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Non-Invasive Hemoglobin Measurement System Using Optical Sensor

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ABSTRACT-The hemoglobin (Hb) concentration in human blood is an important parameter to evaluate the physiological condition. Currently invasive methods are used to measure (Hb) concentration for this purpose blood is taken and analysed. The disadvantage of this method is the delay between the blood collection and its analysis which does not allow a real time patient monitoring in critical situations. This paper proposes a low cost method for the estimation of hemoglobin concentration using Photo-plethesmography (PPG) technique. The proposed method can be used for health monitoring purposes in rural areas.

KEYWORDS*:* Photoplesthysmograph (PPG), Beer Lambert's law, Non-invasive hemoglobin concentration, Reflection Spectroscopy

I. INTRODUCTION

In recent studies it is discovered that more than 40% of Indian people were diagnosed with anemia. And also in the study conducted in America it is discovered that Anemia, high hemoglobin levels can increase risk of developing dementia.

So there is a need for non-invasive measurements as invasive or a pinprick method is uncomfortable. In the perioperative area, the period before and after surgery, it is essential to measure diagnostic parameters such as oxygen saturation, hemoglobin (Hb) concentration and pulse. The Hb concentration in human blood is an important parameter to evaluate the physiological condition. By determining the Hemoglobin concentration it is possible to observe imminent postoperative bleeding and autologous retransfusions.

The level of hemoglobin is expressed in grams per decilitre (g/dl). Normal ranges for new-borns are 17 to 22 gm/dl, for children it is 11 to 13 gm/dl. For adult males it ranges between 14 to 18 gm/dl, and for adult women it ranges between 12 to 16 gm/dl.

Low hemoglobin levels may be a sign of Anemia, Thalassemia, Iron deficiency, Liver disease and cancer. High hemoglobin levels may be a sign of Lung disease, Heart disease, Polycythemia. So it is important to measure hemoglobin concentration non-invasively. Non-invasive measurement methods reduce discomfort to the patient, infections, time required for measurement and helps improve faster diagnosis.

Photoplethysmograph (PPG) can be acquired as light absorbance changes in tissue during cardiac cycle and this can be related to mass of the hemoglobin. For PPG, we use light of wavelength 530.PPG is a simple, low cost reliable optical technique that can be used to detect blood parameters by passing electromagnetic light rays through the skin. The information about blood parameters is obtained non-invasively in contrast to the painful and inconvenient

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invasive methods, with measurements generally made at the skin surface where upon it is easy to record data. During the process, changes in volume caused by blood pressure pulse is detected by illuminating the skin using a light emitting diode (LED) and measuring the amount of the light either transmitted or reflected through a light detector. The output signal from the light detector is processed by signal processing unit and it will give as an input to microcontroller for measurement of haemoglobin concentration.

II. METHODOLOGY

A. Basic Principle

There are many methods involved when it comes to using non-invasive technique. In this paper reflection spectroscopy method is used [4] [5].

The relation between the absorption of light and the material property through which light transmitted is given by Beer Lambert's law [4] [9]. This principle is used to estimate hemoglobin level in this work. According to this law

$$T = I/Io = 10^{-\varepsilon cl} \quad \text{..... [Eq. 1]}$$

$$A = E*c*l = log\ (T) \quad \text{..... [Eq.2]}$$

Where ***T*** is transmittance, ***A*** is absorbance, ***I*** is the intensity of light transmitted through the material, ***Io*** is the intensity of light incident on the material, ***l*** is the length through which light travels inside the material (***l*** = 0.6 cm), ***c*** is the concentration and ***E*** is the molar absorptivity of the material. The reflected light is then monitored, and the input voltage (*Vin)* and the incident and reflected intensities respectively because of their linear dependence on the same [7].

$$\frac{Vin - Vout}{Vin} = 10\text{-}Ecl \quad \text{..... [Eq.3]}$$

B. Block Diagram and Algorithm

The simple block diagram shown in Fig.1 shows the implementation of how the blood components is monitored using a microcontroller [4] [7].

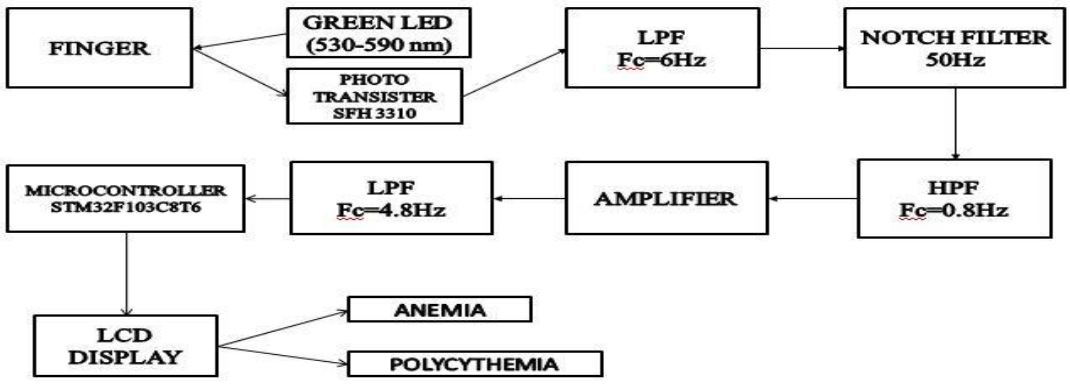

Fig.1 Block diagram of proposed system

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The system consists of a sensor which is placed on the subject's finger. Sensor is used to get information about of mass of hemoglobin present in the blood. Sensor has a pair of photo source and photo detector. Output voltage changes in accordance with the absorbance of light with tissue [2]. As PPG waveform can be divided in to AC and DC part [6], only AC part is considered for the measurement of hemoglobin concentration to achieve Individual discrepancy in the measurement i.e. elimination of errors due to individual's skin pigmentation etc. The peak voltageof AC part of PPG [9] waveform during a cardiac cycle represents the mass of hemoglobin.

The signal acquisition block for PPG [8] consists of a photo detector and LED (green) [1]. Signal acquired here is passed through a low pass filter with a centre frequency of 6 Hz. This eliminates the high frequency noises in the circuit. The notch filter removes the 50 Hz power line interferences. High pass filter of centre frequency 0.8 Hz removes low frequency noise. This is then passed through an amplifier to amplify the signal with the gain 31. The low pass filter with 4.8 Hz centre frequency eliminates the high frequency noise.

The output of the low pass filter signal is converted as digital signal by the Analog to Digital converter (ADC) which is inbuilt in microcontroller. These values will be given to the microcontroller for the measurement of hemoglobin concentration.

In this project we are using microcontroller STM32F103C8T6. It is compact in size and programmed using Arduino IDE and uploads the program using USB cable. This microcontroller processes the digital values and provides corresponding hemoglobin concentration. By using this concentration values we can diagnose anemia and polycythemia conditions.

C. Circuit Analysis

The output from the sensor is a periodic physiological waveform attributed to small variations in the reflected green light and it is caused by the pulsing blood volume inside the finger. The waveform is synchronous with the concentration of hemoglobin.

The output of photo detector is a weak signal. It contains a lot of noises superimposed on the AC signal which is then filtered through a series of signal processing circuits using Op-Amp LM324N.To get rid of the DC component and high frequency noise, the combination of both HPF and LPF as shown in Fig.2 are used. The cut-off frequency of the low pass filter is represented through

$$\text{Cut-off Freq.} = 1/ (2\pi R*C) \quad \text{..... [Eq.4]}$$

The cut-off frequency of the low pass filter is set to 4.8 Hz. The gain of the signal conditioning filter is represented by

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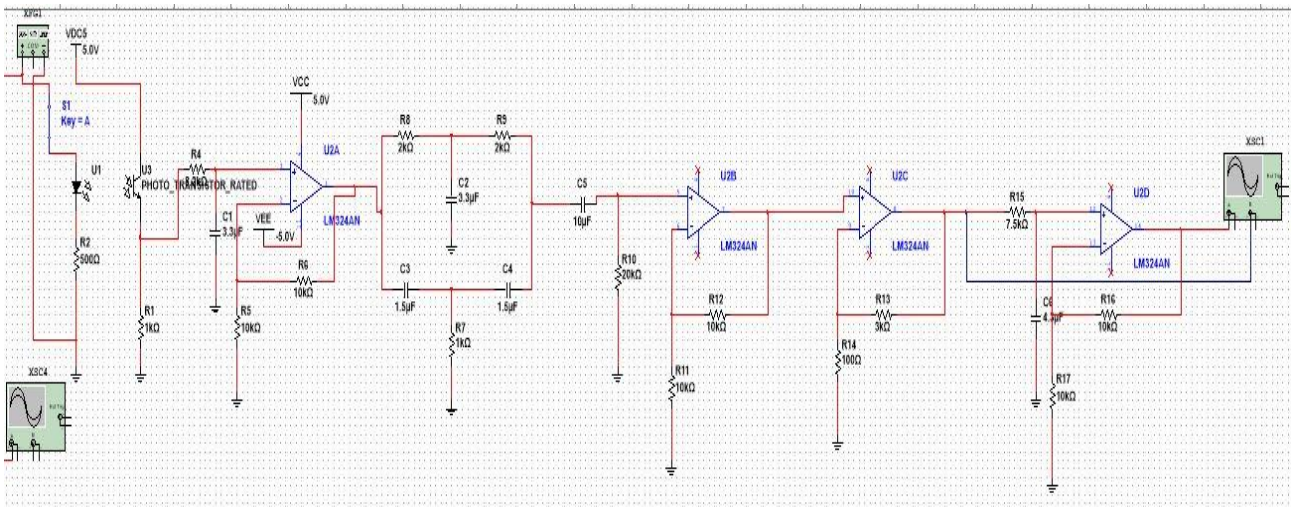

Fig.2 Signal conditioning circuit

Gain at each stage=1+ (Rf/Cf) ..... [Eq.5]

These three stages of filtering and amplification [3] convert the input signal into pulses which are synchronous with the fingertip signal.

III. RESULTS AND DISCUSSIONS

In this project, the input voltage and output voltage of the sensor are used as parameters to the Beer Lambert's Law, both are measured via the microcontroller, and the mean values of the measurement are taken for calculation. The input voltage (Vin) and output of reflected light is taken as substitutes for the incident and reflected intensities respectively due to their linear dependence on the same. Thus, using Eq.3, hemoglobin concentration is estimated.

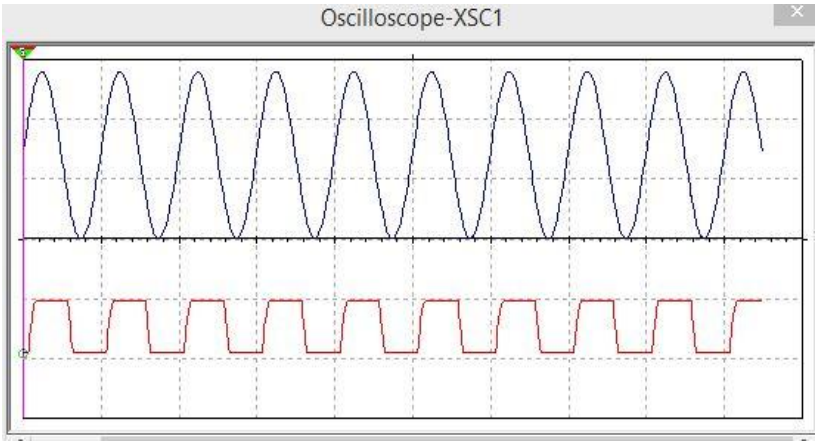

Fig.3 Output of signal conditioning circuit at 2 Hz

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In the above figure (3) the output of signal conditioning circuit is given when the input signal had a 2 Hz Frequency. The output signal is a wide pulse width signal.

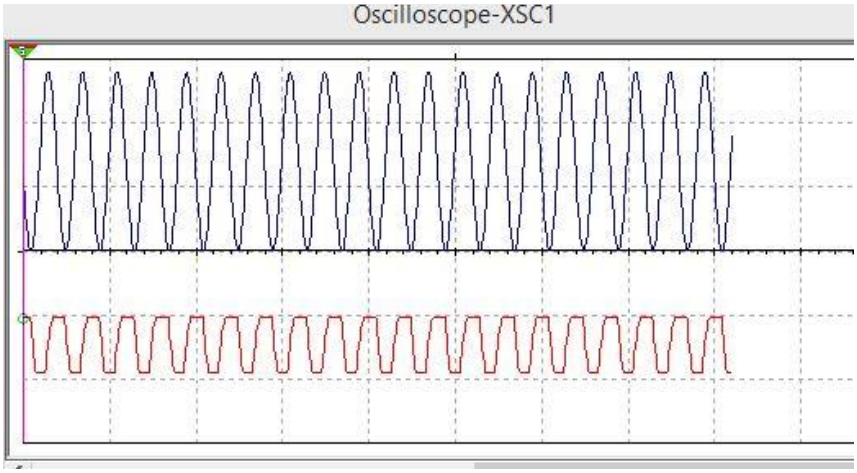

Fig.4 Output of signal conditioning circuit at 5 Hz

In the above figure (4) the output of signal conditioning circuit is given when the input signal had a 5 Hz Frequency. The output signal is a narrow pulse width signal.

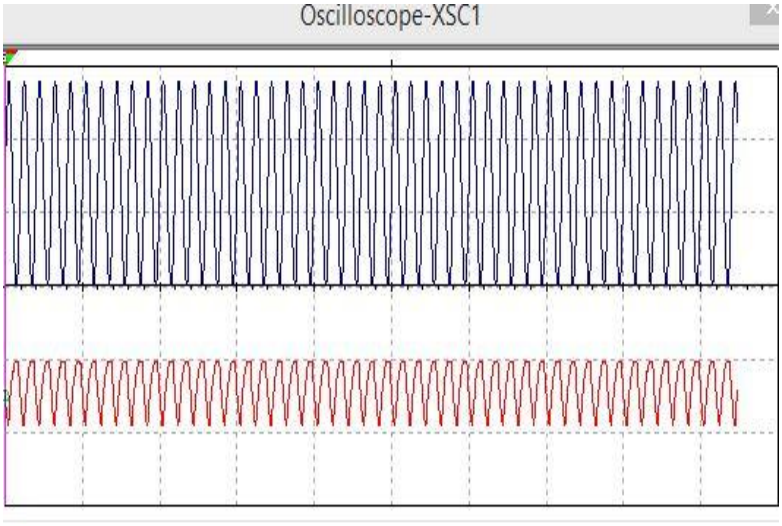

Fig.5 Output of signal conditioning circuit at 10 Hz

In the above figure (5) the output of signal conditioning circuit is given when input signal had a 10 Hz Frequency. The output signal is a narrow pulse width signal.

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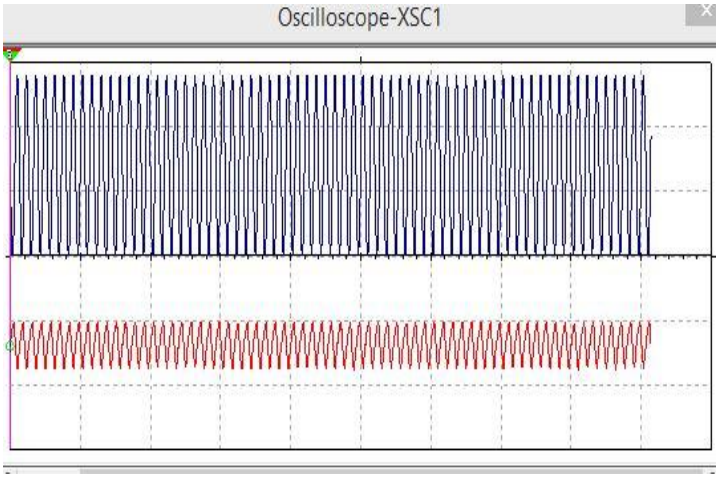

Fig.6 Output of signal conditioning circuit at 15 Hz

In the above figure (6) the output of signal conditioning circuit is given when input signal had a 15 Hz Frequency. The output signal is a narrow pulse width signal.

In above figures there is a variation in output as per change in frequency of input signal is given. Using these results we can determine that if frequency increases there is a change in hemoglobin concentration. The future work includes design portable measurement system for other blood components.

IV. ACKNOWLEDGEMENT

Apart from the efforts of us, the success of this project depends largely on the encouragement and guidelines of others. We take this opportunity to express our gratitude to the people who have been instrumental in the successful completion of this project.

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