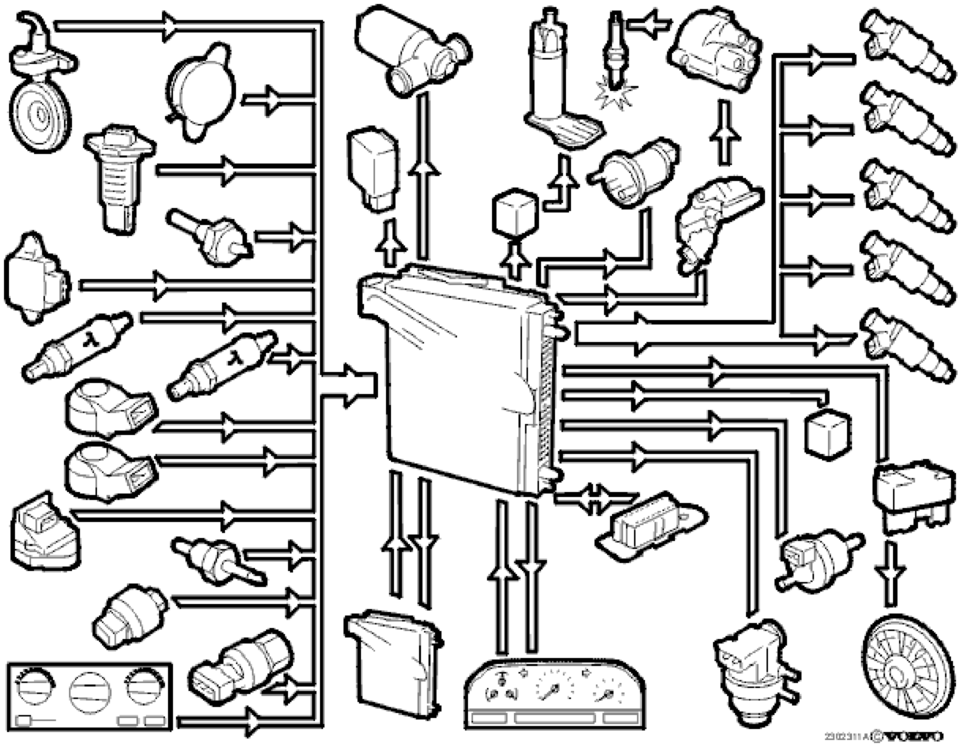
Introduction



Different Electronic Systems

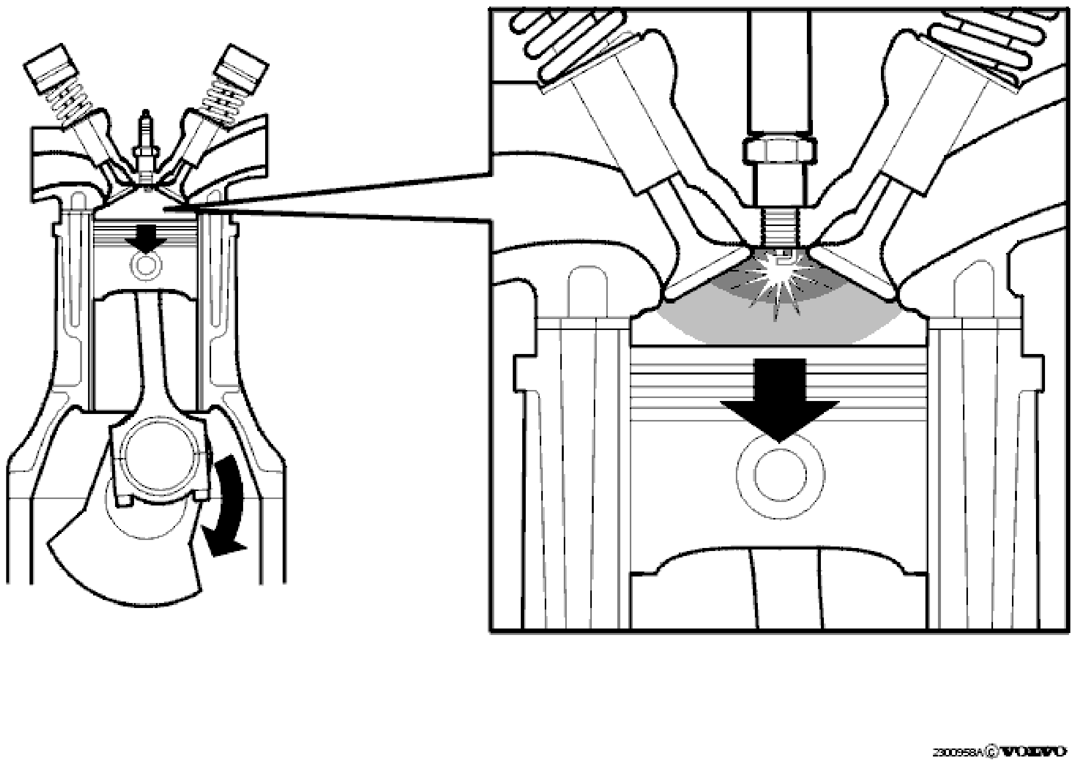
There are a number of different electronic systems for controlling quantity of fuel, idling speed and ignition.

There are for example

- Systems with separate control modules for fuel-, ignition- and idle control.
- System with common control modules for all three functions.
- System which also control other functions including engine cooling fan (FC) and air conditioning etc.
- The differences between the systems in number and type of sensor.
  This depends on which functions the control module controls, who the supplier of the system is and in certain cases also legal requirements. The rapid advances in the field of electronics over the last few years has also contributed to the fact that there are now a number of different systems in our cars.

Even if the systems are different and do not have the same number of functions the basic principles are the same for all systems.

Combustion theory



The mixture burns!

Car engines develop power through the combustion of fuel.
Two things are required for this. Oxygen taken from the air and heat to begin the combustion. The heat in gasoline engines (also called otto engines) comes from a spark plug providing a spark (heat). When combustion begin a flame spreads from the spark plug at a speed of approximately 30 m/s. The entire combustion takes only approximately 2m/s (2/1000 s).

In order for the combustion to be as efficient as possible a number of things are required, including: - The correct relationship between fuel and air.

- The correct relationship between fuel and air.
- Sparking at the correct time.
- That the fuel is finely spread and well mixed with the air.

It does not just require a thorough fuel and ignition system but also optimum design of the intake and exhaust channels, valves (including play), camshafts and combustion chamber etc.

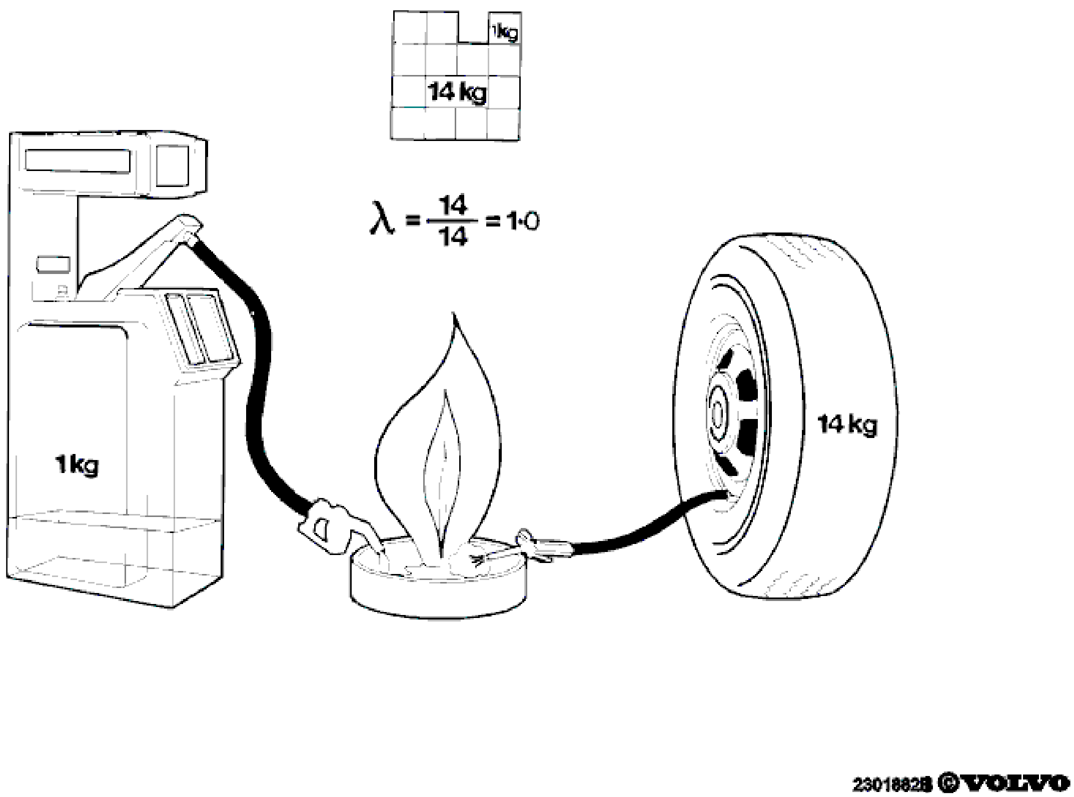
Maximum temperature at combustion: approximately 2500°C

Maximum pressure at combustion: approximately 60 bar

Difference between combustion and explosion

Combustion occurs at a speed of approximately 15-30 m/s.

Explosions occur at a speed of approximately 300 m/s.



How much air is consumed?

Gasoline mainly consists of different hydro-carbons (HC) and the oxygen required to burn these is taken from the air.

Theoretically approximately 14 kg of dry air is required to thoroughly burn 1 kg of gasoline. Exactly how much air is required varies depending on the air quality.

Air factor λ

If at combustion the amount of air supplied is as much as the theoretical requirement the air factor is 1. The Air factor is symbolized by the Greek letter λ (Lambda).

14 kg (supplied air mass) divided by 14 kg (theoretical requirement) = 1.00 ⇒ λ (air factor) = 1

If one operates with too little air supply (rich mixture) λ would be less than 1. With too much air supply (leaner mixture) λ will be greater than 1.

With complete combustion the residual products will be only (H_2O) and carbon dioxide (CO_2). Unfortunately a car engine is not ideal and so there is always a little oxygen and fuel left over which completely or partially unburned.

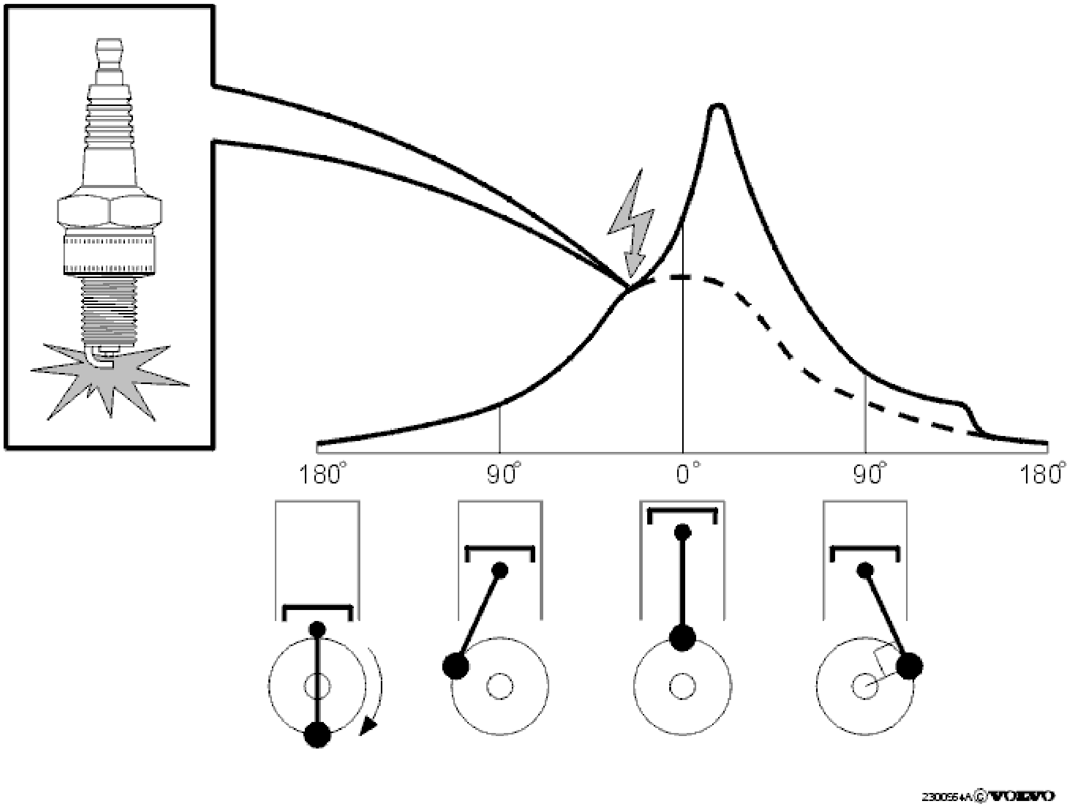
In addition the ideal (λ = 1) must be deviated from in certain circumstances, when starting the car, at wide open throttle (WOT), under acceleration for example.

What does gasoline and air consist of?

In percent weight gasoline consists of 84% C (carbon) and 14.8% H_2 (hydrogen) The rest is oxygen and nitrogen among other things.

Dry air at normal pressure consist as a volume percent of 78% N_2 (nitrogen), 21% O_2 oxygen, 0.92 argon and other noble gases and 0.03% CO_2 (carbon dioxide).

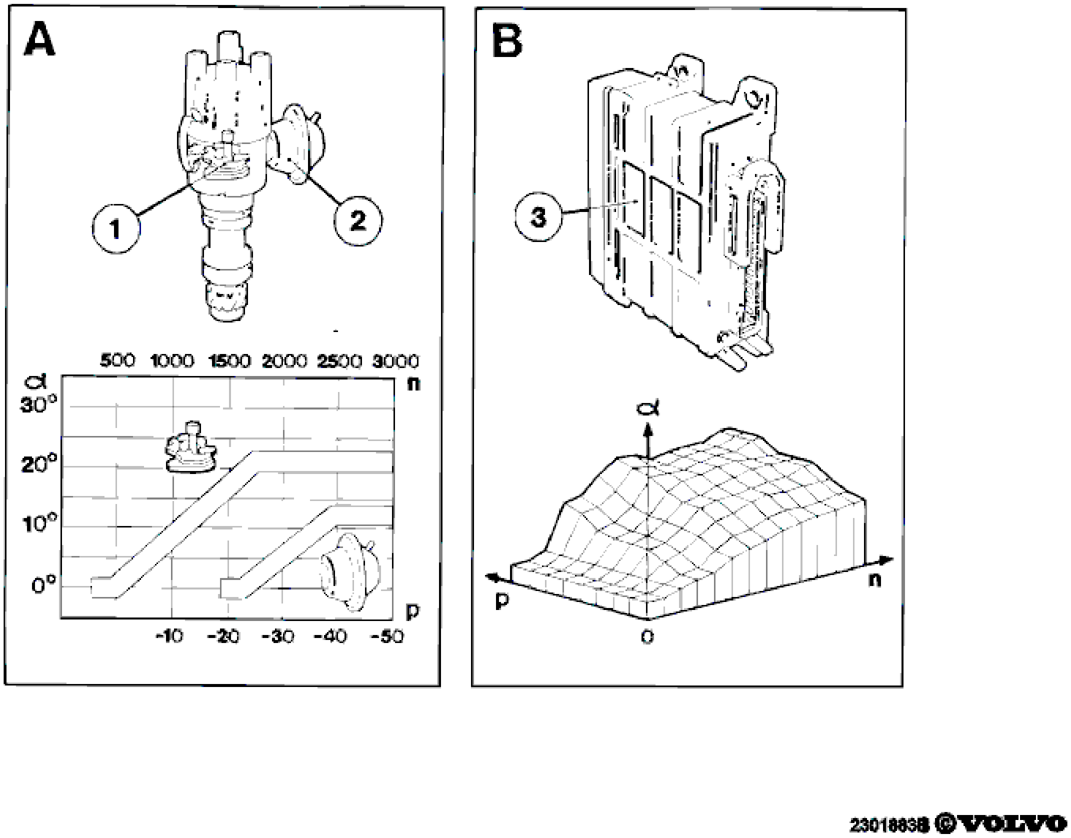
14 kg dry air at normal pressure corresponds to approximately ca 12200 dm^3 (l) if the temperature is approximately +20 °C (1.15 g/l).



When is the best ignition setting?

The best ignition setting is when as much work as possible is taken out of the fuel/air mixture.
To extract as much energy as possible the combustion pressure should be at its greatest just after top dead center (TDC) This is to use the pressure as much as possible before the angle between the connecting rod and the crankshaft lever is 90° . After 90° angle the angle reduces again and means that the extracted power is lost.

Because combustion always takes a certain time the mixture must be ignited before top dead center (TDC) so that the pressure has time to build up.



Why are different ignition settings required depending on engine speed (RPM) and load?

Constant combustion speed

With one and the same mixture relationship between air and fuel the combustion speed (approximately 30m/s) and therefore combustion time (approximately 2 ms) are constant.

Higher engine speed (RPM) requires earlier ignition

Because the combustion speed / time is essentially constant the combustion must start earlier at higher engine speeds.
This is so that pressure has time to build up and that the maximum pressure is achieved at the correct piston position.

On breaker controlled ignition systems this is controlled by a centrifugal regulator(1).

Higher loads require later ignition

With high loads (large opening in the throttle and low engine speed (RPM)) there is a large amount of fuel/air mixture in the cylinders. This gives a high compression.

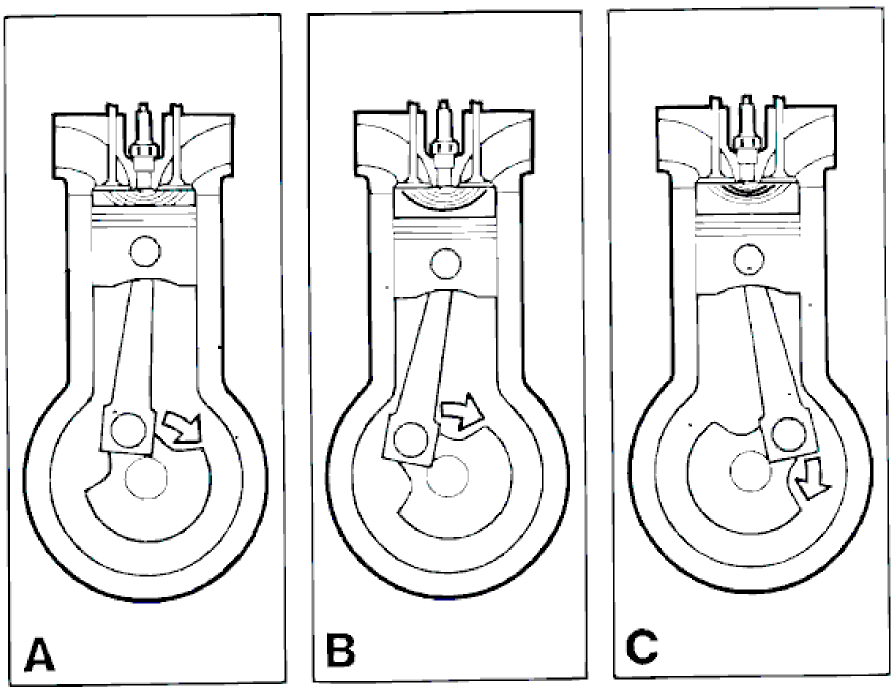
Because the combustion speed / time is

essentially constant the combustion must start later at high loads. Otherwise the high compression and the large amount of mixture that is ignited will result in the combustion pressure being too high too early.

On breaker controlled ignition systems this is controlled by a vacuum controller (2).

The preprogrammed values in the control module

On electronic systems, all control is dealt with by a control module (3). This contains preprogrammed values which result in precise control. A further advantage with the electronic system is that several factors are able to influence the ignition position, for example the engine coolant temperature (ECT).



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When is the correct ignition setting?

Correct ignition setting (A)

There is no set value. It varies depending on, for example, engine speed (RPM), load, the fuel air ratio and temperature.
When selecting the ignition setting, the desired handling, the design of the combustion chamber, the idle trim quality, the condition of the engine

and emission regulation etc must be taken into account.

When discussing the correct ignition setting (A), we mean an ignition setting that takes into account all the factors affected by the ignition. It is also a compromise between the need for high voltage, low fuel consumption and the cleanest possible emissions.

Early ignition (B)

Results in higher combustion temperature but lower exhaust temperature.
The combustion temperature increases because the combustion pressure is higher in the event of earlier ignition. The exhaust temperature falls because the combustion has been completed for a longer period before the exhaust valves open. More energy in the fuel is used for mechanical work and less energy is lost in the form of heat loss. In general, the aim is to regulate the ignition so that it is as early as possible while taking into account the load and engine speed (RPM).

However too early ignition result in too high combustion pressure and too high combustion temperature. It also increases the risk of self ignition, in other words the engine is knocks. Furthermore the release of exhaust gases is affected negatively and there is a risk of engine damage.

Late ignition (C)

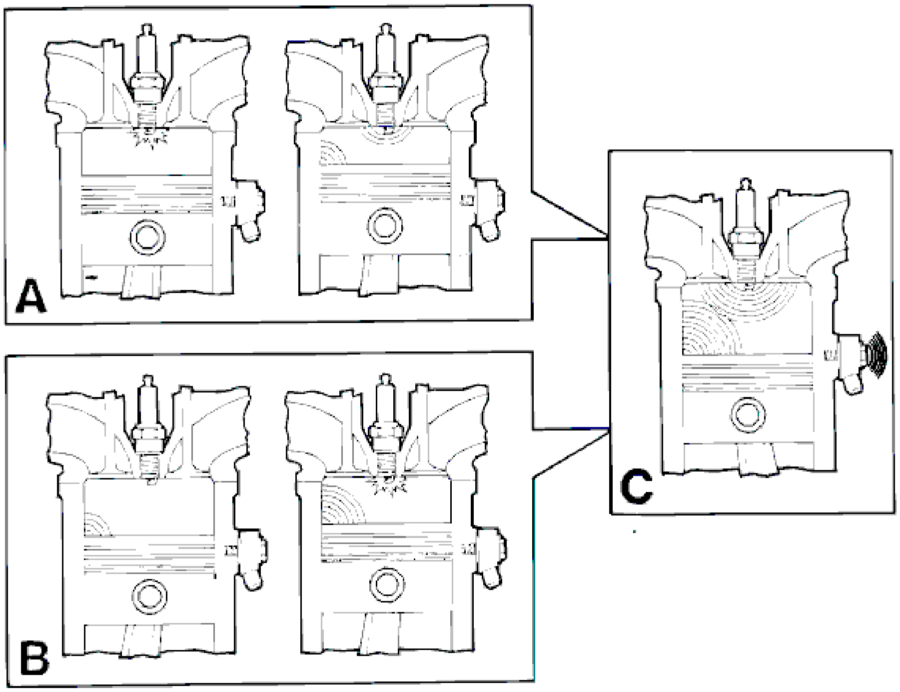
Results in lower combustion temperature but higher exhaust temperature. The combustion temperature will be lower because the combustion pressure is lower. This is because greater amounts of energy are released when the piston is a long way down. The increase in exhaust temperature is because combustion is completed closer to the exhaust valve opening, and less mechanical efficiency is achieved. As a result more energy is converted to heat.

Delayed ignition results in poor power because the increase in pressure comes too late. Therefore the energy content of the fuel is poorly utilized. In addition the emissions are negatively affected and fuel consumption increases.

Different expressions used to describe ignition settings

Earlier ignition = Ignition increase = Increased ignition advance = Ignition occurs when the piston is further from top dead center (TDC).

Later ignition = Ignition reduction = Reduced ignition advance = Ignition occurs when the piston is closer to top dead center (TDC).



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What is knocking?

Combustion normally spreads from the spark plug at a speed of approximately 30 m/s.

In certain cases self ignition can also occur in certain parts of the fuel/air mixture. Self ignition is not combustion. It is an explosion that occurs at a speed above 300 m/s. The result of self ignition is that two or more flames spread out in the combustion chamber. Knocking (harsh metallic sound) is the collisions between different flame fronts.

The effects of knocking

Knock results in an extremely quick and powerful pressure and temperature increase. A knocking series is hazardous for the engine. However a single knocking is normally harmless.

Different types of knock

Self ignition can occur before or after the spark plug has produced an ignition spark.

After the spark has been produced (A)

- When the flame front spreads out from the spark plug, the temperature and pressure increase. This can cause self ignition in another part of the fuel/air mixture. This is sometimes called "compression knock" or "ignition knock".

Before the spark has been produced (B)

- When the flame front spreads out from the spark plug, the temperature and pressure increase. This can cause self ignition in another part of the fuel/air mixture. This is sometimes called "compression knock" or "ignition knock".

How is knock counteracted?

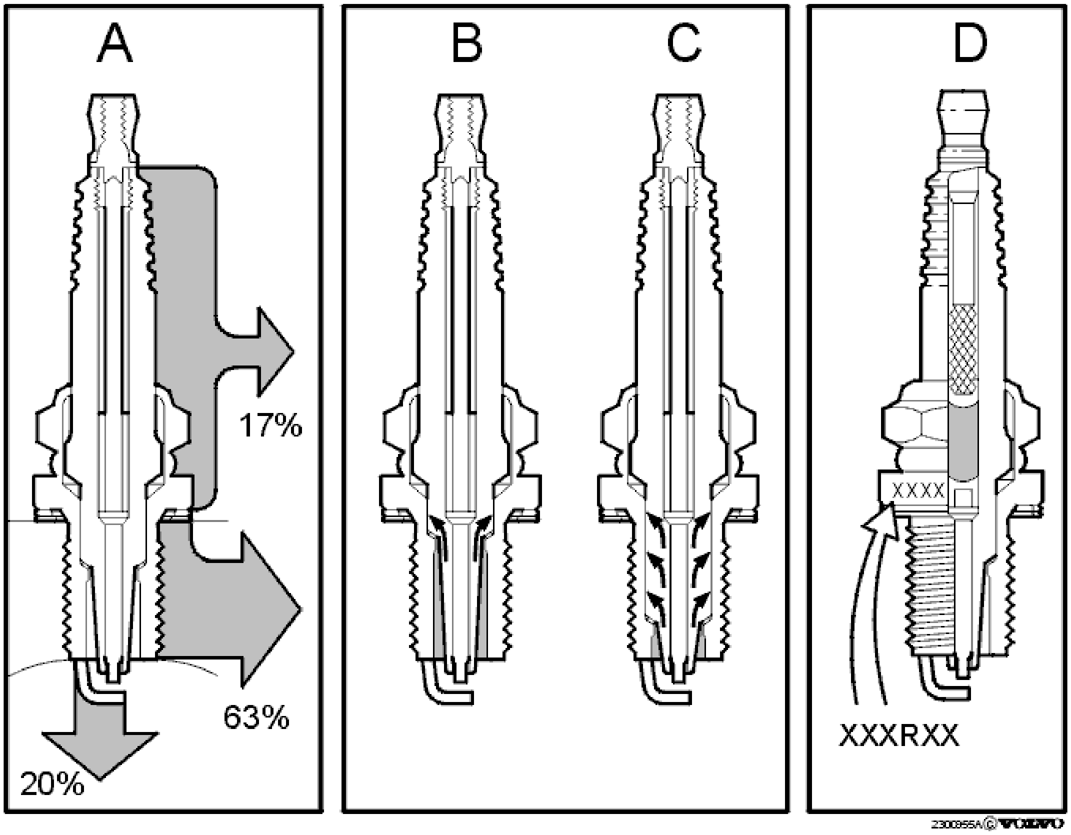
In principle this can be occur in two ways

- Later ignition which results in lower combustion pressure and temperature.
- Richer fuel/air mixture which results in a lower combustion temperature because the fuel cools down.

Some possible causes of knocking

- Premature ignition. Results in increased combustion pressure and increased temperature.
- Fuel with too low octane. The octane content is a gauge of the capacity of the fuel to resist self ignition.
- Too little fuel (lean fuel/air mixture). Results in a high combustion temperature. May be due to, for example, low fuel pressure, a blocked fuel filter, failure to enrichen the mixture during acceleration or at wide open throttle (WOT), or air leakage in the intake system.
- Poor fuel distribution. If the fuel is not mixed efficiently with the air, the temperature may increase in certain parts of the fuel/air mixture. This can be caused by poor swirl development. This can be due to, for example, deposits in or on the injectors or a build up of carbon either on the valves or in the combustion chamber.
- Faulty or worn spark plugs. In the event of incorrect heat range or coating the spark plugs may become too hot. As the spark plug deteriorates the distances between the

electrodes increases. A higher ignition voltage is then required to produce a spark. This can affect the ignition setting.



The spark plugs must be highly tolerant

The spark plugs must be able to tolerate the rapid pressure and temperature variations which occur in the combustion chamber. During the compression phase the temperature can rise to 2500°C and the pressure can reach a value of 60 bar. Shortly thereafter, during the intake phase, there is little negative pressure and the spark plugs come into contact with the fuel/air mixture. The fuel/air mixture temperature may be very close to that of the outside temperature.

Correct operating temperature

The temperature of the spark plug must be approximately 400 °C. This is so to obtain a self cleansing effect which burns of any carbon.

The maximum temperature should not exceed approximately 850 °C so that the spark plug does not cause self ignition.

Excess heat must be led away from the spark plug. Illustration A displays the principle of how excess heat is led away. Approximately 17% of the heat is directed to the surrounding air, 63% should be transferred to components and approximately 20% is transferred out in to the combustion chamber. For this to be achieved, it is extremely important that the spark plug is tightened to the correct torque and that any gasket is in good condition.

Correct heat tolerance

The heat tolerance indicates the heat the spark plug is able to tolerate without becoming too hot and causing self ignition.

Spark plugs are available with different heat tolerance. These are for different engine types and operating conditions so that they operate at the correct operating temperature.

Hot plugs (B) have a long insulator foot which absorbs a great deal of heat. They have little heat transfer.

Cold plugs (C) have a short insulator foot which absorbs little heat. They have god heat transfer qualities.

Ignition system disruption

When the ignition system is operating, sparks are generated at the rotor and spark plugs. This causes voltage peaks (interference pulses) which bounce back in the system. These can disrupt for example radio reception.

Ignition cables with resistance were previously used to dampen these interference pulses. Nowadays it is normal to use rotors and spark plugs with built-in resistance. This is because interference should be dampened as close to the source of interference as possible.

Spark plugs (D) with built-in resistance normally have an "R" in the type designation.

The ignition system should be able to

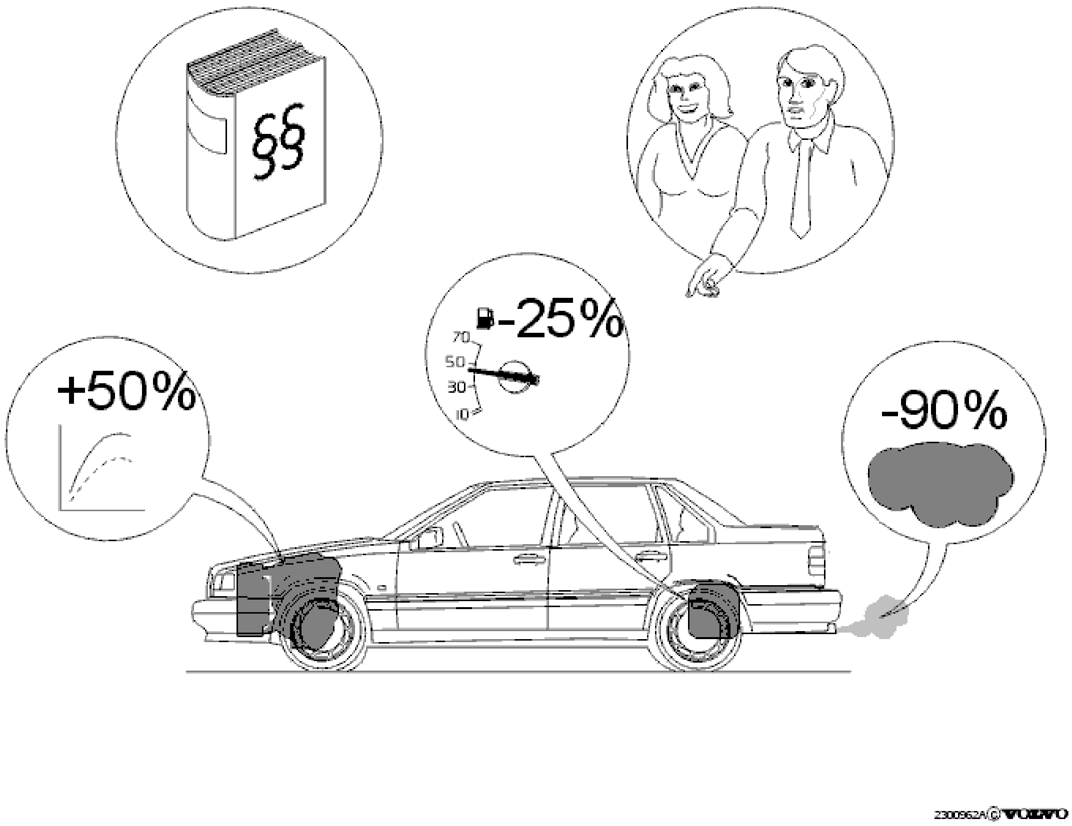
In order to provide a summary of what a modern ignition system must be able to do, the following is a number of numerical examples. Note that the digits are only approximate.

- Produces 25 sparks per second and for each cylinder at 6000 rpm.
- Generate a peak voltage of above 30 kV (30

000 V).

- Transfer the spark to the spark plug in 0.033 - 0.005 seconds.
- Generate a peak voltage in 0.020 - 0.004 seconds. The actual spark time at the spark plugs is only 0.00300 - 0.00047 seconds.

Electronic



Why use an electronic system?

Today the requirement are much higher than for a number of years ago. There are both legal requirements and the wishes of the customer about.

- As little harmful emission as possible.
- Low fuel consumption.
- Good performance.
- Long service intervals and high reliability. In some countries there are, for example, statutory requirements covering the distances a car should be able to cover before emission limits are exceeded. In addition this should be achieved without any service action being taken on the car.
- Quick diagnosis in the event of faults.

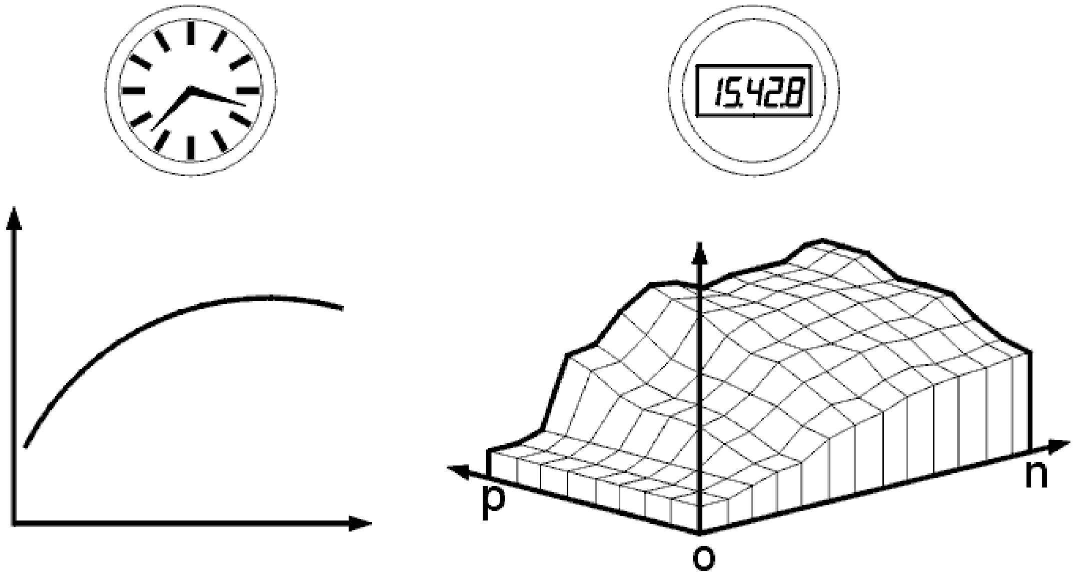
The only way to satisfy such requirements is to use electronic systems.

It is largely due to the electronic systems that it is now possible to construct cars which have, in comparison to cars from the early 1970s:

- ⇒ **90% cleaner exhaust gases**
- ⇒ **50% higher power (calculated using the same engine volume)**
- ⇒ **25% lower fuel consumption**
- ⇒ **three times as long between service intervals**

Some advantages of electronic systems compared with earlier solutions

1. Can be more carefully adapted to the engine. This is because their operational function is digital rather that analogous.
2. Can provide more precise control. For example the ignition can be controlled to fractions of a degree.
3. Can provide control more suited to the operating conditions. This is because they have more sensors which affect the control.
4. Can provide quicker control. The engine speed (RPM) sensor is read off approximately 50 times per engine revolution. In other words 5000 times a second at 6000 rpm. Other sensors usually read off the engine speed (RPM) once per engine revolution. In other words 100 times a second at 6000 rpm.
5. Can interact between different systems. For example the ignition system can in some cases affect the quantity of fuel.
6. Has few components with mechanical wear. This reduces the requirement for maintenance and increases both reliability and service life.
7. Can adapt themselves when the engine wears and the conditions change. The majority of modern systems have so called adaptive functions. This reduces maintenance requirements.
8. Can carry out self diagnostics and warn in the event of certain faults which may result in, for example, emissions exceeding certain limits.



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Analogous compared to digital

Analogous

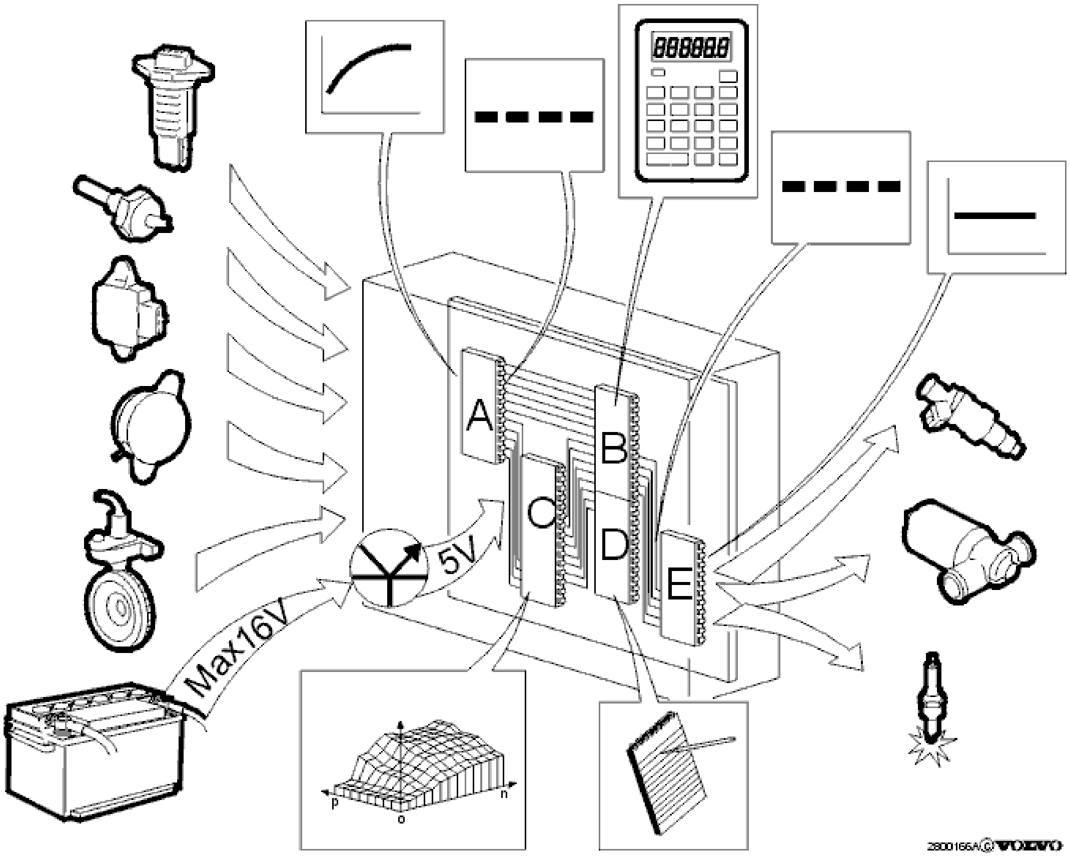
Older systems (such as carburetors and breaker controlled ignition systems) function analogously (analog ≈ uniform). This means that the systems can only govern according to set curves with a quite limited control range.

Digital

Electronic systems operate digitally (digit = number). This means that only the digit values are stored in the control module memory. The number of digits or values is extremely high. The illustration shows an example of how this may look. Each point of intersection between the lines corresponds to a stored value.

The control module reads off the engine operating conditions, for example engine speed (RPM) and air flow. It then checks its memory for the correct numerical value for, for example, the quantity of fuel. If there is no value which exactly corresponds to the engine operating conditions, the control module calculates a reasonable value itself.
In principle, the number of possible values is

infinite and the control range is very large.



How does an electronic module operate?

Voltage regulator

The control module operates internally with a low voltage, usually 5V. This is partly to limit the current and therefore heat generation in the control module. Too much heat can damage the electronics. This is also why all the functions that require high currents, such as ignition coils, are governed by external amplifiers.

The voltage regulator reduces the system voltage to 5V.

If the system voltage should increase above approximately 16V the regulator will no longer be able to fulfill its function. This results in incorrect signals and incorrect control.

A. Analog-digital converter (A/D converter)

The control module operates digitally (pulses, 1s and 0s) while the signals from the signals are analogous.

The A/D converter converts the analog signals to digital (pulses) which the control module is then able to work with. The digital signals are then transferred to the central processing unit (CPU).

B. The Central Processing Unit (CPU)

The CPU is independent and can be compared to a calculator and carries out all mathematical calculations. It works extremely quickly but can only perform one task at a time.

When calculating for example the quantity of fuel, the CPU carries out the following operations

- It "reads" the input signals for engine speed (RPM) and air flow (one at a time)
- Searches for the correct fuel quantity value in the program memory (C). If there is no value which is correct, the CPU calculates a reasonable value itself.
- Registers the fuel quantity value in the internal memory (D).
- Reads the next value, for example the temperature sensor.
- Checks in the program to determine whether the quantity of fuel needs to be adapted for a cold engine.
- Collects the noted values from the internal memory and calculates a new value depending on how much the value needs to be adapted.
- Notes the new value in the internal memory.
- Reads off the other sensors one at a time and calculates a new values if necessary.
- When all operations are complete, the CPU transmits the final value to the D/A converter (E) for control of the quantity of fuel.

C. Program memory (ROM = Read Only Memory)

The CPU can only read but cannot change something in the ROM.

In the ROM all the numerical values are programmed, for example the quantity of fuel, the idling speed and the correct ignition time.

There are different ROM versions depending on how it is manufactured and whether it is possible to make changes to the program.

ROM —The different values are programmed during manufacture.

PROM — The P is short for programmable The memory is manufactured empty and can be programmed later.

EPROM — The E is short for Erasable The memory can be erased and reprogrammed. This is usually done using ultra violet light.

EEPROM — The E is short for electrical. The memory can be erased and reprogrammed using electrical impulses.

D. Internal memory or RAM (RAM= Random Access Memory)

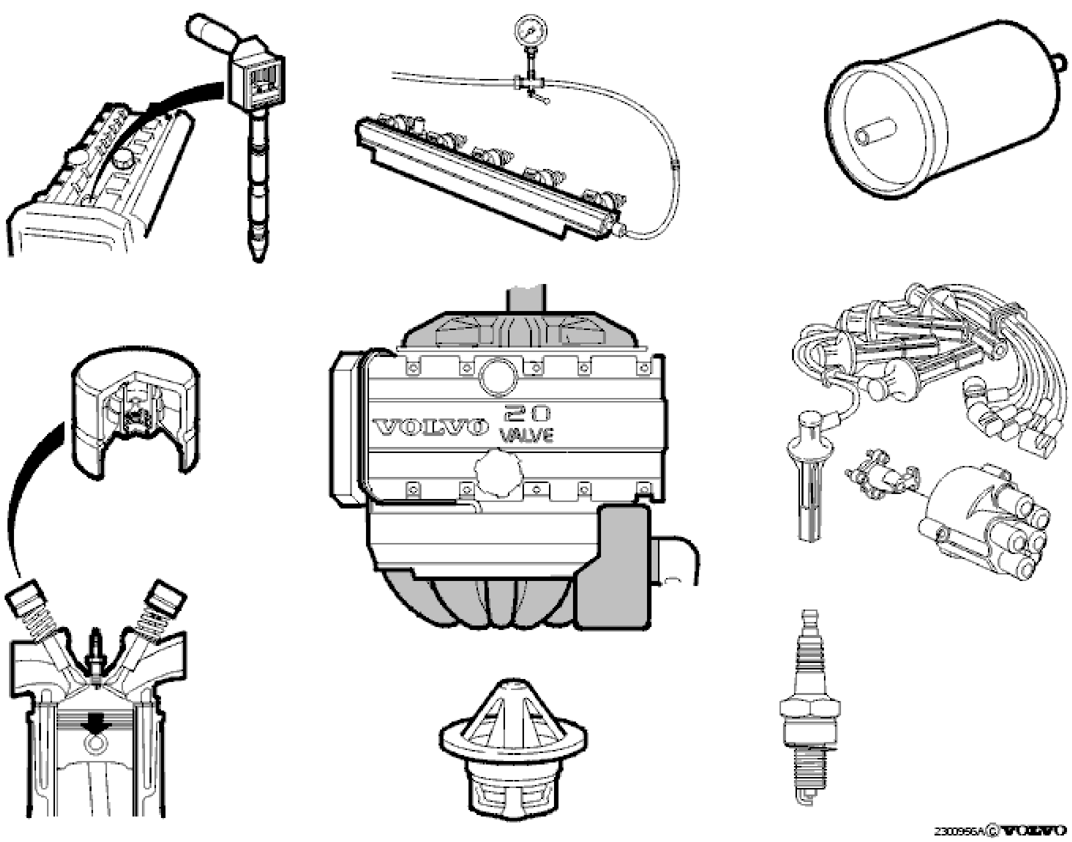
This is used by the CPU to temporarily store calculated values. Can be compared to a notepad.

E. Digital and analogous converter (D/A converter)

The values calculated and sent to the D/A converter by the CPU are digital (pulses).

The D/A converter converts the signals to analog signals, for example a current or voltage with a set strength and time span.

The signals usually pass through an amplifier in the control module because they are quite weak. These are then used to govern the functions controlled by the control module, for example the quantity of fuel, idling speed and ignition time.



What the control module does not know but assumes is correct!

There is not a sensor for everything. Therefore the control module assumes that certain things are correct. Examples of this are:

- The engine is in good mechanical condition, for example the valve clearance, camshaft adjustment and compression etc are correct.
- The air intake, for example the air preheating and air cleaner (ACL) function correctly and that the throttle disc setting is correct.
- There is no air leakage in either the intake or exhaust side.
- The fuel pressure and fuel flow are correct. In other words that the fuel pump (FP), fuel filter and injectors are fault free.
- The cooling system functions as normal, for example the thermostat opens at the correct temperature.
- The components in the ignition system, for example the ignition discharge module (IDM), ignition cables, distributor cap, rotor and spark plugs are not damaged or worn.
- The generator (GEN) charges correctly, for example that the charge voltage is not above 16V or that the battery voltage is below 10.5V.

If the above are not correct the combustion process will be affected.

In the event of a fault, the engine operation, fuel consumption and emissions can be affected. This can in turn result in abnormal signals from the oxygen sensor (HO2S) for example. The electronic systems are often blamed for this and attempts are made to replace components that are not faulty for example.

In systems with adaptive (self learning) function, an automatic adjustment takes place. However the fault may be so large that the adaptive adjustment is overloaded and is unable to compensate for the entire fault.

Worth bearing in mind when fault-tracing

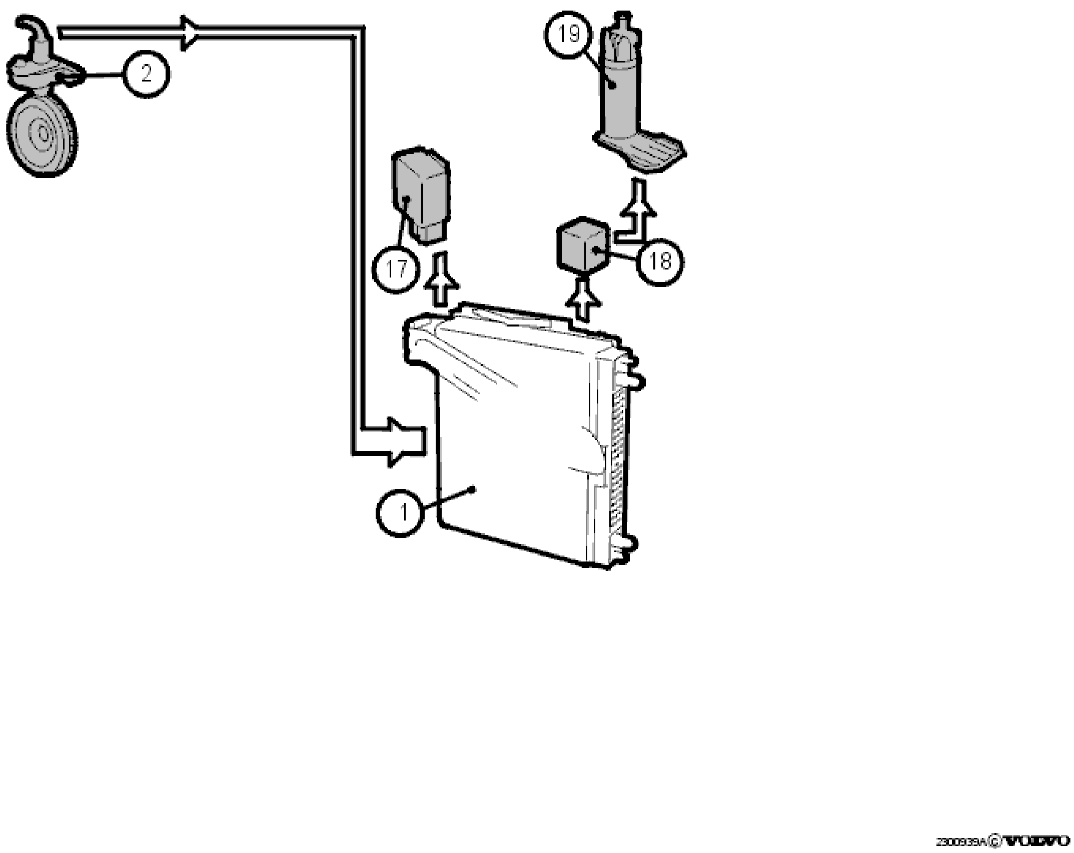
There are many electronic systems in modern cars. Therefore it is easy to simply blame the "complicated" electronics and overlook the normal basics of engine operation. These basic principles are just important today as with carburetor engines!

A common mistake when fault-tracing is to limit oneself too hastily to a certain area without having checked the ignition system and that the engine is in good mechanical condition for example.

Modern Service Manuals can seem intimidating given that the number of pages is often in excess of 350 for an engine management system. However it is an extremely good guide when fault-tracing, which is almost impossible without it. By using the table of contents at the beginning it is easy to find the correct method for localizing the fault.

The electronic components in the management systems are extremely reliable and rarely cause any faults!

Fuel control



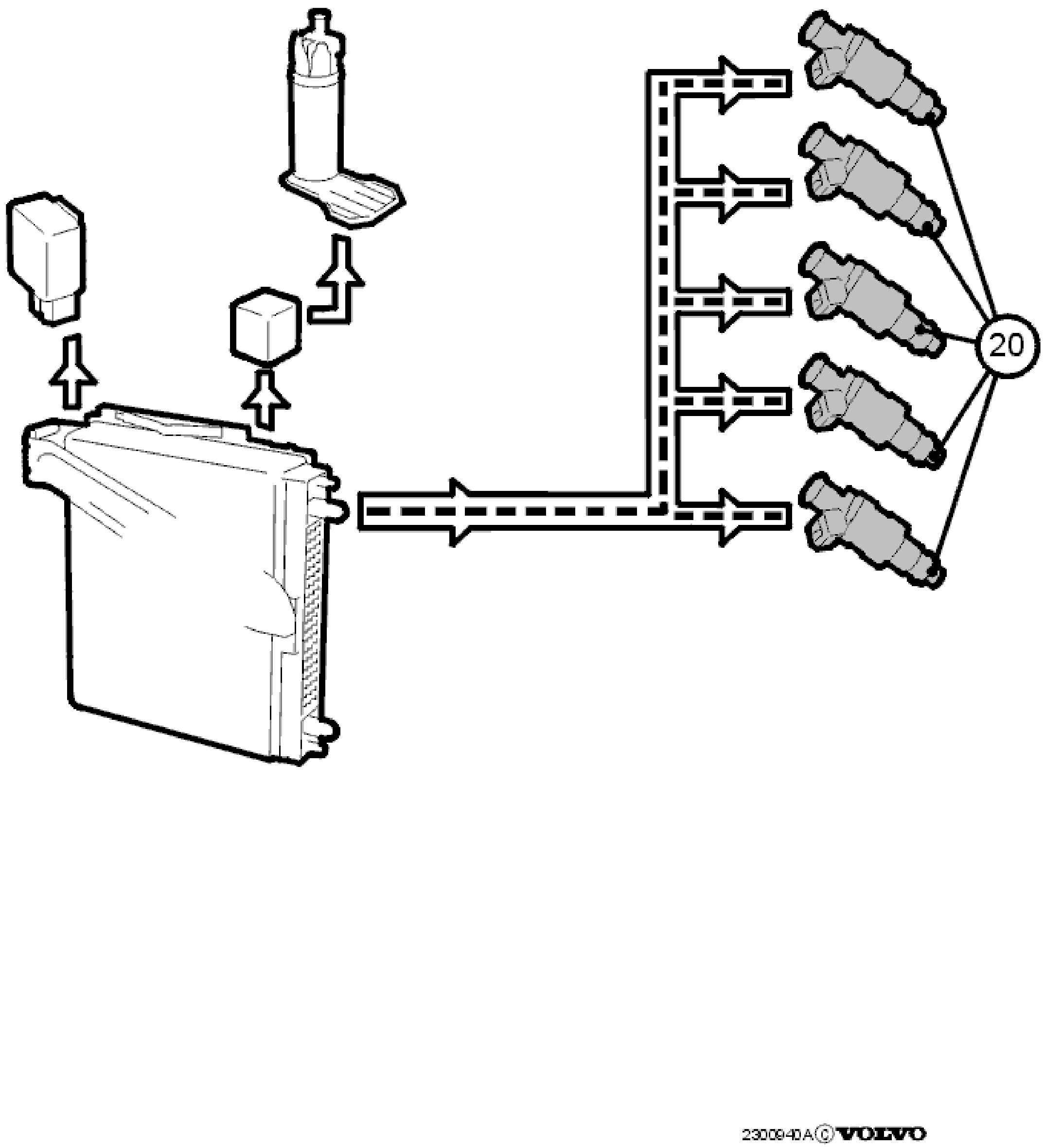
The fuel injection system tasks

- To provide fuel
- To distribute the fuel between the cylinders
- To provide the correct quantity of fuel

Starting fuel pump (FP)

The control module (1) activates the system relay (17) when the ignition is switched on. The relay provides the various components in the system with voltage, for example the injectors, idle air control (IAC) valve and pump relay (18).

On many systems the control module activates the pump relay (18) and therefore the fuel pump (FP) (19) for a few seconds when the ignition is switched on. This is so that the fuel pressure builds up.
The engine must turn for the relay and pump to be reactivated by the control module. The control module receives the signals for this from the engine speed (RPM) sensor (2).



How is the quantity of fuel regulated?

the injectors (20) are supplied with power (+) via the system relay.

The control module regulates the quantity of fuel by grounding the injectors. The longer the ground pulse the longer the opening time and therefore the greater the supply of fuel.

In principle, the length of the ground pulse can vary between 0 ms during engine braking up to approximately 100 ms (100/1000 second) during rapid acceleration.

Because the system voltage affects the speed at which the valves open, the control module adapts the ground pulse accordingly.

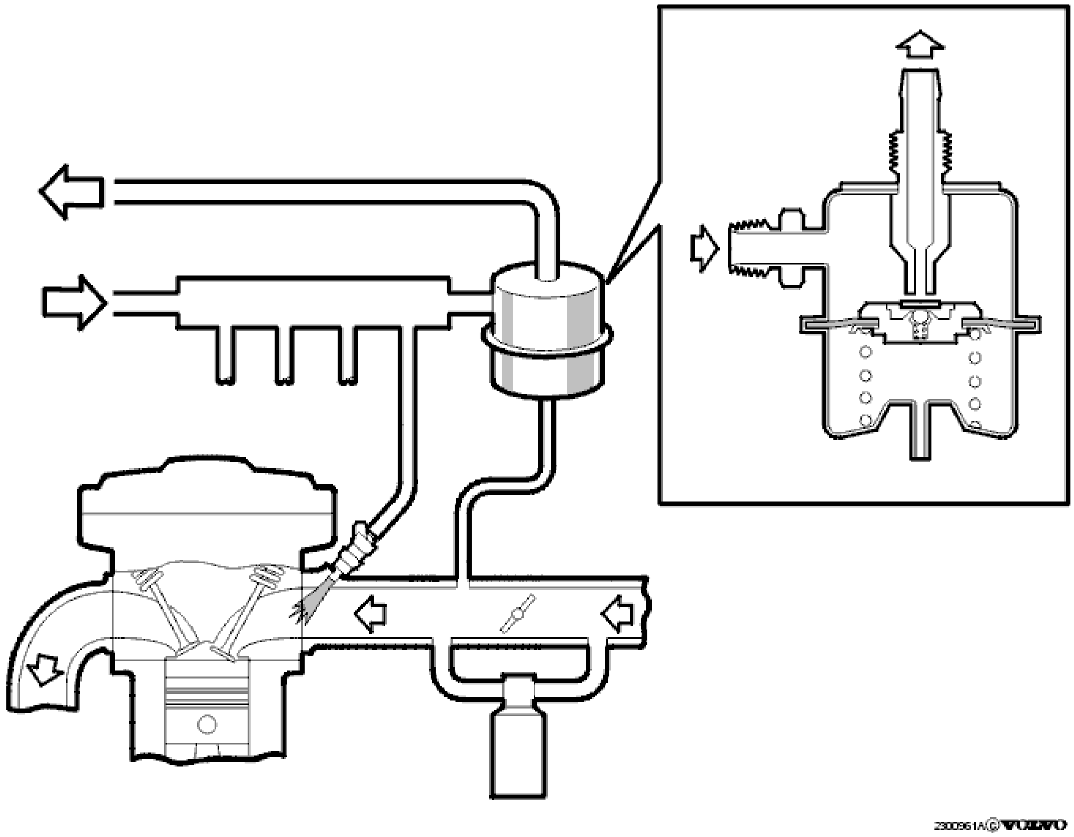
In order for the quantity of fuel to be correct, it is also a precondition that the fuel pressure is correct.

The three main different types of fuel system

Mono point (= one-point). There is a centrally located injector, usually in the throttle body (TB).

Multi point (= several points). Several injectors, normally one per cylinder, located as close to the intake valves as possible.

Sequential injection. In many systems all the injectors open at the same time or in groups. In sequential systems each injector is regulated and opened individually.



Regulating fuel pressure

When engine load varies, the pressure in the intake manifold also varies. The fuel then encounters shifting resistance. Therefore the ease with which the fuel is able to come out of the injectors varies.

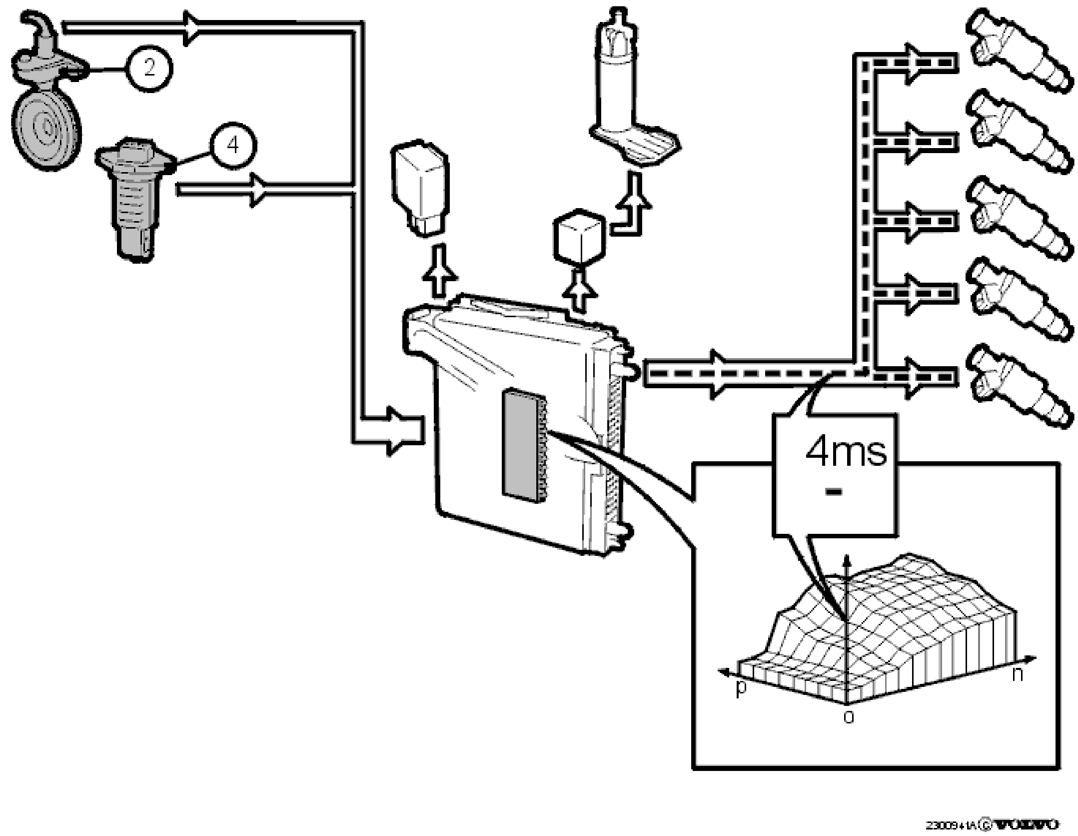
It is only the injector opening time which should affect the quantity of fuel. Therefore the fuel pressure must be regulated in relation to the pressure in the intake manifold.

The fuel pressure regulator is affected by the pressure in the intake manifold. It regulates the fuel pressure so that it is always kept at a constant level above the pressure in the intake manifold. Excess fuel is guided back to the fuel tank.

the injectors are connected to a distributor rail which has a large volume of fuel. This is so that the fuel pressure is not dramatically affected when the injectors open.

Thanks to the pressure regulator, it is only the injector opening time calculated by the control module that affects the quantity of fuel.

What is the correct quantity of fuel?
Signals from a number of sensors are required in order for the correct quantity of fuel to be calculated.
Which are the most important sensors?



The basic volume of fuel

The two most important sensors are the engine speed (RPM) sensor (2) and the volume air flow (VAF) sensor (4).

The control module reads of the signals from these two sensors and is then able to determine how much air enters the engine per engine revolution. It then reads its own memory to check what the opening time or the basic quantity should be, 4 ms for example.

90° before top dead center (TDC) for cylinder 1, the control module receives a special signal from the engine speed (RPM) sensor. The number of degrees before top dead center (TDC) may vary depending on the type of system. The control module is then able to calculate when it should open the injectors. Note that on systems with sequential injection an additional sensor is required for this.

The signal from the engine speed (RPM) sensor is also used to control the engine speed (RPM) limiter. In other words when the injection should be shut off.

Differentiate between air flow and engine load

Air flow: The volume of air per time unit
Load: The volume of air used by each cylinder.

- Low load: Low air flow and high engine speed (RPM).
- High load: Large air flow and low engine speed (RPM).

Different methods for the measurement of air flow

Mass air flow (MAF) sensors which measure the air mass (kg). The mass air flow (MAF) sensor also takes into account the volume of oxygen using the air temperature and pressure.

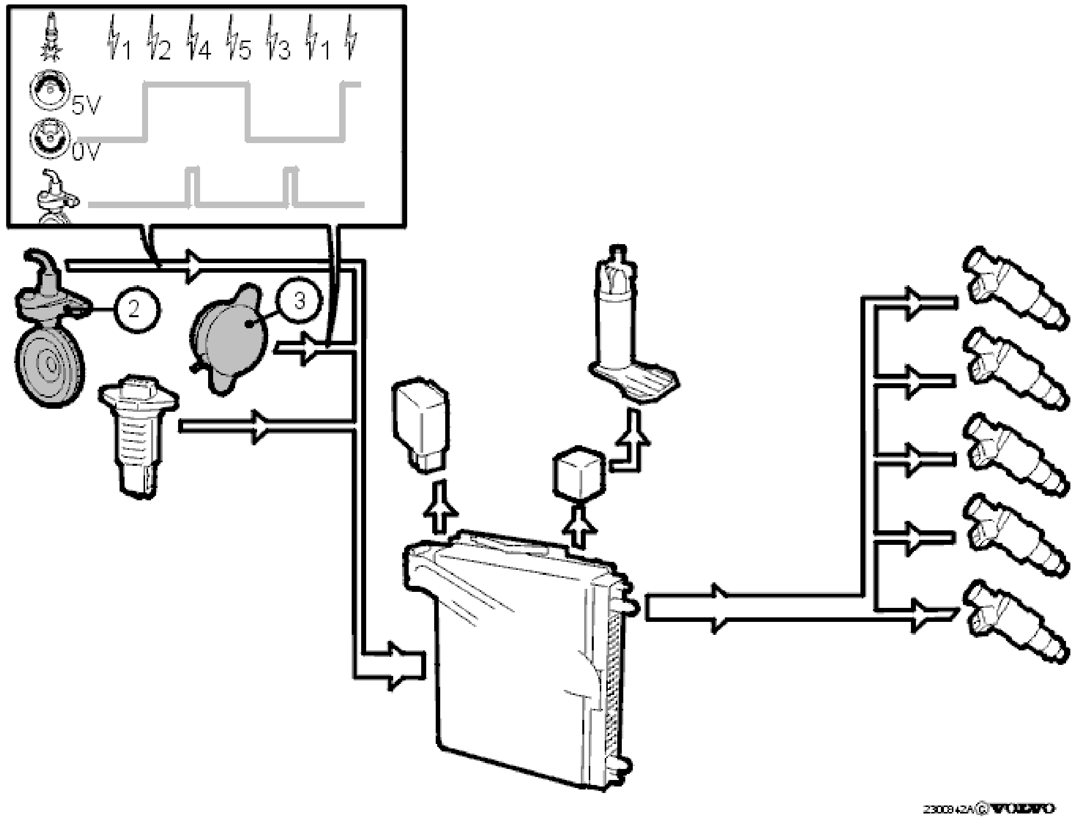
Mass air flow (MAF) sensors which measure the air volume (dm^3).

Pressure gauges which measure the pressure in the intake manifold (kPa).

The air volume and therefore the pressure in the intake manifold is affected by the air temperature. Therefore both the mass air flow (MAF) sensor and the pressure gauge must be supplemented with an intake air temperature (IAT) sensor.

14 kg of dry air at normal pressure is the equivalent of:

- 12174 dm^3 (l) air at +20 °C (1.15 g/l)
- 10853 dm^3 at 0 °C (1.29 g/l)



Camshaft position (CMP) sensor

On engines with sequential injection the control module must determine which of the injectors should be opened.

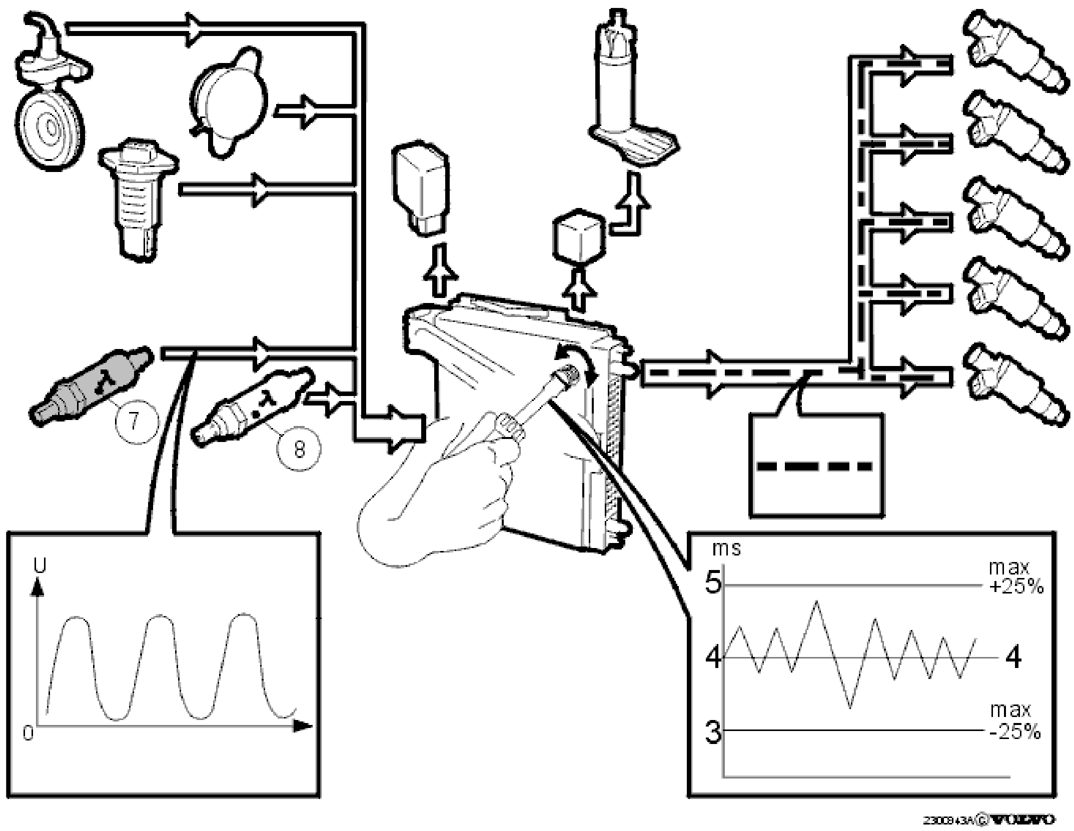
Two signals are required for this.
A signal from the engine speed (RPM) sensor (2) when cylinder 1 are approximately 90° before top dead center (TDC).
A signal which indicates whether the crankshaft is in the first or second revolution of the operating cycle. These signals come from the camshaft position (CMP) sensor (3).

In certain ignition systems the camshaft position (CMP) sensor is also used as a sensor.

What is an operating cycle?

An operating cycle is when all cylinders have ignited once. For this to happen the crankshaft must rotate twice. The camshaft rotates at half the speed of the crankshaft. In other words it has rotated once during one operating cycle. The camshaft position (CMP) sensor provides a type of signal during the first crankshaft revolution in an operating cycle and another type of signal during the second revolution.

This allows the control module to monitor whether the engine is in the first or second revolution of an operating cycle.



Correcting the quantity of fuel

The efficiency of combustion can vary depending on the fuel quality and the condition of the engine amongst other things. This also means that the composition of the exhaust gases varies.

On cars with three-way catalytic converter (TWC) the exhaust gases must have a certain composition for optimal three-way catalytic converter (TWC) efficiency.

Oxygen sensor (HO2S)

Irrespective of combustion efficiency, there is always a little oxygen (O_2 left in the exhaust gases. The oxygen Sensor (7), which is also called the heated oxygen sensor (HO2S), measures the oxygen content of the exhaust gases.

The control module finely adjusts the quantity of fuel using the signal from the oxygen sensor (HO2S).
The control module is able to adjust the basic

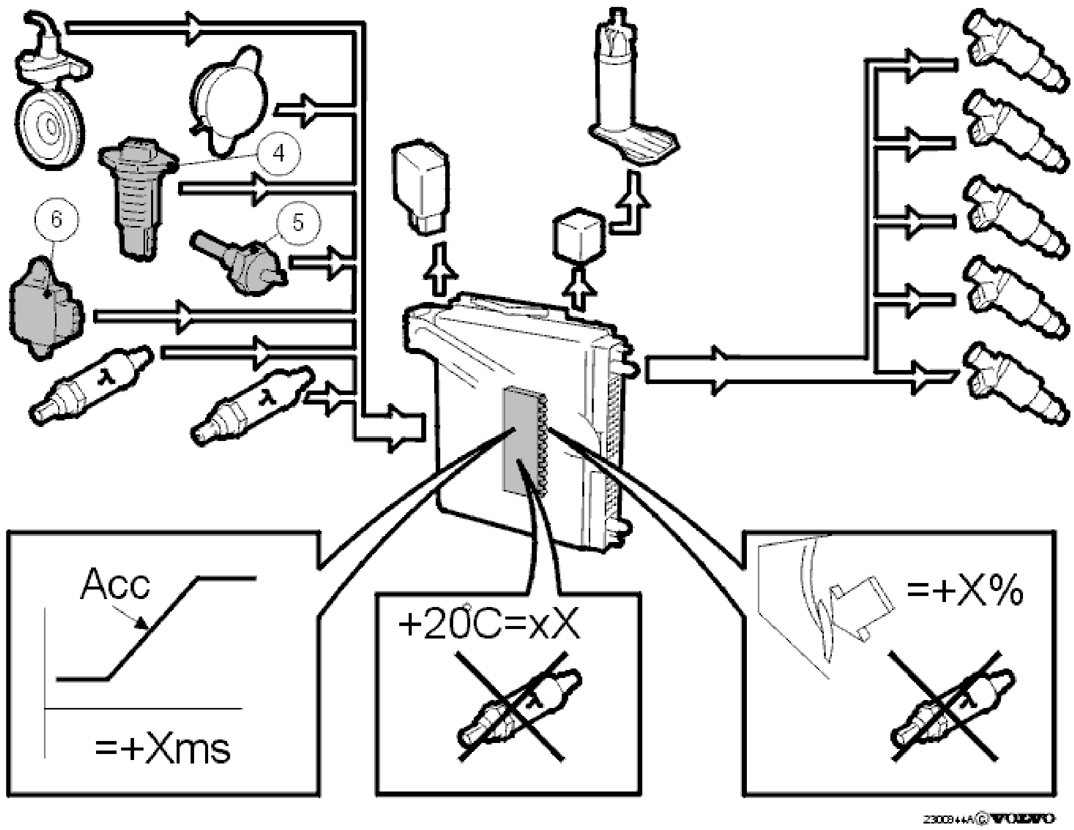
quantity of fuel by +/- 25% based on the signals from the oxygen sensor (HO2S). Assume that the basic quantity corresponds to an injector opening time of 4 ms. The oxygen sensor (HO2S) can act on this so that it becomes a minimum of 3 ms or a maximum of 5 ms.

"Fuel trim"

The control module responds immediately to the signal from the oxygen sensor (HO2S). It either increases or reduces the injector opening time. As a result the fuel / air mixture will at one moment contain too little fuel and shortly afterwards too much fuel. However the average value will be close to the ideal value, in other words $\lambda = 1$. Because the fuel / air mixture changes rapidly from lean to rich, the signal from the oxygen sensor (HO2S) will oscillate.

Rear oxygen sensor (HO2S)

Certain systems have 2 oxygen sensors (HO2S). The second sensor (8) is then position downstream of the three-way catalytic converter (TWC). The purpose of the rear oxygen sensor (HO2S) is to provide even finer adjustment of the quantity of fuel. Furthermore the control module is able to check the efficiency of the three-way catalytic converter (TWC). This is done by comparing the signals from both the sensors.



Compensating the quantity of fuel

Under certain conditions the engine requires more fuel than during normal operating conditions, at start, when the engine is cold, during acceleration and at wide open throttle (WOT) for example.

The control module reads off these conditions via a number of sensors and compensates the quantity of fuel as necessary.

The engine sometimes runs slightly rich, and during this time the control module ignores the signals form the oxygen sensor (HO2S).

Start

A rich mixture is required to guarantee good starting.

There are programmed values in the control module memory. These are used for start in different conditions.

During the actual start the control module does not normally take into account the air flow. It only checks the engine speed (RPM) and the temperature of the engine coolant.

Cold engine

When the engine is cold the friction in the engine is greater. Furthermore some of the fuel condenses and attaches to the cold engine surfaces such as in the intake manifold, on the inlet ducts and the cylinders for example.

The engine coolant temperature (ECT) sensor (5) measures the engine coolant temperature (ECT).

There are programmed values in the control module memory. These indicate how much the basic quantity of fuel should be increased depending on how cold the engine is.

There are different values for cold start and the warming up period for example.

- Cold start: When the starter motor turns the cold engine and when the fuel / air mixture should be ignited.
- The warming up period: The time after start until the engine has reached normal operating temperature.

Acceleration

More fuel is required during acceleration for two reasons. Partly to obtain as high engine power as possible, partly so that the air speed in the intake manifold increases rapidly. Fuel is heavier than air. Therefore fuel does not accelerate as rapidly. With normal fuel regulation this may result in the mixture being too lean. In order to compensate for this, a temporary increase in the quantity of fuel is required.

When the volume air flow (VAF) sensor (4) indicates that the air flow increases rapidly the control module understands that there is acceleration and increases the quantity of fuel. The amount of additional fuel required depends on how heavy the acceleration is.

On systems with mass air flow (MAF) sensors of the hot film type, it is the signal from the throttle position (TP) sensor (6) that indicates to the control module that there is acceleration. (There are two different version of mass air flow (MAF) sensor, the hot film type or the hot wire type, depending on whether it is a wire or film that senses the air mass).

Wide open throttle / full load

More fuel is required during wide open throttle / full load for two reasons.
To obtain maximum power. This is normally obtained at a λ value of approximately 0.9. To lower the combustion and exhaust gas temperatures.

The throttle position (TP) sensor (6) indicates that the throttle is completely open. The control module responds by extending the injector opening time.

On turbocharged engines the information from the volume air flow (VAF) sensor is normally used instead of the signals from the throttle position (TP) sensor to determine whether full load enrichment should be activated or not. This is because a turbocharged engine has extremely high thermal load. Therefore the mixture must be enriched even before wide open throttle (WOT).

On certain turbocharged engines there is a temperature sensor. This measures the exhaust temperature and controls the engagement of full load enrichment.

Engine braking

During engine braking the fuel can be shut off so that fuel consumption is lower and the exhaust gases cleaner. The conditions for the control module to shut off the fuel are:

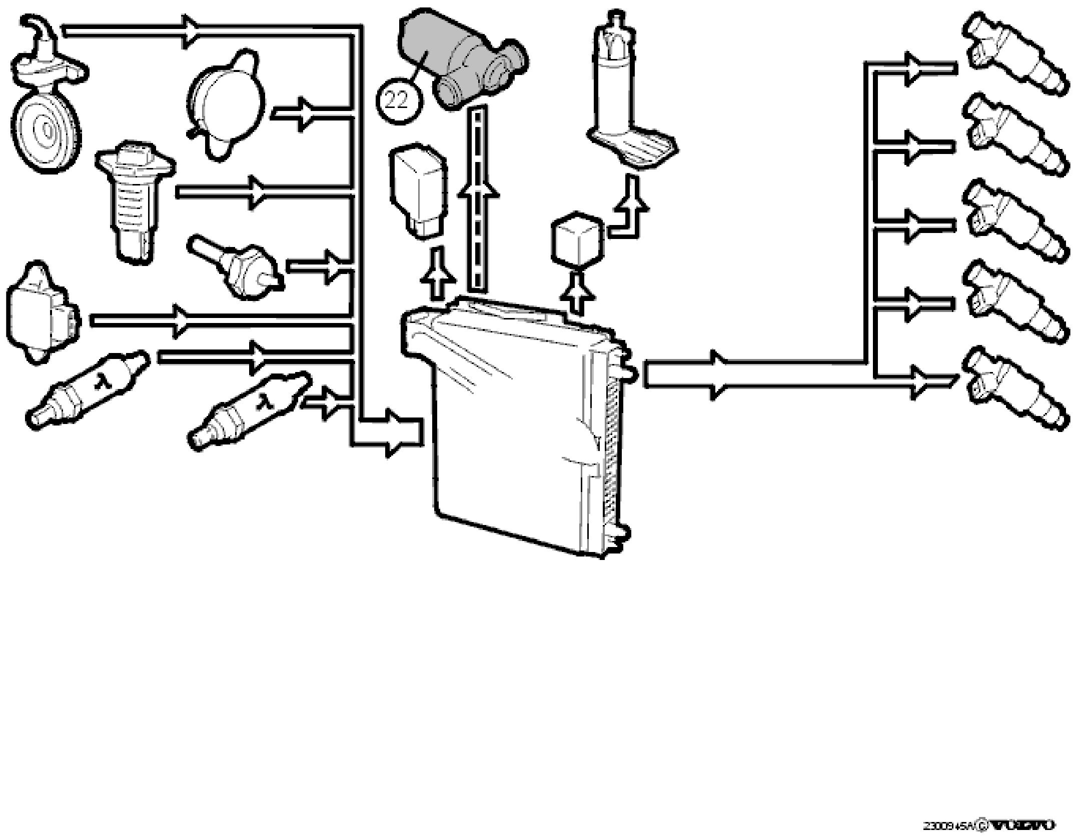
- The throttle is closed.
- The engine speed (RPM) is above a certain level.
- The engine is at normal operating temperature.

On certain systems the control module also takes account of the gear selected in order to determine whether the fuel shut-off system should be engaged or not. This is to avoid activation of the fuel shut-off system in the lowest gears. The control module can determine which gear is selected by comparing the current information about the vehicle speed and engine speed (RPM). Alternatively the engine control module (ECM) receives the information directly from the automatic transmission control module (TCM).

We now have a fuel system which adapts the

quantity of fuel to the different driving conditions.

Idle air control (IAC)



The idle air control (IAC) system tasks

To maintain a stable idling speed by directing the correct amount of air past the throttle.

To adapt the idling speed to different operating conditions.

How is the idling speed controlled?

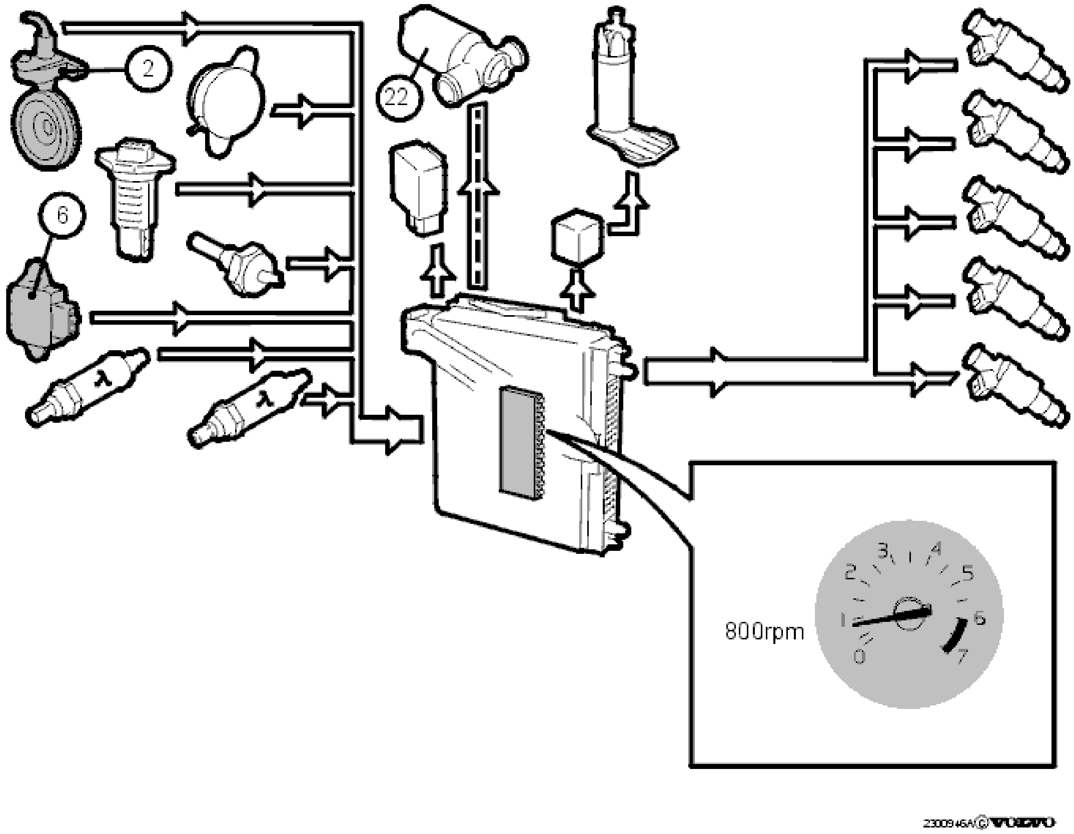
The idle air control (IAC) valve (22) has power supply (+) via the system relay.

The control module regulates the engine speed (RPM) by grounding the idle air control (IAC) valve. The longer the ground pulse the more the valve opens (= greater airflow) and the greater the engine speed (RPM).

Usually the same control module is used to control both the quantity of fuel and the idling speed. Most of the sensors are common to both functions.

When is the idling speed correct?

Signals from a number of sensors are required in order for the control module to be able to calculate this. Which are the most important sensors for the control of idling speed?



Basic control of idling speed

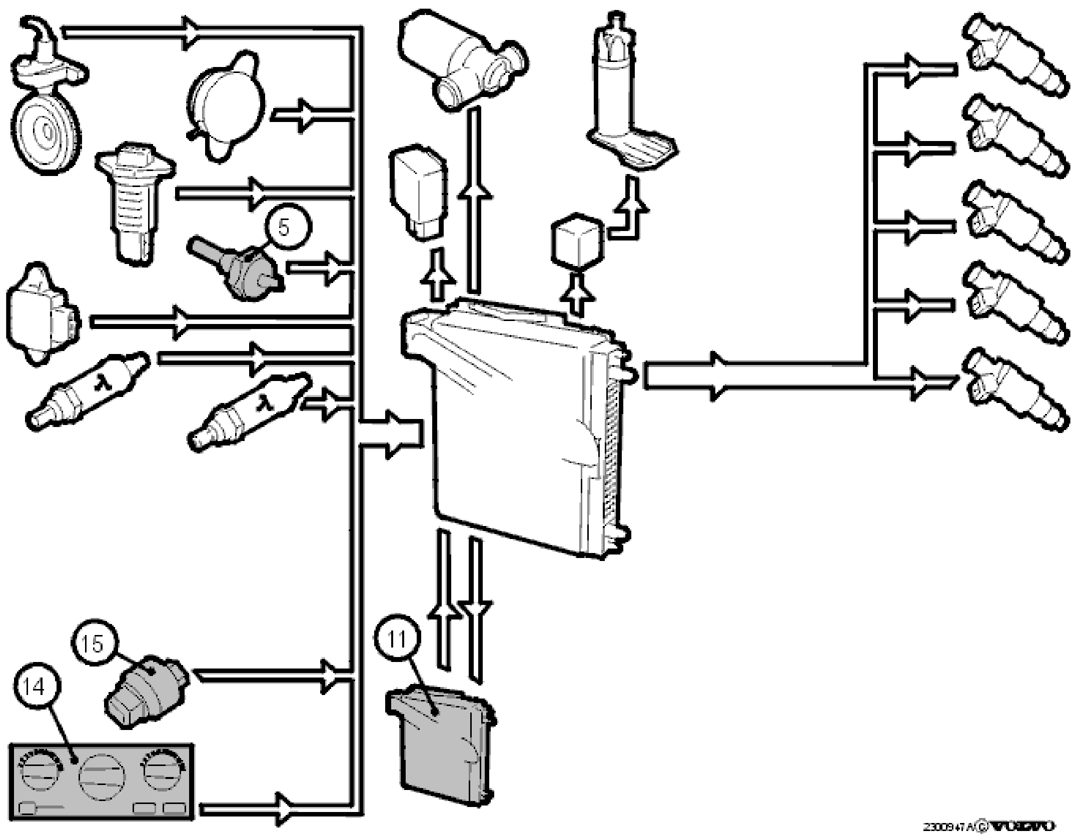
Two sensors are required for this. The throttle position (TP) sensor (6). This provides a signal indicating closed throttle position (CTP). The engine speed (RPM) sensor (2). This indicates that the engine speed (RPM) is low; in other words idling speed.
(Closed throttle + high engine speed (RPM) = engine braking)

The control module reads its own memory to check what the idling speed should be in the current operating condition.

The control module varies the length of the ground pulse to the idle air control (IAC) valve (22). This is so that the idling speed is correct and kept constant.

As soon as the throttle is opened slightly the idle air control (IAC) valve opens a little extra. This to avoid stalling when parking for example when the power steering increases the load on the engine.

During engine braking the valve is slowly closed to the normal idling speed. This means that the negative pressure in the intake manifold is limited. In turn this provides cleaner exhaust gases.



Compensating idling speed

In certain circumstances the idle air control (IAC) valve must open a little extra. This is to obtain the correct engine speed (RPM). Sometimes it must be able to react more quickly than normal.

Cold engine

When the engine is cold there is greater internal friction in the engine. Therefore an increased amount of fuel / air mixture is required. Some engine variants also require higher idling speed.

The engine coolant temperature (ECT) sensor (5) measures the temperature.

The control module reads its own memory to check how much more the idle air control (IAC) valve needs to be open for the idling speed to be correct despite the higher friction. Alternatively, on certain engine variants, the idling speed is raised slightly.

Variation in load at idling speed

When the load varies considerably at idling speed there is a risk of the engine speed (RPM) oscillating too much. In such circumstance increased preparation and quicker control are required.

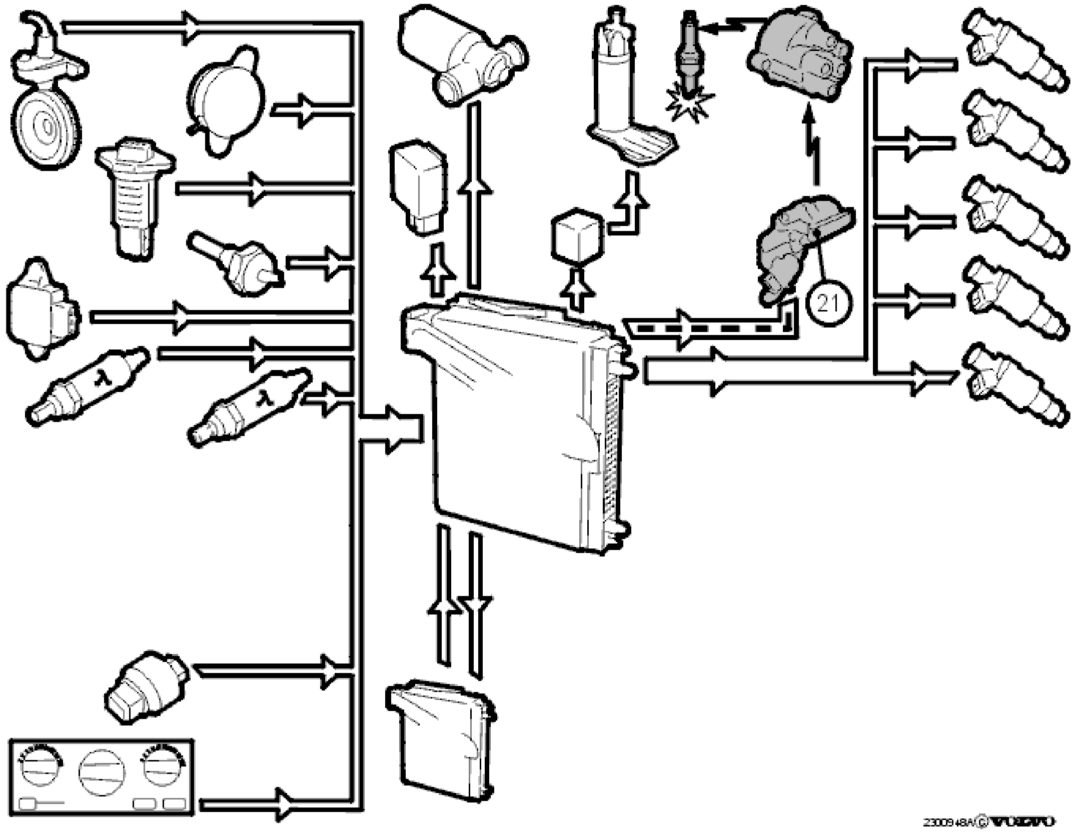
On some systems the quantity of fuel is also increased temporarily when the load is increased This helps the idle air control (IAC) valve to keep the idling speed as stable as possible.

When a gear is selected on cars with automatic transmission a signal is transmitted by the gear shift selector or the automatic transmission control module (TCM) (11).

When the air conditioning is selected a signal is transmitted by the A/C control (14). When the A/C compressor is engaged and disengaged signals are transmitted by the pressure switch (Pressostat) (15).
On some engine variants the idling speed is increased slightly when the A/C is selected. This is primarily to increase the power of the air conditioning system.

This was what was required for idle air trim.

Ignition control



The ignition system tasks

To transform the system voltage (approximately 14 V) to a sufficiently high ignition voltage. In electronic systems this is normally above 30 kV (30 000 V).

Provide an ignition spark to the correct spark plug at the correct moment.

How is the ignition coil charge time and the ignition setting regulated?

There is an ignition discharge module (IDM) included in the ignition system. In principle the task of the ignition discharge module (IDM) is the same as points. In other words to open and close the current through the ignition coil.

Usually a separate ignition discharge module (IDM) outside the control module is used to avoid the high current and therefore the heat generated inside the control module.

The ignition discharge module (IDM) and the ignition coil (21) are supplied with voltage (15 +).

The control module controls the ignition by using signals to the ignition discharge module (IDM) to govern when the ignition coil ground terminal should be opened and closed.

- Charging begins when the ignition coil is connected to ground.
- The period in which the ground terminal is connected is identical with the ignition coil charging time.
- When the ignition coil ground terminal is opened the ignition coil discharges and a high voltage is generated.

How is the ignition coil charge time calculated?

When the control module generates the charge time, it also takes into account the system voltage and engine speed (RPM) (≈ cam angle control). For example, if the system voltage is low or the engine speed (RPM) high, the charging of the ignition coil begins earlier than normal. The charge time is always extended under such conditions. Therefore modern ignition systems always provide a high ignition voltage independent of engine speed (RPM) and system voltage.

What is the correct ignition time?
Signals from a number of sensors are required in order for the control module to be able to calculate this.
Which are the most important sensors?

Basic position, ignition

The two most important sensors are the engine speed (RPM) sensor (2) and the volume air flow (VAF) sensor (4). All engines use the information from these sensors to calculate the ignition setting.

The control module reads off the signals from the sensors. It then checks its memory to determine what the ignition setting should be.

4 cylinder engines

On 4 cylinder engines there is usually a special signal from the engine speed (RPM) sensor 90° before top dead center (TDC) for cylinder 1. The control module is then able to calculate when the ignition coil should be grounded in order to have enough time to charge, and when the ground connection should be broken (ie the spark is produced).

5 cylinder engines

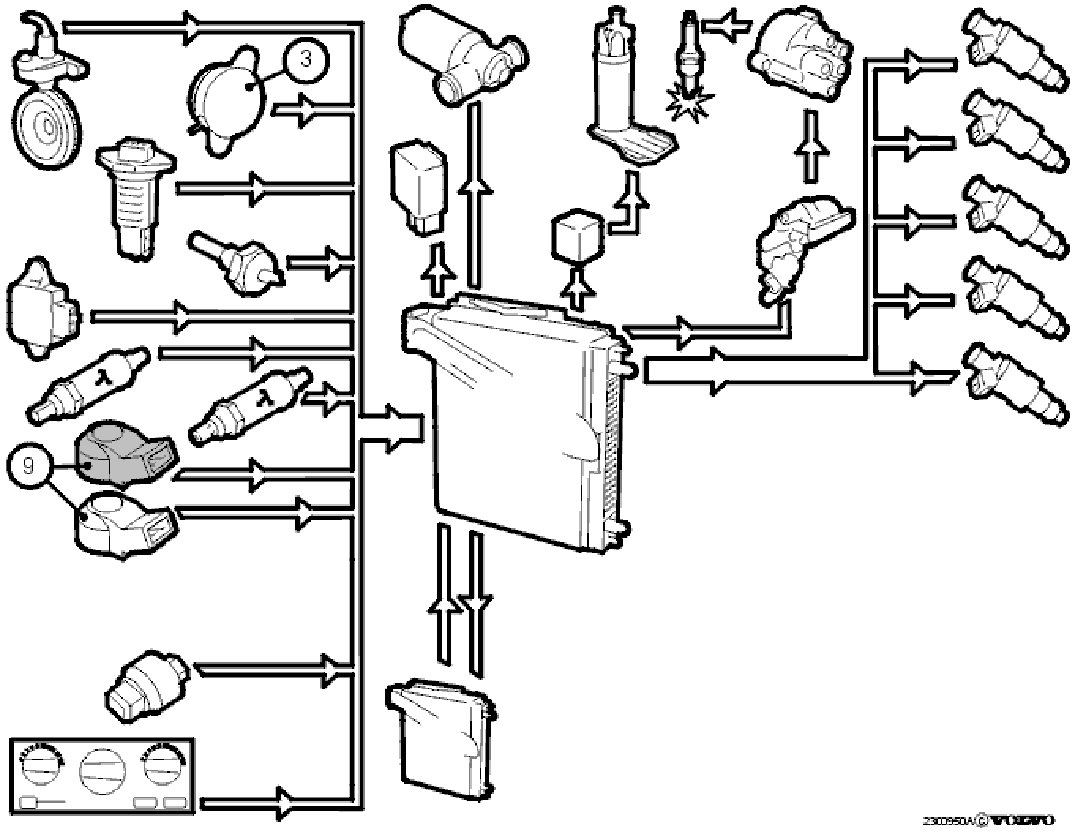
On 5 cylinder engines the amount of time before each cylinder reaches top dead center (TDC) varies when the engine speed (RPM) sensor transmits its reference signal for the crankshaft position.

For example, the signal from the engine speed (RPM) sensor is transmitted 84° before top dead center (TDC) when cylinder 1 reaches TDC and 12° before TDC when cylinder 4 reaches TDC. The control module therefore also requires a signal about which cylinder should be ignited.

This is so that it can calculate when the ignition coil should be connected to ground and when the ground connection should be interrupted (a spark is produced). By using the signals from the camshaft position (CMP) sensor (3) the control module is able to determine whether the crankshaft is in the first or second revolution of the operating cycle. In other words, in this example, cylinder 1 or 4 is in the compression phase.

6 cylinder engines

The signal from the camshaft position (CMP) sensor is also required for engines without a distributor and which have separate ignition coils for each spark plug. Some Volvo 6 cylinder engines have this system. This is so that the control module knows which if the cylinders should be ignited. In other words which ignition coil must be connected when the cylinder pairs (1 - 6, 2 -5 or 3 -4) are approaching top dead center (TDC).



Correcting the ignition setting

With an electronic ignition system it is possible to program the ignition setting irrespective of whether the load etc. is close to the knocking limit.

The closer the ignition setting is to the knocking limit, the better the use of the energy content in the fuel. The system attempts to raise the ignition as much as possible without the engine knocking.

In the event of interference, for example carbon deposits or poor quality fuel, the engine may start to knock. This results in vibrations in the cylinder block.

Knock sensor (KS)

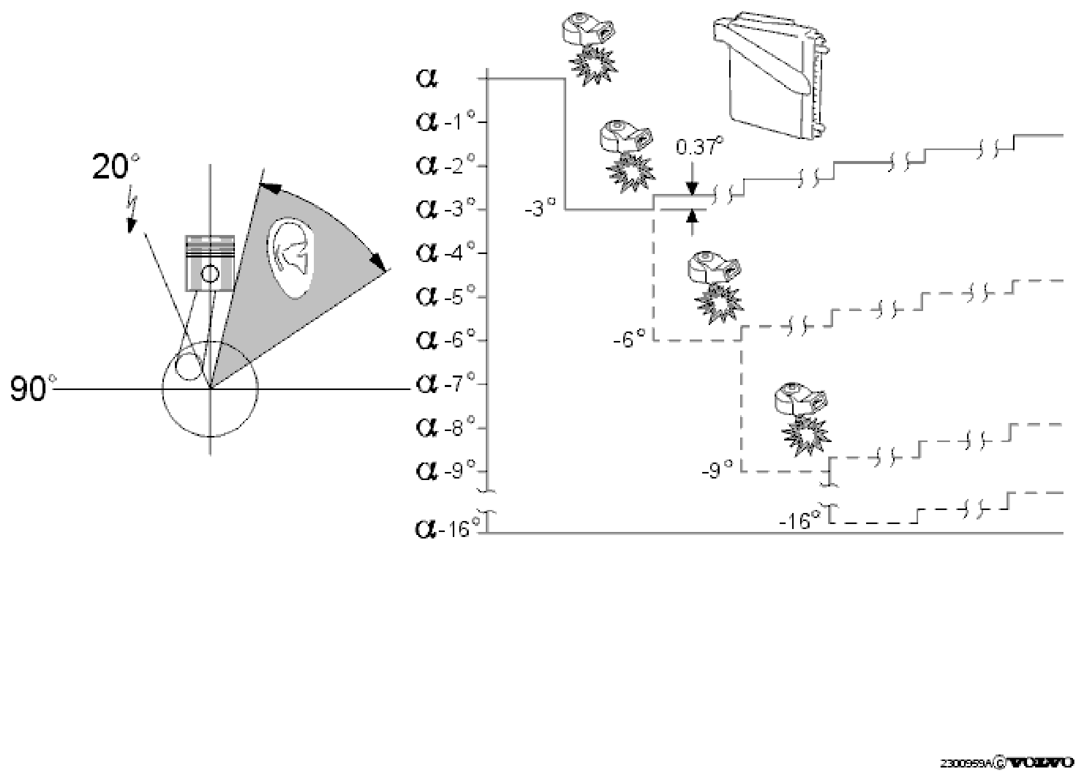
The knock sensor (KS) (9) senses vibrations in the cylinder block and supplies the control module with signals about them.

There is a filter in the control module which only allows through signals from the knock sensor (KS) which have the special frequencies that occur in the event of knocking. In other words the control module will not to react to the normal vibrations in the engine. The normal vibrations change as the engine wears. However the control module continuously updates its memory so that it can tell which are normal at any given time.

If the signal has the correct frequency and is above a certain level, the control module lowers the ignition on the cylinder that has knocked. On certain older systems the ignition is lowered on all cylinders in the event of knocking.

Two knock sensors (KS)

On 5 and 6 cylinder engines with a relatively long stroke and on V engines, two knock sensors (KS) are used. This is because the vibrations in the event of knocking do not always spread throughout the entire cylinder block. On engines with a camshaft position (CMP) sensor, its signals are used so that the control module only listens to the knock sensor (KS) located closest to the cylinder that is igniting.



Knock control

Knock control works in approximately the same way as fuel trim using the oxygen sensor (HO2S). The control module allows something to happen, then it checks what happened and then a correction is carried out. It is quite normal to hear an occasional single knock from the engine with this kind of control process.

Knock control functions in the following manner:

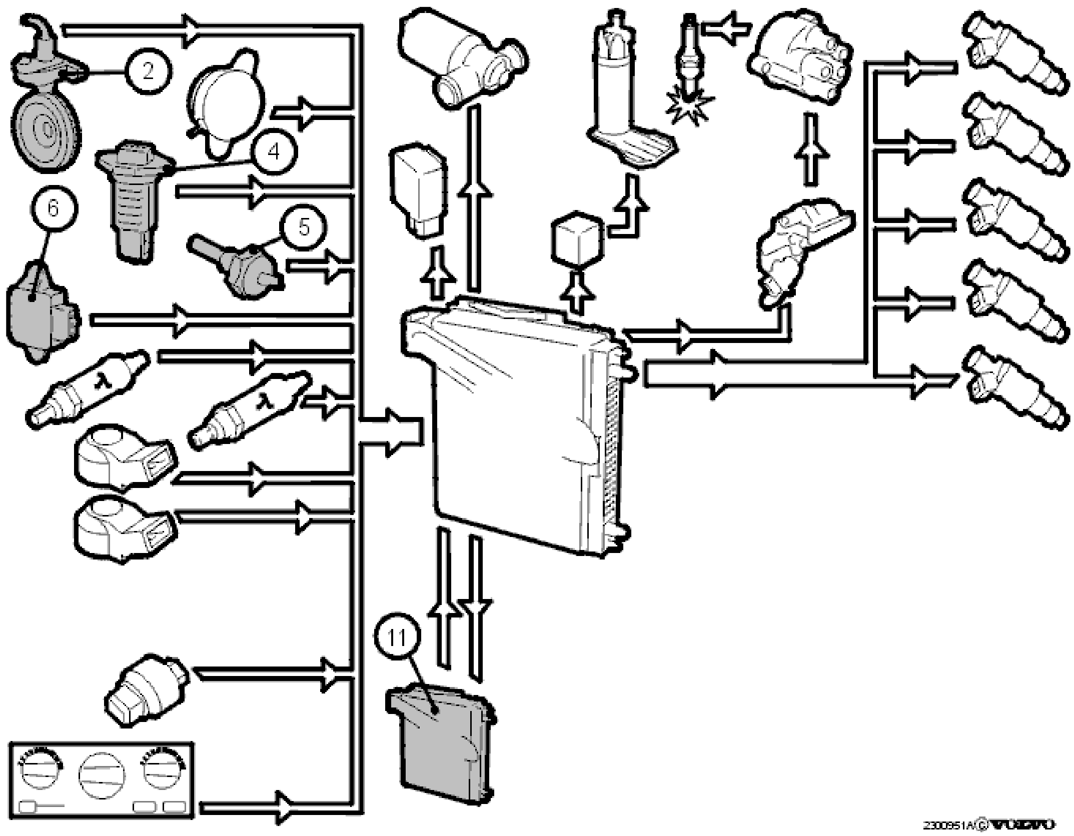
1. The control module reads off the sensor and calculates the correct ignition setting, for example 20° before top dead center (BTDC).
2. The control module ensures that the spark is delivered to the correct cylinder at the correct time.
3. Immediately after top dead center (TDC) (between approximately 15-55°) the control module connects the knock sensor and listens to see if that cylinder is knocking.
4. If the control module hears a knock it is remembered and the cylinder which knocked is also registered.
5. The next time that cylinder should fire the ignition is retarded slightly.
6. If the knocking continues despite retardation the ignition is retarded further the next time the cylinder fires.
7. If there is no knocking after retardation, the control module waits a short time and then advances the ignition gradually.

How much the ignition is retarded, how long the delay before advancing begins is, and how large the steps when adjusting the ignition are varies depending slightly depending on what system and version the car has (the illustration above is just an example).

Knock controlled fuel enrichment

Is only available on certain systems and engine versions, normally turbocharged engines and other powerful engines.

If all cylinders knock sufficiently the ignition system sends a signal to the fuel injection system. The fuel injection system replies by increasing the quantity of fuel. This cools combustion and reduces the risk of knocking. While the fuel injection system injects more fuel in this way the signals from the oxygen sensor (HO2S) are ignored.



Compensating the ignition position

Under certain circumstances the ignition position must be compensated, that is deviate from what is "normal" for the engine speed (RPM) and load.

The control module reads off these conditions via a number of sensors and compensates the quantity of fuel as necessary.

Idling speed, engine braking

When idling there are no great requirements of output power, but at the same time it is important that the engine runs smoothly and comfortably.

To give a good idle quality the top pressure (maximum combustion pressure) is reduced during combustion so that ignition is retarded.

On many systems the ignition position is more or less fixed while idling. The ignition position is only adjusted to prevent the ignition position from being further reduced if the engine speed (RPM) is below a certain value.

When engine braking the control module selects a compromise between the cleanest possible exhaust and low fuel consumption. On later systems it is only relevant at relatively low speeds, because a complete fuel shut off occurs when engine braking at higher engine speeds (RPM).

The signal that the throttle is closed comes from the throttle position (TP) sensor (6). The control module determines whether it is idling or engine braking by reading the signals from the engine speed (RPM) sensor (2).

Cold engine

During the warming up process the engine usually moves the ignition position from the normal setting. This can either be a question of a altitude increase or reduction depending on what operation is required from the engine.

Ignition advance is used to shorten the warming up time of the moving parts in the engine. A higher ignition gives higher combustion pressure and therefore higher engine coolant temperature (ECT).

Ignition retardation is used to shorten the three-way catalytic converter (TWC) warming up time and therefore reduce exhaust emissions. With late ignition the exhaust gases are withdrawn from the cylinder quickly in relation to the combustion finishing. This gives a higher exhaust temperature. More energy is converted to heat which is transferred to the exhausts.

The engine temperature signal comes from the engine coolant temperature (ECT) sensor (5).

Idling, engine at operating temperature

If the engine is very hot (coolant exceeds 105 °C) while idling the ignition is normally advanced. This is to help prevent the engine coolant from boiling (because of the pressure in the system the engine coolant temperature (ECT) must reach a value of approximately 125 °C to boil).

The ignition advance in this case is because ignition is retarded while idling so that the engine runs evenly. By advancing the ignition more energy is introduced in the fuel which is transferred to mechanical operation and less energy is transferred to coolant in the form of heat.

Rapid acceleration

Because the ignition system works near the knock limits there is a risk of transitional knock when there is a sudden increase in load.
This is due to two things

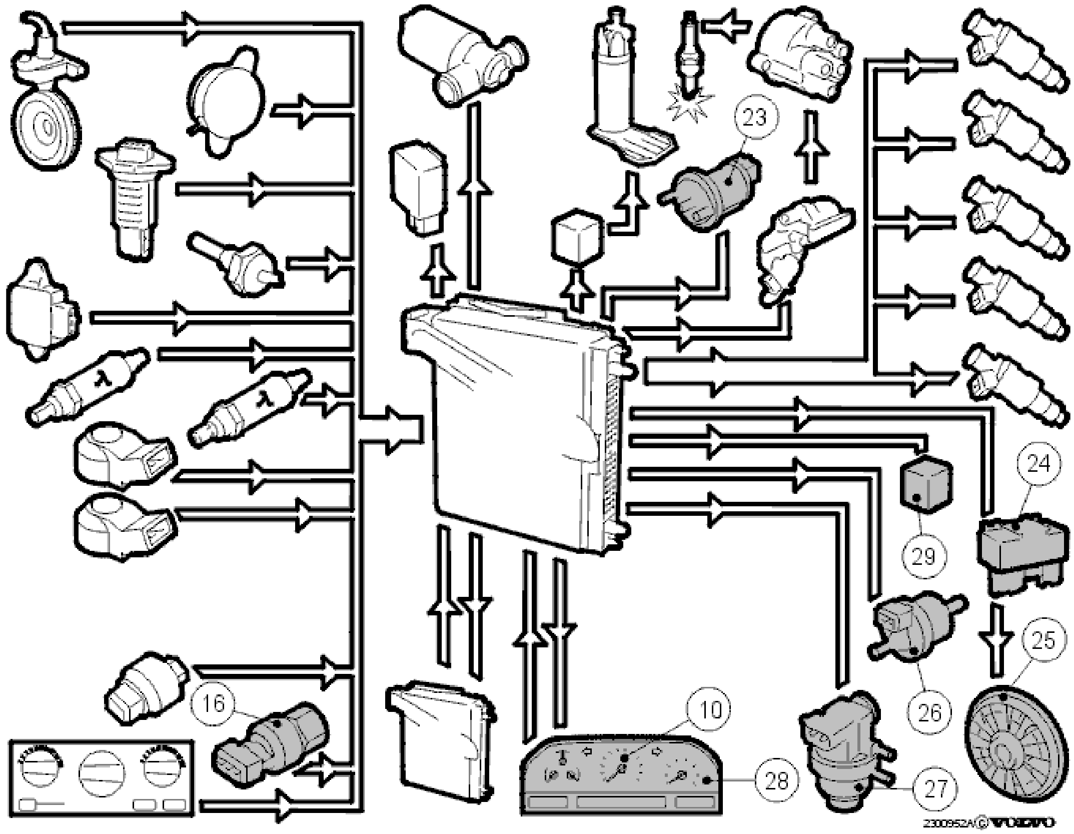
- Air accelerates faster than fuel. It is not guaranteed that the fuel injection system will be able to supply more fuel and the mixture will be temporarily lean.
- The amount of fuel/air mixture increases rapidly and the ignition system does not have time to retard ignition with the normal controls.

Therefore the control module retards the ignition a number of degrees during hard acceleration. The information that it is hard acceleration is received by the control module either from the air flow (4) or throttle position (TP) sensor (6).

Shifting (cars with electronically controlled automatic transmission)
Just before shifting a signal comes from automatic transmission control module (TCM) (11). The engine control module (ECM) replies by retarding ignition for a short time. This gives a temporary reduction of engine torque and the shift is smoother. This function is normally only connected when the driving program selector for the automatic transmission is in economy position.

We now have a fuel system which adapts the ignition setting to the different driving conditions.

Other functions



Other functions can be controlled by the control modules

On certain systems the engine control module (ECM) is also used to control functions other than fuel, ignition and idle air trim. Because the control module already knows the engine drive relationship it is just a question of connecting components and programming the control module.

The control module is often connected to other control systems in order to send information to them. The following can occur.

Air conditioning (AC)

The air conditioning (A/C) compressor is controlled via a relay (29). The control module can disconnect the compressor at:

- Wide open throttle (WOT) for the maximum acceleration, using the signals from the throttle position (TP) sensor signal.
- Hot engine where there is a risk of overheating, using signals from the engine coolant temperature (ECT) sensor.
- Excessive pressure in the air conditioning (A/C) system, using signals from the high pressure

sensor (16) in the AC system.

Engine cooling fan (FC)

Controlled via a relay (24).

The control module can start the engine cooling fan (FC) if

- Engine coolant temperature (ECT) rises above a certain value, based on information from the engine coolant temperature (ECT) sensor.
- AC is selected when the vehicle speed is low, based on information from the speedometer and climate control system.
- Excessive pressure in the air conditioning (A/C) system, based on information from the pressure sensor in the AC system.
- The exhaust temperature is too high. The control module can derive exhaust temperature theoretically based on information about engine speed (RPM), load and throttle position.

If the engine has been under heavy load the engine cooling fan (FC) will occasionally continue running for one or more minutes after the engine has been switched off. This is called engine cooling fan (FC) "run-on". The control module calculates whether the engine cooling fan (FC) should run on by looking at how the engine is loaded and how high the engine coolant temperature (ECT) is.

Evaporative system for fuel vapor

Normally called the EVAP system which stands for "Evaporative Emission System".

The evaporative emission (EVAP) system takes care of fuel vapor in the fuel tank so that it is not released into the atmosphere. The fuel which evaporates is drawn to and stored in a reservoir with a carbon filter which is called a canister. While driving the canister is drained using an electrical canister purge (CP) valve (26).

The control module determines when the canister purge (CP) valve is opened. When the valve is opened the fuel vapor is routed to the intake manifold and is mixed with the air flowing into the engine.

The control module determines when the canister purge (CP) valve is opened. When the valve is opened the fuel vapor is routed to the intake manifold and is mixed with the air flowing into the engine.

Exhaust gas recirculation

Normally called the EGR system which stands for "Exhaust Gas Recirculation".

Exhaust gas recirculation is used to minimize the amount of nitrous oxides (NO_x) left in the exhaust gases. nitrous oxides are a compound of the oxygen and the nitrogen in the air which develop at high pressures and temperatures. By routing a part of the exhaust gases to the engine via an Exhaust Gas Recirculation Valve (EGR Valve) the combustion temperature is lowered. This is partially because exhaust gases contain a relatively high amount of water vapor which requires a lot of energy to heat up and partially because the exhaust gases are inert and take up room but do participate in the combustion process.

The control module controls the EGR valve opening via a solenoid valve/ vacuum converter (27).

The solenoid valve opens only when the engine is at operating temperature at partially open throttle.

Boost pressure reduction

On certain turbocharged engines the boost pressure is controlled by a turbocharger (TC) control valve (23). It is connected to the turbocharger (TC) pressure regulator which controls the boost pressure control (BPC) valve and therefore the boost pressure. The turbocharger (TC) control valve can led off part of the boost pressure from the pressure regulator to the turbocharger (TC) inlet. This means that a relatively high boost pressure can be obtained at low engine speeds (RPM).

The control module controls the boost pressure by varying the valve opening based on information about the throttle position, load, engine speed (RPM), engine coolant temperature (ECT), and any knocking.

On certain engines the boost pressure is also affected by factors such as the gear in use, the driving mode selected and the stop (brake) lamp switch.

Pulsed secondary air injection system (PAIR) pump (not illustrated)

Controlled via a relay.

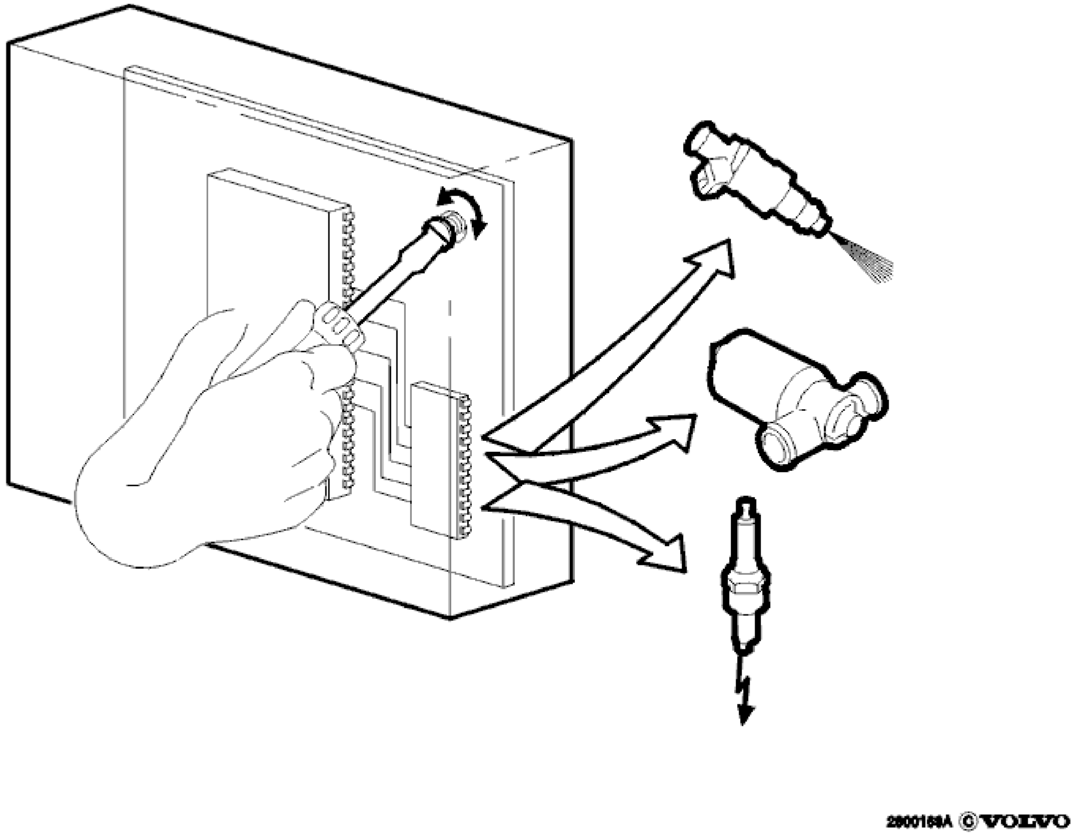
The pulsed secondary air injection system (PAIR) pump is started by the control module and only runs for a short period after a cold start.

The pump blows air into the exhaust system immediately after the exhaust valves so that exhaust afterburning begins. This makes emissions cleaner, CO (carbon monoxide) and HC (hydro-carbons) values are reduced. This also heats the three-way catalytic converter (TWC) faster.

Gauges

The control module sends signals to the combined instrument panel (28) with engine speed (RPM), engine coolant temperature and injected fuel quantity. The instrument panel in turn uses the information for engine speed, temperature and trip computer displays.

The speedometer (10) transmits signals about the vehicle speed and distance covered to the control module. This signal can be used by the control module to evaluate and diagnose signals from the volume air flow (VAF) sensor and control signals to the idle air control (IAC) valve.
In addition the vehicle speed signal can be used to limit the maximum vehicle speed (injection is shut off) and to calculate which gear the car is being driven in.



Adaptation (≈ self learning)

Most modern engine management system are self learning, or as it is usually referred to adaptive functions for fuel, idling speed and ignition setting.

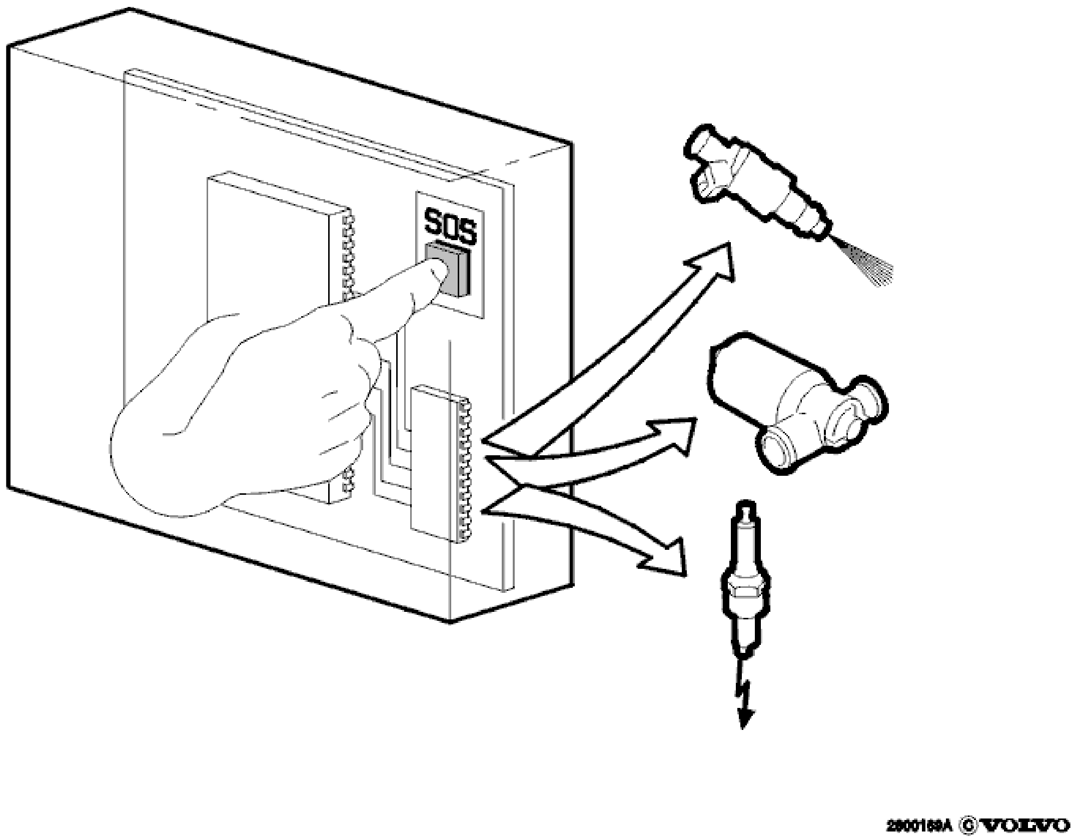
When the engine is new the control module determines what the normal fuel quantities, idle air control (IAC) valve openings and ignition settings for various driving conditions are.

These normal values are modified later, because as the engine is run in the is less, valve play can vary, there may be carbon build up in the cylinders, dirt may stick to the throttle plate and small air leakages may occur on both the intake and exhaust sides. There are a number of factors which are changed when the engine ages.

The control module aligns the control successively to the altered conditions. Soon the "new" normal values are used for control, so that the correct opening on the idle air valve can be set even if the engine has a little air leakage which passes the throttle plate.

The system becomes self learning or self adjusting. The control module cannot however manage too great an adjustment with reaching the stop position. This can occur as a result of late execution of a scheduled maintenance, large air leakage, low fuel pressure etc.

Our sense of smell is also adaptive!
If you enter a room with a strong smell you initially experience this smell as something unpleasant. However after a while you become accustomed to the smell and do not notice it so much. We can therefore say that we have an adaptive sense of smell, because we accustom ourselves to a new "normal position".
When you then leave the room the sense of smell will adapt itself to the cleaner air again.



Emergency program

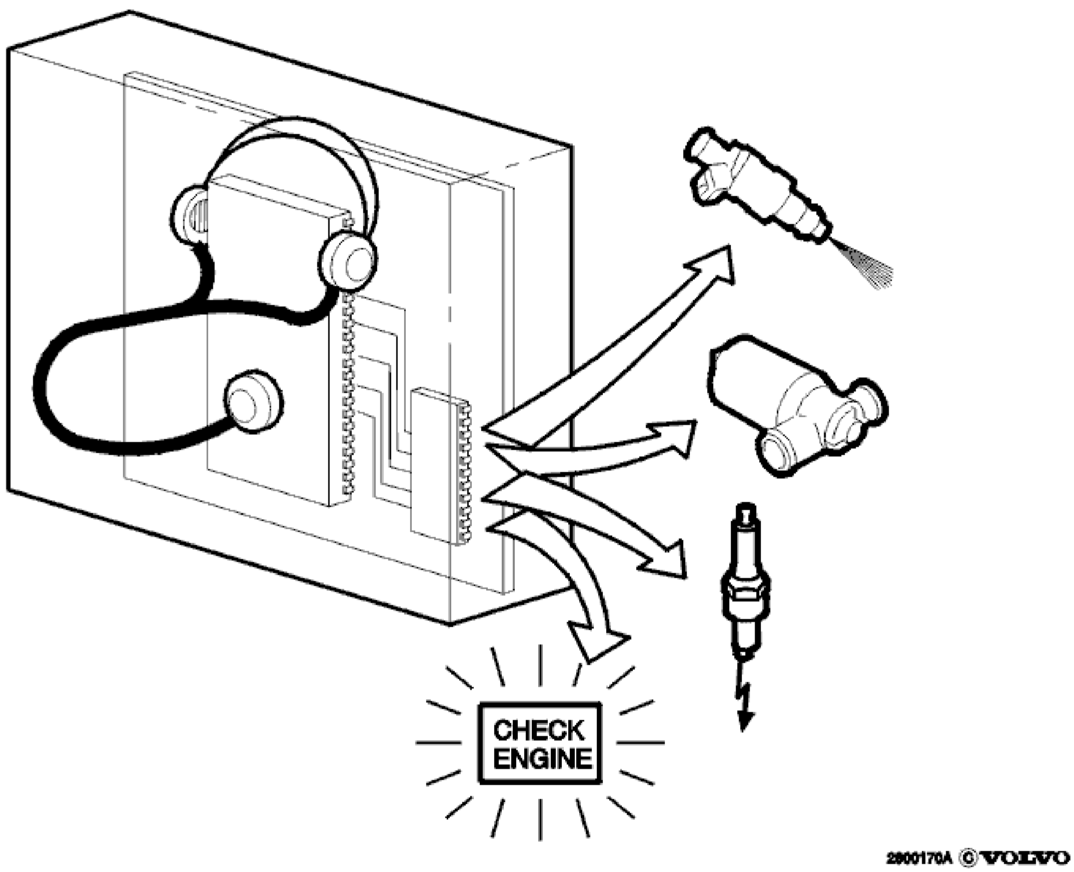
The control module continuously monitors input and output signals.

If any signal is missing or is outside its permitted range the control module connects an emergency program for that signal. The aim is that the car should be driveable even if a fault has occurred.

In the emergency program there are instructions to use another signal to assist certain calculations or to use a fixed value instead of the missing signal.

The number of emergency programs for each system varies as does the number of replacement values which are used in the different cases. However the one signal that no fuel injection or ignition system can do without is the engine speed (RPM) signal. If this is missing the engine stops immediately.

On many systems the function with the emergency program is reversible. This means that if the fault disappears (a loose connection for example) the control module returns to normal function. What is required for this varies between systems. In a number of systems it occurs the next time the ignition is switched on, other systems require the car to be driven a number of times with different loadings for a certain period of time.



Diagnostic functions

All new systems have integrated diagnostic functions, in certain countries this is a legal requirement.

Normally this means that the control module continuously monitors its own function and a number of input and output signals.

If a fault is discovered the control module stores a Diagnostic trouble code (DTC) which also connects, if possible, an emergency program.

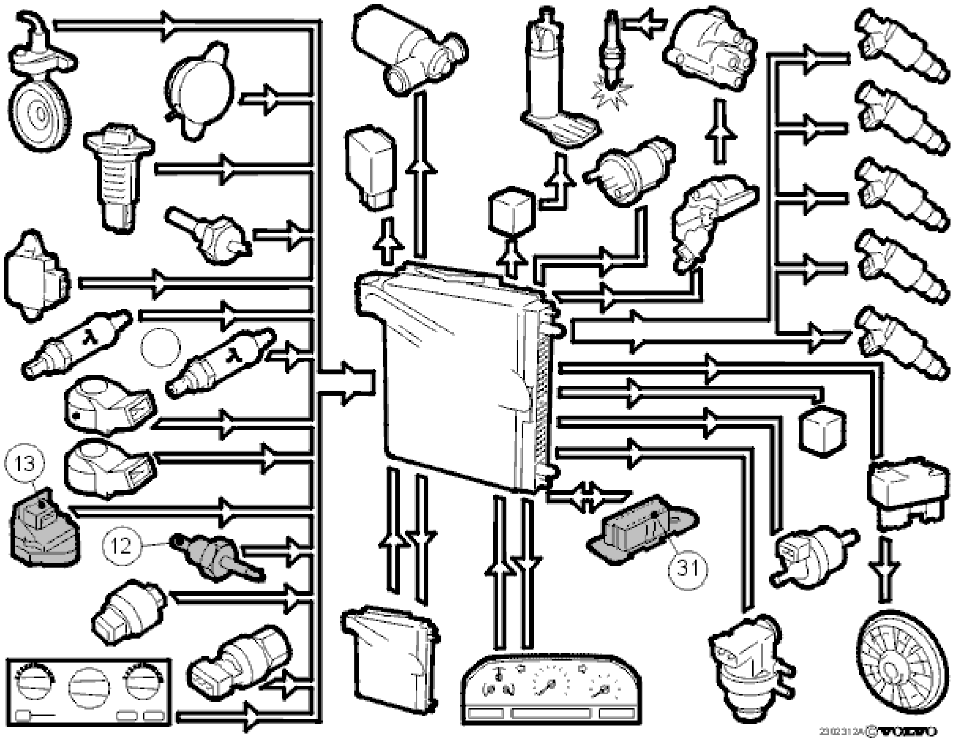
For faults which affect the exhaust output the control module lights a warning lamp in the combined instrument panel. This warning lamp has a k-symbol or the text "CHECK ENGINE".

The on-board diagnostic (OBD) system is used to facilitate fault-tracing. There are up to four diagnostic test modes (DTM) in the engine management system on-board diagnostic (OBD) system:

- Function 1: Monitors for any faults that occur while driving. Faults that have occurred can then be displayed using diagnostic trouble codes (DTCs).
- Function 2: Makes it possible to check that the signals reach the control module from certain sensors. When a sensor is activated the control module replies by giving an acknowledgment code.
- Function 3: Check that certain signals reach the controlled component by the control module activating certain components in a certain order.
- Function 4: One can activate a particular component to see if the component functions and that the control signal from the control module reaches the component.

On newer systems the function with diagnostic trouble codes (DTCs) and warning lamps is reversible. This means that if the fault disappears:

- the warning lamp goes out after a relatively short time.
- the DTC in the control module is erased after a relatively long time.



Special sensors for certain diagnostic functions

In a number of cases (legally required in certain countries) further sensors are required to diagnose certain functions.

I The EGR-system needs a temperature sensor (12) in the exhaust gas recirculation pipe. The control module uses the signal from this temperature sensor to determine if the EGR valve opens or closes.

On a number of cars there is an accelerometer (13) which measures the car vertical movement (up and down). The control module uses the signal to determine whether variation in the engine speed (RPM) is dependent on misfiring or driving on a bumpy road surface.

Data link connector (DLC)

Data Link Connector (DLC) (31) in passenger compartment. Also called On Board Diagnostic II (OBD II) In certain countries this is a legal requirement. The connector is standardized so that a general tool common to all car models can be used. There are also requirements as to which faults the system must be able to diagnose and

how the diagnostic trouble codes (DTCs) should be developed.
(On a number of the older ignition system there is an output/connector without an LED.)

How is the diagnostic information read off?

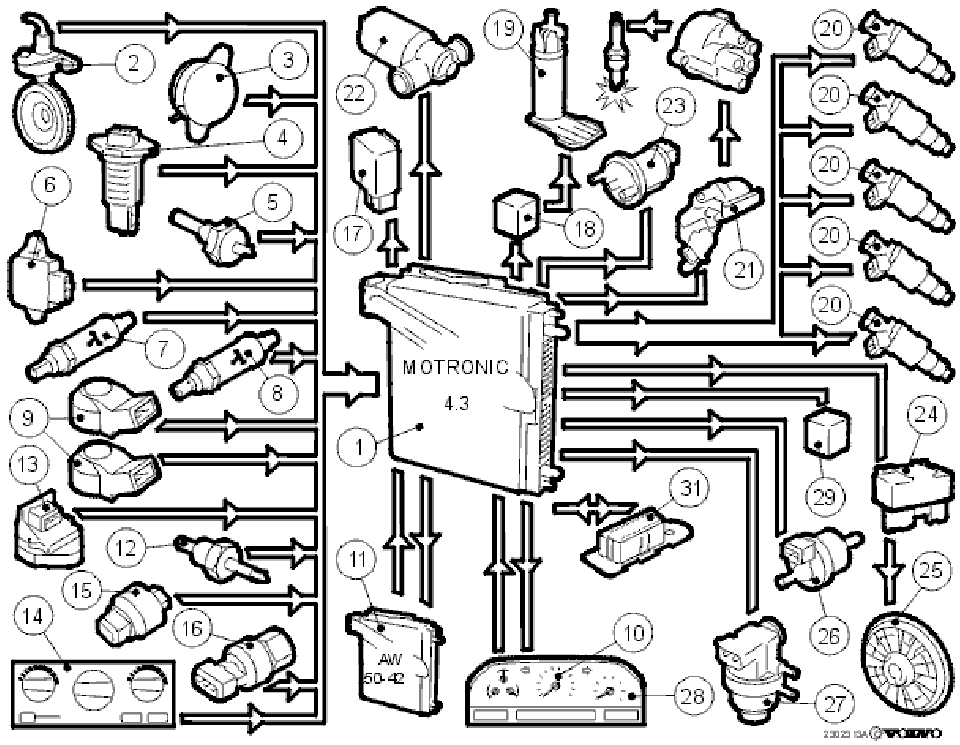
The different diagnostic test modes (DTM) in the on-board diagnostic (OBD) system can be activated in different ways:

- By connecting Volvo Diagnostic Key (text readout unit).
- By connecting Volvo Scan Tool.

Only the Volvo Scan Tool (ST) can give access to all the fault tracing aid that the system can provide for example:

- Reading off the exact values of the input and output signals.
- If the fault is intermittent (temporary) or permanent (constant.
- How many times the fault has occurred etc.
- If the signal is too high or too low (if the fault is caused by a short-circuit to ground or by system voltage).
- Freezing the diagnostic trouble codes (DTCs) and signals during test drives in order to read them off later.

Conclusion



Complete system

- 1. Control module
- 2. Engine speed (RPM) sensor
- 3. Camshaft position (CMP) sensor
- 4. Mass air flow (MAF) sensor
- 5. Throttle position (TP) sensor
- 6. Throttle position (TP) sensor
- 7. Front oxygen sensor (HO2S)
- 8. Rear oxygen sensor (HO2S)
- 9. Knock sensor (KS)
- 10. Speedometer
- 11. AW transmission control module (TCM)
- 12. EGR temperature sensor (USA)
- 13. Acceleration sensor (USA)
- 14. Air conditioning AC
- 15. Air conditioning (A/C) pressure switch (Pressostat)
- 16. Air conditioning (A/C) pressure sensor
- 17. System relay
- 18. Fuel pump (FP) relay
- 19. Fuel pump
- 20. Injectors
- 21. Idle air control (IAC) valve
- 22. Idle air control (IAC) valve
- 23. Turbocharger (TC) control valve

- 24. Fan relay
- 25. Engine cooling fan (FC)
- 26. Canister purge (CP) valve
- 27. EGR controller (USA)
- 28. Combined instrument panel
- 29. Air conditioning (A/C) compressor relay
- 31. OBD II data link connector (DLC)

Now we have a complete system with a control module which can control quantity of fuel, idling speed, ignition setting, air conditioning (switch off the AC compressor), engine cooling fan (FC), EGR system, EVAP system and boost pressure. Furthermore the system is adaptive has emergency programs and an on-board diagnostic (OBD) system.

The system we have used as an example is the Motronic 4.3 on a 1994 model year Volvo 850 Turbo for the USA market.

Even if a part of the system has separate control modules for the fuel, ignition and boost pressure controls and in certain cases fewer functions, the basic principles are the same for all of Volvos electronic engine management systems.

What one learns one might forget. What one has understood one never forgets.