DESIGN AND DEVELOPMENT OF A NONINVASIVE HAEMOGLOBIN METER WITH ANDROID APPLICATION

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ABSTRACT

Haemoglobin (Hb) is the protein molecule in the red blood cells that carries oxygen from the lungs to the tissues in the body and returns carbon dioxide from the tissues back to the lungs. It is very important in the due to the fact that if anyone is deficient of the required level of body Hb, it can lead to kidney failure or anaemia. Haemoglobin measurement is performed by invasive method which means the insertion of a syringe into the vein in the arm or body of a patient in order to collect the blood sample of the person. The level of haemoglobin present in the body depend on the age and gender. After the collection of the sample, the blood is taken to the laboratory for chemical analysis after which the haemoglobin concentration in the blood is detected. Although, the accuracy is high but it has its shortcomings which include delay in result processing and discomfort suffered by patient due to blood transfusion, infected **blood** sample and lack of continuous monitoring in critical situations. Non-invasive Haemoglobin measurement is presently preferred to the invasive because it is user friendly. This system is designed with the combination of the two latest and most demanding technologies which are Android and Embedded systems. Android is a Linux based operating system designed primarily for mobile devices and it is open source. There are so many applications that are already developed on android and are available at free cost for its users. At the controlling section of this system, there is bluetooth module and the microcontroller**.** The bluetooth module receives command from the Android application and transfers this command to the microcontroller. The latter reads the haemoglobin concentration of the patient under test. The haemoglobin level can also be displayed on the liquid crystal display unit. More advanced sensor like photopletismography can be used instead of ECG, so that the system can detect the oxygen level, sugar level, pulse rate and blood pressure.

Key Words: *Haemoglobin, Noninvasive, Anaemia, Android, Pulse Oximeter*

INTRODUCTION

Haemoglobin (Hb) is the protein molecule in the red blood cells that carries oxygen from the lungs to the tissues in the body and returns carbon dioxide from the tissues back to the lungs. Four protein molecules combine to form an Hb molecule and this formation is known as the globulin chains formation (Davis, 2019). Hb helps in maintaining the shape of the red blood cell. The natural shape of the red blood cell is circular with a narrow middle but it does not contain a hole in its center. Abnormal haemoglobin level may throw the shape of the red blood cells into disorder and disrupt their functions. It is also important in human life because if anyone is deficient of the required level of body Hb, there is a chance he is suffering from adverse health challenges which may include cancer, kidney failure or anemia.Hb is measured in grams (g) per deciliter (dl) and its normal range depends on the gender and age of a person. The normal ranges are:

- Newborns: 17 to 22g/dl
- One (1) week of age: 15 to 20g/dl
- One (1) month of age: 11 to 15g/dl
- Children: 11 to 13g/dl
- Adult males:12 to 16g/dl
- Adult females 10 to 14g/dl
- Men after middle age: 12.4 to 14.9g/dl
- Women after middle age: 11.7 to 13.8g/dl

Due to the fact that some laboratories do not differentiate between adult and after middle age Hb values, the values may change slightly (Davis, 2019). When the blood Hb is low, taking into consideration the standard stated above, it is called anaemia which means shortage of enough red blood cells in the body. Common anaemia symptoms includes exhaustion, skin paleness, shortness of breath, abnormal or rapid heartbeat, pain in the chest, headache and trouble with physical activity etc. Any condition that affects your body negatively during the generation of red blood cells will also cause you to have low Hb level (Jewell, 2019). The possible causes of this condition include lack of iron in the diet, lack of folate or vitamin B-12, severe blood loss, internal bleeding, sickle cell anaemia, chronic diseases etc. Other causes include donating blood too often, heavy bleeding during period, alcohol misuse and cancer. World Health Organization stated that half of the anaemia (low Hb) in the world is due to iron deficiency (WHO, 2001). High Hb (polycythemia) which means the presence of too many red blood cells should also be avoided because it is as dangerous as low Hb concentration in the body. It is identifiable by the following symptoms; itchiness, headache, dizziness, getting easily bruised or bleeding, sweating more than usual, painful joint swelling, abnormal weight loss and a yellow tint to the eyes and skin. High Hb concentration may result from your body needing to store more Hb in the red blood cells due to the kind of environment you are exposed to or the kind of lifestyle you choose. Other possible causes of high Hb includes; living at high altitudes where there is not much oxygen, smoking, chronic disease, heart or lung disease as well as being severely dehydrated, heart failure and cancer (Jewell, 2019).

The invasive measurement of Hb level involves the piercing of the finger or arm to collect blood sample which is later analyzed in the laboratory using chemical methods available. This is common in many laboratories even in recent times.

During treatments, patients suffering from anaemia and polycythemia are placed on intensive care unit in order to continuously monitor the Hb level in the blood which may be difficult due the fact that the results are not available on time, extra care needed to be taken to prevent infections and the continuous puncturing of a patient's arm would at certain time leave him in pains (Srivastava *et al*, 2014).

Non-invasive method allows pain free continuous monitoring with extremely low risk of infection. Using this method, instead of using a sample of blood that has been collected to determine the concentration of an individual Hb concentration, a spectrophotometric sensor is used. Therefore, making results available in a matter of seconds thereby hastening up clinical evaluation (Dos Santos, 2015).

Microcontroller, Bluetooth module, Android application and a sensing element (photodiode) were used to facilitate the operation of the system. The Bluetooth module serves as the hardware that allows a wireless communication between the android application and the microcontroller. The microcontroller, on detecting the signal reading of the sensor, measures the blood haemoglobin and sends out the output result to both the Liquid Crystal display and

the android application. Haemoglobin in plants is made up of different groups of hemeprotein belonging to three different classes. Haemoglobin in class one has high natural attraction to oxygen. Their main function is to collect useful nitric oxide at low oxygen level. Nitric oxide helps in plant reproduction, development and their responses to stress. Hb in class two has lower attraction to oxygen. They help in transporting oxygen to developing tissues while class 3 haemoglobins help in regulating the delivery of oxygen at high concentrations (K.J. Gupta *et al*, 2011).It is most times impossible to identify haemoglobin in lower animals, because some of these organisms do not contain muscles. Or, they may have a different circulatory system but not one that deals with oxygen transport (for example, insects and other arthropods). Hb concentration measurement in the blood plays a very important role in the detection, evaluation, and management of chronic diseases and anaemia. The standard for laboratory determination of Hb is haemoglobin cyanide (HiCN). HiCN testing is not regularly used in hospitals because of its complexity, so cyanide-free central laboratory hematology analyzers (e.g., Coulter, Sysmex) have become the clinical standard (Davis *et al*., 2009).

Contrary to this method, the non-invasive method, when used for the same purpose are able to produce similar accurate results with the advantage of being relatively fast and easy to be carried out. A non-invasive method allows pain free and continuous monitoring with minimum risk of infection, allowing immediate clinical follow up to the results. Also most of these diagnostic procedures require little medical and technical knowledge and minimal resources, making them easy for measurement in underdeveloped areas which lack medical infrastructure. Lots of invasive methods of blood parameter estimation have been invented and are still in use. These approaches however tend to be tedious and time consuming, in addition to the extra resources required for their implementation.

Pulse CO-Oximetry is the multiwavelength technology among the first devices to have received Food and Drug Administration clearance for the continuous, non-invasive monitoring of total haemoglobin (SpHb; Masimo, Irvine, CA). (Avcioglu, *et al.*, 2017), Hb monitoring is not yet as accurate as laboratory haemoglobin (lab-Hb), and it was therefore not a substitute for lab-Hb. Nevertheless, attention should be given to its advantages over the invasive that causes delayed in obtaining lab-Hb values. A pulse CO-oximeter which is able to measure Hb concentration using a non-invasive, multi-wavelength sensor for spot check and continuous measurement was developed by Masimo Corporation. The device makes use of a fingertip probe similar to a standard pulse oximeter sensor in measuring the haemoglobin noninvasively. The two types of Hb measuring devices are continuous Hb monitor and spot check Hb monitor, the continuous non-invasive Hb monitor monitors serum Hb continuously and provides immediate Hb levels similar to how a pulse oximeter provides continuous oxygen saturation. According to this journal, spot check monitoring follows the same law as the continuous mornitor but has more clinical use than the continuous monitor. Unlike continuous, it makes use of a point of care device to monitor serum haemoglobin (Joseph, *et al.*, 2015).

Pulse oximetry was invented by Takuo Aoyagi of Nihon Kohden in 1974,at first, it was not really adopted because of its inaccuracy according to Takuo Aoyagi, an electrical Engineer who measured the cardiac output using noninvasive method by dye dilusion method with the use of ear oximeter. He also discovered from his experiment that pulsatile changes could be used to measure pulse saturation (Severinghaus, 2007). The accuracy of pulse oximeter is dependent on a number of factors such as sensor, monitor, optimal image stabilization, patient geometry, pigmentation, acidosis and anaemia. It has been advised that medical practitioners should not rely simply on single measurement when taking important clinical decisions. Other suggested recommendations are; regular calibration of the oximeter and checking sensor accuracy (Singh *et al*, 2017).

The contribution of pulse oximetry to the improvements of patient condition was not because non-invasive measurements replaced invasive laboratory measurements, rather, as was stated in 1989 that it was the continuous property advantage that was so important in this new model of patient monitoring. With continuous Spo_2 monitoring, health care providers became clearly aware that oxygen saturation was reducing when the patient appeared to be well oxygenated. Continuous SpO_2 monitoring also provided non-invasive reassurance that arterial blood was oxygen saturated when other means of clinical assessment were not helpful.

However, health studies did not actually show important improvements in patient outcomes due to pulse oximetry until recently. Earlier studies in the operating room showed no effect of pulse oximetry upon large patient outcomes, such as death or myocardial infarction. SpO_2 changes can occur within seconds, whereas haemoglobin Saturation(SpHb) changes are more likely to occur over a few minutes. Nevertheless, the SpHb changes during urgent surgical hemorrhage are difficult to monitor.

PROBLEM STATEMENT

Presently, a lot of lives have been lost as a result of improper monitoring of the blood haemoglobin. This system is designed to help keep this in check. Generally, the invasive method of measuring blood parameters is adopted but it has the limitation of taking too long to give results and risk of blood sample being infected. Non-invasive system is designed to eliminate the shortcomings of the invasive method.

The aim of this research is to design and develop a Non-Invasive Haemoglobin Meter with android application

DESIGN METHODOLOGY

In designing a non-invasive Hb meter, one or more suitable platforms were used to specific deliberate choices of hardware component and mode of operation of the system.

SYSTEM DESIGN

This study is divided into four sections: power section, phototransistor section, microcontroller section and display section as shown in figure 2 below. The power section is a 5v DC supply from a regulated source through a rectified alternating current source. The sensing section consist of a phototransistor which detects the light ray from the blue Light emitting diode (LED), the LED emits a light ray of high wave length which is transmitted through the patients' finger. The light ray signal is detected by the phototransistor; the signal is then interpreted by the microcontroller via an already embedded code. The liquid crystal (LCD) 16 by 2 displays the interpreted signal transmitted from the microcontroller. The Bluetooth module is used to transmit the data from the microcontroller to the developed android application.

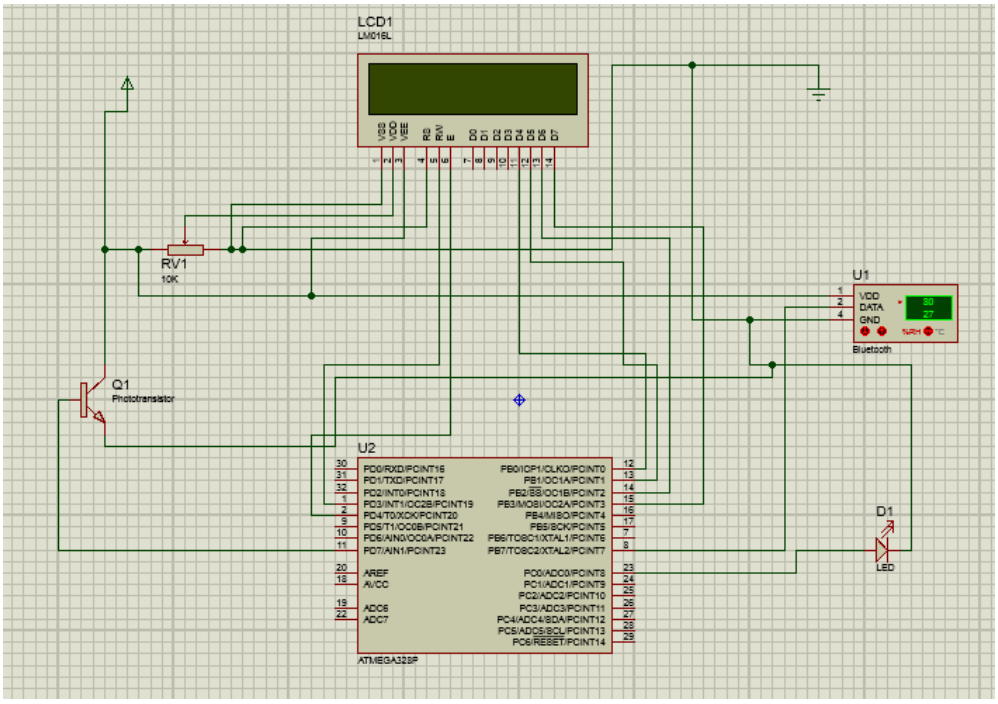

Figure 1: Circuit diagram of the system

Hardware Subsystem

This developed system is made up of different units

1 Microcontroller unit

2. Display unit

3 Phototransistor unit

Microcontroller Unit

The Atmel 8-bit AVR RISC based microcontroller combines 32KB ISP flash memory with read-while-write compatibilities, 1KB SRAM, 23 general purpose I/O line, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/converter (*-channels in TQFP and QFN/MLF packages) programmable watchdog timer with internal oscillator, and five software selectable power saving modes as shown in fig. 3 and fig.4 below. The device operates between 1.8-5.5 volts.

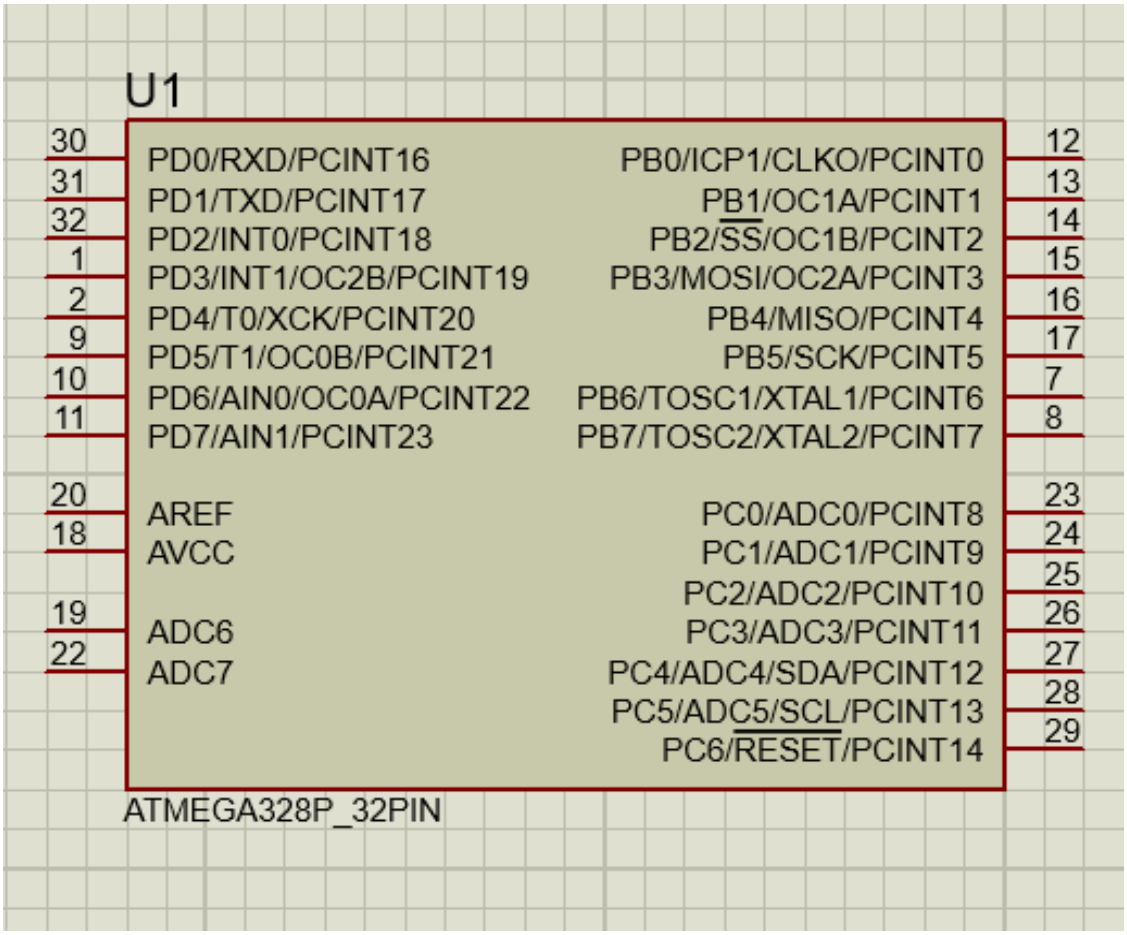

Figure 2: Pin mapping of ATMEGA328PU Microcontroller

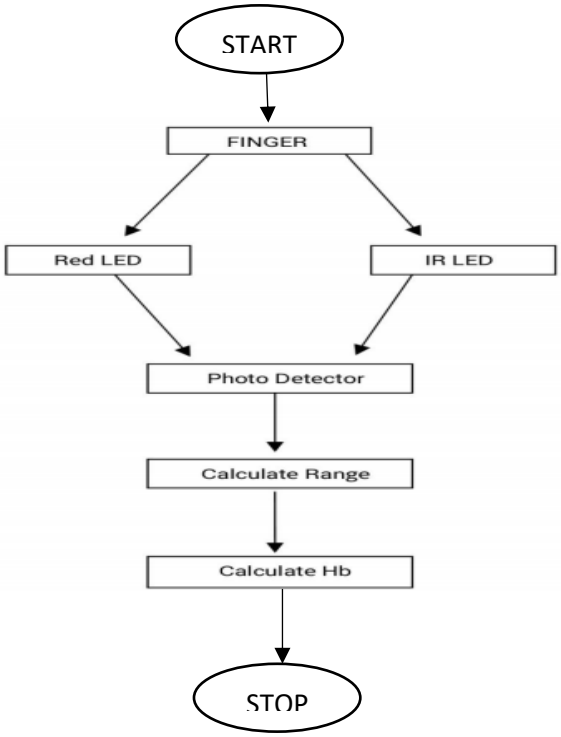

Figure 3: The system flowchart

Android application interface

The android application communicates with the microcontroller via Bluetooth by displaying the result of analyzed sample of Hb parameter. Connection procedure is as followed.

- Power on the Hb meter
- Connect the android phone to the circuitry via Bluetooth
- Launch into the Hb app
- Click on connect and check the Bluetooth name HC-05
- Place your finger tip on the sensor, the meter automatically reads your Hb parameter.
- Click reading from the app and the results is displayed both on the app and on the LCD.

TESTING AND RESULT ANALYSIS

A non-invasive haemoglobin meter was designed, constructed and tested. It was used for different people. Results of different readings taken from 10 patients of different ages, sex and varying Hb levels is achieved using this system. From the results shown in Table 1 below, it can be noticed that the difference between invasive and non-invasive measurement are within a close range.

Table1: Difference between the invasive and noninvasive readings

S/N	Age	Sex	HB level(invasive)	HB level(non-invasive)
1	Ch	M	12.0 g/dl	12.0 g/dl
2	Ch	M	11.0 g/dl	11.2 g/dl
3	Ch	F	7.3 g/dl	7.3 g/dl
4	Ch	F	11.5 g/dl	12.0 g/dl
5	Ad	M	13.0 g/dl	12.9 g/dl
6.	Ad	M	7.0 g/dl	7.2 g/dl
7.	Ad	M	12.0 g/dl	12.2 g/dl
8.	Ad	F	11.0 g/dl	11.5 g/dl
9.	Ad	F	13.0 g/dl	13.0 g/dl
10.	Ad	F	14.0 g/dl	13.7 g/dl

CONCLUSION AND RECOMMENDATIONS

Conclusion

Non-invasive haemoglobin meter with android application was designed using a 5v power supply, a photodiode sensor that served as the hardware interface through which the microcontroller measures the haemoglobin content in the blood of the patient under test, an LCD, Android application and the Bluetooth module which enables the microcontroller to communicate with the designed android application.

The system was used to measure the haemoglobin level of different people of different ages and the results has been verified appropriate by comparing it with laboratory results. Although the invasive one is more accurate.

Recommendations

The following are recommended for future work:
More advanced sensor like photopletismography should be used, so that the system can detect the oxygen level, sugar level, pulse rate and blood pressure.

Back and front mobile application can be used so that medical personnel can interact with the patient whenever they find it difficult to go the hospital.

Government should also provide this type of facility for people in the rural areas so that they can measure their oxygen level without the assistance of laboratory scientist.

Engineers should provide a method of sterilizing the photodiode sensor so that people using the system would not be infected.

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