System of Biomedical Signal Measurement for Psychological Profiling of Soldiers

Krzysztof Różanowski, Jarosław Lewandowski, Jakub Kleczkowski, and Tadeusz Sondej

***Abstract*—We present a project of a system of biological signal measurement for psychological profiling of soldiers. The system consists of specialized modules divided into measurement, communications, and powering blocks. The individual devices of the system communicate with one another thorough a dedicated protocol based on the CAN bus interface. The measurement system was designed as a portable, battery-powered device that could be attached to clothing. Apart from hardware, the system comprises a number of desktop and server applications. For data processing and storage, a number of dedicated applications were designed ranging from server applications to mobile user applications. In the article, we review mechanisms that employ genetic algorithms for a determination of the set of traits of an optimal psychological profile. Moreover, we describe ways of remote transmission of information to data bases with the use of the GPRS system. The presented system is designed as a specialized SOC integrated circuit.**

***Index Terms*—ASIC, biomedical electronics, health-chip, psychological profile.**

I. INTRODUCTION

THE presented measurement system is designed to gather biomedical data in order to determine the effectiveness as well as the level of fatigue in soldiers. The psychological profile is determined based on the data acquired during exercise performed under controlled conditions. Such psychological profiles will enable a proper qualification for particular operational activities. The direct advantages of such a system include an optimization of human resources management in the combat field as well as an adequate task assignment in accordance with psycho-physiological dispositions of soldiers.

The system is powered by portable batteries in order to enable its use during strenuous exercise testing, e.g. running, which is similar in intensity to military combat. The system is designed to be attached to clothing in order to minimize the influence of other measurement devices. The majority of measurement modules were placed in a backpack, and only the elements that required direct physical contact with the body were attached to the skin of the participants. Example measurement systems used for the recording of biomedical signals are presented in [1][7][8][17][16]. However, these authors did not envisage the potential use of such systems for the determination of psychological profiles. The system presented in this article was created based on a pilot study and the assumptions described in [9]. The research was funded by the National Science Center, as part of the “System of psychological profile management in soldiers with the use of the HEALTH-CHIPS technology” project, grant no. DOBR/0053/E/ID1/2013/03.

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II. PSYCHOLOGICAL PROFILE

According to reviews on the subject [2], psychological profiles of soldiers can be determined by numerous variables, which impact its value. The value of a psychological profile depends, inter alia, on the briskness and accuracy of reactions that are, in turn, secondary to spatial memory capacity [13], [14]. Parameters that define a psychological profile such as intellectual resources or psycho-motor effectiveness can be defined under laboratory conditions. However, psychological and/or physical burden can influence the determination of profile parameters. Thus, it is essential to monitor the influence of stress and fatigue on psychological parameters during the determination of a psychological profile.

Profile parameters are determined based on input variables acquired during periods of rest and exercise [9]. Psychological profiles are modeled with reference to three data groups. The first group of data determines the character type with the use of an appropriate questionnaire completed by participants. The second group of data includes information necessary for the determination of motor capabilities such as time of reaction or cognitive function as measured by a short memory test. The tests are performed 10 minutes prior to and after exercise with the use of a dedicated mobile application run on a tablet. The third group of data are physiological parameters registered by the measurement system during exercise. It is assumed that the measurement system registers the level of physical activity. Although the measurement system consists of a number of dedicated measuring devices, in this article we present only two of them – blood pressure measurement module (BPMM) and an auxiliary research module (RM).

III. BLOOD PRESSURE MEASUREMENT MODEL

Blood pressure and the electrical activity of the heart are physiological parameters that well characterize the physiological activity of a man. Therefore, the BPMM was designed for their measurement. Data obtained by the module are a component used to determine the psychological profile. BPMM is used during exercise performed under controlled conditions, for example running on treadmill. The module can be optionally used on combat field. According to the general assumption of the system, of which the BPMM is part, the measurement is non-invasive. The module communicates with the remaining parts of the system via a communications protocol based on a CAN bus interface. We assumed that the local CAN net will contain a power supply. This enabled placing the BPMM in a backpack. Fig. 1 presents a complete BPMM consisting of the device, a tourniquet, and a measuring cable.

Fig. 1. Blood pressure measurement module.

We let the measurement be carried out by a commercial executive module, which allowed for an improved precision without the need to calibrate the device. Moreover, commercially available devices come with necessary documents required for device certification. The BPMM includes the Advantage A+ module, manufactured by SunTech, that communicates with the system via a communications protocol based on the RS-232 interface. The executive module is installed on the PCB board of the BPMM, which allows for the performance of other functions of the system. The BPMM is presented on a block diagram in Fig. 2.

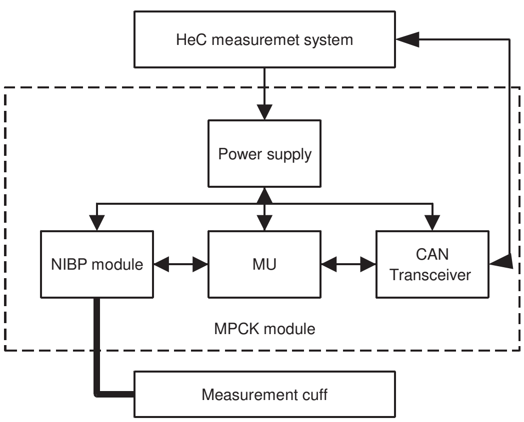

Fig. 2. Block diagram of the BPMM.

The steering module was implemented based on a 32-bit micro-controller with an ARM core (STM32F103RDT6, STMicroelectronics). Its peripheries enable the performance of the assumed functions of the BPMM. The main task of the steering module is to control the executive module that measures blood pressure. Moreover, the steering module can turn off power supply of the executive module, which restricts energy consumption by the BPMM. The micro-controller allows for an implementation of communications protocol in compliance with the CAN bus interface. In order to comply with the CAN 2.0 standard, we used the MCP2551 system (Microchip). As envisaged, the BPMM has a mass memory card (micro SD). The PCB board of the BPMM is also the basis for installation of the executive module, which made it simpler to put the whole device in a case.

We wanted to test the accuracy with which the BPMM measures blood pressure. To this end, we used a Rigel Uni-Sim biomedical signal simulator and performed the measurement with the use of BPMM, following an appropriate connection of the two devices. Fig. 3 presents the measurement post on a block diagram.

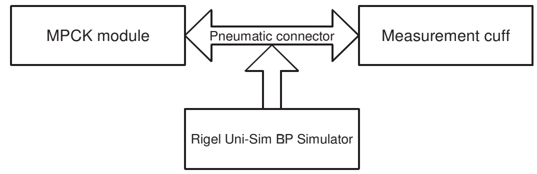

Fig. 3. Block diagram of the measurement post.

Studies were performed for six standard blood pressure values. The range of measurements was set so as to include the values that will be registered under normal working conditions of the device. The acceptable measurement error was determined based on the measurement error of the executive module [12] and the model device [4]. The acceptable measurement error levels were set as follows: blood pressure ±8mmHg; heart rate ±2% or ±3 BPM (the greater of the two). Measurement error analyses are presented in Fig. 4.

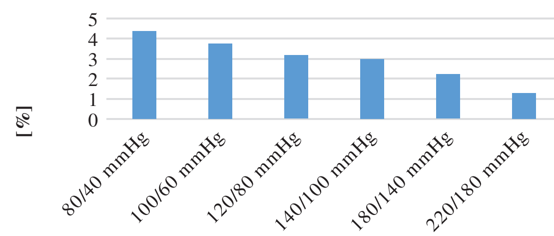

Fig. 4. The relative measurement error.

The system performs all of the functions expected from the BPMM. Owing to the employment of a commercially available measurement module, the system is portable and can be placed in a backpack. This reduces the discomfort during its use.

IV. RM Module

Another module of the measurement system is the research module (RM) that measures the following biomedical signals – the electrical muscle activity (EMG), oxygen saturation of blood (SpO2), respiratory rate, skin conductance, and skin temperature. Moreover, the module registers weather conditions, i.e., atmospheric pressure, air temperature, and air humidity. The registered data are stored on a memory card and made available to other parts of the measurement system via dedicated communications protocols based on UART and CAN interfaces. Moreover, the data can be sent to a computer via a USB port, which allows the RM to be used as a stand-alone measurement device. Fig. 5 presents a block diagram of the device.

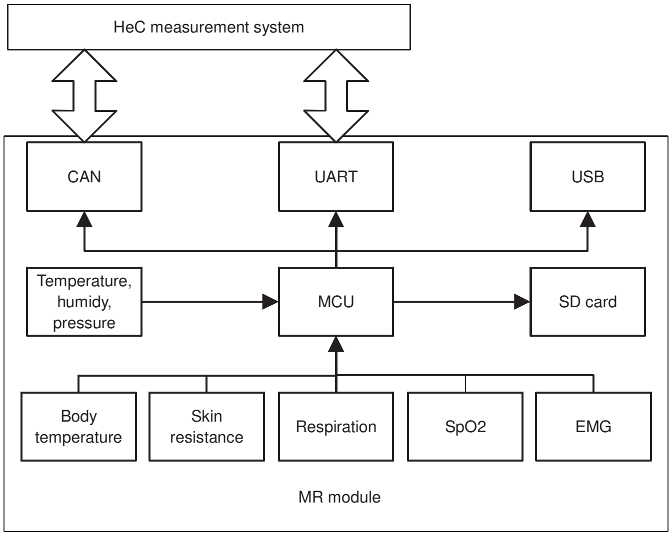

Fig. 5. Block diagram of the RM module.

The RM module was created based on a 32-bit micro-controller with an ARM core (STM32F405VGT6, STMicroelectronics). Owing to a built-in PHY USB controller, it was possible to implement communication via this interface without any additional peripheral systems. Moreover, the micro-controller enables the implementation of a dedicated communications protocol based on CAN interface. We used the SN65HVD230QD system in order to comply with CAN 2.0 standard. The environmental measurements were made with the use of commercially available transducers - BMP180 (Bosch), SHT21 (Sensirion), and DS18B20+ (Maxim). The BMP180 traducer registers atmospheric pressure and air temperature, the SHT21 transducer measures humidity, and the DS18B20 transducer is an additional air temperature sensor. The BMP180 and SHT21 transducers are run on a single I2C controller, which reduced the number of outputs from the micro-controller. The respiratory rate is measured by a respiration belt, whose resistance changes with its tension. The measurement is made by a bridge system based on an AD8226 instrumental amplifier (Analog Devices). A similar system measures skin temperature (by a thermistor) and skin conductance. Due to a low frequency of signal changes, the ADC transducer, built into the micro-controller, was used for the measurement of the above-mentioned parameters. The specifications of the ADC transducers are much higher than those required by the sampling frequency of the above-mentioned signals. Blood oxygen saturation (SpO2) was measured by the PEARL 200 module (Medlab), which is much more accurate than the integrated-circuits designed for this purpose. Muscle electrical activity was measured by the ASD1294 device (Texas Instruments), which is a four-channel ADC transducer dedicated for biomedical applications. It has a high resolution of 24-bits, which together with a programmable amplifier built into each input channel allows for a measurement resolution of 0.1 μV. The maximal sampling frequency of 250 Hz is high enough for the system's applications. As envisaged, the RM module has a mass memory (microSD card). The RM module enables access to data stored on the memory card, via an USB interface. Because the device can work with power supplying interfaces, it was necessary to enable a wide range of power voltage, for which an AC/DC transducer was used. The dimensions of the printed board circuit, produced in a four-layer technology, are 60 x 80 mm (presented in Fig. 6).

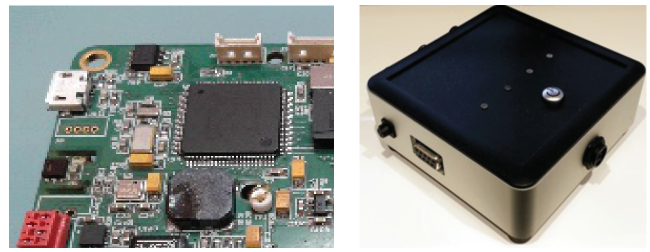

Fig. 6. RM system. Printed board circuit (left) and the system in an aluminum/ABS case (right), 100x100x40 mm in size.

We designed a series of tests in order to determine the accuracy of measurements made by the RM module. The channels used for the measurement of skin conductance, skin temperature and respiration were compared with the recording of a thermistor with a known resistance. Moreover, the results were compared with those made with the Rigol DM3064 multimeter. The EMG recordings were tested with the Rigol DG1032 generator, whereas SpO2 measurements were compared with those obtained with a PC-900 patient monitor (Creative Industry Co.). Lastly, the measurements of the atmospheric pressure and air humidity were compared with those made with the GDH 12 AN,0 barometer (Greisinger). Error of the EMG measurement was determined based on the specifications of the ADC transducer [15] and the Rigol DG1032 generator [5], which was estimated as ± 0.5 μV. The acceptable measurement error of SpO2 was set at ±1%, according to the manufacturer's data [3]. For the measurement of skin conductance, skin temperature, and respiratory rate, the ADC transducer, built into the micro-controller, was used – the acceptable measurement error was determined in compliance with the transducer's specifications, taking into account the measurement error of the Rigol DM 3064 multimeter [11]. The measurement error with respect to air temperature, air humidity, and air pressure was determined based on manufacturers' instructions [1, 10]. Measurement error analyses are presented in Table I.

TABLE I
RELATIVE MEASUREMENT ERROR

Parameter	Relative error [%]
Emg	7.2
SpO2	1.1
Skin resistance	5.5
Body temperature	0.9
Respiration rate	11
Outdor temperature	1
Air pressure	5.4
Humidy	2

V. Summary

The presented measurement system enables recording of numerous biomedical signals both at rest and during exercise. The wide range of the measured parameters allows for an accurate, albeit indirect, estimation of autonomic nervous system activity in terms of the key signals and physiological variables. Taking into account the psychological metric described herein, it allows for an estimation of soldiers' fatigue and thereby their ability to perform operational activities under varying conditions. Owing to the fact that the system is battery-powered, divided into modules, and takes up little space, it can be used in extreme conditions similar to military combat.

The solution presented in this article will be included in a series of experimental studies and will be used for creating universal profiles of effective soldiers that will take into account their psycho-physiological condition, physical agility, and skills.

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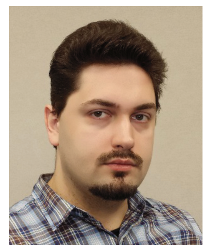

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