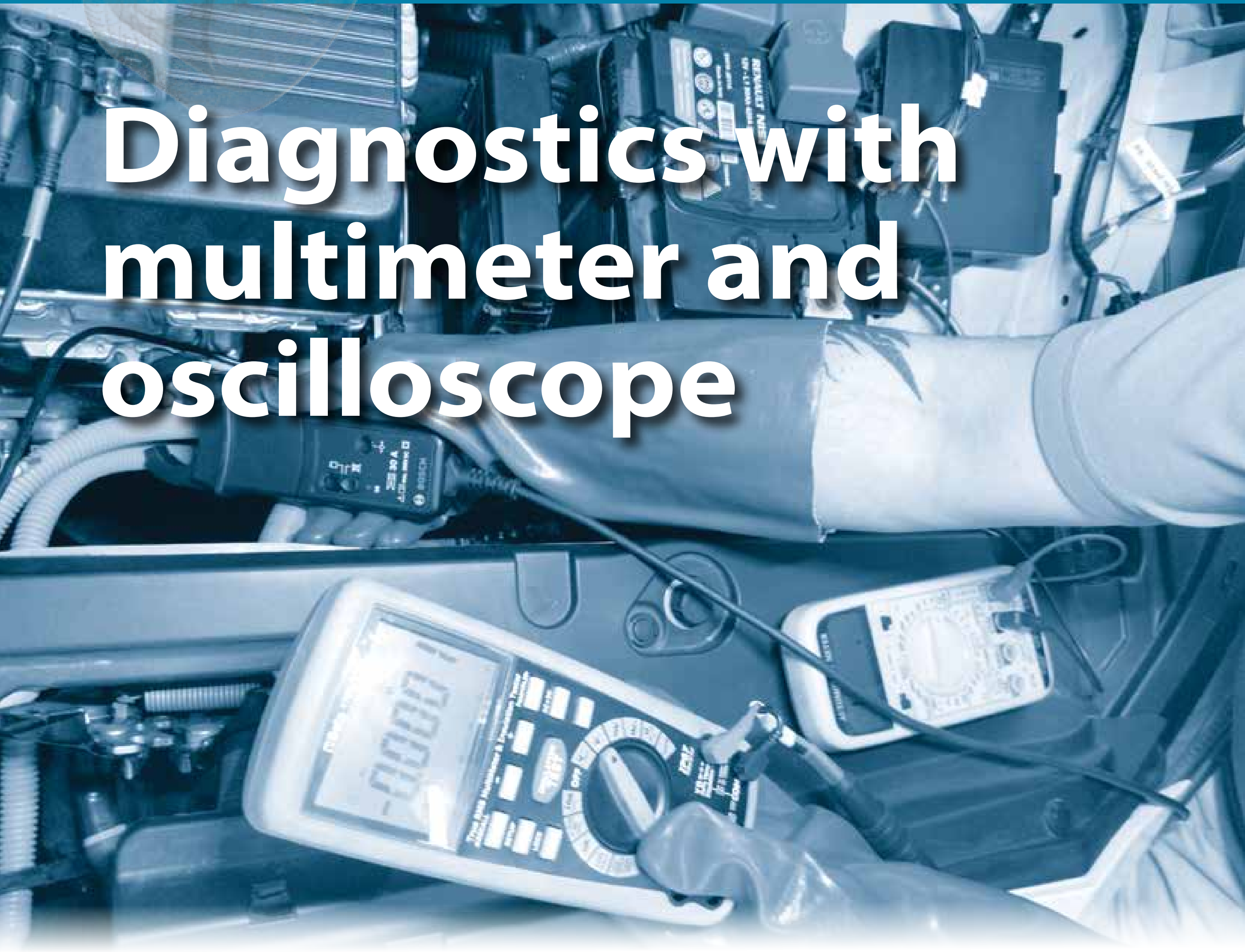
27 Eure!TechFLASH

THE UP-TO-DATE TECHNICAL INSIGHT IN AUTOMOTIVE TECHNOLOGY & INNOVATIONS

EDITION 27

Diagnostics with multimeter and oscilloscope



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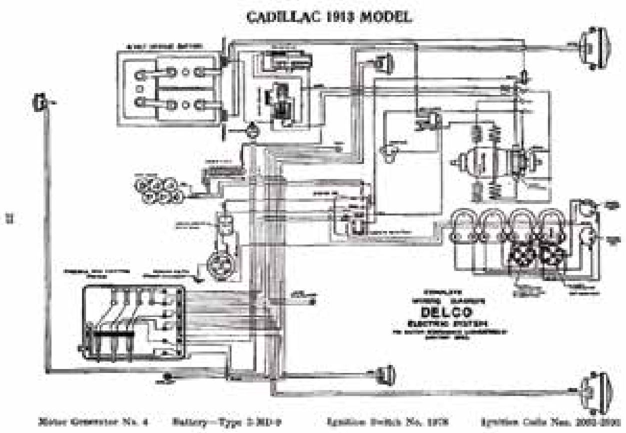
INTRODUCTION

From its beginning until present days, the evolution of cars has been unstoppable. If we look back, we can easily differentiate three evolutionary periods related to the automotive electrical equipment.

In **the first period**, the technical evolution of vehicles focused on the **mechanical systems** to improve their performance and ease of driving. The car's electrical system developed and evolved together with the rest of the vehicle in order to satisfy basic needs such as the ignition of the mixture, engine start-up, battery charge or signaling and lighting.



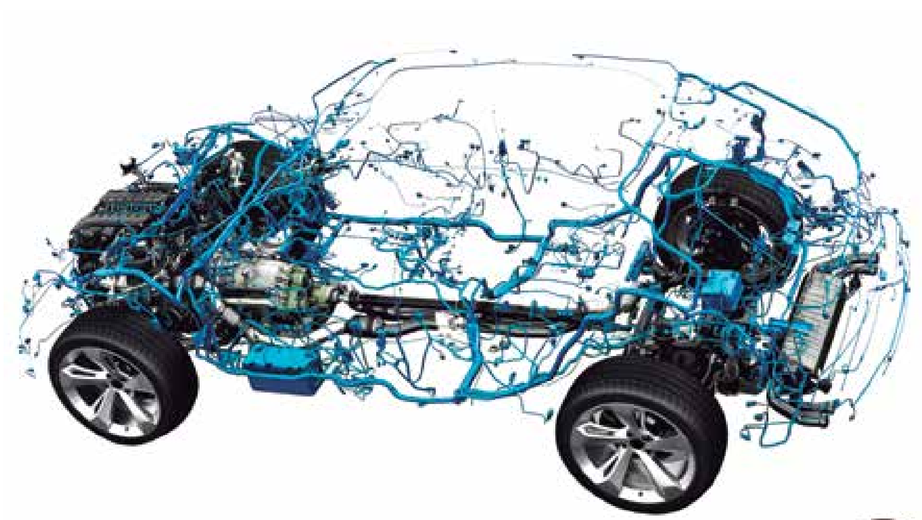
The car electrical installation and number of electrical components increased in a discrete way. However, what is more remarkable is the increase in quality and reliability of the elements rather than their number. The mechanical and electrical systems of the car from that period were clearly independent and, in many cases, their repair as well.

In the **second period**, the electromechanics itself was born, with the electrification of some engine subsidiary systems or the transmission and introduction of new comfort equipment. The electrical wiring and equipment of cars increased in a significant way to offer new functions or automate some already existing ones. The functional dependence increased in such a way that for the adjustment or the diagnostics and repair of some mechanical systems, the usage of specific equipment for electrical testing and measurement is essential.

The **third period** started with the introduction of the **electronics** in cars. The development of memories and processors propitiated in a few years the revolution of the electrical system first and the car as a whole later, to the point of subordinating the operation of great part of the traditional mechanical systems of the vehicle to the control of electronic units that share and process data to manage the operation of electromechanical systems of very diverse nature. In the last two decades, fully electronic systems aimed at entertainment, active safety and driving assistance appeared and multiplied.

Electricity as energy consists in the displacement of particles that are invisible to the human eye. In today's cars, it is used as activation energy or regulation of the operation of certain components, as a basis for the measurement of many physical parameters and as a means of transmitting information.

It's evident that purely mechanical systems are decreasing in cars and are less frequently seen in repair works. The transformation of these mechanical systems into electromechanical systems and the introduction of new totally electrical or electronic equipment increase the need of knowledge and equipment for electrical testing in order to carry out successfully the diagnostic and repair operations.

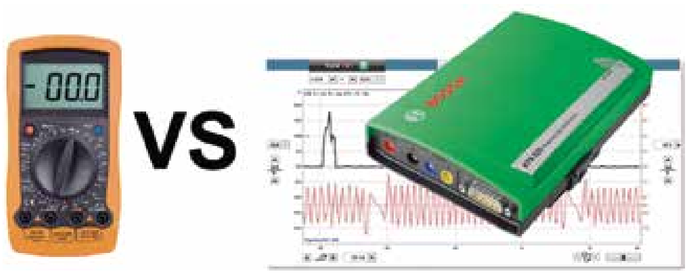


The scope of self-diagnosis that electronic units perform has certain limitations. Its reliability depends directly on the condition of the wiring harnesses, connectors and electrical components that are susceptible to failures, which in many intermittent cases can be located only by means of knowledge and electrical testing.

The 5 senses that allow the human being to perceive reality transmit their "measurements" by means of electrical pulses to brain. However, our capacity to "measure" electricity is practically zero.

Specific tools are required in order to test the electrical systems of cars, being the most important and versatile tools the **multimeter** and **oscilloscope**, which allow us to measure and see what is impossible at a glance.

Their characteristics and technical limitations make them more or less suitable for certain works or checks, an aspect that we want to delve into in this article to contribute to efficient operation and accurate diagnosis, which are fundamental factors for the profitability of the workshop.



SAFETY IN ELECTRICAL MEASUREMENTS

The first factor to take into account when choosing a tool for the electrical testing is that it must be always compatible with the system that is wished to be diagnosed and the safety that it offers for the intended use. If these precepts are not observed, this could cause from measurement errors to work accidents, damage to the diagnosed system or to the measurement tool itself.

The high electrical conductivity of the human body due to its large proportion of water and the electrical operating principle of our nervous system pose an intrinsic risk to man in the presence of electricity.

To avoid any possibility of electrocution, the maximum operating voltage must be known and the possibility that it may increase unexpectedly or accidentally must always be considered. We must bear in mind that, in most cases, the measurement itself is the method for checking the incorrect or abnormal electrical operation of a circuit, which implies some uncertainty.

Electrical measurement tools, including the multimeter and oscilloscope, are designed for specific uses and limited measurement conditions that minimise the possibility of error or damage to the tool during its operation and ensure a given measurement accuracy. These factors are not standardised and are freely chosen by the manufacturer.

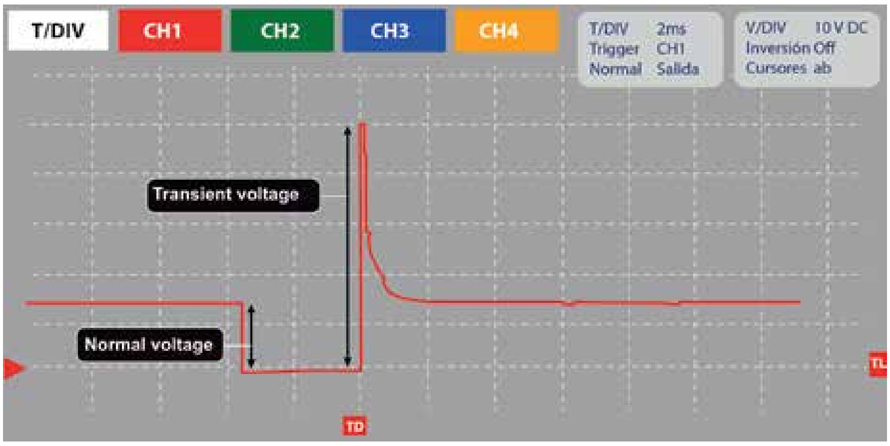
They mainly depend on the specific design of the tool and the quality of its materials or the components used for its manufacturing, which usually condition their cost.

The operator's safety depends on the safety margin during measurement. Therefore, on the electrical operating parameters of the electrical circuit and on the intrinsic protection offered by the measurement equipment.

Electrical measurement devices that are legally marketed must indicate the maximum voltage against which the electrical insulation of the equipment prevents any current leakage that may be dangerous for the operator. The fact of knowing the nominal operating voltage of the circuit on which is being worked and respecting a sufficient margin of mathematical inferiority with respect to this data, the safety in case of a discharge or electrocution must be sufficient in normal and/or predictable conditions.

However, certain intermittent phenomena are seen in the electrical circuits, which are potentially unpredictable and transitory. They must be considered as an additional danger factor.

The so-called "transients" are occasional currents that are produced in the electrical wirings as a result of the operation of certain electromagnetic elements such as motors, electromagnets, transformers or reactances, among others. They take place both in circuits that operate with alternating current and in circuits with direct current.



For the measurement tools up to 1000V, this factor is regulated under the IEC 61010-1 standard, which states that all electrical measurement tools must be identified in a visible manner and meet some minimum requirements stipulated in 4 categories. These categories relate the degree of protection offered by the tool against the energy of transient currents that can be produced in different working environments in which the electrical measurement is common.

- **Measurement category IV (CAT IV):** Direct operations on current distribution lines, also known as connection supplies or transformers. Category IV is used in medium and low voltage lines.
- **Measurement category III (CAT III):** Operations on electrical installations that range from current distribution panels to switches or elements that provide a power supply (sockets). It is also necessary in electric motor supply networks (both single-phase and three-phase motors) and lighting systems.
- **Measurement category II (CAT II):** Measurements on "equipment" that is indirectly connected to an electric network, in other words, through a socket, switch or similar. At household level, the television, oven, fridge and in general everything that operates at 220 V are components that must be verified with measurement equipment that meets category II to ensure an effective protection.
- **Measurement category I (CAT I):** Measurements on "equipment" that is not directly connected to the electric network. In the automotive field, it refers to any car system that is supplied through a 12-volt battery while, at household level, it refers to electrical appliances that work with batteries.

The difference between categories lies in the ability of the measurement tool to dissipate energy of possible voltage peaks (transients) produced in the wiring that is being measured without any damage and without allowing the current to go outside.

The following table shows the peak voltage supported by the measurement equipment according to its category and operating voltage:

Measurement category	Operating voltage	Transient voltage (20 repetitions)	Test source Impedance (Ω =V/A)
CAT I	150 V	800 V	30 Ω
CAT I	300 V	1500 V	30 Ω
CAT I	600 V	2500 V	30 Ω
CAT I	1000 V	4000 V	30 Ω
CAT II	150 V	1500 V	12 Ω
CAT II	300 V	2500 V	12 Ω
CAT II	600 V	4000 V	12 Ω
CAT II	1000 V	6000 V	12 Ω
CAT III	150 V	2500 V	2 Ω
CAT III	300 V	4000 V	2 Ω
CAT III	600 V	6000 V	2 Ω
CAT III	1000 V	8000 V	2 Ω
CAT IV	150 V	4000 V	2 Ω
CAT IV	300 V	6000 V	2 Ω
CAT IV	600 V	8000 V	2 Ω
CAT IV	1000 V	12000 V	2 Ω

Category I tools with voltage of 300-600 V used to be more than enough for the testing purpose in the automotive field until a few years ago, even in continuous measurement in overvoltage. The highest voltages that tools were exposed to in their usage on vehicles corresponded to the inductive response of the primary circuit of the ignition coils or the control signal of some injectors, which in no case exceeded 250V.

Nevertheless, due to technical particularities and working voltages, hybrid and electric cars require the usage of Category III tools and measurement voltage up to 1000V to perform the checks with a sufficient degree of safety. The existence of high-voltage generators and transformers increases the possibility of transient currents and the risk of electrocution in these vehicles. It should be noted that the working voltage of some of the most powerful models currently reaches 800V.

The separation of the high-voltage and low-voltage electrical circuits in hybrid and electric vehicles is functional but not physical. There are components and circuits connected to both circuits. This is the reason why the used tools must comply with the adequate protection levels even when working on low-voltage circuit.

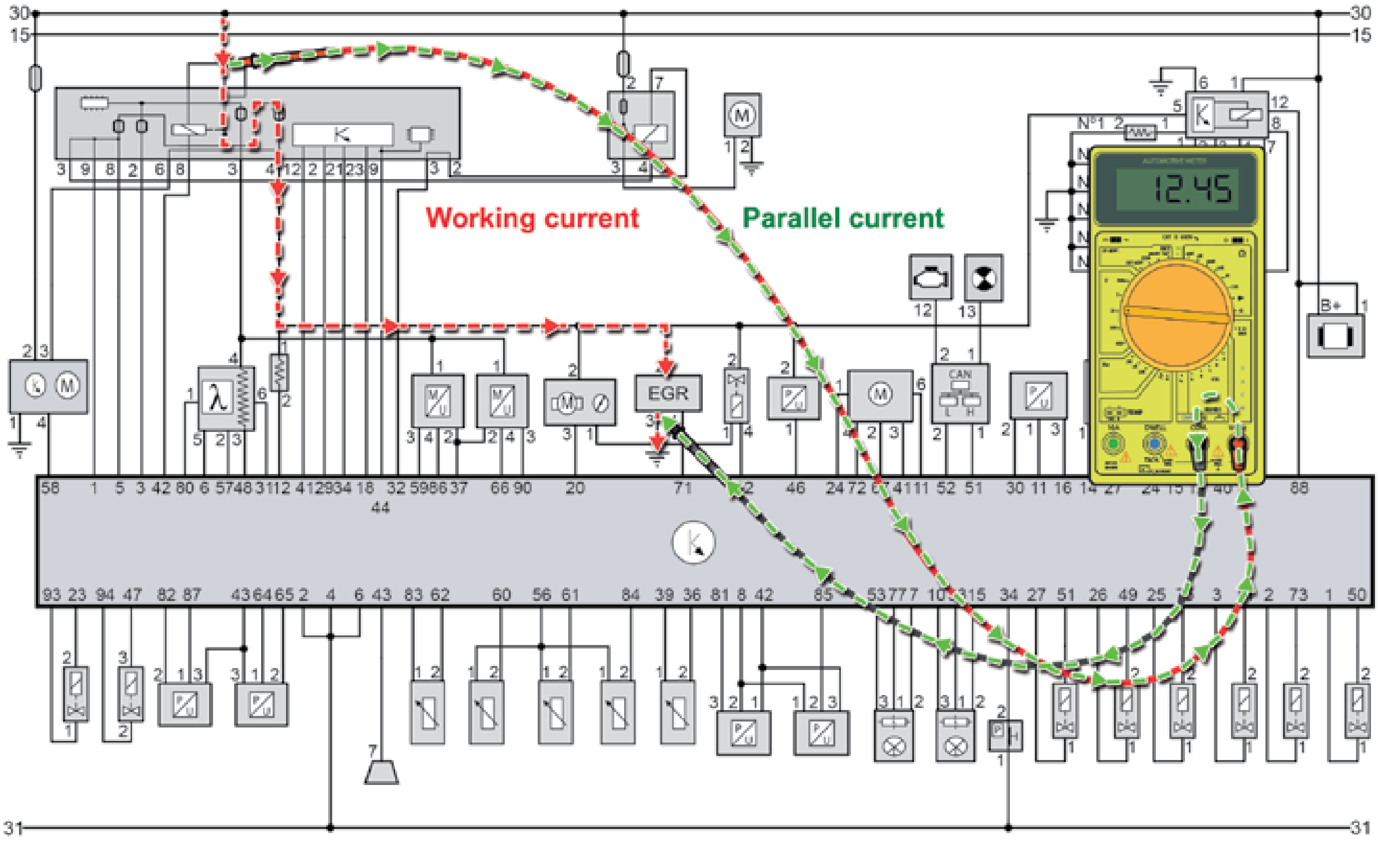
The electrical safety during measurement is determined by the element that offers less protection. The used measuring tips and connection elements must be considered an extension of the measurement tool and must offer the same protection levels. A tool that offers maximum protection is of little use if the connection elements with the circuit, that are usually held with bare hands, reduce the protection level of the assembly and the safety during its usage.

ACCURACY IN MEASUREMENTS

When the diagnosis depends on the obtained values, the measurement accuracy is essential. For this reason, in the technical specifications of the electrical measurement tools, in addition to the safety classification, an input impedance value and a measurement error margin are specified.

In order to check the magnitudes and operation of the electrical systems, the interaction of the measurement tool with the measured circuit must be null or, otherwise minimum, so as not to alter the electrical behaviour of the system during the measurement exercise. At the moment of its connection, the measurement tool is actually a possible additional electrical circuit that is incorporated into the circuit that is wanted to be measured.

The magnitude of the electrical disturbance produced by the measurement tool on the circuit in which the measurement is performed is expressed as input impedance of the tool. It shows the mathematical proportion between the voltage difference that exists in the test tips and the current that flows through the measuring device as a consequence of it. This parallel current between the measurement points may alter to a greater or lesser extent the electrical behaviour or circuit operation. Therefore, the higher the input impedance is, the less the effect produced by the measurement tool on the circuit and the more accurate the measurement will be.



In variable alternating and direct currents, we must take into account the effect as a capacitor or reactance of the measurement tool, which can alter the signal pattern that is intended to be known. This effect is bigger in signals with very high frequency and low intensity, being able to distort, attenuate or amplify the signal in an unpredictable manner in a way that is difficult to identify. It is almost proportional to the input impedance.

The measurement error margin informs about the precision with which the tool determines and shows its results in different measurement ranges available and it mainly depends on the design and quality of its components.

If the magnitude is variable over time, the acquisition speed of the measurement tool becomes important as well. Digital tools are affected by the frequency with which the input value is transformed into digital value and the frequency with which the data displayed on the screen is refreshed respectively.

AUTOMOTIVE MULTIMETER

It is also called volt/ohm meter and, as its name suggests, it offers the possibility to measure several magnitudes. It must be able to measure directly the three fundamental magnitudes of electricity, that is to say, voltage, resistance and current, and it can also incorporate other functions depending on the application field or intended use. Indirectly, by means of connected accessories, it can widen its functions and measurement ranges.

The current digital multimeters replace the analogue tools from the pre-electronic period. They are more accurate than the analogue multimeters and offer more measurement options with wider measurement ranges. Another advantage is that they are supplied by means of an internal battery, which gives them an autonomous power reference that allows them to perform self-calibration.

Several types of digital multimeters can be found on the market, among them the **specific multimeters for the automotive** sector, which allow specific measurements related to the adjustment of the ignition system and engine operation.

The right multimeter for the automotive workshop must meet the following specifications:

- Minimum impedance of 10 MΩ.
- Minimum electrical protection level of 600 V CAT I. For operations on hybrid or electric vehicles, protection level 1000V CAT III or higher.
- Current measurement capacity of less than 40 mA to test the sensors and up to 20 A for the consumers control.
- Voltage measurement in direct and alternating current up to minimum 600V, but preferably 1000V.
- Resistance measurement up to 20 MΩ
- Continuity check and diode test
- Duty cycle percentage indicator (Dwell/Duty).
- Frequency indicator with ranges up to 20 KHz
- Protection by means of a fast internal fuse in accordance with the current measurement scales.

Other recommended characteristics in an automotive multimeter that can help us in diagnostics are:

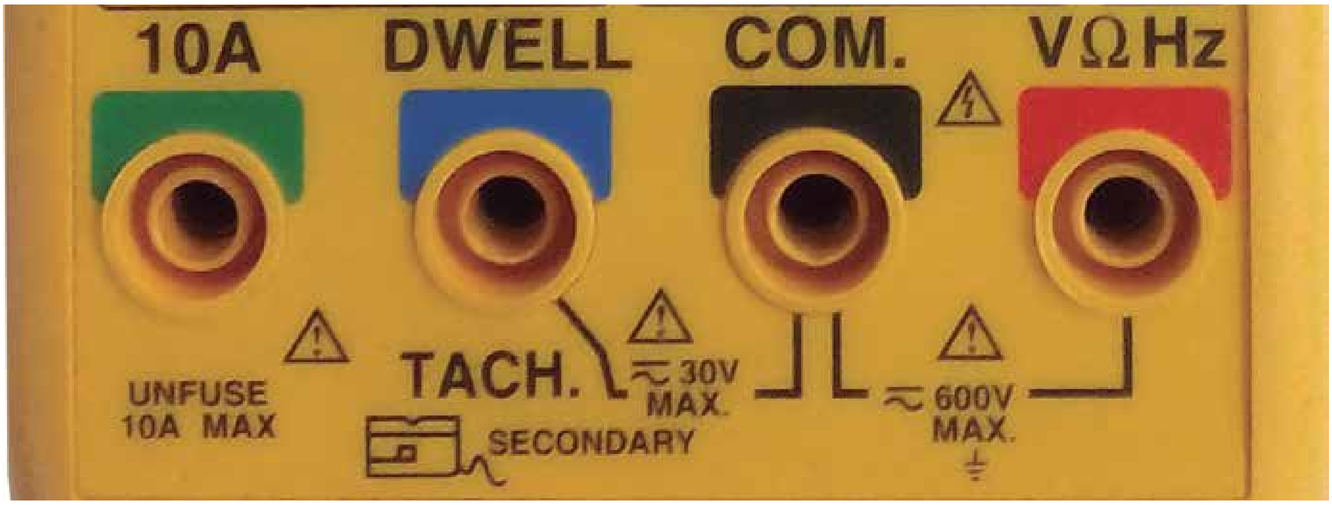
- Direct conversion scales for different range clamp meters.
- Possibility to carry out temperature measurement tests by using an additional sensor.
- Measurement of engine rpm with an inductive clamp.
- Activation time indicator for pulse signals.
- Closure degree indicator for ignition systems with selection of the number of engine cylinders.

Multimeter usage

In addition to the technical functions and specifications of each multimeter, there is a constructive characteristic that is common to all of them and a differential factor that determines how it should be used.

In all multimeters, it is necessary to manually select if the measured current is direct or alternating and modify the position of the connection cables on the tool for the voltage/resistance measurement, current intensity or proportion/frequency of signals. The working principle of the internal circuits of the tool is totally different and incompatible for these functions. In order to avoid additional resistances due to mechanical contacts and excessive electrical consumption, the use of electromechanical switches to modify the input lines is ruled out, so this essential adaptation must be carried out manually.

In the multimeter inputs, text indications and sometimes colour codes are used to indicate the position at which the measurement tip (red) must be placed for the different operations of the tool. The reference tip (black) is always kept in the same connection terminal and is a common input for almost all functions. Its position can be identified by the COM indication and the black colour.



The specific working function of the multimeter is selected by a rotary switch that in some positions also determines a limited measurement range and a scale or format displaying the result. Multimeters usually have several ranges in the same function to offer a greater absolute measurement amplitude with possibility of greater precision for the smallest values.

In the autorange multimeters, this selection is carried out autonomously by a logical circuit, which performs and displays the measurement in the widest measurement scale and successively in smaller scales in order to achieve greater precision. This automatism is based on a mathematical comparison between the value measured in the current range and the maximum range value of the immediately lower range that determines the possibility to display a more accurate result by working in a lower range. It is useful when the input parameter is relatively stable and constant. However, when the input parameter is variable and is situated between two scales, there are often problems understanding the result displayed on the screen due to the variable number of decimals shown in the different ranges.

In multimeters with manual range selector, if the expected value from the measurement (which allows to select the most suitable range for the test) is not known, the same operation must be carried out manually, by selecting each time more reduced ranges so as to obtain the most accurate measurement value. Even though this can seem a disadvantage, in practice it is even beneficial, as it prevents changing results in different formats during the same measurement and makes the comprehension of an absolute value easier. In this case, when the result obtained from the measurement is changing, it is because the parameter itself is changing as well.

The combination of rotary manual selector and also a manual connection of the measurement tips in the tool implies a possibility of 0 impedance, in other words, of electrical bridge between the measurement tips.

For the direct current measurement, the multimeter is connected in series with the circuit by being inserted at one point of it. In order not to interfere in the electrical operation of the circuit, the current must flow through its inside with the lowest resistance possible. Therefore, the impedance must be as close to 0 as possible. However, for the voltage measurement, the tool connection is carried out in parallel on two different points of the circuit.

If due to confusion or carelessness, the cables and selector are placed in a way that determines impedance 0 and the connection on the circuit is performed in parallel, this will lead to a direct bridge or short circuit through the measurement tool. Its consequences are unpredictable and very varied. The blowing or not of the protection fuse will depend on the current intensity of the short circuit, which being the resistance zero will be equal to the maximum supply current of the circuit for any voltage value different to zero. The function of this fuse is to protect the tool and not to protect the circuit on which the measurement is performed erroneously.

MEASUREMENTS WITH MULTIMETER

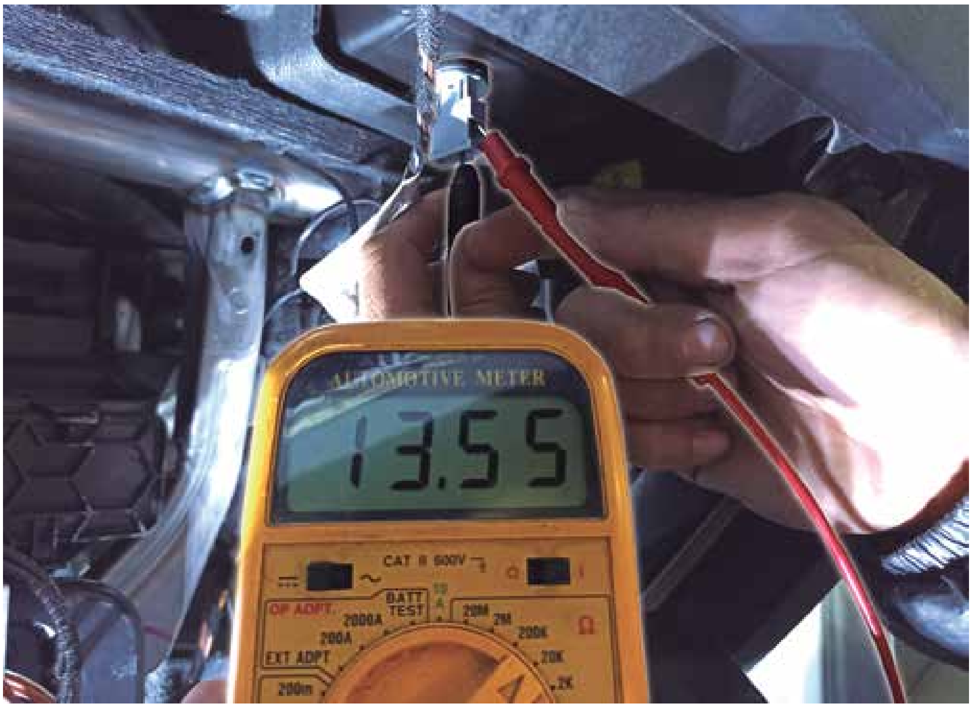
When it comes to measurement and diagnosis, the tool is just as important as its usage. The first aspect refers to choosing a tool that is not only suitable, but also the most adequate or efficient. The second aspect refers to the fact that the operator must know, handle and connect the tool properly. Do not connect the tool in an unreliable way, do not handle it improperly and do not use it when its measurement capacity does not offer enough certainty to perform a reliable diagnosis.

The evolution of the car electrical system in the last 20 years justifies the last statement, reserving the multimeter usage for very specific tests in which it is a more practical and efficient tool than the oscilloscope, which obviously, also has its limitations. Let's see the tests in which the multimeter is the most suitable option.

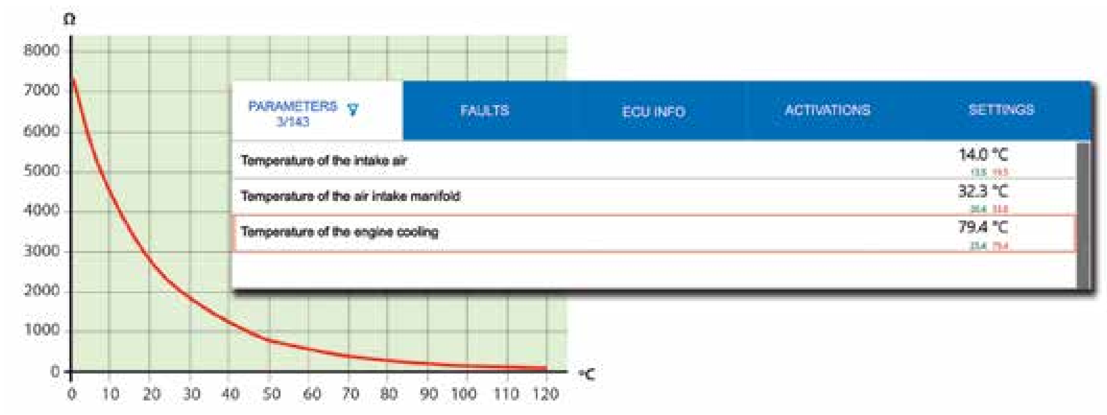
Resistance Measurement

The measurement of the electrical resistance is one of the functions that is impossible to be carried out with an oscilloscope, so the strength of the multimeter is undeniable.

In many occasions, it is performed to check the condition of the electrical lines and some consumers, but as we will see later, it is not the most appropriate method in circuits with variable or continuous current of more than 5 amps. The multimeter accuracy for the measurement of small resistances (R< 1Ω) is generally quite low and any contact resistance in the tool connection considerably distorts the result obtained from the measurement. If we add to this the fact that the voltage drop caused by a resistance depends on the current that passes through it and that, in many cases, the same current modifies the resistive value, we face again inaccuracy and uncertainty.



However, the resistance measurement is the most appropriate method for testing the increasing number of resistive sensors used in the automotive field. The increasing number of circuits for temperature measurement are based on two resistances connected in series that together with a voltage stabiliser create a voltage divider. One of the two resistances has a fixed value and is located inside the electronic unit, while the other one is in contact with the element whose temperature is wished to be known. The variation of the resistive value of the last one, which is known as sensor, determines the circuit current and modifies the voltage in the connection line, which is proportional to the temperature. The average voltage is the proportional electrical magnitude that is digitalised as temperature information.



A relatively small voltage variation in this line, around 100 to 200mV can represent a temperature variation of several tens of degrees, causing a failure that can be easily detected by the self-diagnostic functions of the control units.

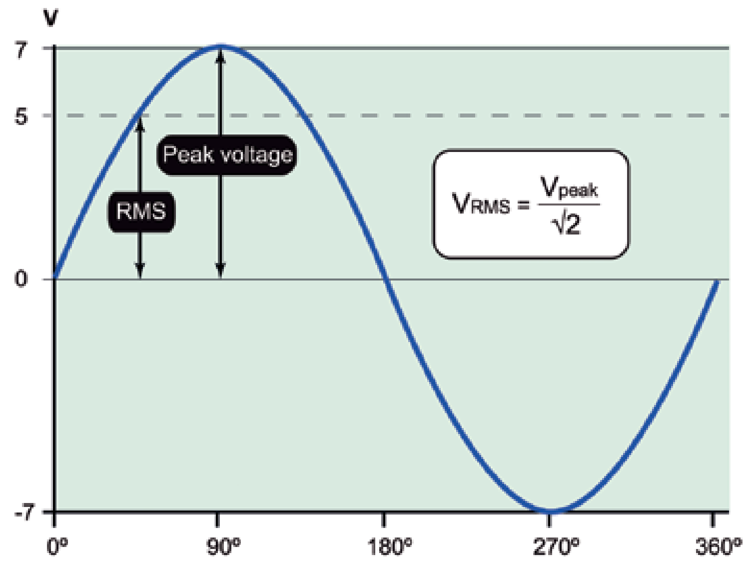
The characteristic variation of the sensor resistance represents the measurement principle. In systems with self-diagnosis data reading, the coherence between the indicated value and the real temperature can be checked by means of a thermometer, but when this possibility does not exist, the only option is to use the characteristic sensor resistance data or tables. The resistance of the sensor element must be checked, always disconnected, at the temperature specified by the manufacturer or at two temperatures close to the normal working margins of the sensor. If the resistance is correct, the problem lies in the wiring or control unit, which implies the check of the stabilised voltage difference that gives rise to the measuring current and variable voltage signal.

Voltage Measurement

The multimeter is also the most appropriate tool to check the differences of electric potential that must keep stable over time, especially when the absolute value of the voltage difference sets a measurement or working range. The multimeter displays the measurements in numerical format, making it easier to detect any variation, however insignificant, by simple mathematical deduction.

By means of the multimeter we will easily identify a variation of 0.2 V (200 mV) in the supply voltage received by the sensor, which gradually ranges between 4.98V and 4.78V, if the test is properly performed, in other words, by connecting the reference tip to the negative supply of the sensor and the red one to the positive. From the very beginning of the check, if we detect that the numbers change and the value gradually decreases or increases, we will recognise this variation and will take it into account, as it may be an indicator of a possible anomaly.

However, if the same variation is measured with an oscilloscope it is often not detected by the human eye, except if it is measured with a very broad time base, something unusual when using this tool. Moreover, in many cases, automotive oscilloscopes have an independent measurement input for each channel (signal line), being the common reference for all channels available and even for the supply of the device. The difference of measured voltage will be then between the signal input line, connected to the positive supply of the sensor and the common reference potential, which can be the same negative supply of the sensor or not. For practical reasons, this reference is usually connected to vehicle's ground or on the negative terminal of the battery, which completely eliminates any actual reference to the sensor supply, which equally depends on the negative potential or the positive one in its connector.



It should be noted that the negative supply of the electronic components often comes from the same electronic unit that receives its signal (electronic ground) or otherwise from the ground point closest to the wiring.

For the measurement of alternating currents, even variable ones, the multimeter suitability if compared with the oscilloscope is even greater. The first factor to be highlighted is that the multimeter displays the actual value or RMS voltage in numerical format, which is usually the verification data supplied for both sensors and inductive type generators.

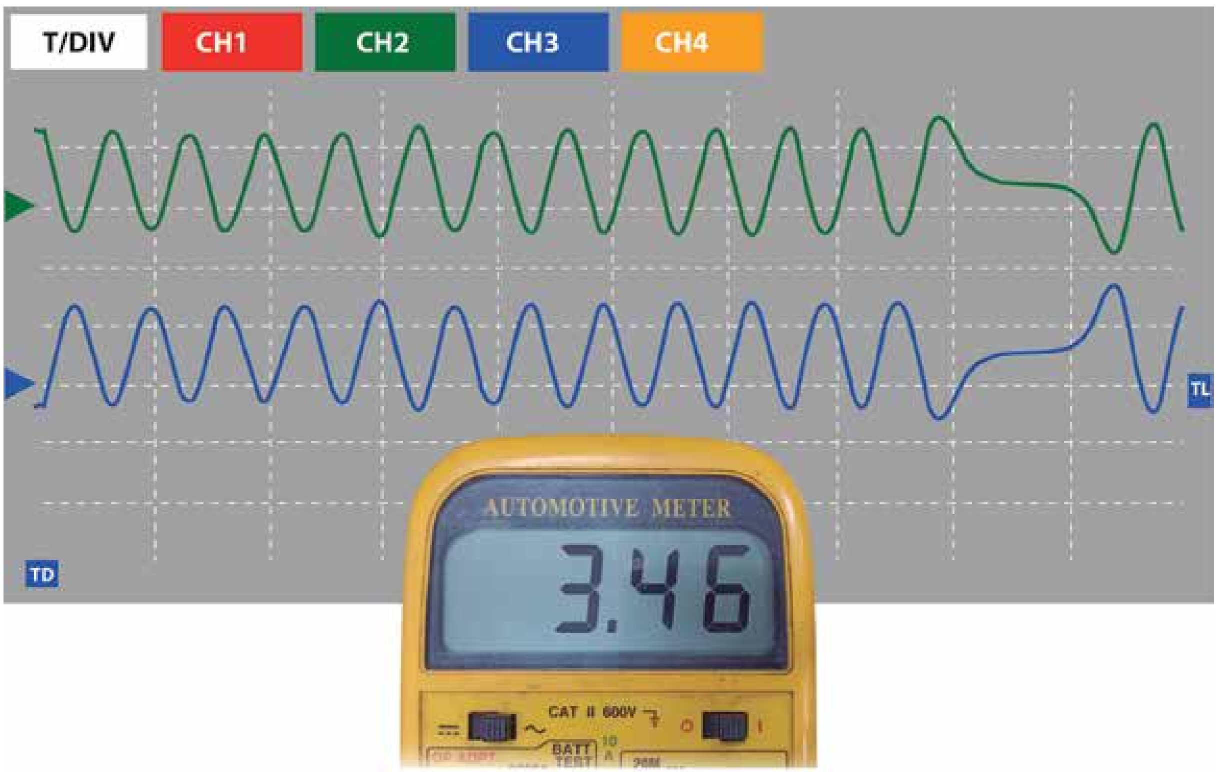
The correct measurement connection of the multimeter in alternating current circuits is simple. One tip in each line, as the current intensity depends on the voltage alternation, which is produced between them, always of opposite polarity. This precept is called phase or counter phase received by the voltages and signals that are produced in these alternating current lines.

In this case, the diagnosis consists in comparing the measurement value with the test value, which in alternating voltages in the automotive field usually increases in accordance with the rotational or working speed of the voltage generating element. Any interruption or non-coherent evolution of the voltage is easily interpretable by using the numbers displayed on the multimeter.

The same check is a little more complicated if using an oscilloscope.

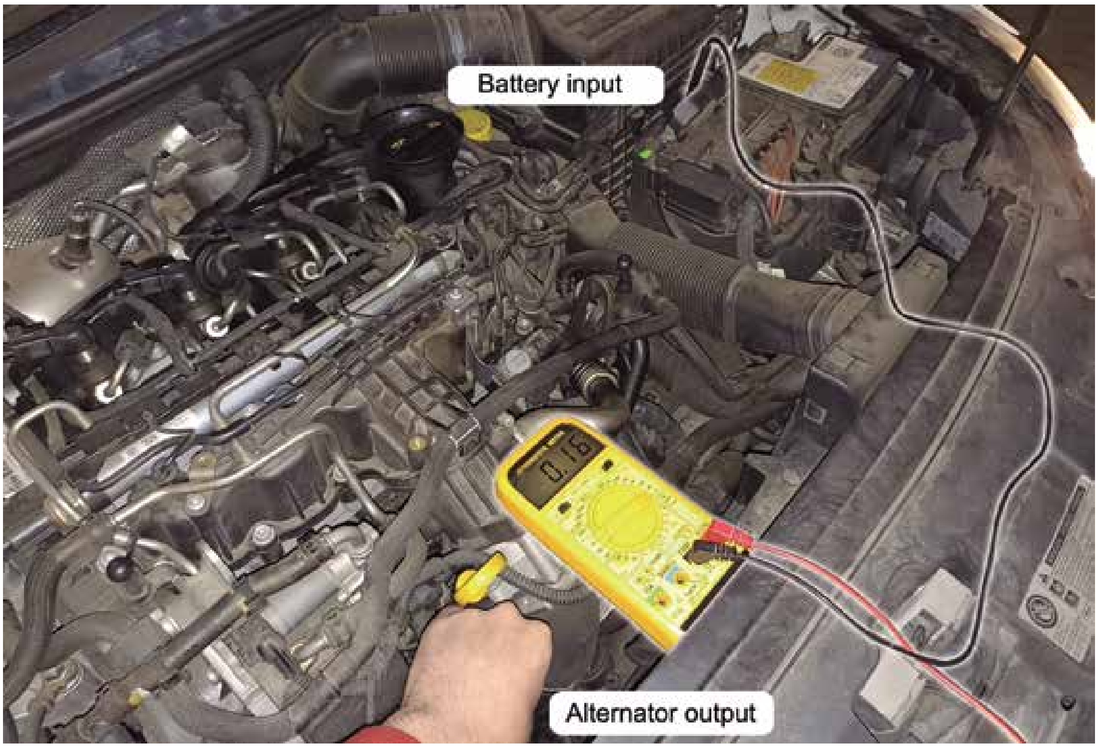
First of all, we must place the signal input and the reference input properly to obtain an actual measurement between the phases and the complete graphical representation of the signal amplitude. Therefore, any common reference or reference to ground is not valid or makes the measurement erroneous.

Then, on the basis of the graphic representation of the oscilloscope, we must calculate the RMS value (effective voltage) of the signal, which is mentally obtained if multiplying by 0.707 half of the total amplitude of the signal so as to compare it with the manufacturer's reference values.



Lastly, for the correct signal display, the need to modify the time base is quite probable as the signal frequency increases so as to be visualised properly and recalculate the RMS value in accordance with the increasing amplitude.

The use of the oscilloscope in order to test alternating signals is a quite common error. It is usually carried out by connecting only the signal line to one of the phases, with the reference to one ground point, therefore, external electric potential that has no relation with the current that is pretended to be tested. The impedance of the oscilloscope in this case works as a capacitor, making the existence and display of an alternating voltage easier even when the sensor circuit or signal generator is interrupted, so the actual current is zero. The effective power of this signal is zero. However, its graphic representation in terms of shape pattern is correct, creating an optical illusion acceptance, which leads to the test error.



The multimeter as an absolute voltage difference meter between its connection tips is ideal for detecting increasing resistances in the supply lines. You just need to place one of the tips at the ends of the line or at its intermediate connectors and force the operation of the circuit at its maximum current. For zero effective resistance, the voltage drop will be non-existent. For any resistance different to zero, the voltage drop will be proportional to the current and the absolute voltage difference between the multimeter tips will be clearly shown on the multimeter display. In general terms, the automotive wiring section is calculated for a maximum voltage drop of 200mV, being any greater value an indicator of an excessive resistance of the conductor or its intermediate connections.

Current Measurement

As the multimeter allows direct measurement and has high sensitivity, it is also a suitable and necessary tool to test leakage currents or consume that cause the accelerated discharge of the battery when vehicles are stationary.

The current measurement with oscilloscope is only possible by using clamp meters that do not offer the required sensitiveness for constant currents with reduced magnitude.

In order to detect these discharge currents, the multimeter must be connected between the negative terminal of the battery and the terminal or connection cable to ground. After switching the ignition off, proceed to simulate the locking of all the vehicle's doors, which must be kept open for access if necessary and check that all courtesy lights are off. Wait the required time for the vehicle to fall asleep and the control units to disconnect before removing the negative terminal from the battery terminal, moment at which the measurement tool will remain inserted at the start point of all the supply circuits of the vehicle.

The maximum acceptable current measured in this situation depends on the electrical equipment of the vehicle, and must now exceed 0.2% of the nominal battery capacity, being the last one the most appropriate for the vehicle. In general, this value is situated between 100 and 240 mA. This discharge limit value ensures the sufficient electric power to start-up the vehicle after a period of 10 days of inactivity.

Verify again the value of discharge current one hour after the first measurement.

If the value of the measured discharge current is higher than the calculated one, proceed to locate the circuit or system responsible for the excessive consumption. To do so, the most efficient method is to remove the fuses distributed in the different connection boxes of the vehicle, starting from the ones with lower value that are usually for the protection of the independent circuits. The removal of the fuse that reduces the consumption measured by the multimeter up to an acceptable value indicates the circuit that causes the excessive consumption. It can be located by disconnecting its elements in sequence with the help of the corresponding wiring diagram.

In the same way that the multimeter is an appropriate tool for the measurement of small currents, we must warn that it is not suitable for currents higher than 5 Ah or very variable currents. The first currents cause the excessive heating of the device and wiring, while for the second currents the display in changing numeric format is not practical. In this case, a clamp meter must be used, as it transforms in proportional voltage the magnetic field that is formed around the conductor as a consequence of the passage of the electrical charges. If the current must be or remain relatively stable, we will use it connected to the multimeter and if it is variable, it is better to connect it to an oscilloscope.

Other Functions

There is a considerable number of functions in the automotive specific multimeters that the oscilloscopes cannot perform. However, if they are not well known and not used properly, they can cause confusion and erroneous diagnostics.

Continuity acoustic warning (Beep): It is very useful for identifying the continuity of the wiring lines thanks to the sound format for positive detection, provided that they are without voltage. For this purpose, the complete wiring harnesses must be disconnected. Otherwise, disconnect both terminals from the battery, as the lines under voltage or polarised lines can distort the detection. The multimeter identifies this possible continuity when the resistance between the measurement tips is lower than 25-35 Ω, for which it passes a small current through the wiring (<1mA). In all cases, after this first possible identification, it must be checked that the electrical resistance of the line is lower than 0.2 Ω to check the effective electrical continuity.

The same function is used many times incorrectly to check the insulation between lines and even in the wiring with regard to ground, but it is obvious that with the detection value of 25-35 Ω, the check of sufficient insulation (test value >1kΩ for 12 V systems) is far from being reliable.

% Duty cycle / Dwell: They are used to measure the proportion of positive or negative voltage respectively in regulated power supply lines. The measurement is reliable as long as the measured signal reaches a voltage difference higher than 5-8V (depending on models) with respect to the fixed potential and its uniformity over time is sufficient. These measurements are valid to test mechanical switches and variable power supply signals, but must not be used to check digital sensors of 5 volts and neither for communication signals between units whose voltage and frequency values are often not compatible with the measurement capacity of the multimeter. Any obtained result may cause confusion.

1974-76 2850 HC engine	1974-76 3300 engine	1974-76 3300 engine
QD	QL	= = =
2.838	3.298	= = =
9.4	9.4	= = =
88	101	= = =
102(1)(2)	102(1)(2)	= = =
Hydraulic lifters	Hydraulic lifters	= = =
1 035±140	1 035±140	= = =
140	140	= = =
AC 44T	AC 45T	= = =
0.85-0.95	0.85-0.95	= = =
30-38(3) Dry threads	30-38(3) Dry threads	= = =
Bosch PFU 6(R)†	Lucas 29D6†	= = =
9 230 062 612†	62941132A†	= = =
0.55	0.55	= = =
30-35	30-35	= = =
4.73-5.84	5.0-6.12	= = =

The positions of ºDwell for a specific number of cylinders are also worth mentioning. In many cases, the adjustment data of the dwell angle for the ignition system of classic vehicles is only available in this format, being therefore the perfect function in order not to perform conversion calculations.

Diode test: Diodes, as a minimum useful connection of two semiconductors are the fundamental pillar of electronics. They are found in most electronic circuits and in some components such as alternators and relays. Sometimes they are inserted in the electrical installation of vehicles. When located between the relay activation terminals, for example, they prevent their activation in case of reverse connection of the battery terminals.

The multimeter allows to test the two typical conditions of the diode, displaying the voltage drop that it causes when it conducts the current, and the non-conduction or absolute resistance when the polarisation is reverse.

So far the measurements and tests in which the multimeter is the most indicated or appropriate tool for the electrical checks.

In the next section of this article we will deal with the particularities of measurements with Oscilloscope and the way to get the maximum performance of it when testing and diagnosing the systems fitted in cars.

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Diagnostics with multimeter and oscilloscope II

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