EMBEDDED SYSTEM BASED NON INVASIVE DEVICE DEVELOPMENT FOR HEMOGLOBIN ESTIMATION

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Abstract- Hemoglobin is an important parameter in the human blood, the deficiency of which leads to anemia. To reduce the complications due to anemia, Hb level needs to be measured. There are mainly two categories namely, invasive methods and non-invasive methods. The invasive method requires painful needle stick to draw a blood sample. Then it is sent to a laboratory for analysis, with results reported back to the physician later, potentially resulting in diagnosis and treatment delay. A non-invasive method allows pain free online patient monitoring system with minimum risk of infection. This paper proposes an optical non-invasive technique for Hb concentration measurement. The system based on single wavelength spectrophotometry. In this system the optical absorption characteristics of oxygenated and deoxygenated haemoglobin are analysed. The light form different wave length LEDs(700nm&805nm) are transmitted through finger and detected by photodiode. The received electrical signal is converted in to digital code and compared with the Hb value measured through conventional laboratory method. The result for one particular wave length (700nm) shows more correlation with clinically measured Hb value.

Keywords- Hemoglobin, Non-Invasive, Spectrophotometry, Optical Method.

I. INTRODUCTION

One of the constituents of blood plasma, red blood cells encompasses a metallic protein compound referred as Hemoglobin (Hb) [1]. The structure of Hb resembles quaternary structure, an edifice of four compounds with substantial presence of Oxy Hb and Deoxy Hb. The oxygen transportation of from alveoli of lungs to the body cells, and of carbon dioxide from body cells back to the alveoli is expedited by this component. The red blood cells count deficiency in blood diminishes its oxygen-carrying capacity and referred as Anemia. This vivacious property highlights the undeniable significance associated with continuous assessment of Hb specifically for pregnant women, individuals, anemic patients and newborn babies primarily to evaluate the presence of anemia or the requirement for blood transfusion. A stable Hb is obtained in the diluent samples by breaking red blood cells through hemolysis process resulting dissolution of internal Hb [2].Contemporary tools to assess hemoglobin in blood entails invasive method, in which the blood sample is collected from the subject by perforating the finger of the same. The popularity of this technique is predominant and extensively employed across the world. The blood sample collection method uses needles resulting direct contact with the blood and it opens up ample scope for infection. A non-sterilized external environment includes multiple utility of the same needle, ambient temperature; inexperienced technicians escalate the possibility of inflicting infection on the subjects under assessment. The usage of superior chemicals, testing equipment and trained technicians may downsize the amount of infection wreaked on the subjects [1]. The modern enhancement of assessment systems facilitates non-invasive Hb measurement schemes offers reassuring opportunity for subjects in the emergency intensive care units [3, 4]. A method referred as pulse oximetry empowers non-invasive techniques to exhibit painless and relatively efficient Hb measurement. The necessity for appraisal of Hb count led to gamut of non-invasive measurement schemes including imaging[5],spectro-photometry[6],opto-acoustic spectroscopy[7,8], transmission spectroscopy[9,10].An additional cluster of schemes under spectrophotometry includes single-wavelength photometry, dual-wavelength spectrophotometry and derivative spectrophotometry[11]. To address the constraints identified in the existing systems this paper presents a novel Hb state measurement system implemented on Embedded technology and utilizes single wavelength spectrophotometry.

The proposition of Hb measurement scheme can be efficiently realized by exploiting single-wavelength spectrophotometry. It is found that HbO_2 and Hb have different absorption characteristics. The absorption, transmission and scattering of light by Hb products are wavelength dependent. The variation of molar extinction coefficient of light by Hb products with wavelength is given in fig 1. Molar extinction coefficient can be converted into absorption coefficient simply by multiplying the same by 2.303. The most noticeable differences between absorption spectrum of HbO_2 and Hb are found between 550 to 800 nm. This phenomenon led to the development of oximetry based on the differential light absorption of oxygenated and deoxygenated blood. Human skin is characterized by variable concentration of melanin. Melanin and hemoglobin strongly absorb light in the ultraviolet (UV) and visible ranges and they present low absorption in the near-infrared range. Almost complete absorption of light takes place up to a

wavelength of 550 nm by HbO_2 and up to a wavelength of 700 nm by Hb. The light absorption is the minimum at the wavelength of 603 nm for HbO_2. Hb and HbO_2 absorb equal quantity of light at the wavelength (isosbestic) of 805 nm. These optical features are used in the estimationof Hb using light sources

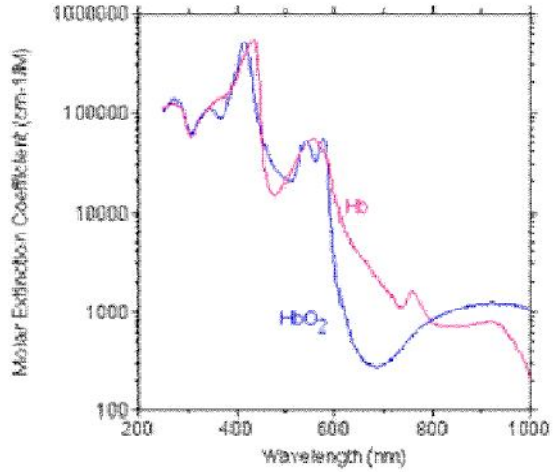

Fig. 1. Molar Extinction Coefficient Of Light By Hb Products With Wavelength

Single wavelength spectrophotometry based Hb measurements schemes are founded on application of Lambert-beer law's statement [12]. The law relates light intensity incident on blood and the absorption and scattering coefficients as described in Equation 1.

$$KL[C_0] = \log\frac{I_{in}}{I_o} + A_{SO} \quad \text{-------} \quad (1)$$

The law can also be applied to light intensity incident on benchmark diluent and the absorption and scattering and absorption coefficients as described in Equation 2

$$KL[C_1] = \log\frac{I_{in}}{I_o} + A_{S1} \text{------} \quad (2)$$

Eq. (3) can be obtained by subtracting Eq. (1) from Eq. (2)

$$C_1 = \frac{1}{KL}\log\frac{I_{in}}{I_o} + \frac{1}{KL}(A_{S1} - A_{SO}) \text{-------} \quad (3)$$

Eq. (4) can be formed by reframing Eq. (3),

$$C_1 = \frac{1}{KL}\log\frac{I_{in}}{I_o} \text{-------} \quad (4)$$

Where I_{in}= incident light intensity
I_0 = emission intensity
A_{SO} = Absorption and scattering
K = Absorptivity
L=Thickness

Observing from a standard area, the Hb concentration in blood defines the amount of light energy that is received from the fingertip. So, the Hb concentration that is specified here is the combination of concentrations of HbO_2 and Hb as the blood is expected to have both the forms at the capillaries where we measure. Taking a cross-section of fingertip, the concentrations of HbO_2 and Hb play a role in the amount of light transmitted for a specific amount of light irradiated to the surface. Based on the optical characteristics described earlier, light sources at wavelengths of 700 nm, and 805 nm are chosen. The strength of the transmitted light is measured as a voltage current. After detection.

Irrespective of the wavelength approximately 5 to 7% of the incident light on the skin is reflected back to the environment. At the wavelength of 741 nm, a portion of the light that has penetrated the skin is scattered and a portion of it is absorbed. The absorption level is decided by the extent of population of Hb in blood. So, the strength of the transmitted light gives an indication of the amount of total Hb (reduced and oxygenated Hb) present in blood

II. BLOCK DIAGRAM

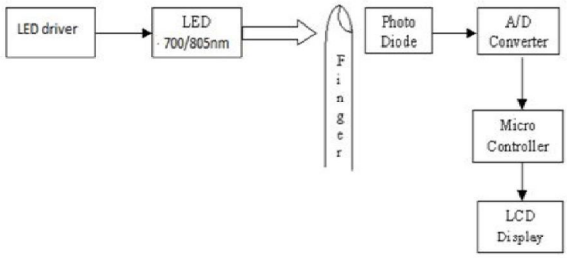

Fig.2. Block Diagram Of Optical Measuring Setup

Fig 2 shows the block diagram of the entire system. The device consists of two LEDs of different wave lengths- 700nm and 805 nm. These wave lengths are selected in particular because it is at these wavelengths that the spectral absorptivity of haemoglobin and oxy-hemoglobin is considerable. The LEDs are derived with transistor driver circuit. The light form the LED made to pass through the finger. The light that gets partially transmitted through blood is received on a photo diode. The output of the photodiode is sent to current - voltage converter, and then it is coupled with Analog to Digital converter. The output of ADC is given to microcontroller for processing. The out is displayed through LCD display.

III. DESIGN AND IMPLIMENTATION

3.1 Transmitter Side

The transmitter side consists of the LED wit Transistor driver, Photo diode and current-voltage converter as shown in the fig 3

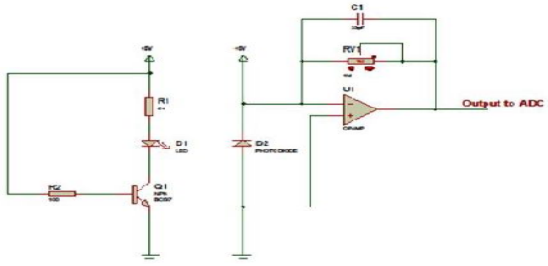

Fig.3. Transmitter Side Circuit Diagram

Since it is single wavelength spectrophotometry one LED used at a time. The 700nm LED capable of radiating the power up to 3.5mW with maximum forwarded voltage (V_f) of 2.3V and forward current (I_f) of 20mA. The 805nm LED capable of radiating the power up to 6.5mW with maximum forwarded voltage (V_f) of 1.93V and forward current (I_f) of 50mA.The transmitted light through blood is detected using the photo detector (SD-7BA). It has the sensitivity range from 320-1150nm and peak sensitivity of 870nm. It is operated at the reverse voltage of 20V and short circuit current of 6.5µA.Both the LED and PD assembled in a pulseoxmetry probe. The output of the detector is given to the current to voltage converter. When LED (805nm) is directly exposed, the decimal value is 1532874. From this we can find the input current to the OpAmp.

Input voltage to ADC = 1532874 * step size
= 1532874 * 2.38 uV = 3.6 V

So the input current to the converter
= 3.6 V / 1 M ohm = 3.6 u A.

3.2 Processor Side

The processor side consists of Analog to digital converter, Microcontroller and LCD display as shown in the fig.4.Here low power, single-cannel, 22-bit delta-sigma ADC(**MCP3551)** is used. It has the reference voltage of 5 Volts.Internally ADC divides the reference voltage by 2. So it uses 21 bit for data and last bit is to represent the over flow.

Step size= full scale / 2^n (n= number of bits (21 bits))
= (5 – 0) / 2097151= 2.38 µV

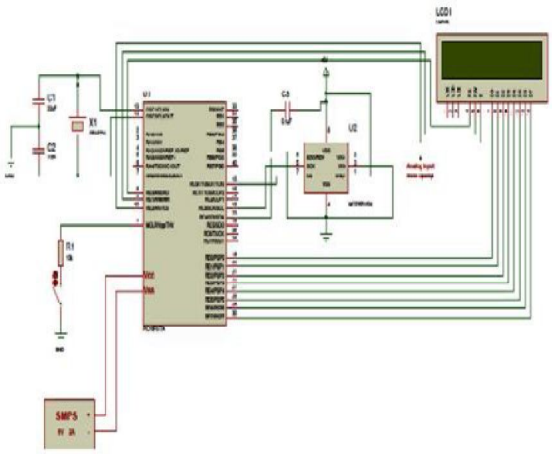

Fig.4. Processor Side Circuit Diagram

IV. RESULTS AND DISCUSSION

Experiments have been carried out with the device being developed at hospital site. The population has different aged and various diseased persons.Their Hb is measured using the standard HPC machine at first. The information is recorded, and then the optical setup is used to measure the Hb level. Experiment is conducted with both 700nm and 805nm LEDs separately. The output of the detector reflects the concentration of Hb value in blood. If more Hb value then less output from detector and less Hb value then high output from detector. The plot between clinically recorded Hb value and observed readings from photo detector for both 700nm and 805nm sources are shown in Fig 5 & Fig 6.The clinically recorded Hb value(mg/dl) taken in X-axis and the optical device readings(digital values) are taken in Y-axis. The nonlinearity observed in both the plots is influenced by various factors like age, gender, different disease and thickness of the finger. By comparing with the plot for 805nm source, the plot for 700nm source shows less non linearity.

CONCLUSIONS

This paper proposes an embedded system based noninvasive device for estimation of hemoglobin in blood. By comparing the readings for both 700nm and 805nm light sources, the output for 700nm shows more linearity than the other one. Also it is observed that the thickness of the finger plays a role on the amount of light transmitted through finger. So it is decided to proceed further with 700nm light source. The final device that has been developed is small in size which considering all the observed factors. The device does not require any operational expertise; it can be used by anybody and everywhere. The work is going on for calibrating the device.

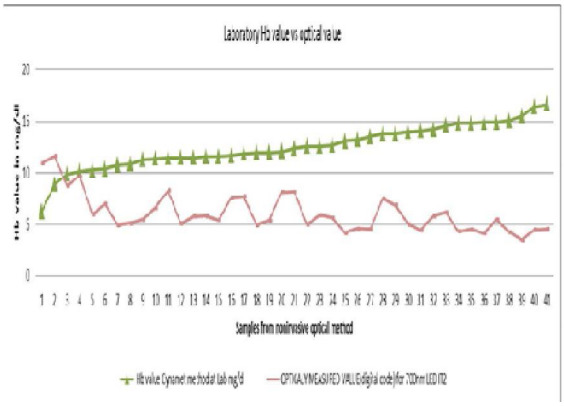

Fig.5. Plot Between Clinically Recorded Hb Value And Detector Output For 700nm Source.

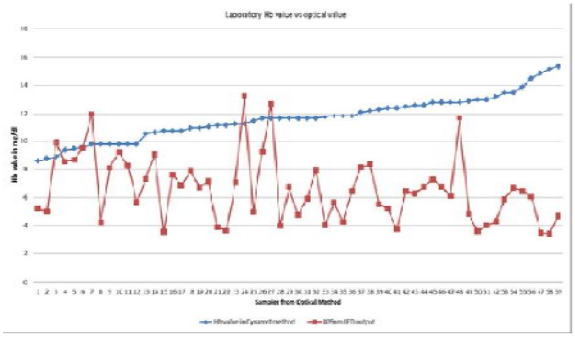

Fig.5. Plot Between Clinically Recorded Hb Value And Detector Output For 805nm Source.

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