TECHNICAL NOTE

PSYCHOPHYSIOLOGICAL AND ENVIRONMENTAL PARAMETERS RECORDER FOR A TRUCK SIMULATOR

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Abstract: This paper describes the recorder integrated with a truck simulator which is a set of measuring devices used for measuring and recording environmental parameters in the simulator's cabin and psychophysiological parameters of a driver, centrally managed by the simulator's information system. The instrument assembly includes a compact meter for physiological and environmental parameters, a flashing light generator, and a system for measuring hand pressure force against the steering wheel. This paper describes the structure and functions of the various elements of the simulator's measurement equipment.

Keywords: physiological parameters recorder, psychophysiology, light flicker, Flicker Fusion Threshold, driver testing, truck driving simulator

INTRODUCTION

Most simulators that can be encountered in the modern world are used for learning how to use a device, improving skills already acquired, or, simply, for fun. However, among the simulators we can also distinguish those that are used as tools supporting various types of scientific, design and ordinary technical research. This group includes wind tunnels, climate chambers, pressure chambers, overload centrifuges, among others. Some simulators combine the functions listed above to enable training or research, as well as research during training. A

special group consists of simulators created in accordance with the recommendations of Directive 2003/59/EC of the European Parliament and of the Council from July 15, 2003 on the initial qualification and periodic training of drivers of certain road vehicles for the carriage of goods or passengers [4]. The truck driving simulator located at the Military Institute of Aviation Medicine (fig. 1) may be included in this group. This simulator was developed as a result of a project funded by the European Regional Development Fund. The project was carried out, among others, in cooperation with ETC-PZL Aerospace Industries Sp. z o.o. [15], which is a manufacturer of simulators, and which has equipped the truck driving simulator with devices that allow measurement and recording of simulator environmental parameters and driver psychophysiological parameters.



Fig. 1. View of the truck driving simulator.

As a result of the modernization carried out within the aforementioned project, the simulator has become a very valuable research and training tool [1]. Its functionality allows to evaluate the method of driving, not only in terms of technical parameters, but also the predispositions and reactions of the human body to the complex and dynamic structure of the road situation. Conducting a comprehensive analysis of measurement results will enable improvement of driver selection and training methods, which has a direct impact on the level of road safety.

OBJECTIVE

The aim of the paper is to present the possibility of measuring selected psychophysiological parameters of the driver in a truck driving simulator.

RECORDER

The truck driving simulator was made using the cab of a Mercedes-Benz Actros car [5], mounted on a moving platform having six degrees of freedom, which is positioned in front of a panoramic screen. Above the simulator cabin, projectors are placed to visualize the traffic situation. Behind the simulator cabin (in a separate room) there is an instructor's station and a set of computers of the simulator's information system. The presented recorder of physiological and environmental parameters of the truck simulator driver consists of: a compact meter, a Flicker Fusion module, a force measurement system, all managed by a dedicated software system.

Compact meter

The compact meter, designed for use with the simulator, is a device with small overall dimensions and low weight. Illustration fig. 2 shows the compact meter.



Fig. 2. Compact meter.

The compact meter was developed based on the extensive experience of MIAM (Military Institute of Aviation Medicine) staff in the design and use of such devices, and a wide range of knowledge concerning the analysis of measurement data from personal recorders of environmental conditions and physiological signals [9].

On the control panel of the compact meter (fig.2) there is a set of four buttons (START, POWER, SHIFT, STOP) which are used to control the operation of the device. Below the buttons is a multi-colored LED that indicates the operating status of the meter.

Figure 3 shows a view of the back panel of the meter. On the back panel there is a clip that allows the device to be attached to the driver's clothing (e.g. trouser belt) and a cover of a battery compartment that powers the compact meter.



Fig. 3. Back panel of the compact meter.

Figure 4 shows the top panel of the compact meter. There are four described sockets of multi-pin connectors used to connect the plugs of measuring electrode cables. The layout and pin count of the connectors precludes erroneous connection. In addition, each of the sockets and respectively the plugs of the electrode cables are marked with a different color.



Fig. 4. Top panel of the compact meter.

The compact meter has the following measurement paths: RESP (respiratory curve), ECG (electrocardiography), EMG (electromyography), GSR (galvanic skin response), ambient temperature, and acceleration in three axes (X, Y, Z). ECG, EMG, GSR measurement is carried out using standard surface electrodes attached to the skin of the test subject. RESP is measured using a thermistor, attached near the subject's nasal opening. Signals from the measuring paths are transmitted wirelessly from the meter to the computer system using the Bluetooth standard. The collected measurement data, when analyzed, can be used to estimate the driver's psychophysiological activity. Figure 5 shows a schematic diagram of the structure of the compact meter.

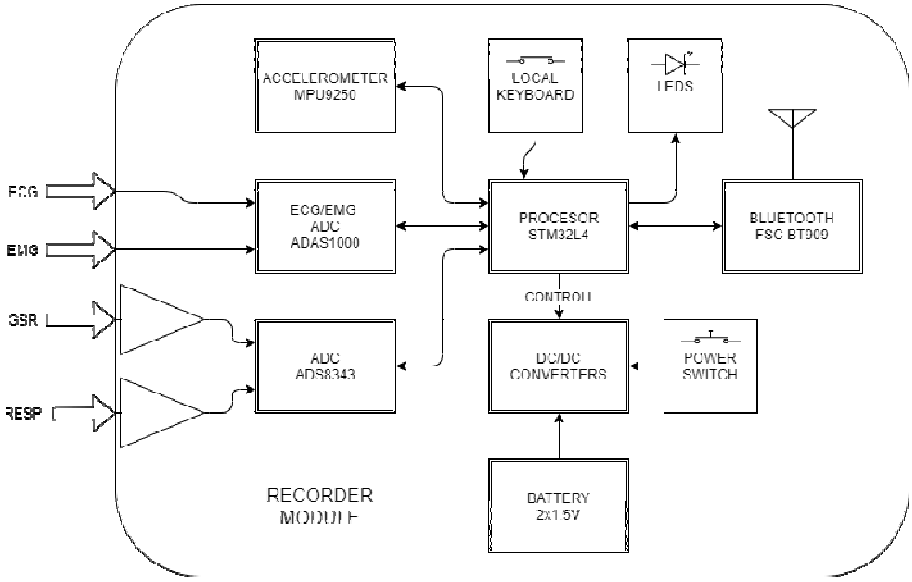


Fig. 5. Schematic diagram of the structure of the compact meter.

In the meter module, a specialized front-end electronic circuit ADAS1000 (ANALOGDEVICES) is used to acquire and process ECG and EMG signals [11]. Among other things, the circuit converts ECG and EMG signals from analog to digital form and then sends them to the STM32L4 circuit (STMicroelectronics) [7]. The STM32L4 circuit is an ultra-fast microcontroller featuring a Cortex-M4 core which design is optimized to reduce power consumption during operation. The microcontroller is responsible for data acquisition from measuring transducers, it is used to manage power supply of the device, wireless communication, operation of signaling diodes and function buttons. An ADS8343 analog-to-digital converter (TEXAS INSTRUMENTS) [8] is used to acquire and process the GSR and RESP signals. The signals after conversion to digital form are sent to the STM32L4 circuit. The MPU9250 circuit (InvenSense – TDK Corporation) is responsible for acceleration acquisition [12]. The MPU9250 circuit is a combination of a three-axis gyroscope and

accelerometer. The FSC BT909 module (Feasycom) is used for wireless communication [6]. This module can operate in BLE (Bluetooth Low Energy) mode. The BLE mode of operation saves about 50% of the energy used for wireless communication compared to the classic Bluetooth standard technology.

Flicker Fusion Module

The Flicker Fusion module is a light source with variable parameters such as color, intensity, on/off frequency, which is emitted according to programmed algorithms. It consists of three parts: head, control module and control software. Figure 6 shows the head of the Flicker Fusion module. The Flicker Fusion module is used to test the threshold frequency of flicker perception and/or the perception of light merging. Its initial value is an individual characteristic [10], which moreover changes with the degree of fatigue in the human body [2]. The Flicker Fusion module in the driving simulator enables the testing and evaluation of simulator driver fatigue.

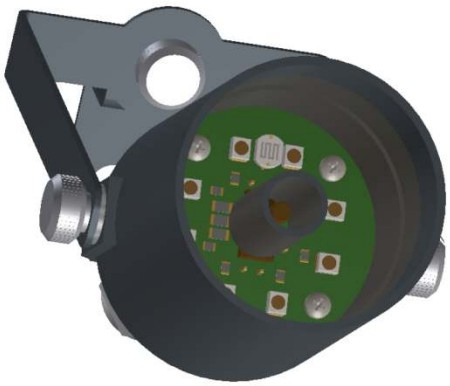


Fig. 6. Flicker Fusion module head.

The Flicker Fusion module head is mounted to the ceiling of the simulator cabin above the driver's head. The mounting system allows proper adjustment of the head position so that the driver can comfortably observe the traffic situation and the light source of the Flicker Fusion module is within the driver's peripheral vision. Figure 7 shows the schematic diagram of the Flicker Fusion module.

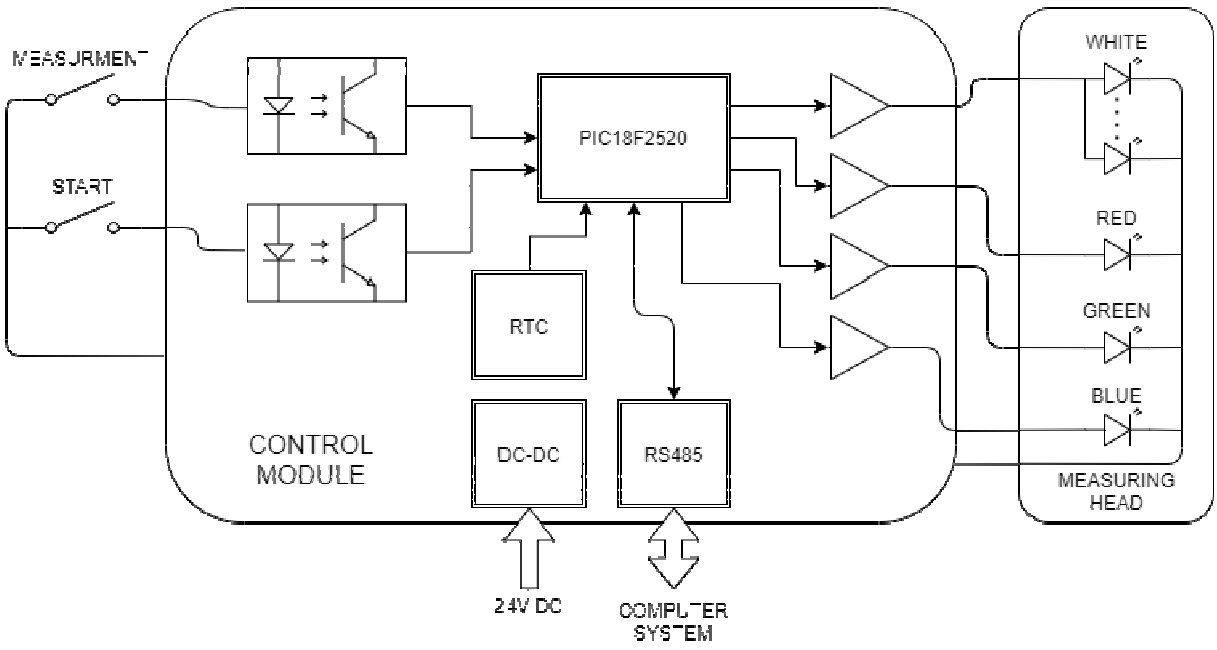
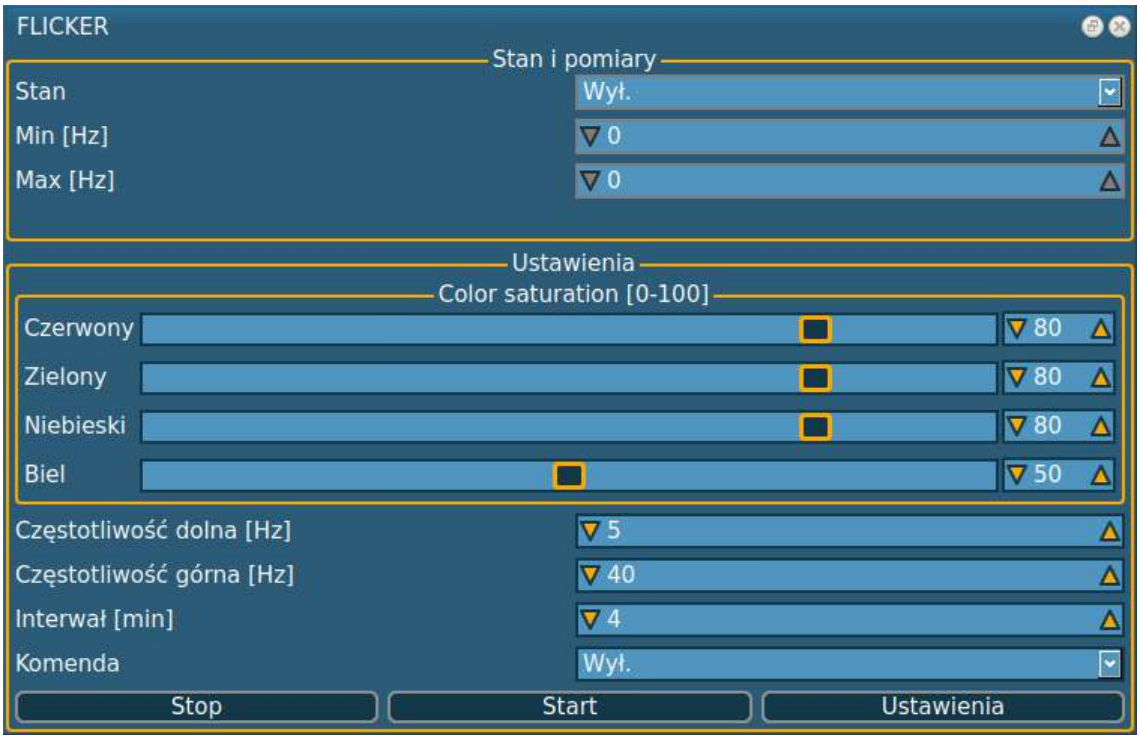


Fig. 7. Schematic diagram of the Flicker Fusion module.

The main electronic circuit of the Flicker Fusion control module is the PIC18F2520 microcontroller (Microchip Technology) [13]. It is responsible for controlling a set of white, red, green, and blue diodes located in the measuring head. The control module is connected to the computer system using an RS485 interface. Figure 8 shows a window with the computer system software configuration interface for setting the operating parameters of the module and the Flicker Fusion head.



Stan i pomiary - Status and measurements; Status; Wył. – Off ; Ustawienia – Settings; Czerwony – Red; Zielony – Green; Niebieski – Blue; Biel – White; Częstotliwość dolna – Low frequency; Częstotliwość górna – High frequency; Interwał – Interval; Komenda - Command

Fig. 8. Information system – configuring the Flicker Fusion module settings.

The software allows to select the color of the light emitted by the head (red, green, blue, white), the frequency of merging or the degree of light flicker. The simulator cabin is also equipped with two control buttons that allow the driver to tune the threshold frequency of flicker perception and the threshold frequency of light merging perception during testing.

Force measuring system

Improper placement of hands on the steering wheel can result in loss of control of the car and dangerous traffic situations. A strain gauge sensor array was used to detect the hand placement and to measure the hand force applied to the steering wheel rim of the driving simulator [3].

The sensors are mounted on the rim of the steering wheel in such a way that they cannot be sensed by touch and are invisible to the driver.

Figure 9 shows a window view of the computer system ("STEERING WHEEL FORCES"), where the graph in the window depicts the rim of a steering wheel divided into measurement segments. The numerical values in the measurement segments represent the

value of the measured hand force applied to the steering wheel rim expressed in Newtons. The black point on the circumference of the pictured steering wheel is a reference point for the position of the steering wheel set to straight ahead.

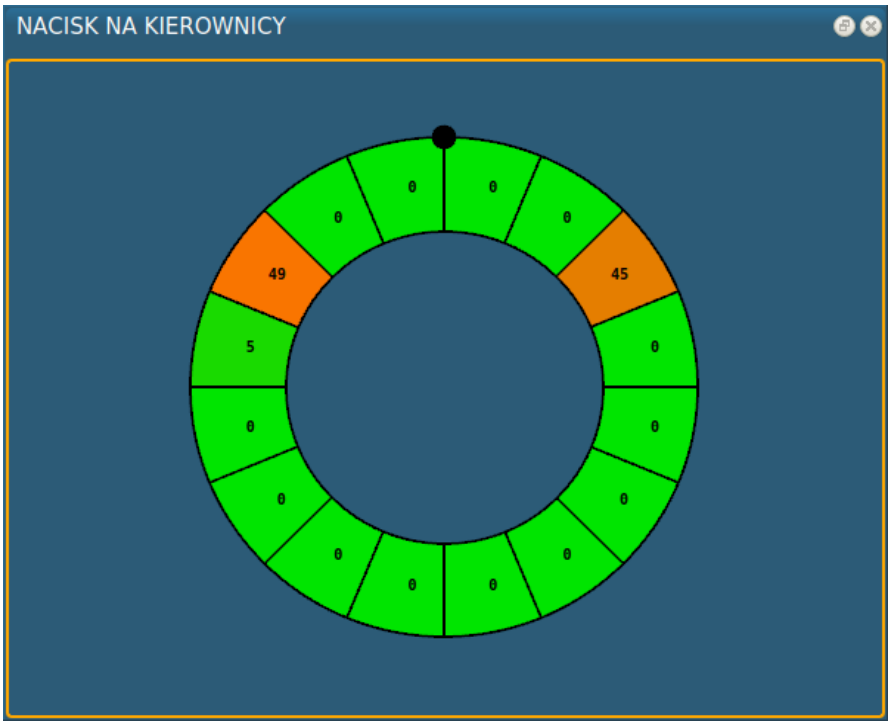


Fig. 9. Information system – visualization of pressure on the steering wheel rim

Figure 10 shows a schematic diagram of the structure of the force measurement system.

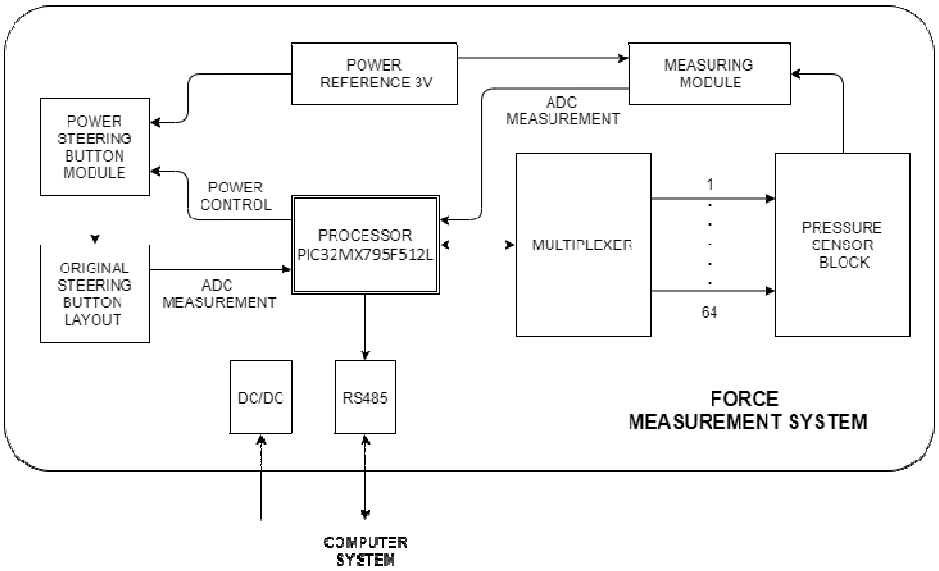


Fig.10. Schematic diagram of the force measurement system.

The main component that controls the force measurement system is the PIC32MX795F512L microcontroller (Microchip Technology) [14]. Force measurement by sensors is done sequentially. A measurement is taken from a single sensor at a time, after which the multiplexer switches power lines, resulting in a measurement from the next sensor. Once the measurements from all sensors have been collected, the measurement sequence is repeated. The measurement line of all sensors is combined, so that measurement is possible with the help of one analog-to-digital converter (ADC) input. The force measurement system is connected to the information system via an RS485 interface.

Information system

The simulator information system is a set of PCs that form a local intranet network. All computers in this network work under control of a GNU/LINUX operating system (the UBUNTU LTS distribution). The set of computers is managed by an “Instructor's Computer” equipped with dedicated software utilities to oversee the driving simulation control process, providing connectivity to the compact meter, the Flicker Fusion system and the force measurement system.

The computer system allows presentation of selected technical and physiological parameters online. Each time, the system records in a database all measurement data and control signals generated during simulator operation, environmental parameter signals and physiological parameter signals. The recorded data can be jointly presented and analyzed offline. An example of this type of analysis is the calculation of heart rate variability (HRV). All signals and parameters, recorded and calculated by the information system monitoring psychophysiological and environmental parameters, are synchronized with the driving parameters of the simulator.

Figure 11 shows a view (a screen shot) of the information system software, showing visualization of online transmission of signals from the measurement paths of the compact meter. It is possible to see RESP, ECG, GSR, and EMG curves change in real time in the software windows.

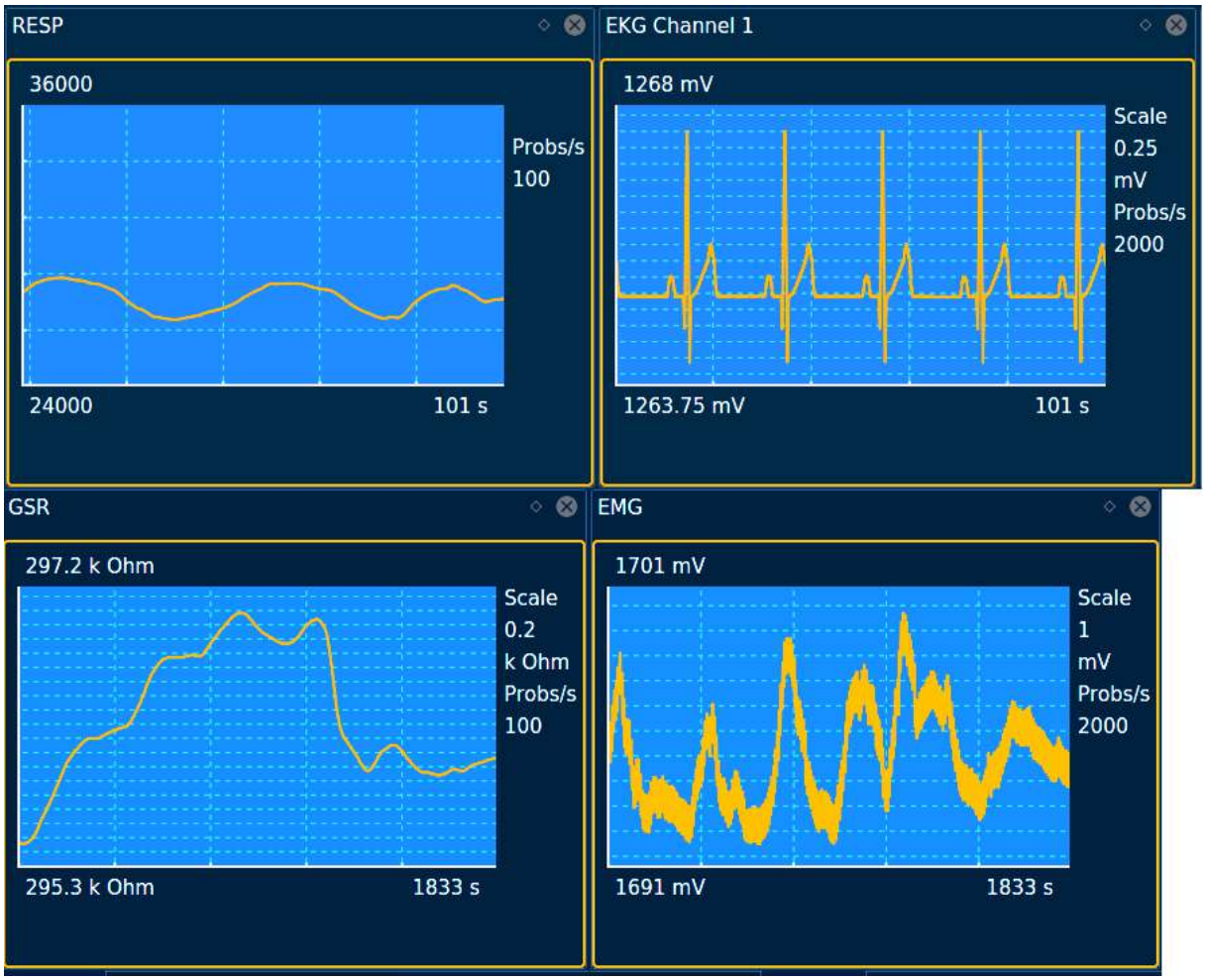
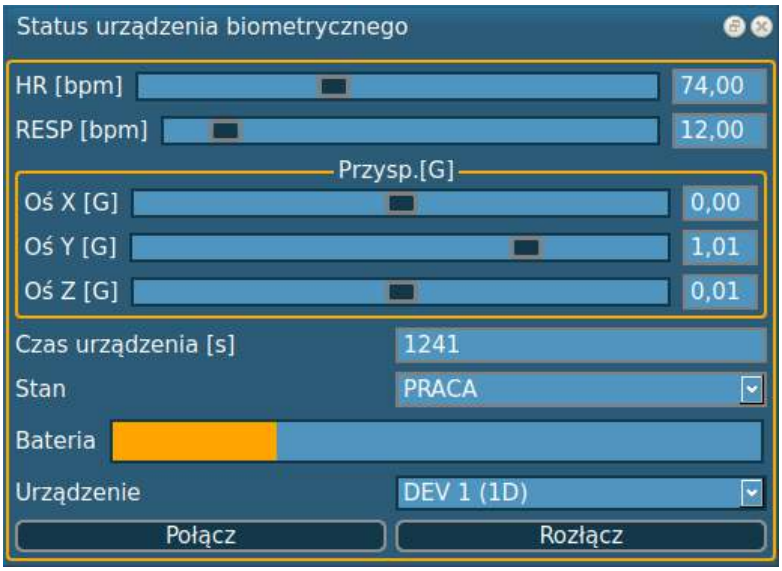


Fig. 11. Information system – window view of online transmission of the following signals: RESP, ECG channel 1, GSR, EMG.

Figure 12 shows a view of the window used to check the status of the compact meter and present the instantaneous measurement values. It presents the following instantaneous numerical values: HR [beats/minute], RESP [breaths/minute], accelerations in the three X, Y, Z axes [m/s^2]. The time measured from the moment of starting up the meter [seconds], its status (On / Off), the level of internal power supply and the number of the device which is connected to the system are presented for the purposes of technical diagnostics.



Status urządzenia biometrycznego - Biometric Device Status ; Przysp. – Acceleration; Oś – Axis, Czas urządzenia – Time of device; Stan – State; PRACA – Work; Bateria. – Battery; Urządzenie – Device; Połącz – Connect; Rozłącz - Disconnect

Fig. 12. Information System – view of the "Biometric Device Status" recorder window

Technical data of the measuring equipment of the simulator

Compact meter:

ECG measurement path:

Resolution: 24 bits;

Sample rate: 500 Hz, 1000 Hz, 2000 Hz;

EMG measurement path:

Resolution: 24 bits;

Sample rate: 500 Hz, 1000 Hz, 2000 Hz;

GSR measurement path:

Measurement range: 10 kohm – 3.5 Mohm;

Resolution: 16 bits;

Sample rate: 100 Hz;

RESP measurement path:

Resolution: 16 bits;

Sampling frequency: 100 Hz;

Measurement path for acceleration in three axes (X, Y, Z):

Measurement range: ±2G, ±4G, ±8G, ±16G;

Resolution: 16 bits;

Sample rate: 100 Hz;

Other:

Overall dimensions: 39mm x 80mm x 117mm;

Power supply: 2x AA(LR6) 1.5V batteries;

Communication with the information system: wireless – Bluetooth class 1;

Communication protocol: PP_port;

Flicker Fusion module:

Supply voltage: 24V DC;

Flicker frequency range: 10-127 Hz;

Light (flashes) color in RGB format: 0-100% (0-255) for each color;

Backlight brightness for the background: 0-100% (0-255);

Communication: RS485 half duplex isolated;

Communication protocol: PP_port;

Galvanic isolation of buttons: 500 V;

Control unit mounting method: T35 (DIN) mounting rail;

Force measuring system:

Measurement range: 0-1000 N;

Sample rate: 100 Hz.

AUTHORS' DECLARATION

Study Design: Marcin Piotrowski, Mirosław Dereń. **Data Collection:** Marcin Piotrowski, Mirosław Dereń. **Manuscript Preparation:** Marcin Piotrowski, Mirosław Dereń. The Authors declare that there is no conflict of interest.

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