EMBEEDED PORTABLE BIOTELEMETRY SYSTEM OF HUMANS

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Abstract: The mobile telemetry system of biological parameters serves for reading and wireless data transfer of measured values of selected biological parameters to an outlying computer. It concerns basically long time monitoring of vital function of car pilot.The goal of this projects is to propose mobile telemetry system for reading, wireless transfer and processing of biological parameters of car pilot during physical and psychical stress. It has to be made with respect to minimal consumption, weight and maximal device mobility. This system has to eliminate signal noise, which is created by biological artifacts and disturbances during the data transfer.

Introduction

This work was created on the basis of need of scanning and telemetry transmission of biological parameters at car pilots at Eco Shell Marathon. Many sports events require the possibility of the scanning (both short-term and long-term ones) of biological parameters at sportsmen or F1 car pilots straight during the physical and psychical stress. By force of telemetry system, it is then actually possible to monitor basic vital functions activity like ECG, heartbeat and breathe frequency, blood oxidation, temperature. In addition, it is possible to monitor and judge to what degree the stress affects these basic vital functions e.g. while driving the F1 car when heightened concentration and pilot's increased reactions at the high speed are needed.

The next significant fact is that by monitoring of pilot's vital functions is in some measure possible to consider a quality of the car construction with respect to comfort and safety. By means of pilot's life functions distant monitoring it is possible to judge objectively pilot's abilities necessary for driving the formula and thereby to minimize the car accidence chance caused by sudden change of health (e.g. exhaustion, sickness, tiredness, cardiac arrest).

This work also treats of usage the Bluetooth technology in biomedical engineering. The Bluetooth technology is used for wireless transmission of some biological signals from measuring device to computer or communication canter to short distance range. Measuring devices including Bluetooth could be more mobile, the manipulation with these devices could be easier and there couldn't be emplacement problems. To check on possibility of usage of Bluetooth technology in biomedical engineering it was used for transmission data from blood pressure monitor, from device for pulse oximetry and ECG data.

Cable replacement is benefit for user. User get more comfort, the manipulation with device is easier. The device is more flexible and more useable. There is the possibility to create wireless network set up from more devices. It is possible to communicate with notebooks, PDA or mobile phones.

Materials and Methods

On the chosen biological parameters, it is possible to monitor the basic life activities that directly reflect actual physical and psychical state of the pilot's state while driving the car in extreme situations. Next condition is not to disturb pilot while scanning the biological parameters. The pilot has to feel comfortably without even a small sensation that his body is connected to system of sensors. Similarly it must be secured the signal artifacts (motion artifacts, artifact caused by imperfect connection of a scan electrode and a skin, etc.) not to be transmitted into scanned signal owing to pilot's movement.

At the sensor selection an cable optimal length was respected not to occur an accidental separation of scanner electrode from the body or on the contrary the sensor cables not to be excessively long to get in the way while pilot's moving.

The following criterion for the choice of scanned biological parameters was an easy accessibility of our own sensors and modules for measurement scanned biological parameters and its affordable price.

The system scans and processes an electrocardiogram, pulse rate, blood saturation by the oxygen (SpO2), plethysmography, body and surroundings temperature, breathe frequency and car speed.

The telemetric chain consist of several functional blocs meant for scanning the biological signals from the pilot, signal processing and wireless transmition to a distance computer. The measuring instruments consist of OEM modules ChipOX and ECG100 read the

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biological parameters (SpO2, plethysmography, body temperature, temperature of surroundings, ECG, pulse rate, breathe frequency also car speed), that are brought to inputs of communication module. The output of the communication module is linked to radio module meant to transmission all these parameters to a distant radio modem of receiver. The receiver is linked to computer that monitors scanned biological parameters. The completely telemetric chain uses communication interface RS232 that means the connection of apparatuses that read biological parameters by the communication module and connection of communication module with sending radio module and subsequently connection of receiving radio module to computer through this interface.

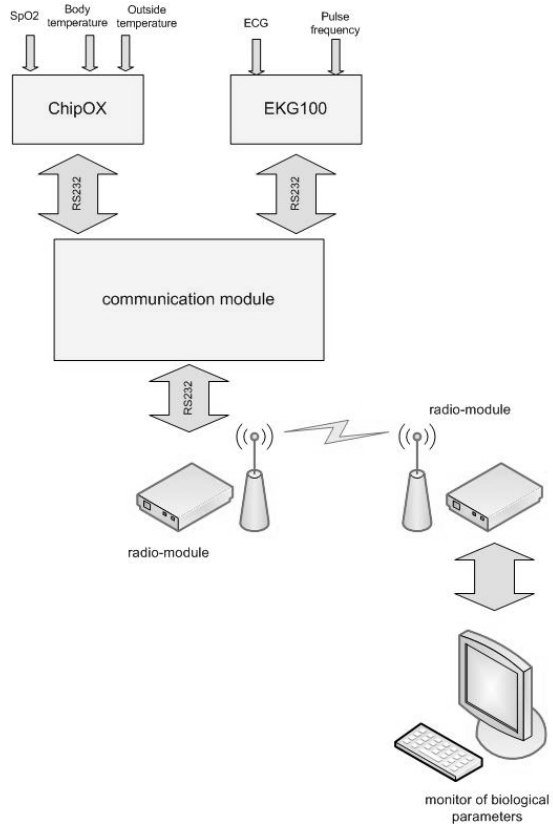

Figure 1: Designed telemetry chain

There is other possibility to connect modules with communication module by Bluetooth wireless communication.

Bluetooth modules which was chosen for realization Bluetooth communication can be used as a component in many types of systems allowing them to communicate wirelessly with other Bluetooth products such as PC-cards, laptops, handheld computers and mobile phones. It allows with an RS232 port or UART interface to communicate wirelessly via Bluetooth with other Bluetooth devices. The module can be configured using the Windows based configuration wizard or using AT commands. It supports Generic access profile, Serial port profile, Dial-up profile and LAN access profile. The module is qualified according to the Bluetooth 1.1 specification. Next function of this module is Wireless multidrop. This feature allows the module to simultaneously communicate with up to three remote Bluetooth devices depending on application and cases. The module automatically forms a wireless multidrop network and distributes all data to all connected devices.

Plethysmograph ChipOX

Pletysmograph OEM module ChipOX measures the non-invasive saturation by oxygen (SpO2), plethysmogram, pulse rate, body temperature and temperature of surroundings.

ChipOx offers 3 analog voltage inputs with maximal input voltage 2400 mV for the measurement of other parameters, which are each sampled with a maximum of 100 Hz, 12 Bits. The sampling rate and the input voltage ranges are freely configurable over the communication protocol.

These inputs were used for body temperature and temperature of surroundings measurement, breathe frequency and car speed were temperature sensor were proposed and realized. The measurement of the rest bioparameters (SpO2, ...) was provided by finger or ear sensor.

Figure 2: Ear sensor SpO2

The pletysmograph is powered from network adaptor or from the battery by DC voltage 6V. For wireless communication with surroundings is the instrument equipped with Bluetooth technology (that is for short distance communication), it is possible to connect the instrument to any radio module supporting the interface RS232 for longer distance data transmission.

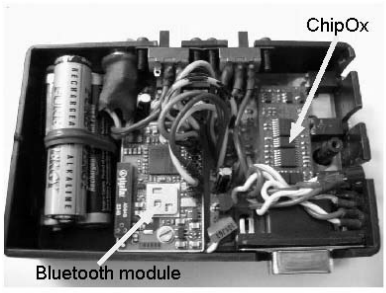

Figure 3: OEM module ChipOx connected with Bluetooth module

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Electrocardiograph ECG100

Electrocardiograph OEM module ECG100 is intended for scanning and measuring electrocardiogram (I, III Einthovens lead) with the assistance of stick electrodes. Power supply of the instrument is secured by DC voltage 9V from the network adaptor or battery. The instrument is provided, identically as a plethysmograph, by ChipOX for the communication with the surroundings. It can communicate by UART protocol. Measured pulse frequency range is between 30 and 245 beats per second and it is measured as sliding average from last eight measured values. Module can detect pacemaker impulses and when leads are not connected.

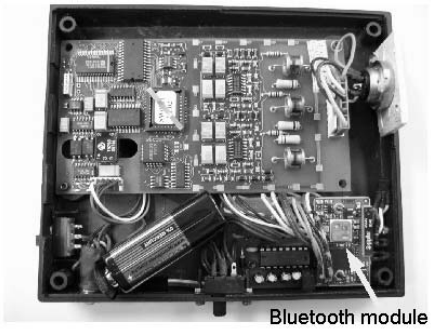

Figure 4: OEM module ECG 100 connected with Bluetooth module

Temperature Sensors

The temperature sensors were proposed and constructed for the body temperature and surrounding temperature scanning. Sensor's foundation is integrated circuit AD22103. The integrated circuit AD22103 by Analog Devices is monolithic temperature sensor designed for supply voltage 3,3V that includes the temperature thermistor sensor and circuits for data processing on one chip. The output is voltage signal that is possible to bring on input A/D convener with no extra complicated modification. The realized temperature sensors are distinguished mainly by high sensitivity, quick response for temperature change and by sufficient accuracy.

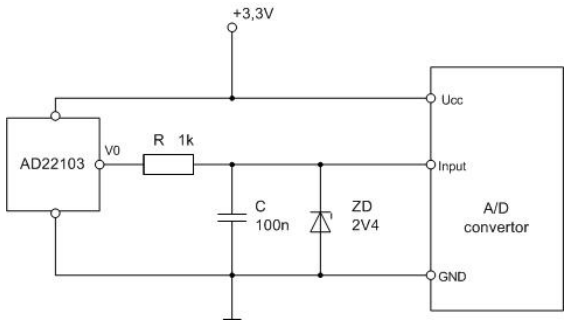

Figure 5: Connection of temperature sensor to the A/D converter

Figure 6: Body temperature sensor

Breathe frequency

Breathe frequency sensor was proposed and constructed for connecting to the nose. There is connection of breathe frequency sensor on figure 7.

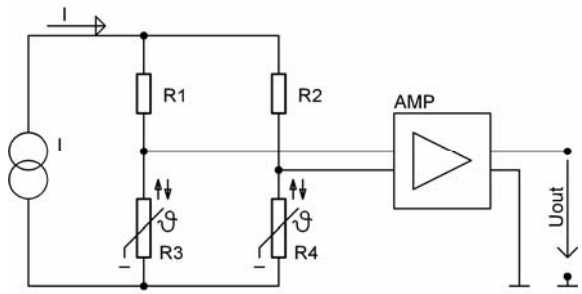

Figure 7: Principle scheme – the measure of breathe frequency

There are two thermistors R_3 and R_4 in the Wheaston bridge. Thermistor R_3 scans the temperature inside the nose and thermistor R_4 scans the temperature outside the nose (see on Figure 8). The result of this configuration is scanning breath and breathing out through the nose.

Figure 8. The sensor of breathe frequency on the nose and sensor only

The amplifier AMP is consisted of accurate operating amplifier AD524 [10]. The differential voltage $U_{R4} - U_{R3}$ is amplified by 100. The maximum output voltage is 2V, which it directly connected to ChipOx.

Car speed

Car speed is measured by magnetic sensor. There is a reed relay as magnetic sensor near a wheel of car. Impulses from a reed relay are processed by converter f/U.

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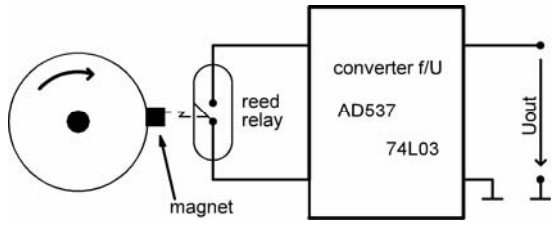

Figure 9: Principle scheme – the measure of car speed

Integrated circuit AD537 is a core of the converter frequency to voltage. The AD537 [10] be used as a high linearity VCO in a phaselocked loop PLL to accomplish frequency-to-voltage conversion by operating the loop without a low-pass filter in the feedback path. The input signal should be a pulse train or square wave from reed relay with characteristics similar to TTL or 5-volt CMOS outputs. The output voltage is 2V for a 100 Hz input frequency.

Communication Module

The proposed communication module is an apparatus used for data collection and data transmission directly into computer with assistance of serial cable or into transmitter for wireless transmission into distant computer. The data represent measured quantity from plethysmograph and electrocardiograph.

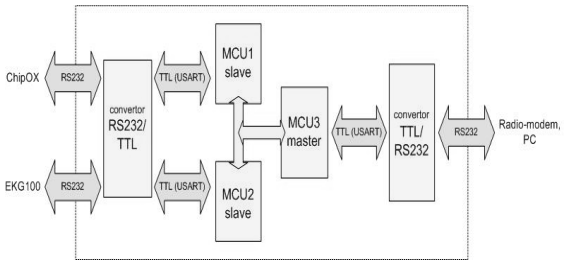

Figure 10: Internal structure of communication module

The module has two data inputs for connection to measuring instruments ChipOX and ECG100 and data input for connection of module to PC or transmitter for wireless communication. One of the main demands for this module is module was to all the data inputs and outputs was designed for serial communication RS232. The purpose of communication module is to receive data from two measuring instruments and to send them through the serial cable or wirellessly to computer. The data that are the outcome of the module bring information about all measured biological parameters like ECG, pulse, plesthysmogram, SpO2 and temperature. The ground of the entire circuit arrangement is composed of three microprocessors from MCU1 to MCU3 from the data transmission view. The microprocessors secure an actual data transmission in the way that data from two inputs are suitably unified into one output. Since (Because) the microprocessors work at voltage level TTL by data communication, it is necessary to adapt both inputs and outputs into the same level, because the circumferences connected to terminal works usually in levels of RS232. The circuits MAX232 are used for this purpose.

Radio modems ADAM _4550 for wireless data transmission

The radio modems are used to its own wireless biological parameters transmission between the communication module and distant computer at the distance of 0,5 to 2 km. ADAM 4550 are types of radio modems that work at frequency of 2,4 GHz. Communication with module is set in serial line through the converter RS 232/RS 485 with transmission speed up to 115,2 Kbps. By using the directional antenna, it is possible to communicate for distance up to 20 km.

Treatment

The whole apparatus for scanning and telemetry transmission of biological parameters was tasted from the point of view its complete functionality with the use of radio modules both for wireless data transmission and also without it by connecting measuring instrument with communication module to computer through serial cable. The electrocardiograph ECG100 and plethysmograph ChipOX were plugged to inputs of communication module. As proofing electrocardiogram were used simulated signals from monitoring tester TESLA LCO120, which similarly generated the pulse rate.

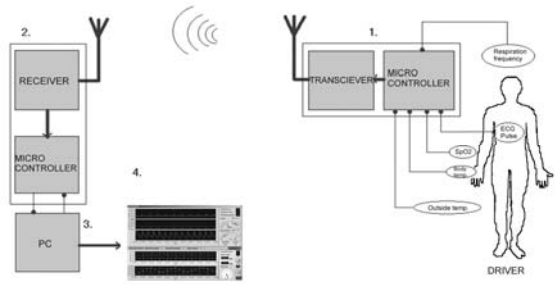

Figure 11: Bbiotelemetric system for monitoring base vital functions of race driver, with wireless data transmitting

The plethysmogram and blood saturation by oxygen were practicably scanned by finger sensor that were connected to pletysmograph, ChipOX. During the trial period was the last scanned parameter the temperature of surroundings scanned by realized temperature sensor. The temperature detector, breath frequency and car speed sensor were linked to one from three analogue input of ChipOX. In addition to the first temperature detector, the second temperature sensor was also connected to perform an orientation comparative measurement.

The next step was tested communication between referenced devices and computer by standard serial line. It was good for test of functionality of devices and ability of communication. Then can be designed, realized and tested Bluetooth communication. The first

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it was point-to-point communication afterwards the point-to-multipoint communication. It was created wireless network of all referenced devices.

It is necessary to set up correct communication protocol of serial communication between device (computer) and Bluetooth module the first. Afterwards could be set up the parameters of Bluetooth communication.

For point-to-point communication were designed three versions of Bluetooth communications parameters. The Bluetooth communication was realized by referenced Bluetooth modules at the computer and device side too. At the basic settings were set up name of Bluetooth device and selected possibility to set up the Bluetooth parameters by Bluetooth. Next was selected operation mode connectable and discoverable. The other devices can connect to it and it can be found when other devices are performing searches. There are digestedly displayed settings of modules for each version of Bluetooth parameters settings in the next table (Table 1). There are written on which event client can connect to server device too. Very good is version two, because the modules can be changed between device and computer without any modification of Bluetooth connection parameters.

Table 1: Settings of Bluetooth communication parameters

Version	Bluetooth module settings on computer side	Bluetooth module settings on device side
1	SERVER Always connected	CLIENT Always connected
2	CLIENT AND SERVER Always connected	CLIENT AND SERVER Always connected
3	CLIENT On data activity Always connected	SERVER

For point-to-multipoint communication was possible to use on computer side USB Bluetooth dongle or referenced Bluetooth module and its function for creating point-to-multipoint network - Wireless multidrop. But after tests it was clear that this function (Wireless multidrop) isn't accordant with engaged wants. As a consequence was chosen USB Bluetooth dongle BT-600 from ACER Company. This USB dongle can work by standard driver for Bluetooth communications included in operating system WindowsXP (2nd service pack). This driver provides to create more than one virtual serial port.

The first was tested point-to-point communication between computer with USB Bluetooth dongle and measuring devices via Bluetooth. Afterwards was designed and realized point-to-multipoint connection between referenced USB Bluetooth dongle and all other referenced devices. The Bluetooth modules on device side were set up in accordance with third version of settings of Bluetooth communication parameters (see Table 1). After the far devices with Bluetooth module were found by the USB Bluetooth dongle (more precisely by drivers in operating system), were these devices added to list of Bluetooth devices. Each of found devices gets own virtual serial port. In the visualisation software, which was created too, was set up only correct name of virtual serial port for each device, and communication could start.

Part of this work is the software for visualisation and saving measured data too. This software, named BIOMONITOR is developed in development system Labview from National instruments, version 6.1. The most important demands were easy intuitive control and very good lucidity of user interface.

It was designed and realized user interface, where each group of measured values has own colour of chart or more precisely colour of background. The part of final software is the Terminal too. Terminal allows to user select which values would to measure at that time. Depending on it the user interface is changed and user can see only that charts and groups of indicators, which are need to indicate measured data.

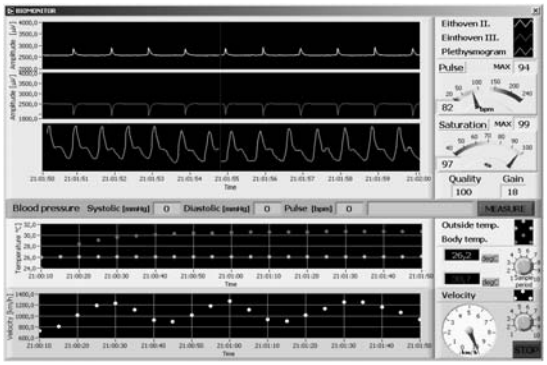

Figure 12: BIOMONITOR user interface

Displayed version of software is suited for visualisation values which are measured in frame of project of Biomedical laboratory VSB-TU Ostrava: Biotelemetry system of pilot for Shell Eco – Marathon.

Results

The aim of this work was the proposal of a telemetric system for biological parameters measurement at F1 pilot for Eco Shell – Marathon. The telemetric system proposal lied in the selection of suitable biological parameters that preferably testified about an actual physical and psychical state of pilot while driving the car, furthermore in selection and design of biological parameters sensors, also proposal and implementation of communication module that is used for electrocardiograph and plethysmograph communication with distant computer.

Also it was realized wireless network of medical devices. The network was realized by Bluetooth

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technology. For Bluetooth communication was used Bluetooth modules created for serial cable replacement on the device side. On the computer side was used USB Bluetooth dongle. All the system is mobile and can be used in every computer which can cooperate with USB Bluetooth dongle. It can be used in computer which include anything else for realize Bluetooth communication. Realized devices can be supplied by accumulators. It is very good, because such devices are flexible and mobile.
It was created software for visualisation and saving measured data. Software is very easy to control and it is very well-designed. Software displays all the measured data at the time. The values measured at the analog inputs of ChipOx module are displayed and saved too.

Conclusions

The contribution of this work is nominated functional telemetric system that can be used to long time monitoring of chosen biological parameters of pilot at Eco Shell – Marathon. Such a monitoring system is important while pilot's basic vital functions monitoring, because it helps to reveal state of health changes on time. Pilot does not have to notice them in such a high speed because of higher claims to his attention. They could cause serious accident. It is also possible to use the proposed telemetry system for ballast testing in sports medicine to monitor sportsman's physical ballast through scanned biological parameters, e.g. by running.

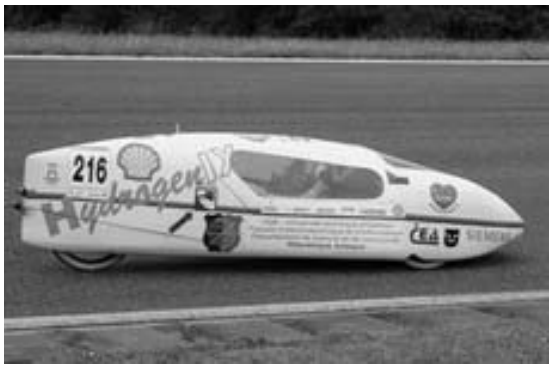

Figure 13: Eco Shell – Marathon competition car equipped with biotelemetry system.

On the top of the results this work can be used in implementation of wireless communication in branch of medical technique. Realized network of devices can be used in many applications of telemedicine, mainly as the system of monitoring base life functions. This network can be used in the field of telemonitoring for example long ill people, elderly people and other.

Acknowledgement

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