Bosch LE jetronic

There is much confusion about the actual type of injection system fitted to many BMW motor cars during the period 1980 to 1989. Many BMW vehicles were equipped with Bosch 'L' jetronic from the mid 1970's until the mid 1980's. From about 1982 Bosch 'LE' jetronic was widely used to replace the 'L' system and 'LE' itself was also phased out from the mid 1980's. Bosch Motronic was also used from about 1982 and by 1989 was fitted to all models. However, there are many variations of Motronic and the various Motronic documents in CAPS should be consulted for more information.

Both 'L' and 'LE' jetronic control the fuel system alone. Both jetronic systems function in conjunction with an electronic ignition system of some description and are analogue systems without a self-diagnostic function. The later Motronic systems also control ignition primary and have become increasingly complex as Motronic has evolved.

In addition, most BMW vehicles are equipped with a SD/ service function from about 1983. The service function operates independently of the injection ECU on 'L' and 'LE' models; but operates in conjunction with Motronic where this system is fitted.

The confusion that arises about the 'L' and 'LE' jetronic systems is compounded by many data books (including some technical documentation from BMW itself) that term both systems as 'L' jetronic - irrespective of which system is actually fitted. There are a number of vital differences between the two systems and the type fitted to the vehicle under test should be identified since test procedures certainly differ and connections to the ECU are quite different. Identification is actually made quite easy if the ECU multiplug is inspected. The 'L' jetronic ECU contains 35 pins and the 'LE' jetronic ECU contains 25 pins.
This document concerns BMW vehicles equipped with 'LE' jetronic and we will now concentrate fully on that model.

Both 4 and 6 cylinder engines use LE jetronic, with a number of minor differences between applications.

Either Bosch LE or LE2 may be fitted to BMW vehicles that are covered by this document. LE (sometimes called LE1) utilises a cold start valve and TTS as an aid to starting the engine from cold. LE2 is an enhancement of the earlier system and identical in most respects to LE. The main difference between LE2 and LE is that LE2 has dispensed with the cold start valve and TTS. During engine start from cold, LE2 pulse duration is increased to provide a richer air/fuel mixture.

A 25 pin connector and multi-plug connects the ECU to the battery, sensors and actuators.

Basic ECU operation

When the ignition is switched on, voltage is applied to the fuel injection relay. Once the engine is cranked upon the starter, cranking voltage is applied to ECU pin 4 and relay terminal 50. The relay windings are energised, the relay contacts close and voltage is output at relay terminal 87 and either 87a or 87b (depending on vehicle). Voltage is thus applied to the ECU at terminal 9, AFS, TS, AAV (electrical type) and the fuel pump.

Once the engine speed rises above 400 rpm, a speed signal from the ignition coil terminal 1 to terminal 1 of the relay and terminal 1 of the ECU holds the relay contacts energised. If the engine speed falls below 400 rpm, the relay will be de-energised and the relay voltage output will cease. The engine will stop.

The Injectors, are supplied with nbv from the main relay and the ECU completes the circuit by pulsing the actuator wire to earth.

Signal processing

As a result of data from the engine sensors, the ECU will calculate the correct injector pulse duration right across the engine rpm, load and temperature range.

Engine load determines the basic injection pulse value and correction factors are applied for starting, deceleration, part and full-load operation. The main engine load sensor is the AFS and the main correction factors are engine speed and engine temperature. Other correction factors are determined from the TS and ATS signals. The engine temperature is determined by a signal from the CTS and the engine speed from the ignition coil terminal number 1.

Service connection.

From about 1983, most BMW vehicles are equipped with a service connection. The service connection contains 15 pins and operates independently of the injection ECU on 'LE' models. A BMW or Bosch service tool can be attached to the service connection for functions like checking the ignition timing or resetting the service lights.

In addition, 6 cylinder engines are equipped with a TDC position sensor. The TDC position sensor is provided for information purposes, and has absolutely no effect on engine operation. When the service tool is connected to the service connector, the TDC position sensor allows timing data to be measured.

Service lights

There is a cluster of LED's on the dash: five green, one yellow and three red. Up to five green LED's will light when the ignition is turned on. However, the LED's will extinguish once the engine is started. When the yellow light comes on, service is due. When one or more of the red lights illuminate, this means that service is overdue & should be attended to immediately. Once the service has been completed, the service lights memory should be reset .In addition to Bosch and BMW tools, a number of proprietary tools are also available for resetting the service lights memory.

Fuel injection
The Bosch LE jetronic system is a multi-point injection system and pulses all injectors at the same time - ie simultaneously and twice per engine cycle. The fuel injectors are mounted in the inlet stubs to the engine inlet valves so that a finely atomised fuel spray is directed onto the back of each valve. In 4 cylinder engines all injectors are pulsed together. In 6 cylinder engines the injectors are pulsed in two banks of three.

Half of the required fuel per engine cycle is injected at each engine revolution. This means that fuel will lie briefly on the back of an inlet valve until that valve opens. During engine start from cold, the pulse duration is increased to provide a richer air/fuel mixture.

The LE jetronic ECU contains a fuel map with an injector opening time for basic conditions of speed and load. Information is then gathered from engine sensors such as the AFS, CTS, and TS. As a result of this information, the ECU will look-up the correct injector pulse duration right across the engine rpm, load and temperature range.

During full-load operation, the ECU provides additional enrichment. During closed throttle operation above a certain rpm (deceleration), the ECU will cut-off fuel injection. Injection will be reintroduced once the rpm returns to idle or the throttle is opened.

Fuel injectors
The fuel injector is a magnetically operated solenoid valve that is actuated by the ECU. Voltage to the injectors is applied from the main relay and the earth path is completed by the ECU for a period of time (called pulse duration) of between 1.5 and 10 milliseconds. The pulse duration is very much dependant upon engine temperature, load, speed and operating conditions. When the magnetic solenoid closes, a back EMF voltage of up to 60 volts is induced.

AFS
The AFS is located between the air filter and the throttle body. As air flows through the sensor it deflects a vane (flap). The greater the volume of air, the more will the flap be deflected. The vane is connected to a wiper arm which wipes a potentiometer resistance track and so varies the resistance of the track. This allows a variable voltage signal to be returned to the ECU.

Three wires are used by the circuitry of this sensor and it is often referred to as a three wire sensor. Nominal battery voltage from the system relay is applied to the resistance track with the other end connected to the AFS earth. The third wire is connected to the wiper arm and returns the output signal to the ECU at pin number 7.

From the voltage returned, the ECU is able to calculate the volume of air (load) entering the engine and this is used to calculate the main fuel injection duration. To smooth out inlet pulses, a damper is connected to the AFS vane. The AFS exerts a major influence on the amount of fuel injected.

ATS
The ATS is mounted in the AFS inlet tract and measures the air temperature before it enters the inlet manifold. Because the density of air varies in inverse proportion to the temperature, the ATS signal allows more accurate assessment of the volume of air entering the engine. However, the ATS has only a minor correcting effect on ECU output.

Voltage is applied to the ATS resistance from the AFS voltage supply and the signal returned to the ECU at pin number 8. The ATS operates on the NTC principle. A variable voltage signal is returned to the ECU based upon the air temperature.

CO adjustment
This system utilises an air bleed screw to trim the CO value. An air channel allows a small volume of air to by-pass the air flowing through the vane. As the by-pass is moved, the air volume acting upon the vane is altered and the vane moves its position. The changed position results in an altered signal to the ECU and a change in fuel volume injected.

CTS
The CTS is immersed in the coolant system and contains a variable resistance that operates on the NTC principle. When the engine is cold, the resistance is quite high. Once the engine is started and begins to warm-up, the coolant becomes hotter and this causes a change in the CTS resistance. As the CTS becomes hotter, the resistance of the CTS reduces (NTC principle) and this returns a variable voltage signal to the ECU based upon the coolant temperature.

The open circuit supply to the sensor from the ECU is slightly under nbv and this voltage reduces to a value that depends upon the resistance of the CTS resistance. Normal operating temperature is usually from 80° to 100° C. The ECU uses the CTS signal as a main correction factor when calculating ignition timing and injection duration.

TS
A throttle switch with dual contacts is provided to inform the ECU of idle position, deceleration, cruising and full-load (WOT)

conditions.

Voltage at nbv is applied to TS terminal 18 from the system relay under cranking or running conditions. The TS earth path is made through the ECU via terminals 2 and 3.

When the engine is at idle the idle contact (terminal number 2) is closed and the full-load contact (terminal number 3) is open. As the throttle is moved to the fully open position, the full-load contact closes and the idle contact becomes open. Under cruising conditions with a part-open throttle, both contacts are open.

AAV
The AAV is used in vehicles that do not have any form of idle speed regulation. A thermal valve or mechanical gate control valve is used to increase the idle speed during cold engine operation. The AAV is mounted in a hose that by-passes the throttle plate. The valve responds to temperature and allows extra air to by-pass the throttle when the engine is cold. Extra air entering the inlet manifold causes the idle speed to increase which prevents low idle speed and stalling with a cold or semi-cold engine.

During cold engine operation, the valve is open and so engine idle speed is increased. As the engine warms-up, the valve gradually closes until it is fully closed at normal operating temperature.

Essentially, there are two methods by which the AAV is opened: The valve may be opened by the rise in temperature of the coolant as the engine is warmed to operating temperature or the valve may be electrically opened.
coolant heated operation
The AAV is mounted in a by-pass hose carrying engine coolant. Once the engine has been started the thermal valve is heated by the rise in temperature of the coolant and slowly closes so that it is totally closed once the engine attains normal operating temperature. Radiated heat from the engine will affect valve operation, and allow the valve to remain closed when the engine is hot and is not being operated.
Electrical operation
The AAV resistance is connected to the relay output terminal. Once the engine has been started voltage is applied to the AAV resistance. The resistance is heated by voltage and the gate valve slowly closes so that it is totally closed once the engine attains normal operating temperature. Radiated heat from the engine will affect valve operation, and allow the valve to remain closed when the engine is hot and is not being operated.

Idle speed adjustment
A by-pass valve is provided that connects the inlet manifold to atmosphere. This allows a metered volume of air to by-pass the throttle and the valve may be adjusted to increase or reduce the idle speed.

CSV (LE and LE1 only)
The cold start valve is a special fuel injector connected to the fuel rail and mounted in the inlet manifold. In conjunction with the TTS, the cold start valve provides additional fuel during engine cranking with the engine cold. Unlike the system fuel injectors, which are pulsed open for a period of time determined by the ECU, the CSV is open continuously during cranking until cut-off by the action of the TTS.

The period of time that the injector operates is solely determined by the TTS which provides the earth path to the injector. Therefore, depending on engine temperature, the injector may not operate for the full cranking period.

Voltage to the CSV is applied from the starter circuit and is only available whilst the engine is being cranked.

TTS (LE and LE1 only)
The Thermo Time Switch provides the earth path to the CSV and is also energised by voltage applied from the starter circuit (only available whilst the engine is being cranked).

The TTS is immersed in the coolant passage and contains a heating element and a set of contacts that will open above a certain temperature. After several seconds cranking with a cold engine, and with the contacts initially closed, the voltage applied to the internal heater element will heat the contacts and cause them to open.

The time involved depends upon the coolant temperature and can be up to a maximum of 8 or 12 seconds in very cold conditions (depending on the type of TTS fitted). Under normal conditions, the time period may be from 1 to 3 seconds. When the engine is hot or semi-warm, the contacts may be open before cranking begins or open almost immediately. In this instance, little or no fuel is injected from the CSV. The cut-off temperature is either 35°C. or 15°C. (depending on type) and the change-over temperature will fall within ± 5°C. of this temperature.

Relays
The LE jetronic electrical system is controlled by a single tachometric system relay with one pair of contacts. The tachometric type relay is energised from a speed signal provided by the ignition system. Without the speed signal the relay will not function.

A permanent voltage supply is made to relay terminal 30 from the battery positive terminal. Once the ignition is switched on, voltage is applied to the fuel injection relay at terminal 15. When the engine is cranked upon the starter, cranking voltage is applied to relay terminal 50. The relay windings are energised, the relay contacts close and voltage is output at relay terminal 87 and 87b (sometimes labelled 87a). Voltage is thus applied to the ECU at terminal 9, the fuel pump, AFS, TS and AAV.

When the engine speed rises above 400 rpm, a speed signal to terminal 1 of the relay from the ignition coil terminal number 1 holds the relay contacts energised. If the engine speed falls below 400 rpm, the relay will be de-energised and the relay voltage output will cease. The engine will stop.

When the ignition is switched on, the relay winding is momentarily energised which closes the relay contacts and connects terminal 30 to terminal 87b or 87 (varies according to model), , thereby providing voltage to the fuel pump circuit.

After a moment the circuit opens and the pump stops. This brief running of the fuel pump allows pressure to build within the fuel pressure lines, and provides for an easier start.

The relay contacts will then remain open until the engine is cranked or run. Once the relay receives a cranking signal from the starter circuit, the winding will again be energised by the ECU, and the fuel pump will run until the engine is stopped.

Fuel pressure system
A roller type fuel pump, driven by a permanent magnet electric motor mounted close to the fuel tank, draws fuel from the tank and pumps it to the fuel rail via a fuel filter. The pump is of the 'wet' variety in that fuel actually flows through the pump and the electric motor. There is no actual fire risk because the fuel drawn through the pump is not in a combustible condition.

Mounted upon the armature shaft is an eccentric rotor holding a number of pockets arranged around the circumference - each pocket containing a metal roller. As the pump is actuated, the rollers are flung outwards by centrifugal force to act as seals. The fuel between the rollers is forced to the pump pressure outlet.

Fuel pressure in the fuel rail is maintained at a constant 2.5 bar by a fuel pressure regulator. The fuel pump normally provides much more fuel than is required, and surplus fuel is thus returned to the fuel tank via a return pipe. In fact, a maximum fuel pressure in excess of 5 bar is possible in this system. To prevent pressure loss in the supply system, a non-return valve is provided in the fuel pump outlet. When the ignition is switched off, and the fuel pump ceases operation, pressure is thus maintained for some time.

Fuel transfer pump
In some models a secondary in-tank fuel transfer pump aids the external pump. The internal fuel pump assembly comprises an outer and inner gear assembly termed a gerotor. Once the pump motor becomes energised, the gerotor rotates and as the fuel passes through the individual teeth of the gerotor, a pressure differential is created. Fuel is drawn through the pump inlet, to be pressurised between the rotating gerotor teeth and discharged from the pump outlet into the fuel supply line.

Fuel pressure regulator
The pressure regulator is fitted on the outlet side of the fuel rail and maintains an even pressure of 2.5 bar in the fuel rail. The pressure regulator consists of two chambers separated by a diaphragm. The upper chamber contains a spring which exerts pressure upon the lower chamber and closes off the outlet diaphragm. Pressurised fuel flows into the lower chamber and this exerts pressure upon the diaphragm. Once the pressure exceeds 2.5 bar, the outlet diaphragm is opened and excess fuel flows back to the fuel tank via a return line.

A vacuum hose connects the upper chamber to the inlet manifold so that variations in inlet manifold pressure will not affect the amount of fuel injected. This means that the pressure in the rail is always at a constant pressure above the pressure in the inlet manifold. The quantity of injected fuel thus depends solely on injector opening time, as determined by the ECU, and not on a variable fuel pressure.

At idle speed with the vacuum pipe disconnected, or with the engine stopped and the pump running, or at WOT the system fuel pressure will be approximately 2.5 bar. At idle speed (vacuum pipe connected), the fuel pressure will be approximately 0.5 bar under the system pressure.

Ignition system
The electronic ignition system fitted to BMW vehicles, equipped with the LE jetronic fuel injection system, comprises a conventional distributor used in conjunction with an inductive trigger and separate amplifier.

Inductive trigger
The primary signal to initiate both ignition and fuelling emanates from an inductive trigger mounted in the distributor. The inductive trigger consists of an inductive magnet that radiates a magnetic field. The distributor shaft incorporates a reluctor containing 4 or 6 lobes set at equal intervals.

As the distributor spins, and the reluctor lobes are rotated in the magnetic field, an AC voltage signal is generated to indicate the ignition point.

The peak to peak voltage of the signal (when viewed upon an oscilloscope) can vary from 5 volts at idle to over 100 volts at 6000 rpm. The amplifier converts the AC pulse into a digital signal.

Ignition operation
When the ignition is switched on, voltage is applied to the amplifier and the ignition coil. The circuit travels through the ignition coil primary windings to the amplifier switching connection. The circuit is then switched off to await a cranking or running signal. Although the circuit is complete, no current is applied until the amplifier pulses the coil to earth.

When the engine is cranked and during running conditions, the amplifier connects the coil negative terminal to earth and current passes through the coil primary windings. The coil begins to build a magnetic field. As the engine rotates and the inductive trigger signals the firing point, the amplifier turns off the coil negative circuit. Whilst the engine is running, the amplifier calculates the coil turn on time so that the correct dwell period is maintained.

The magnetic field in the coil primary windings quickly collapse, and a high voltage is induced in the coil secondary windings. The secondary output travels to the distributor cap via the main HT lead through the medium of the rotor arm. From the distributor, the secondary output is distributed to the correct sparkplug, in the firing order of the engine, via an HT lead.

Amplifier
The amplifier contains the circuitry for switching the coil negative terminal at the correct moment to instigate ignition. The signal received by the amplifier from the trigger is of an insufficient level to switch the coil. The signal is thus amplified by the amplifier to a level capable of switching the coil negative terminal. The amplifier used in this system may be supplied either by Bosch type or Siemens/ Telefunken. The two amplifiers are different in appearance, in circuitry and also in the way that they function.

Bosch
The Bosch amplifier receives the inductive trigger signal and switches the coil negative terminal to provide ignition. The coil switching wire is also connected to the system relay and to the injection ECU so that both components are directly connected to the coil negative signal.

Siemens
The Siemens amplifier also receives the inductive trigger signal and switches the coil negative terminal to provide ignition. The major difference is that a separate amplifier output wire is connected to the system relay and to the injection ECU so that both components are not directly connected to the coil negative signal. The Siemens module therefore provides two outputs. In addition, some modules are connected to the starting circuit so that a cranking signal input is received by the amplifier.

Dwell operation is based upon the principle of the `constant energy current limiting' system. This means that the dwell period remains constant at around 4.0 to 5.0 ms, at virtually all engine running speeds. However, the dwell duty cycle, when measured in percent or degrees, will vary as the engine speed varies. A current limiting hump is visible when viewing an oscilloscope waveform.

Ignition coil
The ignition coil utilises low primary resistance in order to increase primary current and primary energy. The amplifier limits the primary current to around 8 amps and this permits a reserve of energy to maintain the required spark burn time (duration).

Distributor
The distributor contains the inductive trigger and a mechanical advance and retard mechanism. A vacuum advance capsule is mounted upon the distributor body.

The distributor also contains secondary HT components (distributor cap, rotor and HT leads) and serves to distribute the HT current from the coil secondary terminal to each spark plug in firing order.

Ignition timing
Basic timing is set a few degrees before TDC and the value is calculated to provide efficient combustion and maximum power output at a particular speed.

As the engine speed increases, combustion must occur earlier and the ignition point is advanced by two mechanical weights that are flung out by centrifugal force. The weights are returned to their base position by the action of two springs. The distributor shaft assembly is comprised of two shafts, an outer and inner shaft. One shaft is fixed and the other is connected to the weights. As the weights move, the shaft moves to an advanced position.

Because the trigger is attached to the distributor shaft, the moment of trigger will also be advanced and thus the ignition timing is advanced. The amount and rate of advance is determined by spring tension and an advance stop that inhibits weight movement after a preset number of degrees of rotation.

In addition, a vacuum advance facility advances the timing under light throttle cruise condition to provide smooth and economical running. At small throttle openings, cylinder filling is much reduced and this small mixture is lightly compressed during the compression stroke. Modern engines run on lean air / fuel mixtures and the molecules of fuel are thinly spread. The mixture takes longer to burn and the spark must occur earlier.

Vacuum in the inlet manifold is high during light throttle operation and a hose connects the manifold with the distributor advance capsule. At engine speed over idle, vacuum is piped to the distributor advance capsule and acts upon the diaphragm. The advance capsule is connected to the distributor baseplate and pulls the baseplate to an advanced position when it is actuated. The timing is advanced under these conditions. The vacuum connection is arranged so that vacuum advance will not occur at idle, but only when the throttle plate has been slightly opened.

The marks provided on BMW vehicles are the actual base timing point. Base ignition timing is adjusted by turning the distributor in conjunction with a strobe light. When the marks are aligned at idle speed, the base ignition timing is correct.

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