

**Educational and technical aspects of the design  
and construction of the test bench for testing  
the automotive ignition systems**

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The paper deals with educational and technological aspects of the choice and organization of the means of information transfer in the teaching processes. The attention is paid mainly to the problems of design and construction of the test benches intended to be used for acquiring practical skills and understanding operative properties of electrical, electronic, and computer systems applied in the industry, vehicles and other human activity. An original design and physical implementation of a bench for testing the automotive ignition systems is presented as a practical example.

**KEYWORDS:** transfer of knowledge, educational aids, automotive electric systems, educational test benches, testing the ignition systems

## **1. Introduction**

Taking into account the human activity the cars are no more considered as a luxury but largely as a necessary element of existence. On one hand the cars make the private living easier, facilitating communication with other people, improving the comfort of rest organizing, facilitating the supply and organization-administrative provisions as nearly any place unavailable for public transport may be reached. On the other hand, the cars become a necessary condition of professional activity. They improve mobility within the contacts with the contractors, allow to present the products to various business partners or simply enable quick and immediate journey to the work place and back to home.

Since the number of the vehicles grows permanently, the development of the engine control systems and the features related to driving comfort becomes a very important factor. It allows to improve performance and reliability of the drive units, to reduce the number of collisions in the road traffic and to mitigate the consequences of any accidents. Significance of these measures cannot be overestimated as they affect human living and economy of using the cars. Growing complexity of structural parts of the vehicles and their subassemblies results in larger needs of transferring wider and deeper knowledge related to

operative properties of these parts, with a view to improving creative designing, diagnosing, and repairing the fittings of the vehicles and achieving its reliable operation.

The paper considers the educational and technological aspects related to transferring the knowledge on the structure, technological parameters and operative properties of electrical, electronic, computer and sometimes even mechanical systems commonly used in the industry, in the vehicles, and in general human activity. The comments are presented on the role fulfilled by the educational transfer means in shaping the knowledge level and understanding the considered problems by the recipients (i.e. the pupils, students or listeners). Special attention is paid to the role of properly developed and constructed laboratory stands for acquiring the practical capabilities as well as for understanding the theoretical aspects of the acquired knowledge. An original conceptual design and description of physical implementation of the laboratory stand for testing the automotive ignition systems is presented as a practical example.

## **2. The role of educational aids in transfer of knowledge**

The choice of the means of information transfer, taking into account their type, quality, and scale of their application, significantly depends on the field of the knowledge to be transferred. What concerns the type and methodology the means of information transfer used in humanities and in exact sciences differ greatly from one another. The engineering sciences make a particular domain. The transfer of theoretical knowledge and acquiring practical skills may be separated rather clearly. Within the theoretical part the information related to practical aspects of the task performed is transferred too. Any elements of visualization of the presented problems i.e. appropriately chosen and commented drawings, multimedia presentations and animations or short films aimed at imaging the operation and interrelationship between the considered values or objects are here very helpful.

In the technology the acquaintance with wide practical s is a very meaningful aspect. It is due on one hand to deeper understanding and consolidation of the practical information and, on the other, first of all to acquiring practical measuring skills, adopting the methods of diagnosing, control or repair of the systems and their subassemblies, to developing imagination of the taught persons, with a view to enable creative designing of more and more excellent structural solutions of the designed systems and devices.

The most effective way of acquiring the knowledge and practical capabilities consists in carrying out the physical tests on real technical systems with the help of specially designed test benches.

### **3. Specificity of construction of the educational test benches of technical systems**

Appropriate visual imagination of the information as well as physical or manual contact with the considered technical system have invaluable effect on proper development of the knowledge and skills of the recipients. In the process of knowledge transfer related to the structure and operating principles of the definite electric and electronic systems the following needs may arise:

- a) Execution of standard tests on actual systems in their natural operative environment – it allows to develop proper research habits of the taught persons, quick diagnosing and professional service of the considered systems. This, in consequence, allows to create the skills in effective servicing of the considered systems and devices.
- b) Conducting extensive tests on specially constructed test benches, with unnatural distribution of particular variables (physical values) with a view to separate their impact on operation of the whole system. This enables more complete understanding of the relationships existing between the definite values, it provides additional information on the process of knowledge acquisition and optimization efforts. In consequence, the process of designing further, more perfect constructions of the considered systems may be improved.

During the designing and structuring process of the test bench first of all the characteristics of the structured object should be chosen. This consists in answering the question whether the future users will aim at acquiring possibly detailed knowledge with possible partial implementations of separated studies of the effects of particular values on the operation of the considered system, or rather they should, first of all, learn to carry out the complex technological tests on a complete system and to estimate immediately the condition of the tested object and its servicing with a view to restore it to fully operational condition. According to settlement of these questions and the decisions made the primary concept of the test bench may be determined. Specification of the expectations related to the above contribute to the conceptual design.

Further steps comprise the details related to possible tests. They should include all the problems related to security and ergonomics of the tests to be carried out. Proper availability and correct allocation of particular subassemblies and their connection points (terminals) shall considerably affect the advantageous conditions of the measurements and quality of the service of the bench (practical usefulness). Nevertheless, all the safety and health policies should be met as a priority.

In final designing stage the aesthetic aspect of the structured technical object should be taken into account, as it affects psychological sphere of activity of the future users.

#### **4. The choice of the object to be implemented**

The object to be implemented is the automotive ignition system of a spark-ignition petrol engine [1-4].

During the project implementation it should be taken into account that the ignition system is a system having multiple effects, of high-voltage, electromagnetic and mechanical type. This is significant both from the point of view of educational values, that should be considered while implementing the project and the technological factors aiming at ensuring correct operation of the designed test bench.

Taking into consideration that the ignition system is one of the earliest electric systems used in vehicles, its evolution is eventful. In the beginning the classical solutions have been used, with mechanical breaker regulation of the advance angle (according to engine speed and load). Later on a large variety of the solutions of medium generation appeared, that included an electronic breaking element (the ignition module) and electric sensor of the crankshaft position and engine speed. In modern solutions the mechanical advance angle controller is eliminated, while the recent ones are no longer provided with the high-voltage distributor. The distributorless ignition systems are implemented that are fully controlled and regulated with the help of a microprocessor control system. Due to meaningful interaction with the fuel injection system and the fact that most of the sensors providing information on operation of the engine and the condition of its subassemblies and environment, both systems are integrated into ignition-injection microprocessor systems [2-4].

The injection systems are tested on a separate bench. While considering an ignition system to be implemented on the test bench, the ignition system of medium generation has been chosen, taking into account clear operation of its parts, easy understanding of the idea of the ignition system operation and its reliability, as compared to a classical system.

#### **5. The design of the test bench for testing the automotive ignition system and its physical implementation**

##### **5.1. Conceptual design**

The main goal of the work was aimed at construction of the test bench for testing the automotive ignition system of medium generation. The test bench is to be used in the University Laboratory of Electric and Electronic Systems of Vehicles.

The laboratory tests are carried out not only with the systems as a whole but, as opposed to the workshop diagnostics, with their definite parts. To make such an approach feasible the ignition system implemented in the bench must operate

identically as in a real vehicle (that enables to consider it as a single object), but the bench should allow for separating the system subassemblies and interactions with some definite functional features with a view to test them individually and in a multiple way. In order to meet these assumptions the contacts of particular components of the ignition system should be routed in the form of terminals to the top of the upper plate, to allow access to each of the system subassemblies with a view to enable their independent diagnosing.

The designed bench is to be used by the students in order to acquaint with the principles of operation of an automotive ignition system and with the diagnostic methods. Therefore, it should be ergonomic and functional and of universal type. Moreover, it should ensure security during the tests and should comply with the standards [1-7].

## **5.2. Description of the design**

The design includes building a mobile bench of compact and possibly small dimensions, that may be located on a table of 60 cm width. The device should be so designed that it can be displaced by a single person. A casing in the form of a box made of powdercoated steel ensures required mechanical resistance. Rubber-coated, feet located to the bottom of the casing, damp vibration and enable leveling of the bench. The upper plate is made of transparent acrylic glass (commonly called "plexi") 8 mm thick, painted from inside with a view to prevent damage to the printed surface. The author of the bench decided to use plexi considering easy machining, resistance to breaking and aesthetic value. Particular subassemblies of the ignition system are fitted outside the casing, thus enabling the test performer to get familiar with their structure and appearance. The contacts of all the parts of the ignition system are routed to the upper cover in the form of electric laboratory terminals, provided with clear marking. Such a solution is motivated by willingness to encourage the educated people to carry out the connections of the ignition system on his/her own. This improves understanding the interrelationships between particular assemblies. One of the main parts of the device, i.e. the timer-distributor, is located on an exchangeable arm that, in case of fitting another device model, may be replaced by a proper structure. Central part of the upper plate bears a rotary magneto, located coaxially with the shaft of ignition system drive. The magneto is made of acrylic glass and a disk made of stainless steel provided with angular scale, made with the help of laser processing method (Fig. 1). High voltage is applied to the magneto disc, causing electric discharge to the indicating needle fixed to the shaft of ignition system drive. The base of the magneto disk is pinned to upper plate by means of Teflon sliders, serving at the same time as insulators. The design of the main (upper) plate of the bench (with adoption of the conceptual assumptions) is shown in Fig. 2.

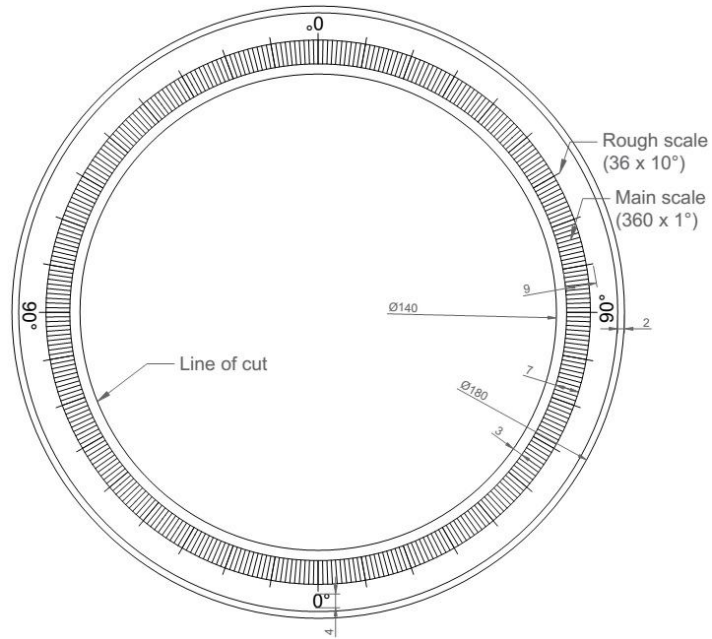


Fig. 1. Design of the disk of rotary magneto [1]

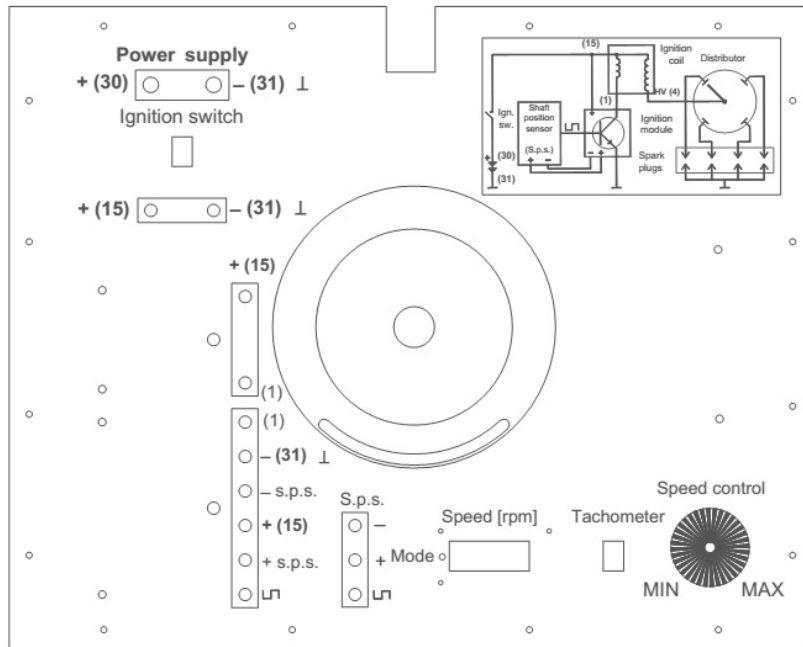


Fig. 2. Working scheme of upper plate of the bench

Rotational speed of the magneto is twice slower than the one of the engine shaft. Hence, it should be infinitely adjustable in the range 500 – 3000 rpm. The author of the bench decided to use an universal motor used for driving home appliances. In order to achieve the required rotational speed a multi-V belt transmission was used. The motor is supplied from 230 V mains with the use of a speed governor offered by AVT (the AVT 1007 model). It is a governor that controls the triac connection angle with the help of a special U2008 system. The speed control potentiometer is located at the upper panel, in the vicinity of digital display of the tachometer (the AVT 5260 model). Scheme of the drive system used in the bench is shown in Fig. 3.

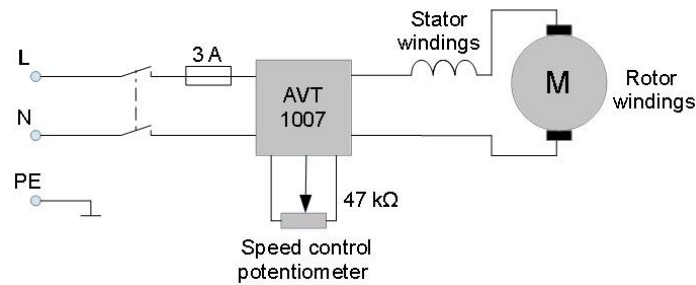


Fig. 3. Scheme of the drive system used in the bench

The ignition system used in the bench (Fig. 4) is taken from Lada Samara 1.5L. It is composed of a bottle-shaped ignition coil, 6-contact transistorized ignition module and timer distributor provided with Hall effect sensor, centrifugal governor, negative pressure regulator and mechanical distributor. The ignition cables connecting the distributor dome with sparking plugs are also taken from Lada Samara 1.5L. The sparking plugs are made in Russia – the A17ДВ model, with rated gap 0.5 mm.

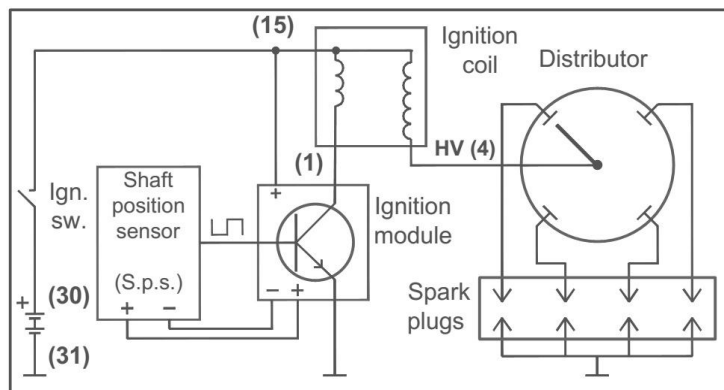


Fig. 4. Scheme of the ignition system used in the bench

A view of the bench for testing the automotive ignition system, built according to the above presented design, is shown in Fig. 5.

For more extensive description, the details related to the conceptual design and the project refer to [1].

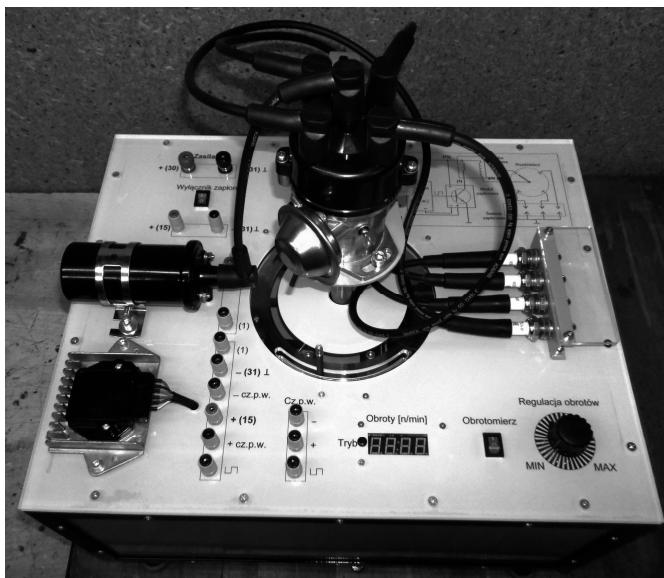


Fig. 5. View of the designed bench

### **5.3 The problems of electromagnetic compatibility**

The electromagnetic compatibility is an important problem related to operating ability of the electrical equipment in electromagnetic field and to possible reduction of electromagnetic disturbance emitted by the equipment. The considered bench, similarly like any laboratory equipment, must meet the requirements of electromagnetic compatibility. Among the main sources of the disturbances caused by the device there are the high voltage generated in it and spark discharges conducive to electromagnetic field and to transmitted disturbances. The disturbances may cause disorders in operation of the nearby located laboratory equipment and, first of all, the dysfunctions of the assemblies of the bench itself. Among others, the electronic systems of tachometer and speed governor are particularly sensitive to such phenomena. In order to reduce the disturbances the ferrite and LC filters are implemented in the power supply circuit, an additional ground is distributed in the ignition system, the signal cables are stranded and screened, the rotary magneto is fully screened [5]. During the project implementation the author introduced many design solutions with a view to ensure the electromagnetic compatibility.



## 6. The tests possible to be performed on the designed test bench

The test–diagnostic bench designed and implemented by the co-author of the present paper allows to carry out many tests relevant to the ignition system of medium generation used in the bench. The following tests may be performed:

- outer inspection of the parts of the ignition system;
- test of the ignition coil;
- test of the timer-distributor;
- test of the crankshaft position sensor;
- operational tests of fully assembled ignition system.

### *Outer inspection of the parts of the ignition system*

The inspection generally includes the operations performed on the ignition system at rest, without any tools. Among these operations there are: inspection of the ignition coil with regard to possible physical damage and oil leakage, verification of the condition of the ignition module casing, correct connections of the low- and high voltage cables and their quality, check of the timer-distributor (particularly appearance of the distributor dome and distributor rotor arm, condition of the distributor electrodes and free motion of the controllers).

### *Test of the ignition coil*

The ignition coil is characterized by many physical and electric parameters. Their correctness should be assessed in order to verify its technical condition. The parameters are as follows: value of resistance of the windings (that should be continuous and kept in the range specified in Table 1), resistance of the coil insulation ( $R_{iz} > 20 \text{ M}\Omega$ ) and value of the voltage induced at secondary side (determined by oscilloscope observation with the use of a HV probe). Example of the voltage pattern registered with an oscilloscope at the secondary side is presented in Fig. 6.

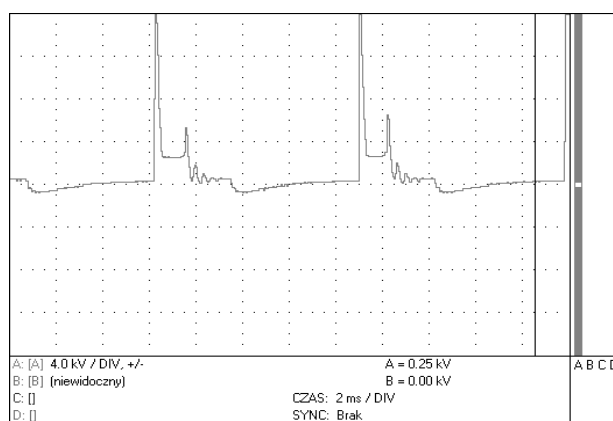


Fig. 6. Oscilloscope pattern of secondary side voltage of the ignition coil

Table 1. Correct resistance ranges of the ignition coil windings

The coil type	Winding	Value of resistance
Classical coil	primary	3-6 $\Omega$
	secondary	3-8 k $\Omega$
Electronic coil	primary	0,3-1,5 $\Omega$
	secondary	2-20 k $\Omega$

*Test of the timer-distributor*

The timer-distributor is the most complex part of the medium-generation ignition system. It consists of the advance angle controller, crankshaft position sensor, and HV distributor. Characteristics of the centrifugal governor is determined by measuring the ignition advance angle (the reading on rotary magneto) as a function of rotational speed, with constant negative pressure in the intake manifold. Characteristics of the vacuum controller depends on the value of negative pressure in the intake channel of the engine, while determination of the characteristics with the help of the designed bench consist in recording the ignition advance angle with rotating magneto and varying negative pressure for stationary rotational speed.

Theoretical patterns of these characteristics are shown in Figs 7 and 8.

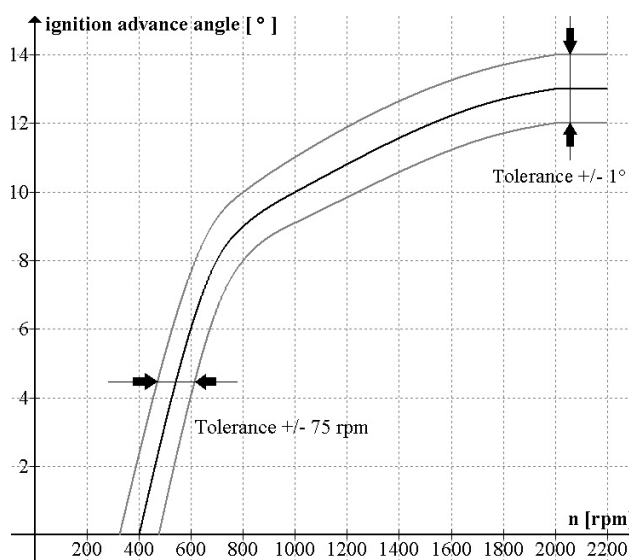


Fig. 7. Exemplary characteristics of the centrifugal governor of the ignition advance angle [8]

Examination of the sensor of the crankshaft position and engine speed (Hall effect) consists in oscilloscope observation of the voltage input signal (with electrically supplied sensor and spinning its rotating part). It should be observed

what is the effect of varying rotational speed on the voltage signal generated. Fig. 9 presents the oscilloscope signal coming from the Hall effect sensor that displays the crankshaft position and engine speed.

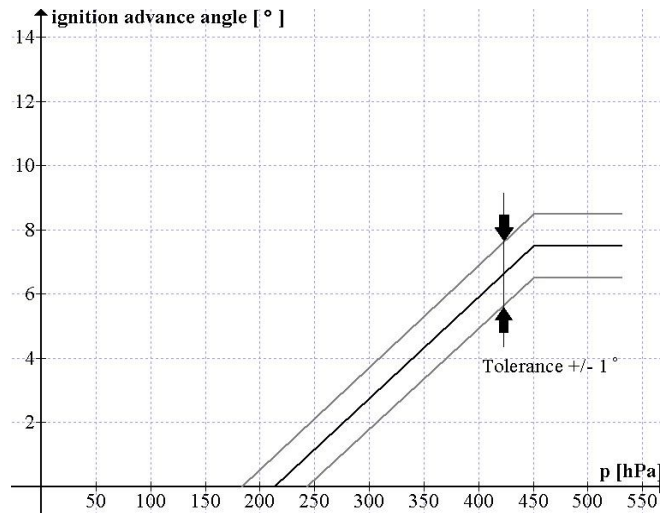


Fig. 8. Exemplary characteristics of the vacuum governor of the ignition advance angle [8]

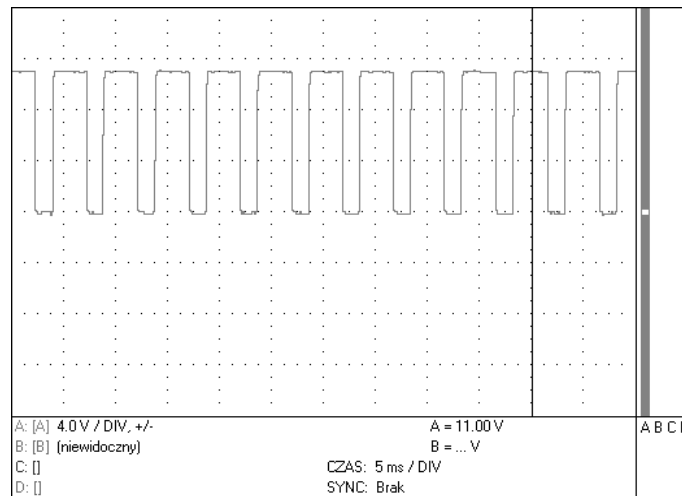


Fig. 9. Oscilloscope record of the voltage signal from the Hall effect sensor

Correct operation of the ignition distributor is assessed based on measuring the asymmetry of the spark generation with the use of rotary magneto. The ignition angles of each of the spark plugs are recorded – they should be activated each 90°.

## **7. Summarizing notes and conclusions**

The persons dealing with technical objects (e.g. with electric and electronic systems of vehicles) should understand the operation of the considered system and should be familiar with diagnostic and test methods aimed at detecting the defects and assessing correct relationships between the components of the system.

Properly chosen and duly designed educational aids in the form of laboratory test benches are essential elements for the process of acquiring the theoretical knowledge and practical skills in the structure, operating properties, diagnostic methods, repairs, and designing the technical objects.

During the designing process of the test-diagnostic bench a compromise was necessary, between the educational needs and technical-practical aspect of its functionality.

The presented test bench was designed and built by the paper co-author. Its educational values may be easily used during laboratory lessons. The bench is ergonomic, safe, and aesthetically made and, in consequence, is suitable to be used in modern laboratory of electrical and electronic equipment of vehicles in the Poznań University of Technology.

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