DEVELOPMENT OF THE REFLECTION-TYPE PULSE OXIMETER

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Near-infrared tissue oximeter is usually used to measure the oxygen metabolism in cells, capillaries and veins [1-5]. The non-invasive measurement of arterial oxygen saturation by pulse oximetry has become a standard of care in many areas of clinical medicine. Tissue hypoxia of one organ may lead indirectly to dysfunction or failure of distant organs through the release of mediators and various toxins [6]. In the case of bowel ischaemia, the loss of mucosal barrier function results in bacterial translocation and endotoxin absorption into portal blood which can amplify the systemic inflammatory response following surgery [7,8]. This may ultimately contribute to the development of multiple organ failure, which remains a common cause of death and morbidity following major surgery despite advances in intensive care management.

The transmission pulse oximeters have been widely used in clinical applications. However, they can only be applied to fingertip or earlobe through which the light can be transmitted. The reflectance oximeter has the advantage of being applicable to any portion of the body. During open-heart surgery reflectance pulse oximetry gives an earlier response at lower perfusion pressures than transmission pulse oximetry because the sensor can be applied on more centrally located areas, such as the head. Reflectance oximeters are more complex because they increase the scattering of light and have not gained wide popularity because of that. The major practical limitation of reflectance pulse oximetry is the comparatively low-level photoplethysmograms recorded from low-density vascular areas of the skin.

Noninvasive monitoring of arterial hemoglobin oxygen saturation (SaO₂) is based on the different absorptions between oxyhemoglobin (HbO₂) and deoxyhemoglobin (Hb) measured at two wavelengths. Typically, a red wavelength of 660 nm, where the absorption by Hb and HbO₂ is significantly different, and an near-infrared wavelength of 830 nm which is very close to isobestic wavelength of 805 nm, are used in the optical sensor. Usually, a normalization is performed by dividing the pulsatile (AC) component of the red and infrared light signal by the corresponding non-pulsatile (DC) components. This yields a normalized (AC/DC)red/(AC/DC)infrared ratio R, which was shown to be linearly related to the oxygen saturation of the arterial blood (SaO₂).

Sensing an arterial pulse is necessary to pulse oximetry. The pulsatile variation in light returning to a detector at the tissue surface results from arterial blood flow at systole, and provides a means of isolating the contribution of arterial blood to the overall light absorption. The photoplethysmograph (PPG) signal is related to the arterial blood flow by the optical behavior of light in tissue.

Reflectance oximeter is developed in the Applied Physics Department TPU. Block diagram of the reflection-type pulse oximeter is shown in Fig.1. The system consists of the optical transducer, receiving part and the data acquisition system. The entire system is designed around an Atmega-16 microcontroller. Data are retrieved via a 10 bit A/D converter which accepts the sensor output and digitizes it. Each LED is connected to a multiplexed output of the current driver and strobed in sequence after which a delay time occurs.

![Fig.1. Block diagram of the pulse oximeter](image)

The first goal is to extract the AC signal by eliminating the DC component. This extraction process is executed by the OPA unit.

The ambient light is considered to be 50 Hz and usually its harmonic noise, such as 100 Hz. Normally, the information in a photoplethysmographic signal resides in the range of 0-30 Hz. According to the Nyquist-Shannon sampling theorem, the lower bound of the sampling frequency is then 60 Hz, but to prevent frequency aliasing caused by ambient noise, sampling frequencies of 240 Hz or higher are required.

The infrared value is more prominent than the red one, because its scattering less. Usually the LEDs are controlled directly by the voltage. The drawback of this method is dependence of light amplitude on temperature. To avoid this drawback the constant current source is designed.
The readings of the red and infrared Leds, recoded by the acquisition system are shown in Fig.2.

![Fig.2. Measured red and infrared signals](image)

Fig.2. Measured red and infrared signals

Initial laboratory evaluations of the pulse oximeter included SpO2 measurements. The Sensor Module was positioned on the forehead using an elastic headband. Baseline recordings were made while the subject was resting comfortably and breathing at a normal tidal rate. Two intermittent recordings were also acquired while the subject held his breath for about 30 seconds. Fig. 3 displays about 4 minutes of SpO2 recordings acquired simultaneously by the sensor.

To improve the signal to noise ratio some kind of filter should be implemented. The moving average is used as a noise reduction filter. The moving average has a good physical foundation and is easy to implement in the macros used for analyzing the measured data.

Measurements in reflectance mode have been performed. The reproducibility and the ability to measure saturations have been investigated.

References


