AfterSales Training

Engine Management Systems

P21

Porsche AfterSales Training

Student Name: ____

Training Center Location: ____

Instructor Name: ____

Date: _________________

PORSCHE®

Electrical Troubleshooting Logic

1 - Do you understand how the electrical consumer is expected to operate?
2 - Do you have the correct wiring diagram?
3 - If the circuit contains a fuse, is the fuse okay & of the correct amperage?
4 - Is there power provided to the circuit? Is the power source the correct voltage?
5 - Is the ground(s) for the circuit connected? Is the connection tight & free of resistance?
6 - Is the circuit being correctly activated by a switch, relay, sensor, microswitch, etc.?
7 - Are all electrical plugs connected securely with no tension, corrosion, or loose wires?

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We have attempted to render the text within this publication to American English as best as we could. We reserve the right to make changes without notice.

Part Number - PNA P21 001 Edition 7/07

Chapter Description **Section**

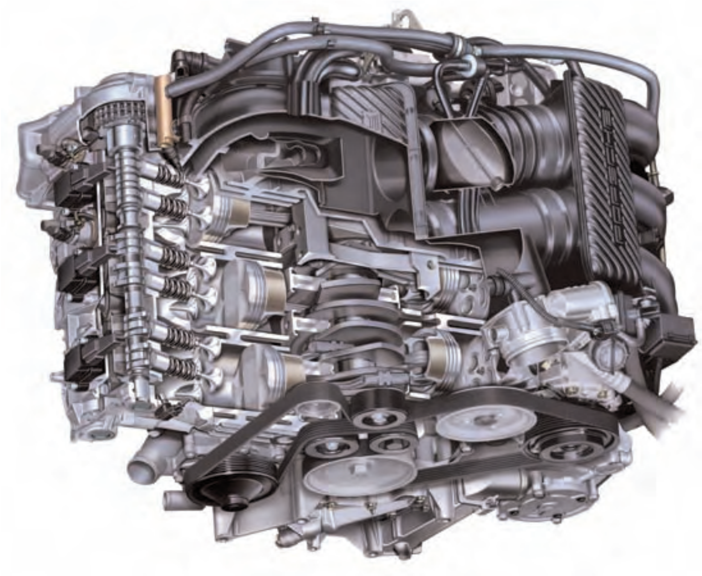
Over the past several years, the engine management and related systems of Porsche vehicles have had to respond to ever-lower emissions standards and increasingly complex legislative requirements. While each new engine design produced more torque and horsepower and lower fuel consumption, engine management systems become increasingly efficient and complex. This has increased the amount of information that the technician must have command of and the complexity of the systems the technican must understand, exponentially. This training book attempts to organize the information and system theory of Porsche engine management in an understandable and organized manner. We hope this will make your study of Porsche engine management a successful undertaking that will improve your ability to repair and diagnose Porsche engine management systems.

Viel Spass!

AfterSales Training Department

Model Year – Porsche System Designations

Model	Model Year	System Designation
911	1984-89	DME 35 Pin Control Unit
911 (964)	1989-94	DME 55 Pin Control Unit
911 (993)	1995	DME 2.10.1
911 (993)	1996-98	DME 5.2
911 (996)	1999	DME 5.2.2
911 (996)	2000-01	DME 7.2
911 (996)	2002-05	DME 7.8
911 (997)	2005	DME 7.8
911 (997)	2006-on	DME 7.8_40
911 Turbo	1986-89	CIS
911 Turbo (964)	1991-94	K-Jetronic, Electronic Ignition System EZ 69 w/Spark Control
911 Turbo (993)	1996-98	DME 5.2
911 Turbo (996)	2001-05	DME 7.8
911 Turbo (997)	2006-on	DME 7.8.1
924S	1986-88	DME 35 Pin Control Unit
928 S	1984-86	LH-Jetronic - EZF
928 S4	1987-89	LH-Jetronic - EZK
928 S4/GT	1990-95	LH-Jetronic - EZK
944	1984-89	DME 35 Pin Control Unit
944 S	1987-89	DME 55 Pin Control Unit
944 S2	1990-91	DME 55 Pin Control Unit
944 Turbo	1986-90	DME 35 Pin Control Unit with KLR
968	1992-95	DME 2.10.1
Boxster (986)	1997-99	DME 5.2.2
Boxster (986)	2000-02	DME 7.2
Boxster (986)	2003-04	DME 7.8
Boxster (987)	2005-on	DME 7.8_40
Cayman (987)	2006-on	DME 7.8_40
Cayenne (V6) 1st Gen.	2004-06	DME 7.1
Cayenne S 1st Gen.	2003-06	DME 7.1
Cayenne Turbo 1st Gen.	2003–06	DME 7.1
Cayenne (V6) 2nd Gen.	2008	MED 9.1 (Bosch)
Cayenne S 2nd Gen.	2008	EMS SDI 4.1 (Siemens)
Cayenne Turbo 2nd Gen.	2008	EMS SDI 4.1 (Siemens)
Carrera GT	2004-06	DME 7.1 x 2 (Master/Slave)



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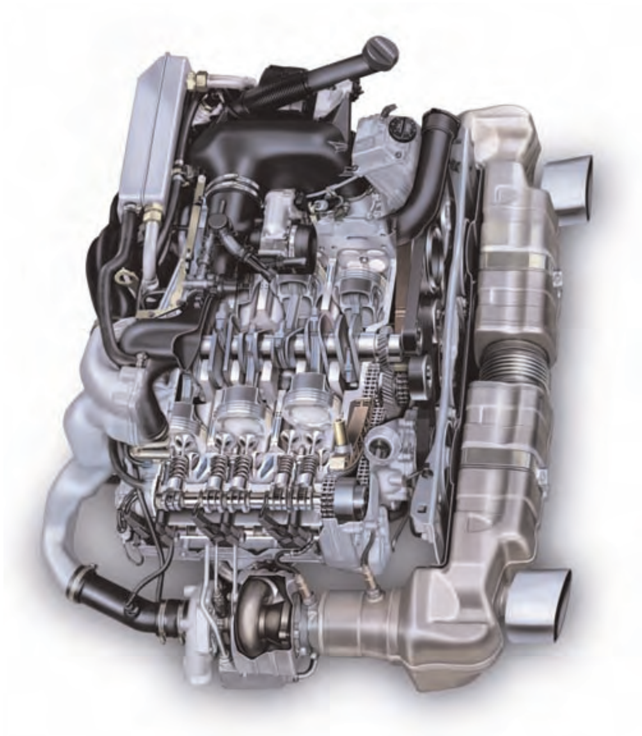
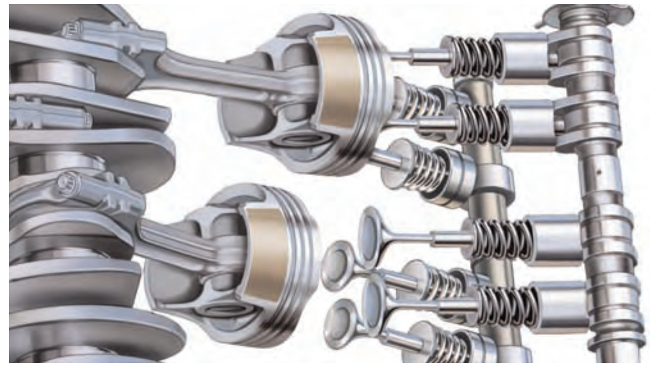
General



By dividing the engine management system into three subsystems, the Engine mechanical, the Fuel system, and the Ignition system, we will be able to gain a better understanding of engine management as a whole, and the relationships between these systems.

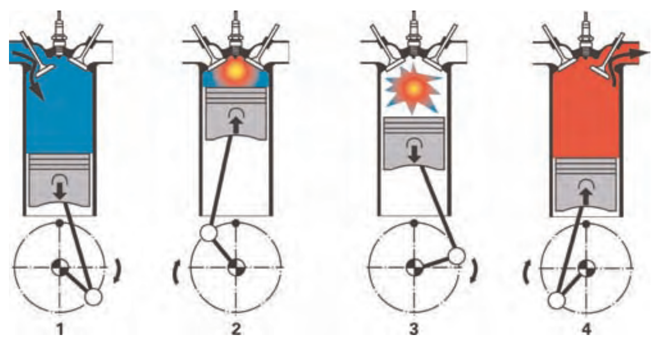
The engine mechanical system compresses the air and fuel mixture provided by the fuel system, and the ignition system ignites the air and fuel mixture to produce torque and horsepower at the crankshaft. A solid knowledge of engine management is essential for understanding of the complex computer controlled systems utilized by Porsche today. As well as being essential for the diagnosis of system faults. So, lets begin our examination of Engine Management with an overview of the engine mechanical system.

Engine Mechanical System



The engine mechanical system consists of the intake system, the engine mechanical (motor-block, pistons, valves, etc.) and the exhaust system. The operational principal of this system is the “Otto” cycle:

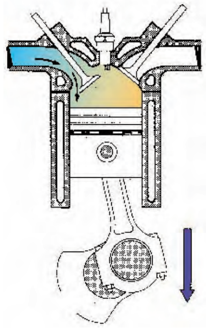
The Four Strokes of the “Otto” (combustion) Cycle



The operation of an internal combustion engine can be understood by looking at the operation of one cylinder of the engine through an entire combustion cycle. The combustion cycle consists of two crankshaft revolutions. During each of these revolutions the piston will travel from the top of the cylinder to the bottom of the cylinder, and then from the bottom of the cylinder to the top. These movements are called strokes and there are four strokes in a combustion cycle (down, up, down, up). The valve train of the engine operates the valves in synchronization with these strokes: opening the intake valve during one stroke and the exhaust valve during another stroke.

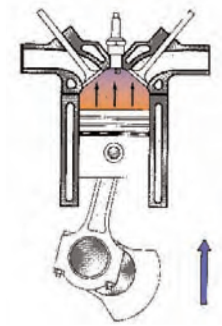
Engine System Basics

Intake (1)



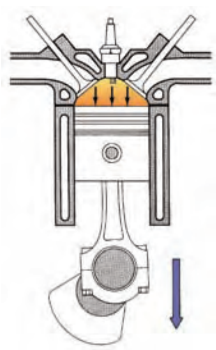
During the intake stroke the piston is moving down and the intake valve is open. As the piston moves down, the air and fuel mixture enters the cylinder to occupy the space vacated by the piston as it moves down. At the end of the intake stroke the piston is at the bottom of the cylinder and the intake valve closes.

Compression (2)



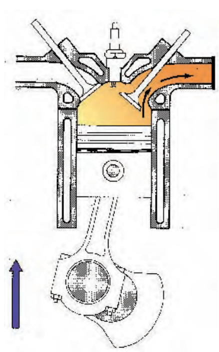
During the compression stroke the piston is moving up and the valves are closed. The piston movement compresses the air/fuel mixture that entered the cylinder during the intake stroke. At the top of this stroke the air/fuel mixture that filled the entire cylinder at the bottom of the intake stroke has been compressed into the combustion chamber. Compressing the mixture by the ratio of the total cylinder volume to the combustion chamber volume.

Power (3)



During the power stroke the valves are closed and the air/fuel mixture has been ignited by the ignition system. The pressure that is generated by the burning of the air/fuel mixture pushes the piston down. This stroke creates rotational force (torque), which is transmitted to the crankshaft via the connecting rod.

Exhaust (4)

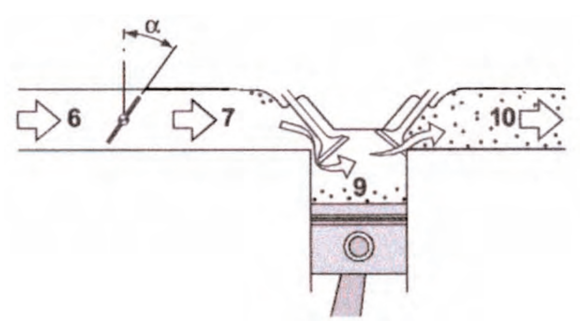


During the exhaust stroke, the exhaust valve is opened and the piston begins moving up and forces the by products of the combustion process out past the exhaust valve and into the exhaust system.

This cycle is repeated continuously as long as the engine is supplied with air/fuel mixture and ignition spark. The valve train that controls the intake and exhaust valves operates at half crankshaft (piston) speed. So, for two revolutions of the crankshaft, the camshaft will only rotate one time and open the two valves it controls (intake and exhaust) once per cycle and in strokes that follow one another, exhaust and intake during the other two strokes the compression and the power strokes, no valves are open.

A one-cylinder engine will only have one power pulse every other crankshaft rotation, as cylinders are added, power pulses are also added. A four-cylinder engine will have two pulses per revolution and a six-cylinder engine will have three. As the number of pulses per revolution increases the smoothness and power of the engine also increases.

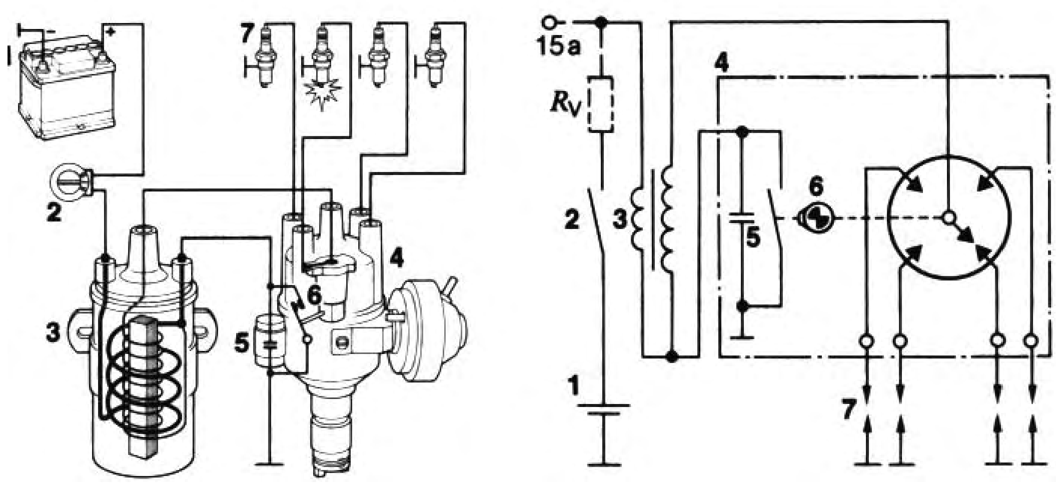
Air Flow Through Engine



When the vehicle is at idle, the throttle plate will close off the intake air flow path and the engine will be held to a low RPM. This will cause the pressure in the intake system (7) to drop below atmospheric pressure (6) since the engine is attempting to pull air past the closed throttle plate. As the throttle plate is opened, the pressure will rise towards atmospheric pressure, at wide-open throttle the pressure will be close to atmospheric pressure.

The exhaust system directs the combustion by-products from the engine (9) to the rear of the vehicle. The pressure in the exhaust system (10) pulses positive/negative, due to the gas inertia of the exhaust flow. The exhaust gas continues to move after the exhaust valve has closed, forming a low pressure in the exhaust runner below the closed valve.

Ignition System



Basic Ignition System Components

1. Battery
2. Ignition switch
3. Coil
4. Distributor
5. Condenser or ignition capacitor
6. Breaker points
7. Spark plugs

The inductive ignition system utilized on current Porsche models generates the high-tension current required for reliable ignition, and then delivers it to the correct spark plug at precisely the right time. To describe how this is achieved, we need to examine the **three main functions** of the ignition system:

1. Produce a **spark** of sufficient intensity to ignite the air/fuel mixture.

2. **Distribute** this spark to the correct cylinder.

3. **Time** the point when the spark is generated in relation to piston position (Ignition timing).

Producing the Spark

When a magnetic field passes through a conductor (for example a coil of copper wire) it generates current flow. The opposite is also the case when a current passes through a conductor (for example a coil of copper wire), it produces a magnetic field. This basic electrical law is the operational principal of the inductive ignition system.

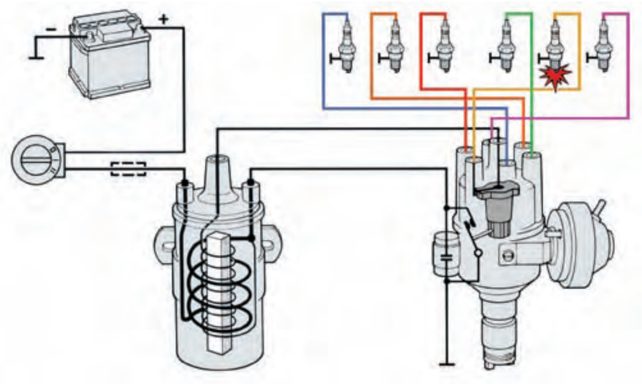
In the automotive ignition system, one coil of wire is connected to power on one end and to ground across a switch on the other. This coil of wire is known as the primary winding and when current passes through it a strong magnetic field is built up. A second coil of wire is connected to the first at the grounded (switched - breaker points) end and to the spark plug on the other. This second coil of wire is known as the secondary winding and is coaxial (sharing the same axis) with the first (primary) winding. The switch is commonly known as the breaker points.

These coils of wire are contained together in one housing referred to as the ignition coil. When the switch is opened and current flow ceases, the magnetic field collapses. This induces a very high voltage in the secondary winding. When this voltage rises to a value high enough to force electrons to jump the gap between the center electrode of the spark plug and the ground electrode, a intense spark is produced, this spark ignites the mixture in the combustion chamber. The relationship between when the points open and crankshaft position is called; ignition timing. The amount of time that the points are closed is referred to as dwell. The more time that the points are closed, the stronger the magnetic field will be and the hotter and more intense the spark.

This inductive process produces heat and for that reason the dwell has to be limited to prevent overheating the coil. The amount of dwell is a balance between having a hot intense spark and preventing damage to the coil and points from overheating.

Ignition System Basics

Distributing the spark to the correct cylinder.

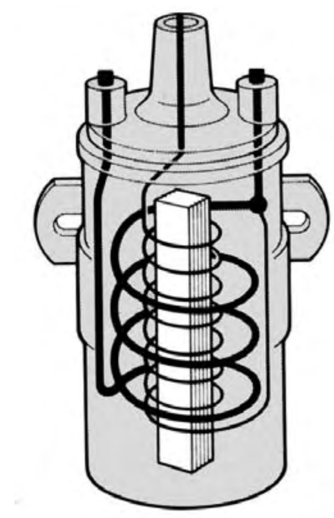


Since an "Otto" engine fires all of its cylinders in two crankshaft revolutions, the ignition distributor rotates at camshaft speed (once for every two crankshaft revolutions). The high tension leads for the spark plugs are spaced evenly around a distributor cap. Each will be indexed with the rotor during one revolution. The distributor rotor is attached to the top of the distributor shaft and connects the coil high voltage connection to the appropriate spark plug via the distributor cap and a high-tension cable.

Notes:

The Ignition Coil

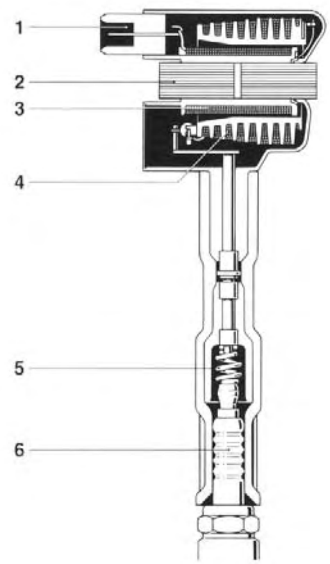
The heart of the ignition system is the ignition coil. The ignition coil consists of two copper windings; the primary winding, and the secondary winding. The primary winding is connected to the battery through the ignition switch and to ground through the points, or, in Porsche systems, via an electronic switch unit (final stage). The primary winding is made of a heavy gauge wire and has fewer coils than the secondary. The normal ratio of the coils of the primary to secondary is 1:100.



The secondary winding is connected to the grounded side of the primary winding on one end, and the spark plug on the other. The secondary winding is made of lighter gauge wire, however, it has many more coils than the primary winding. These two windings are coiled around a soft iron core that helps direct and build the magnetic field. The ignition coil is actually a transformer, more precisely a step-up transformer.

In older systems the coil was filled with oil to prevent the windings from overheating. Newer systems have the windings embedded in a plastic that is heat resistant.

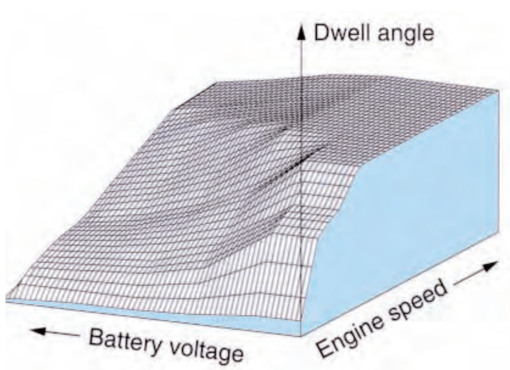
Late model Porsche vehicles have distributorless ignition systems. In these systems each cylinder has its own coil. The cap, rotor and high-tension cables are no longer required.



Single-spark Ignition Coil Components

1. External low-voltage terminal
2. Laminated iron core
3. Primary winding
4. Secondary winding
5. Internal high-voltage connection (via spring contact)
6. Spark plug

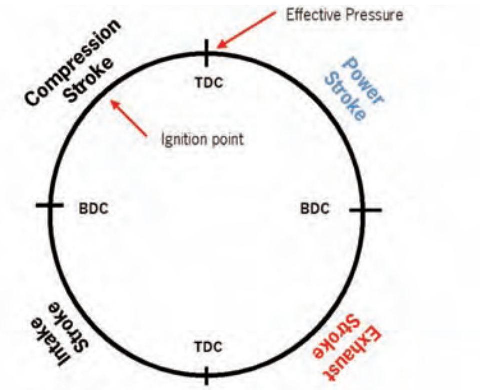
With distributorless ignition systems there is a coil for each spark plug. When six coils share the load that used to be handled by one coil, the amount of sparks per coil is reduced to a level where heat is not as much of a factor. In addition, electronic systems can vary the amount of dwell in relation to system voltage and engine speed creating the optimum amount of dwell for each operating condition.



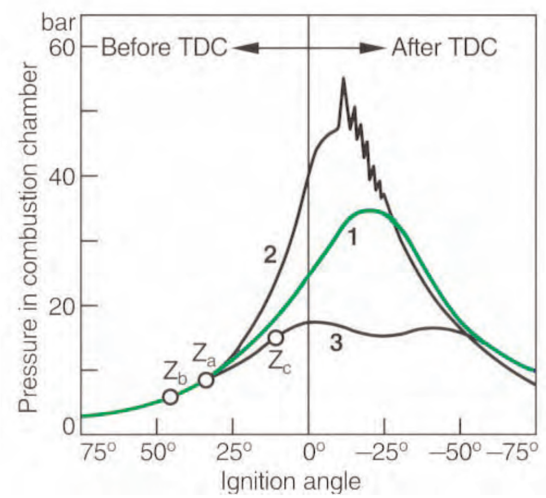
Dwell vs Battery Voltage and RPM

Timing the Spark

The goal of ignition timing control is to produce effective pressure (defined as a gas pressure in the combustion chamber high enough to move the piston) at exactly top dead center.



Because it takes a brief amount of time for the combustion process to produce effective pressure, we have to ignite the mixture before top dead center to produce effective pressure at top dead center.



Ignition angle vs. combustion chamber pressure graph

1. Ignition (Z_a) at correct time
2. Ignition (Z_b) too soon (ignition knock)
3. Ignition (Z_c) too late

If we achieve effective pressure before top dead center, the gas pressure will act against the rising piston and destructive knock will occur. If we achieve effective pressure after top dead center, we lose power and torque.

For best output, achieving effective pressure very close to top dead center is very important. Take a look at the ignition angle vs. combustion chamber pressure graph, you can see the effect of early and late ignition timing on combustion chamber pressure.

Ignition System Basics

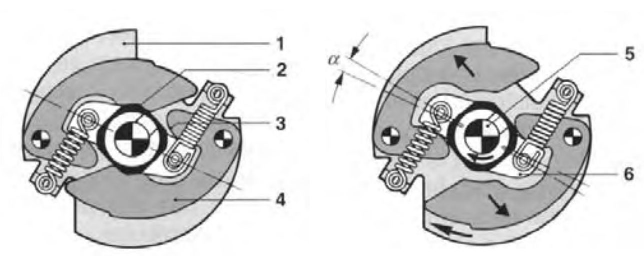
The control of the ignition point is based for the most part on two control inputs:

1. The speed that the engine is turning at.
2. Load that is the amount of torque (Twisting effort) that is required to move the vehicle.

The higher the engine speed, the earlier ignition occurs. The amount of time for the ignition spark to complete combustion is fixed (about 2 milliseconds .002 seconds). As the engine speed increases, 2 milliseconds takes more degrees of crankshaft rotation, so the ignition spark must be generated sooner, more degrees before top dead center, this is ignition advance.

Ignition Advance

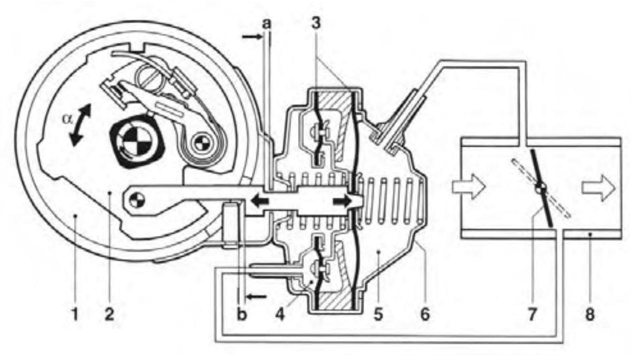
Before the advent of digital electronic ignition systems, ignition advance was created by a centrifugal flyweight system, and a load-controlled advance pressure diaphragm. The initial opening of the breaker points is the ignition point.



Centrifugal advance mechanism in rest position (left image) and operating position (right image).

1 - Support plate
2 - Distributor cam
3 - Rolling contact path
4 - Flyweight
5 - Distributor shaft
6 - Yoke

Centrifugal Advance – The distributor cam opens the breaker points, if the cam is moved in relation to the distributor shaft, the ignition point is in turn advanced. This initial manipulation of the ignition point is created by the centrifugal advance, as engine speed increases, the flyweights move outwards by centrifugal force, causing the cam to advance in relation to the distributor shaft.



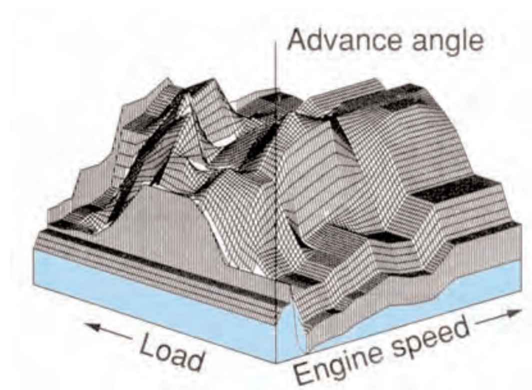
General Breaker Point Ignition System With Vacuum Advance

Vacuum Advance – The breaker points are fixed to the breaker plate (Item 2), this plate is designed to rotate on top of another plate which is securely fastened to the distributor housing. So, if the breaker plate is moved, the ignition point moves accordingly. The advance diaphragm (Item 5) is connected to the pressure port on the intake manifold (Item 8), and when intake pressure is low, the diaphragm pulls the breaker plate in the advance direction. Intake pressure changes with load, so the amount of advance is load dependent.

Notes:

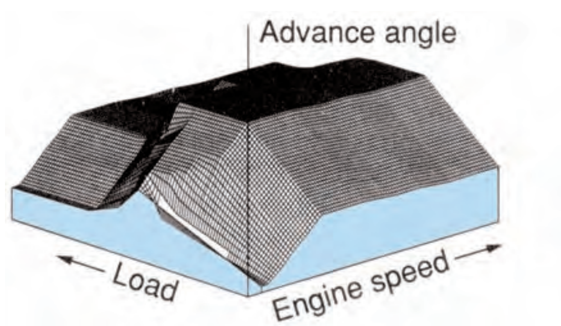
Electronic Digital Ignition

Today's Porsche vehicles use a digital electronic ignition system. With this system, Porsche can create, optimize and store "electronic maps" with the best ignition point for every load and speed combination.



Graph 1 – *This illustration shows a electronically optimized ignition point map which is used in today's Porsche electronic digital ignition system.*

The map above (Graph 1) shows ignition timing on the vertical axis, load and engine speed on the horizontal axis'. So, if we move to the right on the engine speed axis about half way, and then half way to the left on the load axis you end up in the middle of the map. The amount of timing advance is the height of the graph at that point. The bottom of the graph, low load and low speed, is idle, the top corner is highest load and highest speed at wide-open throttle.



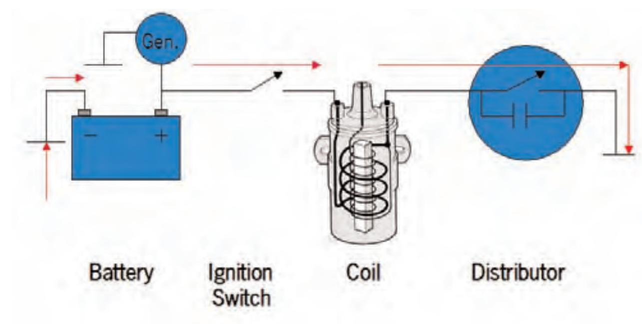
Graph 2 – *This illustration shows what a ignition point map looked like with a previous mechanical advance system.*

Graph 2 shows the timing map that you get from a conventional distributor system. You can clearly see the limitations of conventional ignition control. Graph 1 is the advance amount for optimum performance and fuel economy, this is what a digital electronic system uses to control ignition timing.

In addition, the electronic systems of today have done away with the breaker points and control the current flow in the primary with a transistor. These electronic systems use electronic sensors to detect crankshaft speed and position. Systems without a distributor use a second sensor on the camshaft to identify which stroke the crankshaft is on, this assures that the ignition spark is sent to the correct cylinder.

Electronic Ignition Systems

Prior to electronic ignition systems, breaker point ignition systems were used, however these early ignition systems had several disadvantages.



Conventional Points Ignition System Example

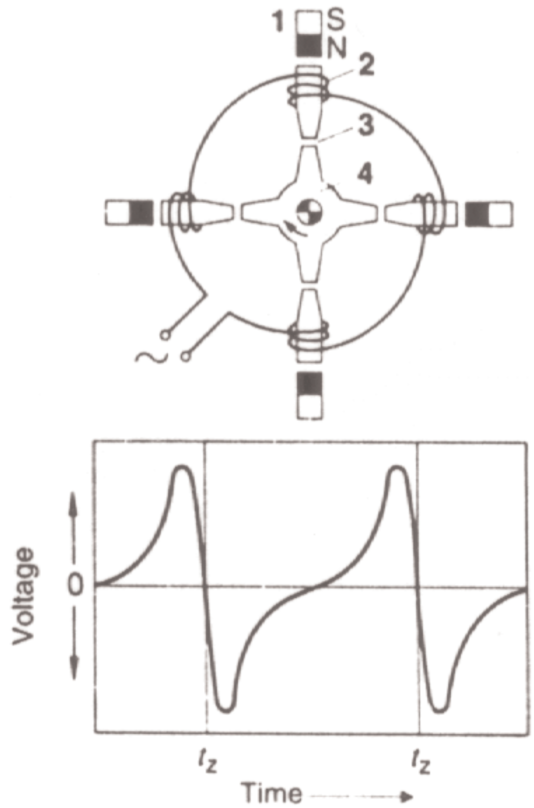
The disadvantages were:

- They have fixed dwell (electronic systems can vary dwell with RPM and system Voltage).
- Mechanical wear of the rubbing block changes dwell and ignition timing.

Notes:

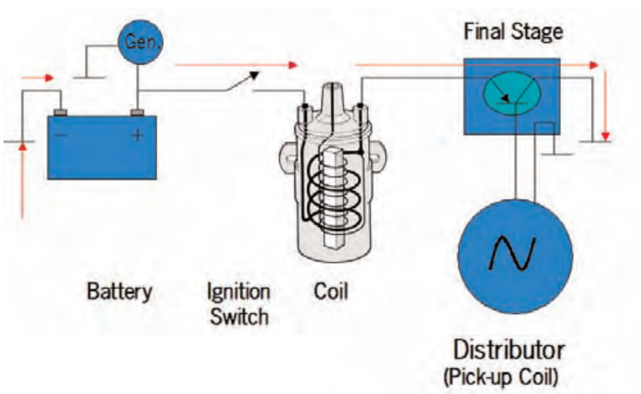
Ignition System Basics

We can replace the points with an inductive sensor.



Ignition distributor with inductive-type pulse generator.

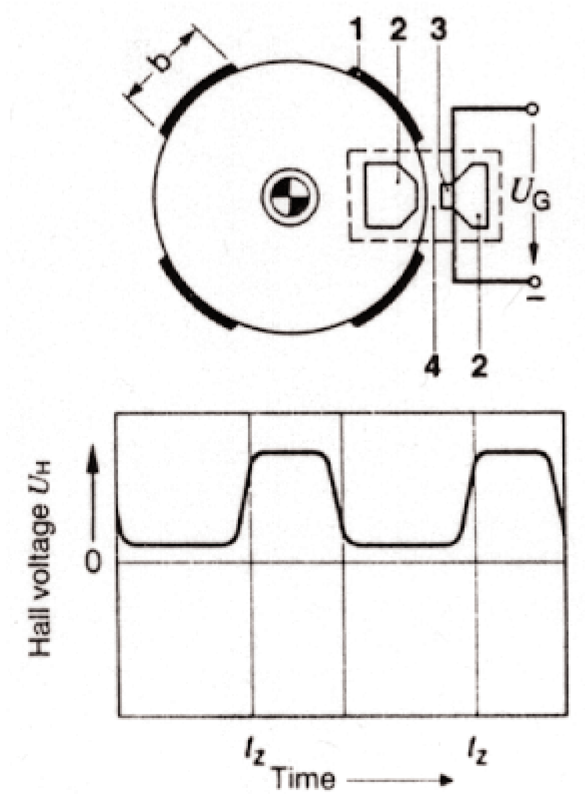
1. Permanent magnet
2. Inductive winding with core
3. Variable air gap
4. Trigger wheel



Electronic Ignition System With Inductive Sensor Example

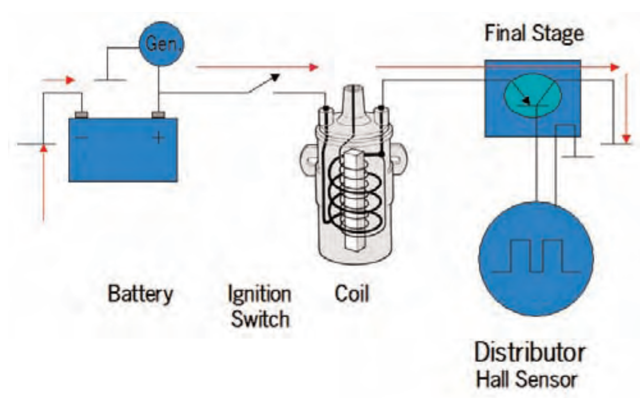
The inductive sensor is used to indicate when the final stage should switch the primary current.

We can replace the points with a Hall sensor.



Ignition distributor with Hall sensor.

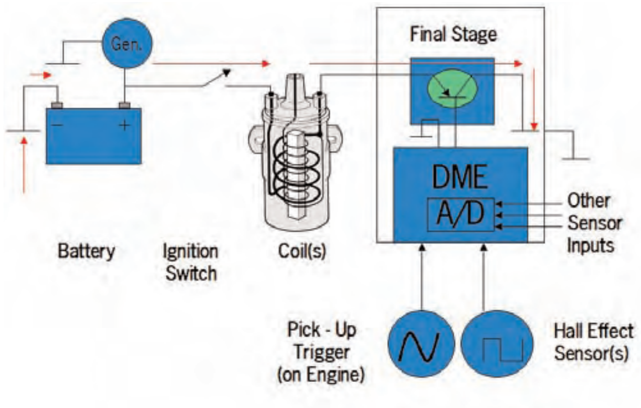
1. Vane with width b
2. Soft magnetic conductive elements
3. Hall IC
4. Air gap, U_G Hall sensor voltage (transformed Hall voltage)



Electronic Ignition System With Hall Sensor Example

The hall sensor is used to indicate when the electronic system should switch the primary circuit.

DME uses both Hall and inductive sensors.



Digital Electronic Ignition System Example

Notes:

Fuel System Basic Introduction

The goal of the fuel system is to maintain the air fuel ratio at the Stoichiometric point. “Stoichiometry”, is the combination of air and fuel that will produce complete combustion of all the fuel in the mixture. This ratio is also referred to as Lambda 1. Lambda 1 and stoichiometry refer to the same mixture ratio. At Lambda 1 the mixture ratio is 14.7 parts air to 1 part fuel, by weight (14.7:1).

$$\textbf{Lambda} = \frac{\textbf{Air Mass Supplied} \text{ (Mass Air Flow)}}{\textbf{Theoretical Requirement} \text{ (Calculated Air Flow)}}$$

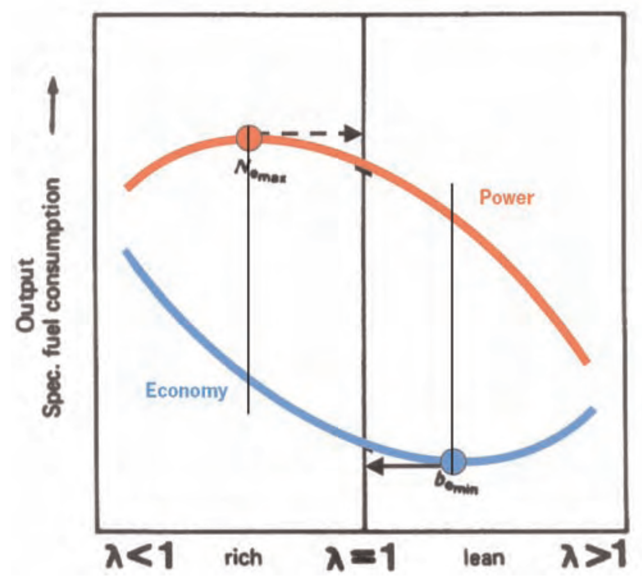
Lambda 1 Air Mass Supplied = Theoretical Req.

Lambda less than 1
Lack of air or rich mixture
In the range – Lambda = .85 - .95

Lambda greater than 1
Excess air or lean mixture
In the range – Lambda = 1.05 - 1.3

When discussing mixture ratio in Porsche fuel systems we use the term Lambda (Short for Lambda1) to indicate a mixture at a ratio of 14.7 to 1 fuel to air by weight. It is also the term we use for oxygen sensors “Lambda sensor”, since Lambda sensors measure mixture.

Below is the Power vs. Fuel economy graph, it illustrates the benefits of an air to fuel ratio at Lambda.



When we analyze the Power vs. Fuel economy graph you can see the advantage of a air fuel ratio of Lambda 1:

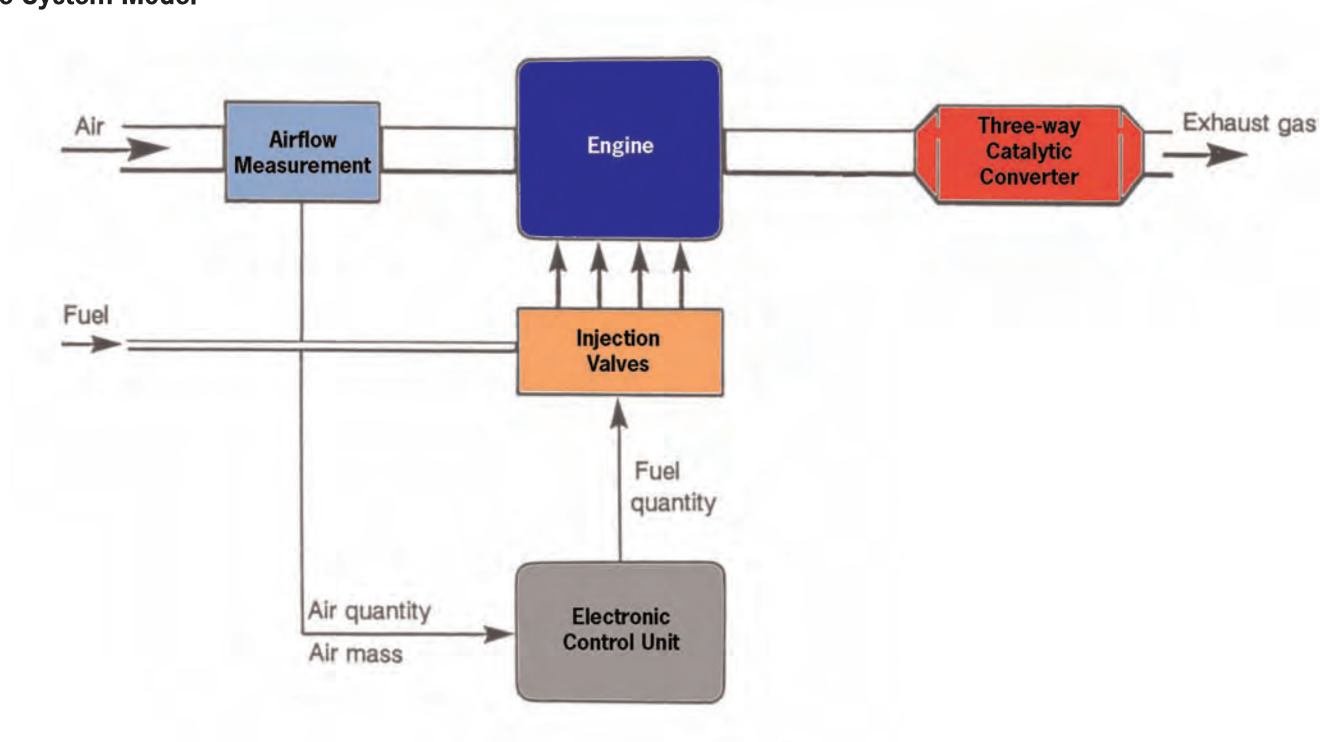
- Notice that the curves have a steep section and a flat section.
- Move mixture to the max power point and you gain only a small increase in power and you have a large increase in fuel consumption.
- Move to the point of lowest fuel consumption and you gain only a small amount of fuel economy and lose a large amount of power.

It becomes obvious that Lambda 1 (14.7 to 1 air fuel ratio) is the right mixture for best power with optimum fuel economy.

We only need to move away from this mixture ratio when the engine is first started and when it is at full throttle. We will talk about why later.

Fuel System Basics

Simple System Model



Let's talk about how the goal of the fuel system is achieved.

The fuel control system is complex on late model Porsche vehicles, however we can gain a solid understanding of how this complex system works by reducing the system to its least complex form. We call this least complex form the simple system model. It consists of the following:

- A fuel pump to supply fuel to the engine.
- Electromechanical fuel injection valves to deliver the fuel.
- An electronic sensor for airflow measurement.
- A control unit to control the system function.
- The engine mechanical system.

In the simple system model the following can be observed:

- Air flowing into the engine is measured by the air flow sensor. This is an input to the electronic control unit.
- The electronic control unit determines the correct amount of fuel to be added to this airflow to achieve the Stoichiometric air fuel ratio.
- The ECU opens the injectors just long enough to inject the correct amount of fuel (with this system we open the injectors at TDC of each crank revolution).
- When the throttle opens further, more air enters the engine.
- The airflow measure from the airflow sensor increases.
- The electronic control unit opens the injectors for a longer period of time in order to maintain the Stoichiometric ratio.

When the air flow changes we change the amount of fuel to maintain Lambda 1; more air more fuel, less air less fuel, always maintaining the air to fuel ratio at Lambda 1 (the Stoichiometric ratio).

This very Simple System Model is our starting point. Now we take the first step towards a more complete understanding of Porsche fuel systems.

Our systems are digital and the following items are added:

- Computer
- Map
- Software program

A map is a table of values (in this case injector opening times for different air flows). A program is a set of instructions that the computer in the engine control unit executes in sequence.

Our digital computer performs the steps of the program one at a time.

- **First –** look at the airflow amount.
- **Second –** get the injector opening time from the injector opening time map. (base fuel delivery).

14Kg/h	23Kg/h	38Kg/h	49Kg/h	80Kg/h	123Kg/h	180Kg/h	220Kg/h
1.62 ms	1.74 ms	1.86 ms	1.94 ms	2.12 ms	2.52 ms	3.23 ms	3.82 ms

Injector Duration Map #1

- **Third –** send a command to the injector operating circuit to open the injector for that amount of time.
- Back to step one, over and over (loop) as long as the engine is running.

Our description of the injector opening time map in the example above is very basic, so let's take a more detailed look. We need to have engine speed as well as air flow in the map, because we need a different amount of fuel at low RPM for an airflow than we will need at a higher RPM for the same airflow. We need to add a speed sensor to the system model to accomplish this.

We will describe how our sensors and actuators function in following sections.

When we add engine speed to our map, we end up with a grid like the injector duration (Map #2) with the upper right being wide open throttle and the lower left is idle.

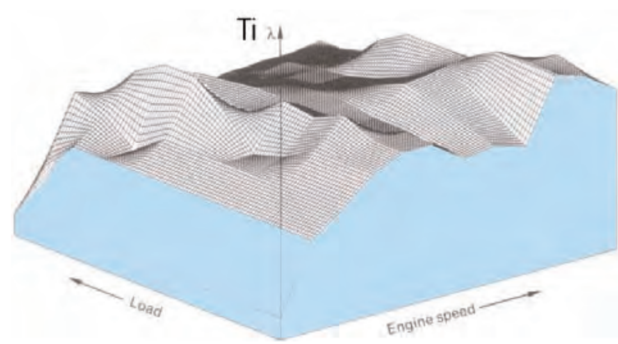
Engine Load

2.8ms	2.9ms	3.1ms	3.2ms	3.4ms	3.9ms	4.6ms
2.6ms	2.7ms	2.8ms	3.1ms	3.3ms	3.8ms	4.2ms
2.1ms	2.1ms	2.3ms	2.9ms	3.2ms	3.9ms	4.1ms
1.8ms	1.9ms	2.2ms	2.8ms	2.9ms	3.8ms	3.9ms
1.4ms	1.6ms	2.1ms	2.2ms	3.1ms	3.7ms	3.8ms
1.2ms	1.4ms	1.7ms	2.1ms	2.6ms	3.6ms	3.7ms
0.9ms	1.4ms	1.6ms	1.9ms	2.1ms	3.1ms	3.6ms

Engine Speed

Injector Duration Map #2

We can turn this into a three-dimension injector duration map like the one below if we show the injector duration as projecting upwards from the grid.



Lambda Map

As you can see, there are a lot more data points in this map than there were in the first example. We can fine tune the fuel amount for each speed/airflow point. This will give the optimum mixture under all operating conditions.

This system model works very similar to our model without engine speed.

- Get the air mass and engine speed from the sensors.
- Go to the map and retrieve the injector opening time (Ti or injector duration).
- Direct the injector final stage to open the injector for that amount of time.

We have more precise mixture control when we add engine speed to our Ti map.

Fuel System Basics

When we change to a digital system, we not only have the ability to have the mixture at Lambda 1 regardless of the operating conditions, we also gain the ability to react to special conditions.

For example:

- We have been operating at cruise with approximately 3000 RPM,
- Suddenly the RPMs fall,
- The throttle position is closed,
- We are in deceleration.

We can have instructions in the fuel program turn the injectors off until the throttle is reopened, or idle RPM is reached thereby reducing emissions.

There are also a number of conditions when we want the mixture richer than Lambda 1.

For example:

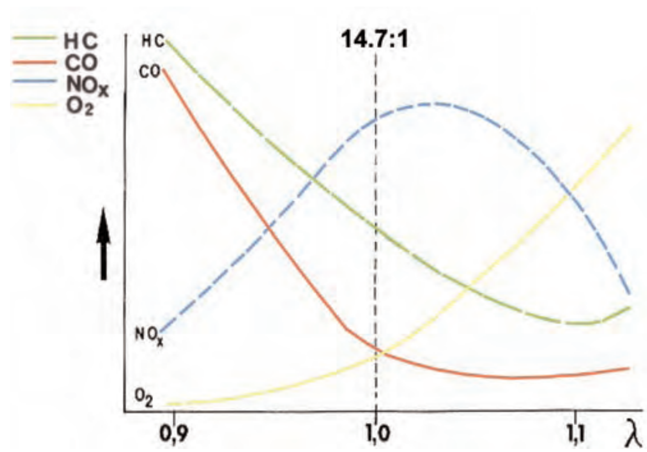
- Cold start – We want to heat the engine up, and, fuel doesn't atomize well when it is cold.
- Full throttle – We want to provide extra fuel to reduce NO_X. The heating that is required to evaporate the fuel lowers the combustion chamber temperature and reduces NO_X.

Digital systems are capable of processing a lot of data in very short periods of time. They are very precise as a result. It is easy to see that we can have a digital system match the mixture to the specific operating conditions.

There is one big disadvantage of operating at Lambda 1. If we analyze the Combustion by Products vs. Lambda 1 graph below we see three events.

1. CO is low at Lambda and increases as the mixture gets richer.
2. HC is low at Lambda and rises when the mixture moves either rich or lean (although not as rapidly as CO).
3. O_2 is low when mixture is rich. It begins to rise at Lambda and continues to rise as the mixture leans (a mirror image of CO).

This third event will become very important later.



Combustion by Products vs. Lambda 1

The one gas that stands out is NO_X, it peaks at Lambda 1. This is a problem since the amount of NO_X that a vehicle can emit is limited by legislation. The HC and CO emissions are limited as well, but NO_X is the largest concern. In order to sell vehicles in the USA, you must have some way to lower the NO_X.

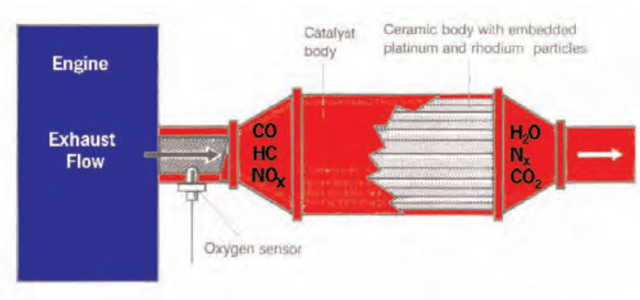
The more efficient that the engine is, the more NO_X it will produce.

This is due to the fact that the atmosphere is about 78% nitrogen, and when you run nitrogen into a very hot combustion chamber (2500° F.), you oxidize that nitrogen producing NO_X. So you must have some system to control NO_X.

The solution we have adopted is the three-way catalytic converter.

As you can see from the illustration below, three-pollutant gases enter in the three-way converter:

1. HydroCarbons (HC or unburned fuel)
2. Carbon Monoxide (CO this stuff will kill you if you breathe it)
3. Oxides of Nitrogen (NO_X a neurotoxin)

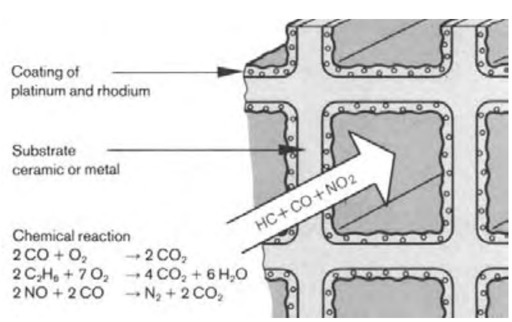


These same gases do not exit. All that comes out of the converter are three non-polluting gasses:

1. H_2O (water vapor)
2. CO_2 (a non poisonous gas that plants like)
3. N_2 (free nitrogen, plants like this as well).

Here is how the catalytic converter works:

- The inside of the catalytic converter consists of a substrate of ceramic.
- In the case of Porsche catalytic converters after 1989, a stainless steel substrate.
- This substrate is coated with a very thin layer of platinum and rhodium (in late model converters we use palladium as well).
- This noble metal layer is deposited over a wash coat that increases the surface area of the layer, the layer can be very thin, it is the total surface area that is critical.



Catalytic Components

Platinum is a catalyst for oxidation of hydrocarbons (it promotes the combining of the hydrocarbons with oxygen while remaining unaffected).

This is how we turn the combustion by product into H_2O and CO_2:

- You put two hydrogen atoms with one oxygen atom and you get water vapor.
- You put two oxygen atoms with one carbon atom and you get carbon dioxide.

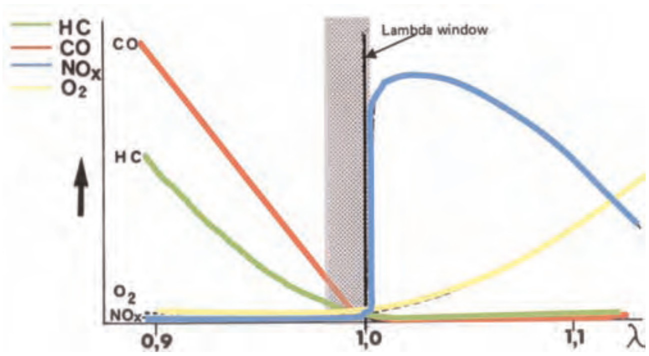
This chemical process is promoted by the surface of the platinum layer. It allows the atoms in the chemical compounds to recombine in the new combinations.

One side effect of oxidation is heat; as the hydrocarbons oxidize, they heat up the catalytic converter. The converter is not completely efficient until it gets to a temperature above 1100° F. (600° C). We have to avoid any condition that would allow an excessive amount of hydrocarbons (like raw fuel) into the converter, since it will overheat the converter and damage it. In extreme cases it could cause a vehicle fire.

Oxidation won't work on NO_X (it is already oxidized), so we utilize the rhodium to reduce (remove oxygen from) the NO_X. Each NO_X we pull apart yields one free nitrogen atom. Depending on which compound of NO_X is being broken up; one or more free oxygen atoms are produced (this is why it's an $_X$, it means all the possible compounds).

It is good that we produce free oxygen. We need it to oxidize the HC and CO. The rhodium catalyst works similarly to the platinum catalyst; its surface allows the NO_X to break apart into its component atoms. This is a very good solution for reducing NO_X and controls HC and CO emissions as well.

There is just one problem. If you look at the emissions after the Catalyst vs. Lambda 1 graph below you will see what the problem is.

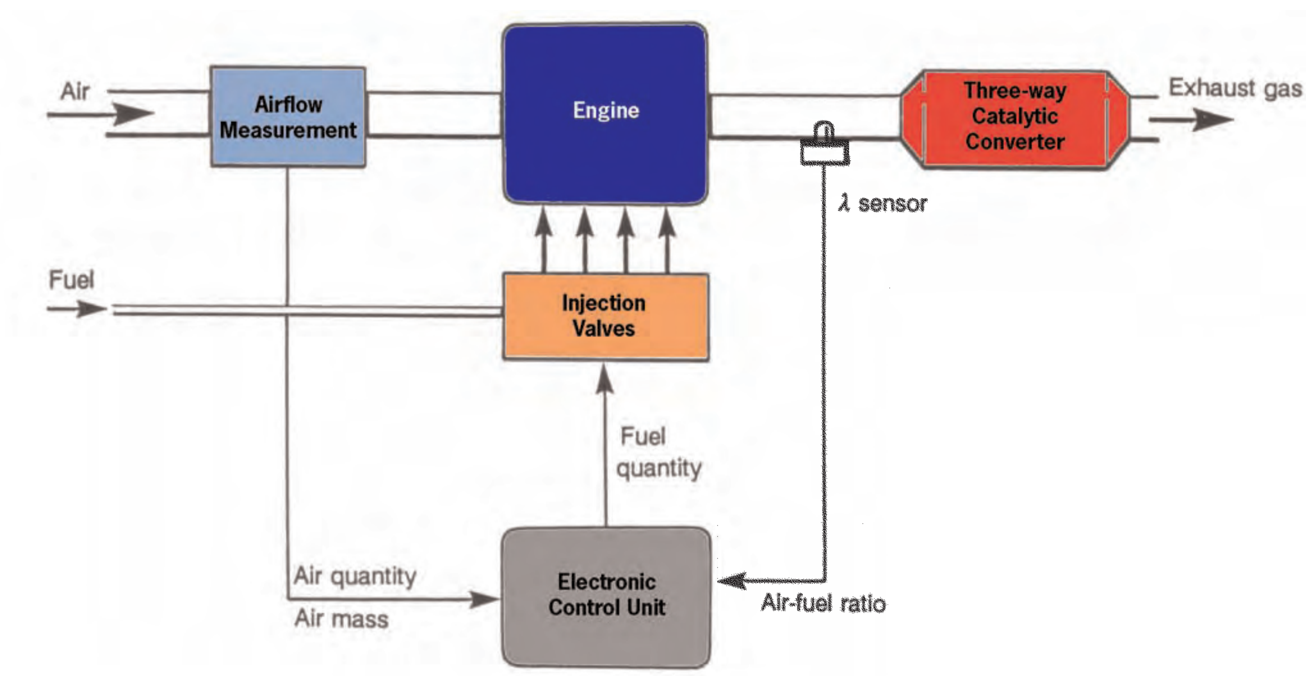


Emissions After – Catalyst vs. Lambda 1

You have keep the air fuel ratio very close to Lambda.

- If you go a little rich, the HC and CO rise above the legal limit.
- If you go a little lean, the NO_X goes right through the roof.

As a result, you must have very good control of the mixture, close to Lambda won't do. You must be very close to Lambda. This takes us back to the simple system model. We need to improve our mixture control in order to be able to keep the air fuel ratio very close to Lambda.



In the above illustration you will notice the change that allows us to achieve our goal is a sensor that measures O_2. We call it a Lambda sensor or oxygen sensor. As you observed in the Combustion by Products vs. Lambda graph, the oxygen content in the exhaust flow is directly proportional to air fuel ratio. This means that you can determine the air fuel ratio by looking at the oxygen content of the exhaust.

This is a different kind of input. The inputs we have talked about up until now give us information about engine conditions not directly controlled by the engine computer. The oxygen sensor tells us about a condition that we are controlling.

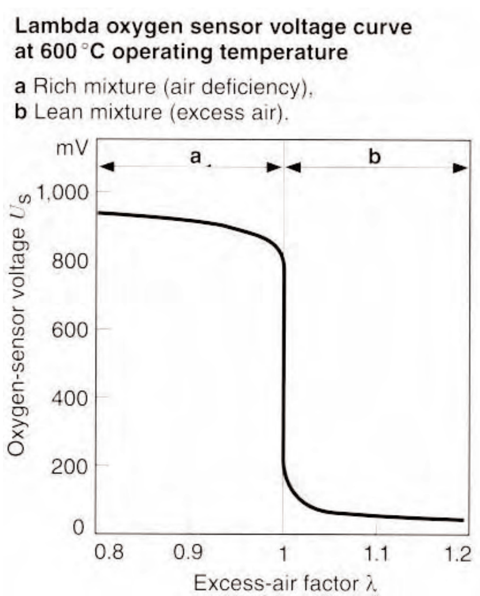
We call this type of input a feedback input as it "feeds back" information about the systems output.

So we change the way our system model works:

- Now we look at the air flow and engine speed,
- Go into the injector duration map,
- Get the Ti for that load speed point,
- Look at the oxygen sensor voltage,
- Modify the Ti a small amount to fine tune the mixture,
- Send the modified Ti to the injector final stage.

This allows us to keep the mixture in the window that will keep our three-way catalyst working correctly to eliminate the NO_X, HC and CO from our tailpipe emissions.

As we mentioned before, the oxygen sensor generates a voltage. This voltage is directly proportional to air fuel mixture as we can see in the Sensor Voltage vs. Lambda graph.

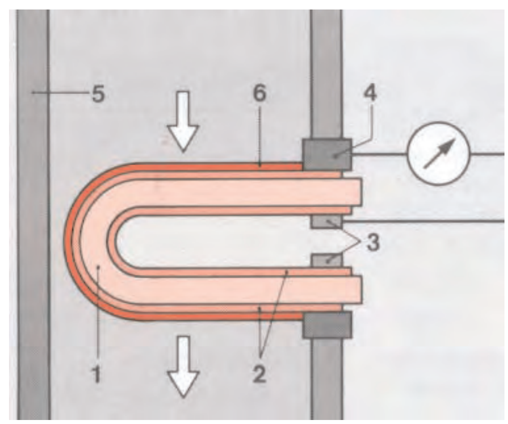


Sensor Voltage vs. Lambda

The oxygen sensor operates on the principal of a galvanic oxygen concentration cell with a solid-state electrolyte; this means that it is a lot like a battery.

The sensor consists of:

- A thimble shaped piece of Zirconium Dioxide ceramic (stabilized with yttrium oxide).
- This thimble is coated with a platinum layer on both sides.
- This layer is porous so it allows gases to penetrate to the ceramic layer. These layers act as electrodes in addition to the layer on the outside.
- The layer on the outside is exposed to the exhaust gas flow and acts as a small oxidation converter so all of the Hydro Carbons in the exhaust that passes into the ceramic have been oxidized. This is important, since we need to have a Stoichiometric (completely oxidized) gas stream at the sensor.
- The inside of the thimble is connected to the atmosphere on Porsche sensors via the inside of the electrical connection cables.



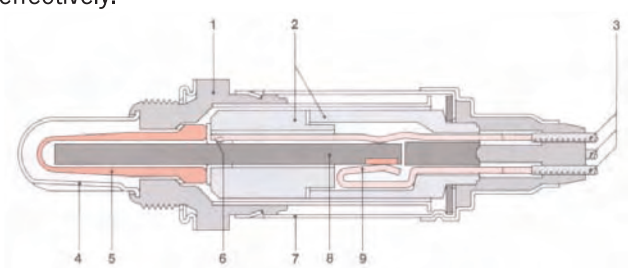
Oxygen Sensor Probe

1. Zirconium dioxide ceramic
2. Platinum electrodes
3. Contact for signal
4. Contact for ground
5. Exhaust pipe
6. Protective ceramic coating

Here is how it works:

- Sensor heats up to 650° F. (350° C).
- If there is a difference in oxygen content between the reference atmosphere on the inside of the sensor and the exhaust stream on the outside, then,
- Oxygen ions will migrate from the inside of the sensor to the outside (this will cause a voltage to be generated across the electrodes.
- If there is a high amount of oxygen in the exhaust stream there is no difference and there will be no migration and therefore no voltage generated.
- The Voltage is directly proportional to the oxygen content and oxygen content is proportional to air fuel ratio.

If we refer to the Sensor Voltage vs. Lambda graph we can see that if we keep the sensor voltage between 0.15 to 0.85 volts 150 millivolts to 850 millivolts, our mixture will be very close to Lambda 1 and our three-way catalytic converter will be able to control our tailpipe emissions effectively.



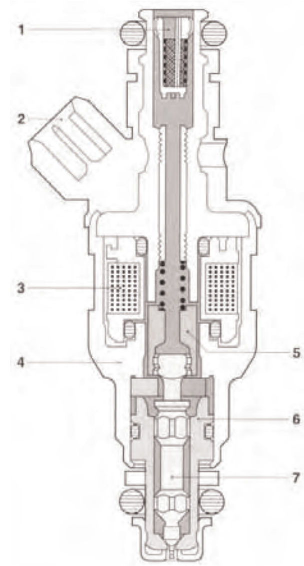
Heated Lambda Sensor

1. Sensor housing
2. Protective ceramic tube
3. Connecton cable
4. Protective tube with slots
5. Zerconium dioxide ceramic
6. Contact section
7. Protective sleeve
8. Heating element
9. Connector cable terminals for heating element

The Lambda sensor above has a internal heating element, this allows the system to go into feedback mixture control faster than a non heated sensor (remember you need 650° F. (350° C) for the sensor to operate). All Porsche oxygen sensors have been the heated type since M.Y. 1985. Later model Porsche vehicles also use planar sensors, these features will be described in the vehicle specific sections.

Let's take a detailed look at the components of our system model so far.

Fuel Injector



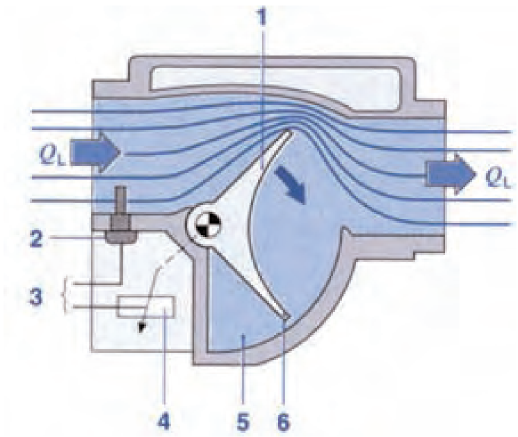
1. Filter in fuel inlet
2. Electrical connection
3. Solenoid winding
4. Valve housing
5. Armature
6. Valve body
7. Valve needle

The injector is an electromechanical valve, or solenoid.

- When current flows in the solenoid winding a magnetic field is created.
- This magnetic field lifts the armature off it's seat allowing fuel to flow. When the current stops, the armature is returned to it's seat by spring pressure and fuel flow stops.
- The injector is installed in the intake manifold with the injector pointing across the intake valve into the combustion chamber.
- The injector is connected to the control unit by a wiring harness with waterproof connector
- The injector is connected to the fuel system by the fuel rail with a connection sealed by an o-ring.

Each injector has a specific flow rate, so each engine has the flow rate of its injectors modified for that specific motor. You need to make sure that the injectors are the correct part number for the application. The injectors used by late model Porsche vehicles have special features like multiple injection orifices and smaller overall diameter of the injector body.

Airflow Meter



1. Sensor plate
2. Air temperature sensor
3. Output ECU
4. Potentiometer
5. Damping chamber
6. Compensation flap
QL. Intake air flow

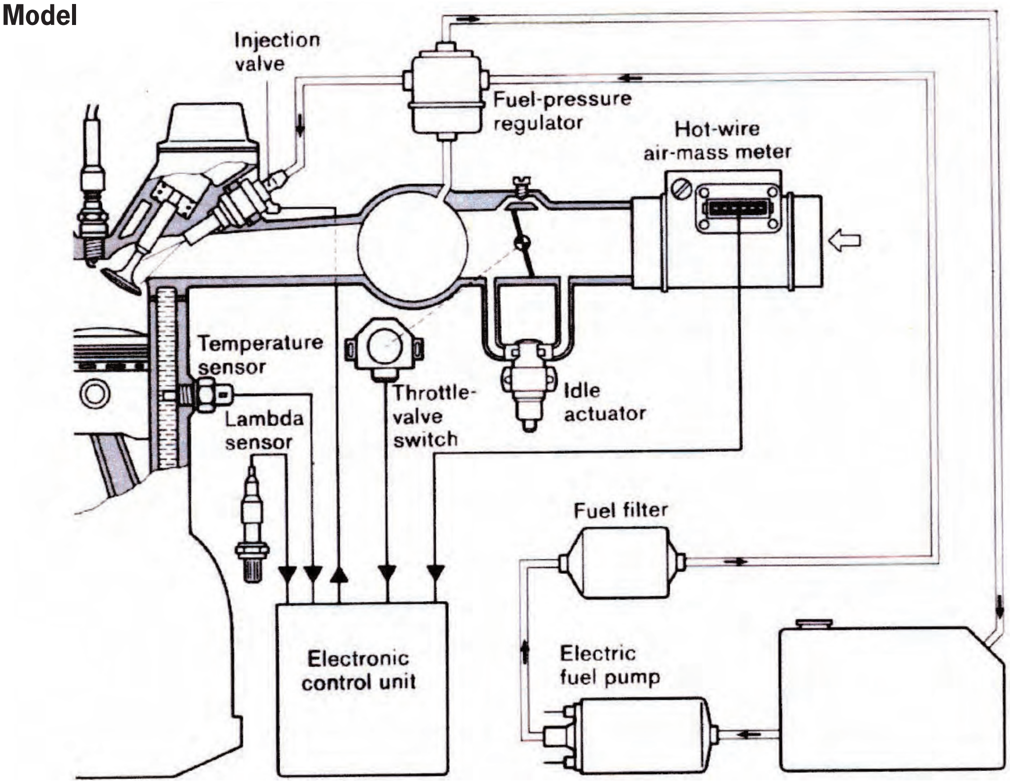
We will assume the airflow measurement from our simple system model is an airflow meter.

- The airflow meter is a chamber with a hinged flap that is moved by the air flowing into the engine.
- The more air flowing into the engine the higher the flap is raised.
- The chamber and the flap are calibrated so that at wide-open throttle the flap is just short of fully open.
- There is a second flap connected at a 90-degree angle to the first flap, this flap acts as a damping control.
- It compresses air in a chamber in the meter housing and this dampens the pulsations caused by the intake strokes.
- The flap has a potentiometer connected to it that indicates airflow to the control unit as an analog voltage that increases as airflow increases. The meter housing has a bypass passage with an adjustable cross section for adjustment this is used to calibrate the system by adjusting the idle CO concentration.

In addition, the airflow meter has an ambient air temperature sensor (intake air temperature sensor IATS) included in the meter housing. This is an NTC temperature sensor (thermistor). The airflow meter is installed in the intake tract after the air filter and before the throttle. It is connected to the control unit by a harness with a waterproof connector.

Notes:

New System Model

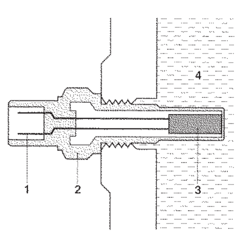


Now that we have described the operation of the basic fuel system, the oxygen sensor mixture fine-tuning system, and three-way catalytic converter. We need to revisit our system model and add more components and discuss system operation in closer detail.

In the system diagram above, you can see we have added some new components to our system model, so lets discuss their function.

Engine Temperature Sensor

The engine temperature sensor is a semiconductor temperature sensor (thermistor) with a negative temperature coefficient (as temperature rises the resistance of the sensor decreases). It is screwed into the coolant jacket.



Engine Temperature Sensor

1. Electrical terminals **2.** Housing
3. NTC resistor **4.** Coolant

The information from this sensor is used to sense engine temperature so that the air fuel mixture can be adjusted to compensate for the effect of cold conditions on starting and running.

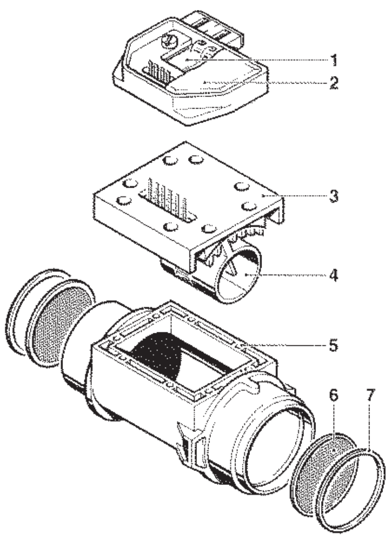
- A cold engine requires more fuel, so if we do not make the mixture richer when starting, the engine will be hard to start or won't start at all.

This is due to several factors:

- The cold intake tract, cylinder walls and combustion chamber, which condense fuel on the surfaces of the intake tract, combustion chamber and reduce atomization.
- After startup, a cold engine requires additional fuel until the intake and combustion chamber heat up and fuel atomization improves.
- A cold engine has more friction and requires more energy to turn over until it reaches operating temperature.
- The enrichment provides additional torque for a smooth cold idle.
- The cold enrichment is gradually reduced as the engine temperature rises to operating temperature and the need for cold enrichment ends.

Air Mass Sensor

In our previous system model we used an airflow measure (the last Porsche model that used an airflow meter was the M.Y. 1994 911 Carrera type 964), with newer models our air fuel mixture is determined by weight, air mass gives us a more accurate measurement. Using air mass also gives us compensation for air density, this is important since dense air has more oxygen and with that, you need to compensate by adding more fuel.

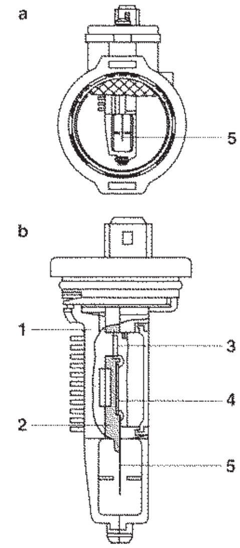


Hot Wire *Air Mass Sensor Components*

1. Hybrid circuit
2. Cover
3. Metal insert
4. Venturi with hot wire
5. Housing
6. Screen
7. Retaining ring

Our new system model has a hot wire sensor. Newer Porsche models use thick film air mass sensors. In addition the air mass sensor contains an intake air temperature sensor. This sensor lets us compensate for the change in the amount of oxygen in the atmosphere caused by temperature.

- Hot air is thinner and has less oxygen per unit.
- Cold air is denser and has more oxygen per unit.
- We need to lean out the air fuel mixture for hot intake air and richen up the mixture when the intake air is cooler.
- We use the intake air temperature for ignition timing control as well we retard the timing as temperature increases.



Hot Film *Air Mass Sensor Components*

a. Housing
b. Hot film sensor (mounted in the middle)
1. Heat sink
2. Intermediate module
3. Power module
4. Hybrid circuit
5. Sensor element

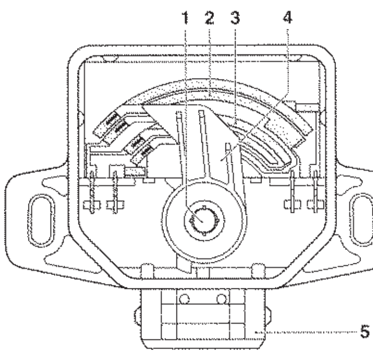
Notes:

Fuel System Basics

Throttle Position Sensor

This input tells the control unit where the throttle is (for example idle or full load position). Before 1995 Porsche used idle and full load contacts. Later engine management systems utilize a potentiometer to indicate throttle position. The throttle position sensor is also utilized to run deceleration fuel cut off and acceleration enrichment.

When the throttle plate is opened rapidly, the air entering the engine has less mass (weight) than the fuel, and therefore moves faster than the fuel. This effect causes a momentary lack of fuel in the mixture (lean condition) that must be compensated for by the fuel system. Otherwise, there would be a hesitation or stumble when the accelerator is rapidly actuated.



Throttle Position Sensor Components

1. Throttle position sensor shaft
2. Resistor track 1
3. Resistor track 2
4. Contact wiper arm
5. Electrical connection

When the engine is decelerating, there is no need for fuel since the inertia of the vehicle keeps the engine turning. In addition, when the throttle is closed and the engine revolutions are high, a low intake pressure is generated, and since liquids boil in a vacuum, any fuel in the intake will immediately turn to fuel vapor and cause a very rich mixture. Because the excess fuel is not needed, the injectors are turned off during deceleration.

The throttle position sensor is also used to control full load enrichment, from approximately 66 degrees of throttle angle the mixture is moved richer than Lambda. This reduces NO_X emissions since it requires heat energy to atomize the additional fuel, the temperature of the combustion chamber is lowered, this in turn reduces NO_X formation. The magic number is 2500° F, if you drop below this temperature, NO_X is substantially reduced. In order to have this enrichment, you must turn off the oxygen sensor system during full throttle enrichment, otherwise the oxygen sensor system would return the mixture to Lambda.

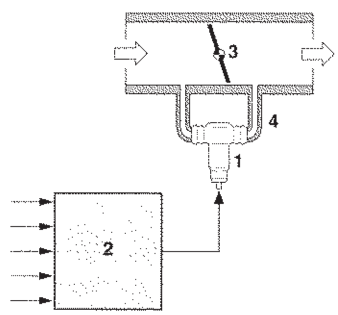
This is called "open loop" operation since the Lambda sensor is not used to close the control loop. The oxygen sensor mixture control is also turned off during cold start, since you must have a mixture richer than Lambda, a cold engine operates in "open loop".

Idle Speed Stabilizer

We have computer control of idle speed in our new system model (notice we dropped the simple).

This works a lot like fuel control:

- It has a map.
- A program looks at inputs.
- The program controls the idle speed stabilizer based on the inputs.



Idle Speed System Diagram

1. Idle valve (bypass valve)
2. ECU
3. Throttle Valve
4. Bypass tract

As you can see in the diagram, the idle speed stabilizer controls the cross section of a bypass around the throttle plate.

- Enlarge the cross section and the idle speed increases.
- Reduce it and the idle speed decreases.

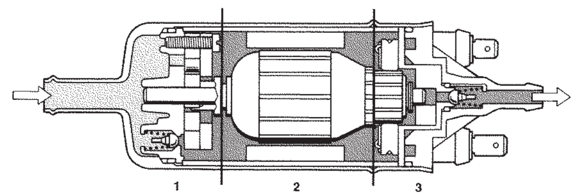
We also call the idle speed stabilizer the idle air control valve or IACV. The idle control system utilizes the ignition timing as well as the idle stabilizer to make small changes in engine speed.

- It advances ignition timing to increase speed and retards ignition timing to reduce speed.
- Only a small change in ignition timing (less than five degrees) is needed. This is done because ignition timing can be changed much faster than the stabilizer can be moved.
- It makes small changes in engine speed with ignition timing control and large changes with the idle stabilizer.
- Because we have digital control with a program, the idle speed stabilization system can compensate for loads like the air conditioning compressor or when electrical demand loads the alternator.

In addition, we can utilize the idle speed stabilization system for special conditions, for example, we open the stabilizer to control the low pressure formed in the intake manifold during deceleration, we also open it while cranking the engine during start up to reduce the load on the starter motor.

Hydraulic Fuel System

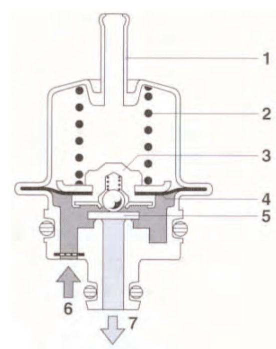
We have added the hydraulic fuel system to our system model. This system starts at the fuel tank and then proceeds to the fuel pump through the fuel filter to the injectors. It also includes a fuel pressure regulator.



Fuel Pump

1. Pump stage
2. Electric motor
3. Pump cover

In our New System Model diagram we show a fuel pressure regulation system with a fuel return to the tank. Later systems are returnless systems that have the regulator in the tank and no line back to the tank from the engine.



Fuel Pressure Regulator

1. Intake manifold connection
2. Spring
3. Valve holder
4. Diaphragm
5. Valve
6. Fuel supply
7. Fuel return

The type of regulator that is shown has a vacuum connection to the intake manifold.

- This reduces fuel pressure when intake manifold pressure is low.
- This is done to compensate for effective fuel pressure. If the underpressure in the intake manifold is for example -5 PSI and the fuel pressure is 35 PSI, then our effective fuel pressure would be 40 PSI.
- So when the regulator has - 5 PSI underpressure applied to its diaphragm it lowers the fuel pressure by 5 PSI making it 30 PSI actual pressure keeping our effective pressure at 35 PSI. Keeping our effective fuel pressure the same no matter what the intake manifold pressure is.

The later Porsche models that have returnless fuel systems compensate for effective pressure by modifying the fuel map when the intake manifold pressure is below atmospheric pressure.

- The fuel system control unit has a driver to control the fuel pump relay that actuates the fuel pump.
- The fuel pump control actuates the fuel pump when the control unit receives system on power from the ignition switch and receives an engine speed signal.
- You only want the fuel pump to operate when the engine is turning over.
- If we had the fuel pump turn on when the ignition switch closed, the fuel pump would run after an accident that stopped the engine and either cause or feed an engine fire.
- Later systems run the fuel pump for a short period of time when the ignition switch is first actuated (anticipatory control).
- In the case of the Cayenne, the pump is turned on when the driver's door is opened.
- This is only done the first time the system sees the input.

We can only have these kinds of control routines when our system is digital. With a digital system its easy, you only need to change the software.

Digital Motor Electronic (DME)

We have described the basics of digital electronic ignition and fuel systems. Now we will discuss how the three basic elements fuel system, ignition system and digital microcomputer are combined in one system Digital Motor Electronic.

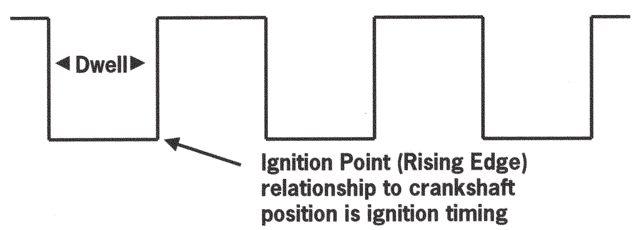
First think about the inputs to ignition control.

- Load
- Speed
- Throttle position
- Engine and ambient temperature

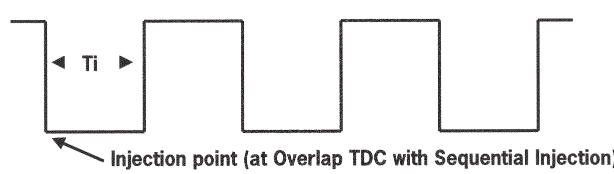
They are the same as the inputs for fuel control.

- Speed
- Throttle position
- Engine and ambient temperature
- We add the oxygen sensor for fuel control but otherwise the same inputs for both systems.

Outputs



A square wave is sent to the ignition system where the period of the wave is dwell; and the relationship between the rising edge of the square wave and crankshaft position is ignition timing.



A square wave is also sent to the injector. The period of the square wave is injector duration (Ti) and the falling edge of the waveform is the beginning of injector operation. This is timed to TDC on the banked injection systems we used up until 1989. In 1989 Porsche begin to use sequential injection where you only operate the injector when the intake valve is open, so we time the injection point to the over lapping TDC.

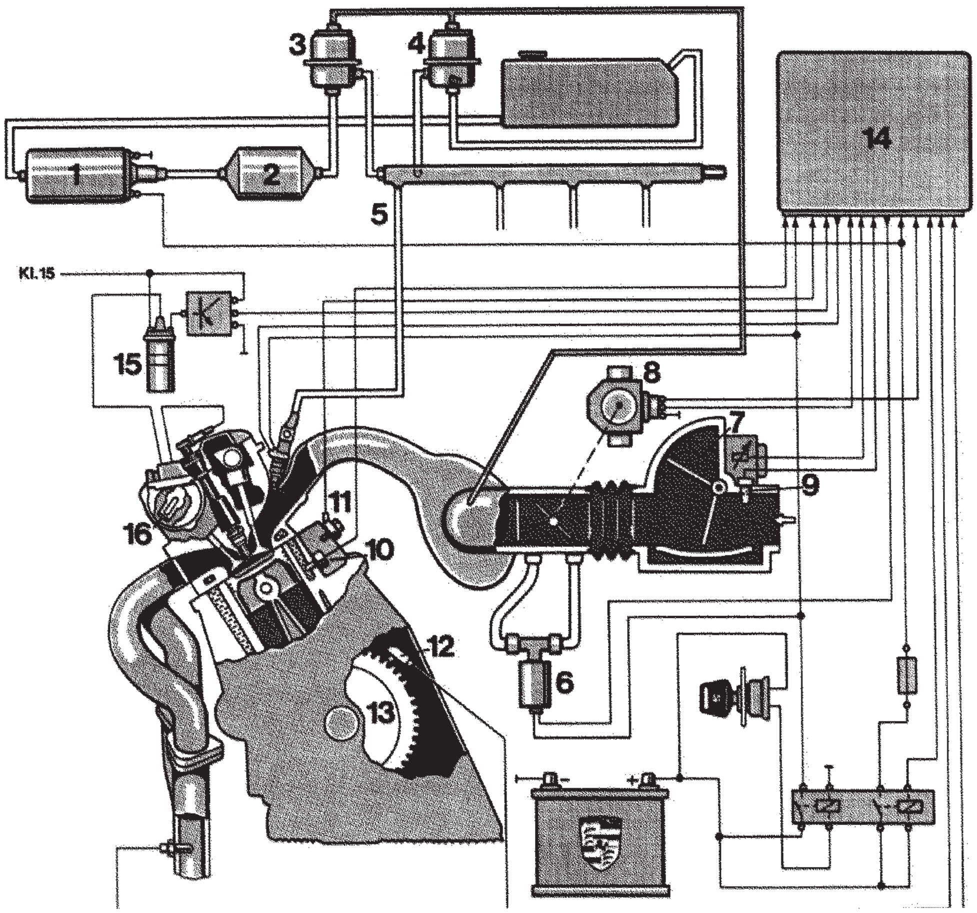
The bottom line is that the inputs and outputs for fuel and ignition control are either the same, or very close to the same for both systems. So combining them in one control unit just made sense.

Adding the microcomputer was the only way you can have data maps stored in memory (for example injection duration and ignition timing maps), and a program that utilizes them to control engine management systems. This achieved exceptional output and performance while maintaining the emissions levels required by law.

With a few exceptions (928s and pre 1996 911 Turbos) Porsche has utilized DME for engine management since M.Y. 1985.

Notes:

Fuel System Basics



Let's utilize a basic DME system to take a closer look at how digital engine management works.

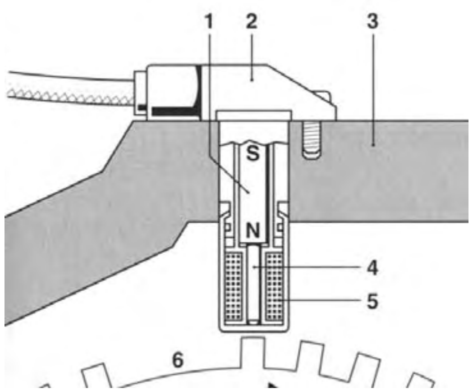
1. Fuel pump
2. Fuel filter
3. Fuel pressure damper
4. Fuel pressure regulator
5. Fuel rail and lines
6. Idle air control valve
7. Airflow meter
8. Throttle position sensor
9. Intake air temperature sensor
10. Engine coolant temperature sensor
11. Knock sensor
12. Engine speed sensor
13. Flywheel with speed sensor ring with teeth missing for reference signal
14. Control unit with microcomputer
15. Ignition coil
16. Distributor cap and rotor

The DME example above is close to the systems Porsche used up until M.Y. 1994, it uses an airflow meter to measure the amount of air entering the engine. After M.Y. 1994, Porsche systems use an air mass sensor to measure the air entering the engine.

Let's examine the new features of the fuel system.

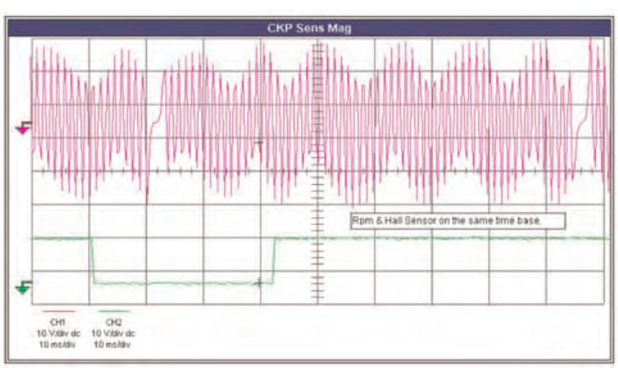
First is the speed and reference sensor. It is an inductive sensor.

- It uses a magnetic field moving through a coil of wire to produce a signal that indicates engine speed.
- It has an area where two teeth have been removed to give a reference to top dead center of cylinder number one.
- The sensor ring on the flywheel would have 60 teeth, but two have been removed for the reference signal.
- This gives us 6 degrees for each tooth, 3 degrees for the high section, and 3 degrees for the low section.
- The computer can determine crankshaft position even further to a fraction of a degree, giving DME the ability to see crankshaft position, acceleration and deceleration in fine detail.



Engine Speed Sensor

1. Permanent magnet
2. Housing
3. Engine Housing
4. Soft iron core
5. Winding
6. Ring gear w/reference point (tooth gap)



Speed Hall Sensor Wave Form

Fuel Pressure Damper

The fuel pressure damper, is a device that reduces pressure pulsations in the fuel rail.

- These pulsations might intrude into the passenger compartment as a buzzing noise.
- We don't need a pressure damper on systems with sequential injection as we are not operating all of the injectors at TDC of each crankshaft revolution, instead, when the intake valve of each cylinder opens we inject fuel.
- This greatly reduces the amplitude of the pressure pulses and eliminates the need for the damper.

Relays

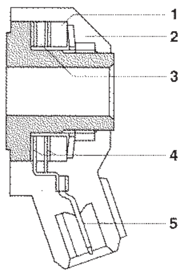
We also see the duplex relay for system power and fuel pump control (DME relay). This type of relay was used up to M.Y. 1997. After 1997, two separate relays were used.

Fuel & Ignition Control Unit

The fuel and ignition control are combined into one control unit, since both the fuel injectors and the ignition final stage are outputs for this system. The other big change is the addition of a knock sensor which operates as a feedback input for ignition control.

Notes:

Knock Sensor



Engine Knock Sensor

1. Seismic mass
2. Casting
3. Piezsoelectric ceramic layer
4. Contact paths
5. Electrical Terminals

With an digital ignition system with a knock sensor:

- You can use a more aggressive ignition-timing map; and then if the sensor detects an ignition knock, the DME can retard the timing of the cylinder that knocked.
- The system determines the cylinder that needs to be retarded by counting. In a six cylinder engine, the same cylinder that the knock was detected from will be back in six ignition cycles, so the system counts six cycles from the knock and retards that cylinder.
- The early systems with knock control moved timing in steps of three degrees, up to a total of nine degrees. The newer systems have different steps and totals, for example, the 911 Carrera (996) move in steps of two and three quarters degrees for a total of twelve degrees.
- Most of the knock control systems also utilize a Hall sensor to determine which reference signal indicates TDC cylinder number one.
- This is needed when there are two knock sensors. For example; on a flat six, if cylinder number one has just fired and the knock sensor that is monitoring the cylinder four through six bank senses a knock, the system can ignore that sensor.
- The knocking cannot be from the ignition of cylinder number 1 and retarding the timing will have no effect on the knock and only reduce the power output of the engine.

This is a step up in the sensitivity of the knock control from systems with only one knock sensor (the only Porsche model that has one sensor was the 944 Turbo). In model year 1997 the distributor cap and rotor were eliminated. Porsche adopted unit ignition, the secondary ignition system (plug wires, distributor cap, and rotor) components were no longer required. All that is necessary is the short high-tension path from the coil unit to the spark plug.

As we study the later versions of DME we will see new inputs and outputs added to enable new functions and faster processors with more memory; however, the basic system operation won't change very much from our system model.

We will utilize the vehicle specific sections that describe each system in detail to describe the new functions of the engine management system.

Notes:

Fuel Trim & Adaptive Mixture Control Systems

The mixture control system has evolved over the last two decades into a self-adjusting system that “learns” and self adjusts.

This system has three main levels of control:

- Main determination of injector duration for entire engine.
- Fuel trim system, adjusting mixture based on oxygen sensor voltage. OBD-II vehicles have two systems, one for each cylinder bank.
- Adaptation system adjusting fuel maps on long-term basis. To understand this system we need to examine these control levels in detail, so we will start at the beginning with a review of main injector duration determination.

Main Mixture Control

The fuel mixture control program calculates the primary injector duration based on the load input from the mass airflow sensor and engine speed from the speed and reference sensor.

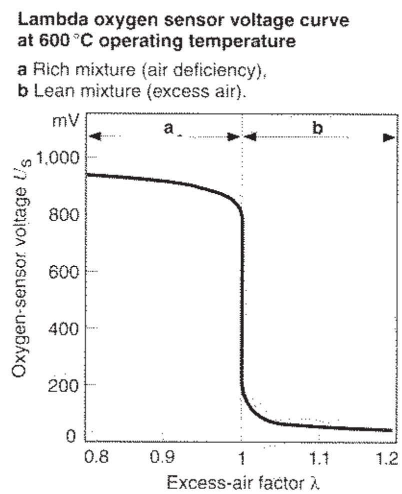
- The program takes the present engine load and engine speed and retrieves an injector duration from the injector duration map.
- The program then modifies the injector duration based on the real time inputs (for example, if the engine coolant temperature is low, time is added to move the mixture rich).
- This injector duration (Ti) is then sent to the injector driver circuit and the injector is opened by this Ti.

Fuel Trim System

The next level of control is the fuel trim system. This system utilizes the oxygen sensor to modify the Ti that the main mixture control sends to the injector driver circuit.

After 1996 (with OBD-II), this system divides the fuel system in half and each bank of the engine has it’s own fuel trim system. These systems make a small change in the Ti based on the oxygen sensor voltage.

- When the voltage goes high, it indicates the mixture is rich and the control moves the mixture lean by reducing Ti.
- When the voltage goes low, it indicates the mixture is lean and the control moves the mixture rich by increasing Ti.

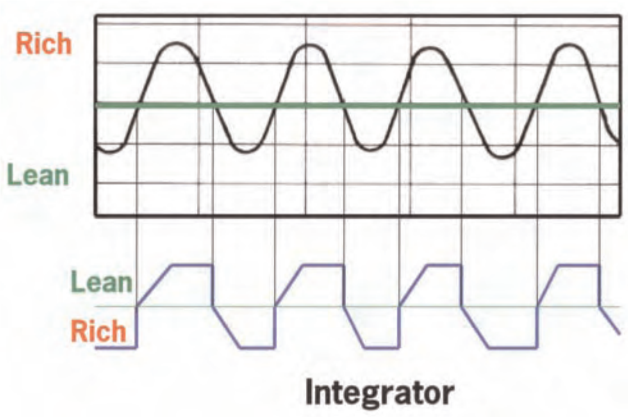


When we analyze the Voltage vs. Lambda graph we see three things:

- When the oxygen sensor voltage is in the area of 150 millivolts to 850 millivolts we are close to Lambda.
- In this area our three-way catalyst will operate at optimum efficiency.
- We will have good control of pollutant emissions.

Fuel Trim & Adaptive Mixture Control

You can see the relationship between oxygen sensor voltage and mixture control in the illustration below.



This control system is referred to as the integrator. This control system is also known as short term fuel trim. It turns the oxygen sensor voltage into a decision to move mixture.

It keeps the oxygen sensor voltage moving between 150 millivolts and 850 millivolts by adding or subtracting time from injector duration.

For example:

- A normal idle Ti could be 2.4 milliseconds.
- A normal idle fuel trim might be + 0.24 milliseconds.
- 2.4 milliseconds + .24 milliseconds = 2.64milliseconds of Ti. The mixture is richer (adding Ti adds fuel).
- This would be a correction for a lean reading.
- The opposite would be true for a rich reading.

The mixture moves up and down and the oxygen sensor voltage follows. The oxygen sensor voltage is always moving between 150 and 850 Millivolts.

There are reasons for the movement between rich and lean:

- When the integrator (short term fuel trim) moves the mixture rich, it creates a lack of oxygen in the catalyst, this is needed for the reduction of NOx.

- When the integrator moves the mixture lean, it creates a surplus of oxygen needed for the oxidation of HC and CO.

This is how a three-way catalytic converter is capable of meeting stringent emissions regulations.

This system however, has a limit to its ability to control mixture. If the deviation from Lambda is large enough to require a movement of more than plus or minus approximately 0.4 milliseconds, the system cannot correct the mixture. The system will default to open loop operation and a fault will be stored.

Adaptation

We will now examine fuel system adaptation (it is an addition to the fuel trim program software) and how it changes the fuel trim system.

First we need to know how the Ti map is generated.

The answer to this is; it comes from the development department at Weissach. Porsche fuel system engineers generate the Ti map with a test engine on a motor dynamometer. They run the engine in each load/speed range and then move the mixture rich and lean until the engine operates at Lambda 1. This gives us a Ti map for an ideal engine (The timing map is generated in the same way).

This is a great method however, not all engines are made equal, and engines change as they age. So one fuel map (one size fits all) can't be perfect for all engines. Even if the map were perfect when the engine was new, it would not be perfect after the engine has been run 100,000 miles.

We have a special addition to the fuel mixture software, it is called adaptation (long term fuel trim). Here is how it works.

- The adaptation program monitors the mixture control system for a time period. For example ten minutes; let's say that during that time period the integrator has had to add .25 milliseconds to the Ti for the entire time.
- We then know that the Ti map is too lean by .25 milliseconds.
- The adaptation program adds .25 milliseconds of time to the fuel map. When the fuel trim system gets a Ti from the fuel map, it only needs to make a small correction since the Ti map has been adjusted to fit the engine that it's in control of.

The adaptation program has no hardware or moving parts. It is a system that exists only as lines of code in the fuel trim system software.

Before we added adaptation to our fuel mixture control system; it was necessary to manually adjust the idle CO by disconnecting the oxygen sensor (to put the system into open loop) and adjusting an air bypass around the airflow sensor. With adaptation we no longer need a CO adjustment. The system automatically adjusts itself, compensating for differences between engines caused by manufacturing tolerances and other conditions (air leaks, wear in internal parts…).

Why bother with adaptation? We already have the integrator. It can just keep adding the .25 milliseconds of Ti without changing the map.

The reasons we need adaptation are:

- We do not always operate in closed loop. If we do not adapt the Ti map we will not have the needed correction when we operate in open loop.
- The fuel trim system works much better when it is operating in the center with the same amount of correction available in both the rich and lean directions.

Adaptation Numbers

Another feature of digital engine management is the ability of the engine management computer to communicate with a diagnostic system. Data such as; inputs, outputs and other information from the operation of the control systems can be monitored. Porsche has had a series of testers: 9268, 9288, PST2 and now PIWIS.

With the system tester we can see a large number of values from the fuel system. One of these is how much the mixture adaptation system has changed the Ti map. We can learn to use this information for diagnostics.

Porsche adaptation systems have different ranges of control:

- One range is adaptation for idle, RKAT (before model year 2000 we called it TRA)
- The Idle range as we have described in our example adds or subtracts injection time in response to oxygen sensor input.
- Another range is adaptation for the load range FRA (in the latest models the FRA is divided into an upper and lower range)
- The load range is slightly different. It does not add and subtract time from the Ti; it multiplies the Ti.

For example:

If you multiply a Ti of 2.4 ms X 1.1 = 2.64 milliseconds.
If you multiply a Ti of 2.4 ms X 0.9 = 2.16milliseconds.

By multiplying the Ti in the load range we are able to make large changes easily. Multiplying isn't as good for the idle range where we need to make small changes.

In addition, in 1996 with OBD-II we divide the fuel trim system into two systems.

One system for cylinder bank 1 – 3
One system for cylinder bank 4 – 6
or
One system for bank 1 – 4
One system for bank 5 – 8

When we divide the fuel trim system in half, there isn't much difference in how the fuel trim system works. There are just twice as many adaptation numbers and oxygen sensors.

Our digital fuel mixture control has a fuel control program operating in a microcomputer and utilizing maps for control. We talked about the injector duration (Ti) map in the digital system section.

There are several other maps, for example:

1. The evaporative emissions purge valve map.
2. The idle control valve map.
3. Ignition control map.

With a digital microcomputer we have the possibility to add new features to the software.

A couple of examples would be:

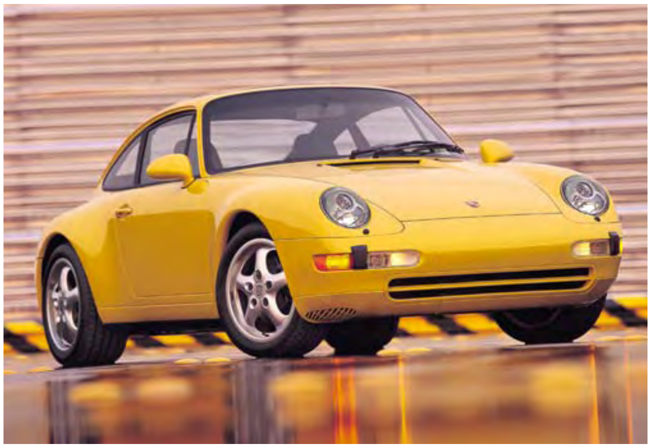
1. VarioCam
2. Resonance Intake System

We just add the hardware to the engine, and instructions to the program to drive the hardware (output). There can also be features that have no hardware. They only exist as lines of code in the fuel system software. These systems will be discussed in a separate section.

Notes:


BB PW 128

Notes:



General

DME 2.10.1 was first used on the model year 1992 - 1995 968 and the 1995 911 Carrera (993). This pre-OBD-II Motronic engine management system utilized a single control unit to manage sequential fuel injection, electronic map ignition, and adaptive features such as; knock control, mixture control, and idle. This system incorporated extensive self testing capabilities.

The following DME 2.10.1 information was first published in the 1995 911 Carrera (993) Service Information Technik book.

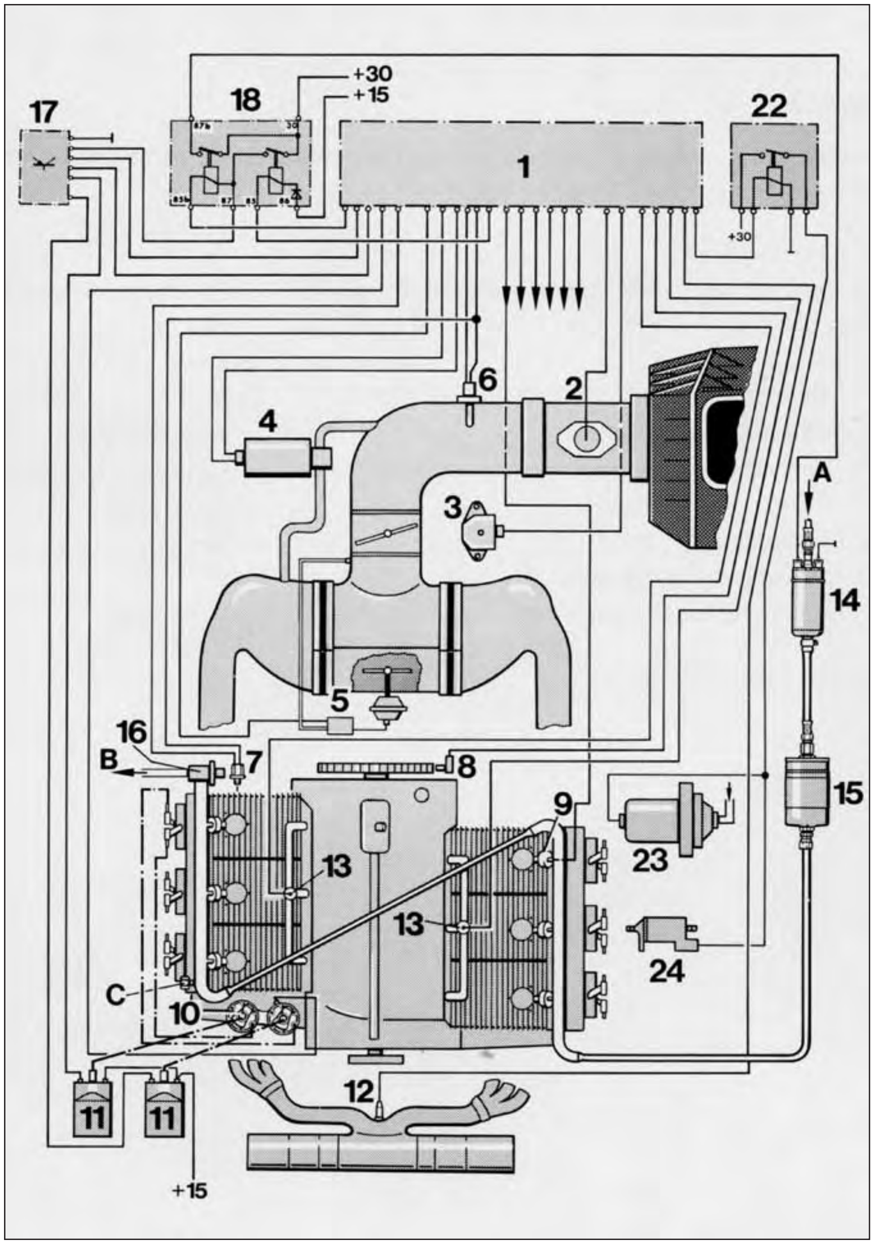
The DME 2.10.1 consists essentially of the following components and basic features:

- Control unit with 64 Kbyte program/data memory
- Sequential injection system
- Electronic-map ignition system with adaptive knock control
- Adaptive mixture control
- Adaptive charging regulation
- Activation of the resonance flap in the intake system
- Carbon canister with electronically controlled venting
- A potential free oxygen sensor
- Hot film mass airflow sensor
- Plausibility test and generation of substitute values
- Extensive diagnostic possibilities with System Tester 9288
- Throttle potentiometer

DME 2.10.1

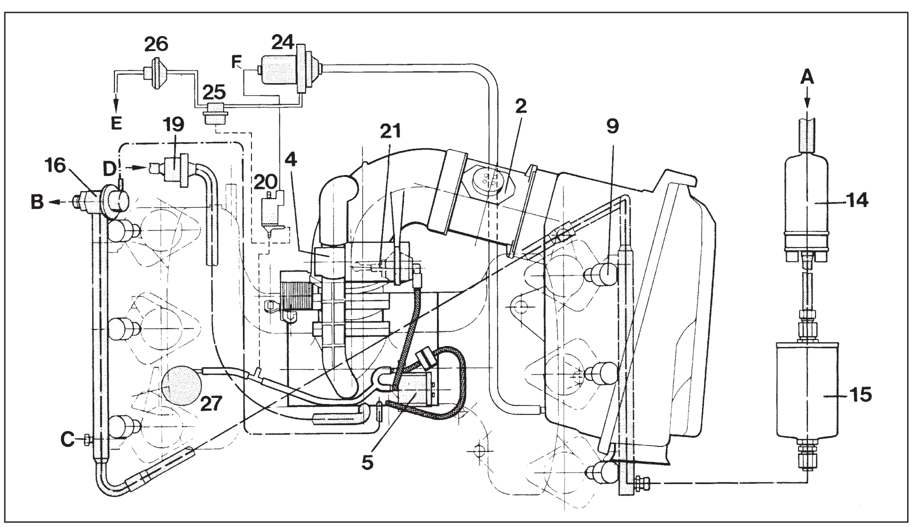
DME – Schematic

1 - DME control unit
2 - Mass airflow sensor
3 - Throttle potentiometer
4 - Intake manifold flap positioner
5 - On-off valve resonance flap
6 - Intake air temperature sensor
7 - Engine temperature sensor
8 - Speed/reference mark sender
9 - Injection vlaves
10 - Distributor
11 - Ignition coils
12 - Oxygen sensor
13 - Knock sensors
14 - Fuel pump
15 - Fuel filter
16 - Pressure regulator
17 - Ignition final stage
18 - DME relay
22 - Auxiliary air pump relay
23 - Auxiliary air pump
24 - Electropneumatic valve
A - Fuel inlet
B - Fuel return line
C - Check connection for fuel pressure



Fuel – Air Flow

19 - Tank venting valve
21 - Vacuum modulator for resonance flap
D - From carbon canister
E - To the camshaft housing – auxiliary air supply
F - Electrical signal from DME



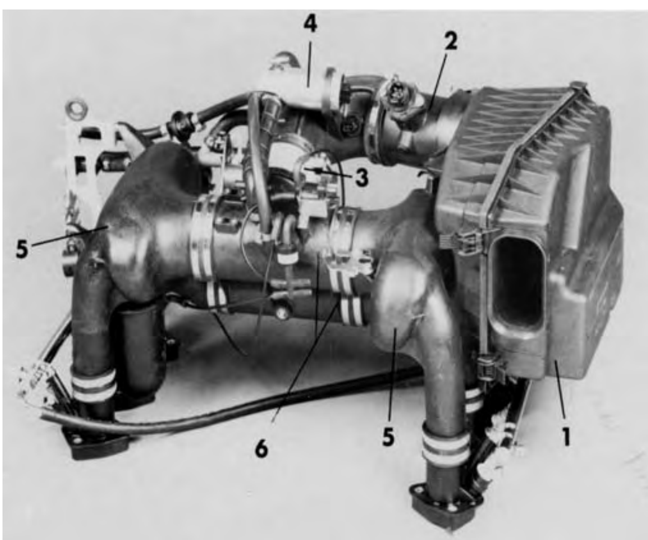
Air Flow

The air required for combustion is drawn in over the air filter, the mass airflow sensor, the throttle body and the two-stage resonance intake system.

The paper cartridge in the air filter is fully recyclable. The resonance intake system is composed of two intake tanks, one for each row of cylinders, which are directly connected to each other via two resonance pipes.

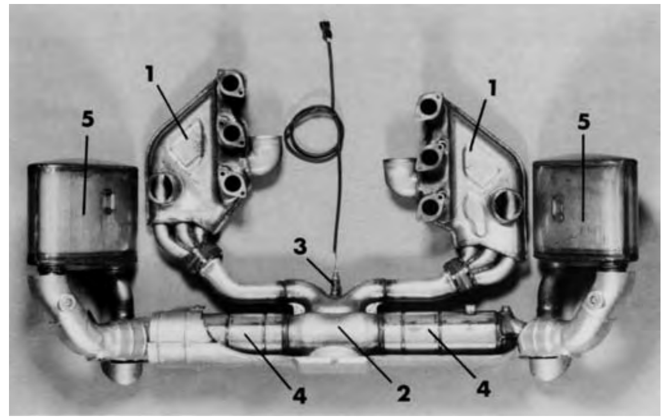
The air is drawn in through the larger diameter pipe, and the smaller pipe is switched on or off line by the resonance flap controlled by the DME control unit.

The air filter housing, the housing for the mass airflow sensor, the connecting piece to the resonance pipes, the intake distributor sections and the insulation plates are made of recyclable plastic and are therefore of lightweight design and very good surface quality.



1 - Air filter
2 - Mass air flow sensor
3 - Throttle body
4 - Intake manifold flap positioner
5 - Intake tank
6 - Resonance pipes

Exhaust Gas Flow



After the exhaust gas has left the combustion chamber, it first enters the exhaust manifold which is designed as a heat exchanger (1). In a mixing chamber (2), the exhaust gas flows of both cylinder banks are combined, and the oxygen contents of the gas is detected by the oxygen sensor (3). The exhaust gas is then separated into two streams, each one of which passes two separate catalytic converters (4) and a muffler (5) for each exhaust line. The catalytic converters are fitted with metallic carriers coated with a special material layer that provides the catalytic reaction.

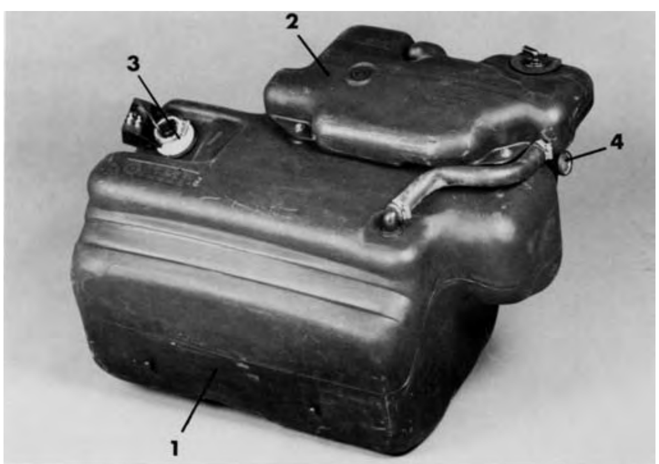
This catalytic contact causes carbon monoxide, unburned hydrocarbon residues and nitrogen oxides to be converted into carbon dioxide, nitrogen and water. The separation of the exhaust gas streams allowed the pressure losses in the exhaust system to be reduced (easier gas flow) and to house an acceptable muffler volume.

Fuel System

The fuel is supplied by an electrical roller-cell fuel pump which feeds a constant quantity of fuel to the injection valves. The fuel quantity required by the engine is controlled by solenoid injection valves insytalled on the engine. The excess fuel not required by the engine is returned to the fuel tank. A fuel pressure regulator ensures a constant pressure differential at the injection valves.

Fuel Tank

The fuel tank is located at the front of the vehicle in front of the heating unit. The capacity is 18.75 gal. (71 l), and it weighs 14.3 lbs. (6.5 kg). The tank is of blown polyethylene (synthetic) and its internal and external surfaces are fluorinated, i.e. during manufacture the tank is flushed in a fluorine gas mixture in a process chamber. The gas reacts with the plastic surface and gives an extremely thin, teflon-type surface coating that is impervious to fuel vapor, there by eliminating any possibility of unpleasant odors.



1 - Fuel tank
2 - Expansion tank
3 - Fuel tank sender
4 - Filler neck

The fuel tank is shaped in such a way that it can be removed without removing the transverse wall and held in place by a single restraining strap.

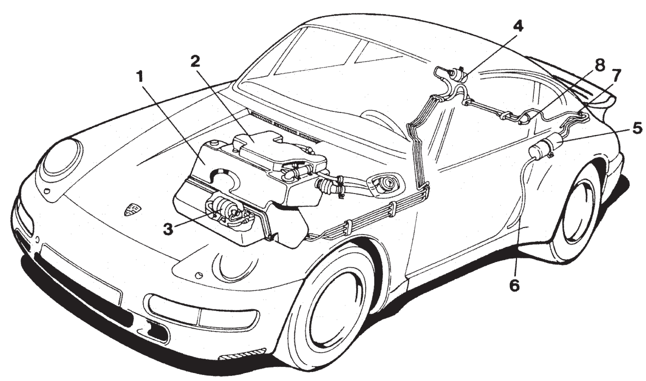
The expansion tank is mounted directly onto the fuel tank with three screws and has two connection pipes. The tank fuel level sender is located on the right hand side of the tank, and the connection to the filler neck is on the left of the tank.

The filler neck has a dished end fitted with a seal and is screwed into the left hand fender. The upper part of the neck is made of metal and its shape varies depending on whether it is used for leaded or unleaded fuel. The filler neck is connected to a viton hose which is impervious to fuel vapor.

The noise reduced fuel pump is mounted under the tank below the vehicle floor and is accessible through a separate cover plate.

The fuel circuit remains virtually unchanged; it runs from the fuel strainer screwed into the fuel tank to the pump, on to the fuel filter, and then across a Z-shaped plastic tube (that must not be kinked) routed below the intake housing to the pressure regulator. The return line ends next to the pump, feeding the fuel back into the fuel tank.

All connections of the pump and tank are accessible via the separate cover plate. The fuel lines are made of steel tube with press fitted rubber hoses. The connecting joints are downstream of the fuel pump and in the engine compartment. The fuel lines are routed in the ribbings along the floor pan and the tunnel of the vehicle, and are held in place with rubber mounts and synthetic clips. The vent lines are made of polyamide.



1 - Fuel tank
2 - Expansion tank
3 - Fuel pump
4 - Fuel filter
5 - Carbon canister
6 - Purge air line
7 - Tank vent
8 - Return line

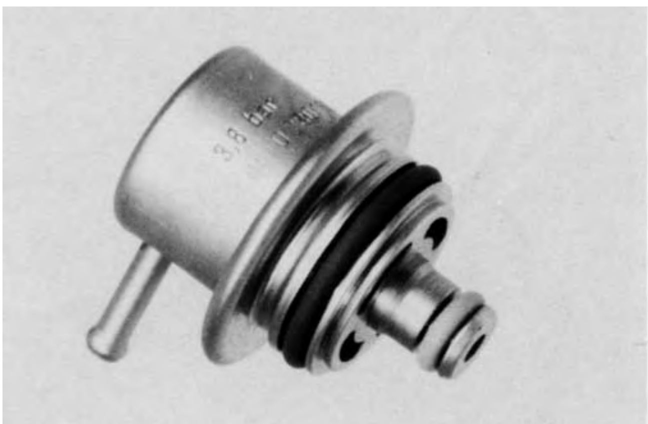
Fuel Pump

The fuel pump is a EKP 4/2 roller-cell pump.

Fuel Filter

The fuel filter is mounted in the engine compartment on the right-hand wheel housing. It has to be replaced every 60,000 miles (96,000 km).

Fuel Pressure Regulator



The fuel is returned to the fuel tank over the return line of the pressure regulator. On the 911 Carrera (993), a miniature pressure regulator is installed at the end of the fuel rail. Depending on the intake manifold pressure, it regulates the fuel system pressure to 3.8 bar ± 0.2 bar.

Injection Valves

The orifice cross-section of the injection valves is larger than on the 272 HP (200 kW) engine. The brass coil in the injection valve has an internal resistance of approx. 16 Ω

Due to the sequential fuel injection system, the electrical connecting wires must never be interchanged. The wires are therefore marked for easy identification.

DME Control Unit

Features of the DME control unit:

- Injection (sequential)
- Ignition (twin ignition)
- Warming up and acceleration enrichment
- Start up control
- Lambda control (adaptive)
- Overrun shutoff
- Knock regulation (selective cylinder control, adaptive)
- Anti-surging
- Torque reduction during Tiptronic gearshift accomplished by ignition retard
- Engine idle speed correlation for Tiptronic-equipped vehicles
- Engine idle speed control with adaptive, automatic engine idle air correlation (system modulation)
- Carbon canister purge
- Resonance flap control
- 55-pin connector
- Diagnosis with System Tester 9288

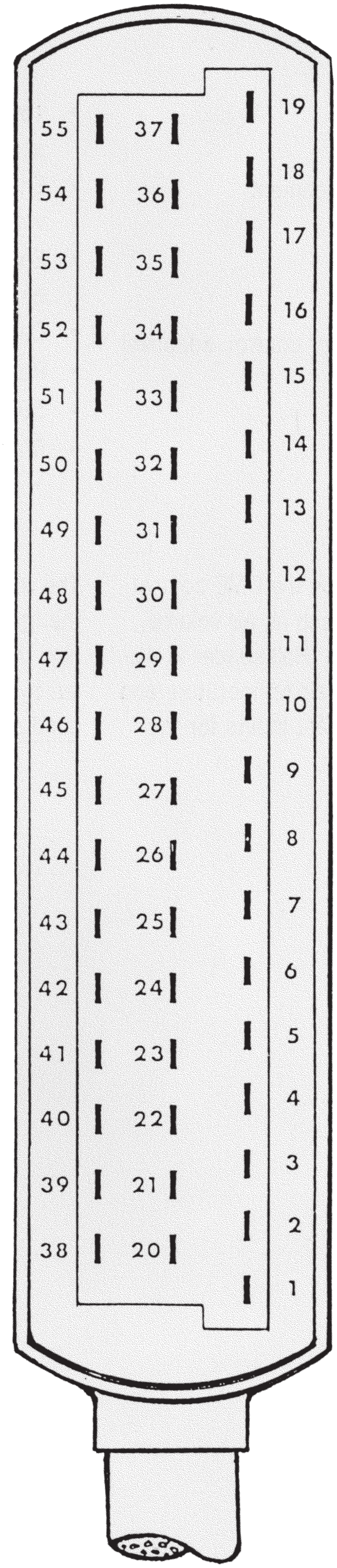
The engine functions are controlled by the DME control unit. Other measured input values, such as air volume, engine rpm, actual camshaft position (Hall sender in distributor), engine temperature, intake air temperature and throttle valve position, are used as data inputs for the control unit.

The main system actuators, such as the injection valves, the ignition final stages, the engine idle speed positioner, the tank vent and the resonance flap, are all controlled by the unit. The control unit is installed under the left hand seat in the car.

DME 2.10.1

Control Unit – Terminal Configuration

55 - Diagnosis K wire
54 - Characteristic map switch
53 - Throttle potentiometer
52 - Throttle position to transmission control unit
51 - Transmission input
50 - Knocking, yes/no
49 - Speed/reference mark sender +
48 - Speed/reference mark sender –
47 - Air intake temperature
46 - Not used
45 - Engine NTC II
44 - Tiptronic coding
43 - Not used
42 - Selector lever switch
41 - Heater control unit
40 - A/C compressor coupling
39 - Not used
38 - Not used
37 - DME relay 87
36 - Ground, DME relay 85
35 - Injection valve cylinder No. 2
34 - Injection valve cylinder No. 4
33 - Tank vent
32 - Auxiliary air pump (USA)
31 - Final stage ignition circuit 2
30 - Ground, knock sensors
29 - Knock sensor 2
28 - Oxygen sensor/CO potentiometer
27 - Terminal 15
26 - Ground, mass air flow sensor
25 - Final stage ignition circuit 1
24 - Ground, remaining final stages
23 - Injection valve cylinder No. 5
22 - Intake manifold flap closed
21 - Check engine monitor (USA)
20 - Oxygen sensor heating
19 - Ground, electronics, all shields
18 - Battery +
17 - Injection valve cylinder No. 1
16 - Injection valve cylinder No. 6
15 - Not used
14 - Ground, throttle flap potentiometer/NTCs
13 - Diagnosis L wire
12 - Positive supply throttle flap potentiometer/Hall sender
11 - Knock sensor 1
10 - Ground, oxygen sensor
9 - Vehicle speed
8 - Hall sender signal
7 - Mass airflow sensor signal
6 - Tachometer counter
5 - Injection valve cylinder No. 3
4 - Intake manifold flap open
3 - Ground, DME relay 85 b
2 - Not used
1 - Resonance flap



Coding the control unit

To be able to retrieve the various maps, a 2-pin connector is branched off from the DME wire harness near the control unit connector.

Note:
On vehicles fitted with Tiptronic, the DME control unit is coded with a special Tiptronic wire harness.

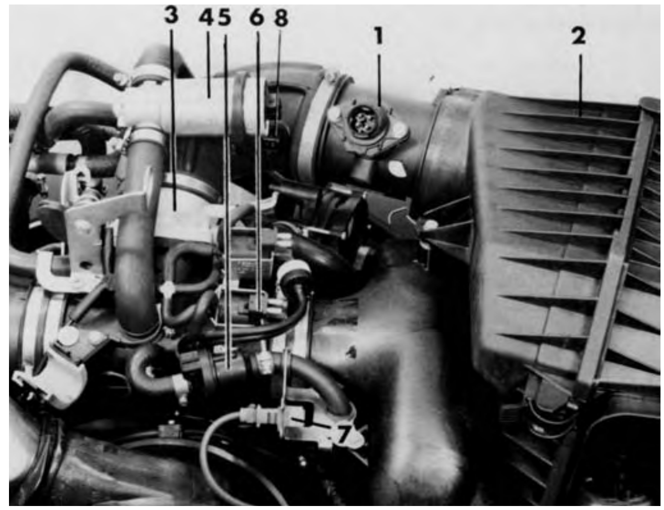
In vehicles equipped with a catalytic converter and appropriately coded DME control unit, the engine idle CO value is adapted, i.e. the control range of the oxygen sensor shifts the map to adapt it to any deviation from the specifications that may have occurred. This allows tolerances of environmental conditions (air pressure etc.) and tolerances within the engine to be compensated. Adaptation of the engine idle CO level eliminates the necessity for a basic setting.

Permanent Positive At The Control Unit

Since the DME 2.10.1 includes a number of adaptive (self-learning) systems (oxygen sensor closed-loop control, charge control, knock regulation), terminal 18 on the DME plug is supplied with a permanent positive voltage. If the plug is disconnected from the control unit or the battery, the engine has to be run to operating temperature and left running for approx. 10 mins. After the next starting sequence to enable the control unit to readapt itself. The control unit contains a volatile fault memory, i.e. all the faults stored in the memory are erased once the control unit has been disconnected from the permanent positive voltage.

Mass Airflow Sensor

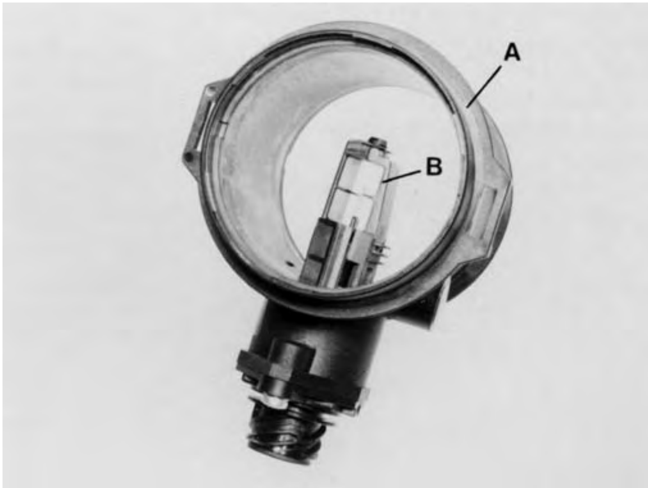
Detection of the air drawn into the intake is performed by a hot film mass airflow sensor (1). It is installed between the air filter housing (2) and the throttle body (3).



1 - Mass airflow sensor
2 - Air filter housing
3 - Throttle body
4 - Manifold flap positioner
5 - Tank vent
6 - Resonance flap shift valve
7 - Plug for knock sensor 2
8 - Intake air temperature sensor

The air mass is required for the following DME control unit functions:

- Injection
- Ignition
- Oxygen sensor control
- Venting of the carbon canister
- Knock regulation
- Plausibility test



A - Mass airflow sensor housing
B - Mass airflow sensor

Advantages of the Hot Film Mass Airflow Sensor:

Measures the passing air mass (gas mass) per time unit independent of its density and temperature.

- Large measurement range
- High sensitivity, particularly at small air flow rates
- No moving parts, therefore no wear
- Insensitive to dirt
- No free burning necessary

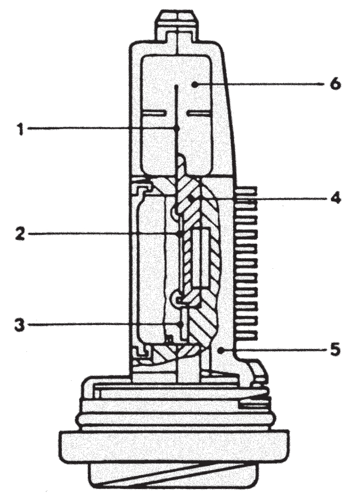
Hot film mass airflow sensor – sensor component

Design of the Hot Film Mass Airflow Sensor

A hot film sensor is installed in a measurement channel. It consists of a ceramic substrate that carries the following thick film resistors:

Heating resistor (R_H)
Sensor resistor (R_S)
Air temperature resistor (R)
Compensation resistor (R_1)

A hybrid circuit and a power electronic component are installed behind the measurement channel in the electronics housing. A heat sink is mounted on the outside of the electronic housing.

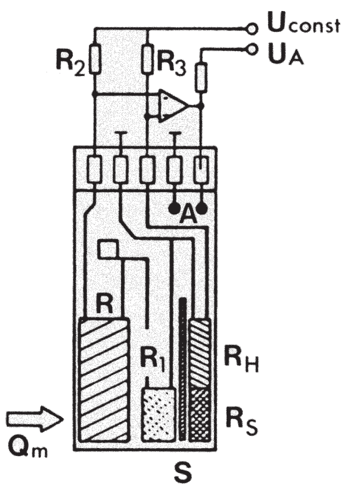


1 - Sensor hybrid
2 - Hybrid
3 - Power electronic component
4 - Intermediate plate
5 - Heat sink for power final stage
6 - Measurement channel

The electronic housing (the complete measuring element) and the measuring channel are fitted into the housing of the mass airflow sensor with two screws. An additional seal is used to seal the measuring element against the air mass sensor housing.

On the inlet and outlet sides of the air mass sensor a protective screen is fitted to smooth out the turbulences in the air and therefore to ensure an even air flow around the hot film. Next to the connection plug, an arrow is imprinted in the housing of the mass airflow to indicate the direction of air flow.

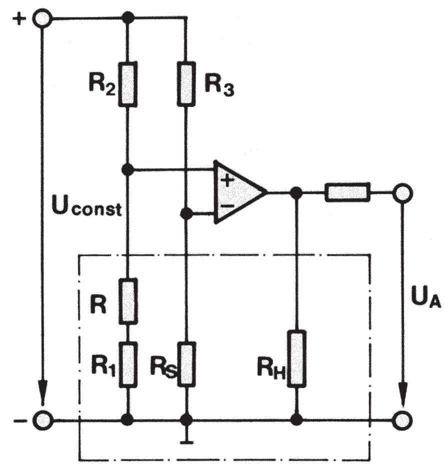
Note:
The measuring element in the air mass sensor housing must never be removed since the components are calibrated during manufacture of the unit.



R - Air temperature resistor
R_1 - Compensation resistor
R_2 - Supplementary resistors
R_3 - Supplementary resistors
R_H - Heating resistor
R_S - Sensor resistor
A - Connections for R_H
S - Air gap for thermal decoupling of heating and R
U_{const} - Voltage supply
U_A - Signal to the control unit

Operation of the Mass Airflow Sensor

The hot film mass airflow sensor has a hot film sensor placed in the intake airflow. The resistors R, R_1 and R_S as well as R_2 and R_3 are combined to form a bridge circuit. The heating resistor R_H is installed outside the bridge. The heating current which is necessary to maintain the heating resistor at a constant temperature determines the bridge voltage. The heating resistor R_H and the sensor resistor R_S are dependent on temperature, and their resistance is reduced with increasing temperature (NTC).



R - Air temperature resistor
R_1 - Compensation resistor
R_2 - Auxiliary resistors
R_3 - Auxiliary resistors
R_H - Heating resistor
R_S - Sensor resistor
U_A - Output voltage
U_V - Supply voltage
R_V - Servo amplifier

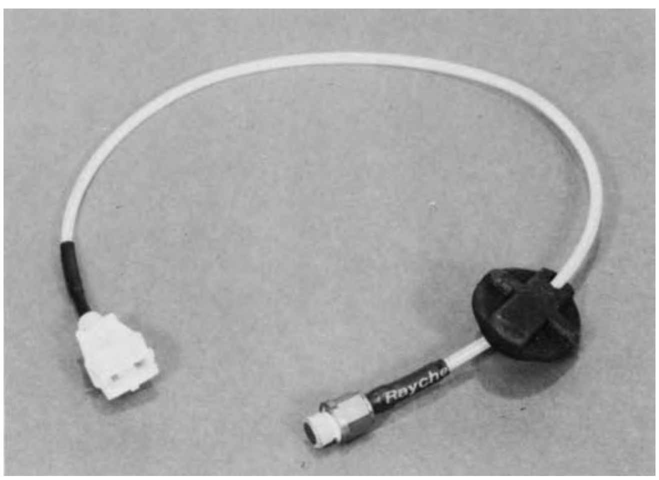
The sensor resistor R_S is fitted to the heating resistor R_H and therefore adopts the temperature of the heating resistor. In the operating state the heating resistor R_H is supplied with a current I_H that causes it to heat up to a temperature that constantly is 320° F. (160° C) above the instantaneous intake temperature. When the air flow rate increases, the heating resistor is cooled down, resulting in an increase in its electrical resistance. In order to maintain the temperature difference between the intake air and the heating resistor R_H, the current I_H is regulated accordingly.

The temperature of the outlet air acts on the resistor R; the compensation resistor R_1 is connected in series to it and compensates for the temperature differences of the bridge circuit across the whole operating range.

The servo amplifier R_V compares the current flow between the temperature resistor R and sensor resistor R_S and influences the current flow I_H to the heating resistor R_H, in order to maintain a constant 320° F. (160° C) temperature and the temperature of the heating resistor R_H. Regulation of this constant temperature differential is performed within in milliseconds.

A change in current is registered as a voltage drop at the measurement connection U_A. This voltage drop is used by the DME control unit as the measuring parameter for the intake air volume. The hot film mass airflow sensor has no moving parts and generates only minimum flow resistance in the intake passage.

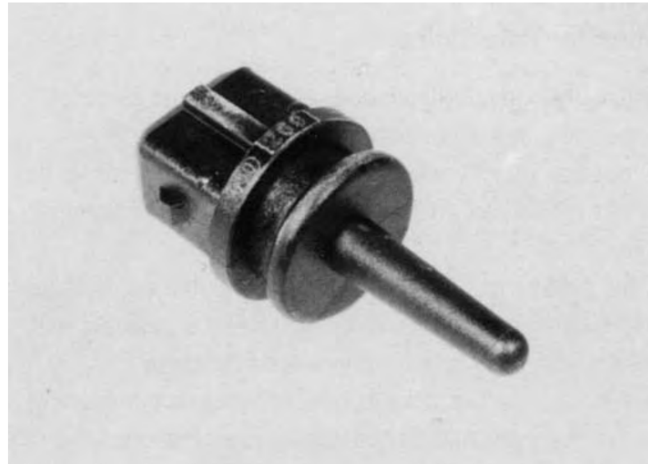
Engine Temperature Sensor



The engine temperature sensor is screwed into the cylinder head of the third cylinder. It has two electrical connections, i.e. corrosion on the temperature sensor threads has no detrimental effect on the resistance characteristics and, hence, on the mixture composition (potential-free temperature sensor).

The temperature sensor is installed with Special Tool 9291 with a 14 mm A/F size. In addition, a coat of lubricating paste must be applied to the threads of the temperature sensor.

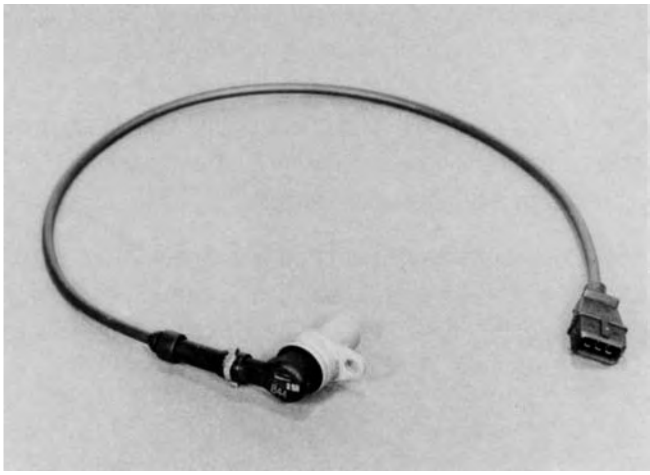
Intake Temperature Sensor



To reduce the knock tendency of the engine at high intake temperatures, the 911 Carrera (993) is equipped with a temperature sensor (NTC) in the rubber shroud between the mass airflow sensor and the throttle body. The signal of this sensor is processed by the DME control unit.

Modification of the timing angle towards “retarding” the timing angle is a continuous process and stars at an intake temperature of 77° F. (25° C). The current value transmitted by the temperature sensor may be retrieved in degrees Centigrade with System Tester 9288 in the “Actual values” menu item.

Speed and Reference Mark Sender (DME)



The DME of the 911 Carrera (993) is combined with an inductive sender for engine speed and reference mark detection. For this purpose, a toothed ring gear is machined onto the flywheel. This ring has a total of 60 teeth. Two of these teeth are replaced by cutouts to generate the reference mark signal. The reference signal is set at 84° BTDC. The air gap between the sender and the flywheel ring gear is adjustable and must be 1.0 ± 0.2 mm.

Throttle Potentiometer

A throttle potentiometer on the shaft is used to determine the angular position of the throttle shaft. The 0 position (engine idle position) of the potentiometer is determined in an adaptive process by the DME control unit.

If the battery has been disconnected or the control unit has been separated from the system, the engine must be restarted with the throttle valve fully closed. A self-adaptive unit always selects the smallest opening angle of the throttle as the engine idle position. If the throttle moves to 'open', the engine idle settings are switched off by the control unit as soon as an opening angle of 1° is reached.

When a throttle opening angle of approx. 66° is reached, the control unit actuates the full-load feature. Using the "Actual values" menu on the system tester, the current opening angle of the throttle can be read off in degrees. In this manner the accelerator cable setting can be checked.

Oxygen Sensor

The 911 Carrera (993) is equipped with the plunge-proof oxygen sensor LSH 25. The oxygen sensor is potential-free and is therefore installed with a new 4-pin plug connector with separately insulated wires.

The oxygen sensor is heated by the DME control unit. Positive supply to the oxygen sensor occurs across the fuel pump relay inside the DME relay (as soon as the engine is started). The ground connection is made via the DME control unit. If the engine has already reached the operating temperature and is then driven at heavy loads and high engine speed, no additional heating of the oxygen sensor is required. In this operating state, the DME therefore cuts off the supplementary sensor heating.

When the throttle is in the zero position, the throttle angle display must be 0°. With the accelerator pedal fully depressed, i.e. with the throttle fully open, the throttle angle display must read 84° ± 3° .

1 - New plug generation
2 - Sensor housing (new) on exhaust side (holes instead of slots)

The oxygen sensor is monitored by the DME control unit. The sensor voltage may additionally be read off using the System Tester and the “Actual values” menu item. If problems occur at the oxygen sensor, start troubleshooting by checking operation of the sensor heater. A voltage of approx. 12 V should be present at the sensor plug when the engine is at idle.

CO Potentiometer

Vehicles with M 150 equipment (without oxygen sensor closed-loop control) do not have the oxygen sensor. The oxygen sensor is replaced by a plug and fuel filler neck is designed to take leaded fuel.

In addition, the DME control unit is coded for operation with open-loop catalytic converter. As the adaptive oxygen sensor control is omitted at the same time, a CO basic setting at engine idle speed is required. For this purpose a potentiometer is installed on a bracket on the right-hand side in the engine compartment. The connecting wire of this potentiometer is connected to the DME control unit harness via an adapter cable instead of the oxygen sensor wire.

Reducing the Engine Idle Speed with Tiptronic

To reduce the creep tendency of vehicles equipped with Tiptronic transmission when a gear is selected and the engine is idling, an engine idle speed reduction is provided.

Operation

On Tiptronic vehicles, the selector lever switch is connected to terminal 42 of the DME control unit. In the P or N selector lever positions, the control unit is connected to ground. If a gear is selected, the ground connection is interrupted. This causes the engine idle speed to drop from 800 ± 40 rpm to 750 ± 40 rpm when the gear is engaged.

Ignition Timing Adjustment with Tiptronic

To reduce shift jerk when changing gears under load, the ignition angle of the engine is retarded briefly in accordance with engine load and rpm both when shifting up and down, thus reducing the engine torque.

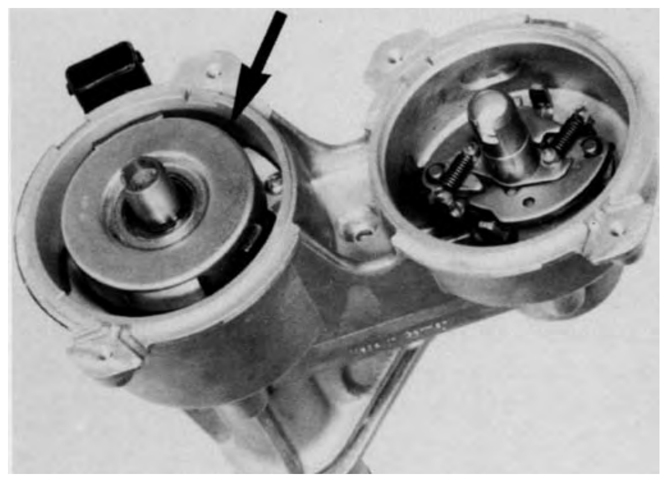
Operation

When a gear is selected, the Tiptronic control unit sends the “meshing” signal to terminal 51 of the DME control unit. The DME acknowledges selection of the gear and retards the ignition angle.

Speed Signal

The speed signal is fed to terminal 9 of the control unit. If the vehicle comes to a stop, if the cylinder head temperature is above 237° F. (114° C) and the throttle valve is in the engine idle position, the DME control untrol unit runs a system adjustment.

Hall Sender



The twin ignition distributor includes a Hall sender that is required to acknowledge the firing TDC position of cylinder no. 1. The Hall signal is required by the DME control unit to correlate the knock sensor signals or to control the sequential fuel injection.

Heating Control Unit Signal

When the heating regulator is set to maximum heating or when a high heating output is required, a signal is sent from the heating control unit to terminal 41 of the DME control unit. When this signal is present, the “deceleration shutoff” feature is no longer valid and, thus, cooling of the heat exchanger at low outside temperatures and longer thrust periods is avoided.

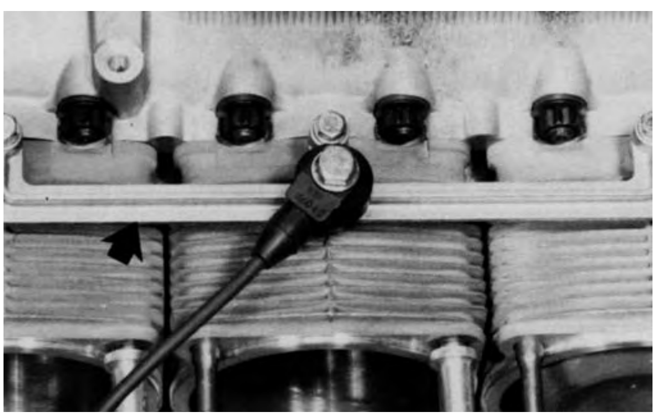
Adaptive Knock Regulation

Knocking combustion can lead to engine damage. For this reason the 911 Carrera (993) engine is equipped with a knock regulator that individually retards ignition timing within each cylinder when uncontrolled combustion occurs in the form of knocking.

Basic Features

The engine is equipped with two knock bridges with a knock sensor screwed into each of those knock bridges. The knock bridges connect the individual cylinders no.1 to 3 and 4 to 6. The knock detection circuit is matched to the bridges which is why no other components may be mounted to the bridges (interference). As is the case with all knock sensors, the correct tightening torque and the correct assembly sequence must be observed. Inadvertent mixup of the connectors of the knock sensors on the wire harness end cannot occur. The plug connector is of green color.

If a knocking combustion is detected, the ignition timing for the respective cylinder is retarded by 3°. If the knocking combustion continues, each knock sensor retards the ignition in 3° stages up to a maximum of 9°. If no more knocking combustion is detected, the ignition timing is advanced to the optimum value or the programmed ignition timing angle again in small steps according to the time elapsed.



Knock sensor bridge with knock sensor for cylinder no. 1…3

To allow the sensor signals of both knock sensors to be correlated according to the firing order, a Hall sender is installed into the double ignition distributor to enable the DME control unit to recognize the ignition point of cylinder no. 1.

Adaptive Feature

In order to perform adaptive knock regulation, the electronic ignition map is subdivided up into 8 engine speed and 4 load ranges. If a knock occurs, the ignition angle is retarded by 3° for the respective cylinder, and is then retuned to the optimized ignition angle in small steps dependent on time. If, however, the corresponding load/engine speed range is exceeded (e.g. during acceleration) while ignition timing is retarded, the last ignition timing angle set (learnt) when the load/engine speed range was left is now adapted. In the next load/engine speed range, the new (optimized) ignition angle stored in the control unit is immediately set. In this manner, longer and unnecessary retarding of the ignition is avoided and the dynamic behavior of the engine is improved. If the engine now returns to the load/engine speed range with the adapted (learnt) ignition angle, the reduced value deviating from the optimum ignition angle is set first. This helps to reduce the total number of knocks.

Voltage Supply for the DME Control Unit over the DME Relays

When the ignition is switched on, a positive voltage is supplied to terminal 27 of the DME control unit across the airbag and alarm control unit. At the same time, the DME relay terminal 85 is grounded via terminal 36 of the DME control unit. The relay closes and a further positive input signal is supplied to terminal 37 of the DME control unit. Once the ignition has been switched off, the DME unit is shut down across terminal 36 with a delay off approx. 2-3 seconds to allow internal tests to be carried out in the control unit.

Sequential Fuel Injection

Sequential fuel injection means that every cylinder is individually supplied with the entire calculated fuel quantity once per working cycle according to the ignition sequence. This produces a very homogeneous air-fuel mixture.

Ignition System

The 911 Carrera (993) engine is equipped with a twin ignition system, i.e. there are two spark plugs per combustion chamber to ignite the air-fuel mixture. This reduces in the spark travel in the cylinder and reduces combustion time while producing a faster pressure increase. In addition, a more stable combustion is achieved thanks to the second spark source, i.e. the differences between one working stroke and another are reduced.

Ignition Final Stage

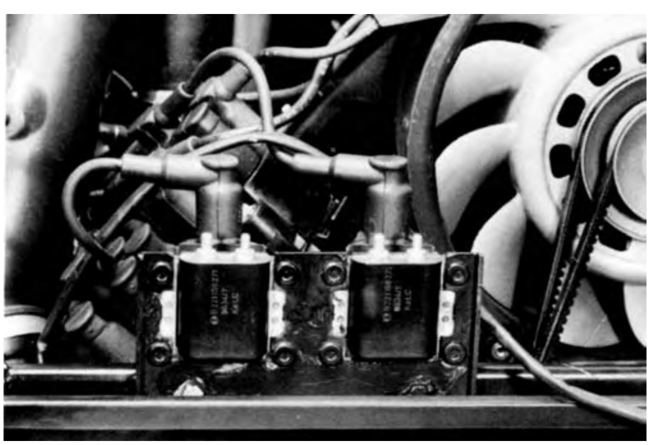
A double final stage with two transistors supplies current to both ignition coils. The double final stage is mounted under the left hand seat, mounted on a bracket next to the DME control unit.

Ignition Coils

Two newly designed ignition coils are installed as a pre-assembled unit on a bracket at the rear left on the engine carrier. In order to avoid any contact with high tension cables, the electrical connections are covered with rubber caps.

In summary, twin ignition offers the following advantages:

- Higher power output than with single ignition
- Lower fuel consumption
- Improved engine idle
- Improved throttle response with a cold engine with less enrichment requirements
- Reduced emissions



Ignition coils on bracket

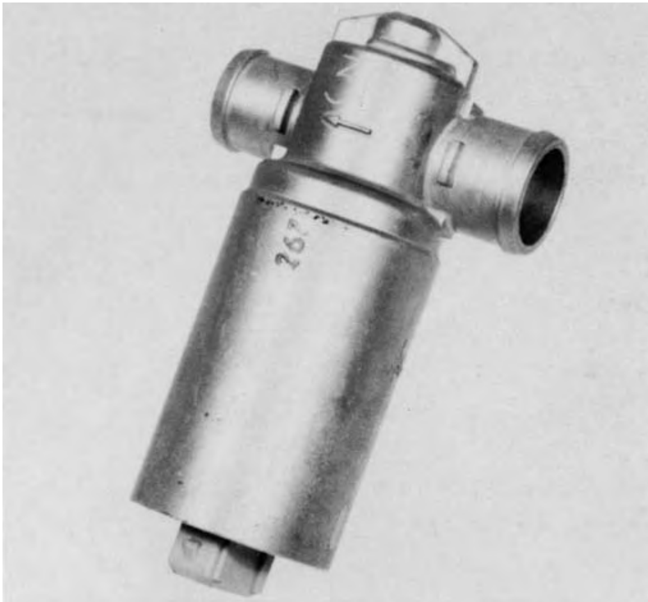
Distributor

The distributor is equuipped with a hose connection to the air guide housing to vent the interior of the distributor.

Ignition Wires

New ignition wire sets are used. The previously used silicon ignition wire have been replaced with Hypalon ignition wires. The spark plug connectors of ignition circuit 1 have only two sealing lips to accommodate the modified rocker cover. The spark plug connectors of ignition circuit 2 are fitted with a lead-in to ensure correct attachment to the spark plugs.

Idle Speed Positioner



A twin coil positioner is used to adjust the correct engine idle speed of 800 ± 40 rpm in conjunction with the DME control unit. The cold engine idle speed is approx. 1,100 rpm.

Operation

The positioner is supplied with two timed electrical input signals from the DME control unit, one for the opening coil and the other for the closing coil. This creates opposed torsional forces on the armature. Due to the inertia of the armature, the positioner adjusts itself to a particular angle that corresponds to the pulse/duty factor of the signal received.

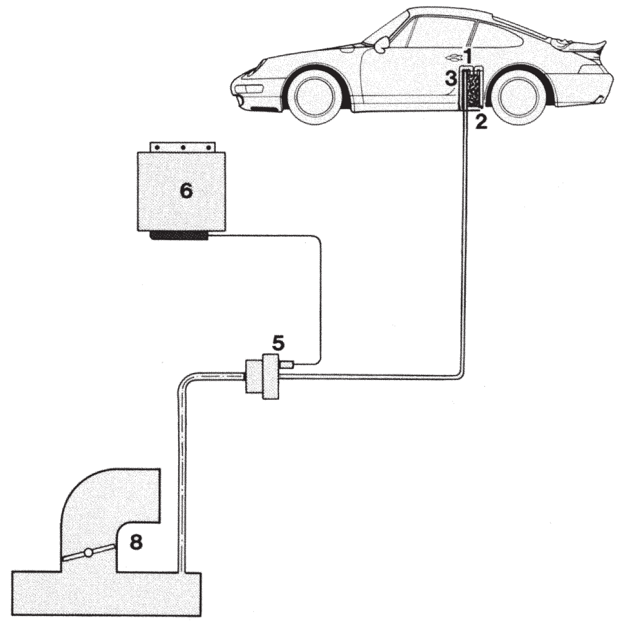
After completion of work on the ignition system, check both ignition circuits with the System Tester for perfect operation by switching off both final stages one after the other and by switching off the individual injection valves.

By modifying the input signals, e.g. when the engine speed changes, the pulse/duty factor of the signal supplied to the positioner changes as well. The programmed nominal rpm is compared with the actual rev. speed in the control unit. The air flow is then modified by the positioner until the nominal rpm and the actual rpm are identical.

Tank Venting

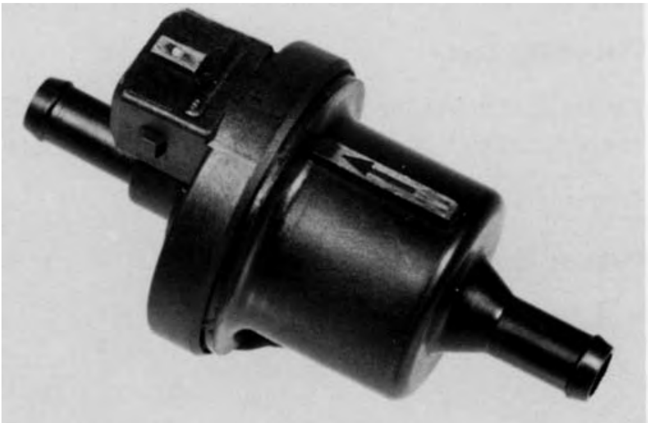
The hydrocarbons created by vaporization of the fuel in the fuel tank are not released to the atmosphere across the tank vent but are instead collected in the carbon canister. This unit is installed in the rear left wheel housing.

To return these hydrocarbons into the combustion process, the carbon canister is purged with air and the carbon is regenerated in the process.



1 - Carbon canister
2 - Purge air line
3 - Line from the fuel tank
5 - Solenoid valve
6 - DME control unit
8 - Throttle

Operation of the Tank Vent



A solenoid valve is installed in the line between the carbon canister and the air intake system. The direction of flow of the solenoid is indicated by an arrow on the plastic housing. The valve is frequency-controlled by the map just above the area for engine idle and when the cylinder head temperature is > 203° F. (95° C). This ensures that the correct amount of purge air is mixed in accordance with the intake air volume. In a no-voltage state the solenoid valve is closed. The valve can be checked with the System Tester using the “drive link test” menu item.

Resonance Flap

The DME control unit activates a vacuum-controlled diaphragm valve which either opens or closes the resonance flap. The resonance flap is closed between 3,000 rpm and 5,500 rpm and at a throttle valve opening angle of > 60°. Due to the ignition sequence, the intake system is alternatively supplied by both tanks. Due to the firing order, air is drawn in an alternating manner from both intake system tanks. If resonance occur, the intake frequency of one row of cylinders matches the natural frequency of the pressure vibrations in the respective tank. The natural frequency is determined by the geometry of the intake pipes, the resonance pipe and the tanks.

A crucial factor, however, is the total length of the pipe from the actual intake cylinder to the next cylinder being supplied, the distribution into intake and the resonance pipe lengths as well as the depth of the tank in the direction of flow. In the no-current state, the resonance flap is open. As soon as the ignition is switched on, however, it is triggered and closed. If the DME control unit detects that the engine is being started, the resonance flap is opened again.

Resonance Flap (A)

Shift Points for the Resonance Flap

Resonance flap open from 0 – 3,500 rpm and from 5,520 – 6,640 rpm

Resonance flap closed from 3,500 – 5,520 rpm when the throttle valve is open by more than 60°.

Plausibility Test

Certain input values are tested for plausibility in the DME control unit of the 911 Carrera (993). If a fault is detected, they are replaced by a value preprogrammed in the control unit.

Fault In	Replacement Value
Mass air flow	Calculation of air volume from throttle angle and engine speed. When a fault is detected at the throttle potentiometer at the same time, only rpm-dependent load line is introduced.
Engine temperature sensor	Mixture formation as for 252° F. (122.2° C) cylinder head temperature.
Oxygen sensor	None, but control unit switches from regulation to control
Temperature sensor – intake air	Ignition angle as for 122° F. (50.2° C) intake temperature
Hall sender and knock sensors	As of a specified engine load, ignition angle of all cylinders is retarded by 6° and knock regulation is off
Oxygen sensor closed-loop	None, but control unit switches from regulation to control
Throttle potentiometer*	Engine idle and full load features are dependent on air flow. Replacement value dependent on rpm, 10 – 45° throttle valve angle.
Speed signal	None, but no system adaptation either

* If implausible values occur at the throttle potentiometer, contact resistances may be present in the plug or directly at the potentiometer.

General

The DME 5.2 Engine Management System was first installed in 1996 - 1998 911 Carrera (993) models and 1996 - 1998 911 Turbo (993) models. The main feature of this system was the introduction of enhanced On Board Diagnostics II (OBD II).

The following DME 5.2 information was first published in the 1996 911 Turbo (993) Service Information Technik book.

To calculate the ignition angle and the injection quantity and to achieve air mass dependent boost pressure control, the 911 Turbo (993) is equipped with a Motronic of version M 5.2.

To reduce mass inertia, two small turbochargers have been installed and are driven in parallel by two separate exhaust flows. This ensures extremely rapid reaction during acceleration and yields a high boost volume at higher exhaust flow rates.

In conjunction with large-size, separate intercoolers, an electronic boost pressure control dependent on air mass, a Motronic system operating in adaptive mode across a wide range and a completely revised exhaust system with on catalytic converter per cylinder bank and Dual Paired Oxygen Sensors control, the 911 Turbo (993) yields an output of 400 hp (300 kW) and a maximum torque of 400 ft.lb.

Additionally, the new 911 Turbo (993) features an enhanced and optimized engine management diagnostic system – OBD II Diagnosis, as described in the Diagnosis section. This 2nd diagnosis stage I mandatory for all US vehicles as of Model Year ’96. The new 911 Turbo (993) uses this system **worldwide**.

Major features of the new Motronic system:

- DME control module with Motronic M 5.2
- Engine control module with 88-pin connector located under left seat
- Electronic control of boost pressure control
- Electronic map ignition system
- Adaptive knock control
- Sequential injection
- Adaptative oxygen sensor regulation
- Stereo dual paired oxygen sensors control with 4 oxygen sensors, potential-free
- New, enhanced diagnosis (OBD II)
- Hall-effect sensor installed in distributor to detect firing TDC of Cylinder No. 1
- Separate fuel mixture control for each cylinder bank
- NTC-based intake air temperature sensor
- Adaptive charge control with twin-coil rotary adjuster
- Air mass metering with hot-film mass airflow sensor
- Electronically controlled secondary air injection system
- Carbon canister with electronic venting
- Throttle potentiometer
- Plausibily check and provision of replacement values
- Sensing of engine temperature with potential-free NTC resistor
- Fuel pump control with anticipatory operation

DME 5.2

DME Control Module

The engine electronics is controlled by the DME control module. For this purpose, measuring parameters such as air mass, rpm, engine temperature, intake air temperature, throttle position, camshaft position (Hall sensor), oxygen sensor signals and knock sensor signals are fed into the DME control module as analog signals. After converting these signals into digital signals, they are processed by the processing unit of the control module. Drive links (actuators) such as injection valves, ignition final stages, Idle Air Control Valve (IACV), frequency valve for boost pressure control, tank vent solenoid, fuel pump control, oxygen sensor heater, Check engine lamp and secondary air injection system are controlled by the DME control module.

Note:
On vehicles with catalytic converter and an oxygen sensor system, the air-fuel mixture is adapted during vehicle operation, i.e. the oxygen sensor system modifies injection timing and, hence, the injection signal accordingly when a deviation from the nominal value is detected. This process compensates for engine-specific tolerances and specific mixture composition faults. Thanks to this adaptive modification of the air-fuel mixture, it is not necessary to adjust the idle CO to a basic setting.

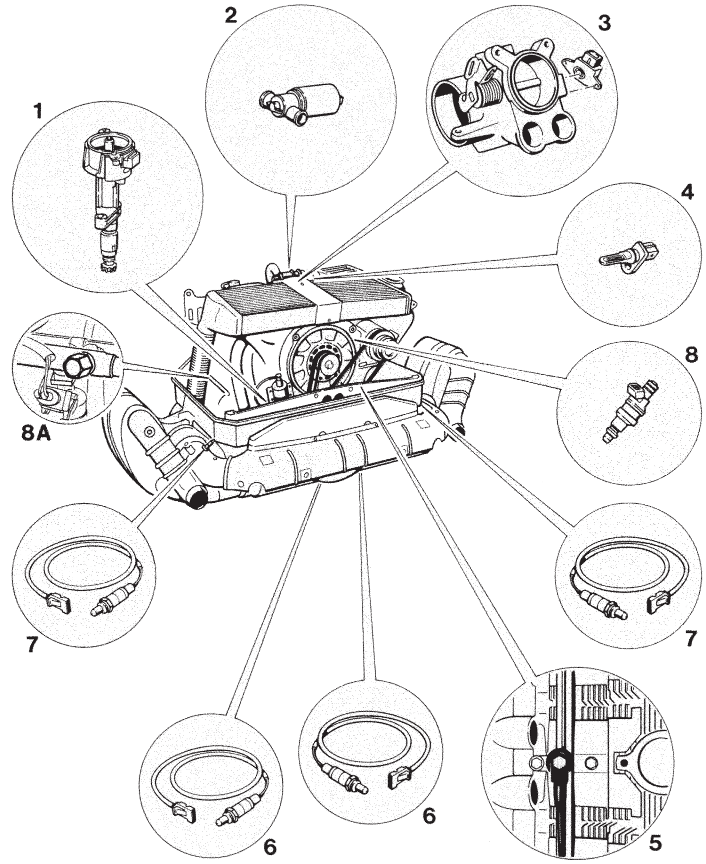
Permanent Positive Voltage at DME Control Module

Since the Motronic M 5.2 includes several adaptative systems, a permanent positive voltage is present at terminal 26 of the DME connector. If the connector is disconnected from the control module or if the vehicle battery is disconnected, the engine must run for 250 seconds before an initial adaptation phase occurs.

In addition, the DME control module has a volatile fault memory. The fault memory must therefore always be read out before the battery is disconnected.

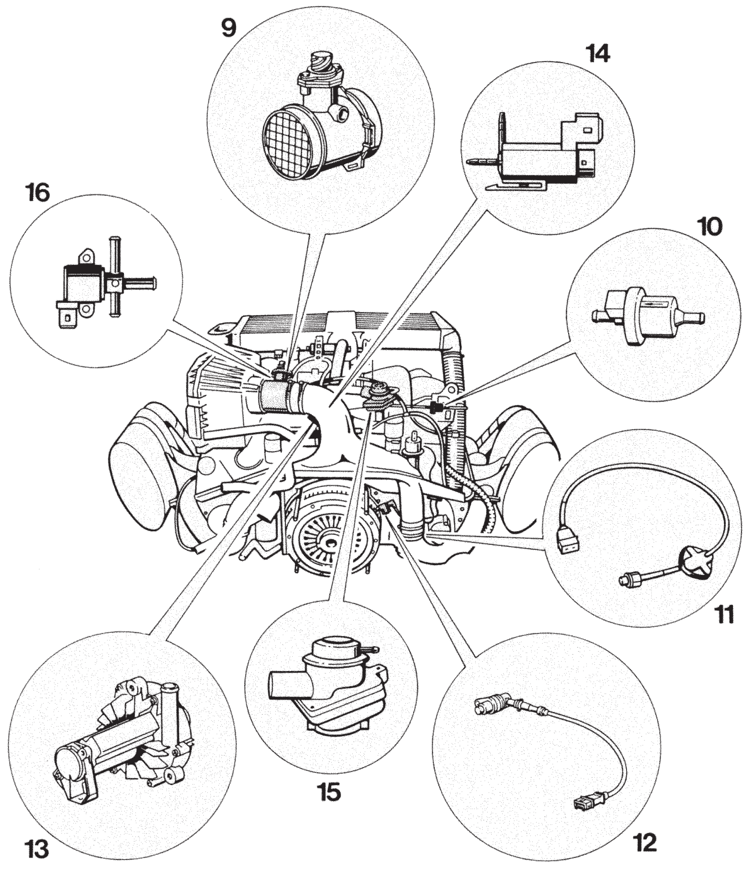
DME Components

1 - Distributor with Hall sensor
2 - Idle air control Valve (IACV)
3 - Throttle potentiometer
4 - Intake air temperature sensor
5 - Knock sensor on bridge
6 - Oxygen sensors ahead of catalytic converter
7 - Oxygen sensors behind catalytic converter
8A - Test connection for fuel pressure



DME Components

9 - Mass airflow sensor
10 - Tank venting valve
11 - Engine temperature sensor
12 - Rpm/reference mark sensor
13 - Air pump
14 - Secondary air solenoid
15 - Pneumatic switching valve for secondary air
16 - Frequency valve for boost air control



Air Ducting

The air drawn in by the engine passes the air filter and the hot film mass airflow sensor. The air flow is then divided into two partial flows that are drawn in by the compressors of the two turbochargers. The compressed air now passes one intercooler per cylinder bank and is cooled off in this process. This design gives a relatively large cooling surface. The partial air flows merge downstream of the intercoolers and are fed across a throttle into the intake housing and the individual cylinders.

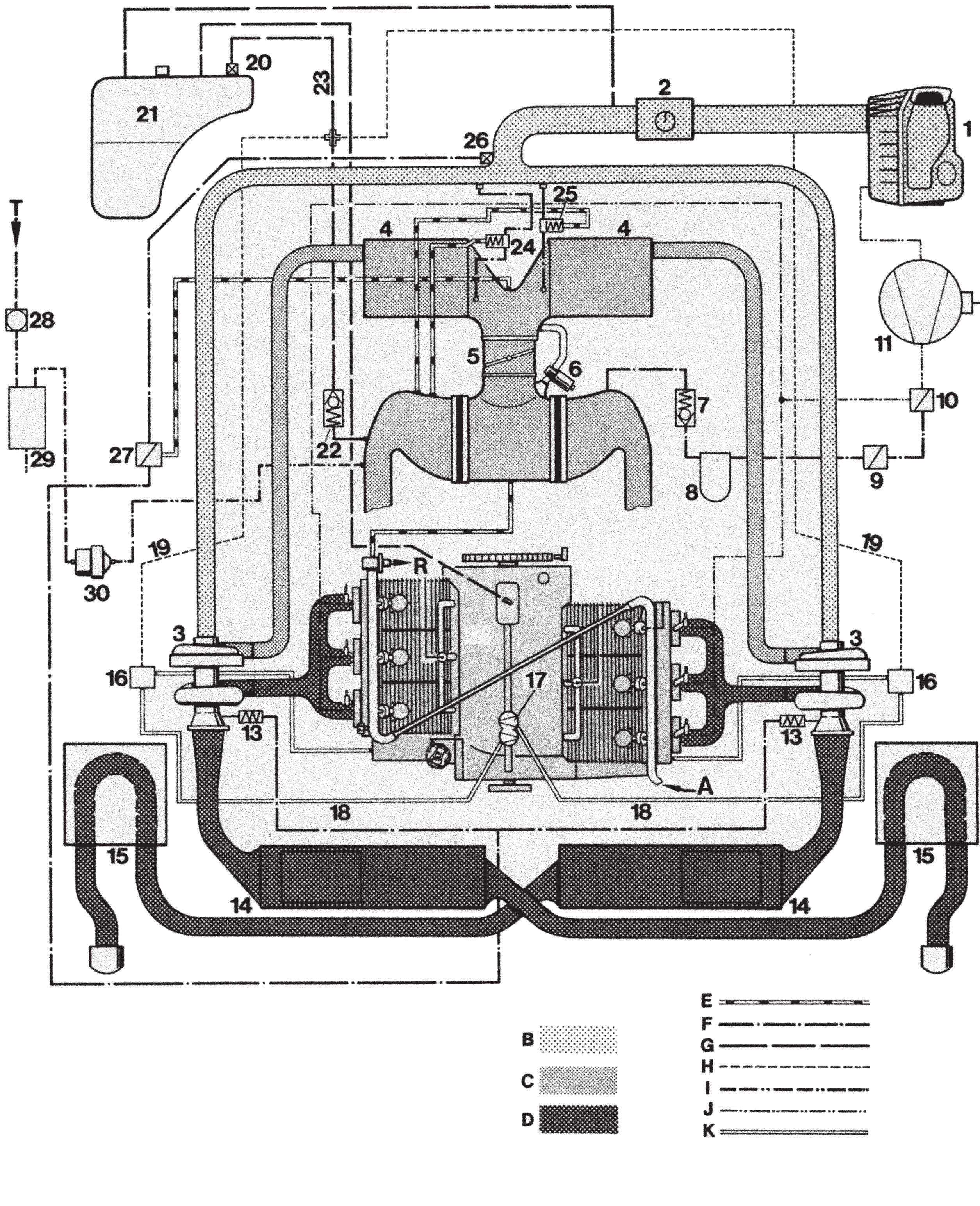
Exhaust Flow

After leaving the combustion chambers, the exhaust gas in an initial stage flows into the exhaust manifolds designed as heat exchangers. Then the exhaust is fed into one turbine wheel of the exhaust turbocharger (one per cylinder bank) with integral bypass flap. Downstream of the turbochargers, the exhaust passes a catalytic converter with metal substrate and rear muffler towards the tailpipes featuring adjustable baffles. Each cylinder bank has its own exhaust system that is a separate unit from the cylinder exhaust ports right to the tailpipes.

This separation of the exhaust flows and the resultant installation of two catalytic converters reduce exhaust backpressure in the exhaust system and, therefore, provide unrestricted gas exchange. The separated exhaust flows and separate mixture control require stereo A/F control to accommodate the new diagnostic system. For this reason, each cylinder bank is equipped with one sensor ahead of and one sensor behind the catalytic converter. This allows exhaust emissions to be reduced to a level that is significantly below US limits.

Air and Boost Pressure Diagram

1 - Air filter
2 - Mass airflow sensor
3 - Turbocharger
4 - Intercooler
5 - Throttle
6 - IACV
7 - Check valve
8 - Vacuum accumulator
9 - Solenoid switching valve
10 - Pneumatic switching valve
11 - Air pump
12 - Air pump relay
13 - Bypass valve diaphragm capsule
14 - Catalytic converter
15 - Rear muffler
16 - Oil drip pan
17 - Twin oil pump
18 - Intake line
19 - Vent line
20 - Throttle, 2 mm dia.
21 - Oil tank
22 - Check valve
23 - Vent line
24 - Recirculating air valve, left turbocharger
25 - Recirculating air valve, right turbocharger
26 - Throttle, 4 mm dia.
27 - Frequency valve for boost pressure control
28 - Rollover safety valve
29 - Carbon canister
30 - Tank venting valve
A - From fuel pump
R - Tank return
T - Tank venting line
B - Turbocharger intake side
C - Turbocharger delivery side
D - Exhaust side
E - Intake manifold pressure
F - Control line for boost pressure control and secondary air injection
G - Vent lines
H - Vent line for turbocharger lubrication
I - Intake line for carbon canister
J - Auxiliary air line
K - Oil line for turbocharger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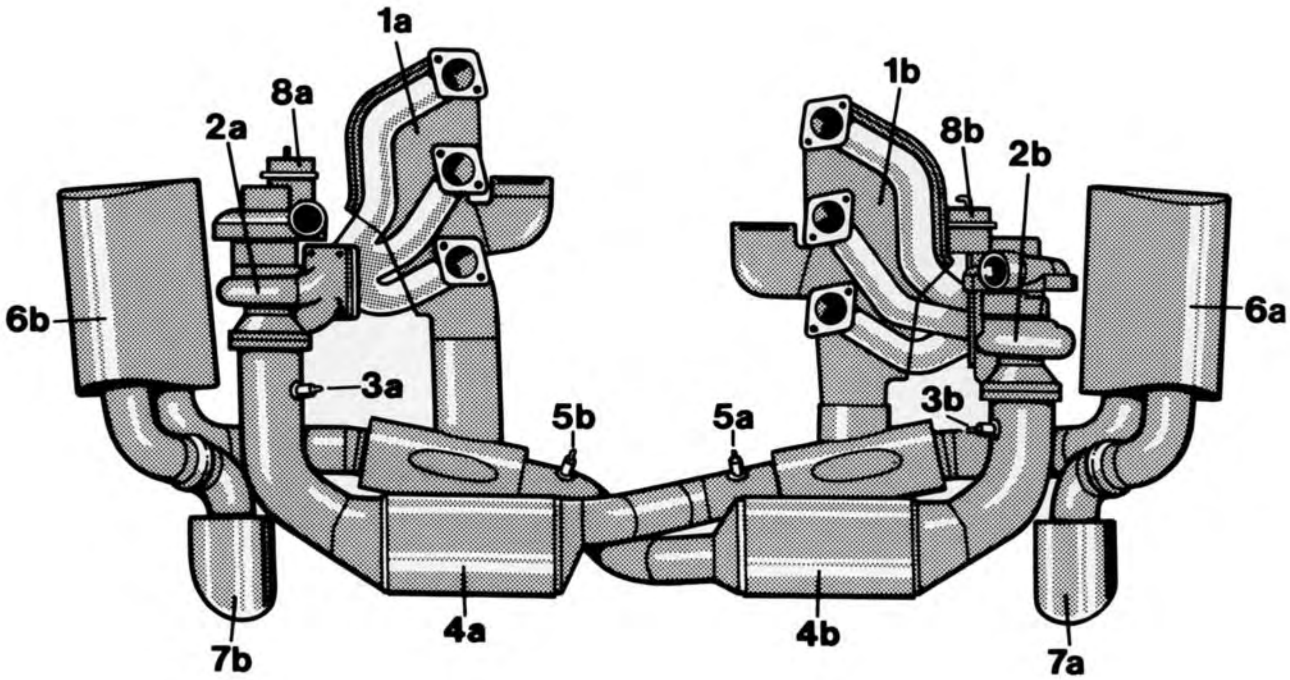


Overview of Exhaust System

1a - Heat exchanger, cylinder 1 – 3
2a - Turbine wheel, cylinder 1 – 3
3a - Oxygen sensor ahead of cat. conv., cylinder 1 – 3
4a - Catalytic converter, cylinder bank 1 – 3
5a - Oxygen sensor behind cat. conv., cylinder 1 – 3
6a - Rear muffler, cylinder bank 1 – 3
7a - Tailpipe, exhaust flow for cylinder 1 – 3
8a - Diaphragm servo - turbocharger bypass flap, cylinder 1 – 3
1b - Heat exchanger, cylinder 4 – 6
2b - Turbine wheel, cylinder 4 – 6
3b - Oxygen sensor ahead of cat. conv., cylinder 4 – 6
4b - Catalytic converter, cylinder bank 4 – 6
5b - Oxygen sensor behind cat. conv., cylinder 4 – 6
6b - Rear muffler, cylinder bank 4 – 6
7b - Tailpipe, exhaust flow for cylinder 4 – 6
8b - Diaphragm servo - turbocharger bypass flap, cylinder 4 – 6

Note:
When measuring exhaust emissions, make sure that exhaust flows are separated and that the exhaust of cylinders 1 to 3 exits from the left tailpipe (seen in direction of travel) and the exhaust of cylinders 4 to 6 from the right exhaust tailpipe. In addition, an exhaust sampling connector is located behind each turbine wheel to measure raw emissions.

Fuel System

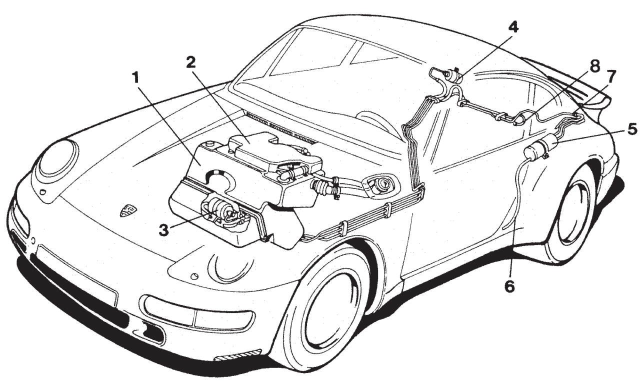
The fuel is supplied by an electric roller-cell pump that keeps fuel delivery to the injection valves at a constant level. The fuel quantity required by the engine is supplies to the engine by electromagnetic injection valves.

Fuel Tank

The fuel tank is located in the luggage compartment ahead of the heater. It is made of blown polyethylene plastic. The noise-insulated fuel pump is located under the tank and is accessible from the vehicle floor through a separate cover.

Fuel Circuit

The fuel flows from the fuel strainer screwed into the fuel tank to the pump, then to the fuel filter and across a Z-shaped Tecalan plastic pipe below the intake housing to the pressure regulator. This Tecalan pipe must never be kinked or pinched. From the pressure regulator, excess fuel is returned to the tank across the return pipe that enters the tank near the fuel pump.



1 - Fuel tank
2 - Reservoir
3 - Fuel pump
4 - Fuel filter
5 - Carbon canister
6 - Scavenging air pipe
7 - Tank vent
8 - Return pipe

Fuel Pump

The fuel pump is a roller-cell design. To provide the required fuel pressure and the required fuel quantity, the fuel pump is activated briefly by the DME control module whenever the ignition is switched on. To allow this feature to become activated, however, the engine must rev up at least to idle rpm when the ignition is switched on repeatedly and a waiting time of approx. 5 seconds must have elapsed after the engine has been switched off.

Injection Valves

The injection valves are designed for the engine output of 400 hp (300 kW). The valve coils are made of brass and have an internal resistance of approx. 16 Ω. Due to the sequential injection system, the feed wires must never be interchanged and have therefore been marked to provide positive identification.

Fuel Filter

The fuel filter is installed to the wheel housing on the right-hand side of the engine compartment.

Fuel Pressure Regulator

A miniature pressure regulator is used on the 911 Turbo (993). It is installed at the end of the fuel ring pipe on the left-hand side of the engine near the intake pipe of cylinder No. 2 and controls fuel system pressure depending on the intake pipe pressure to 55 psi (3.8 bar) ± 2.9 psi (0.2 bar).

Mass Air Flow Sensor

The air mass inducted into the engine is detected by a hot film mass airflow sensor.

The air mass is required by the DME control module for the following functions:

- Activation of specific adaptation features
- Fuel injection
- Calculation of engine load
- Ignition
- Oxygen sensing
- Venting of carbon canister
- Knock control
- Boost pressure control
- Control of specific diagnostic features

Advantages of the hot film mass airflow sensor:

- Passing air mass per unit time is measured independent of air density and temperature
- Large measuring range
- High sensitivity, especially at low air flow rated
- No wear (no moving parts)
- Insensitive to dirt loading
- No burn-off period required
- Insensitive to shocks and vibration

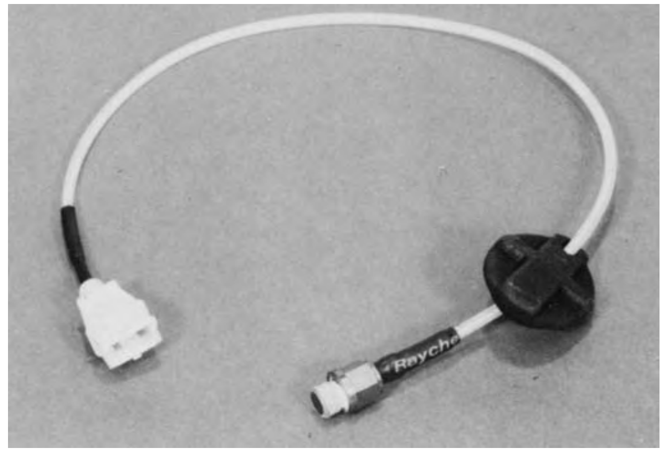
Operation of the Mass Airflow Sensor

The heart of the hot film mass airflow sensor is a hot film sensor placed in the intake air flow. The heating current required to keep the hot film sensor at a constant temperature is determined by the voltage signal to the DME control module.

In operation, the hot film is exposed to an intensive current that causes it to heat to a constant 320° F. (160° C) above the momentary intake temperature. As the air flow rate increases, the hot film is cooled down. To keep the temperature difference between intake air and hot film at a constant level, the heating current is readjusted.

At the measurement connector, a change of the heating current is detected as a voltage change. This voltage signal represents the measuring parameter of the inducted air mass to the DME control module.

Engine Temperature Sensor



The engine temperature sensor is screwed into the cylinder head of cylinder No. 3. It has two electrical terminals to make sure that the resistance characteristics and, therefore, mixture formation are not impaired in case contact resistances are present at the threads (potential-free).

Special Tool 9291 is used to install the temperature sensor. The current engine temperature can be read out with System Tester 9288.

Intake Air Temperature Sensor

Intake Air temperature Sensor (Black Arrow)

To reduce knock tendencies inside the engine at high intake air temperatures, the 911 Turbo (993) is equipped with an intake air temperature sensor (NTC) in the intercooler that provides a signal that is processed by the DME control module.

The ignition angle is modified continuously towards a "retarded" setting as the intake air temperature increases. The intake air temperature sensor also reduces the air mass supplied to the engine across the turbocharger if intake temperatures are very high. As with the engine temperature, the intake air temperature can also be checked with System Tester 9288.

RPM Reference Mark Sensor

The DME of the 911 Turbo (993) uses an inductive pickup to detect the rpm and reference mark. For this purpose, a ring gear with a total of 60 teeth is milled on the flywheel. Two of these teeth have cutouts to provide the reference mark signal.

The distance of the sensor to the ring gear is adjustable and must be 1.0 ± 0.2 mm.

Since the 911 Turbo (993) operates with a misfire detector to accommodate the requirements of the new OBD II, the tolerance between ring gear and sensor is adapted when the engine is coasting. This valve can also be read out with the System Tester.

Throttle Potentiometer

A potentiometer fitted to the throttle linkage is used to detect the throttle position. The 0 position (idle position) of the potentiometer is detected in an adaptive manner by the DME control module.

Adaptive means that the DME control module always detects the smallest throttle opening angle as the idle position.

Note:
If the battery or the control module connector has been disconnected, start the engine with the throttle remaining closed.

System Tester 9288 may be used to read out the current opening angle of the throttle in %. This is helpful to check the throttle cable adjustment. When the throttle is in zero position, the reading must be 0 % throttle angle. When the accelerator is fully depressed and the throttle is, hence, fully open, the throttle opening angle must be 100 %.

Oxygen Sensors

The 911 Turbo (993) is equipped with four LSH-25c immersion-proof oxygen sensors to accommodate the dual paired oxygen sensors control system. The oxygen sensors are potential-free and have 4-pin connectors with individually sealed wires.

As the immersion-proof oxygen sensor obtains its reference air across the connector, take care not to apply grease or contact spray to this connector since this may impair the oxygen exchange.

1 - Oxygen sensor connector
2 - Sensor housing (exhaust side)

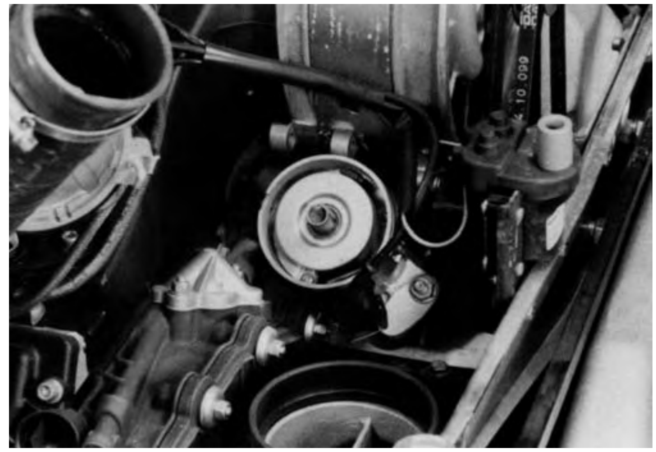
The oxygen sensor is heated across the DME control module. On the positive side, the oxygen sensors are supplied across DME relay terminal 87 b.

Ground for the sensor heaters is switched separately for two sensors at a time by the DME control module. If the engine is at operating temperature and is being run at high loads, the additional sensor heater may be switched off. Under these operating conditions, the DME control module therefore switches off the sensor heater.

The oxygen sensors and their heating system are monitored by the diagnosis system. In this process, the sensor signals are processed to provide indications of sensor dynamics, sensor aging and any drift of the sensor control state. If a fault occurs (specified values are exceeded), it is stored in the fault memory by the DME control module.

The different sensor voltages may be read out with the System Tester 9288.

Hall-Effect Sensor



The ignition distributor is fitted with a Hall sensor that is required to detect firing TDC of cylinder No. 1. The Hall sensor signal is required by the DME control module to perform cylinder-selective knock control.

Speed Signal

The vehicle speed is present at DME connector terminal 79. If the vehicle slows down to standstill and if the engine is at operating temperature with the throttle in idle position, the Motronic automatically adapts itself.

Heater Control Module Signal

When the heater regulator is set to maximum heating, requiring high heater output, the heater control module feeds an electrical signal to terminal 10 of the DME control module.

When this signal is present, the DME control module no longer activates the “coasting shutoff” feature, thus preventing the heat exchangers from cooling off at low outside temperatures and longer coastdown periods.

Knock Control

The 911 Turbo (993) engine is provided with an adaptive knock control system that selectively retards the ignition timing of the respective cylinder when a knocking combustion condition occurs.

Operation

The engine has two knock bridges that hold one knock sensor each. These knock bridges form a link between the individual cylinders No. 1 to 3 and 4 to 6, respectively.

The knock detection circuit is designed for these bridges, and no additional components must therefore be mounted on these bridges (to prevent interference). As with any knock sensor, correct tightening torque and assembly sequence are essential. The wiring harness is designed in such a way that any mixing-up of the knock sensor connectors is impossible.

If a knock condition is detected, the ignition timing of the respective cylinder is retarded by 2.25°. If the knock condition persists, ignition timing is retarded to a maximum of 12°. In 2.25° steps per knock signal.

If the maximum retard setting of 12° is not sufficient, the boost pressure controller reduces boost to reduce the danger of knocking during combustion. If no knock condition is detected any further, the ignition timing is readvanced incrementally to its optimum setting, i.e. the programmed setting, in a time-dependent manner.

In the case of an engine speed of 2,000 rpm, for example, eight operating cycles are required, and at 6,000 rpm, 25 cycles are required until the programmed map is attained again.

DME Relay

When the ignition is switched on, a positive voltage is fed to the DME control module (terminal 56) across the airbag and alarm control modules.

In this process, the DME control module connects terminal 85 of the DME relay to the ground across terminal 27. The relay then closes and another positive signal is fed to the DME control module.

After switching off the ignition, the DME is switched off across terminal 27 with a certain time lag (approx. 2 to 3 sec). This lag is required to allow internal tests in the control module to be run (watch dog).

Sequential Injection

Sequential injection means that the full calculated fuel quantity is metered to each cylinder individually once per cycle in accordance with the firing order. This ensures a more uniform mixture formation.

Ignition Final Stage

The ignition final stage of the 911 Turbo (993) was built into the DME control module so that the primary circuit is established across coil terminal 1 to the DME control module terminal 49 and the ignition final stage built into the control unit and across terminal 55 to ground point V of the vehicle.

Ignition Coil

The ignition coil mounted fully preassembled to a bracket at the left rear engine mount. To prevent touching wires carrying high voltages, the electrical connections are covered with rubber caps.

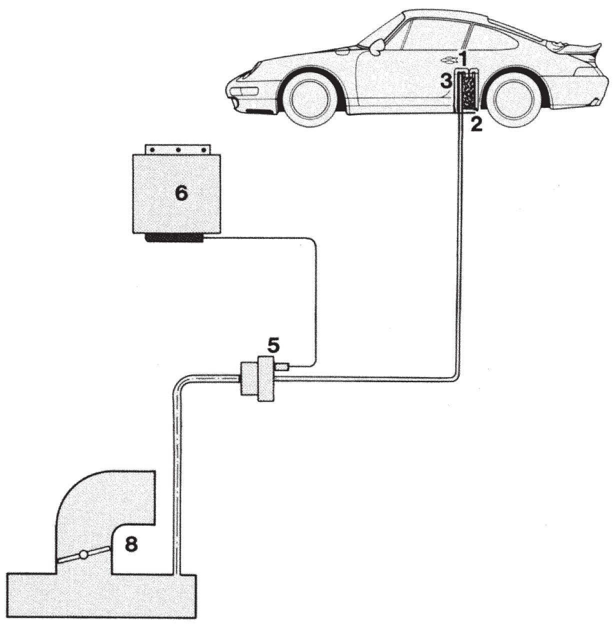
Idle Air Control Valve (IACV)

A twin-coil control valve is used to adjust the correct idle speed of 800 ± 40 rpm in combination with the DME control module. The idle speed of the cold engine is approx. 1,100 rpm.

Tank Vent

The hydrocarbons generated by evaporation of fuel in the fuel tank are not routed to the ambient air across the tank vent but are instead collected in a carbon canister. This canister is located in the rear left wheel housing.

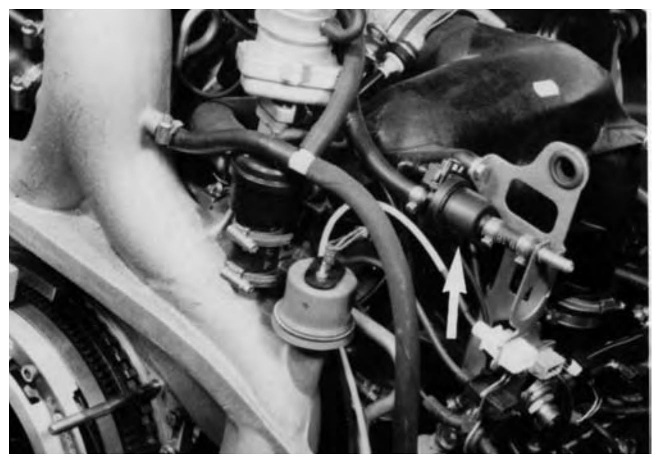
To return these hydrocarbons into the combustion process, the carbon canister is flushed with air and the carbon is regenerated.



1 - Carbon canister
2 - Scavenging air hose
3 - Hose from fuel tank
5 - Solenoid valve
6 - DME control module
8 - Throttle

Operation of the Tank Vent

A solenoid valve is built into the line between the carbon canister and the intake system. The direction of flow is indicated by an arrow on the plastic housing of the solenoid. From a cylinder head temperature > 203° F. (95° C), the valve is timed under map control. This causes the pulse/duty factor to increase as the air flow rate at the mass air flow sensor increases. When the mixture drifts from Lambda = 1 towards a rich or lean setting, this is detected by the control module across the oxygen sensing system and is corrected by readjusting the mixture control during the tank venting phase. The first tank venting phase after starting the engine and reaching the required cylinder head temperature ends 250 seconds after starting the engine. This is followed by a 100-second mixture adaptation phase. Then, in turn, the next tank venting phase occurs, and so on.

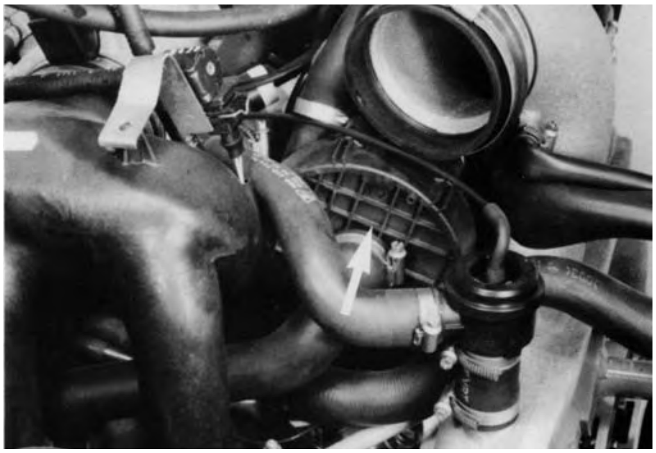


Solenoid Valve (Arrow)

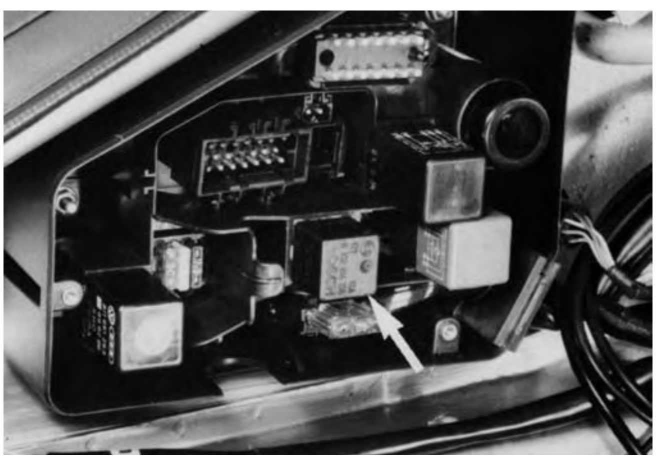
The system makes sure that the correct purge air quantity is added in accordance with the intake air quantity. When no voltage is applied, the solenoid is closed. The “Drive link test” menu item may be used to test the valve with System Tester 9288.

Secondary Air Injection

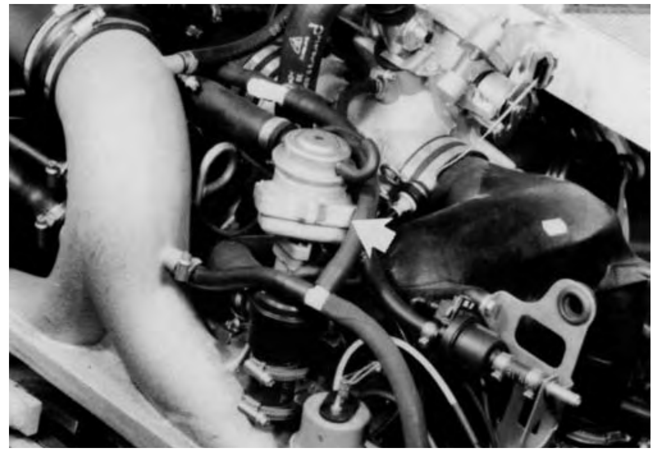
On the 911 Turbo (993), the air pump is triggered by the DME control module for a duration of approx. 120 seconds after a waiting time of 2.6 seconds in order to ensure faster warm-up of the catalytic converter and to reduce emissions when the engine is started at a temperature between 10° F. (–12° C) and + 140° F. (60° C).



When the input conditions are met, the control module connects terminal 37 to ground. This causes the air pump relay to close. This relay is located on a relay plate on the left side of the engine compartment.



Now the air pump and the solenoid switching valve are connected to positive across terminal 87 of the air pump relay.



The air pump now starts to operate and, at the same time, the pneumatic switching valve opens due to the vacuum taken from the vacuum tank and supplied by the solenoid valve. In this process, the air fed by the air pump is supplied across an air line to the pneumatic switching valve and the check valve to the camshaft housing.

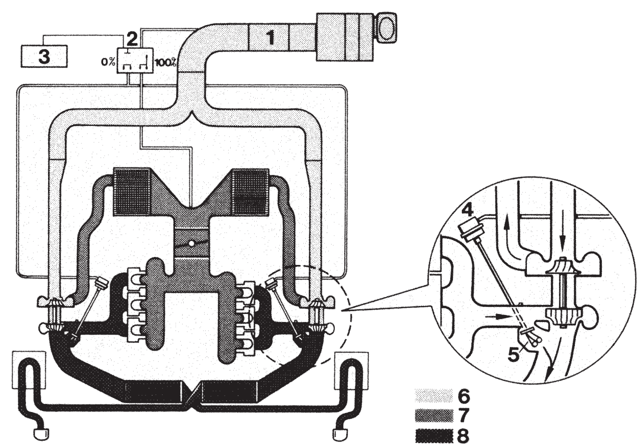
Additional passages for the air injection system are machined in the camshaft housing. A cross passage in the cylinder head allows the air to be injected into the exhaust port.

Boost Pressure Control

General

The 911 Turbo (993) engine is based on the air-cooled naturally-aspirated engine of the 911 Carrera (993). The main differences are found in the intake and exhaust systems.

Schematic Overview of Boost Pressure System



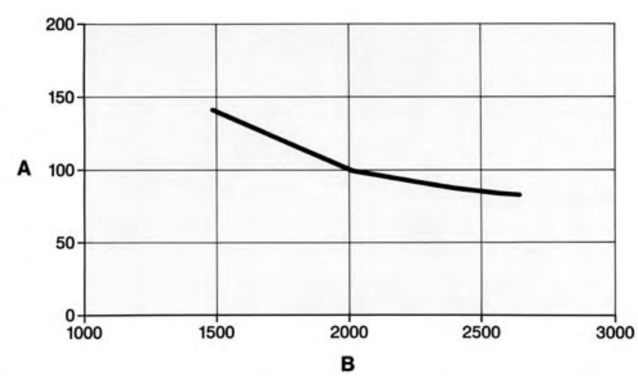
1 - Hot film mass airflow sensor
2 - Frequency valve
3 - DME control module
4 - Diaphragm capsule
5 - Bypass valve
6 - Turbocharger inlet side
7 - Turbocharger delivery side
8 - Exhaust system

Air Ducting

Downstream of the mass airflow sensor, the intake air flow is split towards the left and right exhaust turbochargers. The compressed partial flows enter separate intercoolers optimized for minimum pressure loss. The intercoolers are located above the engine and below the engine compartment air inlet grill and are passed by cooling air under the effect of the pressure differential between the environment and the engine compartment.

The large cooling surface and the great block depth of the intercoolers ensure good cooling at low boost air pressure losses. The outlet volumes of both coolers form one single housing. The reunited boost air flows pass the throttle and the low-resistance plastic intake distributor to enter the cylinder heads. The flat-six engine offers ideal conditions for turbocharging. As the cylinders are combined in groups of three at offsets of 240°, the exhaust flows enter the turbine in virtually direct sequence or with minimum overlap. Short manifold tubes leading directly into the turbine inlet provide an intensive boost effect and, hence, high turbine efficiency, especially at low engine rpm.

Efficiency of the exhaust turbine with closed bypass valve (bypass valve opens at 2,700 rpm).



A - Turbine efficiency in %
B - Engine speed in rpm

By splitting the exhaust flows into two partial flows, small turbo units with low mass inertia can be used. The dynamic engine characteristics during torque buildup when the vehicle is accelerated contribute to achieving significant improvements over engines with only one turbocharger.

Since synchronized operation of the turbochargers is critical on twin-turbocharger engines, provisions have been made to accomplish this by using a symmetrical exhaust system design and by narrowing down tolerances of the turbocharger components relevant to the control system. As a result, the maximum difference of exhaust backpressure of both engine halves does not exceed 5%.

The bypass valve and its control system are integral parts of the exhaust turbocharger. A diaphragm is used as an actuator. A frequency valve allows the control pressure at the diaphragm capsule to be adjusted to any value between ambient pressure and the pressure present downstream of the intercooler. The control pressure at the diaphragm capsule acts on a diaphragm surface that, in turn, acts against a spring. The diaphragm travel is transmitted to the bypass valves across an adjustable linkage. At a pulse/duty factor of 100%, the diaphragm capsule is vented and the bypass valve is closed. At a pulse/duty factor of 0% the full pressure is transmitted to the diaphragm capsule and the bypass valve is opened. Between these extreme settings, the DME control module is able to set the pulse/duty factor as required. The bypass exhaust gas is drained into the opened turbine outlet passage.

The exhaust gas from both cylinder banks flows separately to the tailpipe. The downstream components, e.g. catalytic converter and rear muffler, are designed for low pressure losses. Metal substrate catalysts are particularly suitable for this purpose. As a result, catalytic converters with metal substrates are used on the 911 Turbo (993).

Mass Air Flow Control

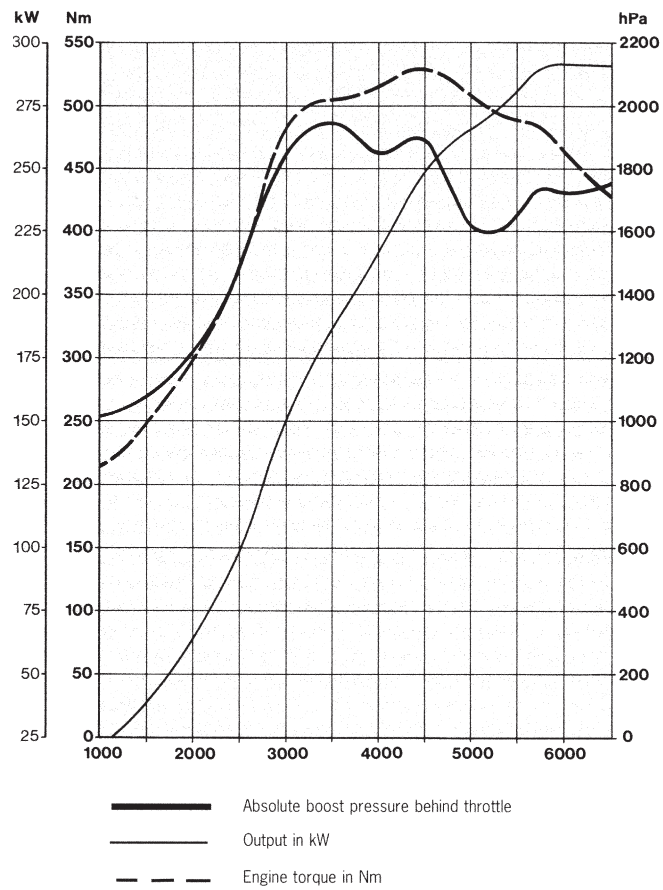
The 911 Turbo (993) engine places high demands on response and torque characteristics across the entire rpm range. The supercharging potential is dependent on the exhaust energy available. The exhaust turbochargers of the 911 Turbo (993) engine have been designed for optimum exhaust flow rates at medium rpm levels.

Thanks to its small size, the exhaust turbine has a positive effect on acceleration. For this reason, high demands are placed on mass air flow control. To avoid overrevving the turbocharger rotor and to prevent excessive air flows, the individual ambient factors that have an effect have to be taken into account.

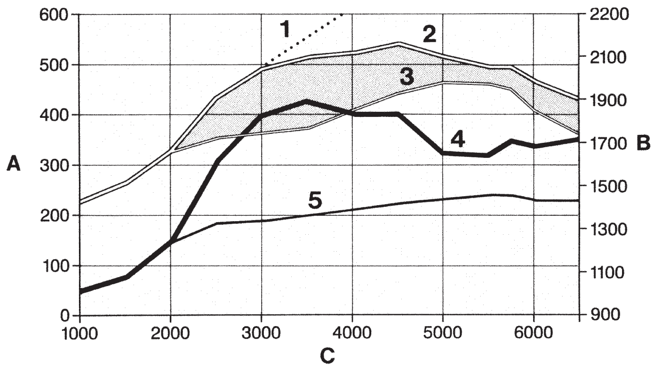
In order to be able to optimize overall efficiency and response and to provide programmable output characteristics, it must be possible to control the air mass depending on the following parameters:

- Throttle position
- Engine speed
- Charge air temperature
- Ambient pressure
- Dynamics detection
- Knock detection

A large closed-loop control range ensures operational safety of the engine, e.g. when using 95 Octane instead of 98 Octane fuel.



The schematic diagram shows boost pressure buildup, engine output and torque at a throttle opening angle of 72°.



A - Torque
B - Engine speed
C - Absolute pressure behind throttle

1 - Full load curve, pulse/duty factor = 100% (entire exhaust gas passes to turbines)
2 - Torque curve at controlled boost pressure
3 - Torque curve at controlled basic boost pressure
4 - Absolute pressure under boost pressure closed-loop control
5 - Absolute pressure under boost pressure open-loop control

The schematic diagram shows the range available for torque control when the throttle is fully open. The 100% pulse/duty factor curve (1) indicates the torque that the engine would generate when the entire exhaust flow were directed across the turbines.

The 0% pulse/duty factor curve shows the torque or the basic boost pressure, respectively, that results when the bypass valve is open.

The Control Concept

The air mass measured by the hot-film mass airflow sensor is compared to the specified nominal value that is stored in a map. Several parameters are provided to correct this specified value if required. The difference between the measured air mass and the specified value represents the regulating deviation that determines a new pulse/duty factor for the frequency valve inside the boost pressure controller (comparable to the oxygen sensor controller built into the control module) and that modifies the bypass valve cross-section by modulating the pressure acting on the diaphragm capsules. In addition, two diagnostic functions are available to switch off boost pressure control and to suppress fuel injection.

Establishing the Specified Value

The performance desired by the driver is reflected by the throttle potentiometer position. A specified value is then calculated in the stored map in conjunction with the engine speed. The air mass is controlled in such a manner that the driver is able to dose the desired torque very accurately.

Correcting the Specified Value Using the Charge Air Temperature

To prevent knock conditions in the engine, the air mass behind the intercooler is reduced at high temperatures. This reduction is dependent on rpm and torque. Even at ambient temperatures of 86° F. (30° C), the engine is able to sustain its maximum output for at least 2.5 minutes. The reduction of the air mass only becomes effective after this time has elapsed.

Correcting the Specified Value Using the Intake Air Density

The fact that the air density decreases at higher altitudes is compensated by additional boost if sufficient exhaust energy is available to the exhaust turbine. This way, at 9800 ft (3,000 m) above sea level and at 3,500 rpm the 911 Turbo (993) will reach the same torque that is available at sea level. The pressure ratio to be generated by the compressor increases in this case, and the exhaust turbocharger speed has to be increased. To avoid exceeding the max, turbocharger speed of 167,000 rpm, air mass and, hence, output are reduced at higher engine speeds. The correction values applied to the specified values in accordance with air density and engine speed are stored in a characteristic map. The air density is continuously determined by the DME control module by comparing throttle opening angle, engine speed and air mass. The deviation of the calculated result from the actual geographical altitude is approx. 5%. This corresponds to approx. 1600 ft (500 m) altitude.

Correcting the Specified Value Using Knock Control

The knock control system corrects the specified air mass if required. If heavy knock occurs, not only is the ignition angle "retarded" (see section on knock control) but the air mass is reduced as well. The knock control system reacts in three successive phases:

1st phase: Ignition angle is retarded rapidly.

2nd phase: Mixture is enriched according to the retarded ignition setting.

3rd phase: Air mass is reduced at larger retard settings.

In the initial phase, the ignition angle is immediately retarded. This increases exhaust temperatures. To avoid damage to the exhaust turbine and to the catalytic converter, the mixture is enriched in the second phase if a total retarding amount is exceeded that has been programmed in accordance with load and rpm (i.e. cumulative retarding of the cylinders of one engine side).

If the cumulative retard setting increases beyond another, higher predefined threshold, the air mass is reduced in the third phase. This air mass reduction occurs in a linear manner until the actual value drops below the air mass threshold again. Then the air mass is increased again until the specified value is reached. This reduction of the air mass is adapted by the DME control module.

The combination of retarding the ignition angle, mixture enrichment and air mass reduction allows the DME control module to react rapidly and to ensure engine operation at optimum efficiency and torque.

Safety Features

Switching to Air Mass Open-Loop Control

When the following faults occur, a switchover is made from closed-loop control to open-loop control:

1. High regulating deviation from specified air mass value
2. Combustion misfire detected
3. Lambda adaptation limit detected
4. Faulty mass air flow sensor, throttle signal or knock sensors

When the air mass closed-loop control is switched off, a load and rpm-dependent map specifies the pulse/duty factor. Depending on ambient conditions, the air mass will then be up to 25% less.

1. Regulating Deviation

If the measured air mass deviates from the specified value by a certain amount for a longer period, a switchover to open-loop control is made. The deviation may be caused e.g. by a faulty exhaust turbocharger or a blocked exhaust system. These faults are highly critical as the control system tried to obtain the specified air mass from the remaining exhaust turbocharger. If engine speeds are above 3,800 rpm, this may lead to critical turbocharger speeds.

To prevent erroneous recognition, the deviation must be present for a certain period. An insufficient actual air mass value may be compensated at higher engine speeds and higher engine loads by increased charger speeds. At lower engine loads and engine rpm, however, the control range is not sufficient to allow conditions to be compensated without faulty detection. For this reason, diagnosis of the deviation is only active at high engine loads and engine speeds between 2,800 rpm and 3,800 rpm.

2. Combustion Misfire

Detection of combustion misfire allows a blocked exhaust system, for example, to be traced.

A blocked exhaust system normally leads to combustion misfire on the affected cylinder bank. For this reason, the DME control module shifts from air mass closed-loop control to air mass open-loop control when a misfire condition is found.

3. Lambda Adaptation Limit

If a leak is present in the intake, pressure of exhaust system, a deviation of the air/fuel ratio is detected via the oxygen sensing system and is adjusted accordingly. If the adaptation value exceeds a certain threshold, a shift from air mass closed-loop control to air mass open-loop control is made. The time span until an oxygen sensing fault is detected depends on the tank vent phases occurring in the control module and the mixture adaptation phases.

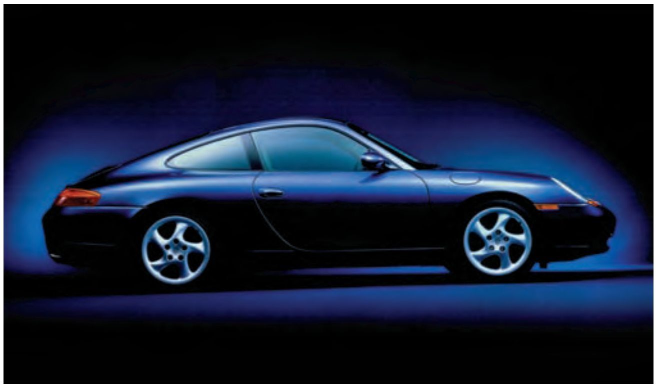
Loss of Measurement Signals

Closed-loop control is no longer possible if the air mass signal or the throttle signal fails. If the knock sensor signals fail, a switchover to air mass open-loop control and to a higher safety margin to the knock limit is made.

Excessive Boost Pressure

Engine overload, e.g. caused by insufficient pressure on the diaphragm capsule of the bypass valve, will rapidly lead to mechanical and thermal overloads. If the air mass is briefly measured to be above a preset threshold, injection is suppressed in a rotating manner. This means that in an initial stage 20% of the injection signals (injection quantity) are suppressed, and if engine overload persists, 40% of the injection signals are suppressed after 1.2 seconds.

This results in a significant reduction of boost due to a reduced exhaust flow rate. This ensures that the catalytic converter will not be damaged. A complete injection sequence will only occur in the lower part-load range again.



General

The DME 5.2.2 Engine Management System was first installed in the model year 1997 Boxster and then the 1999 911 Carrera (996).

The following DME 5.2.2 information was published in the 1999 911 Carrera (996) Service Information Technik book.

The 911 Carrera (996) has a Motronic (DME) of version M 5.2.2 to generate the injection signal, to calculate the ignition angle as well as to provide adaptive control functions for various systems and to carry out diagnostic functions.

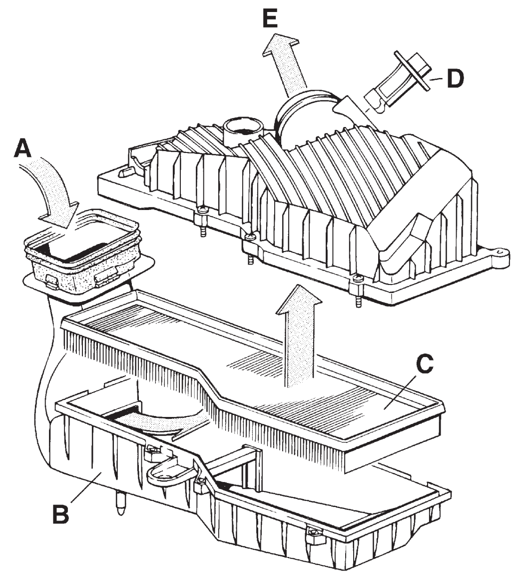
The principal features of the 911 Carrera's DME:

- Engine is fitted with DFI system
- Sequential injection
- Separate fuel mixture control for each cylinder bank
- Adaptive stereo oxygen sensor control
- Potential-free oxygen sensors
- Ground-side control of oxygen sensor heating units
- Hall-effect sensor installed in the intake camshaft for cylinder line 1 - 3
- Actuation of VarioCam valves for cylinder line 1 - 3 & 4 - 6
- Hot-film mass airflow sensor with recognition of flow direction
- Intake air temperature sensor installed in hot-film airflow sensor
- Induction control with twin-coil rotary adjuster
- Adaptive throttle potentiometer
- Adaptive knock control
- Determination of oil temperature
- Temperature sensor to determine engine temperature and to provide analog display on instrument cluster
- Engine compartment temperature sensor to control engine compartment scavenging blower
- Radiator fan controlled by DME control unit
- Actuation and disabling of start relay
- Control of air-conditioning compressor relay
- Actuation of check-engine light in the case of combustion faults which may damage the catalytic converter
- Resonance intake system w/integrated resonance flap
- Torque reduction for traction control by cancellation of ignition angle and suppression of injection
- Electronically controlled venting of carbon canister
- Deactivation of fuel pump by airbag control unit in crash
- Reduction of torque when Tiptronic shifts gear
- Device for feed forward control when checking oxygen control loop (e.g. for exhaust-gas test)

Additional features for USA vehicles:

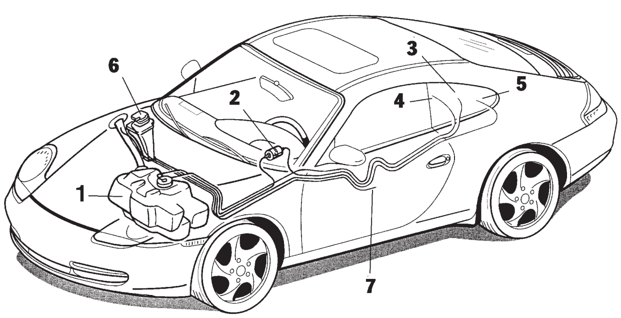
- Complete OBD II diagnosis with activation of check-engine light
- Secondary air system
- 2 additional oxygen sensors after catalytic converters
- Additional Hall-effect sensors for intake camshaft for cylinder line 4 - 6
- Extended tank ventilation diagnosis w/system leak test
- Modified error memory management when check-engine light is actuated
- Modified carbon canister

Airflow



The air (A) drawn in by the engine flows into the throttle housing (E) via the air filter (C) with mass airflow sensor (D). A muffler which reduces air intake noise caused by vibrations is integrated in the air filter housing (B).

Fuel Supply



1 - Fuel tank
2 - Fuel filter
3 - Fuel supply
4 - Fuel return
5 - From carbon canister
6 - Carbon canister
7 - Scavenging air pipe

Fuel Circuit

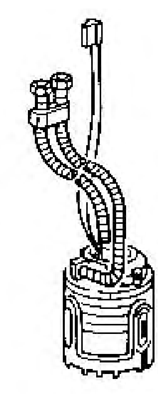
An in-tank pump draws the fuel from the fuel tank (installed at the front of the vehicle) and pumps it into the fuel filter. Afterwards, the fuel enters the fuel manifold for cylinder line 1 - 3. The inlet to this manifold is located at cylinder 3. The test connection for fuel pressure is located at the manifold for cylinder line 1 - 3, which like the manifold for cylinder line 4 - 6 is made of metal and coated yellow.

Both manifolds are linked by a Tecalan fuel pipe which must never be pinched or kinked, otherwise it would be permanently damaged. The pressure regulator is inserted into the manifold for cylinder 4 - 6 at the end of the pipe system, level with the 4th cylinder. From here, a return pipe leads off to the fuel tank.

Fuel Pipes

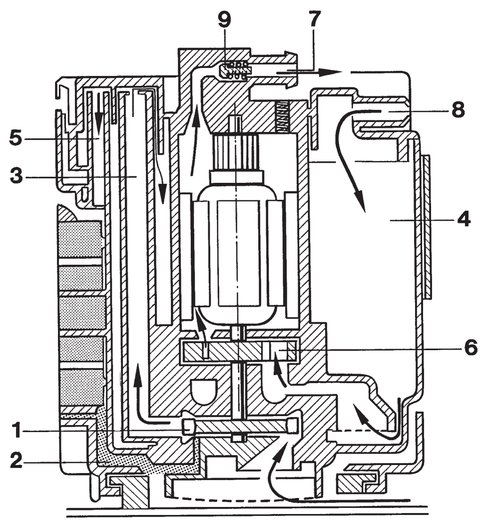
The plastic fuel pipes have connectors which allow components to be connected quickly, simply, and precisely. Great care must be taken when handling these pipes since damage to the sealing faces as well as dirt may cause leakage.

Fuel Pump



An in-tank pump is used in the 911 Carrera (996). This provides advantages with regard to noise and residual fuel suction behavior since it is installed in the fuel tank (noise damping) and, is attached directly to the specially designed base of the fuel tank (suction behavior) by means of a bayonet ring.

Construction



The pump is designed as a two-stage system. The first stage functions according to the flow-wheel principle (1). The fuel is forced-flow ventilated by a special channel (2) as it is drawn from the fuel tank to remove any gas and vapor bubbles. It is then led into the reservoir chamber (4) via an ascending pipe (3). The precisely defined cross-section of the overflow pipe (5) produces slight positive pressure in the reservoir chamber which prevents the formation of a gas bubble mixture and also ensures the precharging of pressure for the main stage. The pressurization of the fuel and the preceding ventilation process are necessary to guarantee a good hot-feed behavior of the system. The second stage of the fuel pump (main feed pump) is configured as an internal gear pump (6) and pumps the fuel out of the reservoir chamber (7), through a filter, and then into the fuel filter and fuel manifold pipes. The returned fuel is led back to the reservoir chamber via a return pipe (8). This completes the fuel circuit. When the engine is switched off, the pressure retention valve (9) closes the pipe loop and ensures that the necessary positive pressure to prevent the formation of vapor bubbles is provided.

Actuation

To ensure that the required fuel pressure and the necessary amount of fuel are provided, the DME control unit actuates the fuel pump for approx. 1 second whenever the ignition is switched on (pump priming). To trigger another pump priming operation, the running engine must be switched off and the ignition then switched on again. In addition, the fuel pump is activated by the DME control unit whenever the engine speed exceeds 15 mph.

Safety Functions

When the engine has been started, the airbag control unit sends a signal to the DME control unit, the frequency and pulse duty factor of which is defined as “airbag not triggered”. When the airbag is triggered, the pulse duty factor changes this signal. This change causes the DME control unit to switch off the fuel pump.

Fuel Filter

The fuel filter is installed in the center tunnel above the pipes leading to the radiator. Due to the construction of the filter, special attention must be paid to the fuel-flow direction. In the 911 Carrera (996), an ground cable is connected to the filter housing. This cable diverts voltage potentials caused by flowing fuel and differing material characteristics (filter housing: aluminum; fuel pipe: Tecalan) of the components to ground.

Fuel Pressure Regulator

A miniature fuel pressure regulator installed in the fuel manifold for cylinder line 4 - 6 (level with the intake pipe for cylinder 4) is used in the 911 Carrera (996). It adjusts the fuel system pressure to 55 psi (3.8 bar) ± 2.9 psi (0.2 bar), depending on the intake pipe pressure.

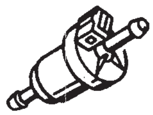
Injection Valves

The injection valves are specially designed for the Carrera engine. The coils of the valves are made of brass and have an internal resistance of approx. 12 Ω. One end of the valve is inserted into the fuel manifold (secured by a clip). The other end is inserted into the intake pipe. Due to the sequential injection system, the electric feed wires must never be interchanged. The DME control unit changes the injected quantity by altering the opening times for the valves.

Tank Venting System

Fuel vapor is collected in the carbon canister. This canister is mounted in the front, right-hand wheel arch. The fuel vapor collected in the carbon canister is fed back into the combustion cycle. The carbon canister is purged with fresh air thus regenerating the carbon.

Functioning



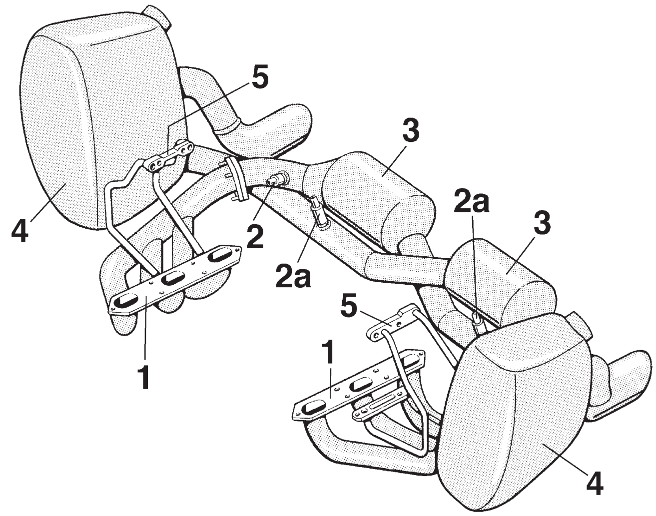
An electromagnetic valve is installed in the line between the intake housing and carbon canister. The flow direction of the one-way valve is imprinted on the plastic housing. The valve is secured above the alternator attached to the intake housing.

The tank venting valve is clocked under map control with warm engine and active oxygen regulation. The resulting pulse duty factor is dependent on the airflow rate of the engine and the load density of the carbon canister. When the mixture drifts from lambda = 1 towards a rich or lean setting (caused by the purging of the carbon canister), this is detected by the control unit via the oxygen sensing system and is corrected by readjusting the mixture control during the tank venting phase. The first purging phase is performed after the engine is started and when the appropriate operating conditions are reached (engine temperature and oxygen regulation operations). It is ended by the DME control unit 250 seconds after the engine has been started. The mixture adaptation phase is then performed for 100 seconds. The next tank venting phase occurs, and so on.

Operation of Tank Venting Valve

The tank venting valve is constructed in such a way that it is closed when the ignition is off. If the ignition is switched on, the DME control unit applies a positive potential to the tank venting valve via terminal 54. When the engine is started and the operating conditions described previously are reached, the tank venting valve is once again connected to ground by the DME control unit, via terminal 61, and opens. When the engine is switched off but the ignition switch on, the Porsche System Tester 2 can be used to check that the valve is functioning correctly.

Exhaust Gas Flow



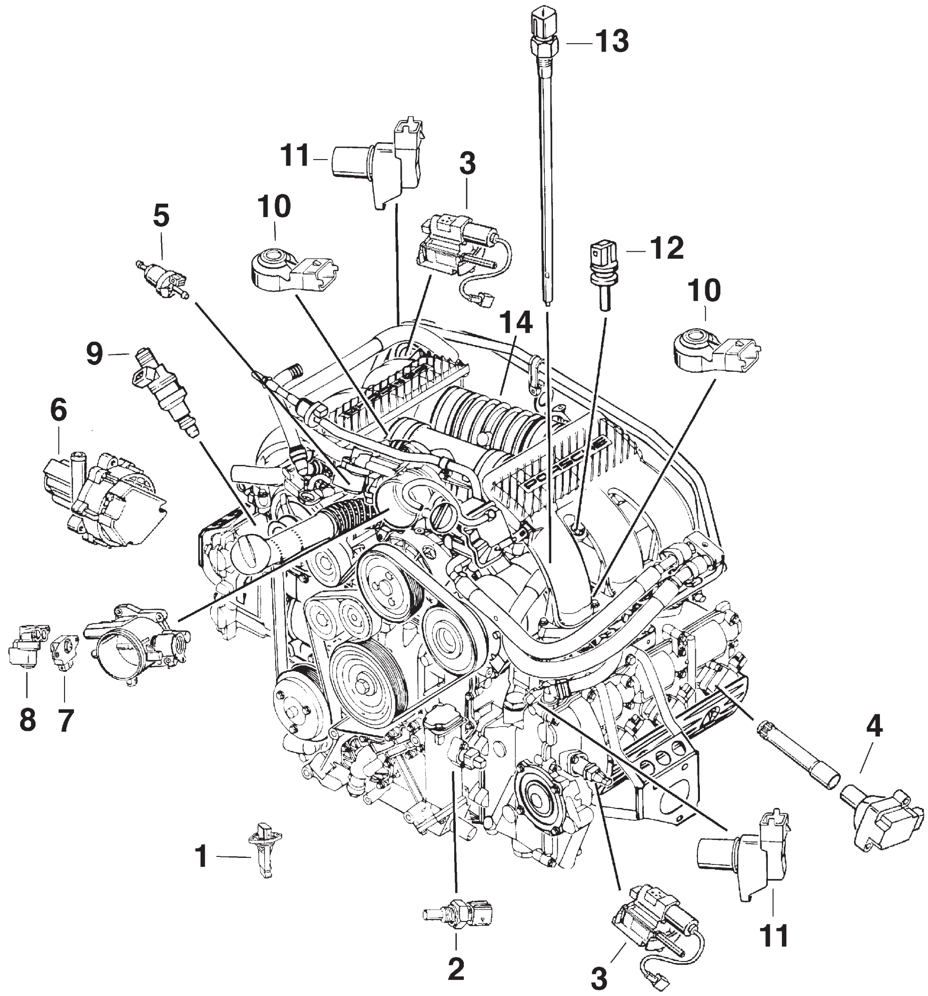
The exhaust gases are collected by one exhaust gas manifold (1) for each cylinder line. From there, the exhaust gases flow to an oxygen sensor (2) provided for each of the two cylinder lines. The exhaust gases then enter a metallic-monolith catalytic converter (3) provided for each of the two cylinder lines. The exhaust gas sampling points (each sealed with a screw) are located between the oxygen sensors and catalytic converters. The exhaust gases flow from the catalytic converters through the muffler (4) before they finally reach the end of the exhaust pipe. The exhaust system is mounted to the engine by the brackets (5).

Additional Information Regarding USA Vehicles

Two oxygen sensors (2a) required for testing the efficiency of the catalytic converters are also installed between the catalytic converters and the rear muffler.

DME Diagram

1 - Mass airflow sensor
2 - Engine temperature sensor
3 - VarioCam valve
4 - Ignition coil
5 - Tank venting valve
6 - Secondary air pump
7 - Throttle potentiometer
8 - Idle speed air control valve
9 - Injection valve
10 - Knock sensors
11 - Hall-effect sensors
12 - Engine compartment temperature sensor
13 - Oil temperature sensor
14 - Resonance flap



DME Control Unit

The engine electronics are controlled by the DME control unit, the processor of which processes the previously digitized analog signals from the various system components. The processor speed, i.e. the cycle time of the processor, is 16 MHz and the total storage capacity is 144 KB. If used in combination with the Porsche System Tester 2, it is now possible to change, expand, or complement certain data externally via the diagnosis socket.

The DME control unit is installed in the passenger compartment under the storage shelf behind the rear seat backs.

As a result, engine-specific tolerances are corrected when the mixture is being produced. Adaptation of the fuel/air mixture also means that it is not necessary to adjust the idle speed CO to a basic setting.

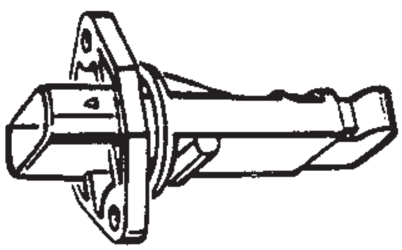
Furthermore, when the engine has been switched off, the engine compartment fan may continue to run depending on the current engine compartment temperature. This means that the control unit is supplied with power via the DME relay and terminal 54 for a programmed time after terminal 15 has been deactivated. The engine compartment cooling fan may switch on during this time.

Note:
Since the control units are programmed for operation with oxygen sensing system and catalytic converters, adaptation of the air/fuel mixture takes place when the engine is running. This means that the control unit together with the oxygen sensing system compensates deviations from the programmed injection precontrol by correcting the injection period.

Hot-Film Mass Airflow Sensor

The 911 Carrera (996) has a hot-film airflow sensor (HFM 5) from Bosch. The mass airflow sensor's shape means that it can be installed in one direction only. It is secured in place with M 5 Torx bolts. The plug is new and coded. As with previous mass airflow sensors, the new HFM 5 is subjected to a laser adjustment process in a “master tube” at the manufacturer's, i.e. a particular air mass generates a precisely predetermined voltage signal.

As a result, the tolerance of the HFM characteristics is below 3% across the entire detection range up to a mass air flow of 640 kg/h. The response time of the hot film is less than 15 ms at a mass air flow of 10 kg/h.



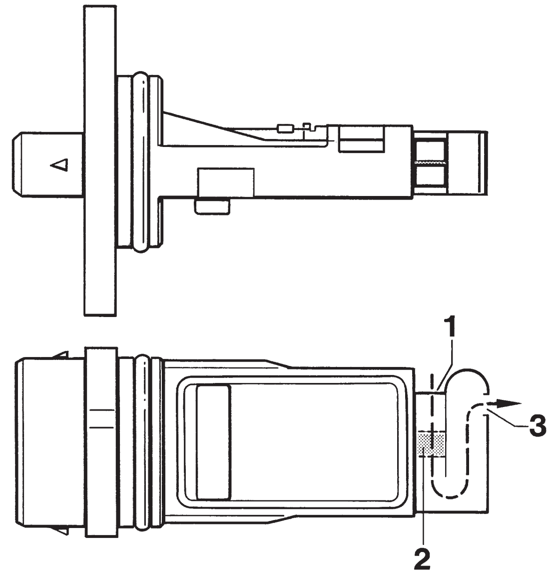
This mass airflow sensor, also referred to as a micro-mechanical hot-film mass airflow sensor due to its size, is inserted into the air filter housing.

Like the previous HFM, the new HFM 5 is also immune to dirt. After 100,000 miles, the characteristics deviation for the HFM 5 is less than 3% resulting from dirt deposits forming on the hot-film element.

The operating voltage range is 9-17 Volts. The output voltage of the mass airflow sensor (the voltage to the DME control unit) is between 0 - 5 Volts. Apart from the power which the on-board voltage supply provides for the mass airflow sensor, the actual measuring element is supplied with a regulated voltage of 5 Volts from the control unit so that fluctuations into the on-board voltage supply, e.g. caused by switching on the consumers, do not have an effect on the measuring process.

Deviations from the supply voltage are thus also included in calculation of the mass air flow performed by the DME control unit. As a result, there are no negative effects on the determination of mass air flow since the control unit calculates the relationship between the supplied supply voltage and the output voltage of the mass airflow sensor.

Air Flow Through The Measuring Element

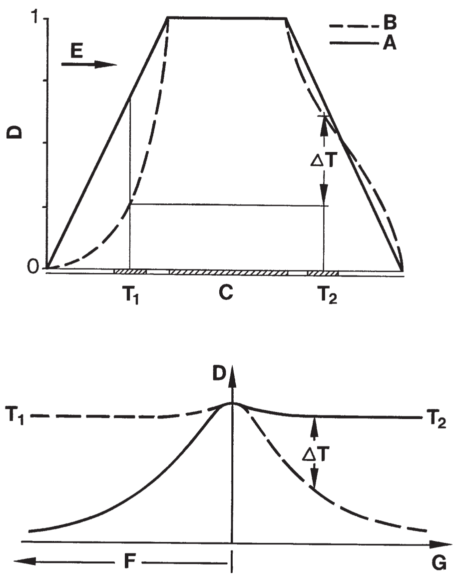


On the side opposite the plug, the measuring element has an air channel with air inlet openings (1). This channel is positioned in the intake air flow of the engine. Behind the air intake opening, there is the actual hot film with temperature resistors in the measuring channel (2). After the hot film, the air flowing through the measuring channel is deflected and guided to the upper part of the housing and back into the intake airflow (3).

The arrangement of the air inlet openings relative to the air channel and air discharge opening of the air channel causes a predefined difference in pressure which, together with the muffler between the intake housing and air filter unit, minimizes air fluctuations and therefore pulsation at the hot-film measuring element and thus ensures uniform, linear mass air flow determination.

Measuring principle

The complete hot-film element is divided into the heated area which, in the case of the HFM 5, is heated to a constant temperature by means of the electronics, and the two temperature resistors T_1 and T_2.



C - Heated area
D - Temperature
F - Return flow
G - Air mass

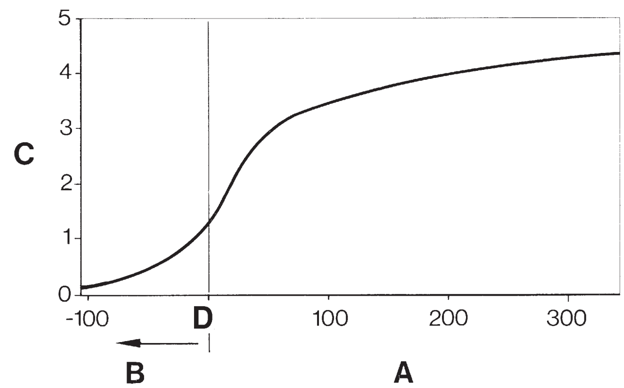
These two temperature resistors are heated by the heated area (C). If there is no mass air flow, T_1 and T_2 are heated to the same temperature (curve A). If a mass air flow is now applied, the temperature resistor (T_1) positioned at the front relative to the flow direction will be cooled more than the temperature resistor (T_2) behind the heated area. A difference in temperature (ΔT) between T_1 and T_2 is therefore produced together with a corresponding temperature characteristic curve (curve B).

The result of the temperature difference evaluation is derived using the following formula:

$\Delta T = T_2 - T_1$

The height of the temperature difference gives the voltage supplied to the DME control unit. Using this measuring method, it is also possible to use the mass airflow sensor to detect the flow direction of the intake air.

The diagram below shows that the mass airflow sensor voltage (can be read using the Porsche System Tester 2) must be approx. 1.3 V without air flow. The voltage increases as the air flow becomes greater. Voltages lower than 1.3 V are produced by a mass air return flow.



A - Air mass m (in kg/h)
B - Return flow
C - Signal voltage U (V)
D - Air mass at idle speed

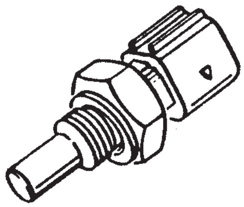
Intake Air Temperature Sensor

The intake air temperature sensor is installed in the mass airflow sensor housing and is therefore situated in the intake air flow of the engine. It is supplied with voltage from the DME control unit via terminal 43 and its ground is connected to the HFM 5. The intake air temperature sensor functions according to the NTC principle.

The signal from the intake air temperature sensor is used by the DME control unit to calculate the default load signal if the mass airflow sensor fails. It corrects the load which is calculated by the control unit and dependent on the throttle potentiometer. With higher air temperatures, the default load signal is downwardly corrected.

The falling air density is also compensated. In addition, the risk of knocking during combustion increases as the intake air temperature rises. Therefore, the ignition angle 9° is corrected towards “late” with high engine temperatures (> 194° F./90° C) and high intake air temperatures (> 86° F./30° C).

Engine Temperature Sensor



The engine temperature sensor is a double NTC, i.e. there are two resistors in the sensor housing. The plug contact is new.

One temperature resistor (resistance can be measured between contact 2 and 3 in the plug housing) supplies the signal used to display the coolant temperature on the instrument cluster. The other temperature resistor (can be measured between contact 1 and 4 in the plug housing) informs the DME control unit of the coolant temperature.

The signal from the temperature sensor is used by the control unit;

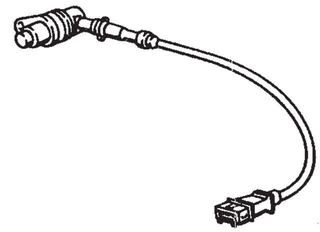
- to calculate the injection signal during the warm-up phase,
- to enrich the mixture when the engine is started,
- to determine the ignition angle in the warm-up phase,
- to control the electric fans.

The engine temperature sensor is located in the coolant duct housing.

Thermoswitch for Engine Compartment Fan

To determine the engine compartment temperature, an NTC has been installed between the intake pipes for cylinders 4 and 5. The engine compartment fan is actuated by the DME control unit depending on the respective engine compartment temperature and various other factors.

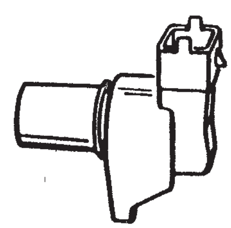
Pulse Generator



The DME uses an inductive sensor to detect the rotational movement of the crankshaft. For this purpose, a sensor wheel is attached to the engine's flywheel. This sensor wheel is a ring gear is stamped from sheet steel and spot-welded to the flywheel and has 60 teeth. A gap produced by 2 missing teeth serves as the reference mark and lies 84° before the TDC of the 1st and 4th cylinder.

Important:
If the flywheel is removed or installed, great care must be taken since force applied to the steel gear may result in its deformation. This would cause a varying gap as the crankshaft rotates and could contribute to signal corruption. The pulse generator is installed in a hole drilled into the crankcase. The gap cannot be adjusted.

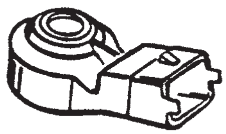
Hall-Effect Sensor



A new, plug-in, plastic covered Hall-effect sensor used to determine the ignition TDC of the 1st cylinder is installed at the 3rd cylinder in the camcase for cylinder line 1 - 3.

The Hall signal is generated by a rotor which is attached to the intake camshaft for cylinder line 1 - 3. Apart from determination of the ignition TDC of the 1st cylinder and the associated assignment of the injection signals (sequential), the ignition signals (permanent high-voltage distribution), and the knock sensor signals (knock control), the Hall-effect sensor signal is also used for diagnosis in the VarioCam system.

Knock Sensor



Two knock sensors are used. Knock sensor 1 monitors cylinder line 1 - 3 and is attached to the crankcase level with the 2nd cylinder. Knock sensor 2 is attached to the crankcase at cylinder 5 and monitors cylinder line 4 - 6.

The knock sensors function according to the piezo-electric principle and are tuned to the frequency of the engine. The plug contact is molded onto the knock sensor housing and the plug contacts are protected against corrosion by a special coating. As with other knock sensors, it must also be ensured that the correct mounting torque is applied.

Functioning

If the knock sensor voltage together with an amplification factor calculated by the control unit reaches a maximum voltage threshold, the DME control unit interprets this as "knocking combustion". If knocking is detected, the calculated ignition angle is reset at the appropriate cylinder (cylinder selected). The maximum late setting per cylinder is dependent on the engine speed and may be up to 15° CS towards "late". If knocking combustion is no longer detected, the ignition angle is gradually returned to its optimum value.

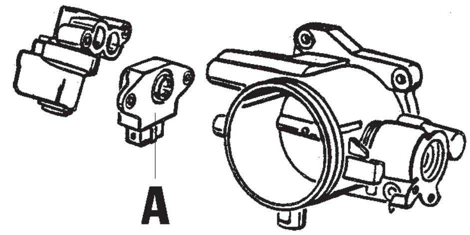
Safety Function

If a fault has been detected by the DME control unit at knock sensor 1 or knock sensor 2, at the Hall-effect sensor, or when the engine load signal was calculated, the calculated ignition angle is for safety reasons automatically reduced by 9° CS.

The following must apply before knock regulation is activated:

- Engine temperature > 109° F. (42.7° C)
- Engine load > 2.5 ms/revolution

Throttle Potentiometer



The throttle position is determined via a potentiometer (A) fitted at the throttle valve. The DME control unit supplies the potentiometer with a regulated voltage (5 V). Depending on the potentiometer position (throttle opening angle), a higher or lower drop in voltage occurs at the potentiometer. The DME control unit uses the voltage drop and the corresponding current flow to determine the smallest opening angle for the throttle. This angle is defined as the ìidle speed positionî.

Oil Temperature Sensor

The DME control unit uses the oil temperature to calculate the switching speed for the VarioCam system. The oil temperature sensor and the oil level sensor form a single component and are screwed into the crankcase.

Reserve Fuel Light

When the ignition is switched on, a positive potential is applied to terminal 39 of the DME control unit via the instrument cluster. If the reserve fuel light goes out when the engine is started, the potential changes to ground. If the reserve fuel light then lights up again or does not goes out, the DME control unit stores this information if combustion faults are detected.

Air Conditioning

When the air-conditioning system is switched on, the heating/air-conditioning control unit sends a signal to the DME control unit (terminal 69). The size of the signal depends on the current power consumption of the air-conditioning compressor and results in changes in the basic air quantities which the DME control unit supplies to the engine using the idle speed air control valve.

The DME control unit then sends a signal to the air-conditioning relay via terminal 62, this closes and connects the compressor coupling.

The following conditions must apply before the air-conditioning relay is actuated:

- Engine temperature between 37° F. (3° C) and 242° F. (117° C)
- Intake air temperature >32° F (0° C)
- Time after engine start > 5 seconds

Additional function

If, when the air-conditioning system is switched on, the engine undergoes heavy acceleration, the compressor is switched off for 15 seconds. If the AC button is actuated and the engine started, the air-conditioning relay is not activated until the system detects that the engine is running. If an automatic exhaust emission test is carried out, the air-conditioning compressor switches off.

If the DME control unit performs the tank venting diagnosis, the current compressor status is retained for the duration of the diagnosis.

Pressure Switch

The air-conditioning system pressure switch closes with pressures > 232 psi (16 bar). Ground potential is applied to the DME control unit via terminal 14. This causes the radiator fan to be switched to speed 2 when the engine is running.

Oxygen Sensor

Due to the stereo oxygen sensing system, the exhaust system has two submersible oxygen sensors. These are potential-free, i.e. the DME control unit applies ground to the oxygen sensor. The sensors are installed in each exhaust gas flow before the catalytic converter.

Oxygen Sensor Heating System

The sensors are heated electrically as well as by the flow of exhaust gas. In addition, the oxygen sensor injection and ignition relay is also activated when the DME relay is switched. This relay applies a positive potential to the oxygen sensor heating elements. The DME control unit switches ground to the heating resistors.

Oxygen Sensing System

Mixture formation is regulated individually for each cylinder line (stereo oxygen sensing system). In addition, 2 oxygen regulators which are each controlled by an oxygen sensor before the catalytic converter per cylinder line are also integrated in the DME control unit. The oxygen regulation values and the adaptation data can be read out using the Porsche System Tester 2.

Tiptronic Transmission

If the vehicle has a Tiptronic transmission, the DME control unit receives this information via the engine cable harness whereby terminal 38 of the DME control unit is connected to ground.

A constant data exchange between the DME control unit and the Tiptronic control unit occurs when the engine is running (see Tiptronic transmission). During this data exchange, the Tiptronic control unit informs the DME control unit of shifting operations in the transmission triggered by the Tiptronic control unit. To optimize shifting, the DME control unit reduces the ignition angle thus reducing the engine torque.

Starter

The starter is activated by the DME control unit. This improves starting behavior and at the same time reduces wear.

Vehicle Speed

The DME control unit receives information regarding vehicle speed at terminal 79. The DME control unit requires this information for various calculative functions (system adaptation, diagnosis functions, etc.). The speed signal is picked up from the rear, right-hand wheel.

Exhaust Emission Test

The oxygen sensing circuit can be checked simply as part of an exhaust emission test required by law. For this purpose, a 6-pole plug connector is installed in the engine compartment (on the right-hand side relative to the direction of travel) next to the air filter. If terminal 2 and terminal 1 are connected, ground is applied to the DME control unit output terminal 42 thus triggering the test.

During testing, the tank venting valve is first actuated (closed). The precontrol factor for the injection map is adjusted by an appropriate amount towards “lean”. The oxygen value is simultaneously frozen for a short period of time. If the exhaust gas is now measured in the end pipes, an increase in the oxygen factor in the exhaust gas is detected. During the testing process now being performed, the oxygen regulator is activated again and corrects the change in mixture (precontrol). (The oxygen display on the exhaust emission tester must now return to its tolerance field.)

If the plug bridge is now removed, the precontrol factor is again set to its initial value and the oxygen regulator is again frozen for a short period of time. Since the oxygen regulator has been adjusted towards “rich”, the mixture is now too rich (can be measured using the exhaust emission tester).

After a short time, the oxygen regulator returns to its average value and the test ends.

The engine speed signal is applied to terminal 6 of the 6-pin plug. The test can be started when the following operating conditions apply:

- No faults in the engine temperature measuring circuit
- No functions activated with Porsche System Tester 2
- Idle speed
- Oxygen regulators 1 and 2 active
- Engine temperature > 140° F. (60° C)
- Time after engine start > 30 seconds

The time factors programmed for testing the regulation circuit are selected such that the time intervals required by law for the exhaust emission tests (correction of incorrect values) are observed.

Traction Control (TC)

The advantages and influence of TC with regard to the handling characteristics of the vehicle are described in the chapter “Running gear”. Here, only the influence of the traction control system upon the DME system is described.

Functioning

While the engine is running, the DME control unit calculates the actual engine torque from the following variables: engine load signal (TL), current ignition angle, and engine speed (n). If the TC control unit detects that the wheel slip for the rear axle of the vehicle is too great, the TC control unit generates a signal which is sent as a nominal engine torque to the DME control unit via the data cable in the form of a pulse-width modulated duty factor.

If, when the nominal engine torque (from the TC control unit) is compared with the actual engine torque (calculated in the DME control unit), a deviation is detected (rear axle has too much slippage), the DME control unit reduces the engine torque by disabling injection and adjusting the ignition angle towards “late” until the nominal engine torque and actual engine torque are identical. In this state, there is virtually no spinning of the rear wheels. Activation of the TC function (reduction of the torque by the DME control unit) is indicated by a green light in the instrument cluster.

If the TC control unit requests a reduction in torque which requires the disabling of individual cylinders, the appropriate injection pulses for the cylinders to be disabled are completely suppressed (injection valve is closed). An injection pulse which has already begun will always be completed despite the TC requests. If a cylinder is released within the corresponding injection period, the remaining injection period is not completed.

Two disabling patterns which permit up to 12 reduction steps are processed within the DME control unit. The disabling pattern changes after 6 calculated injection pulses. A feature to prevent the engine from stalling is provided. It is programmed such that the torque cannot drop below a specific engine speed (1200rpm).

Disabling of the corresponding cylinders occurs alternately and corresponds to the injection sequence. When the individual injections are restored, a factor is added to the respective injection signal. This factor is based on the current operational status of the engine and ensures that, after a cylinder has been disabled (temperature drop, etc.), it receives an optimum air/fuel mixture required for combustion.

Ignition System

An ignition system with permanent high-voltage distribution is installed. As a result, the DME control unit now takes over the tasks of the ignition distributor, i.e. the calculated ignition angle (depending on the engine speed, engine load, and various correction factors) is directed, according to the firing order, by the DME control unit to the 6 ignition final stages integrated in the control unit. These final stages control the primary current circuit via the individual spark coil directly attached to the spark plugs. The control cables are labeled and attached to the compact plug connector molded onto the housing of the ignition coil.

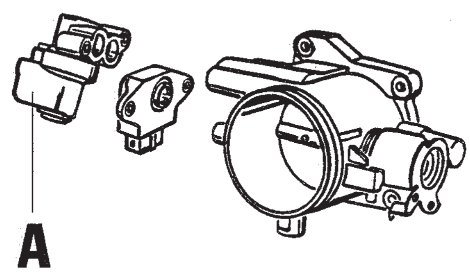
The connection between the individual spark coil and the spark plug is established using a spark plug connector with an internal resistance of 2kW. The electric cable and the 3-pin, coded plug contact are used to supply the individual spark coil with a positive potential (terminal 3) and negative potential (terminal 2). Terminal 1 on the individual spark coil leads to the ignition final stage. The coils are supplied with voltage when the injection, ignition, and oxygen sensor relays are closed.

Sequential Injection

The DME operates using sequential injection. This means that the quantity of fuel calculated for the respective operating condition of the engine is metered to each cylinder individually once per cycle in accordance with the firing order (but always in the overlapping TDC).

Here, the commencement of injection is variable. It is based on engine load, engine speed, and engine temperature. This type of injection ensures the lowest possible condensation losses, highly uniform mixture formation (for each cylinder) and, in turn, the greatest possible level of efficiency.

Idle Speed Air Control Valve



A compact twin-coil control valve (A) is used. It is directly mounted onto the throttle housing without additional air ducting hoses.

In conjunction with the DME control unit, the basic quantity of air required for the corresponding operating condition of the engine is supplied via the control valve bypass.

Deviation from a programmed basic quantity of air when the engine is at idle speed is adaptively corrected by the DME control unit under the following conditions:

- Idle speed
- Zero vehicle speed
- Engine temperature > 175° F. (79.5° C)

In conjunction with the DME control unit, the idle speed air control valve also regulates the idle speeds required for the different operating conditions of the engine.

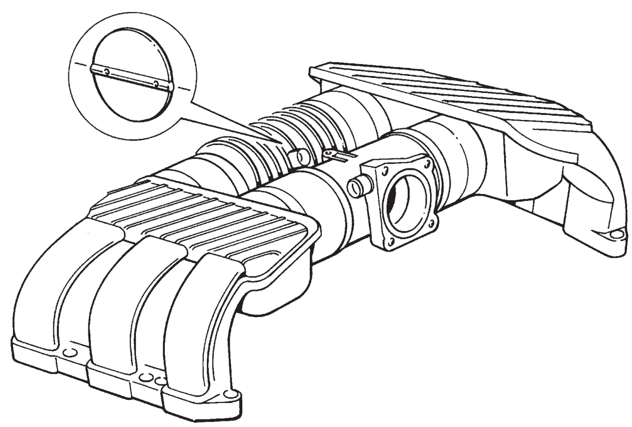
Idle Speed

The idle speed for all transmission variants (manual transmission and Tiptronic) is 700 rpm (warm engine/coolant temperature > 140° F. (60° C), with air-conditioning system switched on: 820 rpm - manual transmission.

However, if the engine oil temperature exceeds 289° F. (143° C) or less than 11.03 V is applied to terminal 15 (power supply) of the control unit, the idle speed is increased to 850 rpm by the control unit.

Downward adjustment of the increased speed after undervoltage is performed after the next transition from partial load to idle speed if the supply voltage was higher than 11.03 V.

Resonance Flap



An intake system divided by a resonance flap allows utilization of oscillations along the intake air column across a broad speed range (resonance supercharging). Due to the different working cycles of the individual cylinders, air is drawn from both reservoirs in the intake system alternately. The mass air flow in the intake system is excited by the alternating induction. In the case of resonance, the intake frequency of a cylinder line matches the frequency of the compressive oscillations in the pertaining reservoir. This frequency is determined by the geometry of the intake pipe, the resonance pipe, and the reservoirs. However, the overall length of the pipes from the intake cylinder to the subsequent intake cylinder, the division within the intake and resonance pipes as well as the reservoir depth in the flow direction are the deciding factors.

The DME control unit activates a diaphragm valve controlled by negative pressure. This valve opens or closes the resonance flap. The resonance flap is closed when de-energized, but is actuated and open whenever the ignition is switched on. If, after the starting process, the engine reaches the programmed idle speed, the resonance flap is closed again.

Switching points of the resonance flap:

- Resonance flap not actuated between 700 rpm and 3,120 rpm and from 5,120 rpm.
- Resonance flap actuated between 3,120 and 5,120 rpm, if the throttle is open by more than 30%.

Activation of the Engine Compartment Fan by the DME Control Unit

To reduce the temperature of the engine compartment, a fan actuated by the DME control unit is installed under the ventilation grille of the engine cover.

If the fan is active, fresh air is fed into the engine compartment. The fan can only be actuated 100 seconds after the engine has been started.

Functioning

1 - With engine running or ignition on:
If the engine temperature is higher than 216° F. (102° C) and the engine compartment temperature is higher than 140° F. (60° C), the engine compartment fan is switched on for 30 seconds by the DME control unit and the engine compartment is thus ventilated.

2 - Engine compartment fan if vehicle is stationary and engine is switched off (after-running of control unit):
If the engine compartment temperature is higher than 140° F. (60° C) when the engine is switched off (ignition off) or if the engine stalls (engine speed: 0 rpm), after-running of the DME control unit lasting 20 min. begins. The DME relay remains active.

After-running of the fan continues until the programmed time has expired (20 min.) or until the next engine start after which the engine runs for more than 100 seconds. If the engine compartment temperature is higher than 184.5° F. (84.75° C) during after-running of the control unit, the engine compartment fan is started and runs for 30 seconds.

If, at the end of the operation period (30 seconds), the engine compartment temperature is still higher than 184.5° F. (84.75° C), the engine compartment fan is started and runs for another 30 seconds, etc. If the temperature now drops below the threshold 185° F. (84.75° C), a polling pause lasting 10 seconds occurs.

Note:
If the engine temperature has not dropped below 176.4° F. (80.25° C) after the engine compartment fan has been running for 25 seconds, a fan fault is registered and the coolant level warning light is activated (flashes).

Electric Fans

There are two radiator modules installed in the front of the vehicle (on the left- and right-hand side). These radiators are each fitted with an electric fan. They can be operated at two speeds and are activated by the DME control unit whenever the following conditions apply:

Electric fan, speed 1 (Ground to DME control unit, terminal 35)

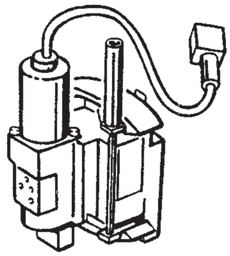
- Coolant temperature higher than 206° F. (96.75° C) or air conditioning switched on.

Electric fan, speed 2 (Ground to DME control unit, terminal 36)

- Coolant temperature > 216° F. (102° C) or air-conditioning fluid pressure switch closed (coolant pressure > 232 psi /16 bar).

Note:
The electric fans for the radiators are only triggered when the engine is running!

VarioCam



To increase the torque and to improve cylinder charging, the engine has two VarioCam actuators which are installed in the chain tensioners of the camshafts. The two actuators are operated by electromagnetic valves activated by the DME control unit.

Functioning

When the ignition is switched on, the electromagnetic valves of the camshaft adjusters are supplied with positive potential. If the engine is started, the control unit applies ground to terminal 25 (camshaft adjuster for cylinder line 4 - 6) and to terminal 52 (camshaft adjuster for cylinder line 1 - 3) if the following conditions are fulfilled (VarioCam activated):

1 - Engine oil temperature between 20° F. (-3° C) and 271° F. (133° C)
2 - Engine speed > 1,300 rpm
3 - Throttle opening > 5%

or

1 - Engine oil temperature > 271° F. (133° C)
2 - Engine speed > 1,480 rpm
3 - Throttle opening > 3.9 %

The ground potential is deactivated by the DME control unit (VarioCam deactivated) if:

Engine speed > 5,120 rpm

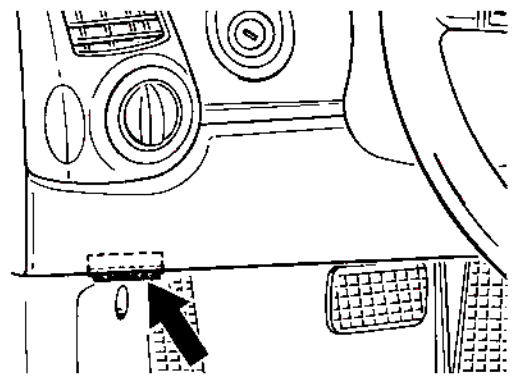
Check-Engine Warning Light

The check-engine warning light is installed in the instrument cluster. With all models, apart from USA vehicles (OBD II as standard), the warning light is only activated in the case of combustion faults which could damage the catalytic converters.

Functioning

If combustion faults are detected by the DME control unit and if the frequency at which these faults occur could result in thermal damage to the catalytic converter, the check-engine light flashes. If the engine load or engine speed is reduced by the driver (see Owner's Manual), the warning light ceases to flash and is permanently lit. In addition, the injection valve at the appropriate cylinder is closed by the DME control unit.

Diagnosis



Monitoring of signals by the DME control unit allows the system to perform reliable and precise diagnosis. It is also possible to activate certain additional functions such as the actuator test and switching input test using the Porsche System Tester 2 and to check that they are functioning correctly.

Reading out the fault memory and deleting the fault memory can be performed using the Porsche System Tester 2. The diagnosis socket is installed underneath the knee protection bar on the driver's side.

USA Vehicles

Since USA vehicles must fully satisfy the OBD II standard, the components on the following pages have been added to the DME system of these vehicles:

Hall-Effect Sensor

An additional Hall-effect sensor has been installed at the intake camshaft for cylinder line 4 - 6. This sensor sends a signal to the DME control unit (also terminal 21) when the Hall-effect sensor for cylinder 1 - 3 registers a crank angle of 120°. With USA vehicles, this additional Hall signal is used for diagnosis of the VarioCam system for cylinder line 4 - 6. If the Hall-effect sensor for cylinder line 1 - 3 has failed, the DME control unit can still be triggered by the additional Hall signal at the ignition TDC for the 1st cylinder.

Oxygen Sensor After Catalytic Convertor

To check the efficiency of the catalytic converters, an additional oxygen sensor is installed in the exhaust-gas circuit after each of the two catalytic converters. The signals from these sensors are sent to terminal 76 and 77 of the DME control unit. If the engine fulfills the operating conditions required to allow diagnosis of the catalytic converter, the DME control unit calculates the amplitude ratio using the signal from the oxygen sensors before and after the catalytic converter. This ratio is dependent on the oxygen storage capability of the catalytic converter. This allows an old or faulty catalytic converter to be detected.

The two oxygen sensors after the catalytic converters differ from the oxygen sensors before the catalytic converters in their coding only (i.e. a gray connector and a connector with different coding). Of course, the oxygen sensors are also electrically heated after the catalytic converters.

The operating conditions for catalytic converter diagnosis are:

- Catalytic converter temperature higher than 788° F. (420 C)
- Engine speed between 720 rpm and 2,400 rpm
- Engine load (TL) between 0.8 ms/rev. and 2.6 ms/rev.

Auxiliary Air Pump

To reduce pollutants contained in the exhaust gas during the warm-up phase and to achieve the emission limits of the roll test in the USA, USA vehicles have a secondary air system. For this reason, an electric air pump has been mounted on the left-hand side of the engine compartment. This pump is activated by the DME control unit and blows the additional air through air ducts to the discharge valve. A pneumatic switching valve which is closed when the secondary air system is inactive thus preventing the flow of additional air is installed between the air pump and the discharge valve.

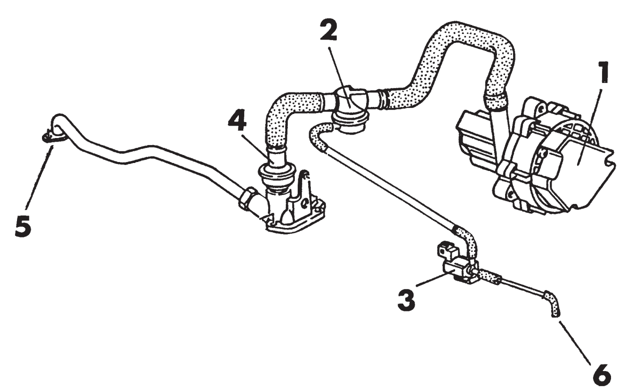
Functioning

If the engine is started in a temperature range between minus 51° F. (10.5° C) and plus 113 ° F. (45° C), the secondary air system is activated for a period of time dependent on the start temperature (min. 50 seconds, max. 179 seconds).

The secondary air system is only activated if the following engine-related operating conditions apply:

- Engine load (TL) between 0.7 ms/rev. and 4.7ms/rev.
- Air mass (ML) not greater than 300 kg/h
- Engine speed between 680 rpm and 2,800 rpm
- Altitude adaptation factor greater than 0.76, corresponding to less than 7,800 ft. (2,400 meters) above sea level.

Overview of the Secondary Air System



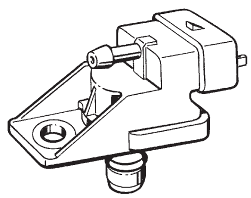
1 - Air pump
4 - Non-return valve
2 - Pneumatic switching valve
5 - To the cylinder heads
3 - Electromagnetic valve
6 - To the vacuum chamber

Tank Venting System

From model year '99, a test for tank system leakage will be required for vehicles with OBD II. This test can detect leaks in the tank system measuring up to 1 mm in diameter.

Apart from the already familiar components of the tank venting system (e.g. carbon canister and tank venting valve), a pressure sensor for differential pressure in the tank and a shut-off valve for the purge air line used to seal the tank venting system are also to be installed to make this new diagnosis function possible.

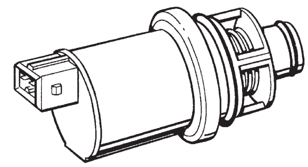
Pressure Sensor



The sensor element functions according to the piezoelectric principle. It is supplied with 5 V by the DME control unit. The sensor element, suitable electronics for signal amplification, and a temperature compensation unit are integrated on a silicon chip. The silicon chip is surrounded by a housing which forms the inside of the sensor cell. The active surface is exposed to ambient pressure via an opening in the cap and via a reference connector and is protected against moisture by a silicone ball. The tank system pressure is led to the diaphragm's fuel-resistant rear side via a delivery nozzle.

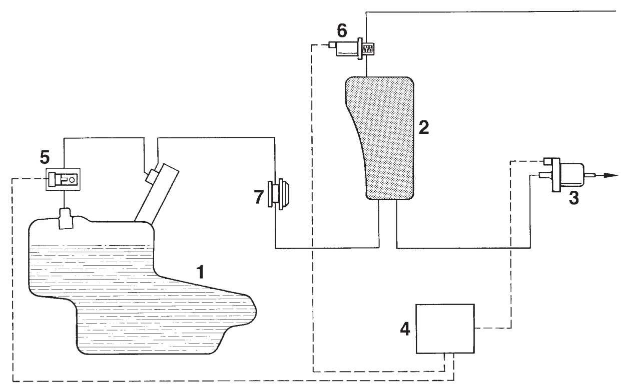
The pressure sensor is supplied with 5 V by the DME control unit. The analog output signal from the pressure sensor ranges between 0.5 V and 4.5 V depending on the differential pressure. This electrical signal is used for the tank leak test.The electrical output of the sensor is designed such that faults caused by cable breaks or short circuits are detected by an appropriate circuit in the subsequent control unit electronics. The diagnosis ranges beyond the characteristics boundaries are provided for fault diagnosis. The pressure sensor is installed in the pipe between the tank and carbon canister located underneath the vehicle's battery.

Shut-Off Valve



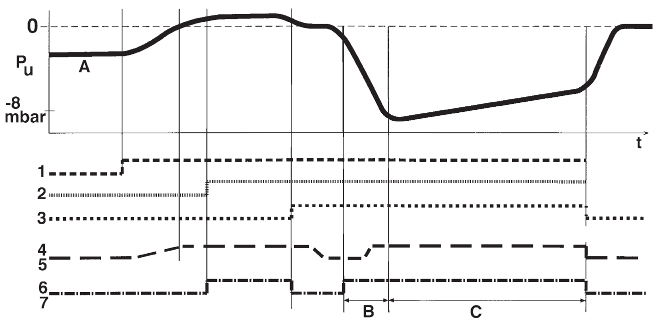
An electromagnetic shut-off valve is installed at the outlet of the purge air line of the carbon canister. This valve is used to seal off the tank system from the outside air during the leak test. The shut-off valve is actuated by the DME control unit.

Overview of the Tank System



1 - Tank
5 - Pressure sensor
2 - Carbon canister
6 - Shut-off valve
3 - Tank venting valve
7 - Vacuum limiting valve
4 - DME control unit

Functioning of the Tank Leak Test



A - Tank pressure characteristic condition fulfilled
B - Vacuum build-up phase
C - Vacuum reduction phase
Pu - Vacuum in mbar
t - Time axis
1 - Diagnosis
2 - Pressure increase calculation
3 - Start/end of diagnosis
4 - Tank venting valve closed
5 - Tank venting valve open
6 - Shut-off valve closed
7 - Shut-off valve open

If tank venting is functioning normally, the tank venting valve is opened by the DME control unit depending on the load state of the cartridge and the mass air flow of the engine and the system is evacuated. This produces a slight vacuum (A) in the system up to the tank. If the conditions for diagnosis are fulfilled (1), the tank venting valve is first closed (4). The vacuum in the tank reduces since the shut-off valve continues to remain open. The shut-off valve is now also closed (6), and the increase in pressure caused by the evaporation of fuel in the tank (2) is detected by the pressure sensor and is included as a pressure reduction gradient in the subsequent pressure reduction calculation.

If there is no increase in pressure, the diagnosis is terminated and it can be assumed that there is a large leak in the system (e.g. the fuel tank cap is not fitted). The shut-off valve now opens briefly (7) and the tank venting valve is opened (5) via a progression ramp until a defined duty factor is reached (10 - 13%). When the duty factor is reached, the shut-off valve is closed (7). Since the shut-off valve is already closed and the tank venting valve is still open, the previously mentioned vacuum increases in the system (B). If the vacuum is not reached, the DME control unit terminates the diagnosis and assumes that there is a large leak in the system (e.g. leaking shut-off valve).

Diagnosis is also terminated in the case of excessive cartridge loading or excessive fuel evaporation caused by fuel swashing in the tank (both cases indicated by a severely fluctuating oxygen regulator or an oxygen regulator with severe “lean”π correction). If the vacuum of 8 mbar is reached, the DME control unit also closes the tank venting valve (4).

Taking the pressure increase gradient into consideration, the drop in pressure in the system is now measured over a programmed period of time (C). The drop in pressure must not exceed a value which corresponds to a leak in the system measuring > 1 mm in diameter. The diagnosis is complete after a total time of approx. 30 seconds.

Diagnosis Conditions

The tank system diagnosis is performed under the following conditions:

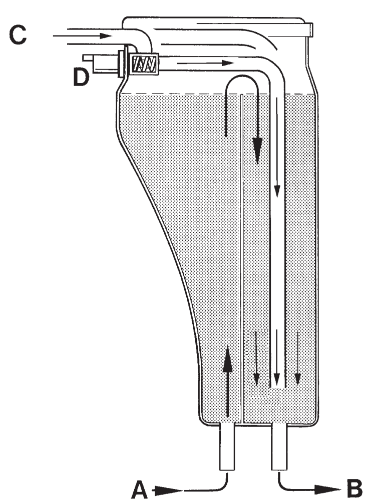
1 - Engine idling
2 - Vehicle stationary
3 - Engine temperature < 129° F. (54° C) when started
4 - Intake air temperature between minus 54° F. (12° C) and plus 185° F. (85° C)
5 - Loading of carbon canister not excessively high
6 - No excessive gas vapor generation in the tank (pressure gradient)
7 - Time after engine start > 1,000 seconds
8 - Detected altitude < 2,400 m

The diagnosis can also be performed as part of a brief test function using the Porsche System Tester 2, whereby the waiting time of 1,000 seconds can be disregarded from the conditions listed above.

Carbon Canister

From model year '99, a shed test is included in the FTP roll test. Here, after completion of the FTP test (special roll test with predefined driving cycles), the fuel in the vehicle's tank is heated to plus 140° F. (60° C) using a heating blanket. This causes severe gas vapor generation of the fuel. Since this test is performed with the engine switched off, the volatile fuel enters the carbon canister and then into the open air via the purge air line.

After a waiting time, the HC concentration in the room in which the shed test is being performed is measured. The HC concentration must not exceed a legally prescribed value. For this reason, a 2-chamber carbon canister is used. The separation of the cartridge into 2 chambers and the layout of the purge air line virtually doubles the length of the path to be taken by the fuel vapors through the carbon canister. This considerably improves the efficiency of the carbon canister.



A - From the tank
C - Purge air line
B - To the engine
D - Shut-off valve

Actuation of the Check-Engine Warning Light

Beginning with OBD II, US regulations demands the actuation of the check-engine warning light in the case of all faults in the DME system which affect exhaust emissions. From model year '99, the warning light will be actuated if a suspected fault is confirmed in 2 driving cycles. One driving cycle is reached if the engine is allowed to run for 120 seconds after it has been started.

Notes:

Notes:

E-Throttle Systems – Sports Cars 7.2, 7.8 and Cayenne 7.1, MED 9.1 & EMS SDI 4.1

In model year 1999 with the introduction of the 911 Carrera 4 (996), Porsche introduced the 7.2 motronic system with electronic throttle control. In model year 2000 the 7.2 system with electronic throttle control became standard on all Porsche models. All subsequent Porsche models have been equipped with electronic throttle control.

The following section contains information on the Porsche engine management systems with electronic throttle control. There are vehicle specific descriptions of E-Throttle operation in the "System Descriptions – E-Throttle" that follow this generic description section. This section is an overview that presents E-Throttle in a clear and simple manner. We will also look at the function of the components of this system that are new to us.

Let us begin with a description of how electronic throttle control operates.

Basic Principal of E-Throttle

The most significant change with electronic throttle control is the priority in the control sequence. In the systems we have described so far:

- The first event in the control sequence is the driver puts his/her foot on the accelerator pedal and opens the throttle.
- The air mass and the engine RPM then rise.
- The engine management system increases the injector duration and advances the ignition timing.
- The amount of torque the engine produces increases and the vehicle speed increases.

With E–Throttle when the driver puts his/her foot down, the engine control unit:

- Senses the accelerator pedal position via the pedal position sensor.
- Opens the throttle valve via the electric motor in the throttle body.
- Increases the injector duration by increasing pulse width.
- Advances the ignition timing, the amount of torque the engine produces increases so the vehicle speed increases.

The result is, the vehicle speed increases.

With E-Throttle the driver becomes an input to the control system. The driver cannot open the throttle directly, instead initiates a request that the control unit open the throttle.

With E-Throttle, the response between the input of the pedal sensor and the movement of the throttle valve is almost instantaneous.

There is the possibility of the system overriding the driver. Why and when would this be done?

- When the torque produced would induce unstable handling (wheel spin caused by torque – excessive torque breaks wheels loose)
- When downshifting while decelerating and too low a gear is selected – causing the wheels to break loose. The throttle is opened to reduce the engine braking effect.
- When the lateral acceleration is so high that the PSM cannot maintain vehicle stability if torque rises any further.
- When the engine is unloaded and high RPMs might damage the engine. (Over revving)

In normal operation, the E-Throttle functions like a throttle cable vehicle (The throttle follows the pedal position). Intervention is only initiated when it is necessary to maintain vehicle stability or to protect the engine.

The E-Throttle system eliminates the idle stabilizer. The E-Throttle system controls idle with the throttle plate. The E-Throttle also eliminates the cruise control servo and control unit.

E-Throttle

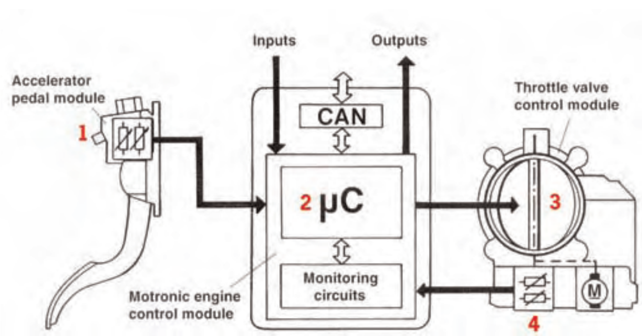
System Operation

The E-Throttle system consists of three main components.

- Accelerator Pedal Position Sensor
- Engine Management Control Unit
- Throttle Valve Control Module

When the driver depresses the accelerator pedal:

1. The pedal position sensor potentiometers send a pedal position signal to the engine management control unit.
2. Based on this signal, the control unit determines the desired throttle valve position.
3. The control unit sends current to the motor connected to the throttle plate, and it moves.
4. The motor moves the throttle plate until the signals from the throttle plate potentiometers indicate that the desired throttle valve position has been reached.



1. Pedal module potentiometers send a request signal to the processor.
2. Processor makes a decision based on all of the inputs.
3. Processor sends a drive signal to the electric motor.
4. Throttle valve potentiometers send back a signal verifying the motor has moved.

Throttle Valve Control Module Self Test and Monitor

The E-Throttle system performs a self- test of the throttle valve control module each time the ignition is switched on, if the time before the engine is started is longer than 10 seconds.

The following items are checked:

- Closing spring test
- Opening spring test
- Emergency position test (where the throttle plate parks when the electric motor is not energized)

An adaptation can also be performed with the tester.

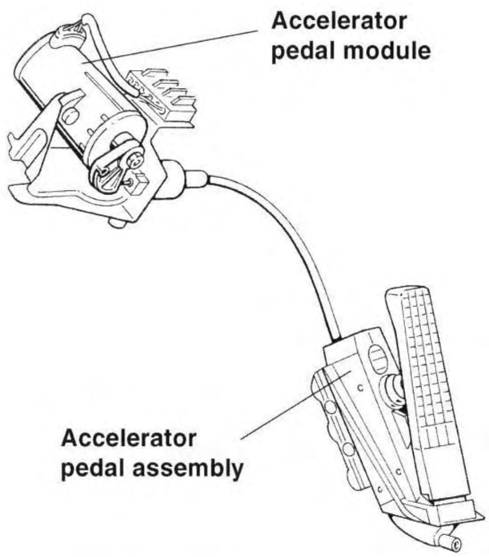
- When the adaptation is performed the engine management control unit closes the throttle plate completely to determine its “mechanical stop”.
- It then remembers this position and establishes an “electrical stop”.
- Afterward the throttle is not closed beyond the electrical stop.
- This prevents the throttle from wearing a groove in the throttle body that the throttle would bind in.

There is a wide open throttle electrical stop, however; this is not set during an adaptation, it is established by the engine control unit. The control unit can find wide open throttle by monitoring air mass.

This is how the engine control unit determines wide open throttle:

- When the throttle plate is opened the air mass should rise.
- The throttle is opened to the point where the air mass begins to fall.
- The throttle has just gone beyond wide open throttle.
- The wide open throttle point is just before the air mass began to fall.

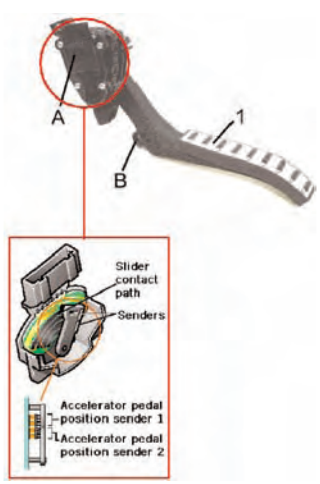
Accelerator Pedal Module



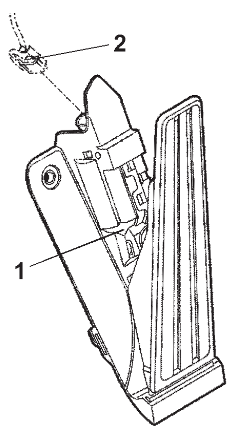
911 Carrera (996) & Boxster (986) Pedal Assembly.

911 Carrera (996) and Boxster (986) retained the accelerator pedal assembly and connected it to the accelerator pedal module with a cable.

Cayenne, 911 Carrera (997) and new Boxster (987) have a combined unit with the pedal and the pedal module combined. **The accelerator pedal position sensor modules are not serviceable and should not be disassembled or repaired if defective they must be replaced.**

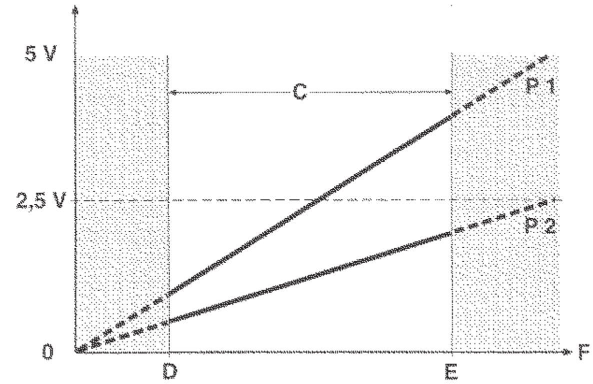


Cayenne Pedal Assembly.



1- Accelerator pedal unit with intregal potentiometers 1 and 2.
2- Electrical connection.

911 Carrera (997) & Boxster (987) Pedal Assembly.



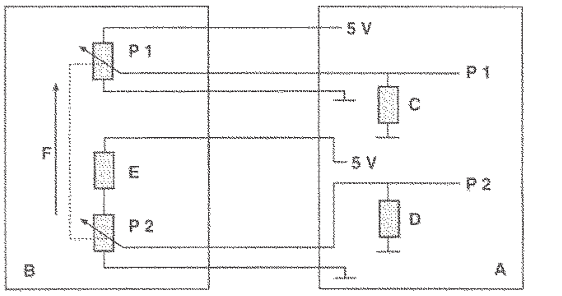
The graph above has accelerator pedal position across the bottom and voltage rising on the vertical. Several observations can be made from this graph:

- You can see that the potentiometer voltages rise as the throttle is opened.
- The voltage of potentiometer 1 (P1) is twice the voltage of potentiometer 2 (P2).
- The potentiometers have a larger measuring range than the mechanical movement range C of the throttle plate.

This is why the gray area below idle D and above full throttle E are shown. The voltages in these areas are not possible (they are mechanically inaccessible). If a voltage in these ranges is sent to the engine management control unit, a defect in the pedal position sensor is detected and a fault is indicated.

E-Throttle

The circuits below are for the two position sensors in the throttle pedal.



There are several important points to note about these circuits:

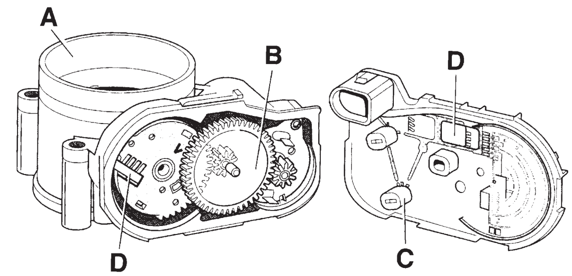
- The two potentiometers P1 and P2 are electrically isolated (there is no connection between the two circuits).
- The engine management control unit has two parallel processors for E-Throttle that cross check each other to guarantee no malfunction will cause defective operation of the system.
- The resistor at E has a resistance equal to the resistance of the potentiometer P2, this causes the resistor E to drop 2.5 volts.
- This leaves P2 to operate at half the applied 5 volts or 2.5 volts.
- P1 operates with a range of .5 volts to 4.5 volts.
- P2 operates with a range of .25 volts to 2.25 volts.

The maximum voltage that P2 can drop is only half that of P1. Stated another way, P1 will drop twice the voltage of P2 for a given pedal position.

The Boxster (987) and 911 Carrera (997) use a non-contact inductive sensor in the pedal assembly in place of the potentiometer.

Throttle Valve Control Unit

The throttle valve control units used on Porsche vehicles are all of the same design. They differ only in the amount of air they are designed to flow. The throttle valve control unit consists of four main components.

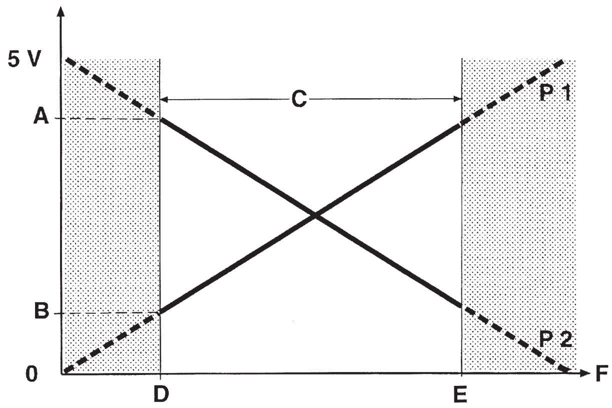


A - Throttle housing with throttle valve
B - Throttle valve drive unit
C - Cover with motor connectors
D - Potentiometer circuit in cover

The pedal assembly and throttle valve control module are not serviceable and should not be opened. If defective, they must be replaced.

The following steps outline throttle valve control unit operation:

- The electric motor of the throttle valve control unit receives a PWM current from the engine management control unit.
- This causes the motor to act against one of the two springs in the throttle housing.
- When there is no power supplied to the motor, the throttle valve will park between the two springs in the alternative air position.
- To move the throttle plate in either direction towards close or open, the motor must act against one of these two springs.
- When the throttle is moved from full closed to full open the motor must change polarity at the alternative air position.
- The spring below the alternative position helps move the throttle in the open direction and the motor slows movement.
- After the alternative air position, the motor must work against the upper spring.
- The potentiometers in the cover of the throttle valve control unit feed back the position of the throttle valve to the engine management control unit.

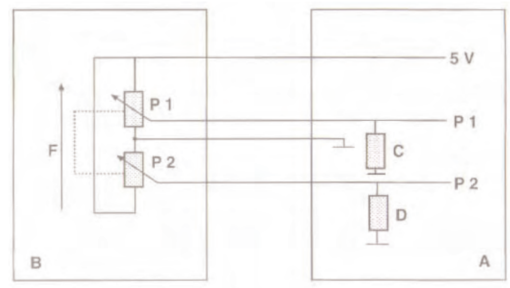


The voltage graph above is similar to the previous graph for the accelerator pedal module. On the horizontal axis is movement of the throttle valve. On the vertical is the voltage of the potentiometers.

- The voltage of potentiometer 1 rises as the throttle plate opens.
- The voltage of potentiometer 2 falls as the throttle plate opens.
- At half throttle the voltages are equal.

As with the pedal position sensor, the mechanical operation range is C and voltages below D or above E are used for fault detection.

- Potentiometer 1 is used as the operating input potentiometer.
- Potentiometer 2 is used to check that potentiometer 1 is operating correctly.
- The air mass is also used to cross check the throttle position potentiometers (virtual potentiometer 3).



In the throttle adjusting unit circuit diagram above, you see that the potentiometers are one circuit (they share a single 5V reference). You can use air mass and engine rpm as indicators of throttle position. As a result, it isn't necessary to build in the same level of redundancy that you see in the pedal position circuit.

If the throttle position potentiometers are defective, you can look at air mass and RPM and see that the indicated throttle position and the air mass and RPM are not rational (i.e. for a given air mass and RPM, we are seeing a throttle position that is not possible).

You can also see how the circuit is set up to give us P1 rising and P2 falling as the throttle opens.

- The bottom of P1 is connected to ground and the top of P2 is connected to ground.
- Conversely, the top of P1 and bottom of P2 are connected to the 5-volt reference.

This gives us potentiometers with opposite voltage characteristics.

There are also clamping resistors at C and D. These serve two purposes:

1. To protect the evaluation circuit (analog to digital converter etc…) from over voltages.
2. To clamp the line voltage to a set value when an open circuit occurs.

The voltage is clamped to diagnose opens in the potentiometer lines. The resistor will pull the voltage coming out of the evaluation circuit to a set value. (the voltage being dropped by the resistor isn't changing) The diagnostic program will recognize a fault when it sees the potentiometer signal line go to this value and remain there.

Emergency Operation and Monitoring

The accelerator pedal position sensor, and the throttle valve control module; are continuously monitored by the engine control unit for electrical defects and plausibility.

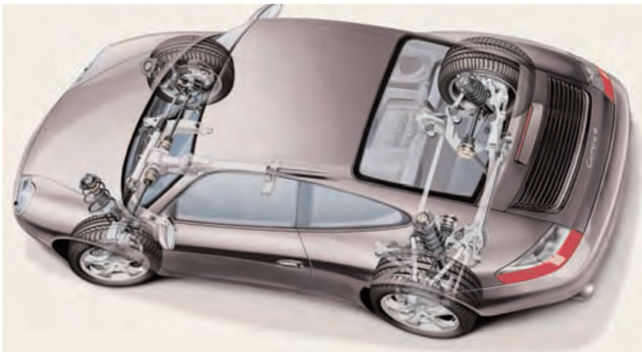
If a defect is detected, operation in a limited mode will be initiated. Some defects, for example; a total failure of both potentiometers in the pedal position sensor will render the vehicle inoperative. The same would be true of both potentiometers in the throttle valve control module.

The system cannot operate if the position of the accelerator pedal or the throttle plate cannot be determined. The emergency mode operational details are described in the following system description section.


S MU 5766

Notes:

E-Throttle 7.2



General

The model year 1999 911 Carrera 4 (996) was the first Porsche equipped with Motronic (DME) ME 7.2. This Motronic possessed the same functions as the Motronic M 5.2.2 used in the 1999 911 Carrera (996).

The following DME 7.2 information was first published in the 1999 911 Carrera 4 (996) Service Information Technik book.

The principal differences concerned the actuation of the throttle (a throttle adjusting valve instead of a throttle cable - E-Throttle*) and a torque-oriented control unit for charging the engine with the appropriate quantity of fresh gas. This meant that both mechanical movement of the accelerator pedal (throttle cable) and components such as idling speed positioners and cruise control actuators were no longer required.

In addition, other functions such as PSM (Porsche Stability Management), torque reduction with TC or Tiptronic operations, torque increase with air conditioning or rapid heating of the exhaust system (catalytic converter) could be easily realized to reduce pollutant emissions. Of course, the ME 7.2 was also fully diagnosable. The diagnosis software required for this was provided by the Porsche System Tester 2, with update 4.0. The modifications to the diagnosis system of the control unit and the diagnosis possibilities are described in the Technical Manual.

* E-Throttle = Electrically actuated throttle

The main functions of the Motronic ME 7.2 were:

- Torque-oriented function structure.
- Engine charging determination and engine charging control.
- Sequential, cylinder-specific fuel injection.
- Direct ignition with cylinder-specific knock control
- Adaptive stereo A/F control.
- Rapid heating of catalytic converters after cold start.
- Trimetal catalytic converter for the German and US markets.
- Load-dependent tank ventilation.
- Idle-charge compensation via throttle adjusting unit.
- Detection of misfiring which may cause damage to catalytic converter, and actuation of check-engine warning light.
- Precise monitoring of all Motronic functions plus entry in fault memory.
- Activation of VarioCam valves.
- Actuation of resonance flap integrated in intake system.

USA Vehicles

The differences compared to the engine management system for vehicles for the RoW and German markets were as follows:

- A Hall-effect sensor also mounted to the intake camshaft of cylinder bank 4 - 6
- Additional oxygen sensors attached downstream of each catalytic converter. They permanently monitor the efficiency of the catalytic converters
- A secondary air system installed to reduce pollutant emissions as the engine warms up
- An active carbon canister divided into two individual chambers. The carbon canister is needed to satisfy the US shed test
- A shut-off valve for each scavenging air pipe and a pressure sensor to determine the fuel tank pressure and fuel tank vacuum for the obligatory fuel tank leak test

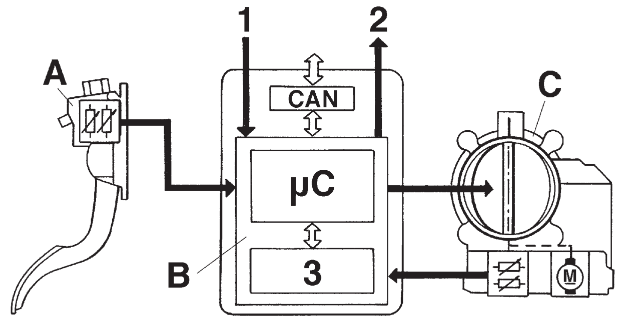
The differences were:

- Torque-oriented function structure of the Motronic control unit based on physical variables.
- Modified Motronic control unit with integrated pressure sensor, monitoring module, and new plug generation.
- Accelerator pedal module with pedal valuator.
- Throttle adjusting unit with electric drive motor instead of the purely mechanical throttle.
- Additional functions such as idle air control, vehicle speed control, or rapid heating of the catalytic converter provided by the Motronic.
- Trimetal catalytic converter for vehicles in Germany and the USA.

Torque-oriented Function Structure

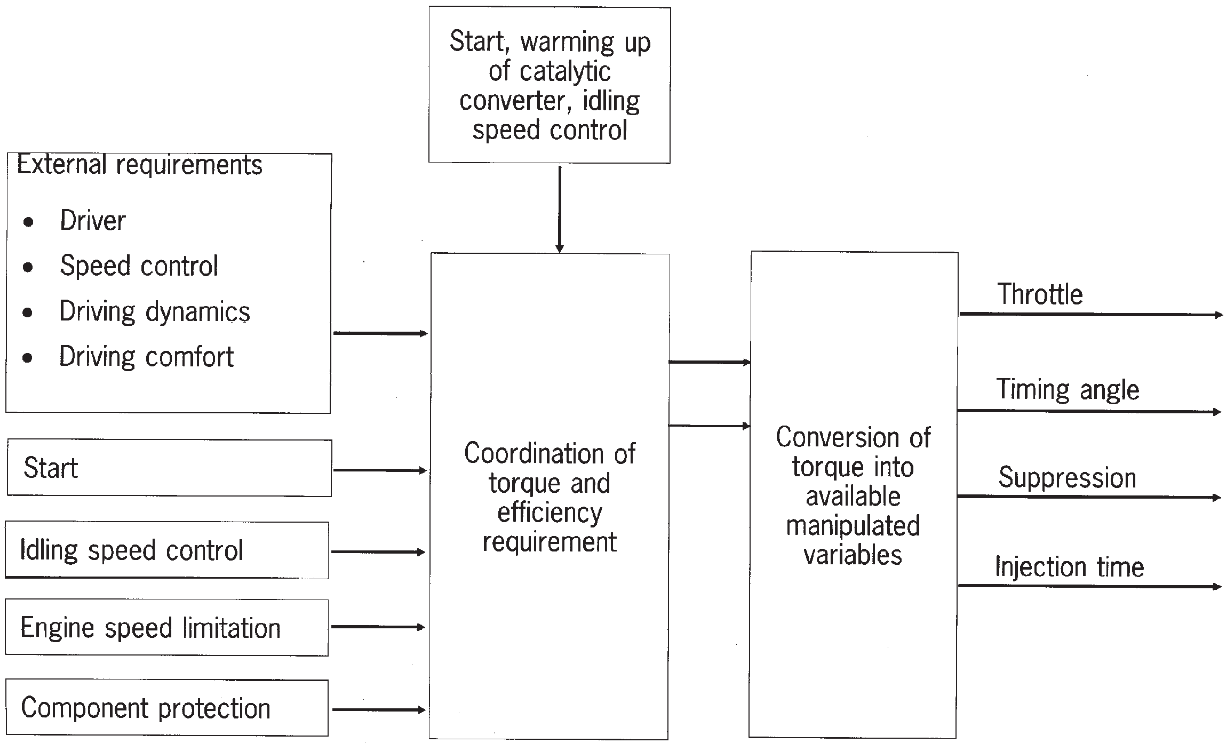
The ME 7.2 has a new system architecture with the following characteristics:

- The implementation of physical functions. This means that both the variables of an individual function (e.g. the determination of cylinder charging) and the interfaces between the function and function groups are defined as physical variables.
- Another feature is the introduction of torque control: many subsystems within the Motronic such as idling speed control or engine speed limitation as well as the systems for drive and overall vehicle control (Tiptronic, Porsche Stability Management, and so on) each place demands on the basic Motronic system. In the past, these intervention actions were defined and regulated independently from each other on the basis of the available manipulated variables such as cylinder charging, timing angle, and fuel mass. Since these intervention actions can be described as physical and defined as a torque-related requirement, the ME 7.2 constitutes a torque-guided system, which coordinates the above-mentioned requirements as well as the resulting nominal torque incorporating the available manipulated variables for throttle valve and timing angle.
- An oxygen sensing coordination function which coordinates the intervention actions vis-á-vis the fuel/air mixture (enrichment or enleanment of the air/fuel mixture by means of various functions) in a similar way completes the new system architecture.



E-Throttle 7.2 Components

A - Accelerator pedal module.
B - Motronic control unit.
C - Throttle adjusting unit connected to Motronic control unit.
1 - Information to Motronic control unit.
2 - Actuators.
3 - Monitoring Module.

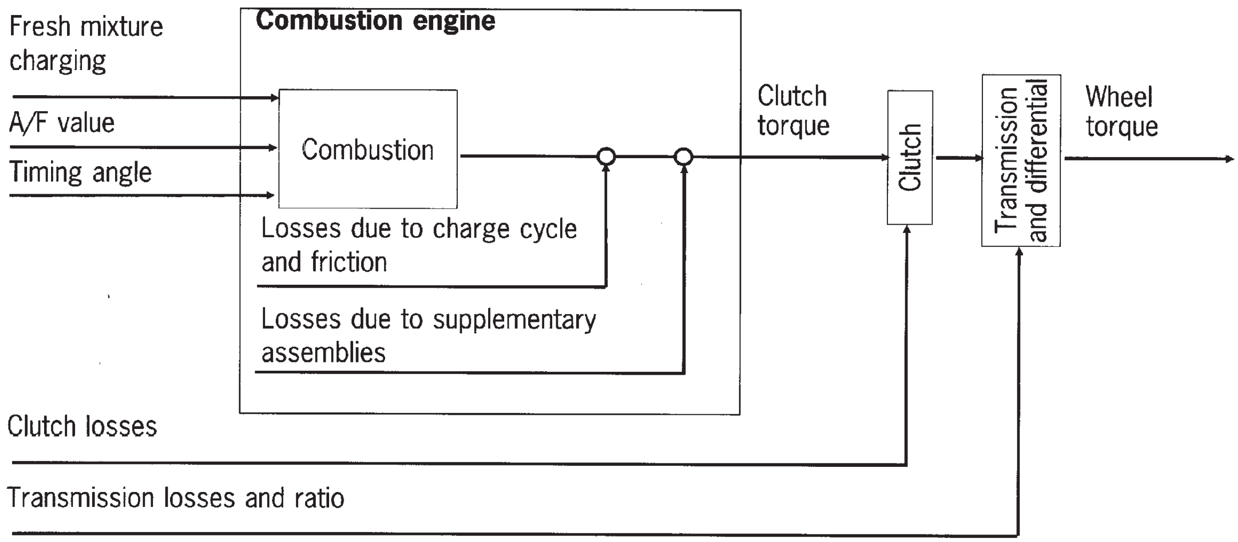


The Principle Behind Torque Guidance

The output engine torque must allow any driving condition desired by the driver (determined via the pedal valuator) and ensure operation of all components and supplementary assemblies. In addition, external requirements from the drive train and driving dynamics control systems must also be met. The basic concept of the ME 7.2 system is based on the coordination of these requirements placed on the engine on a uniform, physical level. All of this can be formulated as a torque requirement.

The current torque requirement of the driver is determined from the position of the accelerator pedal (pedal valuator). Vehicle speed control, driving dynamics control (PSM), and the Tiptronic control unit can communicate their torque requirement to the Motronic control unit in the same way. However, protective functions such as electronic engine speed control and catalyst overheating prevention can be defined such that they limit the maximum permitted torque. The engine control module with E-Throttle has the task of coordinating the different torque requirements of the individual consumers and protective functions in order to determine the required control activities for the engine whereby the timing angle and throttle position are provided as the main manipulated variables.

The advantage of this approach is that the individual power consumers can pass on their torque requirement to the "coordinator" integrated in the control unit regardless of the current operating state of the engine. They do not need to carry out the actual intervention action, nor do they require any information concerning the status of other functions. This rules out any mutual interference between the individual functions with regard to the manipulated variables. Since torque coordination is the only instance where intervention actions are performed in the engine, the maps and characteristics for the key functions necessary for intervention are solely dependent on the engine. For this reason, no cross-coupling exists between the individual function groups, which simplifies the synchronization to the new control unit generation.



Basic Structure of Torque Guidance

The basic variable for the torque structure of the ME 7.2 is the inner torque of the engine (mi) resulting from the combustion process. The inner torque is that which is produced by the gas pressure in the high-pressure phase of the piston movement cycle. If losses due to friction and the charge cycle are deducted from the inner torque, this gives the indexed torque.

The task of torque guidance is to adjust the inner torque using a suitable selection of manipulated engine variables such that all losses caused by supplementary assemblies, friction losses, and other losses upstream of the wheel torque are covered and that the engine torque is sufficient to meet the driverís requirements.

To enable the inner torque to be adjusted, the torque coordinator of the ME 7.2 has two possible control options, a fast option by means of varying the timing angle and/or suppressing individual cylinders, and a slow option by means of actuating the throttle. The faster option is the timing angle option which is responsible for dynamic torque adjustment. The slow option, also referred to as the charging option, is responsible for stationary operation with optimum A/F value. To generate the nominal torque, the manipulated variables are coordinated taking into consideration consumption and emission values so that optimum control is possible.

Option 1 (fast option)

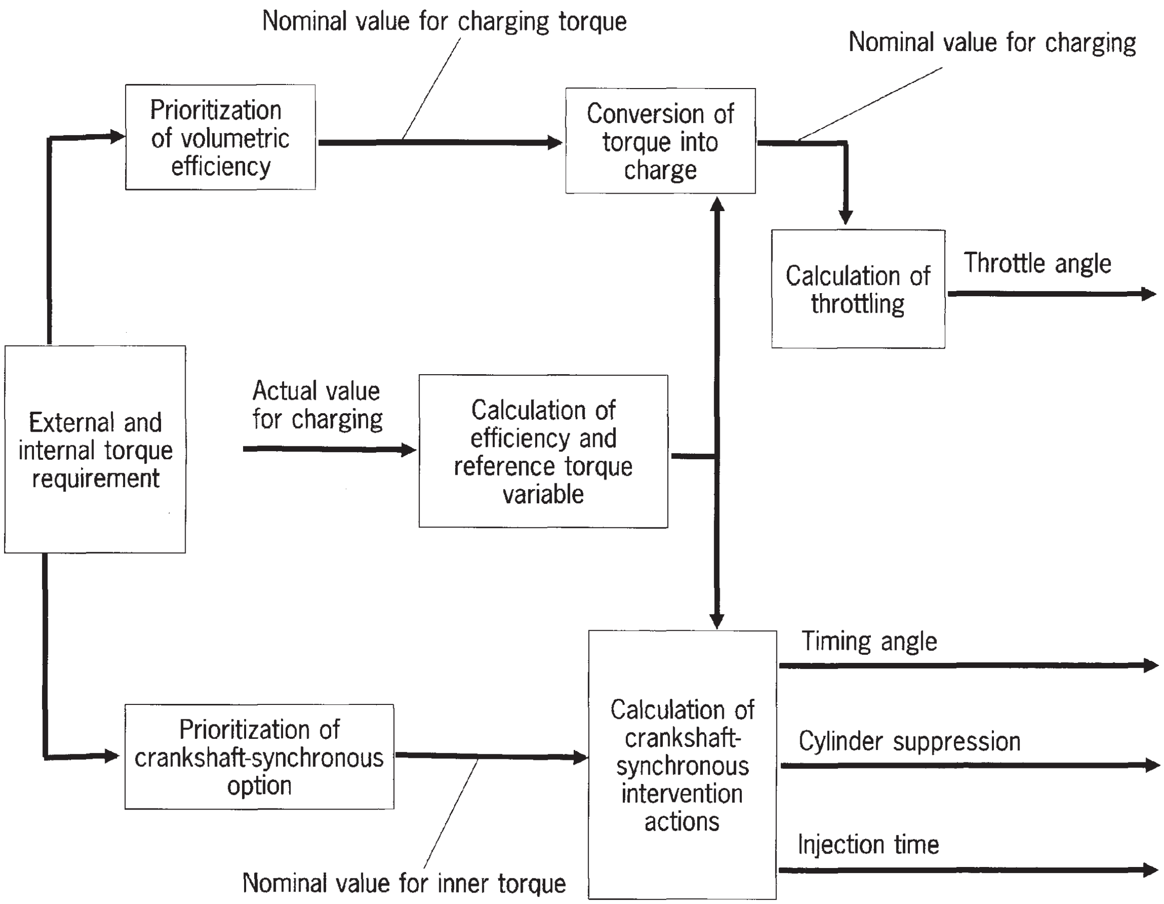
All manipulative actions which influence the torque regardless of charging are contained in the crankshaft synchronous option:

- Timing angle.
- Cylinder suppression.
- Injection time.

Option 2 (slow option)

The charging option controls those manipulated variables which influence charging:

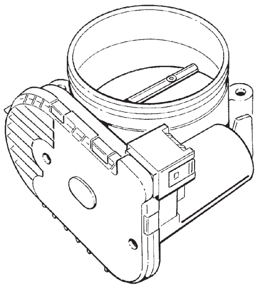
- Throttle angle and, therefore, the quantity of air drawn in by the engine.



The mass air flow required for a certain torque (r_L = relative air charge) is determined using an arithmetic model and provided via the throttle.

The fuel volume required for the given situation and the optimum timing angle are realized via Option 2.

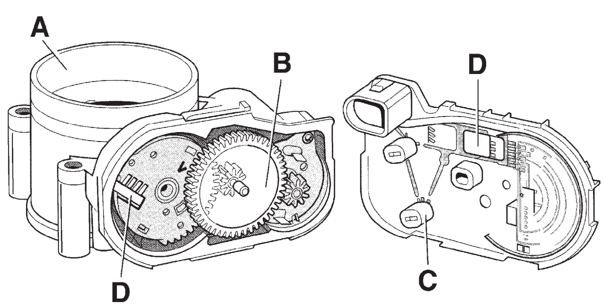
Throttle Adjusting Unit



The throttle adjusting unit comprises:

- Throttle body with throttle valve.
- Throttle drive with transmission.
- Angle sensor for throttle drive.

The throttle drive (B) is actuated by the Motronic control unit and regulates the rate of air flow necessary to fulfill the torque requirements. Feedback with regard to the current throttle position is provided by two potentiometers which serve as angle sensors (D). For safety reasons, 2 angle sensors whose resistance characteristics oppose each other are used. If an angle sensor fails, the remaining sensor takes over to ensure that the E-throttle continues to function normally.

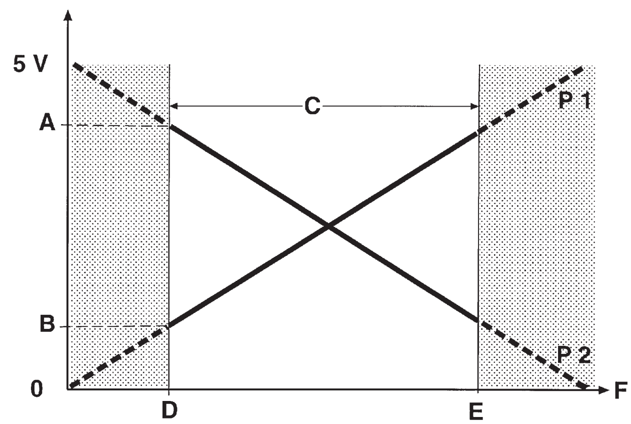


A - Throttle body with throttle valve.
B - Throttle drive.
C - Body cover with electrical connections.
D - Angle sensor for throttle drive.

Note: The throttle adjusting unit must not be opened.

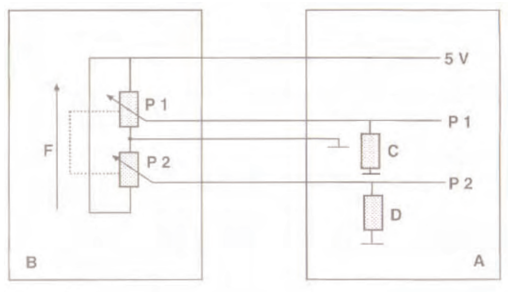
The Principle Behind Throttle Angle Determination

- The throttle position is determined via 2 potentiometers which are supplied with 5 V by the control unit.
- In contrast to Potentiometer 1, Potentiometer 2 has a falling characteristic curve to allow detection of short-circuits along the signal lines.
- If a signal line is interrupted, the control unit resistor adjusts an appropriate signal to a defined level which means “Throttle fully open”. This causes the throttle to be moved to its “closed” position (safety function).



A - Programmed lower mechanical stop, Potentiometer 2
B - Programmed lower mechanical stop, Potentiometer 1
C - Mechanical accessible area
D - Lower mechanical stop
E - Upper mechanical stop
F - Throttle position
P1 - Potentiometer 1
P2 - Potentiometer 2

Electrical Circuit of Throttle Adjusting Unit

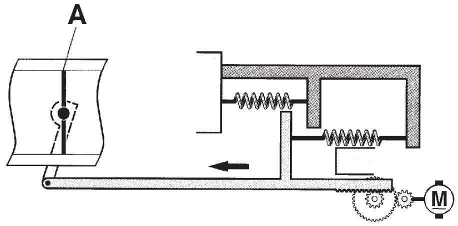


P1 - Potentiometer 1
A - Control unit
C - Pull-down resistor
P2 - Potentiometer 2
B - Throttle adjusting unit
D - Pull-down resistor

Functional Positions of Throttle Adjusting Unit

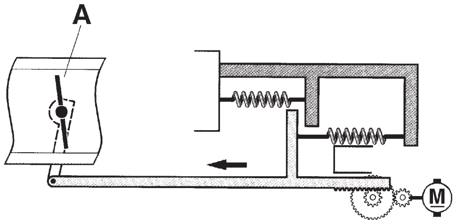
The Motronic control unit detects four important functional positions of the throttle adjusting unit:

1. **The lower mechanical stop.**
   The throttle is closed. This position is required for adaptation of the angle sensors.



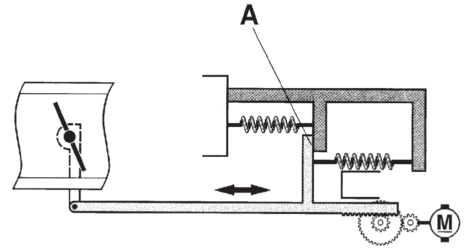
A - Lower Mechanical Stop

2. **The lower electrical stop.**
   This stop is determined by the control unit and is just above the lower mechanical stop. Under operating conditions, the throttle can remain closed only until the lower electrical stop is reached. This prevents the throttle from "jamming" in the throttle body.



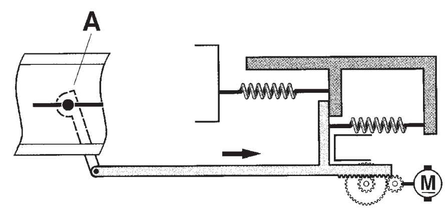
A - Lower Electrical Stop

3. **The alternative air function.**
   The throttle assumes this position when in its de-energized state. It produces an alternative airflow via a "mechanical" air gap whereby normal driving with increased idling speed is very restricted.



A - Alternative Air Function

4. **The upper electrical stop.**
   This stop is determined by the control unit and does not need to be adapted (learned). To ensure that the precise angle position of the throttle can be determined, the angle sensors of the throttle drive must be adapted.



A - Upper Electrical Stop

Range Test For Angle Sensors

- Mechanically inaccessible voltage ranges (see diagram on page 6.8) are used to detect short-circuits and wire breaks.
- The range test for the master potentiometer (under normal operating conditions, Potentiometer 1) is continuously active in an upward and downward direction.
- Due to the closed position control loop, corruption of the signal from the master potentiometer caused by contact resistance results in a throttle movement which compensates the contact resistance.
- The range test in the upward direction for Potentiometer 2 is continuously active under normal operating conditions.
- Due to possible contact resistance, under normal operating conditions the range test in the downward direction for Potentiometer 2 is only active outside the idling range (test as per engine speed criterion).
- A fault at one of the potentiometers triggers back-up throttle operation whereby the remaining potentiometer is monitored with the charging signal.
- A fault at both potentiometers triggers the safety shutdown function of the injection valves (engine switches off) since the position of the throttle is unknown.

Synchro Test For Throttle Sensors

- Both potentiometer signals are converted to appropriate throttle angles taking into consideration the adaptation values at the lower mechanical stop.
- Due to the mechanical coupling, the difference between the two throttle angle sensors lies within a programmable tolerance.
- Due to possible contact resistance, the synchro test is only carried out outside the idling range.
- If a fault is detected, the faulty potentiometer is determined using the charge signal. Back-up throttle operation with the correctly functioning potentiometer is initiated.

Diagnosis of Throttle Adjusting Unit

Functional test before each engine start:

- Testing of closing spring.
- Testing of opening spring.
- Testing of alternative air position.

Adaptive functions which are only carried out under certain conditions:

- Adaptation of throttle actuator by programming the lower mechanical stop and the alternative air position.
- Adjustment of signal amplifier.

The conditions for adaptation of the throttle adjusting unit are:

1. Adaptation is necessary if the control unit or the throttle adjusting unit has been exchanged (these conditions are recognized automatically by the control unit or can be activated using the Porsche System Tester 2).
2. Adaptation may be carried out if the ignition has been left switched on for a long time without the engine being started.

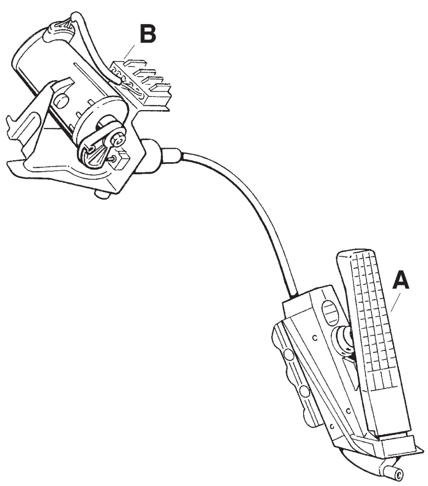
Functional test while the vehicle is being driven.

- The position of the throttle is monitored.
- The setting ranges of the throttle are monitored.
- The output modules of the throttle adjusting unit are monitored.
- The vehicle voltage is tested continually.

Accelerator Pedal Position

For the Motronic control unit, the accelerator pedal position is the fundamental input information reflecting the driverís power requirements. For this purpose, a pedal valuator which is connected to the accelerator pedal via a cable is mounted under the knee protection bar in the driverís footwell.

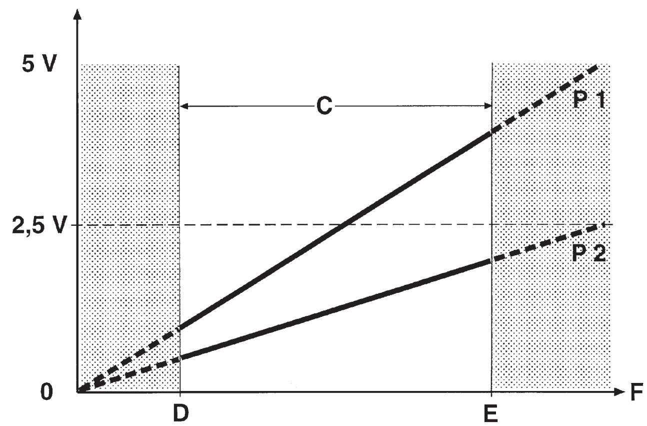
Accelerator pedal positions which are interpreted as being larger than they are in reality would lead to undesired and excessive engine power which would not be recognized at another point in the system. For this reason, determination of the driverís requirement is central in calculating the torque and controlling the electronic throttle.



A - Accelerator
B - Pedal valuator

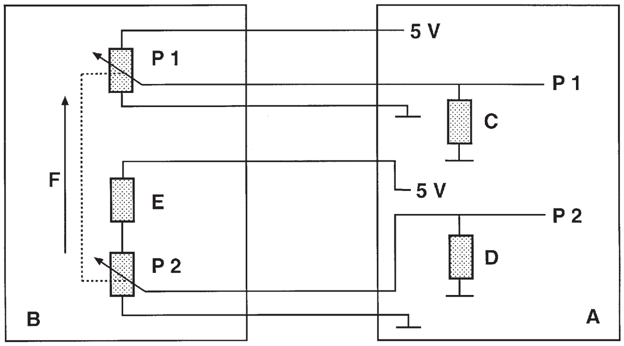
Determination of The Accelerator Pedal Position

- The accelerator pedal position is determined using 2 potentiometers which are each independently supplied with 5 V by the Motronic control unit.
- Potentiometer 2 has a balanced ballast resistor which is identical to the bulk resistance. Consequently, its characteristic ascent is only half that of Potentiometer 1 (important in the diagnosis of short-circuits along the potentiometer signal lines).
- If a wire-break occurs along a signal line, the appropriate signal is connected to ground by the appropriate control unit input resistor (safe condition).



P1 - Potentiometer 1
P2 - Potentiometer 2
C - Mechanically accessible range
D - Idling position
E - Full-throttle position
F - Accelerator pedal position

Electric Circuit Of Pedal Valuator



P1 - Potentiometer 1
P2 - Potentiometer 2
A - Control unit
B - Throttle adjusting unit
C - Pull-down resistor
D - Pull-down resistor
E - Ballast resistor

Range Test For Pedal Valuator Sensors

- Mechanically inaccessible voltage ranges are used for detecting short-circuits and wire-breaks.
- The upward range test is continuously active.
- Due to possible contact resistance, the downward range test is only active outside the pedal idling range.
- A fault at one potentiometer triggers back-up operation with the other potentiometer to be triggered.
- A fault at both potentiometers leads to fulfillment of the alternative air requirement.

Synchro Test For Pedal Valuator Sensors

- Before being compared with the signal from Potentiometer 1, the signal from Potentiometer 2 must be multiplied by 2 since its characteristic ascent is half that for Potentiometer 1.
- Due to the mechanical coupling, the difference between the signal from Potentiometer 1 and the doubled signals from Potentiometer 2 must lie within the programmed tolerance.
- Due to possible contact resistance, the synchro test is only active outside the pedal idling range.
- A detected fault triggers back-up operation with the two potentiometer signals at their minimum value.

Alternative Measures In Back-up Pedal Valuator Operation

If one potentiometer fails, the accelerator pedal position for back - up operation is calculated using the signal from the remaining potentiometer. However, this results in restricted monitoring of the pedal valuator and the system.

The maximum pedal value is therefore limited to 40% (maximum limitation) and the pedal value increases by only 10% per second (rise limitation). If the brake is actuated, the pedal value equals zero (idling setpoint).

Self-diagnosis And Back-up Function

The ME 7.2 with electronic accelerator pedal is a safety-related system. Possible faults must be detected automatically by the system. Incoming information relating to the status of the engine or the driver's demands with regard to power is fed to the control unit by means of a double sensor system.

The CPU of the control unit comprises two independent hardware components which continuously monitor one another mutually during operation to ensure that the system is functioning correctly. If a malfunction in the partner module is detected, the output module of components in the control unit which determine power output (throttle, injection valve) can be deactivated independently by the functional computer and monitoring module or limited to a defined value.

Example 1

If an angle sensor for the throttle drive occurs or in the case of an implausible signal:

- Intervention actions which increase torque, such as engine drag torque control or Tiptronic functions, are suppressed.

Requirement:

An intact angle sensor and plausible air mass flow. The air mass flow is derived from the signal from the air mass sensor and the engine speed.

Example 2

If the throttle adjusting unit fails or has a control error:

- The throttle drive is deactivated. The throttle assumes its alternative air function. It is possible to continue operating the engine with an increased idling speed. The driver's requirements are as far as possible realized by adjusting the timing angle only. The engine throttles up only slightly.

Requirement:

The alternative air function is only performed if both throttle angle sensors were reliably detected at their alternative air position.

Example 3

The Motronic control unit cannot clearly determine the throttle position or the throttle is jammed between the electrical stops (does not move):

- The throttle drive is deactivated. If possible, the throttle is moved to its alternative air position.
- The injection valves are deactivated at a programmed engine speed (approx. 1200 rpm).

Important!
The throttle adjusting unit must not undergo any repair work. If the throttle adjusting unit is faulty, the complete unit must be changed.

Example 4

The signal from one of the two potentiometers of the pedal valuator has failed:

- Pedal value is limited to a defined value (approx. 60%).
- If the accelerator pedal is actuated quickly, the engine torque only increases slowly (up to 60%).
- If the brakes are applied, the throttle is moved to the idling position.
- Cruise control no longer operational.

Note:
In the idling position, the potentiometers of the pedal valuator are not tested. If, for example, the electrical connection at the pedal valuator is interrupted, nothing is stored in the fault memory of the control unit. However, the engine then only runs at idling speed since, when the accelerator pedal is actuated, the change with regard to the driver's requirement is not detected.

Example 5

Both potentiometers of the pedal valuator have failed:

- The engine only runs at idling speed and a fault entry is made in the control unit.

Driving Speed Control (cruise control)

The basic functions of the cruise control system (set, resume, and so on) as well as the cruise control switch and its functions are identical to the 911 Carrera (996) and Boxster models.

However, due to the E-Throttle function of the Motronic ME 7.2, an additional control unit and actuator is not required for the cruise control system since these functions are taken over by the Motronic control unit and the throttle adjusting unit.

The required information is stored in the Motronic control unit:

- Main cruise control switch.
- Set current vehicle speed (cruise control lever).
- Accelerate (cruise control lever).
- Decelerate (cruise control lever).
- Resume (cruise control lever).
- Gradual increase of nominal speed (cruise control lever).

E-Throttle 7.8

General

The model year 2001 911 Turbo (996) was equipped with the ME 7.8 Motronic engine management system. ME 7.8 functions virtually the same as its ME 7.2 predecessor with the exception of some additional and modified functions.

The following DME 7.8 information was first published in the 2001 911 Turbo (996) Service Information Technik book.

The ME 7.2 and 7.8 features:

- Hot-film air mass measurement
- Individual ignition coils for each cylinder with solid-state HT distribution
- Sequential fuel injection
- Electronic idle-speed control
- Throttle control via E-Throttle function
- Closed fuel tank system
- Stereo oxygen sensor control

Additional or modified sensors and functions of ME 7.8:

- Wide-band oxygen sensors (LSU4) upstream of catalytic converters
- Modified Hall sensor signal (Camshaft Position)
- Boost pressure sensor with integrated intake air temperature sensor
- VarioCam Plus control
- Electric boost pressure timing valve
- Electric solenoid valve for overrun air recirculation valve control
- Control of three-speed radiator cooling fan
- Control of two-speed engine compartment scavenging blower
- On-board diagnosis
- Data interface to instrument cluster (data transmitted via CAN*****)

***** CAN = Controller Area Network. Communication with the PSM control module and Tiptronic control module (if fitted) is also via the CAN interface. This permits bi-directional data exchange between the connected control modules.

E-Throttle

As with ME 7.2, the throttle valve is controlled by an electric motor via a two-stage gear on the throttle valve. A mechanical throttle cable is no longer used. The volume of air drawn in by the engine is controlled electronically across the entire load and engine speed range via the ME 7.8 Engine Control Module (ECM).

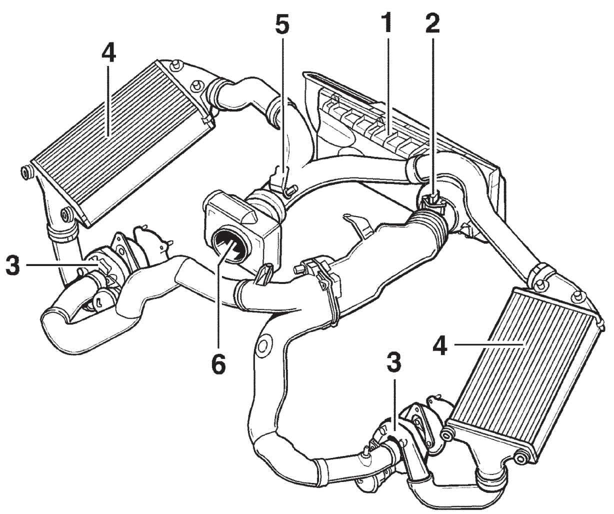
The advantages of the E-Throttle system are:

- Improved driveability
- Natural integration with PSM
- Improved cruise control function
- Reduced engine emissions

To reduce exhaust emissions during the warm-up phase, the catalytic converter is heated to its operating temperature quickly by modifying the ignition timing (retard direction). The associated reductions in torque from this can be compensated for with the E-Throttle. Engine speed limiting via the E-Throttle and the possibility to suppress the injection signal reduces emissions and the thermal load placed on the catalytic converter.

Air Ducting

Intake air flows through the air filter (1) and air mass sensor (2). The air flow is then split into two and drawn in by the two turbocharger compressors (3). The air that has been compressed and heated by the turbochargers is then cooled through the two intercoolers (4). The intercoolers are mounted behind the left and right rear wheels. The two flows of compressed air merge again upstream of the throttle valve control unit. The air is then distributed to the individual cylinders by the intake manifold.



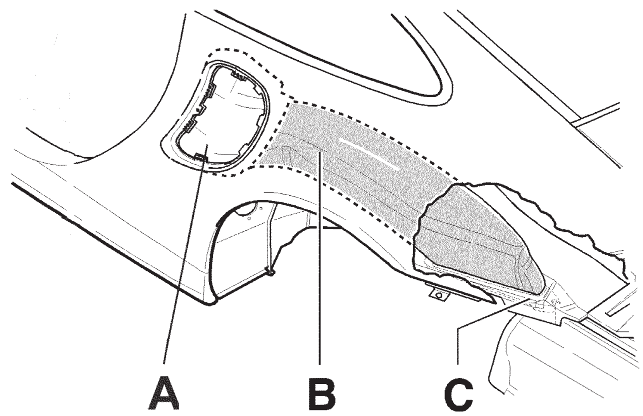
Intake Air Duct Layout

1 - Air Filter Housing
2 - Hot-Film Air Mass Sensor
3 - Turbocharger
4 - Intercooler (Charge-air radiator)
5 - Pressure Temperature Sensor
6 - Throttle Valve Adjustment Unit

Ducting Of Cooling Air To Intercoolers

Advantages of intercooling:

- Cooled air has a higher density; thus improving volumetric efficiency.
- Lowers the air temperature, reduces the temperature of components, and reduces the possibility of pre-ignition (pinging).

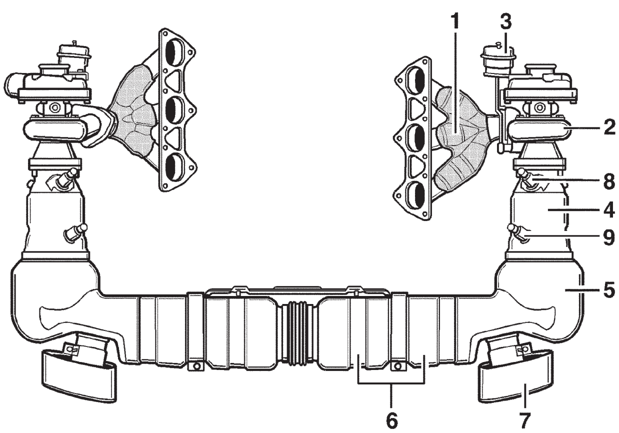


Ram Air Supply to Intercoolers

A - Air inlet
B - Air Duct
C - Intercooler (Charge-air radiator)

Exhaust System

The exhaust system up to the rear silencers (6) consists of separate left and right exhaust system branches. The exhaust gases are merged and mixed in the rear silencer, with one tailpipe (7) per exhaust system branch. The exhaust gases are fed to the turbochargers (2) via partially air-gap-insulated exhaust manifolds. The exhaust manifolds (1) have extremely short pipe lengths to reduce the energy lost by the exhaust gases before reaching the turbochargers. The short pipes also allow the catalytic converters to heat up quickly.

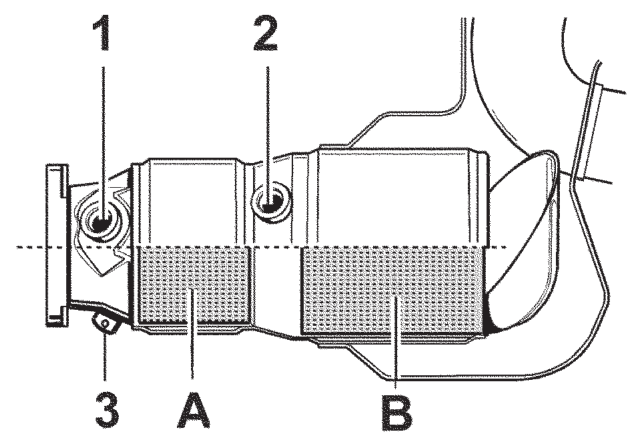


Exhaust System Layout

1 - Partially Insulated (Air Gap) Exhaust System
2 - Turbocharger
3 - Boost Pressure Control Valve
4 - Primary Catalyic Converter
5 - Main Catalytic Converter
6 - Rear Muffler
7 - Exhaust Tailpipe
8 - Wide-band Oxygen Sensor LSU4
9 - Offset Oxygen Sensor LSF4

Catalytic Converters

The engine-compartment catalytic converters are mounted immediately downstream of the turbochargers. The first catalytic converter (primary catalytic converter) with its small volume reaches operating temperature very soon after the engine has been started. As a result, the volume of pollutants is reduced during the warm-up phase as well as when the engine has reached operating temperature. The main catalytic converter is used to reduce the exhaust-emission level further to below the specified emission limits, even after a long service life. The new 911 Turbo is classified as an LEV (Low Emission Vehicle) in the USA.



Catalytic Converter Construction

A - Primary Catalytic Converter
B - Main Catalytic Converter
1 - Position of Wide-band Oxygen Sensor (LSU4)
2 - Position of Offset Oxygen Sensor (LSF4)
3 - Exhaust Gas Sampling Point Upstream of Catalytic Converter

Turbocharging

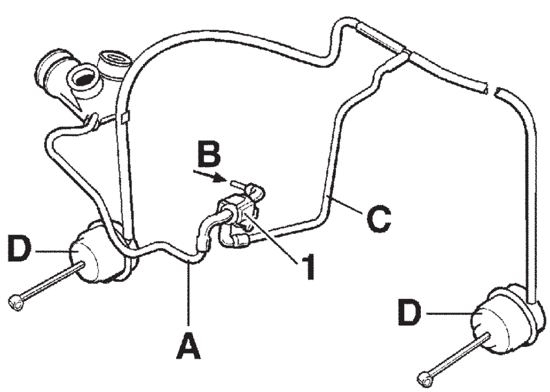
As with the previous model, the turbochargers of the new 911 Turbo (996) are installed parallel to each other. The small diameter of the intake ducting and the short exhaust manifolds ensure immediate turbocharger response in the lower speed range as well as high torque under full-load conditions.

The speed of the turbochargers with the engine idling is approx. 8,000 rpm, and approx. 125,000 rpm at full load. The control system limits the maximum speed to approx. 150,000 rpm at altitudes above 2,000 meters (fatigue limit).

The flanges of the turbochargers have been modified compared to those of the earlier 911 Turbo (993).

Boost Pressure Control

The ME 7.8 ECM controls the boost pressure timing valve (1) to regulate the opening pressure of the boost pressure control valves. The boost pressure control valves (D) are connected to the turbocharger bypass valves (wastegates) via control rods. The signal to the timing valve is pulse-width-modulated (PWM) for accurate control of the boost pressure.



Turbocharger Boost Control System Layout

1 - Boost Pressure Timing Valve
A - Induction Side (vacuum)
B - Pressure Side Upstream of Throttle Adjuster
C - Control Side (timed)
D - Boost Pressure Control Valve (wastegate control)

The desired engine torque is calculated by the ME 7.8 ECM based on the accelerator pedal potentiometer input (driver requirement), the engine speed input, and a number of other factors. The intake air volume required for a certain torque is determined by calculating the air-mass and is adjusted by controlling the boost pressure. With the new Turbo, it is the boost pressure that is regulated, and not the air mass (as was the case of the 911 Turbo 993).

The boost pressure is regulated based on the absolute pressure “reference variable.” This reference variable is measured by the boost pressure sensor. Behavior according to altitude and temperature is similar to the air mass based system of the previous Turbo model.

The combination of the boost pressure sensor, airmass sensor and E-Throttle improve torque considerably. Boost pressure diagnosis is also more accurate since the effective boost pressure is an input signal to the ME 7.8 ECM.

Boost Pressure Adaptation

The 911 Turbo (996) features adaptive boost pressure control. For diagnostic purposes, the adaptive boost pressure control correction value can be read out of the ECM memory using the Porsche System Tester 2 and now with the PIWIS Tester. The adaptation range for boost pressure control is approx. ± 15%. Regulation begins at a deviation of greater than ± 30%. The opening frequency (duty cycle factor) of the boost pressure timing valve depends on the amount of boost required. Full boost pressure is available from a speed of approx. 2,500 rpm. The boost pressure is regulated at higher speeds.

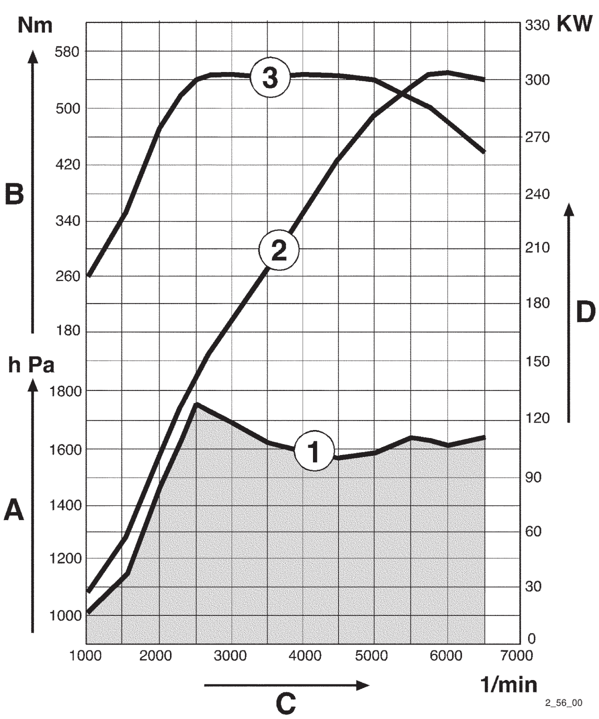
A control pressure, which acts on the diaphragms of the boost pressure control valves to open the bypass valves (wastegates), is modulated between boost pressure and atmospheric pressure. When de-energized, the boost pressure timing valve is closed. The boost pressure is applied directly to the boost control valve diaphragms and, as a result, the boost pressure control valves open the bypass valves at a low boost pressure.

If the boost pressure timing valve fails, the basic boost pressure is limited to approx. 300 to 400 mbar. This prevents the maximum boost pressure from being exceeded and results in reduced performance. The boost pressure upstream of the throttle valve is determined according to driving style.

In the case of a steady to slightly dynamic driving style (part-load range), the tuning of the engine is optimized for fuel efficiency. This is achieved by permitting only slight pressure upstream of the throttle valve. The throttle valve is opened wide enough so that only a slight drop in pressure is possible via the throttle valve.

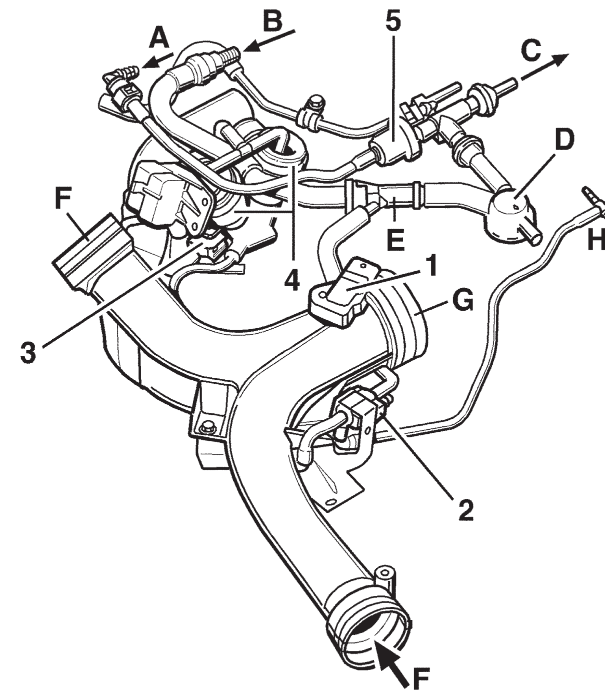
With a very dynamic driving style, a higher pressure is generated upstream of the throttle valve. As a result, the turbocharger is already running at a relatively high speed when the throttle valve is opened from the part-load range. The desired full-load boost pressure is thus reached more quickly.

Boost Pressure Curve



A - Absolute Pressure (hPa) **B -** Torque (Nm)
C - Engine Speed (rpm) **D -** Engine Power (kw)

1 - Pressure curve with regulation intervention (the boost pressure is reduced by approx. 20% in the regulation phase with a basic boost pressure of approx. 300 to 400 mbar).
2 - Power Curve
3 - Torque Curve



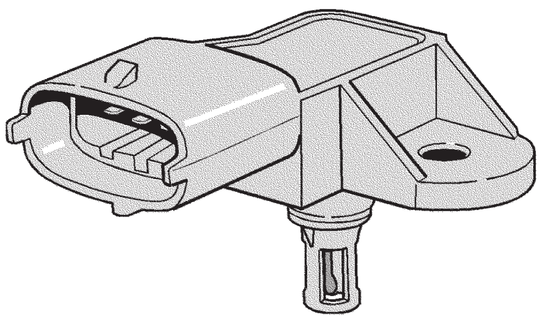
Turbo Charger Boost Control Components

1 - Pressure Sensor with Temperature Sensor
2 - Boost Pressure Timing Valve
3 - Deceleration Air Recirculation Switching Valves
4 - Deceleration Air Recirculation Valves
5 - Tank Bleeder Valve

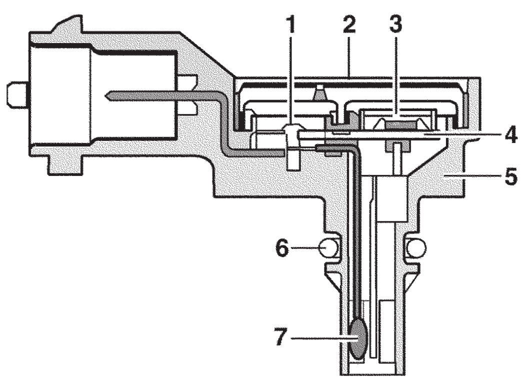
A - From Fuel tank
B - From Brake Booster
C - Tank Bleeding at Full Load
D - Idle Speed/Part Load Suction
E - Vacuum Amplifier
F - From Intercoolers (charge air radiators)
G - To Throttle Valve Adjustment Unit
H - To Boost Pressure Control Valves (barometric diaphragm)

Pressure Sensor With Integrated Intake Temperature Sensor

In the new Turbo, the pressure sensor and temperature sensor are integrated into a single housing. The sensor is installed in the intake pipe, immediately upstream of the throttle valve adjuster.



Boost Pressure Sensor With Intregrated Intake Air Temperature Sensor

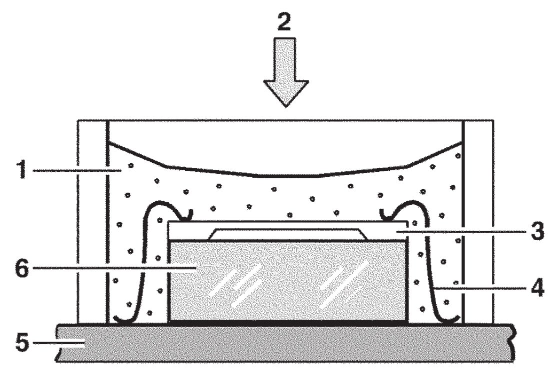


Cross Section View Of Pressure/Intake Air Temperature Sensor

1 - Bond Connector
2 - Cover
3 - Pressure Sensor Chip
4 - Ceramic Substrate
5 - Housing With Pressure Sensor Flange
6 - Sealing Ring
7 - NTC Element of Temperature Sensor

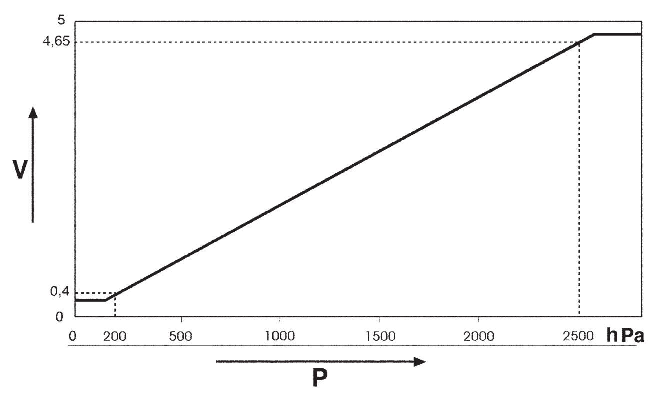
Pressure Sensor

The sensor element of the micromechanical pressure sensor consists of a pressure membrane with an integrated silicon chip. A change in pressure causes the membrane to expand. This expansion is detected as a change in resistance (piezoresistive effect). The evaluation circuit (including the correction logic) is integrated on the chip. A pressure sensor with a pressure range of up to 2.5 bar is used in the 911 Turbo (996).



Pressure/Intake Air Temperature Sensor Construction

1 - Protective Gel
2 - Effect of Intake Pipe Pressure
3 - Pressure Sensor Chip
4 - Bond Connector
5 - Ceramic Substrate
6 - Glass Base

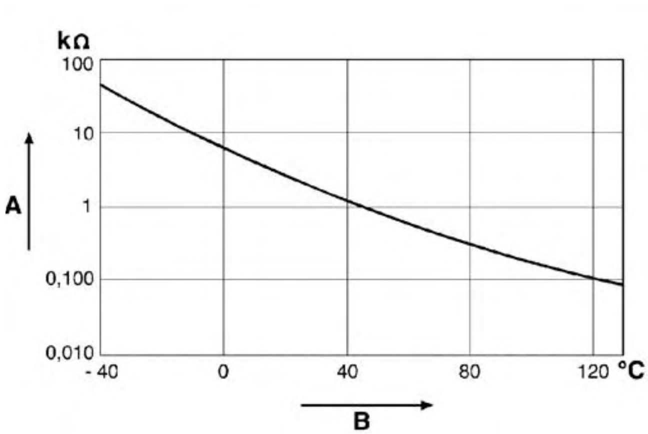


Pressure Sensor Characteristic Curve

P - Pressure (hPa)
V - Voltage (VDC)

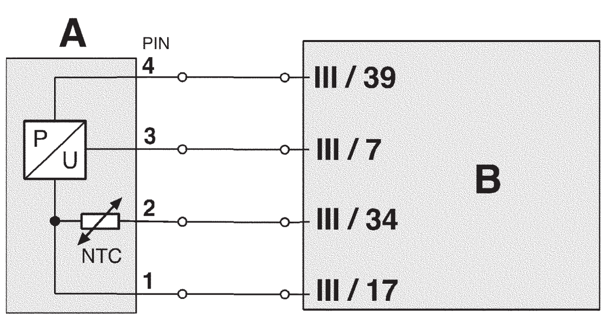
Intake Air Temperature Sensor

The integrated air temperature sensor protrudes through the pressure sensor flange into the intake air stream. The sensor measures the actual air temperature in the intake pipe downstream of the intercoolers (charge-air radiators).



Intake Air Temperature Sensor Characturistic Curve

A - Resistance (kΩ)
B - Voltage (VDC)



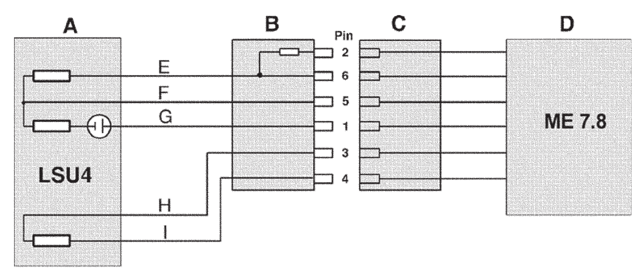
Pressure Sensor With Temperature Sensor Terminal Assignment

A - Pressure Sensor With Temperature Sensor
B - ME 7.8 ECM
1 - Sensor Groud (-)
2 - Intake Air Temperature Signal
3 - Supply Voltage (5 volt reference)
4 - Intake Pipe Pressure Signal

Oxygen Sensing System With New LSU4 Wide-band Oxygen Sensors

A wide-band type oxygen sensor (LSU4) is installed on each cylinder bank upstream of the catalytic converters. The wide-band sensor supplies an accurate and constant signal across a broad lambda range. Precise measurement is therefore possible in both the rich and the extremely lean range.

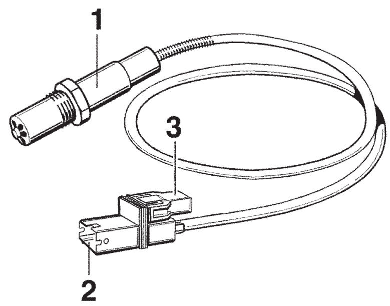
A regulating electronics system is integrated within the ME 7.8 ECM for each wide-band oxygen sensor. The ECM also includes the regulating electronics for maintaining LSU4 wide-band oxygen sensor temperature (approx. 1400° F. /750° C). Six wires lead from the ME 7.8 ECM (D) to the oxygen sensor harness connector (C) in the engine compartment. Five wires then lead from the connector (B) to the sensor (A).



Wide-Band Heated Oxygen Sensor (LSU4) Schematic

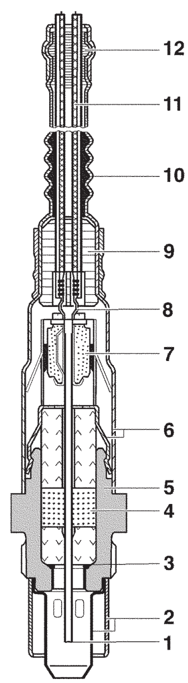
A - Wide-band Oxygen Sensor (LSU4)
B - Harness Connector With Intregated Trimmer Resistor
C - Plug Connection (engine wiring harness)
D - ME 7.8 ECM
E - Oxygen Pump Cell Current
F - Ground (-)
G - Sensor Cell Voltage
H - Sensor Heating Voltage
I - Ground For Sensor Heating Ground (regulated via ME 7.8 ECM)

A trimmer resistor is attached to the plug connection of each oxygen sensor. The resistor is laser-calibrated specifically for each sensor during production.



Wide-Band Heated Oxygen Sensor (LSU4)

1 - Wide-Band Oxygen Sensor (LSU4)
2 - 6-pin Harness Connector (on left and right side of engine compartment)
3 - Intrgrated Trimmer Resistor



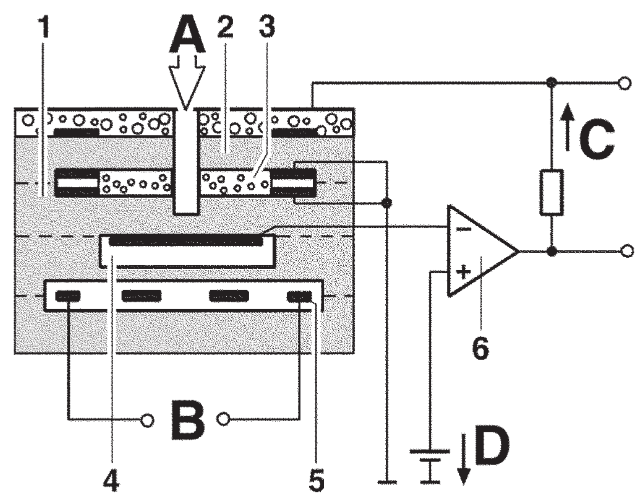
Wide-Band Oxygen Sensor Cross-Section

1 - Sensing Element (Nernst concentration cell and oxygen pump cell)
2 - Double Protection Tube
3 - Sealing Ring
4 - Sealing Package
5 - Sensor Housing
6 - Protective Sleeve
7 - Contact Holder
8 - Contact Clip
9 - Grommet
10 - Molded Hose
11 - Five Wire Harness
12 - Seal

Construction Of The Wide-band Oxygen Sensor LSU4

The LSU4 wide-band oxygen sensor uses the combination of a Nernst concentration (sensor) cell with an Oxygen pump cell to determine the oxygen content of the exhaust gas.

The Oxygen pump cell (2) and the Nernst concentration cell (1) are constructed of zirconium-dioxide (ZrO2), and each is coated with two porous platinum electrodes. The cells are arranged so that there is a gap of 10...50 µm between them. This measuring gap [Diffusion chamber (3)] is connected to the surrounding exhaust-gas through an exhaustgas opening (A). An electronic circuit (6) controls the voltage applied to the pump cell so that, the composition of the exhaust gas in the Diffusion chamber (3) remains constant at = 1. An integrated heater maintains an operating temperature of at least 1100° F. (600° C).



Wide-Band (LSU4) Oxygen Sensor Construction

A - Exhaust Gas
B - Heater Voltage
C - Oxygen Cell Pump Current
D - Reference Voltage/Sensor Voltage

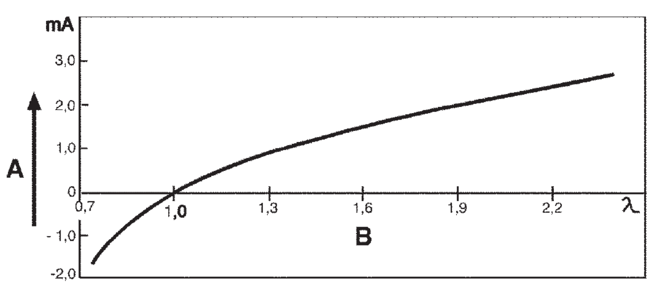
1 - Nerst Concentration Cell
2 - Oxygen Pump Cell
3 - Diffusion Chamber
4 - Reference Air Channel
5 - Heating Element
6 - Regulating Circuit

Operation Of The Wide-band Oxygen Sensor LSU4

When heated to at least 1100° F. /600° C (normal operating temperature 1400° F./750° C), the Nernst cell (1) produces a voltage which corresponds to the difference in the oxygen concentration in the exhaust gas (A) to the oxygen concentration in the sensor's diffusion chamber (3). An electronic circuit controls the "pump" current (C) through the oxygen-pump cell (2) so that, the composition of the exhaust gas in the diffusion chamber (3) remains constant at lambda=1. This corresponds to a voltage at the Nernst concentration cell of UN = 450 mV.

In the case of "lean" exhaust gas, UN < 450 mV, the oxygen-pump cell (2) is controlled so that, the oxygen ions are "pumped" out of the diffusion chamber (3).

While, in the case of "rich" exhaust gas, UN >450 mV, the current is controlled so that oxygen-pump cell (2), "pumps" oxygen ions into the diffusion chamber (3). It can be said, that, pump current is proportional to the oxygen concentration in the "lean" exhaust gas and to the deficiency of oxygen in 'rich' exhaust gas. Together with its control electronics (ECM), the sensor (LSU4) provides a clear, continuous signal throughout a wide lambda range [>0.7 to infinity (air)].



Oxygen Pump Cell Current In Relation To Lambda Value

A - Oxygen Pump Cell Current (ma)
B - Lambda Value (air/fuel ratio)

Advantages Of Wide-band Oxygen Sensor LSU4

- Linear (continual) characteristic curve
- Precise measurement in broad lambda range from > 0.7 to infinity (lean-air)
- Short response times < 100 ms
- On line (closed-loop) quickly

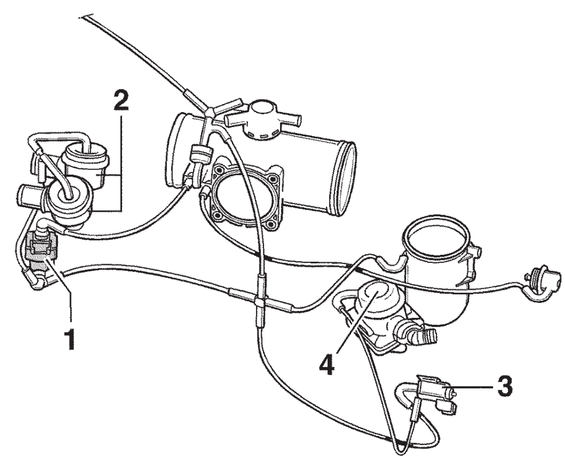
Post Catalytic Converter Oxygen Sensor

Modified LSF4 (offset) oxygen sensors are used downstream of the catalytic converters (previous vehicles had LSH25 offset sensors).

Electric Switching Valve For Overrun Air Recirculation

The opening of the deceleration air recirculation valves is controlled via an electric switching valve. The ME 7.8 ECM can activate the switching valve irrespective of the intake pipe pressure. In the event of a sudden transition from high load to deceleration, the overrun air recirculation valves are opened and turbocharger boost pressure is redirected back to the suction side of the compressor.

Operational Plan and Installation Position



Deceleration Air Recirculation Hose Routing and Component Layout.

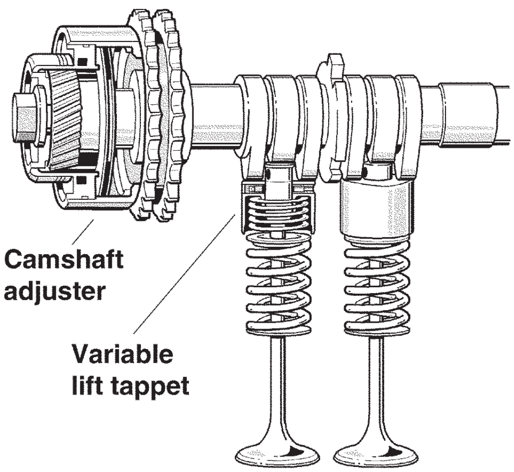
1 - Deceleration Air Recirculation Switching Valves
2 - Deceleration Air Recirculation Valves
3 - Secondary Air Injection Switching Valve
4 - Valve For Secondary Air Injection

Advantages:

- The controlled opening of the air recirculation valves reduces the noise in the intake tract and reduces fuel consumption.
- The electric air recirculation valves together with the vacuum reservoir allow the air recirculation valves to function irrespective of the intake pipe pressure.
- The system is configured so that the pneumatic air recirculation valves continue to be opened by the intake pipe pressure if the electric air recirculation valve fails.

VarioCam Plus

The intake camshaft adjustment system (VarioCam) has been upgraded to the VarioCam Plus system by the addition of an intake valve stroke control function. The two systems of the VarioCam Plus are actuated independently of each other by the ME 7.8 ECM.



VarioCam Plus System – Adjustable Tappet Controls Valve Stroke (3mm or 10mm valve lift) and Camshaft Adjuster Controls Valve Timing (advance or retard cam timing)

An electrohydraulic switching valve is attached to each of the cylinder heads of cylinder bank 1 and 2. Engine speed, accelerator pedal position, engine oil and coolant temperature as well as gear detection (and vehicle speed) are all required as input variables.

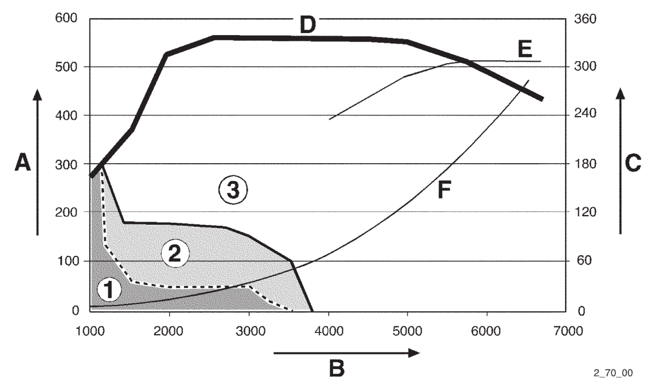
The switch-over points are calculated according to the needs of the driver based on the programmed shift maps in the ME 7.8 ECM. Adjustment of the throttle valve position, mixture formation, ignition timing and actuation of the switching valves occur simultaneously during the switch-over operation. The end result is an optimal compromise between maximum power and maximum torque.

Other operating phases of the engine have also been optimized thanks to variability of the system. This includes better fuel economy, lower emissions (including the cold-start and warm-up phases), improved driveability and idle quality.

Valve Stroke Adjustment System

The electrohydraulic 3/2-way switching valve is closed when de-energized. When closed, the valve stroke of the inlet camshafts is 3 mm. With the small valve stroke (3 mm), the new Turbo can reach a maximum speed of 90 mph (150 km/h).

When the system is switched over to the large valve stroke (10 mm) with performance-oriented cam timing, speeds of over 180 mph (300 km/h) are possible. Due to the configuration of the ME 7.8 ECM with E-Throttle, the switching operations are so smooth that they are hardly noticed by the driver.



Switching points of camshaft and valve stroke adjustment systems.

1 - Timing Retarded, Valve Stroke 3 mm
2 - Timing Advanced, Valve Stroke 3mm
3 - Timing Advance, Valve Stroke 10 mm

A - Torque (Nm)
B - Engine Speed (rpm)
C - Power Output (kW)
D - Torque
E - Power Output
F - Road Resistance in Top Gear

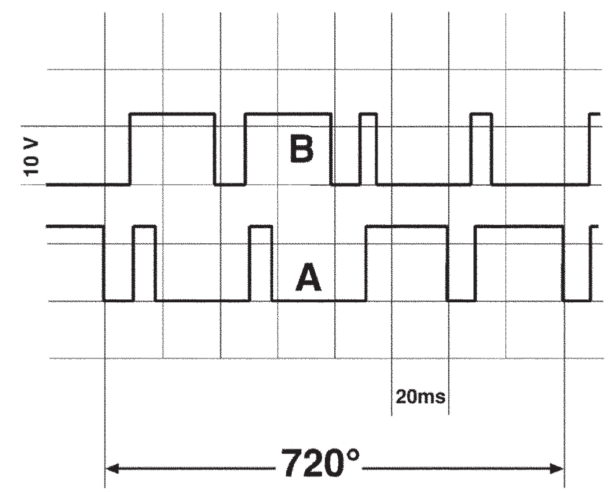
Camshaft Adjustment System

With the new Turbo, the adjustment range of the inlet camshaft is 30° CA (Crankshaft Angle). The electrohydraulic 4/3-way switching valve is closed when de-energized and the cam timing is set to the retard position (minor valve overlap). To ensure a high level of driving comfort, the system is switched over to advanced timing and the large valve stroke before the boost pressure builds up.

Electrical faults affecting the VarioCam Plus can be read out of the ECM memory using the Porsche System Tester 2.

Camshaft Position Sensors, Bank 1 and 2

The Hall sensors on the camshaft for cylinder banks 1 and 2 supply a modified quick-start signal to the ECM. With this signal, the ECM requires less than one engine revolution to determine the position of the crankshaft and camshafts. With this system, the engine will start even if there is no engine speed sensor signal.



Signal from camshaft position sensors (Hall Sensor).

Three-speed Radiator Fan Control

The radiator cooling fan switching stages are based on coolant temperature and other relevant information:

1st Stage:

At approx. 212° F. (100° C), and/or air-conditioning compressor is ON and intake air temperature of air-conditioning system > 46° F. (8° C).

2nd Stage:

At approx. 221° F. (105° C), and/or high A/C refrigerant pressure.

3rd Stage:

At approx. 226° F. (108° C) with vehicle speed >6mph (10 km/h) and engine not idling.

The cooling system is configured so that the 3rd stage is activated only under extreme conditions.

Two-speed Engine Compartment Scavenging Blower

To prevent engine components from getting too hot, specifically from the heat of the exhaust system, the engine compartment scavenging blower is activated at idle speed and with the ignition switched on.

Warning: Special care must be taken when working on components in the engine compartment with the ignition switched on. Risk of injury from dangerous high voltage is possible!

Switching Stages

1st Stage:

Ignition ON and/or engine running.

2nd Stage:

At coolant temperature of approx. 221° F. (105° C) or engine compartment temperature of approx. 167° F. (75° C) (OFF at approx. 140° F./60° C).

After-run Phase:

The after-run phase is active for max. 40 minutes after shut down.

Requirement: Engine compartment temp. with ignition OFF must be >77° F. (25° C)

- After-run ON for 3 minutes at engine compartment temp. >172° F. (78° C).
- The switch-on condition of > 172° F. (78° C) is then checked every 10 seconds.

Diagnosis – OBD II

Fault Memory Management

The on-board diagnosis system displays a visual warning in the instrument cluster if an emission related fault or a fault that may damage the catalytic converter occurs. The OBD functions are adapted to the different legal regulations in the USA (OBD II), Europe (Euro OBD) and the rest of the world.

If an emission-related fault occurs, the ME 7.8 ECM activates the Check Engine lamp and the fault is stored in the ME 7.8 ECM. A flashing Check Engine lamp indicates a combustion fault which may damage the catalytic converter. If the detected fault is not catalytic converter damaging and not emission-related, the Check Engine is not turned on, although the fault is stored in the ME 7.8.

The ambient conditions are stored (freeze frame) together with the detected fault. This information can be read out of the ECM memory using the Porsche System Tester 2. This makes troubleshooting much easier since the operating data for the first and last occurrence of the fault is provided.

Fault Confirmation

If a fault is detected during a diagnosis monitor routine, it is registered as a pending fault until it is confirmed during a second drive cycle with a new monitor routine (at least 120 seconds after the engine has been started).

Erasing Counter

A separate counter for erasing the fault is assigned to each detected fault. The counter determines how long the fault will stay in memory. When a fault is first detected, the erasing counter is set at a certain value.

If a pending fault is not present during the next monitor routine, the erasing counter is set to a fault-specific value (e.g. 10). The erasing counter is then reduced by 1 after every drive cycle. (i.e. the engine is started and the coolant temperature has increased from 86° F./30° C to > 158° F./70° C).

When a pending fault has been confirmed (i.e. the Check Engine Light has been turned on), the erasing counter is set to 40. This value is retained until the fault is no longer present. If the fault no longer exists, the erasing counter is reduced by 1 after every warm-up cycle (i.e. the engine is started and the coolant temperature has increased from 86° F./30° C to > 158° F./70° C).

If the erasing counter reaches 0, the fault is erased from the memory and the check engine light is turned off.

Note: To ensure that the Check Engine lamp is functioning correctly, it is illuminated for 10 seconds whenever the ignition switch is on.

Brief Information On Other Components

Coolant Temperature Sensor - The NTC coolant temperature sensor is a simple 2- pin sensor. Its signal is sent to the ME 7.8 ECM and supplied to the instrument cluster via the CAN interface. The same type of sensor is also used for the oil temperature sensor.

Oil Level Sensor - The oil level sensor consists of an electrically heated resistance wire. The sensor is installed in the oil reservoir tank. The processor in the instrument cluster determines the oil level from the immersion depth in the engine oil and the respective cooling behavior.

Engine Compartment Temperature Sensor - Identical to that used in the Boxster (986) and 911 Carrera (996) vehicles.

Engine Speed Sensor

Vehicles with manual transmission: New generation of contacts. The sensor holder is attached using shear bolts to ensure a tamper-proof mounting position. The distance to the flywheel is 1.0 ± 0.2 mm.

Caution: The ME 7.8 ECM could be damaged if the sensor is mounted too close to the flywheel (less than 0.5 mm).

Vehicles with Tiptronic transmission: New generation of contacts. Can also be used in all 911 Carrera (996) and Boxster (986) vehicles.

Knock Sensors - The knock sensors are also fitted with the new generation of contacts (contacts can be retrofitted).

Oil Pressure Sensor - Identical to oil pressure sensor used in the 911 Carrera (996) vehicles.

Fuel Cooler - To maintain a low fuel temperature, a fuel cooler that is cooled by the A/C system is fitted in the engine compartment.

Spark Plugs - Spark plugs with 2 electrodes are used in the 911 Turbo (996).

Spark Plug Connectors - The spark plug connector seals are longer than the spark plug connectors used in 911 Carrera (996) vehicles.

Ignition Coils - Identical ignition coils used in the 911 Carrera (996) and Boxster (986) vehicles.

Electric Boost Pressure Timing Valve - Compared to the 911 Turbo (993): lower coil resistance, strengthened connections, larger air-flow rate and the valve has a coating to prevent the accumulation of sticky deposits.

Bleeder Valve For Fuel Tank - The valve has a larger housing to allow a primary filter to be integrated and to minimize noise.

Fuel Pump - The electric fuel pump has a higher delivery rate for the increased performance of the 911 Turbo (996).

E-Throttle 7.8.1

The model year 2007 911 Turbo (997) was equipped with the ME 7.8.1 Motronic engine management system.

The following DME 7.8.1 information was first published in the 2007 911 Turbo (997) Service Information Technik book.

General

With the new 911 Turbo (997), Porsche is using a turbocharger with variable turbine geometry on an gasoline fueled engine for the first time. The focus here is on new developments and modifications compared with the 911 Turbo (996).

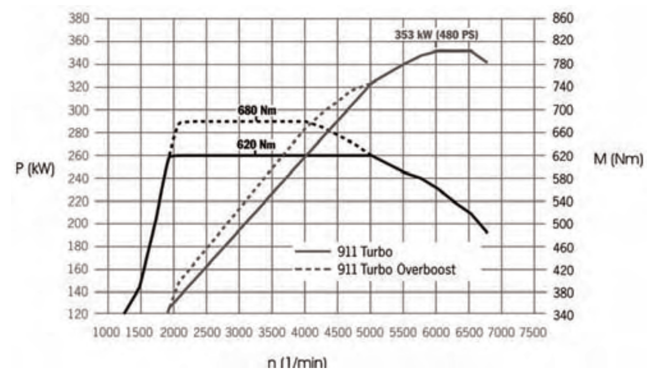
Motronic Control Unit ME 7.8.1

The further-developed Motronic control unit ME 7.8.1 is used worldwide. It is based on the ME 7.8 of the 911 Turbo (996) and the further development of the current 911 generation. The new Motronic control unit features a processor speed of 40 MHz with a memory capacity of 1 MB.

Summary of Modifications

- Variable-geometry turbocharger
- Higher power and torque values
- Component reinforcement
- Overboost function in conjunction with the “Sport Chrono Package Turbo” option
- Advanced VarioCam Plus
- Further developed dry sump lubrication with 9 oil pumps
- Increased cooling performance, including 2-stage oil cooling
- Enhanced charge air cooling

Power/Torque Diagram



Engine Data:

Displacement . . . . .3,600 cm^3
Bore . . . . .100 mm
Stroke . . . . .76.4 mm
Power output . . . . .480 bhp (353 kW)
At engine speed . . . . .6,000 rpm
Max. torque . . . . .460 ft lb. (620 Nm)
At engine speed . . . . .1,950 - 5,000 rpm
Max. torque (Overboost) . . .505 ft lb. (680 Nm)
At engine speed . . . . .2,100 - 4,000 rpm
Compression ratio . . . . . . .9.0 : 1
Governed speed . . . . .6,750 rpm (6th gear 6,800 rpm)
Idling speed . . . . .740 +/- 40 rpm

E-Throttle Pedal Unit

The 911 Turbo (997) is provided with an electronic accelerator pedal unit from the current 911 (997) series.

CAN Communication For The Motronic Control Unit (DME)

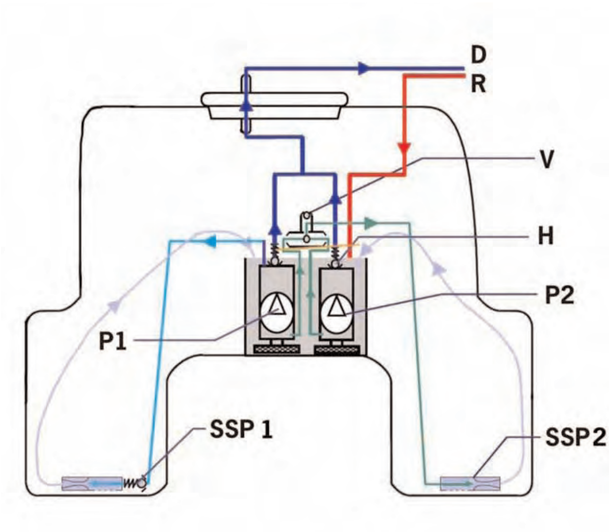
On the 911 Turbo (997), diagnosis of the DME control unit is performed for the first time via CAN.

The DME control unit communicates with the following control units via CAN:

- Gateway control unit
- Driver authorization control unit
- Tiptronic control unit
- PSM control unit
- PTM control unit
- Steering angle sensor
- Yaw velocity sensor
- Airbag control unit
- Air conditioning control unit

Fuel Tank

The tank of the new 911 Turbo corresponds to that of the current 911 Carrera 4 models. With a refill volume of approx. 17.6 gals. (67 liter), this has a capacity of approx. .75 gal. (3 liter) more than the tank of the 911 Turbo (996). The fuel level for the fuel reserve is 2.6 gals. (12 liters). The 911 Turbo (997) still has a return line from the pressure regulator in the engine compartment to the fuel tank. The battery and the battery tray must be removed in order to access the new position of the return line connection.



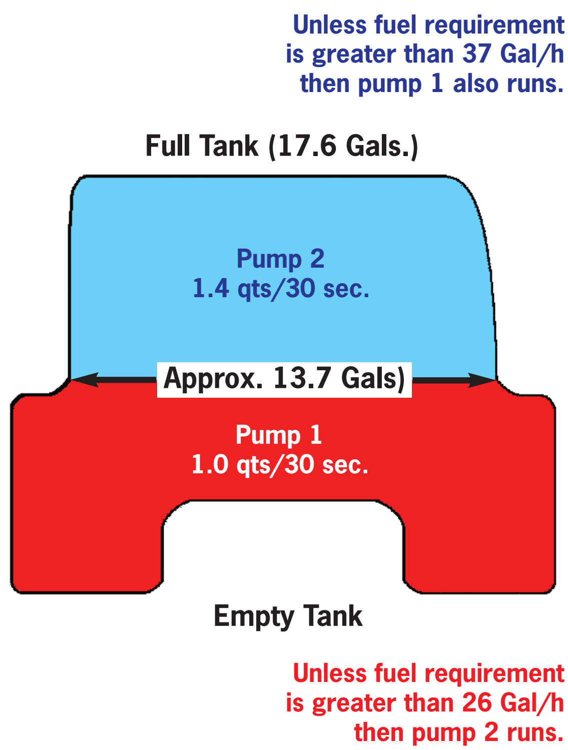
P1	Fuel pump 1
P2	Fuel pump 2
SSP1	Sucking jet pump, right
SSP2	Sucking jet pump, left
H	Pressure holding valve
V	Distributor valve
D	Pressure side to engine
R	Return line from pressure regulator

Fuel Pumps

The fuel tank of the 911 Turbo (997) has 2 fuel pumps which are integrated into the common pump chamber (tandem pump). The fuel pump 1 delivers 1 qt. (1.1 liters) in 30 seconds, and fuel pump 2 delivers 1.4 qts. (1.5 liters) in 30 seconds. The two fuel pump relays are activated as required by way of switching points in the DME control unit.

Fuel pump 1 runs with a tank content of less than 13.7 gal. (52 liters). Fuel pump 2 is activated when a computed fuel requirement of greater than 26 gal/h (100 l/h).

Fuel pump 2 runs with a tank content of greater than 13.7 gal (52 liters). Fuel pump 1 is activated when a computed fuel requirement of greater than 37 gal/h (140 l/h).
The fuel is pumped out of the tank pockets by the two sucking jet pumps. The high-pressure sucking jet pump on the right side of the vehicle is supplied only by fuel pump 1. The low-pressure sucking jet pump on the left side of the vehicle is operated by one or both pumps depending on the fuel level and load condition. The quantity of fuel delivered by both fuel pumps can be checked as described in the Technical Manual.



Fuel Filter

The fuel filter is located on the left-hand side of the engine compartment and must be changed every 60,000 miles (90,000 km) or after 6 years.

Fuel Pressure Regulator

The fuel pressure regulator is installed on the fuel distributor rail on the right (cylinder row 4 - 6 or bank 2) in the engine compartment. A return line runs from the fuel pressure regulator to the fuel tank. The Technical Manual describes how to check the fuel pressure. The holding pressure should be > 29 psi (2 bar) after 1 hour.

New EV-14 ST Injection Valve

The advanced EV 14 ST Extended Tip injection valve from the EV series is used. This new 6-hole injection valve has another injection point located in the intake pipe, which results in an even better mixture preparation and therefore a reduction in emissions.

Tank Ventilation System

The compact tank vent valve (TEV-5) in the engine compartment is designed for a higher throughput, especially in the case of small pressure differences compared with the previously installed valve (TEV-2). The tank vent line is routed directly from the tank vent valve into the intake pipe.

Carbon Canister

The functionality of the tank vent systems/carbon canister corresponds to that of the 987/997 vehicles. USA vehicles have a carbon canister with tank leakage diagnostic module (DM-TL) which is located in the front luggage compartment.

Ignition System

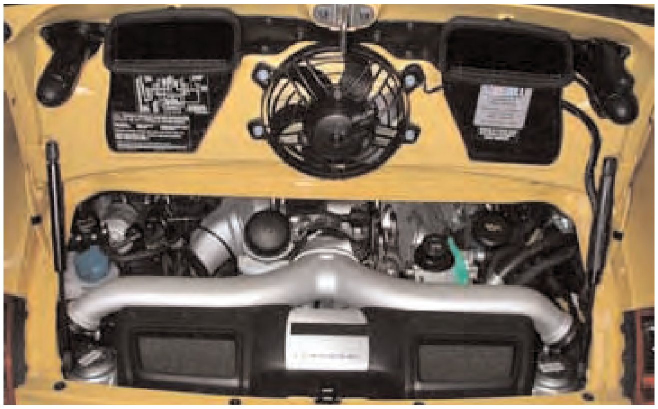
The individual ignition coils and spark plug connectors are the same as for the previous model.

Spark Plugs

New spark plugs are installed. These double-platinum spark plugs (center and ground electrodes are made of platinum) operate in accordance with the air gap principle. The change interval for the spark plugs is 40,000 miles (60,000 km) or after 4 years.

Intake Air Side, Air Routing

Rear Lid



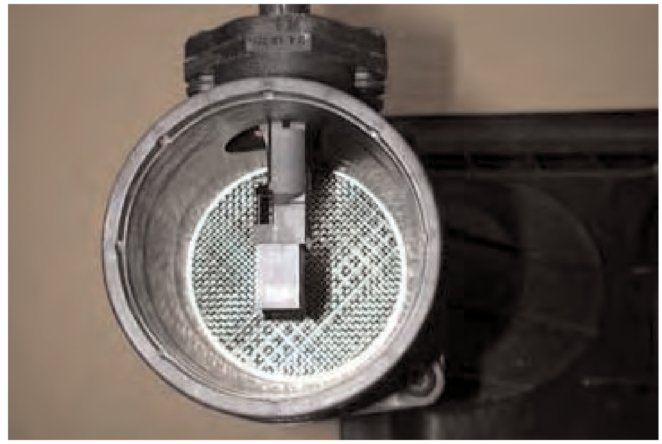
The inner part of the lid has two separate intake ducts which are routed to the air cleaner housing.

Air Cleaner

The air cleaner housing and the air cleaner element were newly developed for the new 911 Turbo. The air cleaner housing was lined inside with foam in order to obtain an optimum intake sound. It was possible to reduce the intake resistance and optimize the charge cycle by way of the 2-channel intake via the rear lid, the new air cleaner element and two separate intake pipes to the turbochargers on the left and right.

In addition, it was also possible to reduce the frequency of cleaner replacement. The air cleaner element now has to be replaced only every 40,000 miles (60,000 km) or after 4 years. The top part of the new air cleaner (housing) has been provided with a design cover made of aluminium to visually upgrade the engine compartment. This cover is embossed with the logo “VARIABLE TURBINE GEOMETRY”.

2 Hot-film Mass Air Flow Sensors HFM 5-6.4



One hot-film mass air flow sensor HFM 5-6.4 is located in each of the turbocharger intake pipes on the left and right behind the air cleaner. The mass air flow sensors are matched to the overall air mass of the engine. Each of the two mass air flow sensors can measure an air mass of up to 800 kg/h.

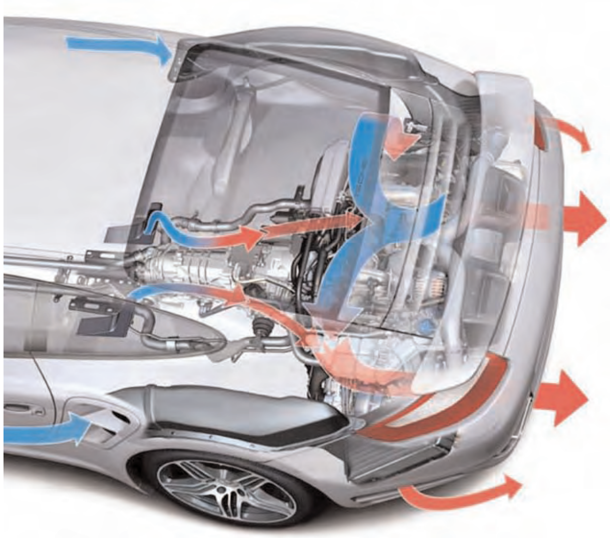
Diverter Control

When the throttle is closed quickly (deceleration), the boost pressure increases in the pressure system in front of the throttle because the compressor of the turbocharger continues running. The new 911 Turbo (997) is also equipped with a diverter valve for each cylinder bank to blow off the excess boost pressure. In contrast to the 911 Turbo (996), however, this is not accommodated separately, but is integrated in a space-saving and compact manner in the compressor housing of the turbocharger. The Motronic control unit activates the electro-pneumatic switching valve, which then opens the diverter valve by means of a vacuum.

Charge Air Cooling

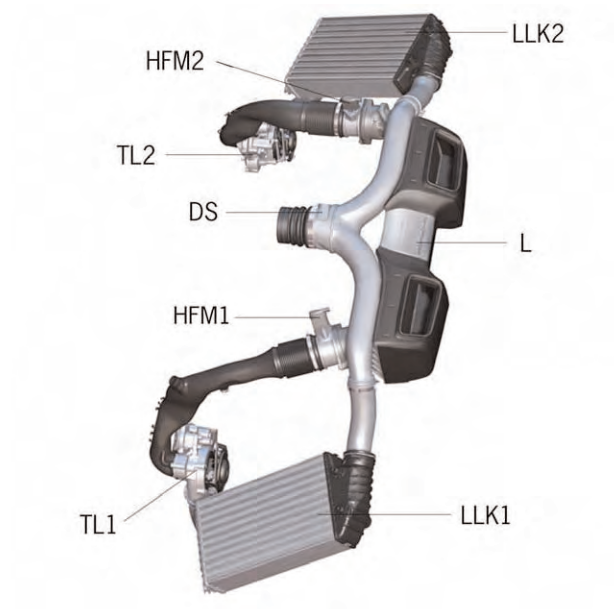
Flow Duct To Charge Air Cooler

The inlet trim elements in the rear side panels were modified. These possess a characteristic design for the new 911 Turbo, including an additional bar in the middle of the inlet duct. The form and position of this bar were specially designed, and the bar does not hamper air flow into the flow duct in spite of the slight reduction in the cross-section of the inlet. In addition, the manufacturing method for the plastic parts was modified to achieve an increased duct cross-section with lower production tolerances. The result is a reduction in flow resistance by approx. 10 % combined with a higher air throughput.



Charge Air Coolers

The charge air coolers have been further developed compared with the 911 Turbo (996) and the air flow onto the cooler surfaces improved. The result is more efficient charge air cooling and therefore higher power and torque values.



L	- Air cleaner
HFM 1	- Mass air flow sensor, left
HFM 2	- Mass air flow sensor, right
TL 1	- Turbocharger, left
TL 2	- Turbocharger, right
LLK 1	- Charge air cooler, left
LLK 2	- Charge air cooler, right
DS	- Boost pressure sensor

Outgoing Air Routing Through The Rear Apron

The outlet openings for the outgoing air of the charge air coolers were provided with a new design in the completely newly developed rear apron.

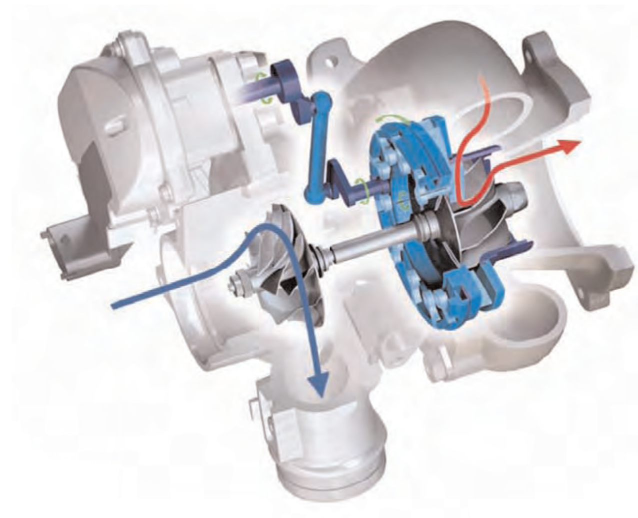
Boost Pressure Sensor/Intake Air Temperature Sensor

The boost pressure sensor measures the pressure upstream of the throttle adjusting unit (electronic throttle) as well as the air temperature before the air enters the intake system, and supplies this information to the DME control unit. The boost pressure is controlled by way of the position of the vanes in the turbocharger. Throttle adjusting unit (electronic throttle) The throttle adjusting unit (electronic throttle) has a diameter of 74 mm.

Intake System

Both the intake pipes from the air cleaner to the turbocharger and the pressure pipes from the turbocharger to the throttle were modified with respect to their flow properties and the flow resistances reduced. The intake distributor is still made of plastic and is now produced in one piece. Compared with the intake distributor of the 911 Turbo (996) with a separate intake pipe support made of aluminium, the one-piece design offers weight advantages and improved flow transitions to the cylinder head. In addition, the dimensioning of the intake distributors was adapted to the new turbocharger concept. The intake distributor of the new 911 Turbo has a silver paint finish to improve the engine compartment design. A weight saving of approx. 4.4 lbs. (2 kg) was achieved for the intake system compared with the 911 Turbo (996).

Turbocharger With Variable Turbine Geometry



The exceptional driving performance is due above all to the newly developed turbocharger technology of the six-cylinder engine. By using extremely high-temperature resistant materials, it was possible to develop an exhaust turbocharger with variable turbine geometry which is capable of withstanding the high exhaust temperatures produced by gasoline fueled engines of up to 1832° F (1000° C). A turbocharger with variable turbine geometry combines the respective advantages of small and large turbochargers, and permits optimum utilization of the exhaust energy for charging at any engine operating point; in addition, there is no longer any need for wastegate valves.

The result of the new technology is a significant increase in torque and performance: the opposed cylinder engine delivers 480 bhp (353 kW) at 6,000 rpm, 60 bhp (44 kW) more than the engine of the previous model, and this with an unchanged displacement of 3.6 l. At the same time, the nominal torque increases from 415 ft lbs (560 Nm) to 460 ft lbs (620 Nm) in a much wider rpm range: On the new Turbo, the maximum value is now in the range between 1,950 and 5,000 rpm.

Variable Turbine Geometry

The greatest development potential for exhaust turbochargers is solving the conflict between good response at low engine speeds and high specific performance values at high engine speeds. Variable turbine geometry with variable vane adjustment in front of the turbine wheel has shown itself to be the optimum solution for further improving turbocharger response and thereby the response of the turbocharged engine.

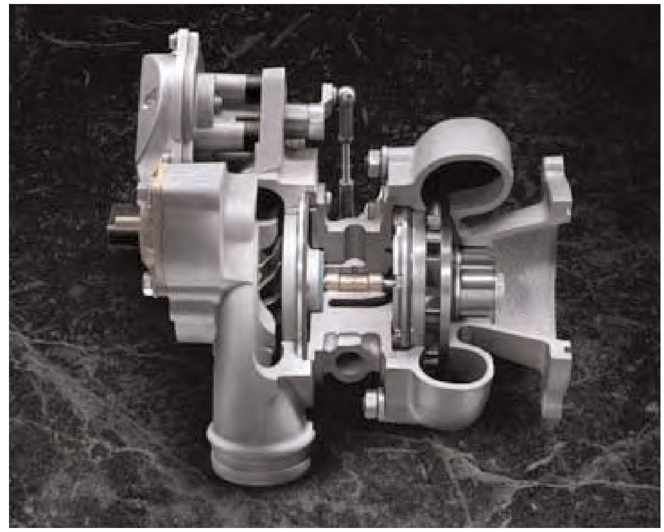
The new 911 Turbo with variable turbine geometry again sets new standards for Otto engines with exhaust turbocharging.

Technical Challenge

The design of variable turbine geometry is based on adjustable vanes which guide the exhaust mass flow from the engine onto the turbine of the turbocharger in a variable and targeted manner. The use of variable turbine geometry for Otto engines is made more difficult by the significantly higher exhaust temperatures. Compared with temperatures of approx. 1472° F (800° C) in the case of diesel engines, the maximum exhaust temperatures at the turbine inlet on Otto engines with exhaust turbocharger are significantly higher at approx. 1832° F (1,000° C). This leads to considerable additional stressing of the material and high demands on design realization. The delicate adjusting elements of the vanes in the hot exhaust stream are particularly critical. In addition to the high-temperature resistance of individual components, it is also necessary to take into account high temperature fluctuations in design.

In view of a possible temperature range from cold starting at -20 F (-30° C) up to a maximum regulated exhaust temperature (at the turbine inlet) of approx. 1832° F (1,000° C), it is necessary to take into account the different material expansion factors and safeguard the functioning of the entire adjustment system, including the many individual components. This is guaranteed, by selection of suitable materials, oil cooling, as well as by additional water cooling of the bearing housing. This can be activated via the Motronic system by an electric coolant pump both at low speed (< 2,000 rpm) combined with high coolant temperature (> 208° F/98° C) as well as after the engine is switched off.

Technical Principle



On the new 911 Turbo, the boost pressure is controlled only by adjusting the vanes (without bypass valve). This is done by way of an adjusting ring, which is actuated by an electric servo motor via a coupling rod (one "boost pressure adjuster" per turbocharger).

Small turbochargers have good response characteristics (small "turbo lag") due to the small acceleration mass of the turbine wheel and the high flow momentum of the exhaust gas. This momentum is generated in the turbine housing in the transition to the turbine wheel by way of small flow cross-sections with high flow speeds. However, the small flow cross-sections in both the turbine housing and turbine wheel increase the flow resistance for high air throughputs and therefore high engine speeds, and also produce high exhaust backpressures ("choking"). As a result, the maximum engine power is limited.

Large turbochargers have poor response characteristics (large "turbo lag") due to the high acceleration mass of the turbine wheel and the low flow momentum of the exhaust gas. In contrast to small turbochargers, however, the exhaust backpressures are lower for high air throughputs due to the larger flow cross-sections in the turbine housing and turbine wheel. This results in less exhaust work for the pistons, as well as an improved charge cycle with a lower residual gas amount in the cylinder and better cylinder filling, for example. This results in a higher maximum engine power.

Vane Adjustment System

The principle of variable turbine geometry is essentially based on the following two physical characteristics:

- Variable vane gap
- Variable air impact angle

The adjustment system with adjusting ring and movable vanes is the mechanical heart of an exhaust turbocharger with variable turbine geometry. It consists of 11 adjustable vanes which are interconnected by the adjusting ring. The adjusting ring is connected in turn via a coupling rod with the electric servo motor which is responsible for controlling adjustment of the vanes.

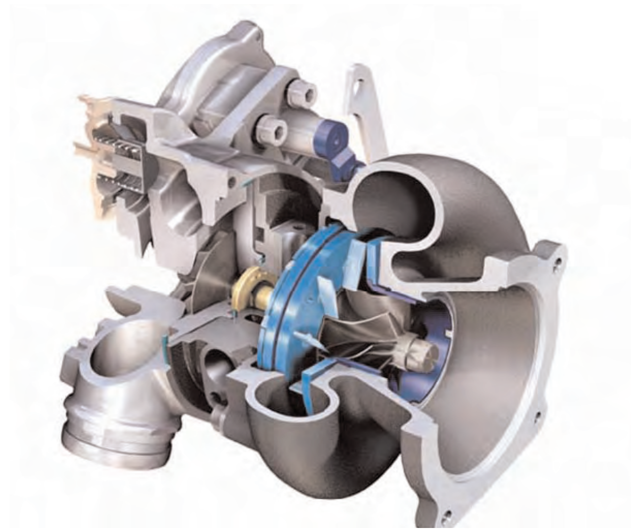
With variable turbine geometry, small turbochargers are simulated by closed vanes (small vane gap) and large turbochargers by open vanes (large vane gap). With the respective advantages, variable turbine geometry permits both very good response with high torque values even at low speeds, as well as high output values at high speeds. The high torque is therefore available for a significantly larger rpm range.

The variable vane gap is achieved by turning the adjusting ring and thus turning the vanes. A small vane gap reduces the flow cross-section. The resultant higher gas speeds mean that the exhaust gas is directed onto the turbine vanes with high momentum. The turbine wheel therefore rotates more quickly and drives the compressor wheel located on the same shaft. This in turn compresses the air which is supplied to the engine for combustion. As a result, the engine receives more air more quickly and accelerates more dynamically.

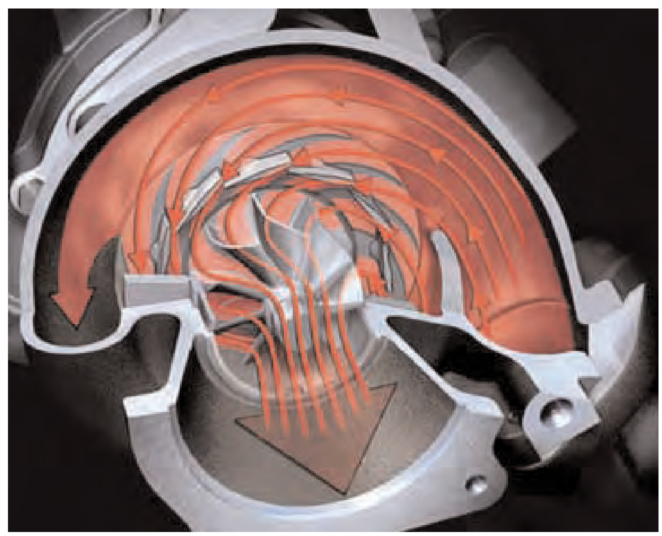
Vane Adjustment

Adjustment of the vane system and of the vane gap allows the exhaust mass flow to be directed onto the turbine wheel with maximum effectiveness for every operating point throughout the whole rpm range, thereby allowing the boost pressure to be adjusted to the corresponding setpoint value. This control technology combined with selection of a suitable turbine size makes it possible to dispense with the bypass valve (wastegate) usually required for engines with exhaust gas turbocharging. Adjustment of the turbine vanes does not just change the vane gap, it also changes the impact angle of the exhaust gas on the vanes.

This variable impact angle assists the dynamic response of turbocharging using variable turbine geometry.



Vanes Closed



Small vane gaps do not just result in higher gas speeds in the vane gap. In this vane position, the impact angle of the exhaust gas on the turbine vanes is more direct and therefore produces higher angular momentum of the turbine wheel. If the vanes are closed at low engine speeds, the exhaust gas is accelerated in the small air gap and impacts on the turbine wheel radially with high energy. As a result, the compressor wheel located on the same shaft is accelerated quickly and increases the boost pressure. This in turn leads to good response characteristics of the turbocharger and thus high dynamic engine and vehicle acceleration.

Vanes Open

If the exhaust mass flow increases (increasing engine speed and load), the vanes are opened by the DME control unit according to a control map when the desired (maximum) boost pressure is reached. The adjustment duration for the vanes from open to closed and vice versa is only approx. 100 milliseconds.

Electric Boost Pressure Adjuster

A precondition for optimum functioning of a turbocharger with variable turbine geometry in conjunction with an gasoline fueled engine is adjustment or control by an electric boost pressure adjuster. This is bolted directly onto the turbocharger and actuates the above-described adjusting ring with the integrated, electronically controlled servo motor via a short coupling rod.

The most important advantages compared with the pneumatic adjusting devices used for diesel engines are as follows:

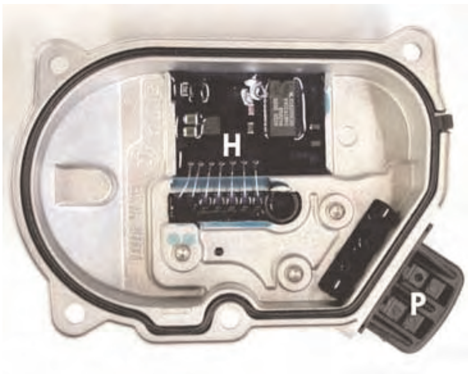
- Fast reaction time (delay max. 100 ms).
- Optimum response characteristics.
- Freely selectable vane position independently of the pressure in the system.
- Optimum control quality of the desired boost pressure.
- Control possible without overshoot.
- Optimum diagnosis and fault detection.

Design Of Electric Boost Pressure Adjuster

M - Electric motor (DC)
S - Sensor magnet
G - Spur gear drive

The boost pressure adjuster consists of an aluminium housing, which accommodates the DC motor with sensor magnet as well as a two-stage spur gear drive with a drive shaft/lever. A two-stage spur gear drive is connected between the DC motor and drive shaft. An aluminium cover with glued-in bonded hybrids and a screwed-in four-pin connector is screwed onto the housing. The hybrid electronic components are designed for an operating temperature from - 40° F (- 40° C) to 266° F (130° C).

Position Sensor



A contactless incremental Hall sensor is used to detect the position of the output shaft. The hybrid electronics integrated in the adjuster housing is responsible for position control and control of the DC motor. The sensor magnet wheel is mounted on the DC motor shaft, while the sensor (pick-up) itself is located on the hybrid electronics. The main advantage of the contactless sensor is freedom from wear.

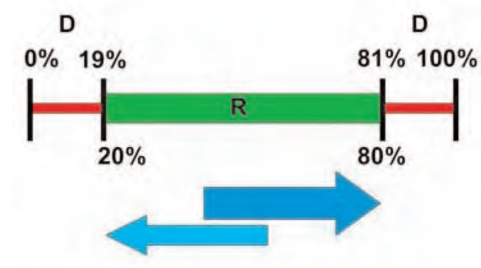
In addition to digital position control and related setpoint/actual value evaluation and driver control, the electronic components also perform actual value output as well as diagnostic and fault detection routines.

Each boost pressure adjuster is connected to the DME control unit by two signal lines. The DME control unit sends a setpoint (PWM signal) or special pulse/duty ratios (e.g. command to travel to and learn end stops) via one of the lines. The electric boost pressure adjuster then sends the actual value (PWM signal) and special pulse/duty ratios (self-diagnosis of electric adjuster for fault memory entry in the DME) to the DME via the other line.

Control By The Motronic Control Unit ME 7.8.1

Optimum adjustment angles are set by way of functions in the engine control unit depending on the engine operating point, so that the target engine torque is reached as quickly as possible. The optimum vane positions for maximum efficiency were determined for the complete engine map as part of extensive application work. The goal was above all to optimize the response behavior particularly for dynamic acceleration. Variable turbine geometry allows a full torque characteristic to be achieved even at low engine speeds and also provides a wide power spectrum in the nominal output range.

Diagnosis Of Electric Boost Pressure Adjuster



The electric boost pressure adjuster features an integrated diagnostic function which transmits a fault to the DME control unit by way of a corresponding pulse/duty ratio.

- The nominal mechanical adjustment range or control range (R) extends from 20 % (vanes open) to 80 % (vanes closed).
- The pulse/duty ratio is approx. 40 % when the ignition is switched on.
- The pulse/duty ratios 0 % to 19 % and 81 % to 100 % are special pulse/ duty ratios for diagnostic routines (D) and for teaching the adjusting device.

Boost Pressure Adjuster Test

When the ignition is switched on, the function "Test boost pressure adjuster" is available on the PIWIS Tester in the DME control unit under the system test function. A corresponding fault is entered after this test in the event of malfunctions.

In order to check functioning of the adjusting device, the electric boost pressure adjuster is supplied with a pulse/duty ratio of 16 % and 84 % after the ignition is switched off. The function test is also audible for the customer.

Teaching The Electric Boost Pressure Adjuster

It is necessary to perform adaptation of the electric boost pressure adjuster if a turbocharger or the electric boost pressure adjuster itself is replaced. When the ignition is switched on, the function "Boost pressure adjuster adaptation" is available on the PIWIS Tester in the DME control unit under the system test function. During this adaptation, the mechanical limit stops (20 % and 80 %) are taught again and stored in the boost pressure adjuster.

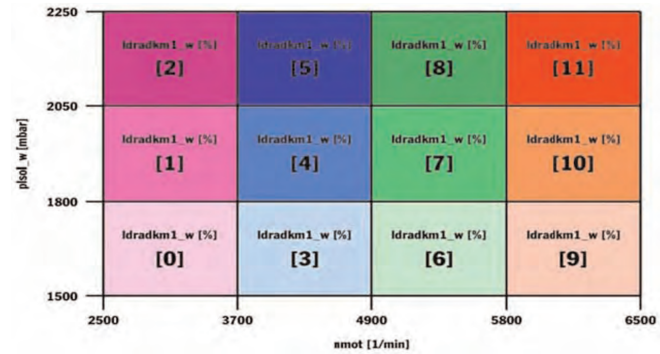
Adaptation Of Boost Pressure Control

The boost pressure is a variable which is influenced by engine tolerances and ambient conditions. The following ambient conditions influence the boost pressure with respect to the maximum engine torque, protection of the engine and turbocharger as well as fault entries.

- Air pressure (the boost pressure is adapted from an altitude of
  > 5,900 ft (1,800 m) in order to protect the components of the turbocharger).
- Ambient temperature and intake air temperature (charge air temperature) (the boost pressure is reduced at an ambient temperature
  < approx. 32° F (0° C), or a charge air temperature < approx. 50° F.
  (10° C).
- Fuel quality (knock resistance under thermodynamic loading).

The adaption ranges 0 to 11 are available for boost pressure adaptation. These are divided into 3 load ranges (boost pressure) and 4 engine speed ranges. Adaptation of +/- 15 % is possible for each range before a fault is entered.

Table Of Boost Pressure And Speed Thresholds



plsol – Boost pressure in mbar
nmot – Engine speed in rpm

Partial Load Adaptation

The adaptation ranges 0 / 3 / 6 / and 9 are available for partial load or reduced full load due to ambient conditions (e.g. poor fuel quality).

Full Load Adaptation

The adaptation ranges 1 / 4 / 7 / and 10 are provided for full load under normal conditions.

Full Load With Overboost

The adaptation ranges 2 and 5 are available for full load with Overboost (Sport Chrono activated). The adaptation ranges 8 and 11 are not normally adapted.

Sport Chrono Package Turbo (Optional)

The Sport Chrono Package Turbo is offered for the first time for the new 911 Turbo. The package contents correspond to those of the Sport Chrono Package Plus from the current 911 Carrera (997) generation, but are supplemented by the functions, Overboost , PTM control and modified starting program for the optional Tiptronic S.

The "Sport Chrono Package Plus" offers the driver distinctively sporty settings for various vehicle functions, therefore providing a completely new sporty driving experience. The accelerator pedal characteristic, engine behavior at the speed limit and in the event of load changes, PSM intervention thresholds as well as the characteristics of PASM and Tiptronic S are all changed at the push of a button. The Sport Chrono program also allows the driver to control these advantages as required to take into account contemporary conditions.

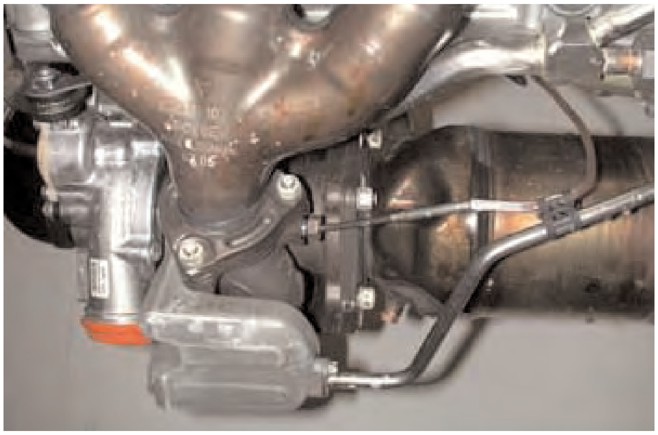
Additional Function – Overboost

Overboost is a brief excess increase in the boost pressure (max. 10 s) for acceleration under full load (fully depressed accelerator pedal). The function is activated after operation of the Sport button on the center console and fast depression of the accelerator pedal. Overboost is performed with the assistance of the boost pressure control and results in an increase in the maximum boost pressure by approx. 2.9 psi (0.2 bar) (20 %). As a result, the maximum torque is increased from 460 ft lb (620 Nm) to a maximum of 505 ft lb (680 Nm) between 2,100 rpm and 4,000 rpm (the torque is regulated linearly to the "normal" full-load value between 4000 and 5000 rpm) and permits a significant improvement in acceleration performance and elasticity. The higher boost pressure does not just result in an abrupt increase in mechanical loading of the components, but above all also significantly increases thermal stressing. This is due in particular to the continuously rising charge air and combustion chamber temperatures.

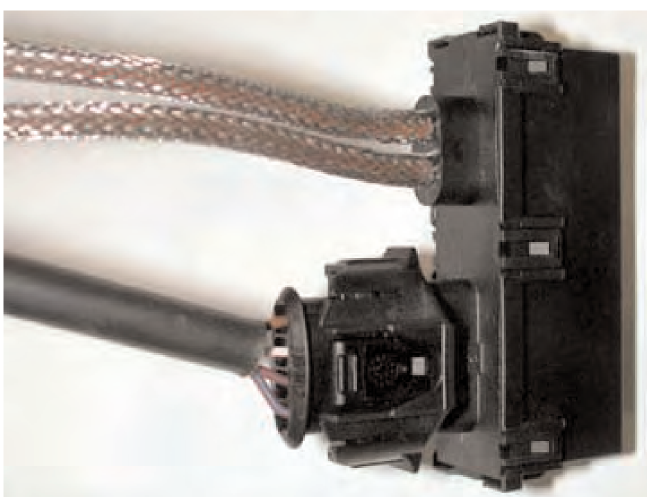
The Overboost function is restricted to 10 seconds in order to take these factors and the maximum component loading into account. After this time, the original full-load boost pressure without Overboost is restored. The Overboost function can be reactivated again as soon as the engine load is relieved briefly by the throttle closing (e.g. after a gearshift).

Overboost operation is indicated by an arrow symbol in the boost pressure display of the instrument cluster. The arrow next to the boost pressure display indicates the brief Overboost operation, which is possible only in conjunction with activated Sport function (text "SPORT" shown on display). The boost pressure indication is shown as a digital value and as a graphic representation in the multi-function display. The boost pressure can increase up to approx. 1.2 bar (17.4 psi) when the Sport button is pressed; a pressure of approx. 1.0 bar (14.5 psi) is reached when this function is not activated.

Exhaust Temperature Sensors, Banks 1 and 2



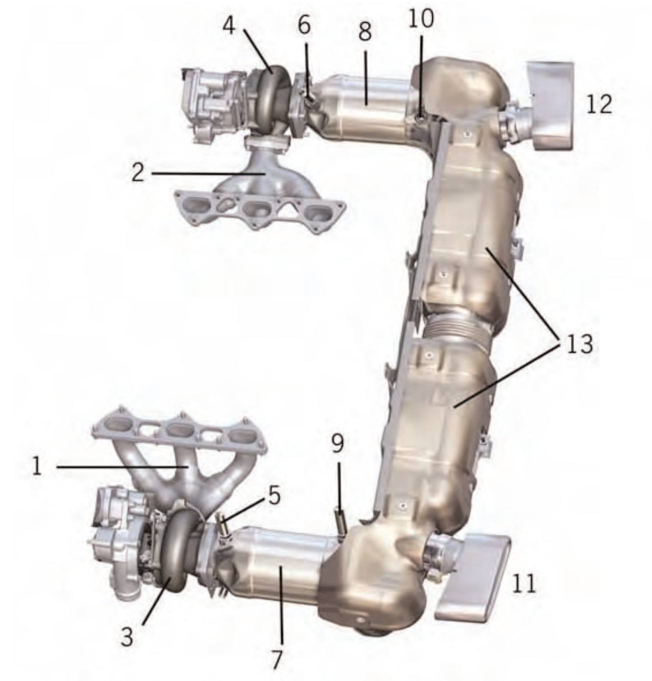
The signal from the exhaust temperature sensors of banks 1 and 2 installed at the turbine inlet is used in the DME control unit for component protection. The exhaust temperature is evaluated for each bank in the DME control unit, and is restricted to a maximum temperature of 1,767° F. (980° C) by enrichment or boost pressure adjustment. The two sensors are combined into one component unit together with their control unit. The measured signals are evaluated in this control unit.



The control unit sends a pulse/duty ratio (PWM) to the DME. The pulse/duty ratio range is from 4 % (corresponds to 25° F/- 4° C) to 96 % (corresponds to 2,030° F/1,110° C). The control unit has a self-diagnosis function. If the control unit detects a cable break/short-circuit to the sensor or in the evaluation circuit, it sends the special pulse/duty ratio of 98 % to the DME and this leads to an entry in the fault memory.

Exhaust System/Emission Control

The exhaust system has been partially newly developed. The new 911 Turbo complies with all worldwide emission regulations with a standard exhaust system. The weight was reduced by using thin-wall technology for the muffler and ceramic main catalytic converters. It was therefore possible to reduce the overall weight of the exhaust system by approx. 8.8 lb/4 kg (16 %) compared with the 911 Turbo (996).



1 – Air-gap insulated exhaust manifold left
2 – Air-gap insulated exhaust manifold right
3 – Turbocharger, left
4 – Turbocharger, right
5 – LSU broadband oxygen sensor, left
6 – LSU broadband oxygen sensor, right
7 – Ceramic main cat. converter, left
8 – Ceramic main cat. converter, right
9 – LSF step oxygen sensor, left
10 – LSF step oxygen sensor, right
11 – Tailpipe cover, left
12 – Tailpipe cover, right
13 – Muffler

Ceramic Main Catalytic Converter

It was possible to further improve the emission values by the use of state-of-the-art catalytic converter technology with one 3-way ceramic main catalytic converter for each cylinder bank and by improved secondary air injection after cold starting (Europe: EU4; USA: LEV II).

Tailpipe Covers

The rear apron of the new 911 Turbo was completed redesigned. In addition to modified side outlet openings for the outgoing air of the charge air coolers, the new 911 Turbo is also equipped with integrated exhaust tailpipes. The tailpipes were relocated to a higher position compared with the 911 Turbo (996), and are integrated in the rear apron of the new 911 Turbo as a distinguishing feature and characteristic design element – analogous to the Carrera GT. In order to protect the rear apron against the high temperatures of the exhaust tailpipes, a shield made of high-temperature-resistant plastic capable of withstanding temperatures up to 536° F (280° C) is installed in the area surrounding the tailpipe.

Secondary Air Injection

The function of the secondary air injection system, with one secondary air valve per cylinder bank, each of which is pressure opened by a pump, is the same as in the current 997 vehicles. The secondary air valves with additional check valve were adopted from Cayenne Turbo.

The following switch-on conditions apply to activation of secondary air injection when the engine is started for the first time:

- Engine temperature (coolant): 14° F (- 10° C) to 108° F (42° C).
- Time: Max. 120 seconds after engine start
- Mass air flow as switch-off condition: Secondary air injection is switched off after a time delay as from a mass air flow of > 200 kg/h.

S - Secondary air valve, left
V - Electrically operated switching valve for air recirculation control
P - Auxiliary electrical water pump

VarioCam Plus

The new 911 Turbo (997) is provided with the latest development version of the variable valve control VarioCam Plus with continuous adjustment of the intake camshafts and valve lift switching of the intake valves. This system permits optimization of engine output and torque on the one hand and, on the other, also makes it possible to reduce fuel consumption and exhaust emissions while improving running smoothness.

Both individual systems of the VarioCam Plus (camshaft adjustment and valve lift switchover) are controlled by the Motronic control unit ME7.8.1. This control unit has been designed specifically for these requirements with a high processor capacity. This is necessary because the input values for “engine speed”, “accelerator pedal position”, “engine oil and water temperature” as well as gear speed detection are required to control VarioCam Plus. The demand for torque or power is compared with the stored program maps. A decision on how VarioCam Plus must react is made in milliseconds.

Camshaft Adjustment Of The Intake Camshafts

The 911 Turbo (997) features continuous adjustment of the intake camshafts by vane adjusters. The load and speed dependent adjustment range of the intake camshafts is 0 to 40 ° crankshaft angle.

Valve Lift Switching Of The Intake Camshafts

The small valve lift was increased from 3.0 mm (996) to 3.6 mm in order to make more efficient use of the advantages of VarioCam Plus with continuous camshaft adjustment and a larger adjustment range with respect to consumption, output and exhaust emissions. The valve lift adjustment system consists of switchable flat-base tappets on the intake side of the engine which are operated by means of an electrohydraulic 3/2-way switching valve.

Since there are two different cam forms on the intake camshaft, the corresponding valve lift curves act on the engine when the respective cams are switched. The flat-based tappets consist of two nested tappets which can be locked against each other by way of a pin. The inner tappet is in contact with the small cam and the outer tappet with the large cam. A hydraulic compensating element for the valve clearance is always integrated in the power flow of the tappet.

Cold Start

VarioCam Plus already significantly improves cold starting of the engine, and also allows emissions to be reduced during the warming-up phase.

Idle Speed

The engine is operated with the small intake cam (3.6 mm) at idle speed. Optimum timing is guaranteed thanks to fully variable camshaft adjustment. The small valve lift permits a reduction in fictional loss, a significantly increased charge movement thanks to the extremely short opening times, as well as lower emissions from previous combustions in the combustion chamber. This results in consumption and emission reductions of up to 10 % at the same time as significantly improved idling quality.

Partial Load

Operation with internal exhaust gas recirculation is optimum under partial load conditions for the purpose of dethrottling and in order to reduce the engine consumption. For this purpose, the camshaft phasing for the small valve lift is adjusted in order to achieve a large overlap, therefore allowing a large proportion of time for exhaust recirculation.

Full Load

In full-load operation, a high torque and high maximum output are achieved on the one hand through a low-loss charge cycle and, on the other, by an uncompromising cam contour design with a maximum valve lift of ten millimeters and correspondingly adapted opening and closing times of the valve strokes.

E-Throttle 7.1.1 – Cayenne (1st Generation)

General

The model year 2003/2004 Cayenne S and Turbo were the first Porsches equipped with Motronic (DME) ME 7.1.

The following DME 7.1.1 information was first published in the 2004 Cayenne S/T Service Information Technik book.

The newly developed 4.5-liter V8 naturally aspirated and V8 turbo engines in the Cayenne were specially designed for maximum specific power, as well as high torque over a broad rev band. The engine develops its power effortlessly and loves to rev, accompanied by a unique Porsche exhaust sound. It has outstanding emissions and fuel consumption characteristics and meets all applicable exhaust emission and noise legislation world-wide. It combines great reliability with a low need for service. Control of the electronic fuel injection using Motronic control module ME 7.1.1 permits continuously variable camshaft adjustment (VarioCam) and feedback with broad-band oxygen sensors.

Development Objectives for the Cayenne

- High specific output
- Outstanding torque curve
- Compliance with all legislative emissions requirements
- Low specific fuel consumption

The following engineering content was implemented in the Cayenne S and the Cayenne Turbo:

- Utilization of Motronic 7.1.1
- Electronic throttle valve control (E-Gas)
- Engine drag torque control (MSR)
- Air-gap insulated exhaust system up to the primary catalytic converter
- Broad-band LSU oxygen sensors ahead of the catalytic converters
- LSF oxygen sensors behind the catalytic converters
- CAN networking and MOST media network
- VarioCam with continuous adjustment of the intake camshafts
- Immobilizer with transponder system
- Returnless fuel system
- OBD II or EOBD adapted to different regulations world-wide

Cayenne S

- Maximum power 340 hp @ 6000 rpm
- Maximum torque 310 lb ft @ 2500 – 5500 rpm
- Idle speed 580 rpm
- Engine rpm limited to 6500 rpm with Tiptronic S (6700 rpm with manual transmission) through E-Gas and fuel cutoff.
- Intake manifold with variable induction charging
- Special spark plugs

Cayenne Turbo

- Maximum power 450 hp @ 6000 rpm
- Maximum torque 458 lb ft @ 2250 - 4750 rpm
- Idle speed 580 rpm
- Engine speed limited to 6500 rpm by E-Gas and fuel cutoff
- Special platinum spark plugs with 1 ground electrode
- Exhaust gas turbocharging
- Water-cooled turbocharger
- Supplementary turbocharger oil scavenging

Motronic (DME) ME 7.1.1

Electronic control of the Cayenne engine is by handled by the Motronic ME 7.1.1 The DME control module is located on the right side of the cowl.

The DME control module carries out the following tasks:

- Optimal fuel mixture under all operating conditions
- Reduction of fuel consumption
- Combustion control
- Monitoring and regulation of exhaust gas readings

The Motronic control module was adapted to the specific requirements of the V8 engine and contains the following functions or controls:

- Static high-tension ignition distribution with individual ignition coils
- Knock control with automatic adaptation of the ignition map to fuel quality
- Newly developed software to actuate the vane-type camshaft adjuster (position control)
- Throttle valve controlled by electric motor (E-Gas)
- Engine idle speed control (via E-Gas)
- Cruise control system regulation (standard for USA)
- Engine drag torque control (MSR)
- Hot-film mass airflow sensing using 2 HFM 5 CL air flow sensors
- Sequential fuel injection
- Fuel tank leak testing with leak diagnosis pump (USA only)
- Two-channel oxygen sensor feedback for independent control of the fuel-air mixture for both cylinder banks
- On Board Diagnostics
- Actuation of radiator fans
- Torque interface (via CAN) to Tiptronic S and PSM
- Actuation of secondary air injection

Cayenne Turbo Additional

- Absolute pressure-controlled boost pressure regulation
- Actuation of the electric run-on coolant pump
- Actuation of the vacuum pump to back up the brake pressure booster

Check-Engine Warning Light

The Check Engine warning light is used to monitor emissions (on vehicles for the U.S. it is also activated in the event of leaks in the fuel tank system). Emissions monitoring provides early detection of malfunctions, which can result in increased output of pollutants or subsequent damage to the catalytic converters. The Check Engine warning light and a message in the multi-function display in the instrument cluster indicates this. These malfunctions are stored in the trouble code memory of the DME control module.

As a functional check, the warning light illuminates when the ignition is switched on and goes out about 4 seconds after the engine is started.

- Check Engine warning light comes on steady – emissions related error
- Check Engine light flashes – error leading to catalytic converter damage

CAN Networking of the Motronic Control Module (in CAN drive)

Electronic networking allows the exchange of data and electronic information between the control modules. Data exchange in the drivetrain takes place over the two copper wires of the high-speed CAN. This CAN data bus combines the individual control modules into a total system. The K-wire is used for diagnosis.

The DME control module communicates with the following systems over the CAN data bus:

- ABS/PSM control module
- Steering angle sensor
- Tiptronic control module
- Airbag control module
- Air-conditioning control module
- Instrument cluster
- Rear control module (immobilizer) etc.

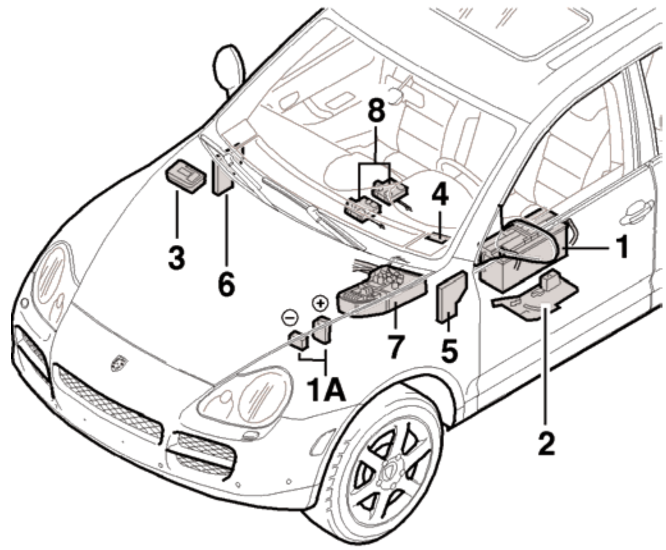
Immobilizer

The DME control module obtains the relevant information for arming the immobilizer over the CAN from the control module for convenience systems, which is installed in the right rear.

Crash Shut-Off

Depending on the impact angle and the impact speed, the airbag control module sends a signal whereby either the fuel pump is shut off by the DME control module (re-start possible), or the cutoff relay is opened directly (re-start possible only after re-activating the relay).

DME Power Supply



Overview of Component Locations

1 - Battery under driver's seat.
1A - Positive and ground connections in engine compartment.
2 - Current distributor with cut-off relay under driver's seat.
3 - DME control unit in the right cowl.
4 - Diagnostic connection under the instrument panel, left footwell.
5 - Fuse carrier instrument panel, left side.
6 - Fuse carrier instrument panel, right side.
7 - E-box in the cowl with fuse carrier, relay carrier 1 and relay carrier 2.
8 - Relay carrier 1 and 2 as needed below instrument panel (equipment dependent).

Safety Caution: Cut-Off Relay

The cut-off relay separates the battery from the electrical system in the event of an accident. After it is triggered, it must be re-set manually.

Starter

The DME control module interrupts actuation of the starter interlock relay and thus terminal 50 actuation to the solenoid if an RPM threshold is exceeded.

Fuel Supply

The use of the most up-to-date engine technology makes possible fuel consumption, which is low in relation to the performance potential and weight of the vehicle.

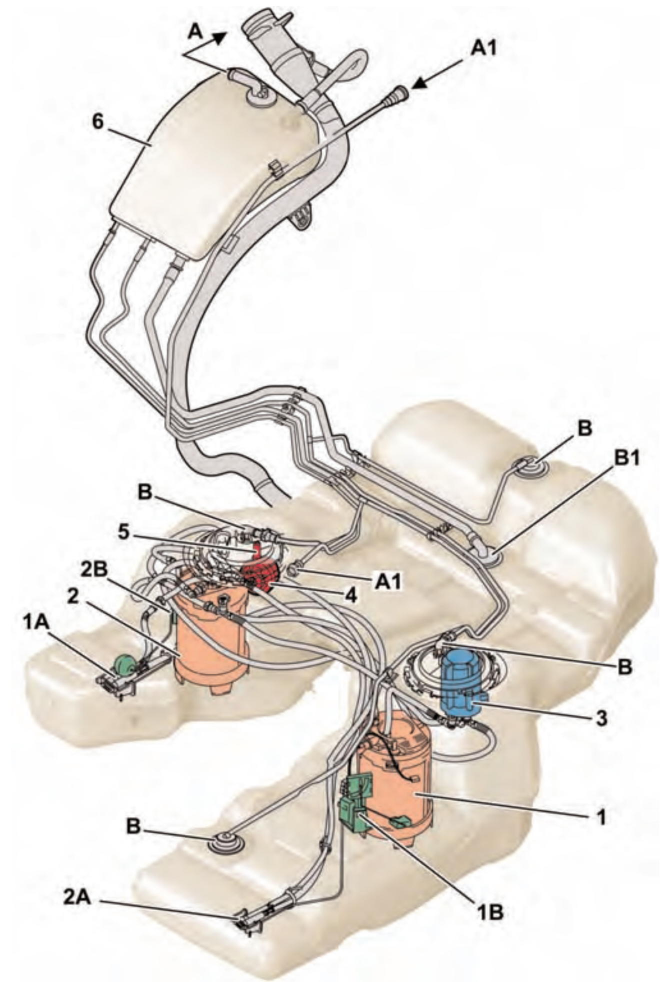
In order not to compromise operation of the catalytic converters and oxygen sensors, unleaded fuel must be used exclusively.

The engines were designed optimally for 93 Octane fuel with respect to power and fuel consumption. If 90 Octane fuel is used, ignition timing is automatically adjusted to a retarded ignition map by the control unit.

Fuel Tank

The fuel tank is located ahead of the rear axle and is additionally protected from below by high-strength plastic covers. The fuel tank is made of high-density, multi-layer polyethylene with a capacity of approximately 26.5 gallons (of which approximately 4 gallons is reserve).

The filler opening is located on the passenger side in the quarter panel above the rear wheel.



Component Location in the Fuel Tank

1 - Left Fuel Pump
1A - Vacuum Booster Pump For The Left Fuel Pump
1B - Left Fuel Pump Sender
2 - Right Fuel Pump
2A - Vacuum Booster pump For The Right Fuel Pump
2B - Right Fuel Tank Sender
3 - Fuel Filter
4 - Fuel Pressure Regulator
5 - Fuel Pressure line To The Engine
6 - Percolation Tank (for ventilation lines B and B1)
A - To Activated Charcoal Filter
A1 - From Activated Charcoal Filter To The Fuel Tank Ventilation Valve In The Engine Compartment

Returnless Fuel System (RLFS)

A returnless fuel system (**RLFS** = **R**eturn **L**ess **F**uel **S**ystem) is used on the Cayenne. In this system the fuel pressure regulator as well as the fuel filter is integrated into the fuel tank. As a result, no return line from the fuel distributor in the engine compartment to the fuel is required with this system. Only the quantity of fuel injected by the fuel injectors is pumped to the fuel distributor in the engine compartment. Doing away with the return line has the benefit that no fuel heated in the engine compartment is returned to the fuel tank to increase fuel temperature there. This further reduces the formation of fuel vapor in the tank.

Fuel Pump (Left-side and Right-Side)

Two electric fuel pumps with integral pressure-side operated vacuum booster pumps are installed. Fuel pump 2 comes into operation depending on demand and fuel level in the tank.

The operating principle is the same as that of the sports cars. In each case, a two-stage full-flow pump is combined in one, with a pre-stage for charging and a main stage for pressure build-up. The vacuum booster pump for fuel pump (1) is located in the right half of the fuel tank, the one for fuel pump (2) in the left half. So fuel is picked up at four different locations in the tank. This ensures a supply of fuel even in difficult terrain. With this cross-over delivery, the tank can be drained on a level road by each pump.

When the driver's door is first opened, the signal from the door contact switch (via CAN) is additionally used to briefly activate the fuel pump. Fuel pressure is already built up before the engine is started. In the event of an accident with airbag deployment, the fuel pumps are switched off.

Regulation of Fuel Quantity

As a result of the on-demand regulation of fuel flow capacity, fuel heating in the tank is reduced. The DME control module switching on fuel pump 2 only as required, while fuel pump 1 is always activated. With the following switching criteria, fuel pump 2 is additionally switched on to increase flow capacity. At engine start and then 2 seconds run-on (with a hot start 5 seconds run-on). With a calculated fuel consumption of approximately > 13.2 gal./hour the pump is switched on, and at about < 12 gal./hour switched off again. With a fill level of approximately < 2.5 gallons in the tank, it is switched on and with about > 4 gallons it is switched off again.

Fuel Filter

The fuel filter does not need to be changed. It is integrated into the left-side sending unit. The connections at the fuel filter for the left-side and right-side fuel pumps are different in diameter.

Fuel Pressure Regulator

The pressure regulator is also built into the fuel tank below the right-side tank flange.

Fuel pressure, which is present right up to the fuel injectors, is about 58 psi (4.0 bar) from idle to wide-open throttle. The quantity injected is thus dependent on intake manifold pressure, which is measured by the DME control module when calculating injection duration.

Fuel Supply Sender

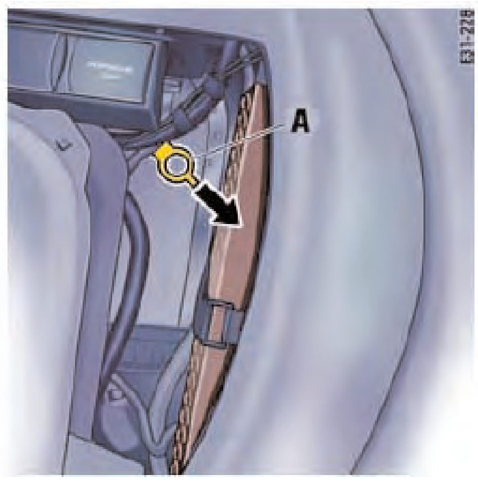
The information from the two senders for the fuel supply is reported to the instrument cluster to calculate the fuel supply. To prevent corrosion and poor contact, the potentiometer sliding contacts are gold-plated.

Fuel Gauge

With the ignition switched off, fuel tank contents are displayed. If the amount of fuel falls below about 4 gallons, the reserve warning light is activated.

Emergency Unlocking of the Fuel Filler Flap

If the power locking system should fail, the fuel filler flap can still be unlocked mechanically.



Open the rear hatch, remove the cover from the right-side storage bin in the baggage compartment and pull the emergency release in the direction of the arrow (A), the filler flap will pop open.

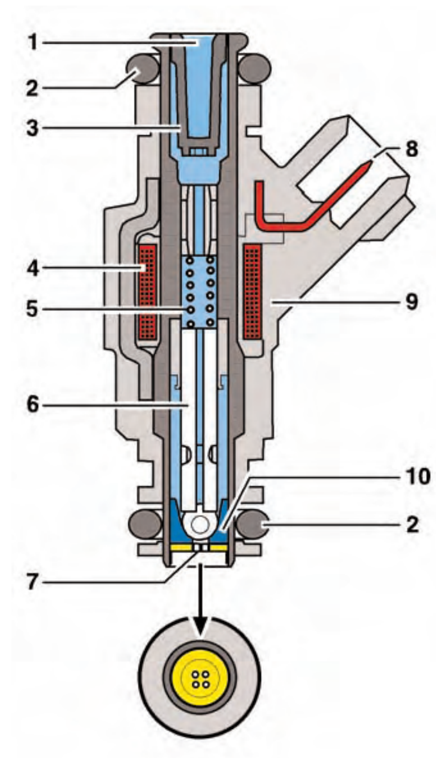
Fuel injector (EV-6)

Small external dimensions and low weight characterize this fuel injector. The risk of vapor lock with hot fuel is very low. As a result, it is well suited for use with returnless fuel systems, since fuel temperature in the fuel injector compared with systems with a return is higher.

Fuel is atomized with a perforated disk (4 holes). The stamped injection orifices provide great consistency in the quantity of injected fuel as well as insensitivity to fuel deposits. Good tightness in the area of the injector seat is ensured through the cone/sphere sealing.

In the Cayenne S, the fuel injectors are designed for a maximum injection volume of 210 g/min. In the Cayenne Turbo, this volume was adapted to 349 g/min because of the increased engine performance.

The DME control module activates each fuel injector sequentially. This allows injection of the fuel for each cylinder in a precisely defined time interval, even when driven in a sporting manner, which contributes to reducing fuel consumption and the emission of pollutants.



Fuel Injector Layout

1 - Fuel Connection
2 - Seal O-ring
3 - Filter Screen
4 - Winding
5 - Spring
6 - Needle Valve With Solenoid Armature And Sealing Ball
7 - Perforated Injection Disk
8 - Electrical Connection
9 - Injector Housing
10 - Injector Seat

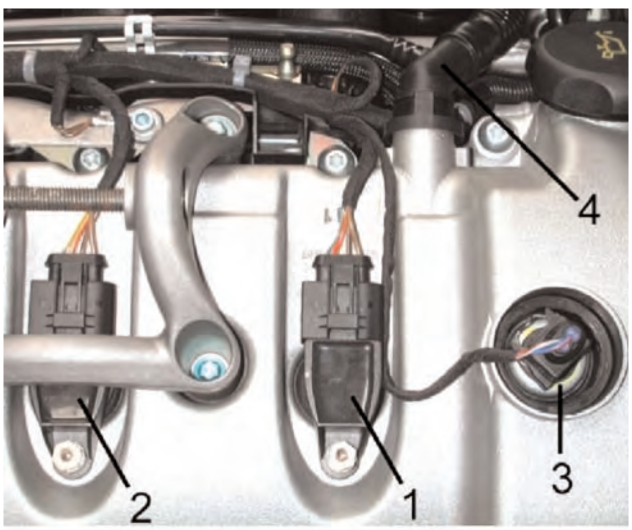
Ignition System

The Cayenne has static high-tension ignition distribution with individual coils, which are mounted directly to the spark plugs. The benefits of this system are:

- Highly reliable ignition
- Minimal electromagnetic interference with other electronic components
- No need for spark plug wires and distributor

Ignition Coil

The Motronic ME 7.1.1 assumes control of the individual coils with the firing order 1-3-7-2-6-5-4-8. Through the steps described and with the benefits of the ignition system, reliable ignition is achieved, maximizing performance and minimizing emissions and fuel consumption.

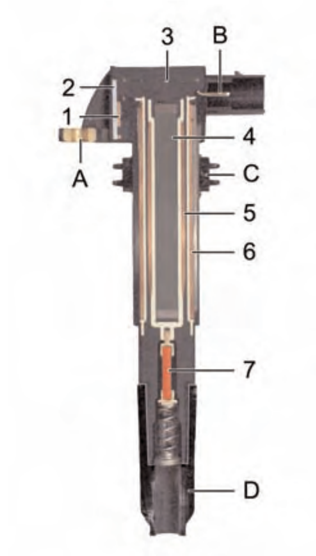


1 - Ignition Coil Cylinder 1 (bank 1 right front)
2 - Ignition Coil Cylinder 2
3 - VarioCam Valve (bank 1)
4 - Crankcase Ventilation

With this new coil design, the final stage electronics are combined in the ignition module housing. The housing is connected electrically and mechanically by the short high-voltage connector to the spark plug in the plug recess.

There is a supplementary mechanical attachment through a threaded connector. The ignition coil is sealed at the 4-pin connector as well as in the plug recess against water. Ignition coil pin-out.

Pin 1 - Body ground
Pin 2 - Engine ground
Pin 3 - B+ terminal 15
Pin 4 - Ignition signal (trigger input)



Ignition Coil Construction

A - Mounting Eye
B - Connector Terminal
C - Plug Recess Gasket
D - High Voltage Connector To Spark Plug
1 - Power Output Stage
2 - Cooling Plate For Power Output Stage
3 - Electronics Board With Integral Diagnostic Function And Current Limiter
4 - Magnetic Core
5 - Secondary Winding
6 - Primary Winding
7 - Electrical Resistance

Note:
The coil must be pulled straight out of the valve cover and not tipped to the side when it is removed or the coil may be damaged.

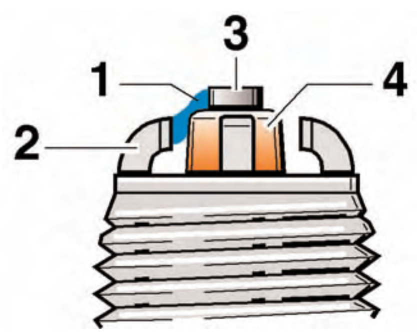
Operation of Electrical Components in the Ignition Coil

The ignition coil ensures optimal combustion of the air-fuel mixture in the engine combustion chamber. If the coil is triggered for an excessive time, the primary current in the coil is driven down, so that spark-free engine shutdown is ensured.

Diagnostic functions are also integrated. When an error is detected, pin 4 (trigger input) is switched to high impedance. This is detected in turn by the DME and the error is entered in the trouble code memory.

Cayenne S Spark Plugs

With these glide spark plugs the 4 ground electrodes are located to the side of the ceramic insulator. As a result, the sparks (1) always glide over the surface of the insulator (4) and jump through a small gas path to the ground electrode (2), producing better ignition properties. The primary benefit of the glide spark plug lies in the self-cleaning effect of the insulator tip since any shunts occurring between the center electrode and ground electrode are eliminated through the sliding sparks, particularly during cold starts. These spark plugs make possible a change interval of 60,000 miles (90,000 km) in the Cayenne S.



Construction of the Cayenne S Glide Spark Plug

1 - Glide Spark Path
2 - Ground Electrode
3 - Center Electrode
4 - Insulator

Cayenne Turbo Spark Plugs

Special platinum spark plugs with one ground electrode are used in the Cayenne Turbo, allowing a change interval of 40,000 miles (60,000 km). Through the use of a very thin center electrode, voltage requirements are correspondingly reduced, to ensure adequate voltage reserves for the ignition system over its entire service life.

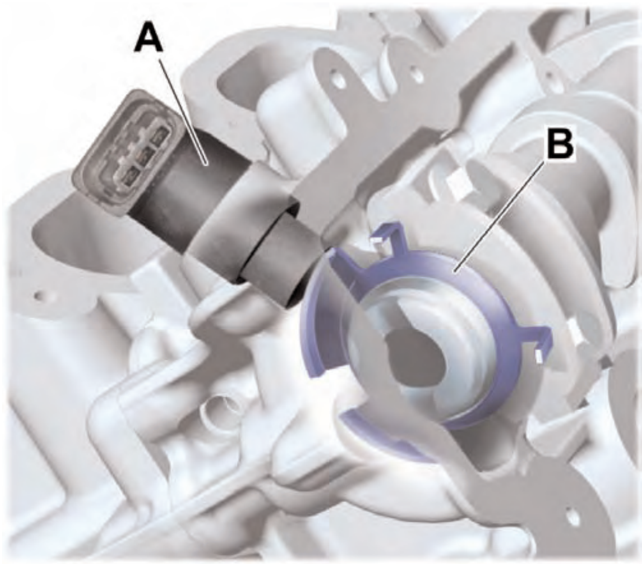
The use of glide spark plugs is not possible especially with turbocharged engines, since ceramic nicks can be caused on the insulator tip by higher combustion pressures, which in turn can result in reduced change intervals or premature failure of the spark plug.

Engine Speed Sensor

The inductive engine speed sensor on the bell housing registers engine RPM and the current position of the crankshaft by means of 57 windows in a flange on the flex plate. One window is made wider to indicate crankshaft position to the DME control unit.

Hall Sensor

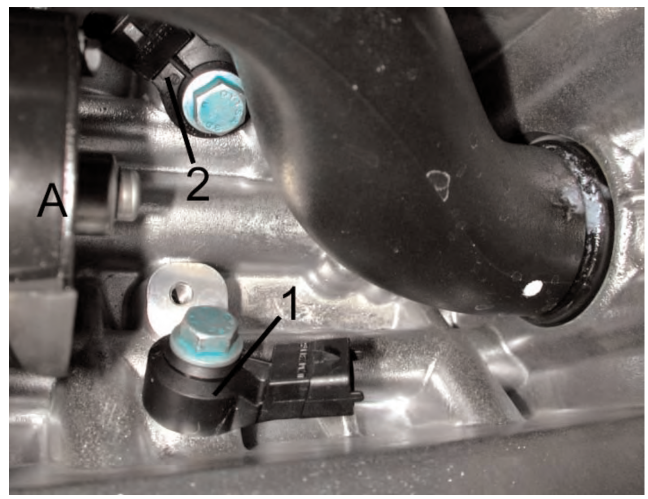
A modified rotor is mounted on the intake camshafts for both banks of cylinders. Based on the rotor position, the Hall sensor determines the current position of the intake camshaft 4 times per camshaft revolution and passes this value on to the control module. Thus the exact position of both intake camshafts is determined, which is the precondition for continuous camshaft adjustment.



A - Hall Sensor
B - Camshaft Rotor

Knock Sensor Bank 1 and 2

The knock sensors are mounted on the crankcase below the intake manifold. They detect the structural acoustic oscillations of the crankcase. The mechanical vibrations are transmitted with the help of the piezoelectric effect as electrical voltage signals to the DME control module. If the DME control module detects "knock," the ignition timing at the cylinder in question (cylinder-selective) is retarded. Retardation takes place in steps of 3º CA (crankshaft angle) and can be advanced again in stages of 0.75º, which takes place within 10 to 20 seconds. Maximum retardation of ignition timing is 18º of crankshaft angle up to 1600 RPM, over 1600 RPM it is limited to 15º of crankshaft angle.



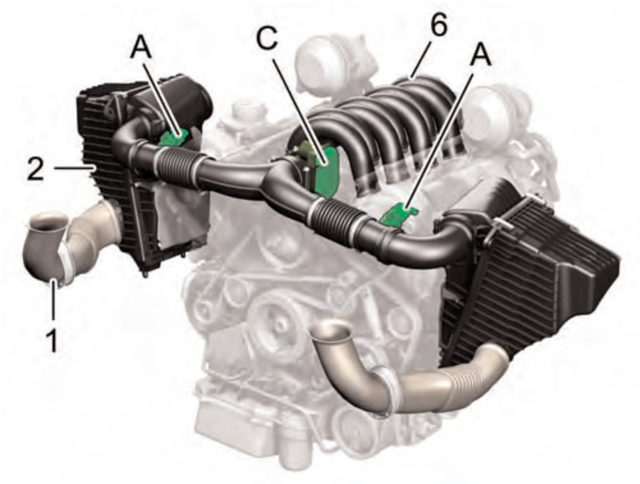
1 - Knock Sensor - Bank 1
2 - Knock Sensor - Bank 2
A - Starter

If a knock sensor, Hall sensor or engine speed sensor fails, adjustment is retarded for safety. In this case, ignition timing up to 4400 RPM is retarded by 15º of crankshaft angle. Above 4400 RPM up to 6000 RPM retardation is reduced to 12º of crankshaft angle.

Air Flow

Cayenne S

Air flow from the air duct (intake pipe) behind the front end, through an air filter on both the left and right to the two mass air sensors. Then the intake air flows together ahead of the throttle valve control unit (E-Gas) and is delivered to the engine through the intake manifold.



Cayenne S Air Flow Layout

1 - Air Duct (intake pipe)
2 - Air Filter Housing With Filter Insert
6 - Composite Intake Manifold
A - Hot Film Mass Airflow Sensor
C - Throttle Valve Control Unit (E-Gas)

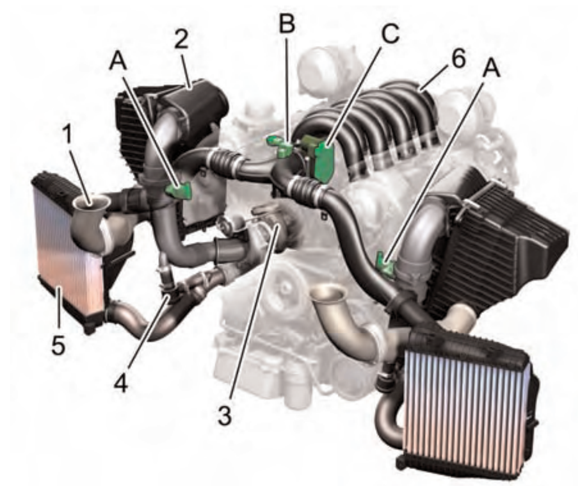
Air Filter Elements

The two air filter elements for the Cayenne S and Cayenne Turbo must be changed every 75,000 miles (120,000 km). In dusty areas, the air filter elements should be cleaned more frequently and replaced if necessary.

Cayenne Turbo

Air flows from the air duct (intake pipe) behind the front end, through an air filter on both the left and right to the two mass air sensors. Then the intake air is delivered to the compressors of the two turbochargers. Then the compressed and heated charge air is recooled by means of a charge intercooler located in each of the wheel housings. Boost pressure and charge air temperature of the intake air that is being delivered to the engine is registered in the combined airflow ahead of the throttle valve control unit. Cooling the compressed charge air achieves good cylinder filling and low component temperatures.

You can find a description of boost pressure control in the Turbocharger section.



Cayenne Turbo Air Flow Layout

1 - Air Duct (intake pipe)
2 - Air Filter Housing With Filter Insert
3 - Exhaust Turbocharger
4 - Deceleration Air Recirculation Valve
5 - Charge Air Intercooler
6 - Composite Intake Manifold
A - Hot Film Mass Airflow Sensor
B - Charge Air/Intake Temperature Sensor
C - Throttle Valve Control Unit (E-Gas)

HFM 5 CL Hot-Film Mass Air Sensor

The venturi mass air sensors on the left and right are supplied as a replacement part with the measuring venturi. The mass air sensor must not be removed from the measuring venturi, since these parts were matched on a flow bench. The diameters of the measuring venturis are different based on the different air throughput between Cayenne S (low) and Cayenne Turbo (high).

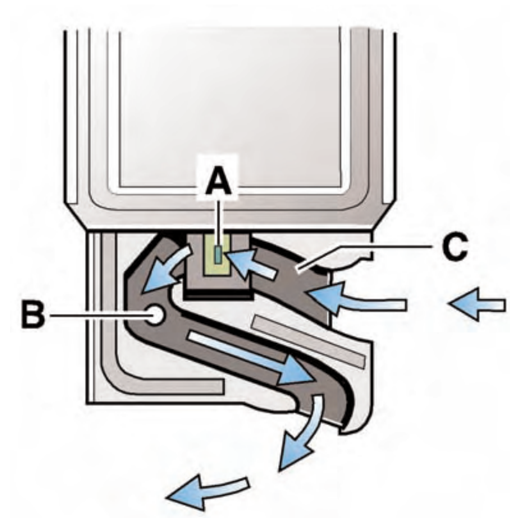
On the Cayenne S the signal from the intake air temperature sensor is sent to the DME control module by a mass air sensor.

On the Cayenne Turbo the mass air sensors and measuring venturis are matched to the high air throughput. Air temperature is registered by the boost pressure-charge air sensor, which is mounted ahead of the throttle valve. The values measured are made available to the DME control module.

Venturi Mass Air Sensor

S - Cayenne S (small diameter)
T - Cayenne Turbo (large diameter)

As a result of the C-shaped air duct, these mass air sensors are less sensitive to dirt particles and water drops, since they reach the sensor element only after a reversal of the air stream. A transverse hole through the air passage serves to reduce pulsation errors.

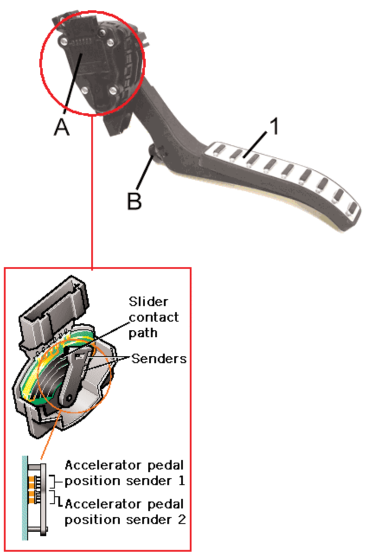


A - Sensor Element
B - Cross Drilling
C - C-Shaped Air Passage

To calculate the total air mass, which serves as the primary load signal, the air mass from the left and right mass air sensors are added together in the control module. Should one or both mass air sensors fail (for example, as the result of an open or short circuit), or if the total air mass (sum of the two mass air sensors) deviates from a tolerance range calculated in the control module, an error is stored and a substitute value is created from throttle valve angle and engine speed.

Accelerator Pedal

With the newly developed accelerator pedal in the Cayenne, the accelerator position sensor is integrated into the pedal assembly. Therefore no throttle cable is required. The characteristic curves of the two integral potentiometers are comparable with those of the ME 7.2 systems and act as an input signal (driver request) to calculate the torque-oriented operational construct, which triggers the engine management system accordingly.



1 - Accelerator Pedal
A - Pedal Potentiometer
B - Spring-pressure Unit

On vehicles with Tiptronic, Kickdown is recognized electrically by way of the characteristic curve of the potentiometers. A spring-pressure unit is installed for driver feedback.

Learning Kickdown Adaptation

In order to achieve reliable conformance between electrical recognition of Kickdown and the increase in power when the pedal is operated, adaptation must be carried out. The result of this adaptation is stored in the EEPROM of the DME control module and as a result it is retained even after disconnecting the battery terminals.

Kickdown adaption is necessary under the following conditions:

- Initial vehicle start-up at the end of the line
- Service replacement of the engine control module (ECM)
- Service replacement of accelerator pedal module

Throttle Valve Control Unit (E-Gas)

The range of operation of E-Gas corresponds basically to the operation described for vehicles with Motronic ME 7.2 and ME 7.8. In the case of the electronic throttle valve control unit (E-Gas), the throttle valve is adjusted by an electric motor over a two-stage gear. Thus electronic control of the air inducted by the engine is possible over the entire load range.

Operating characteristics (relationship between engine torque and accelerator pedal position) are clearly established with E-Gas, which offers the following benefits:

- Increased driver comfort
- Engine speed can be better controlled and limited
- Reduction of engine emissions
- Improved cruise control operation
- Improved shift comfort with Tiptronic S
- Assistance for the traction control systems (e.g. PSM, MSR)
- Engine protection in the event of failures in the area of boost pressure control (Cayenne Turbo)

As the result of active intervention by the throttle valve control unit (E-Gas), the following functions are made possible:

- On deceleration, with unacceptably high engine braking when downshifting, engine drag torque control (MSR) prevents all the drive wheels from locking on a slippery road by slightly opening the throttle valve.
- If braking functions are not sufficient to stabilize the vehicle when PSM is activated, E-Gas intervenes in engine control. A change in engine torque is initiated by changing the ignition timing and intervening in throttle valve adjustment.

Throttle valve control unit (E-Gas) adaption must be performed under the following circumstances:

- Following a reset (e.g. disconnecting the battery)
- If the connectors at the DME control module were separated

To perform adaptation, switch on the ignition for 1 minute (do not start the engine and do not operate the accelerator pedal), then switch off the ignition for at least 10 minutes. The throttle valve stop (close) is re-adapted.

Cruise Control (Standard USA)

The Motronic control module implements this function by positioning the throttle valve control unit (E-Gas) accordingly. Cruise control is operated through the lower left lever on the steering column to select a speed between about 25 and 131 MPH.

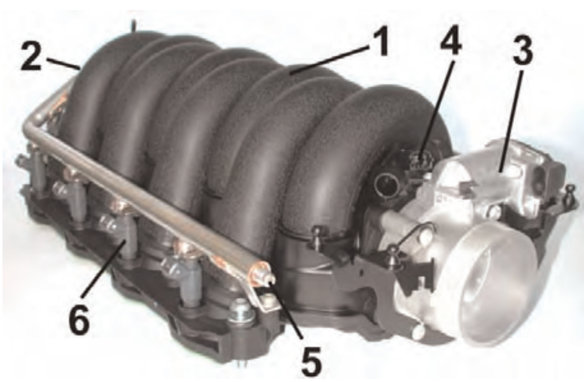
Intake Manifold

The principle of pulse manifold charging was followed when designing the intake manifold. Through proper layout of the intake runner lengths and intake runner diameters, in conjunction with optimized intake port geometry as well as continuous adjustment of the intake camshafts, it was possible to achieve a wide torque curve.

The benefits of the plastic intake manifold, manufactured in several steps (multi-process technology) are:

- Minimization of pressure losses
- Equal intake runner length
- High component rigidity with low weight

This manufacturing process brings benefits in pulse tuning and acoustics resulting from component rigidity. In addition, the optimal surface finish inside the intake manifold lowers pressure losses and improves torque.



Composite Intake Manifold Layout

1 - Composite Intake Manifold
2 - Vacuum Reservoir (at the rear integrated in the intake manifold
3 - Throttle Valve Control Init (E-Gas)
4 - Heating Element For Crankcase Ventilation
5 - Connection For Measuring Fuel Pressure
6 - Fuel Injector

A two-piece vacuum reservoir (which has a pre-stage with a calibration drilling as a buffer) is integrated in the rear section of the intake manifold. It is needed in the Turbo to activate the overrun recirculation air valves and to activate the leak diagnosis pump.

Electrically Heated Crankcase Ventilation

The crankcase ventilation on the Cayenne engines has an electric heating element that prevents icing of condensate in this area. This heating element is integrated in the connecting pipes for the crankcase ventilation. The connecting pipe is installed behind the throttle valve control unit.

The heated copper ring in the heating element contains a PTC with an electrical resistance of 5 – 13 ohms (68° F./20° C). As soon as outside temp falls below 37° F. (3° C), the heating current is switched on by the DME control module and controlled through an outside temperature-dependent duty cycle between 3A and 0A.

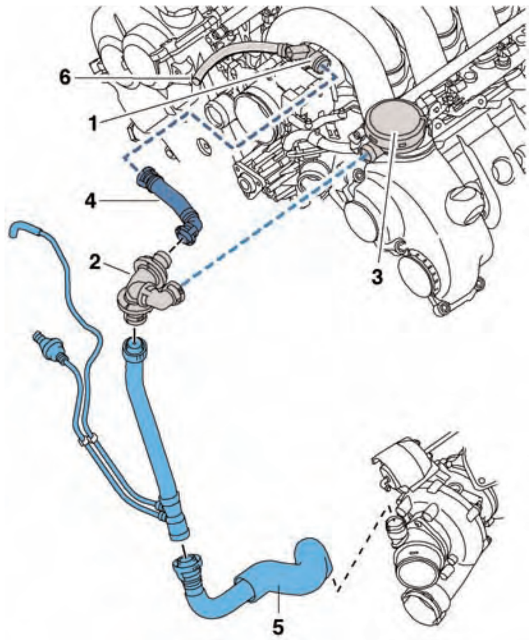
When it is first switched on, current draw may rise to 5A for a short period.

Crankcase Ventilation Heating Element

1 - Connector For Electric Heating
A - From Engine Ventilation - Bank 1
B - From Fuel Tank Ventilation Valve
C - Connection To Composite Intake Manifold

Fuel tank ventilation, as well the ventilation system for the turbocharger oil catch tank on the Turbo is taken to the intake system via the connecting pipe for the heated crankcase ventilation.

Through the arrangement of the non-return valves, the airflow on the Cayenne Turbo reaches the intake manifold at idle and under boost pressure it reaches the intake side of the left turbocharger.



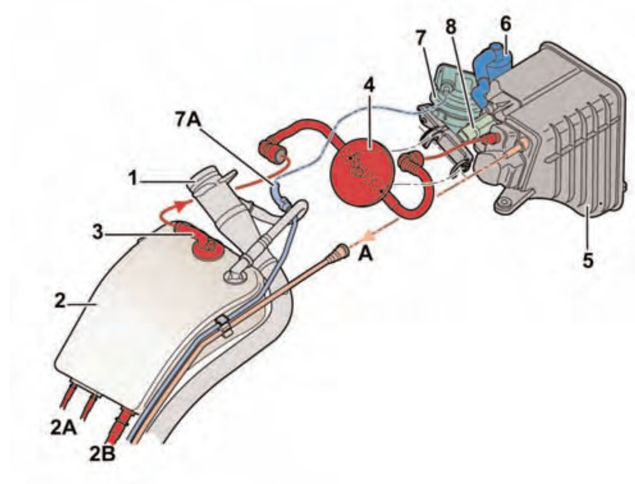
Cayenne Turbo Crankcase Ventilation

1 - Heating Element For Crankcase Ventilation
2 - Non-return Valves - Intake Side/Pressure Side
3 - Oil Vapor Separator
4 - Tube To Intake Manifold
5 - Hose To Intake Side Of The Left Turbocharger
6 - Connection For Fuel Tank Ventilation

Fuel Tank Ventilation ORVR Vehicles

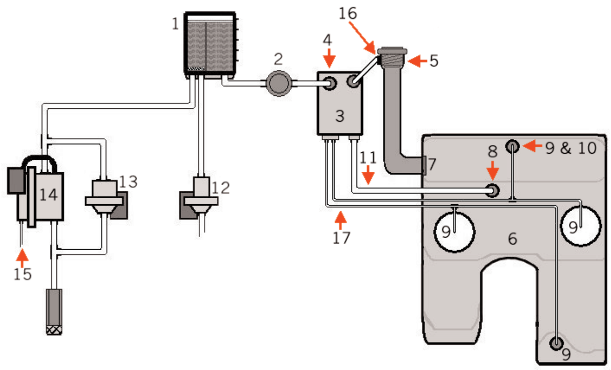
As a result of the legal provisions in the U.S. The ORVR system (**O**n-Board **R**efueling **V**apor **R**ecovery) ensures that the resulting HC vapors are directed into the activated charcoal filter during refueling and do not escape into the atmosphere.

In addition, the OBD II system (On-Board Diagnostic System) monitors the fuel system for leaks with the aid of a leak diagnosis pump (LDP). The LDP system performs leak checks regularly and can detect leaks 0.5 mm or more in diameter.



Fuel Tank Ventilation Layout

1 - Filler Neck
2 - Percolation Tank (ORVR one-piece)
2A - Fuel Tank Operating Ventilation
2B - Refueling Ventilation
3 - Connection To Carbon Canister
4 - Pressure holding Valve
5 - Carbon Canister (ORVR with flange for leak diagnosis pump)
6 - Water Separator With Filter Element and Fresh Air Induction
7 - Leak Diagnosis Pump
7A - Vacuum Line From Intake Manifold To Leak Diagnosis
8 - Shut-off Valve
A - To Fuel Tank Ventilation Valve (in engine compartment)



Simplified Evaporative Emissions, ORVR with LDP Diagram

1 - Evap Canister
2 - Vacuum Limiting Valve
3 - Percolation Valve
4 - Over Pressure Relief Valve
5 - Filler Neck
6 - Fuel Tank
7 - Spring Loaded Flap
8 - Fill Limit Venting Valve
9 - Rollover Valves
10 - Over Pressure Valve
11 - Refueling Vent Line
12 - Evap Valve
13 - Evap Valve Shut-off Valve
14 - LDP
15 - Vacuum Inlet From Intake Vacuum Reservoir
16 - One Way Check Valve
17 - Tank Vent Lines

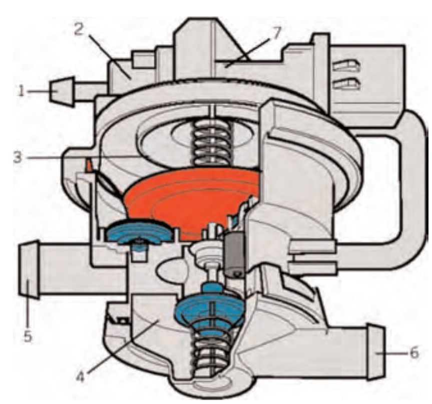
During normal venting operation the Hydrocarbon laden fumes from the fuel in the Fuel Tank (6) rise to the Percolation Tank (3) via the Tank Vent Lines (17) and Refueling Vent Line (11). The pressure in the tank is regulated to about 40 Millibar by the Vacuum-Limiting Valve (2) so as not to allow the fuel to boil in the low pressure. The fumes stored in the Evap Canister (1) where they are purged to the engine by the DME controlled Evap Valve (12) during purging.

During refueling the fuel vapors rise to the Percolation Tank (3) via the Refueling Vent line (11) and Vent Lines (17) until the fuel level rises to close the float valve in the Fill Limit Vent Valve (8). The Fill Limit Vent Valve (8) closing causes the pressure in the Filler Neck (5) to rise and shut off the fuel filling nozzle.

Leak Diagnosis Pump

The leak diagnosis pump consists of a diaphragm pump and an electrical frequency valve. Intake manifold vacuum from the vacuum reservoir integrated at the rear in the intake manifold reaches the vacuum side of the diaphragm pump through the electrically cycled valve, and positive pressure in the millibar range is created. Depending on how quickly this positive pressure is built up, and the fuel tank provides counter-pressure, a reed switch on the diaphragm provides feedback to the DME. By evaluating the time differentials and pump strokes, the integrity of the fuel system or the size of the leak is recognized. Leakages less than 0.25 mm in diameter are recognized as a minor leak and displayed through the “Check Engine” light after the leak is confirmed. Larger leakages, as well as an open fuel filler cap, are diagnosed as a gross leak.

Following a lengthy shut-down phase (so that fuel temperature is as low as possible) the diagnostic sequence is started under constant driving conditions (e.g. interstate highway driving). Leak diagnosis can be performed once or twice each day during vehicle operation if conditions are met (differential of starting temperature to engine shut-down temperature > 108° F. (42° C).

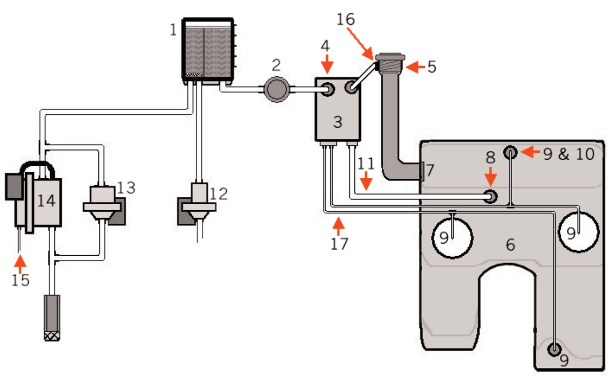


Cross Section Leak Diagnosis Pump

1 - Vacuum Connection (from vacuum reservoir in intake manifold)
2 - Electric Frequency Valve For The Diaphragm Pump
3 - Vacuum Side Of The Diaphragm Pump
4 - Pressure Side Of The Diaphragm pump
5 - Connecting pipe To The Charcoal Filter (pressure side)
6 - Connecting Pipe To The Water Separator/Filter Element
7 - Electrical Reed Switch

Evap Shut-Off Valve

The shut-off valve (13) sits in a by-pass to the leak diagnosis pump and voltage is only applied during diagnosis, closing the by-pass. At the conclusion of diagnosis, the valve is opened again to dissipate the positive pressure built up in the fuel tank.



Overview of Leak Diagnosis

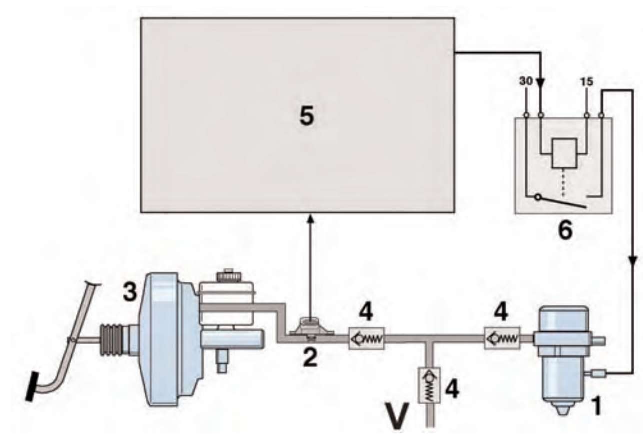
During a leak diagnosis check the Evap Valve (12) and the Evap Vent Valve (13) are closed by the DME. The DME then cycles the Electric frequency valve for the diaphragm pump (2, top of page) allowing manifold vacuum to enter from vacuum reservoir in intake manifold (1, top of page) this causes the Vacuum side of the diaphragm pump (3, top of page) to rise and draw air in the Connecting pipe to the water separator/filter element (6, illustration to left). The vacuum is then released as the pressure is built from this pumping action the Connecting pipe to the activated filter charcoal filter (5, illustration to left) raises the pressure throughout the evap system. The rising pressure causes the Electrical Reed Switch (7, illustration to left) to make contact and send a signal to the DME

If the pump cannot build enough pressure to keep the reed switch closed during the checking phase of the test, this indicates a minor leak to the DME. If the pump cannot build enough pressure to close the reed switch during the test phase of the test this indicates a major leak to the DME.

Vacuum Pump to Assist the Brake Booster (Cayenne Turbo)

On the Cayenne Turbo an electric vacuum pump is installed to improve brake boost. It is located in the engine compartment on the right strut tower under the styled cover. Under engine operating conditions with reduced vacuum supply (e.g. catalytic converter heating following a cold start, parking maneuvers, driving at high altitudes), the vacuum pump is activated by the DME control module.

The DME control module acquires the pressure through a pressure sensor in the vacuum line from the brake booster and activates the vacuum pump, as required. Depending on the current ambient pressure, for example at 1000 mbar ambient pressure, the pump is switched on at a brake booster pressure of around 500 mbar and switched off again at about 300 mbar. On-time in normal operation without brake use is about 7 to 10 seconds, at high altitudes the switch-on point is lowered.



1 - Electric Vacuum Pump
2 - Pressure Sensor
3 - Vacuum Brake Booster
4 - Non-return Valves
5 - DME Control Module
6 - Relay
V - Vacuum To Engine

Exhaust System

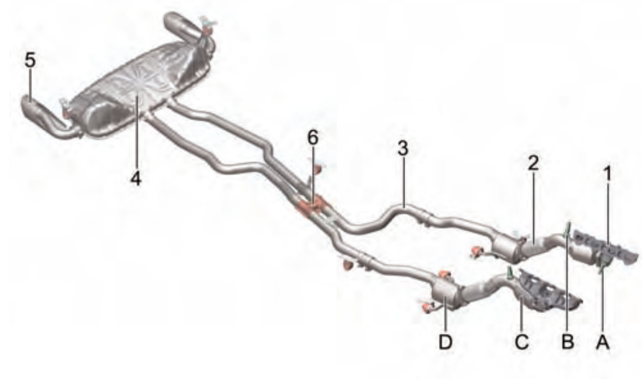
The Cayenne S and Cayenne Turbo underscore the engine note through a typical Porsche load-dependent exhaust note, which was tuned through the rear mufflers and tail pipes and satisfies all applicable legal requirements. To achieve long life and long-term attractive appearance, the entire exhaust system is made of stainless steel, which has particularly good corrosion resistance. The exhaust system consists of two exhaust tracts. Exhaust gases are taken through air-gap insulated exhaust headers with the shortest possible pipe length to the preliminary catalytic converters. The short pipe lengths not only speed up heating of the catalytic converters, but also reduce energy losses in the exhaust gases.

By arranging the flex pipes between the pre-catalytic converters attached to the engine and the main catalytic converters attached to the body, the transmission of engine vibration to the body was effectively eliminated. The left and right exhaust tracts come together again in the rear muffler.

Cayenne S Exhaust System

By means of a cross-connection (cross-over point only on Cayenne S), that is, a pipe which connects both exhaust tracts, the two exhaust tracts, or the oscillating exhaust gas columns, are linked together after the primary catalytic converters. This positively influences the torque curve in the lower RPM range.

The rear muffler in the Cayenne S has individual tail pipe tips on the left and right.



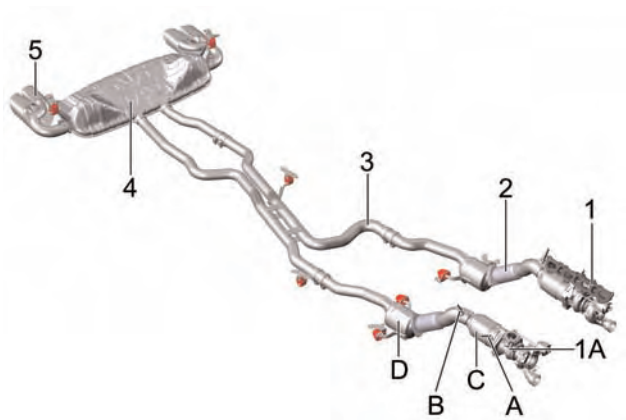
1 - Exhaust Header
2 - Decoupling Element
3 - Exhaust Pipe
4 - Rear Muffler
5 - Tail Pipe Enclosure (cross-over, Cayenne S only)
6 - Cross Connection (cross-over, Cayenne S only)
A - LSU Oxygen Sensor (ahead of catalytic converter)
B - LSF Oxygen Sensor (after catalytic converter)
C - Preliminary Converter
D - Main Catalytic Converter

Cayenne Turbo Exhaust System

The exhaust system on the Cayenne Turbo was matched to the increased requirements and different exhaust gas velocities and exhaust gas pulsations through exhaust pipes with a larger cross section.

As a result of the smoothing of the exhaust gas pulsations in the turbochargers, the demands on the rear muffler are different than with the Cayenne S. An optimal exhaust note is achieved through specific damping and pipe routing inside the rear muffler together with the tail pipes.

Differing from the Cayenne S, the exhaust pipes for the Cayenne Turbo do not have a crossover point. The rear muffler on the Cayenne Turbo is also installed as a visible design element. Exhaust gases leave the Cayenne Turbo through two tail pipe tips on the outer left and right, whose design differs from the Cayenne S.



1 - Exhaust Header
1A - Exhaust Turbocharger
2 - Decoupling Element
3 - Exhaust Pipe
4 - Rear Muffler
5 - Tail Pipe Enclosure
A - LSU Oxygen Sensor (ahead of catalytic converter)
B - LSF Oxygen Sensor (after catalytic converter)
C - Preliminary Converter
D - Main Catalytic Converter

Exhaust Treatment

Contributing factors to the excellent emissions numbers for the Cayenne include the modern control concept of the DME, the On-Board Diagnostic System (OBD II and EOBD) as well as the exhaust system with metallic catalytic converters and two-channel oxygen sensor feed back. Two oxygen sensors per cylinder bank handle monitoring of exhaust gases and functional monitoring of the catalytic converters. They provide the information to the DME control module for regulating exhaust gas figures. The lowest possible emission of pollutants is achieved through this two-channel oxygen sensor feedback. To reduce pollutants during warm-up, the catalytic converters are heated up rapidly as the result of measures in the engine management system, such as, retarded ignition and injection of secondary air in the exhaust tract for afterburning. The corresponding opening of the throttle valve control unit compensates for the associated reduction in torque.

Emissions Standard

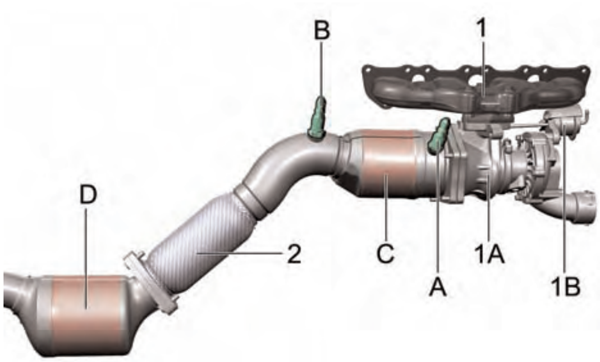
In Europe the Cayenne S and Cayenne Turbo are classified as Stage 4 (EU4) and in the U.S. as an LEV I (Low Emissions Vehicle). Both Cayenne engines are substantially below the threshold values of the EU4 guideline, which goes into effect in 2005 as well as all other applicable legislative directives.

EU4 – Europe: These vehicles meet EOBD (European On Board Diagnosis) and have four oxygen sensors (the oxygen sensors downstream of the catalytic converter run the control system), 3-way catalytic converter systems with two preliminary and two primary catalytic converters, as well a secondary air system for each cylinder bank.
LEV I – USA: Unlike EU4 these vehicles satisfy OBD II (On Board Diagnostics II) and ORVR (on-board recovery of vapors during refueling)

Preliminary and Primary Catalytic Converters

The preliminary and primary catalytic converters are made of metal. This allowed the coated inner walls to be of a thinner design than, for example, ceramic catalytic converters and the result is a greater total surface area for the catalyzing passages. This ensures faster warm-up, long life and greater efficiency in the conversion of pollutants.

Metallic converter substrates have only about 1/3 the wall thickness of ceramic substrates. They are more compact and have more active surface to convert pollutants. In the warm-up phase, the operating temperature for exhaust gas treatment is reached more quickly. In addition, a metallic catalytic converter is less sensitive to heat, impacts and ages more slowly. Because of lower exhaust gas pressure, increased engine performance is achieved.



Cayenne Turbo System

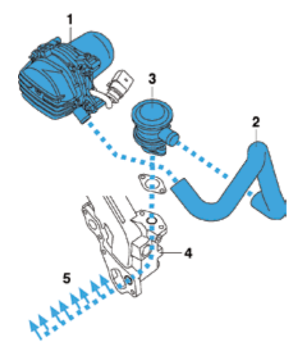
A - LSU Oxygen Sensor (ahead of preliminary catalytic converter)
B - LSF Oxygen Sensor (after the preliminary catalytic converter)
C - Preliminary Catalytic Converter
D - Main Catalytic Converter
1 - Exhaust Header
1A - Exhaust Turbocharger
1B - Boost Pressure Control Valve
2 - Decoupling Element

Because of the high temperatures that a catalytic converter needs to effectively begin the process of exhaust gas treatment as quickly as possible after a cold start, the exhaust gases are delivered to the pre-catalytic converters through double-walled, air-gap insulated exhaust headers with the shortest possible pipe lengths for rapid heating. As far as the main catalytic converter, which is designed as an underfloor converter, all exhaust pipes are air-gap insulated to reduce heat losses. In addition, heating of the pre-catalytic converters after a cold start is improved by means of secondary air injection.

Secondary Air System

The V8 engines in the Cayenne have separate secondary air systems for the left and right cylinder bank, mounted at the rear of the appropriate cylinder head. The secondary air blower for banks 1 and 2 are activated through relays by the DME control module. This builds up pressure over the connecting hoses up to the secondary air valves. At about 80 mbar delivery pressure from the blower, the diaphragm in the secondary air valves is opened; as a result, the injected secondary air arrives behind the exhaust valves through the distribution pipe in the appropriate cylinder head. The injection of secondary air after the exhaust valves results in a reduction of CO and HC, which are generated in greater amounts in the cold start phase with lambda < 1.

Additionally, the catalytic converters reach their light-off temperature of about 662° F. (350° C) as a result of the heat released during afterburning. During the first cold start, the condition for air injection is reached when coolant temperature is between 14° F. (–10° C) and 86° F. (30° C). In the range close to idle, secondary air injection runs for up to about 100 seconds, at part throttle this is reduced to about 40 seconds. If the inducted volume of air of about 340 kg/h is exceeded during secondary air injection, secondary air injection is switched off. A supplementary non-return valve is integrated in the secondary air valve of the Cayenne Turbo, which prevents opening as the result of pressure spikes in the exhaust system. End stage diagnostics monitors the relays, the operation of the secondary air system is monitored by closed loop Oxygen sensor control.



Secondary Air System

1 - Secondary Air Blower
2 - Connecting Hose
3 - Secondary Air Valve
4 - Flange With Air Passage
5 - Air Flow Behind The Exhaust Valves

Two-Channel Closed Loop Control

Both banks of cylinders have a separate Oxygen sensor control loop, through which the optimal mixture composition is determined for each one individually. The left and right exhaust tracts are equipped with two Oxygen sensors for monitoring the operation of the catalytic converters. In addition to the conventional jump Oxygen sensors (LSF), which are installed after the pre-catalytic converters, the more sensitive broad-band Oxygen sensors (LSU) are installed ahead of the pre-catalytic converters. This keeps fuel consumption and exhaust emissions as low as possible under all operating conditions.

LSF Oxygen Sensor after the Pre-Catalytic Converters

The planar LSF Oxygen sensor is a further development of the heated oxygen sensor. Functionally it corresponds to the LSH heated Oxygen sensor, with a jump curve from 0 to 0.9 volts at lambda 1. In contrast to the LSH, ceramic films form the solid body electrolyte in the LSF Oxygen sensor.

LSF means Flat Oxygen Sensor

Special properties of the LSF Oxygen sensor:

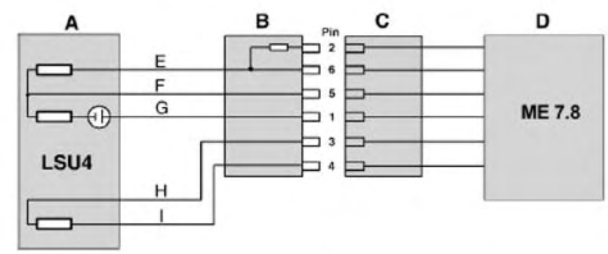
- Reaches operational status quickly
- Low heating requirements
- Stable control characteristics
- Small size, low weight

The sensor element of the planar Oxygen sensor is constructed from ceramic films and has the shape of an elongated plate with a rectangular cross section. The individual functional layers (electrodes, protective layers, etc.) are produced using the silk-screen process. Laminating the different printed films on top of each other allows for the integration of a heating element in the sensor element.

Broad-Band Oxygen Sensor Ahead of the Pre-Catalytic Converters

An LSU4 wide-band oxygen sensor is installed on each cylinder bank upstream of the catalytic converters. In the engine compartment, a sensor-specific, laser calibrated trimmer resistor is attached to the plug connection of these oxygen sensors. This resistor is specially calibrated to each individual sensor during production.

Six cables lead off from the ME 7.1.1 control unit to the plug connector in the engine compartment. Five cables then lead off from the plug connection to the LSU4 wide-band oxygen sensor.



LSU4 wide-band oxygen sensor Schematic

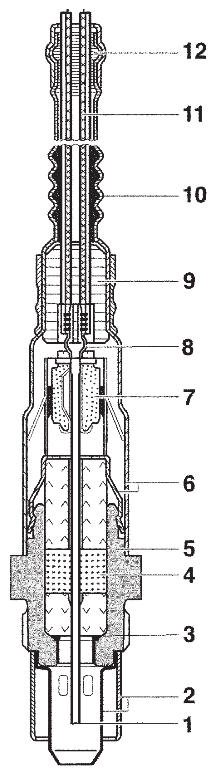
A - Wide-band Oxygen Sensor (LSU4)
B - Plug Connection (oxygen sensor) With Integrated Trim Resistor
C - Plug Connection (engine wiring harness)
D - ME 7.1.1 Control Unit
E - Pump Current
F - Ground (-)
G - Nernst Voltage (Vn)
H - Sensor Heating (V Bat.)
I - Ground (-) For Sensor Heating (regulated via ME 7.1.1)

The sensing element of the LSU4 wide-band oxygen sensor is a combination consisting of a Nernst concentration cell (sensor cell) and an oxygen pump cell which transports oxygen ions. The LSU4 wide-band oxygen sensor can be used from lambda > 0.7 to infinity (pure air). Accurate measurement is thus possible in both the rich and lean range. Used in conjunction with the regulating electronics, it supplies a clear and constant signal across a broad lambda range.

To reduce emissions, the engine is run with a stochiometric air/fuel mixture of lambda 1 as soon as the operating behavior of the engine and the temperature of the components permit this. However, the LSU4 wide-band oxygen sensors used in this oxygen sensing system allow the air/fuel mixture to be adjusted to a certain setpoint value(which may deviate from lambda 1) in both the warm-up phase and the full-load range. As a result, the exhaust gas and running behavior fluctuate only slightly since the ME 7.1.1 control unit also regulates these ranges.

Benefits of the Broad-Band LSU Oxygen Sensor

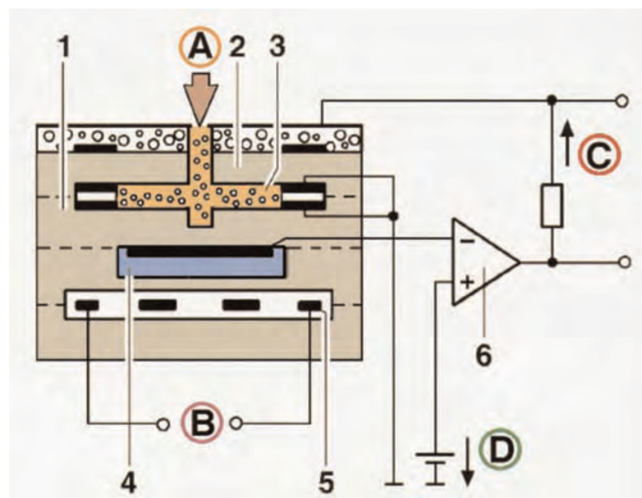
- Constant characteristic curve
- Precise measurement in broad lambda range from > 0.7 to infinity (air)
- Short response times < 100 ms
- Fast availability



Construction of the Broad-Band LSU Oxygen Sensor

1 - Sensing Element (combination comprising Nernst concentration cell and oxygen pump cell)
2 - Double Protection Tube
3 - Sealing Ring
4 - Sealing Package
5 - Sensor Housing
6 - Protective Sleeve
7 - Contact Holder
8 - Contact Clip
9 - Grommet
10 - Moulded Hose
11 - Five Connecting Cables
12 - Seal

In the ME 7.1.1 control unit, a special operating electronics system is integrated for each wide-band oxygen sensor. This system contains the regulating electronics for the oxygen pump cell and the Nernst concentration cell used to generate the sensor signal. In addition, it also includes the regulating electronics for keeping the temperature at the LSU4 wide-band oxygen sensor at approx. 1382° F. (750° C). In the ME 7.1.1 control unit, the current for the oxygen pump cell is regulated to ensure that the composition of the gas in the diffusion gap of the oxygen sensor reaches the predefined lambda value.

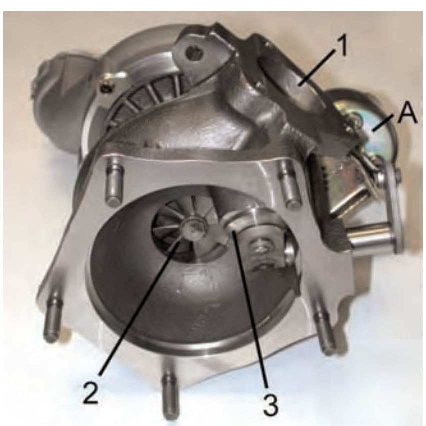


A - Opening For Exhaust Gas
B - Heater Current
C - Pump Current
D - Oxygen Sensor Voltage/Reference Voltage
1 - Nernst Concentration Cell (for generating voltage)
2 - Oxygen Pump Cell
3 - Measurement Cell (defusion slot)
4 - Reference Air Passage
5 - Oxygen Sensor Heater
6 - Closed Loop Circuit (in the DME control module)

Exhaust Turbocharging (Cayenne Turbo)

The two turbochargers, which are arranged in parallel, provide effortless power with the appropriate boost pressure control. Air flows into these turbochargers at a radial and an axial angle, due to the mixed flow turbines which also have a low moment of inertia. These innovative turbochargers are manufactured by IHI. As the result of low intake manifold volume, short exhaust headers and the Mixed Flow Turbines excellent response characteristics are achieved. These turbochargers are designed for a maximum speed of 160,000 RPM (continuous operation). So that the maximum RPM is not exceeded, the DME control module reduces boost pressure as needed above an altitude of 2,200 meters.

A cast steel turbine housing was used to achieve high turbine entry temperatures and consequently optimal wide open throttle consumption. By water cooling the turbochargers, Coking in the turbine bearing housing under high thermal loads is prevented (coking is when the oil is overheated until it becomes a solid and blocks the lubrication passages). To cool the turbochargers while the engine is not running, the electric coolant circulation pump, which is installed behind the wheel house cover at the left front, can be switched on. The electric coolant circulation pump is switched on as needed in run-on operation together with the electric cooling fans by the DME control module.



Turbocharger

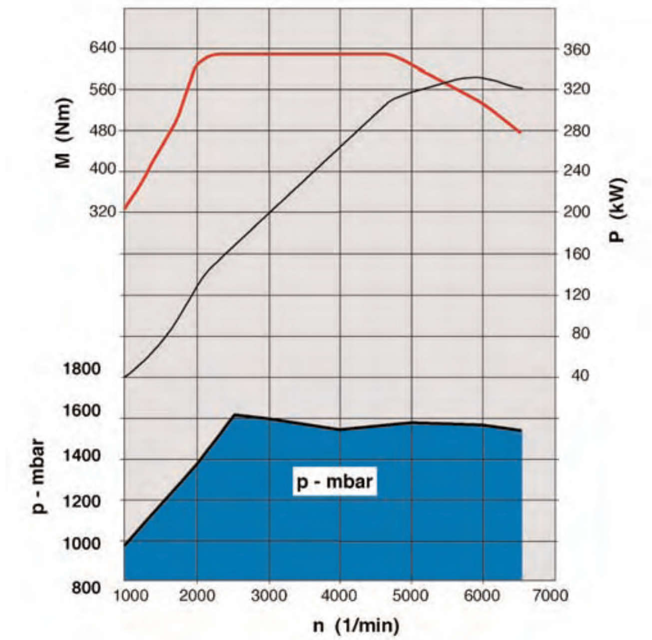
1 - Flange To Exhaust Header
2 - Exhaust Turbine
3 - Bypass Valve (wastegate)
A - Pressure Unit For Boost Pressure Control

Oil supply and oil scavenging from the turbochargers on the Cayenne Turbo was designed for universal operating conditions (e.g. up to a 45° slope) for the vehicle.

Boost Pressure Control

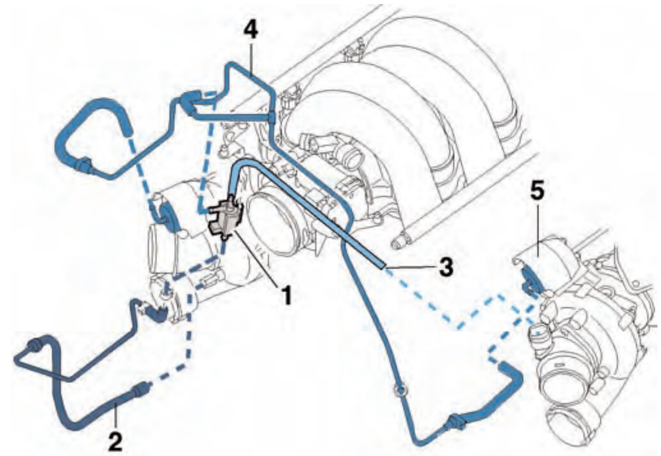
Depending on driving style, the boost pressure is regulated ahead of the throttle valve. With a steady or not very lively driving style, engine tuning at part throttle is constantly optimized in the direction of low fuel consumption by permitting only low pressure ahead of the throttle valve. It is opened correspondingly wide to bring about a low pressure drop. With a very brisk driving style, a higher boost pressure is set ahead of the throttle valve. The effect is that when the throttle valve is opened at part-throttle operation, the turbochargers are already running at higher speed and thus full-throttle boost pressure is attained very quickly. This principle can minimize “turbo lag.”

The required engine torque of the engine is calculated depending on the accelerator pedal potentiometer (driver request), engine RPM and other factors in the torque-oriented operational construct in the DME control module. Boost pressure in the Cayenne Turbo is controlled by absolute pressure. Maximum torque can be kept constant for a long period with respect to geographical altitude and temperature. The diagnostic capability of the system was expanded to include leak detection in the intake system. The engine charge required for a particular torque is determined through the calculation of mass air and implemented by specifying and controlling boost pressure. The graph applies to 92 RM/2 fuel and sea level at average temperatures.



p - Boost Pressure in mbar Absolute (pressure)
n - Engine Speed (rpm)
M - Torque in Nm
p - Power in kW

In the Cayenne Turbo, boost pressure is registered by the pressure sensor and controlled to the required boost pressure calculated by the DME control module. The electric frequency valve for boost pressure control is activated by an appropriate duty cycle, by which pressure is applied to the boost pressure control valves on the turbochargers, and the bypass valves (waste gate) in the turbochargers open. Turbocharger RPM is reduced, and boost pressure is limited. The electric frequency valve is activated by the DME control module when accelerating at a maximum 95% and a steady state at about a 60% to 80% duty cycle. Maximum boost pressure at wide-open throttle is up to about 24 PSI (1650 mbar) and is already reached at a speed of 2500 RPM. In the remainder of the RPM curve, boost pressure is cut back and at rated power (331 kW @ 6000 RPM) it is about 22 PSI (1500 mbar).



Boost Pressure Control Components

1 - Frequency Valve For Boost Pressure Right Control
2 - Pressure Side (boost pressure from right turbocharger)
3 - Pressure (from the intake side of the left turbocharger)
4 - Regulated Control Pressure To The Boost Pressure Control Valves
5 - Pressure Unit On The Turbocharger

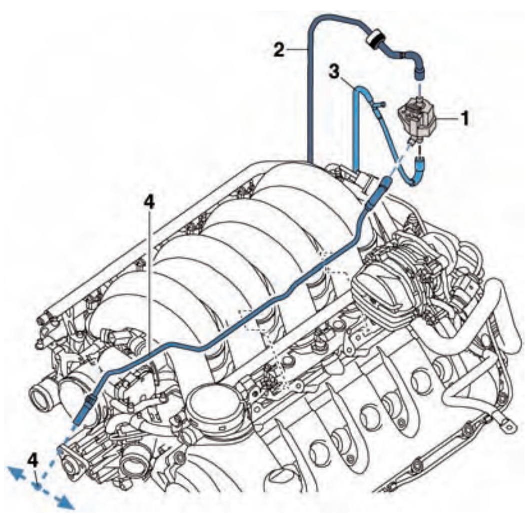
The cross sectional opening of the frequency valve for boost pressure control is dependent on the boost pressure requested. The frequency valve for boost pressure control changes its opening time to atmospheric pressure in accordance with its activation (duty cycle) through the DME control module. From boost pressure and atmospheric pressure, a control pressure is modulated, which actuates the pressure units of the boost pressure control valves accordingly and thereby opens the waste gates on the turbochargers. In a de-energized state, the frequency valve for boost pressure control is switched so that boost pressure acts directly on the pressure units and thus the boost pressure control valves open the waste gates at a low boost pressure.

Boost Pressure Adaptation

The Cayenne Turbo has adaptive boost-pressure control. For diagnosis the adapted value among the actual values of the DME can be read out as “boost pressure adaptation.” The adaptation range of boost pressure control is 0±25 %. Above a deviation of more than about 25% the switch to open-loop is made and a trouble code is stored. In open-loop, boost pressure is lowered by about 20%, reaching a maximum of 20 psi. Should the frequency valve for boost control fail, basic boost pressure is reduced even further for safety reasons. The consequence is a noticeable lack of power and performance.

Electrical Switching Valve for Recirculating Air on Deceleration

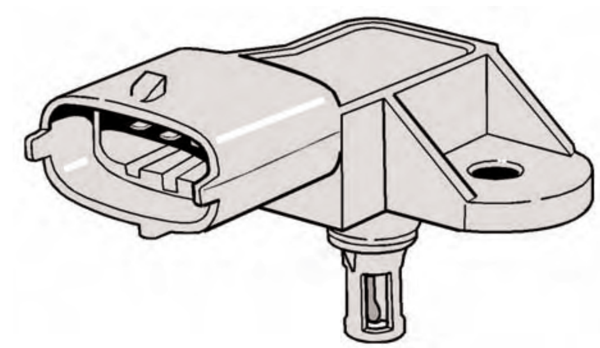
To prevent the turbochargers from slowing on a sudden transition from high load to deceleration, an electrical switching valve is used to control recirculating air. The DME can activate this electric switching valve, which actuates the recirculating air valves independently of intake manifold pressure. Controlled opening of the recirculating air valves reduces noise in the induction system and has positive effects on fuel consumption. Through the electric recirculating air valve in conjunction with the vacuum reservoir, operation of the recirculating air valves independently of intake manifold pressure can be achieved. The system is designed so that if the electric switching valve should fail, the decel recirculating air valves can continue to be opened through manifold pressure.



Connections for Recirculating Air

1 - Electrical Switch Valve For Recirculation Air On Deceleration
2 - Intake Manifold Pressure
3 - Vacuum From Vacuum Reservoir
4 - Actuation For Recirculating Air Left And Right

Pressure Sensor with Temperature Sensor



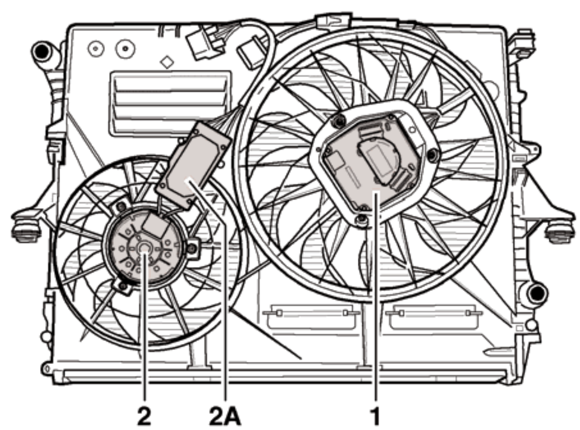
The pressure sensor registers pressure and air temperature ahead of the throttle valve control unit and makes these signals available to the DME control modules.

Coolant Temperature Gauge/Coolant Warning Light

The coolant temperature sensor (NTC), which is threaded into the coolant distribution pipe at the right rear of the engine, sends its signal to the DME control module, which passes on this information over CAN. The temperature is displayed in the instrument cluster by the coolant temperature gage. At a coolant temperature of > 255° F. (124° C) the coolant warning light is additionally switched on and switched off again at < 246° F. (119° C).

Electric Fans 1 and 2 for the Cooling System

Electric fan 1 has a maximum power of 600 watts, electric fan 2 of 300 watts. For continuous control, the DME control module changes the duty cycle for the end stages of fans 1 and 2.



1 - Electric Fan 1 (with integral output stage)
2 - Electric Fan 2 (with external output stage)
2A - Output Stage For Electric Fan 2

Control of fan speed is dependent on coolant and ambient temperature. The coolant thermostat begins to open at about 182° F. (83° C) coolant temperature and reaches its maximum opening at about 210° F, (98° C). The two stepless fans 1 and 2 are activated at about 200° F. (93° C) and reach their full performance at about 220° F. (105° C).

With the air-conditioning switched on, the fans are also activated, above a pressure of about 290 psi (20 bar) in the air-conditioning system maximum fan demand is reached. Above a coolant temperature of > 245° F. (118° C) the air-conditioning compressor is switched off (zero delivery).

Above 78 mph (125 km/h), the speed of both fans is reduced and at 87 mph (140 km/h) they are completely switched off, however whenever coolant temperature rises above 245° F. (116° C), they are switched on again and off again at below 220° F. (105° C).

Fan Run-On

To cool the engine compartment the fans are switched on with the ignition OFF, depending on coolant temperature and the last driving cycle (map on fuel consumption). The switch-on threshold is between 195° F. (90° C) and 200° F. (93° C) and running time is between 15 seconds and a maximum of 13 minutes. Once fan run-on is concluded, the fans will not start again with “Engine OFF.”
In the Cayenne Turbo, the electric coolant run-on pump, which provides cooling for the turbocharger (to prevent oil coking), is activated through this function.

The run-on pump is located behind the left front wheel wheelhouse liner. In addition, this pump is activated on the Cayenne S and Cayenne Turbo by the air-conditioning control module to utilize residual engine heat.

VarioCam

To reduce fuel consumption and increase maximum torque, a continuous variable, stepless camshaft adjuster (VarioCam) is used on the intake camshafts. The DME control module regulates the position of the intake camshafts under the control a map. The vane-type adjusters can shift the intake camshafts for cylinder banks 1 and 2 between 0° to 50° crankshaft angle (25° camshaft angle). The variable position of the camshaft can be regulated from high torque at low RPM up to maximum power at high RPM, which also achieves a reduction in fuel consumption.

Vane-type VarioCam adjuster on the intake camshaft

Activation of the Hydraulic Solenoid Valves for Stepless Adjustment of Valve Timing

The control module determines the current position of the intake camshafts (actual angle) to the crankshaft from the RPM sensor signal and the Hall sensor signal. The position control in the control module receives the desired specified angle via the programmed map values (rpm, load, engine temperature). If there is a difference between the specified angle and the actual angle, the electronic controls in the control module activates the hydraulic solenoid valve to actuate the positioner for the intake camshaft in accordance with the direction requested. Actuation of the valve is carried out through a pulse-width modulated square signal. Voltage is switched between 0 volts and 12 volts in a 4ms cycle (250 Hz), with the ratio of on-time and off-time being changed. Depending on conditions, a control current is set which determines piston position in the hydraulic solenoid valve (and thus opens the different oil lines), allowing a range of adjustment from 0° to about 50° of crankshaft angle.

System Descriptions – E-Throttle 7.1.1

The stepless VarioCam system with the vane-type adjuster provides the following benefits:

- Higher torque in the lower RPM range for better pulling performance
- Reduction of raw emissions for better exhaust gas numbers
- Maximization of catalytic converter heating for better exhaust gas numbers

Idle

The engine runs with small valve overlap. This provides great idle stability at low RPM. This idle stability is achieved through good cylinder charging and associated even combustion. Valve overlap means that intake and exhaust valves are open together. The effect is that fresh gases flow in while exhaust gases flow out at the same time.

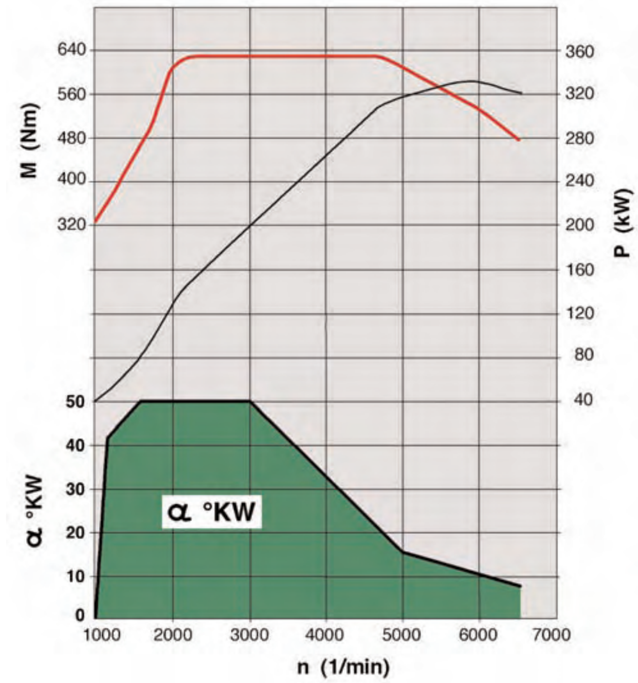
Part Throttle

At part throttle, operation with high residual gas content in the combustion chamber, meaning already burned air-fuel mixture, is optimal for reducing charge cycle losses and for improving combustion uniformity. Besides reducing fuel consumption this results in better emissions characteristics. In the part-throttle range the engine is load-dependent, that is, it is operated with different degrees of valve overlap depending on engine RPM and accelerator pedal position. The movement of the charge, which provides good turbulence in the cylinders, promotes combustion.

Wide-Open Throttle

With the throttle valve fully open, the optimal closing timing for the intake valves is permanently set for any RPM with the continuously adjustable intake camshaft (vane-type VarioCam). This prevents the backflow of fresh gases from the combustion chamber. At medium RPM and at wide-open throttle, the engine is running with the greatest valve overlap and early closing of the intake valve.

At high RPM and at wide-open throttle, the engine is operating with small valve overlap and late closing of the intake valve. It is imperative not to permit any discrepancies in valve timing between the two intake camshafts on both banks of cylinders.



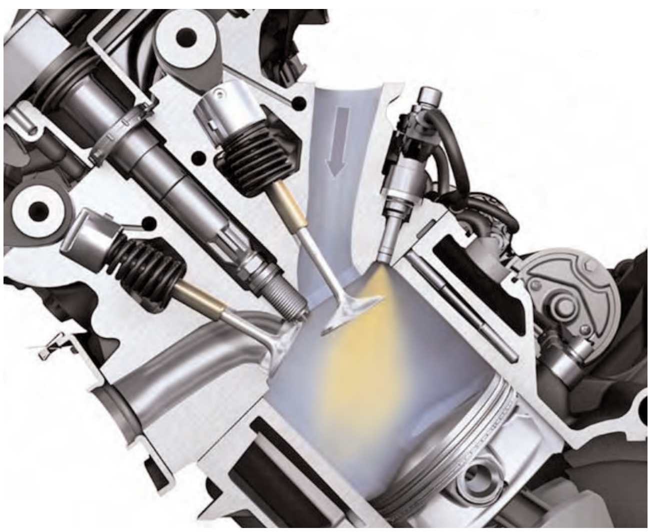
Cayenne Turbo VarioCam Shift Graph

a - VarioCam Adjustment Angle in ° Crankshaft Rotation
n - Engine Speed In RPM
M - Torque In Nm
P - Power In kW

E-Throttle MED 9.1 (Bosch) **& EMS SDI 4.1** (Siemens) **– Cayenne** (2nd Generation)

The following MED 9.1 (Bosch) **& EMS SDI 4.1** (Siemens) **information was first published in the 2008 Cayenne/S/T Service Information Technik book.**

Direct Fuel Injection (DFI)



A totally redesigned generation of engines with DFI is used for the new Cayenne models: a 3.6 l V6 engine for the Cayenne, a 4.8 l V8 naturally aspirated engine for the Cayenne S and a 4.8 l V8 bi-turbo engine for the Cayenne Turbo.

Development objectives for the new DFI engines:

- More power and torque.
- Reduced fuel consumption.
- Reduced weight.

These objectives have been achieved thanks to the following enhancements and new technologies:

- Increased displacement for more power and torque.
- Use of direct fuel injection (DFI).
- Higher compression ratio.
- Sport button as standard.
- VarioCam Plus (for V8 engines).
- Demand-controlled oil pump (for V8 engines).
- New intake systems adapted specifically for each engine.
- VarioCam Plus (for V8 engines) for controlling the intake camshaft and valve lift.
- New sports exhaust system (optional for Cayenne S with Tiptronic S).
- Demand controlled variable oil pump for improved engine efficiency (for V8 engines).

The most important technical components of the direct fuel injection system are:

- The fuel low pressure system.
- The fuel high pressure system.
- The fuel rail (central high pressure distribution pipe).
- The fuel injectors.
- Modifications to the cylinder head.
- Special recessed pistons for the relevant engine.

Porsche is using direct fuel injection (DFI) for the first time in its new generation of Cayenne engines. DFI offers numerous advantages compared to intake manifold injection. The main objective here is to achieve an air/fuel mixture adapted specifically to the respective operating and charge states of the engine using an injection system and mixture formation. This provides the perfect solution for meeting the various demands relating to economy, power, vehicle handling and emissions. With direct fuel injection, the fuel is injected directly into the combustion chamber and mixture formation takes place almost completely in the combustion chamber.

The direct fuel injection system used in the new Cayenne models is characterized by the following:

- Homogeneous operation.
- Better cylinder filling.
- Reduced knock sensitivity.
- Higher compression ratio.
- High pressure stratified charge ignition.
- Dual injection.

The direct fuel injection system used in the new Cayenne engines is based on homogeneous operation. The mixture of air and fuel is distributed as evenly as possible in the combustion chamber, thereby allowing optimal combustion. With this system, the fuel is injected directly into the combustion chamber at a pressure of up to 1740 psi (120 bar).

Within the injector, the fuel jet creates a vortex (rotated around the longitudinal axis). This rotation forms a conical cloud of fuel. The fine atomization produced by this allows faster evaporation of the fuel. The fuel evaporation process takes the required heat energy from the air, thereby cooling the air. This reduces the cylinder charge volume and additional air is drawn in through the open intake valve, which in turn improves cylinder filling.
The reduced temperature level also helps to meet the prerequisites for the higher compression ratio in all new Cayenne engines since knock sensitivity has been improved. The higher compression ratio in turn increases engine efficiency.

Start Phase of DFI Engines

High pressure stratified charge ignition is used in the DFI systems of the new Cayenne engines in order to optimize cold starting with regard to fuel consumption and emissions. With this ignition system, fuel injection occurs very late – just before the end of the compression stroke – when starting the engine. The high pressure stratified charge ignition system injects fuel directly only once into the specially molded piston recess so that a stratification, which creates an ignitable mixture, is formed around the spark plug. The piston recess ensures that the injected fuel is directed straight to the spark plug. This reduces both the amount of fuel required and the emissions compared to intake manifold injection.

Catalytic Converter Heating Phase in DFI Engines

Once the high pressure stratified charge ignition system starts the engine, engine management switches to the catalytic converter heating phase. In this operating state, a dual injection system helps to bring the catalytic converter to the temperature required for optimal conversion as quickly as possible by increasing the exhaust emissions temperature.

The 2nd injection of fuel into the piston recess occurs just before the end of the compression stroke with the intake valves closed. The air/fuel mixture is ignited very late and this increases the exhaust emissions temperature. As a result, emissions during the start phase are reduced and the secondary air pumps are no longer required for all engines.

Upper Load Range of DFI Engines

Dual injection always occurs in the upper load range up approx. 3500 rpms. The amount of fuel required for combustion is distributed in two consecutive injection processes. In the upper load range, both injections occur during the intake stroke (intake synchronous injection) with the intake valves open, thereby ensuring reduced fuel consumption through improved homogenization.

Piston Recesses in DFI Engines

The piston recesses are important for high pressure stratified charge ignition and for dual injection during the catalytic converter heating phase. They allow late injection of fuel in order to create an ignitable air/fuel mixture around the spark plug for late ignition.

Note!

Intake manifold injection

> With the intake manifold injection system, the fuel is injected into the intake duct earlier and mixture formation takes place partly in the intake duct and partly in the combustion chamber. During the intake process, fuel is deposited on cylinder walls and valves and as a result, this fuel is no longer available for combustion. This is particularly the case during the start phase of the engine at low temperatures and the consequence of this is that the amount of fuel used exceeds the amount of fuel that is actually needed for combustion.

Sport Button

All new Cayenne models already have a Sport button as standard, which is located centrally in the center console under the shift lever or Tiptronic S gear selector. This button allows the driver to choose between the vehicle's fuel consumption tuning (normal mode) and sport tuning (sport mode). When the Sport button is pressed, a "SPORT" logo lights up in the instrument cluster.

In the Motronic area, pressing the Sport button (in High-Range mode only) affects the following systems, depending on the vehicle equipment:

- When the Sport button is activated, a more sporty accelerator pedal characteristic produces a more spontaneous engine response, underpinning the sporty character. This is achieved via a steeper rise for the electronic throttle characteristic. This means that the throttle is opened further and faster with the same accelerator pedal travel when the Sport button is pressed.
- Maximum full-load torque is available at all times in the Sport button's sport mode. In normal mode, electronic engine management restricts the engine management functions in order to optimize fuel consumption. If full power is required in a certain driving situation (e.g. when passing), it can be achieved at any time by initiating a kick down. Engine management switches to the sport mode map at this time.
- The Sport button lends a sportier feel to the transitions between traction and deceleration, as well as between deceleration and traction. This means that throttle activation and ignition are switched to a more direct map when accelerating and particularly when decelerating, resulting in a more spontaneous and dynamic load cycle.
- The sports exhaust system available for the Cayenne S in combination with Tiptronic S is also activated using the Sport button.

Sport mode remains active until either the Sport button is pressed a second time or the driver switches off the ignition. This deactivates sport mode and the settings revert to normal mode.

Cayenne V6 DFI Engine

On the new Cayenne V6 engine, displacement has been increased by 0.4 liters to 3.6 liters with a compression ratio of 12.25. Engine power has increased by 40 HP to 290 HP, while the torque is now 285 ftlb. (385 Nm), an increase of +56 ftlb. (+75 Nm). Idling rpm is 680 and maximum engine rpm is 6700.

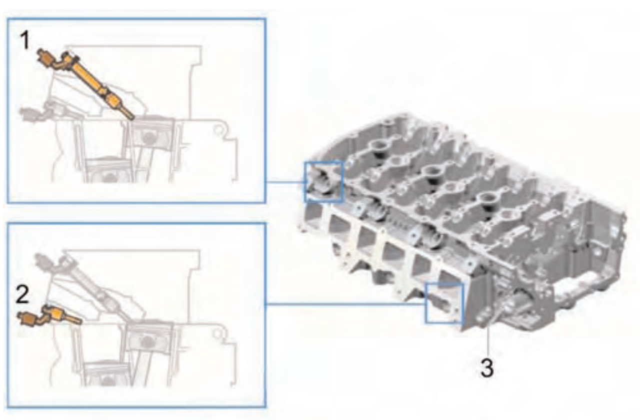
Significant modifications to the V6 DFI engine:

- Direct fuel injection (DFI).
- New engine control unit Bosch MED 9.1.
- New extended twin branch exhaust system and additional main catalytic converter.
- New cylinder head for DFI.
- New recessed pistons.
- Continuous camshaft adjustment on intake and exhaust side.
- Intake system with variable intake manifold.

Motronic Control Units MED 9.1

The new DME control unit MED 9.1 from Bosch has been specially adapted to suit direct fuel injection and the modified engine specifications of the V6 DFI engine. It can be programmed with the country-specific data records of the Cayenne V6.

Cylinder Head



The design of the direct fuel injection system, with two separate high pressure rails, the arrangement of the fuel injectors **-1-** (for cylinders 1, 3, 5) and **-2-** (for cylinders 2, 4, 6) as well as the high pressure pump **-3-**, has made it necessary to redesign the cylinder head.

Piston Recesses

The piston recesses **-1-** on the V6 engine have been adapted for the purpose of achieving optimal stratification of the air/fuel mixture during the late injection processes that characterize high pressure stratified charge ignition as well as during the catalytic converter heating phase. The compression ratio has been increased from 11.5:1 to 12.25 due to improved inner cooling. This reduces fuel consumption and optimizes engine power.

Motronic Control Unit EMS SDI 4.1

A completely new DME control unit EMS SDI 4.1 developed by Siemens is used for the V8 engines. This is designed specifically to meet the requirements for using the direct fuel injection system and VarioCam Plus. The control of fuel injectors, which are the main elements of the direct fuel injection system, is particularly important here. The DME control unit can be programmed for individual countries using the data records for Cayenne S and Cayenne Turbo.

Cayenne V8 DFI Engines

The totally redesigned family of V8 engines includes a naturally aspirated engine for the new Cayenne S and a turbocharged version for the new Cayenne Turbo. Specific design work and tuning has resulted in an identical parts concept between the naturally aspirated and turbo engine.

Key changes:

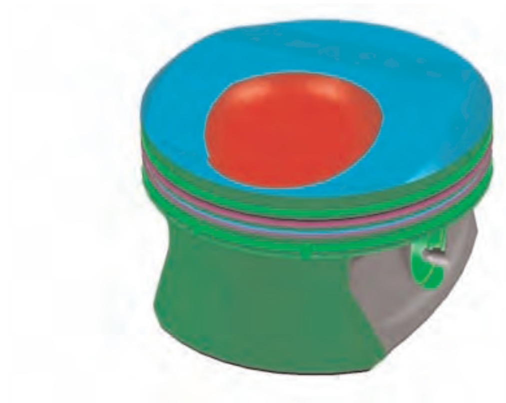
- Direct fuel injection (DFI).
- Engine control unit Siemens EMS SDI 4.1.
- Increased displacement.
- New cylinder head for DFI.
- Special recessed pistons for Cayenne S and Cayenne Turbo.
- Use of VarioCam Plus.
- Demand controlled variable oil pump.

Cayenne S DFI Engine

On the new V8 naturally aspirated engine in the Cayenne S, the displacement has been increased by 0.3 liters to 4.8 liters with a compression ratio of 12.5. Engine power has been increased by 45 HP to 385 HP, while the torque is now 370 ftlb. (500 Nm) – an increase of +59 ftlb. (+80 Nm). Idling rpm is 580 rpm (550 rpm for AT with transmission range engaged) and maximum engine rpm is 6700. The new DME control unit EMS SDI 4.1 has been specially adapted to suit direct fuel injection and the modified engine specifications of the V8 naturally aspirated engine.

- DFI direct fuel injection.
- Intake system with variable intake manifold.
- Enhanced exhaust system.
- New sports exhaust system (optional, in conjunction with Tiptronic S).

Piston Recess



The piston recesses are specifically designed to suit the characteristics of the V8 naturally aspirated engine during late injection with the high pressure stratified charge ignition system and during the catalytic converter heating phase.

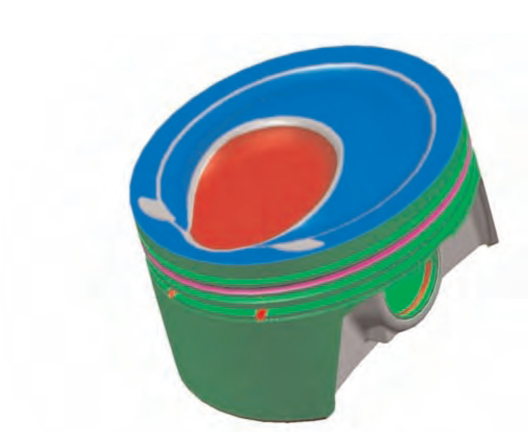
The increase in the compression ratio from 11.5 to 12.5:1 on the V8 naturally aspirated engine as a result of DFI serves to optimize both engine power and fuel consumption.

Cayenne Turbo DFI Engine

On the new Cayenne Turbo, displacement has also been increased by 0.3 liters to 4.8 liters with a compression ratio of 10.5. Engine power has increased by 50 HP to 500 HP, while the torque is now 518 ftlb. (700 Nm – an increase of +56 ftlb. (+80 Nm). Idling rpm is 580 rpm (550 rpm for AT with transmission range engaged) and maximum engine rpm is 6700. The new DME control unit EMS SDI 4.1 has been specially adapted to suit direct fuel injection and the modified engine specifications of the V8 turbo engine.

- DFI direct fuel injection.
- New intake system.
- Adaptation of turbochargers and boost pressure control.

Piston Recess



The piston recesses are specially adapted to the characteristics of the V8 turbo engine. The increase in the compression ratio from 9.5 to 10.5:1 as a result of DFI serves to optimize both engine power and fuel consumption.

Fuel Supply

The engine is designed to provide optimum performance and fuel consumption if unleaded premium fuel with 93 octane () is used. If unleaded premium fuels with a lower octane number is used, the engine's knock controller automatically adapts the ignition timing. The maximum filling approx. 26 Gals. (100 liters), with a reserve of approx. 3 Gals. (12 liters).

Safety

Always read and follow the safety instructions in the Technical Manual, Group 2 when working on the fuel supply system.
> Fuel low-pressure system in DFI engines.

Technical Manual

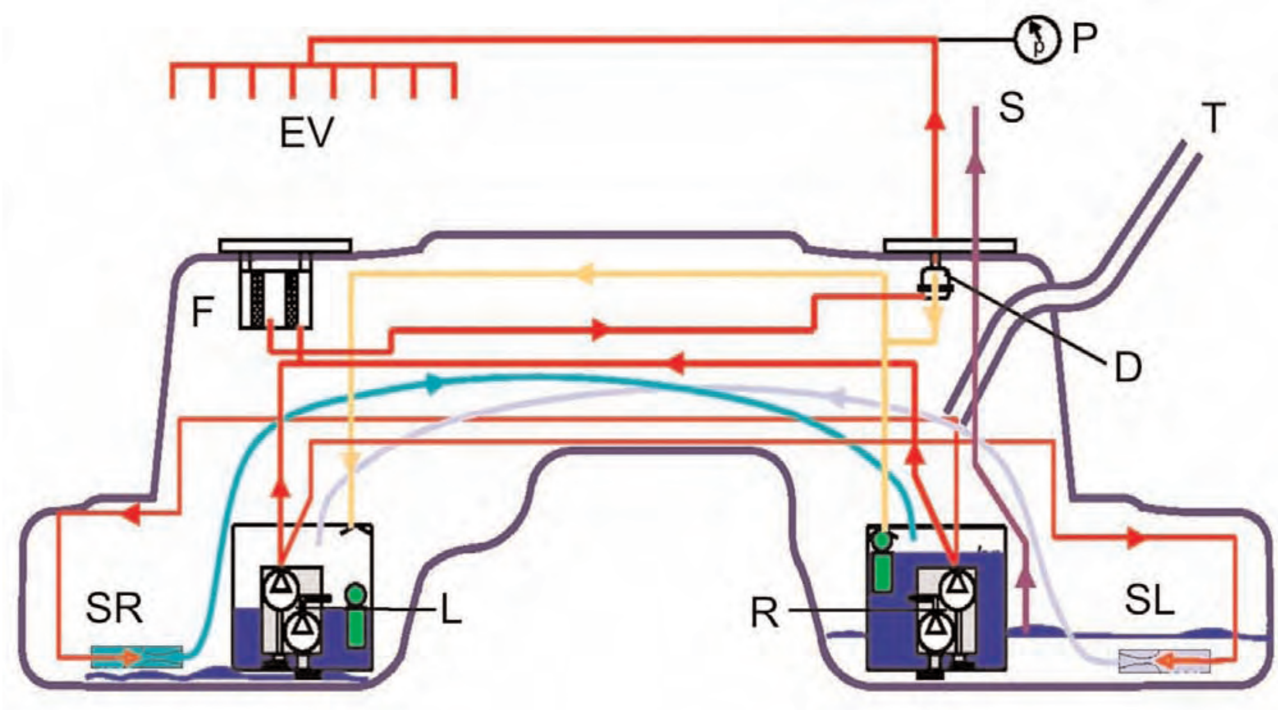
The procedure for checking the fuel pressure and the amount of fuel delivered by the fuel pumps is described in the Technical Manual.

- The low pressure system delivers the fuel from the fuel tank to the high pressure pump on the cylinder head.
- The new Cayenne vehicles have a returnless fuel system (RF).
- The demand control function of the fuel delivery rate reduces fuel heating in the tank by switching on the second fuel pump.

The fuel tank is not symmetrical. The left half of the tank has a higher volume than the right side. There is a "hump" in the middle so that both chambers are separated from each other once a certain fuel level is reached in the tank. When the tank is half full, the left fuel pump is activated because the left half of the tank has the higher volume. The fuel pumps are each supplied by one sucking jet pump whose hoses are routed diagonally and which "helps itself" to fuel from the other half of the tank.

The fuel pressure and the way in which the two fuel pumps are activated has changed compared to Cayenne vehicles up to model year 2006. On Cayenne vehicles up to M.Y. 2006, the left fuel pump was permanently activated and the right pump was only activated as required (for starting, higher delivery rate, etc.).

Functional diagram of the low pressure side in the fuel tank.



T - Tank filler neck
R - Fuel pump unit in right side of tank
L - Fuel pump unit in left side of tank
SL - Sucking jet pump for left fuel pump
SR - Sucking jet pump for right fuel pump

F - Fuel filter (does not need to be changed)
D - Fuel pressure regulator (approx. 80 psi/5.5 bar)
EV - Fuel injectors (cylinders 1 to 6 or 1 to 8)
P - Fuel pressure approx. 80 psi/5.5 bar

Fuel Pressure On The Low Pressure Side.

For DFI engines, the fuel pressure on the low pressure side has been increased to approx. 80 psi/5.5 bar (this was previously approx. 58 psi/4 bar). The left or right fuel pump is operated as the main pump in order to distribute the higher load to both fuel pumps, depending on the fuel level.

The fuel pumps are activated if the level of fuel in the tank is reduced and if the engine requires more fuel:

- Fuel level > 15.8 gal. (60 liters) to 26 gal. (100 liters): When the tank is relatively full, the right fuel pump is activated; if more fuel is required (> 13 gal./50 liters/h), the left pump is activated.
- Fuel level > 4 gals/15 liters to 15.8 gals/60 liters: When the tank is half-full, the left fuel pump is activated; if more fuel is required (> 13 gals/50 liters/h), the right pump is activated.
- Fuel level < 4 gals./15 liters: If the tank is relatively empty, both pumps run continuously.

Other switching functions include:

- If the ignition was switched off for more than 30 minutes, the left fuel pump is activated for approx. 1 to 2 seconds when the driver's door is first opened in order to build up fuel pressure even before the ignition is switched on.
- Both fuel pumps are activated while starting the engine and for several seconds after starting the engine.

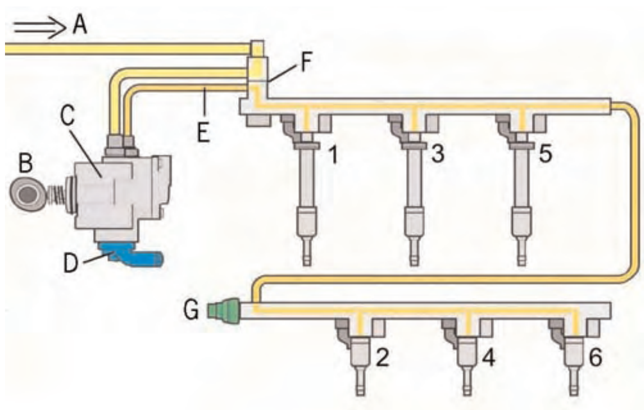
Fuel High Pressure System in DFI Engines

The fuel high pressure system generates an injection pressure of up to 1740 psi (120 bar) in the combustion chamber. The components of the V6 engine and the V8 engines are different.

The following pages describe the functions of the components of the V6 DFI engine first, and then those of the V8 DFI engines.

V6 DFI Engine

The fuel high pressure system in the V6 DFI engine is made up of the following parts/components.



A - Low pressure (approx. 80 psi/5.5 bar from the fuel tank)
B - Camshaft
C - Fuel high pressure pump
D - Flow control valve (for fuel high pressure)
E - High pressure line
F - Pressure control valve (max. 1740 psi/120 bar)
G - Fuel pressure sensor
1, 3, 5 - Fuel injectors on high pressure rail, bank 1
2, 4, 6 - Fuel injectors on high pressure rail, bank 2

Fuel High Pressure Pump

The fuel high pressure pump creates a high pressure of up to 1740 psi (120 bar), which is required for injection. It is controlled by demand and adapts the fuel quantity according to engine requirements via a flow control valve. This piston pump with one piston is located on the cylinder head. The high pressure pump is driven by the timing chain via a double-cam gear wheel. The double-cam gear wheel uses a roller to actuate the pump piston, which creates the fuel high pressure in the pump.

C - Fuel high pressure pump with flow control valve
G - DS Fuel pressure sensor

Note!

Pressure variations can occur on the low pressure side while measuring fuel pressure at idling speed due to the piston pump on the high pressure side with one piston.

Technical Manual

Always read and observe the specifications in the Technical Manual when securing all fuel lines in the high pressure area.

Flow Control Valve For Fuel High Pressure

The control valve for fuel high pressure located underneath the fuel high pressure pump operates as a flow control valve. The Motronic control unit maintains the fuel high pressure going to the fuel rails of cylinder bank 1 and 2 at a pressure of between 508 psi (35 bar) and 1450 psi (100 bar) via the control valve. If the control valve fails, the Motronic control unit goes into emergency operation, whereby the engine can still run in a limited way with low pressure (80 psi/5.5 bar).

Fuel Pressure Sensor

The fuel pressure sensor is installed on the lower fuel rail (cylinder bank 2) and informs the Motronic control unit about the current pressure in the fuel high pressure system. The Motronic control unit evaluates the signal and regulates the fuel high pressure via the fuel pressure control valve in the high pressure pump. If the fuel pressure sensor fails, the fuel pressure control valve is activated with a fixed value by the engine control unit.

Pressure Control Valve

The pressure control valve is located on the fuel rail of cylinder bank 1. The valve opens a connection to the fuel low pressure system if the fuel pressure in the high pressure system exceeds 1740 psi (120 bar).

Two High Pressure Rails

Two high pressure rails are used in the V6 engine. The fuel is pumped from the high pressure pump to the two distribution rails on cylinder bank 1 and 2 via the high pressure line. The same fuel pressure is available for all fuel injectors from there.

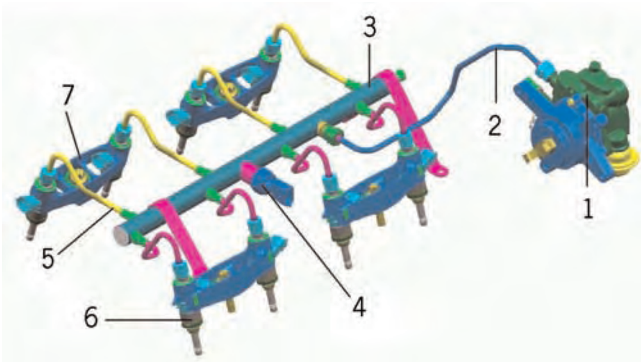
Fuel Injectors/High Pressure Injectors

The electromagnetically operated fuel injectors are located in the cylinder head. They are activated by the Motronic control unit in accordance with the firing order. Following activation, they inject fuel directly into the combustion chamber at a pressure of 580 psi (40 bar) to 1740 (120 bar). The injectors for both cylinder banks are on the intake side of the cylinder head. This arrangement allows the injectors for cylinders 1, 3 and 5 to run through the inlet port on the cylinder head. The injectors for cylinder bank 1 are therefore longer than the injectors for cylinder bank 2.

Since the injectors are inserted from the same side for both cylinder banks, the piston recesses of cylinder bank 1 and 2 must be molded differently so that the injected fuel is whirled around and mixed perfectly with the air that is drawn in. This is necessary because the fuel injectors and intake valves on both cylinder banks are arranged in different angles.

In addition to the amount of fuel injected and the injection time, the shape and alignment of the fuel jet is also important here. A defective injector is detected by the misfire detection system and is not activated again.

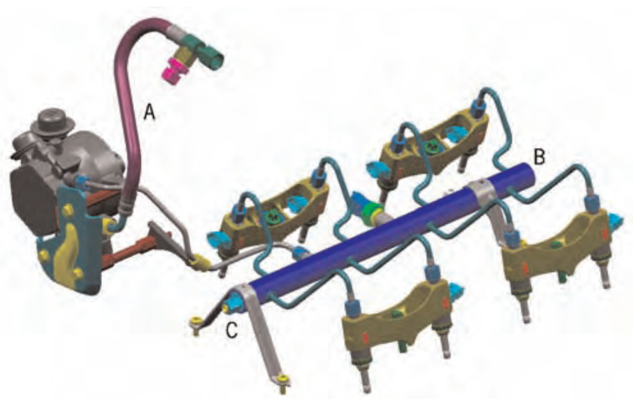
Fuel High Pressure System in V8 DFI Engines



The fuel high pressure system in V8 DFI engines is made up of the these parts/components.

1 - Fuel high pressure pump with flow control valve, pressure control valve and temperature compensator
2 - High pressure line
3 - Fuel rail
4 - Fuel pressure sensor
5 - Fuel line (for fuel injector on cylinder 1)
6 - Fuel injector (cylinder 5)
7 - Retainers for two fuel injectors

Fuel Temperature Sensor (on low pressure side)



A - Low pressure fuel line
B - Fuel rail
C - Test port

At start of production, all Cayenne V8 engines have a fuel temperature sensor on the low pressure side, which will be replaced by a temperature model in the DME in later production. Depending on the amount of fuel required and the fuel temperature, the DME control unit, together with the flow control valve, regulates the amount of fuel on the high pressure side upstream of the high pressure injectors.

Fuel High Pressure Pump

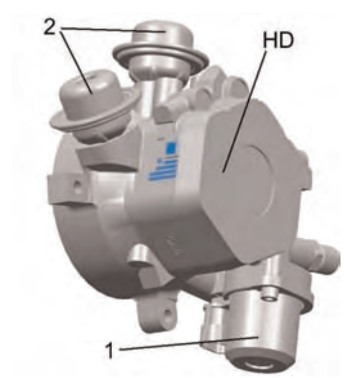
The fuel high pressure pump pumps the amount of fuel required for injection and builds up a fuel pressure of up to 1740 psi (120 bar). The axial piston pump is driven by the inlet camshaft. The Cayenne S and Cayenne Turbo are equipped with different high pressure pumps.

Cayenne V8 Naturally Aspirated Engine

The high pressure pump used in the Cayenne S is a three-piston pump with a maximum delivery rate of approx. 47.5 gals./180 liters/h at 1740 psi (120 bar). It builds up pressure and ensures flow control. The following components are integrated into the high pressure pump: Flow control valve with pressure reducing function for the fuel high pressure side, pressure control valve, bypass valve, a temperature compensator on the oil side and a fuel strainer on the inlet side with a mesh width of approx. 50 µm. Fuel is distributed via a central high pressure rail with separate lines leading to the fuel injectors.

Cayenne Turbo

The high pressure pump **-HD-** used in the Cayenne Turbo is a six-piston pump with a maximum delivery rate of approx. 58 gals./245 liters/h at 1740 psi (120 bar). It builds up pressure and ensures flow control.



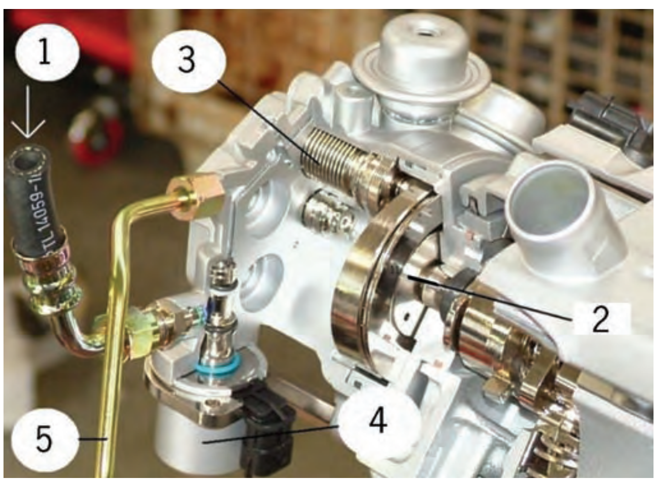
The following components are integrated into the high pressure pump:

Flow control valve **-1-** with pressure reducing function for the fuel high pressure side, pressure control valve, bypass valve, two temperature compensators on the oil side **-2-** and a fuel strainer on the inlet side with a mesh width of approx. 50 µm. Fuel is distributed in the same way as for the V8 naturally aspirated engine via a central high pressure rail with separate lines leading to the fuel injectors.

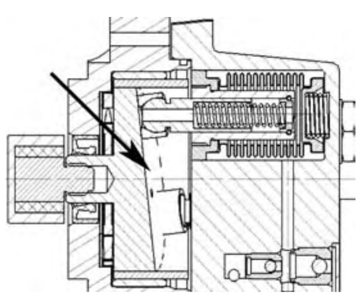
Flow Control Valve For Fuel High Pressure

The electric control valve for the fuel high pressure side **-1-** is located on the fuel high pressure pump and operates as a flow control valve. The Motronic control unit regulates the delivery rate of the high pressure pump in the fuel supply to the pump via the control valve. When the engine is switched off, the fuel high pressure is reduced by an integrated pressure reducing valve. The fuel pressure sensor monitors the required fuel pressure (approx. 580 psi/40 to 1740psi/120 bar).

- If the control valve fails, the Motronic control unit goes into emergency operation, whereby the engine can still run in a limited way with low pressure (80 psi/5.5 bar). In this case, the bypass valve in the pump opens and provides a direct route from the low pressure side to the high pressure side.
- The bypass valve is also activated for filling the empty fuel rail on new engines or following repairs in order to reduce starting times.

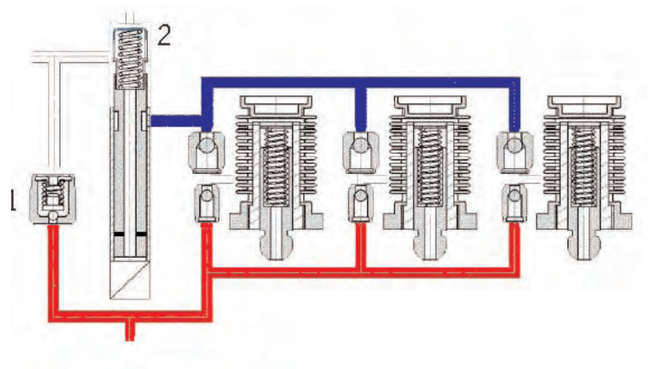


1 - Low pressure (approx. 80 psi/5.5 bar from the fuel tank)
2 - Wobble plate
3 - Fuel high pressure pump
4 - Flow control valve (for fuel high pressure)
5 - High pressure line to fuel rail



Arrow in illustration is wobble plate.

Bypass Valve (including pressure relief valve)



1 - Bypass valve, including pressure relief valve
2 - Volume control valve
Blue - Low pressure inlet from the in-tank fuel pump
Red - High pressure to the injectors

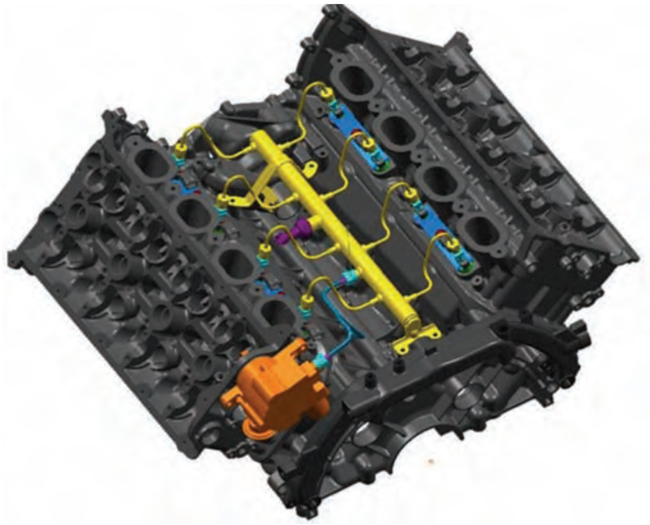
Pressure Control Valve

The pressure control valve is integrated into the fuel high pressure pump. This safety valve opens a connection to the fuel low pressure system if the fuel pressure in the high pressure system exceeds approx. 2030 psi (140 bar).

High Pressure Line

The high pressure line connects the high pressure pump to the fuel rail.

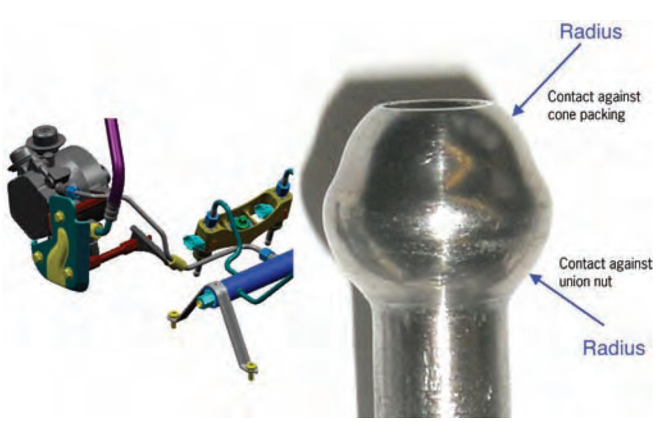
Central High Pressure Rail



The central high pressure rail in V8 engines is located in the engine's inner V. From here, the fuel is supplied via individual lines to the fuel injectors for cylinders 1 to 8. The high pressure rail provides the same pressure for all injectors. The volume of the high pressure rail is adapted according to the amount of fuel the engine needs (V8 naturally aspirated engine 100 cm^3, V8 Turbo 150 cm^3).

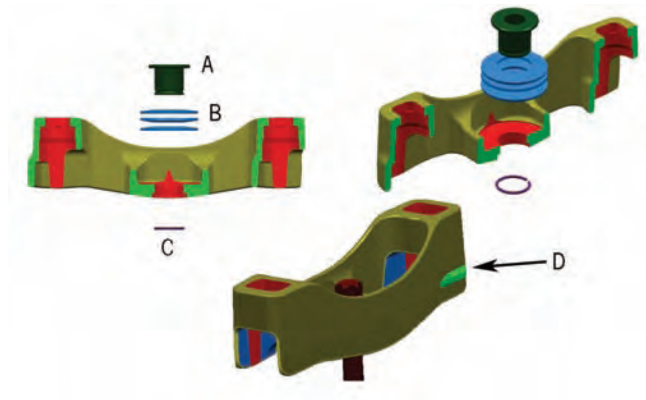
- The rail volume is determined by the required pressure variation behavior and the shortness of the starting time.

High Pressure Fuel Line



Sealing contact area of the high pressure fuel lines.

Fuel Injector Retainer Components



A - Buffer
B - Disc spring
C - Lock washer
D - Rib to prevent in correct assembly

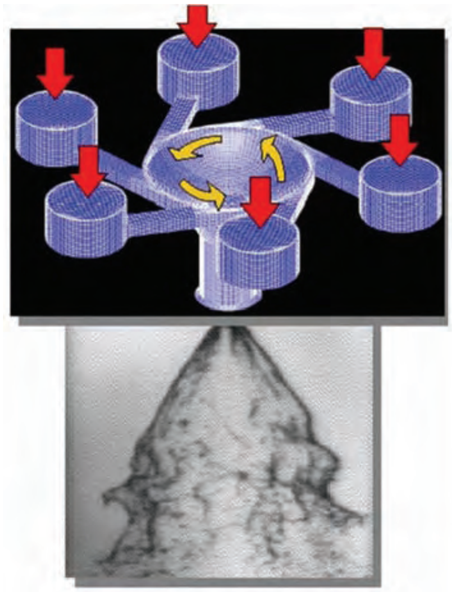
Fuel Pressure Sensor

The fuel pressure sensor is installed on the central high pressure rail under the intake system and informs the Motronic control unit about the current pressure in the fuel high pressure system. The Motronic control unit evaluates the signal and regulates the fuel pressure on the high pressure side via the flow control valve.

Fuel Injectors/High Pressure Injectors

The electromagnetically operated fuel injectors are on the intake side of the cylinder head. They are activated by the DME control unit in accordance with the firing order. Following activation, they inject fuel directly into the combustion chamber at a pressure of 580 psi (40 bar) to 1740 psi (120 bar). During this process, a vortex is created even before the fuel emerges at the valve tip.

The Cayenne S and Cayenne Turbo are equipped with different injectors, designed specifically to suit the engine's fuel requirements. The injectors can be differentiated by their part numbers and a color marking. The piston recesses in the V8 naturally aspirated engine and the V8 Turbo are also different so that the injected fuel can be whirled around and mixed perfectly with the air that is drawn in.



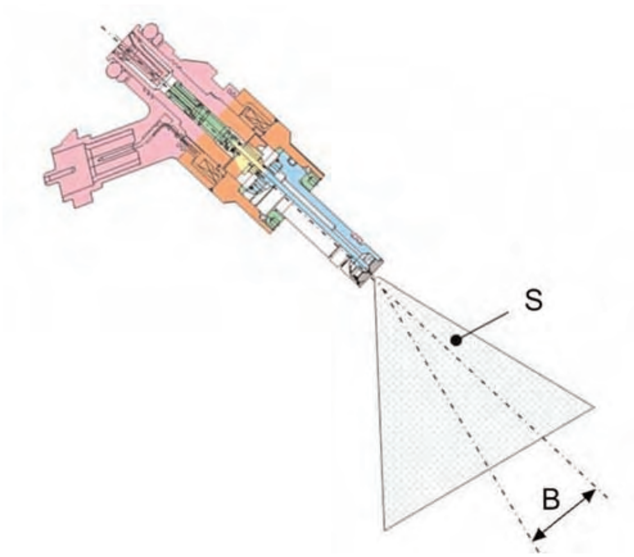
Fuel Injectors -V8 Naturally Aspirated Engine

At a fuel pressure of 580 psi (40 bar) and an injection time of 0.6 ms, the amount of fuel injected is approx. 5.5 mg/stroke. While at a fuel pressure of 1740 psi (120 bar) and an injection time of 5.8 ms, the amount of fuel injected is approx. 67 mg/stroke.

Fuel Injectors -V8 Turbo

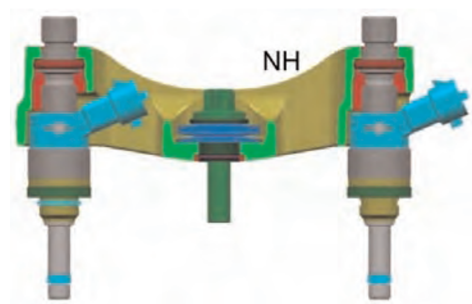
At a fuel pressure of 580 psi (40 bar) and an injection time of 0.6 ms, the amount of fuel injected is approx. 7.8 mg/stroke. While at a fuel pressure of 1740 psi (120 bar) and an injection time of 6.1 ms, the amount of fuel injected is approx. 107 mg/stroke.

In addition to the amount of fuel injected and the injection time, the shape and alignment of the fuel jet is also important.



S - Spray angle (taper angle of the fuel jet, approx. 69° on the naturally aspirated engine, 68° on the turbo engine).
B - Bend angle (distance between the injection jet and the axis of the fuel injector; approx. 8.5° on the naturally aspirated engine, approx. 7.5° on the turbo engine).

Retainers For Fuel Injectors



The four retainers **-NH-** for the two injectors ensure the following:

- Installation as a pre-assembled unit with injectors installed.
- Twist-lock protection for screwing on fuel lines.
- Exact installation position for aligning the fuel jet in the combustion chamber.
- Correct pretensioning of the fuel injectors in the cylinder head.
- Vibration damper for reducing the transmission of vibrations from the cylinder head to the injectors.

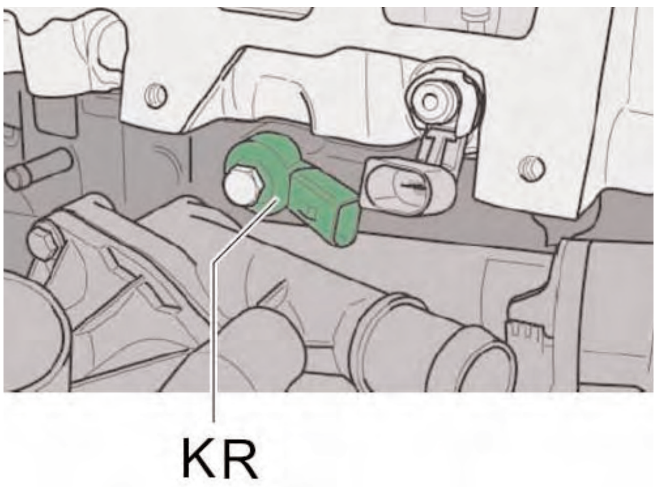
Ignition System

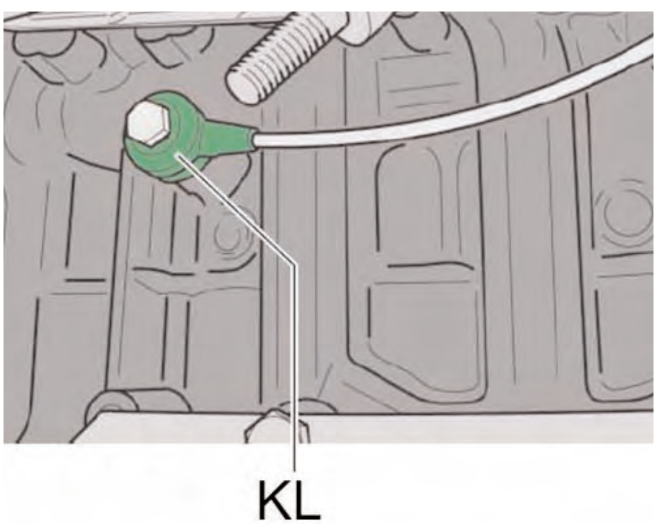
General

The ignition systems used in the V6 and V8 engines largely correspond to the systems used in previous engines. The ignition system map in the DME control unit has been designed to meet DFI specific requirements.

V6 DFI Engine

Knock Sensors





One knock sensor is bolted to the crankcase on the left **-KL-** and another on the right **-KR-**. They detect knocking in individual cylinders. To prevent knocking, the cylinder selective knock control system monitors the electronic ignition timing control system. Based on the signals from the knock sensors, the DME control unit adjusts the ignition timing angle for the knocking cylinder until the knocking stops.

If a knock sensor fails, the ignition timing angles of the affected cylinder group (1-3-5 or 2-4-6) are retarded. This means that a safety ignition timing angle is set to "late". Knock control for the cylinder group of the remaining, intact knock sensors is unaffected. If both knock sensors fail, the DME control unit goes into knock control emergency operation during which the ignition timing angles are generally retarded, thereby reducing engine power considerably and increasing fuel consumption.

Ignition Coils – V6

The V6 engine still has static high-voltage ignition distribution with individual ignition coils directly on the spark plugs. The DME control unit activates the individual ignition coils individually in the firing order 1-5-3-6-2-4 for each cylinder. The individual ignition coils in the Cayenne V6 have an integrated output final stage, but unlike the Cayenne V8 engines, the diagnostic function is integrated in the Motronic control unit. If an ignition coil fails, fuel injection for the affected cylinder is deactivated. This can happen on up to two cylinders.

Spark Plugs

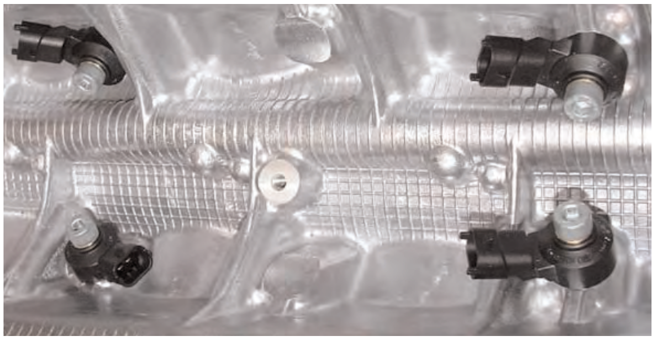
The V6 engine has air gap spark plugs with one ground electrode, which must be changed every 36,000 miles (60,000 km) or after 4 years according to the Technical Manual.

Note!

Spark plug replacement intervals have changed for M.Y. 2008 when compared to the 2003-2006 Cayenne models.

V8 DFI Engines

Knock Sensors



All V8 DFI engines have four knock sensors arranged in the V of the engine block. These four knock sensors are required for exact knock detection in V8 DFI engines since stronger vibrations are transmitted to the cylinder head via the fuel injectors during high pressure fuel injection.

Ignition Coils

The Cayenne has static high-voltage ignition distribution with individual ignition coils attached directly to the spark plugs. The newly enhanced ignition coils in V8 DFI engines work according to the same principle as previous V8 ignition coils.

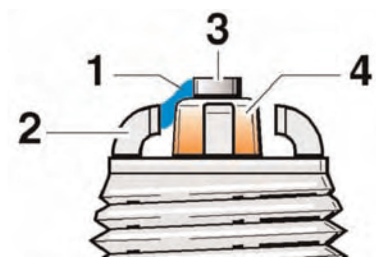
This system offers the following advantages:

- High level of ignition safety.
- Minimum electromagnetic interference with other electronic components.
- No requirement for ignition cables and distributor ignition.

The DME control unit activates the individual ignition coils individually in the firing order 1-3-7-2-6-5-4-8 for each cylinder. Safer ignition processes and therefore optimized power, together with minimized emissions and fuel consumption are obtained as a result of the measures and advantages described. All parts in this enhanced component are installed as a complete unit in a special rod ignition module housing. This is connected electrically and mechanically to the spark plug in the spark plug recess via the short high-voltage plug. The component is also secured mechanically using bolts. The ignition coil is sealed at the four-pin plug and in the spark plug recess to protect it from spray water.

Cayenne S Spark Plugs

The V8 naturally aspirated engine has nickelyttrium spark plugs with four ground electrodes, which must be changed every 36,000 miles (60,000 km) or after 4 years according to the Technical Manual.



Structure of the surface gap spark plug in the Cayenne S:
1 - Surface gap
2 - Ground electrode
3 - Center electrode
4 - Insulator Cayenne Turbo spark plugs

The four ground electrodes are arranged around the ceramic insulator in these surface gap spark plugs. The sparks **-1-** cross the surface of the insulator **-4-** and arc across a small gas gap to the ground electrode **-2-**, which improves the ignition properties. The main advantage of the surface gap spark plugs is the self cleaning effect of the insulator foot tip, since any shunts that occur between the center electrode and the ground electrode through the surface gaps, in particular during a cold start, are eliminated.

Cayenne Turbo Spark Plugs

The V8 turbo engine has air gap spark plugs with one double-platinum ground electrode, which must be changed every 24,000 miles (40,000 km) or after 4 years according to the Technical Manual.

Note!

Spark plug replacement intervals have changed for M.Y. 2008 when compared to the 2003-2006 Cayenne models.

Intake Air Side, Air Routing

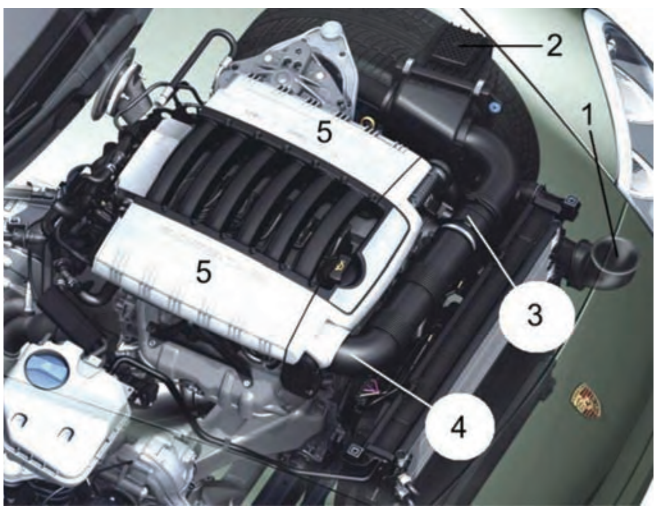
General

The intake systems in all new Cayenne models have been redesigned for direct fuel injection (DFI) in order to achieve a high torque curve. The air cleaner elements must be changed every 72,000 miles (120,000 km) or after 4 years according to the Technical Manual.

Note!

Air filter replacement intervals have changed for M.Y. 2008 when compared to the 2003-2006 Cayenne models.

Cayenne V6 Intake System



1 - Air intake behind the left headlight
2 - Air filter housing (with sound opening)
3 - Pipe mass air flow sensor
4 - To electronic throttle
5 - Intake system

The illustration shows the intake system, from the air intake behind the left headlight, the air filter housing with sound opening and the pipe mass air flow sensor to the electronic throttle.

The redesigned intake manifold charging system offers considerably improved filling for the V6 engine. This has resulted not only in an optimal torque curve, but has also improved performance.

Long Intake Manifold For High Torque

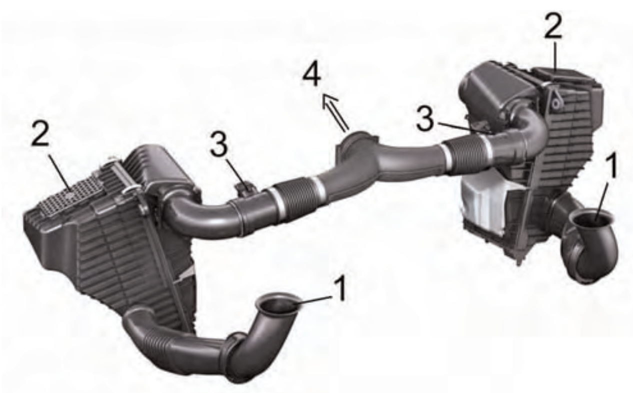
1 - Electronic throttle
2 - Torque accumulator
3 - Power accumulator
4 - Electropneumatic shift valve
5 - Vacuum unit
6 - Operating sleeves (sealed)

The operating sleeves in the intake system move into torque position when the engine is started and until an engine rpm of 4200 is reached and this is apparent from the repositioning of the operating sleeves (in direction of travel at the left front of the intake manifold). The vacuum unit pulls the lever to the left (in direction of travel). The operating sleeve seals the reflection point to the power accumulator, which renders the reflection point to the torque accumulator effective. The effective intake manifold length is approx. 610 mm in torque position.

Short Intake Manifold For High Power

If the engine rpm exceeds 4200, the power position is activated by opening the operating sleeves. The vacuum unit then presses the lever to the right (in direction of travel). The operating sleeve opens the reflection point to the power accumulator, which renders the short intake manifold effective with a length of approx. 235 mm. If activation does not occur, the system remains in power position.

Cayenne S Intake System



1 - Air intakes behind the left and right headlights
2 - Left and right air filter housings (with sound opening)
3 - Left and right pipe mass airflow sensors
4 - To electronic throttle 2

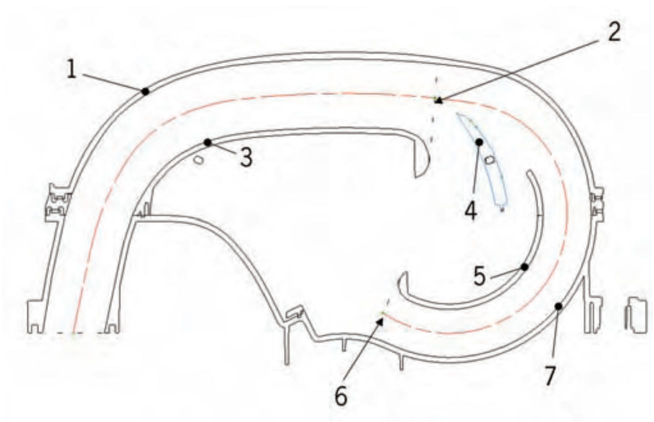
The illustration shows the intake system, from the air intakes behind the left and right headlights, the air filter housings with sound opening and the two pipe mass air flow sensors to the electronic throttle.

Variable Intake System

1 - Electronic throttle
2 - Variable intake system
3 - Diaphragm cell for switching flaps
4 - Connecting link
5 - Shaft for switching flap for cylinder bank 1
6 - Shaft for switching flap for cylinder bank 2

A new feature of the Cayenne S variable intake system is that intake manifolds of different lengths can be used due to a switching mechanism within the intake system. The variable intake system combines the advantage of long intake manifolds (for high torque in the lower rpm range) with short intake manifolds (for high specific power in the upper rpm range). A high torque curve is achieved, depending on the position of the intake manifold switching flap in conjunction with the optimized intake duct geometry.

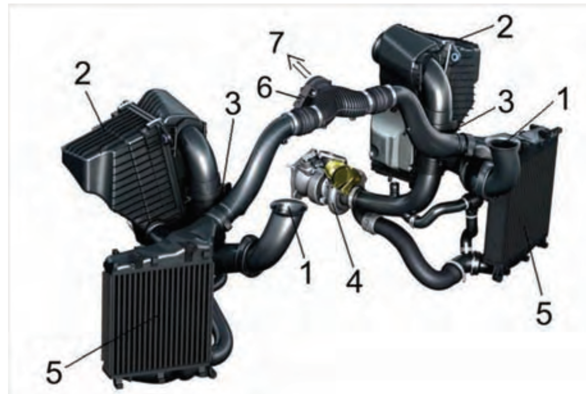
The DME control unit activates an electropneumatic shift valve, which switches a vacuum to the diaphragm cell. The switching flaps for cylinder bank 1 and 2 are actuated synchronously via a connecting link. In the torque setting up to approx. 4150 rpm, the long intake manifold is effective with a length of approx. 538 mm, while in the power setting, at an engine speed of more than approx. 4150 rpm, the short intake manifold is effective with a length of approx. 284 mm. If the electropneumatic shift valve is not activated, the variable intake manifold remains in power position.



1 - Upper shell
2 - Effective pipe length at power position (284.2 mm)
3 - Middle shell
4 - Sealed plastic flaps on a steel shaft
5 - Inlay
6 - Effective pipe length at torque position (538 mm)
7 - Lower shell

The variable intake system is made of a shell shaped fiber reinforced polyamide. A total of five plastic shells are welded together here. Four switching flaps are installed on a steel shaft for each bank and are coated with silicon for a reliable seal. The weight of the intake system in the 4.8 l naturally aspirated engine compared to the 4.5 l engine is reduced by approx. 10.5 oz (0.3 kg) despite the integration of the switching flaps for the variable intake manifold system.

Cayenne Turbo Intake System



1 - Air intakes behind the headlights
2 - Left and right air filter housings
3 - Leftand right pipe mass airflow sensors
4 - Left turbo (right turbo is behind the charge air cooler)
5 - Left and right charge air cooler
6 - Pressure sensor with temperature sensor
7 - To electronic throttle

The illustration shows the intake system, from the air intakes behind the left and right headlights, the air filter housings, the two pipe mass air flow sensors, the turbocharger and the charge air cooler to the electronic throttle. A sensor in front of the electronic throttle records the boost pressure and air temperature.

Turbo Pressure System

The pressure system in the new Cayenne Turbo is manufactured in a plastic shell design like the variable intake system in the Cayenne S. The pressure system comprises three shell elements, where the bottom shell is identical to the variable intake system. It is also made of plastic, for example, to ensure a low weight. Unlike the V8 naturally aspirated engine, the switching flaps are not required since the charge effect is produced by the two turbochargers. As a result, the low-loss short intake manifold lengths are effective for the entire map. The weight of the pressure system in the 4.8 l turbo engine compared to the 4.5 l engine is reduced by approx. 3.3 lbs. (1.5 kg).

Positive Crankcase Ventilation – Cayenne Turbo

With the enhanced positive crankcase ventilation system, it was possible to reduce the amount of fuel produced during combustion and entering the engine oil through the combustion gases, which pass the piston rings and penetrate the crankcase (blow-by gases). The enhanced aeration and ventilation system (Positive Crankcase Ventilation - PCV) now ventilates the crankcase with a steady stream of fresh air, which accelerates the evaporation of fuel that is carried in. For this purpose, fresh air is removed between the charge air cooler and throttle valve and is delivered to the crank chamber via a line.

The pressure that exists at any time between the removal position and the crankcase causes a steady flow of fresh air through the crankcase in all map points. To ensure sufficient vacuum in the crankcase in all map points, the vacuum in the intake manifold is used in the partial load ranges. A pressure regulating valve regulates this vacuum until the required value is reached. In the operating range with accumulated boost pressure (full load) in which there is no vacuum in the intake manifold, the vacuum upstream of the compressor is used.

To prevent the PCV system from freezing during the winter, the blow-by gases on both naturally aspirated and turbo engines are supplied to the combustion air through a heated adapter.

Exhaust System, Emission Control

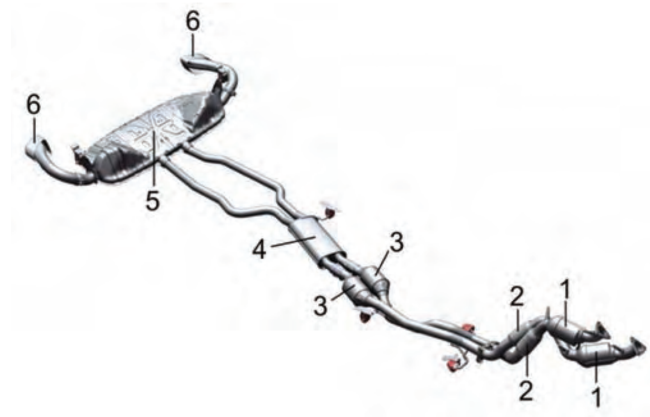
General

The exhaust systems in all new Cayenne models have been redesigned for direct fuel injection (DFI) in order to achieve maximum performance with minimum emissions.

All exhaust systems include the following:

- Two pre-catalytic converters.
- Two main catalytic converters.
- Two oxygen sensors (LSU) in front of the catalytic converters.
- Two oxygen sensors (LSF) behind the catalytic converters.
- Exhaust standard EU4 and LEV2 (USA emission standards).

Cayenne V6 Exhaust System

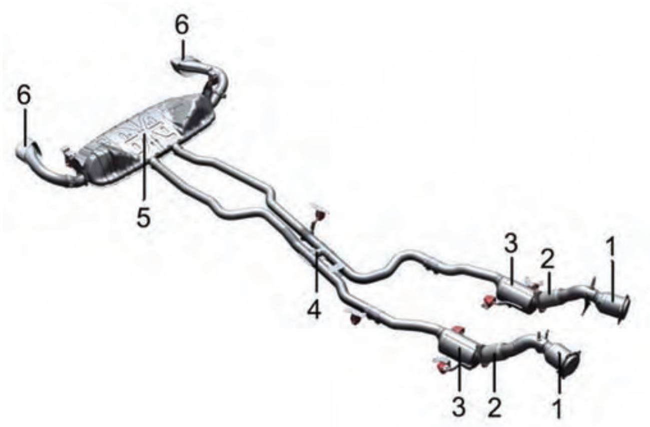


1 - Pre-catalytic converters (metal substrate)
2 - Decoupling elements
3 - Main catalytic converters (ceramic substrate)
4 - Front muffler with crossover pipe
5 - Main exhaust muffler
6 - Exhaust tailpipes with trim

The exhaust system has two pre-catalytic converters and new in the V6 engine, two main catalytic converters as well as a crossover pipe between the two exhaust tracts. The pre-catalytic converters installed in USA vehicles are different to those used in RoW vehicles.

The exhaust quality is monitored by two oxygen sensors (LSU) in front of the pre-catalytic converters and two oxygen sensors (LSF) behind the pre-catalytic converters. In addition, the V6 exhaust system as far as the rear muffler has been designed as a dual flow system. This improves the gas cycle by reducing the exhaust back pressure and ensuring better matching of the gas oscillations in the exhaust system. Behind the two main catalytic converters, there is a crossover pipe in the front muffler that connects the exhaust tracts. As a result, the torque curve is positively influenced at the lower end of the rpm range by an improved gas cycle.

Cayenne S Exhaust System

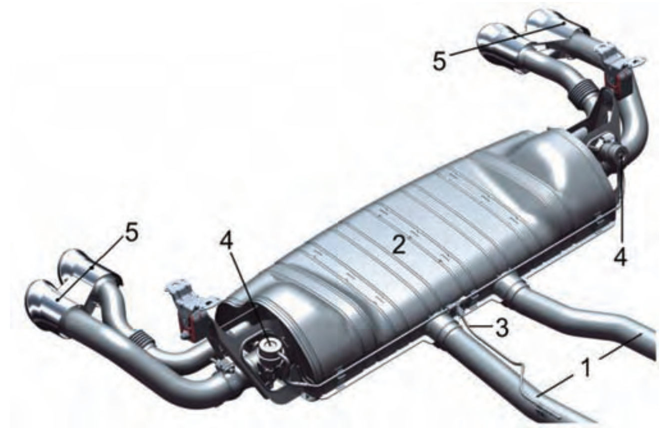


1 - Pre-catalytic converters (ceramic substrate)
2 - Decoupling elements
3 - Main catalytic converters (metal substrate)
4 - Crossover pipe
5 - Muffler
6 - Exhaust tailpipes with trim

The new Cayenne S features an enhanced exhaust system. To keep emissions to a minimum, it is important that the catalytic converter reaches its optimal operating temperature quickly. To achieve this, the exhaust manifolds in all Cayenne models are short in order to use the high exhaust emissions temperature to heat the catalytic converters.

The modified pipe guide on the exhaust manifold has also resulted in a significantly improved torque. The redesigned connection of the exhaust tracts to shorter, air gap insulated exhaust manifolds means that the catalytic converter heats up faster due to the reduced thermal mass. The weight of the entire system has also been reduced by other measures, e.g. the use of new pre-catalytic converters and pipes with thin walls.

Cayenne S Sports Exhaust System (Optional only for Tiptronic S)



1 - Dual flow exhaust system
2 - Sports exhaust system muffler
3 - Vacuum line for activation
4 - Diaphragm cell for switching
5 - Two tailpipes at the left and right with twin tailpipe trim

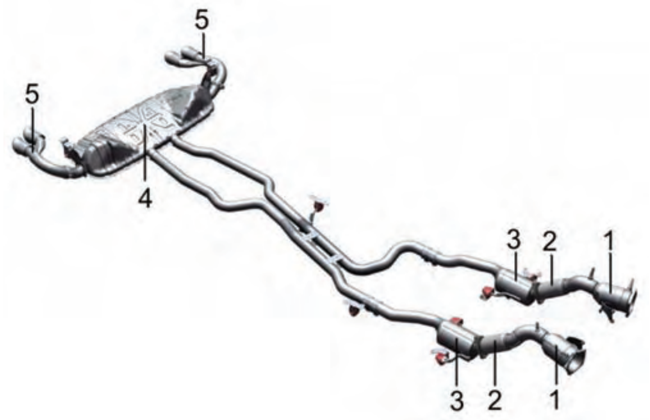
A sports exhaust system is offered for the first time for the new Cayenne S. The sports exhaust system is activated using the standard Sport button. The sound of the sports exhaust system is controlled while taking the load, speed, engine rpm and gear into account. Like the standard exhaust system up to the muffler, the sports exhaust system has two pre-catalytic converters and two main catalytic converters, the two exhaust tracts of which are linked together via a crossover pipe after the main catalytic converters.

The modified muffler in the sports exhaust system produces an sportier V8 sound. The design of the tailpipes resembles the standard dual tailpipes used on the new Cayenne Turbo. However, a connecting web gives them a unique look reserved exclusively for the Cayenne S with sports exhaust system.

Note!

Water fording depth is reduced when the sports exhaust system is installed. Consult vehicle owner’s manual for specifics.

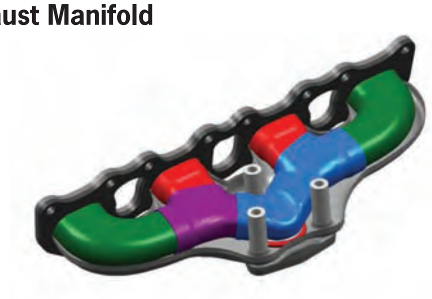
Cayenne Turbo Exhaust System



1 - Pre-catalytic converters (metal substrate)
2 - Decoupling elements
3 - Main catalytic converters (metal substrate)
4 - Muffler
5 - Tailpipe at the left and right with twin tailpipe trim

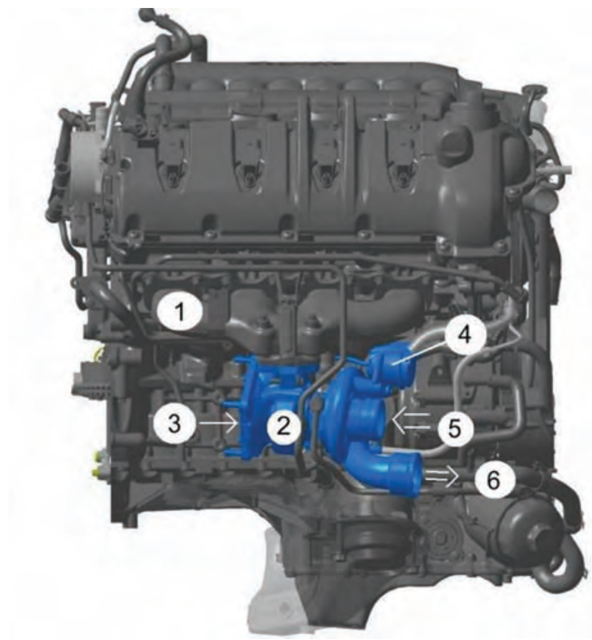
Compared to the previous model, this exhaust system has been designed specifically to suit the new DFI engine in the Cayenne Turbo.

Exhaust Manifold



This illustration shows the internal design of the Cayenne Turbo exhaust manifold. The internal design of the double-wall, air gap insulated exhaust manifold has been further enhanced compared to the 4.5 liter engine.

Turbocharger



1 - Exhaust manifold
2 - Exhaust turbine
3 - Flange to pre-catalytic converter
4 - Pressure unit for boost pressure control through the bypass valve (wastegate)
5 - Intake side (from air filter)
6 - Pressure side (to charge air cooler, electronic throttle)

The two turbochargers are arranged in parallel. A low intake manifold volume, short exhaust manifold and a redesigned turbocharger that has been adapted to suit the air consumption of the 4.8 liter DFI engine ensure a good response. A new larger radial turbine is used here compared to the previous 4.5 liter turbo engine. The illustration shows the water cooled turbocharger for the right cylinder bank with the pressure unit for boost pressure control as well as the lubricating oil supply and suction lines.

Boost Pressure Control

1 - Electronic throttle
2 - Cycle valve for boost pressure control
3 - Tank vent valve
4 - Positive crankcase ventilation

The pressure sensor in front of the throttle valve reports the boost pressure to the DME control unit. Depending on the current required and actual boost pressure, the DME control unit activates the cycle valve for boost pressure control according to a pulse/duty factor. This modulates a control pressure, which adjusts the bypass valves (**-W-** wastegate) on the turbochargers via the pressure units for boost pressure control in order to regulate the boost pressure.

Other Functions Of The DME Control Unit

VarioCam Plus Control on V8 DFI Engines

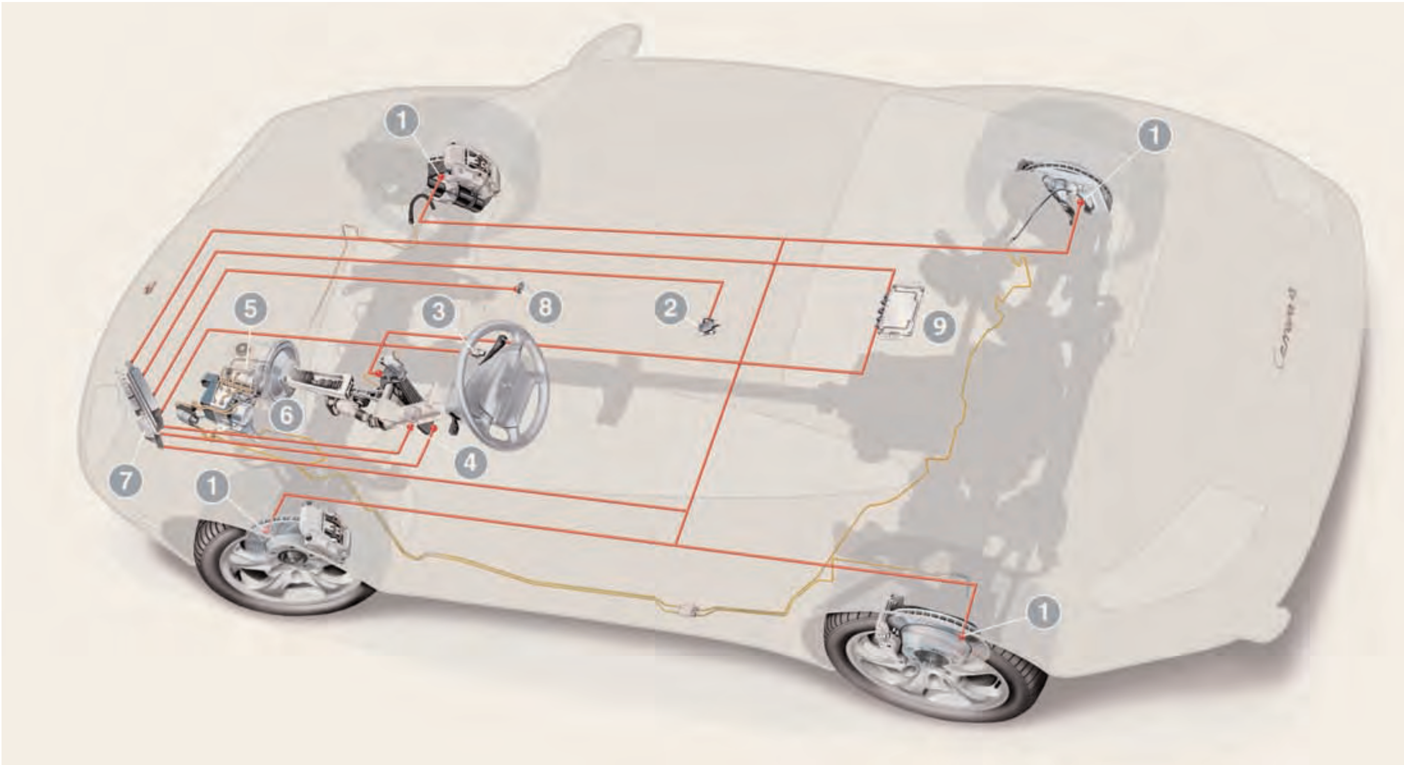
VarioCam Plus technology is used for the first time in V8 engines in the Cayenne model range. This system, which may be familiar to you from the current sports car generation, enables intake valve lift switching in addition to intake camshaft adjustment. This ensures optimum running quality, low fuel consumption and low emissions as well as high power and torque ratings in conjunction with the intake system.

Variable Oil Pump on V8 Engines

The DME control unit is responsible for the demand controlled operation of the variable oil pump, while adjustment is performed hydraulically. Engine management uses the input values for engine speed, temperature and torque. Based on this information, the engaged gear wheel width and therfore the geometric displacement volume of the gear wheel set is changed through the axial movement of a gear wheel (moved hydraulically) and this in turn changes the oil pressure. The pump ensures that only the pumping action required for the relevant load range of the engine is initated. This reduces the energy consumption of the oil pump to a minimum and also ensures demand controlled lubrication.

Control of Electric Radiator Fans

The DME control unit also activates the two drivers for the electric radiator fans in order to achieve infinitely adjustable control.



Subject **Page**

Special Control Systems

Systems That Effect Engine Management System Operation Via Data Transfer

Notes:

Notes:

Special Control Systems

There are a number of sub systems that are controlled by the engine management system and not part of the mixture control ignition control function. These systems work with the engine management system however are not involved in mixture and ignition control.

The function and purpose of these systems will be described in this section:

- Turbocharger Control
- Cam Timing Control
- Intake Tuning Systems
- Fan Control

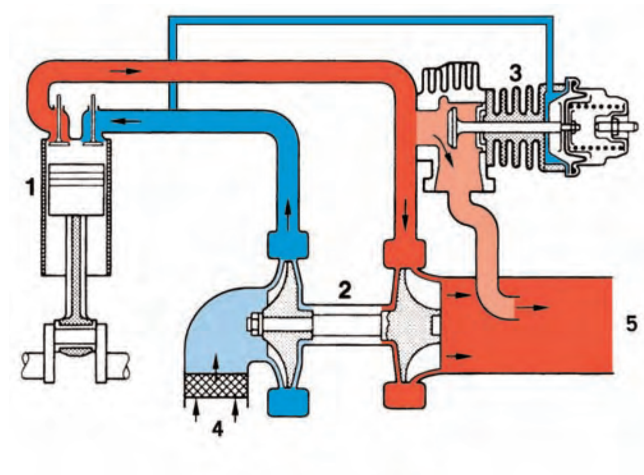
In addition, there are systems that send data and requests for intervention to the engine management system, and, receive data from and operate in synchronization with the engine management system.

The relationship between these systems and engine management will also be described:

- Tiptronic
- Stability Management
- ASR
- EDC
- Sport Chrono

Turbocharger Control

Porsche has utilized exhaust gas turbocharging to improve the performance of power plants since the 1970s. In the 1980s we began to control the turbocharger with electronic control systems. To understand how electronic control of turbocharger works, we need to examine how a basic waste gate control system works.



Basic Turbocharger System

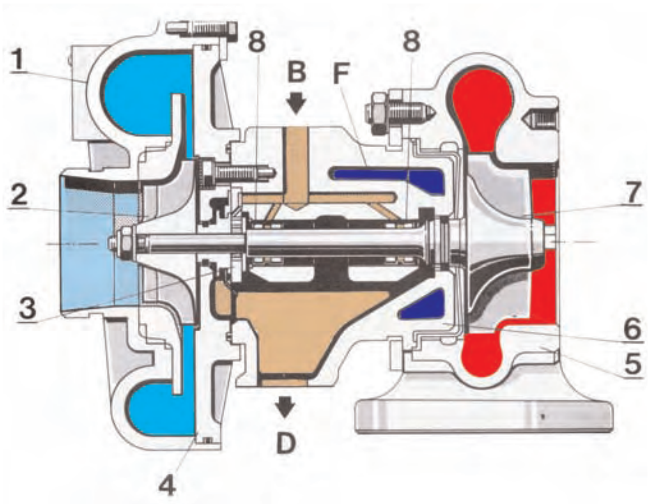
1 - Combustion Chamber
2 - Turbocharger
3 - Wastegate
4 - Air Intake
5 - Exhaust

The turbocharger at #2 is basically a supercharger, other variations of superchargers require some type of mechanical drive system to pump air into the engine.

A turbocharger utilizes a turbine in the exhaust flow to drive the impeller in the intake to pump air into the engine combustion chamber #1. The impeller is on one end of the drive shaft in the compressor housing and the turbine is on the other end in the turbine housing. The shaft has oil pressure lubricated bearings in the center section. In water cooled Porsche models, the bearing section has a water cooled section between the bearings and the turbine housing to keep the heat from the exhaust from heating the oil in the bearings and passages to the point that they become blocked by burnt oil (coking).

Compressor Section

Turbine Section

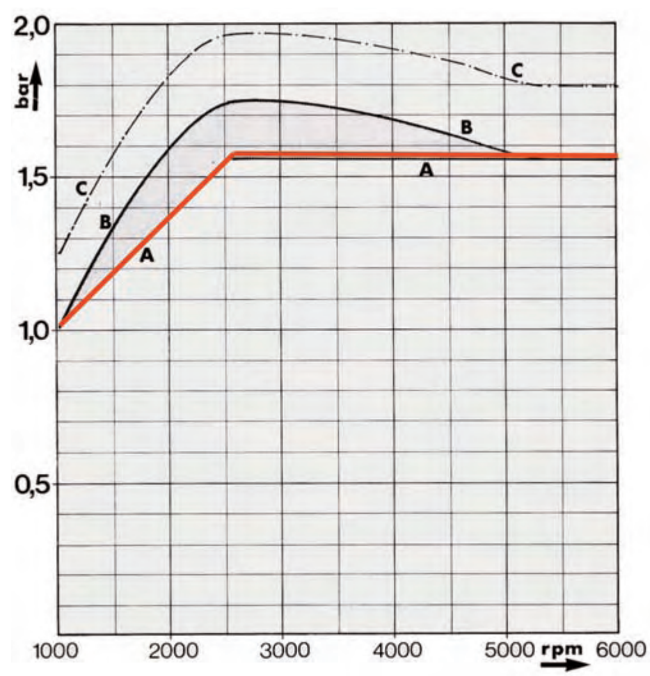


1 - Compressor Housing
2 - Compressor Wheel
3 - Axial Bearing
4 - Compressor Back Wall
5 - Turbine Housing
6 - Bearing Housing
7 - Rotor
8 - Sleeve
B - Oil Pressure From Engine
D - Oil Return Flow
F - Water Jacket

The speed of the turbine and impeller is not controlled by engine speed, but is a function of the balance between the energy that compressing the air charge requires, and the energy that the exhaust gas puts into the turbine. The speed of the rotating assembly can be very high, speeds up to 100,000 RPM are not uncommon.

If the turbocharger did not have a control system, the volume of air the compressor pumps and the amount of pressure in the intake would rise to a level that would damage the engine. To control the volume and resulting pressure generated by the turbocharger, we use a waste gate (#3 in Basic Turbo Charger System illustration). A waste gate is a pressure-controlled bypass around the turbocharger for the exhaust gas.

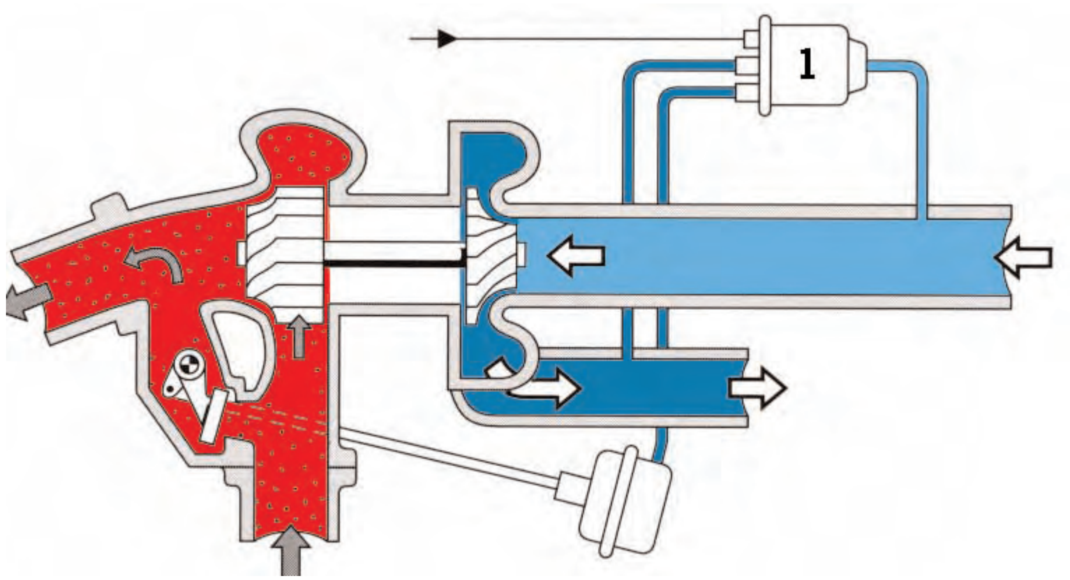
The turbocharger is a restriction to the exhaust gas flow, so when the gas flow is given a path around this restriction it chooses the path of least resistance, the amount of exhaust gas passing through the turbocharger is lowered thereby lowering the volume of air pumped into the engine. The waste gate which is a valve connected to a pressure-cell controls the size of the bypass. The pressure cell acts against a spring that holds the valve closed. The pressure cell is connected to the intake manifold by a pressure line, when intake pressure rises to a level that overcomes the spring, the pressure begins to open the valve. As pressure rises higher, the bypass opens further until the balance point of the system is reached and the pressure stabilizes at the maximum allowed by the waste gate. We can see this pressure curve in the Pressure/RPM graph marked as A.



Pressure/RPM Curve

This is how a waste-gate without electronic control works. The boost rises steeply as RPM rises until it reaches it's maximum level and then flattens out.

Electronic Turbocharger Control



Porsche first used digital electronic turbocharger control in 1986 on the 944 Turbo, most of the turbocharged Porsche motors since have had digital electronic turbocharger control.

With digital electronic turbocharger control the basic system operates like our previously described wastegate system. The difference is there is an electronic solenoid valve #1 that can vent the pressure that acts on the wastegate pressure cell to atmosphere (at the compressor stage inlet). When this happens, the turbocharger will not be controlled by the wastegate since the pressure that would open the bypass is vented or partially vented to atmosphere.

The air volume and pressure produced by the turbocharger will now rise above the non electronic wastegate control curve. We see this new control curve in the Pressure/RPM graph as B, the shaded area is the additional pressure electronic control provides. At C is the safety curve where the fuel injectors would be shut off to avoid damage to the engine from excessive boost.

Turbo charger control needs to know what the pressure in the intake manifold is in order to control the wastegate, for this reason there is a pressure sensor connected to the intake manifold.

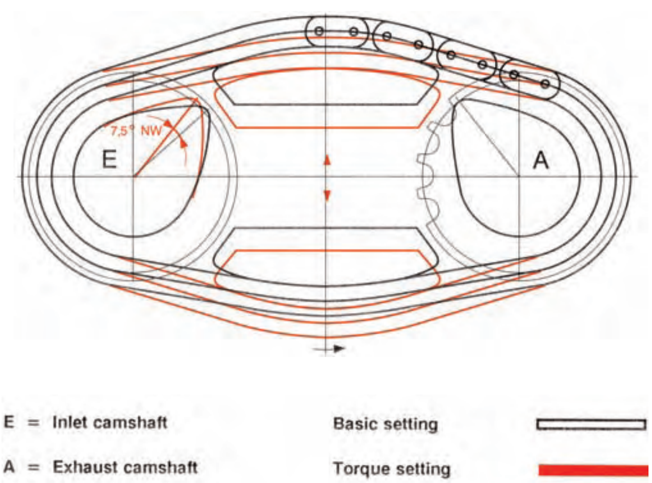
With digital control of the turbocharger, we have mapped control of the wastegate. Later systems have adaptive control, the vehicle specific sections have details of the control strategies for the turbo charger. For the most part, cycling the wastegate control is the main function that engine management has to provide for turbocharger control. Other functions that can be provided, include control of electric coolant pump and the boost recirculation control.

Special Control Systems

Cam Timing Control

In 1992 with the VarioCam equipped 968, Porsche began to use digital electronic control of camshaft timing. In 1997 the Boxster (986)was equipped with VarioCam and all subsequent Porsche power plants have incorporated digital electronic cam timing control. Many have valve lift control as well.

Until 2002 and the advent of VarioCam Plus on the naturally aspirated 911 Carrera (996) all of the cam adjustment systems made the cam timing change in one step so they were either off or on all of the timing change or none.



The operational principal of the one step VarioCam is illustrated in the graphic. We see the non actuated position in black (this is how a non VarioCam 944 operates all of the time). The exhaust camshaft is chain driven off of the crankshaft and the intake camshaft is chain driven off of the exhaust camshaft. If we push the guide block down (the position shown in red), we advance the intake cam without moving the exhaust cam. The 968 intake cam is moved by 15 degrees, the Boxster intake cam is moved by 25 degrees.

Control is via a solenoid hydraulic valve to advance the cam.The DME grounds the solenoid and oil pressure moves the piston attached to the lower chain guide to the advanced position. The upper chain guide is attached to the tensioner that acts against the slack side of the chain.

The initial actuation is at approximately 1500 RPM, at higher RPM (approximately 5500), the cam timing is returned to the base position, since at higher RPM the advanced cam timing would interfer with resonant intake charging and reduce performance.

The operations of the actuator and control solenoid hydraulic circuit are described in the following illustrations.

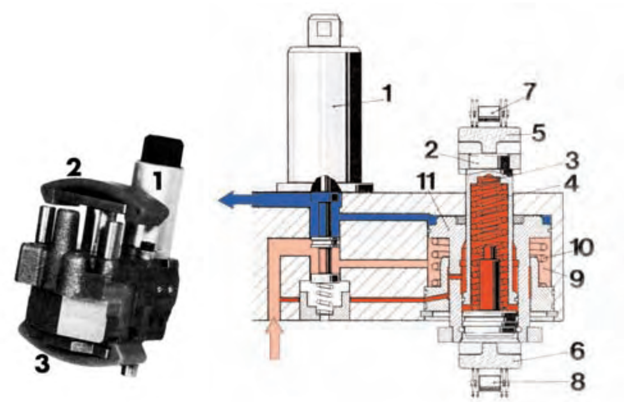
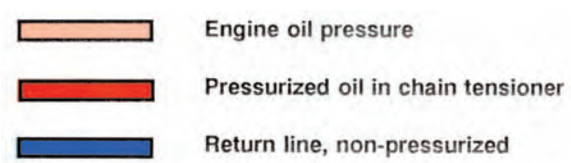


Figure 1 **Figure 2**



Basic Setting

Figure 1 - Adjustment of the chain tensioner is performed by hydraulic pressure cylinders and spring packs. Switchover pulses to the solenoid (1) are produced by the DME control units. When deenergized, both chain guides 2 and 3 are at raised position.

Figure 2 - Solenoid (1) deenergized. Oil pressure (red) fills interior of chain tensioner (2) and supports force of springs (3) and (4). Both tensioner chain guides (5) and (6) rest on the roller chain links (7) and (8). Oil pressure (light red) is also fed into the annular chamber (9) and supports the spring (10). Piston (11) remains at top. Non-pressurized oil (blue) is diverted.

Figure 3

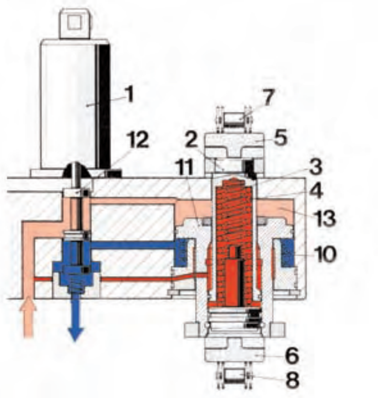


Figure 4

High Torque Setting

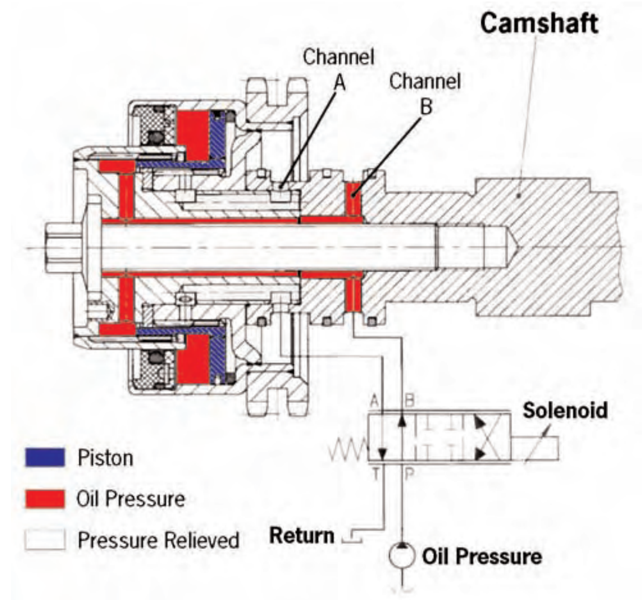
Figure 3 - Solenoid (1) is actuated by the DME control unit, engine oil pressure forces both chain guides (2) and (3) “down”. This corresponds to the “high torque” setting in the middle RPM range.

Figure 4 - Solenoid (1) is energized and forces control piston (12) down. Oil pressure (red) fills and tensions the tensioner. Oil pressure (light red) now also enters the large annular chamber (13) and forces the complete actuator with piston (11) down, overcoming the force of the spring (10) at the same time. Non-pressurized excess oil (blue) is diverted.

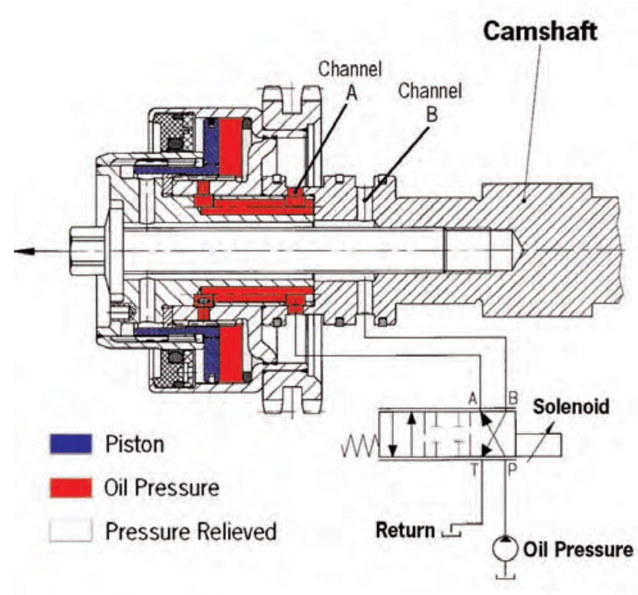
The systems in the 968 and Boxster are similar in operation, the only added sensor is an oil temperature sensor, which is required so the actuation RPM can be raised when oil temperature raises to the point that oil pressure drops off.

This form of cam timing control is easy for DME, all that is needed is a pin on the control unit that can be held to ground, an oil temperature sensor, and the software to control when to energize the actuator.

In 2001, the 911 Turbo (996) was equipped with VarioCam Plus. This system also moves the cam timing in one step, however, it utilized a sliding helical gear adjuster for the exhaust and intake cams which were driven by the same chain.



Piston position - retarded, minor valve overlap.



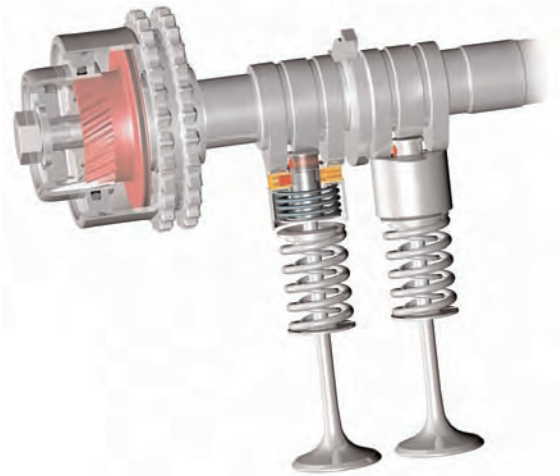
Piston position - advanced, major valve overlap.

With VarioCam Plus, once the adjuster is adjusted to the advanced position, it remains at the advanced position until engine speed drops below actuation RPM.

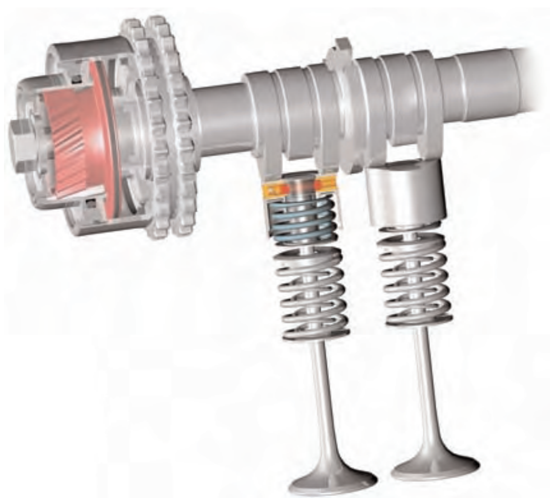
In addition to advancing intake cam timing, VarioCam Plus changes the valve lift from 3 mm to 10 mm on the 911 Turbo and 3 mm to 11 mm on the 911 Carrera (996). The actuation RPM for both functions is load dependant. The valve lift is changed by having two cam profiles and hydraulically locking the lifter in order to increase the valve lift.

Special Control Systems

Electronic control for the valve lift function is very similar to cam timing control. All the DME needs to do is switch a pin to ground when the software determines that the conditions for large valve lift have been met.

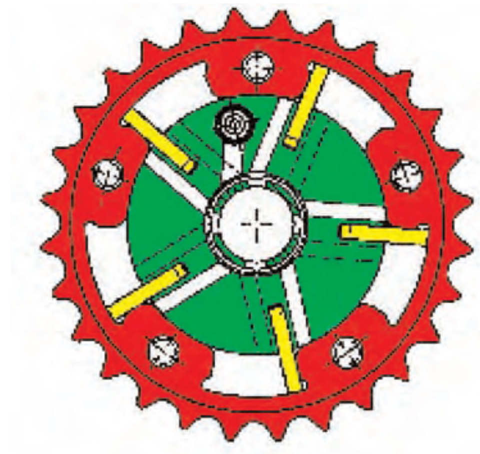


VarioCam Plus shown in idle speed range – inner tappet controls valve stroke (3 mm valve lift) and camshaft adjuster unit is in "retard" position (minor overlap).

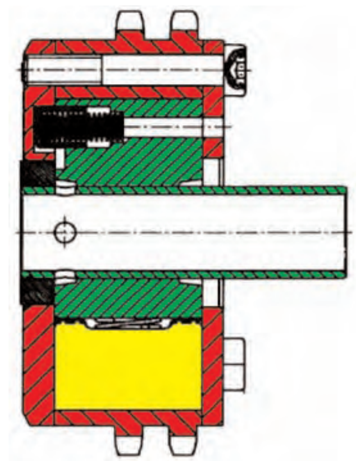


VarioCam Plus shown in upper full-load range – tappet is interlocked (10 mm valve lift) and camshaft adjuster unit is in "advance" position for peak torque and power.

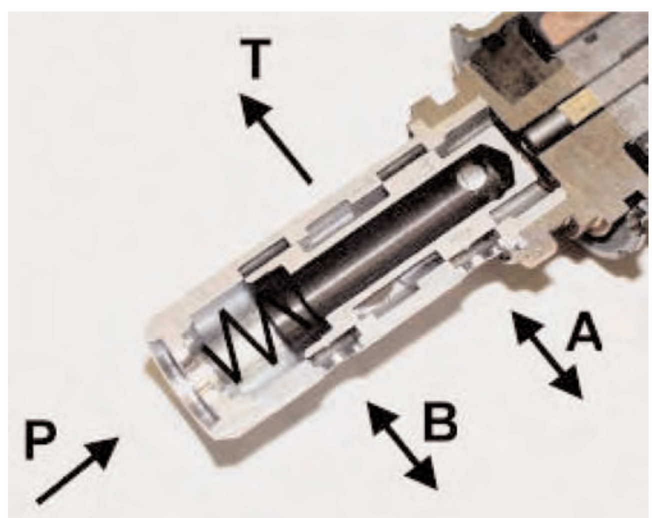
In 2002, the naturally aspirated 911 Carrera (996) was equipped with VarioCam Plus, this version of VarioCam Plus included <u>infinitely</u> adjustable cam timing (vane cell adjuster). As in all of the previously utilized cam timing adjustment systems, the exhaust cam remains fixed and the intake cam is moved. The difference is the intake cam can be moved to any position in its adjustment range. This is achieved by cycling the solenoid hydraulic valve between its three positions advance, retard and hold.



Camshaft Vane Adjuster - Front View Cutout



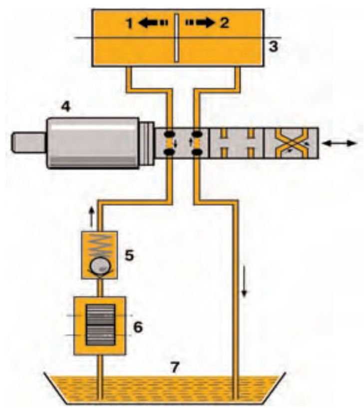
Camshaft Vane Adjuster - Side View Cutout



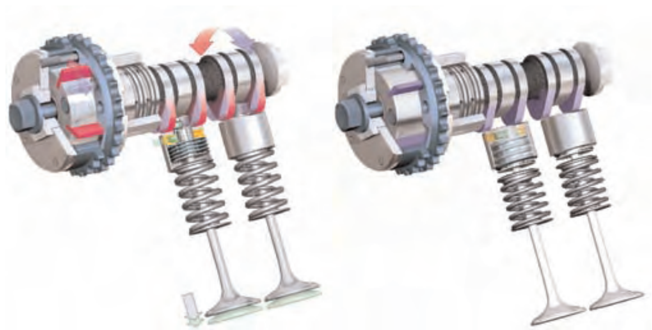
Solenoid Valve Operation

P = Oil pressure in
T = Oil return
B = Retard cells
A = Advance cells

Non-return Valve Operation

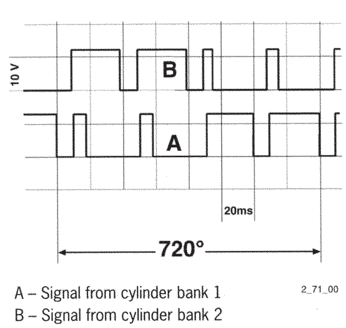


1 - Direction of Adjustment - Retard
2 - Direction of Adjustment - Advance
3 - Camshaft Adjuster
4 - 4-way Solenoid Valve
5 - Non-return Valve
6 - Oil Pump
7 - Oil Sump



911 VarioCam Plus

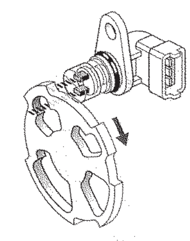
This new system uses the same cam position sensors as the 2001 911 Turbo (996); they sense cam position four times per cam revolution and with one sensor per bank, this doubles to eight times per cam revolution and four per crankshaft revolution. This allows the cam timing control system to very accurately determine camshaft position. In addition, these signals are utilized for the fast start system. The DME stores the stop position of the engine so that the DME can begin to immediately actuate injectors and ignition without waiting to see the cam position.

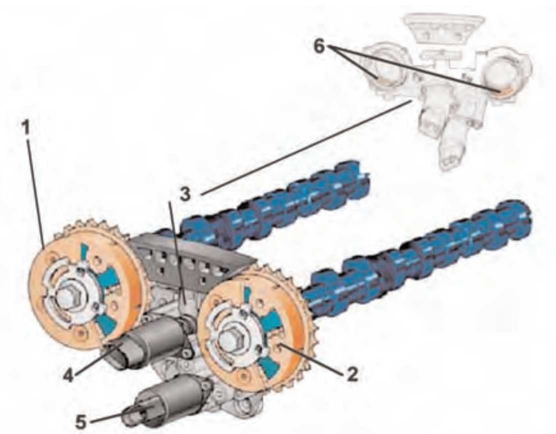


Signal from camshaft position sensors (Hall sensor)

The VarioCam system decides where it needs the intake cam to be positioned, and operates the hydraulic solenoid valve to put it there. With the PIWIS Tester we can see both the actual cam position and the position determined by the camshaft timing control system. The 911 Carrera (996) also utilizes valve lift control. In 2003, the Boxster (986) and Cayenne V8 were equipped with vane cell adjusters, however no valve lift control.

In 2005 with the introduction of the Cayenne V6 both camshafts were equipped with vane cell adjusters. The V6 motor also has a double Hall sensor system on each camshaft. The advantage of having a vane cell adjuster on the exhaust cam is for the main part to control NOx emissions.



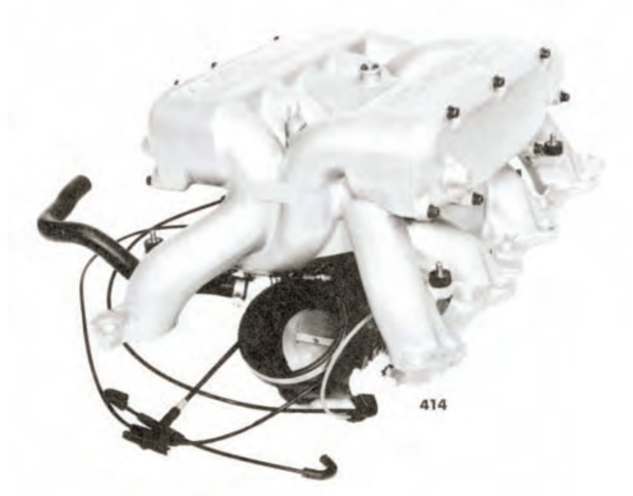


1 - Vane cell adjuster, intake camshaft
2 - Vane cell adjuster, exhaust camshaft
3 - Timing case
4 - Valve for variable camshaft control, intake
5 - Valve for variable camshaft control, exhaust
6 - Oil channels to annular groove of camshafts

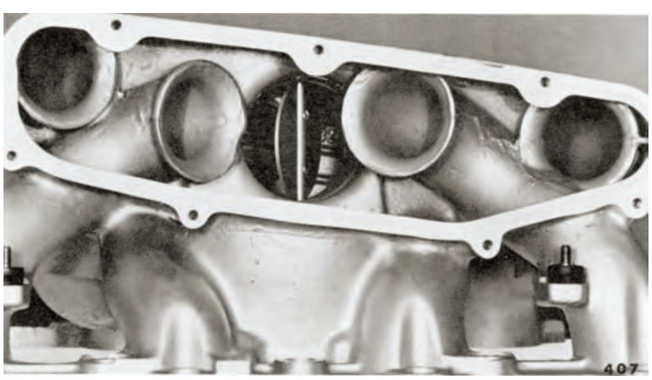
As we can see, cam timing control is simple, electronically speaking. On the most complex system, the 2002 911 Carrera (996), there are two one position solenoids, and two pulse-width-modulated solenoids controlled via software. Both utilize a programmed map using engine speed, load, and engine temperature to index cam position. **The mechanical components are more complex, but the payoff in torque and horsepower are worth the effort.**

Intake Tuning Systems

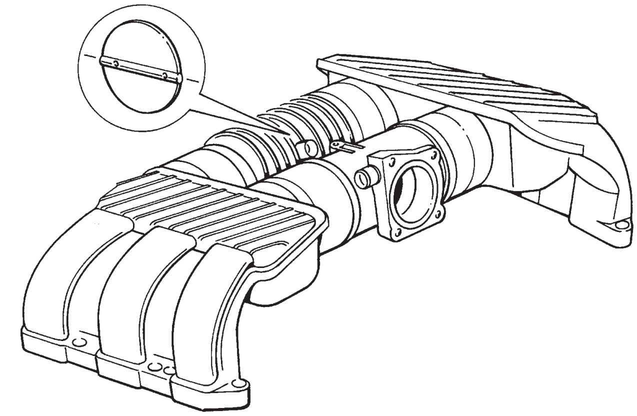
Porsche has utilized the naturally occurring pressure oscillations in the intake tract to improve the volumetric efficiency of Porsche motors since the 1980s. By utilizing the physics of intake tract operation, Porsche engineers have been able to design intake systems that give Porsche motors the volumetric efficiency of supercharged motors without having superchargers.



In 1987, the 928S was equipped with a resonance-tuning flap. This is in a tubular passage between the two plenums, one over bank 1 to 4, and one over bank 5 to 8. A vacuum motor actuated by an electric solenoid controlled by the LH control unit opened this flap. The switching point of the flap was determined from a load/RPM map.



This system was also utilized on the 911 Carrera (964) and later on the 911 Carrera (993), (996) and Boxster S (986). It is still in use on the 911 Carrera/S (997 and Boxster/S (987) models.



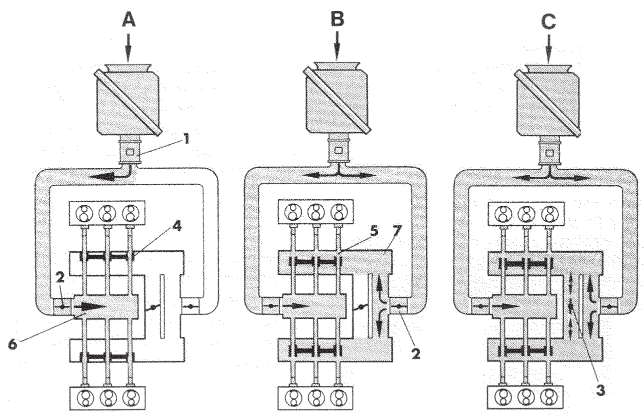
To understand how resonance tuning systems work, we need to return to the Otto cycle. When the intake stroke is occurring, the intake valve is open, the piston is descending, and the air fuel charge is rushing down the intake runner. As the piston approaches the bottom of the stroke, the intake valve closes. However, the air fuel charge that is in the intake tract cannot immediately stop moving, it has mass and inertia, so it continues to move down the intake runner.

With the intake valve closed, the intake tract becomes a sealed chamber, so the air fuel charge is compressed on top of the intake valve. When the inertia bleeds off, this compressed air fuel charge expands back up into the intake tract as a pressure wave. It is this pressure wave that resonant intake tuning utilizes to move air into the motor.

The design of the intake manifold causes the pressure wave to arrive at a companion cylinder while its intake valve is open and force additional air fuel mixture into that cylinder. The tuning flap changes the intake geometry so that this pressure wave effect is operational for a wider RPM band.

VarioRam

In 1996 the 911 Carrera (993) was equipped with a intake that included a system that mechanically changed the length of the intake runners in addition to a resonance tuning flap. This system utilized two intake paths. Only one intake path is utilized with long runners when the system switches to short runners the second intake path becomes effective. Two vacuum motors that are controlled by a single switching solenoid control the sliding intake sections.

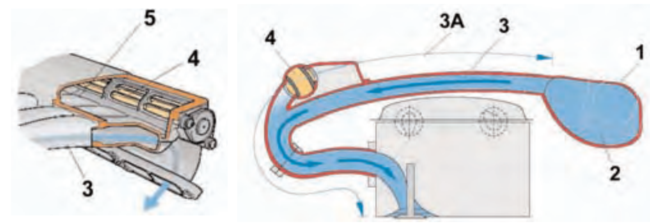


1 - Air mass sensor
2 - Throttle valve
3 - Tuning flap
4 - Vacuum controlled slides
5 - Pipe gap
6 - Central intake rail
7 - Tuned intake pressure charging system

The VarioRam system has three operating modes that are based on load and rpm. They are:

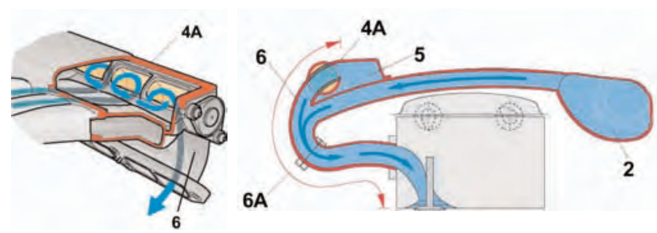
A - Long runners, one intake path,
B - Short runners, two intake paths,
C - Short runners, two intake paths and resonance chamber open.

The Cayenne V6 utilizes a power collector. This system exploits the pressure differential between the intake tract and the combustion camber when the intake valve first opens. It is similar in operation to the sports car system, however it utilizes a sealed chamber connected to the intake by short runners that is opened at 4250 RPM.



The cylinder draws the air through the long torque runners directly from the main collector, which achieves very good cylinder charging at low engine speeds.

1 - Air entrance (e-gas)
2 - Main collector
3 - Torque runners
3A - Length of torque runners approx. 30˝ (770 mm)
4 - Switching roller in torque mode (closed)
5 - Power collector

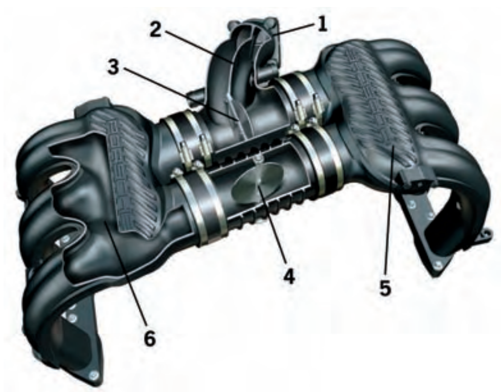


The air supply of the power collector takes place through the torque and power runners of the non-inducting cylinders. The vacuum wave created at the start of the intake process is reflected at the end of the power runners in the power collector. After a short time it moves back to the intake valve. The shortened resonance tube length of the power runners produces a high level of volumetric efficiency at high engine speeds and consequently good cylinder charging.

2 - Main collector
4A - Switching roller in power mode (open)
5 - Power collector
6 - Power runners
6A - Length of power runners approx. 18˝ 450 mm)

Special Control Systems

The Boxster/S (987) utilizes a double flow distribution flap in addition to a resonance-tuning flap. When the double flow distribution flap is closed, the intake is separated as if the engine were two three-cylinder engines running in parallel. The flap is closed in the lower RPM range where this increases torque, and opened in two higher RPM ranges. The RPMs of these ranges differ between Boxster (987) and Boxster S (987).



1 - Flange to electronic throttle

2 - Partition wall of double-flow dist. pipe

3 - Distribution pipe flap

4 - Tuning flap

5 - Intake distributor, left bank

6 - Intake distributor, right bank

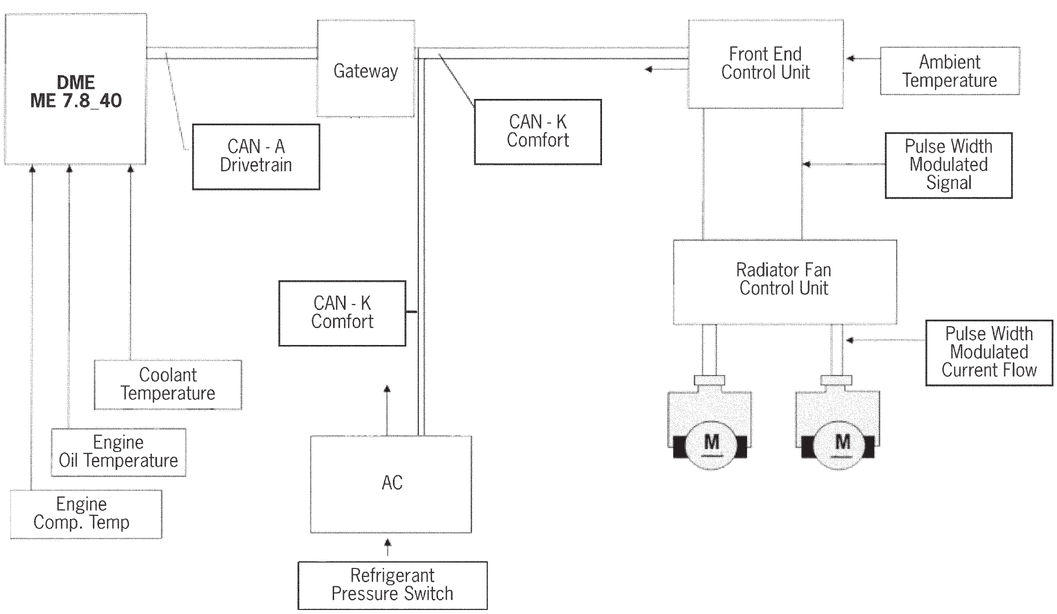
The 911 Carrera S (997) has a resonance chamber in its air cleaner housing with a flap that closes the resonance chamber off. This flap is opened at approximately 4000 RPM and closed again at approximately 6000 RPM and is controlled by the engine management control unit. However it has no effect on performance, it is for acoustics only.

All of these systems utilize electric solenoid controlled vacuum motors to control the flap movement. The engine management control unit has a map for flap control – some based on load and RPM, and some solely on RPM.

The specifics of how each system works can be found in the vehicle specific sections.

One common feature of these control systems is they actuate the flap one time when the ignition is turned on and the engine is not started – this is to check system operation. When we perform maintenance, these flaps should always be checked for correct function. If they do not operate, performance will suffer. These systems are monitored by the diagnostic system in the engine management control unit for electrical malfunction open circuit, short circuit to power and short circuit to ground.

Fan Control



Boxster (987) and 911 Carrera (997) Fan Control Chart

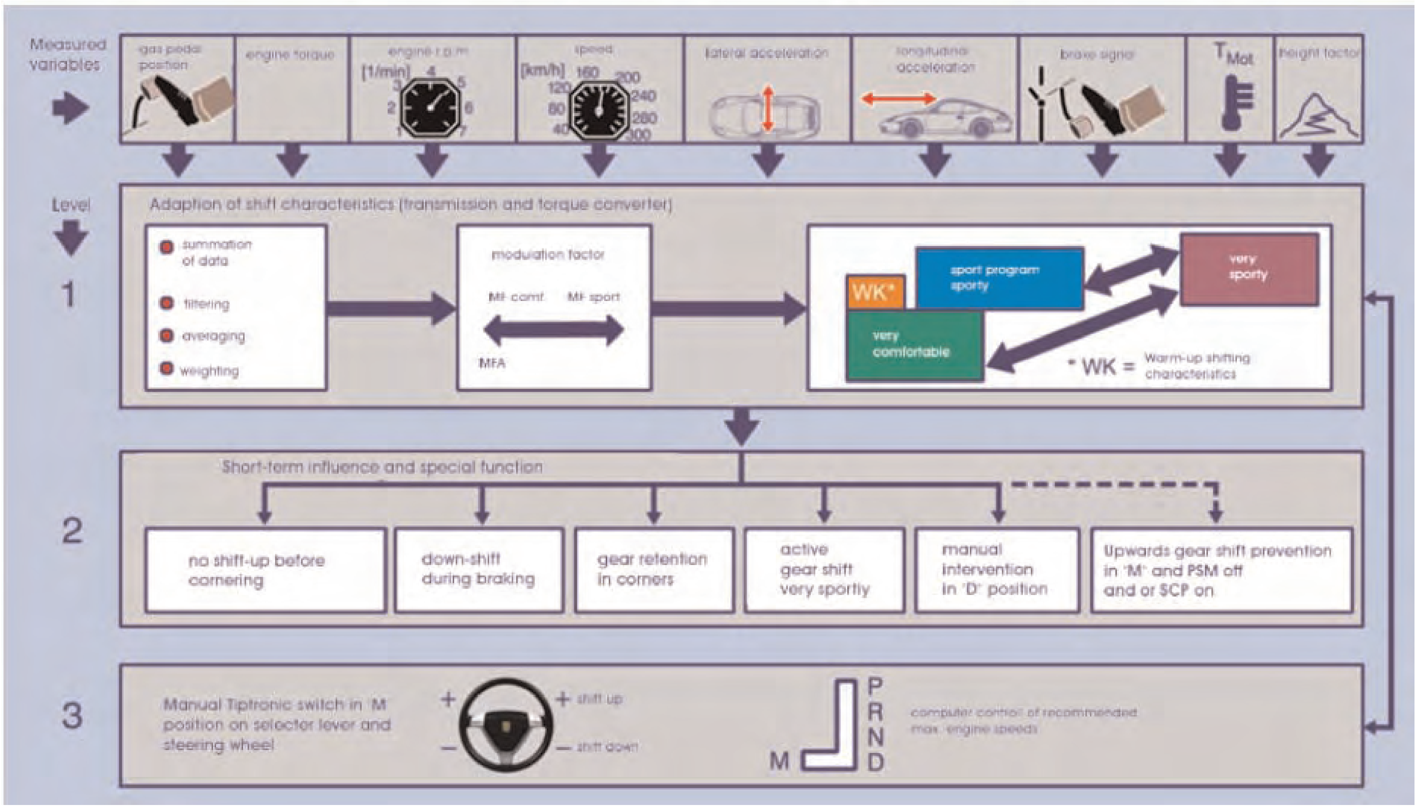
Beginning with the Boxster (986) the radiator cooling fans of Porsche vehicles are controlled by the engine management control. With the exception of the 911 Turbo (996) that has three speeds up until 2005, these system had only two speeds, low and high. In addition, the engine management controls the engine compartment ventilation fan, this is why there is a road speed input to engine management (the fan is not needed when the vehicle is in motion). With 911 Carrera (997) and Boxster (987) fan control is a distributed system that communicates via the CAN bus and the radiator fans are infinitely variable.

Systems That Effect Engine Management System Operation Via Data Transfer

There are several systems that have effect on the operation of engine management via programs in the engine management control unit that utilize data from other systems.

Tiptronic Transmission

Porsche has had the engine management system act on information from the transmission going back to the 928. The 928 has a switch that closes when the transmission shifts from 1st to 2nd so the ignition control can retard the ignition timing to soften the upshift.



All Porsche vehicles with Tiptronic transmissions have communication between the engine management control and transmission control so the transmission and engine can operate in coordination. The data transfer is bi-directional with load, RPM, throttle position, "ambient conditions" and engine temperature transferred from engine management to transmission control, and requests to retard ignition timing and gear selector position are sent from transmission control to engine management.

When the engine is cold, the transmission control engages a catalyst warm up shift program to speed catalyst warm up. This is why the transmission control is OBD-II relevant and why the MIL can be turned on by the transmission control unit. In 1997, the Boxster was the first Porsche vehicle to utilize a CAN bus system. It was used to connect the Tiptronic control unit to the Engine Management Control Unit.

Special Control Systems

Stability Management

The 1995 911 Carrera (993) was equipped with ABD (automatic brake differential). Porsche traction control began to utilize information from the engine management system. ABD actuates the rear brakes to eliminate wheel slip and it utilizes load information from engine management to determine the limit for brake actuation (when load is high the brake application time limit is shortened).

As Porsche stability management has evolved, the interaction between engine management and stability management has become more complex with more data shared between systems and more intervention in engine management by stability management.

Traction Control (TC)

The 1997 Boxster (986) introduced TC (traction control), this combined ABD and ASC (anti-slip control). When this system detects a poor traction condition, it will limit the amount of torque that the engine produces. The engine management can reduce the amount of fuel injected, and retard the ignition timing to reduce torque to the limit determined by ASC. ASC remains a component of subsequent stability management systems, with E-throttle, the engine management has control of throttle position as well as the timing and fuel metering. This allows E-throttle to control the amount of torque produced very precisely.

Engine Drag Control (EDC)

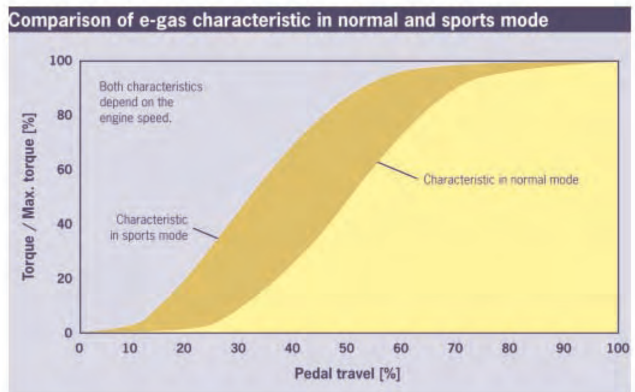
The 911 Carrera 4 (996) in 1999 came equipped with PSM (Porsche Stability Management) with ASC as an element of the system.

Another engine management related system component is EDC (Engine Drag Control). When EDC detects the rear wheels braking loose when decelerating with engine braking, it instructs the engine management control to open the throttle to reduce the amount of engine braking produced.

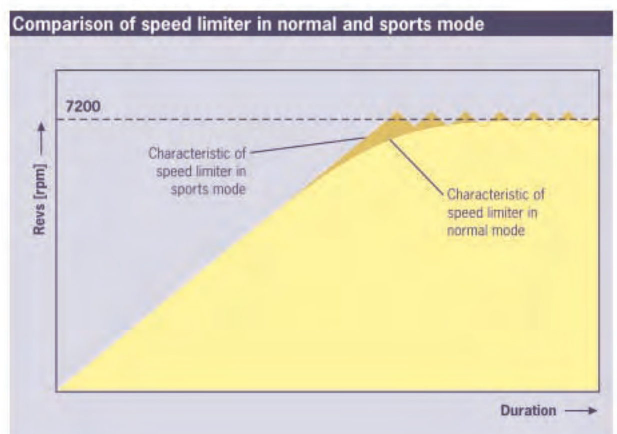
Sport Chrono

The 2005 911 Carrera (997) and Boxster (987) have Sport Chrono as an option, when this system is active the engine management switches the E-throttle to a faster rise of the throttle opening curve and a more aggressive RPM limiter.

Sports Chrono Functions of the Motronic



E-throttle Characteristic



Speed Limiter Characteristic

Notes:

Notes:

Porsche Emission Control Systems and OBD-II

As we discuss the emissions control systems on Porsche vehicles we will discover that these systems are enfolded by the OBD-II system, and when we study the Porsche OBD-II system we are studying Porsche emissions controls in a comprehensive manner. Examining these systems inside the framework of OBD-II as a complete system will organize and simplify our study of emission systems.

We will divide OBD-II into five topics:

I. OBD-I - Comprehensive Component Monitor

II. Dynamic Monitors
Monitors run continuously
Monitors run once per key cycle

III. Malfunction Indicator Light and Fault Management

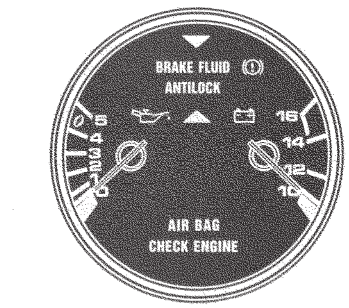
IV. P-Code System

V. CARB ISO (Generic scan tool mode)

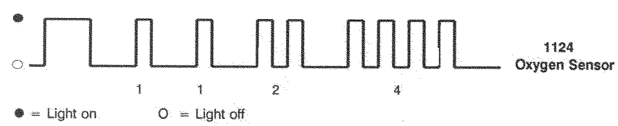
By dividing the emission system into these five subjects we will have a clear and understandable description of Porsche emission systems and how they operate. The first two subjects; Comprehensive Component Monitor and Dynamic Monitors contain descriptions of the physical systems of Porsche emissions control and how they are monitored. The other three topics are directly related to OBD-II fault management and legislative requirements.

OBD-I (Comprehensive Component Monitor)

OBD-I was introduced to Porsche vehicles in 1991. The system consisted for the most part as software in the DME control unit, the only hardware involved was the light in the instrument cluster. With OBD-I, if an emissions related component failure is detected by the diagnostic program a check engine warning light is illuminated. In addition, the fault is stored in memory and can be read out as a "blink code".



Check Engine Light Location



Blink Code

To read out the blink code, all you had to do is turn the ignition switch to the run position and then press the accelerator pedal to the floor (closing the full load contact) for five seconds. The check engine light would then blink out the fault. If the fault corrected itself (for instance an intermittent open) the light would go out, however the fault would still be kept in memory. This system utilized the diagnostic that had been in the control unit since 1988 and was interfaced by utilizing the 9268 diagnostic tool.

Ok, so why is this important to us in learning about OBD-II?

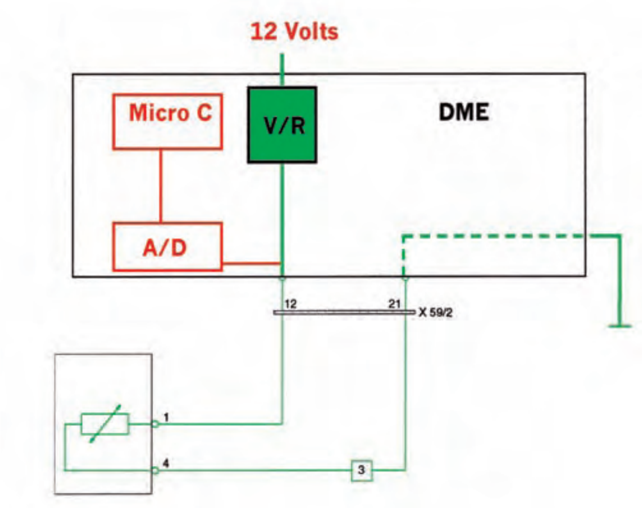
It is important because it is part of OBD-II where we call it the Comprehensive Component Monitor. The engine management system with OBD-II checks itself in the same manner as the check engine light system did.

So how does the malfunction indicator light/comprehensive component monitor work?

Well the first element is the digital computer which is the heart of the DME control unit – without a digital computer we could not have on-board diagnostics. The second element is the diagnostic program that is run by the computer – without software the computer can't perform any function.

These two elements, the digital microprocessor and the software program that it runs are what is really unique about digital engine management, and what gives digital systems the ability to self diagnose.

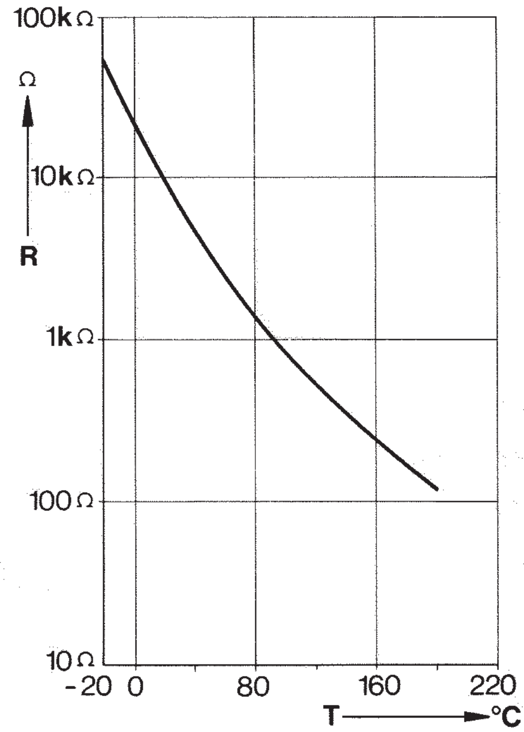
Let's take a look at how the system would diagnose a simple sensor circuit – the engine coolant temperature sensor. This will allow us to understand how these monitors work.



System Diagram

As you can see in the diagram above, the sensor is in series with the voltage regulator. It is an NTC resistor. This means that as temperature increases, the resistance of the sensor decreases.

Above the sensor, the voltage regulator in the control unit supplies a five volt reference, and below it is connected to the sensor ground circuit.



NTC Resistor Chart Showing Temperature Versus Resistance.

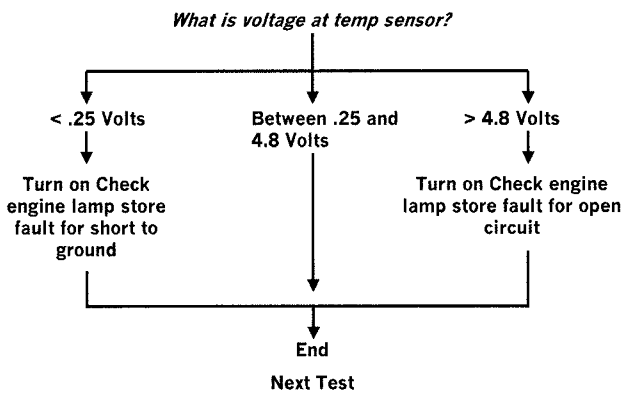
This will cause the voltage drop across the sensor to decrease as temperature increases. The voltage drop has a finite range. It cannot be at 0 because the sensor can be a very low resistance, but can never be without any resistance. In addition, it cannot be at five volts because the sensor can have a very large resistance, but not an infinite resistance (an infinite resistance is a open circuit).

As we can see in the system diagram, the microcomputer is separated from the sensor circuit by the analog to digital converter. The microcomputer must be separated from the analog circuit due to the voltage level that it operates at. The microcomputer operates at micro amps and volts and the voltages and amperages in the analog circuit would damage the microcircuit. In addition, the digital computer cannot process an analog signal. The actual voltage must be converted into a binary number for the microcomputer to process it.

The microcomputer is really just a complex adding machine. All the data it deals with must be converted into numbers that can be transmitted as 0 or 1. The computer will only do what its program tells it to do. This program is just a list of commands that the microcomputer executes one after the other.

If the commands are not written correctly the microcomputer will execute the incorrect command – it does exactly what the commands in its program tell it to do. So the better the diagnostic program is written the better the diagnosis.

Here is an example of how a diagnosis of an engine temperature sensor might be written:



As you can see, if there is no problem, the program proceeds to the next test. If a fault is found, it is stored in the fault memory and the check engine light is turned on and then the next test is preformed. When the program has run completely through, it starts over and runs again. The program will continue this repetition over and over the entire time that the engine is running.

This program performs circuit tests as in our example on all of the circuits in the engine management system, and in addition, it performs rationality checks on the sensors. For example; if the voltage of the temperature sensor doesn't move a certain amount in a given time, it is diagnosed as defective, even though it is within its range. We know that the engine temperature must rise if the engine is running.

This diagnostic system program runs in the background of OBD-II and is one of the three diagnostic tests that are run continuously. All components of the system are checked by the Comprehensive Component Monitor for:

- shorts to ground
- shorts to power open circuits
- rationality (is the value measured by the sensor a value possible for a correctly operating system).

With OBD-II the malfunction indicator light will not be turned on immediately when a fault is detected. It will be stored in memory and the light is turned on only when the OBD-II fault management system has determined the fault is legitimate. This usually will take two key cycles and the fault must be present for a time frame set by the diagnostic program.

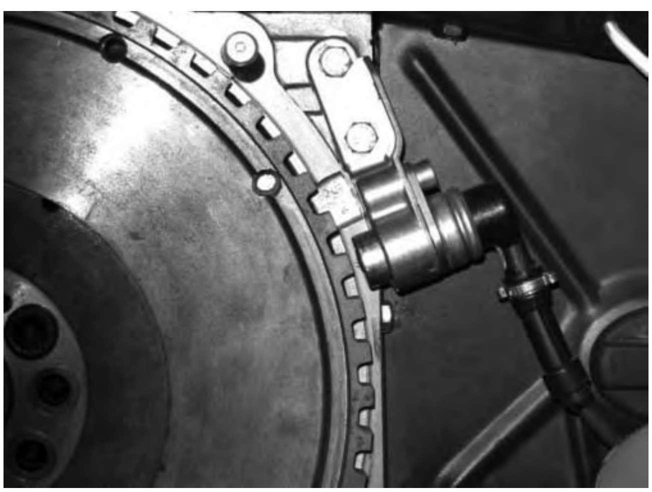
Monitors Run Continuously

1. Misfire Monitor
2. Mixture Control Monitor

Misfire Monitor

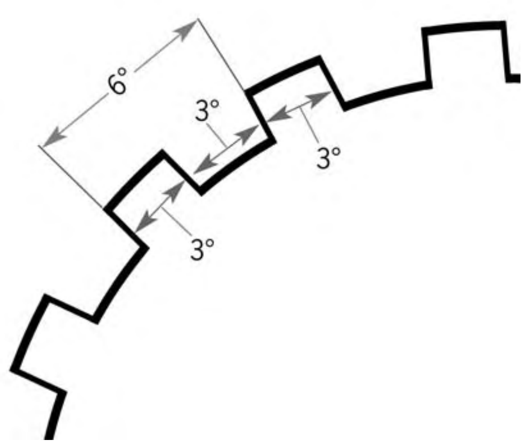
The misfire monitor detects any condition that causes the mixture in the combustion chamber not to ignite. When the hydrocarbons (fuel) in the combustion chamber do not ignite, they pass down the exhaust system into the catalytic converter where they cause overheating that will damage the converter. This is due to the oxidation process that takes place in the converter. Oxidation (burning) of the hydrocarbons is promoted by the platinum and rhodium catalyst. Relatively small amount of hydrocarbons that are normally in the exhaust flow will not overheat the converter. This makes it essential that misfire conditions be detected by the OBD-II system and indicated to the driver by the malfunction indicator light.

The misfire monitor detects misfire by monitoring the acceleration of the crankshaft that occurs when a spark plug fires and the combustion process forces the piston down the cylinder, thereby accelerating the crankshaft. The system utilizes the speed and reference sensor that is part of the engine management system to detect the acceleration of the crankshaft caused by the combustion process.



Flywheel With Sensor Ring and Inductive Sensor

As you can see in the illustration the inductive sensor with coil and iron core is positioned to sense the teeth of the sensor ring. The frequency of this signal (number of teeth per second) is directly proportional to crankshaft speed. There is a reference point that is determined by removing two teeth. There would be 60 teeth if the two removed to make the reference signal were in place. This makes each tooth and the void next to it 6 degrees in length, each tooth is 3 degrees in length.



Sensor Ring Tooth Degree Diagram

With the flywheel divided into sixty segments and each segment divided into two 3-degree segments (the high section and the low section), the computer can determine crankshaft movement in less than a degree. Remember the processor is operating with a clock speed of 20 to 30 million cycles per second, so the processor can do a lot of math when the flywheel moves only a portion of a degree.

With a six-cylinder engine, the system divides a crankshaft rotation into three 120-degree segments and looks for acceleration in each segment. From this it can determine not only that a cylinder has misfired or not, but identify the cylinder that has misfired. The program that evaluates misfire is complex. It has to be able to distinguish between deceleration caused by rough roads, potholes, shifting, and other non misfire causes, and deceleration caused by misfire.

When the fuel level is in the reserve range, it flags any misfire that occurs with the information that the misfire occurred when the fuel level was in the reserve range.

In order to determine if crankshaft deceleration is occurring, the misfire monitor must establish a baseline of crankshaft motion (what the crankshaft rotation looks like when there is no combustion).

We call this process flywheel adaptation and it has to take place the only time that there is no combustion, during deceleration.

In addition to establishing the flywheel adaptation, the misfire program can tell if there is damage to the sensor ring or flywheel. The misfire monitor is unique in that it is the one monitor that will turn on the malfunction indicator light immediately. All of the other monitors have some amount of time that the fault must be present before the light will be turned on. This is due to the damage that can happen to the catalytic converter if misfire occurs in a high RPM/load range or for too long of a period of time.

Mixture Control Monitor

The mixture control monitor utilizes the mixture adaptation system to detect mixture control system malfunctions. When the active mixture control FR (integrator), or the adaptive long-term fuel trim system moves out of a specified range, a fault is detected. If the fault is present for a specified time period and is outside the allowed range for two key cycles, the MIL (malfunction indicator light) is illuminated and a fault is stored. This monitor is part of the mixture control software and is active whenever the engine is running. When a fault is detected, the mixture adaptation system locks and makes no further corrections. The mixture control is already closely monitoring injection time and long term fuel trim, so modifying the software to detect when the fuel trim system has developed a malfunction does not require large changes to the system.

All of the monitors we have discussed so far are continuous monitors that operate all of the time in the background. They run from the time that the engine is started until the vehicle is shut down. These monitors are for the most part software modifications and require little or no additional hardware be added to the vehicle.

Now we will examine the monitors run once per key cycle. Many of them require additional components.

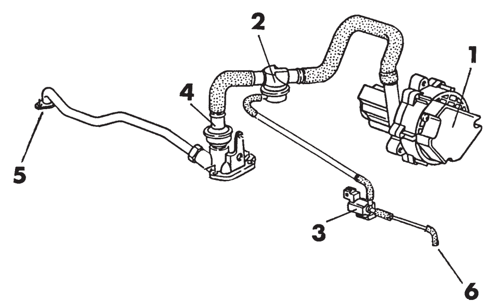
Monitors Run Once Per Key Cycle

These monitors are the big difference between OBD-II and earlier systems. They are unique in that they require some special conditions in order to run such as a certain load level, engine RPM, or temperature.

1. Air Injection Monitor
2. Evaporative Monitor
A. Fuel Tank Ventilation
B. Fuel Tank Pressure Test

3. Catalyst Aging Monitor
4. Oxygen Sensor Monitor
5. Oxygen Sensor Heater Monitor

Air Injection Monitor



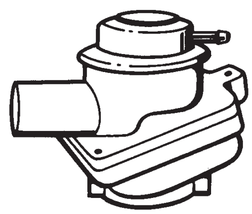
Air Injection System Components

1 - Air pump
2 - Pneumatic switching valve
3 - Electromagnetic valve
4 - Non-return valve
5 - To the cylinder heads
6 - To the vacuum chamber

The air injection systems on Porsche engines with OBD-II operate only for the first several minutes after start up. They utilize electric air pumps since this eliminates any load on the engine when the air pump is not operating. The length of time that the air pump operates is dependent on the engine temperature at the time of start up.

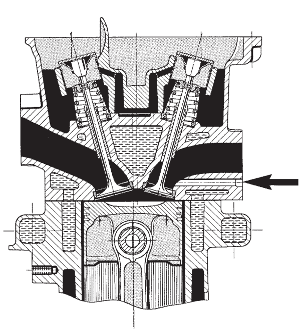
The system consists of a control valve and an electric air pump and a manifold system with a one-way non-return valve to keep the exhaust gas pressure in the exhaust. Up until M.Y. 2005, Sports Cars have a vacuum operated shut off valve to ensure that no air is pulled into the exhaust system when the pump is not running (this would drive the mixture rich as the mixture control system would see the extra O_2 as a lean condition and correct for it). The valve is controlled by an electromechanical vacuum switching valve that energizes and applies vacuum to the valve, opening it when the pump is switched on. This is achieved by having the Engine Management Control Unit ground the low side of the power relay for the pump and the coil for the vacuum-switching valve at the same pin.

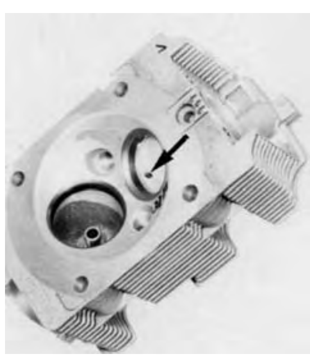
Cayenne models and Sports Cars after 2005 use a combination one way/control valve that allows flow into the exhaust after the air pressure rises to 80mbar, avoiding the complication of the shut off valve and vacuum switching valve of the earlier system.



Secondary Air Injection Pneumatic Switching Valve

The passages for the air injection system are designed into the motor and inject the air directly into the exhaust port via passages drilled or cast into the engine components.





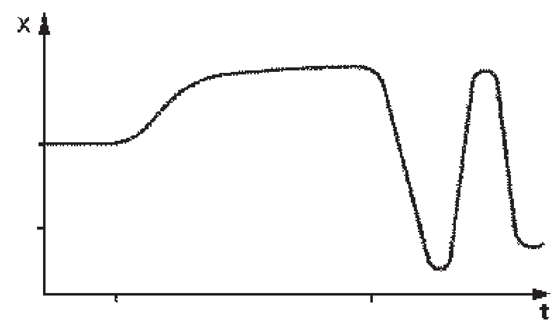
Cylinder Head Air Injection Passage (arrow)

The point of injecting air into the exhaust is to promote oxidation of excess HC that is present during start up. In addition to controlling HCs, the heat produced by this process heats up the catalytic converter and enables early light off of the catalyst.

Operation of Air Injection Monitor

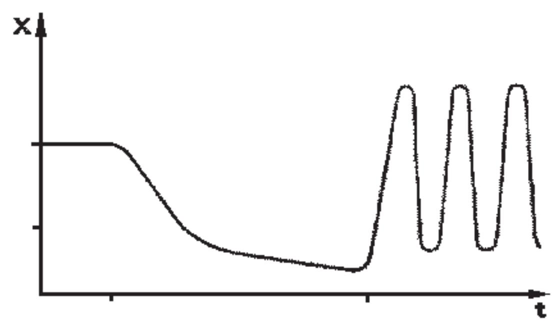
The monitor for air injection monitors the oxygen sensors in order to detect if air is actually being injected into the exhaust. It looks for the oxygen sensors to drive the voltage low (think back to our discussion of oxygen sensor basics low voltage high oxygen content in exhaust), since normally the sensor voltage would be high due to the rich start up mixture. The only way that the sensor voltage will fall to ground is if air is actually being injected into the exhaust.

Oxygen Sensor Voltage Without Secondary Air



X - Oxygen sensor voltage
t - Time

Oxygen Sensor Voltage With Secondary Air



X - Oxygen sensor voltage
t - Time

If the voltage falls when the air pump is actuated, then air is being injected. If there is no drop or a weak drop, the system has some problem that is keeping air from being injected. The comprehensive component monitor checks the circuit of the air pump control and with Sports Cars before 2005, the vacuum control solenoid.

Evaporative Emissions System Monitor

The evaporative emissions system monitor has two main sub systems:

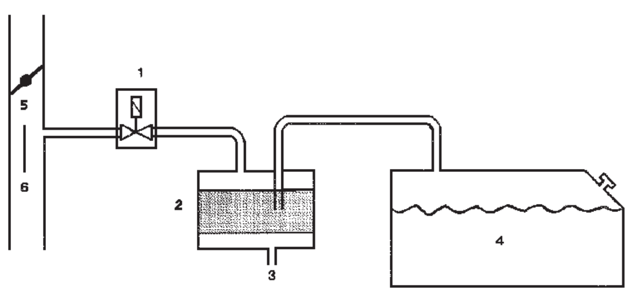
1. Fuel Tank Ventilation Monitor
2. Fuel Tank Leakage Monitor

These two systems check the same system, however, they operate independently and for the most part at different times. The tank ventilation monitor is very similar vehicle to vehicle, and with the tank leakage monitor, there are three different systems.

In addition, there are some features that all OBD-II vehicles have that are not actually functioning components of the emissions system but have an effect on how well the systems function. For example, all Porsche models from 2002 have returnless fuel systems with the exception of Turbo and GT3. This reduces the temperature of the fuel in the tank, and therefore the amount of HC vapors generated in the tank.

Fuel Tank Ventilation Monitor

To understand the tank vent monitor we must first examine the operation of the evaporative emissions control system.



1 - EVAP canister purge valve
2 - EVAP canister
3 - Purge air
4 - Tank
5 - Intake manifold
6 - To the engine

Pictured above is a basic evaporative emissions system. It is similar in concept to the system used on all Porsche vehicles. This system has two operation modes, static and dynamic (engine off and engine running). In the static mode, fuel vapors form in the tank #4 and then flow across the carbon in the EVAP canister #2 and out the flushing air line to atmosphere at #3. As the vapors cross the carbon (not a large volume of vapor and not at a high flow rate) the HCs in the vapors are absorbed by the carbon and held in the EVAP canister.

This process continues the entire time the vehicle is static. After the engine has run long enough for it's temperature to rise above the level required for tank vent operation, the EVAP canister purge valve opens and air flows into the flushing air line at #3 and across the carbon in the EVAP canister and through the purge valve into intake manifold. As the air crosses the carbon in the EVAP canister (a large amount of air at a high flow rate) it picks up the HCs that were deposited in the carbon during the static mode and carries them into the intake where they become part of the fuel used in the combustion process. The fuel mixture control system must adjust the Ti to compensate for the additional fuel that is delivered by this system.

The mixture control system operates the purge valve from a map that must be compensated for the amount of fuel that has been stored in the EVAP canister. The amount of HC stored in the EVAP canister can vary greatly. If the vehicle has been operating for an extended period at highway speeds, there will be almost no HCs stored and when the purge valve is opened it is an air leak.

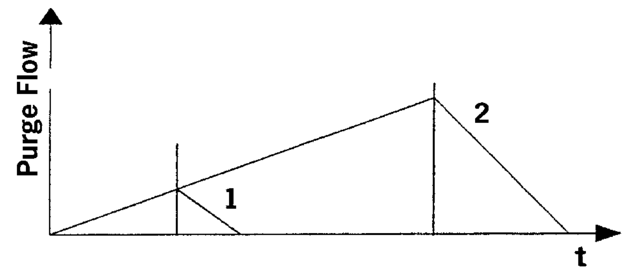
The tank ventilation system operates as part of the mixture control system and is even used to compensate for short-term mixture control deviations (if for example an air leak occurs, the mixture control will increase the purge valve on time until the system can adapt).

Diagnostic Monitor

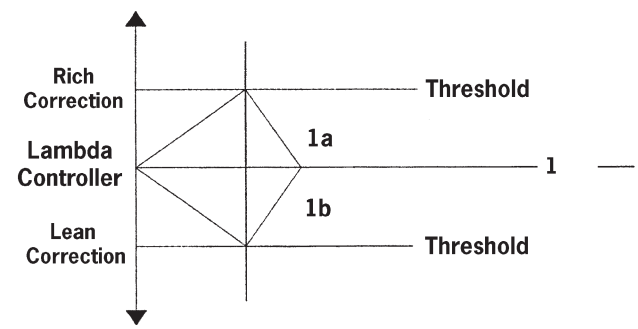
To determine if vapors are flowing through the purge valve (this is the main indicator that the system is functional), the monitor looks at the oxygen sensor. If the sensor moves high or low a sufficient amount when the purge valve is opened, the system is determined to be operating correctly.

However, it can be that the valve is operating correctly and the sensor voltage does not move. This would occur when the mixture coming from the system is at the stoichiometric ratio, in this case the oxygen sensor voltage would not move when the purge valve opens. To detect this condition, the monitor also looks at the idle control system when the purge valve is opened, the idle control has to lower the amount of air entering the engine in order to maintain the specified idle RPM, then the system is determined to be operating correctly. This is why this monitor needs idle condition to complete its function.

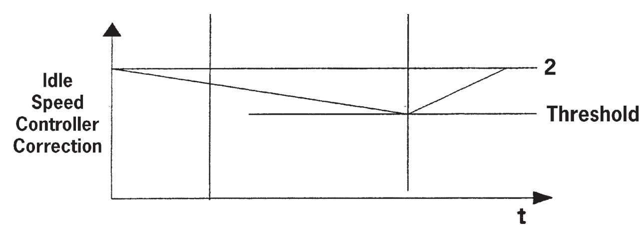
Tank Venting Tests



1. Lambda purge flow <> 1: System is functional if fresh air (1a) or HC (1b) detected.
2. Lambda purge flow = 1: Throttle unit actuator will reduce the flow rate through the throttle due to additional flow through the purge valve.



1a. Fresh air via EVAP canister.
1b. Fuel vapor via EVAP canister.



2. Lambda purge flow = 1: Throttle unit actuator will reduce the flow rate through the throttle due to additional flow through the purge valve.

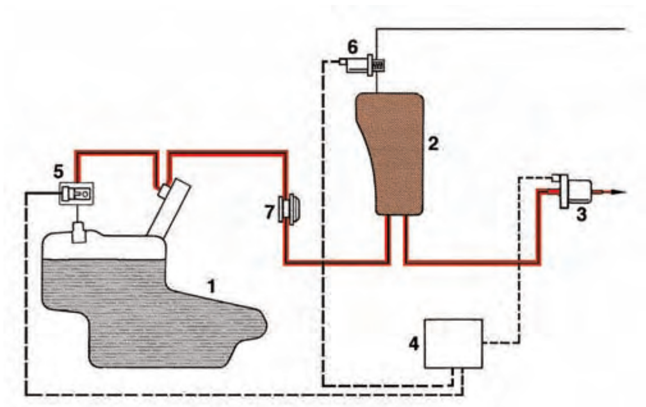
Fuel Tank Leak Detection Tests

Porsche vehicles utilize three types of tank pressure testing:

1. Pressure sensor with flushing air line shutoff valve – Sports Cars up until 2004.
2. Leak detection Pump – All Cayenne models
3. DMTL – Sports Cars 2005 and later

In addition we have On Board Refueling Vapor Recovery on all models overlaying the tank venting and tank leak detection systems.

Sports Cars up to 2004 – Tank Pressure Sensor and Flushing Air Line Shut-off Valve



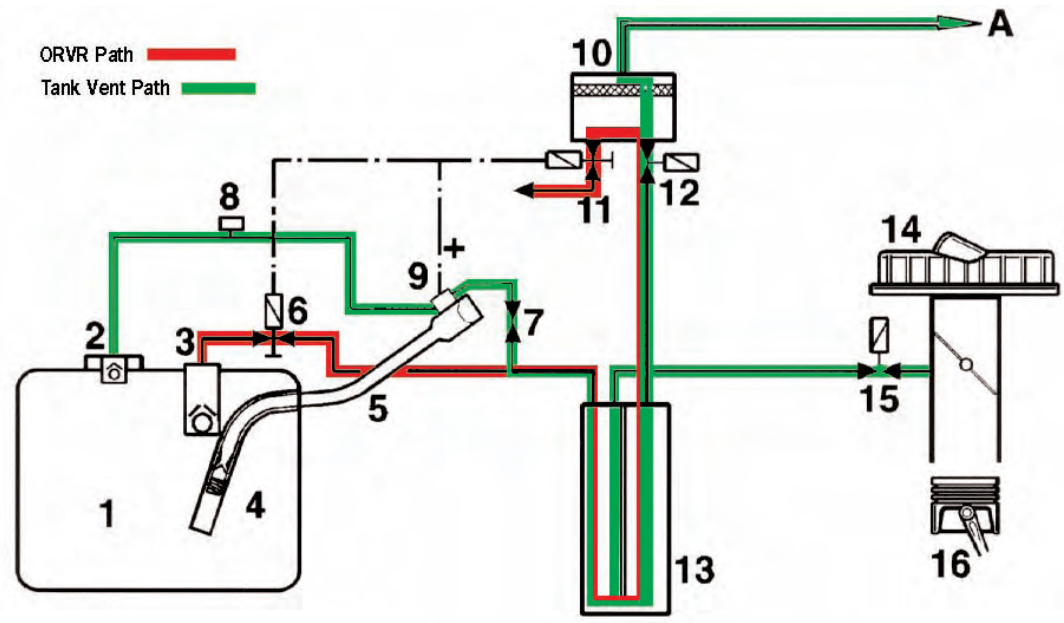
System Overview

1 - Fuel Tank
2 - EVAP Canister
3 - Purge Valve
4 - DME
5 - Tank Pressure Sensor
6 - Shutoff Valve
7 - Vacuum Limit Valve

Leak check diagnosis of the sports car fuel tank utilizes the vacuum in the intake manifold to generate a low pressure in the tank, and a pressure sensor to monitor tank pressure. The pressure sensor (5) monitors tank pressure, it is a piezoelectric sensor that generates a voltage directly proportional to the pressure in the sensor. When the conditions for diagnosis are met and diagnosis is initiated, the purge valve (3), and shutoff valve (6) are closed, a slight pressure rise will then occur in the tank caused by fuel evaporation. Then the purge valve will be opened and a low pressure will be generated in the tank. This pressure will not be as low as the intake manifold vacuum due to the vacuum limit valve (7). This valve limits how low the pressure in the tank can go. This is done because if the pressure gets too low it will cause the fuel to evaporate at a much higher rate (liquids boil in a vacuum).

Once the pressure in the tank is low enough, the purge valve is closed and a waiting time is started, if the pressure remains constant, the tank is leak tight (a small increase is allowed). The size of the leak is determined by how rapidly the pressure rises (if the pressure rises rapidly to ambient, a large leak is indicated, perhaps a loose gas cap).

Diagram of Tank Leakage Test System with ORVR



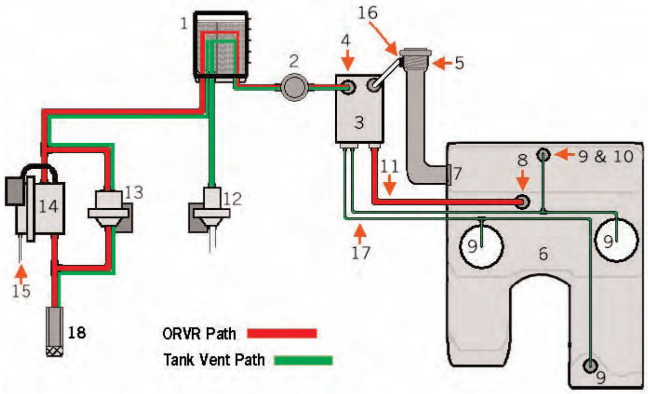
1 - Fuel tank
2 - Rollover valve
3 - Fill level limit valve
4 - Spit-back valve
5 - Filler pipes
6 - ORVR valve
7 - Underpressure limit valve
8 - Pressure sensor
9 - Operative venting valve
10 - Filter casing
11 - Fresh air valve
12 - Shut-off valve
13 - Active carbon canister
14 - Air filter
15 - Tank venting valve
16 - Engine

In the diagram above we can see the ORVR path indicated in red. The ORVR system is not electronic, it has two electromechanical solenoids, the ORVR valve at (6) and the fresh air valve at (11), they open when the reed switch at (9) is closed by a magnet on the back of the filler pipe flap.

The ORVR is not monitored by the engine management system, it only operates during refueling and cannot affect the tank leak test. The spit back valve at (4), only allows liquid fuel to pass into the tank, it will not allow the vapors in the tank to pass back up the filler pipe. So as the tank fills, the vapors in the tank are forced to take the path indicated in green through the active carbon canister where the HCs are captured. When the fill limit valve at (3) closes the vapor path, the gas station filler nozzle will shut off.

It is important that the tank not be topped off after the nozzle shuts off. We see that the ORVR overlays the tank ventilation system (vapor path shown in green) and the tank leak system – so we have three vapor systems interconnected in this diagram. Looking at the diagram as one system can be confusing, however if we look at the diagram one system at a time, system operation becomes clear.

Cayenne Evaporative Emissions System



1 - Carbon Canister
2 - Vacuum Limiting Valve
4 - Over Pressure Relief Valve
3 - Percolation Tank
5 - Filler Neck (with metal flap)
6 - Fuel Tank
7 - Spring Loaded Flap
8 - Fill Limit Venting Valve
9 - Roll Over Valves
10 - Over Pressure Valve
11 - Refueling Vent Line
12 - Evaporative Valve
13 - Evaporative Vent Shutoff Valve
14 - LDP
15 - Vacuum Inlet from Intake Vacuum Reservoir
16 - One Way Check Valve
17 - Tank Vent Lines
18 - Fresh Air Vent With Filter

The Cayenne vapor collection system has five venting points on the tank; fuel vapors would collect in the high points of the tanks irregular shape if the extra vapor paths were not provided. In addition, the Cayenne has a percolation chamber between the tank and the active carbon canister where heavy fuel vapors are allowed to condense back into liquid and return into the tank.

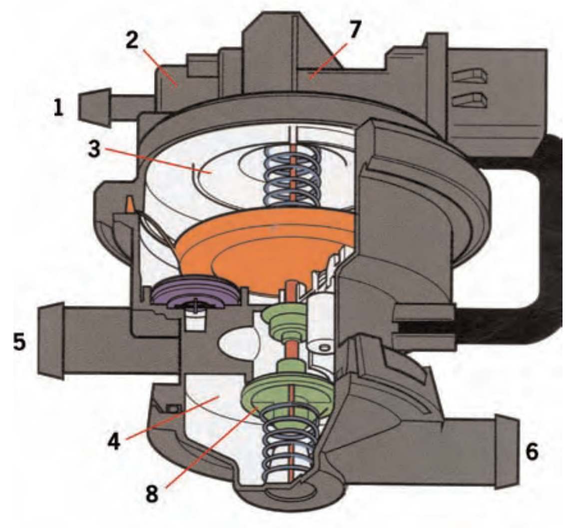
Like the Sports Cars, the Cayenne vents the tank to atmosphere across the active carbon canister. The fuel vapor-purging path for Cayenne is shown in green and has a vacuum-limiting valve (2) to reduce fuel evaporation. Fresh air enters via the air filter at (18) and moves through the active carbon canister at (1) where the HCs are picked up. The vapors then flow across the purge valve at (12) and into the intake manifold. The ORVR vapor path for the Cayenne is shown in red. The ORVR of the Cayenne has no electrically controlled valves. Similar to the sports car system, it has a vapor control valve at the bottom of the filler pipe at (7). This allows liquid fuel in but no vapors out. The vapors are forced to exit at the fill limit valve at (8) and then through the active carbon canister (1) to atmosphere at the air filter at (18).

The Cayenne has three systems connected to the fuel tank:

1. Evaporative Emissions,
2. ORVR, and,
3. Tank Leak Check.

If we look at one system at a time operation is much easier to understand.

Cayenne Tank Leakage Monitor

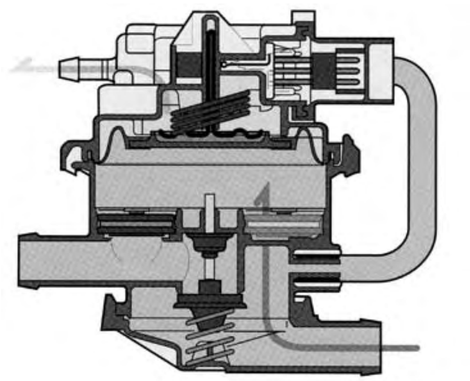


LDP *(leak detection pump)*

1 - Vacuum connection (from vacuum reservoir in intake manifold)
2 - Electric frequency valve for the diaphragm pump
3 - Vacuum side of the diaphragm pump
4 - Pressure side of the diaphragm pump
5 - Connecting pipe to the carbon canister (pressure side)
6 - Connecting pipe to the water separator/filter element
7 - Electrical Reed Switch
8 - Mechanical EVAP shut-off valve (always closed when monitor is active)

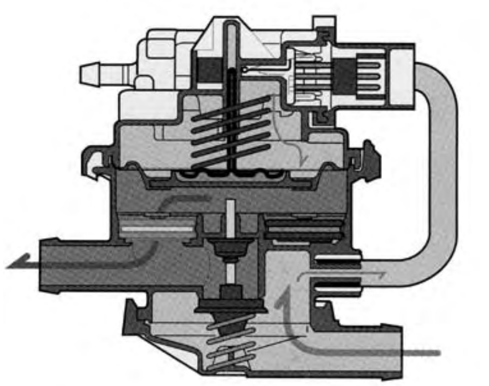
As we see from the system diagram for Cayenne, the LDP is in series with the EVAP vent air filter and in parallel with the EVAP vent shut off valve, so when the EVAP vent shut-off valve closes, the only path into the tank is the LDP. The LDP is a vacuum operated pump and pumps air into the tank which is a sealed system, since during diagnosis the purge valve is closed.

The LDP is a diaphragm pump, above the diaphragm is a chamber that when the leak test begins is alternately connected to vacuum and atmosphere by an electric frequency valve operating at approximately 40% duty cycle.



Diaphragm Lifting

When the upper chamber is under vacuum, the diaphragm lifts and compresses the spring that normally holds it in the down position. When the upper chamber is vented to atmosphere, the diaphragm is moved by the spring to the down position. The bottom chamber is connected to atmosphere via the air filter over a one-way valve that only allows flow in (intake valve) and to the sealed tank via a one-way valve that only allows flow out (outlet valve). As the diaphragm moves up and down it pulls air in across the inlet valve and out across the outlet valve pumping air into the tank.



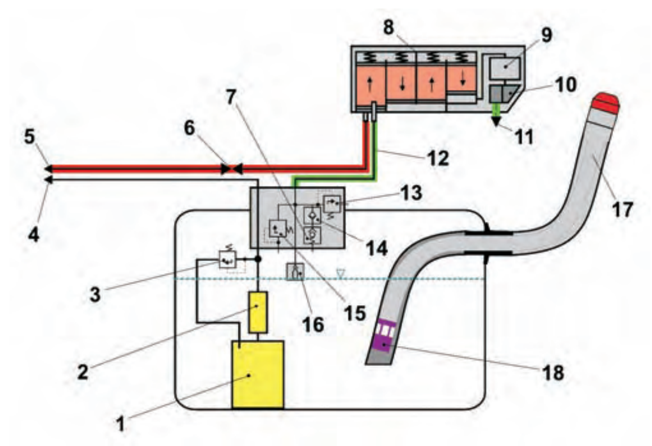
Diaphragm Falling

As the tank pressurizes, the diaphragm has to act against the pressure built up in the tank, and as the pressure beneath the diaphragm becomes higher than the pressure above the diaphragm, the diaphragm stops falling completey down and begins to operate with a shorter stroke. When the pressure in the tank reaches a point where it overcomes the spring above the diaphragm, the diaphragm is locked in the fully raised position.

In the top of the LDP is a reed switch and a magnet. The magnet holds the reed switch in the closed position. As the diaphragm raises, a metal plate connected to the diaphragm slides between the reed switch and the magnet and the reed switch opens.

The LDP frequency valve operates for a fixed period of time and then shuts off. If the reed switch has not opened, a major leak is detected, if the reed switch opens too soon, a small leak is detected, and if the switch remains closed for the required diagnostic period, the tank passes the leak test. In the bottom of the LDP there is a mechanical EVAP vent shut-off valve, it is opened when the diaphragm is in its full-relaxed position and duplicates the function of the electrical EVAP shut-off valve.

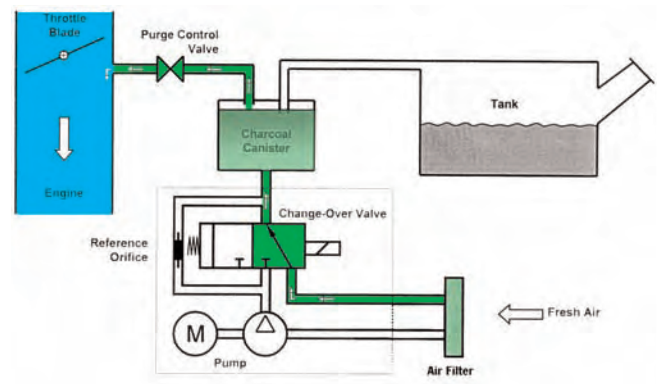
DM-TL Fuel Tank Leak Test Sports Cars from 2005



1 - Fuel pump with pre-chamber
2 - Fuel filter
3 - Fuel-pressure regulator
4 - Fuel pressure line to the injection valves
5 - Purging line to the intake manifold
6 - Evaporative emissions purge valve
7 - Roll-over valve
8 - Four chamber carbon canister
9 - Tank leakage diagnostics module DM-TL
10 - Filter for DM-TL
11 - Vent to atmosphere
12 - ORVR vapor line
13 - Overpressure control valve (max. 130 mbar)
14 - Pressure control valve
15 - Excess-pressure control valve
16 - Fuel limit control valve
17 - Fuel filler pipe
18 - Anti-spitback valve

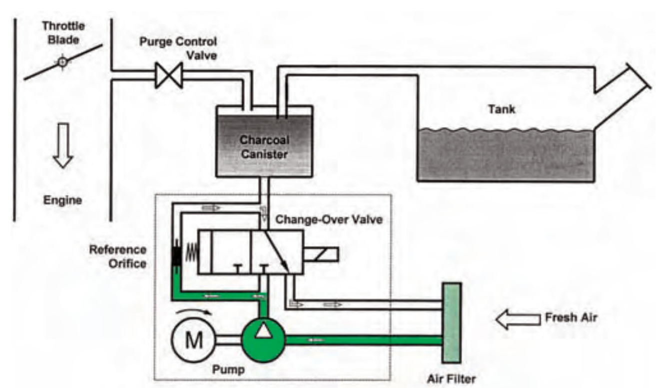
The fuel vapor-venting path of the 2005 Sports Cars shown in red is simplified compared with the earlier sports car system. Air enters through the air filter in the DM-TL, flows across the activated carbon canister picking up HCs, and then flows into the intake manifold via the venting valve. The ORVR vapor path shown in green is also simplified, there is a valve at the bottom of the fuel filler pipe to prevent vapors from venting up the filler pipe during fueling, and a fill limit valve as in the earlier ORVR. With DM-TL, ORVR and Evaporative emissions share vapor lines, this reduces the number of lines in the system.

DM-TL Fuel Tank Pressure Test



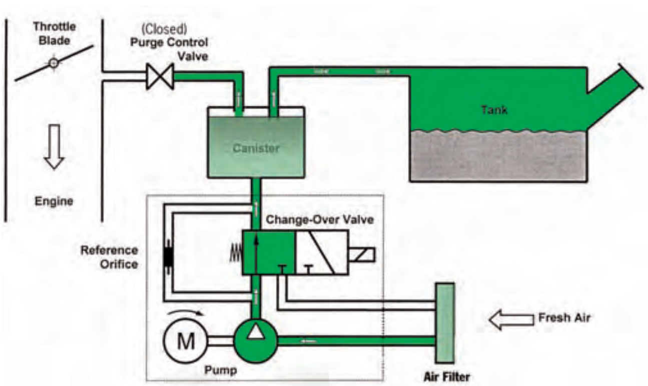
Tank Venting Canister Purge

When we look at the diagram of the DM-TL diagnosis module, we see that it consists of a pump, a two-position switching valve, and a .5mm (.02 in) orifice. It is connected on one side to the fuel tank across the active carbon canister, and on the other side to atmosphere across the air filter. When diagnosis is not active, the valve connects the atmospheric vent with air filter to the active carbon canister.



Diagnosis Reference Measurement

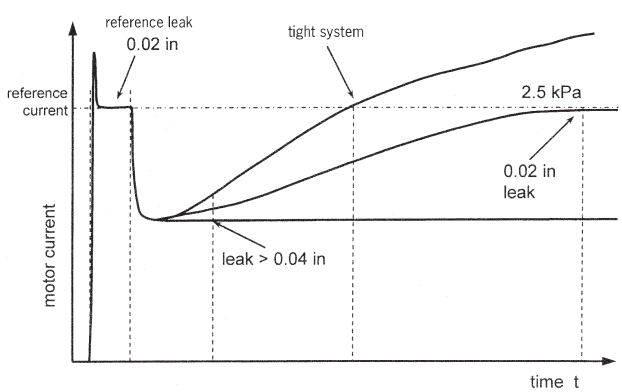
When diagnosis is initiated, the DM-TL valve is in a position that connects the pump to the reference orifice, and, the pump is switched on. The amount of current the pump consumes when pumping against the reference orifice is measured and stored by the diagnosis program. The purge valve is closed and the DM-TL valve is then moved to a position that closes off the path to atmosphere and opens a passage to the tank across the active carbon canister.



Diagnosis Leak Test

The pump begins to pressurize the tank and active carbon canister, and at this point, the amount of current that the pump consumes falls off. As the fuel tank and active carbon canister pressurize, the current rises. If the fuel tank active carbon canister and connecting pipes are leak tight, the current rises above the level previously recorded by the diagnosis program.

If the current rises to the level previously recorded (when pumping against the reference orifice), then the leak is .5mm (.02 in.) in size. If the current is less than this level, the leak is larger than 0.5mm. The diagnosis is run for a specified time period and there is a coarse and fine test.



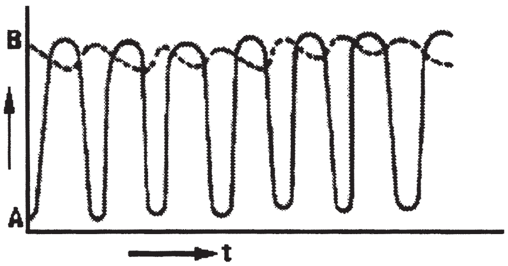
Evaporative Emissions and Tank Leak Check General notes:

The comprehensive component monitor checks all of the circuits and electric components in the evaporative emissions and tank leakage systems. It will store a fault if there is a malfunction detected in the components, or circuits, whenever the system is operating.

If the active monitor detects a malfunction, the MIL will be illuminated when the conditions for confirming that fault are met. An appropriate fault will be stored in memory. This occurs only when the monitor is running. The diagnostic monitors run when the conditions for operation are met. This is not necessarily every time the vehicle is operated.

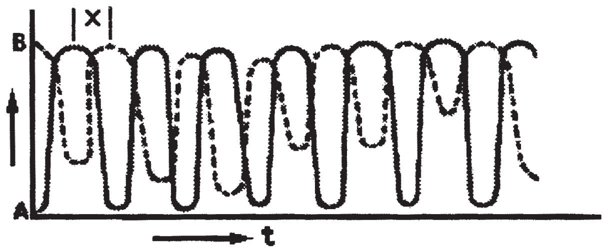
The required conditions for diagnosis are different for the three systems, and can include engine temperature, load, RPM, time, and other variables. For example; the pressure sensor tank leak test and LDP tank test must be run when the engine is running, while the DM-TL leak test can be run without the engine running, or even with the key off. So when we repair a defect in the tank, or connected lines and components, it is important to perform a short test. If we do not this, the system may not run the diagnosis for a period of time. When it does, the MIL will turn back on if the vehicle is not repaired.

Catalyst Monitor



Three-way Catalyst OK (TWC)

A: Sensor amplitude ahead of TWC
B: Sensor amplitude after TWC



Three-way Catalyst not OK (TWC)

A: Sensor amplitude ahead of TWC
B: Sensor amplitude after TWC
X: Delay due to gas running time

The goal of the catalyst monitor is to find out if the catalyst is doing its job of lowering the N0x, HC, and CO emissions in the exhaust flow. To do this, we install a second 0_2 sensor after the catalyst (or in the case of a system with two catalysts per bank after the first catalyst). If the catalyst is operating correctly, the 0_2 level at the second sensor will be relatively low. If the second sensor looks just like the first (mixture control) sensor, then the catalyst is not doing it's job and is defective and needs to be replaced.

We can see in the two examples above, when the catalyst is operating correctly, the 0_2 sensor in front moves in a range between 100mV and 900mV, and the sensor behind the catalyst, in a range between 800mV and 900mV (this can be broader but will be above 500mV).

The voltage is high and that means 0_2 is low. This is due to the fact that when the catalyst is operating correctly, it uses up the 0_2, turning the CO and HC into $C0_2$ and H_2O. It not only needs the 0_2 in the exhaust stream, it also uses up the 0_2 from catalyzing the NO_X and reducing it to free 0_2 and N.

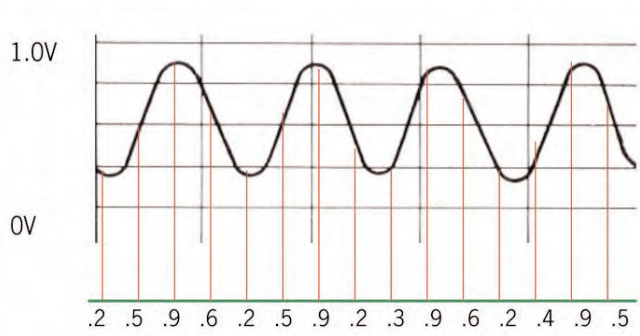
So when we see the rear 0_2 sensor with a high voltage signaling, a low 0_2 content, we know the exhaust emissions contain a low amount of CO, HC and NO_X, and that the catalytic converter is in good condition.

If we see that the rear sensor is the same as the front sensor, we know the catalyst is not operating and the tailpipe emissions will be above the legal limit.

The reason that this monitor is run only once per key cycle and has special conditions, is that if we don't run it when the catalyst has had a chance to get up to operating temperature and has a good amount of flow, we can fail a good catalyst.

To understand the way the engine management computer looks at inputs, we need to remember that it has no eyes, so it cannot look at the waveforms of the two sensors and compare them as we do. The processor can only deal with numbers it is just an adding machine a complex fast adding machine but still just an adding machine.

So what the diagnostic monitor does is sample the O_2 voltages at a regular interval for a period of time. When it has a sufficient sample (around 60), it performs math on the collected data and comes up with a equivalent value for each sensors amplitude. Then it computes the ratio between the two sensor values.



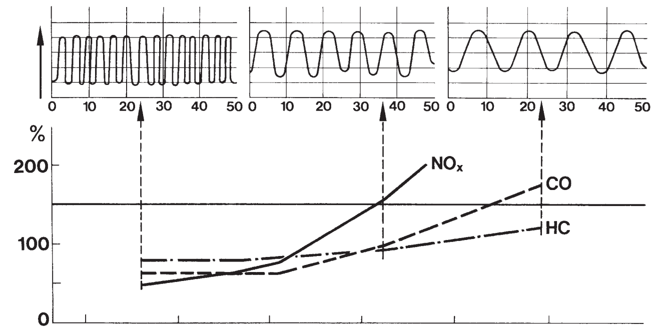
O_2 *Sensor Wave Form*

If the ratio is 1, then the catalyst is defective since the front sensor and rear sensor have the same wave form. The catalyst is not fuctional, a low number, .05 for example is good because the two waveforms are different, and the catalyst is working. The pre-conditions for the sampling of the sensor amplitudes include, time after start up, engine temperature, catalyst temperature, engine RPM, engine load, and air mass.

The catalyst monitor is the longest monitor. It can take up to 14 minutes to run after the pre-conditions are met. With the catalyst monitor we see the main difference between OBD-II and the system before OBD-II. With the earlier system, the catalyst could be replaced with a piece of pipe and the check engine light would remain off.

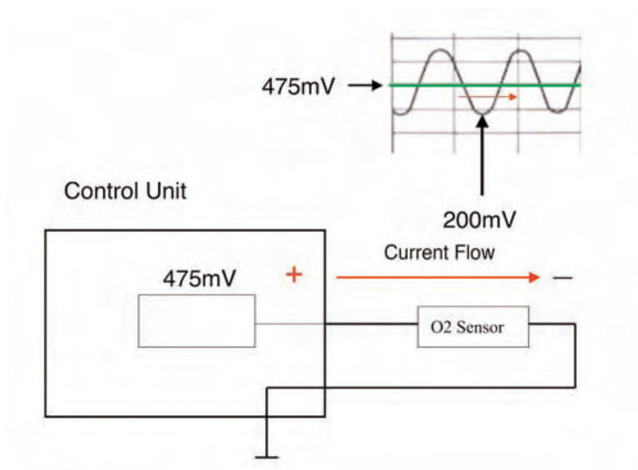
Oxygen Sensor Monitor

The Oxygen sensor monitor gives the oxygen sensors a complete check up. If a sensor has ceased to operate, or is slow or out of range, this monitor will detect its defective condition and illuminate the MIL and store an appropriate fault.

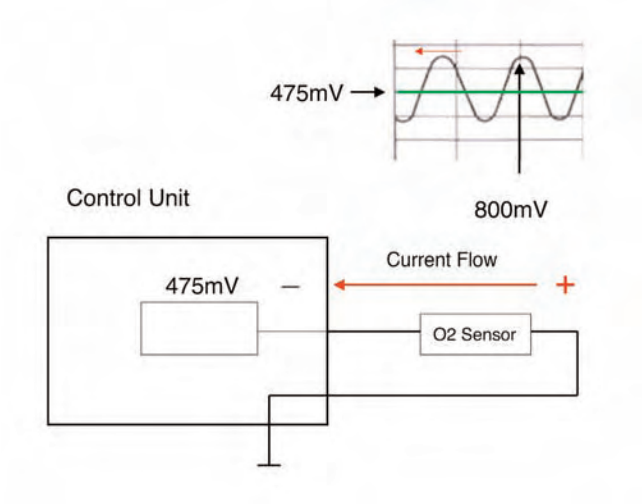


In the diagram above, we can see the effect on emission levels when the sensor slows down and the average amplitude of the signal rises.

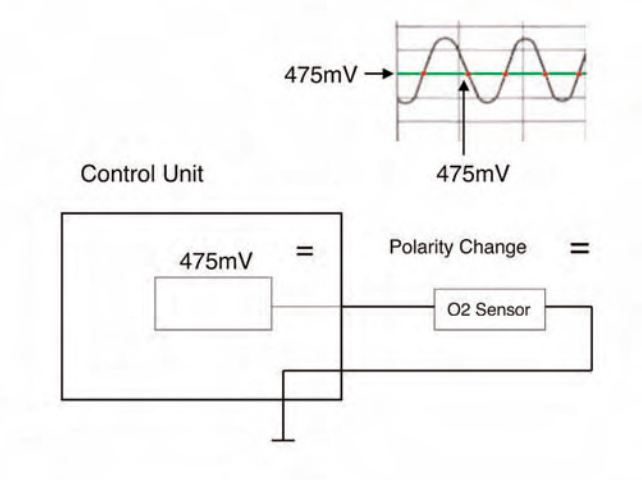
The O2 sensor evaluation circuit has approximately 475 mV at the terminal that the O_2 sensor is connected to the control unit at.



So when the O_2 sensor voltage drops to 200 mV, the circuit is more positive at the control unit and more negative at the sensor.

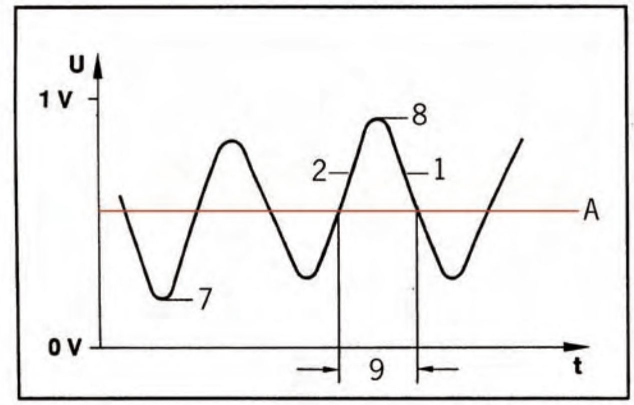


When the sensor is generating 800 mV, the circuit is more negative at the control unit and more positive at the sensor. This means that whenever the sensor passes the 475 mV point, it changes polarity, making the points that the O_2 waveform crosses the 475 mV reference voltage stand out to the evaluating circuit.



These polarity changes are used to direct the mixture control system, when to switch from rich to lean, and which direction to switch. The cross count is also used by the sensor monitor to determine if the sensor is switching as many times per minute as it should, or in other words, what the period of the sensor signal is.

When the line stands at 475 mV, the monitor detects an open circuit on the sensor signal line. When the line is above one volt, the monitor detects a short to power (most likely the heater circuit), and when it stands at ground, a short to ground.



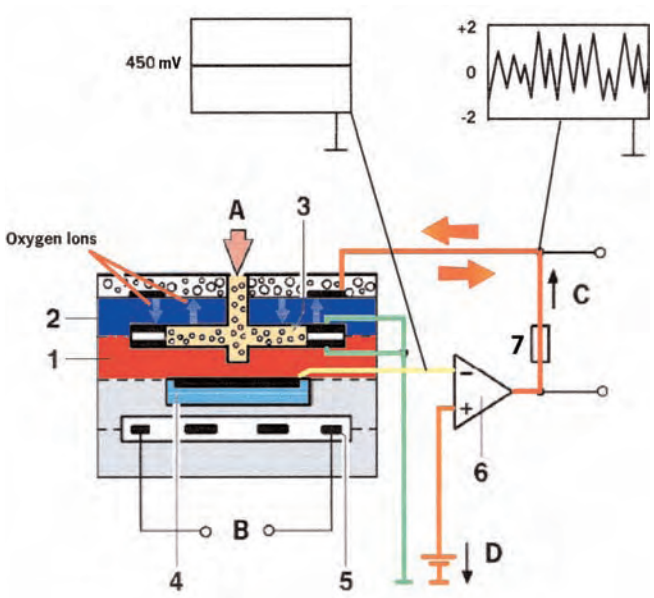
O_2 *Sensor Evaluation*

A - Threshold of 440 mV
1 - Rich to lean threshold voltage
2 - Lean to rich threshold voltage
7 - Minimum sensor voltage during test
8 - Maximum sensor voltage during test
9 - Time between two transitions

The monitor also looks at minimum voltage and maximum voltage, how long it takes the sensor to move from lean (low signal) to rich (high signal), and if the rising waveform is the same length as the falling waveform. It compares all of these values to limits programmed into the monitor. If the sensor has values outside the allowed parameters, a fault is stored and the MIL is actuated. Like the catalyst monitor, the Oxygen sensor monitor must have special conditions to run load, RPM, engine temperature, air mass, time after engine start.

Wide Band Oxygen Sensors

Wide band oxygen sensors have a distinct advantage over narrow band oxygen sensors (Lambda sensors) and that is that wide band sensors can begin to control mixture within approximately 30 seconds of engine start and remain in control of mixture as long as the engine is running. This has the obvious benefit of improved emission levels, fuel consumption and performance. Both DME 7.8 and DME 7.1 are normally equipped with wide band sensors in front of the catalyst. Only the version of 7.8 used on the naturally aspirated 911 Carrera (996) and Boxster (986) use narrow band lambda sensors.



A - Exhaust Gas
B - Heater Current
C - Pump Current
D - Reference Voltage
1 - Nernst Cell
2 - Pump Cell
3 - Diffusion Gap
4 - Reference Air
5 - Nernst Cell Heater
6 - Op Amp
7 - Measuring Resistor

Operation

The heart of the wide band sensor is a Nernst concentration cell this is the engineering term for a lambda oxygen sensor. So in the middle of the wide band sensor is a narrow band sensor, this sensor cell lies between the reference air channel at #4 and the exhaust gas flow coming in at A into measurement cell #3. The output from the sensor cell is connected to the negative terminal of an operational amplifier in the control unit. The other measurement terminal of the operational amplifier is connected to a fixed reference voltage at D. The Op amp compares the two voltages and based on the polarity and amplitude difference between the two voltages, the Op amp generates a current at its output.

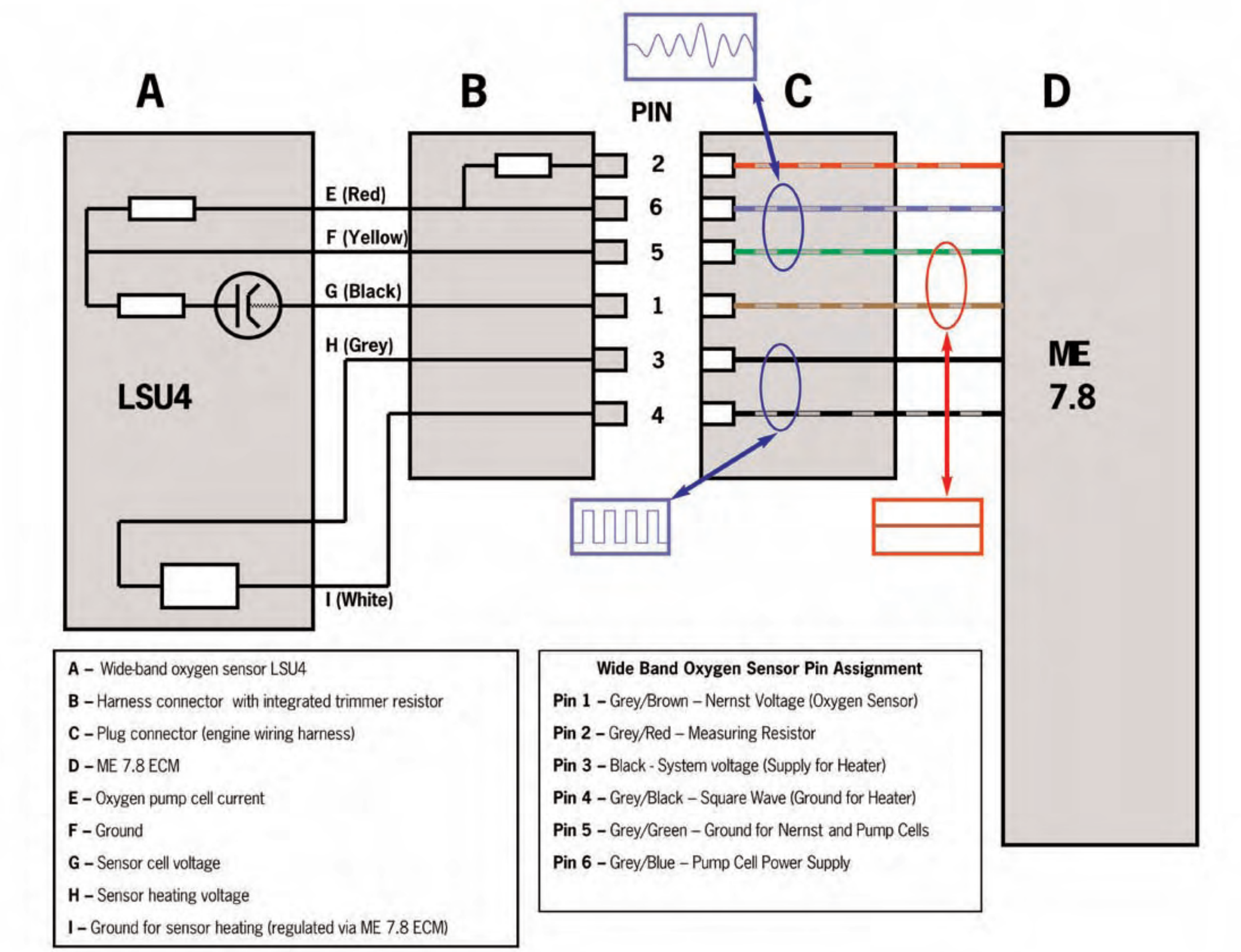
This current flows into or out of a second nernst cell #2 (it turns out that when we put an oxygen differential across a nernst cell it generates a voltage, and when we put a voltage across a nernst cell it moves oxygen), when the current flows in, it moves oxygen into the measurement cell, and when it flows out it pumps oxygen out. By pumping oxygen out of and into the measurement cell the Op amp keeps the difference between the reference voltage and the Nernst cell voltage stable. This means that the Nernst cell voltage is kept at 450 mV by the current flowing from the Op amp.

It turns out that the voltage drop across the measuring resistor at #7 is directly proportional to mixture in the wide band. Wide band sensors are planar sensors. They are not thimble shaped like a conventional oxygen sensor, instead they are a bar of ceramic material like a stick of gum but much smaller and narrower and about the same thickness.

Newer narrow band sensors and all Porsche wide band sensors are planar in design. The wide band sensors have a small hole in their upper surface that allows the exhaust gas flow to act on the measurement cell. In the connector of the wide band sensor there is a special laser trimmed resistor that is adjusted during production to calibrate the sensor.

Wide band sensors have a sensor heater that controls the sensors temperature. This heater is fed a modulated square wave to control the sensor temperature. It is important that the wide band sensor be quickly heated up so it can begin to control mixture as quickly as possible and kept at operating temperature to ensure accurate operation.

Wide Band Oxygen Sensor Wiring Diagram



In the sensor wiring diagram we can see the color codes of the wires and the connection points to connect an oscilloscope to measure the voltage drop across the measuring resistor, the nernst cell voltage and the heater square wave.

The oxygen sensor monitor for wide band sensors operates much like the sensor monitor for narrow band Lambda sensors. The sensor design is different, but the output wave form is similar.

Sensor Heater Monitor

The Oxygen sensor heaters are important for correct operation of the mixture control system, and it is obvious that if the oxygen sensors are not working correctly, the OBD-II system would not function properly. The oxygen sensor heaters are provided with power by the same relay that powers up the fuel injectors and the engine management control unit switches the grounds of the heaters.

The heaters are actuated only when needed; as engine load rises to the point that the oxygen sensors are heated sufficiently by the exhaust gas flow, the control unit switches the ground for the heaters off.

The heater circuits are monitored by the oxygen sensor heater monitor for:

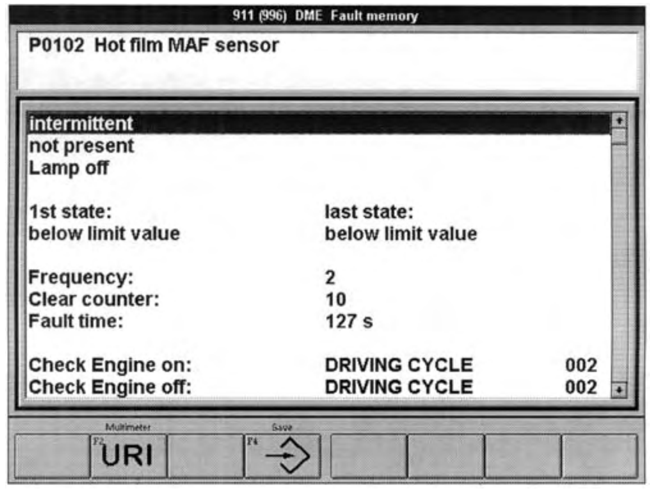
- opens shorts to power,
- ground,
- and plausibility.

The oxygen sensor heaters each have an resistor across them. In the control unit, the voltage drops of these resistors are used to monitor the function of the heaters. We know that if the voltage drop of the monitoring resistors is within the programmed limits, the heaters are functioning correctly.

The sensor heater monitor also looks at the resistance of the oxygen sensors. This is determined by a complicated calculation on the sensor voltage and current via Ohms law. We know that when a sensor's temperature is low, its resistance is high, so when the oxygen sensor heater is not working correctly, the resistance of the sensor will rise. The PIWIS Tester can be used to see this sensor resistance. We have a limit for resistance in the OBD diagnosis manual.

When we look back over the section on OBD-II, we can see that if there is a malfunction in the engine management system, the diagnostic system will find it most of the time. Occasionally, we will have a situation where a sensor will be out of range far enough to cause a performance problem, but not far enough to set a fault. **The one problem for the technician with OBD-II is when we don't fix the problem, the MIL comes back on. When we repair a MIL lamp on a engine management system malfunction, we must make sure the monitors involved are run when we test drive the vehicle.**

Malfunction Indicator Light (MIL) and Fault Management



P-Codes – Standardized Trouble Codes – SAE J 2012
9DTC-Diagnostic Trouble Codes

Diagnostic Trouble Codes that are monitored by the engine control module are standardized, which means that all manufacturers must use the same Diagnostic Trouble Codes.

The Diagnostic Trouble Codes (DTC) ia always a 5-digit alphanumeric value, **example: "P0100"**

All **P0xxx** codes are standardized codes. However each manufacturer can use other DTCs in addition to the standardized codes. This applies when the manufacturer integrated additional functions in the control module that can be diagnosed and that exceed the law. These codes are identified as **"P1xxx", for example: "P1100"**

The **first** digit of the code (letter) identifies the system the code has set. There are 4 systems:

B – For Body

C – For Drive Train

P – For Engine

U – For Future System

For OBD II only the **P** code is required.

The **second** digit identifies the generic code **(**P**0xxx)**, or the manufacturer code **(**P**1xxx)**.

The **third** digit identifies the major subassembly where a malfunction occurred. They are:

P0**1xx** – Fuel

P0**2xx** – Air Ratio

P0**3xx** – Ignition System

P0**4xx** – Additional Emission Controls

P0**5xx** – Vehicle Speed and Idle Speed Control

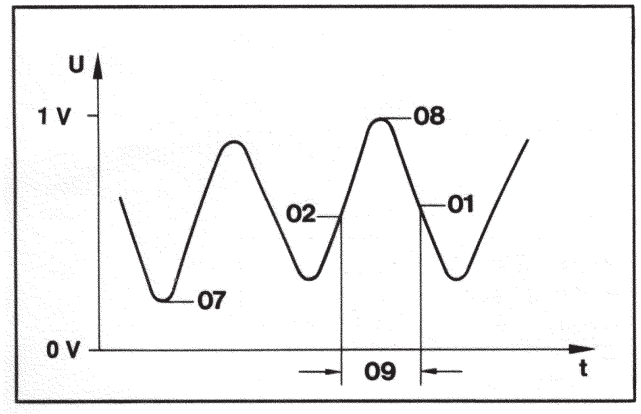
P0**6xx** – Control Module and Initiating Signals

P0**7xx** – Transmission

CARB ISO

Mode 5

In mode 5, the values of the last test conducted on each oxygen sensor can be called up.



The following PID's are supported for the oxygen sensors upstream of the catalytic converter (banks 1 and 2, sensor 1).

$01 Rich To Lean Threshold Voltage

```
Mode 45Pid$01 Adr$17
R.toL.Sen.Volt

B1 - S1          0.440 V
```

Programmed fixed value.

$02 Lean To Rich Threshold Voltage

```
Mode 45Pid$02 Adr$17
L.toR.Sen.Volt

B1 - S1          0.440 V
```

Programmed fixed value.

$07 Minimum Sensor Voltage During Test

```
Mode 45Pid$07 Adr$17
Min. Voltage
Requ.: 0.002: 0.395 V
B1 - S1      0.010 V
```

The required range and the actual value are indicated.

$08 Maximum Sensor Voltage During Test

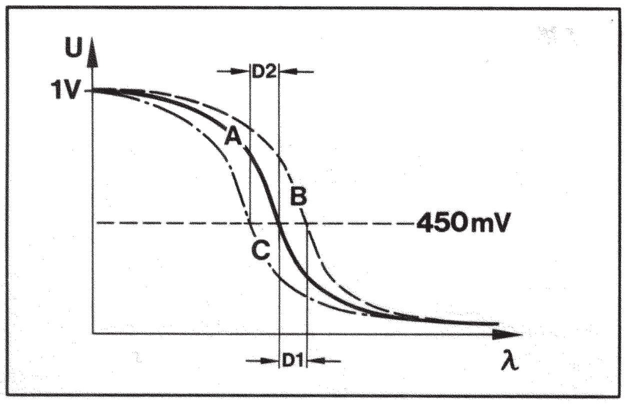
```
Mode 45Pid$08 Adr$17
Max. Voltage
Requ.: 0.495: 0.945 V
B1 - S1      0.830V
```

The required range and the actual value are indicated.

$09 Time Between Two Transitions

```
Mode 45Pid$09 Adr$17
Time between
Requ.: 0.20: 1.20 sec
B1 - S1     0.40 sec
```

The required range and the actual value are indicated.



A - Sensor OK
B - Sensor characteristic offset e.g. by silicone
C - Sensor characteristic offset e.g. lead
D1 - Sensor offset towards leaner mixture (PID 31)
D2 - Sensor offset towards richer mixture (PID 30)

$30 Oxygen Sensor Offset Towards Richer Mixture

```
Mode 45Pid$30 Adr$17
< 10.2 sec
Requ.: 0.00: 1.20 sec
B1 - S1     0.00 sec
```

The required range and the actual value are indicated.

$31 Oxygen Sensor Offset Towards Leaner Mixture

```
Mode 45Pid$31 Adr$17
< 10.2 sec
Requ.: 0.00: 1.20 sec
B1 - S1     0.00 sec
```

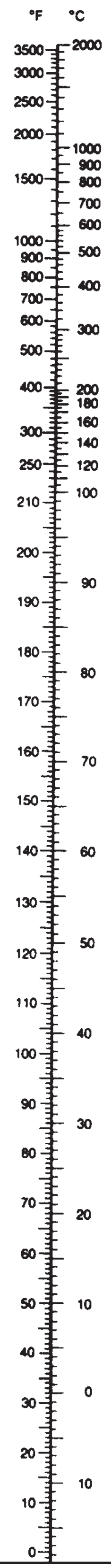
The required range and the actual value are indicated.

$32 Average Period

```
Mode 45Pid$32 Adr$17
< 10.2 sec
Requ.: 0.00: 4.00 sec
B1 - S1     1.80 sec
```

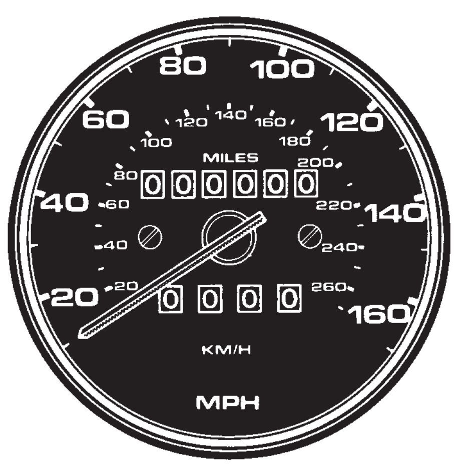
The required range and the actual value are indicated.

Temperature Conversion



Metric Conversion Formulas

INCH	X	25.4	=	MM
MM	X	.0394	=	INCH
MILE	X	1.609	=	KILOMETER (KM)
KM (KILOMETER)	X	.621	=	MILE
OUNCE	X	28.35	=	GRAM
GRAM	X	.0352	=	OUNCE
POUND (lb)	X	.454	=	KILOGRAM (kg)
kg (KILOGRAM)	X	2.2046	=	lb (POUND)
CUBIC INCH	X	16.387	=	CUBIC CENTIMETER (cc)
cc (CUBIC CENTIMETER)	X	.061	=	CUBIC INCH
LITERS.	X	.0353	=	CUBIC FEET (cu.ft.)
CUBIC FEET (cu.ft.)	X	28.317	=	LITERS
CUBIC METERS	X	35.315	=	CUBIC FEET (cu.ft.)
FOOTPOUND(ft lb).	X	1.3558	=	NEWTON METER (Nm)
Nm (NEWTON METER).	X	.7376	=	ft lb (FOOT POUND)
HORSEPOWER (SAE)	X	.746	=	KILOWATT (Kw)
HORSEPOWER (DIN)	X	.9861	=	HORSEPOWER (SAE)
Kw (KILOWATT)	X	1.34	=	HORSEPOWER (SAE)
HORSEPOWER (SAE)	X	1.014	=	HORSEPOWER (DIN)
MPG (MILES PER GALLON)	X	.4251	=	Km/l (KILOMETER PER LITER)
BAR.	X	14.5	=	POUND/SQ. INCH (PSI)
PSI (POUND SQUARE INCH). . . .	X	.0689	=	BAR
GALLON.	X	3.7854	=	LITER
LITER.	X	.2642	=	GALLON
FAHRENHEIT	-	32÷1.8	=	CELSIUS
CELSIUS	X	1.8+32	=	FAHRENHEIT



Notes:

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