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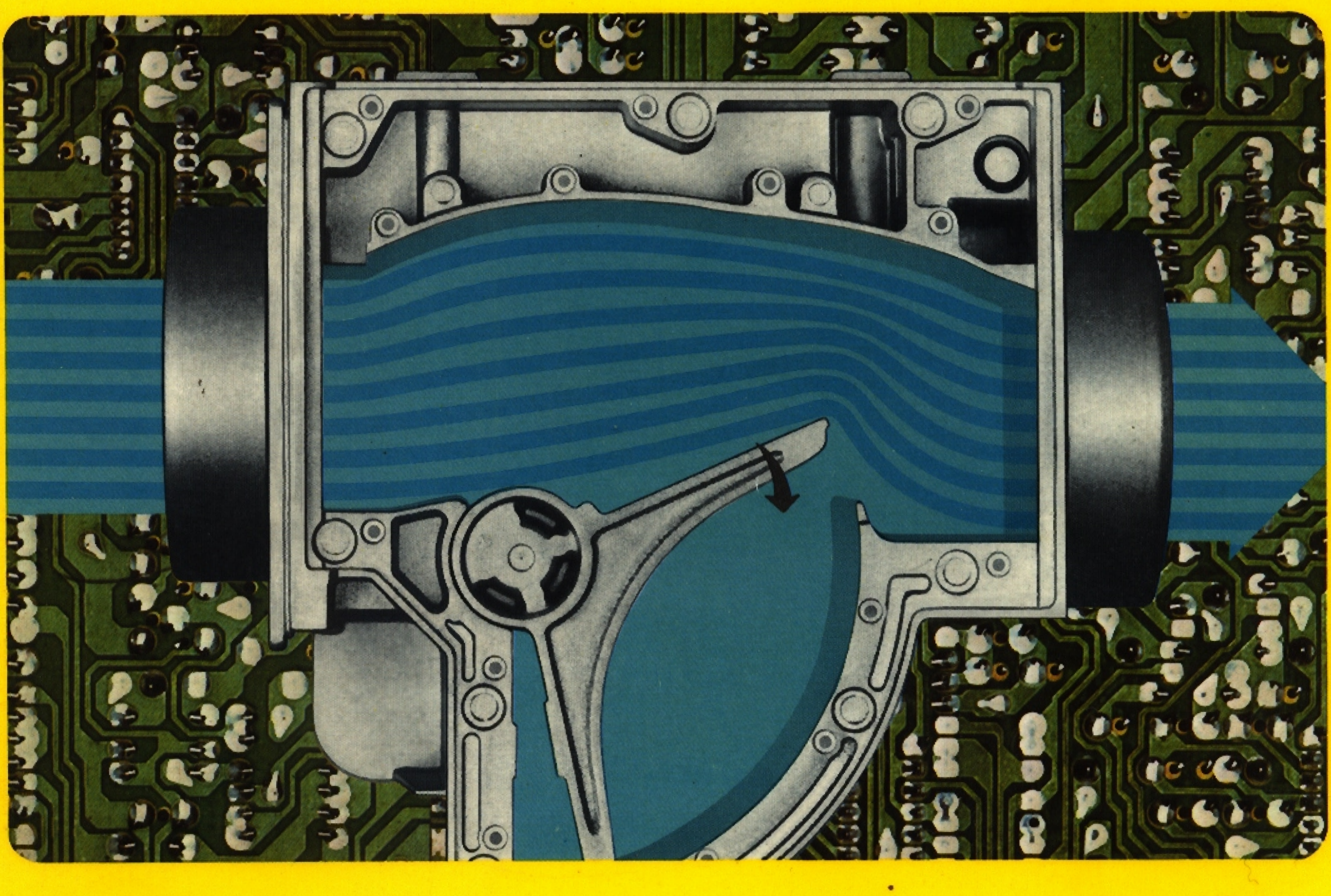

L-Jetronic

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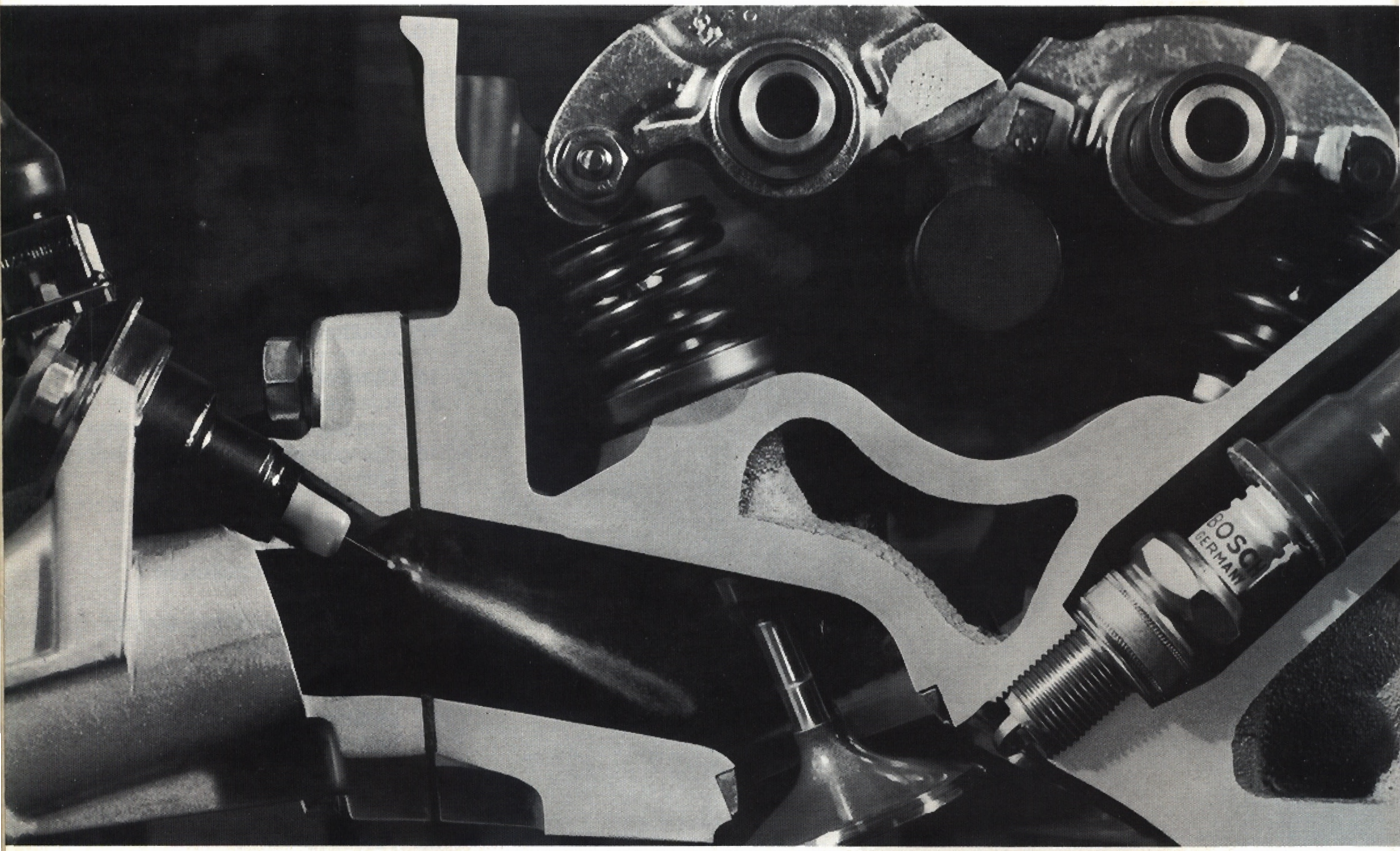
L-Jetronic

A gasoline fuel-injection system
from **Bosch**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Jetronic fuel-injection systems have proved their worth in millions of cases since they were introduced. The continuous further development of the control unit and the sensor have led from the D-Jetronic to the L-Jetronic and made this fuel-injection system more precise and more reliable. New circuit variations in the evaluation of the sensor signals have led to more economical and more comfortable operating qualities of the engine. Thanks to the use of the Lambda sensor and the Lambda closed-loop control integrated into the control unit, the L-Jetronic can already fulfill the exhaust-gas requirements of tomorrow. This booklet tells you all you need to know about the latest developments in L-Jetronic.

The spark-ignition engine

The spark-ignition engine is an externally ignited internal-combustion engine which converts the energy contained in fuel into kinetic energy.

In the spark-ignition engine an air-fuel mixture is formed outside the combustion chamber. This mixture is fed into the combustion chamber where it is compressed. Combustion of the mixture is caused by time-controlled external ignition. The spark-ignition engine operates in timed phases.

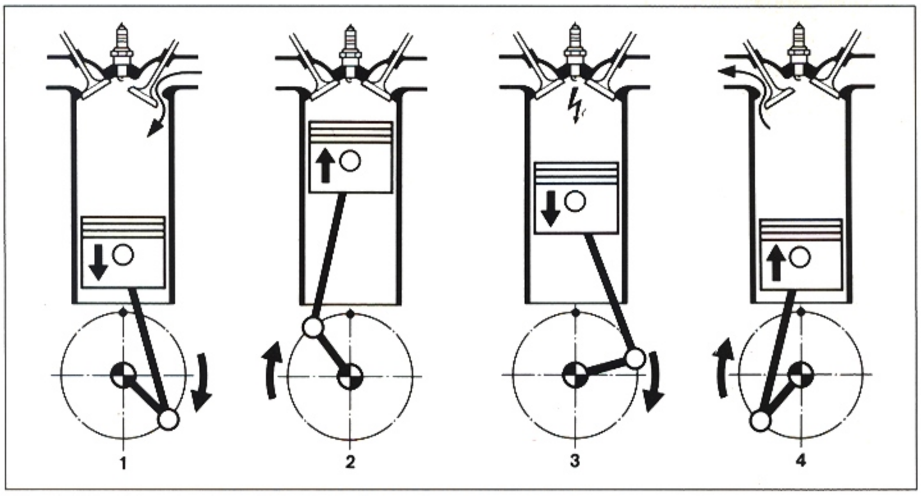


Fig. 1 ***Working strokes of the 4 stroke engine***
1 Suction stroke, 2 Compression stroke, 3 Working stroke, 4 Exhaust stroke

Principles of operation

An ignitable air-fuel mixture is ignited and burnt inside a working cylinder. The combustion heat given off increases the pressure of the pre-compressed gases. This combustion pressure is higher than the pre-combustion pressure and produces mechanical work via the pistons and the crankshaft. After each power stroke the burnt gases are exchanged for a fresh air-fuel mixture. In the motor-vehicle engine this change of gas takes place usually in accordance with the 4-stroke principle.

4-stroke principle
The exchange of gas in the 4-stroke spark-ignition engine is controlled by valves which open or close the inlet and outlet ports of the cylinder depending on the position of the crankshaft.
The 4 strokes of a working cycle are:
- suction
- compression
- combustion (work)
- exhaust

1st. stroke: suction
Inlet valve: open
Outlet valve: closed
Piston movement: downwards
Combustion: none

The downward moving piston increases the volume of the combustion chamber, enabling a fresh air-fuel mixture to be sucked past the open inlet valve and into the cylinder.

2nd. stroke: compression
Inlet valve: closed
Outlet valve: closed
Piston movement: upwards
Combustion: none

The upward moving piston reduces the volume of the combustion chamber thereby compressing the air-fuel mixture. The compression factor is approx. 7 ... 10, according to the type of engine.

3rd. stroke: combustion (work)
Inlet valve: closed
Outlet valve: closed
Piston movement: downwards
Combustion: yes

The compressed air-fuel mixture is ignited by the ignition spark at the spark plug. As the mixture is burnt its temperature increases and the pressure in the cylinder increases. The pressure of the combustion gases drives the piston downwards in the cylinder and by means of the connecting rod produces movement of the crankshaft.

4th. stroke: exhaust
Inlet valve: closed
Outlet valve: open
Piston movement: upwards
Combustion: none

The upward moving piston reduces the volume of the combustion chamber, whereby the burnt gases (exhaust) are expelled through the open outlet valve. The stroke cycle repeats itself after the 4th. stroke. In the actual cycles of the internal-combustion engine the opening times of the valves overlap somewhat, whereby gas flows and oscillations are utilized for improved filling and emptying of the cylinder.

Efficiency of the spark-ignition engine

The efficiency of the spark-ignition engine depends to a large extent upon the following criteria:
compression
combustion process
air-fuel mixture,
as well as upon its mechanical design.

Compression
The higher the compression, then the higher the thermal efficiency of the internal-combustion engine becomes and the better the fuel usage. The maximum compression is limited by the octane requirement. Knocking means an irregular combustion of the ignited mixture and leads to overstressing and damaging of the engine. With regular (homogenous) air-fuel mixture and by using the flow effects in the intake path, the octane requirement can be adjusted in the direction of higher compression.

Combustion procedure
For the quality of the combustion process it of is prime importance that the fuel mixes intimately with the air so that it can be burnt as completely as possible during the power stroke. Furthermore it is important that the flame front progresses spatially and in regular form during this period until the whole mixture has been burnt. The combustion process is considerably influenced by the point in the combustion chamber at which the mixture is ignited, and by the mixture ratio as well as the manner in which the mixture is fed into the combustion chamber.

Air-fuel mixture
The specific fuel consumption of a spark-ignition engine is for the most part dependent on the mixture ratio of the air-fuel mixture. Consumption is at its lowest with an air-fuel ratio of approx. 15 kg air to 1 kg fuel. Taking an example this means that approx. 11,500 l of air are necessary to burn 1 l of fuel. The exact (theoretical) value for complete combustion, also known as stoichiometric ratio, is 14.7 : 1.
Since motor-vehicle engines operate most of the time in the part-load range, they are designed for low fuel consumption in this range. For other ranges (idle, full load) a richer fuel mixture-composition is more favourable. The fuel induction system must be able to fulfill these varying requirements.

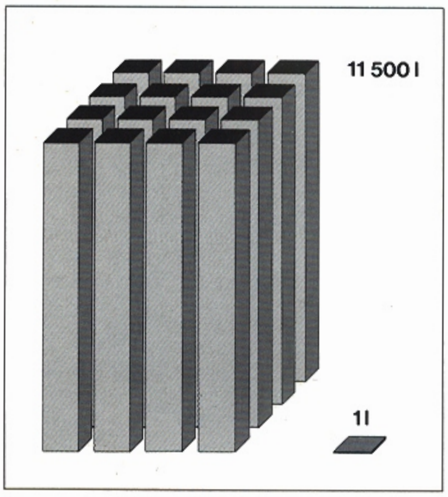


Fig. 2 ***Stoichiometric air-fuel ratio for ideal combustion with low pollution***

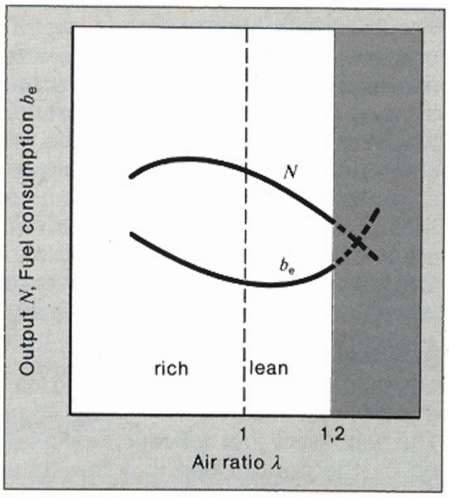


Fig. 3 ***Influence of air ratio on output N and consumption b_e in a spark-ignition engine***

The air ratio

To indicate how far the actual, available air-fuel mixture differs from the ideal, theoretical value necessary (14.7 : 1), the air ratio λ (lambda) has been chosen.

$$\lambda = \frac{\text{input air amount}}{\text{air amount required in theory}}$$

$\lambda = 1$
The input air amount corresponds to the amount necessary in theory.

$\lambda < 1$
Lack of air or rich mixture, increased power output.

$\lambda > 1$
Excess of air or lean mixture, reduced fuel consumption, reduced power output.

$\lambda > 1.2$
The mixture is so lean that combustion can no longer take place.

Fuel-induction systems

Fuel-induction systems, whether carburetor or fuel-injection systems, are intended to produce an optimum air-fuel mixture. Fuel induction for the spark-ignition engine is carried out by a carburetor or a fuel-injection system. The carburetor is still the most common form of fuel induction, but nowadays there is a marked tendency to use manifold injection for fuel induction.
This trend has arisen as a result of the advantages offered by fuel injection in connection with the demands for economy, efficiency and, last but not least, for low-pollution exhaust gas.
The reason for these advantages is that manifold injection permits extremely precise metering of the fuel as a factor of the operating and loading condition of the engine, whilst taking into account the environmental influences. The composition of the mixture is thereby maintained at such an exact level that the pollution content in the exhaust gas is relatively low. In addition, the arrangement of one injection valve per cylinder results in an improved distribution of the mixture.
Since the carburetor can be dispensed with, the induction paths can be constructed in the best possible way, thus permitting improved filling of the cylinders, which in turn leads to a more favourable torque.

Mechanical systems

Nowadays the K-Jetronic is the most widespread mechanical fuel-injection system; one that does not require any form of drive and which injects fuel continuously. This system is described in detail in the booklet "K-Jetronic" (VDT-U 3/1) in the Bosch Technical Instruction series.

Electronic systems

The L-Jetronic is an electronically-controlled fuel-injection system. It is a further development of the D-Jetronic. At regular intervals the fuel is injected electronically via injection valves into the intake manifolds. You will find a description of the system in this booklet.

Fuel injection in motor racing

TOP TUNING

with fuel-injection pumps

Fuel injection was first used in racing car engines at the beginning of the fifties. After 1951 experiments were made in the USA on Indianapolis racing cars. First of all it was direct injection that became generally accepted in motor racing. This type of injection, whereby gasoline is fed directly into the combustion chamber of the cylinder head, became popular with the post-war Silver Arrows of Daimler-Benz. Injection was carried out by in-line pumps, as is common with today's diesel engines.
1954 saw the appearance of the Mercedes-Benz W196 with fuel injection. Shortly after this the British racing-engine manufacturers BRM and Vanwall went over to fuel injection. Now there are no more engines in Formula 1 racing which are supplied with fuel by carburetors. The Ferrari, Matra, Alfa Romeo and BRM 12 cylinder engines all use fuel-injection pumps for their fuel supply, just like the Ford V8 Cosworth engine which is still used in racing and with which James Hunt became World Champion in 1976. These 31 engines turn out between 450 and 525 HP.
Fuel injection became predominant relatively quickly in Formula 1, the highest motor sport class, relatively quickly. One of the reasons was certainly the almost total lack of restrictions governing the fuel-induction system used. Nevertheless, the carburetor continued to dominate the touring-car class for a long time. The racing laws prescribed namely an approximation to a series, so that fuel induction had to be maintained as standard even with increased output.
When the restrictions on the type of fuel induction to be used were lifted for the higher racing classes 2 and 4, and the present group 5, there was no stopping the breakthrough of fuel injection on a broad basis. The result is a 10 per cent increase in output compared to the spark-ignition engines.

L-Jetronic

The L-Jetronic is an electronically controlled fuel-injection system which injects fuel intermittently into the intake manifold. It does not require any form of drive.

Task

The task of the gasoline injection is to supply to each cylinder just the correct amount of fuel as is necessary for the operation of the engine at that particular moment. A prerequisite for this, however, is the processing of as many influential factors as possible relevant to the supply of fuel. Since, however, the operating condition of the engine often changes quite rapidly, a speedy adaptation of the fuel delivery to the driving situation at any given moment is of prime importance. The electronically controlled gasoline injection is particularly suitable here. It enables a variety of operational data on any particular location on the vehicle to be processed and converted into electrical signals by sensors.

These signals are then passed on to the control unit in the fuel-injection system. The control unit processes the signals and calculates the exact amount of fuel to be injected.

Advantages

High output

The elimination of the carburetor enables the induction paths to be designed in the best possible way and a higher torque can be achieved with better filling of the cylinders. The fuel is injected directly in front of the inlet valves. Only air is fed to the engine through the intake manifolds. To achieve an optimal distribution of air and filling of the cylinder they can be designed to make the maximum use of air-input flow.

In this way a higher specific output and a torque curve appropriate to practice can be achieved.

Less fuel

With the help of the L-Jetronic the engine only receives the amount of fuel that it actually needs. Each cylinder receives the same amount of fuel in all operating conditions. In the case of carburetor fuel induction systems, unequal air-fuel mixtures occur for the individual cylinders of the engine as a result of segregation processes in the intake manifolds. Optimum fuel distribution cannot be achieved if a mixture is created which is suitable for supplying sufficient fuel even to the worst-fed cylinder. This results in high fuel consumption and unequal stressing of the cylinders. In a Jetronic system each cylinder has its own injection valve. The injection valves are controlled centrally; this ensures that each cylinder receives precisely the same amount of fuel, the optimum amount, at any particular moment and under any particular load. Only the correct amount of fuel is injected, never more than is necessary.

In a flash

The L-Jetronic adapts to changing load conditions almost without hesitation. The necessary fuel delivery is calculated by the control unit in a few thousandths of a second and is injected through the injection valves directly in front of the intake valves of the engine.

Exhaust gas with low pollution

The concentration of pollutants in the exhaust gas is directly related to the air-fuel ratio. If you wish to operate the engine with the least pollutant emissions, then a fuel induction is necessary which is capable of maintaining a certain air-fuel ratio.

The L-Jetronic works so precisely that the exactness of the mixture formation necessary for observing the present-day exhaust regulations, can be maintained.

Fig. 4 ***Output and torque curve***
a = with Jetronic, b = with carburetor

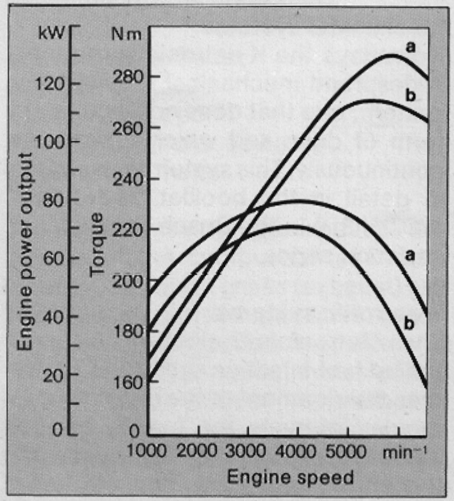
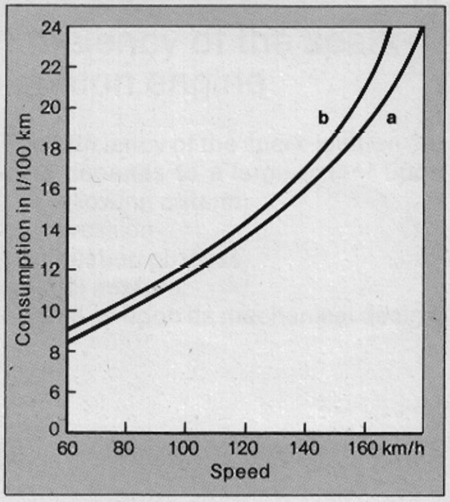


Fig. 5 ***Fuel consumption***
a = with Jetronic, b = with carburetor



Our fuel injection systems save fuel by the barrel!

An "E" or an "I" on the rear of the car denotes "Gasoline fuel-injection". It can save up to 16% fuel according to the manner of driving and the traffic situation. With a middle-class fuel-injection car, it is possible to save an average of 200 liters on a yearly mileage of 20,000 km.

The relevant measurements were carried out at the Technical University in Vienna: A car with a standard carburetor engine underwent a cleverly thought out test program. The same vehicle was then converted to Bosch gasoline fuel-injection and the test program was repeated. Technical difference: Bosch gasoline fuel-injection.

The journey covered hundreds of kilometers, through heavy city traffic, along country roads and expressways. The result was quite clear: in practical driving situations in cities and on country roads a vehicle with gasoline fuel-injection saves up to 11% of fuel compared to the same model with carburetor. With overrun-cutoff (switching off the fuel supply during overrun) up to 16% can be saved.

A result confirmed by tests which we have been making since 1951, the year we started making fuel-injection systems.

What is the secret?

The Bosch gasoline fuel-injection system measures out the fuel so that just enough as is necessary for the particular driving condition is supplied. This applies whether it is warm or cold, whether the engine is lightly or heavily loaded. In our "Technical Center for Gasoline Fuel-Injection" K- and L-Jetronic are adapted to the engines in close cooperation with all the well-known motor-vehicle manufacturers.

In order to guarantee the optimum fuel utilization we use climatic and cold test stands to simulate the most varied environmental conditions as are found, for example, in the Sahara or in the Arctic.

Over 100 models with Bosch gasoline fuel-injection

The first series production of Bosch gasoline fuel-injection systems started in 1951. Since then they have proved their worth nearly 7 million times over. Due to the many advantages, such as fuel economy, higher output, reduction of pollutants in the exhaust gas and improved starting and warm-up behaviour, cars of nearly all classes are now being fitted with Bosch gasoline fuel-injection.

Principle

A pump supplies fuel to the engine and creates the pressure necessary for injection.
Injection valves inject the fuel into the individual intake tubes. An electronic control unit controls the injection valves.
The L-Jetronic consists principally of the following function blocks:

Induction system

The induction system supplies the engine with the necessary amount of fuel. It consists of air filter, manifold, throttle valve and the individual intake tubes.

Sensors

The sensors (probes) register the variable quantities which characterize the operating condition of the engine. The most important variable is the amount of air drawn in by the engine and registered by the air-flow sensor. Other sensors register the position of the throttle valve, the engine speed, the air and the engine temperature.

Control unit

The signals delivered by the sensors are evaluated in the electronic control unit and from these signals are generated the appropriate control impulses for the injection valves.

Fuel system

The fuel system supplies fuel from the tank to the injection valves, creates the pressure necessary for injection and maintains it at a constant level. The fuel system also includes: supply pump, fuel filter, distributor pipe pressure regulator, injection and cold-start valves.

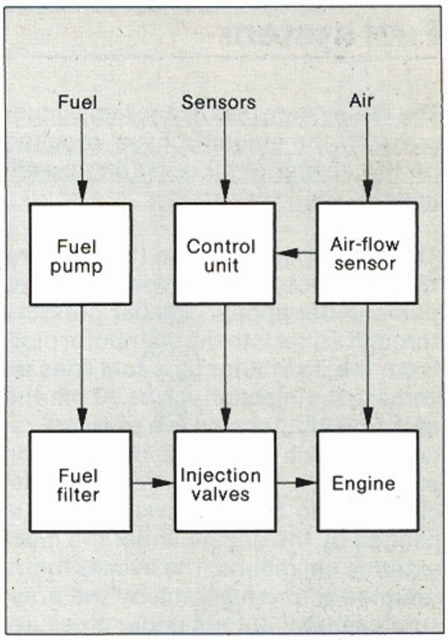


Fig. 6 ***Principle of the L-Jetronic (simplified)***

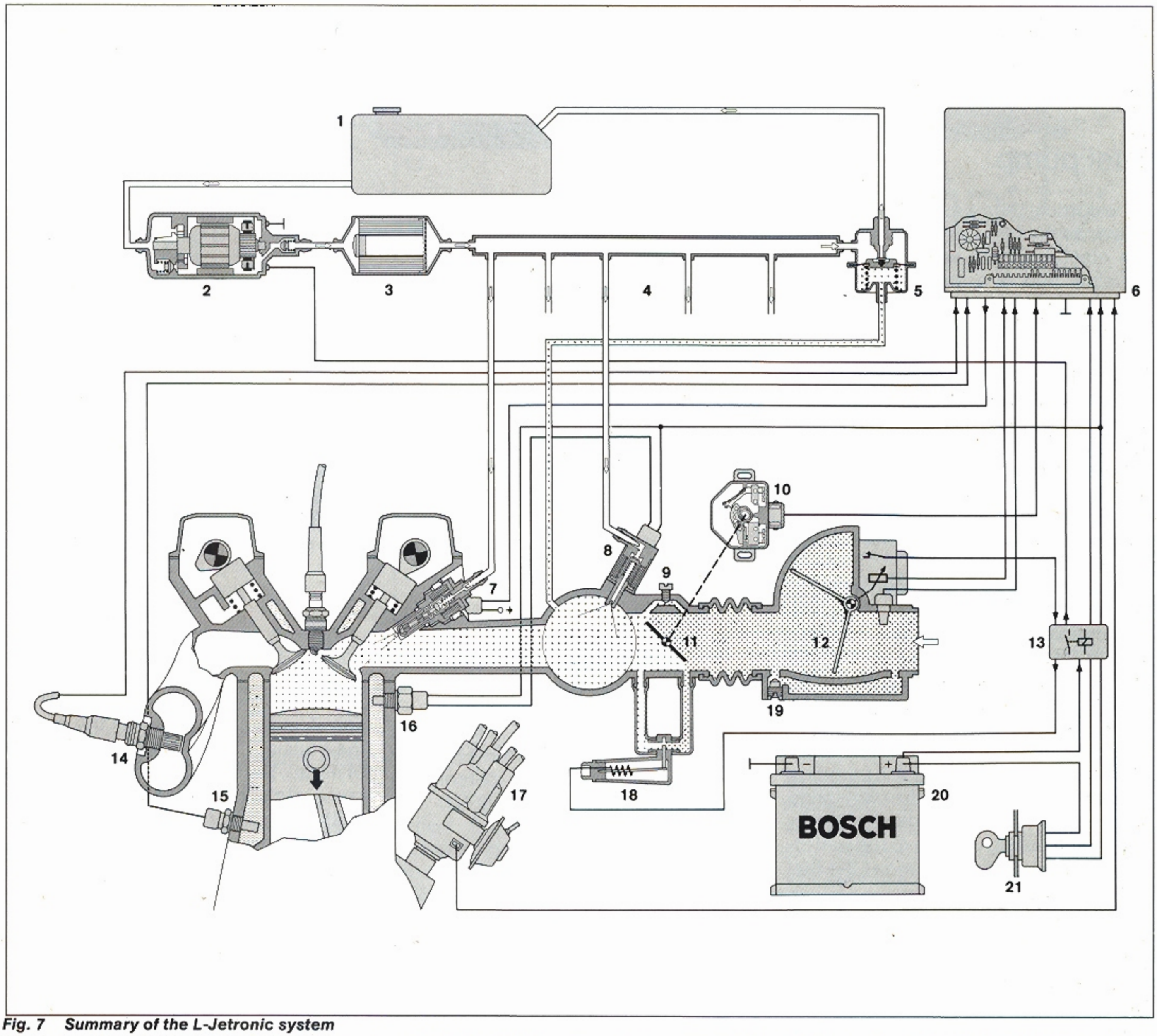


Fig. 7 Summary of the L-Jetronic system
1 Fuel tank, 2 Electric fuel pump, 3 Fuel filter, 4 Distributor pipe, 5 Pressure regulator, 6 Control unit, 7 Injection valve, 8 Start valve, 9 Idle-speed adjusting screw, 10 Throttle-valve switch, 11 Throttle valve, 12 Air-flow sensor, 13 Relay combination, 14 Lambda sensor (only for certain countries), 15 Engine temperature sensor, 16 Thermo-time switch, 17 Ignition distributor, 18 Auxiliary-air device, 19 Idle-mixture adjusting screw, 20 Battery, 21 Ignition-starter switch

Fuel system

The fuel system makes available under pressure the amount of fuel required by the engine in all operating conditions.

The fuel is pumped from the fuel tank by an electrically driven roller-cell pump under approx. 2.5 bar pressure through a filter into the distributor pipe. From the distributor pipe fuel lines diverge to the injection valves. At the end of the distributor pipe is a pressure regulator which maintains the injection pressure at a constant level. More fuel circulates in the fuel system than is needed by the engine under the most extreme conditions. The excess fuel is returned to the fuel tank by the pressure regulator but not under pressure. The constant flushing through of the fuel system enables it to be continually supplied with cool fuel. This helps to avoid the formation of fuel vapor bubbles and guarantees good hot-starting characteristics.

Fuel pump

An electrically driven roller-cell pump serves as the fuel pump. The pump and the electric motor are in a common housing and are permanently surrounded by fuel. Faulty seals and lubricating problems are thereby avoided. At the same time the electric motor is well cooled. There is no danger of explosion because there is never an ignitable mixture in the common housing for pump and motor. The pump supplies more fuel than the internal-combustion engine needs at maximum, in order to maintain the pressure in the fuel system under all possible operating conditions.
The roller-cell pump itself consists of a cylindrical hollow chamber in which an eccentrically fitted rotor disc rotates. This is fitted with metal rollers which are held in pocket-shaped recesses around the circumference. When the rotor disc rotates the rollers are pressed outwards by centrifugal force and act as a circulating seal. A pumping operation is effected by the circulating roller seals which periodically generate an increasing volume at the fuel inlet and a decreasing volume at the fuel outlet.
When starting, the pump runs for as long as the starting switch is operated. Once the engine has started the pump remains switched on. A safety circuit prevents fuel from being delivered when the ignition is switched on, but when the engine is stationary (e.g. after an accident).

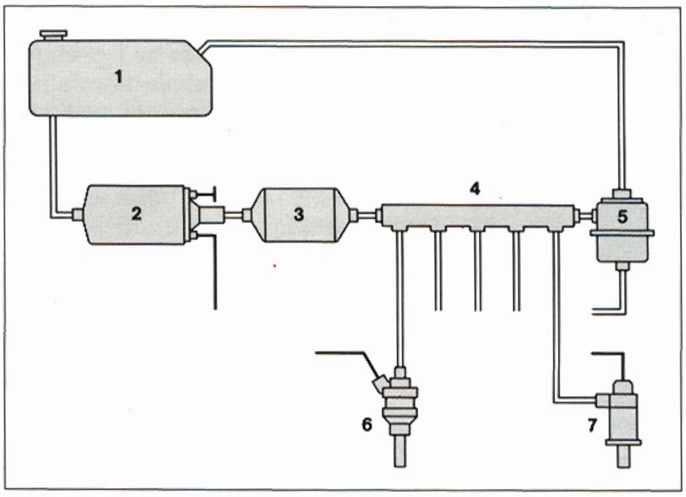


Fig. 8
Block diagram of fuel system
1 Fuel tank
2 Fuel pump
3 Fuel filter
4 Distributor pipe
5 Pressure regulator
6 Fuel-injection valve
7 Start valve

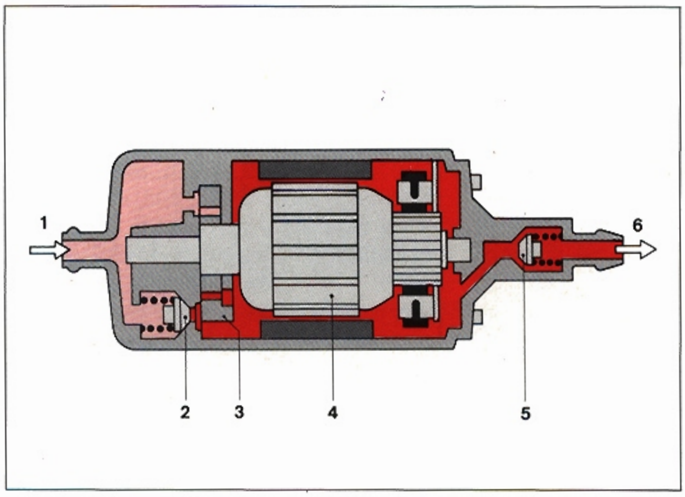


Fig. 9
Electric fuel-pump
1 Intake (suction) side
2 Pressure limiter
3 Roller-cell pump
4 Motor armature
5 Non-return valve
6 Pressure side

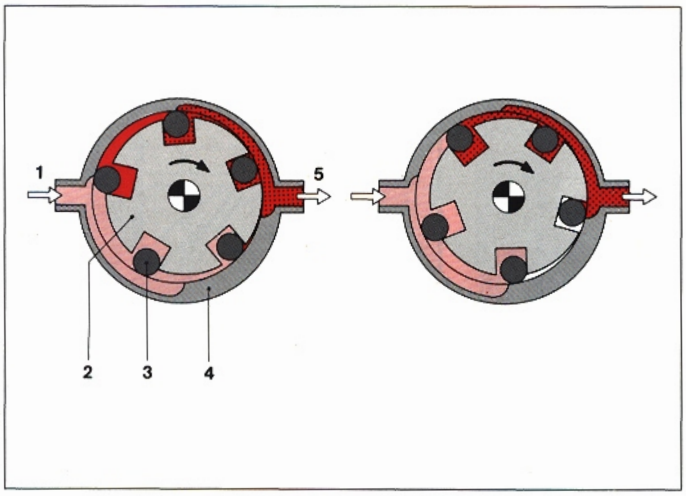


Fig. 10
Pumping procedure Roller-cell pump
1 Intake (suction)
2 Rotor disc
3 Roller
4 Pump housing
5 Pressure side

□ *Fuel not under pressure*
■ *Fuel supply*
▩ *Fuel under pressure*

The fuel pump does not require any maintenance and is fitted in close proximity to the fuel tank.

Fuel filter

The fuel filter prevents impurities in the fuel from getting any further.

A filter is fitted into the fuel circuit after the fuel pump. The filter contains a paper insert with a medium pore size of 10 μm, backed up by a strainer which retains any loose paper particles. The direction of flow indicated on the filter must be strictly adhered to for this reason. A support plate holds the filter in the housing. The filter housing is made of metal. The filter is to be replaced as a complete unit; its service life depends on the amount of dirt in the fuel and, depending upon the volume of the individual filter, amounts to 30,000–80,000 km.

Pressure regulator

The pressure regulator controls the pressure in the fuel system.

The pressure regulator is fitted at the end of the distributor pipe. The pressure regulator is a diaphragm-controlled overflow type which maintains the fuel pressure at 2.5 or 3 bar according to the individual system. It consists of a metal housing divided into two chambers by a beaded diaphragm: a spring chamber for the pre-stressed helical spring which rests on the diaphragm and a chamber for the fuel.
When the set pressure is exceeded, a valve controlled by the diaphragm opens the inlet to an overflow channel through which the excess fuel can flow back to the fuel tank without pressure. The spring chamber of the pressure regulator is connected by a fuel line to the intake manifold of the engine behind the throttle valve. This results in the fuel-system pressure being dependent on the absolute pressure in the manifold and the pressure drop across the injection valves therefore being identical for every throttle-valve position.

Distributor pipe

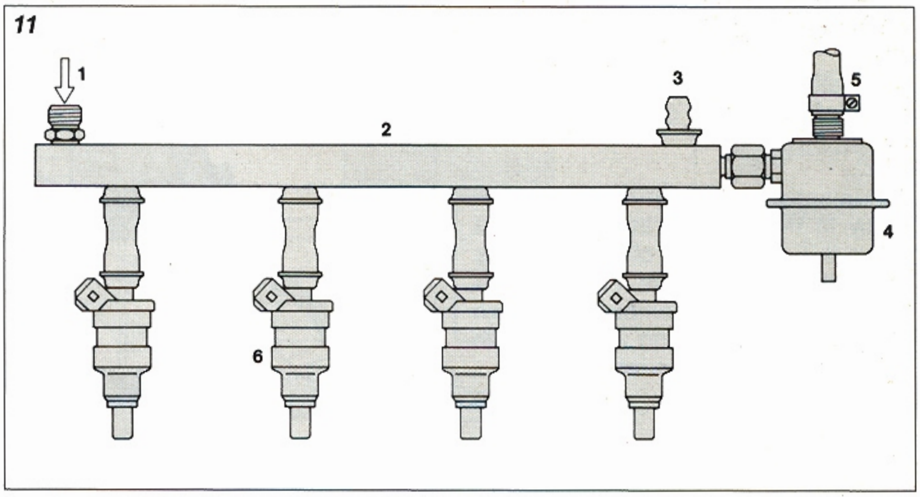
The distributor pipe guarantees the same fuel pressure at each injection valve.

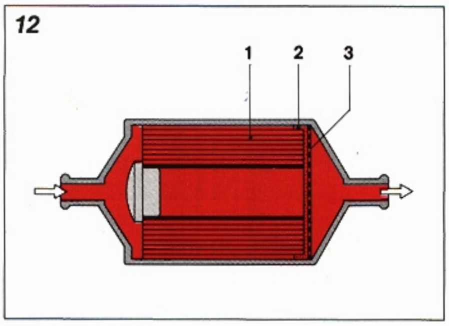
The distributor pipe has a storage function. Its volume compared with the amount of fuel injected during each working cycle of the engine is large enough to prevent variations in pressure. The injection valves connected to the distributor pipe are therefore subjected to the same fuel pressure. The distributor pipe also facilitates easy fitting of the injection valves.

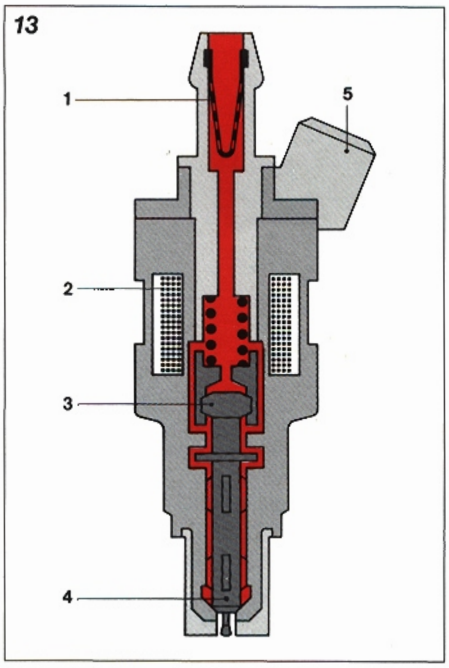
Fuel-injection valve

The injection valves inject the fuel into the individual intake manifolds of the cylinders in front of the engine inlet valves.

Each engine cylinder has its own injection valve. The valves are solenoid-operated and are opened and closed by means of electric impulses from the control unit. The injection valve consists of a valve body and the needle valve with fitted solenoid armature. The valve body contains the solenoid winding and the guide for the needle valve. When there is no current in the solenoid winding the needle valve is pressed against its seat on the valve outlet by a helical spring. When a magnetic field is generated in the solenoid winding the needle valve is lifted by approximately 0.1 mm and the fuel can flow out through a calibrated annular orifice. The front end of the needle valve is provided with a specially ground pintle for atomizing the fuel. The pull-in and release times of the valve lie in the range of 1 to 1.5 ms. To achieve good fuel distribution with low condensation loss, wetting of the intake manifold walls must be avoided. A particular spray angle in connection with a particular distance of the injection valve from the inlet valve must therefore be maintained specific to the engine concerned. The injection valves are fitted with the help of special holders and are mounted in rubber mouldings in these holders. The heat insulation thereby achieved prevents the formation of fuel-vapor bubbles and guarantees good hot-starting characteristics. The rubber mouldings also ensure that the injection valve is not subjected to excessive vibration.







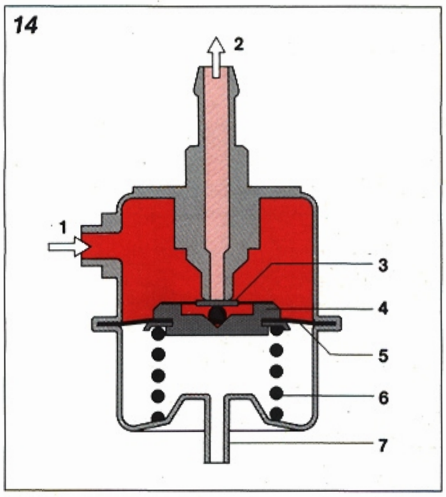


Fig. 11 Distributor pipe
1 Fuel inlet, 2 Distributor pipe, 3 Connection for start valve, 4 Pressure regulator, 5 Return line, 6 Injection valves

Fig. 12 Fuel filter
1 Paper filter, 2 Strainer, 3 Support plate

Fig. 13 Injection valve
1 Filter, 2 Solenoid winding, 3 Solenoid armature, 4 Needle valve, 5 Electrical connection

Fig. 14 Pressure regulator
1 Fuel connection, 2 Fuel-return connection, 3 Valve plate, 4 Valve holder, 5 Diaphragm, 6 Compression spring, 7 Vacuum connection

Mixture formation

The mixture formation is carried out in the intake manifold and in the engine cylinder.

The injection valve injects its fuel directly in front of the inlet valve and when this opens, the cloud of fuel is drawn along with the air which is sucked in and an ignitible mixture is formed by the swirling action which takes place during the intake cycle.

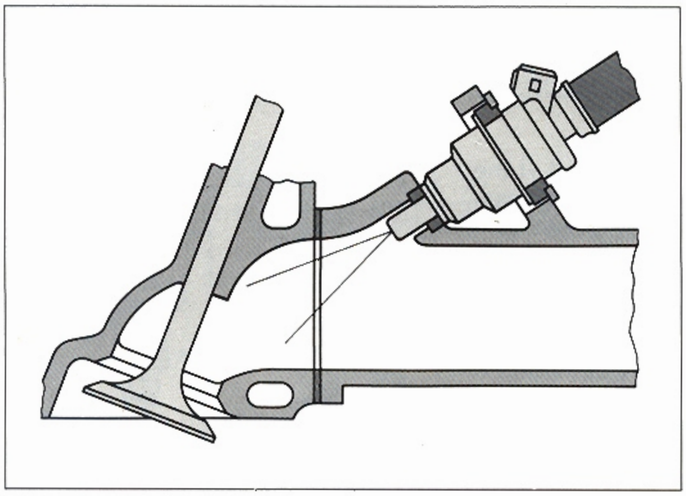
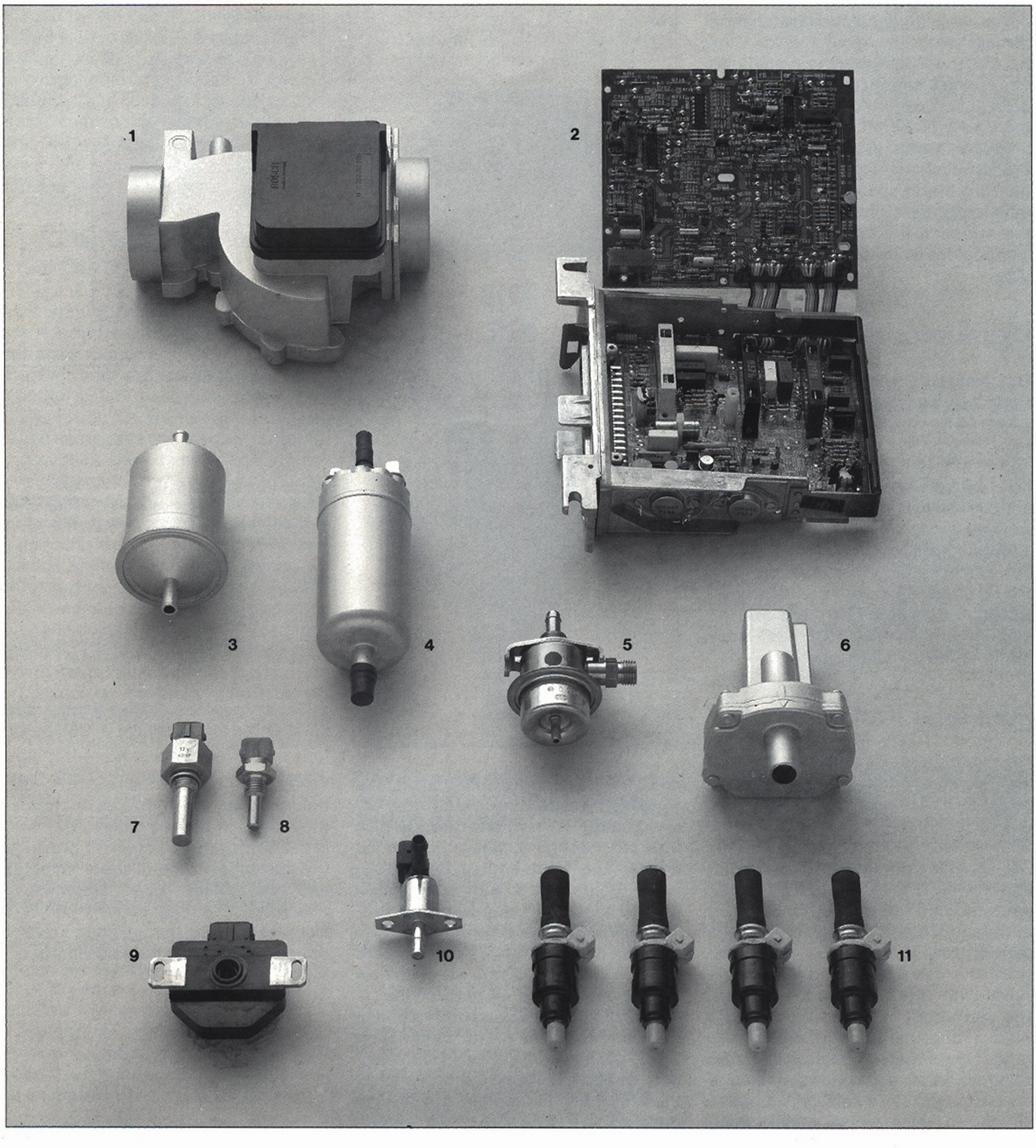


Fig. 15
Injection-valve mounting

Fig. 16
Components of the L-Jetronic
1 Air-flow sensor
2 Control unit
3 Fuel filter
4 Fuel pump
5 Fuel pressure regulator
6 Auxiliary-air device
7 Thermo-time switch
8 Temperature sensor
9 Throttle-valve switch
10 Start valve
11 Injection valves



Control system

The operating temperature of the engine is calculated by means of sensors and fed into the control unit in the form of electric signals. The sensors and the control unit form the control system.

Variable quantities and operating condition

The variable quantities characterizing the operating condition of the engine can be distinguished according to the following system:

- Main variable quantities
- Variable quantities for compensation
- Variable quantities for precision compensation

Main variable quantities

The main variable quantities are the engine speed and the amount of air drawn in by the engine. These determine the amount of air per stroke which then serves as a direct measure for the loading condition of the engine.

Variable quantities for compensation

For operating conditions which deviate from normal operation the mixture must be adapted to the modified conditions. We are concerned in this connection with the following operating conditions: starting, warm-up, load adaptation. The calculation of starting and warm-up conditions is carried out by sensors which transmit the engine temperature to the control unit. For compensating various loading conditions, the load range (idle, part-load, full-load) is transmitted to the control unit via the throttle-valve switch.

Variable quantities for precision compensation

In order to achieve optimum driving behaviour, further operating ranges and influences can be considered: transitional behaviour when accelerating, maximum engine-speed limitation and overrun can all be calculated by the sensor as mentioned above. The signals from this sensor have a particular relationship to each other in these operating ranges. These relationships are recognized by the control unit and influence the control signals of the injection valves accordingly.

Combined effect of variable quantities

All the variable quantities together are evaluated by the control unit in such a manner that the engine is always supplied with the amount of fuel necessary for its operation at that particular moment. In this way optimum driveability is achieved.

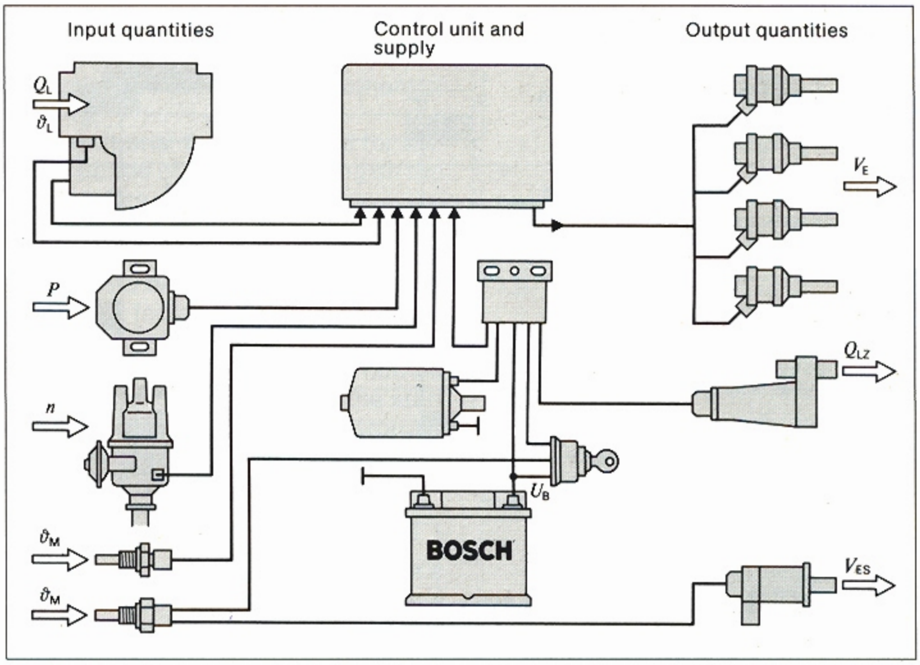


Fig. 17 Signals and control quantities fed into the control unit
Q_L air drawn in, ϑ_L air temperature, n engine speed, P engine load-range, ϑ_M engine temperature, V_E fuel quantity injected, Q_{LZ} auxiliary air, V_{ES} excess fuel for starting, U_B vehicle-system voltage

Calculating engine speed

Information on engine speed and the start of injection is passed on to the L-Jetronic control unit in breaker-triggered ignition systems by the contact-breaker points in the ignition distributor, and in breakerless ignition systems by terminal 1 of the ignition coil.

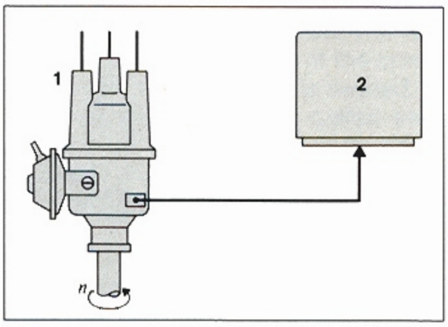


Fig. 18 Calculating engine speed with a breaker-triggered ignition system
n engine speed, 1 ignition distributor, 2 control unit

Processing of impulses

The impulses delivered by the ignition system are processed in the control unit. First of all they pass through a pulse-shaping circuit which forms rectangular pulses from the signal "delivered" in the form of damped oscillations. These rectangular pulses are fed into a frequency divider.

The frequency divider divides the pulse frequency given by the ignition sequence in such a manner that two pulses occur for each working cycle regardless of the number of cylinders. The start of the pulse is at the same time the start of injection for the injection valves. For each turn of the crankshaft each injection valve injects once, regardless of the position of the inlet valve. When the inlet valve is closed, the fuel is stored and the next time the inlet valve opens it is drawn into the combustion chamber together with the air. The duration of injection depends on the amount of air and the engine speed.

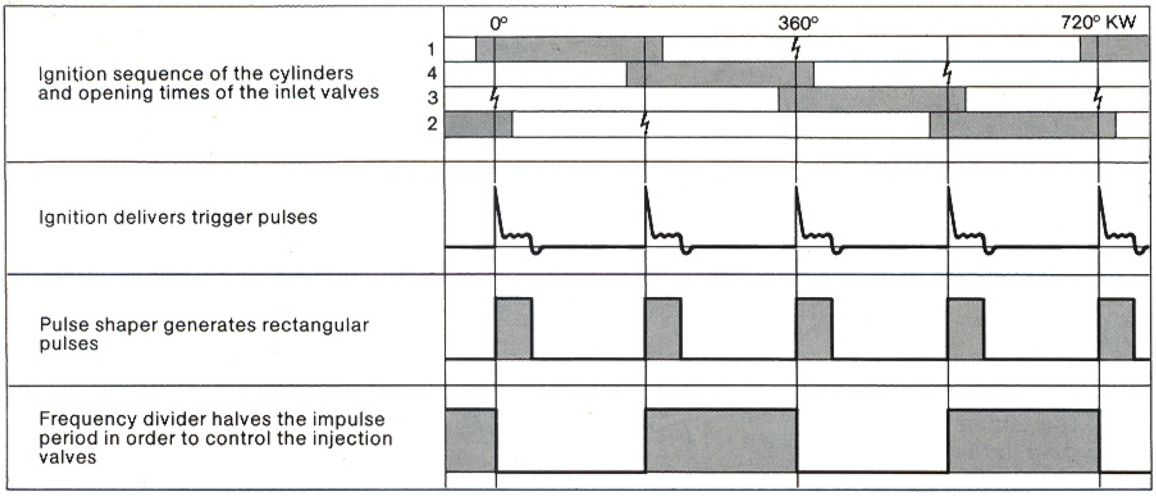


Fig. 19
Processing the ignition pulses in the control unit
in a 4-cylinder engine
°KW = °crankshaft

Measuring the air flow

The amount of air drawn in by the engine is a measure of its loading condition.

All the air drawn in by the engine is measured and serves as a main variable quantity for the fuel distribution. The amount of fuel determined from the air-flow sensor output and the engine speed is referred to as the basic fuel quantity.
The air-flow measurement registers all changes which can take place in the engine during the service life of the vehicle, e. g. wear, combustion-chamber deposits, changes to the valve setting. Since the quantity of air drawn in must first pass through the air-flow sensor before entering the engine, this means that during acceleration the signal leaves the sensor before the air is actually drawn into the cylinder. In this way, namely by supplying more fuel in advance, fuel enrichment for acceleration is achieved.

Air-flow sensor
The principle is based on the measurement of the force emanating from the stream of air drawn in by the engine. This force has to counteract the opposing force of a return spring acting upon the air-flow sensor flap. The flap is deflected in such a manner that, together with the profile of the measurement duct, the free cross-section increases along with the rise in the quantity of air passing through it.
The change in the free air-flow sensor cross-section depending on the position of the sensor flap, was selected so that a logarithmic relationship results between flap angle and air throughput. The result is that at low air throughput, where measurement precision must be particularly high, the sensitivity of the air-flow sensor is also high. In order to prevent the oscillations caused by the engine suction strokes from having more than a minimum effect upon the sensor-flap position, a compensation

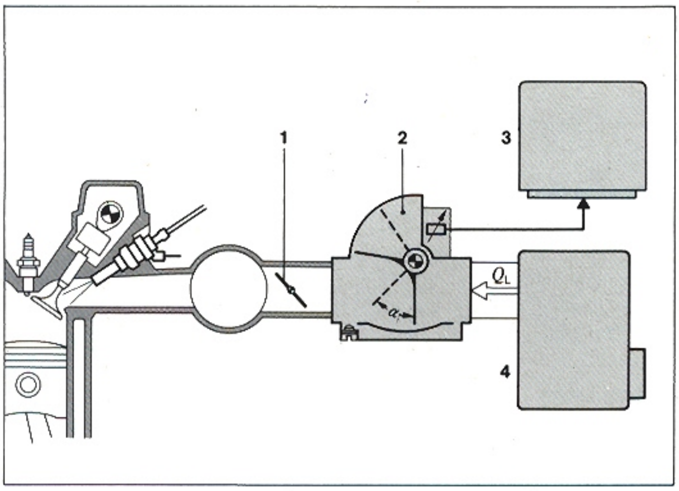


Fig. 20
Air-flow sensor in the intake system
1 Throttle valve
2 Air-flow sensor
3 Control unit
4 Air filter
Q_L Amount of air drawn in

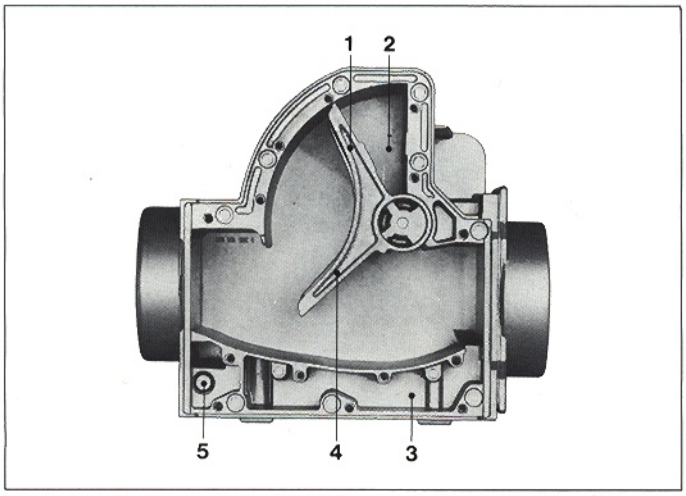


Fig. 21
Air-flow sensor (air side)
1 Compensation valve
2 Damping chamber
3 Bypass
4 Sensor flap
5 Idle-mixture adjusting screw (Bypass)

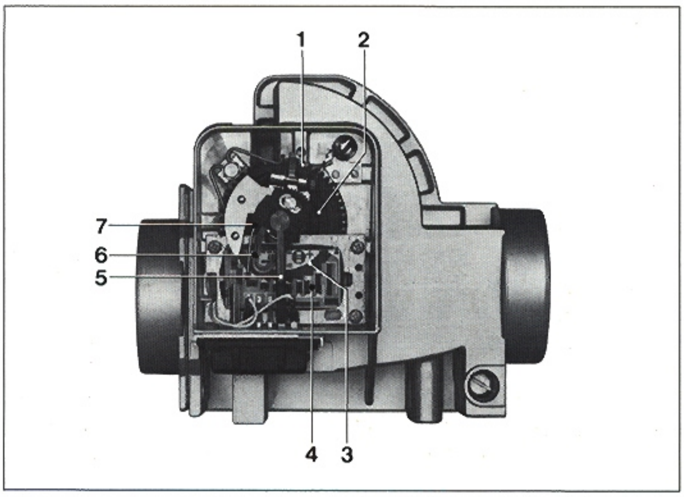


Fig. 22
Air-flow sensor (connection side)
1 Ring gear for spring preloading
2 Return spring
3 Wiper track
4 Ceramic substrate with resistors and conductor straps
5 Wiper tap
6 Wiper
7 Pump contact

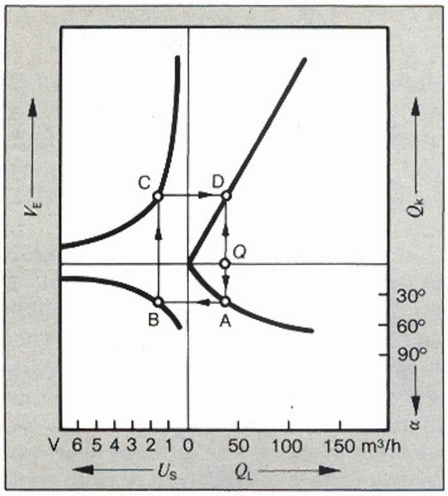


Fig. 23 The relationships between air quantity, sensor-flap angle, voltage at the potentiometer and fuel quantity injected
Starting with a certain volume of air Q_L flowing through the air-flow sensor (point Q), we can derive the theoretically required amount of fuel Q_K (point D). In addition, the sensor flap is deflected to a certain flap angle α (point A) depending on the amount of air. The potentiometer activated by the air-flow sensor flap sends a voltage signal U_S to the control unit (point B). The control unit controls the injection valves, whereby point C represents the amount of fuel injected V_E. It can be seen that the amount of fuel theoretically required and the amount of fuel injected are the same (line C–D).

flap is incorporated as an integral part of the sensor flap. The pressure oscillations have the same effects upon both flaps. The moments of force cancel each other out so that the measurement is not affected. The angular position of the sensor flap is transformed by a potentiometer into a voltage. The potentiometer is calibrated such that the relationship between air throughput and voltage output is inversely proportional. In order that ageing and the temperature characteristic of the potentiometer have no effect upon the accuracy, only resistance values are evaluated in the control unit. In order to set the air-fuel ratio at idle, an adjustable bypass duct is provided through which a small amount of air can bypass the sensor flap.

The diagram shows the relationships between the air quantity, the angle of the sensor flap, the potentiometer voltage and the fuel injected.

Cold starting

When the engine is started additional fuel is injected for a limited period depending on the temperature of the engine.

When a cold engine is started fuel in the air-fuel mixture condenses and is thereby lost. To compensate for this and to facilitate the starting of the cold engine, extra fuel must be injected at the moment of starting.

This additional fuel is injected for a limited period of time depending on the temperature of the engine.

This procedure is known as "cold-start enrichment". During this procedure the mixture becomes "richer", i. e. the excess-air factor is temporarily lower than 1.

Cold-start enrichment can be carried out in two different ways: by the start control with the help of the control unit and injection valves or by means of a thermo-time switch and a start valve.

Start control

By extending the period during which the injection valves inject, more fuel can be supplied during the starting phase. The control unit controls the start procedure by processing the signals from the starting switch and from the engine temperature.

The construction and method of operation of the temperature sensor are described in the chapter "Warm-up".

Start valve

The start valve is ooerated by a solenoid, the winding of which is situated in the valve. In the neutral position a helical spring presses the movable armature of the solenoid against a seal, thereby shutting off the valve. When a current is passed through the solenoid the armature, which now rises from the valve seat, allows fuel to flow. The fuel then flows along the sides of the armature to a nozzle where it is swirled. In this form of nozzle, a so-called swirl nozzle, the fuel is particularly finely atomized and enriches the air in the intake manifold behind the throttle valve with fuel.

Thermo-time switch

The thermo-time switch limits the duration of injection of the start valve depending on the temperature of the engine.

The thermo-time switch is an electrically heated bimetal switch which opens or closes a contact depending on its temperature. It is housed in a hollow threaded pin which is located in a position where typical engine temperature prevails. The thermo-time switch determines the length of time the start valve is to be switched on. The time during which the start valve is switched on depends on the heating of the thermo-time switch by the warmth from the engine, the ambient temperature and by the electrical heating in the switch itself. This self-heating is necessary in order to limit the maximum time that the start valve is switched on and to prevent the engine from being over-enriched and "drowned". The electrical heating is the main factor governing the measurement of the time during which the valve is switched on when starting, (e. g. at −20° C it switches off after approx. 8 seconds). When the engine is warm, the thermo-time switch is heated so much by the heat from the engine that it is constantly open. When starting with a warm engine, therefore, no extra fuel for starting is injected by the start valve.

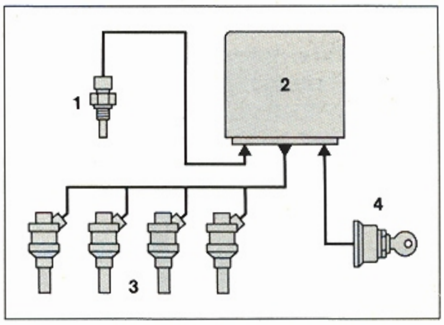
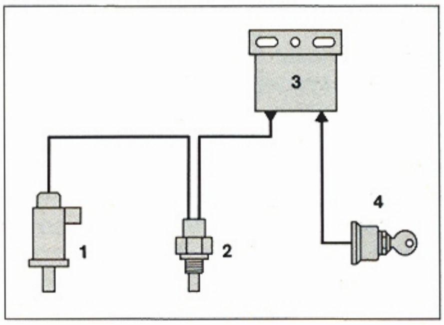


Fig. 24 Cold-start enrichment by start control
1 Engine-temperature sensor, 2 Control unit, 3 Injection valves, 4 Ignition-starter switch

Fig. 25 Cold-start enrichment by start valve
1 Start valve, 2 Thermo-time switch, 3 Relay combination, 4 Ignition-starter switch



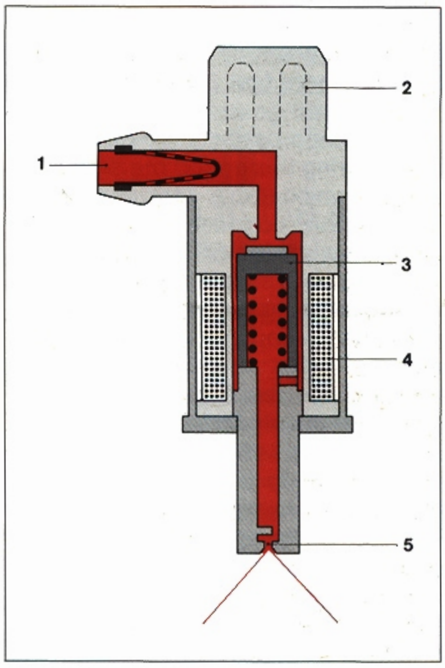


Fig. 26 Start valve
1 Fuel inlet, 2 Electrical connection, 3 Solenoid armature, 4 Solenoid winding, 5 Swirl nozzle

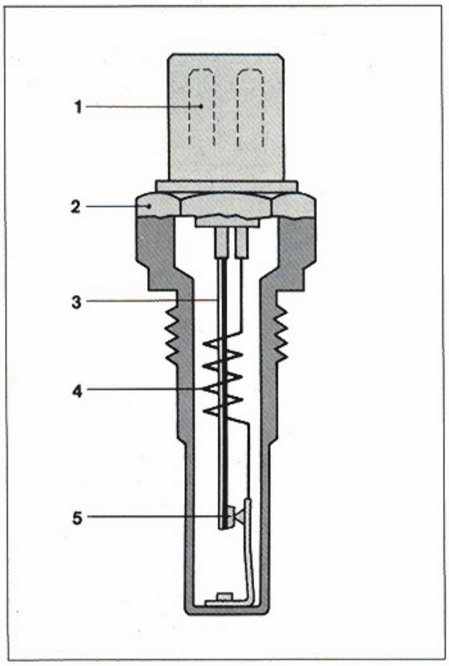


Fig. 27 Thermo-time switch
1 Electrical connection, 2 Housing, 3 Bimetal, 4 Heating winding, 5 Switch contact

Warm-up

During the warm-up period the engine receives more fuel.

The warm-up period follows the cold start. During this period the engine requires considerable fuel enrichment because fuel condenses on the cylinder walls when they are still cold. In addition, without supplementary fuel enrichment during the warm-up period a major drop in engine speed would be noticed after the additional fuel sprayed into the engine by the start valve had been cut off.

For example, at a temperature of −20°C, two to three times as much fuel must be injected immediately before starting than when the engine is at normal operating temperature, depending on the type of engine.

In this first part of the warm-up phase there must be an enrichment dependent on time, the so-called after-start enrichment. This enrichment has to last about 30 s and, according to temperature, gives in the order of between 30% and 60% more fuel.

When the after-start enrichment has finished the engine only needs a slight enrichment of the mixture; this being controlled by the engine temperature. The diagram shows a typical enrichment curve with reference to time with a starting temperature of 20° C.

In order to trigger off this control procedure, the control unit must receive information on the engine temperature. This task is performed by the temperature sensor.

Temperature sensor

The temperature sensor consists of a hollow threaded pin in which an NTC resistor is embedded. NTC stands for “negative temperature coefficient” and means that the electrical resistance of this resistor, which is made of a semi-conductor material, decreases as the temperature increases. This change is used for measurement purposes.

In water-cooled engines the temperature sensor is installed in the engine block where it is immersed in the coolant. Here, it gradually assumes the temperature of the coolant. In air-cooled engines the temperature sensor is installed in the cylinder head of the engine.

Idle-speed control

During the warm-up phase the engine receives more fuel due to the influence of an auxiliary-air device. This is to overcome the frictional resistance in the cold engine and to guarantee a stable idling speed.

There are increased frictional resistances present in a cold engine which must be overcome at idling speed. The engine is therefore allowed to take in more air through the auxiliary-air device by bypassing the throttle valve. Since this additional air is measured by the air-flow sensor and is taken into account when the fuel is metered, the engine receives more air-fuel mixture. With a cold engine a stable idling speed can therefore be achieved.

Auxiliary-air device

In the auxiliary-air device a bimetallic strip operates a blocking plate which controls the cross-section of the bypass channel. The cross-section opening of this blocking plate is adjusted depending on the temperature, so that the opening is large enough for cold-starting but becomes smaller as the engine temperature increases until it eventually closes. The bimetallic strip is heated electrically. In this way a limited opening time can be achieved, according to the individual type of engine.

The auxiliary-air device is fitted in a position where it can sense the temperature of the engine. This prevents the auxiliary-air device from coming into operation when the engine is warm.

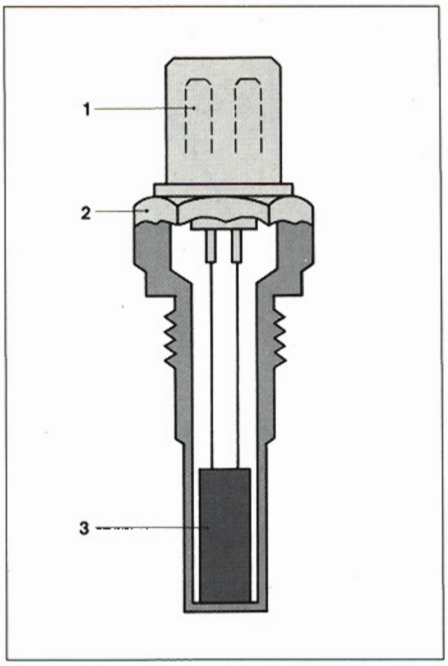


Fig. 28 Temperature sensor
1 Electrical connection, 2 Housing, 3 NTC resistor

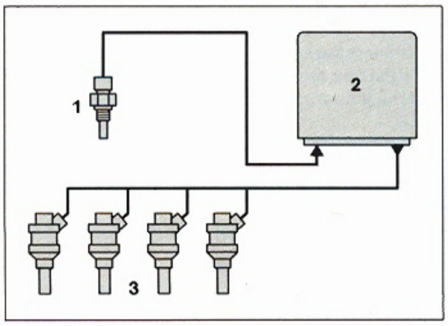


Fig. 29 Warm-up enrichment
1 Engine temperature sensor, 2 Control unit, 3 Injection valves

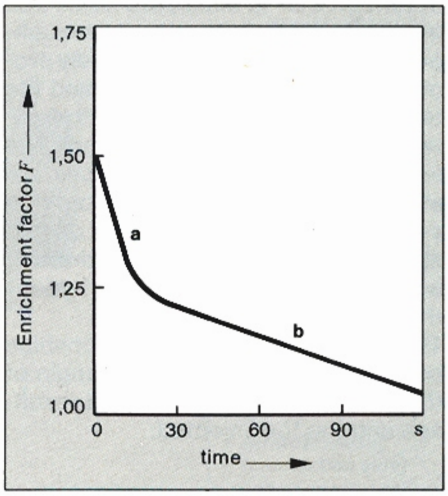


Fig. 30 Warm-up enrichment curve
Enrichment factor as a function of time, a proportion mainly dependent on time, b proportion mainly dependent on engine temperature

Adaptation to load

Different loading ranges necessitate different mixture compositions. The fuel-requirement curve is determined for all operating ranges by the air-flow sensor curve for the specific engine.

Idle

If the air-fuel mixture is too lean when idling, this can result in misfiring and uneven running of the engine. If necessary, the mixture should, therefore, be enriched for this operating condition. An adjustable bypass is provided in the air-flow sensor for adjusting the mixture ratio. A small amount of air passes through this bypass, thereby avoiding the sensor flap.

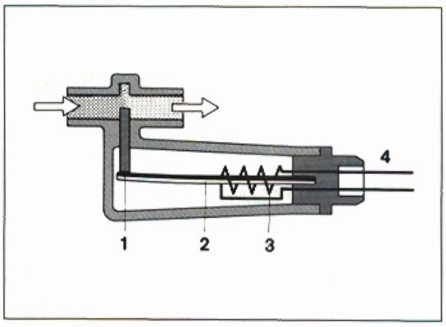


Fig. 31** **Auxiliary-air device
1 Blocking plate, 2 Bimetallic strip, 3 Electric heating element, 4 Electrical connection

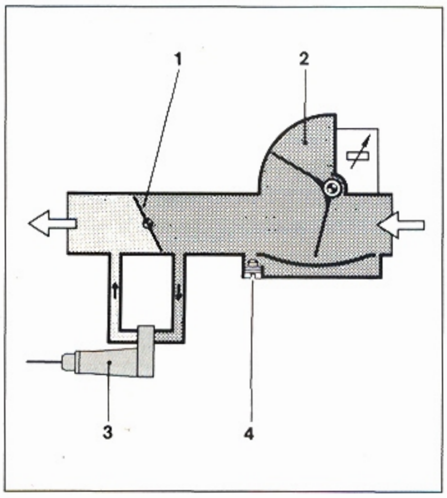


Fig. 32** **Idle-speed control
1 Throttle valve, 2 Air-flow sensor, 3 Auxiliary-air device, 4 Idle-mixture adjusting screw

Part load

By far the greater part of the time the engine will be operating in the part-load range. The fuel requirement curve for this range is programmed in the control unit and determines the amount of fuel supplied. The curve is plotted so that the fuel consumption of the engine is low in the part-load range.

Full-load

In the full-load range the engine must give its greatest output. This is achieved by enriching the mixture compared with its composition in the part-load range. The extent of the enrichment is programmed in the control unit for the specific engine. Information on operation in the full-load range is passed from the throttle-valve switch to the control unit.

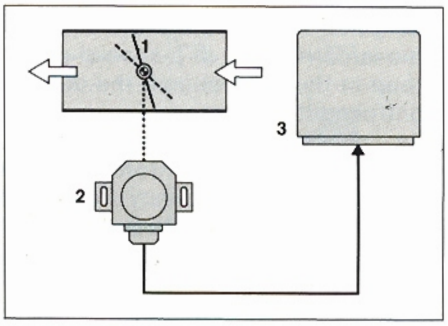


Fig. 33** **Idle/full-load correction
1 Throttle valve, 2 Throttle-valve switch, 3 Control unit

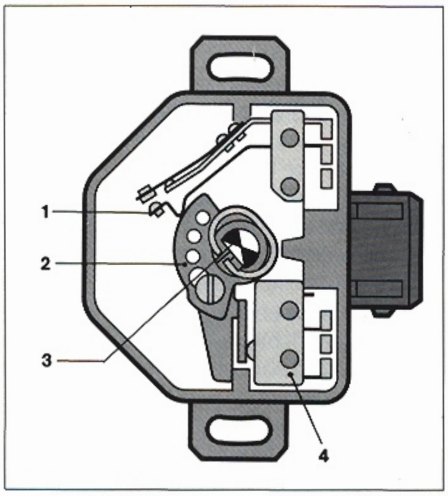


Fig. 34** **Throttle-valve switch
1 Full-load contact, 2 Contact path, 3 Throttle-valve shaft, 4 Idle contact

Throttle-valve switch

The throttle-valve switch is fitted to the intake manifold and is operated by the throttle-valve shaft. In each of the end positions “full-load” and “idle” a contact is closed.

Acceleration

During acceleration additional fuel is injected.

When changing from one operating condition to another, deviations in mixture occur which are corrected to improve driveability.
If the throttle valve is suddenly opened at a constant engine speed, then both the amount of air which reaches the combustion chamber as well as that which is necessary to raise the pressure in the intake manifold to the new level, flow through the air-flow sensor. The sensor flap then deflects briefly beyond the fully-open-throttle position. This overswing increases the metered fuel quantity (acceleration enrichment), and the result is good transitional response.
During the warm-up phase this acceleration enrichment may not be sufficient. In this operating conditon the speed with which the sensor flap deflects is also taken into account by the control unit processing the electrical signal from the air flow sensor.

Adaptation to the air temperature

The quantity of fuel injected is adapted to the air temperature.

The quantity of air necessary for combustion depends on the temperature of the air drawn in. Cold air is denser. This means that with the same throttle-valve position the volumetric efficiency of the cylinders drops as the temperature increases. To register this effect a temperature sensor is fitted in the intake duct of the air-flow sensor. This sensor measures the temperature of the air drawn in and passes this information onto the control unit which then controls the amount of fuel metered to the cylinders accordingly.

Additional adaptations

In order to optimize the driveability of a particular vehicle model under certain driving conditions, a variety of different adaptation facilities can be incorporated.

Engine-speed limitation
With the existing engine-speed limitation the ignition is short-circuited by the distributor rotor when a certain max. speed has been reached.
This method is no longer possible in vehicles with catalysts, since the fuel still injected would pass into the catalyst unburnt. This leads to thermal failures of the catalyst. An electronic engine-speed limitation offers a solution here. Triggering of this circuit is carried out by the control unit itself. The speed-dependent signal is compared with a fixed limit. If the limit is exceeded the injection signals are suppressed.

Overrun operation (coasting)
During the transition to overrun operation the fuel supply can be cut off above a certain engine speed, i. e. the injection valves remain closed. For this process the control unit evaluates the signals from the throttle-valve switch and from the engine speed. If the speed sinks below a certain value or if the idle contact opens again in the throttle-valve switch, then the fuel supply is resumed again.
The engine speed above which the injection pulses are suppressed is controlled as a factor of the engine temperature.

Control unit

As the central unit of the system, the control unit evaluates the data delivered by the sensors on the operating condition of the engine. From this data, control pulses for the injection valves are formed, whereby the quantity of fuel to be injected is determined by the length of time the injection valves are opened.

Processing of information and generation of injection pulses

The frequency of the injection pulses is calculated from the engine speed. The engine speed and the quantity of air drawn in determine the basic injection time.

The generation of the basic injection time is carried out in a special circuit group in the control unit, the division control multivibrator.
The division control multivibrator (DSM) receives the information on speed n from the frequency divider and evaluates it together with the air-quantity signal U_s. For the purpose of intermittent fuel injection the DSM converts the voltage U_s into rectangular shaped control impulses. Duration t_p of this impulse determines the basic injection quantity, i. e. the quantity of fuel to be injected per suction stroke without considering any corrections. t_p is therefore regarded as the "basic injection time". The greater the quantity of air drawn in with each suction stroke, the longer the basic injection time. Two border cases are possible here: if the engine speed n increases at a constant air throughput Q, then the absolute pressure sinks downstream of the throttle valve and the cylinders draw in less air per stroke, i. e. the cylinders are not filled as much. As a result less fuel is needed for combustion and the duration of the impulse t_p is correspondingly shorter. If the engine output and thereby the amount of air drawn in per minute increase and providing the speed remains constant, then the cylinders will be filled better and more fuel will be required: the impulse duration t_p of the DSM is longer. During normal driving, engine speed and output usually change at the same time, whereby the DSM continually calculates the basic injection time t_p. At a high speed the engine output is normally high (full load) and this results in the end effect in a longer impulse duration t_p and therefore more fuel per injection cycle.

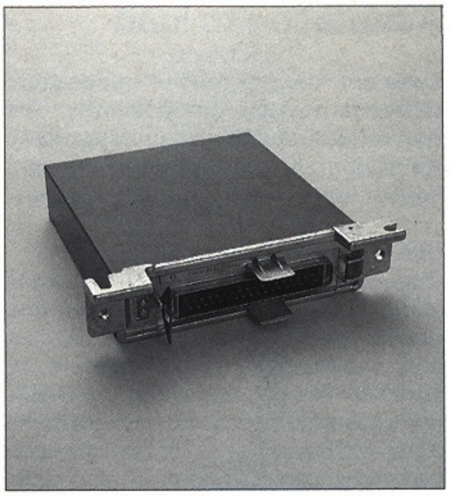


Fig. 35 ***Control unit***

The basic injection time is extended by the signals from the sensors depending on the operating condition of the engine.

Adaptation of the basic injection time to the various operating conditions is carried out by the multiplying stage in the control unit. This stage is controlled by the DMS with the pulses of duration t_p. In addition the multiplying stage gathers information on various operating conditions of the engine, such as cold start, warm-up, full-load operation, etc. From this information the correction factor k is calculated. This is multiplied by the basic injection time t_p calculated by the division control multivibrator. The resulting time is designated t_m. t_m is added to the basic injection time t_p, i. e. the injection time is extended and the air-fuel mixture becomes richer. t_m is therefore a measure of fuel enrichment, expressed by a factor which can be designated "enrichment factor". When it is cold, for example, the valves inject two to three times the amount of fuel at the beginning of the warm-up period.

Voltage correction
The operating time of the injection valves depends very much on the battery voltage. The resulting response delay would have too short an injection duration without an electronic voltage correction. The result would be an insufficient fuel quantity for injection. The lower the battery voltage the less fuel the engine would receive. For this reason a low battery voltage, e. g. after starting with a heavily discharged battery, must be compensated for with an appropriately selected extension t_s of the pre-calculated pulse time in order that the engine receives the correct fuel quantity. This is known as "voltage compensation".
For voltage compensation, the effective battery voltage as the controlled variable is fed into the control unit. An electronic compensation stage ex-

tends the valve control pulses by the amount t_s of the voltage-dependent response delay of the injection valves. The total duration of the injection pulses t_i consists of the sum of $t_p + t_m + t_s$.

Injection pulses
The injection pulses generated by the multiplying stage are amplified in a following final stage. The injection valves are controlled with these amplified pulses.
All the injection valves in the engine open and close at the same time. With each valve a series resistor is wired into the circuit as a current limiter.

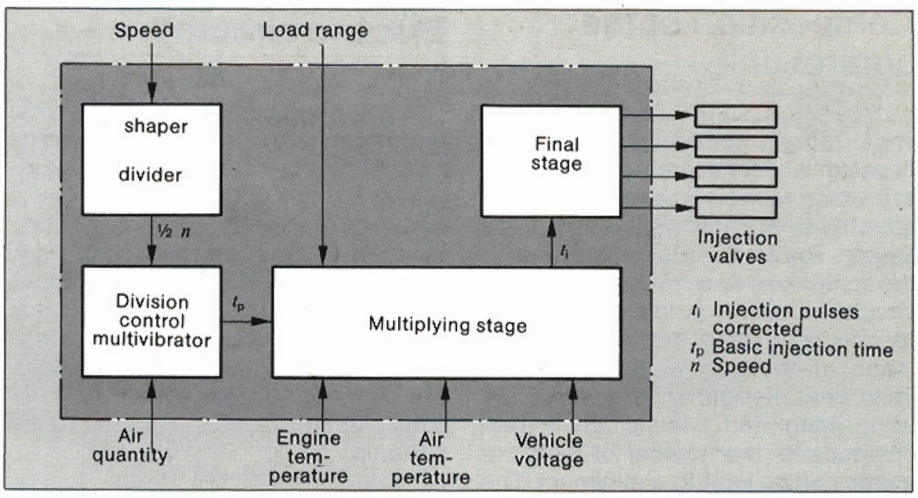
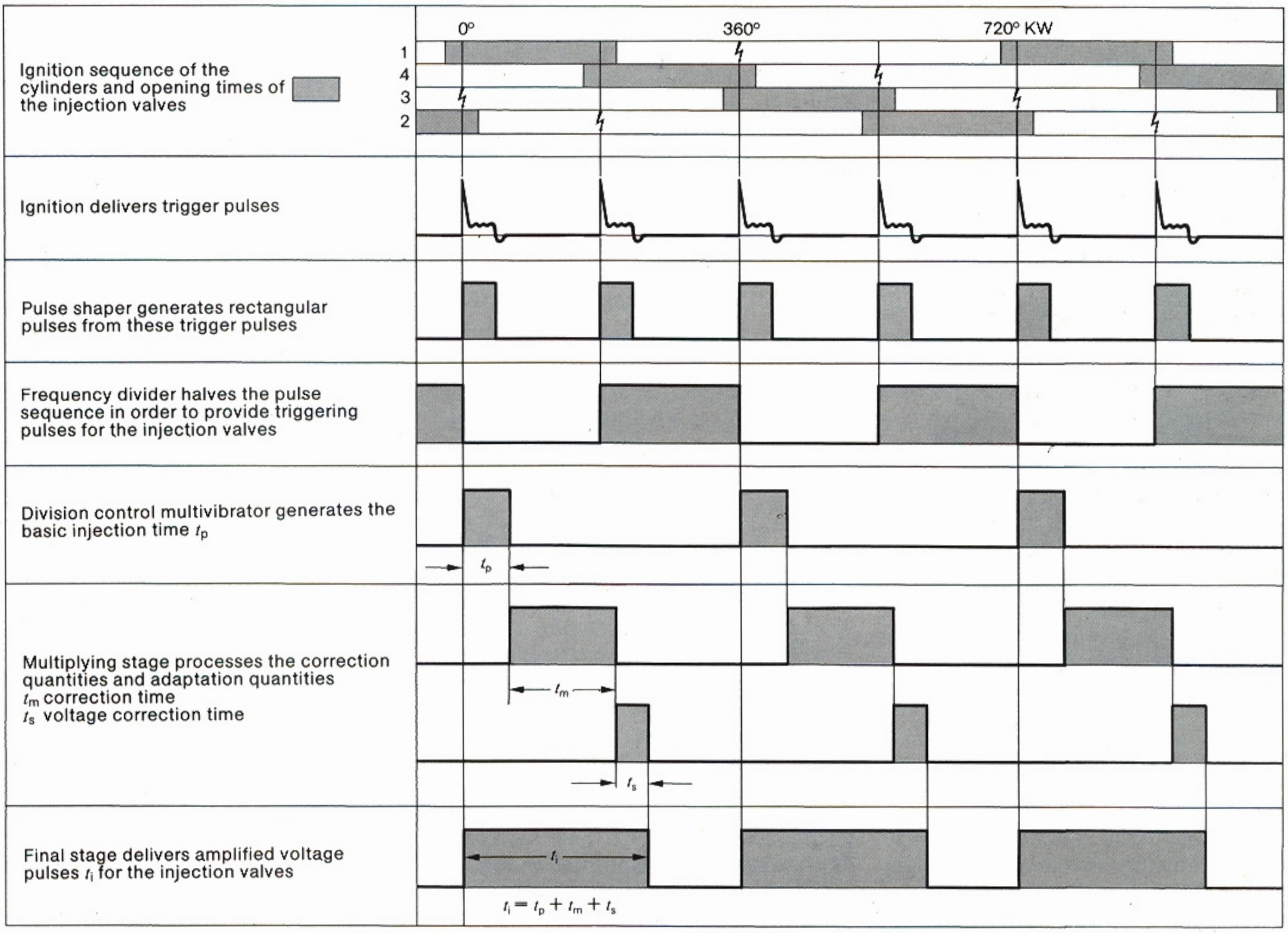


Fig. 36 ***Block diagram of the control unit***



The final stage of the L-Jetronic supplies 3 or 4 valves simultaneously with current. Control units for 6 and 8-cyl. engines have two final stages with 3 and 4 injection valves respectively. Both final stages operate in unison. The injection cycle of the L-Jetronic is selected so that for each revolution of the camshaft half the amount of fuel required by each working cylinder is injected twice.
In addition to controlling the injection valves through series resistors some control units have a regulated final stage. In these control units the injection valves are operated without series resistors. Control of the injection valves takes place then as follows: as soon as the valve armatures have operated at the beginning of the impulse, the valve current is regulated for the rest of the impulse duration to a considerably reduced current, the holding current. Since these valves are switched on at the start of the impulse with a very high current, short response times are the result. By means of the reduction in current strength after switching on, the final stage is not subjected to such heavy loading. In this way up to 12 valves can be switched with one final stage.

Fig. 37 ***Generation of the injection pulses in the control unit for a 4-cyl. engine.***
°KW = °crankshaft

Composition of the control unit

The L-Jetronic control unit is in a metal housing which is protected against splash water and is fitted where it is not affected by the heat radiated from the engine. The electronic components of the control unit are arranged on printed circuit boards; the output components for the final stage are on the metal frame of the control unit, whereby good heat dissipation is assured. By using integrated circuits and hybrid components the number of parts required can be kept to a minimum. The combining of functional groups in integrated circuits (e.g. pulse shaper, pulse divider, division control multivibrator) and components in hybrid form increases the reliability of the control unit.

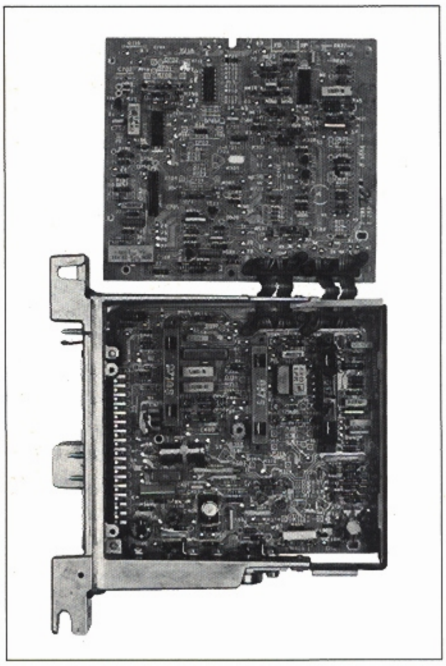


Fig. 38 Control unit (opened up)

A multiple plug is used to connect the control unit to the injection valves, the sensors and the vehicle electrical system. The input circuit in the control unit is designed so that the latter cannot be connected with the wrong polarity and cannot be short-circuited.
Special Bosch testers are available for carrying out measurements on the control unit and on the sensors. The testers can be connected between the wiring harness and the control unit with multiple plugs.

Electric circuitry

The complete circuitry of the L-Jetronic has been designed so that it can be conneced to the vehicle electrical system at a single point.
At this point you will find the relay combination which is controlled by the ignition starter switch, and which switches the vehicle voltage to the control unit and the other Jetronic components.
The relay combination has two separate plug connections, one to the vehicle electrical system and one to the Jetronic.

Safety circuit

In order to prevent the electric fuel pump from continuing to supply fuel e.g. after an accident, it is operated by means of a safety circuit. A switch operated by the air-flow sensor when air is passed through, controls the relay combination, which in turn switches the electric fuel pump. If the engine stops when the ignition is switched on, i.e. when there is no longer any air throughput, the supply of current to the pump is interrupted. During the starting procedure the relay combination is controlled in a corresponding manner via terminal 50 from the ignition switch.

Connection diagram

The example shown here is a typical connection diagram for a vehicle with a 4-cyl. engine.
Please note with the wiring harness that terminal 88z of the relay combination is connected directly and without a fuse to the positive pole (terminal post) of the battery in order to avoid interference and voltage drops caused by contact resistances.

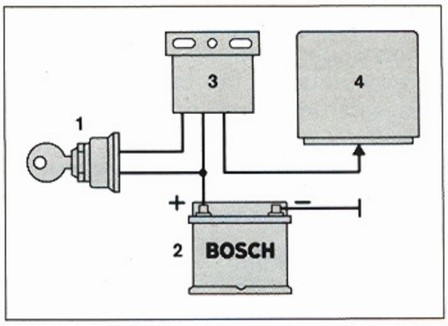


Fig. 39 Voltage supply (diagram)
1 Ignition and starter switch, 2 Battery, 3 Relay combination, 4 Control unit

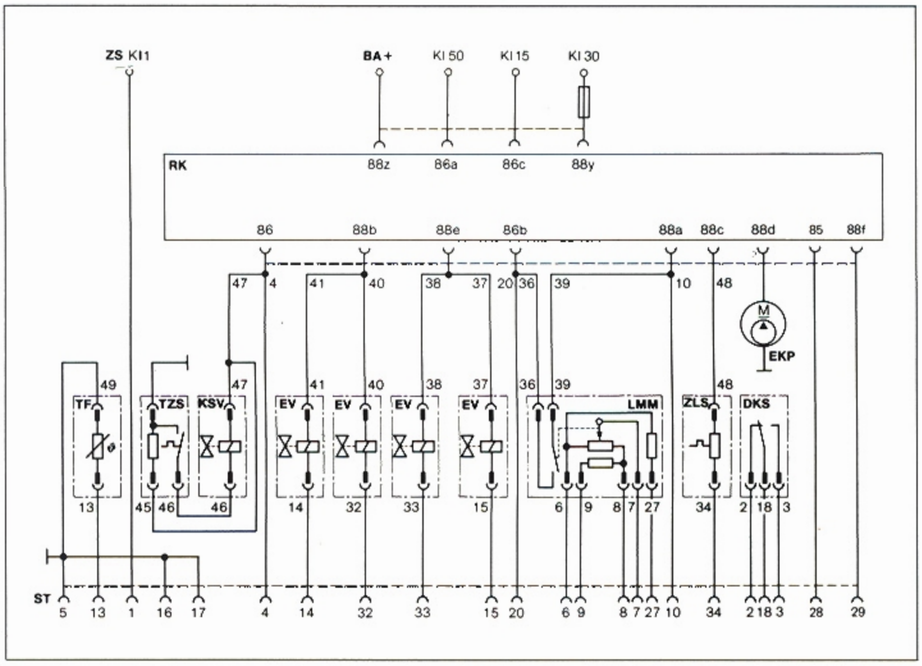


Fig. 40 Example of a connection diagram
(L-Jetronic with regulated final stage)
TF Engine temperature sensor, TZS Thermo-time switch, KSV Start valve, EV Injection valve, LMM Air-flow sensor, ZLS Auxiliary-air device, DKS Throttle-valve switch, EKP Electric fuel-pump, RK Relay combination, ZS Ignition coil, BA Battery, ST multiple plug to control unit

Terminals 5, 16, 17 of the control unit as well as terminal 49 of the temperature sensor are to be connected with separate cables to a common ground point.

Reduction of noxious emissions

The noxious emissions from the spark-ignition engine can be effectively reduced by means of catalytic treatment

The fuel combustion in the working cylinder of an engine is more or less incomplete. The more incomplete the combustion, the greater the amount of harmful materials in the exhaust gas. There is no such thing as complete combustion of fuel, not even when there is an excess of oxygen. This means that the exhaust will always have a certain harmful content. In order to reduce the effect on the environment, the exhaust gas must be purified.

All chemical procedures necessary for exhaust detoxication can be grouped under the heading "Aftertreatment of exhaust gas". This includes the chemical conversion of noxious exhaust constituents such as carbon monoxide, hydrocarbons and nitrogen oxide into harmless constituents. For the aftertreatment of exhaust gas there is an effective catalytic process. A prerequisite of this process, however, is optimal mixture composition. An optimal, i.e. stoichiometric mixture composition exists when, with the amount of air drawn in, just enough fuel is gasified or is injected to enable in theory a complete combustion to take place, i.e. a combustion without excess of oxygen or fuel. Such a mixture is characterized by an air ratio λ of exactly 1.00.

The actual difficulty in purifying exhaust gases by means of "catalytic aftertreatment" is in strictly maintaining $\lambda = 1.00$ for every operating condition of the engine. A deviation of a mere 1% is enough to impair the aftertreatment to a considerable degree. It is impossible to keep the mixture composition constantly within a limit which should be considerably less than 1% if an open-loop mixture control is used. For this purpose, highly accurate and practically inertia-less closed-loop mixture control is necessary. The reason for this is that the open-loop mixture control, e.g. with L-Jetronic, cannot monitor and feed back the result, although it calculates and meters out the fuel quantity needed. We speak here of an open-loop control. On the other hand, the closed-loop mixture control measures the composition of the exhaust gas and uses the result for correcting the fuel quantity calculated.

The diagram shows how the emission of noxious matter is influenced by the mixture composition and by aftertreatment. The necessity for the highest possible control accuracy can be recognized by the considerable increase in the harmful carbon monoxide (CO) just under $\lambda = 1.00$ as well as by the sudden increase of the equally harmful nitrogen oxide (NO_x) just over $\lambda = 1.00$.

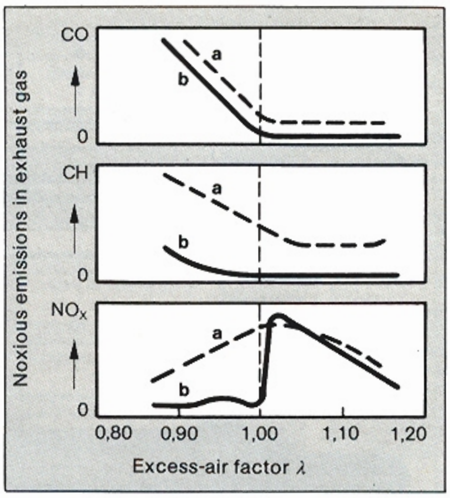


Fig. 41 Effect of the catalytic exhaust detoxication with Lambda closed-loop control. Optimal mixture setting range: $\lambda = 0.99 \dots 1.00$
Noxious proportion a: without aftertreatment, b: with aftertreatment, CO carbon monoxide, CH carbohydrates, NO_x nitrogen oxide

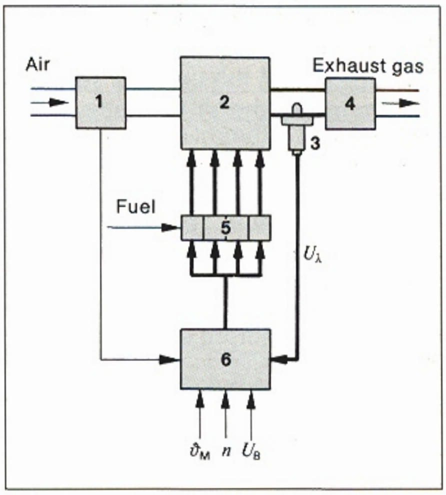


Fig. 42 Functional diagram of the L-Jetronic with Lambda closed-loop control
1 Air-flow sensor, 2 Engine, 3 Lambda sensor, 4 Catalyst, 5 Injection valves, 6 Control unit with regulator, U_λ Sensor voltage, U_B Vehicle voltage, n Engine speed, ϑ_M Engine temperature

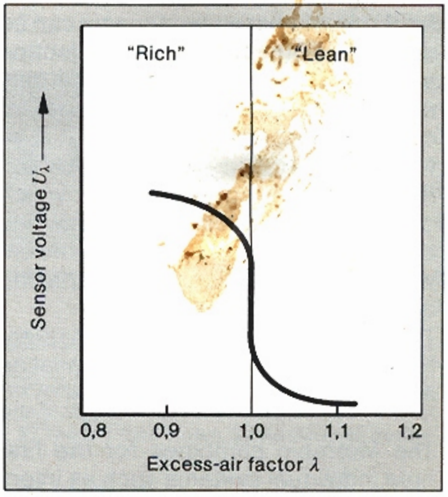
Lambda closed-loop control

With the Lambda closed-loop control the air-fuel ratio can be maintained extremely accurately.

With the closed-loop control, using a special sensor, the Lambda sensor, deviations from a certain air-fuel ratio can be recognized and corrected. The control principle is as follows: the Lambda sensor measures continually the residual oxygen content in the exhaust gas, this being a measure for the composition of the air-fuel mixture supplied to the engine. The Lambda sensor in the form of a measuring sensor in the exhaust pipe supplies information on whether the mixture is richer or leaner than $\lambda = 1$. When there is a deviation from this value, the output signal of the sensor makes a voltage jump which is evaluated by the control unit. In this way the control unit becomes a (closed-loop) control unit. The Lambda closed-loop control influences the duration of the injection (= quantity), these being calculated beforehand by the injection control. In this manner the fuel can be apportioned so exactly that the air-fuel ratio is optimal in all engine conditions. Tolerances and aging of the engine are of no importance here. If, for example, $\lambda = 1.03$ (slightly lean mixture), then the Lambda closed-loop control compensates for the excess air with an increase in the fuel supply. The closed-loop control works the opposite way when, e.g. $\lambda = 0.97$ (slightly rich mixture). This continual, almost inertia-less setting of the mixture at $\lambda = 1$ is the prerequisite for enabling the catalyst switched into the circuit to burn the harmful particles to an effective degree.

In addition to this basic task the closed-loop control supervises other control and adaptation duties. Closed-loop operation is impossible, however, until the operating temperature of the Lambda sensor has been reached. During this period the system is switched to open-loop control. The closed-loop control monitors furthermore the function of the sensor during operation. If a fault should occur, then the system is controlled to give a medium Lambda value.

Fig. 43 Sensor voltage as a factor of the air ratio



The Lambda sensor

The signal from the Lambda sensor is dependent on the air-fuel ratio.

The Lambda sensor measures the oxygen content of the exhaust gas. This oxygen content is dependent on the air-fuel mixture. The special feature of the Lambda sensor is that deviations in the air ratio $\lambda = 1$ lead to a spontaneous change in the output signal of the sensor.

The sensor consists principally of a special ceramic body, the surfaces of which are fitted with platinum electrodes through which gas can pass. The sensor works on the principle of the ceramic material, which is doped with certain metal oxides, becoming conductive at high temperatures. If the oxygen content on each side of the electrodes varies in size, then an electric voltage occurs at the electrodes. This voltage represents the measuring signal.

The sensor is arranged in the exhaust pipe from the engine in such a manner that the outer surface of the ceramic body lies in the exhaust-gas flow. The inner part, however, is in contact with the outside air. The demands placed on a λ-sensor are, by their very nature, severe. High thermal, mechanical and even chemical stresses occur, all of which are mastered by the sensor thanks to its clever design.

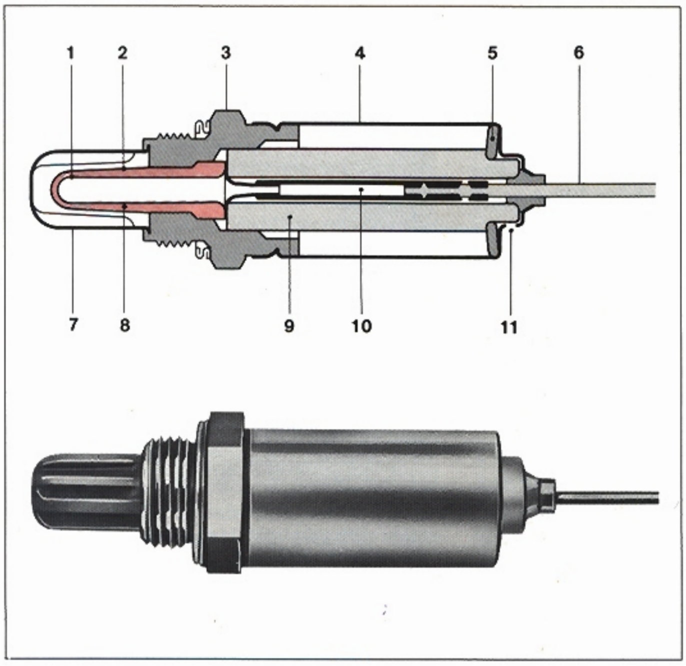


Fig. 44
The Lambda sensor from Bosch
1 Electrode (+)
2 Electrode (−)
3 Housing (−)
4 Protective sleeve (air side)
5 Disc spring
6 Electrical connection
7 Protective tube (exhaust side)
8 Sensor ceramic
9 Support ceramic
10 Contact part
11 Vent opening

Further development of electronically controlled injection systems

“Bosch Motronic”

The efficiency of the present-day micro-computers makes it possible to combine the functions “gasoline injection” and “ignition”, so that the basic cost of the micro-computer itself as well as of the voltage supply and the housing is only necessary once. Apart from this, almost all the sensors can be used for both the gasoline injection and the ignition. These, too, are only necessary once. We therefore have increased reliability and less cost than for two separate systems. Bosch has therefore developed a system which contributes considerably in reducing costs, in reducing the impact on the environment and in improving the driving comfort of motor vehicles.

The Motronic is an integrated system for the electronic control of gasoline injection and ignition.

The Motronic combines for the first time individual systems such as injection and ignition in a digital engine control system. We are concerned here with a computerized control for the engine, i.e. the application of a microcomputer in the electronic control unit. The use of a digital control unit makes the system flexible on the one hand and on the other hand guarantees a constant exactness (long-duration constancy) and the ability to reproduce, as and when required, the engine data which only needs to be stored once. In addition to the main item of the Motronic, the micro-computer which consists of a micro-processor in which data and programs are stored, and of the input and output circuit, the system is characterized by fewer fast-moving parts for the ignition and common pickups for injection and ignition. In this way maintenance is kept at an absolute minimum. In practice this means that the adjustment of the mechanical governor and of the vacuum can be dispensed with and in its place comes an integrated fully electronic (breakerless triggered) computerized ignition in the Motronic system with inductive speed and reference mark sensor.

Method of operation of the Motronic
The system operates with a digital control unit which contains a micro-computer as its principal component. The micro-computer in turn has a microprocessor as its principal component. The program store of the micro-computer is used for storing all data which characterize the operation of the engine under various operating conditions. Also stored is a working program which controls both the flow of signals to the store and the signals prepared by the sensors into the micro-processor. By comparing the actual values with those stored the micro-processor can calculate the operating condition of the engine at any particular moment. If there are any deviations from the optimum mode of operation, the microprocessor effects the necessary corrections for injection and ignition by sending appropriate control pulses to the final output stages in the control unit. The final output stages then control the ignition coil and the injection valves accordingly.

Injection subsystem

The intermittent, electronically-controlled injection is based on the L-Jetronic. One of the main differences, however, is the way in which the signals are processed. This is now done digitally in the common control unit. The speed sensor is an inductive sensor on the flywheel ring gear.

The triggering-off point for the injection of fuel through the solenoid-operated injection-valves is orientated to the signal of a reference-mark sensor on the flywheel ring gear.

The computer calculates the basic fuel amount from the quantity of air and from the speed. The air quantity per stroke is calculated and used as a basic signal for injection and the ignition-point map (load). In addition to the basic signal, other corrections are considered, depending on engine temperature, intake-air temperature, throttle-valve position etc. for optimum engine operation.

Ignition subsystem

Instead of the mechanical governor and the vacuum adjustment in the ignition distributor, there is an ignition-point map stored in the control unit. This map is far superior to the former adjustment and is adapted to all engine ranges.

A dwell-period control which determines the dwell period (dwell angle) dependent on the speed and supply voltage, adapts the ignition energy to the specific need and prevents unnecessary energy consumption in the ignition coil.

A particular advantage of the Motronic is that the ignition timing point in the full-load range is set for maximum torque, except in those ranges where consideration must be given to the octane requirement. In the part-load range the ignition timing point is set for minimum consumption whilst at the same time adhering to the limits of exhaust-gas emission. Changes in load are registered by the Motronic immediately. At each revolution of the engine the computer enquires of the operating condition of the engine and with the help of the programmed values, calculates therefrom the new dwell angle. This brings speedy adjustment to modified operating conditions.

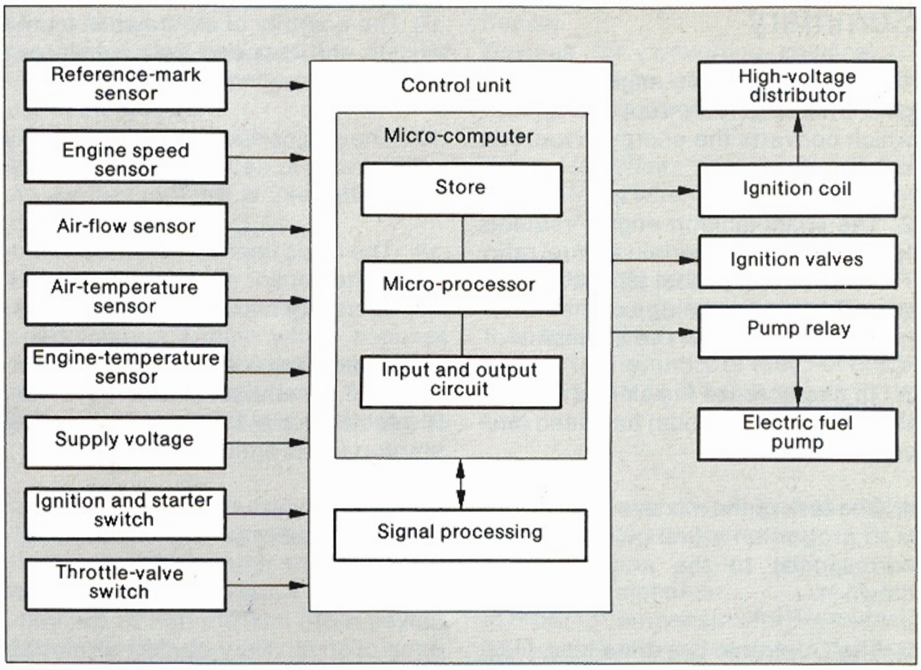


Fig. 45 ***Motronic block diagram***

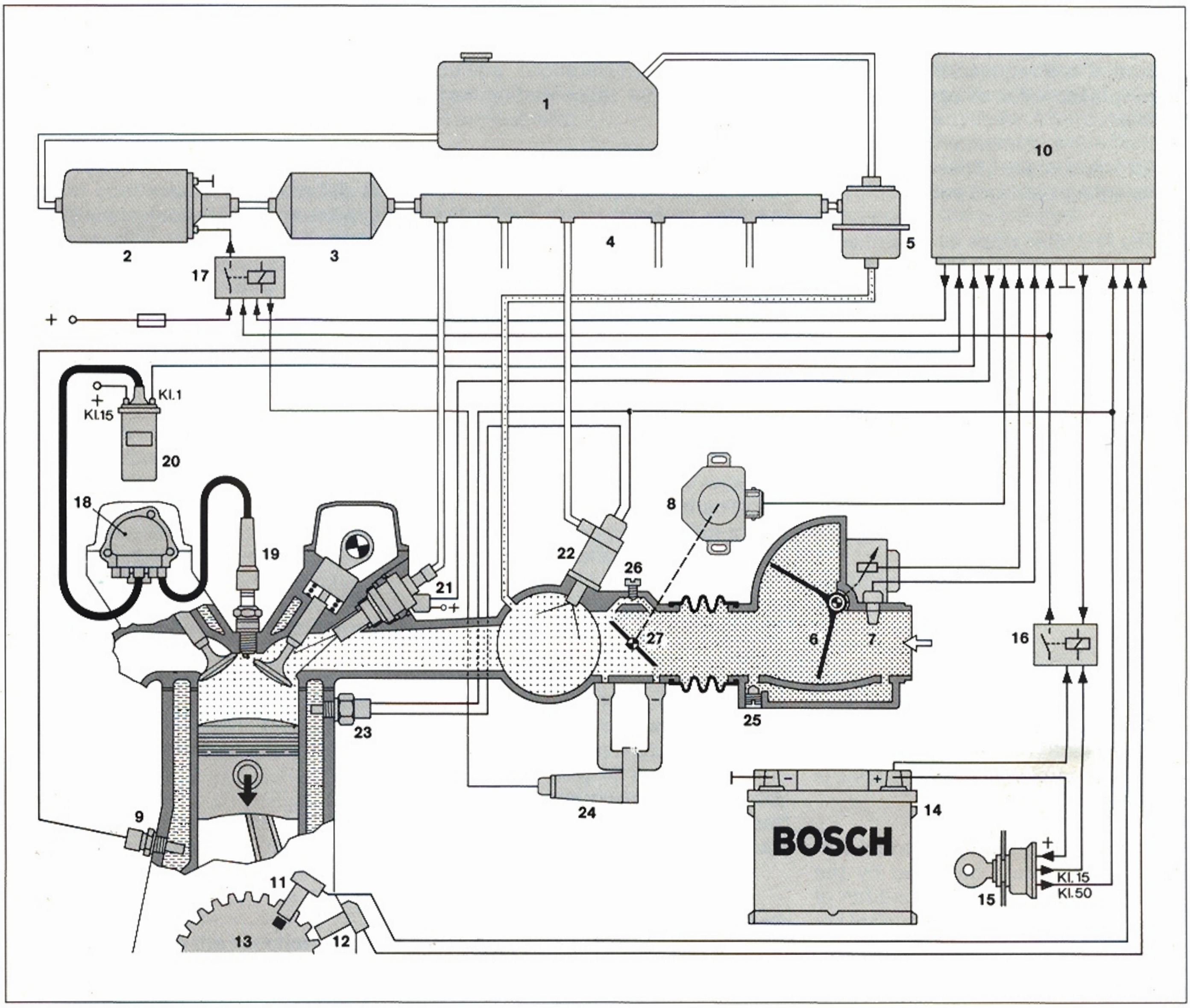


Fig. 46 ***Diagram of the Motronic system***

1 Fuel tank, 2 Fuel pump, 3 Fuel filter, 4 Distributor tube, 5 Pressure regulator, 6 Air-flow sensor, 7 Intake-air temperature-sensor, 8 Throttle-valve switch, 9 Engine-temperature sensor, 10 Control unit, 11 Reference-mark sensor, 12 Speed sensor, 13 Flywheel, 14 Battery, 15 Ignition and starter switch, 16 Main relay, 17 Pump relay, 18 High-voltage distributor, 19 Spark plug, 20 Ignition coil, 21 Injection valve, 22 Start valve, 23 Thermo-time switch, 24 Auxiliary-air device, 25 Idle-mixture adjustment-screw, 26 Idle-speed adjustment-screw, 27 Throttle valve.

Summary

1. The spark-ignition engine is an engine with externally supplied ignition which converts the energy in fuel into kinetic energy.

2. The spark-ignition engine requires for its operation a certain air-fuel ratio. The theoretically ideal air-fuel ratio is 14:1. Certain operating conditions require a correction of the mixture.

3. To characterize the air-fuel mixture the air ratio λ (Lambda) has been chosen.

4. The task of the mixture preparation is to proportion a fuel quantity which corresponds to the amount of air drawn in.

5. The L-Jetronic is a drive-less, electronically controlled injection system with intermittent fuel injection.

6. The fuel system supplies the amount of fuel required by the engine under pressure for all operating conditions.

7. An electrically driven roller-cell pump serves as a fuel pump.

8. The fuel filter stops all impurities in the fuel from entering the engine.

9. The distributor tube guarantees equal fuel pressure in all injection valves.

10. The pressure regulator controls the pressure in the fuel system.

11. The injection valves inject the fuel into the intake tubes of the cylinders in front of the inlet valves of the engine.

12. The mixture is formed in the intake tube and in the cylinders of the engine.

13. The operating condition of the engine is detected by sensors and passed on to the control unit in the form of electric signals. The sensors and the control unit form the control system.

14. As a central unit the control unit evaluates the data delivered by the sensors on the operating conditon of the engine. From this data, control impulses for the injection valves are generated, whereby the quantity of fuel to be injected is determined by the opening duration of the injection valves.

15. The frequency of the injection impulses is based on the engine speed.

16. The quantity of air drawn in by the engine, and its speed, are a measure of the engine loading.

17. The engine speed and the quantity of air drawn in determine the basic injection time.

18. The basic injection time is extended by the sensor signals according to the operating condition of the engine.

19. Depending on the engine temperature, an additional quantity of fuel is injected for a limited period during starting (start enrichment).

20. During warm-up the engine receives more fuel (warm-up enrichment).

21. During warm-up the engine receives more mixture due to the influence of an auxiliary-air device in order to overcome the increased friction when cold and to guarantee a stable idling.

22. During acceleration additional fuel is injected (acceleration enrichment).

23. At full load the mixture is enriched.

24. The quantity of fuel injected is adapted to the air temperature.

25. Additional adaptation measures can be adopted to optimize the driving behaviour, depending on the specific vehicle.

26. If the engine stops with the ignition still switched on, the electric fuel pump is switched off.

27. The harmful emissions from the spark-ignition engine can be effectively reduced by means of catalytic aftertreatment.

28. The air-fuel ratio can be maintained very exactly by means of the Lambda closed-loop control.

29. The signal from the Lambda sensor is dependent on the air-fuel ratio.

30. The Motronic is an integrated system for the electronic control of gasoline injection and of the ignition.

Suggestions for Further Reading

A number of technical dissertations on the subject of Jetronic systems has appeared. Their contents lie outside the scope of this booklet. The following works are to be recommended:

O. Glöckler, N. Rittmannsberger, H. Scholl: Weiterentwicklung der elektronisch gesteuerten Benzineinspritzung "Jetronic" (The further development of electronically-controlled gasoline injection "Jetronic").
ATZ 73 (1971) 4, 126–132

H. Scholl:
Elektronische Benzineinspritzung mit Steuerung durch Luftmenge und Motordrehzahl (Electronic gasoline injection by means of air quantity and engine speed), Bosch Technische Berichte 4 (1972/74), 190–199

R. Zechnall, G. Baumann:
Reines Abgas bei Ottomotoren durch geschlossenen Regelkreis (Pure exhaust-gas in spark-ignition engines by means of closed-loop control).
MTZ 34 (1973) 1, 7–11

O. Glöckler, B. Kraus:
L-Jetronic – Elektronisches Benzineinspritzsystem mit Luftmengenmessung (L-Jetronic – Electronic gasoline injection with measurement of air quantity).
Bosch Technische Berichte 5 (1975/77) 1, 7–18

Technical terms

Air-fuel ratio
Ratio of the air quantity to the fuel quantity in the mixture drawn in by the engine.

Air-flow sensor
Device for measuring the quantity of air drawn in.

Altitude correction
Atmospheric density decreases as altitude increases. With fuel supply at a constant level the air-fuel mixture would become too enriched. The fuel quantity is therefore modified. This procedure is known as altitude compensation.

bar
Unit of measure for pressure
1 bar = approx. 1 kgf/cm^2.

Basic fuel quantity
The injected fuel quantity minus all quantities arising as a result of corrections.

Bimetal
Two metals mechanically connected to each other with differing thermal expansion coefficients. The bending of the metal caused by heating is used for purposes of measuring and controlling.

Bypass
A passage providing an alternative route around the throttle valve.

Catalyst
Material which causes a chemical reaction, without changing itself.

Condensation loss
With a cold engine fuel particles from the air-fuel mixture condense on the walls of the intake manifold and combustion chamber which are still cold. In this way the mixture becomes leaner.

Cylinder-flooding protection
Safety circuit in Jetronic systems which prevents the cylinders from becoming completely full of fuel.

Damping volume
Space in the air-flow sensor in which the damping flap moves (shock – absorber function).

Duration of injection
Time during which the injection valves are open.

Electrode
Conducting part which serves to conduct electricity to a medium.

Gasoline injection
Supply of the fuel quantity to the drawn-in air quantity by means of the injection system.

Ignitable mixture
An air-fuel mixture is ignitable in the range of $\lambda = 0.7 \ldots 1.3$.

Intake manifold
Part of the induction system of the spark-ignition engine which supplies air to the engine. From the intake manifold the intake tubes lead to the cylinders. The throttle valve is on the intake manifold.

Intake tube
The cylinders are supplied with air via the intake tubes which are connected to the intake manifold.

Integrated circuit
Electronic circuit consisting of permanently connected semiconductor components on a, usually, very small supporting plate. Short designation IC.

Lambda (λ), air ratio
See air-fuel ratio

Lean mixture
Excess air, $\lambda > 1$, air quantity supplied greater than theoretical air requirement.

NTC resistance
Temperature-dependent semiconductor resistor, the resistance value of which decreases with increasing temperature (NTC resistor). NTC means Negative Temperature Coefficient.

Overrun
Mode of driving whereby the engine is driven by the vehicle, e.g. when going downhill.

Part load
Load range between idle and full load.

Potentiometer
Electrical resistor, the resistance value of which can be mechanically altered.

Relay combination
Circuit consisting of two relays. The control unit is switched on by the relay combination and the fuel pump and auxiliary air-device are also started up.

Return pressure oscillation
Sudden increase in pressure in the intake manifold caused by misfiring.

Rich mixture
Lack of air, $\lambda < 1$, air quantity supplied smaller than theoretical quantity of air required.

Sensor
Devices for converting physical dimensions into others, e.g. heat or pressure into electric signals.

Start of injection
The moment when the injection valves open.

Stoichiometric ratio
Ratio of the quantity of air necessary theoretically for complete combustion of a certain quantity of fuel. For gasoline the ratio is 14 : 1, i.e. 14.7 kg air to 1 kg fuel.

Warm-up
Transition from cold engine to engine warm enough for operating.

Warm-up enrichment
In order to compensate for the thinning of the air-fuel mixture due to condensation losses, an additional quantity of fuel is fed to the engine.

Working cycle
(of the internal-combustion engine)
A working cycle consists of all processes in the cylinder, from a particular state up till the moment when that particular state is repeated. In a 4-stroke engine a working cycle includes two revolutions of the crankshaft.

Test questions

A The spark-ignition requires

☐ a) excess air
☐ b) a certain air-fuel ratio
☐ c) excess fuel

B The L-Jetronic

☐ a) injects intermittently
☐ b) injects continuously

C The fuel pump is driven by

☐ a) the spark-ignition engine
☐ b) an electric motor

D The pressure regulator regulates the fuel pressure

☐ a) independent of the pressure in the intake manifold
☐ b) dependent on the pressure in the intake manifold

E The injection valves inject the fuel

☐ a) into the intake manifold
☐ b) in front of the injection valves
☐ c) into the combustion chamber

F The sensors

☐ a) control the injection valves
☐ b) register the operating condition of the spark-ignition engine
☐ c) conduct the signals into the control unit

G The start of injection is determined

☐ a) by the ignition distributor
☐ b) by the crankshaft

H The air-flow sensor measures

☐ a) the pressure in the intake manifold
☐ b) the pressure in the intake tubes
☐ c) the quantity of air drawn in by the engine

J During cold starting

☐ a) the intake manifold is heated
☐ b) more fuel is injected
☐ c) less fuel is injected

K During warm-up

☐ a) the mixture is enriched
☐ b) the fuel pressure is increased

L The auxiliary-air device

☐ a) increases the engine speed
☐ b) stabilizes the engine speed
☐ c) makes the mixture leaner

M The throttle-valve switch

☐ a) closes and opens the throttle valve
☐ b) switches the fuel pump on
☐ c) signals the throttle-valve position to the control unit

N The control unit

☐ a) controls the sensors
☐ b) evaluates the sensor signals
☐ c) supplies pulses to the injection valves

O The basic injection time is calculated from the

☐ a) engine speed
☐ b) engine speed and air quantity
☐ c) air quantity

P The correction variables effect

☐ a) an extension of the basic injection time
☐ b) a reduction of the basic injection time

Q When the battery voltage sinks

☐ a) the injection pulses are lengthened
☐ b) the injection pulses are shortened

R With stationary engine and ignition switched on

☐ a) the fuel pump works
☐ b) the fuel pump does not work

S With a catalyst it is possible

☐ a) to cool the exhaust gas
☐ b) to purify the exhaust gas

T The Lambda sensor

☐ a) measures the exhaust-gas temperature
☐ b) measures the remaining oxygen content in the exhaust gas
☐ c) is a sensor

The correct answers to these questions can be found on the following pages:

A: page 4
B: page 6
C: page 8
D: page 9
E: page 9
F: page 11
G: page 11
H: page 12
J: page 13
K: page 14
L: page 14
M: page 15
N: page 16
O: page 16
P: page 16
Q: page 16
R: page 18
S: page 19
T: page 20

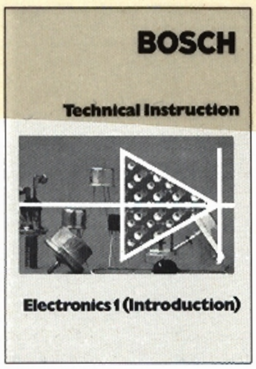
Technical Instruction

The titles shown below have so far appeared in the Bosch Technical Instruction series.

These publications can be obtained from your local Bosch representative; if unknown, please send for list.

If you are interested in further teaching aids, such as training charts, audio-visual presentations with synchronized commentary, please send to your local Bosch representative for our special catalogs.

Further titles in preparation.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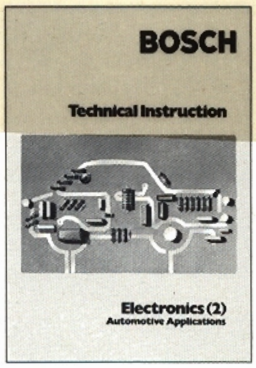
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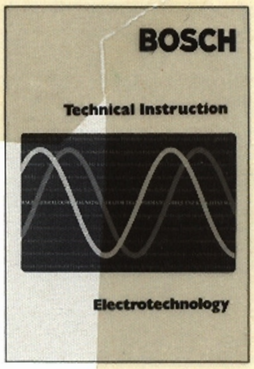
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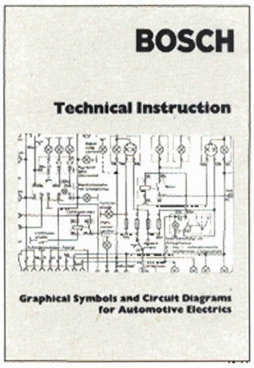
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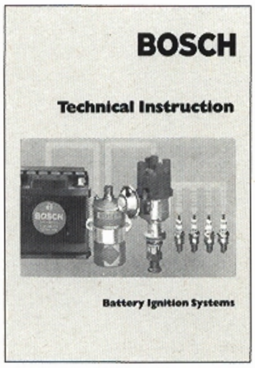
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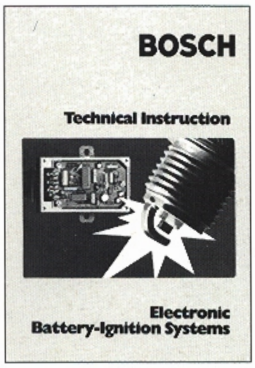
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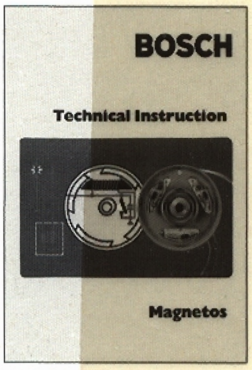
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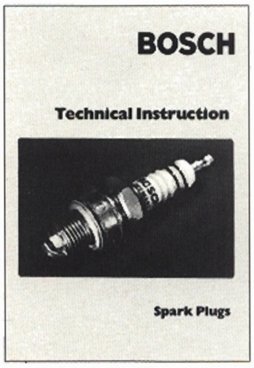
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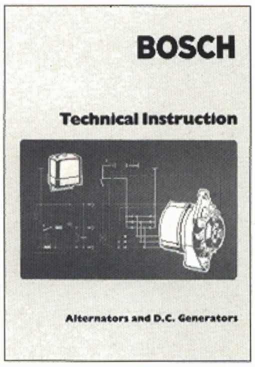
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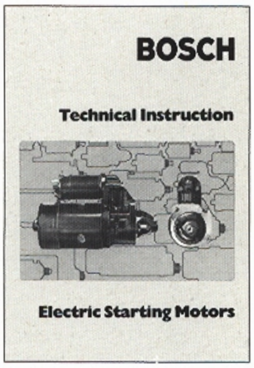
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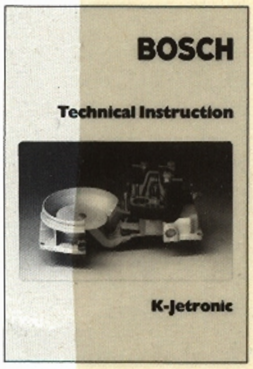
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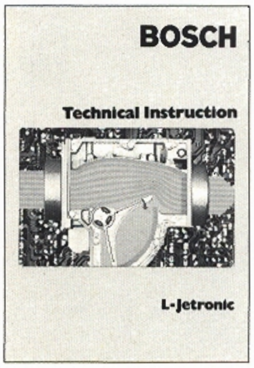
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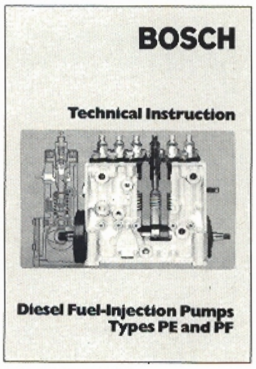
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Types PE and PF

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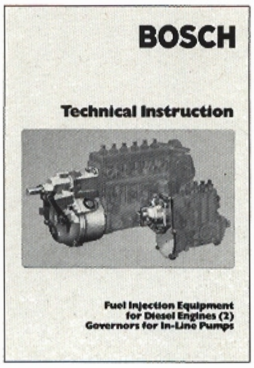
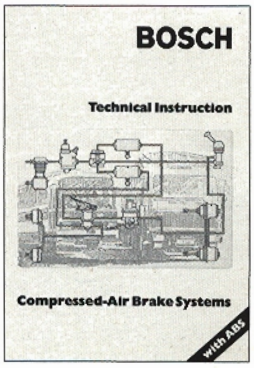

BOSCH
Technical Instruction
Fuel Injection Equipment for Diesel Engines (2)
Governors for In-Line Pumps

VDT-UBP 210/1 En


BOSCH
Technical Instruction
Compressed-Air Brake Systems
with ABS

VDT-U 4/1 En