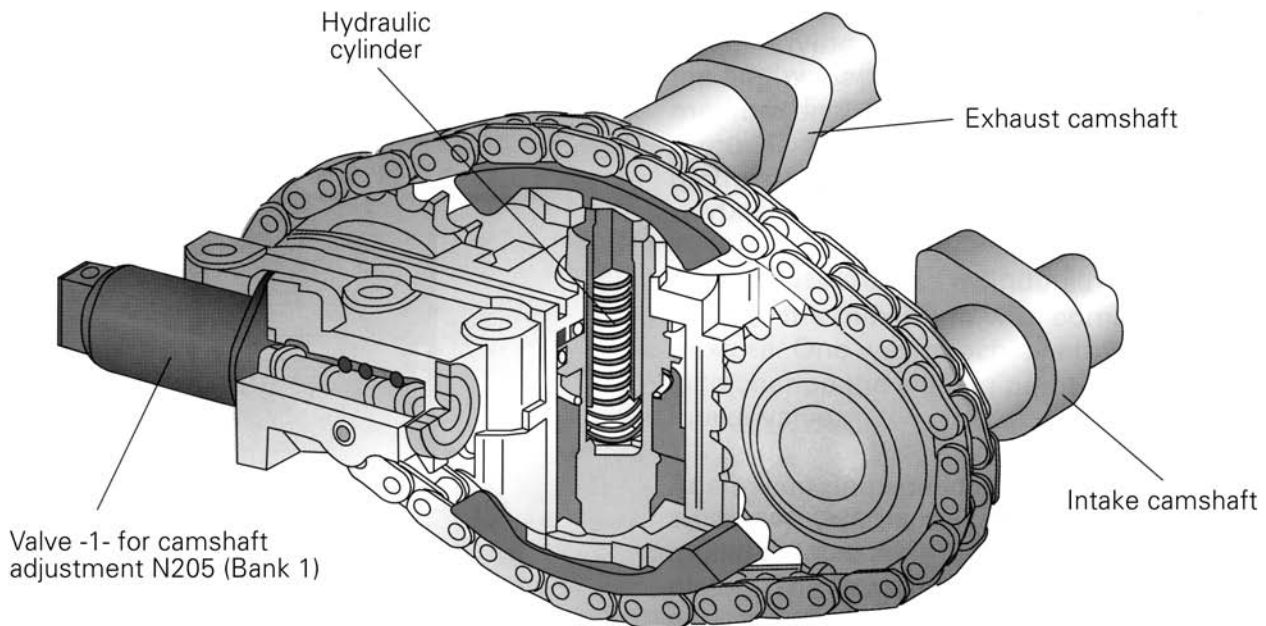
Motronic M5.9.2 Component Differences

Valve -1- for camshaft adjustment N205

Valve -2- for camshaft adjustment N208

The 2.8 liter 5V V6 used in the A4 and A6 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:

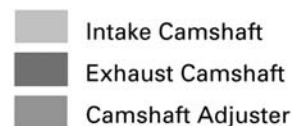
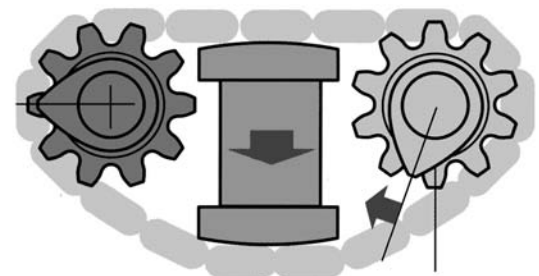
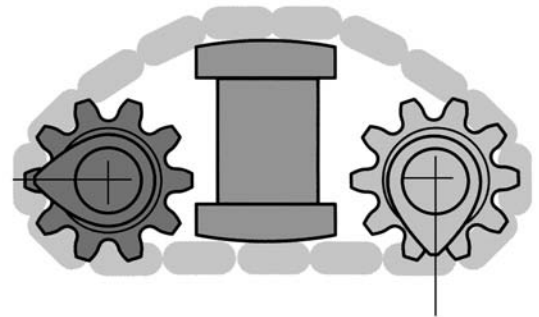
Each cylinder bank has a camshaft adjuster to keep the drive chains properly tensioned. Working with each tensioner is a solenoid valve that uses engine oil pressure to effectively move the slack side of the chain from one side of its travel to the other. By changing position of the slack side of the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



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Motronic M5.9.2 Review

Review

1. **Technician A says that the Motronic M5.9 engine management system is a further development of Motronic M5.4.2.**

Technician B says that the Motronic M5.9.2 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 variable camshaft geometry used on the 2.8 liter 5-valve V6 engine?**

- a. Optimum low RPM torque.
- b. Minimum exhaust emissions.
- c. Reduced engine acoustic signature.
- d. Maximum high RPM power.

3. **Technician A says that the BARO sensor F96, used on the 1.8 liter turbocharged 4-cylinder Motronic M5.9.2 engine measures intake manifold pressure.**

Technician B says that the BARO sensor F96, used on the 1.8 liter turbocharged 4-cylinder Motronic M5.9.2 engine is built into the ECM.

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. **Which of the following is NOT an advantage of planar heated oxygen sensors?**

- a. Quick response time.
- b. Short warm-up, fast on-line time.
- c. Greater stability over time.
- d. No heating element is required.

5. **5V A4 and A6 engines use Camshaft Position Sensors with trigger wheels attached to the camshafts. Which statement best describes the trigger wheel configuration?**

- a. One window on each trigger wheel.
- b. One window for G40 and six windows for G163.
- c. Six windows for G40 and one window for G163.
- d. Three equally spaced windows on each trigger wheel.

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 Idle Air Control (IAC) valve functions as an electronic dashpot during deceleration.**

Technician B says that the Motronic M5.9.2 throttle valve control module has no user serviceable internal 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

8. **Motronic M5.9.2 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 M5.9.2 V6 camshaft adjustment valves N205 and N208 change camshaft timing by:**

- a. 22° in relation to the camshaft.
- b. 22° in relation to the crankshaft.
- c. Variable between 0° and 22° in relation to the camshaft.
- d. Variable between 0° and 22° in relation to the crankshaft.

Motronic ME 7

The newest generation of engine management systems is the Bosch™ Motronic ME 7. This new system was implemented on all model year 2000 vehicles.

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.

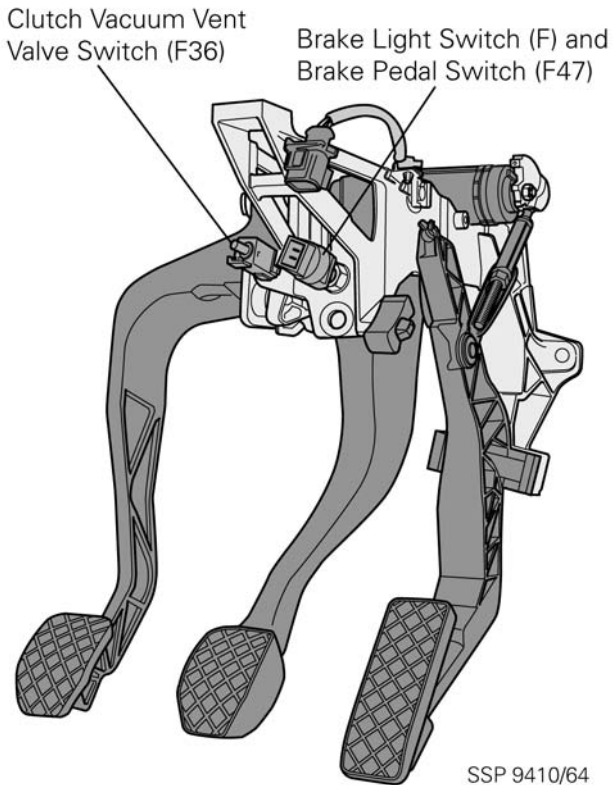
For more information on the ME 7 system, refer to the Audi ME 7 SSP #942003.

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

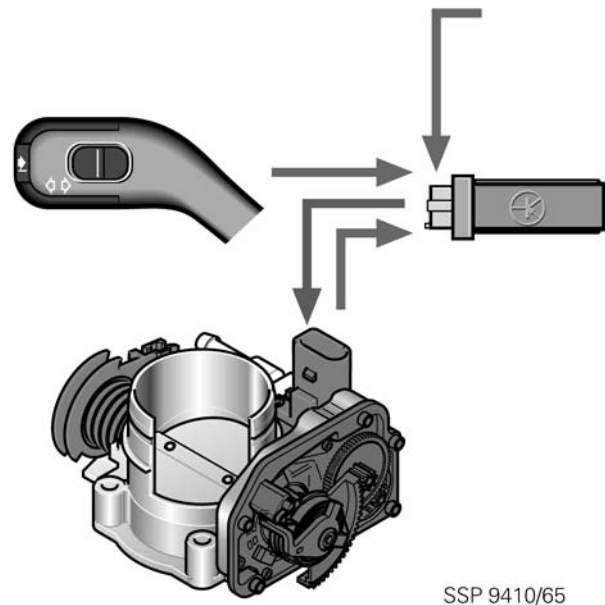


Cruise control

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:

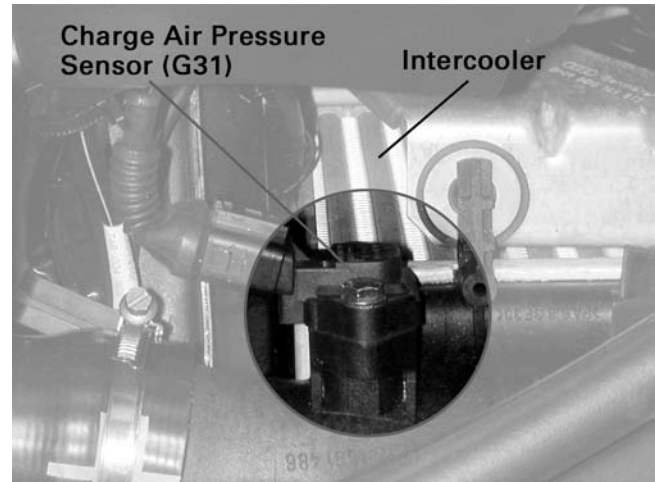
Charge Air Pressure sensor G31 is a piezo-electro sensor. Operation is via a 5V reference from the Motronic ECM, with a varying resistance to indicate manifold absolute pressure. Atmospheric pressure provides a signal of approximately 2.5V. Range of operation for the ECM to recognize a plausible signal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

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.

Electronic throttle control

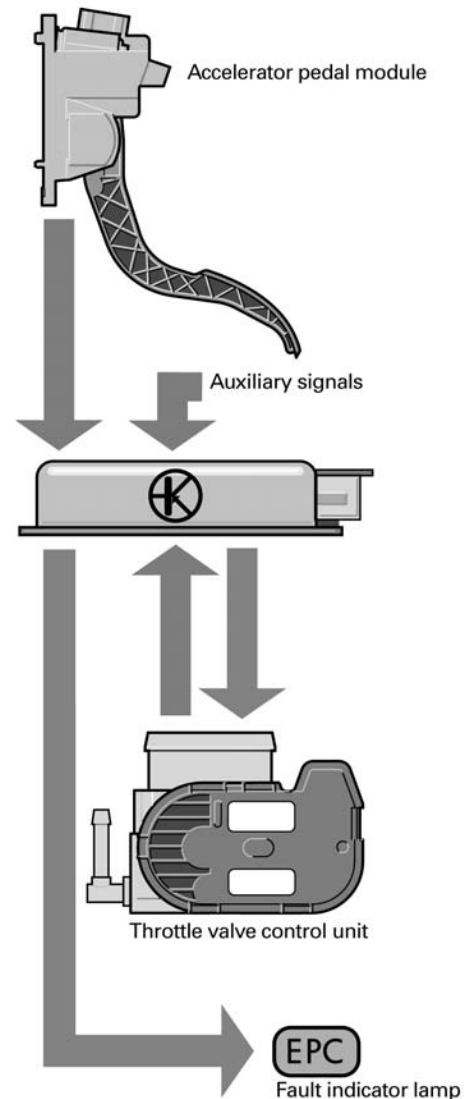
The ME 7 engine management system utilizes electronic throttle control. This enables the Motronic ECM to control the intake charge volume and velocity for optimization of engine torque.

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 eliminates the use of a mechanical link between the accelerator pedal and the throttle valve housing.

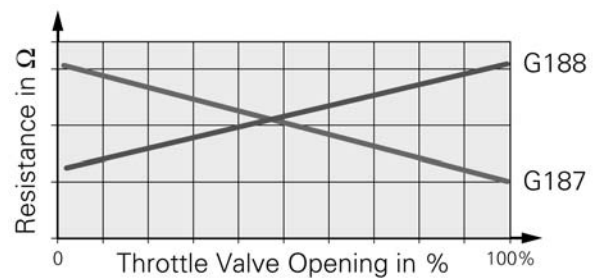
The Motronic ECM J220 positions the throttle valve according to torque demands, allowing the ECM to control throttle angle. This is a key factor in torque management.

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.



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Motronic ME 7

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.

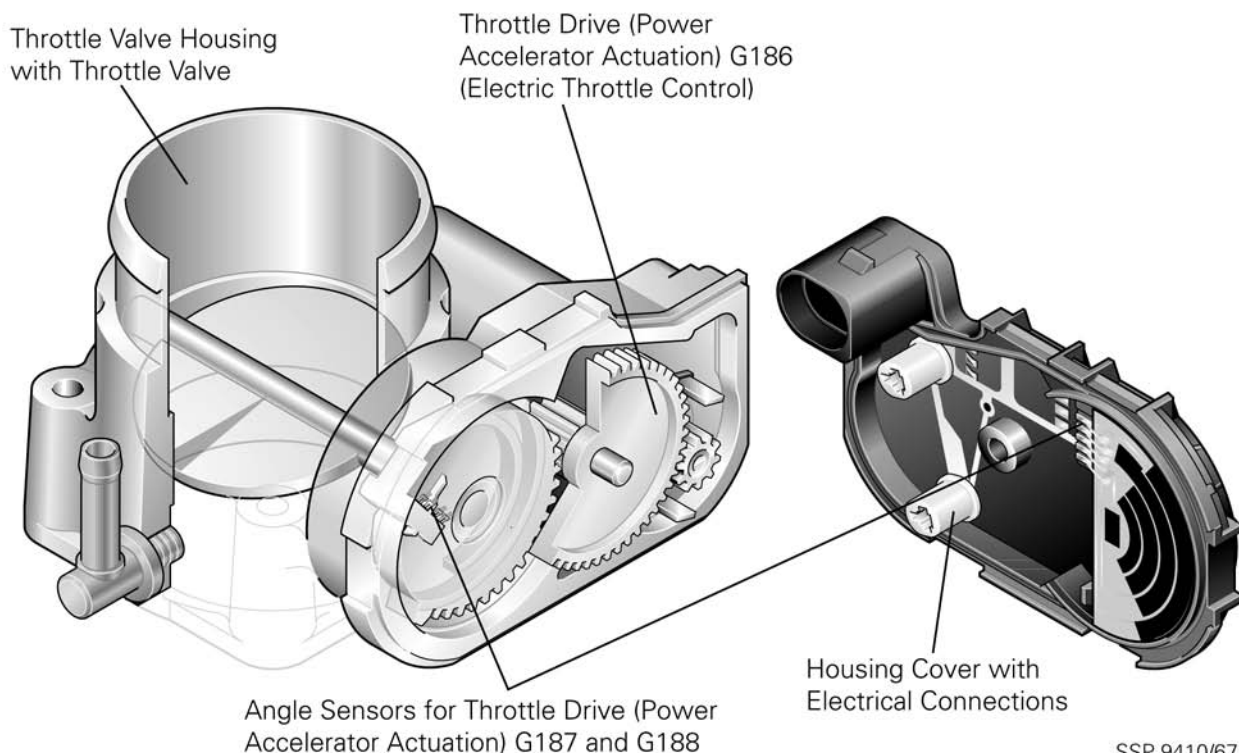
The Throttle drive is an electric motor that operates the throttle valve by way of a set of reduction gears. Its position is continually monitored by angle sensors G187 and G188.

- 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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Accelerator pedal module

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

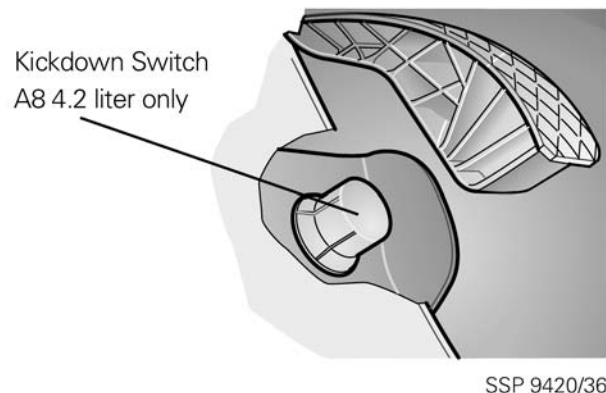
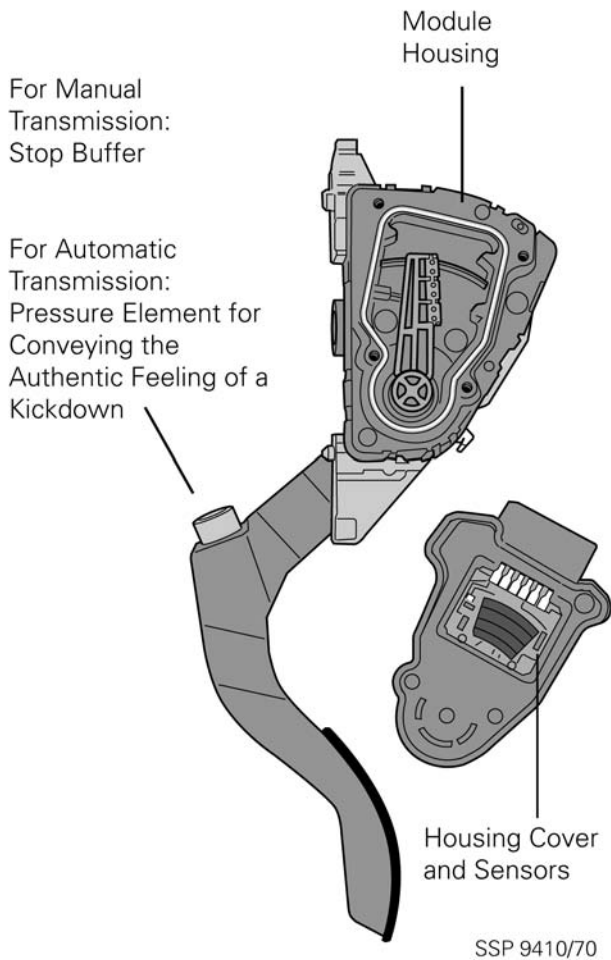
The components of the accelerator pedal module are:

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

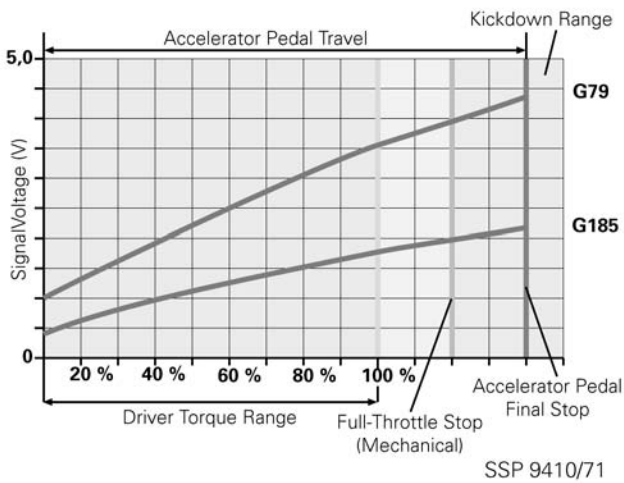
The redundant throttle position sensors are linear to each other on different scales. Like the throttle drive sensors, the duplicate sensors are for self-diagnosis.

There is no longer a separate switch for the kickdown function on the TT, A4 and A6. When the normal voltage limit of the accelerator position sensor is exceeded, the Motronic ECM recognizes the signal and interprets it as a kickdown. The resulting signal is transmitted to the Transmission Control Module (TCM) via the CAN data bus.

A separate switch is used in A8 models to provide kickdown information. Located in the driver's footwell, it also functions as the accelerator pedal stop. Full throttle and kickdown positions must be calibrated accordingly.



Motronic ME 7



- Operation:

The sensors provide an analog signal to the ECM referencing accelerator position. The kickdown function is also incorporated into the module.
- 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 Audi ME 7 SSP #942003.

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:

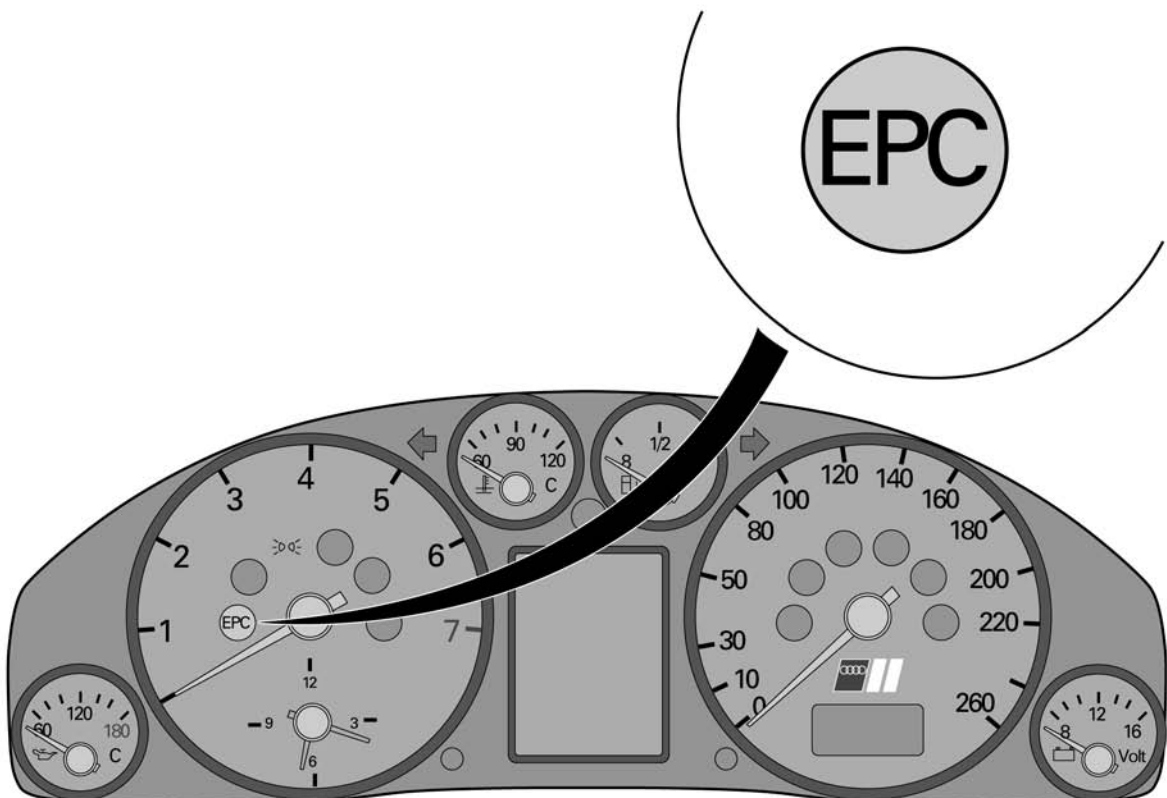
There is no substitute function for K132.

- On Board Diagnosis:

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

Note:

*A faulty indicator lamp has no influence on
EPC functionality. However, a DTC will be
stored in the memory.*



SSP 9420/35

Motronic ME 7

Heated Oxygen Sensors (HO2S) G39/G108

Broadband planar heated oxygen sensors (Bosch LSU 4.7)

Although this technology is not yet used on Audi vehicles, a brief functional overview is included for future reference.

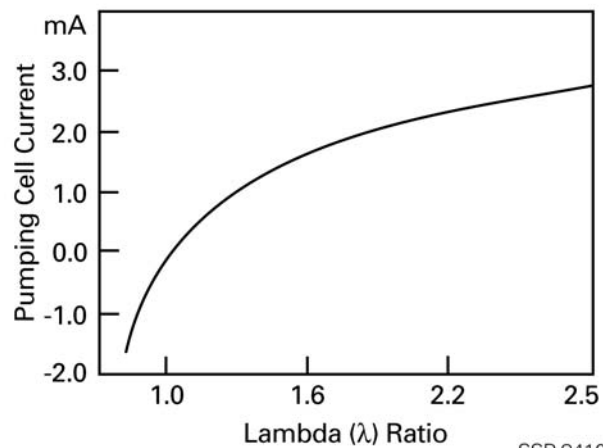
The Bosch LSU series pre-catalyst oxygen sensors as used on the Motronic ME 7 vehicles are a new design. Post-catalyst sensors are the LSF as described in the M5.9.2 chapter. Advantages of this new 6 wire sensor include:

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

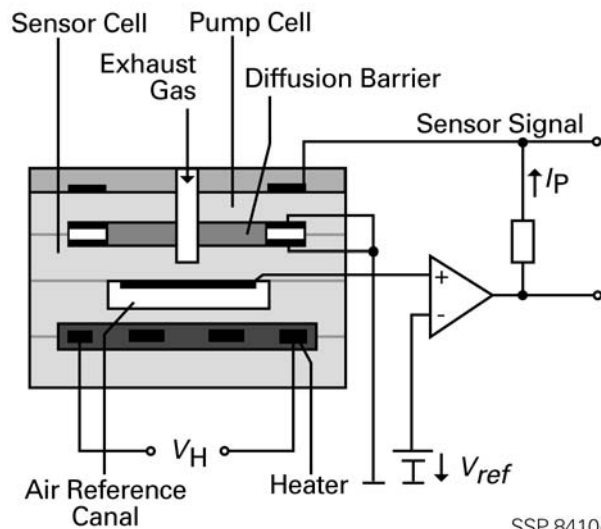
The LSU sensor is designated as a broadband sensor due to its ability to accurately measure larger changes in exhaust mixture. The way the sensor functions is similar in concept to a hot film Mass Air Flow (MAF) sensor. The new design is able to track mixture changes nearly twice as far in the lean direction. 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 milliampere 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.



SSP 8410/196



SSP 8410/197

Review

- 1. The ME 7 system is referred to as:**
 - a. A "torque based engine management system"
 - b. A "horsepower based engine management system"
 - c. A "crank synchronous system"
 - d. 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 N80
 - 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

Audi Electronic Service Information Service (AESIS) navigation

Throughout the Level One Instructor Led Course the technician is required to successfully navigate through AESIS 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 AESIS, 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 Service 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 AESIS 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 AESIS, 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 time). The toll-free number is:

- **800-426-0930**

Audi HELP line/Tech-tip line

Eventually even the most experienced technicians come across a problem that proves extremely difficult to resolve. Audi 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:

- **800-388-2834 English/French** Monday through Friday, 9:00 AM to 7:00 PM Eastern time
- **800-839-5499 English** FAX
- **514-331-0477 French** FAX

Occasionally the specialists are busy, and the caller will be put on hold. During this time, Audi 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-A24)
- 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 Quattro)
- 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 repair 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 Audi Help line?**

Suggested reading and reference

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

- **Electronic Stability Program**
published 12/99, order 961903
- **New Technology 2000**
published 12/99, order 993903
- **EVAP Systems, Operation and Diagnosis**
published 11/99, order 941903
- **V8 5V**
published 09/99, order 921903
- **The 2.7 Liter V6 Biturbo**
published 07/99, order 992903
- **The CAN Data Bus**
published 10/99, order 991013
- **TT**
published 11/98, order 893803
- **On Board Diagnostic II**
published 09/97, order WSP 521 230 00
- **The 1998 Audi A6**
published 09/97, order WSP 521 229 00
- **1997 Model Change Information**
published 01/97, order WSP 521 416 00
- **On Board Diagnostic II**
published 08/96, order WSP 521 228 00
- **1996 Model Change Information**
published 11/95, order WSP 521 223 00
- **The New Audi A4**
published 09/95, order WSP521 222 00
- **On Board Diagnosis II**
published 08/95, order WSP 521 410 00

Technician's Reference

- **The New Audi Cabriolet**
published 11/93, order WSP 521 221 00
- **1993 Model Change Information**
published 10/92, order WSP 521 219 00
- **Motronic Engine Management for Audi S4 & V8 4.2 Liter**
published 1992, order WSP 521 218 00
- **The New Audi 90**
published 1992, order WSP 521 215 00
- **1992 Model Change Information**
published 12/91, order WSP 521 404 00
- **The New Audi V6 Engine with MPI Engine Management System**
published 08/91, order WSP 521 213 00
- **The New Audi 100**
published 1991, order WSP 2521 212 00
- **1991 Model Change Information**
published 1990, order WSP 521 211 00
- **The New 20-Valve Turbo Engine**
published 1990, order WSP 521 209 00
- **The New Audi V8 Quattro**
published 1989, order WSP 521 301 00
- **Audi Coupe Quattro with 20-Valve Engine**
published 1989, order WSP 521 200 00
- **1989 Model Change Information**
published 1989, order WSP 521 180 00
- **The New Audi 100 and Audi 200**
published 06/88, order WSP 521 170 00
- **The New Audi 80 and Audi 90**
published 1988, order WSP 521 151 00
- **2.3 Liter Engine with CIS-E III Engine Control System**
published 12/86, order WSP 521 146 00

- **CIS-Electronic Fuel Injection**
published 1986, order WSP 521 142 00
- **The 1984 Audi 4000 Model Line**
published 1983, order WSP 521 119 00
- **Audi 5000 Turbo**
published 1980, order W42 550 881 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 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, Volkswagen/Audi 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

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 dependent 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.

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

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

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.

Glossary

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**.

< - 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."

Self Study Program
Course Number 941003

