



**IGNITION COILS
IN VEHICLES**
FUNCTION, DIAGNOSTICS,
TROUBLESHOOTING



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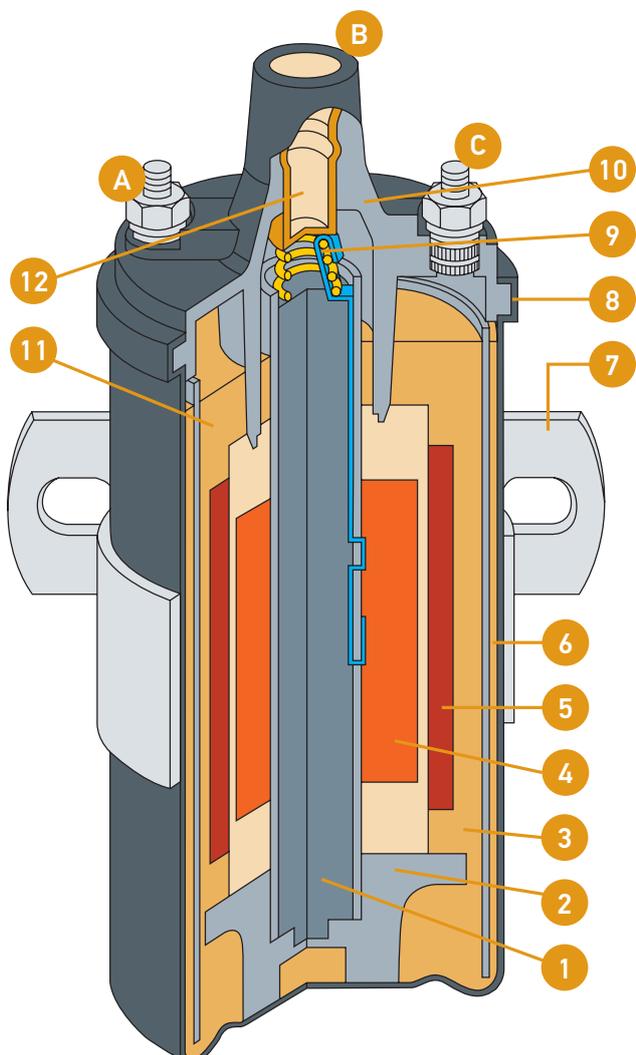
THE DESIGN OF AN IGNITION COIL

The design of a conventional ignition coil is basically similar to that of a transformer. The ignition coil's task is to induce a high voltage from a low voltage. Alongside the iron core, the main components are the primary winding, the secondary winding and the electrical connections.

The laminated iron core has the task of amplifying the magnetic field. A thin secondary winding is placed around this iron core. This is made of insulated copper wire about 0.05-0.1 mm thick, wound around up to 50,000 times. The primary winding is made of coated copper wire about 0.6-0.9 mm thick, and is wound over the secondary winding. The Ohmic resistance of the coil is about 0.2-3.0 Ω primary and 5-20 k Ω secondary. The winding ratio of primary to secondary winding is 1:100. The technical structure may vary depending on the ignition coil's area of application. In the case of a conventional cylinder ignition coil, the electrical connections are designated as terminal 15 (voltage supply), terminal 1 (contact breaker) and terminal 4 (high-voltage connection).

The primary winding is connected to the secondary winding via a common winding connection to terminal 1. This common connection is known as the "economy circuit," and is used to simplify coil production. The primary current flowing through the primary winding is switched on and off via the contact breaker. The amount of current flowing is determined by the coil's resistance and the voltage applied at terminal 15. The very fast current direction caused by the contact breaker changes the magnetic field in the coil and induces a voltage pulse, which is transformed into a high-voltage pulse by the secondary winding. This passes through the ignition cable to the spark plug's spark gap and ignites the fuel-air mixture in a petrol engine.

The amount of high voltage induced depends on the speed of change in the magnetic field, the number of windings on the secondary coil and the strength of the magnetic field. The opening induction voltage of the primary winding is between 300 and 400 V. The high voltage on the secondary coil can be up to 40 kV, depending on the ignition coil.



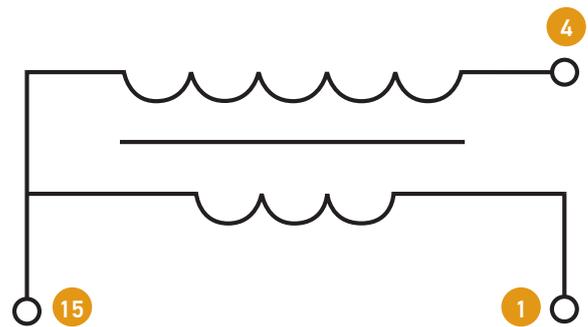
- | | |
|---------------------|-------------------------------|
| 1 Iron core | 9 High-voltage spring contact |
| 2 Insulation | 10 Insulating cover |
| 3 Sealant | 11 Insulation material |
| 4 Secondary winding | 12 High-voltage output |
| 5 Primary winding | |
| 6 Metal sheath | A Terminal 15 |
| 7 Mounting clip | B Terminal 4 |
| 8 Housing | C Terminal 1 |

IGNITION COILS FOR IGNITION SYSTEMS WITH ROTATING HIGH-VOLTAGE DISTRIBUTION,

These cylinder ignition coils are used in vehicles with ignition distributors in contact-controlled or transistor-controlled ignition systems. The three-pin electrical connection corresponds to that of a conventional ignition coil.



The primary circuit receives its voltage supply through terminal 15. The contact breaker is connected to terminal 1 of the ignition coil, and supplies the primary winding with ground. The high-voltage wire of the ignition distributor is connected to terminal 4. Whereas conventional ignition coils are still being used with older vehicles, ignition coils with integrated electronic control units are now used in vehicles that are equipped with a transistor ignition.



DUAL-SPARK IGNITION COILS

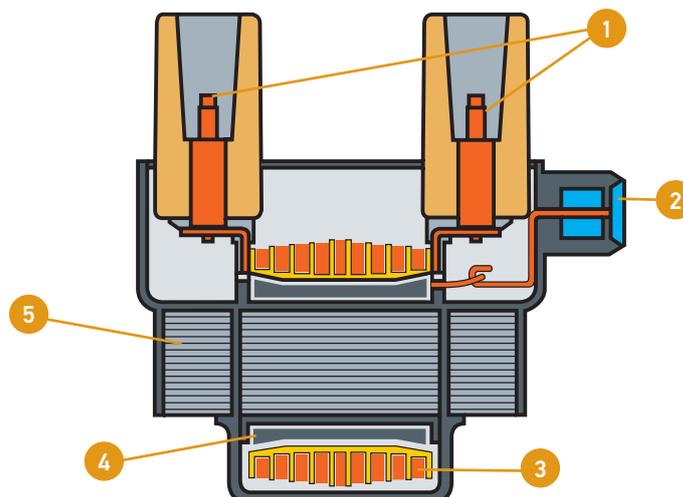
Dual-spark ignition coils are installed in ignition systems with static high-voltage distribution. These ignition coils are used with engines with an even number of cylinders.

The primary winding and secondary winding of the dual-spark ignition coil each have two connections.

The primary winding is connected to the voltage supply at terminal 15 (plus), and to the output stage of the ignition or electronic control unit at terminal 1 (ground). The secondary winding is connected to the spark plugs with the outputs (4 and 4a).

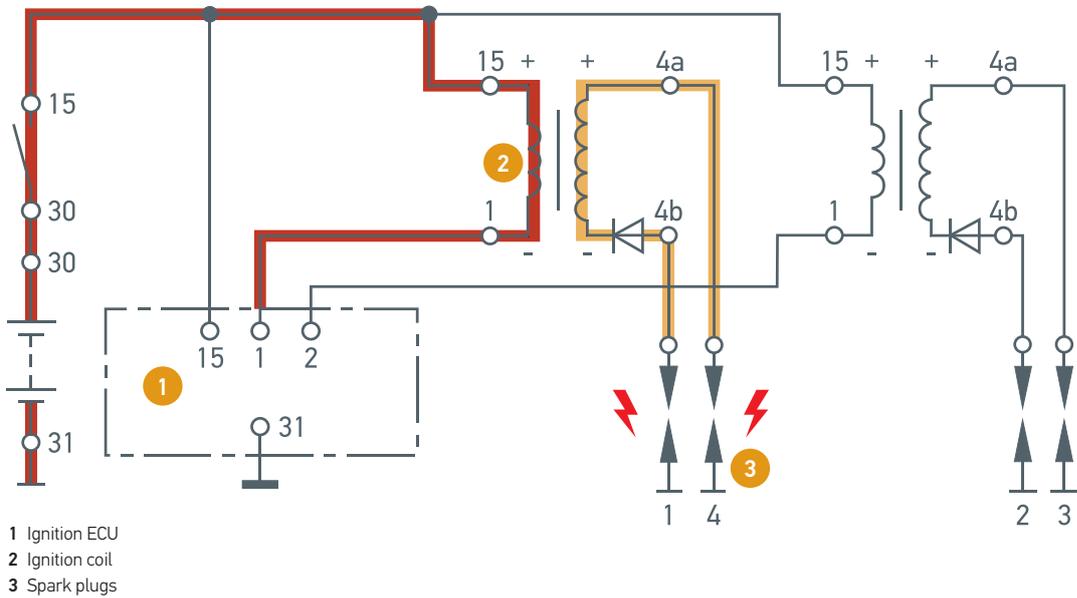
In these systems, two spark plugs are supplied with high voltage by each single ignition coil. Since the ignition coil generates two sparks simultaneously, one spark plug has to be in the working cycle of the cylinder and the other offset by 360° in the ejection cycle.

In a four-cylinder engine, for example, cylinders 1 and 4 are connected to one ignition coil, and cylinders 2 and 3 to another. The ignition coils are triggered by the ignition output stages in the electronic control unit. This receives the TDC signal from the crankshaft sensor in order to begin triggering the right ignition coil.



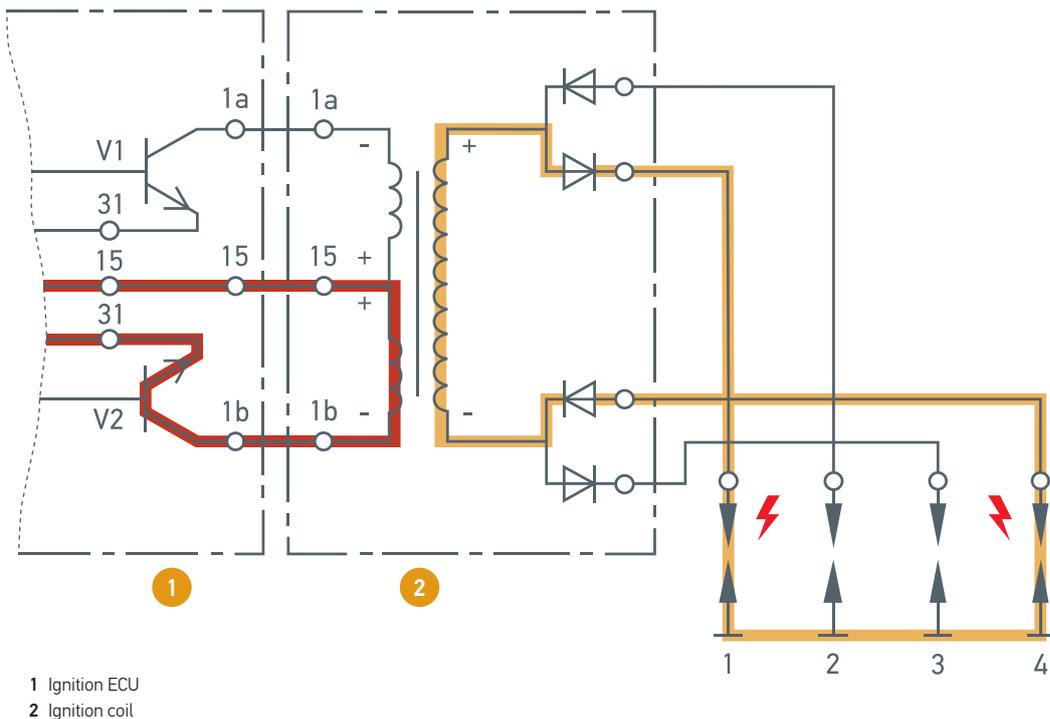
- 1 High-voltage connection
- 2 Low-voltage connection
- 3 Secondary winding
- 4 Primary winding
- 5 Iron core

DUAL-SPARK IGNITION COILS

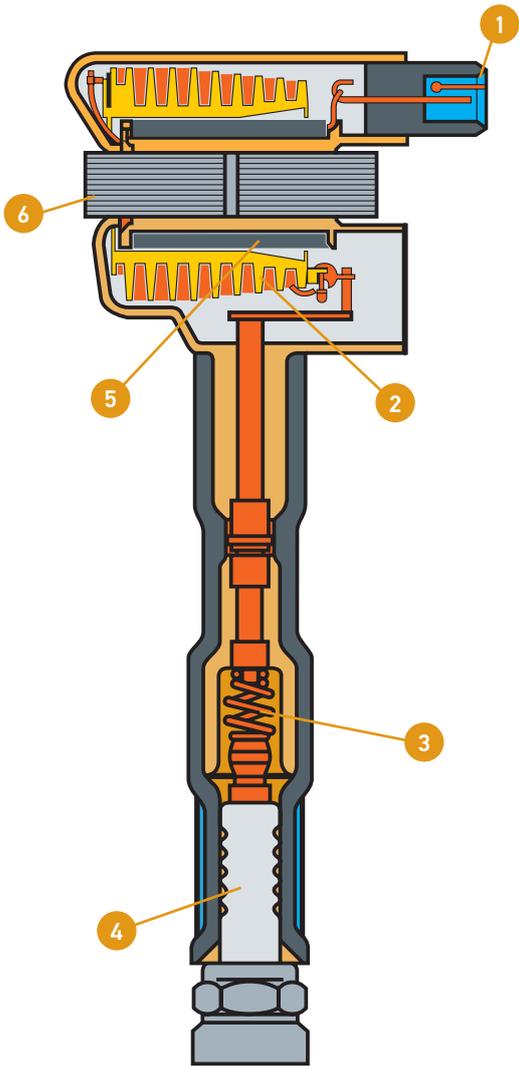


FOUR-SPARK IGNITION COILS

Four-spark ignition coils replace two dual-spark coils in four-cylinder engines. These coils each have two primary windings, each of which is triggered by an electronic control unit output stage. There is only one secondary winding. There are two connections for the spark plugs at each of its outputs; these are switched contrarily using diode cascades.



SINGLE-SPARK IGNITION COILS



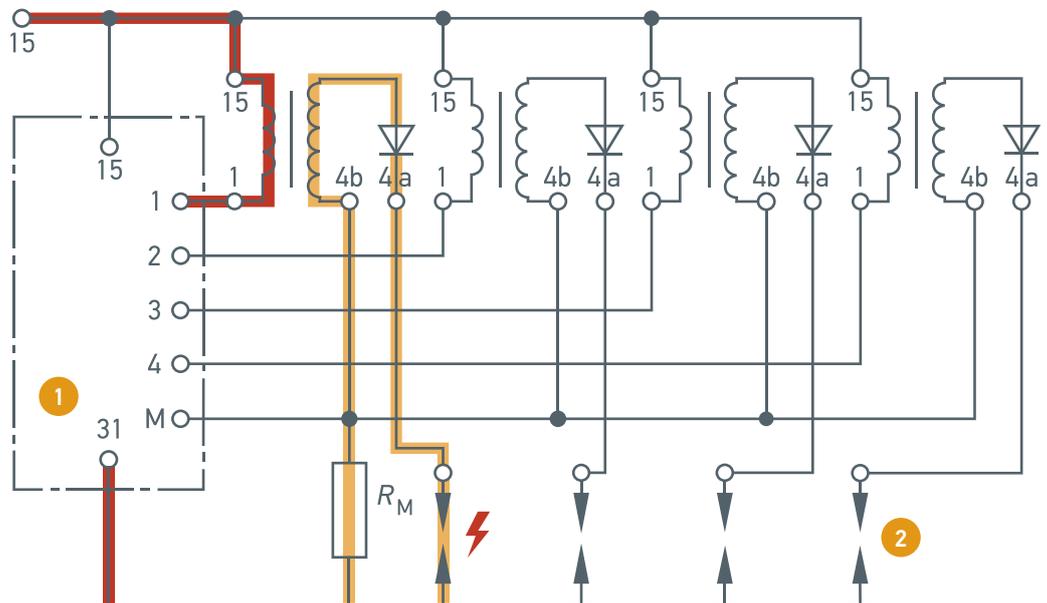
In systems with single-spark ignition coils, one ignition coil with a primary and secondary winding is assigned to each cylinder. These ignition coils are usually installed directly at the cylinder head, above the spark plug.

These coils are also connected to the primary winding at terminal 15 (voltage supply plus), and to the electronic control unit at terminal 1 (ground). The secondary winding is connected to the spark plug at the output of terminal 4. If there is also a terminal 4b, this connection is used to monitor misfiring. Triggering takes place according to the sequence specified by the electronic control unit.

A single-spark coil's circuit corresponds to that of a conventional ignition coil. In addition to this, a high-voltage diode is used in the secondary circuit to suppress the "closing spark." This diode suppresses the unwanted spark produced when the primary winding is switched on as a result of the self-induction in the secondary winding. This is possible because the secondary voltage of the closing spark has opposite polarity to the ignition spark. The diode blocks in this direction.

For single-spark coils, the second output of the secondary winding is routed to ground via terminal 4b. A measuring resistor is installed in the ground wire to monitor ignition; this provides the electronic control unit with a measurement of the drop in voltage caused by the ignition current during sparkover.

- 1 Low-voltage connection
- 2 Secondary winding
- 3 High-voltage connection
- 4 Spark plug
- 5 Primary winding
- 6 Iron core



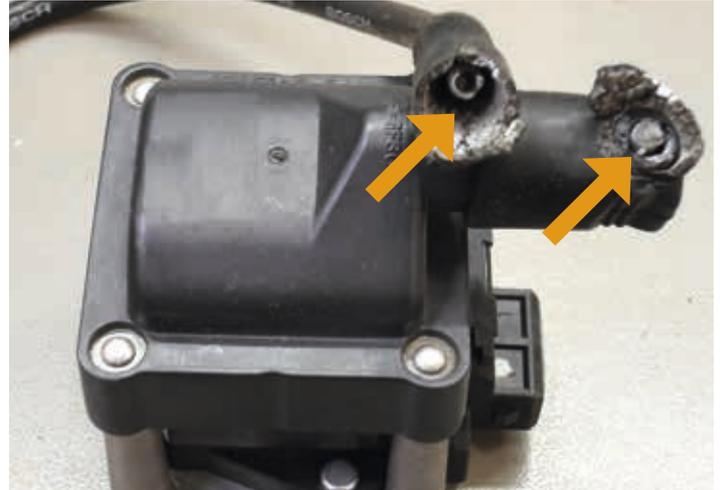
- 1 Ignition ECU
- 2 Spark plug

POSSIBLE CAUSES OF FAILURE



INTERNAL SHORT CIRCUITS

Overheating of the coil caused by the aging process, a faulty ignition module or a faulty output stage in the control unit.



ERROR IN THE CONTROL VOLTAGE

The coil charging time increases on account of the voltage supply being too low, this can lead to premature wear or overload on the ignition control unit or the output stages in the electronic control unit. This can be caused by faulty wiring or a weak battery.



MECHANICAL DAMAGE

Damage to the ignition cables caused by marten bites. A faulty valve cover gasket and resulting engine oil leaks can damage the insulation of plug slot coils. Both of these causes lead to sparkover, and thus premature wear.

CONTACT ERROR

Contact resistance in the wiring due to humidity penetrating in the primary and secondary area, also frequently caused by engine washing or the use of grit in winter.

A FAILURE CAN MANIFEST THROUGH THE FOLLOWING SYMPTOMS:

- Engine does not start
- Vehicle misfires
- Poor acceleration or loss of power
- Engine control unit switches to limp-home mode
- Engine warning lamp lights up
- Error code is stored

DIAGNOSTICS

DISMANTLED STATE

There are different ways of checking the ignition coil:

Testing the resistance values of the coils using the Ohmmeter.

Depending on the ignition system and ignition coil design, the following reference values apply: (observe the manufacturer's specifications)

Cylinder ignition coil (transistor ignition system)

Primary: 0.5 Ω – 2.0 Ω /Secondary: 8.0 k Ω –19.0 k Ω

Cylinder ignition coil (electronic ignition system with map-controlled ignition)

Primary 0.5 Ω – 2.0 Ω ./Secondary: 8.0 k Ω –19.0 k Ω

Single-spark or dual-spark ignition coil (fully electronic ignition system)

Primary: 0.3 Ω –1.0 Ω /Secondary: 8.0 k Ω –15.0 k Ω



PRACTICAL TIP

Note:

If a high-voltage diode is built into an ignition coil to suppress sparks, it is not possible to measure the resistance of the secondary coil.

In this case, the following method is helpful:

Connect a voltmeter in series between the secondary winding of the ignition coil and a battery. If the battery is connected in the diode's conducting direction, the voltmeter must display a voltage. After reversing the polarity of the connections in the blocking direction of the diode, no voltage may be displayed. If no voltage is indicated in either direction, it can be assumed that there is an interruption in the secondary circuit. If a voltage is indicated in both directions, the high-voltage diode is faulty.

INSTALLATION POSITION

THE FOLLOWING TESTS CAN BE USED:

Visual inspection

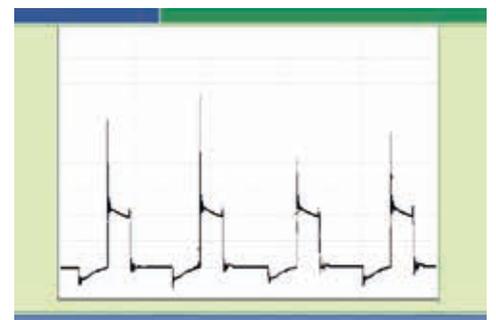
- Test the ignition coil for mechanical damage
- Check the housing for hairline cracks and sealant leaks.
- Check the electrical wiring and plug connections for damage and oxidation.

Test the electrics using a multimeter or oscilloscope

- Check the voltage supply to the ignition coil
- Check the triggering signal from the ignition distributor, ignition ECU or engine control unit
- Illustration of the high-voltage curve using an oscilloscope or ignition oscilloscope

Testing with the diagnostic unit

- Read out the error memory of the ignition system or engine control unit
- Reading out parameters



During all testing work on the ignition system, it must not be forgotten that errors that are established during tests with the oscilloscope are not necessarily errors caused by the electronic system; they can also be caused by a mechanical problem in the engine. This may be the case, for example, if compression is too low in one cylinder, which means the oscilloscope shows the ignition voltage for this cylinder to be lower than that of the other cylinders.

Although "diagnosable engine management systems" are installed in today's vehicles, a multimeter or oscilloscope must be used when checking ignition systems. In order to interpret the measuring results or images correctly, additional employee training is usually required. One important pre-requisite for successful diagnostics is a careful visual inspection at the beginning of the troubleshooting process.

Note:

PRACTICAL EXAMPLE FOR ERROR DIAGNOSTICS IN DAY-TO-DAY GARAGE WORK

We would like to demonstrate the diagnostics procedure for a dual-spark ignition coil using the following example, "misfiring".

Vehicle: Alfa Romeo 147 1.6 TS with dual-spark ignition

Each cylinder has a main plug and a secondary plug. The ignition coils are triggered by the ignition output stages

integrated in the engine control unit. In this example, the repair procedure is shown using a Mega Macs diagnostic unit. The schematic illustrations, pictures and descriptions are intended solely as explanations of the document text, and cannot be used as the basis for carrying out installation and repair work.

PRACTICAL TIP

Before starting diagnostics, take into account the following factors:

- In order to allow correct allocation of the vehicle, it is important that the vehicle documents (registration documents) are included with the job sheet.
- Check the battery voltage. Insufficient voltage supply may cause system failure or result in incorrect measurements or voltage drops.
- Check the system-related fuses. A quick look in the fuse box might eliminate the first cause of the error.



DIAGNOSTIC CONDITION: Engine mechanics, battery, starting system and fuel system OK.

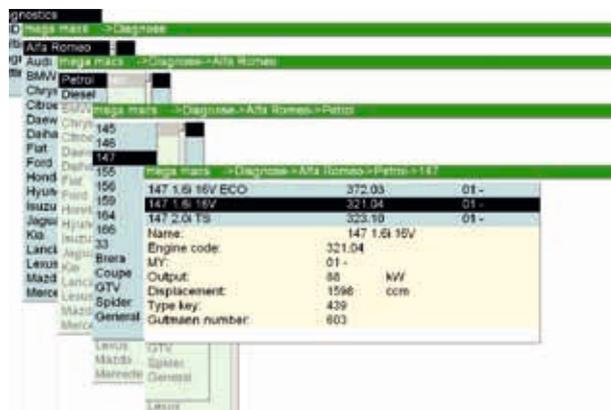


CUSTOMER COMPLAINT

- The customer has reported a functional problem with the engine control system
- Warning information on the instrument cluster

Error: Engine monitoring system

TROUBLESHOOTING

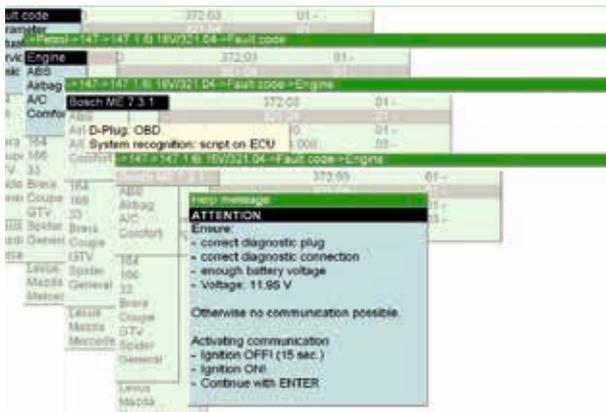


1. Using the diagnostic unit

Connect the diagnostic unit to the 16-pin OBD plug. Depending on the vehicle manufacturer and date of registration, a different diagnostic socket and additional adapter may be required.

Carry out the following applications on the diagnostic unit:

- Select program
- Select vehicle
- Select fuel type
- Select model
- Select vehicle type



- Select required function
- Select system: Depending which diagnostic unit is used, additional safety instructions can be displayed here.
- Start error diagnostics

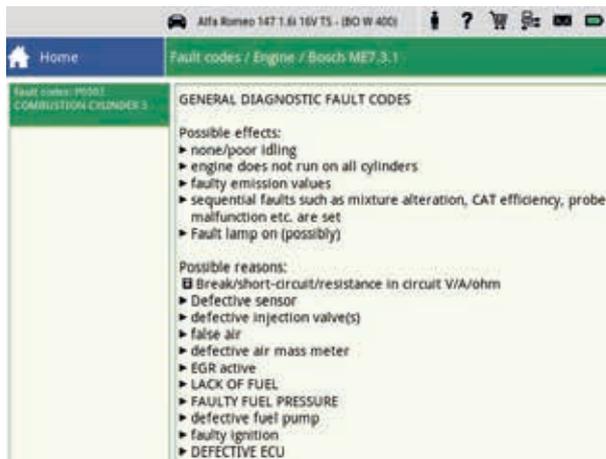
Sufficient battery voltage and the correct connector are required in order to establish communications with the control unit. Insufficient supply voltage to the control unit could be an indication of a wiring defect or a defect in the vehicle battery.



2. Read out the error memory

In this case, error P0303 was stored.

- Combustion cylinder 3
- Misfire detected in cylinder 3



3. Evaluate the details

Here, additional information about a possible reason for the error is stored

- Ignition faulty
- Injection valve faulty
- Control unit faulty

Note:

If several error codes are displayed, clear the error first. Once this is done, carry out a test drive with the diagnostic unit connected. Monitor the parameters and read out the error memory.



4. Determining the cause of the error

Preparations for engine diagnostics

- Prepare any additional diagnostic units that may be necessary, such as a multimeter or oscilloscope
- Find the technical documents
- Remove the engine cover (if necessary)



5. Carry out a visual inspection

Before the actual diagnostic process begins, the engine wiring harness and plug connectors must be checked for damage as far as possible. Kinks, lack of strain relief and "marten bites" in the wiring harness are all possible causes of this.



6. Check the voltage supply to the cylinder 3 ignition coil

- Remove the connector from the ignition coil
- Measure the voltage at the two-pin plug on the harness side
- Connect the red cable from the multimeter to PIN 2 (+), and the black cable to engine ground (-)

Switch on the ignition. A voltage of more than 10.5 V should be measured. Measured value: 11.93 V. Measurement OK.



PRACTICAL TIP

In order to check the voltage supply under load, we recommend repeating the measurement while actuating the starter. In order to prevent unnecessary fuel injection, you must remove all the injection valve connectors first.



7. Check the primary triggering for the cylinder 3 ignition coil.

- Remove the plug from the ignition coil
- Connect the oscilloscope or diagnostic tester to the measurement module
- Connect the probe tips to PIN 1 and PIN 2 using the two-pin connector
- Detach the plug connectors from the injection valves
- Start the engine

A signal should be clearly recognisable on the oscilloscope. In this example, the measurement is successful.



8. Remove the ignition coil for further testing.

- Remove the connector from the ignition coil
- Remove the high-voltage cable for the second spark plug
- Remove the fixing screws
- Pull the ignition coil out vertically, keeping it parallel to the plug slot

In order to prevent the spark plug connector from being damaged, do not turn the ignition coil in any way.

PRACTICAL TIP

Check the plug slot for soiling caused by oil and water penetration. Remove and check the spark plugs.



9. Carrying out resistance measurement

- Use the multimeter to check the removed ignition coil. Connect an ohmmeter directly to the component plug PIN 1 and PIN 2 in order to measure the primary winding.
- Set point: 0.3 Ω – 1.0 Ω
 - Actual value: 0.5 Ω (OK)



To measure the secondary coil, measure the test probes directly at the high-voltage outputs of the ignition coil.

- Set point: 8.0 k Ω – 15.0 k Ω
- Actual value: ∞ (interruption secondary coil)

Always consult the vehicle manufacturer's specifications for these measurements.

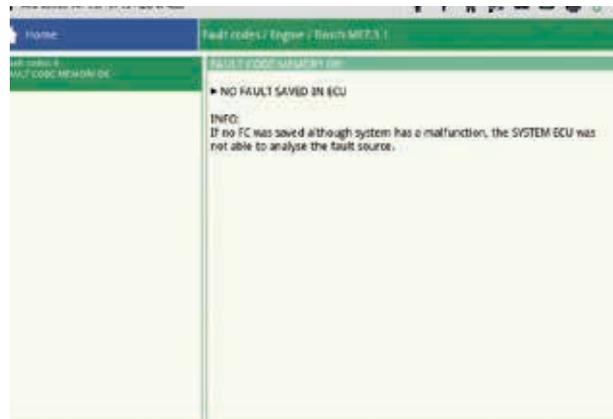


PRACTICAL TIP

The ignition coils in this vehicle are identical and can be swapped for testing.

10. Replacing the ignition coil

Here, care must be taken that the spark plug connector and the high-voltage cable for the second plug fit properly. Attach the ignition coil using the fixing screws. Once this is done, insert all the plug connections for the ignition coil and the injection valve plugs.



11. Clear the error memory

During the diagnostic work, additional errors are detected by the control unit. These must be cleared before the test drive.

12. Carrying out a function check

Carry out a test drive with the diagnostic unit connected. Once this is complete, read out the error memory again.



NOTE:

Always take the vehicle manufacturer's specifications into account during all testing and diagnostic work. Depending on the manufacturer, additional vehicle-specific testing methods may have to be taken into consideration.



SAFETY INSTRUCTIONS

During work on electronic ignition systems, contact with live components can result in potentially fatal injuries. This applies not only for the high-voltage live secondary circuit, but also for the primary circuit. For this reason, testing and repair work should only be carried out by trained specialist staff.

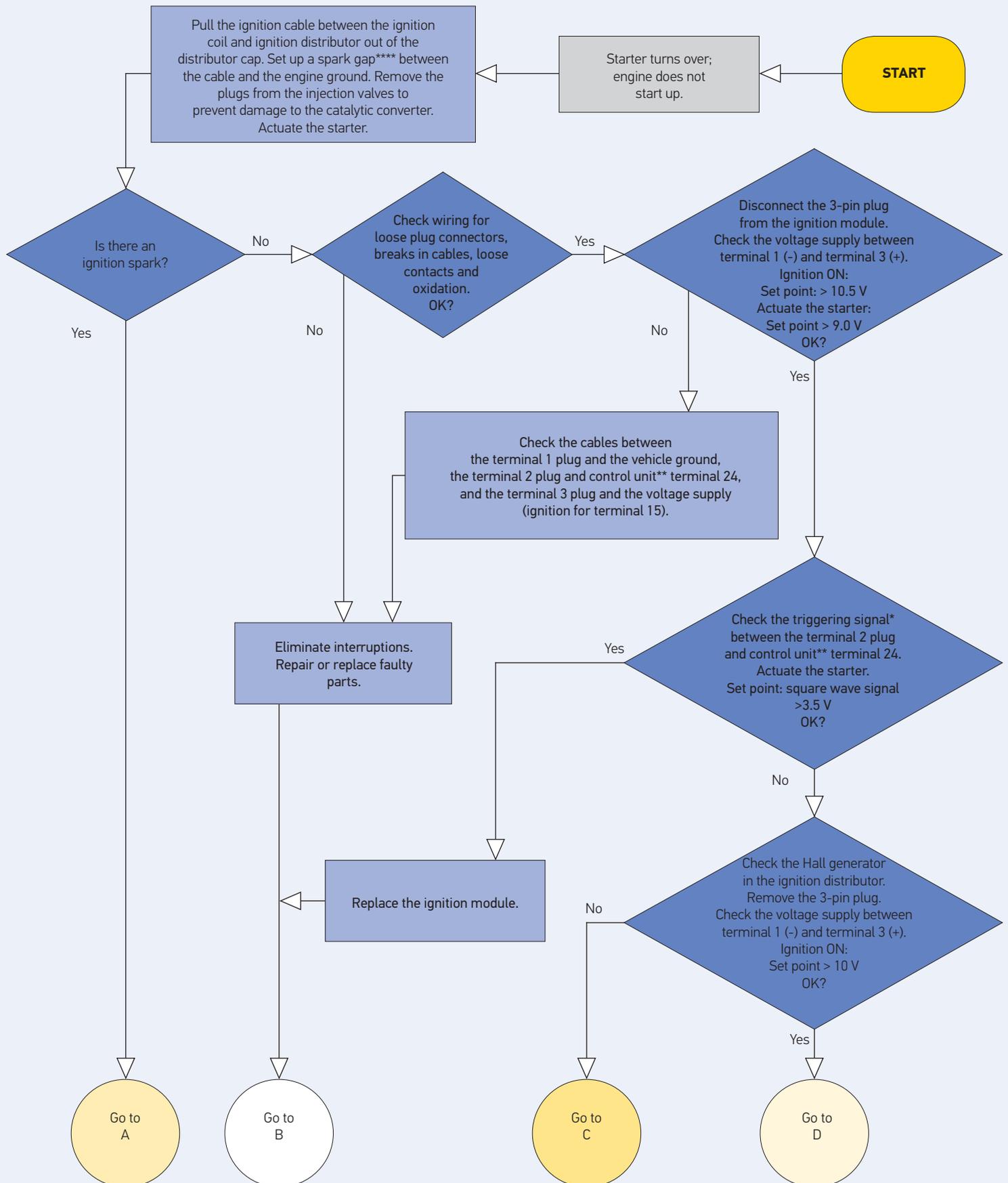
Please observe the following safety measures:

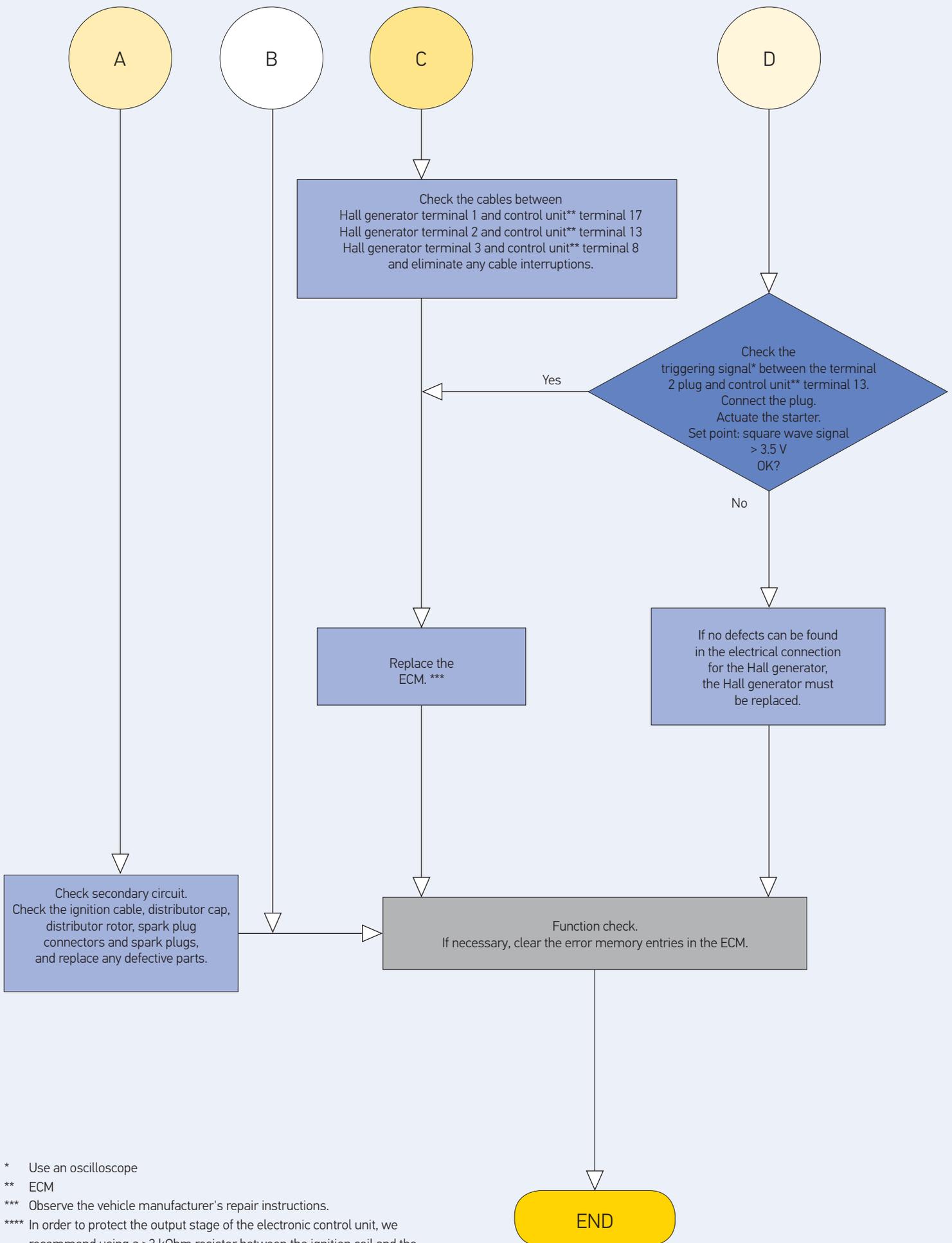
- Do not touch or remove the ignition cable, distributor cap or spark plug connector while the engine is running.
- Only connect or disconnect control units, plug connectors or connection cables when the ignition is switched off.
- Only perform engine washing when the engine is at a standstill and the ignition is switched off.
- During all tests on the ignition system that require the engine to turn over at starter speed, the voltage supply to the injection valves should be interrupted in order to protect the catalytic converter.

TROUBLESHOOTING TREE FOR IGNITION COIL WITH INTEGRATED IGNITION CONTROL UNIT (IGNITION MODULE)

Example: VW/engine code APQ, DME MP 9.0.

Pre-requisite for diagnostic work: Engine mechanics, battery, starting system and fuel system OK.





* Use an oscilloscope

** ECM

*** Observe the vehicle manufacturer's repair instructions.

**** In order to protect the output stage of the electronic control unit, we recommend using a >3 kOhm resistor between the ignition coil and the spark gap.

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