

User's guide for DT-C002



Injection and ignition systems





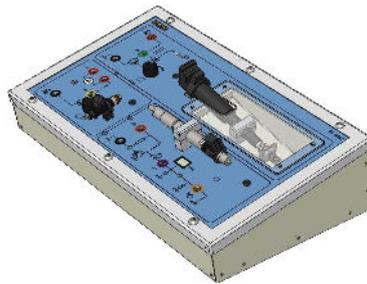
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Introduction

The DT-XXXX model

The DT-MXXX model consists of a number of benchtop learning modules, which together cover all the sensors (DT-M where M stands for Measure) and actuators (DT-C where C stands for Control). These components correspond to the latest models in production within the automotive industry.

Module DT-C002



Module DT-C002 lets trainees acquire skills and expertise in injection and ignition technologies. The module facilitates this learning by allowing the trainee to control a pencil coil, a traditional petrol injector and a piezoelectric diesel injector.

Using the module

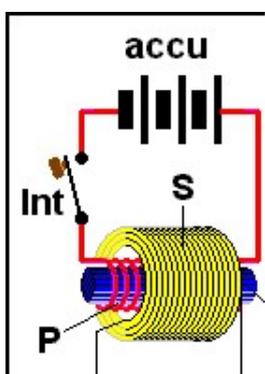
Using the sockets on the front face, the trainee wires up the various components so as to control them in the same way as they are controlled on the vehicle.

1 Ignition

1.1 Purpose of ignition systems

In petrol engines, a spark is needed to ignite the mixture of air and petrol. The subsequent combustion raises the pressure of the gases formed which expand and thus generate the motive power. This type of IC engine operation is called “controlled ignition”, in contrast to the “compression ignition” present in diesel engines.

1.2 Operation



The principle of operation of the induction coil (or Ruhmkorff coil) is that of a step-up voltage transformer consisting of a primary winding **P** and a secondary winding **S**. The primary consists of a few dozen turns of insulated copper wire with a fairly large diameter (about one millimetre) whereas the secondary consists of a few tens of thousands, or even hundreds of thousands, of turns of very fine wire (a few tenths of a mm in diameter). These two coils are wound around a common soft iron magnetic core **N**, made of a bundle of parallel iron wires. Dividing up the core reduces the losses due to eddy currents, also known as Foucault's currents. To prevent the high voltages generated in the coil from breaking down the insulation between the secondary wires, arcing and then causing short-circuits, careful consideration must be given to the design of this insulation.

A direct current (generated by the car battery) is passed through the primary winding **P**. Any variation in the magnetic field produced (and particularly the sudden interruption of the current controlled by a switch **Int**) induces a voltage in the secondary winding **S** whose value is proportional to the number of turns on



P over the number of turns on **S**. This *turns ratio* is very high for an induction coil, such that it can generate voltages of several kilovolts. When the current is interrupted (by opening the primary circuit) the voltage induced reaches a maximum and produces a spark which can jump across an air gap separating the secondary winding's output terminals.

Most modern vehicles are fitted with an induction coil-type ignition system with one ignition circuit per cylinder (static distribution of the high voltage and coil-on-plugs) managed by the ECU.

These systems consist of an induction coil with a primary and secondary winding, an output stage used to carry current to the primary winding (integrated into the ECU) and a spark plug connected to the high voltage secondary winding.

The output stage applies (before the ignition point is reached) a current to the induction coil's primary winding. A magnetic field establishes in the primary winding which persists for as long as the primary circuit is closed. At the instant when the ignition point is reached, the output stage cuts the current to the primary winding (ideally as a clean break with no bounce back). The magnetic field rapidly collapses and, as a result of the coupling between the coils, a high voltage is generated in the secondary winding through electromagnetic induction. It is this high voltage which produces the spark in the spark plug.

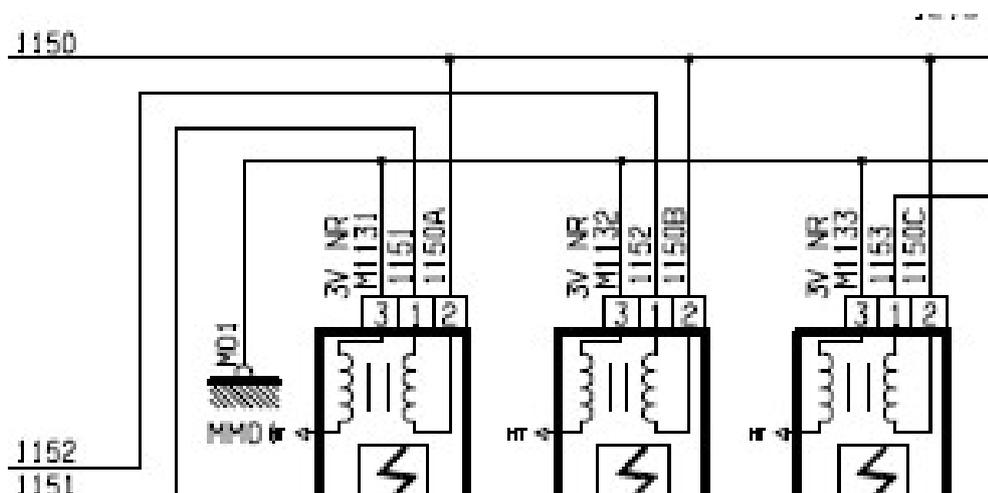
1.3 Coil-on-plug system (direct ignition)

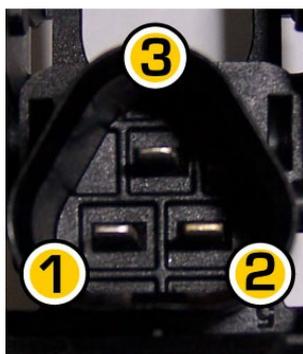
The main feature of this system is that each spark plug has its own ignition coil. This technical solution avoids having to transmit high voltages through the engine compartment, and thus overcomes the issues associated with power losses, response times and interference with other electronic components. Moreover, since the ECU controls the current in the primary circuit, it is isolated from the high voltage circuits. Finally, each spark plug is connected to its own output from the ECU (with a common ground). This technique allows independent management of each of the engine's cylinders.

Ignition coil



Use of a pencil coil-type ignition coil developed for the EP6DT engine.
PSA wiring diagram



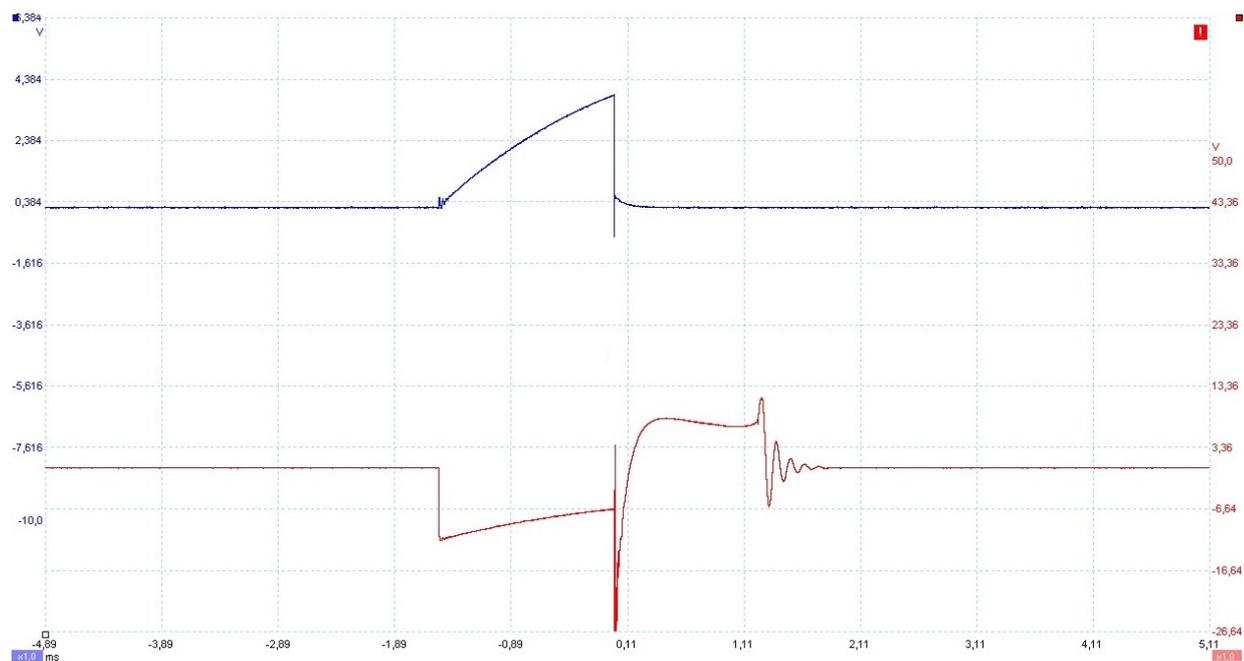


3-channel connector:

Channel No.1: coil control, by grounding with GI3000 or other means

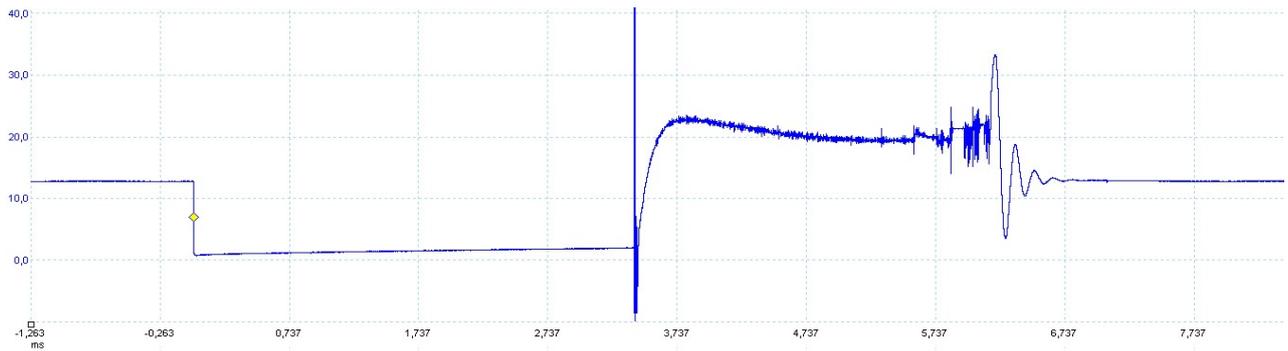
Channel No.2: 12 V power supply

Channel No.3: Direct ground for the coils.

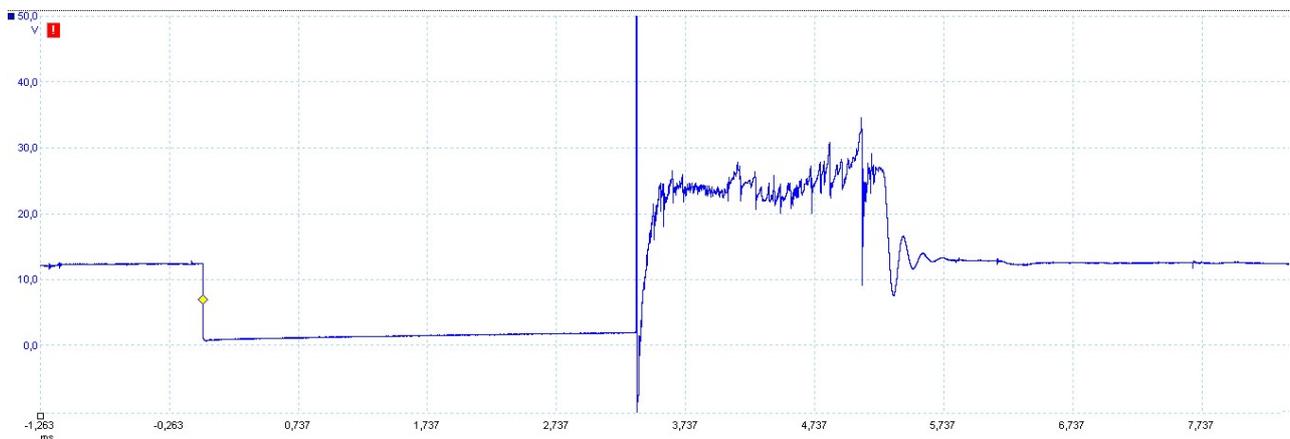




Ignition at idle

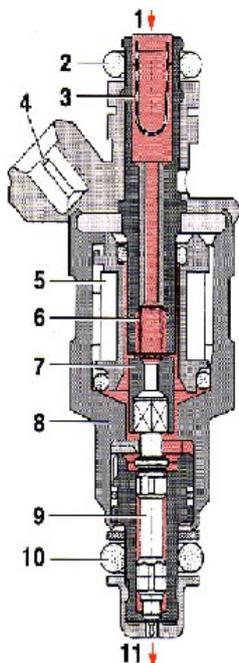


Ignition at 4,000 rpm



2 Injection

2.1 Traditional petrol injector



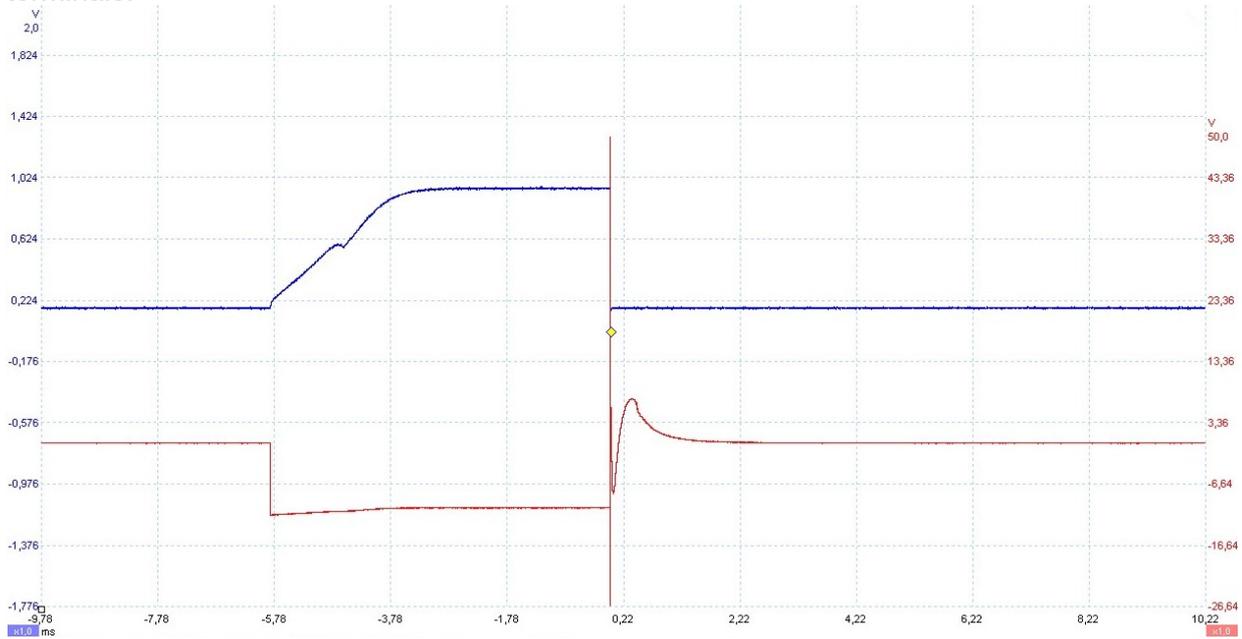
- 1 petrol inlet
- 2 seal with the rail
- 3 filter
- 4 electrical connection
- 5 electromagnet
- 6 core (valve) return spring
- 7 core
- 8 injector casing
- 9 needle
- 10 cylinder head seal
- 11 atomised petrol jet tip

Operation. The pressure difference between the cylinder head during the intake stroke and the fuel in the common rail is maintained at about 3 bar so that the amount of fuel injected depends only on the period of time during which the injector is open. The ECU controls the injector by sending control pulses (generated by grounding the circuit) whose duration and number vary depending on parameters such as air flow rate, engine speed and other variables. The electrical pulses from the injection computer generate a



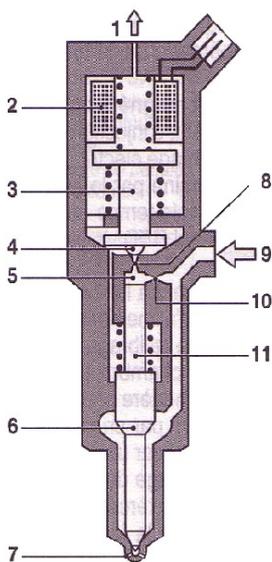
magnetic field in the electromagnet's winding, the core is attracted and the injector's tip rises off its seat. The winding's resistance is approximately 14.5 ohms.

The blue line plots the current passing through the injector's coil and the red line plots the voltage at its terminals.



2.2 Diesel injector

HDi



- **Electromagnetic injector:**
- 1 fuel return line
 - 2 magnetic coil
 - 3 electromagnet core
 - 4 ball
 - 5 control chamber
 - 6 applied pressure zone on needle
 - 7 injection nozzle
 - 8 outlet throttle
 - 9 high-pressure orifice
 - 10 inlet throttle
 - 11 control plunger

The fuel arriving at the HP orifice flows through the supply passage to the nozzle and to the inlet throttle which leads into the control chamber. This control chamber is linked to the fuel return line by an outlet throttle which can be opened by a solenoid.

When the outlet throttle is closed (by the ball), the hydraulic force exerted on the control plunger exceeds the force applied in the opposite direction by the pressure on the needle's pressure zone. The needle is thus pushed down onto its seat and seals the HP channel which leads into the combustion chamber.

When the engine is switched off, the pressure forces are insufficient and the nozzle's spring seals off the injector from the cylinder head.

As soon as the solenoid is energised, the outlet throttle is opened. The inlet throttle is designed such that it prevents the pressure from balancing completely and as a result the pressure in the control chamber drops, which leads to a drop in the force on the control piston. At this instant, the hydraulic force becomes less than the force exerted by the pressure on the needle's pressure zone which opens the HP channel into the combustion chamber. The fuel is then atomised.



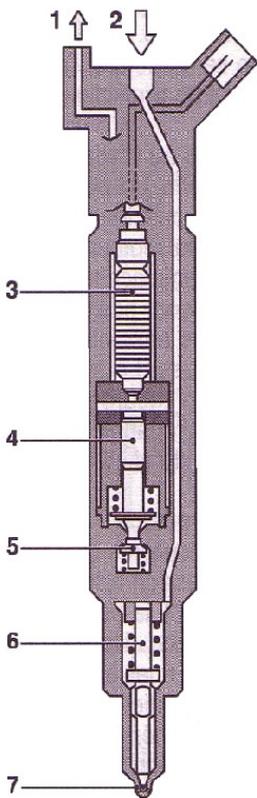
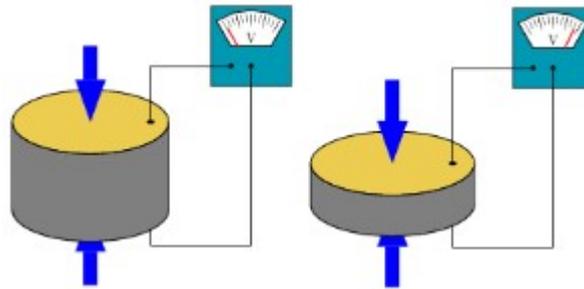
As soon as the solenoid is not energised, the armature drops due to the force of the spring and the ball blocks the inlet throttle passage. The pressures in the control chamber and rail start to balance. This increase in pressure closes the needle rapidly.

This indirect control of the needle via a hydraulic amplification system is necessary because the solenoid cannot generate the forces needed to open the needle rapidly and precisely. Any excess fuel which is not injected passes through the outlet throttle and returns to the tank.

In order to obtain a shortest possible response time (about 300 μ s), the ECU generates a peak and hold command. The peak phase lasts for 300 μ s with a voltage of 80 V and a current of 20 A. The hold phase requires 12.5 V and a current of 12 A.

Piezoelectric injector (on the right-hand side of the module)

Some solid materials (such as quartz or synthetic ceramics) are electrically polarised (i.e. a voltage is created) by the action of a mechanical stress and conversely they deform when a voltage is applied to them. The first phenomenon is called the direct piezoelectric effect, and the second is the reverse piezoelectric effect. These two effects are in fact two manifestations of the same phenomenon.



The direct piezoelectric phenomenon is used in numerous sensors, such as the cylinder head intake stroke pressure sensor. The reverse effect is used for actuators such as the injector described in this section. The voltage applied generates a mechanical deformation which raises the needle and releases the vaporised fuel into the chamber.

Electrical symbol for a piezoelectric element:



The injector

Piezoelectric injector:

- 1 fuel return line
- 2 high-pressure orifice
- 3 piezoelectric actuation module
- 4 electrical amplifier
- 5 valve
- 6 injector needle
- 7 injection hole

These new injectors are operated not by a solenoid, but by a piezoelectric actuator, which allows a marked increase in speed of action. The structure of the injector has to be modified (refer to the diagram above). The actuator controls the needle directly and hydraulically, which eliminates the need for any mechanical linkage between these two elements. There is no friction or deformation of the elastic elements of the connectors and fixings. The reduced weight of the needle and the minimisation of the return of fuel results in the following advantages:

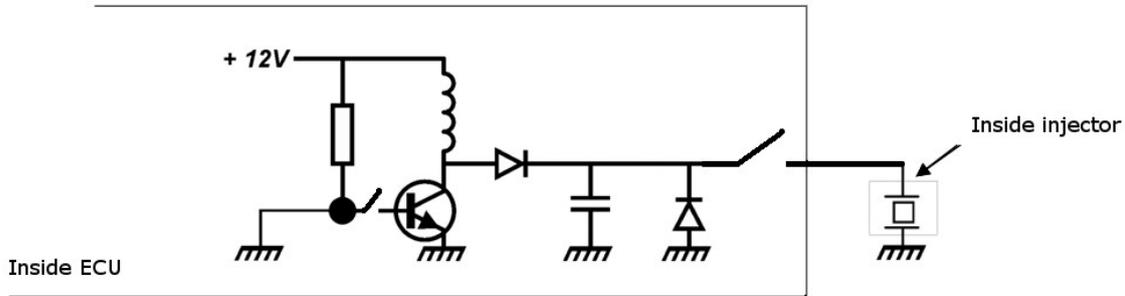
- Smaller overall size
- Lighter weight
- Option to inject several times per engine cycle
- Shortening of the interval between each injection



- Less powerful high-pressure pump
- More reactive control

Control of the piezoelectric injector

So that the piezoelectric element can deform sufficiently to inject the fuel, about 100 volts have to be applied to it. Clearly the voltage which the ECU applies to the terminals of the injector must be greater than the 12 V available from the vehicle’s battery. The phenomenon used to achieve this is the self-induction of a secondary coil, as described above in the section on ignition.

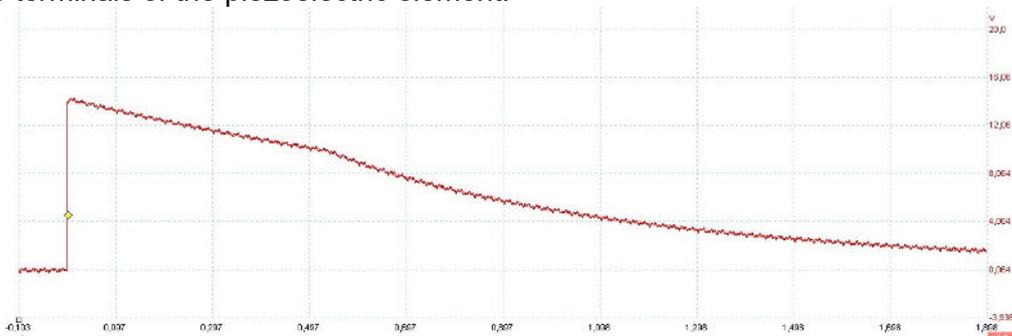


The sudden disconnection of power to the coil, managed by controlling the transistor, creates self-induction of a secondary coil whose voltage peak is used to charge the capacitor. By repeating this operation a number of times, the voltage at the capacitor’s terminals increases until the ECU closes the HV switch (on the right-hand side in the diagram above) which discharges the capacitor through the piezoelectric element of the injector, deforms the synthetic ceramic and opens the injector.

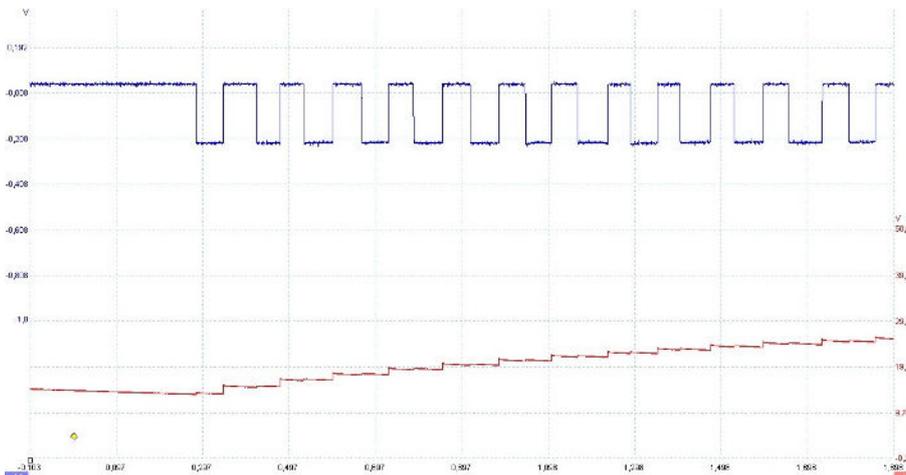
Comment:

Bosch piezoelectric injectors have a return spring which closes the injector (as on the module) whereas Siemens injectors have a more complex control circuit for returning the needle to its initial position which does not require a return spring.

Voltage at the terminals of the piezoelectric element.



The blue line shows the output voltage from the transistor and the red line indicates the charge in the capacitor.





3 User file

3.1 USER AND INSTRUCTION MANUAL



The module should only be opened by certified and authorised persons.

Installing and starting up benchtop learning module DT-C002

Connect the module to the power supply provided.

Wire up the components to operate the system as indicated in the user manual supplied with module DT-C002.

Environment

Module DT-C002 is designed for benchtop use. It must be installed in a dry place away from dust, steam and combustion fumes.

The module requires approximately 400–500 lux of light

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

The benchtop learning module is protected against potential user error.

Calibrating and maintaining benchtop learning module DT-C002

Calibrating: set in the factory.

Maintenance frequency: none.

Cleaning: use a clean and very soft cloth and a window-cleaning product.

Number of work stations and position of user

Module DT-C002 is considered to be a single work station.

The module user will remain seated throughout the practical exercise.

Lockout/Tagout procedure

Switch off the power supply by setting the switch to 0

Unplug the 230 V connector.

Store module DT-C002 in a secure room while out of use.

Residual risk

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

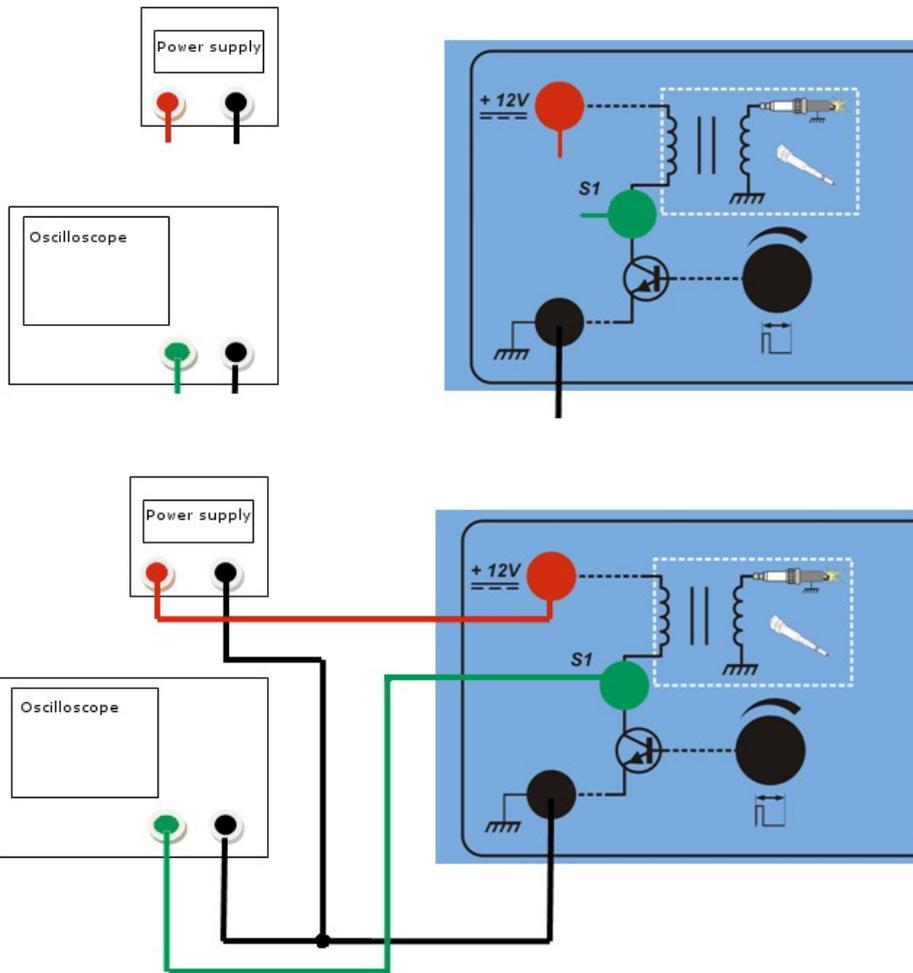
Transporting module DT-C002

The benchtop learning module must be switched off and disconnected before transport.



3.2 Practical exercises: ignition

Suggest a wiring diagram which could be used to operate the spark plug and record the voltage at S1.

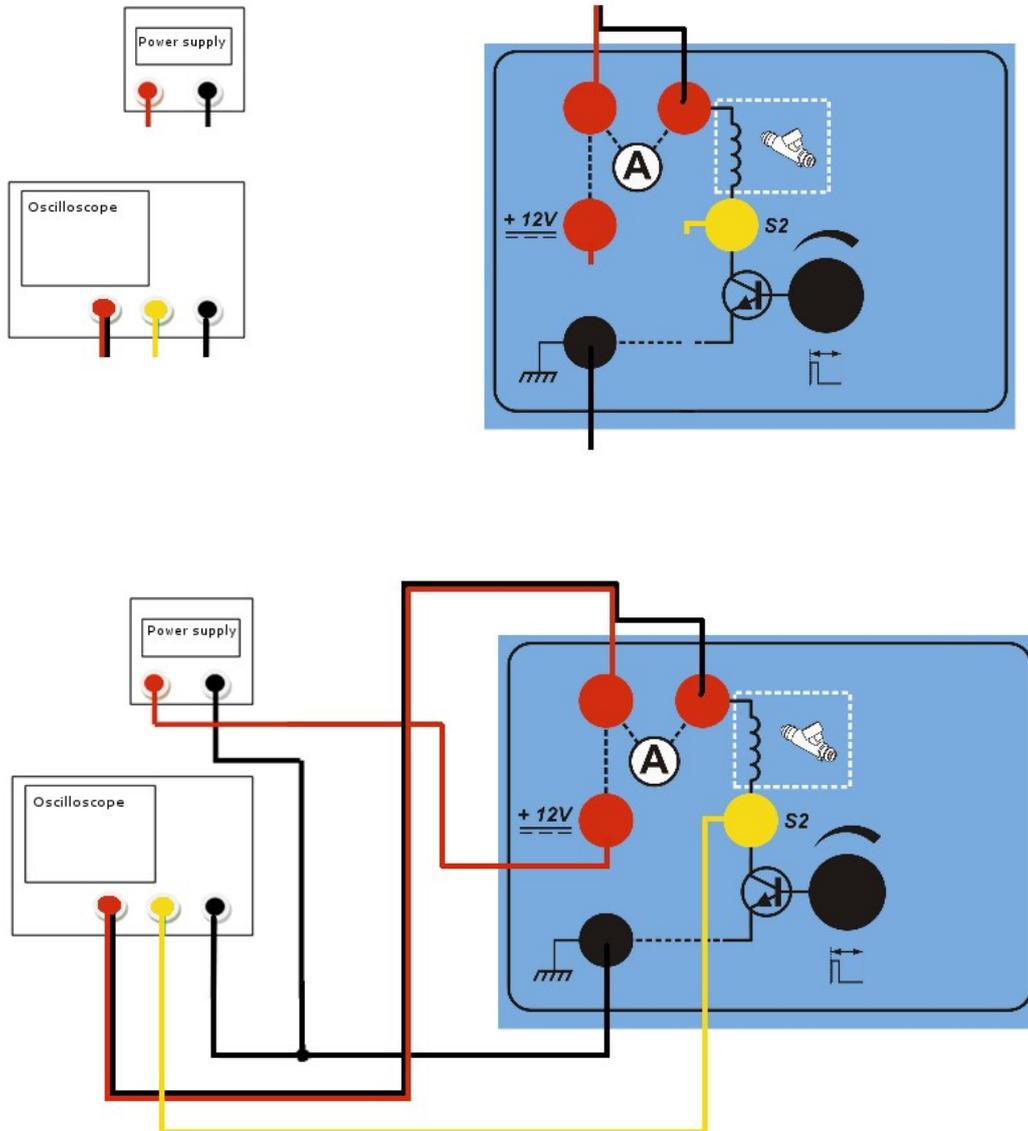


Connect up the module as per your suggestion, vary the speed and explain the operation of the ignition using the plots recorded and based on the content of the teaching session.



3.3 Practical exercises: electromagnetic injector

Suggest a wiring diagram which could be used to operate the injector, record the voltage at S2 and record the current passing through the injector's coil.

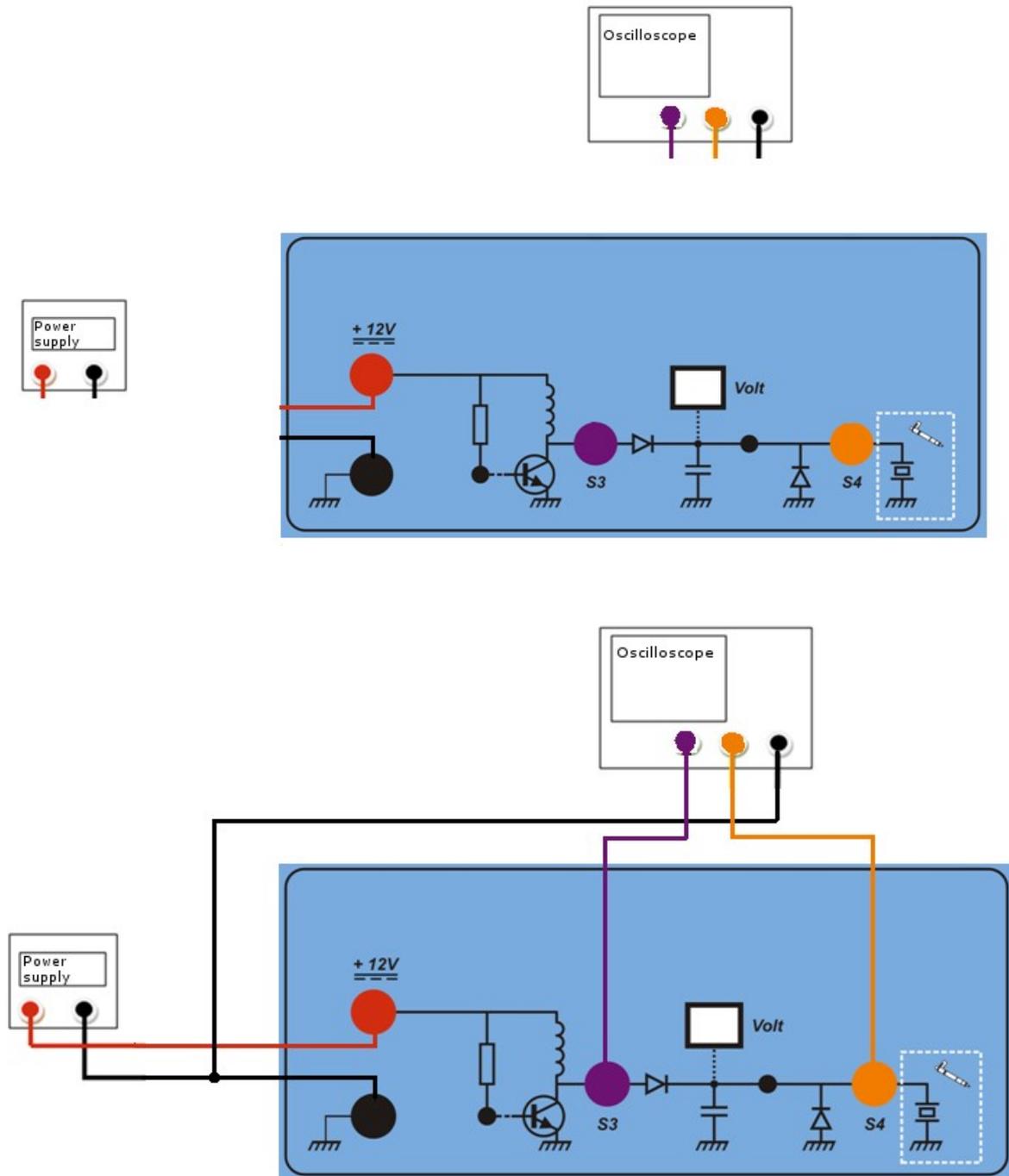


Connect up the module as per your suggestion, vary the speed and explain the operation of the electromagnetic injector using the plots recorded and based on the content of the teaching session.



3.4 Practical exercises: piezoelectric injector

Suggest a wiring diagram which could be used to operate the injector and to record the voltage at S3 and at S4 across the injector's coil.



Explain the operation using the plots recorded and based on the content of the teaching session.

Diagnostics

The difference in the technology between the two injectors does not allow a diagnostic to be run. Explain why this is not possible.



CE DECLARATION OF CONFORMITY

Via this declaration of conformity with the requirements stated in directive 2004/108/EC relating to electromagnetic compatibility, the company:

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

Declares that the product indicated below:

Make	Model	Product name
EXXOTEST	DT-C002	BENCHTOP LEARNING MODULE: Study of injection and ignition

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

- Low Voltage Directive 2006/95/EC of 12 December 2006
- Machinery Directive 98/37/EC of 22 June 1998
- Electromagnetic Compatibility directive 2004/108/EC of 15 December 2004

and meets the requirements of the following standard:

- NF EN 61326-1 of 07/1997 +A1 of 10/1998 +A2 of 09/2001
 Electrical equipment for measurement, control and laboratory use. EMC requirements.

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 & electronic equipment
- Directive 2011/65/EC of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (ROHS).

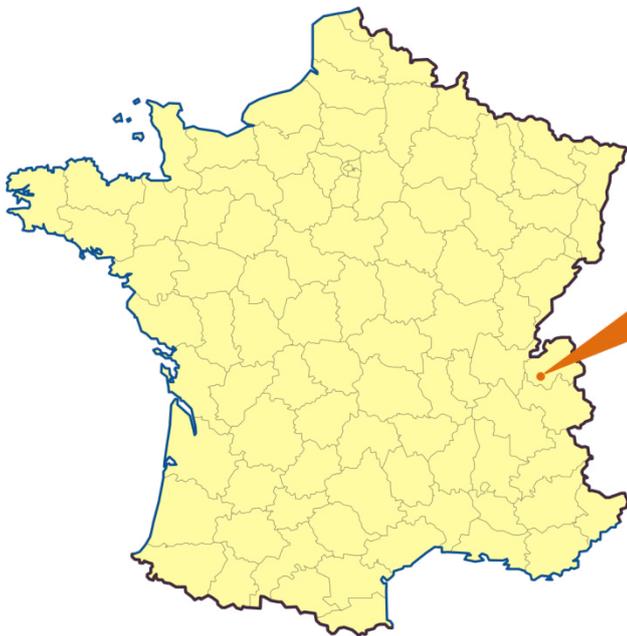
Signed in Chavanod, France, on 02 June 2009

Stéphane Sorlin, Chairman





Latitude : 45° 53' 49" / Longitude : 6° 4' 57"



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