## HITACHI INTEGRATED FUEL INJECTION-IGNITION

### INTRODUCTION

The Hitachi system fitted to the Barchetta model with 1747 i.e. 16v engine belongs to the category of digital electronic ignition systems with static advance and timing integrated with an electronic fuel injection of the phased multiple intermittent type.
The integrated system can be divided into the following subsystems:

ELECTRICAL/ELECTRONIC SYSTEM
AIR INTAKE SYSTEM
FUEL SUPPLY SYSTEM
EMISSION CONTROL SYSTEMS

The system can measure the following parameters via appropriate sensors:

1. instantaneous engine rpm;
2. position of each pair of pistons in relation to TDC of cylinder 1;
3. air flow drawn in by the engine;
4. position and speed of variation in position of the throttle valve;
5. coolant temperature;
6. actual mixture strength (by means of the Lambda probe signal);
7. presence of knocking;
8. vehicle speed;
9. battery voltage;
10. whether the air conditioner compressor is switched on.

This information, generally of analogue type, is converted into digital signals by analogue/digital (A/D) converters so that it can be used by the control unit.
In particular, any point of operation of the engine is identified, at each instant, by two parameters:

- the engine speed, measured in revolutions per minute (rpm);
- the engine load, which consists of the quantity of air drawn in by each cylinder.
  This quantity is calculated on the basis of the intake air flow and is represented by the parameter TP, measured in milliseconds (ms).

Resident in the control unit memory is the software program, which consists of a set of strategies, each of which manages a precise control function of the system.

By using the above-mentioned information (inputs), each strategy works out a series of parameters, based on the mapped data stored in special areas of the control unit, and subsequently controls the actuators (outputs) of the system, which are the devices which enable the engine to operate, such as:

1. fuel injectors;
2. ignition coils;
3. various types of solenoids;
4. fuel pump;
5. control contactors.

**NOTE** *The HITACHI fuel injection-ignition does not require any adjustment as it is of the self-adjusting and self-adaptive type.*

**NOTE** *In the drawings and diagrams, the numbers in squares indicate the corresponding pins on the HITACHI engine control unit (the number followed by A indicates the connector A, the number followed by B indicates the connector B).*

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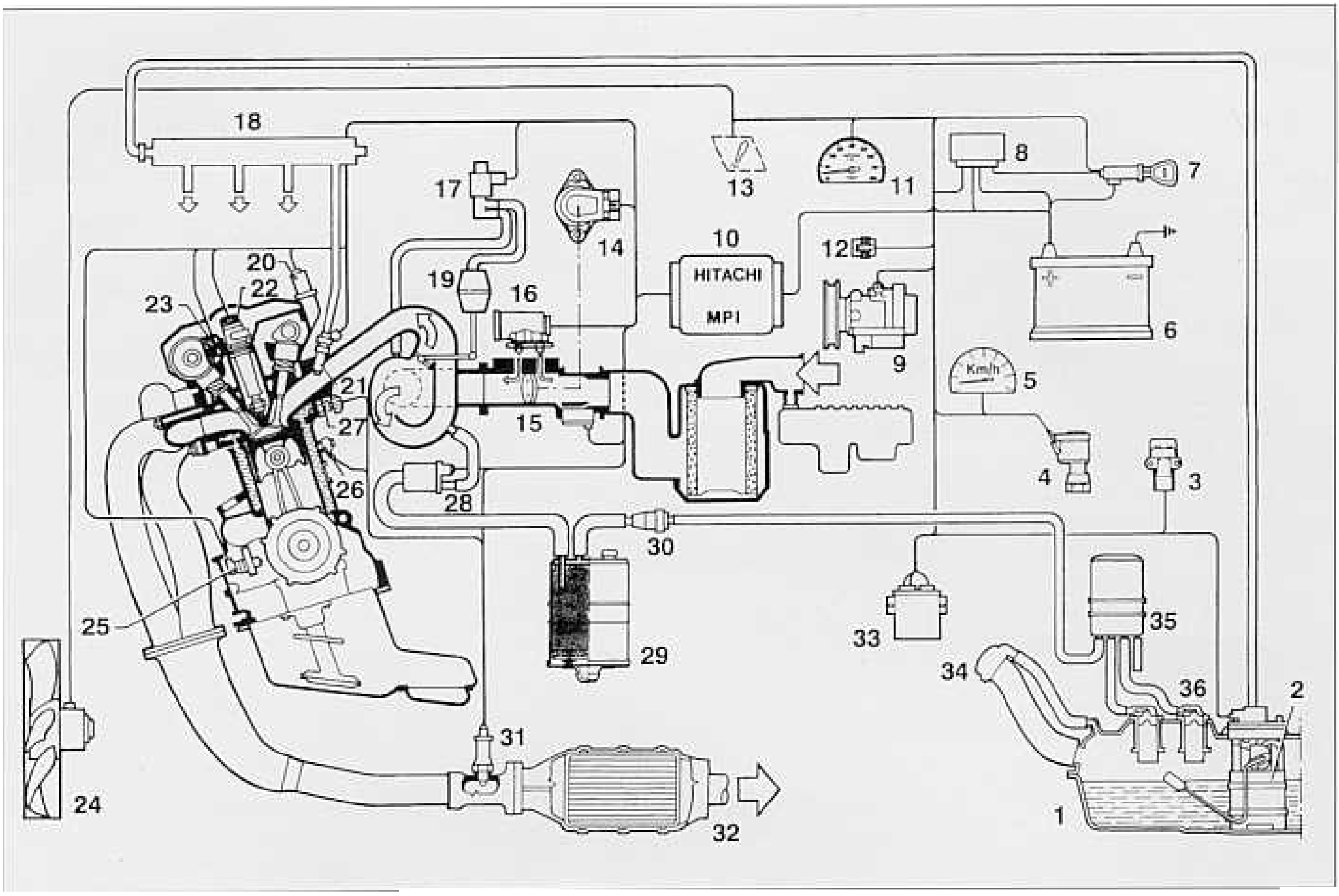
### FUNCTIONAL DIAGRAM OF HITACHI FUEL INJECTION-IGNITION

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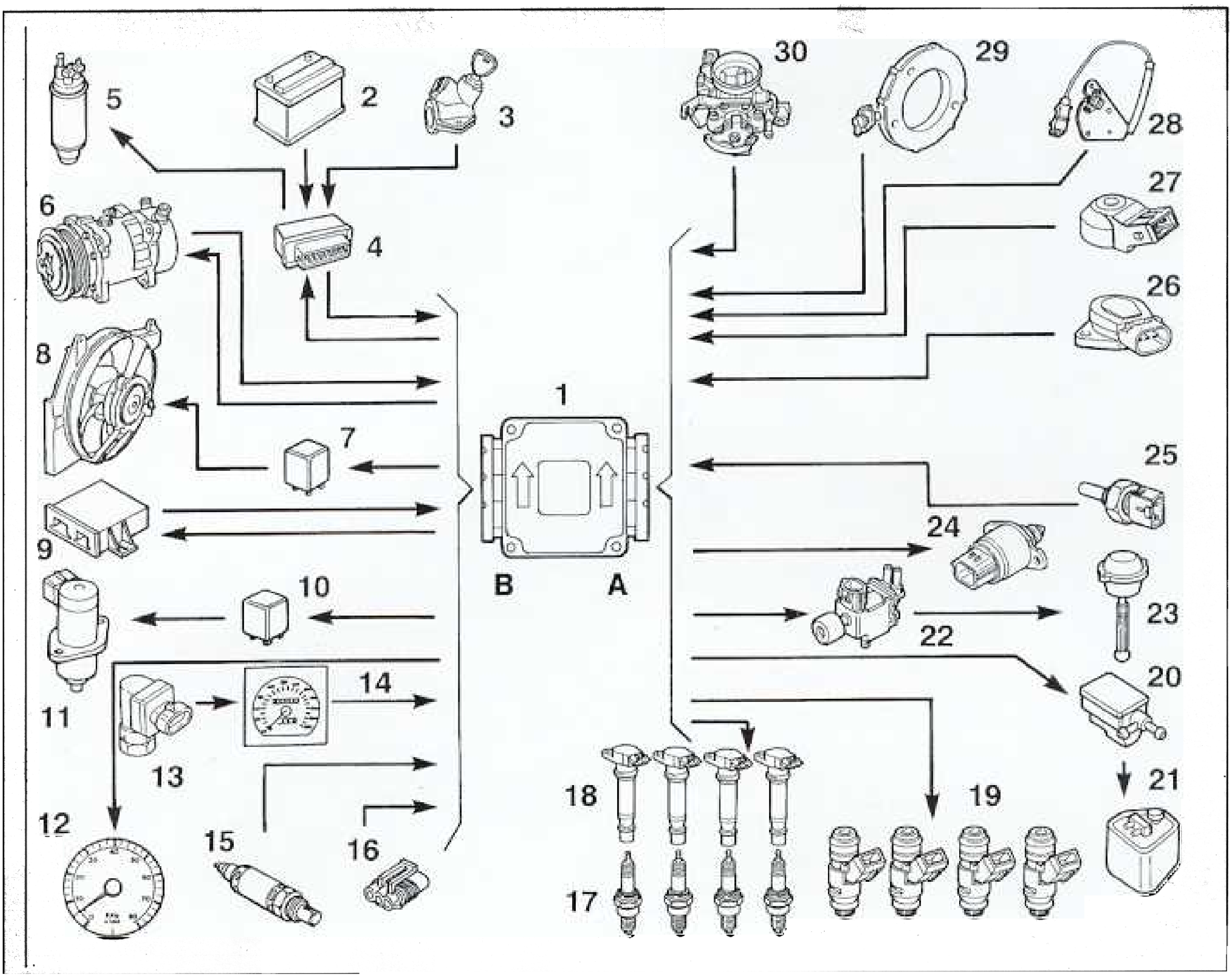
1. Fuel tank
2. Cage comprising: electric fuel pump, pressure regulator, filter, fuel gauge sender unit
3. Inertial switch
4. Vehicle speed sensor
5. Speedometer
6. Battery
7. Ignition key
8. Double contactor
9. Air conditioner compressor
10. HITACHI engine control unit
11. Rev counter
12. Diagnostic instrument connector
13. System fault warning light
14. Throttle position sensor
15. Throttle body with integrated air flow meter
16. Engine idle speed adjustment actuator
17. Modular manifold actuator control solenoid
18. Fuel manifold
19. Modular manifold actuator
20. Timing variator solenoid
21. Fuel injector
22. Coil
23. Engine timing sensor
24. Radiator fan
25. Engine rpm sensor
26. Knock sensor
27. Coolant temperature sensor
28. Charcoal filter scrubbing solenoid
29. Charcoal filter
30. Ventilation valve
31. Lambda probe
32. Catalytic converter
33. FIAT CODE control unit
34. Filler cap with safety valve
35. Fuel vapour separator
36. Anti-roll valve

## DIAGRAM OF INPUT/OUTPUT INFORMATION BETWEEN CONTROL UNIT AND SENSORS/ACTUATORS OF THE HITACHI FUEL INJECTION-IGNITION

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1. HITACHI engine control unit
2. Battery
3. Ignition switch
4. Double contactor
5. Electric fuel pump
6. Air conditioner
7. Radiator fan contactor
8. Radiator fan
9. FIAT CODE control unit
10. Timing variator fan contactor
11. Timing variator fan
12. Rev counter
13. Vehicle speed sensor
14. Speedometer
15. Lambda probe
16. Diagnostic instrument connector
17. Spark plugs
18. Coils
19. Fuel injectors
20. Charcoal filter scrubbing solenoid
21. Charcoal filter
22. Modular manifold actuator control solenoid
23. Modular manifold actuator
24. Engine idle speed adjustment stepper motor
25. Coolant temperature sensor
26. Throttle position sensor
27. Knock sensor
28. Engine timing sensor
29. Engine rpm sensor
30. Air flowmeter

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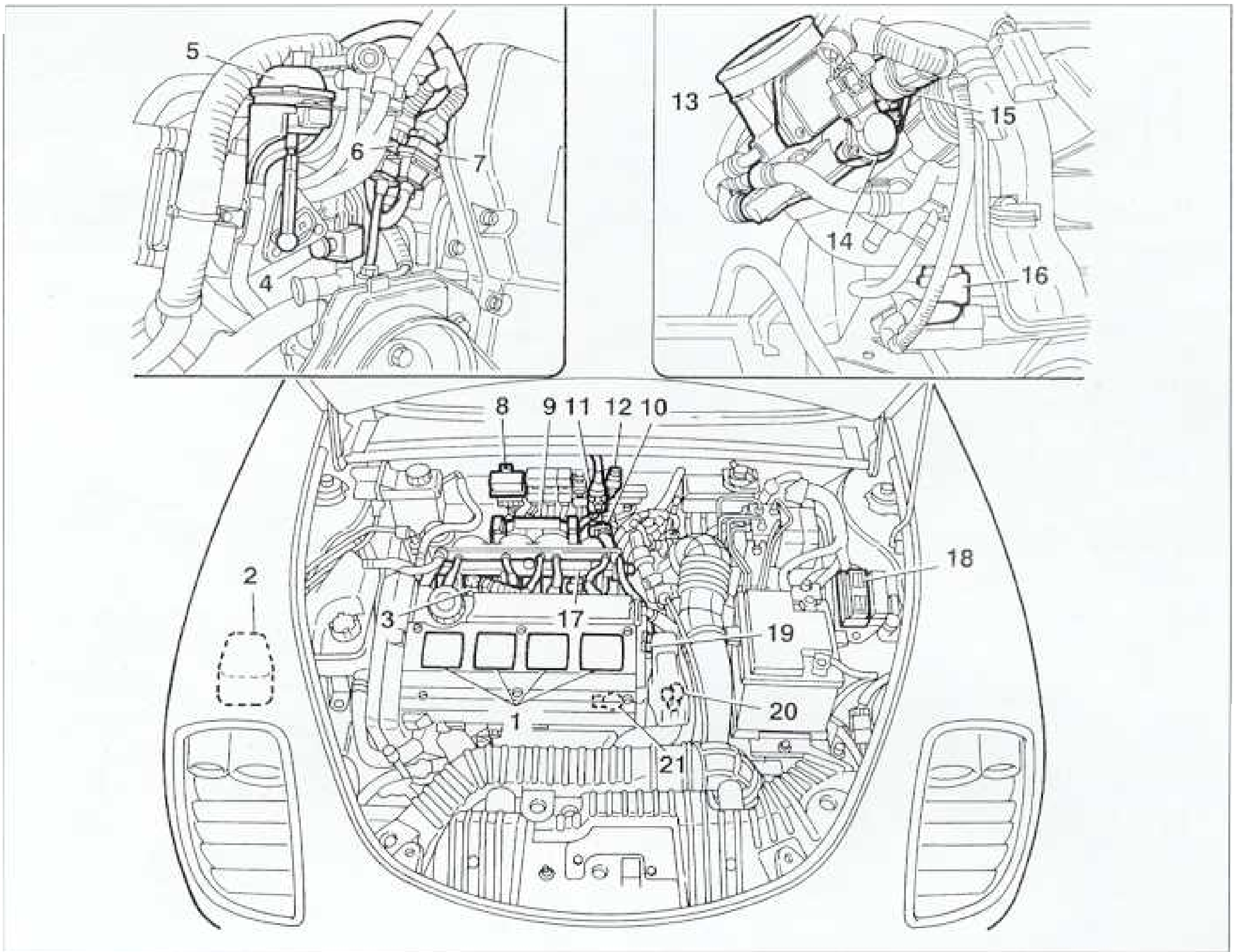
## LOCATION OF THE HITACHI FUEL INJECTION-IGNITION COMPONENTS IN THE ENGINE COMPARTMENT

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1. Coils
2. Charcoal filter
3. Timing variator solenoid
4. Modular manifold actuator solenoid
5. Modular manifold actuator
6. Knock sensor connector
7. Engine timing sensor connector
8. Double contactor
9. HITACHI engine control unit
10. Interface connector
11. Lambda probe connector
12. Diagnostic socket connector
13. Throttle body with air flowmeter
14. Throttle position sensor
15. Engine idle speed adjustment actuator
16. Charcoal filter scrubbing solenoid
17. Fuel manifold with fuel injectors
18. System fuses
19. Coolant temperature sensor
20. Vehicle speed sensor
21. Engine rpm sensor

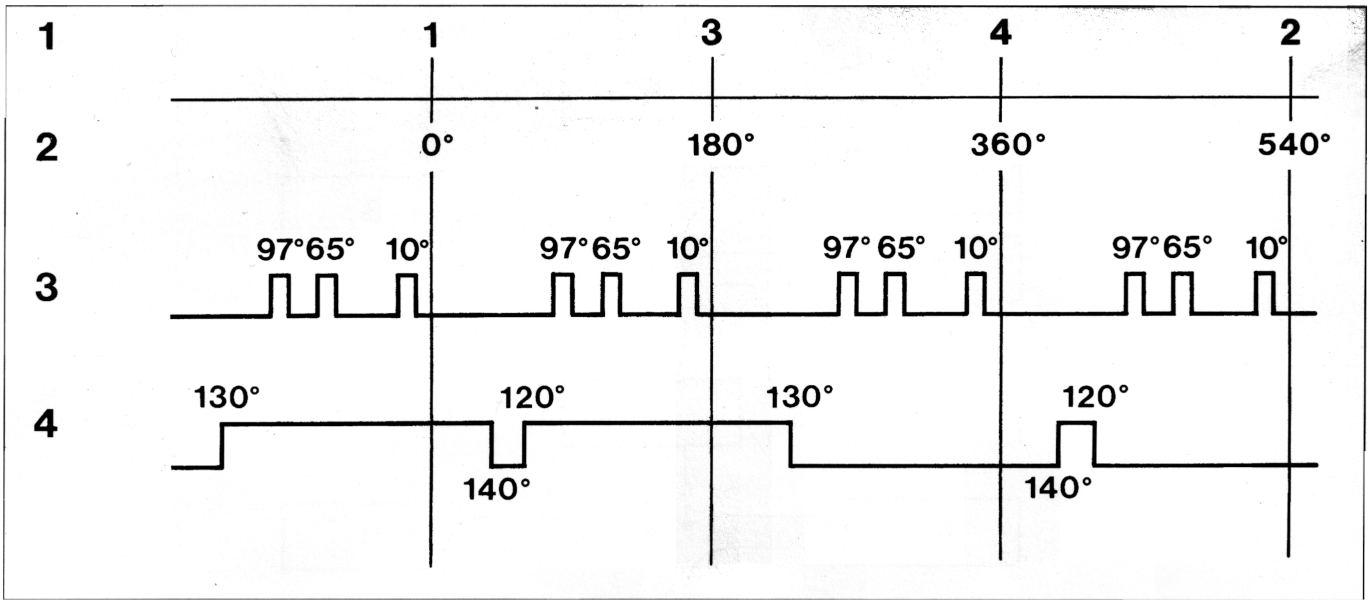
## SYSTEM MANAGEMENT STRATEGIES

### MANAGEMENT OF THE SIGNAL PICTURE

During starting, the control unit recognizes the timing of the fuel injection and ignition, which are of fundamental importance of all the strategies.
This recognition is based on the interpretation of the succession of signals coming from the phonic wheel sensor, located on the crankshaft and the engine timing sensor, located on the camshaft.

**NOTE** *The term "picture signal" means the set of signals coming from the sensor on the crankshaft and the sensor on the camshaft which, as they are characterized by a very clear reciprocal position, supply to the control unit a synchronized sequence of signals which the control unit can recognize.*

In particular, the picture signal is made as follows:
- phonic wheel on crankshaft: this has two symmetrical sets of teeth, located at 10°, 65° and 97° in advance in relation to each TDC;
- wheel on camshaft: this has two long windows and a short window, whose width and position provide the signal as shown in the figure.

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1. cylinder TDC
2. Crankshaft angles
3. Crankshaft phonic wheel signal (engine rpm sensor)
4. Camshaft wheel signal (engine timing sensor)

**NOTE** *The numbers relating to the signals indicate the crankshaft angles in advance in relation to the subsequent TDC.*

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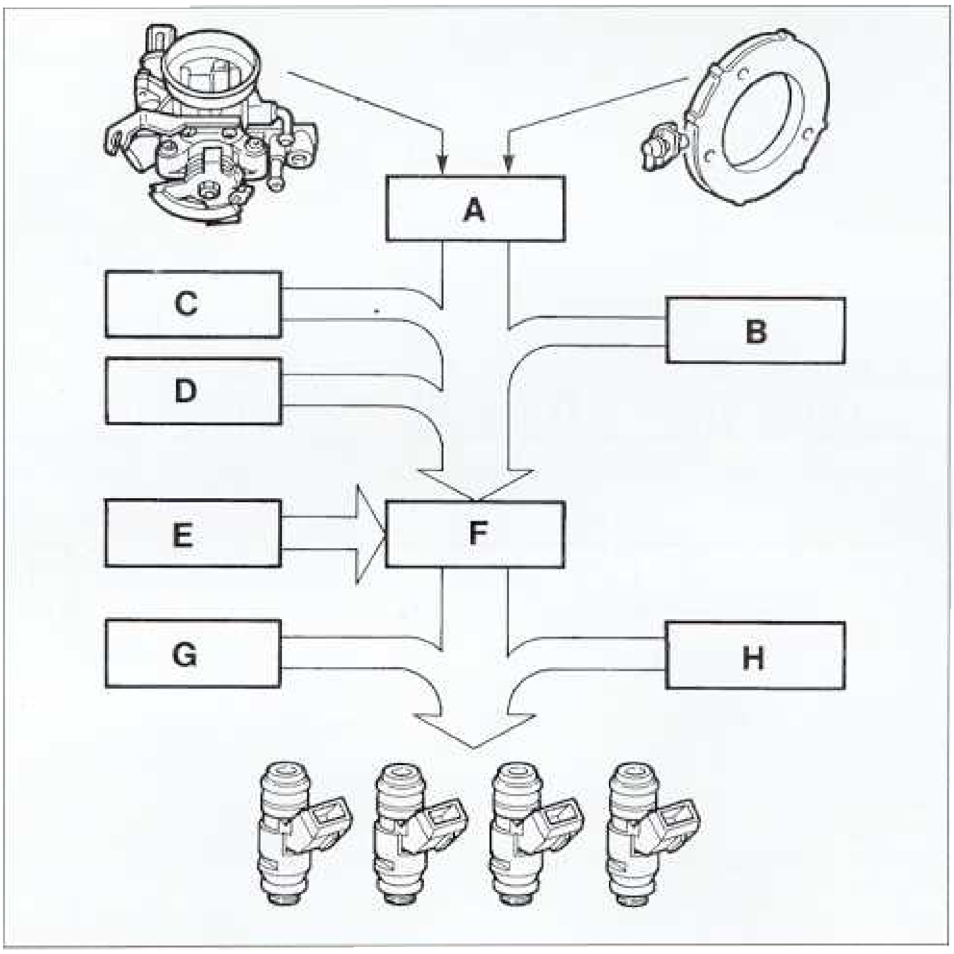
## MANAGEMENT OF FUEL INJECTION

The purpose of the fuel injection management strategies is to supply to the engine the correct amount of fuel at the desired moment in accordance with the engine's operating conditions.

**NOTE** *The air flowmeter directly measures the mass of air drawn in, so rendering the presence of the intake air temperature sensor unnecessary.*

Fuel injection management basically consists of calculating the fuel injection time, determining the injection timing and subsequent implementation by driving the injector.
The "basic" fuel injection time depends on the fuel injector characteristics and corresponds to the quantity of fuel to be injected into each cylinder. This quantity is determined by multiplying the quantity of air drawn in by each cylinder (calculated on the basis of the quantity of air drawn in and the engine rpm) by the required mixture strength in relation to the point of operation of the engine.
The final injection time is determined by a calculation algorithm in which the "basic" time is corrected by a set of coefficients which take account of the different operating conditions of the engine, which are detected by the various sensors present in the system.

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A: "basic" injection time
B: corrective coefficients:
- low engine temperature
- high engine temperature
- starting and post-start.
- throttle fully open
- deceleration
- acceleration

C: feedback strength control
D: self-adaptivity
E: cut-off
F: intermediate injection time
G: extra-pulse
H: unphased injection management

### Mixture strength control (feedback control)

**NOTE** *The following ratio defines the mixture ratio and is indicated by the Greek letter $\alpha$ (alpha).*

$$\frac{\textbf{amount of air drawn in by the engine}}{\textbf{amount of fuel injected}}$$

*The following ratio defines the stoichiometric mixture and is indicated by the letter $\alpha_{st}$:*

$$\frac{\textbf{theoretical amount of air required to burn all the injected fuel}}{\textbf{amount of fuel injected}}$$

*The following ratio defines the mixture strength and is indicated by the Greek letter $\lambda$ (lambda):*

$$\frac{\textbf{amount of air drawn in by the engine}}{\textbf{theoretical amount of air required to burn all the injected fuel}}$$

It may easily be deduced that $\alpha / \alpha_{st} = \lambda$.
The stoichiometric ratio depends on the type of fuel: for the current unleaded petrols, it is about 14.7 - 14.8, which corresponds to a strength lambda = 1.
The mixture is *rich* (or *heavy*) when the quantity of air is less than the stoichiometric quantity, and in this case lambda $<1$:
the mixture is *weak* (or *lean*) when the quantity of air is less than the stoichiometric quantity, and in this case lambda $>1$.

The function of the strategy is to correct the "basic" fuel injection times so that the mixture strength continuously oscillates at high frequency between 0.98 and 1.02.
The oscillation frequency varies in accordance with the engine load and rpm, and is a few dozen Hertz.

**NOTE** *1 Hz = 1 oscillation per second*

In conditions of:
- cut-off,
- throttle valve more than 70° open and high engine load
- engine temperature below 25°C,

the strategy is disabled.

### Self-adaptivity

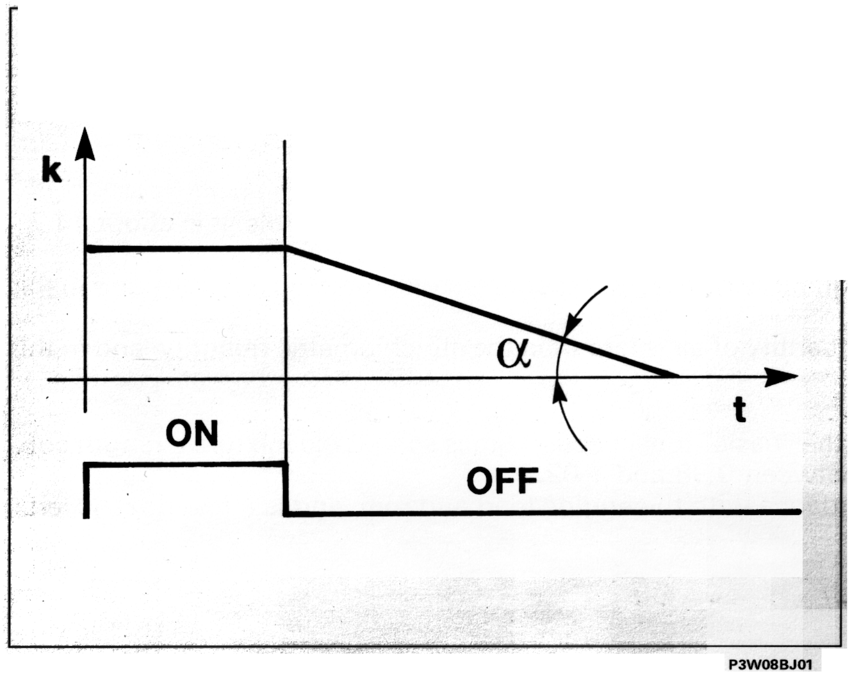
The control unit has a self-adaptivity function which memorizes deviations between the basic mapping and corrections imposed by the Lambda probe which occur persistently during operation. These deviations (due to ageing of the components of the system and engine) are stored in memory permanently, allowing the operation of the system to adapt to the gradual changes in the engine and components compared with their characteristics when new.

The strategy is disabled while the charcoal filter scrubbing solenoid is open.
If the control unit is replaced, a road test should be carried out which allows the engine to warm up to temperature and the self-adaptivity function of the control unit to intervene (especially during pauses at idle speed).

### Starting and post-starting

During starting, it is not possible to recognize the engine timing, so timed fuel injection cannot be used.

During the first few revolutions of the engine, a first simultaneous injection is carried out (also because the significant fluctuations of the engine speed do not allow correct calculation of injection timing), and injection becomes phased subsequently.
The "basic" fuel injection time is increased by a multiplicative coefficient during the entire period of cranking of the engine by the starter motor.
Once the engine has started, the coefficient is gradually reduced until it disappears within a certain period, which is longer the lower the engine temperature.




k: enrichment coefficient
t: time
α: decrement in accordance with engine temp.
ON: engine cranked (crank)
OFF: engine running (run)

### Operation when cold

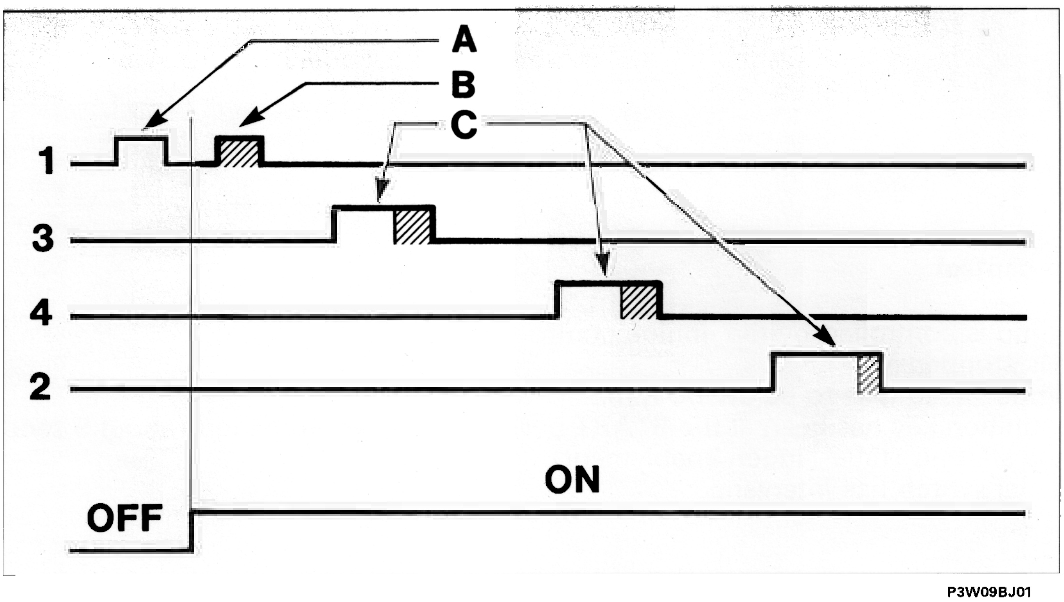
In these conditions, the mixture tends to be weaker because of the reduced evaporation and high condensation of the fuel on the internal walls of the inlet manifold; moreover, the higher viscosity of the lubricating oil causes an increase in the passive resistances of the engine.
The "basic" fuel injection time is corrected by a multiplicative coefficient in accordance with the engine temperature and speed.

### Full load operation

The strategy is enabled when the throttle valve opens to over 70°.
The "basic" fuel injection time is multiplied by a coefficient (depending on the engine speed) of about 1.1.

**Operation in acceleration**

During this stage, the control unit increases the amount of fuel delivered.
The "basic" fuel injection time is multiplied by a coefficient in accordance with the engine temperature and the speed of opening of the throttle valve (average value 1.2).
If the sudden change in injection time is calculated when the injector is already closed, the control unit re-opens the injector (extra pulse) in order to be able to adjust the mixture strength as quickly as possible. Subsequent injections are instead already increased on the basis of the above-mentioned coefficients.




A: normal injection time
B: re-opening of injector (extra-pulse)
C: injection time including enrichment
OFF: engine at stationary speed
ON: engine at transient speed

**Operation in deceleration**

During this stage, a negative transient strategy is implemented to reduce the quantity of fuel delivered; the "basic" injection time is multiplied by a coefficient in accordance with the engine temperature, speed and load at the moment immediately preceding the start of deceleration.

**Operation in cut-off**

The fuel cut-off strategy is implemented when the control unit recognizes the throttle valve in the minimum position (throttle potentiometer signal) and the engine speed is over 1600 rpm (with engine hot).

The engine fuel supply is re-enabled upon recognition of the throttle in a non-closed position or when the engine speed falls below 1200 rpm (with engine hot).

### Engine speed limiter

The strategy limits the maximum speed that can be reached by the engine by enabling the cut-off gradually, as indicated by the table.
Maximum speed: 7150 rpm

| method \ cylinders | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 cylinder | o | | | |
| 2 cylinders | o | | | o |
| 3 cylinders | o | | o | o |
| 4 cylinders | o | o | o | o |

### Fuel pump control

The fuel pump is controlled by the engine control unit via a contactor.
The pump is stopped:
- if the engine speed falls to below 50 rpm;
- after the ignition key has been at the START position for a certain period (about 5 seconds) without the engine starting (time-lagged enablement);
- if the inertial switch has intervened.

### Fuel injector control

The injectors are controlled in a sequential and phased manner. However, during starting the injectors are driven for the first time in parallel.
The phasing of the injectors varies in accordance with the engine speed.

## MANAGEMENT OF THE FIAT CODE ANTI-THEFT FUNCTION

The system has an anti-theft function. This function is carried out via a specific control unit (FIAT CODE), which can dialogue with the engine control unit, and an electronic key comprising a special transmitter for sending a recognition code.
Whenever the ignition is switched off (STOP), the FIAT CODE system completely deactivates the engine control unit.
When the ignition is switched on (MAR), the following operations take place in sequence:
1. the engine control unit (whose memory contains a secret code) sends to the FIAT CODE control unit a request for the latter to send the secret code to deactivate the function block;
2. the FIAT CODE control unit answers by sending the secret code only after in turn receiving the recognition code transmitted by the ignition key;
3. the recognition of the secret code enables the deactivation of the block on the engine control unit and the normal operation of the latter.

**NOTE** *It is highly inadvisable, during fault diagnosis, to carry out tests using another engine control unit, as the FIAT CODE control unit would transfer the (unknown) recognition code to the test control unit, which would then be unusable on other vehicles.*