Damian GONSCZ, Henryk URZĘDNICZOK, Wiesław DOMAŃSKI
THE DEPARTMENT OF MEASUREMENT SCIENCE, ELECTRONICS AND CONTROL, SILESIAN UNIVERSITY OF TECHNOLOGY
Akademicka 10 street, 44-100 Gliwice

Laboratory stand for the analysis of conducted disturbances in the car electrical circuits

Abstract

The paper deals with technical aspects of the measurements of conducted disturbance levels in the electrical circuits of typical car vehicles. The work includes project, execution and a testing of new laboratory stand for analysis disturbances in the electrical circuits of car. The block diagram of the laboratory stand is shown in Fig. 1. Designed structure of the electrical installation is typical for the classic cars. The structure includes only the basic electrical circuits. The voltage level assumed in the installation is equal 12 VDC (car accumulator power supply). The commercial car loads (lighting, audio, ignition system, low power electric motors, etc.) are installed in the laboratory stand (Fig. 2). The selected test results of the laboratory stand (ignition system and power supply parameters in circuits) are presented in the chapter 3. The laboratory stand also allows to execute among others the immunity tests of selected components against electrostatic discharges.

Keywords: automotive EMC testing, measurements of conducted disturbances, immunity tests against typical disorders.

1. Introduction

The EMC (eng. *electromagnetic compatibility*) testing of vehicles comprises different special measurements of levels of the conducted and radiated emission. The EMC analysis also requires carrying out immunity tests of typical basic electronic components of car and the independently entire car against selected conducted and radiated disturbances. Issues of immunity testing in the automotive area are already discussed in papers [1] and [2]. The analysis of conducted disturbances propagated in car electrical circuits is one of the most important stages of EMC testing of vehicles [3], [4]. These research are carried out for both new vehicles entering the world market as well as under modifying existing installations in older cars. Many dysfunctions of prototype electronic equipments are caused by disturbances in the supply lines both during normal vehicle work and a during temporary particular operating conditions. The power supply lines of the selected electrical and electronic loads of vehicle are most frequently analyzed. Analysis of the levels of disturbances in the electrical wires are done usually in the field of time and frequency. Knowledge of the parameters of real conducted disturbances is necessary because a case of immunity testing against real disturbances is required the execution in the EMC research of a new product dedicated to a specific vehicle model. The new electronic module must be resistant to disturbances. This is very important in the case of changing the older type of electronic modules to modern solutions when upgrading vehicles. The electronic modules of modern cars are much more sensitive to conducted disturbances in their power and signal circuits.

The prepared laboratory stand allows to estimate the parameters of conducted disturbances from the typical on-board electrical devices of car vehicles. Knowledge of the amplitude, shape and time duration of disturbances in the electrical installation allows us to undertake research into the development of modern filtering solutions dedicated to specific types of car receivers. The author's experience shows that the disturbances in the automotive power supply lines are generated mainly by electrical receivers. The modern electrical onboard loads these are usually nonlinear electronic power devices which inject to the power supply wires the disturbances with high amplitude. In this case the topology of the wires is much less important in the EMC analysis. An very important issue is the problem of disruption analysis generated by the ignition system (petrol engines). The ignition system always generates the conducted disturbances and the radiated disturbances with high frequency. The radiated interference are very easy introduced into the other electrical circuits. The most vulnerable for these effects are signal and control lines.

The block diagram of laboratory stand for the analysis of conducted disturbances in the car electrical circuits is shown in the Fig. 1.

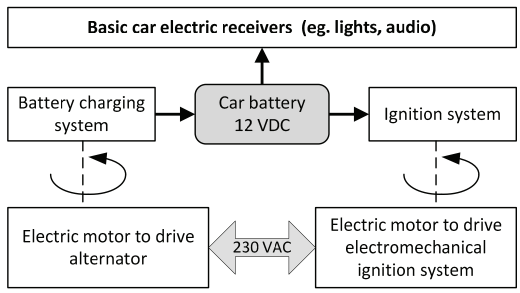

Fig. 1. Block diagram of laboratory stand for the car electrical installation analysis

The above block diagram also includes two electric motors used to drive the alternator and the electromechanical ignition system.

2. Construction of the laboratory stand

The developed laboratory stand is made in a compact form. The view of stand is shown in Fig. 2. Additional parts of laboratory stand are the battery charging system with the independent electrical drive (230 VAC) and the car battery (Fig. 3 and Fig. 4). For user safety the battery charging system is enclosed in a metal casing.

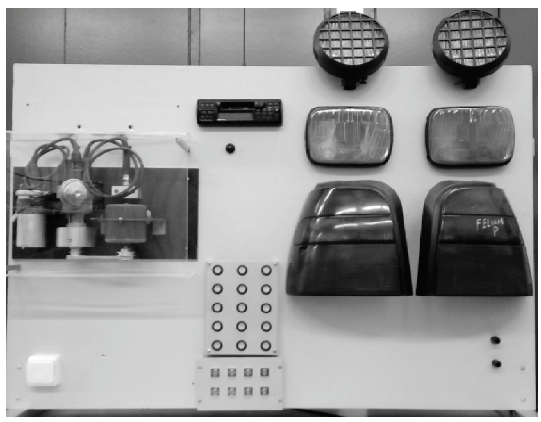

Fig. 2. View of main part of laboratory stand for the car electrical installation analysis

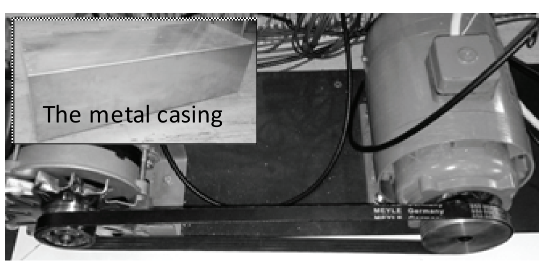

Fig. 3. View of charging system for car battery

The car battery is placed in a casing with a mechanical circuit breaker and a matched over current protection. The battery parameters are: nominal voltage 12 V, electrical capacity 72 Ah and starting current 660 A.

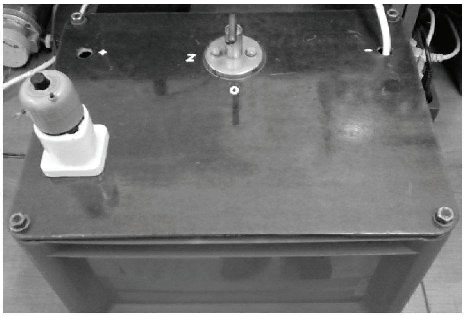

Fig. 4. View of portable car battery 12 VDC

A classic electromechanical ignition system is installed in the prototype laboratory stand. This is a deliberate choice because this type of ignition module generates the most values of conducted and radiated disturbances. The diagram of the ignition system is shown in the Fig. 5.

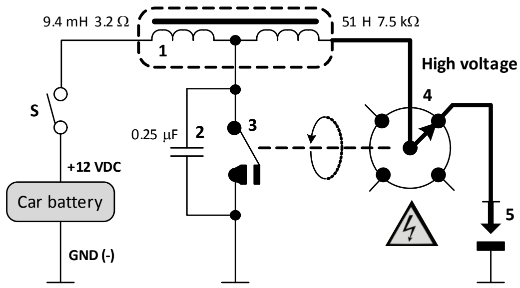

Fig. 5. The diagram of the electromechanical ignition system

The above circuit consists of a typical ignition coil (1), a capacitor (2) a mechanical breaker (3), a mechanical high voltage splitter (HV commutator) (4) and a spark plug (5). For the simplicity only one circuit of spark plug is used in the ignition system. The author's experience shows that the types and models of circuit components do not effect significant on the EMC research results, so these data are not presented in this paper. In this case, the structure of the ignition system and its hardware solution (classic analog or semiconductor) are the most important. The photo of the real ignition system is shown in the Fig. 6.

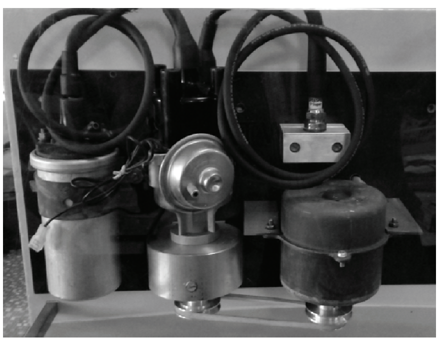

Fig. 6. View of the real ignition system used in the laboratory stand

For the safety the ignition system is covered with a plexiglass casing. For drive of system the low power electric motor (230 VAC) is used. In a project it is also possible to change of rotational speed of ignition system by second gear ratio of the V-belt (about 2000 rpm or 3500 rpm). The default value of rotational speed in the stand is equal 2000 rpm. This is a typical value for a slow ride of car with a petrol engine.

The basic car electrical installation is implemented in the new designed laboratory stand. The view of the connections structure of the electrical circuits is presented in the Fig. 7.

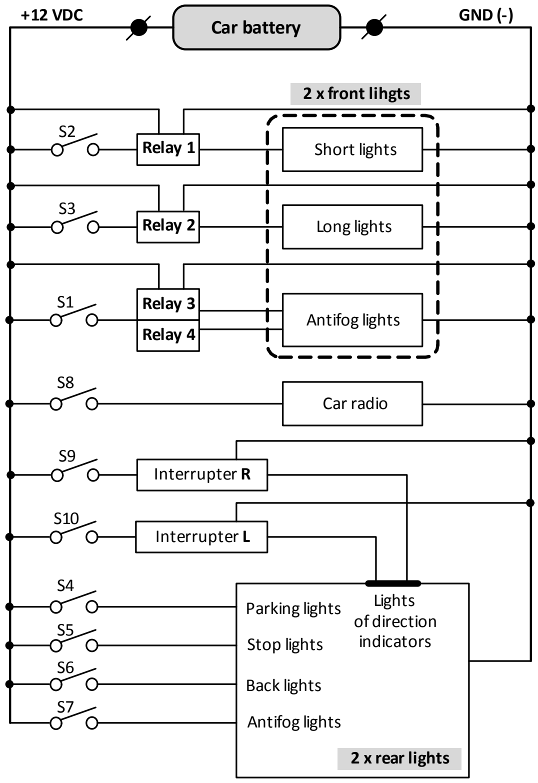

Fig. 7. The topology of circuits for car electric loads in the laboratory stand

The classic halogen (H4) with power 55/60 W and typical car tungsten lighting are used in the laboratory stand. The relays and the interrupters are used in the typical electromechanical versions because the laboratory stand represents a basic electrical installation of classic cars.

The front board (Fig. 2) also includes a panel of switches and measuring BNC sockets. The view of panel is shown in the Fig. 8.

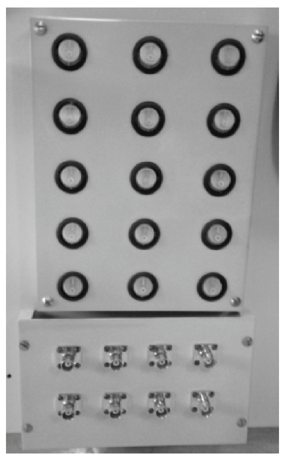

Fig. 8. Panel view of switches and measuring BNC sockets

The switches control the circuits of electrical receivers. BNC connectors are used to connect the power supply analyzer to selected circuits (eg. circuits of lighting, audio, direction indicator lights, alternator, car battery, ignition system). In order to perform a timing analysis of disturbances in the electrical circuits, the AutoWave recorder/generator is implemented in the laboratory stand. The parameters of this instrument are described in the papers [1] and [2].

3. Selected test results of the laboratory stand

The ignition module was tested in the first stage. This module is the important source of conducted distortions injected into other wires (mainly by common ground potential) and it is a source of substantial radiated electromagnetic disturbances too. The simulation model (Fig. 9) of the ignition system according to Fig. 5 was created [5]. The LTspice software was used for the computer simulations.

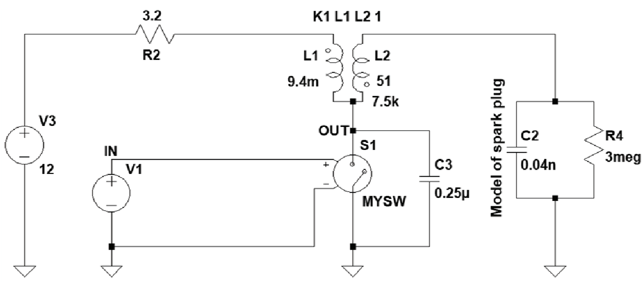

Fig. 9. Part view of simulation model of the ignition system

The resistor R2 limits the DC component of current of the primary circuit (12 V / 3.2 Ω). In the real case it is the internal resistance in the ignition coil. Model of the ignition coil has electrical parameters identical to real coil used in the stand. For example, the voltage waveform of the secondary winding of the coil is shown in the Fig. 10.

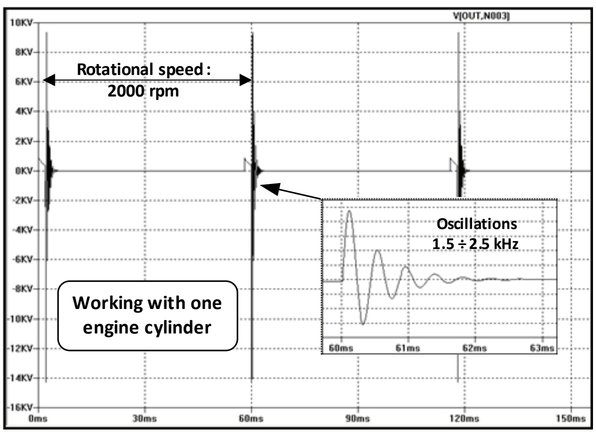

Fig. 10. Voltage waveform of the secondary winding of ignition coil – simulations

The waveform has oscillations with frequency about a few kHz. Similar oscillations resulting from resonances are observed in real measurements. These resonances are effect of equivalent capacity of the spark plug model (Fig. 9) and the real parasitic capacitances of the ignition coil.

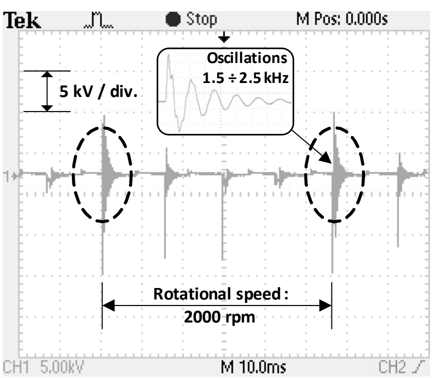

Fig. 11. Voltage waveform of the secondary winding of ignition coil - measurements

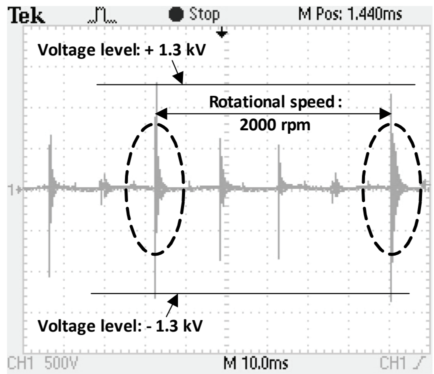

Fig. 12. Voltage waveform of the primary winding of ignition coil - measurements

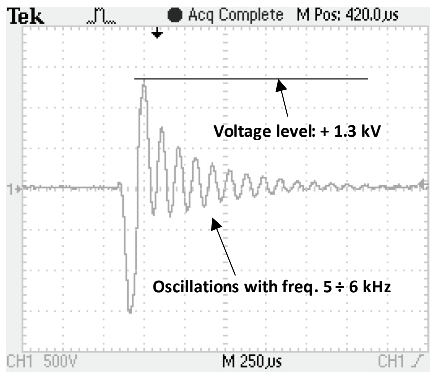

Fig. 13. The observed oscillations in the voltage waveform of the primary winding of ignition coil - measurements

The observed voltage waveform by oscilloscope of secondary winding of the coil is shown in the Fig. 11. The slopes of voltage waveform with a short rise times and high voltages and resonance oscillations are usually a source of radio interferences. The voltage waveforms of the primary winding of ignition coil are shown in the Fig. 12 and Fig. 13. In this case the oscillations have slightly higher frequencies.

The laboratory measurements were performed to determine the levels of radiated disturbances generated by the electromechanical ignition system (Fig. 14) [6].

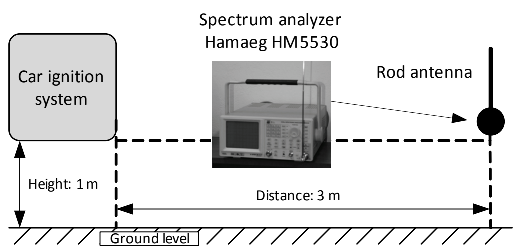

Fig. 14. Setup of the laboratory stand for measurements of radiated emission

Spectrum of electromagnetic background and a spectrum of radiated disorders are presented in the Fig. 15. The analysis was done in a typical frequency band from 30 MHz to 1 GHz.

For cognitive purposes the measurements of power supply parameters in selected circuits of laboratory stand were performed. Research has determined which electrical loads are the source of the greatest electromagnetic interferences.

Exemplary electrical motor of car windscreen was included to laboratory stand too. This component isn't standard equipment of constructed stand. View of the disturbances of on-board power supply caused by the working of electrical motor of windscreen are shown in the Fig. 16.

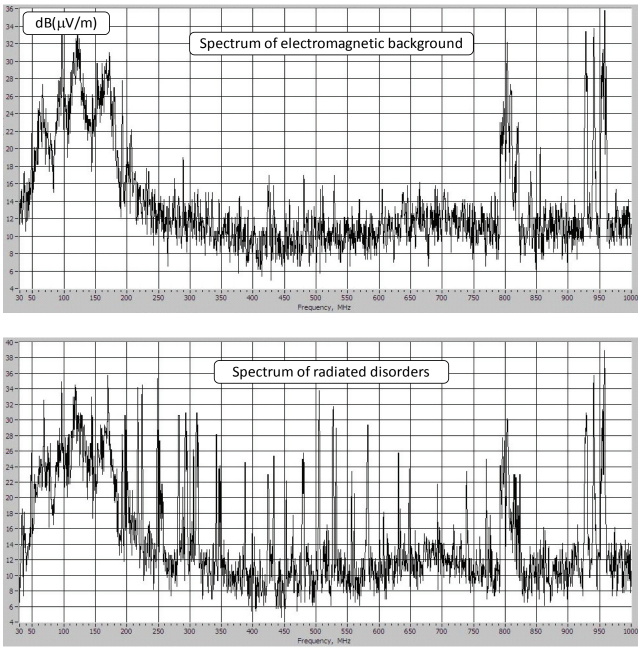

Fig. 15. The measurement results of the radiated disturbances generated by typical electromechanical ignition system

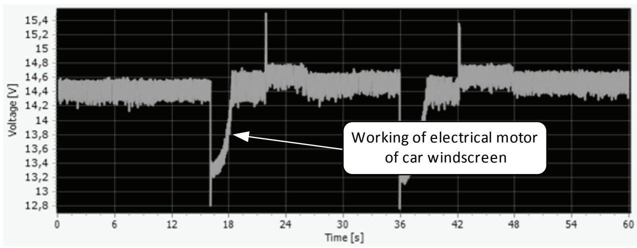

Fig. 16. Interference of power supply from the working of typical electrical motor of car windscreen

4. Conclusions

The designed and made laboratory stand can serve both research purposes and didactic process too. The knowledge of time and frequency parameters of disorders in the selected car electrical circuits allows to studies the ways of minimizing these disorders. The new laboratory stand is very flexible solution. It is possible to expand of the panel with additional on-board car devices. One can implementation a modern electronic modules with a large scale of integration. For example: CB radio, GPS navigation, airbag controller, etc.

The elaborated LTspice model of the ignition system very good reproduces the parameters of the work of the real device. This allows for further work on modeling and laboratory studies on the optimization of the ignition system angled EMC requirements. It was confirmed that the main elements of the ignition system which generate radiated interferences are the high voltage wires. The unscrewed spark plug (not shielded in the combustion chamber) does not increase the level of radio interferences. The frequency range of the highest disturbance levels is very wide from 100 MHz to 800 MHz.

As part of the research a trials of filtration of the disturbances generated from some car electrical receivers were conducted. Minimization of conducted disturbances in the vehicle on-board electrical installations is a difficult process. The common mode disturbances are biggest problem. This is a problem of common reference potential for different circuits. This is usually a metal body of vehicle. The efficiency of the car EMI filter is limited due to the lack of ground potential as is the case with stationary AC or DC power supply.

The lab stand also allows you to do some immunity tests of automotive devices against electromagnetic disturbances (eg. test against electrostatic discharge – ESD). Many vehicle manufacturers create its own models of conducted disturbances for the immunity testing [1]. The newly developed car electric device must obtain positive test result for each required of test (ISO standards and models defined by car manufacturers).

The presented laboratory stand is a good training ground for scientific research and cognitive tests in the field of didactics.

5. References

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Damian GONSCZ, Ph.D.EE.

He received a PhD in the discipline of electrical engineering in 2003. He currently works at the Faculty of Electrical Engineering of Silesian University of Technology. He is assistant professor in the Department of Measurement Science, Electronics and Control. Author is a member of Polish Society for Theoretical and Applied Electrical Engineering and Metrology Commission of Polish Academy of Sciences too. Author carries out scientific research in the area of electromagnetic compatibility.

e-mail: damian.gonscz@polsl.pl

Henryk URZĘDNICZOK, MSc, PhD, eng.

He graduated from the Silesian University of Technology, Faculty of Electrical Engineering, specialization of automation and electrical metrology. His research interests include sensors, conditioning circuits and measuring transducers, in particular cover issues of calibration and static as well as dynamic correction of non-selective sensors.

e-mail: henryk.urzedniczok@polsl.pl

Wiesław DOMAŃSKI, MSc, PhD, eng.

In 2005 at the Silesian University of Technology in Gliwice he obtained the title of doctor of technical sciences from the discipline of electrotechnic and was employed as an assistant professor in the above-mentioned Institute. Scientific interests relate to the measurement of non-electrical quantities, including measurements of gas concentrations by non-selective sensors and the implementation of a multi-dimensional inverse problem.

e-mail: wieslaw.domanski@polsl.pl