IMPLEMENTATION OF PULSE OXIMETRY MEASUREMENT TO WIRELESS BIOSIGNALS PROBE

Martin Jagelka[1], Michal Jeleň[2], Erik Vavrinský[1], Martin Daříček[1], Martin Donoval[1]

[1]Institute of Electronics and Photonics, Slovak University of Technology in Bratislava, Bratislava, Slovak Republic

[2]Technological Institute of Sport, Slovak University of Technology in Bratislava, Bratislava, Slovak Republic

Abstract

Monitoring of heart rate variability (HRV) and oxygen saturation is important in medicine as well as training of top athletes. Our work describes the implementation of pulse oximetry functions in sensor system for measurement of biosignals. It allows us to follow along even pulse biosignal and the flow rate of blood.

Keywords

pulse oximetry, biosignals, wireless measurement

1. Introduction

The heart is very important organ and its failure has usually fatal consequences. Therefore it is important to monitor its activity in everyday live. A basic indicator of proper heart´s function is heart rate variability (HRV). It shows many problems, existing diseases, or even diseases that still not show other symptoms. This is the main reason why developing different diagnostic methods for the heart rate monitoring. Pulse measurement plays an important role in training, rehabilitation processes and post-operative conditions. Monitoring of oxygen saturation (StO_2) is also important in these areas. Through to monitoring of oxygen in the blood we are able to predict the collapse of the human body [1], so StO_2 is as important as heart rate and other parameters during workout. Decreased oxygen saturation causes performance degradation [2], loses concentration, technique [3] and in the worst case may cause unconsciousness [4].

2. Pulse oximetry

Pulse can be measured in many ways, most often technique is monitoring an electrocardiography (ECG). Heart rate is then determined as RR interval, which is the time interval between the maximums of the ECG. But if we want to determine StO_2 also, we have to use another method. One of the most common methods to measure oxygen saturation and heart rate at same time is pulse oximetry. It is an optical method when we are shining through tissue and detecting light that does not absorbs. There are two types of pulse oximetry, first transmission and second reflective. Transmission pulse oximetry need an external light source that is placed on the opposite side of the sensor, and is shining really through the body part. Therefore, this method can be only used on terminal parts of the body such as fingers, nose, ears, etc. Reflective pulse oximetry uses external light source shining to the tissue on sensor side and sensor are measuring reflected light that does not absorbs in tissue. This method can be used almost on any part of the body such as palm, abdomen, thigh, etc. [5].

In practice, there are systems that can monitor heart rate and oxygen saturation together. However, their use is limited to measuring at rest. When measuring simultaneously heart rate and sto2 during physical activities those systems fail. The main purpose of R&D team was to prepare a pulse oximetry's design, which is able to measure person at rest and in motion, respectively with high accuracy. Then send the collected data to a computer by wireless transmission.

To increase the application value we chose the reflective pulse oximetry, which was integrated into the existing system for wireless biosignal measurement (BioSense). This integration of pulse oximetry has remarkable benefit to biosignal measurement, because there is doesn't exists similar device with such versatility for everyday use. For better sensitivity we are using two sensors, which allow us to measure HRV and StO_2 during the training.

Our measuring system consists of two light emitting diodes (LED) with specified wavelengths of emitted light, it is a couple of red and near infrared LEDs. The wavelengths of the LEDs are chosen in case of the optical properties of blood. The oxygenated hemoglobin has maximum light absorption of 940 nm and on the other site reduced hemoglobin has this maximum of 660 nm [6]. Due to this difference we are able to determine the ratio of oxygenated and reduced hemoglobin. This ratio determines directly the level of StO_2. This pair of diodes is coupled with photodiode, which has comparable sensitivity to both of used wavelengths of emitted lights. Thanks to this we are able to determine the StO_2 level by intensity of captured reflected light without any additional adapting of the system.

All of the measurement processes are controlled by BioSense, which handle microcontroller JN5148 with integrated RF communication module. Signal processing is based on 24-bit analog to digital converter with software adjustable sample rate and gain [7] (see Fig. 1).

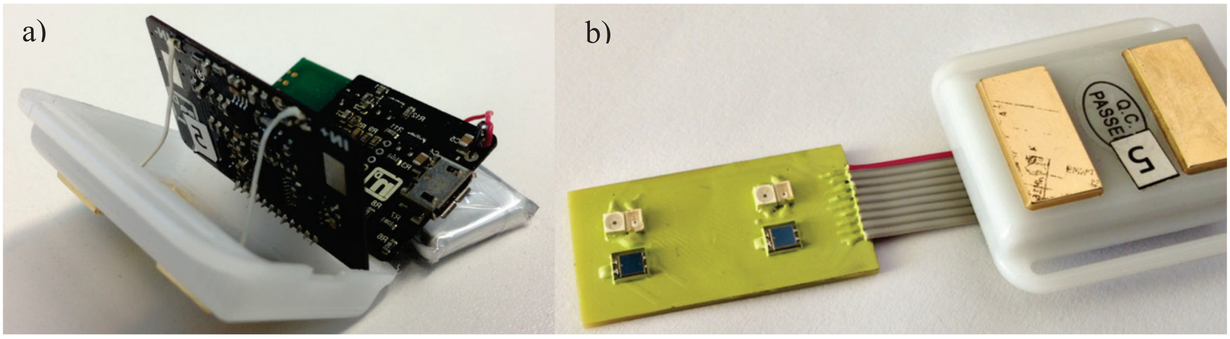

Fig. 1: a) Probe for measuring biosignal form BioSense system. b) Modified probe with integrated pulse oximetry on extension board.

3. Experiment

For verification of applicability of pulse oximetry we performed two basic experiments. First was designed for heart rate monitoring in real conditions, and the second one for determining StO_2 level. As you will see BioSense with pulse oximetry has the possibility of applying in everyday life.

A. Continuous measurement

We performed reflective and transmission pulse oximetry in this experiment to compare this two methods. For transmission measurement we used daylight as a light source, because of simplicity of setup whole system. We found that in this configuration, we are able to measure HRV without additional light source, but this setup can be use only outside in a sunny day, but with enormous noise which

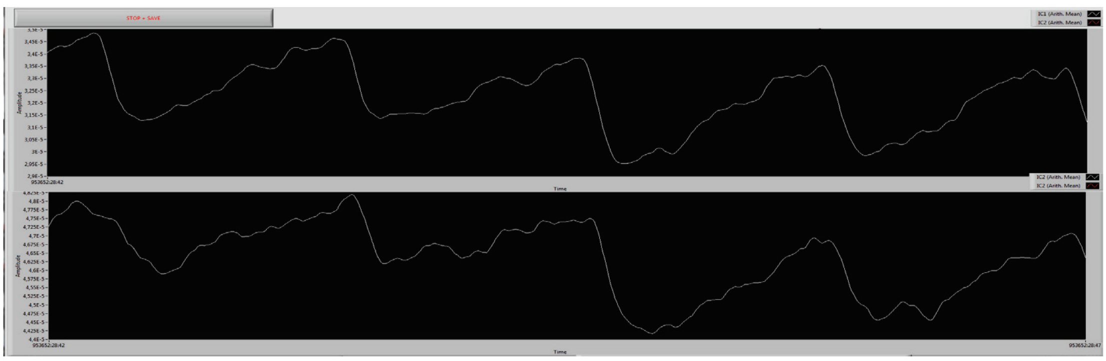

Fig. 2: Signals from both sensor in continuous measurement.

cannot be filtrated. Furthermore, we were testing more useful configuration namely reflective pulse oximetry. We used integrated red light in continuous mode and we were detecting reflected light that does not absorbed in tissue. Absorption of light is proportional to blood supply in measured tissue which is bound with pulse. This is the simplest way to determine heart rate of proband, on almost any part of body. We tested various positions of sensors such as finger, palm, jawbone, abdomen and thigh. The best results was measured on finger and palm (see Fig. 2).

B. StO_2 measurement

To measure oxygen saturation, we used reflective pulse oximetry. We planed a special diagram for switching LEDs to maximize efficiency of StO_2 measurement. We used pulses with duration of 50 µs with 1 ms period (see Fig. 4). On signal from sensor we applied high pass filter with 100 Hz cutoff frequency for better observation of measured data. We can see differences between signals from red and near infrared light, which determine the oxygen saturation (see Fig. 3).

better attaching system for pulse oximetry and increasing of user comfort during measurement.

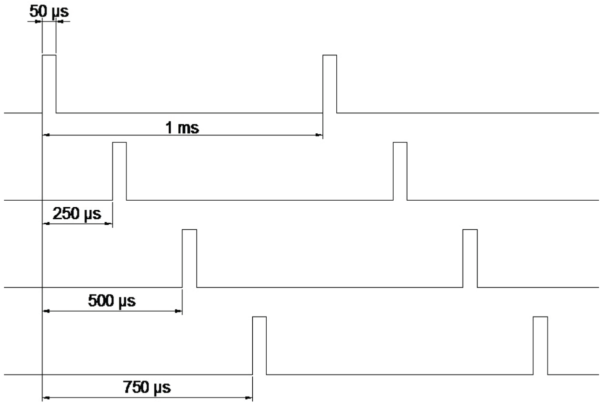

Fig. 4: LED switching timing diagram.

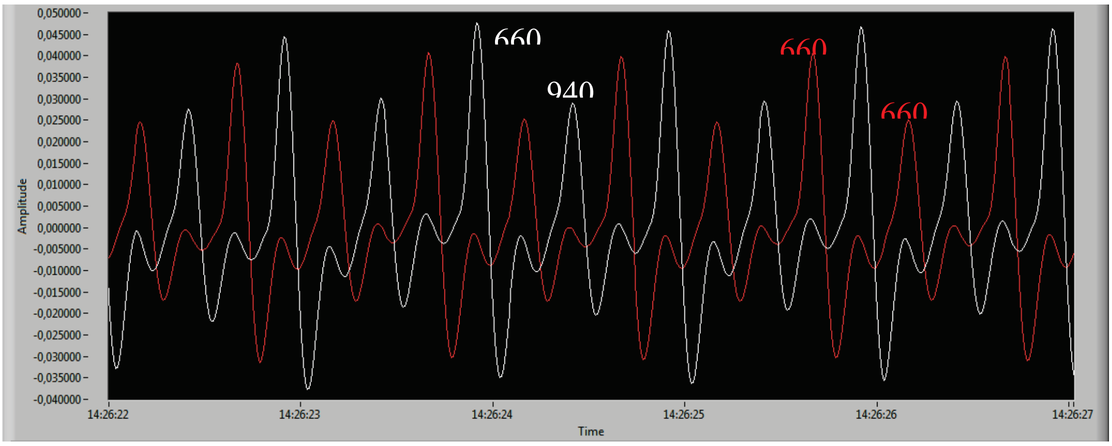

Fig. 3: Signal from both sensors, shows dependence of the wavelength of used light.

4. Conclusion

Through an experiment, we were able to verify qualities of BioSense with integrated pulse oximetry. We executed that we can observe heart rate and StO_2 level on almost any part of the body. Our pulse oximetry measurement system is useful not only in laboratory conditions, but also in everyday life, thanks to integration in BioSense, for monitoring of human health. We are able to determine the critical value of oxygen saturation, when nervous system is starts collapsing and also can identify ventilatory threshold, which can be useful for training as well as rehabilitation process and post-operative conditions. Now we are focused on improving stability and sensitivity in wearable applications. We are working on

Acknowledgement

This work was supported by Slovak Grant Agency though grant no. 1/1177/12 and by Slovak Research and Development Agency under contract No. VMSP-II-0016-09.

References

[1] CURRY, J. P., LYNN, L. A., Threshold monitoring, alarm faigue, and the patterns of unexpected hospital death. In *The official journal of the anesthesia patient safety foundation,* 2011, vol. 26, no. 2, p. 32-35.

[2] WEHLIN, P. J., HALLÉN, J. Linear decrease in *V̇*O2max and performance with increasing altitude in endurance athletes. In *Eur. J. Appl. Physiol*, 2006, vol. 96, p. 404–412.

[3] GABBETT, T. J. Influence of fatigue on tackling technique in rugby league players. *In J Strength Cond Res*, 2008, vol. 22, no. 2, p. 625-632.

[4] O´DRISCOLL, B. R., HOWARD, L. S., DAVISON, A. G. BTS guideline for emergency oxygen use in adult patients. In *Thorax*, 2008, vol. 63, p. vi1 – vi68.

[5] YOCUM, B. L., MENDELSON, Y., PEURA, R. A., Design of a reflectance pulse oximeter sensor and its evaluation in swine. In *Bioengineering Conference, 1989, Proceedings of the 1989 Fifteenth Annual Northeast*, 1989, p. 239–240.

[6] SINEX, J. E., Pulse oximetry: principles and limitations. In *American journal of emergency medicine*, 1999, vol. 17, no. 1, p. 59–66.

[7] DAŘÍČEK, M., JAGELKA, M., SLÁDEK, L., HORÍNEK, F., MIKLOVIČ, P., Wireless probe for human body biosignals, In *Lékař a technika,* 2012, vol. 2, p. 42–45.

Martin Jagelka
Institute of Electronics and Photonics
Slovak University of Technology in Bratislava
Ilkovičova 3, 812 19 Bratislava
Slovak Republic
E-mail: martin.jagelka@stuba.sk