IoT Based Dual wavelength Non-Invasive Haemoglobin Sensor System

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Abstract: Haemoglobin is main constituent for characterizing the physiological conditions of a body. For pregnant ladies, haemoglobin is the main factor for prevention of risk factors caused due to anaemia and polycythemia vera. This will used during pre screening test for donating blood and to obtain complete blood count. Hb is calculated from invasive technique in which blood samples are taken using needle which causes pain and discomfort, delay is more in analysing and to receive results, it doesn’t allow real time monitoring. But an non-invasive test enable painless and obtain real time monitoring. Red and IR LED are passed through the finger, according to the amount of light absorbed by the tissue, remaining transmitted light detected by a photodiode, the haemoglobin levels i.e. Hbo2 and HHb can obtained by interpreting the ratio of red to IR. This method allows pain free online patient monitoring with minimum risk of infection and facilitates real time data monitoring allowing immediate clinical reaction to the measured data.

Keywords: Haemoglobin, LED sensors, NODEMUC, PC display, dual wavelength plethysmography.

1. INTRODUCTION

Haemoglobin is the iron-containing protein molecule in red blood cells that carries oxygen from the lungs to the body's tissues and returns carbon dioxide from the tissues back to the lungs. There are mainly two different types of haemoglobin present in the blood i.e. Oxygenated haemoglobin and de-oxygenated haemoglobin. Hbo2 is nothing but when oxygen binds to the heme component of the protein haemoglobin in red blood cells molecule whereas for HHb it is not attached. Measuring of Hb is essential for all
individuals, especially in pregnant ladies, because the low levels leads to anaemia and high levels of haemoglobin leads to polycythemia. The normal haemoglobin range for men is 13.5 to 17.5 and for women 12.0 to 15.5 gm/dl. There are two different ways to measure Hb, one way is invasive and the other is Non-invasive methods. Invasive techniques are Hemocue, Cynameth, copper sulphate gravimetric method. In Cynameth method, blood is mixed with potassium cyanide, potassium ferri cyanide and drabkin solution then haemoglobin converts to cynameth haemoglobin, when a light is passed through that solution some amount of light is absorbed[4,5], that absorbance is compared with that of the standard haemoglobin cyanide solution by using a formula to obtain the amount of haemoglobin, but for this ejection of blood is required. Another way to calculate is Non invasive e.g. spectro photometry, opto-acoustic and transmission spectroscopy. These methods are based on spectrophotometry and beer lambert’s law. Spectrophotometry is a method to measure how much a chemical substance absorbs light by measuring the intensity of light as a beam of light passes through sample solution. The principle of Beer-Lambert’s law which states that absorption is directly proportional to absorbent and density of the absorbent of an object. Different types of spectrophotometry includes single Wavelength and dual wavelength spectro photometry, multiple spectro photometry. The design uses dual wavelength spectro photometry[6,8].

2. EXISTING INVASIVE METHOD

In invasive techniques hematology analyzers are used to predict haemoglobin in which cells are passed in single stream they are struck by laser which gets scattered. The light scatter at different angles i.e. between 10 and 70 deg is used by VCS instruments. The scattered light gives information about cell surface and granularity [13]. Based on the degree of light scatter, the analyzer obtain a measure of the average haemoglobin content but these analyzers are very costly and patient feel discomfort during ejection of blood.

![Fig a: Hb measurement taken on a blood flow model](image.png)

3. EXISTING NON-INVASIVE METHOD

The recent studies by Ranganathan proposed a Single wavelength spectrophotometry to calculate the HB. It is found that Hbo2 and Hb have different absorption characteristics. The absorption transmission and scattering of light by Hb products are wavelength dependent the light absorption is minimum at wavelength 603 nm for Hbo2, HB and Hbo2 absorbs equal amount of light at 805 nm.
which is isosbestic point[10]. These optical features are used in the estimation of Hb using Light sources. By using Beer-Lambert’s[4] law principle

\[
OD = ecl = \frac{\text{OUTPUT VOLTAGE}}{\text{TRANSMITTED VOLTAGE}}
\]

OD-optical density,
I₀-light intensity of incident light,
I-intensity if transmitted light,
e-extinction coefficient of haemoglobin
c-concentration
L-length of light path.

Haemoglobin concentration is calculated. By comparing the readings for both 700nm and 805nm light sources, the output of 700nm shows more linearity than the other one. Also it is observed that thickness of the finger plays a role on the amount of light transmitted through finger. In design part, SD-7BA photodiode range of 320-1150nm is used which has peak sensitivity at 805nm, microcontroller Mcp3551 that uses low power, has single channel, 22-bit delta sigma ADC which is used for conversion from analog ppg signal to the value of Hb[1].

4. PROPOSED NON INVASIVE METHOD

Design system uses dual wavelength spectrophotometry and Beer-Lambert’s law principle. The developed haemoglobin sensor system consist of a number of hardware modules, which include appropriate light sources, constant light intensity circuit, power amplifier, NODEMCU, and PC. The sensor consist of emitter as LEDs, with centre wavelengths of = 660nm, = 940nm. These two wavelengths are selected because at 660 nm wavelength absorbance of de-oxy haemoglobin greatly exceeds the absorbance of oxy-haemoglobin where as at 960nm wavelength absorbance of oxy-haemoglobin greatly exceeds the absorbance of de-oxy haemoglobin (figure 1). These LEDs are installed in the upper shell of a finger clip. And single receiver photodiode is installed in the lower shell of the finger clip. The probe is placed to the patient’s body usually on the finger. Red and infrared light is then emitted sequentially through the body tissue. Some light is absorbed by the tissue and remaining light is transmitted which is sensed by photodiode. Output voltage of photodiode increases linearly with light intensity and vice versa.[2]

To operate Led’s sequentially a H-bridge circuit is used which consists of two p-n-p and two n-p-n transistors. The output waves that are obtained from the Led’s are to be filtered to remove the DC component signal due to bones, tissues, skin. The two AC signals are to be ratio

\[
\text{Ratio} = \frac{ac \text{ voltage(red LED)}}{ac \text{ voltage(IR LED)}}
\]

the received ratio is to be calibrated for the resulted Haemoglobin value. To digitalise this analog signal 40 pin Arduino NODEMCU is used which is having inbuilt ten bit analog to digital converter. The software for NODEMCU is used to timely operate the LED’s and also for calibration. The
nodemcu has inbuilt wifi module which makes it most suitable because the results of Hb are shown directly in a website so, that in an emergency, doctor can know the patient condition from far distant place.[3]

Fig 1 depicts the absorption spectra of oxy haemoglobin and deoxy haemoglobin, at different wavelengths both LED’s absorb different levels.

![Absorption spectra of de- oxy and oxy-haemoglobin](image1)

Fig.1: Absorption spectra of de- oxy and oxy-haemoglobin[5,8]

Fig2 tells the overall block diagram of the proposed non invasive haemoglobin sensor system.

![Block diagram of the proposed system](image2)

![H-bridge circuit to operate LED’s](image3)

![Circuit design of proposed system](image4)

![Proposed prototype overview](image5)
5. RESULT AND DISCUSSION

The design uses spo2 probe which consists 670 nm and 940 nm is tested on various subjects and output ratio is measured using software the ratios are converted to the haemoglobin values and various subjects involves both men and women of age 18-21. The laboratory readings and calculated non-invasive readings are tabulated below. By calibration and analysis developed system readings are close to the laboratory readings.

The prototype output is displayed on the local website that can be checked by the doctor from anywhere in the world, which helps in taking precautions during emergency conditions.

![Fig 6. Output on mobile using IoT](image1)

![Fig 7: Haemoglobin value output on webpage](image2)

| s.no | Description | age | sex | Invasive values | NonInvasive values |
|------|-------------|-----|-----|-----------------|-------------------|
| 1    | Patient 1   | 20  | M   | 14.3            | 14.11             |
| 2    | Patient 2   | 21  | M   | 16.7            | 16.3              |
| 3    | Patient 3   | 20  | F   | 11.7            | 11.3              |
| 4    | Patient 4   | 35  | F   | 11.8            | 11.45             |
| 5    | Patient 5   | 42  | M   | 16.5            | 16.2              |
| 6    | Patient 6   | 17  | M   | 14.7            | 14.53             |
| 7    | Patient 7   | 20  | M   | 15.6            | 15.87             |
| 8    | Patient 8   | 20  | M   | 13.9            | 13.45             |
5. CONCLUSION

The prototype model of a Non invasive sensor unit for haemoglobin measurement is designed and developed. This paper clearly tells that invasive techniques causes discomfort to patients and delay in measuring haemoglobin, whereas Non-invasive methods are real time and comfort. This paper describes about the measurement of haemoglobin using non-invasive method in order to estimate Hb using a portable homemade device, which is user friendly and used for real time applications.

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