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Non Invasive Haemoglobin Measurement Techniques-A Review

Pragya Gupta[1] and Nathi Ram Chauhan[2]

Department of Mechanical and Automation Engineering,
IGDTUW, Delhi-110006, India
E-mail: pragyakhandelwal1122@gmail.com

Abstract—*Haemoglobin (Hb) is a major component of red blood cells. The main function of Hb is to carry oxygen from the lungs to the body tissues and to carry carbon dioxide back to the lungs from the body tissues. Currently, invasive methods had been used to measure the Haemoglobin in blood, in which blood is ejected from a person and analysis is done by chemical method. There are various disadvantages of invasive method such as discomfort, risk of infection, requirement of skill person, time taking process. Thus, this technique does not allow real-time Haemoglobin reading to patient in acute situations. However, the non-invasive method allows pain free, real time monitoring. This paper presents a non-invasive technique that provides Hb concentration measurement.*

Keywords*: Haemoglobin, Photoplethysmography, oxyhemoglobin and deoxyhemoglobin*

1. INTRODUCTION

The two main components of haemoglobin are oxyhemoglobin and deoxyhemoglobin. It contains iron which is essential for the transport of oxygen and carbon-di-oxide. As it is a major component of the respiratory system, the continuous monitoring of the haemoglobin count is required for monitoring health of a patient, especially for new-born babies, patient suffering from polycythaemia/anaemia and pregnant women [1]. The red colour of blood is because of presence of Haemoglobin in Blood. If Haemoglobin level becomes very low than normal limit then the problem occurs such as anaemia and if its count is very high it causes polycythaemia. Several non-invasive methods have been used to estimate haemoglobin count in the blood. The basic principle of optical method is the analysis of light absorbance based on Beer-Lambert law. Other method is based on varying the conductivities of blood at different concentrations. Current methods of estimation of haemoglobin are all invasive and there are various disadvantages associated with it like chance of infection through the needle, requirement of a trained staff for extraction of blood, and mainly it is time taking process.With advancement in technology a number of non-invasive methods like transmission spectroscopy [2], reflection spectroscopy [3], imaging [4, 5] and opto-acoustic spectroscopy [6] have been utilized for the measurement of the haemoglobin count in blood. The photoplethysmography is optically obtained plethysmogramwhich illuminates the skin and measure changes in light absorption at the location of an extremity like finger, earlobe, toe etc. The photoplethysmography (PPG) output is basically a pulsating waveform which contains both AC and DC parts. The pulsating AC part is because of the variation of volume of blood during the systolic and diastolic state. The DC part is because of respiration, attenuation by epidermis, skin, tissue, bone, and thermoregulation [7]. During the systole, the blood flows from the lungs to the other parts of the body. Hence because of this, the arteries expand and amount of blood flowing through it increases. On other hand, during diastole, the blood flows from the body to lungs. And thereby during this process, as the size of arteries decreases, volume of blood also decreases. This change in the volume of blood is the characteristic of PPG waveform. The principle of estimation of haemoglobin is due the PPG signals formed because of the differential absorption of oxyhemoglobin and deoxyhemoglobin at different wavelengths, i.e., at red and infrared illumination.

2. SYSTEM OVERVIEW

The non-invasive continuous haemoglobin measurement is based on photoplethysmography technique, and system is described below:

2.1 Schematic Diagram

Fig.1 shows the schematic diagram which is used for the measurement of Haemoglobin count in blood by non-invasive PPG technique.

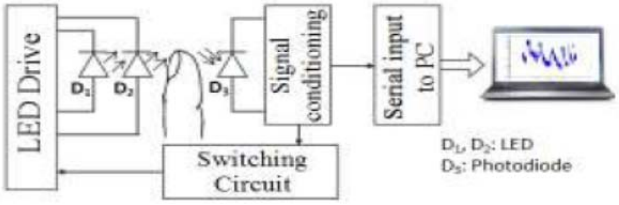

Fig. 1: Schematic Diagram of the non-invasive system

The optical source (LED/LASER)is allowed to transmit through the patient at an extremity like the finger. It consists of two lightemitting diodes (D_1 and D_2) on one side, and also an optical receiver photodiode on the other side. The LED D_1 transmits light at a wavelength λ_1 and LED D_2 transmits light at wavelength λ_2. The optical sensitivity of a photodiode is chosen such that it includesboth $\lambda_1$and λ_2. A switching circuit has been used to time multiplex, i.e., alternatively switch ON and OFF the LED such that only one LED is ON at a time and also demultiplexion has been done so that the photodiode output could be obtained as PPG1 and PPG2 signals corresponding to λ_1 and λ_2[7]. The PPG signals are extracted and fed to a computer system to perform further analysis. The light illumination is obtained by using a red light emitting diode operating at 660nm and infraredlight emitting diode operating at 950nm. Then, the demultiplexed output from the photodiode is allowed to send to a signal conditioning circuit which consists of a trans-impedance amplifier. The two signals thus obtained are given to abandpass filter. The DC parts are removed by using subtractors using two op-amps.The result obtained from this is the pulsating signal corresponding to red and infrared wavelength. The LEDs could be driven using a power supply circuit and the intensity of the LEDs could be adjusted using a potentiometer.The detector part consists of a photodiode connected to a logarithmic amplifier. The objective of this circuit is to convert the current generated by the photons incident on the photodetector into a voltage waveform. The controlsignals could be used to perform the multiplexing operation. When red LED is used, the connection is given to bandpass filter1 and when infrared LED is used, the connection is given to bandpass filter2. This switching technique is such that either red LED or infrared LED is ON alternatively [10]. The switching signal could be used to multiplex and switch ON the LEDs as shown in Fig.2.

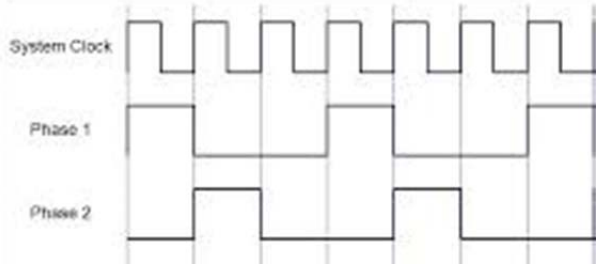

Fig. 2: Control signal used to switch the LEDs ON and OFF

An electrical signal consist of both AC and DC components. The time multiplexed signals differentiates between the absorbance of light because of blood flowing through veins (DC part) and that due to the fluctuating component of the total absorbance (AC part). As the photodetector receives the remaining light, it converts it into electrical signals which consist of both AC and DC components. The direct component presents in electrical signal demonstrate the transmission of light through that part of body which are not pulsating such as bone, skin and veins. Whereas an alternating components present in an electrical signal demonstrates transmission of light through those body part which are pulsating such as arteries and capillaries. But, the challenging task here is to maintain the light intensity of LED constant as both the AC and DC components will be affected by varying intensity of LED. Thus another circuit for maintain constant LED light intensity must be present in a system. Also, the choice of operating wavelength of LED is very critical, as chosen wavelength of light must be absorbed by the haemoglobin present in blood. Thus wavelength of 660nm and 940nm is a great choice as it is strongly absorbed by Hb and HbO_2 respectively.

2.2 Sensor Design

The non-invasive haemoglobin measurement system consists of a various hardware components, which includes:

(a) Light source (LED/LASER)
(b) Constant Light intensity circuit
(c) Photodiode/Trans-impedance amplifier
(d) Microcontroller
(e) LCD/LED Display

Fig. 3 is a schematic representation of non-invasive haemoglobin measurement method.

2.2.1 Light Source

The Haemoglobin measurement system consists of an two LED's as an optical source having wavelength of 660nm and 940nm. The reason for selecting these wavelengths is because at a 660nm wavelength absorbance by haemoglobin is maximum whereas at 900nm wavelength absorbance by oxyhaemoglobin is maximum. Thus two LED's has been installed in the circuit so that both, oxyhaemoglobin and reduced haemoglobin could absorb maximum light. These LEDs have been installed in the upper part of a finger clip. It has also been observed that LASER could also be used as a light source instead of LED.

2.2.2. Constant Light intensity circuit

If intensity of LED varies light absorbance by haemoglobin and oxyhaemoglobin varies, and hence the result would show an error. Thus to maintain constant intensity of Light, constant light intensity circuit is used. It will drive the LED and maintain constant intensity of Light.

2.2.3. Photodiode/Trans-impedance amplifier

Trans-impedance amplifier is a current to voltage converter. It is required as output of a photodiode is a current, and it must be converted to voltage for further processing. In this system OPT101 photodiode amplifier has been used as detector. The transmitted light has been received by OPT101 photodiode. As the light intensity of LED increases output voltage of photodiode also increases linearly. There are various

advantages of using OPT101 photodiode - suitable for battery operated device, suitable for both wavelengths, integration of photodiode and trans-impedance amplifier reduces size of the system, reduces leakage current, noise due to stray capacitance etc.

2.2.4. Microcontroller

The role of microcontroller is very crucial as it has been used to do time multiplexing of light sources. It has also been used to do the calculation part. To convert the analog signal into digital signals microcontroller has been used so that it can be interfaced with any common LED/LCD display.

2.2.5. LED/LCD Display

Display is required to have a graphical user interface. A 16x2 LCD is generally used for this system.

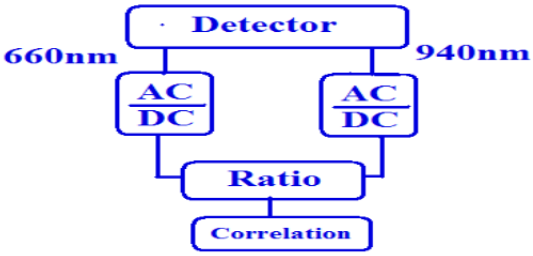

Fig. 3: Block diagram representation of haemoglobin measurement sensor system

3. MATHEMATICAL ANALYSIS:

Beer-Lambert's law has been used to analyse the absorption of light in blood. This law is given by the following equation:

$$D = Log\left(\frac{I_0}{I}\right) = \alpha cL \quad (1)$$

Where D is the optical density, I_0 is the intensity of light coming out from the finger, I is the transmitted light intensity, α is the molar extinction coefficient of haemoglobin present in blood, c is the concentration of haemoglobin (in gm/dL) , and L is the length of light path or thickness of human finger. As the sample contains both oxygenated and deoxygenated haemoglobin, equation (1) can be further expanded as,

$$OD^{\lambda} = \{\alpha_{Hb}^{\lambda}[Hb] + \alpha_{Hb0_2}^{\lambda}[Hb0_2]\}L \quad (2)$$

Where OD^{λ} is the optical density or absorbance at wavelength λ and $\{\alpha_{Hb}^{\lambda}[Hb]$, $\alpha_{Hb0_2}^{\lambda}[Hb0_2]$ are the extinction coefficients at wavelength for molar concentrations of deoxygenated haemoglobin, [Hb], and oxygenated haemoglobin, [HbO2], respectively. Let, length of light path L is 0.9 cm. Both [Hb] and [HbO2] can be estimated by calculating the light absorbance at the two different wavelengths.

4. RESULTS

The graph between chemically measured haemoglobin count and Non- invasively calculated AC/DC ratio of 660nm and 940nm is plotted. The plotted graph for 660 nm and 940nm is shown in Fig 4.

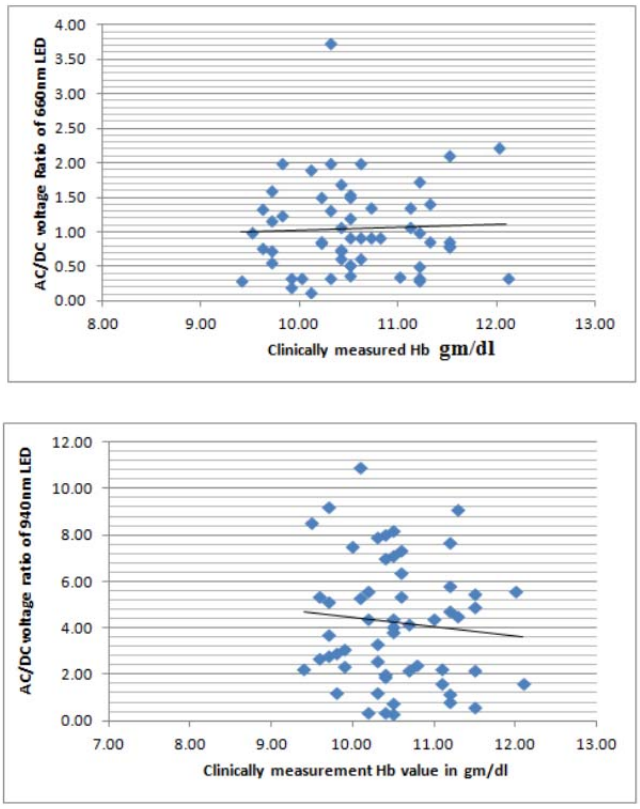

Fig. 4: Plot of chemically measured Hb vs. AC/DC ratio of 660nm, and 940nm

The AC/DC ratio of 660nm to that of 940nm has been compared to chemically measured Haemoglobin value as shown in Fig.5.

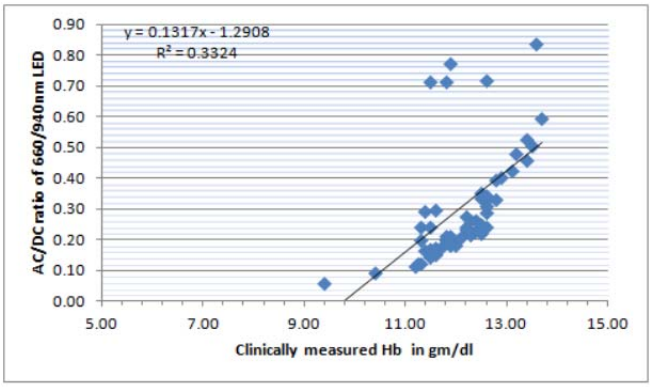

Fig. 5: Graph of chemically measured Hb vs.AC/DC ratio of 660nm/940nm LED

5. CONCLUSION

A non-invasive haemoglobin sensor system has been developed for estimation of haemoglobin count in blood. The whole system uses two different light source, photodiode, microcontroller and display. Thus system design and hardware implementation has been found as simple and no special skilled manpower is required. Various estimations has been done and results has been compared which clinically observed value. It has been found that non-invasive method of measuring Haemoglobin offers a fast, accurate and reliable readings.

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