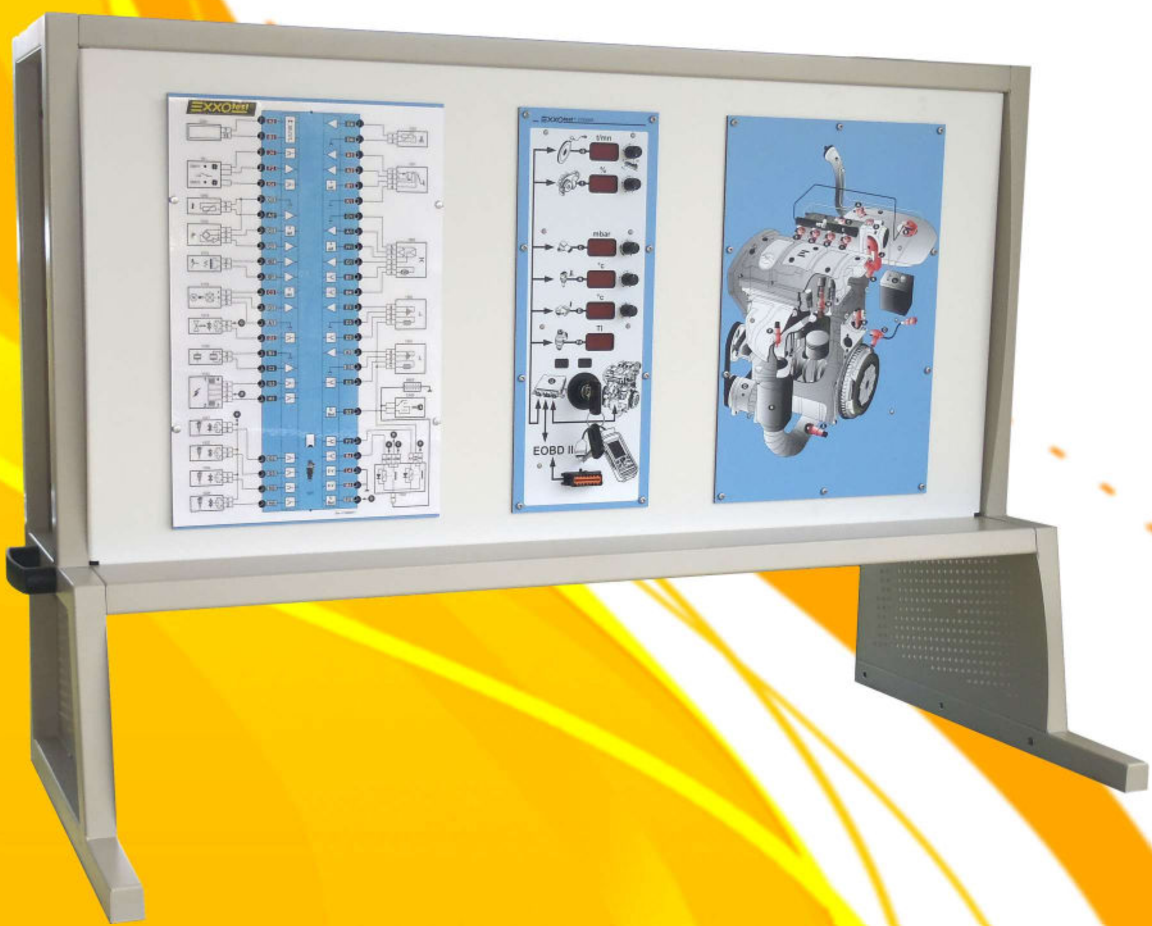
User's guide for MT-E5000

PHASED SEQUENTIAL PETROL INJECTION MODEL WITH ELECTRONIC THROTTLE CONTROL



EXXOTEST®
EDUCATION

DM : 00309241-v1

1. RESOURCES FILE

1.1. Bosch 7.4.4 Injection System

The ECU is equipped with a 112-pin connector.

The electronic control unit processes the information received from the various sensors and probes and uses it to perform the following functions:

Calculating injection time and phasing and controlling the injectors based on the following parameters

- Driver actions (accelerator pedal position sensor, cruise control)
- Torque requirement from other ECUs (automatic gearbox, air conditioning, stability control)
- Thermal condition of the engine (coolant thermistor)
- Mass of absorbed air (inlet air thermistor, inlet air pressure sensor and engine speed sensor)
- Engine running conditions: starting, idling, steady state, transient states, injection cutout and acceleration input speed (electronic throttle control, engine speed sensor, vehicle speed information)
- Richness control (two oxygen sensors for L4 depollution)
- Canister circuit purging (purge canister solenoid valve)
- Inlet pressure (inlet air pressure sensor)
- Battery voltage (battery)
- Knock detection (knock sensors)
- Position of the variable timing solenoid valves

Calculating the timing and controlling ignition based on the following parameters

- Engine speed (engine speed sensor)
- Cylinder reference (cylinder reference sensor)
- Inlet pressure (inlet air pressure sensor)
- Knock detection (knock sensor)
- Air conditioning compressor status (information from air conditioning ECU or pressure switch)
- Stability of idling and non-idling engine speed
- Cylinder 1 positioning (cylinder reference sensor)
- Cylinder 4 positioning (cylinder reference sensor)
- Thermal condition of the engine (coolant thermistor)
- Vehicle speed information (ABS or ESC ECU)
- Mass of absorbed air (inlet air thermistor, inlet air pressure sensor and engine speed sensor)
- Battery voltage (battery)
- Position of the variable timing solenoid valves

Managing the following internal functions

- Idling control (electronic throttle control)
- Fuel feed (fuel pump)
- Oxygen sensor heating
- Canister purging (purge canister solenoid valve)
- Maximum engine speed limitation by cutting out injection
- Torque compensation at full power steering lock (power steering fluid pressure switch)
- Variable timing
- Power latch (ECU power supply maintained after switching off ignition)
- Self-diagnostics

Managing the following external functions

- Engine speed information*
- Coolant temperature information*
- Coolant temperature warning information*
- Fuel consumption information
- Diagnostic indicator*
- Minimum fuel reserve**
- Dialog with after-sales diagnostic tools and regulatory tool
- Dialog with other ECUs (automatic gearbox, built-in systems interface, ESC)
- Engine immobiliser (electronic immobiliser)
- Engine cooling (fan unit control)
- Enabling air conditioning compressor activation (internal strategies)

* to the cluster via the built-in systems interface
** information from the built-in systems interface, specific to EOBD
(This information is used to disable misfire detection).

1.1.1. Operating Strategies

Starting phase

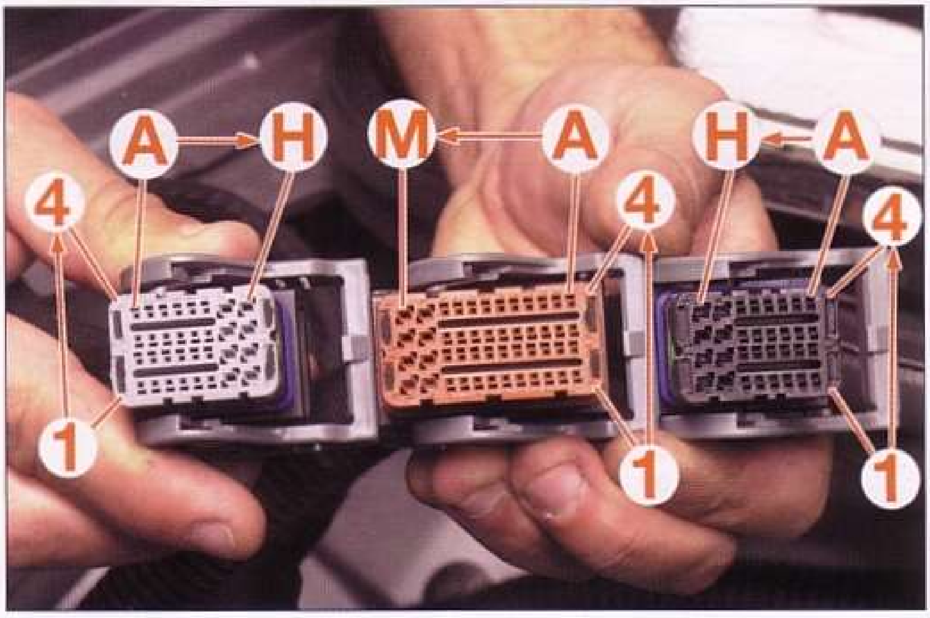
With the ignition on, the ignition-injection control unit (1320) supplies the injection multifunction double relay (1304) by grounding.

The supply relay and power relay making up the double relay (1304) are bonded simultaneously. The fuel gauge pump (1211) is supplied.

If the ignition-injection control unit (1320) does not receive starting information via the engine speed sensor (1313) within one second of the ignition being switched on, the power relay command is interrupted and the fuel pump stops running.

If the engine speed information from this sensor exceeds 20 rpm, the ignition-injection control unit (1320) keeps the power relay grounded.

To enable starting, the ignition-injection control unit (1320) needs to know the exact position of the engine to identify the cylinder in the compression phase. It uses the signal emitted by the cylinder reference sensor (1115) for this purpose. Recognition is carried out on all cylinders.



BROCHAGE DU CALCULATEUR DE GESTION MOTEUR

Correction in the starting phase

The ECU commands a constant periodic flow rate, via the injectors, during starting motor action. The quantity of fuel injected in asynchronous mode (not in phase with TDC) depends only on the following elements:

- Coolant temperature
- Atmospheric pressure

Once started (the engine is considered started from a speed defined on calibration), the engine receives a quantity of fuel injected in synchronous mode (in phase with TDC). This injected quantity varies constantly with:

- Changes in the engine temperature
- The pressure in the inlet manifold
- Engine speed

Idling speed is then managed by the electronic throttle control.

Driving comfort

The ignition-injection control unit (1320) manages all settings relating to driving comfort. During phases such as:

- Gear shift, either at the demand of the automatic gearbox (via CAN) or by depressing the clutch pedal (information from switch 7306)
- Deceleration, or on depressing the brake pedal (information relayed by switch 7308)
- Engine torque change request by the ESP ECU (via CAN)
- Cruise control. The ignition-injection control unit (1320) monitors cruise control when requested by the built-in systems interface; it also disables the function on use of the brakes (information relayed by switch 7308) or the clutch (information relayed by switch 7306).

The ignition-injection control unit (1320) adjusts the spark advance and the throttle valve position to determine the optimum torque required for driving comfort.

Operation in transient states

In transient states (acceleration or deceleration), the injection time calculation is corrected according to variations (in speed or amplitude) in the following information:

- Engine speed (engine speed sensor)
- Driver actions (accelerator pedal position sensor, cruise control)
- Throttle valve position information (electronic throttle control)
- Inlet pressure (inlet air pressure sensor)
- Coolant temperature (coolant thermistor)
- Inlet air temperature (inlet air thermistor)

Cutout on deceleration

On slowing down the engine (below a certain speed), when the throttle valve is closed (Foot Up position), the injection ignition ECU cuts injection to:

- Reduce fuel consumption
- Minimise pollution
- Prevent the catalytic converter temperature rising

Reaction to acceleration input

Reaction to acceleration input corresponds to the resumption of injection (after cutout on deceleration). The acceleration input speed is established at a higher speed than the idling setpoint. The definition of this speed will prevent stalling due to engine inertia on deceleration.

1.1.2. Power Latch (Maintaining ECU power supply after switching off ignition)

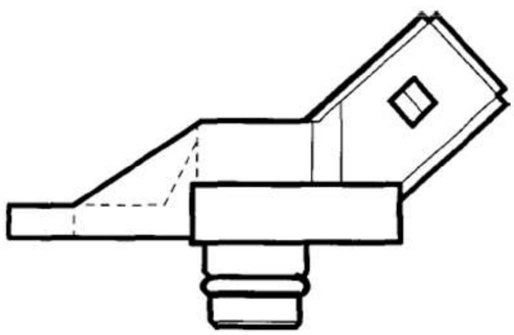
This function allows the ECU to manage the following parameters:

- Engine post-cooling (max. duration 6 minutes)
- Saving of the electronic throttle control teach-in parameters in the EEPROM (min. and max. stop)

The ignition-injection control unit (1320) has an EEPROM flash memory
On switching off the ignition, the ignition-injection control unit (1320) keeps the injection multifunction double relay (1304) for a minimum of 15 seconds. This time is necessary to save the new teach-in parameters since the ignition was last switched off.
Once these 15 seconds have elapsed, the ignition-injection control unit (1320) is no longer supplied; its consumption is zero.

1.1.3. Inlet Air Pressure Sensor

The pressure sensor constantly measures the pressure in the inlet manifold. This is a piezoresistive sensor (resistance varying in relation to pressure). It receives a 5 V supply from the ECU and, in return, delivers voltage proportional to the pressure measured.



Once this information has been transmitted to the ECU, the following actions are possible:

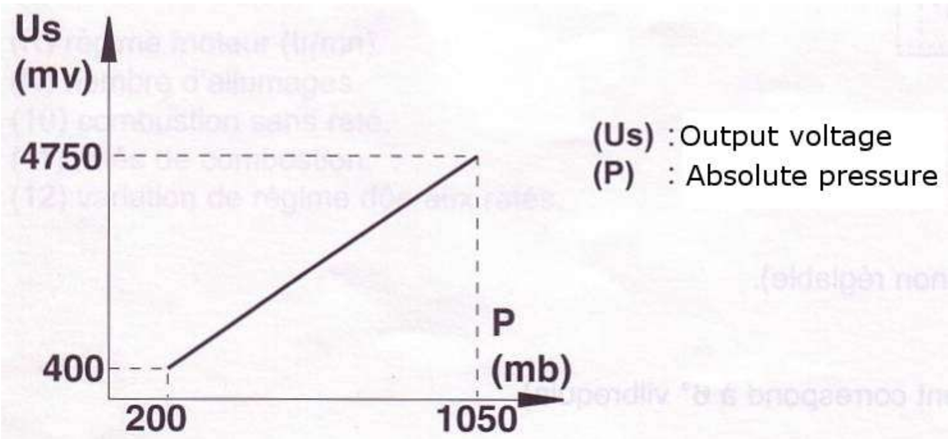
The injected flow rate can be adapted to the various engine load states to vary the spark advance.
An altimeter correction is also provided to calculate the injection time.

In fact, the mass of air absorbed by the engine varies with the following:

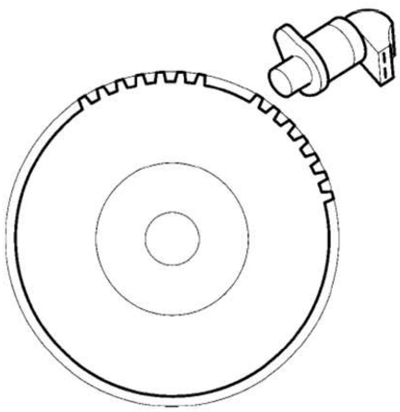
Atmospheric pressure (and, therefore, altitude)
Air temperature
Engine speed

Pressure is measured:

On ignition
At very high load and low speed (e.g. on climbing a mountain road, therefore with a change in altitude and atmospheric pressure)

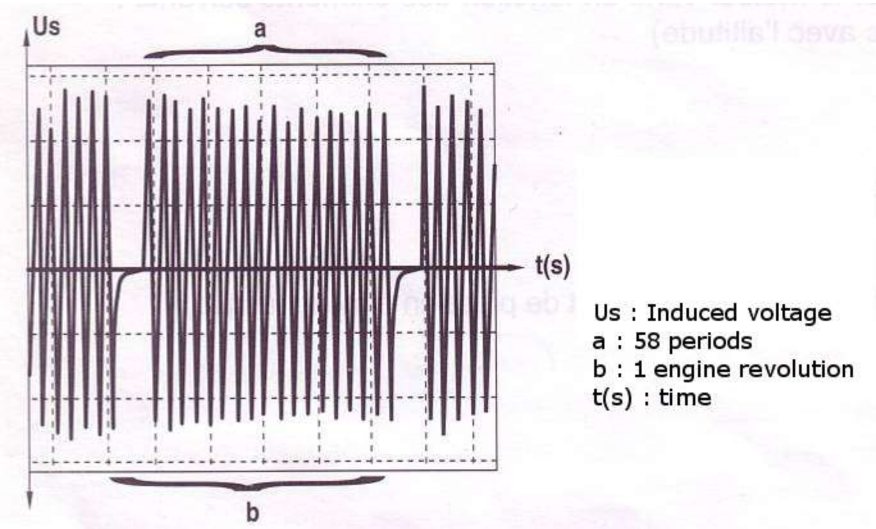


1.1.4. Engine Speed Sensor



The speed sensor consists of a magnetic core and a winding. It is placed opposite a 60-tooth ring gear from which two teeth have been removed to determine the TDC (Top Dead Centre) position.

A variation in the magnetic field is created as the flywheel teeth pass by the sensor. This variation induces an AC voltage in the winding (sine-wave signal). The frequency and amplitude of this signal are proportional to engine speed.



Sensor characteristics:

- Resistance = 390 Ω
- Gap = 1 mm ± 0.5 (not adjustable).

Ring gear characteristic:

- 60–2 = 58 teeth (one tooth corresponds to 6° on the crankshaft).

The speed sensor voltage is transmitted to the injection ECU and indicates:

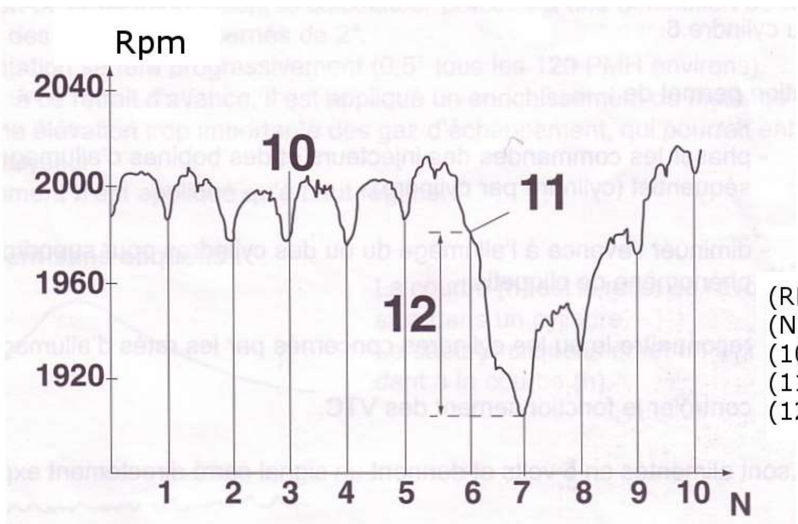
- The engine speed
- Sudden variations in speed

These variations in speed may be positive or negative, resulting from vehicle acceleration or deceleration. The ECU deduces poor road conditions from this information and disables the misfire diagnostic function.

This information allows the ECU to manage the states (engine stopped, engine started) and the various engine modes (acceleration, cutout, reaction to acceleration input, etc.).

The ECU detects possible misfiring via the engine speed sensor. Two accelerations corresponding to the two combustions should be recorded on the flywheel on each crankshaft rotation.

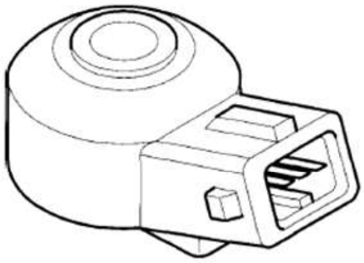
If acceleration is not detected, this represents a misfire. Misfiring lights up the diagnostic indicator; numerous misfires therefore cause it to flash.



(RPM) Engine speed
(N) Number of ignitions
(10) Combustion without misfiring
(11) Misfiring
(12) Engine speed variation due to misfiring

1.1.5. Knock Sensor

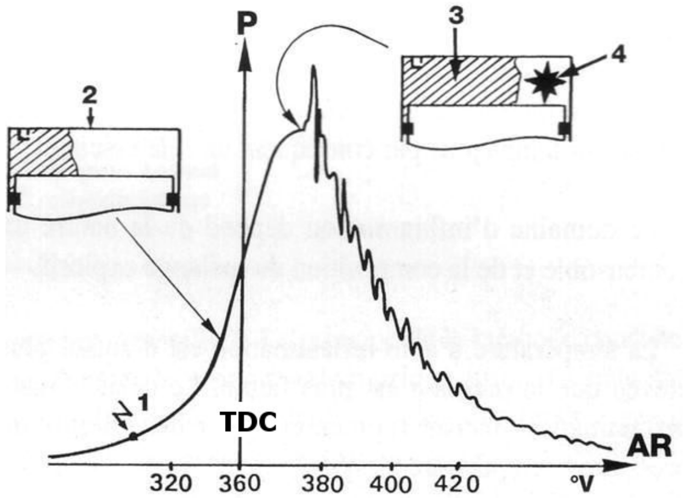
The piezoelectric knock sensor is mounted on the engine block.



Nature of the phenomenon:

Knocking is the instantaneous, massive self-ignition of the still unburned charge brought to high temperature and pressure by the movement of the piston and by the release of energy due to flame front propagation. A local increase in pressure ensues, followed by vibrations of the gaseous mass which balance out the pressure in the combustion chamber and thus create the characteristic knock. Due to cyclic dispersion, this phenomenon does not occur on each cycle.

The figure on the right shows a pressure diagram under knocking conditions. We firstly see a normal combustion phase; then intense vibrations appear and continue through a part of the expansion phase. The characteristic knock, corresponding to a frequency of 5000 to 10000 Hz, can easily be detected by an informed user. However, in some running conditions, particularly at high engine speeds, this noise becomes very difficult to distinguish from normal engine or vehicle noise. Physical detection methods – such as the examination of the pressure diagram, or the installation of vibration detectors – must then be used.



Pressure diagram with intense knocking
P: Pressure
AR: Crankshaft angle
1: Ignition point
2: 1st phase of normal combustion
3: burned gas
4: self-ignition

Knocking does not have any damaging effect if it occurs episodically and only concerns a small fraction of the gaseous mass.

However, prolonged intense knocking not only leads to unacceptable pressure loss, but also to abnormally high thermal and mechanical stress (very high local pressures reaching 180 bar) leading to engine damage.

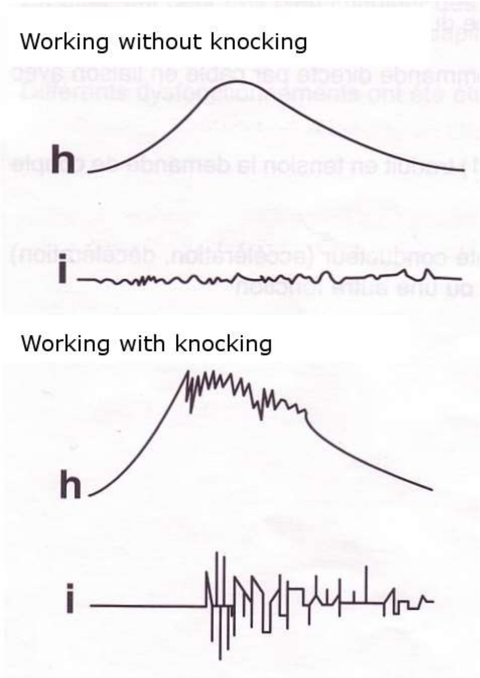
The various incidents encountered in the presence of destructive knocking (at full load and high engine speed) are, in order of occurrence and therefore of seriousness:

- Erosion of the combustion chamber (by cavitation)
- Cylinder head gasket deterioration or failure
- Piston ring land failure
- Pistons seizing or even fusing in the presence of violent knocking. In this case, a runaway phenomenon occurs.

Condition for occurrence

Knocking occurs if fresh gases are liable to self-ignite before being absorbed by the flame front as it propagates. The time factor therefore plays an essential role.

The explosion range depends on the nature of the fuel and the composition of the mixture. The lower the pressure, the higher the self-ignition temperature will be. Self-ignition time decreases rapidly at high temperature and pressure values.

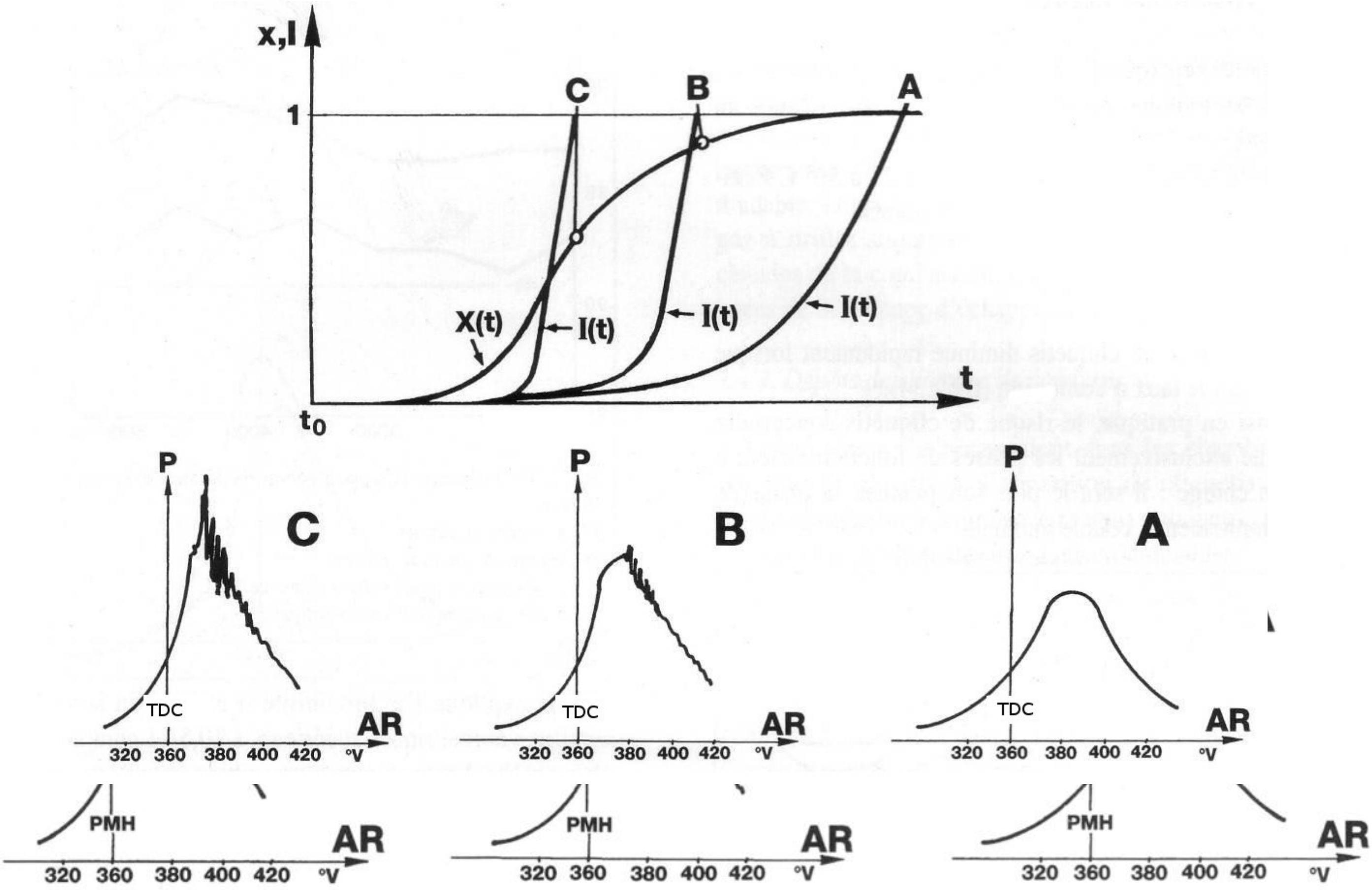


The curve (h) reflects the evolution of the pressure in a cylinder.
The knock sensor emits a signal (i) corresponding to the curve (h)

The signal (i) of the sensor is higher in intensity and frequency

Characterisation of knock tendency – Possible means

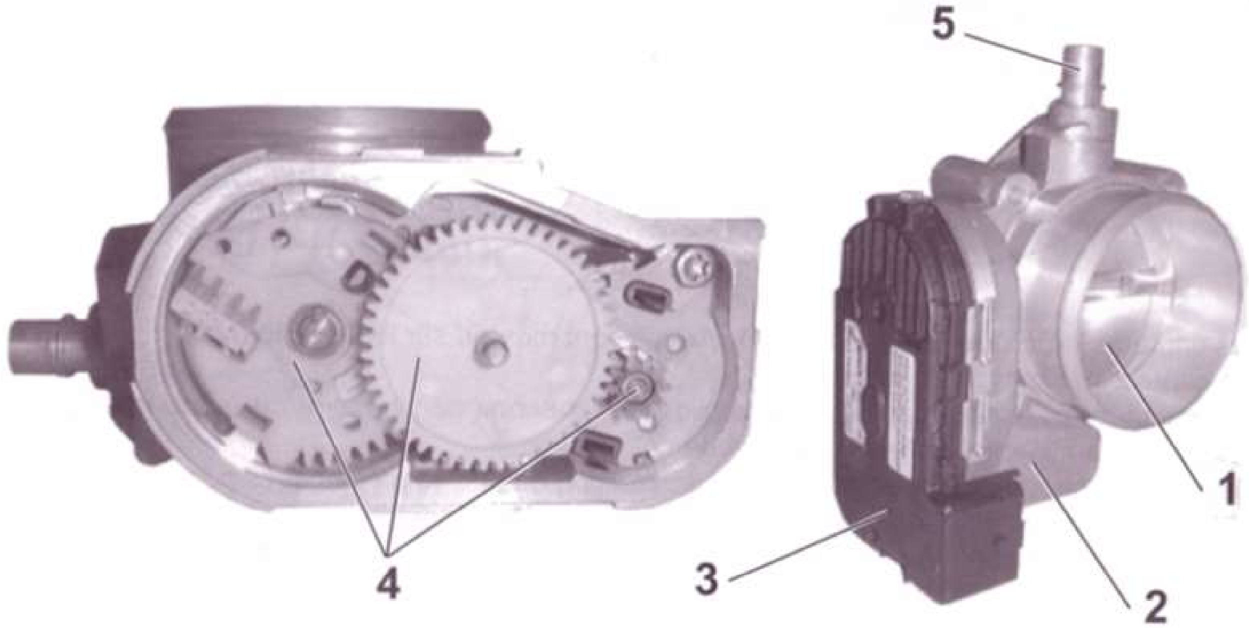
- Measuring the quantity of energy released by self-ignition: complexity of the measuring instruments
- Relative variation of a parameter (compression ratio, spark advance) having a major effect on knocking.
- Modifying the composition of the fuel causing knocking (notion of octane rating).
- This sensor delivers a voltage corresponding to the engine vibrations. After receiving this information, the ECU reduces the spark advance of the cylinder(s) concerned by 7°. It will then be gradually re-incremented (0.5° every 120 TDCs approximately).
- Along with reducing the spark advance, a richer air/fuel ratio is applied to avoid an excessive increase in exhaust gases which could lead to catalytic converter damage. Enrichment is only applied at high engine speed.



Conditions of occurrence of knocking.
X: Burnt burnt fraction
I : Integral of self-ignition time
P: Pressure
T: Time

AR: Crankshaft rotating angle
A: normal combustion (without knocking)
B: nascent knocking
C: Intense knocking

1.1.6. Electronic Throttle Control



- Throttle valve (1)
- Motor (2)
- Double-track throttle potentiometer (3)
- Drive gears (4)
- Positive crankcase ventilation inlet from engine (5)

Throttle opening is no longer directly controlled by a cable connected to the accelerator pedal. An accelerator pedal position sensor (1261) now translates the driver’s torque demand into voltage.

The ECU uses this voltage to manage the driver’s intentions (acceleration or deceleration) in the same way as the signal from another ECU or other function such as:

- Air conditioning
- Automatic gearbox
- ESC
- Cruise control
- Engine cooling

This new engine load management function enables engine torque to be managed efficiently. The throttle valve position is determined by the action of the motor which is itself controlled by the ECU. As idling is also managed by this motor, the idle control solenoid valve no longer exists.

The various engine modes are therefore managed by controlling the motor, making it possible to:

- Provide an additional air flow (cold starting)
- Regulate an idle speed, based on the thermal condition of the engine, the engine load, engine ageing, and consumers
- Improve the transient phases
- Improve return to idle condition (dashpot effect).

A double-track potentiometer positioned on the throttle valve spindle informs the ECU of the exact throttle valve position. This potentiometer is not adjustable. This information is used to identify the Foot Up and Foot Down positions. The electrical diagnostic and the backup modes have been designed to maximise driver safety.

- We can well imagine having electrical issues on the motor control and therefore not having the throttle valve opening indicated by the ECU. Various malfunctions have been studied in combination with backup modes:

Motor no longer activated (circuit open or short circuit)

The ECU will receive two inconsistent electrical signals:

- Driver actions (accelerator pedal position sensor)
- Throttle valve position (throttle valve position sensor).

The throttle valve is in the rest position. This rest position is not the position of the throttle valve when the engine is idling. In fact, unlike other systems not equipped with electronic throttle control, the throttle valve is not in a rest position on idling, but open approximately 8°.

On the other hand, when the throttle is no longer powered, it drops back to its mechanical stop – its rest position. In the event of failure in this position, and thanks to the shape of the throttle housing body, a sufficient air flow will enable the driver to “limp home” to a repair centre and not remain stranded by the roadside. In this case, the ECU will manage the flow rate of the injectors and the spark advance according to the driver’s actions to increase the engine speed and move the vehicle.

Throttle angle	0	2	4	6	8	10	15	20	25	30	35	40	45	50
Air flow kg/h	3.2	15.5	30.5	48	76	94	167	290	435	595	757	939	1116	1360

Throttle angle	55	60	65	70	75
Air flow kg/h	1620	1870	2150	2360	2770

Motor permanently activated (short circuit)

The ECU will receive two inconsistent electrical signals:

- Driver actions (accelerator pedal position sensor)
- Throttle valve position (throttle valve position sensor).

- In this case, the ECU will continue to accept the Driver actions information to manage the flow rate of the injectors and the spark advance, but will limit the engine speed to 1100 rpm.

Motor no longer activated according to driver actions

The ECU permanently monitors the information from the accelerator pedal position sensor and the information from the inlet air pressure sensor. The ECU can then ensure that the throttle valve position is consistent with the engine speed.

If inconsistency is detected, the ECU will then adopt a degraded mode (diminished engine performance). The diagnostic indicator on the instrument cluster lights up in this degraded mode.

One of the two tracks on the throttle valve position sensor is faulty (short circuit or circuit open)

The ECU will take the information from the track detected as correct. It will then adopt a degraded mode (diminished engine performance). The diagnostic indicator on the instrument cluster lights up in this degraded mode.

<u>Teach-in procedure</u>

A teach-in procedure is necessary for this system to work properly. The teach-in procedure consists in learning the maximum closed and open positions of the throttle valve.

This is to be done after:

Replacing the ECU
Replacing the electronic throttle
Repairing the electronic throttle as a result of fault detection
Downloading ECU files
Telecoding the ECU

Throttle control teach-in procedure

Reconnect the wiring harnesses
Switch on the ignition
Leave the ignition for at least ten seconds (do not switch off the ignition during this ten-second period and do not press the accelerator pedal)
Switch off the ignition and leave off for 15 seconds (the ignition-injection control unit saves the throttle control teach-in parameters on the EEPROM – this is the POWER LATCH phase).
Beware: Do not switch the ignition on again during this 15-second period.

IMPORTANT

If this teach-in procedure is omitted, the system cannot properly manage the engine torque according to the throttle valve opening. This is because the ECU does not know the exact maximum closed and open positions of the throttle valve.

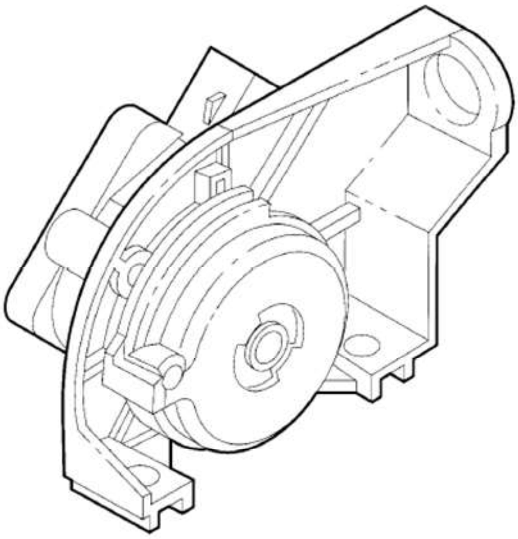
This engine malfunction will last until the ignition is switched off and the POWER LATCH sequence ended (minimum duration of 15 seconds).

Throttle position teach-in is also conducted automatically during the engine's life to overcome wear on the minimum throttle valve stop. The ECU does this by systematically comparing the minimum throttle valve stop stored in the memory with the one measured during the sequence. If this value differs by *x* mV, the ECU will conduct a teach-in.

-

1.1.7. Accelerator Pedal Position Sensor

The pedal sensor is installed in the engine compartment and linked to the accelerator pedal by a cable. The sensor has a double contactless potentiometer.



It receives a 5 V supply from the ECU and transmits to the ECU two variable voltages reflecting how far the accelerator pedal is depressed. One of these voltages is twice the other.

The ECU manages this information in the same way as the signal from another ECU or other function such as:

- Air conditioning
- Automatic gearbox
- ESC
- Cruise control
- Engine cooling

The ECU will manage the following strategies based on these various “consumers”:

- Idling
- Acceleration
- Deceleration
- Injection cutout
- Transient states

When the engine is started, throttle valve opening is preprogrammed to a specific position if the driver’s action is below this threshold.

Teach-in procedure

A teach-in procedure is necessary for this system to work properly. This procedure consists in learning:

- The rest position of the pedal sensor so that the accelerator pedal rest position is known
- The maximum position of the pedal sensor so that the accelerator pedal fully down position is known

The accelerator pedal position sensor teach-in procedure is to be done after:

- Replacing the ignition-injection control unit
- Replacing the accelerator pedal position sensor
- Repairing the accelerator pedal position sensor as a result of fault detection
- Downloading ignition-injection control unit files
- Telecoding the ignition-injection control unit

Pedal sensor teach-in procedure

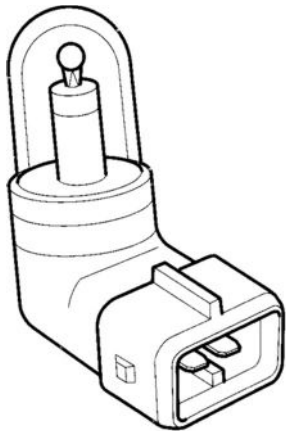
- Accelerator pedal at rest
- Switch on the ignition
- Depress the accelerator pedal fully
- Release the accelerator pedal
- Start the engine without accelerating

IMPORTANT

If this teach-in procedure is omitted, the ECI will not know:

- The exact rest position of the pedal sensor in relation to the accelerator pedal rest position
- The exact fully down position of the pedal sensor, information that is needed to manage the driver’s torque demands.

1.1.8. Inlet Air Temperature Sensor

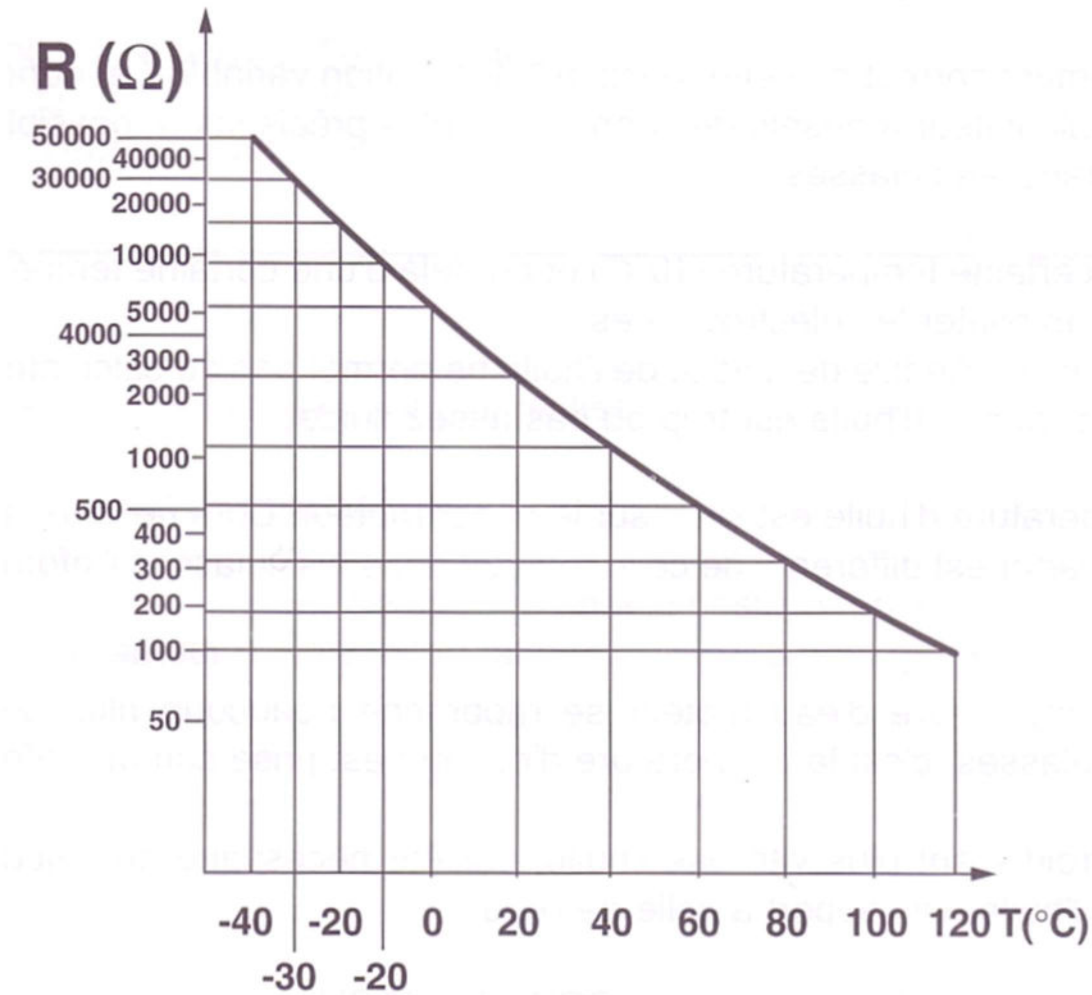


Installed between the electronic throttle housing and the air filter, the inlet air temperature sensor (thermistor) receives a 5 V supply from the ignition-injection ECU.

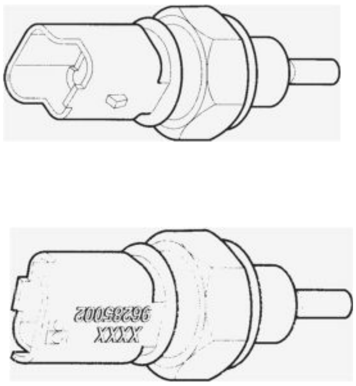
This thermistor informs the ECU of the temperature of the air admitted by the engine.

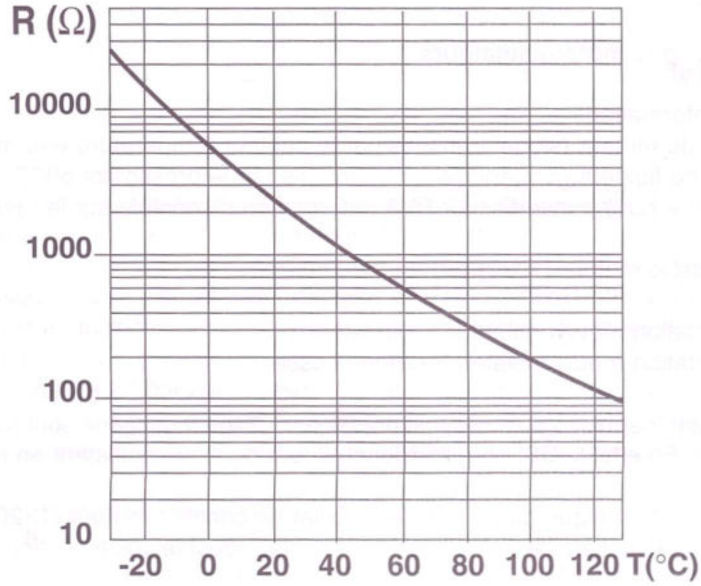
The ECU uses this information and the engine speed and inlet pressure information to calculate the mass of air absorbed.

The electrical resistance of this NTC (negative temperature coefficient) thermistor falls as the temperature rises.



1.1.9. Coolant Temperature Sensor

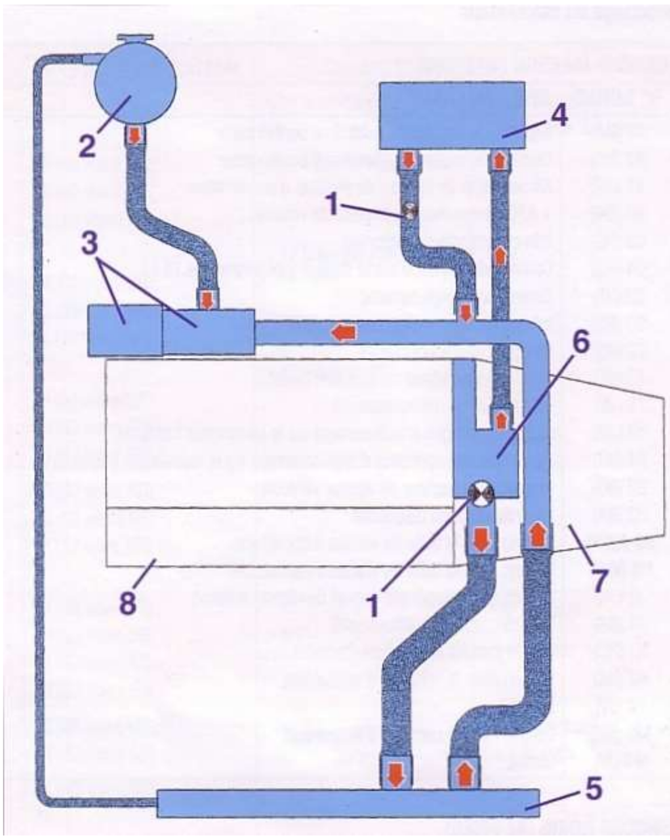




Installed on the water outlet unit, the coolant temperature sensor (thermistor) receives a 5 V supply from the ECU.

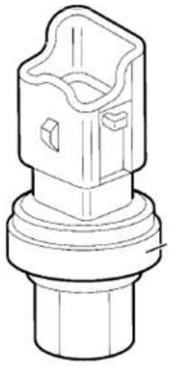
This thermistor informs the ECU of the water temperature in the cooling circuit, and therefore of the engine's thermal condition.

The electrical resistance of this NTC (negative temperature coefficient) thermistor falls as the temperature rises.



COOLING CIRCUIT DRAWING :
1 : drain screw
2 : expansion tank
3 : water pump
4 : passenger compartment radiator
5 : engine radiator
6 : thermostat
7 : gearbox
8 : engine

1.1.10. Pressure Switch



Positioned on the vehicle's air conditioning system, the pressure switch transmits a voltage proportional to the pressure of the refrigerant to the ignition-injection ECU. The information is used to enable or disable the activation of the air conditioning compressor and to control electric fan speed.

Depending on the vehicle, a linear or three-function pressure switch is used.

1.1.11. Electric Fan Control

Depending on the following information:

- Thermal condition of the engine (signal transmitted by the coolant thermistor 1220)
- Refrigerant pressure (signal transmitted by pressure switch 8007)
- Automatic gearbox converter oil temperature (information available on the CAN)

The ignition-injection control unit (1320) controls:

- The low-speed fan supply relay
- The high-speed fan supply relay

The thermal condition of the engine and refrigerant pressure information is available on the CAN. The BSI manages fan activation at medium speed.

Depending on the thermal condition of the engine, the ignition-injection control unit (1320) ensures post-cooling by maintaining the supply to the injection multifunction double relay (1304).
This controls the low-speed fan supply relay.

Fan (1510) activation parameters

Low speed – the fan is activated if either of the following conditions is met:

- Coolant temperature from 96 to 102°C in the temperature rise phase or down to 94°C in the temperature fall phase, then the fan is stopped.

- Refrigerant pressure from 11 to 17 bar in the pressure rise phase or from 14 to 8 bar in the pressure fall phase, then the fan is stopped.

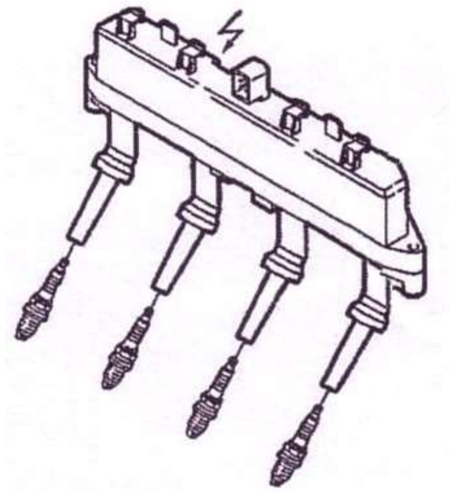
High speed – the fan is activated if either of the following conditions is met:

- Coolant temperature from 102 to 120°C in the temperature rise phase or down to 99°C in the temperature fall phase, then the fan is switched to low speed (controlled by the ignition-injection ECU).

- Refrigerant pressure from 17 to 22 bar in the pressure rise phase or from 18.5 to 14 bar in the pressure fall phase, then the fan is switched to low speed (controlled by the BSI).

Post-cooling (low speed)
It is triggered after switching off the ignition if the coolant temperature is over 105°C.

1.1.12. Ignition Coil



The ignition is of twin static type with a compact coil unit and no high-voltage leads. The compact coil unit comprises two coils with high-voltage outputs located directly above the spark plugs. Each coil comprises a primary winding linked to a secondary winding. Each secondary output is directly connected to a spark plug. This technology improves ignition quality.

The ECU has two power stages and controls each coil primary winding alternately.

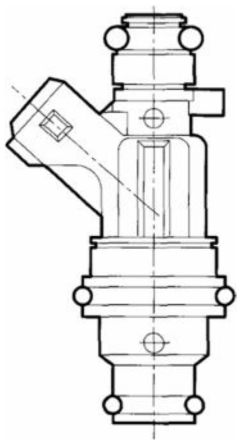
The engine speed and crankshaft position information allows the ECU to control the two primary windings at the right time and in the correct order.

The spark advance is controlled by the ECU based on mapping. The main parameters of this mapping operation are the **engine speed** and the **inlet pressure**

Ignition sequence 1 - 3 - 4 - 2

1.1.13. Injectors

With the pressure held constant at 3.5 bar in the common rail by the pressure regulator, the quantity of petrol is controlled only by the injection time.



The injectors are of the twin-jet type and supplied with 12 V power. They are controlled by grounding once per camshaft rotation. The ECU controls the injectors separately by earthing them in the order 1-3-4-2 when the inlet valves are closed. These controls are enabled by the reference information for cylinders 1 and 4.

This is known as “sequential injection”. The amount of fuel injected depends on the injector opening time (“injection time”).

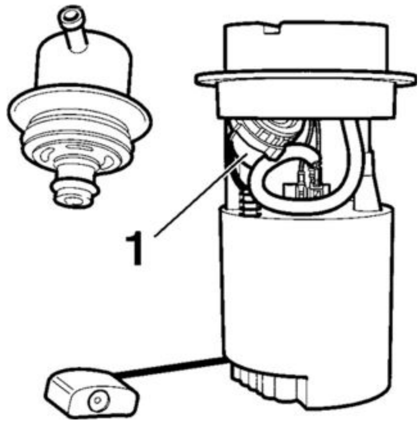
Electrical pulses from the injection ECU generate a magnetic field in the electromagnet’s winding, the core is attracted and the injector’s tip raises off its seat.

The winding’s resistance is approximately 14.5 ohms. The returnless rail-type fuel injection system has no reference in relation to the inlet pressure. The injection time is therefore corrected according to the inlet pressure. This correction is integrated into the enrichment strategies and the correction due to battery voltage.

1.1.14. Pressure Regulator

Depending on the vehicle, it is located:

- either on the fuel pump bracket (1),
- or next to the fuel pump on the tank.



This new location allows a “returnless” injection rail to be installed. In this type of assembly, the regulator is no longer dependent on the engine vacuum. This used to be the case to maintain a constant pressure difference between the upstream and downstream areas of the injector and to always have the same flow rate for a given injection time.

This link has been replaced by a different calculation of the injection time, taking into account the information from the inlet air pressure sensor.

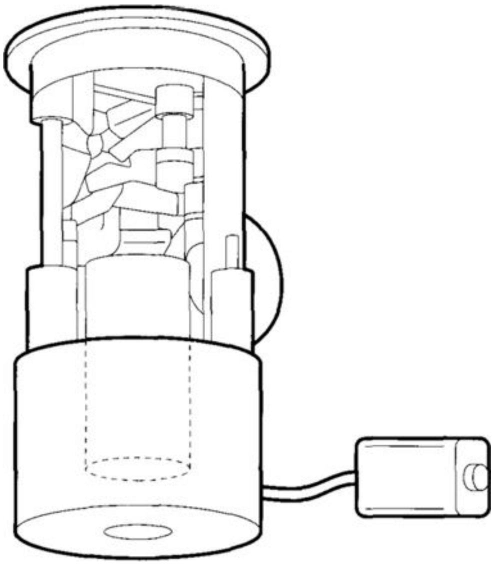
The purpose of this regulator is to maintain:

- a supply pressure during engine operation,
- a residual pressure, when the engine is off for a certain length of time.

The purpose of maintaining a residual pressure is to make it easier to restart the engine when warm by preventing the formation of a vapour lock. This is because, at a certain temperature, there is a risk of bubbles forming in the fuel circuit leading to poor fuel atomisation.

This residual pressure is 3.5 bar.

1.1.15. Fuel Pump



The Bosch EKP 10 or Marval in-tank fuel pump delivers approximately 150 litres per hour.

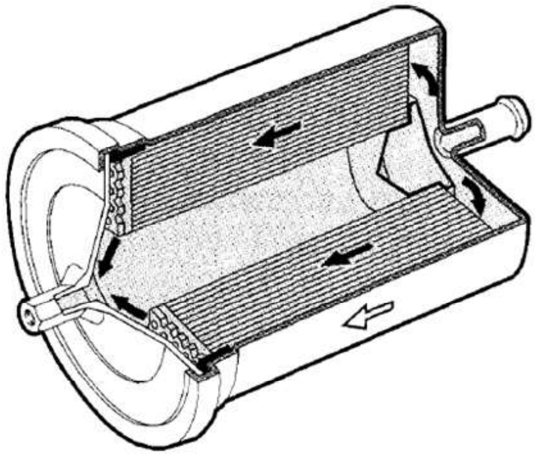
The pump output is greater than engine requirements to avoid creating a fall in feed pressure when the engine requirement is suddenly increased (acceleration).

A non-return valve is integrated into the pump to maintain a residual pressure for the same reasons as the pressure regulator. The ECU controls the injection multifunction double relay (1304) (power relay R1) by grounding as soon as the engine speed exceeds 20 rpm.

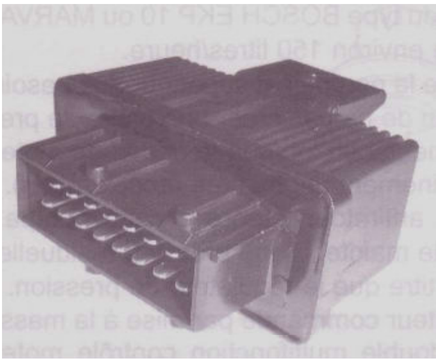
1.1.16. Fuel Filter

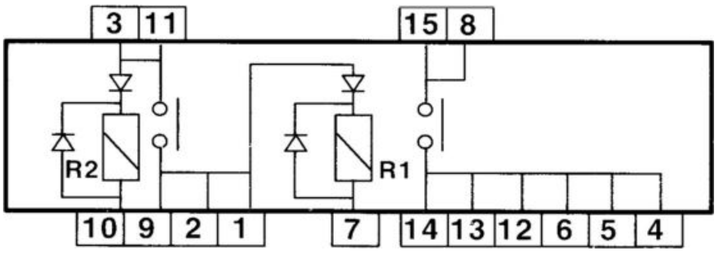
It is located between the pump and the injection rail. This filter contains a paper cartridge with a filtration level of 8–10 microns. The filter has a surface area of approximately 3000 cm² (i.e. approximately 55x55 cm) and is designed to filter any impurities from the fuel.

Ensure the filter is fitted in the direction of fuel flow as indicated by an arrow on the filter body.



1.1.17. Multifunction Double Relay





R1: Power relay **R2: Supply relay**

The main supply to the system is by means of a double relay, which provides three operating states:

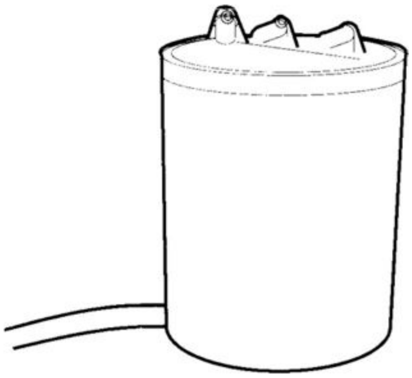
Ignition on: power to certain system components such as the injectors, the ignition coils, the fuel pump, the purge canister solenoid valve, the variable timing solenoid valves, the oxygen sensor heating elements and the ignition-injection ECU is maintained for one second, and is then cut off if the engine is not running (no engine speed signal).

Engine running: the above-mentioned components are powered.

After the ignition is switched off: the power supply to the ignition-injection ECU is maintained for at least 15 seconds via supply relay R2. This allows the ECU to manage engine cooling and the teach-in of the throttle valve maximum closing and opening positions.

1.1.18. Canister Reservoir

The canister contains an activated carbon filter. It is located between the fuel tank and the purge canister solenoid valve.



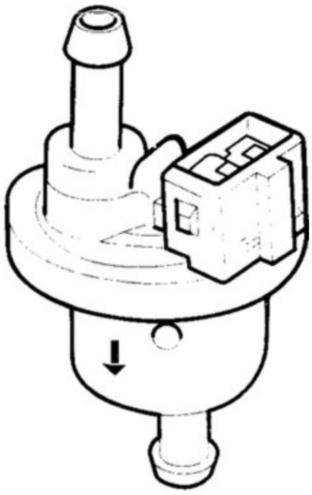
The fuel vapours in the fuel tank are absorbed by the activated carbon.

Absorption helps avoid:

- Pressure increases in the fuel tank
- Vapour release into the atmosphere (through recycling by then engine).

1.1.19. Purge Canister Solenoid Valve

The purge canister solenoid valve is located between the canister and the throttle housing. It receives a 12 V supply from and is controlled by the ECU. The purge canister solenoid valve is used to recycle the fuel vapours contained in the canister reservoir, depending on the engine operating conditions. For example:



- The canister is purged at full load
- When decelerating, the canister is not purged to avoid an excessive dashpot effect.

The solenoid valve control is of the PWM (pulse width modulation) type. This is a normally closed solenoid valve, which means that it is closed when it is not energised.

This type of solenoid valve complies with the SHED environmental standard which aims to limit emissions of fuel vapours into the atmosphere when the vehicle is stationary (engine off).

The fuel vapours contained in the canister are recycled downstream of the throttle.

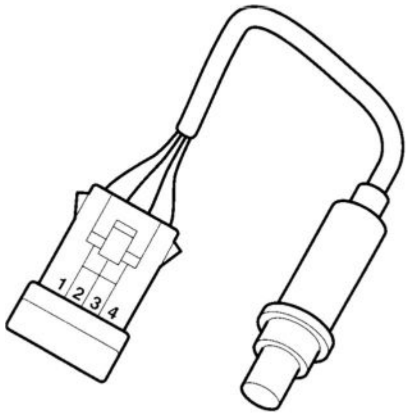
1.1.20. Upstream Oxygen Sensors

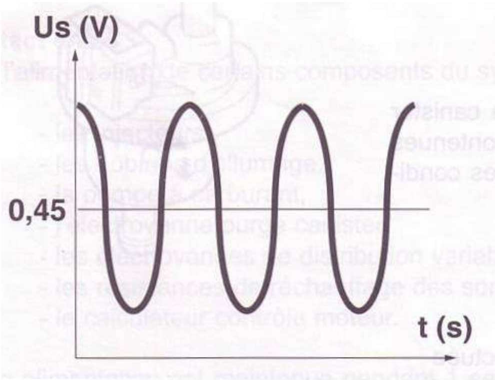
Note:

In the case of K' depollution, upstream oxygen sensors are the only type necessary.

These sensors are installed on the exhaust, at the inlet to the catalytic converter and permanently supply a voltage indicating the oxygen content of the exhaust gases (combustion quality) to the ECU.

These voltages are analysed by the ECU and are used to correct the injection time. The system is therefore in a closed loop. The signal varies from 0.1 Volt to 0.9 Volt for normal operation.





(Us) : Output voltage
(t) : Time

Rich mixture :
- Sensor voltage : approx. 0.9 Volt

Poor mixture :
- Sensor voltage : approx 0.1 Volt

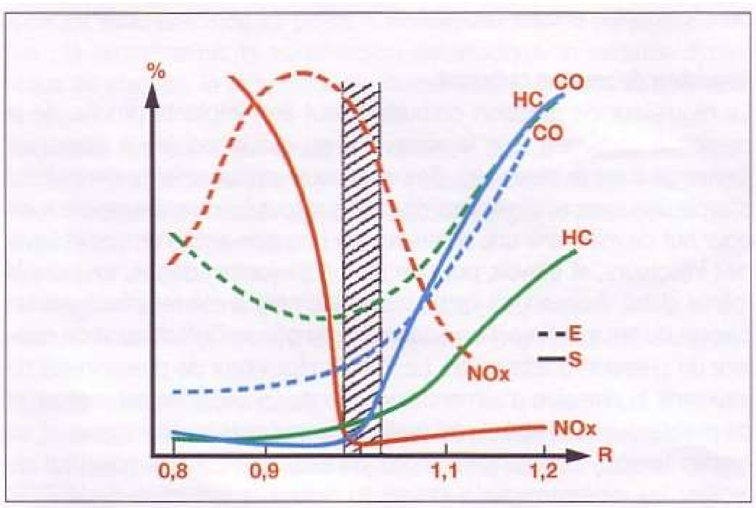
An internal heating device brings the sensor quickly up to its operating temperature – in excess of **350°C** in this case.

The heating element is activated by the ECU which controls its temperature. When the exhaust gas temperature is over 800°C, the oxygen sensor is no longer activated.

In some engine running phases, the system operates in an “open loop”, i.e. the ECU ignores the signal supplied by the sensor.

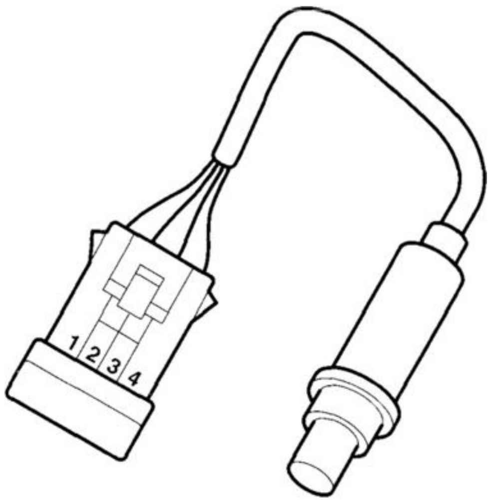
These phases are, for example:

- when the engine is cold (temperature less than 20°C)
- at high engine load.



View of the various gases burned during catalysis

1.1.21. Downstream Oxygen Sensor



In the case of L4 depollution, two types of oxygen sensor are required:

- Upstream oxygen sensor
- Downstream oxygen sensor

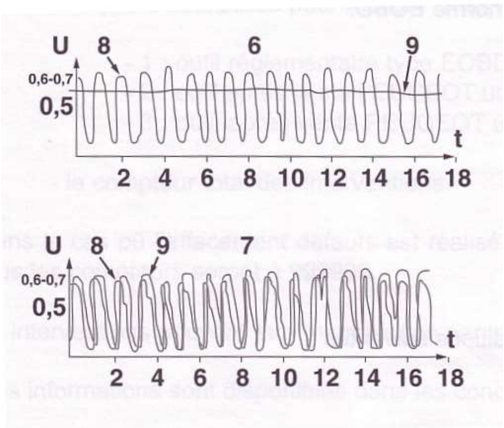
The upstream and downstream sensors have identical characteristics.

The sensor heating device is strictly identical to the one for the upstream sensor. Only the length of the wires differs.

This sensor is installed on the exhaust, at the catalytic converter outlet, and permanently supplies a voltage indicating the oxygen content of the exhaust gases (and hence combustion quality and catalytic converter efficiency) to the ECU.

This voltage is analysed by the ECU and is used to correct the injection time and deduce the efficiency of the catalytic converter.

The signal must vary very little for normal operation.



(t) : Time
(U) : Voltage (direct and alternative)
(6) : Catalytic converter in good condition
(7) : Defective catalytic converter
(8) : Upstream sensor signal
(9) : Downstream sensor signal

Impact of depollution standard L4

Depollution standard L4 is stricter than standard L3 on two main points:

- Pollutant emissions
- The control cycle for homologation

This standard mainly focuses on pollutant emissions with a cold engine. The injection systems as previously designed cannot comply with this standard, meaning that new ECU strategies and new components are necessary.

Principles adopted to comply with this depollution standard:

Optimise the efficiency of the catalytic converter in the cold phase (faster catalyst light-off)
Sequential injection

New components:

Downstream oxygen sensors
Specific ignition-injection ECU

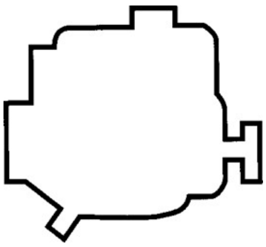
Differences on the diagnostic aspect:

Diagnostic strategies
Backup mode
Operation of the injection/ignition test indicator

1.1.22. Injection/Ignition Test Indicator (for L4 Depollution)

The operation of the diagnostic indicator differs from the known procedure for ECUs not complying with depollution standard L4. On the other hand, the symbol is strictly identical. It is designed to warn the driver when the regulatory gas emissions limit is exceeded.
The driver must then take the vehicle to a repair centre immediately.

Indicator operation



Ignition off
The indicator is out.

Ignition on, engine off
The indicator is lit.

Engine running
No permanent major fault:
If ignition has been on for more than three seconds before the engine starts, it will go out immediately.
If ignition has been on for less than three seconds before the engine starts, it will go out after three seconds.

Presence of a permanent major fault with the indicator lit

The indicator will remain lit to warn the driver.
It will go out when this fault successfully passes three diagnostic sequences.

Presence of a permanent major fault with the indicator flashing

The indicator will flash after misfiring to warn the driver (risk of irreversible catalytic converter damage).
It will go out when this fault successfully passes three diagnostic sequences.

2. USER FILE

2.1 User and Instruction Manual

Installing and starting up benchtop learning model MT-E5000

Turn the ignition key to position St, and connect the model to the 230 V mains supply (check the position of the power supply switch on the side of the model)

Then actuate the control buttons (key switch) to operate the system as indicated in the user manual supplied with model MT-E5000.

There are no moving parts on the MT-E5000.

Environment

Learning model MT-E5000 can be placed on a bench if you do not have the optional MT-TABLE.

It must be installed in a dry place away from dust, steam and combustion fumes.

To allow correct use, the box requires approximately 400 to 500 lux of lighting.

The machine may be placed in a practical exercise room. Its operating noise level does not exceed 70 decibels.

The simulator is protected against potential user error.

Calibrating and maintaining model MT-E5000

Calibration: factory setting.

Maintenance frequency: none.

Cleaning: use a very soft, clean cloth with a window cleaning product.

Number of work stations and position of user

Model MT-E5000 is a single work station.

The model user will stand throughout the practical exercise.

Lockout/Tagout procedure

Turn the ignition key to position St.

Unplug from the 230 V supply.

Check that there is no current by turning the ignition switch to “Start” – if nothing happens, then there is no current.

Remove the ignition key and place it in a lockable cabinet.

Check that the rear covers are fitted.

Store model MT-E5000 in a secure room while out of use.

Residual risk

The trainer is the only person authorised to access the rear of the model.

For the entire duration of the practical session, the trainee shall work on the front of the model.

Transporting model MT-E5000

The model must be switched off and disconnected before transport. Ensure that nothing is left on the shelves.

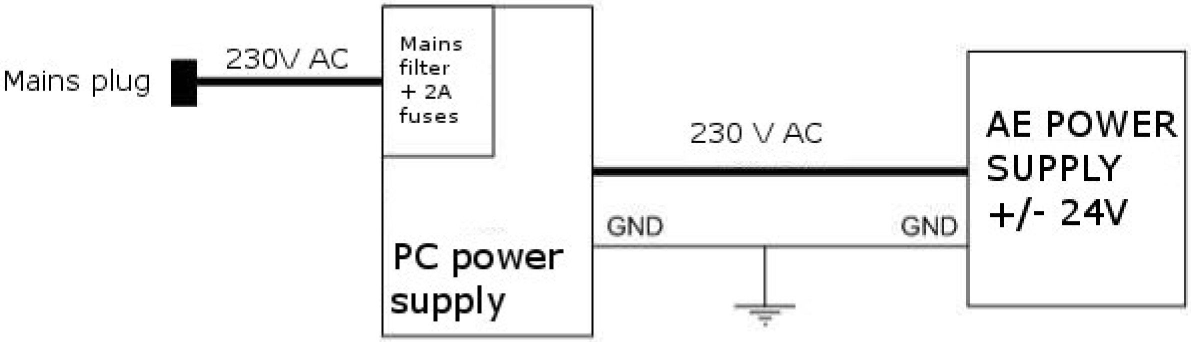
At least two people wearing safety footwear and protective gloves, and using the handles provided, are required to carry the model.

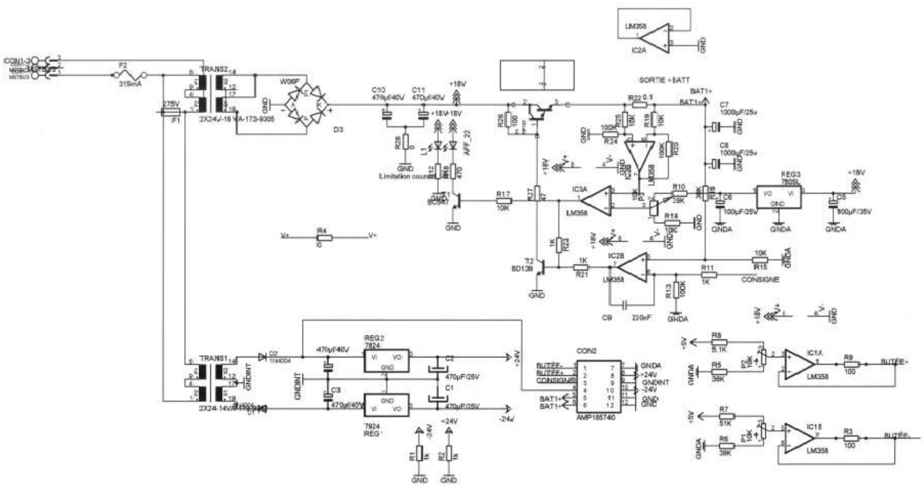
2.1.1. Side View of Model MT-E5000

The two rear panels are removable (for internal access). They are held closed by the side locks.

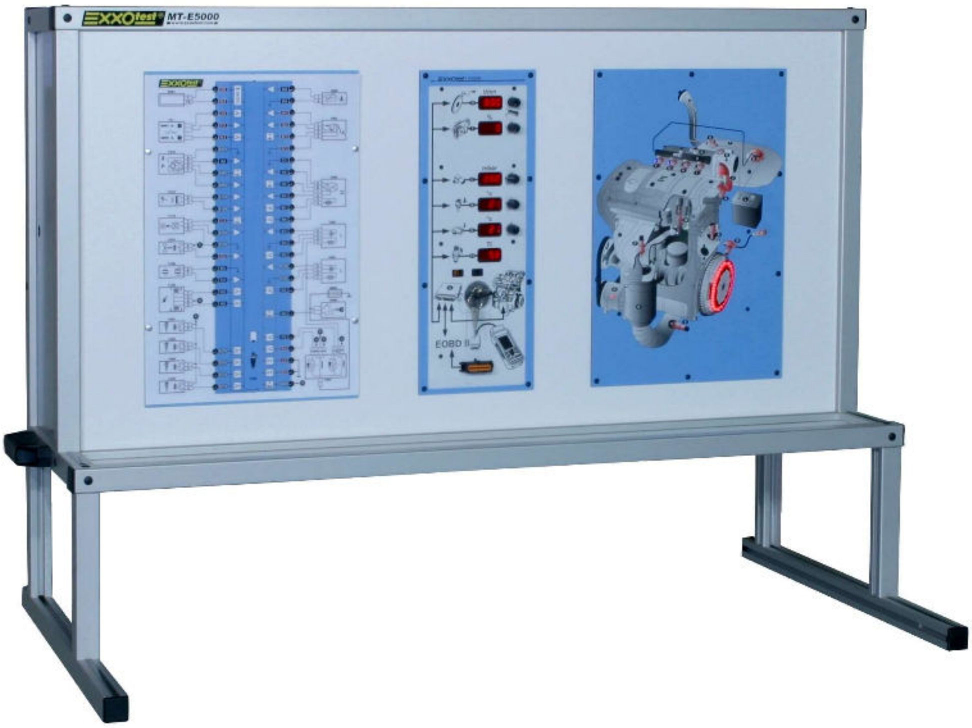
A handle on each side is used to carry the model.

Wiring diagram of 230 V part



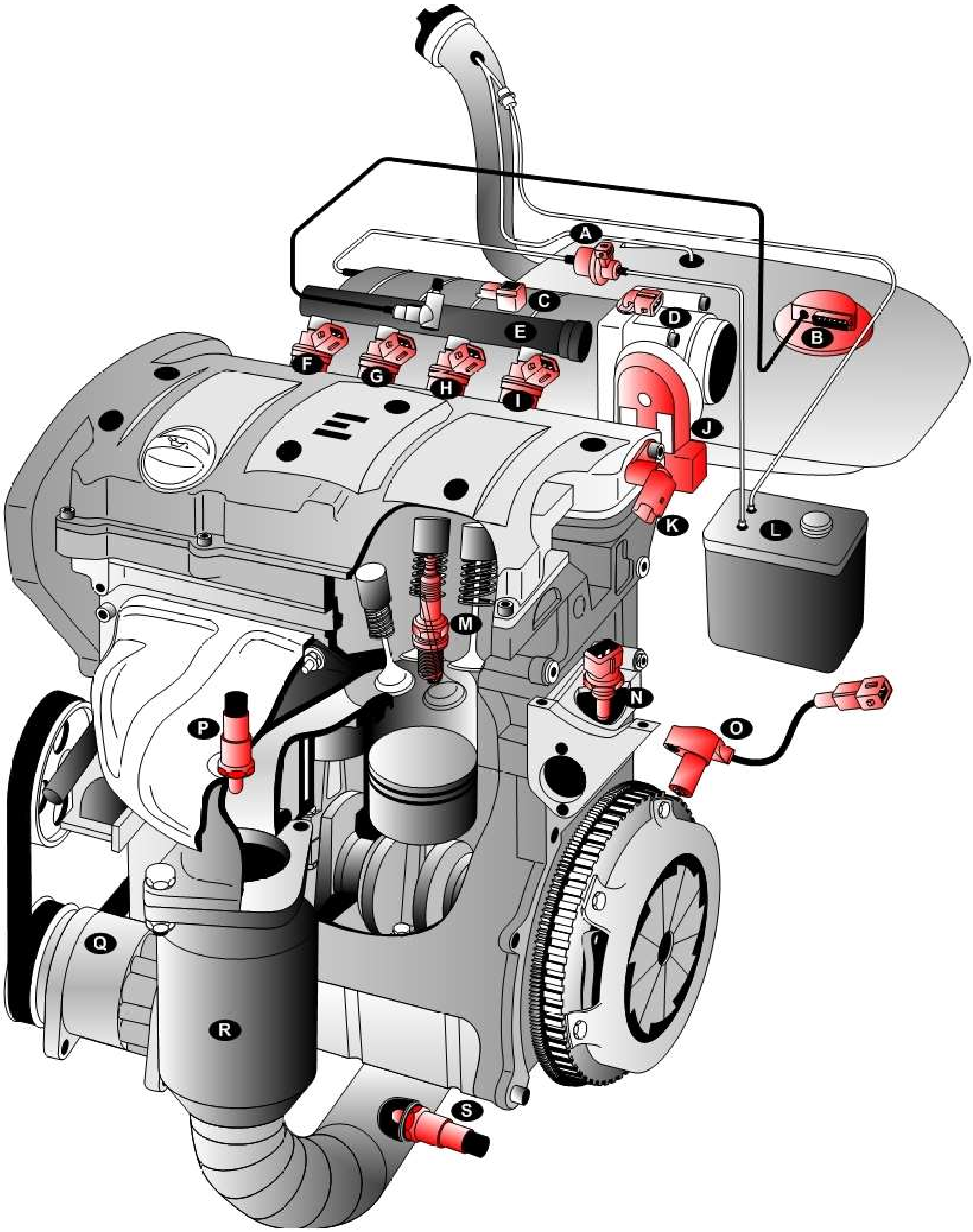


2.1.2. Presentation of Model MT-E5000

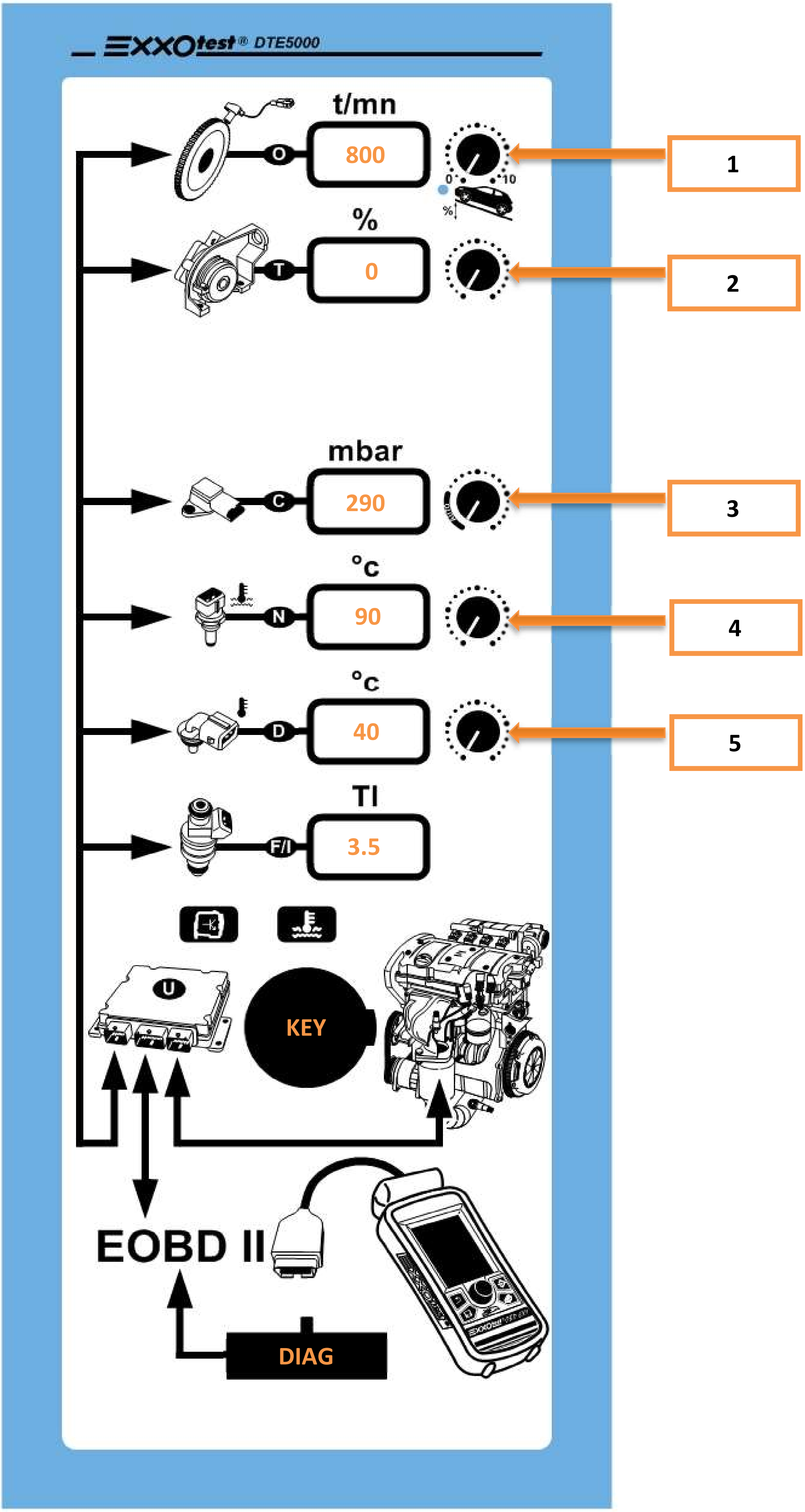


The Exxotest® CL 550 reader is supplied with the MT-E5000

2.1.3. Petrol Engine Illustration (Right Panel)



Ref.	Description
A	Purge canister solenoid valve
B	Fuel pump, pressure regulator and petrol gauge
C	Inlet manifold pressure sensor
D	Air temperature sensor
E	Injection rail
F	Injector 4
G	Injector 3
H	Injector 2
I	Injector 1
J	Electronic throttle control
K	Phase (camshaft position) sensor
L	Canister reservoir
M	Cylinder 1 spark plug
N	Coolant temperature sensor
O	Engine speed sensor
P	Upstream oxygen sensor
Q	Air conditioning compressor
R	Catalytic converter
S	Downstream oxygen sensor

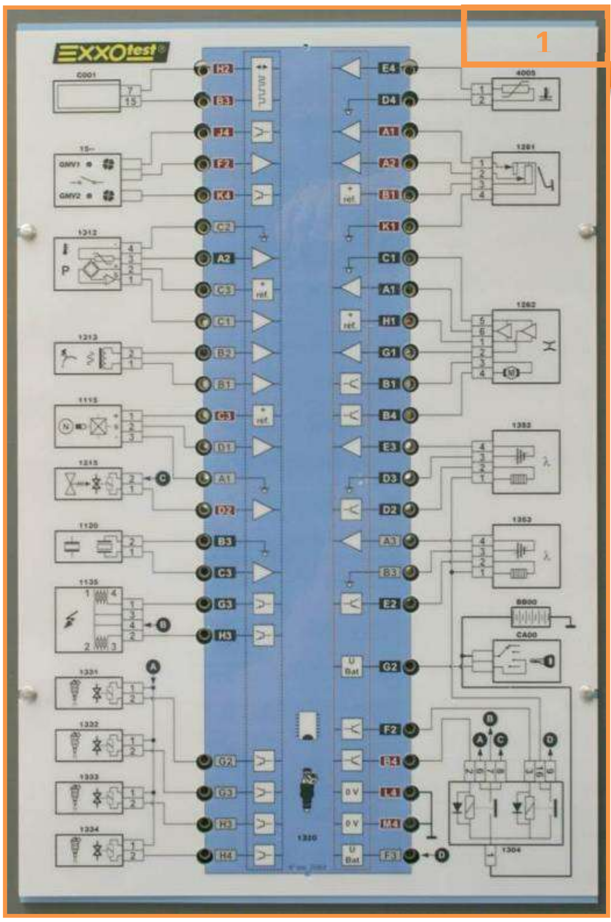

EXXOtest® DTE5000
t/mn
800
0
10
%
%
0
mbar
290
°c
90
°c
40
TI
3.5
KEY
EOBD II
DIAG
1
2
3
4
5

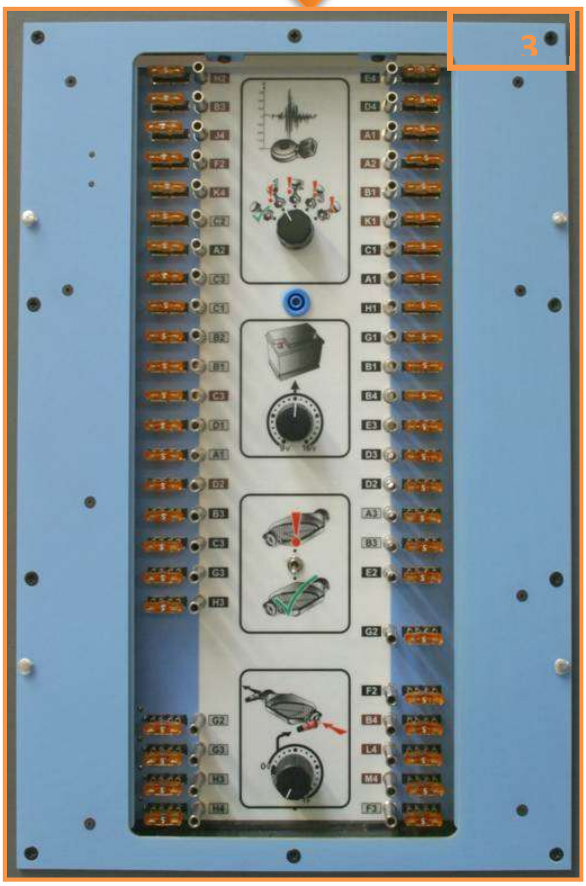
Ref.	Description
O	Engine speed in rpm (engine speed sensor 1313)
T	Accelerator pedal position shown as % (potentiometer sensor 1261)
C	Inlet manifold pressure in mbar (pressure sensor 1312)
N	Engine coolant temperature in °C (thermistor 1220)
D	Inlet air temperature in °C (thermistor 1240)
F/I	Injection time in ms (injector grounding time)
U	Ignition-injection control unit (1320)

Ref.	Description
1	Simulation of road profile from 0 to 10% (uphill)
2	Accelerator pedal variation (driver demand)
3	Inlet manifold pressure variation
4	Coolant temperature variation
5	Air temperature variation

Ref.	Description
	Engine management fault indicator
	High coolant temperature warning (temperature over 118°C)
CLE¶	Key switch (ignition and starting)
DIAG¶	16-pin EOBD II connector, for diagnostics tool

2.1.4. Ignition-Injection Control Unit (Left Panel)

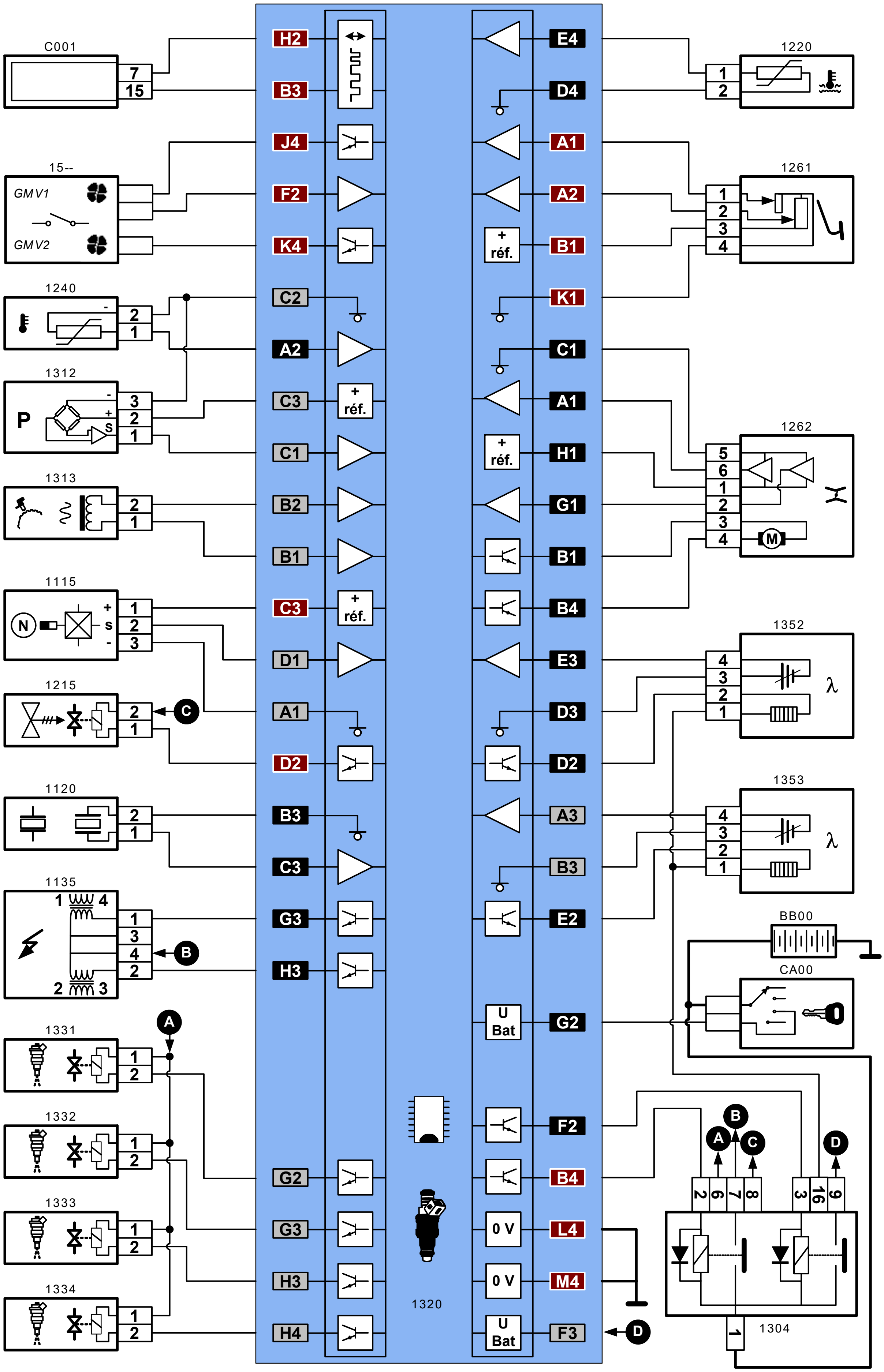




1 Flexible fascia with schematic representation, component number and PSA terminal number.

2 A blue panel lies beneath the flexible fascia with the channel numbers and a lock for access to the fuses and faults.

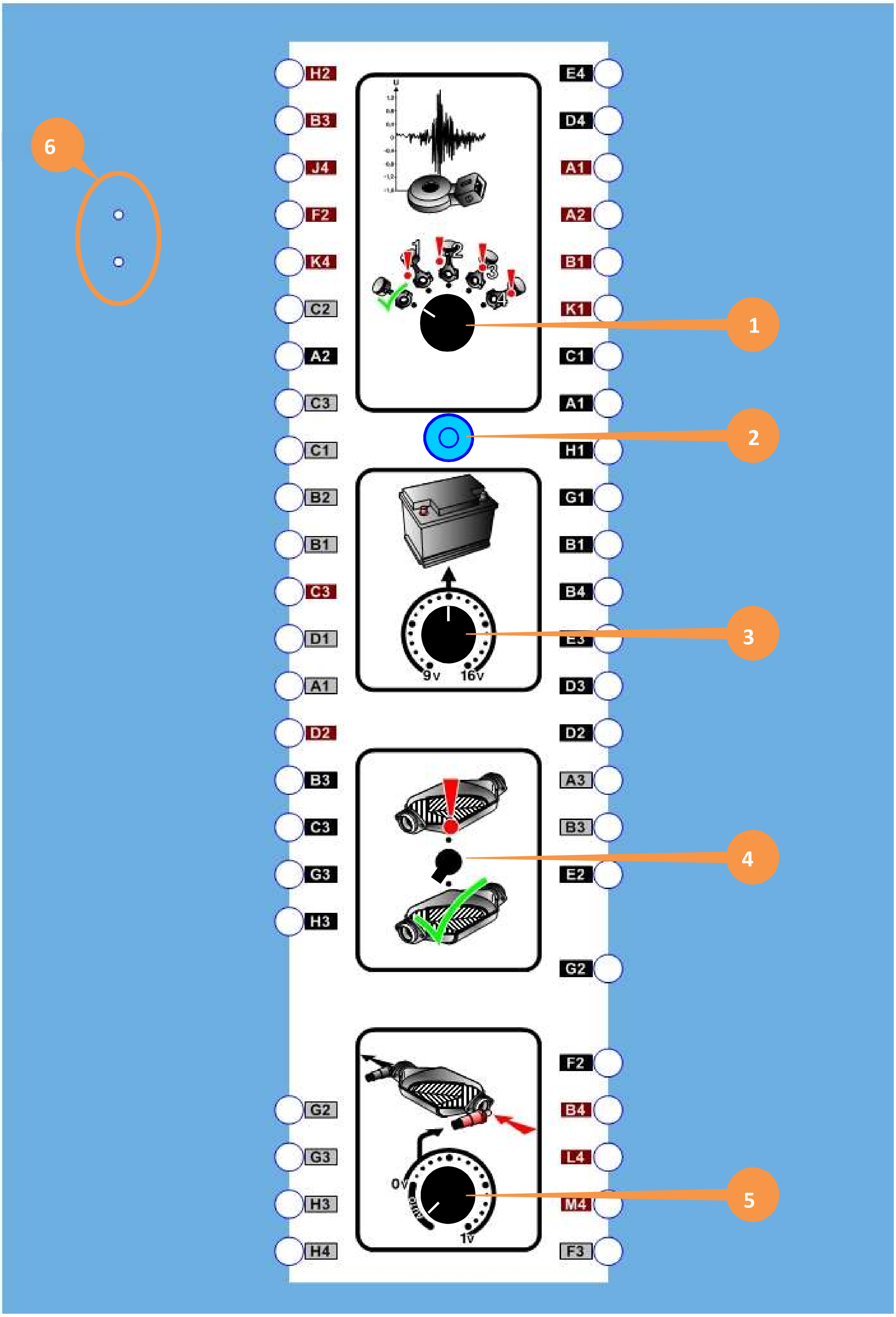
3 Inside face of the left side of the model with access to the fuses and scheduled faults.


C001
15--
GMV1
GMV2
1240
1312
P
1313
1115
N
1215
1120
1135
1331
1332
1333
1334
1220
1261
1262
M
1352
λ
1353
λ
BB00
CA00
1304
1320
réf.
U Bat
0 V
H2
B3
J4
F2
K4
C2
A2
C3
C1
B2
B1
C3
D1
A1
D2
B3
C3
G3
H3
G2
G3
H3
H4
E4
D4
A1
A2
B1
K1
C1
A1
H1
G1
B1
B4
E3
D3
D2
A3
B3
E2
G2
F2
B4
L4
M4
F3
A
B
C
D

Parts list

Reference	Description
BB00	Battery
C001	Diagnostic connector
CA00	Ignition switch
1115	Cylinder reference sensor
1120	Knock sensor
1135	Ignition coil
1215	Purge canister solenoid valve
1220	Coolant thermistor
1240	Inlet air thermistor
1261	Accelerator pedal potentiometer sensor
1262	Electronic throttle control
1304	Injection multifunction double relay
1312	Inlet manifold pressure sensor
1313	Engine speed sensor
1320	Ignition-injection control unit
1331	Injector cylinder 1
1332	Injector cylinder 2
1333	Injector cylinder 3
1334	Injector cylinder 4
1352	Downstream oxygen sensor
1353	Upstream oxygen sensor
15..	Fan

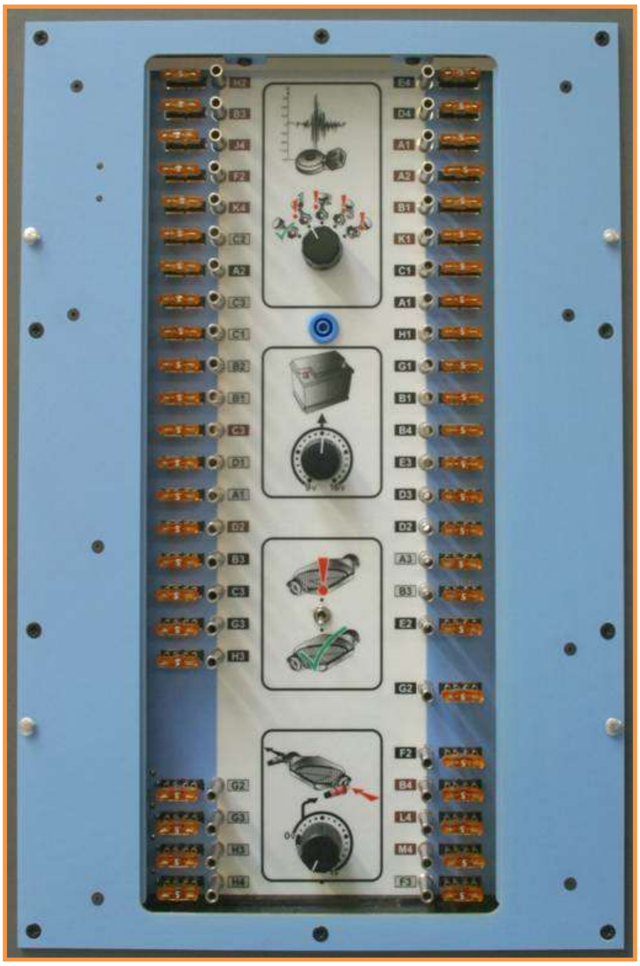
2.1.5. ECU Inside Face



Parts list

Ref.	Description
1	Selector simulating knock on one of the four cylinders.
2	This socket delivers a square-wave signal for oscilloscope synchronisation. The trailing edge corresponds to the TDC of cylinders 1 and 4, and the leading edge to the TDC of cylinders 2 and 3.
3	Potentiometer simulating battery voltage from 9 V to 16 V.
4	Switch simulating catalytic converter failure.
5	Potentiometer simulating voltage across terminals of upstream oxygen sensor
6	Fan 1 and Fan 2 control LEDs

2.1.6. Generating Faults



Faults can be generated in two different ways:

Change of parameters using the potentiometers or selectors described above.

Clean break on one or more of the ECU terminals: removal of one or more protective fuses.

Fault code management

EXXOtest OBD-EX1 conducts comprehensive diagnostics on the model in compliance with EOBD standards.

The device monitors the good working order of the model in real time via the **'Instant data'** menu which provides a view of the signals and their variations.

It can also be used to read and erase fault codes.

All the codes are EOBD standards defined in SAE J2012.

EOBD codes managed by the model

Description		EOBD code
Upstream oxygen sensor	Low voltage	P0131 Fault indicator lit
	High voltage	P0132 Fault indicator lit
Downstream oxygen sensor	Low voltage	P0137 Fault indicator lit
	High voltage	P0138 Fault indicator lit
Throttle valve sensor	Track A low voltage	P0122 Fault indicator lit
	Track A high voltage	P0123 Fault indicator lit
	Track B low voltage	P0222 Fault indicator lit
	Track B high voltage	P0223 Fault indicator lit
Double-track pedal sensor	Track A low voltage	P0122 Fault indicator lit
	Track A high voltage	P0123 Fault indicator lit
	Track B low voltage	P0222 Fault indicator lit
	Track B high voltage	P0223 Fault indicator lit
Electronic Throttle Control	Controlled throttle valve open	P0507 Fault indicator lit
Inlet pressure sensor	Low voltage	P0107 Fault indicator lit
	High voltage	P0108 Fault indicator lit
Coolant thermistor	Low voltage	P0117 Fault indicator lit
	High voltage	P0118 Fault indicator lit
Battery voltage	Low voltage	P0112 Fault indicator lit
	High voltage	P0113 Fault indicator lit
Canister solenoid valve	By detection of self-induction	P0500 Fault indicator lit

Description	Terminals	Failure	Symptom	EOBD code
DIAG connector	H2 and B3 BN	Fuses disconnected	None	No code
Fan 1 command 96°C<temp.<102°C	J4 Brown	Fuse disconnected	Water indicator lit. Fan 1 malfunction	No code
Fan return signal	F2 Brown	Fuse disconnected	Water indicator lit Fan 1 and Fan 2 in normal operation	No code
Fan 2 command 102°C<temp.<120°C	K4 Brown	Fuse disconnected	Water indicator lit. Fan 1 running but not Fan 2	No code
Air thermistor	C2 GY, A2 BK	Fuses disconnected	Fault indicator lit Degraded mode at 65°C	P0113
Manifold pressure sensor	C3 and C1 GY	Fuses disconnected	Fault indicator lit No variation with potentiometer, but still variation bound to engine speed, degraded mode: throttle angle / engine speed	P0107
Engine speed sensor	B1 and B2 GY	Fuses disconnected	Fault indicator lit Engine off or starting impossible	P0335
Camshaft sensor	C3 BN, D1 and A1 GY	Fuses disconnected	Fault indicator lit. Starting impossible	P0340
Purge canister solenoid valve	D2 BN	Fuse disconnected	No solenoid valve control	No code
Knock sensor	B3 and C3 BK	Fuses disconnected	No signal	No code
Ignition coil 1 and 4	G3 BK	Fuse disconnected	Fault indicator lit Cutout of injectors 1 and 4	P0351
Ignition coil 2 and 3	H3 BK	Fuse disconnected	Fault indicator lit Cutout of injectors 2 and 3	P0352

Injector 1	G2 GY	Fuse disconnected	Fault indicator lit Cutout of injector 1	P0201
Injector 2	G3 GY	Fuse disconnected	Fault indicator lit Cutout of injector 2	P0202
Injector 3	H3 GY	Fuse disconnected	Fault indicator lit Cutout of injector 3	P0203
Injector 4	H4 GY	Fuse disconnected	Fault indicator lit Cutout of injector 4	P0204
Coolant thermistor	E4 and D4 BK	Fuses disconnected	Fault indicator lit Water indicator lit Degraded mode at 95°C Fan 1 and Fan 2 running	P0118
Double-track pedal sensor	A1 BN	Fuse disconnected	Fault indicator lit Normal operation (acceleration and deceleration)	P0223
	A2 BN	Fuse disconnected	Fault indicator lit. Normal operation (acceleration and deceleration)	P0123
	A1 and A2 BN	Fuses disconnected	Fault indicator lit Degraded mode at 800 rpm No acceleration	P0223 and P0123
	B1 BN	Fuses disconnected	Fault indicator lit Degraded mode at 800 rpm No acceleration	P0223 and P0123
	K1 BN	Fuses disconnected	Fault indicator lit Degraded mode at 800 rpm No acceleration	P0223 and P0123
Electronic throttle	C1 BK	Fuses disconnected	Fault indicator lit Degraded mode at 800 rpm	P0223 and P0123

control			No acceleration	
	H1 BK	Fuses disconnected	Fault indicator lit Degraded mode at 800 rpm No acceleration	P0222 and P0122
	A1 BK	Fuses disconnected	Fault indicator lit Normal operation	P0223
	G1 BK	Fuses disconnected	Fault indicator lit Normal operation	P0123
	A1 BK and G1 BK at same time	Fuses disconnected	Fault indicator lit Degraded mode at 800 rpm No acceleration	P0223 and P0123
	B1 BK	Fuses disconnected	Fault indicator lit Normal operation	P0122
	B4 BK	Fuses disconnected	Fault indicator lit Degraded mode at 800 rpm No acceleration	P0222
	B1 BK and B4 BK at same time	Fuses disconnected	Fault indicator lit Degraded mode at 800 rpm No acceleration	P0223 and P0123
Upstream oxygen sensor	E3, D3 and D2 BK	Fuses disconnected	Fault indicator lit Engine over 2000 rpm Degraded mode and no oscillation (U=0.595 V)	P0132
Downstream oxygen sensor	A3, B3 GY and E2 BK	Fuses disconnected	No fault	No code
Ignition switch	G2 BK	Fuses disconnected	No permanent + No engine starting	No code

Injection multifunction double relay	F2 BK, B4 BN	Fuses disconnected	No grounding of relays No engine starting	No code
	F3 GY	Fuses disconnected	No permanent + No engine starting	No code
Knock failure	C3 BK	Position of knock selector on cylinder 1, 2, 3 or 4	Coil filling time remains identical. Spark advance increased 3° every 100 TDCs up to max. 9°.	No code
Battery voltage failure	G2 BK and F3 grey	Potentiometer varying battery voltage from 9 V to 16 V	Variation of injection time, coil filling time, etc.	P0562 and P0563
Catalytic converter failure	E3 BK, A3 GY	Button on faulty catalytic converter	The downstream sensor sends an identical signal to the upstream sensor but with a ¼-period delay	No code

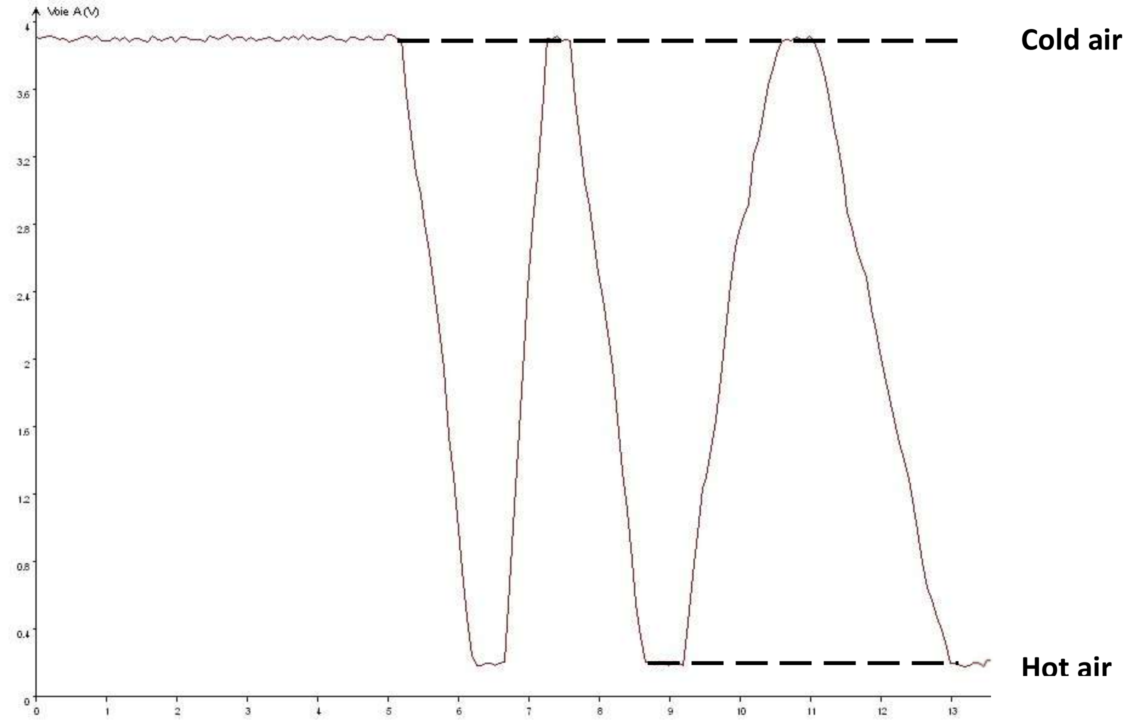
2.1.7. Measurements Across ECU Terminals

Brown connector	Description	Measurements
A1	Weak pedal position sensor signal (track B)	0%=0.22V and 100%=2.1V Graph 8
A2	Strong pedal position sensor signal (track A)	0%=0.44 and 100%=4.2V Graph 8
B1	Pedal position sensor supply	+ 5V reference
B3	ISO diagnostic bus (EOBD connector terminal 15)	Line L, diag tool communication
B4	Double relay 2 control	Rest = 12V, active = 0V
C3	Phase sensor supply	+ 5V reference
D2	Canister PWM control	12V rest and PWM work Graph 4
F2	Fan return signal	Rest=0V, Fan 1=6V and Fan 2=12V
H2	ISO diagnostic bus (EOBD connector terminal 7)	Line K, diag tool communication
J4	Fan low speed control	Rest=12V, Fan 1 control=0V
K1	Accelerator pedal sensor ground	0V
K4	Fan high speed control	Rest=12V, Fan 2 control=0 V
L4 M4	ECU ground	0V

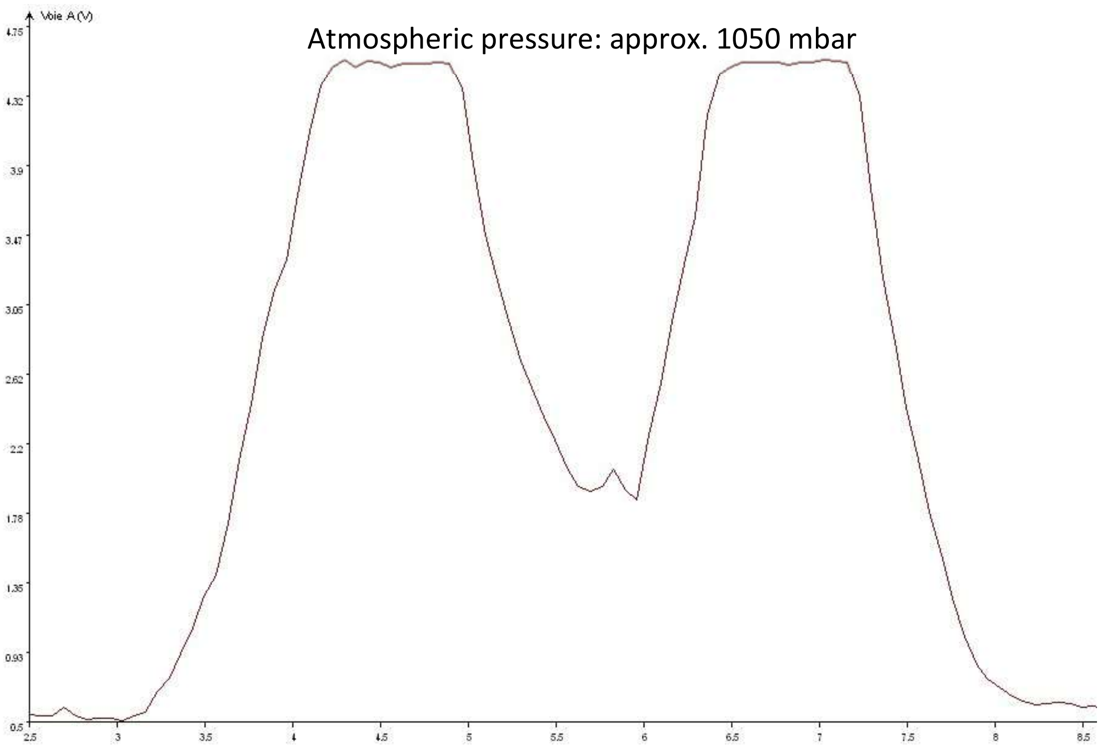
Black connector	Description	Measurements
A1	Electronic throttle copy signal (track B)	0%=3.8V and 100%=0.5V **Graph 9**
A2	Air thermistor signal	-20°C=4.13V and 70°C=0.4V **Graph 1**
B1	Electronic throttle PWM control	PWM **Graph 10**
B3	Analog ground	0V
B4	Electronic throttle PWM control	PWM **Graph 10**
C1	Electronic throttle ground	0V
C3	Knock sensor signal input	**Graph 5**
D2	Upstream sensor heater control	12V rest, 0V work
D3	Upstream oxygen sensor ground	0V
D4	Coolant thermistor ground	0V
E2	Downstream sensor heater control	12V rest, 0V work
E3	Upstream oxygen sensor signal	**Graph 11**
E4	Coolant thermistor signal	-20°C=4.7V, 120°C=0.26V **Graph 7**
F2	Double relay 1 control	Rest=12V, Active=0V
G1	Electronic throttle copy signal (track A)	0%=1.2V and 100%=4.5V **Graph 9**
G2	Ignition ON	Rest=0V, Ignition on=Battery voltage
G3	Cyl. 1 and 4 ignition coil control	Coil control signal **Graph 6**
H1	Electronic throttle copy supply	+5V
H3	Cyl. 2 and 3 ignition coil control	Coil control signal **Graph 6**

Grey connector	Description	Measurements
A1	Phase sensor ground	0V
A3	Downstream oxygen sensor signal	**Graph 11**
B1	Speed sensor negative signal	Engine speed-bound sine wave 60-2 **Graph 3**
B2	Speed sensor positive signal	Engine speed-bound sine wave 60-2 **Graph 3**
B3	Downstream oxygen sensor ground	0V
C1	Inlet pressure sensor signal	1050mbar=4.67V and 300mbar=0.85V **Graph 2**
C2	Air thermistor ground	0V
C3	Inlet pressure sensor supply	+ 5V reference
D1	Phase sensor signal	Square-wave signal on camshaft **Graph 3**
F3	ECU supply	Rest=0V, Active=Battery voltage
G2	Injector 1 open command	Ground **Graph 6**
G3	Injector 2 open command	Ground **Graph 6**
H3	Injector 3 open command	Ground **Graph 6**
H4	Injector 4 open command	Ground **Graph 6**

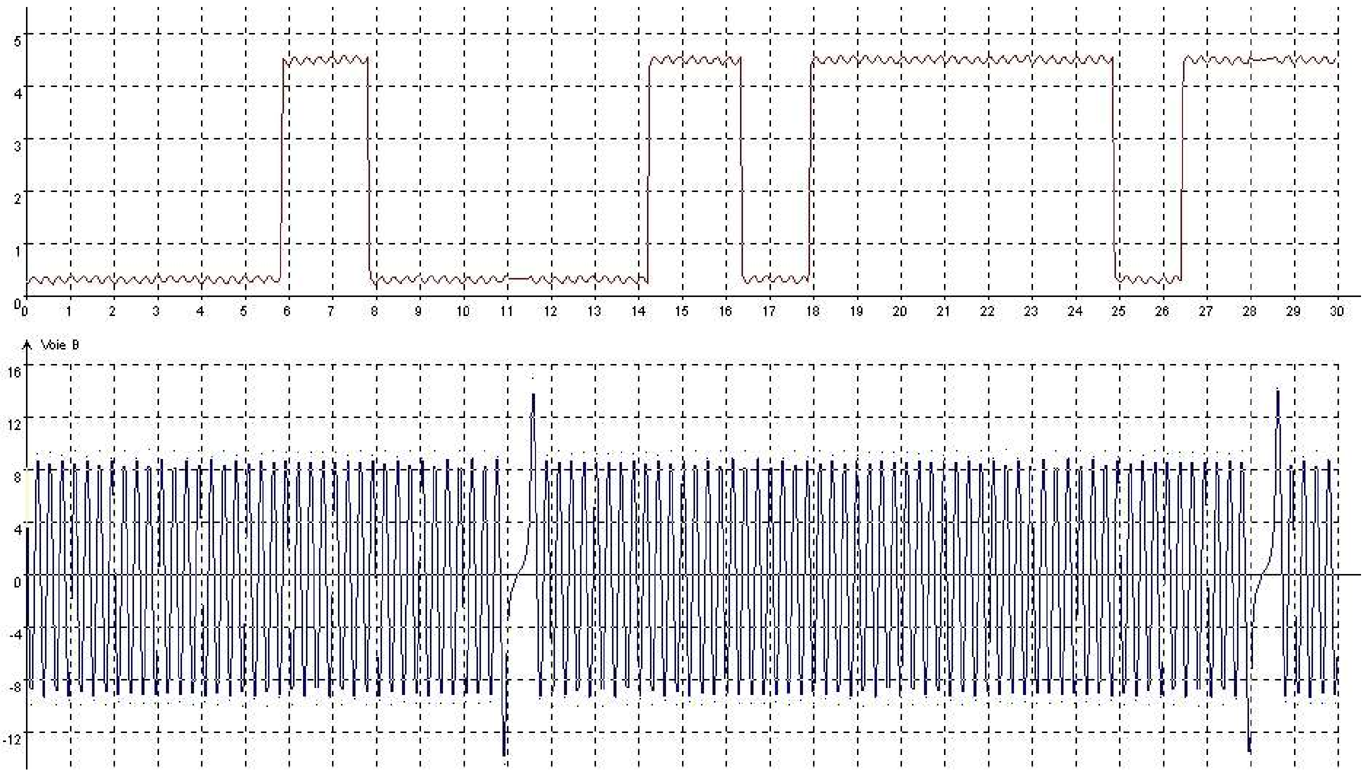
Graph 1: Air temperature



Graph 2: Inlet manifold pressure sensor

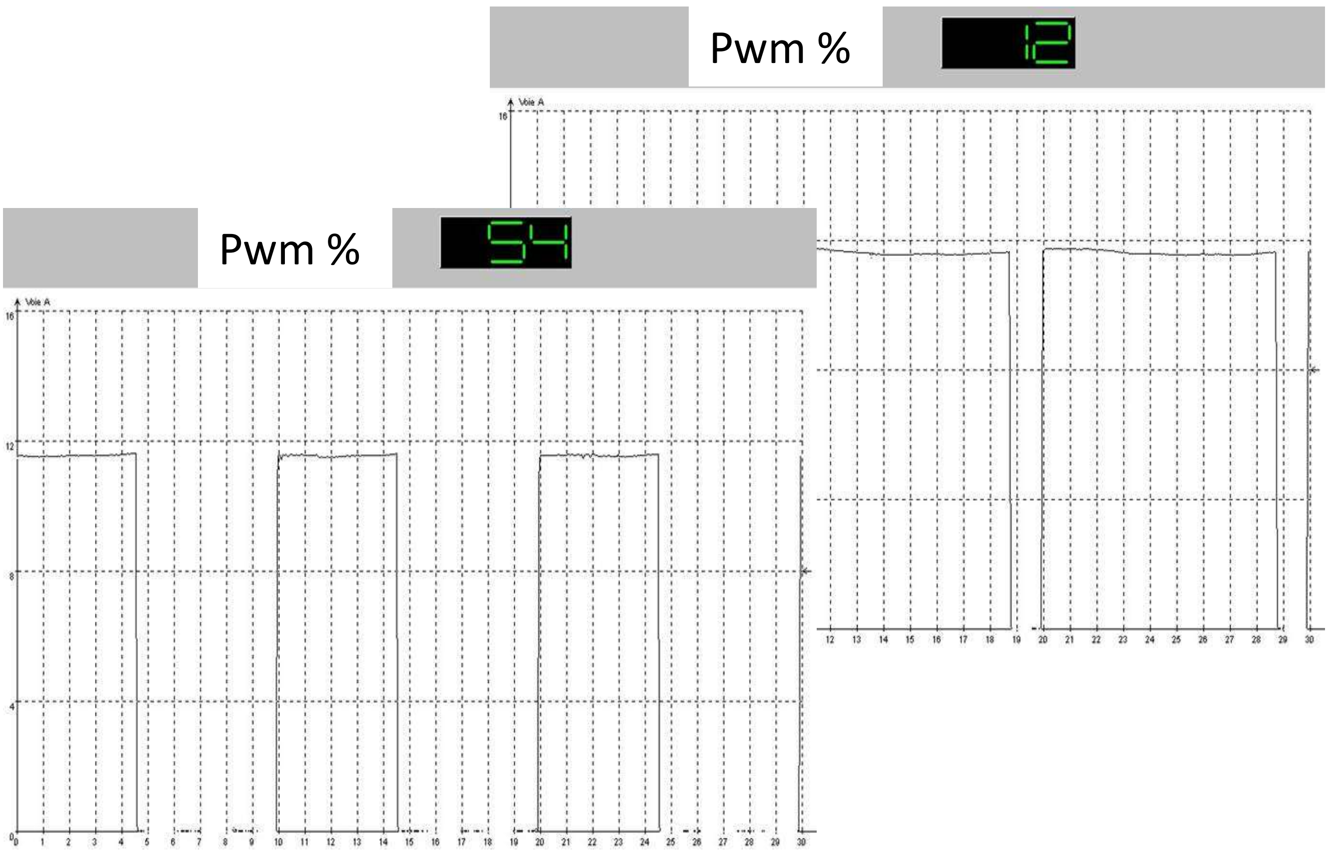


Graph 3: TDC sensor signal



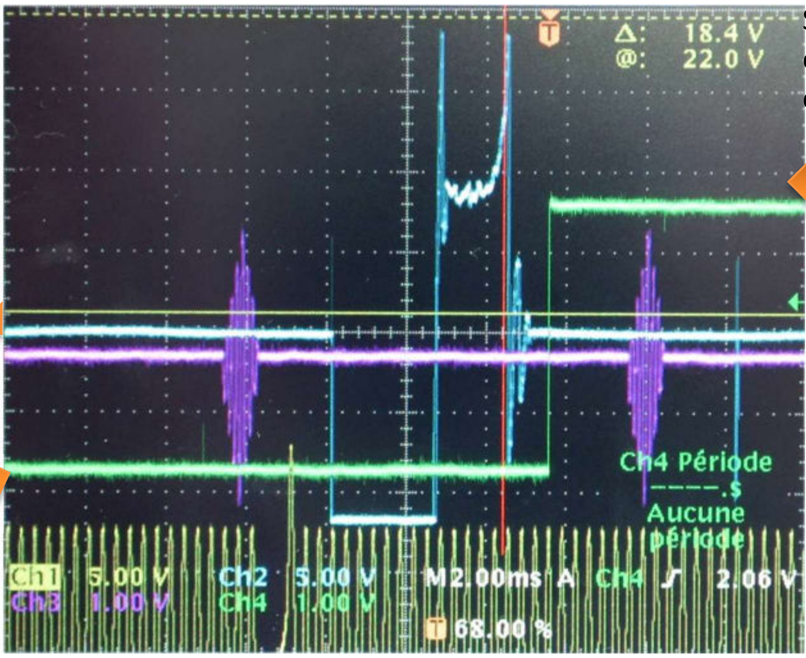
Graph 4: Purge canister control signal

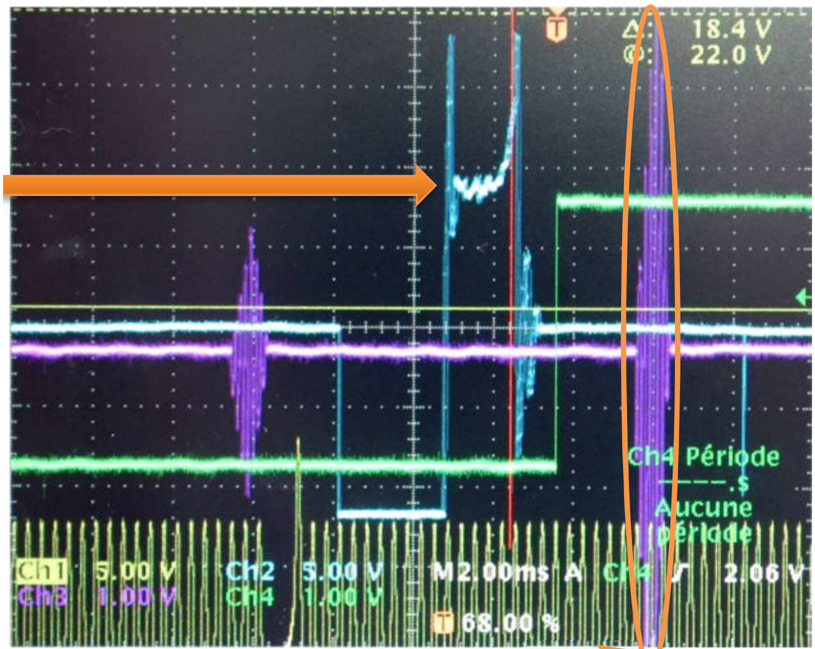
Canister control from 12% to 54%.



Graph 5: Knock signal

Measured with a laboratory oscilloscope at a set speed.

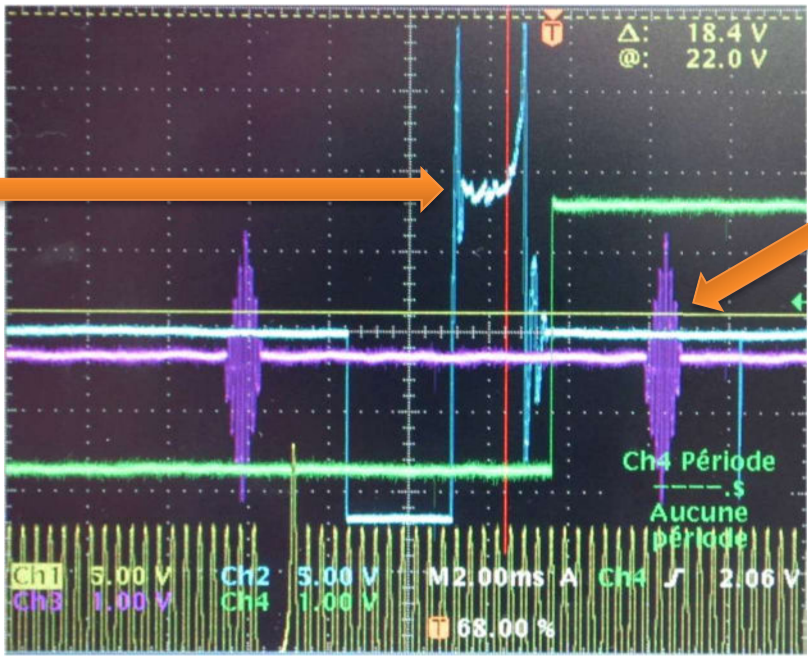




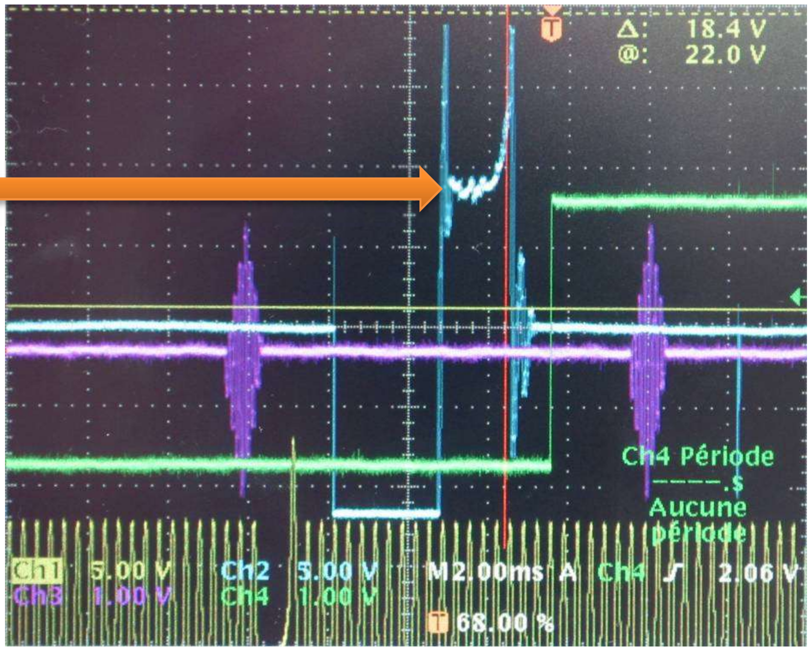
Return to initial advance once knock has disappeared.

Ignition between 12^{th} and 13^{th} tooth

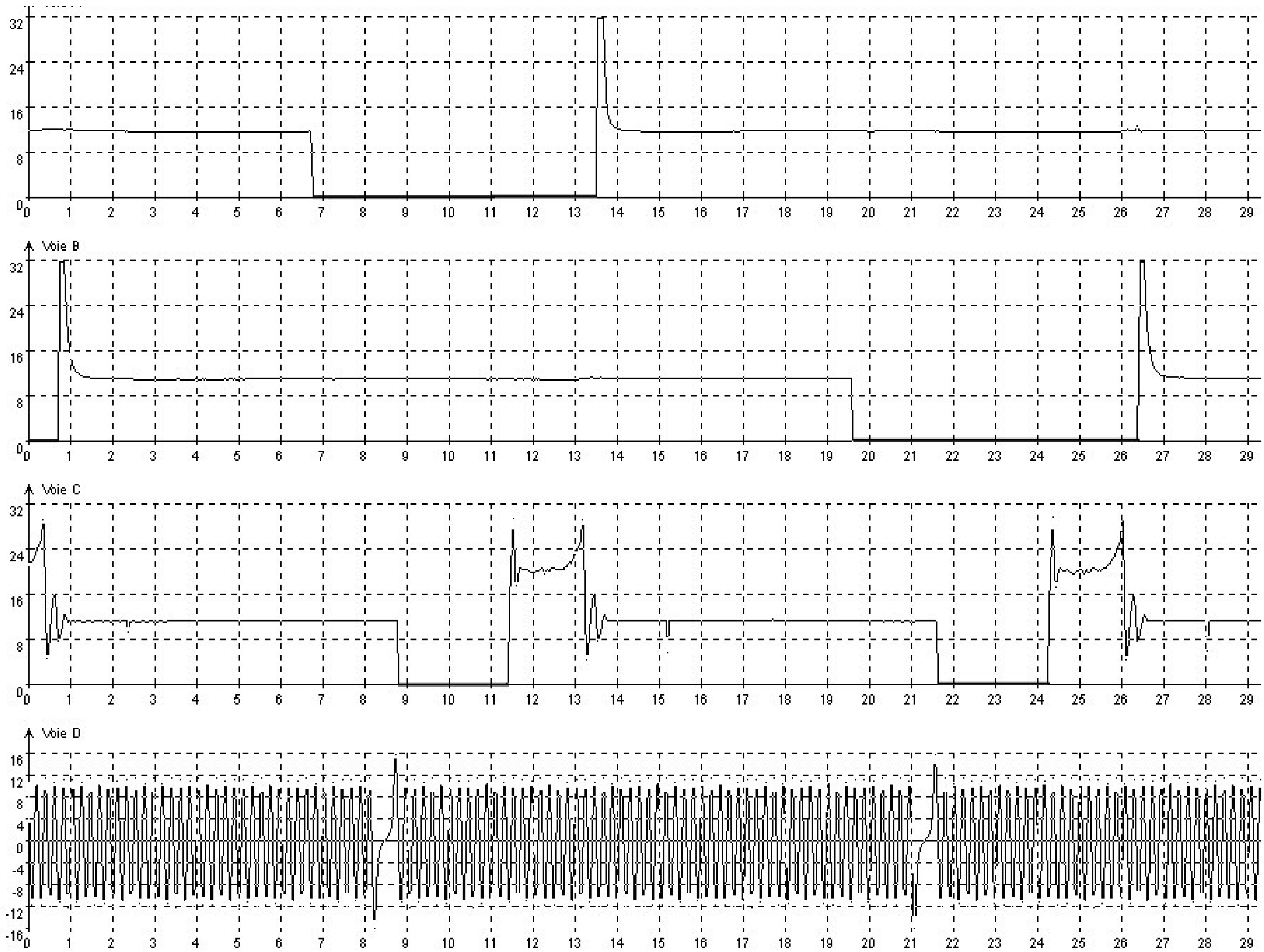
Knock stops



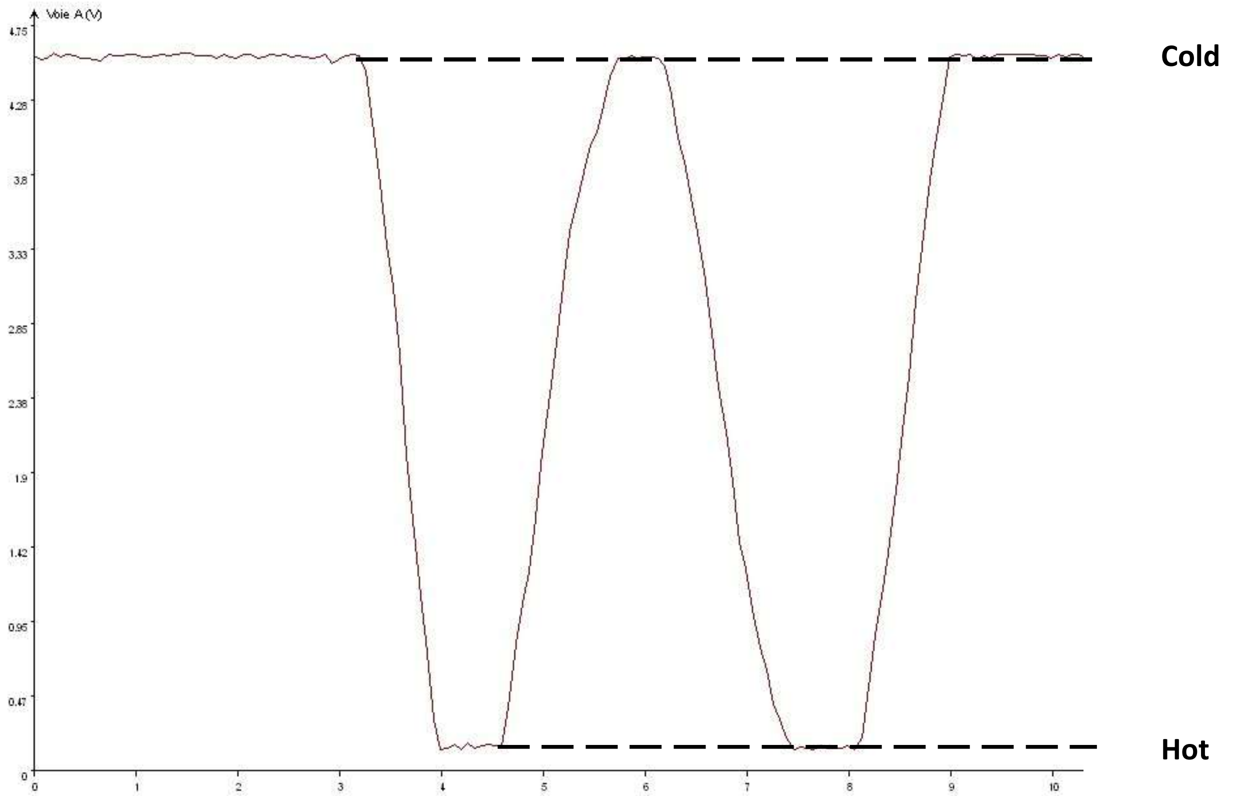
Ignition just before 12^{th} tooth



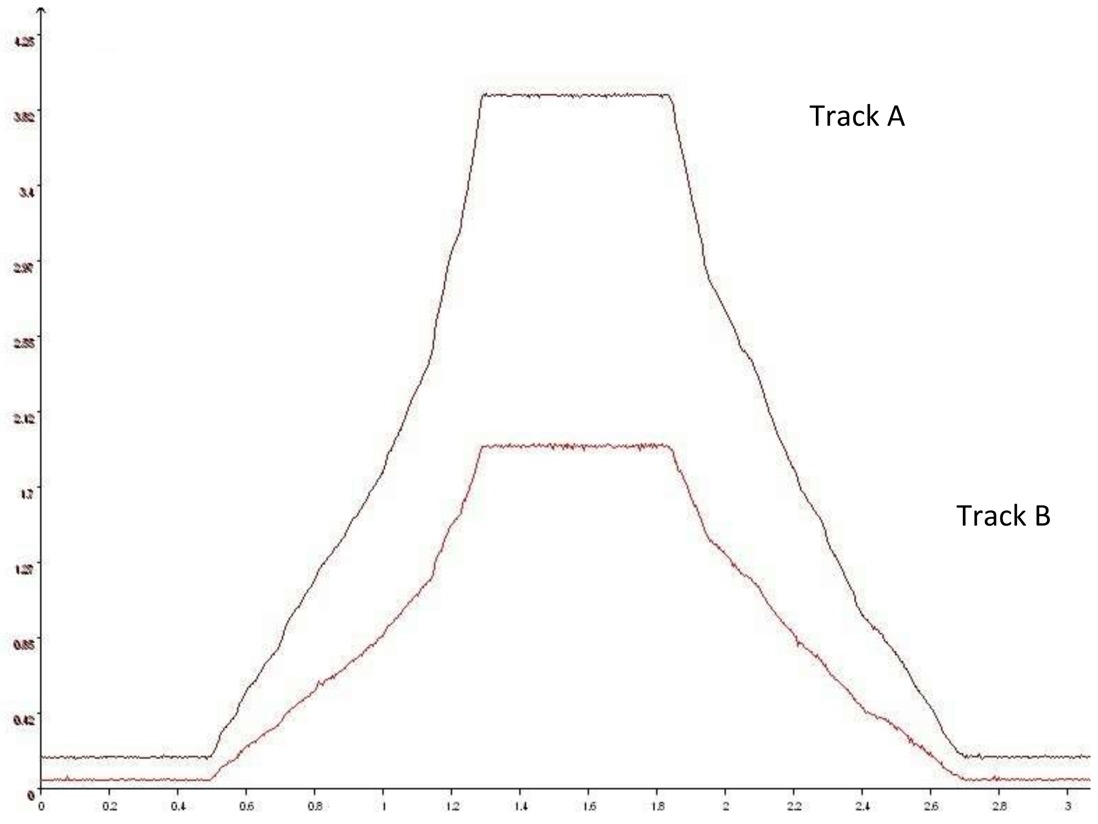
Graph 6: Ignition and injection



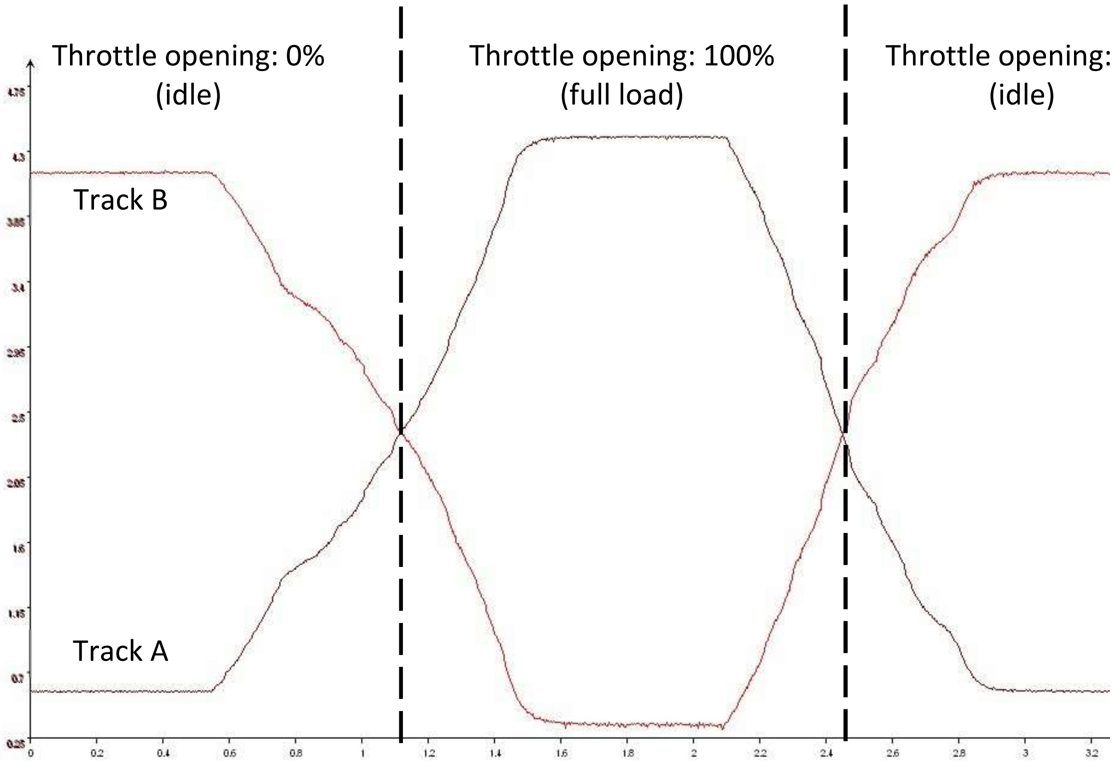
Graph 7: Coolant thermistor



Graph 8: Double-track accelerator pedal potentiometer

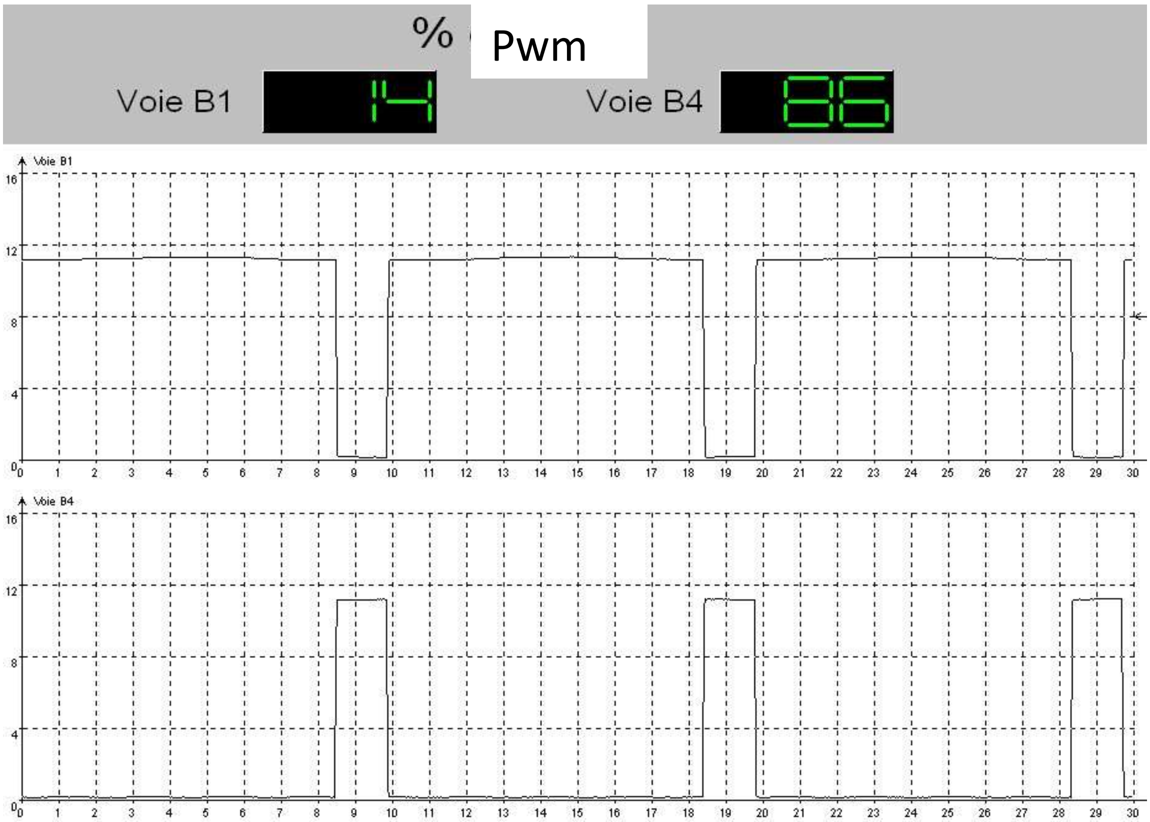


Graph 9: Electronic throttle position copy



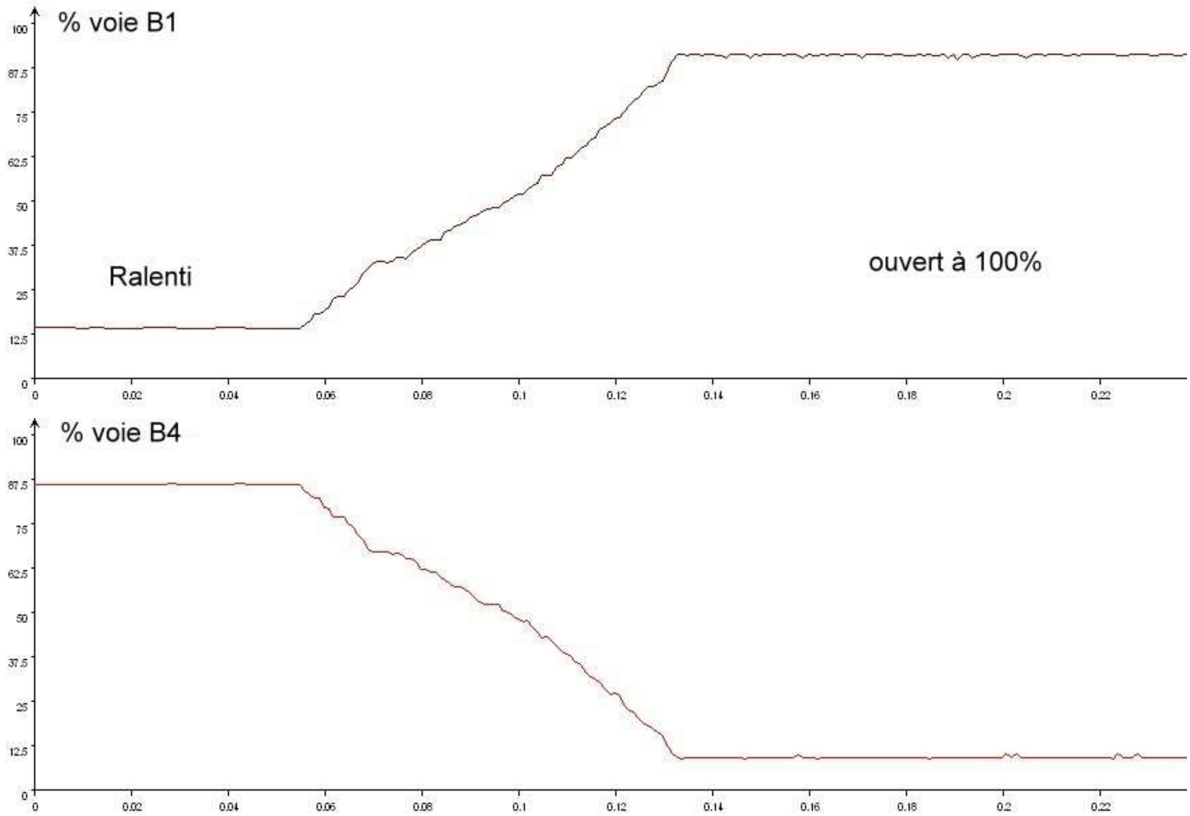
Graph 10: Electronic throttle PWM control

Electronic throttle control on idling.



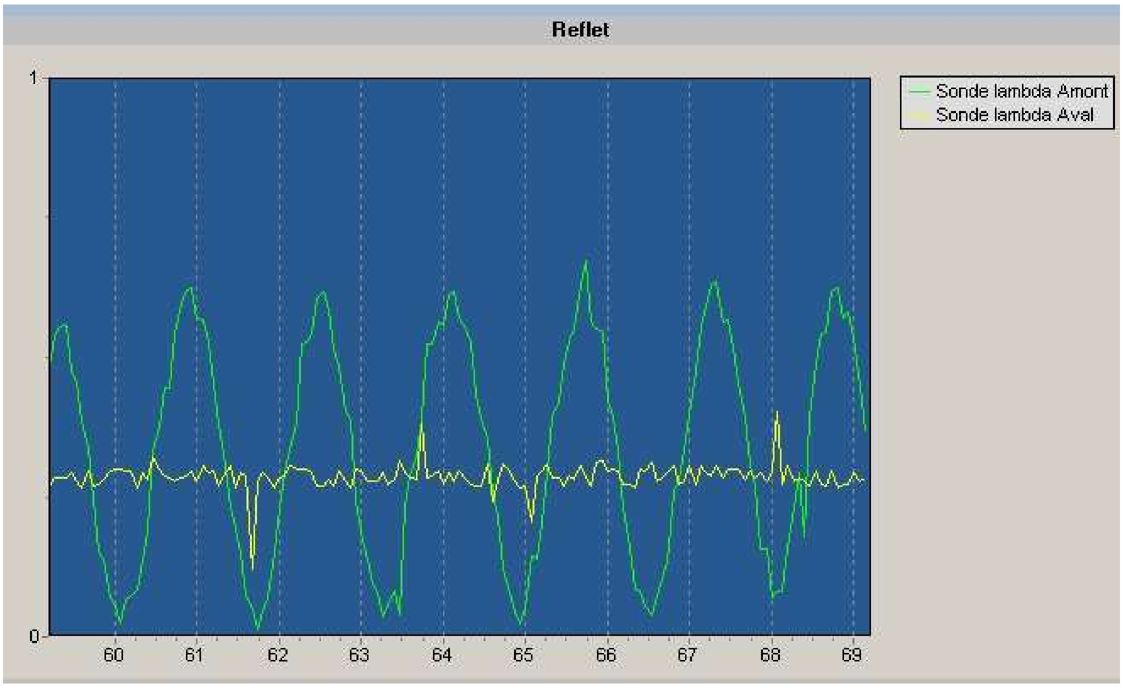
Electronic throttle control on accelerating to 100%.

Comparison of channel B1 and B4 control percentage curves

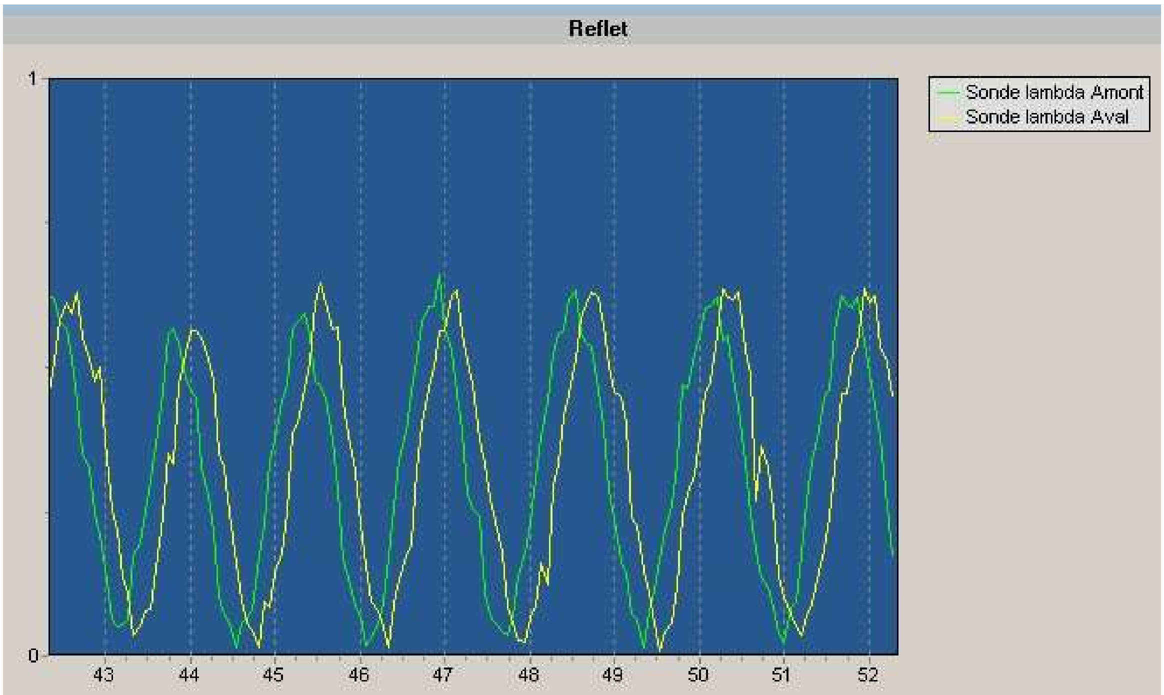


Graph 11: Upstream and downstream oxygen sensors

Normal operation.



Operation with catalytic converter failure.

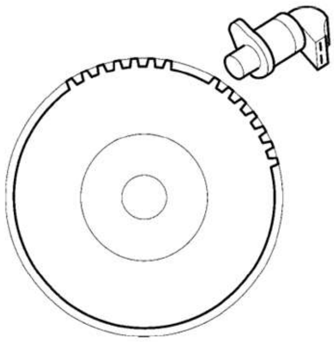


3. EXERCISE FILE

3.1 Practical Exercise 1 – Position/Engine Speed Sensor

1. What does the TDC sensor do?

Information from this sensor	Answer
Position information	X
Engine speed information	X
Wheel speed information	
Engine acceleration information	X



2. What type of sensor is it?

Sensor type	Answer
Inductive	X
Hall effect	
Piezoelectric	
Piezoresistive	
Thermistor	

The sensor comprises a permanent magnet, a winding and a low-carbon steel core in front of which the teeth of the target pass.

As the gap with the sensor changes, a variation in the magnetic field is created resulting in a variable induced voltage across the winding terminals.

3. Where is it located? Fill in the table below

Engine speed sensor location	Answer
On the wheel hub target	
On the flywheel target	X
On the camshaft target	

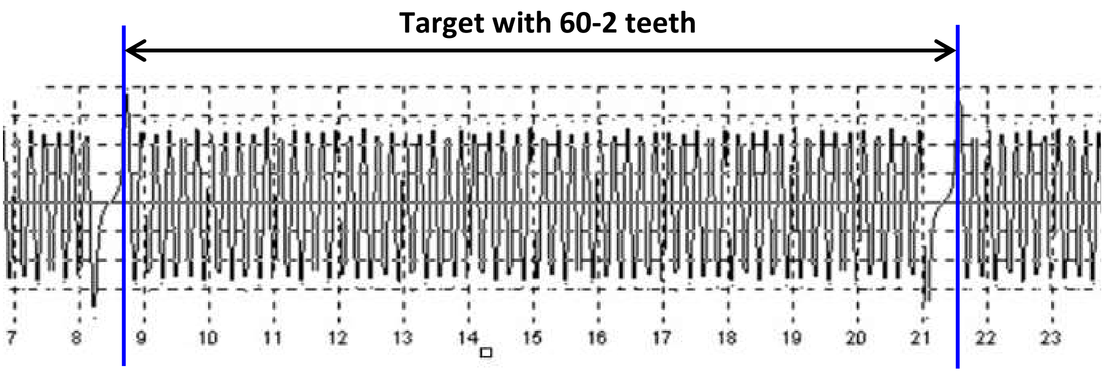
4. This type of inductive sensor is used for functions other than engine speed. Which?

Other use of inductive sensor	Answer
ESP	X
Air conditioning	
ABS	X
ASR	X

Located on a wheel hub target, it sends vehicle speed information to the ABS ECU which transmits it to the injection ECU.

5. Measure the signal from the engine speed sensor on the model using an oscilloscope (e.g. REFLET), then count the number of teeth on the signal for an engine revolution?

The flywheel has 60-2 teeth on the model.



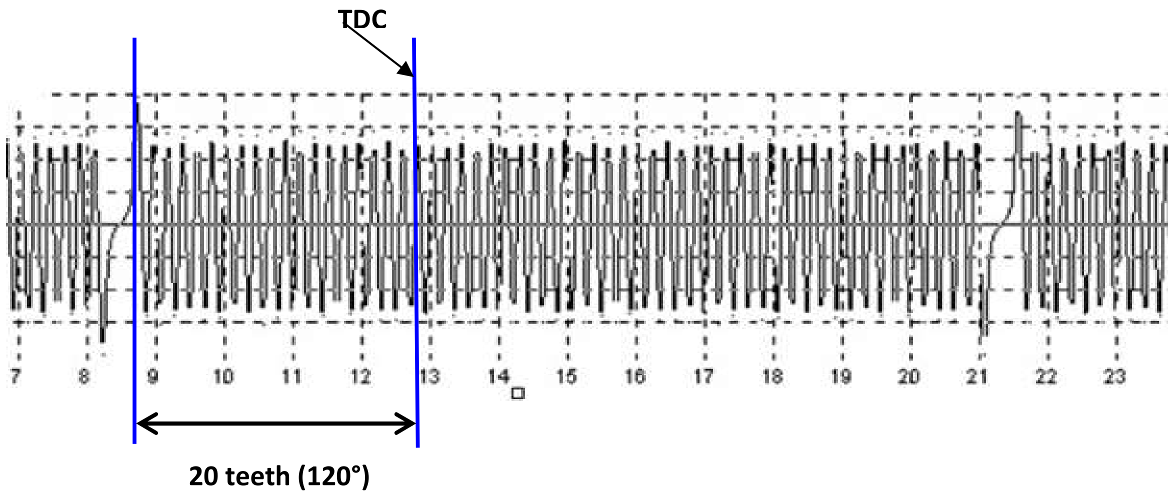
6. Does the flywheel target have 60-2 teeth on all vehicles?

No, there are different targets with a different number of teeth. The number of teeth and the TDC marker are specific to each engine. For example, PRV V6 with three large teeth 120° apart.

7. Given that TDC is 120° after the missing tooth, determine the number of teeth and locate the TDC position on the engine speed signal

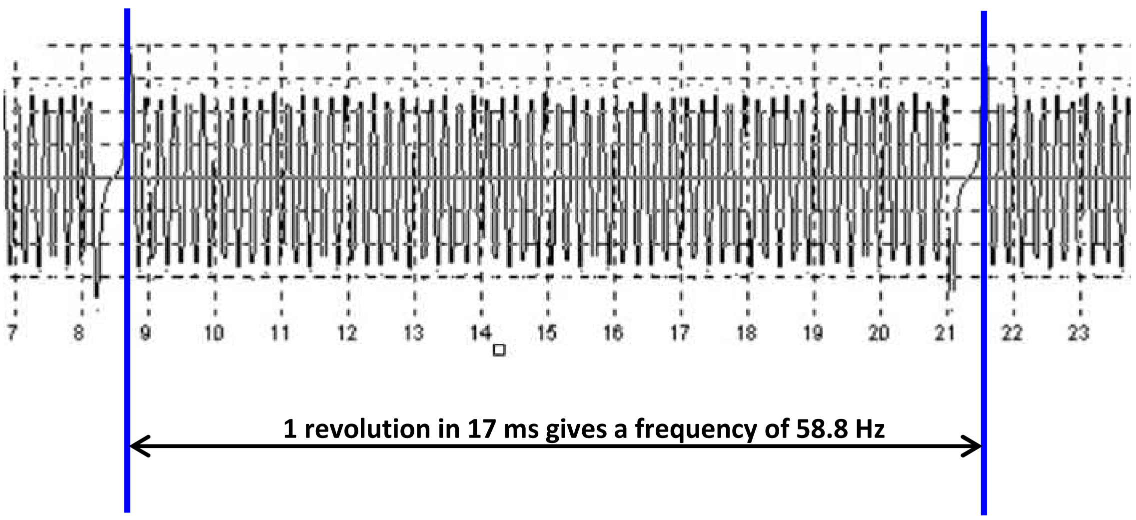
Given that a revolution equals 360° and there are 60 teeth. The rule of three is then applied:
*60 * 120 / 360 = 20 teeth*

Number of teeth	Degrees
60	360
20	120



8. Using the signal transmitted by the engine speed sensor, determine the frequency with which the pulses caused by the target teeth occur for an engine speed of 3500 rpm

To calculate the frequency, we consider that f=1/P
where f = frequency, expressed in Hz, and P = period (1 engine revolution), expressed in s.
Given that P = 17 ms, hence 0.017 s, f = 1 / 0.017 = 58.8 Hz

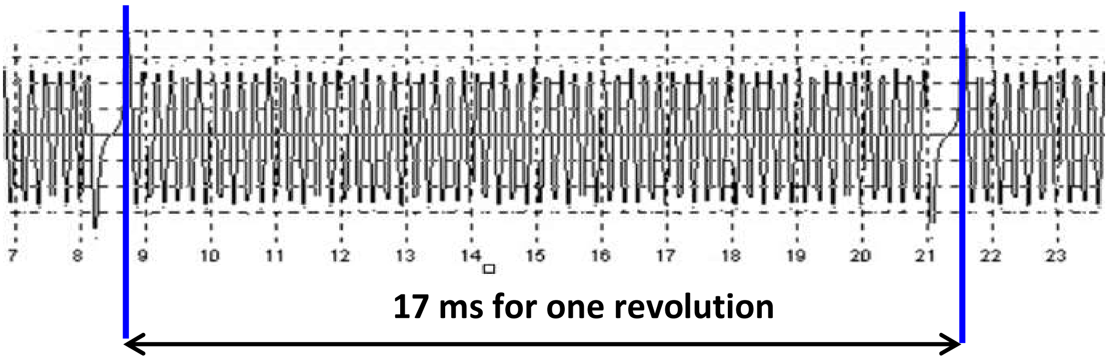


9. Measure the signal from the position/engine speed sensor on the model using an oscilloscope (e.g. REFLET), at a speed of 3500 rpm. Check the accuracy of the engine speed on this signal.

For 3500 revolutions in 1 minute (or 60,000 ms):

*(60000 * 1) / 3500 = 17 ms*

Time in ms	Speed in rpm
60000	3500
17	1

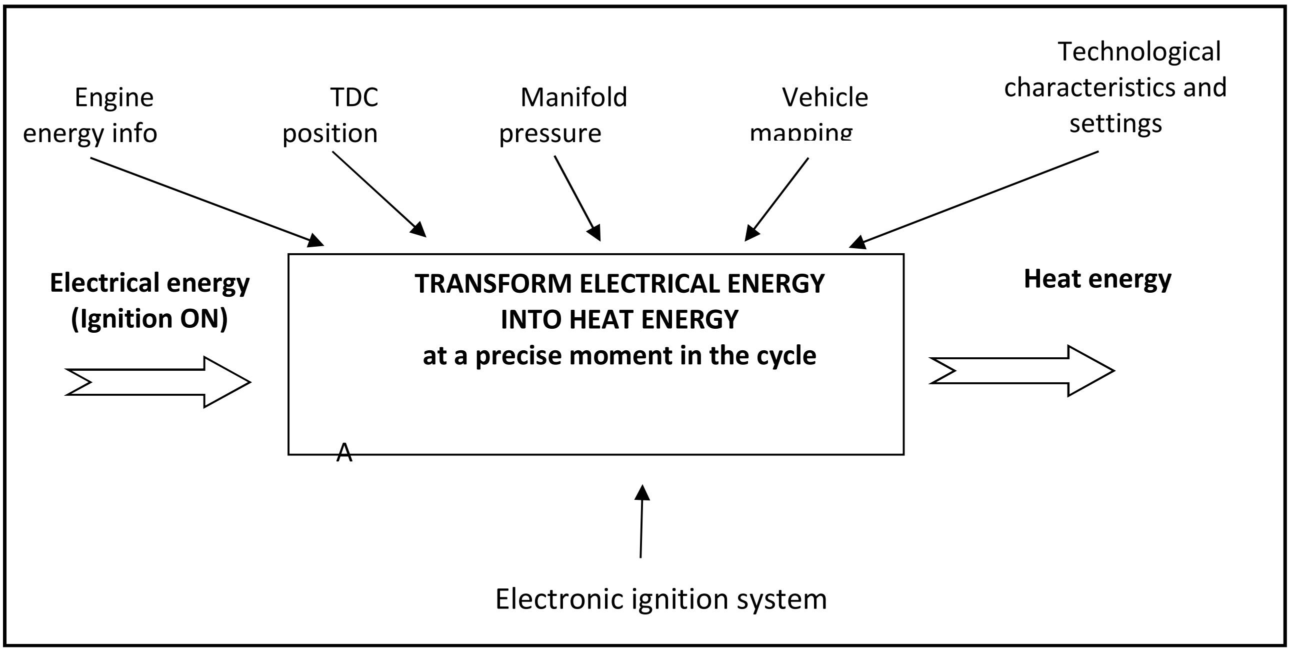


3.2 Practical Exercise 2 – Ignition

Functional analysis

The overall ignition system function is to transform low-voltage DC electrical energy from the battery into heat energy at the spark plug electrodes at a precise moment in the engine cycle.

This energy depends on the temperature and pressure conditions within the combustion chamber on sparking.



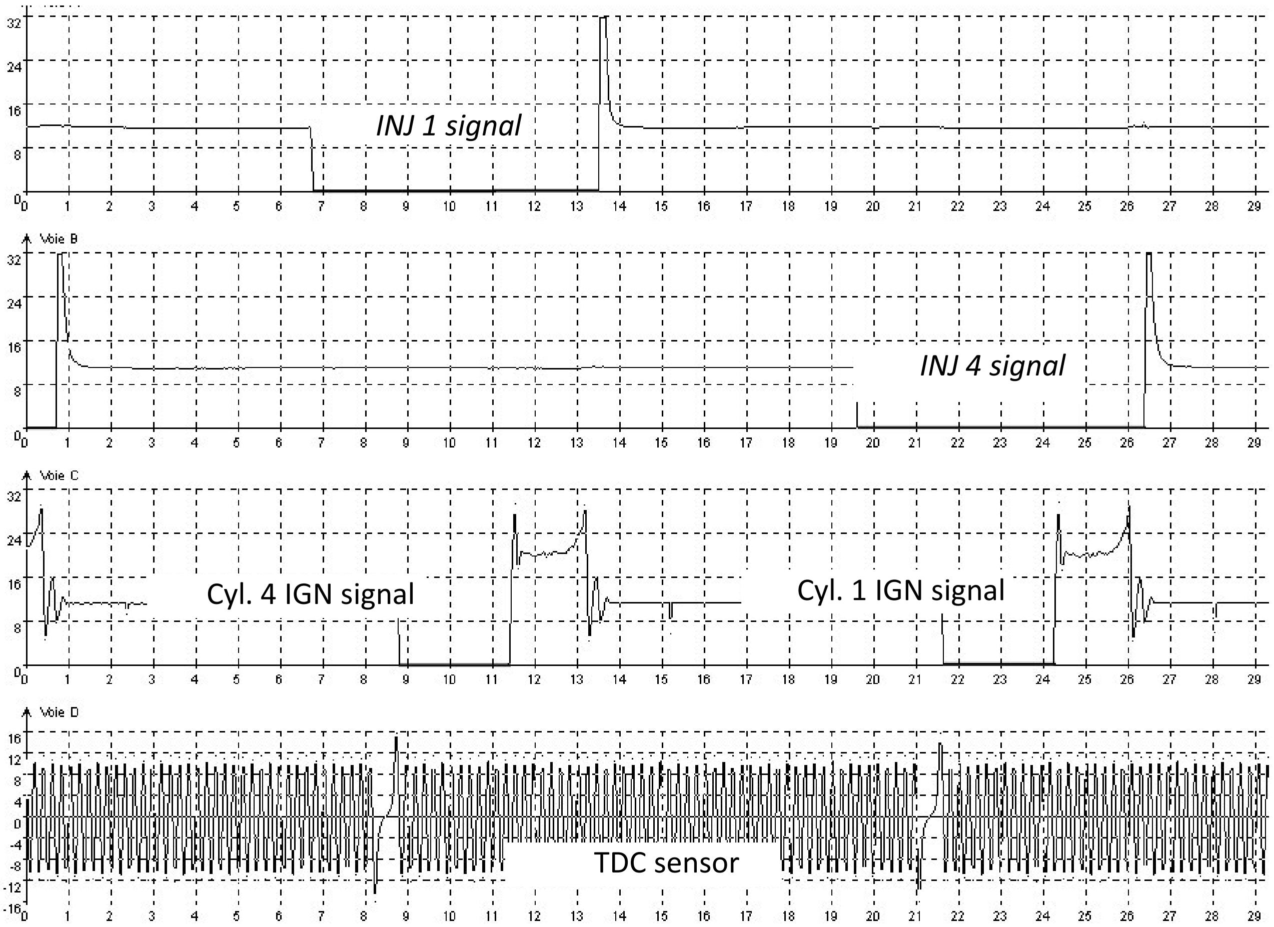
1. With which type of ignition is model MT-E5000 equipped?

Ignition type	Insert a cross where applicable
Static ignition with external module on injection ECU	
Static ignition without module integrated into injection ECU	
Static ignition with module integrated into injection ECU	
Ignition with distributor	
Twin static ignition with compact coil unit	X
Twin static ignition without compact coil unit	
Sequential static ignition with coil unit	
Sequential ignition with two external modules and a coil per cylinder	

2. What is the combustion sequence for this four-stroke petrol engine?

Combustion sequence	Insert a cross where applicable
1 - 2 - 4 - 3	
1 - 3 - 4 - 2	X
1 - 4 - 2 - 3	

3. Using a four-trace oscilloscope, record the signal from injectors 1 and 4, the cylinders 1 and 4 ignition signal and the engine speed.
Then indicate where these signals are located.



4. Why do we have a spark advance?

	Insert a cross where applicable
Combustion of the mixture is immediate.	
Combustion of the mixture is not immediate.	X

	Insert a cross where applicable
The spark must therefore be generated at the plug with an advance	X
The spark must be generated at TDC	

This spark advance will constantly vary according to the various phases of engine operation to obtain:

- Power and/or engine torque
- Minimum fuel consumption
- Minimum exhaust gas emissions

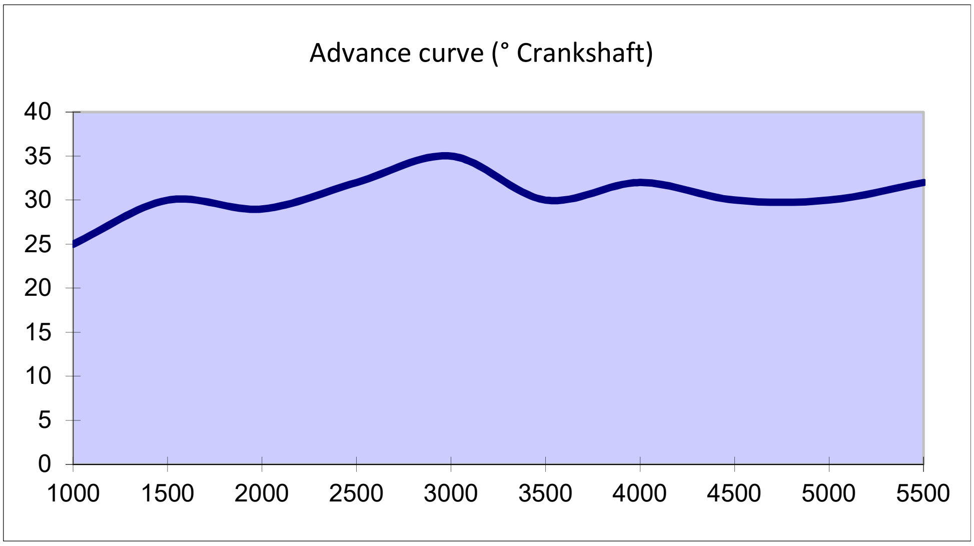
5. On a vehicle or model, take an EOBD reader such as OBD-EX1, then fill in the table below (spark advance in relation to engine speed).

Test conditions: coolant T° = 90°C, air T° = 20°C, max. load

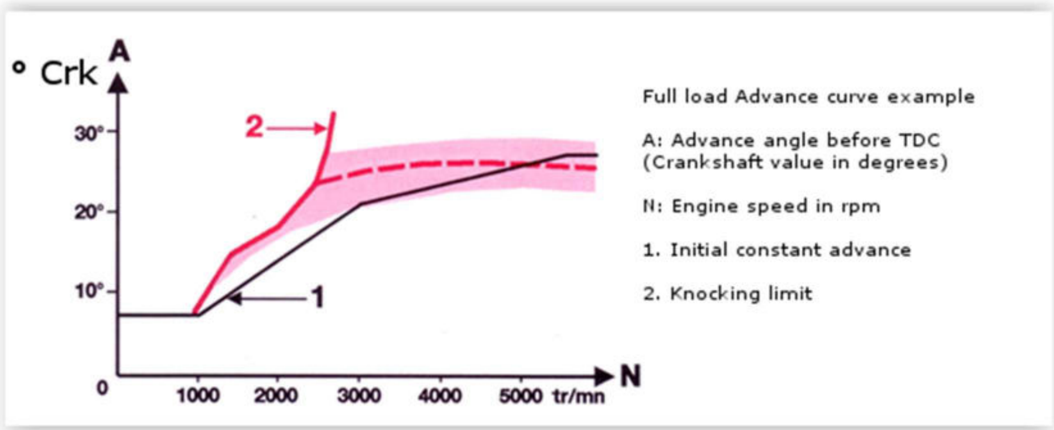
Engine speed (rpm)	Spark advance (degrees)	Engine speed (rpm)	Spark advance (degrees)
1000	25°	3500	30°
1500	30°	4000	32°
2000	29°	4500	30°
2500	32°	5000	30°
3000	35°	5500	32°

Plot the corresponding graph.

Model MT-E5000



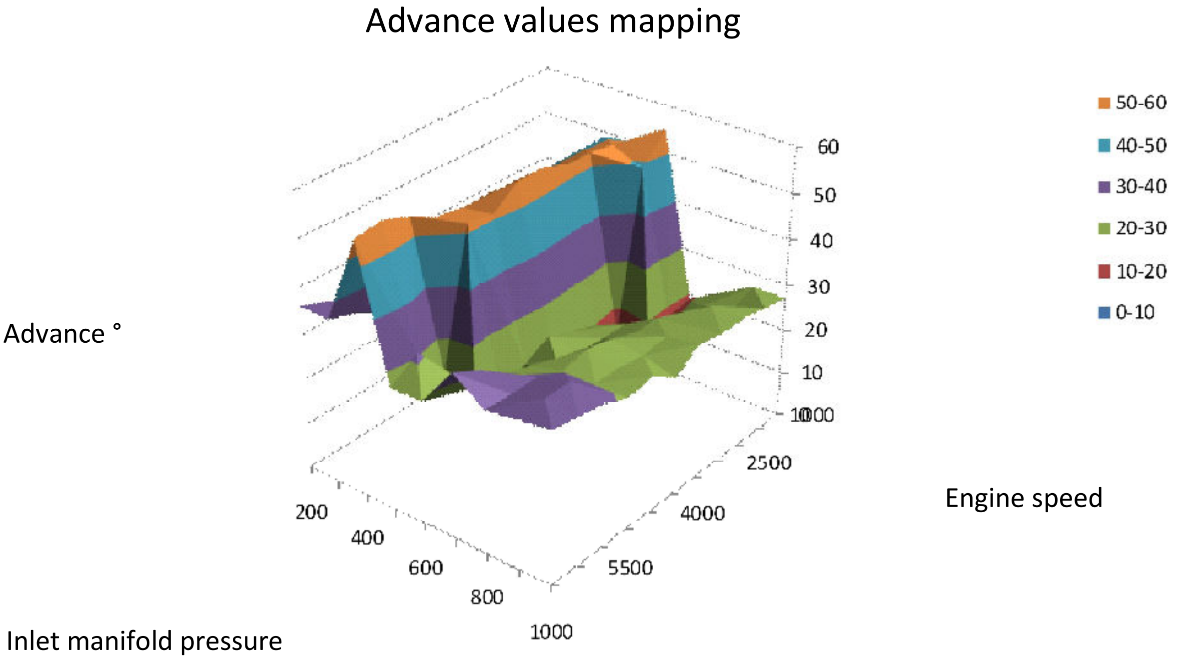
Conventional vehicle (without engine load)

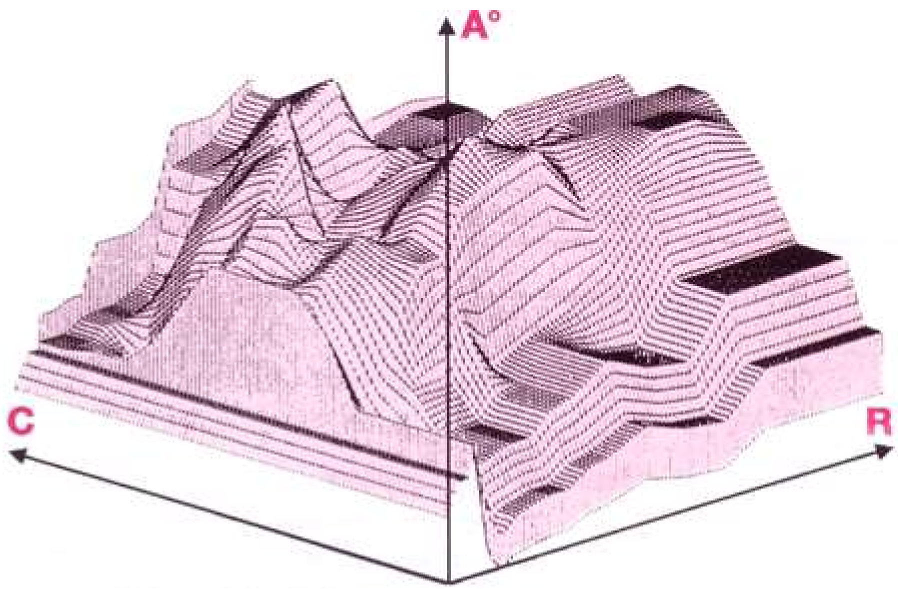


<u>6. Using model MT-E5000 and an EOBD reader such as OBD-EX1, fill in the table below (spark advance in relation to manifold vacuum and engine speed)</u>

Test conditions: coolant T° = 90°C, air T° = 20°C, min. load

	1000 rpm	1500 rpm	2000 rpm	2500 rpm	3000 rpm	3500 rpm	4000 rpm	4500 rpm	5000 rpm	5500 rpm	6000 rpm
200 mBar	26	30	29	32	35	30	32	30	31	34	36
300 mBar	26	30	29	32	35	30	32	30	31	34	36
400 mBar	49	49	49	48	49	50	50	51	54	56	55
500 mBar	50	52	53	53	55	55	54	52	23	31	27
600 mBar	55	49	15	20	22	24	21	18	23	25	27
700 mBar	19	18	20	23	23	23	25	27	29	33	36
800 mBar	23	23	23	27	27	29	30	29	31	31	31
900 mBar	27	25	29	28	29	28	29	29	33	33	32
1000 mBar	27	28	29	29	30	26	30	29	31	32	33





Mapping of the ignition advance values as a function of the load and engine speed parameters
A: Ignition advance angle
C: Engine load dependent parameter (vacuum collector)
R: Engine speed parameter

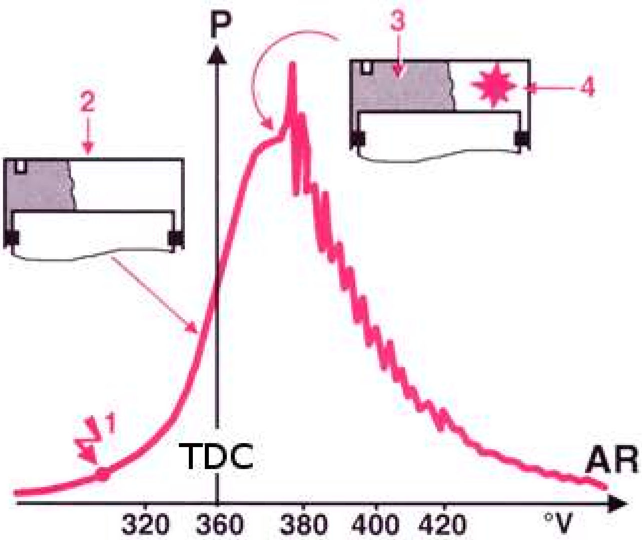
3.3 Practical Exercise 3 – Knock Sensor

1. <u>Define "knocking"</u>

Knocking is a damaging phenomenon which occurs in the engine on abnormal combustion. Very high pressure and temperature in the combustion chamber cause a sudden explosion or detonation. This creates a second flame front which will meet the first one and generate waves throughout the combustion chamber. These vibrations are exerted in particular on the piston on the downward stroke. A characteristic metallic knocking noise is heard, which is also known as "pinking" or "pinging".

2. <u>When does knocking occur?</u>

Knocking occurs after combustion begins normally, after sparking at the plug.



Pressure diagram in the combustion chamber in the presence of knocking and as a function of the rotation of the crankshaft

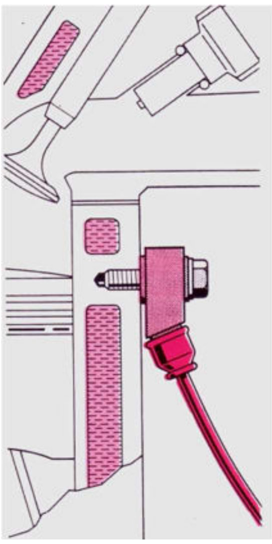
P: Pressure in bar
AR: Angle of rotation of the cranckshaft
1: Ignition point
2: Normal combustion
3: Gas already burnt
4: Auto-ignition of the rest of the mixture causing knocking

3. What does the knock sensor do?

It transmits characteristic information of the engine vibrations to the ECU. It therefore detects the appearance of knocking in each cylinder.

4. What type of sensor is it?

Sensor type	Answer
Inductive	
Hall effect	
Piezoelectric	X
Piezoresistive	
Thermistor	



5. Where is it located?

The knock sensor is located on	Answer
The cylinder head	
The engine block	X
The inlet manifold	
The gearbox	

6. State the main causes of knocking and explain.

- Spark advance

Excessive spark advance offsets combustion in relation to TDC and leads to a significant increase in pressure and temperature at the end of combustion.

- Fuel octane rating too low

Fuel with a low octane rating is, by definition, prone to knocking.

- Richness of the mixture

If the mixture is too lean, combustion is much slower and results in a greater temperature rise than with a stoichiometric mixture.

- Compression ratio

A high compression ratio increases the speed of combustion and significantly reduces self-ignition time. Therefore the higher the compression ratio, the greater the risk of significant knocking. This is a recurrent issue on turbo engines.

- Spark plug heat range

Unsuitable spark plugs for the engine can cause dangerous knocking.

- Engine fouling

Carbon deposits forming in the combustion chamber of an engine create hot spots which can initiate self-ignition of the mixture, and therefore cause knocking.

- Inlet temperature: If the inlet temperature is too high, the temperature rises at the end of combustion and therefore generates a knocking tendency.

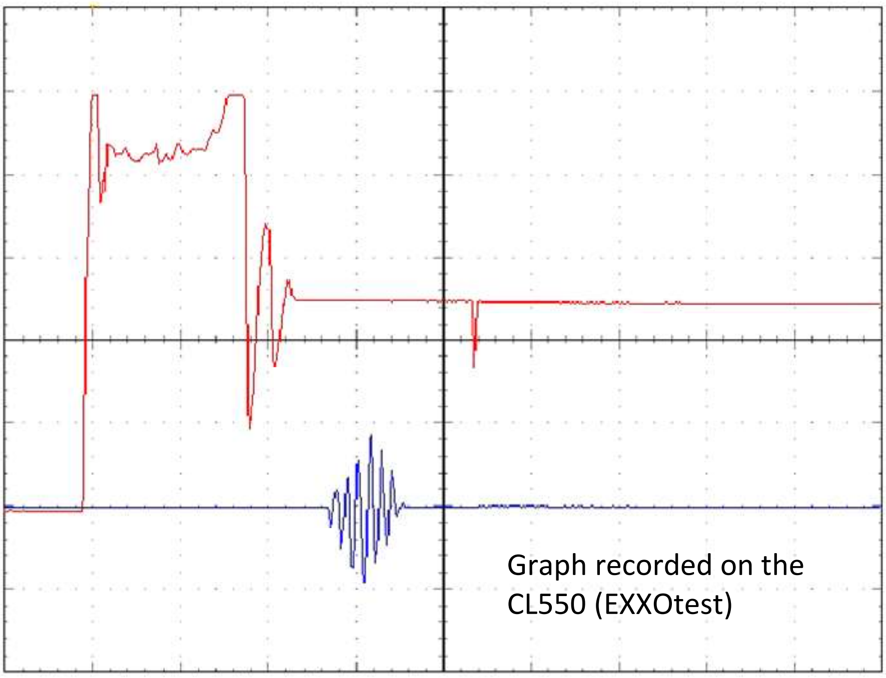
7. State a serious consequence of knocking

A persistent knock can have very serious consequences. The heavy strain exerted on the piston head by the vibrations and the very sharp temperature rise can melt the piston head as if it were heated by a blowtorch flame, and thus damage the piston ring grooves and even perforate the head.

8. Once knocking has been detected, the ECU will initiate a strategy by modifying a parameter. Which one?

Strategy	Answer
Increasing spark advance	
Reducing spark advance	X
Increasing injection time	

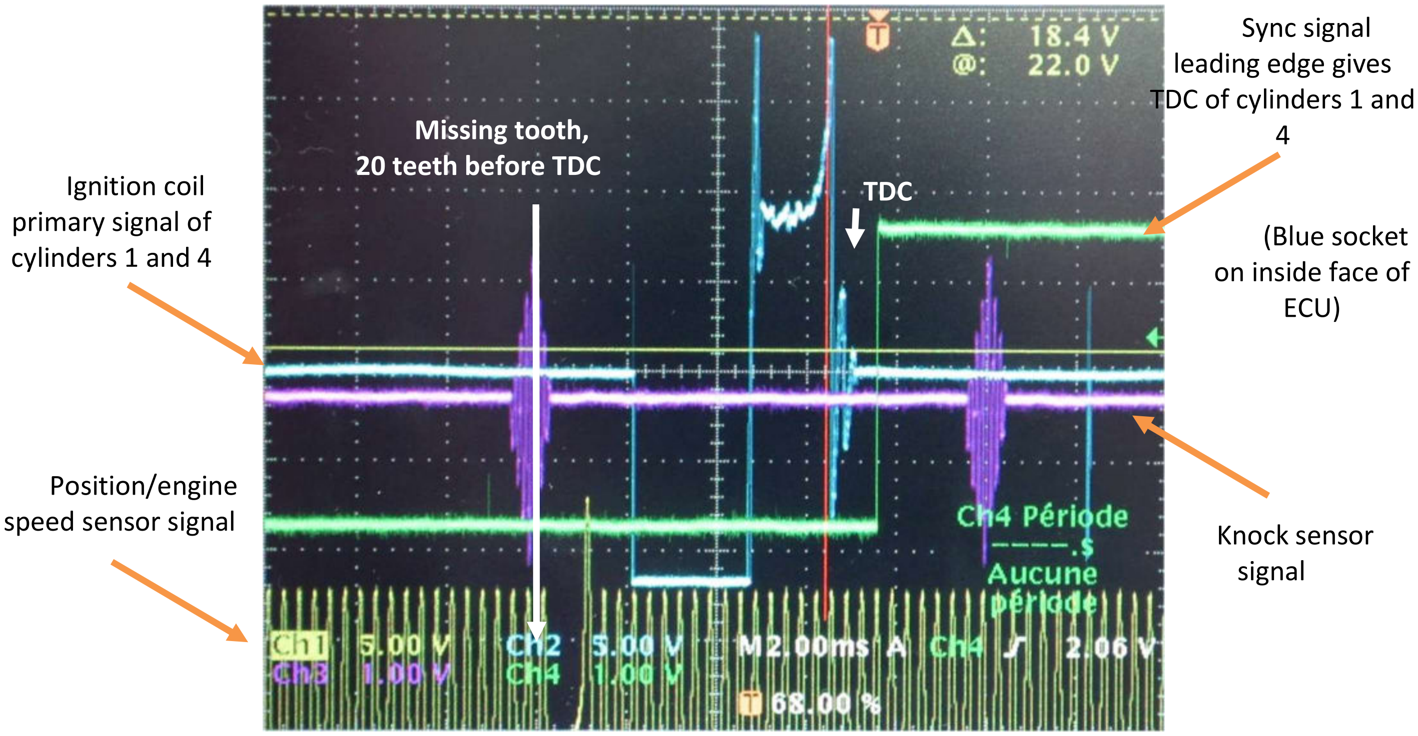
9. Using the model and an oscilloscope (CL550, for example), record the ignition signal and the knock signal.



Refer to graphs 5 (Knock signal) in the User File and the enclosed CL550 graph.

10. <u>Using the model and a two- or four-trace oscilloscope (CL550, for example), record the ignition signal and the engine speed signal.</u>
 <u>Identify TDC (20 teeth after the missing tooth) and check on detecting the knock whether the advance is increased or reduced.</u>

Refer to graphs 5 (Knock signal) in the User File.
Observe the reduced advance on detecting the knock.



3.4 Practical Exercise 4 – Phase Sensor

1. What type of sensor is it?

Sensor type	Insert a cross where applicable
Inductive	
Variable resistance	
Hall-effect	X
Piezoelectric	

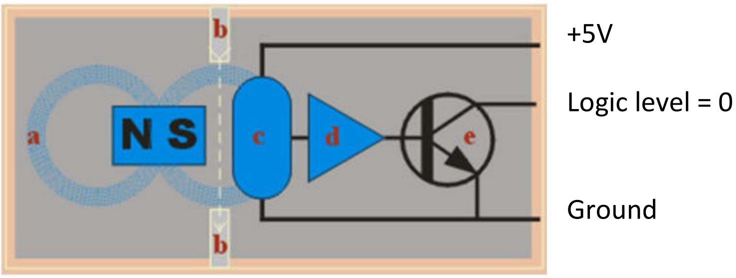
Hall-effect sensors are commonplace in automotive ignition systems where they replaced traditional contact breakers.

It is located on the ca … n of the camshaft(s).

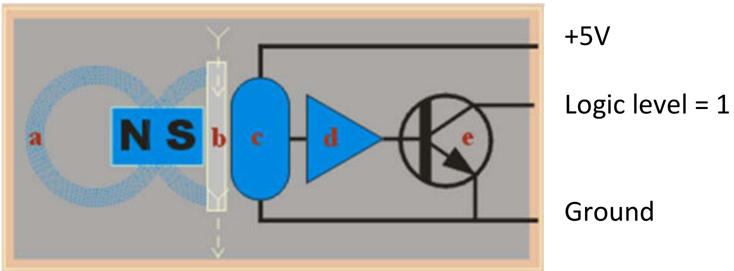
a: magnetic flux
b: target
c: Hall pad
d: amplifier
e: transistor

2. Hall-effect sensor operation

In the absence of a target, the permanent magnet acts on the wafer and the signal emitted by the wafer is amplified. As the transistor is saturated, the output logic level is 0.



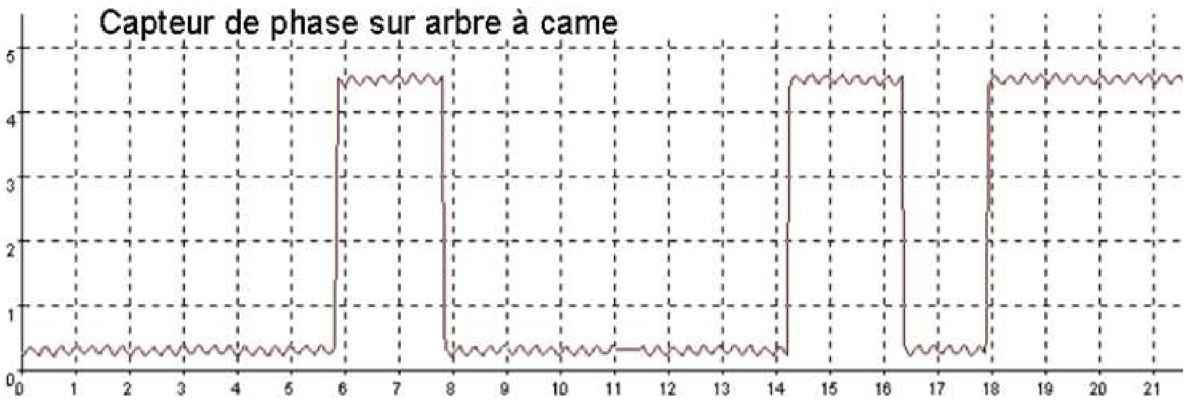
When the target passes between the magnet and the wafer, it is no longer subjected to a magnetic field and no longer delivers a signal. The transistor is blocked, the output logic level switches to 1.



3. Where is it located?

Sensor position	Insert a cross where applicable
On the flywheel	
On the camshaft	X
On one of the balance shafts	

4. On model MT-E5000 or on a vehicle, record the phase sensor signal with an oscilloscope (Reflet or CL500, for example).



5. What type of signal is it?

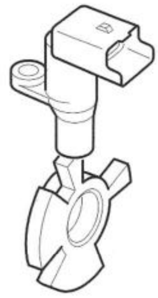
Signal type	Answer
Sine-wave	
Square-wave	X
PWM	
Variable voltage	

The use of the Hall-effect sensor is advantageous as its signal can be directly exploited by simple electronics.

6. On the model, how many teeth does the camshaft target have?

The target integral with the camshaft comprises two large and two small teeth.

Number of teeth	Answer
4 teeth	X
2 teeth	
2 large and 2 small teeth	X

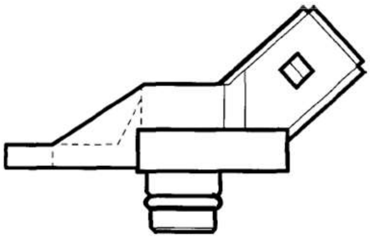


7. How many crankshaft (engine) revolutions are there for a camshaft revolution? Using an oscilloscope (Reflet or CL500, for example), record the phase sensor signal and the engine speed sensor signal then fill in the table

Number of revolutions	Answer
½ revolution	
1 revolution	
2 revolutions	X

8. Steady the model at an engine speed of 3500 rpm, record the phase sensor signal with an oscilloscope, then calculate the camshaft speed.

3.5 Practical Exercise 5 – Inlet Pressure Sensor



1. What does the inlet pressure sensor do?

Type of pressure measured	Answer
Exhaust pressure	
Inlet manifold pressure	X
Turbo pressure	X

2. What type of sensor is it? Complete the table

Sensor type	Answer
Inductive	
Hall effect	
Piezoelectric	
Piezoresistive	X
Thermistor	

3. Characteristics of the inlet pressure sensor

Sensor family	Answer
Active	
Passive	X

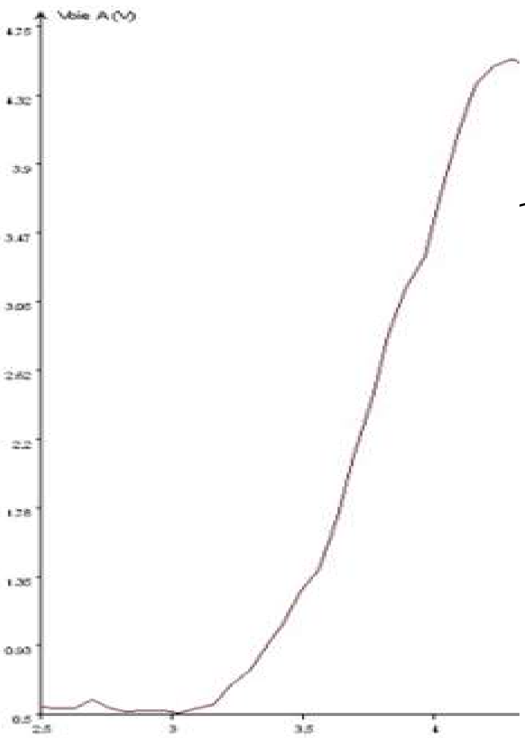
Supply voltage	Answer
5 V	X
8 V	
12 V	

Output voltage	Answer
0 V	
Proportional to the pressure	X
12 V	

4. <u>Where is it located?</u>

Sensor location	Answer
Exhaust manifold	
Inlet manifold	X
Cylinder head	
Air filter	

5. <u>Using the model, measure and plot the sensor signal in relation to inlet pressure.</u>
<u>Confirm that the voltage is proportional to pressure (U = F (P)).</u>



Voltage varies in relation to pressure

Inlet pressure

3.6 Practical Exercise 6 – Injection

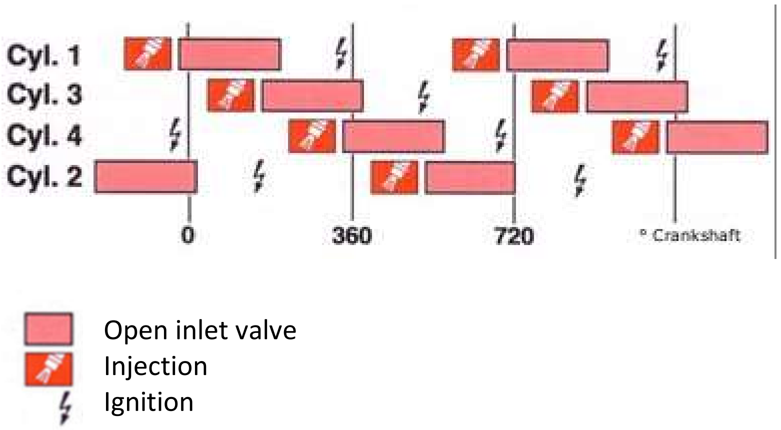
1. What type of injection system is found on model MT-E5000?

Choice of answers	Insert a cross where applicable
Single-point injection	
Simultaneous multipoint injection	
Semi-sequential multipoint injection	
Phased sequential multipoint injection	X

2. Explain the operation of this injection system

Choice of answers	Insert a cross where applicable
The injectors are all controlled together	
The injectors are controlled in pairs	
The injectors are controlled one by one	X

Diagram of phased sequential injection with opening of the inlet valves



3. Which sensor does the ECU use for this phasing?

Choice of answers	Insert a cross where applicable
Coolant thermistor	
Inductive sensor on flywheel	X
Knock sensor	
Hall-effect cylinder reference sensor	X

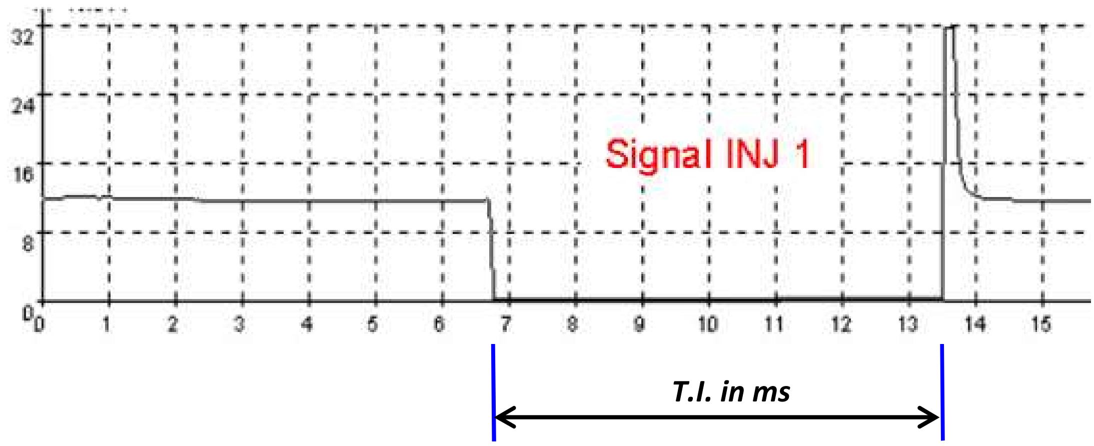
4. Give the injection sequence

Injection sequence	Insert a cross where applicable
1 - 4 - 2 - 3	
1 - 3 - 4 - 2	X
1 - 2 - 4 - 3	

5. What is the T.I. in ms indicated by one of the displays on the model?

Choice of answers	Insert a cross where applicable
Injector open time	
Injector command time	X
ECU initialisation time	
Coil filling time	

6. Using an oscilloscope, record the graph of an injector command on the model. Show where the injection time (TI) is on the graph



7. On which information will the ECU establish its **base injection time**?

Choice of answers	Insert a cross where applicable
Engine speed	X
Coolant temperature	
Air temperature	
Battery voltage	
Oxygen sensor voltage	
Throttle position	
Inlet manifold pressure	X

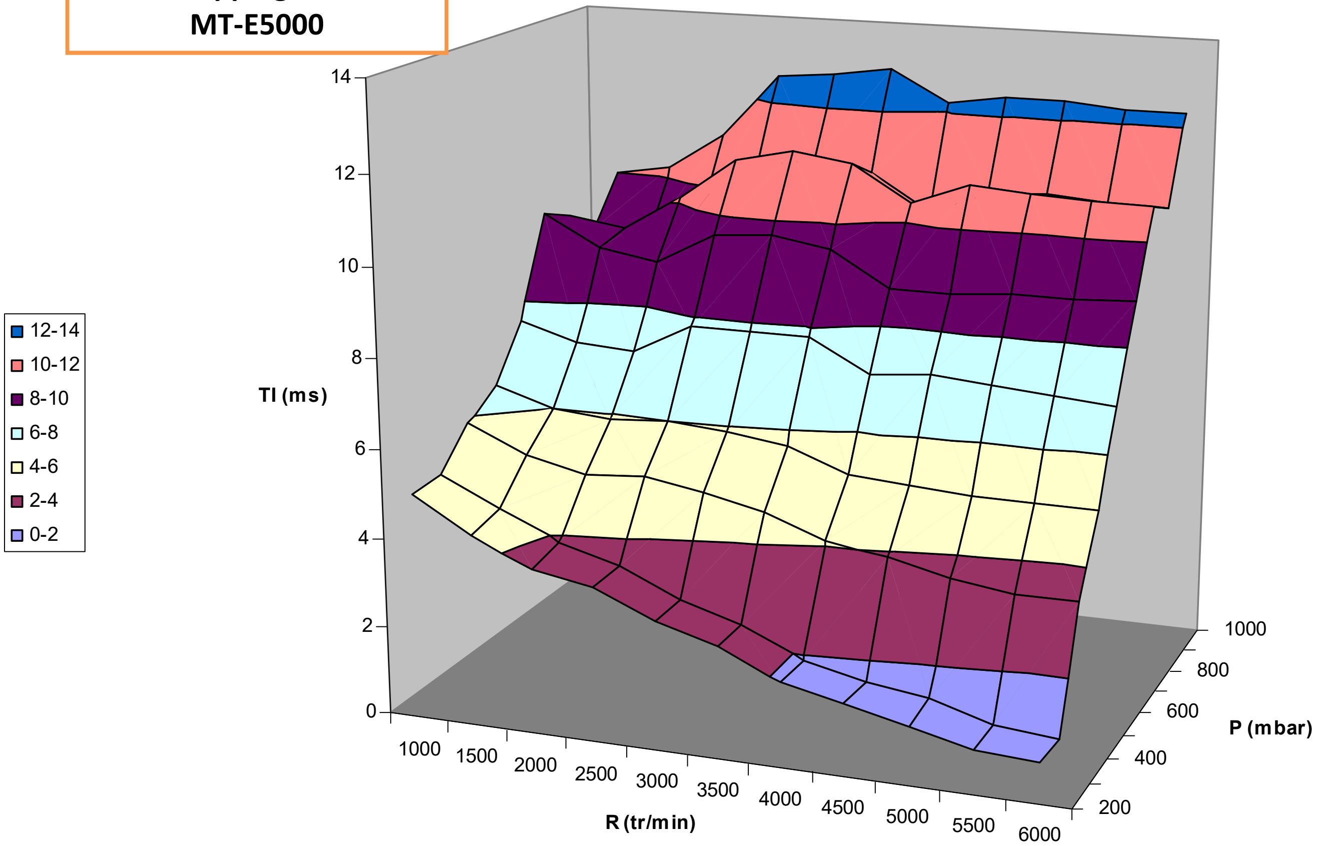
8. The ECU will modify the **base injection time** in relation to **correction data**. What does this data include?

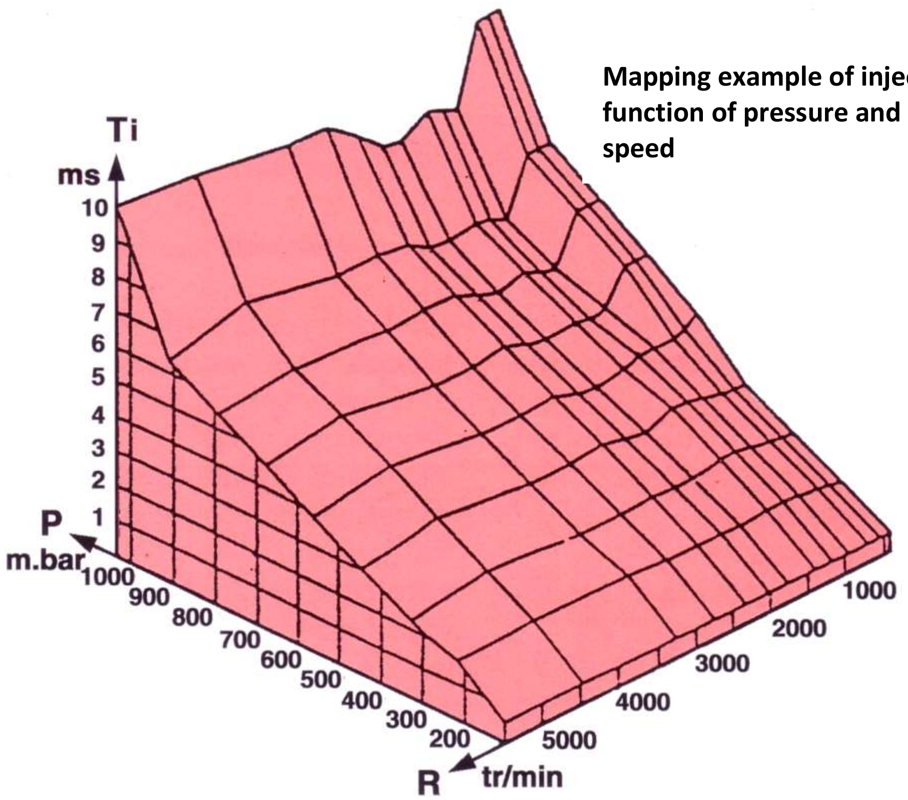
Choice of answers	Insert a cross where applicable
Engine speed	
Coolant temperature	X
Air temperature	X
Battery voltage	X
Oxygen sensor voltage	X
Throttle position	X
Inlet manifold pressure	

9. Using the displays on the model, record and map the injection time in relation to inlet pressure and engine speed

	1000 rpm	1500 rpm	2000 rpm	2500 rpm	3000 rpm	3500 rpm	4000 rpm	4500 rpm	5000 rpm	5500 rpm	6000 rpm
200 mbar	5.1	4.3	3.7	3.5	2.9	2.5	1.9	1.6	1.3	1	0.9
300 mbar	5.1	4.5	3.9	3.5	2.9	2.5	1.9	1.6	1.4	1	0.9
400 mbar	5.9	5.3	5	5.1	4.9	4.6	4.1	3.9	3.6	3.4	3.4
500 mbar	6.4	6	5.9	6	5.9	5.7	5.2	5.1	5	5	5
600 mbar	7.6	7.2	7.1	7.8	7.8	7.8	7.1	7.2	7.1	7	6.9
700 mbar	9.8	9.1	8.9	9.6	9.7	9.5	8.7	8.7	8.8	8.8	8.9
800 mbar	9.5	9.3	10.1	11.1	11.4	11.2	10.4	10.9	10.8	10.7	10.7
900 mbar	8.9	8.8	9.6	10.7	10.9	10.7	9.9	10.4	10.5	10.4	10.4
1000 mbar	10	10.2	11.1	12.6	12.7	12.9	12.2	12.4	12.4	12.3	12.3

TI mapping on model MT-E5000

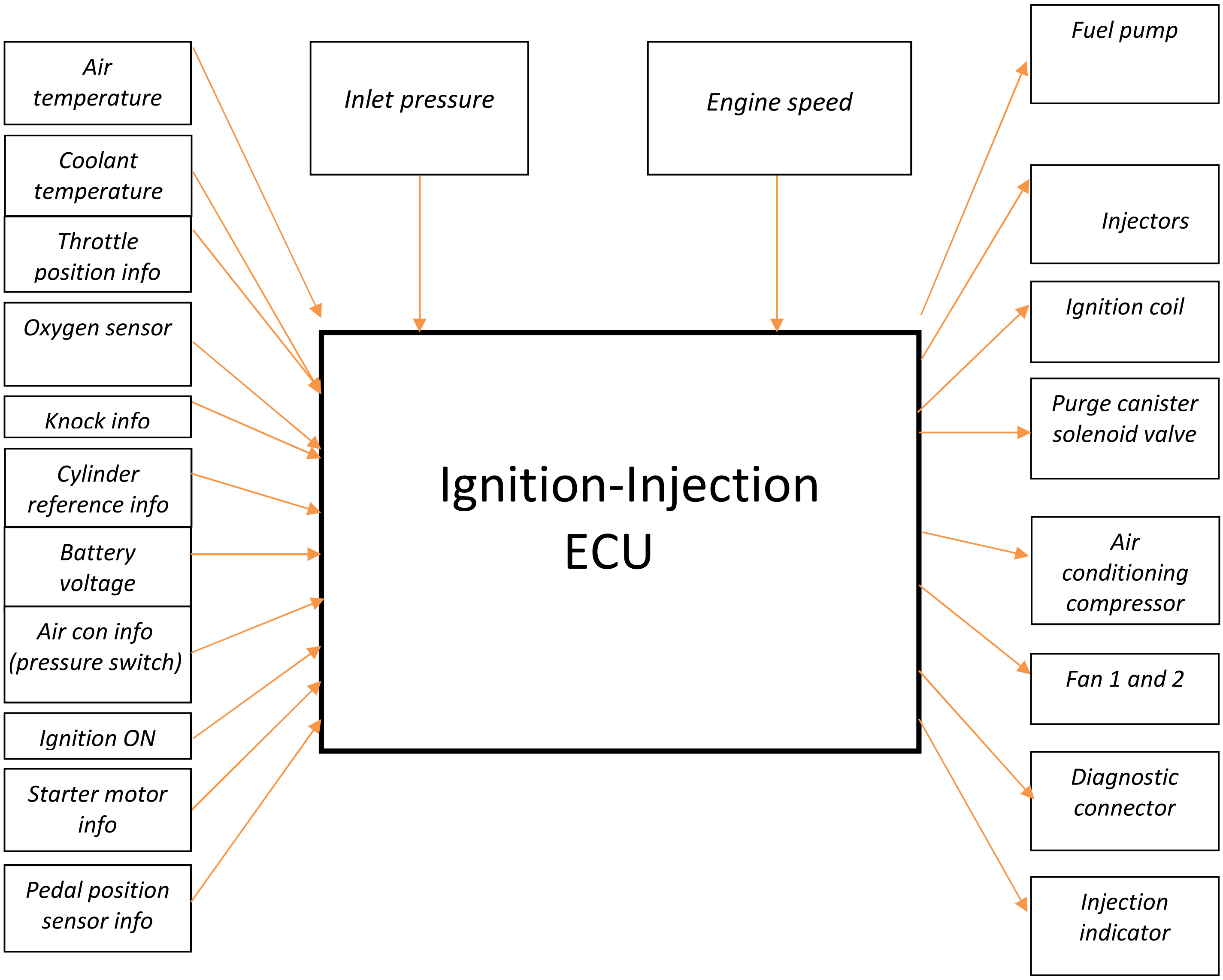




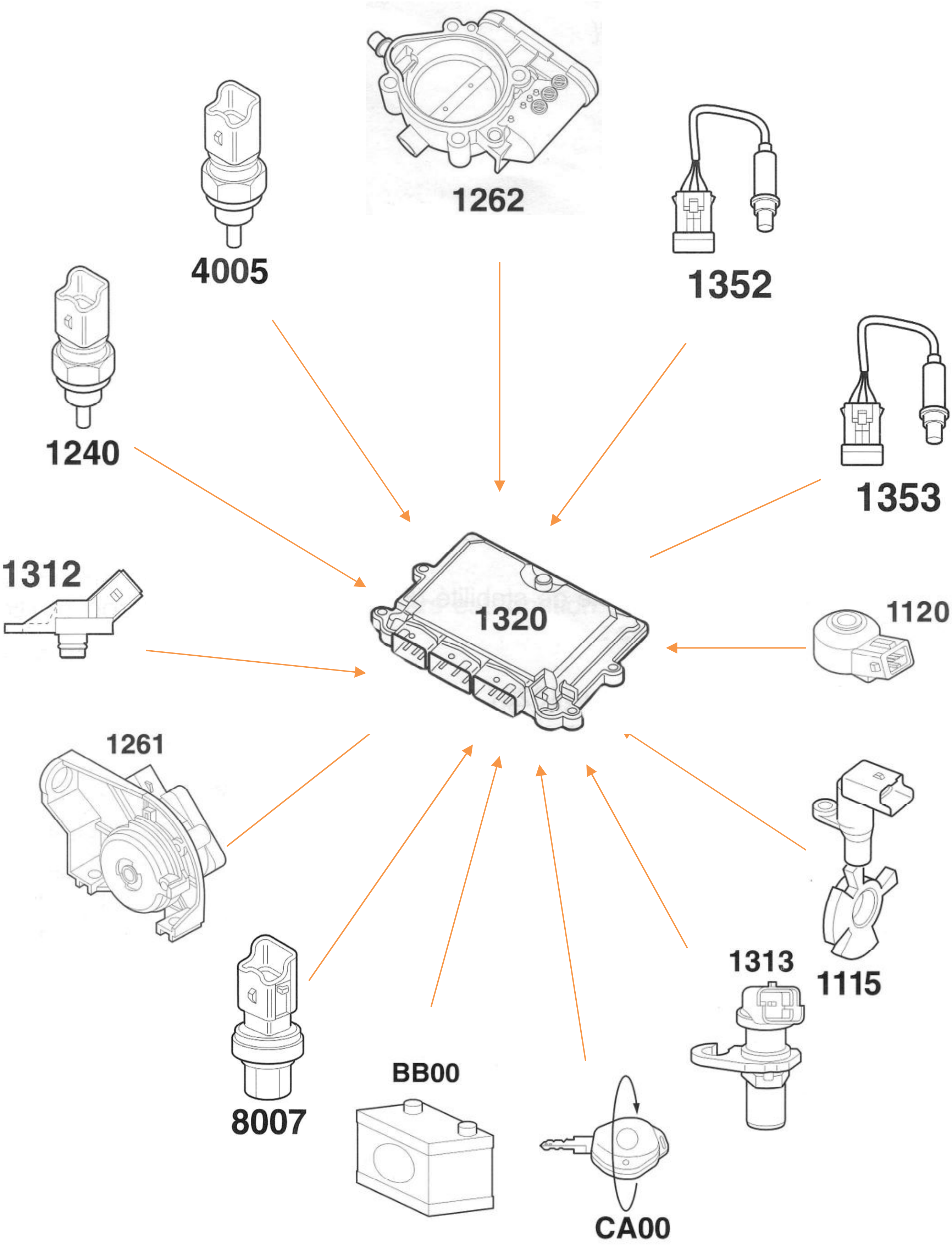
Mapping example of injection time function of pressure and engine speed

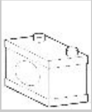
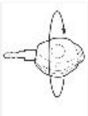
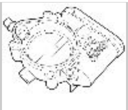
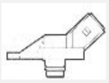
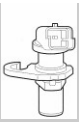
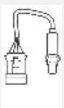
3.7 Practical Exercise 7 – Ignition-Injection Control Unit Inputs/Outputs

1. Complete the functional analysis



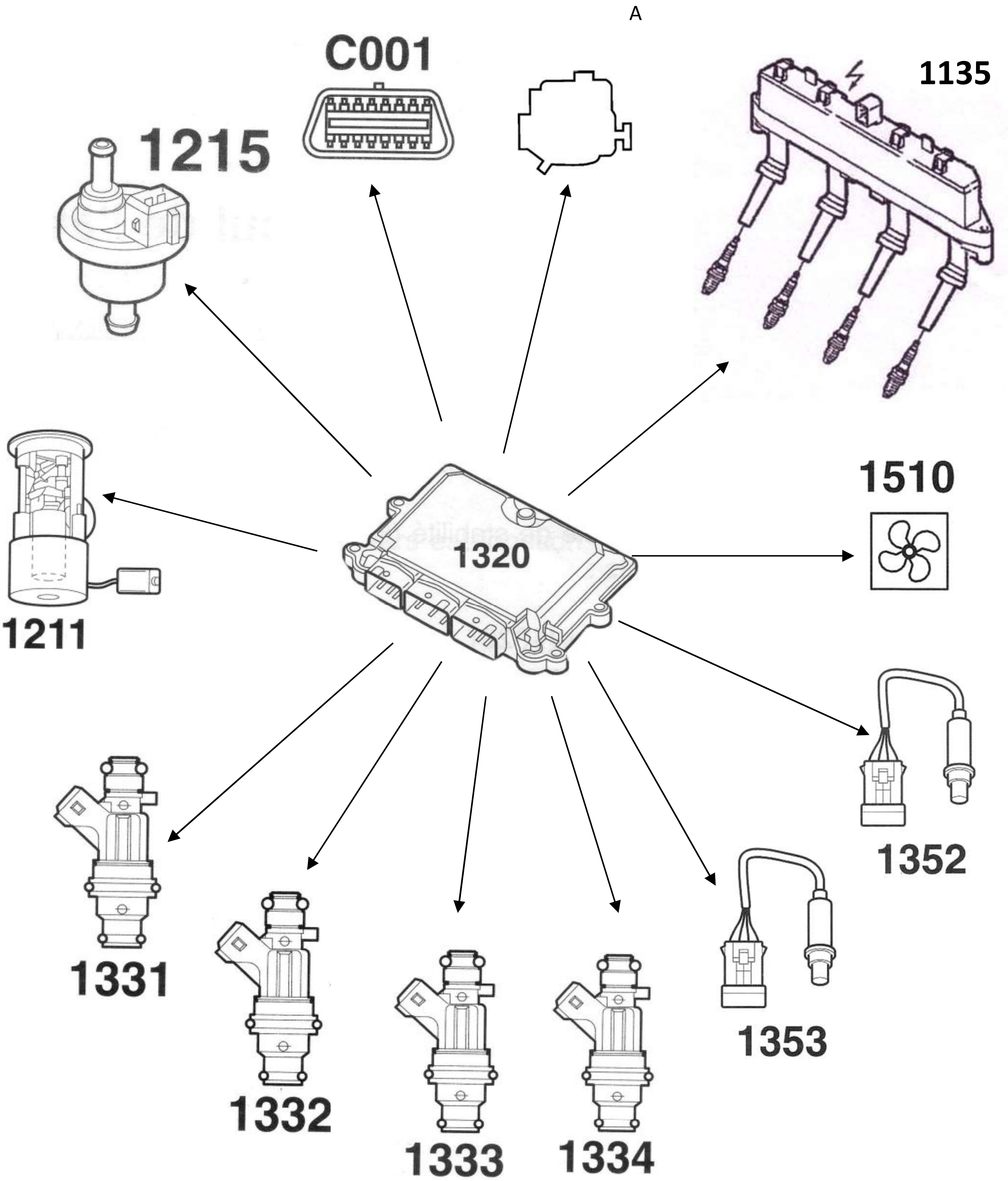
2. ECU input diagram – complete the table

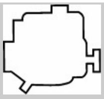
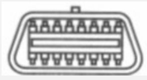
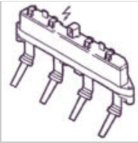
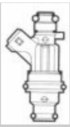
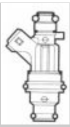
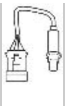
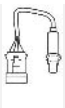


Ref.	Illustration	Description	Function
BB00		Battery	Supplies electrical energy to the vehicle on starting. Acts as a buffer in the electric circuit with the engine running.
CA00		Ignition switch	Accessory, On and Start information Engine immobiliser check
1115		Phase sensor	Cylinder reference information
1120		Knock sensor	Knock information
1240		Inlet air thermistor	Air temperature information
1261		Accelerator pedal potentiometer sensor	Driver action information
1262		Electronic throttle control	Electronic throttle position information
1312		Inlet manifold pressure sensor	Inlet pressure information
1313		Engine speed sensor	Engine speed information
1320		Ignition-injection ECU	Injection and ignition control
1352		Downstream oxygen sensor	Information on oxygen content in exhaust gases after passing through catalytic converter
1353		Upstream oxygen sensor	Information on oxygen content in exhaust gases before passing through catalytic converter
4005		Coolant thermistor	Coolant temperature information

8007		*Pressure switch*	Air conditioning system pressure information

3. <u>ECU output diagram – complete the table</u>



Ref.	Illustration	Description	Function
A		Injection indicator	Warning on instrument panel
C001		Diagnostic connector	Standardised connection for diagnostic device
1135		Twin static ignition coil	Provides the voltage required to obtain a spark at the plug
1211		Fuel pump	Provides a suitable fuel flow rate and pressure for injection system and engine operation
1215		Purge canister solenoid valve	Evacuates fuel vapours to the inlet manifold.
1320		Ignition-injection control unit	Injection and ignition control
1331		Injector 1	Opens on command to inject petrol
1332		Injector 2	Opens on command to inject petrol
1333		Injector 3	Opens on command to inject petrol
1334		Injector 4	Opens on command to inject petrol
1352		Downstream oxygen sensor	Commands sensor heating
1353		Upstream oxygen sensor	Commands sensor heating
1510		Fan	Ventilates the cooling radiator to maintain optimum engine temperature

3.7 Practical Exercise 8 – Coolant Temperature Sensor

There are two types: NTC sensors and PTC sensors.

1. <u>What does the coolant temperature sensor do?</u>

This sensor proves an electrical image of the variation in engine coolant temperature to the ECU. This information is important as it will determine the ECU strategy for cold starting, for activating the fan at low and high speed, and for the injection time.

2. <u>What type of sensor is it? Complete the table</u>

Sensor type	Answer
Inductive	
Piezoresistive	
Thermistor	X
Piezoelectric	
Hall effect	

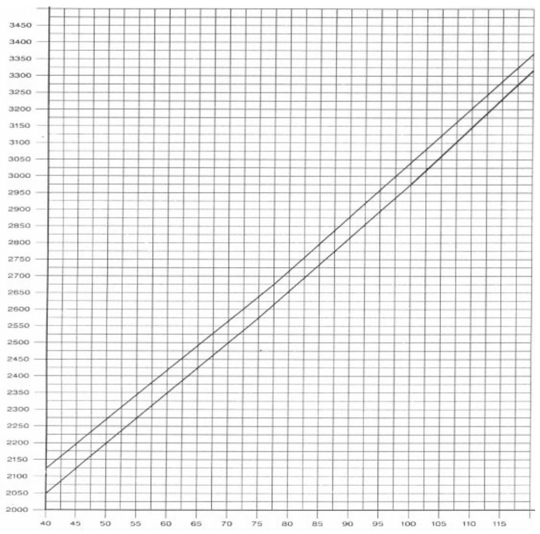
It's a thermistor. Its resistance varies with temperature in a non-linear manner.

3. <u>Where is it located?</u>

It is located on the water unit or cylinder head.

Coolant sensor located on	Answer
Cooling radiator	
Heating radiator	
Water unit	X
Water pump	

1. What does PTC mean? Provide a definition.

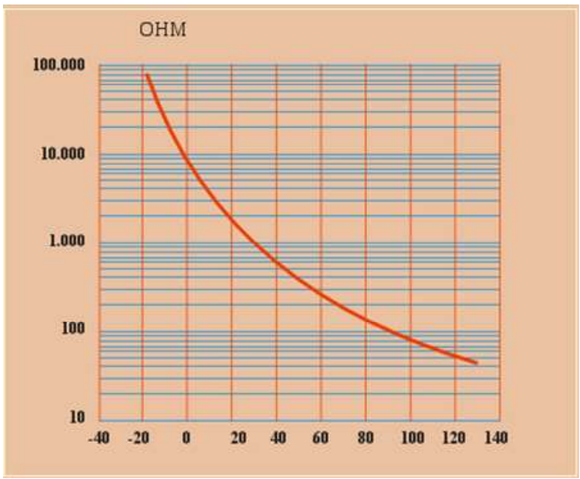


The abbreviation PTC means Positive Temperature Coefficient. The resistive value of the sensor increases as the temperature increases.

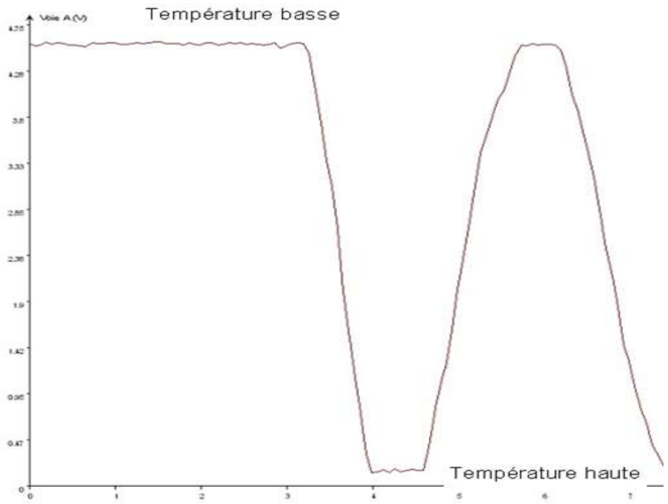
2. What does NTC mean? Provide a definition.

The abbreviation NTC means Negative Temperature Coefficient. The resistive value of the sensor decreases as the engine temperature increases.

Example of changing parameters

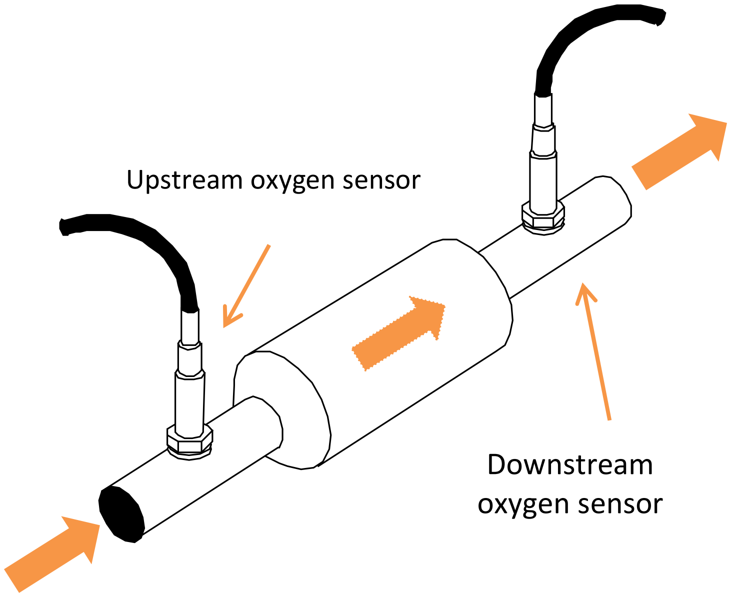


3. Using the model, measure and plot the signal (voltage) of the coolant thermistor in relation to the coolant temperature. Is it an NTC or PTC thermistor? Provide an explanation.

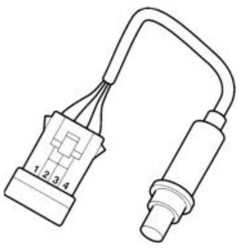


It can be seen from the curve that resistance decreases as the temperature increases. It is therefore an NTC (negative temperature coefficient) thermistor.

3.9 Practical Exercise 9 – Oxygen Sensor



1. What does the upstream oxygen sensor do?



The oxygen sensor measures the oxygen content of exhaust gases and transmits the information to the ECU as a voltage.

The ECU corrects the injection time based on this information to adjust the richness of the mixture.

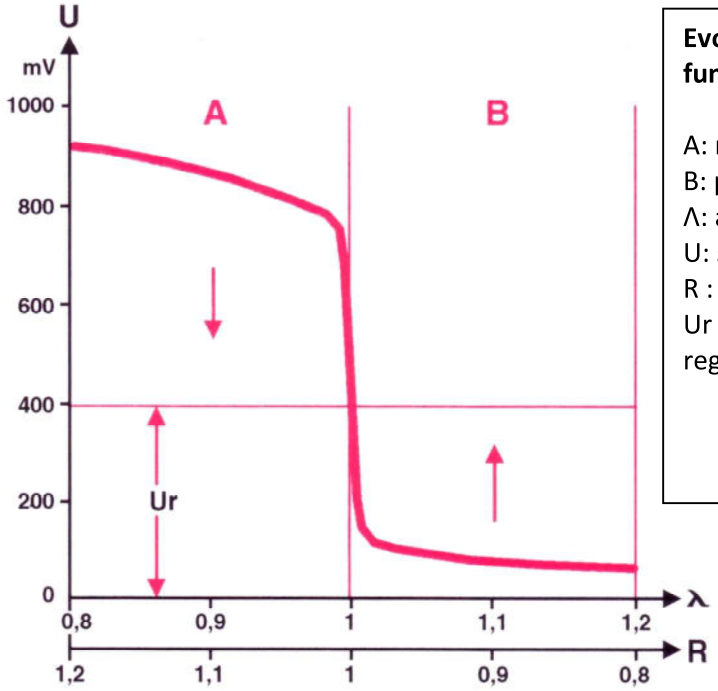
2. Where is it located?

The upstream sensor is located on	Answer
The inlet manifold	
The exhaust before the catalytic converter	X
The exhaust after the catalytic converter	
The cylinder head	
The air filter	

The sensor is installed on the exhaust line, at the entry to the catalytic converter (upstream).

3. <u>Define richness</u>

Richness is the relation between the actual air/fuel ratio and the theoretical air/fuel ratio. For a lean mixture, richness R is less than 1. For a rich mixture, richness R is greater than 1.



Evolution of sensor's voltage function of gas mixture

A: rich mixture (loss of air)
B: poor mixture (air excess)
Λ: air coefficient
U: sensor's voltage
R : mixture
Ur : average voltage of regulation

4. <u>Define the air coefficient λ (lambda ratio)</u>

The air coefficient is the ratio between the introduced air mass and the theoretical air mass. Thus, for a rich mixture, the quantity of air is lower and $\lambda < 1$. For a lean mixture, the quantity of air is higher and $\lambda > 1$.

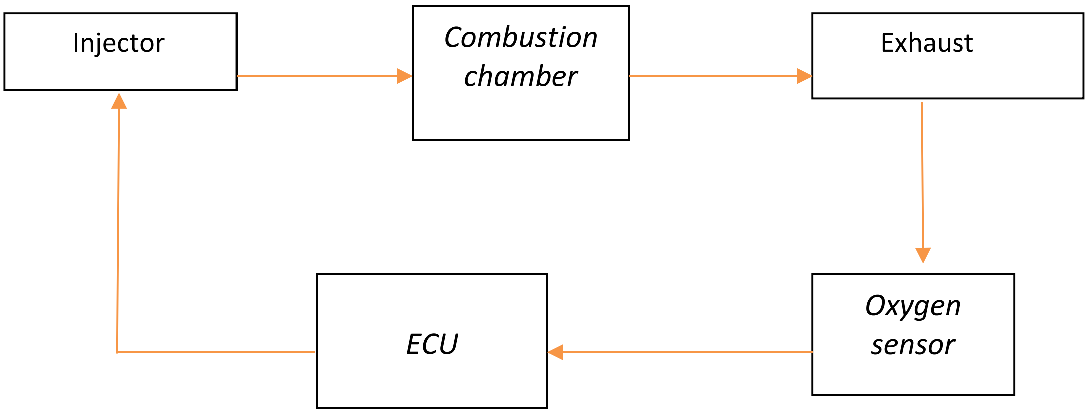
5. <u>Give the ratio between the air coefficient and richness</u>

The ratio is $\lambda = 1 / R$.

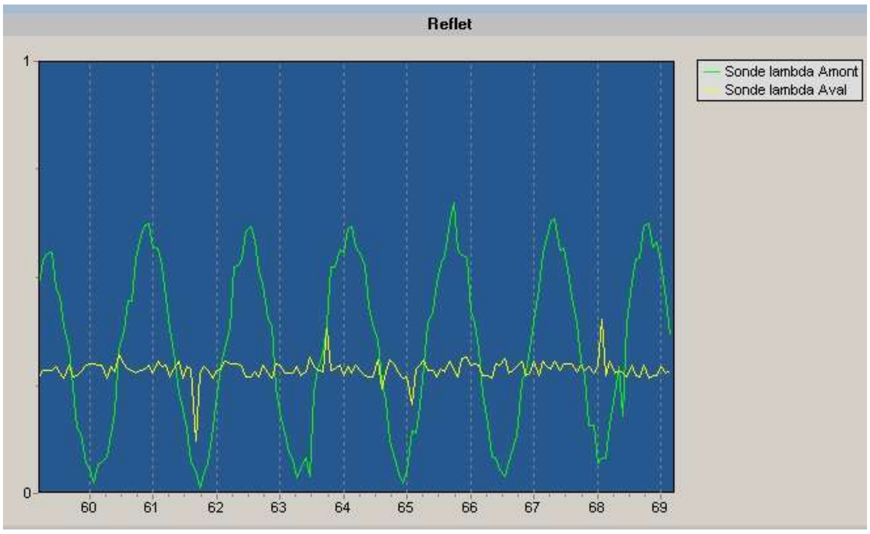
6. <u>With a sensor voltage of around 0.1 V, will the ECU generate a leaner or richer mixture? Why?</u>

The ECU will generate a richer mixture because, with a voltage of around 0.1 V, richness R is less than 1 which indicates a lean mixture (excessive air).

7. Complete the richness loop diagram below



8. Record the signals from the upstream and downstream oxygen sensors on the model in normal operation (with the Reflet plotter, for example).



9. What do you notice on the downstream sensor signal?

This sensor emits a constant voltage signal of around 0.4 V, whereas the upstream sensor produces a sine-wave signal.

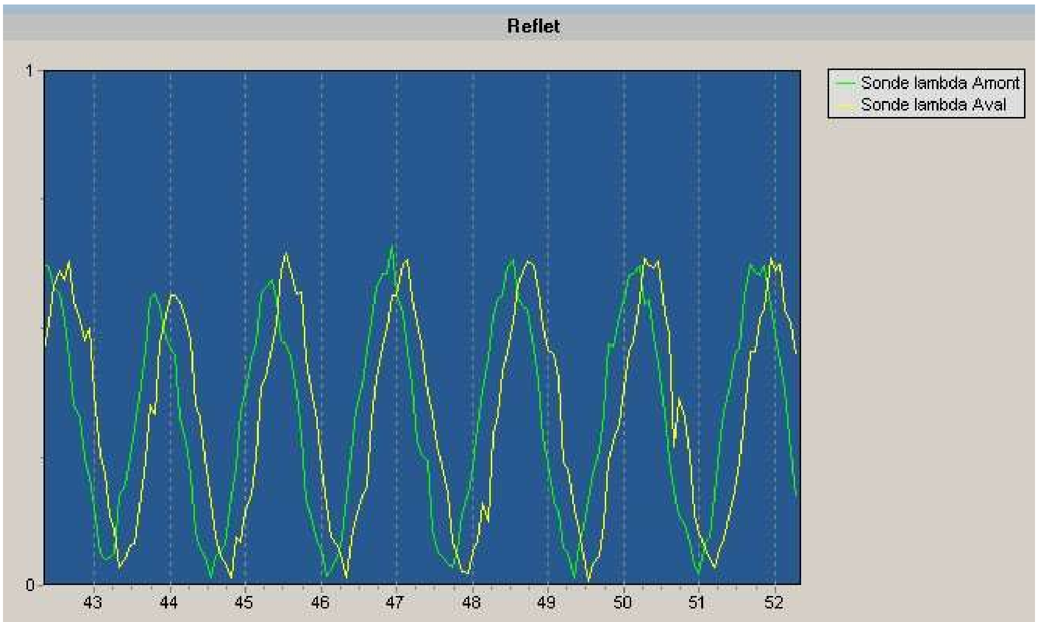
10. What does the downstream oxygen sensor do?

The downstream sensor emits a constant voltage signal to the ECU that indicates the oxygen content of the exhaust gases. It therefore plays a part in controlling the catalytic converter.

11. Where is it located?

The downstream sensor is located on	Answer
The inlet manifold	
The exhaust before the catalytic converter	
The exhaust after the catalytic converter	X
The cylinder head	
The air filter	

12. Record the signals from the upstream and downstream oxygen sensors on the model with a catalytic converter fault (with the Reflet plotter, for example).



13. What do you notice on the downstream sensor signal?

The downstream sensor signal is identical to the upstream sensor signal but out of phase (delayed) by a quarter of a period.

14. What can be deduced from this?

Given that the signal oscillates in an identical way to the upstream sensor, we can deduce that the catalytic converter is faulty (inefficient).

DECLARATION CE OF CONFORMITY

By this declaration of conformity under the terms of Electromagnetic Compatibility Directive 2004/108/EC:

S.A.S. ANNECY ELECTRONIQUE
Parc Altaïs - 1 rue Callisto
F–74650 CHAVANOD

Declares that the following product:

Make	Model	Description
EXXOTEST	**MT-E5000**	**BENCHTOP LEARNING MODEL:** **Phased sequential petrol injection**

I - has been manufactured in accordance with the requirements of the following European directives:

- Low Voltage Directive 73/23/EC of 19 February 1973
- Machinery Directive 98/37/EC of 22 June 1998
- Electromagnetic Compatibility Directive 2004/108/EC of 15 December 2004

and complies with the requirements of standard:

- EN 61326-1 of 07/1997 +A1 of 10/1998 +A2 of 09/2001

Electrical equipment for measurement, control and laboratory use. EMC requirements.

according to the following specifications:

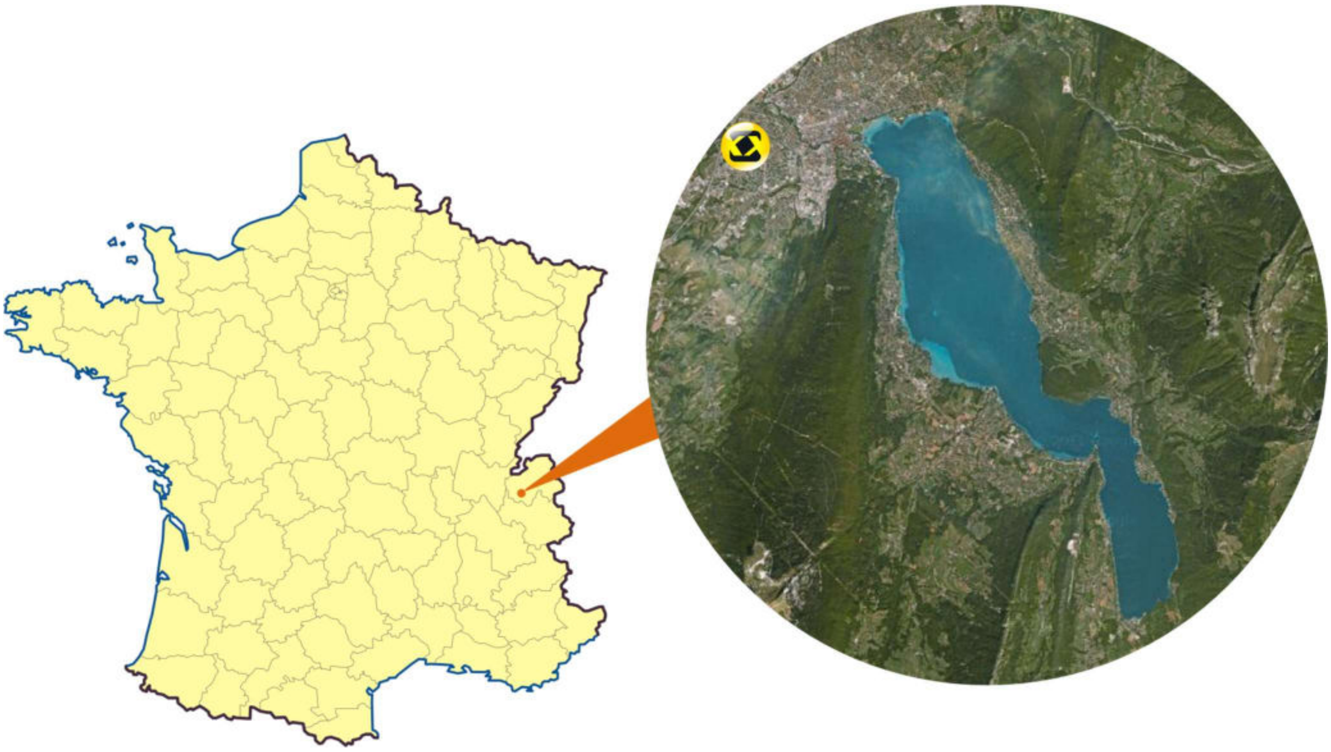
EN 55022:2003:	Class B
IEC 801-2:1991:	Severity Level 3
IEC 801-3:1984:	3 V/m.
IEC 801-4:1988:	Severity Level 2

II – has been manufactured in compliance with the requirements of European directives relating to the design of Electrical & Electronic Equipment (EEE) and the management of Waste Electrical & Electronic Equipment (WEEE) in the EU:

- Directive 2002/96/EC of 27 January 2003 on waste electrical and electronic equipment
- Directive 2002/95/EC of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Signed in Saint-Jorioz on 24 July 2007

Stéphane Sorlin, Chairman



Visit our website www.exxotest.com
This document is available in the Download Area.

Espace Téléchargements

Register now!

ANNECY ELECTRONIQUE, Designer and Manufacturer of Exxotest and Navylec equipment
Parc Altaïs, 1 rue Callisto, F-74650 CHAVANOD. Tel. +33 (0)4 50 02 34 34 – Fax: +33 (0)4 50 68 58 93
RC ANNECY 80 B 243 – SIRET 320 140 619 00042 – APE 2651B – VAT No. FR 37 320 140 619
ISO 9001:2008 FQA No. 40001142 by L.R.Q.A.