Development of a Photoplethysmography Signal Processing Method for Oxygen Measurement Concentration

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***Abstract*— Pulse oximetry is a well-known procedure used to measure the level of oxygen (oxygen saturation) in the blood. The measurement of oxygen saturation level is of highly significance in supervising a patient's health condition. This is most commonly supervised by a normal pulse oximeter, which has been extensively endorsed around the world as a measurement standard during procedures such as anaesthesia, surgery or post-operative recovery, which is easily available at any medical store. Measuring oxygen level frequently is very important for aged people, pregnant women and in patients in other such critical medical conditions. This paper presents a low cost method to measure the level of oxygen using Photoplethysmgraphy (PPG)-based technique. The method is based on a model using attenuation of light when it passes through human part of body (e.g., fingertip) having skin, tissue, bone and blood. The PPG signal thus extracted is comprised of both AC and DC components. The key work in this paper is based on separating AC and DC contents within the PPG signal. The DC component of the signal primarily represents the absorption in the intensity of light source, ambient light, sensitivity of the detector, tissue bed, bone, venous blood, capillary blood, and non-pulsatile arterial blood. The AC component captures the pulsating arterial blood and is of our main interest. By capturing the required AC content from the PPG signal, we can then determine the oxygen saturation level by extracting relevant features.**

Keywords- PPG, oxygen saturation, AC signal, DC signal, Beer-Lambert Law.

I. INTRODUCTION

Most people suffer from the inadequacy of oxygen in the body, which is due to improper breathing, poor diet and various types of pollution causing damage to the body cells. Therefore, measuring oxygen level frequently is crucial for the proper functioning of the body. The measurement of oxygen in humans is mostly done by pulse oximetry which is readily available and is one of the most preferred methods. However, measuring oxygen level using PPG is through a non-invasion method in this work, which is determined by measuring the oxygen saturation (SpO_2) and is one of the most accurate techniques [1]. The pulse oximetry available these days is exceptionally good in measuring the level of oxygen with the exception that the subject should be at supine rest. In some cases, we have seen that if the subject moves around, the accuracy is not reliable.

II. METHODOLOGY

It is quite evident that the technological progress in the field of PPG signal acquisition and measurement of oxygen is outstanding. It is not at all astonishing to see the work that has been already done in the field of biomedical engineering. In this study, a method of calculating oxygen level in the body is proposed by detecting the peaks of the PPG signals in the time domain. According to the Beer-Lambert law, which relates the optical path length and effective absorption of the intensity of transmitted light, the relationship between intensity of transmitted light and SpO_2 as given in [2] as shown below:

$$s = \frac{\varepsilon_{Hb}(\lambda_R) - \varepsilon_{Hb}(\lambda_{IR}), R}{\varepsilon_{Hb}(\lambda_R) - \varepsilon_{HbO_2}(\lambda_R) + [\varepsilon_{HbO_2}(\lambda_{IR}) - \varepsilon_{Hb}(\lambda_{IR})], R} \tag{1}$$

where s = oxygen level

ε_{Hb} = coefficient of de-oxygenated hemoglobin

ε_{HbO_2} = coefficient of oxygenated hemoglobin

By using the two light sources, red and infrared lights and calculating a ratio of the AC component to the DC component for each light source, we can calculate *R*, which is the normalized ratio of the red to the infrared transmitted light intensity and can be represented below.

$$R = \frac{(I_{AC} / I_{DC})_{RED}}{(I_{AC} / I_{DC})_{IR}} = \frac{(I_{RED} / I_{IR})_{AC}}{(I_{RED} / I_{IR})_{DC}} \tag{2}$$

Thus, by calculating the ratio of AC to DC components, we can find *R*, which rather gives us the oxygen concentration for every single pulse of PPG signal. By this method, the oxygen level determined is the average value of SpO_2 over the eight seconds interval as has been the practice in reported literature.

III. EXPERIMENTATION

The experiment part consists of the analysis and thorough study that has been done to measure the level of oxygen in the human body. The basic concept of the experiment is to derive the AC content, using which we estimate the

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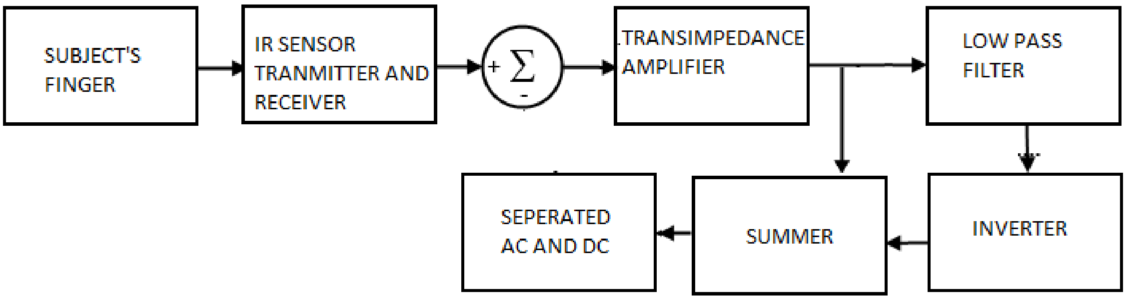

Figure 1. AC and DC component separation procedure

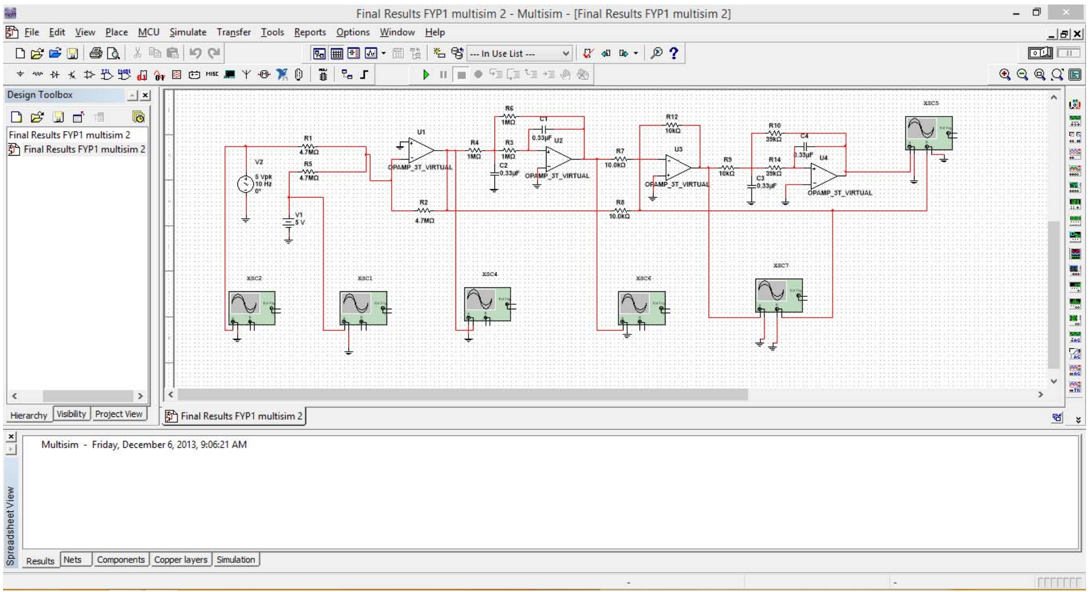

Figure 2. AC and DC component separation procedure

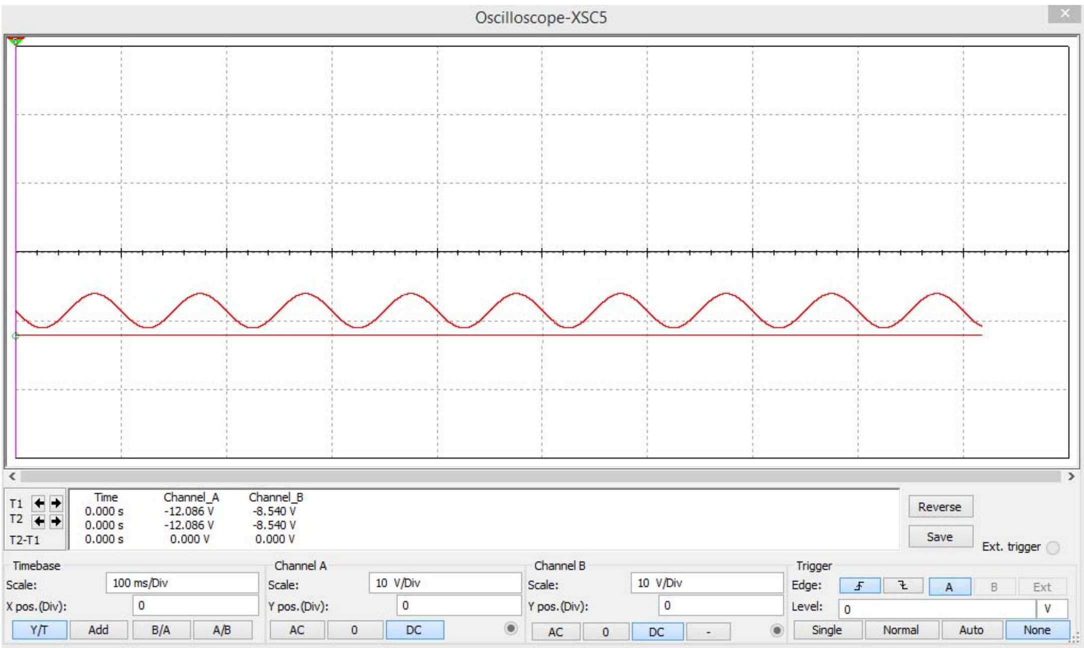

Figure 3. Simulated Circuit

oxygen level since the DC signal represents tissues and bones. Initially, we simulated a circuit with the block diagram as shown in Figure 1. The block diagram was then simulated using Multisim 12.0 by National Instruments Corporation. The simulated circuit is shown as in Figure 2.

IV. RESULTS

The results after simulating the circuit in Figure 2 clearly show the separation of AC and DC as shown in Figure 3. The PPG signal with separated AC and DC content is shown in Figure 4. Based on our observation, the result is quite identical to the one we obtained from the simulation as it is evident from Figure 3.

After the separation of AC and DC signal we can determine the value of coefficient of de-oxygenated hemoglobin, coefficient of oxygenated hemoglobin and R. Then, we substitute the values in the equation from Section II to find the oxygen level in the body.

Current of varying magnitude is passed through LED for generating light of equivalently variable intensity. The light is allowed to pass the fingertip for being received by a light detector on the other side. The light detector, called photodetector is reproducing light variation as a variable colour which is ultimately into a voltage equivalent output using a current to voltage converter. This voltage component contains both AC (pulsating part such as arterial blood) and DC (representing bones and tissues). When passed through a low pass filter, the DC part is reproduced inverted which on summation to the original PPG signal will read to recover the AC part only.

Signal of the original PPG which is obtained in different milliwatts has the capability of acquiring AC components of identical patterns with varying amplitude for a subject under given physical and medical conditions.

Oxygen saturation in the arterial blood can be thus estimated by the AC part of the IR PPG obtain photodiode by taking original IR PPG signal from a given number of volunteers. The pulsating portion of the resulting alone shows that for an increase intensity of the source as a result of the increase in current is leading to having increased amplitudes values while slope of the PPG signals remain constants. In other words, the pattern of the AC part for a subject remains the same under given medical and physical conditions. For different physical condition, the breathing pattern changes and so does the AC part of the resulting PPG.

Figure 4 shows the result of the practical circuit which was designed in the laboratory. The value of the coefficient of de-oxygenated hemoglobin, coefficient of oxygenated hemoglobin and *R* which is the ratio of the normalized ratio of the red to the infrared transmitted light intensity can be calculated by different techniques and varies from person to person depending upon the age, gender and many other factors [3]. The normal value of the oxygen concentration in a human body varies from 95% - 100 %. We apply these coefficients to calculate the oxygen concentration level [2].

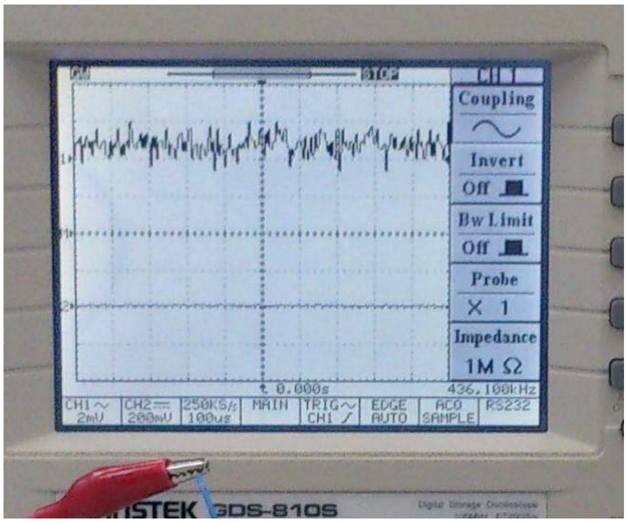

Figure 4. Practical Results

Table I: Oxygen Measurement Results

Component	Subject
DC level IR	3.89911
AC level IR	0.2614
DC level Red	3.71914
AC level Red	0.01059
Ratio	0.424771
Oxygen Level	94.44 %

Table I shows the oxygen measurement results. The oxygen level in this case is 94.44 % which shows a subject under normal physical and medical conditions of human body [4].

V. CONCLUSION

In this paper, a low cost pulse oximetry is designed which is able to determine the oxygen level in the body. The value of *R* can be determined by LAB VIEW [3], [5]. In this circuit, two LED's are used and in between the two LED's the subject's finger is placed. Usually we use little finger because the thickness is less as compared to the other fingers. The normal clinical value of the oxygen level lies in between 95% - 100%. This experiment can be applied on different number of subjects whether in rest or in motion. In some cases, the result might vary a bit from the normal pulse oximetry which is commercially available. This is due to the noise caused by the wires used in the circuit. Therefore, if manufactured on an advance level, this noise can be eradicated to get more accurate results.

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