

반사광을 이용한 손목시계형 혈중산소포화도 (SpO₂) 측정기

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A Wearable Watch-type Reflectance-based Blood-oxygen Saturation (SpO₂) Level Estimation

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Abstract

Transmission and reflectance are two non-invasive techniques to perform pulse oximetry. This paper presents a design of reflectance-based pulse oximetry for watch-type wearable device, in which sensor and detector are located on the same surface of the body part. The basic principle of a pulse oximeter is based on the measurement of the red and infrared (IR) light absorption. Oxygenated blood has significant differences of light absorption characteristics than deoxygenated blood under red (660 nm) and infrared (940 nm) wavelength. Infrared is absorbed more by oxygenated hemoglobin than red. So the hardware implementation is included placing of the two LEDs (red and IR) with single photo-detector in the middle on the patient's wrist to get the corresponding pulsatile signals which are used to estimate the SpO₂.

1. Background

Oxygen saturation (SpO₂) is the measurement of oxyhemoglobin (HbO₂) in arterial blood. SpO₂ is an important vital measurement because it shows the levels of blood oxygenation. Traditionally, SpO₂ is measured by invasively drawing blood samples. This method, however, is not ideal and it is unable to provide clinicians with real-time measurements. With the need for a noninvasive way to measure SpO₂, pulse oximetry was developed [1-6].

Pulse oximetry is a simple non-invasive method of monitoring the percentage concentration of haemoglobin saturated with oxygen, termed oxyhaemoglobin, to the total haemoglobin concentration. The percentage oxygen saturation in the patient's blood as measured by the pulse oximeter, %SpO₂, can be stated as [7]

$$\%SpO_2 = \frac{HbO_2}{Hb + HbO_2} \times 100\% \quad (1)$$

The Beer-Lambert law is applied to penetrated light to obtain SpO₂ value [8]. Sensor used to measure SpO₂ is assembled in a probe which has two LEDs (red and infrared) and one photo-detector. The red and infrared LEDs are driven alternately. The amount of light absorbed can be determined by converting intensity of light into electrical energy through photo-detector. Through this process, oxygen saturation in the blood can be measured. Typical output of photo-detector contains DC and AC components [8, 9]. The absorption ratio of Hb and HbO₂ can be used to estimate the SpO₂ level. Therefore, SpO₂ value can be obtained by

calculating the R value as follow:

$$R = \frac{AC_{Red}/DC_{Red}}{AC_{IR}/DC_{IR}} \quad (2)$$

where AC and DC are the changing and static components of the transmitted red and infrared signals that pass through the measuring site and are received at the photo-detector.

Once the R value is calculated, the SpO₂ value is determined from R by using (3) [10].

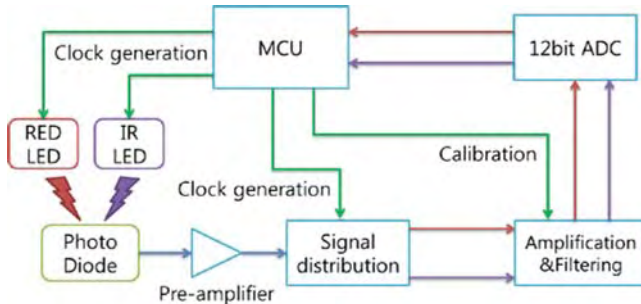
$$\%SpO_2 = k \times R \quad (3)$$

where k is proportionality constant, which can be considered by calibration results.

2. Methods

The system block diagram is shown in Fig. 1. The photo-detector diode is in the middle and which surrounded by the red and infrared LEDs (see Fig. 2b). The LEDs are rapidly and sequentially excited by two current sources (one for each LED) whose dc levels depend on the LED being driven. The switching of the two LEDs is controlled by the two control signals, red and infrared timing given to the LED driven circuit. The alternative burst of red and infrared light can then pass through the site. The control signals are generated by microcontroller unit (MCU). The signal from photo-

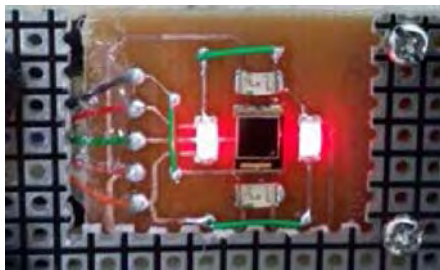
detector was amplified by Pre-amplifier and then analog switch circuit is used to distribute the red and infrared signal. And then, each individual signal was driven to the filtering and amplifier circuit. The 12-bit Analog-to-Digital Converter (ADC) is used to convert the analog to digital signal for MCU input. With the input signal of MCU, the SpO₂ level is calculated through Digital Signal Processing (DSP).



(Fig. 1) System block diagram.

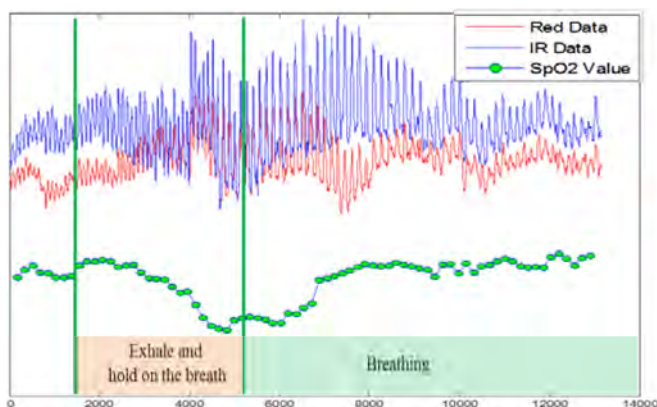


(a)



(b)

(Fig. 2) (a) Watch-type wearable oxygen level estimation prototype. (b) Red, infrared, and photo-detector sensors.



(Fig. 3) Pulsatile signal of red and infrared with the corresponding SpO₂ level.

3. Result and Discussion

As shown in Fig. 3, the acquired raw data of red and infrared LED are used to estimate the oxygen saturation level (SpO₂). We exhaled and hold on the breath for about 30 seconds and as can be seen the two signals are gradually come close to each other. As result, the SpO₂ level (green dot) reduced during that period.

Notice that the oxygen level did not reduce immediately at the point where the exhalation is started; correspondingly, it was not increasing right after inhalation. As illustrated in Fig. 3, the oxygen level reducing period seemingly shifted from the exhalation period.

This preliminary result shows the potential of watch-type wearable device to measure oxygen level that can be useful in various applications such as sleep apnea monitoring. There are much more works to do in the future in order to develop and implement on this proposed system to be more effective.

References

- [1] Chen, Wei, et al. "Non-invasive blood oxygen saturation monitoring for neonates using reflectance pulse oximeter." Proceedings of the Conference on Design, Automation and Test in Europe. European Design and Automation Association, 2010.
- [2] Jung, Sang-Joong, et al. "Design of a low-power consumption wearable reflectance pulse oximetry for ubiquitous healthcare system." Control, Automation and Systems, 2008. ICCAS 2008. International Conference on. IEEE, 2008.
- [3] Haahr, Rasmus G., et al. "An electronic patch for wearable health monitoring by reflectance pulse oximetry." Biomedical Circuits and Systems, IEEE Transactions on 6.1 (2012): 45-53.
- [4] Mendelson, Y., R. J. Duckworth, and G. Comtois. "A wearable reflectance pulse oximeter for remote physiological monitoring." Engineering in Medicine and Biology Society, 2006. EMBS'06. 28th Annual International Conference of the IEEE. IEEE, 2006.
- [5] Duun, Sune, et al. "A novel ring shaped photodiode for reflectance pulse oximetry in wireless applications." Sensors, 2007 IEEE. IEEE, 2007.
- [6] M.EI-Khoury, J. Soda, V. Neuman, and J. Krauss, "Portable SpO₂ Monitor: a fast response approach," IEEE. International Conference on Portable Information Device, 2007, pp. 1-5.
- [7] G. Maruf Azmal, A. AI-Jumaily, and M. AI-Jaafreh, "Continuous Measurement of Oxygen Saturation Level using Photoplethysmography Signal," Proc. of the International Conference on Biomedical and Pharmaceutical Engineering, 2006, pp. 504-507.
- [8] J. G. Webster, Design of pulse oximeters: CRC Press, 1997.
- [9] J. Cho, N. Kim, H. Seong, and Y. Kim, "Accuracy Improvement for Low Perfusion Pulse Oximetry," in 5th Kuala Lumpur International Conference on Biomedical Engineering 2011, 2011, pp. 258-261.
- [10] A. Wongjan, A. Julsereewong, and P. Julsereewong, "Continuous Measurements of ECG and SpO₂ for Cardiology Information System," in Proceedings of the Int' MultiConf. of Eng. and Computer Scientists, 2009.