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Data Acquisition System for Automotive Testing According to the European Directive 2004/104/EC

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Abstract**—**This article presents an interactive system for data acquisition in vehicle testing according to the test process defined in automotive directive 2004/104/EC. The project has been designed and developed by authors for the Spanish company Applus-LGAI. The developed project will result in a new process, which will involve the creation of braking cycle test defined in the aforementioned automotive directive. It will also allow the analysis of new vehicle features that was not feasible, allowing an increasing interaction with the vehicle. Potential users of this system in the short term will be vehicle manufacturers and in a medium term the system can be extended to testing other automotive components and EMC tests.

Keywords**—**Automotive process, data acquisition system, electromagnetic compatibility (EMC) testing, European Directive 2004/104/EC.

I. Introduction

THE objective of automatic vehicle testing is mainly to have data acquisition systems that interact with the vehicle allowing unfettered assays according to the European automotive directive 2004/104/EC [1], [2]. Those systems must provide better customer service reducing the margin of error during testing processes. Specifically, the Spanish Applus-LGAI company [3] makes statutory vehicle inspection services, together with emission & gas testing solutions worldwide. Authors have designed and implemented a system that will increase productivity and keep vehicle EMC (electromagnetic compatibility) test processes of APPLUS-LGAI with a high competitive height against competition technological level.

The entry into force of the new automotive directive 2004/104/EC, which includes a number of elements to be monitored during the tests, including a braking cycle, must be done remotely. The main reason is for the very high electromagnetic fields that exist in the vehicle during the test. Therefore, it is mandatory the complete automation for this kind of automotive testing. On the other hand, the emerging demand for new test methods by vehicle manufacturers, due to the increasing incorporation of electronics in vehicles, is essential to the evolution of the available methods for measurement and data acquisition in such an application.

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Monitoring systems currently used are limited to the use of video cameras and a limited number of data acquisition systems. They cannot check all parameters involved in the vehicle test. In addition, these systems used for interaction with the vehicle are usually little “friendly” as they require the use of many instruments and connections, involving dedication of excessive trial preparation and test time. In addition, the current monitoring system does not allow verification of all the required parameters in the new European automotive policy. There are no performance systems for vehicle pedals, power windows, safe, buttons, etc. during these tests. This project has succeeded in developing systems that allow action on all these devices. The necessary tools to solve all these problems have been designed and developed by the authors. Thus, this article presents the project needed to automate the EMC testing of automotive, based on sensors and actuators systems. This project will allow getting real-time operation of the vehicle and, in turn, to get possible activation control signals. The prototype performed centralizes all the interaction systems with the vehicle and the same data collection through the developed system software test and R&S EMC32-A.

Currently, the amount of data that can be supplied to a customer who is not present at the trials is very limited and it can be increased considerably with the implementation of this project thanks to adding captured data by the acquisition system for data tables assay. Finally, this will allow the client to analyze the information after the test, without having to travel to the automotive facilities where vehicle testing is performed.

II. General Features of the Designed System

The implemented electronic system consists of a set of cards with specific purposes, with Europe double format background 2, and housed in a 19” rack. Although its basic architecture (Fig. 1) contains a microcontroller card, a solenoid valve-based card and a fiber optic input-based card, the system can be expanded with a card based on solenoid valves, and still another card based on fiber optic inputs. Thus, the main features of such cards are explained below:

a) **Microcontroller card:** This is the card that controls the I/O rack from CAN messages exchanged with the central computer that controls the whole application. The card incorporates the following functional blocks:

- **Power supply:** This is the electronic module located in the microcontroller card. It generates a stabilized voltage of +5*V*, –5*V*, and +24*V*. The DC power supply source generates a +24-volt signal using a voltage transformer from 115-230*V* to ±12*V* or, alternatively, using an external battery. This subsystem provides not only all the electronic regulation, but all the security level required for the aforementioned power supply voltages.

- **CPU Module:** This module is based on an ATMEL AT89C51CC03 microcontroller [4] including the following elements: Transceiver for communication via CAN bus, RS-232 and RS-485, and LCD display with 2 rows of 16 characters per line, 4-button keypad, 4 analog input channels, 2 analog output channels, 8 switches, 8 opto-isolated digital inputs, 8 opto-isolated digital outputs, 8 direct digital inputs, 8 direct digital outputs, 4 switch customization (for additional features), 8 LED diodes to indicate the function, real time clock, LEDs for signaling in the front panel, and an I2C bus.

b) **Solenoid valve-based output card:** This card is responsible of controlling pneumatic actuators via the corresponding single and double acting valves. The main elements included in such a card are the following:

- 8 single-acting solenoid valves with air inlet and outlet on the rack front panel.
- 4 double-acting valves with air inlet and outlet on the rack front panel.
- 16 LEDs for general indication of operation on the front panel of the rack.
- Selection jumper to configure the card as 1^{st} or 2^{nd} card.

c) **Relay-based and optical fiber-based input/output card:** This card is the interface for input and output of digital signals through emitters and detectors based on optical fiber. Optionally, it can manage direct digital input signals and switching relays. The main elements included are:

- 6 optical inputs for reflection based on optical fiber.
- 10 optical fiber-based inputs.
- 10 direct digital inputs (optional).
- 48 LED diodes for indication of switching in the front panel of the rack.
- 8 output relays with contact normally open.
- Selection jumper in order to configure the card as 1^{st} or 2^{nd} card.

III. Microcontroller Card

The microcontroller board is responsible of controlling the inputs/outputs signals of the system according to the control signals received via CAN bus. It consists of the following modules:

a) Power module.
b) CAN bus interface.
c) RS-232 and RS-485 communication interface.
d) CPU module.
e) Digital input/output (optoisolated and direct) module.

The power supply subsystem consists of a line transformer with a 115/230 V_{ac} in the primary and 12/0/12 V_{ac} in the secondary, a bridge rectifier, a voltage regulator ref. 7805 of +5 *V*, and a negative voltage generator ICL7660 in order to provide –5V (Fig. 2). The transformer is used to provide 24 V_{dc} (52 *VA*) from the main AC voltage of 115 or 230 V_{ac}. This device is optional and rarely mounted on the board, since the system is usually fed to +24 *V* via an external battery connected to CN1 terminals.

The CAN bus interface consists of the integrated circuit ATA6660 (Fig. 3) [5]. It sets the CAN connection between the rack and the central computer (by DB-9 connector CN3). Information is exchanged with CAN 2.0A standard frames using a baudrate of 500 *kbit/s*. If jumper *Jp*1 is short-circuited, a line terminating resistor (R_4=120 Ω) has to be added. Connector CN3 and its corresponding transmitting and receiving LED diodes (*D*3 and *D*4) are arranged on the front panel.

The interface RS-232/RS-485 (Fig. 4), built with the integrated circuit MAX232 (*U*2 and *U*3), provides dual functionality. On the one hand, with jumpers *Jp*2, *Jp*3, *Jp*16, and *Jp*17 closed ("*on*" state), this communication channel is enabled for programming the µC. On the other hand, once the microcontroller is programmed, if channel RS-232 communications has to be used in any application, simply *Jp*16 and *Jp*17 jumpers must remain open ("*off*" state).

CPU module is based on a microcontroller card which contains, as seen in Fig. 5, the µC ATMEL AT89C51CC03UA model. This µC is programmed via the RS-232 interface through the actuation on *P*1 (ISP) and *P*2 (Reset) buttons. Besides the microcontroller integrated circuit there is the integrated circuit DS1307 that is a battery-powered 3-*V* real-time clock [6], in order to set the system date and time.

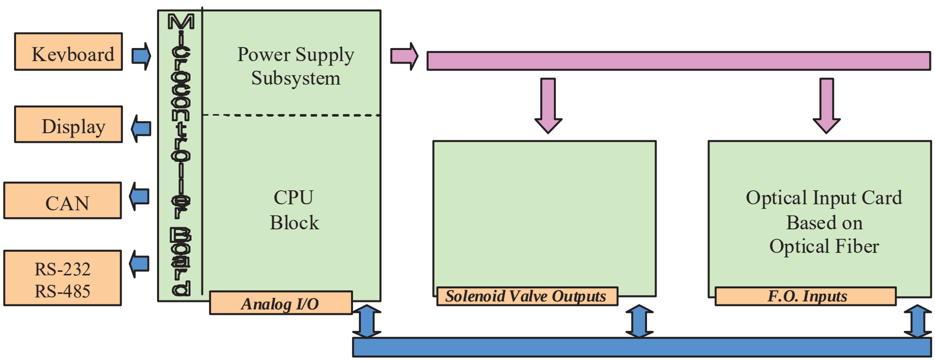

Fig. 1 Block diagram of the system

Fig. 2 Partial photograph that represents the power supply subsystem

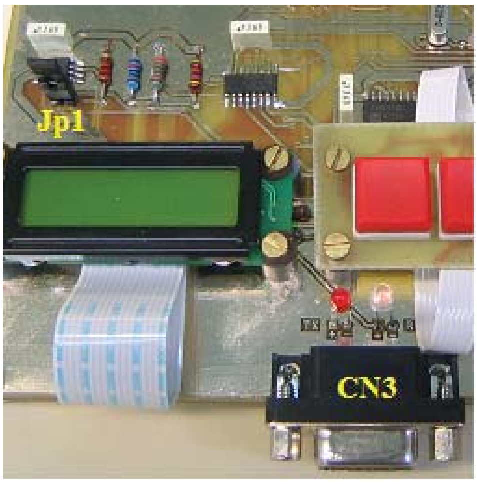

Fig. 3 Partial photograph that shows the CAN bus interface and LCD screen

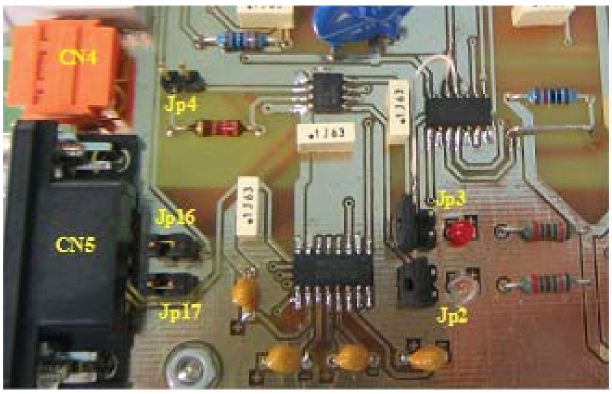

Fig. 4 Partial photograph that shows the interface RS-232/RS-485

The programming of the aforementioned µC ATMEL AT89C51CC03UA (Fig. 5) is performed using the communications channel RS-232 together with FLIP software from ATMEL company through connector CN5 (DB-9 connector) on the back of the microcontroller card. In order to prepare the µC for the programming operation, it is necessary to supply power to the card, and press simultaneously *P*1 (ISP) and *P*2 (Reset) keys, and, then, release first *P*2 and then *P*1.

Optionally, a RS-485 serial transmission channel is available in the card which has been implemented with the integrated circuit MAX485 and, using the connector CN4 (Fig. 4) located at the back of the microcontroller card, this channel can be enabled by setting the suitable connection in *Jp*2 and *Jp*3. However, when the RS-485 channel is used in any application RS-232 communication channel remains disabled.

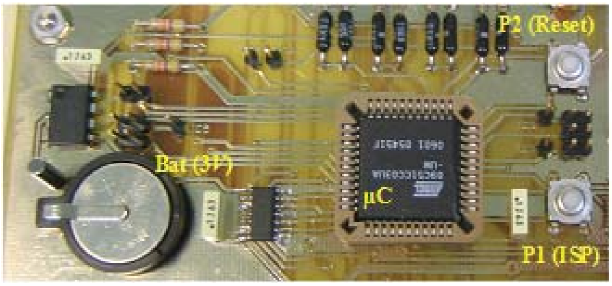

Fig. 5 Partial photograph showing the microcontroller subsystem

The communication line RS-485 also has an adapted line resistance (R_7=120 Ω) that can be connected, if necessary, thanks to a suitable jumper (*Jp*4).

On the card some peripheral blocks are included in order to increase the functionality of the system. Consequently, it contains a LCD display with 2 rows and 16 columns. Thanks to this display, the date and time of the system and the corresponding digital state of its various inputs/outputs can be displayed. To carry out this process, four buttons that constitute the keyboard are included. It is also included a set of 12 switches in order to interact manually on output devices, to access to additional functions, or to be used in future applications. In fact, for future applications, a set of eight LED diodes for displaying events is included.

The system includes an electronic block with 4-channel 10-bit analog input, and 2-channel 10-bit analog output. Each analog input channel supports voltage range of 100 *mV*, or 1 *V*, individually selectable through connections *a*-*b*-*c* of *Jp*5, *Jp*6, *Jp*7, and *Jp*8 (Fig. 6) (for instance, *a*-*c* *Jp*5 ⇒ 0-100 *mV* range; *b*-*c* *Jp*5 ⇒ 0-1 *V* range). All channels are protected with 14-V_{rms} varistor elements. In addition, all channels (in input and output sides) are single-ended (operation in single mode); that is, with input and output signals referenced to ground. For analog outputs, when connecting *c*-*a* of *Jp*12, an output voltage from 0 to 2 *V* and a maximum current of 1 *mA* is provided. These four analog inputs, two analog outputs, and ground connections are included in connector element CN6 (Fig. 6), located on the back the microcontroller card.

A. CAN Messages Exchanged by the SYSTEM

In normal operation, the computer reads the status of input devices and stores it in a set of positions of the internal memory. In another set of positions of this internal memory, the computer stores the status of the whole output devices. These internal memory positions, in 8-byte packets, are sent every 100 *ms* to the central control equipment by six messages of 8 bytes each (48 bytes that include the state of inputs and outputs).

The initiative to change any state of any of the output devices is carried out by the central control equipment by sending a single message with the device address (2 bytes), and its corresponding status (1 byte). The microcontroller card periodically reads the states of output devices from its internal memory and updates the status of the respective devices.

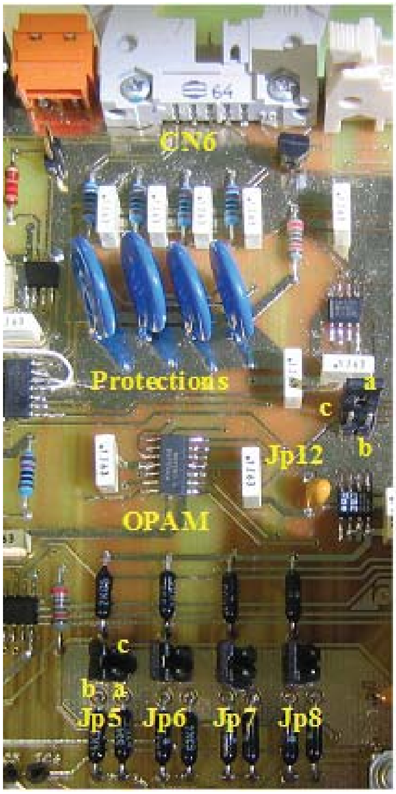

Fig. 6 Partial photograph that shows the analog I/O subblock

IV. Output Card of the Solenoid Valves

This card includes 8 single-acting pneumatic solenoid valves grouped in pairs (4×2 single effect), and 4 double acting pneumatic solenoid valves (4×1 double effect). It is controlled by the microcontroller card thanks to the power supply line present in connector CN9, and the data bus in connector CN11 (Fig. 7).

V. Input Board for Optical Fiber and Relays

This card includes six optical amplifiers & sensors based on reflection through optical fiber (model E3X-NA11 2M [7]), ten optical sensors for optical fiber (model 2523Z HFBR [8]), eight 24-*V* relays with their corresponding voltage-free normally-open contacts present in connector CN14, and eight +5-*V* digital inputs (TTL levels) in connector CN16. It is controlled by the microcontroller card through the voltage line presented in connector CN9, and data bus in connector CN11. Each switching contact of the relays supports a maximum current of 1 *A*.

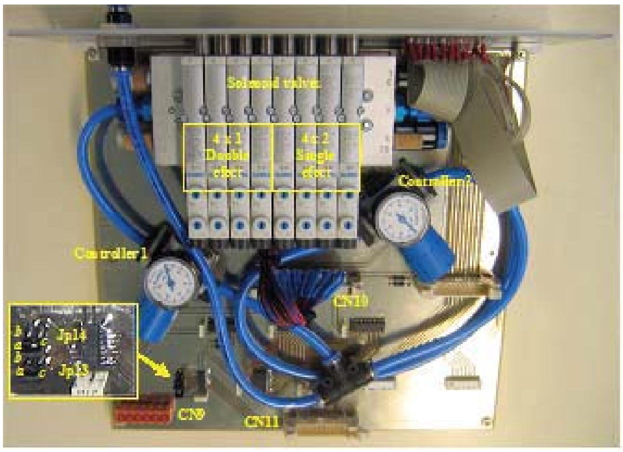

Fig. 7 Photograph representing the output card of the solenoid valves

Fig. 8 Photograph of the implement system carried out by the paper authors' research group together with the Spanish company Applus-LGAI

VI. Conclusions

The paper presents the design and implementation of an open modular system (Fig. 8) that has been developed by our research group. Thus, it can be adapted to other test systems implemented by the company APPLUS when interaction is required for the equipment under test (EUT). This system is applicable to testing vehicles, automotive components, etc. The final implementation will lead to increased productivity by reducing the dedication of the engineers to the visual monitoring of the test processes.

In particular, this project will result in a new process, which involves the creation of braking cycle test defined in automotive directive 2004/104/EC, a new feature that has not been analyzed in an automatic way so far. Authors consider that automotive manufacturers will benefit from this new system in order to speed up the components tests and other electromagnetic compatibility verifications.

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