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Anaemia and Polycythaemia detection Using Non-Invasive Method

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Abstract

The proposed work is to design and develop an algorithm to evaluate the total haemoglobin level in the blood. The doctors should have a track of the haemoglobin level of their patients in hospitals because it plays a vital role during delivery, operations, monitoring patients in Intensive Care Units (ICU), donation of blood etc. At present the measurement of haemoglobin is a strenuous process as it is done using invasive methods and it might cause infections & is painful. In this approach a finger probe with five LED's and a Photodetector is used. The output voltage from the photodetector is passed through a signal conditioning amplifier (to eliminate noise and to enhance the voltage signal). The acquisition of signal from the finger is done through the Photoplethysmography (PPG) principle. The non-invasive method can be used over invasive methods because it is painless, infection free and the real-time results are obtained. The accuracy of the device is compared with the haemoglobin level measured from a pathological laboratory. haemoglobin is measured in g/dl (grams per decilitre).

Keywords: Haemoglobin, Pulse Rate, Temperature, Absolute error

1. Introduction

Human Blood contains White blood cells, Red blood cells, Plasma and Platelets. Haemoglobin is a protein that gives the red pigment and maintains the shape of RBC. It contains Fe and carries O_2 from the Lungs to the body tissues and collects CO_2 released by the tissues back to Lungs. Two parts it has, namely heme and globin, heme contains iron and transports oxygen while globin is a complex macromolecular protein that keeps the haemoglobin liquefied. When haemoglobin combines with oxygen it is called *oxyhaemoglobin* and when it combines with carbon dioxide it is called *carboxyhaemoglobin*. It also acts as a buffer and interacts with other ligands. Haemoglobin measurement is a vital test that is performed during diagnosis of various medical issues such as Anaemia, Polycythemia, Sickle Cell Anaemia, thalassemia & other blood related disorders, it is also a part of normal routine tests that is to be done during pregnancy, before any surgery etc. Anaemia is a condition where the Haemoglobin level is below the threshold level, symptoms such as weakness, fatigue, shortness of breath etc.are observed. Polycythemia is a condition where the Haemoglobin level is above the maximum prescribed level, symptoms such as blurred vision, headaches etc are observed. Haemoglobin is measured in Grams per Deciliter. Haemoglobin levels for a Male can vary from 13.5 to 17.5g/dl and for Females from 12.0 to 15.5g/dl.

Haemoglobin test is done conventionally using a syringe till date, though the accuracy is higher with conventional testing, it is prone to infections, needs manpower and it takes time to obtain the results and can be performed only in authorised laboratories and hospitals. It is done by taking the blood sample and diluting it in a solution of potassium ferricyanide & potassium cyanide, this oxidises the iron in haemoglobin to ferric state to

form Methaemoglobin& hemiglobincyanide (HiCN). The absorbance of the obtained HiCN is compared to standard HiCN in order to determine the haemoglobin level. During Pandemics such as COVID-19 people (especially the senior citizens) cannot afford going out to a laboratory for testing by risking their lives. The Government itself prefers electronic portable devices for measuring certain vital parameters of the human body for door-to-door testing in times of such Pandemics. The non-invasive method is based on the PPG principle, that is based on determining the Volumetric changes in the blood. Other features besides haemoglobin level measurement are Pulse Rate and Body Temperature measurement. Pulse Rate is the number of heart beats per minute and body temperature is determined.

The Pulse Rate for at normal conditions ranges from 60 to 100 beats per minute. Absolute Error is defined as the difference between the obtained value and the actual value, it is calculated to show the accuracy in the obtained results. In a journal published by University of Limerick, one LED was used to determine the haemoglobin and later three LEDs were used and the absolute error had improved significantly. In the proposed system five LEDs are used to improve the absolute error and to produce more accurate error. . In a journal published by University of Limerick, 1 LED was used to determine the haemoglobin level. In

another journal 3 LEDs were used and the absolute error had improved significantly. In the proposed system 5 LEDs are used to improve the absolute error and to produce more accurate error.

2.Existing Method

Till date Conventional method using syringe is done to determine haemoglobin levels in people. Though is a accurate method it poses some disadvantages such as, it is painful, may cause infection, takes time for getting the result and it cannot be done at doorstep as this method can be performed only in authorised laboratories. Hence non-invasive technique for determination of haemoglobin would be ideal for instantaneous result and to have a painless diagnosis.

In the existing method three LEDs were used to detect the haemoglobin of humans. In this method accuracy was very less compared to the conventional method and the device used was a single purpose device. Hence, it is not reliable and expensive.

Table1: Error Measurement by Existing Method

SUBJECTS	GENDER	MEASUREMENT BY INVASIVE METHOD	MEASUREMENT BY NON-INVASIVE METHOD (3LEDs)	ERROR IN MEASUREMENT
1	F	12.1	11.13	0.97
2	M	11.9	10.95	0.95
3	M	11.5	10.11	1.39
4	F	9.6	8.31	1.29

F-Female, M-Male

3 Proposed System

Haemoglobin is a strong bio-marker for human beings and it is an important factor in blood. The haemoglobin measurement plays a major role during medical emergencies such as accidents, deliveries, operations, patient monitoring in Intensive Care Units (ICU). The measurement of haemoglobin using invasive methods is accurate and consistent but is painful and may cause infections

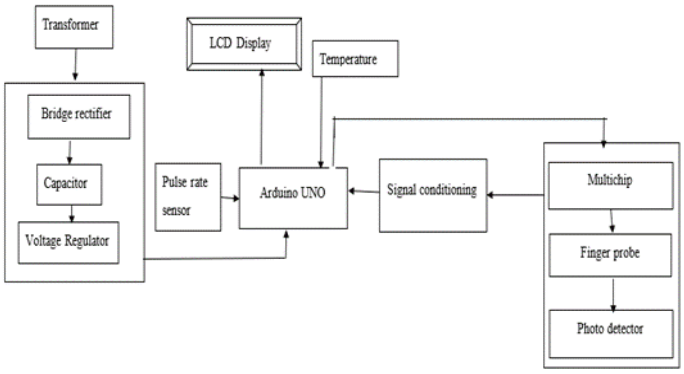

Fig.1: Block Diagram of the Proposed work

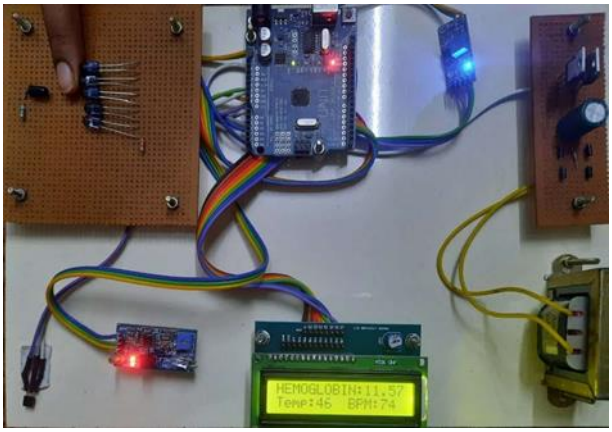

Fig 2: Proposed prototype model

With the increase in Medical emergencies over the years, Non-invasive method of measurement is more reliable compared to invasive method. There are a number of existing proposals in Non-Invasive methods, the major drawback of those are that they are less accurate compared to invasive methods. The major objective of the proposed system is to increase the accuracy of haemoglobin measurement done using Non-Invasive method. To Calculate total haemoglobin level in human beings, the level of Deoxy-haemoglobin and Oxy-haemoglobin of the respective person is required. Haemoglobin is measured in Grams per Decilitre (gm/dl).

In the proposed system five LEDs are connected to Multi Chip LED on one side and the photodetector on the other side of the finger probe. The LEDs used are infrared LEDs of different wavelength such as 660nm, 760nm, 810nm, 860nm, 930nm respectively. The light transmitted from the infrared LEDs is passed through the fingers and absorbed by the Photodetector on the other side. The wavelength of the lights are chosen based on the absorption level of haemoglobin species. The Deoxy-haemoglobin in blood is absorbed maximum at the wavelength ranging between 600 to 800nm and Oxy-haemoglobin is absorbed between wavelengths from 820 to 1000nm. At 810 nm both Oxy-haemoglobin and Deoxy-haemoglobin are absorbed, hence it is known as Isosbestic point.

The Photoplethysmography (PPG) signal for all the five LEDs are recorded in Arduino Software separately. The signal produces a low output voltage and the signal voltage is passed through the signal conditioning amplifier to minimize the noise and amplify the signal voltage. The amplified signal is given to the microcontroller (Arduino) interfaced with Analog to Digital Converter (ADC). The temperature and pulse rate sensors are also placed near the finger and the values obtained are given to the microcontroller. All the parameters i.e. temperature, pulse rate and haemoglobin are displayed on the Liquid Crystal Display (LCD).

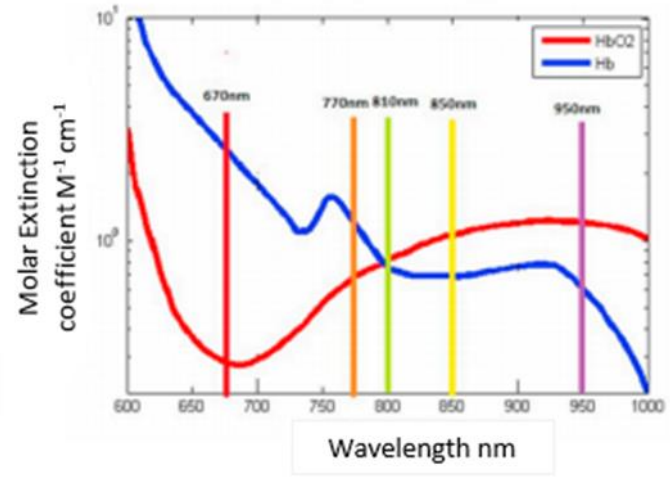

Fig.3: LED Wavelength response

The System requires less power. It works in 5V DC supply. A 5-9V battery can be directly used.

AC Source can also be used to source the system using appropriate conditioning elements. The 230V AC supply is step-down using a step-down transformer. The AC step down voltage is converted to DC voltage using

a Full Bridge Rectifier, to obtain continuous DC output voltage. This DC voltage is converted as per the requirement by eliminating noise by a Filter, which is the fed to the Microcontroller.

4. Methodology

The foremost intent of this paper is to estimate the total haemoglobin level that is found in RBCs of the human body. It is done through non-invasive methods using various components in order to improve the measurement accuracy and to obtain reliable results in real time.

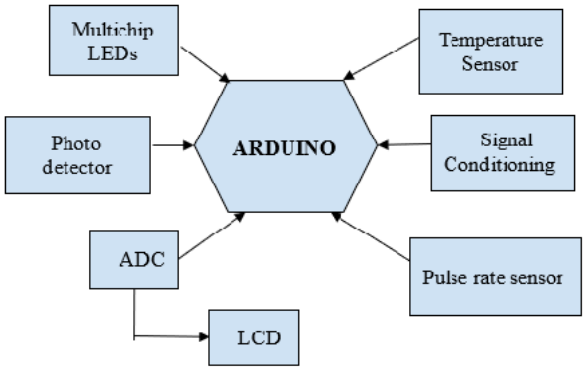

Fig.4: Functional Diagram of Proposed System

1 Multi-Chip LEDs

Multi-chip infrared LEDs of different wavelengths in the order 660nm, 760nm, 810nm, 860nm, 930nm are used. Multi-chip LEDs are cost effective, compact, radiation of heat is low and gives optical efficiency. Each LEDs is activated in a successive manner and it is safe as only less power is emitted and fingertips are uncovered in less than a minute .

2 Photodetector

A Photodetector converts the transmitted light from LEDs that penetrate through the finger, into voltage to obtain electrical signals. They are necessary for various implementations like process control, safety and security. The photodetector quiescent current is 120μA, and acts on a single supply voltage. The supplied voltage is then passed to the signal conditioning unit.

3 Signal Conditioning Amplifier

A Signal conditioning amplifier is used to eliminate the noise that occurs along with the voltage signals which are in the order of millivolts. An active bandpass filter of 0.72 Hz to 2.82 Hz along with appropriate gain is employed for minimizing the noise distortion. In addition, with this it is also used to amplify the low voltage signal obtained from the photodetector to a considerable voltage level.

4 Arduino UNO

The Arduino Uno is a microcontroller board. It goes through 14 digital input/output pins, 16MHz crystal oscillator generating low frequency, an integrated circuit, a USB interface, power LED indicator, an ICSP header and a reset button. In this method of estimation haemoglobin with 5 LED probes, it holds the advantage of being non-invasive, real-time, and cost-effective as it involves the use of Arduino Uno in Embedded Platform, besides providing good accuracy.

5 Temperature Sensor

To keep an eye on the temperature of the human body while measuring the haemoglobin level, a thermistor is used. The operating range is -55°C to 150°C. A Thermistor is a temperature-sensitive resistor that outputs an analog signal which is interpreted to obtain the reading in Celsius (**°C)**.

6 Pulse Rate Sensor

A pulse rate sensor is used to monitor physical parameter heartbeat rate in real- time. It is an integrated amplifying circuit working on PPG principle that senses the changes in volumetric blood flow during heartbeat as a change in the amount of infrared light channeled through the body. The information is then addressed to the microcontroller to compute the beat per minute (BPM) rate

7 Analog To Digital Converter

The analog to digital converter functioning is a 10-bit ADC. The amplified signal in the microcontroller is interfaced with ADC, which turns the analog voltage into a digital value. ADC converts an analog input value into quantifiable digital data so that it makes the process easier, more accurate and reliable by minimizing the errors.

8 Liquid Crystal Display

A liquid crystal display is interfaced with an Arduino to provide a user confederate to display the data in digital form. All the data acquired from analog to digital converter is finally displayed in LCD in real time monitoring itself. It consumes less power.

The System requires less power. It works in 5V DC supply. A 5-9V battery can be directly used.

AC Source can also be used to source the system using appropriate conditioning elements. The 230V AC supply is step-down using a step-down transformer. The AC step down voltage is converted to DC voltage using a Full Bridge Rectifier, to obtain continuous DC output voltage. This DC voltage is converted as per the requirement by eliminating noise by a Filter, which is the fed to the Microcontroller.

5.Software

A technique called Photoplethysmography (PPG) is used to determine the haemoglobin level in the blood. It is a optical measurement used to detect the blood volume changes in the microvascular tissue bed. A light source(LED) is used to illuminate the skin and measure the changes in light absorption is detected using a photodetector. The same principle is used in the heart rate sensors as well.

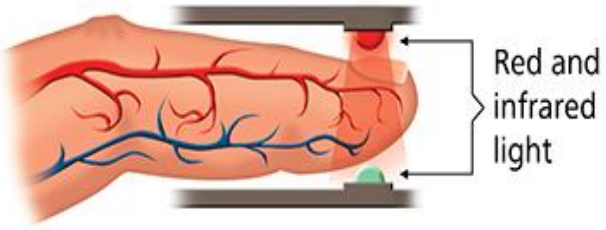

Fig.5: PPG Transmissive Mode

There are two modes of operation in PPG:

1. Transmissive mode
2. Reflective mode

Transmissive mode is used here to measure the haemoglobin level and heart rate. In this mode light from Infra-red(IR) LED is transmitted through the medium and the change in intensity of light is calculated by the Photodetector(PD).

The program to estimate the total haemoglobin level is fed into the microcontroller through the Arduino software. The PPG signals of all the five wavelengths are recorded on the serial monitor and it is stored for offline analysis. From the PPG graph obtained the peak and valley voltage of each wavelength are detected. The Haemoglobin is calculated and displayed on the liquid crystal display based on the code fed.

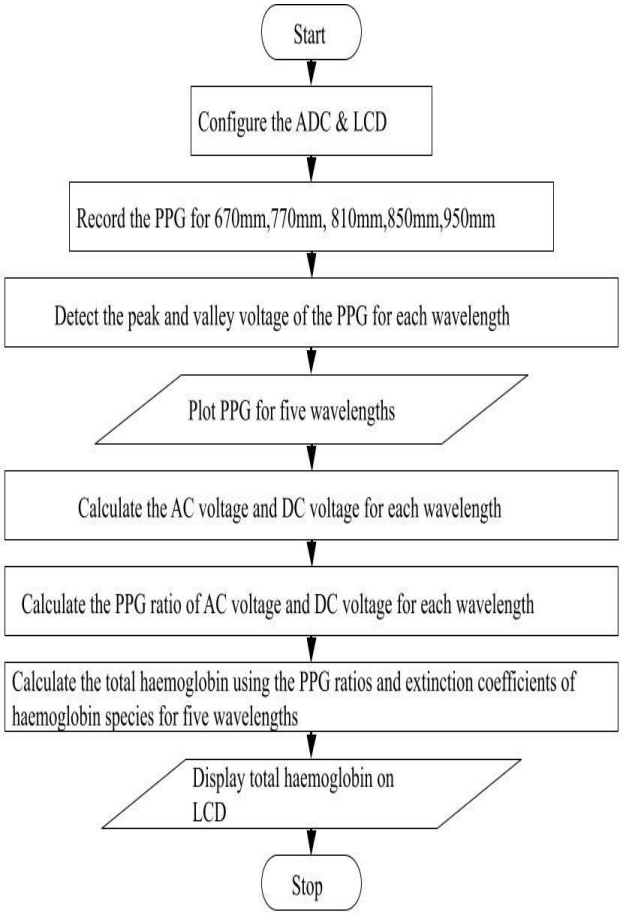

Fig.6: Flow chart for PPG

The Total haemoglobin level is the sum of oxy-haemoglobin and deoxy-haemoglobin. The oxy-haemoglobin and deoxy-haemoglobin levels are detected individually and finally to find the total haemoglobin level the absorbance of light has to be calculated, it can be deduced using Lambert-Beer law. The absorbance of light is given by

$A = \varepsilon^{\gamma} * C *$ …….. (1)

Where, A is absorbance

γ is the wavelength

C is concentration of absorbent (mol)

L is optical path length in the cm

ε is the extinction coefficient of the substance at a specific wavelength, mol-l cm-l.

The equation (1) is used to determine the absorbance of light by a single component, for the calculation of total haemoglobin this equation has to be summed for oxy and deoxy-haemoglobin.

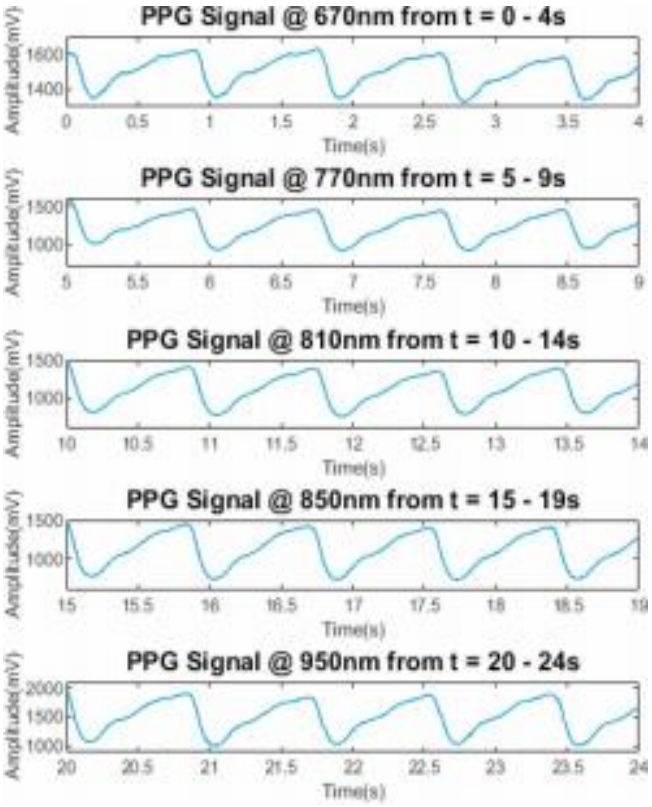

Fig.7: PPG signal at different wavelengths

Pulse Rate Sensor

Pulse rate sensor is used to measure the heart pulse per minute. It also works on PPG principle and hence integrating Haemoglobin and Pulse rate measurement would make it a more efficient system, occupying less space.

Alike haemoglobin measurement pulse rate measurement also consumes less power and requires a voltage of around 5V. It has an efficiency of 90-94%. The flow diagram of a pulse rate sensor is depicted in Fig 8.

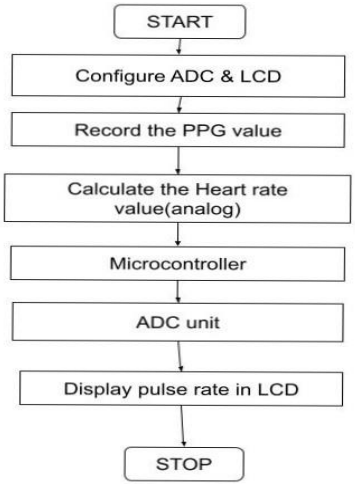

Fig.8: Flow diagram of Pulse rate sensor

6. Results And Discussion

The table below shows the comparison of measurement of haemoglobin using Invasive method with the measurement of haemoglobin level using Non-Invasive method. The estimation of haemoglobin with three and five LEDs using Non-Invasive method are tabulated. All the three values are compared. It is inferred that

haemoglobin level estimated with five LEDs using Non-Invasive method is more accurate than estimated with three LEDs and the values obtained are close to the haemoglobin estimated through Invasive method.

Table 2: Error Measurement by Proposed Method

SUBJECTS	GENDER	MEASUREMENT BY INVASIVE METHOD	MEASUREMENT BY NON-INVASIVE METHOD (5 LEDs)	ERROR IN HEMOGLOBIN MEASURED	BLOOD PRESSURE PER MINUTE(BPM)	TEMPERATURE
1.	F	12.1	11.99	0.11	69	49
2.	M	11.9	11.53	0,37	71	43
3.	M	11.5	11.22	0.28	69	47
4.	F	9.6	9.12	0.48	79	35

F-Female (12 - 15.5g/dl), M-Male (13.5 – 17.5g/dl).

If the haemoglobin result obtained is less than the normal range then the condition is called Anaemia and when the value obtained is more than the range specified then the condition is known as Polycythaemia.

7. Conclusion

The system is designed and developed for estimating the total haemoglobin level present in Red Blood Cells (RBC) of humans by monitoring the patient's health in real-time with the help of an Arduino based embedded platform using **Photoplethysmography** (PPG) principle. This is done by non-invasive method using various integrants like finger probes, LEDs of different wavelengths sequentially in the order (670nm /770nm /810nm /850nm /950 nm), a photodetector, analog to digital converter, signal conditioning amplifier, trans-impedance amplifier. It was perceived that the haemoglobin measurement obtained with five wavelengths through the non-invasive method was comparatively good with that of three LEDs results, thus showing good linearity with the Regression Coefficient (R2 = 0.964) and found that the mean absolute error between reference values and the estimated haemoglobin is 0.3499g/dL. Additionally, a temperature sensor and a pulse rate sensor are incorporated to look after the patient's physiological state unobtrusively and comfortably. The non-invasive method is encouraged to measure Haemoglobin level since it is a vital factor in hospitals to supervise haemoglobin count during operations, blood donations, to screen for anaemia that results in shortness of breath, blood pressure test, observing patients in intensive care units, dialysis, etc. Concluding that, this system can substantially improve the performance of patient's health monitoring as it is cost-effective, compact in size, painless, non-infectious, portable testing and consumes less power. Furthermore, to reduce the complications and make it operator-independent we put forward a mobile application idea using IoT (Internet of Things) as an added abstraction for future scope. The application will assist patients in continuous observation and medication control.

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