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Design Of An Optical Sensor Based On Non-Invasive Anemia Detection System

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Abstract: Abstract-Hemoglobin is an important part of red blood cells for transporting oxygen and carbon dioxide. Hemoglobin concentration in the blood can be used as a physical condition parameter. A low hemoglobin level is called anemia and a high hemoglobin level is called polycythemia. WHO has determined the anemia cut off level of hemoglobin concentration based on age, sex, and condition (pregnant or not). Currently, accurate and reliable hemoglobin concentration measurement uses invasive methods such as cyanmethemoglobin and automated hematology analyzer. But these methods are expensive, not in real time, and with a high infection risk, they also need special techniques. Non-invasive methods offer a better alternative because it has a low infection risk, gives instant results, and is portable in size. This work developed a non-invasive hemoglobin measurement for anemia diagnosis based on optical spectroscopy. The system utilized LED and photodiode as an optical sensor placed on the fingertip. Since photodiode just could obtain DC component, so the signal conditioning circuit which consisted of HPF, LPF, and amplifier was used to obtain the AC component of the signal. This system used a microcontroller to control the operation of the hardware and to calculate the hemoglobin concentration.

Keyword-Hemoglobin; optic; spectroscopy; non-invasive; anemia.

I. INTRODUCTION

amount of hemoglobin drops below normal is called anemia, and when it exceed normal is called polycythemia [2]. WHO has determined the anemia cut off level of hemoglobin concentration. Children 6-59 months old is 11 g/dL, children 5-11 years old is 11.5 g/dL, children 12-14 years old and non-pregnant women are 12 g/dL, pregnant women is 11 g/dL, and men (15 years old and above) is 13 g/dL [5]. The major cause of anemia is iron deficiency. Other minor causes include acute and chronic inflammation, parasite infections, red blood cell production or survival, and nutritional deficiencies (folate, vitamin A and vitamin B12) [5]. Anemia indicated by fill of eakness, fatigue, drowsiness and dizziness and can cause dead [6].Anemia screening is recommended as part of the domestic medical screening exam for newly arriving refugees [7]. If not properly diagnosed and treated, anemia may impair cognitive, behavioral and psychomotor development in children; increase risk of preterm birth, low birth weight and neonatal/ maternal mortality in pregnant women; and decrease work capacity and earning potential in adults [8–10]. The gold standard Hgb measurement test is the complete blood count (CBC) done on a hematology analyzer and typically requires a venous blood draw, trained laboratory techni- cians, and expensive analytical equipment

Hemoglobin is the main component of red blood cell [1] which is used to transport oxygen from the lungs to the other tissues in body, exchange oxygen with carbon dioxide, and then transporting carbon dioxide back to the lungs to exchange it for oxygen [2]. Hemoglobin contains four protein molecules called globulin chains. In every globulin chain, there is important central structure called the heme molecule. Heme molecule contains iron that is responsible to transporting oxygen and carbon dioxide and make red color in blood [2]. Hb concentration in blood is used to evaluate the individual physiological condition [3]. The need for hemoglobin for every person is vary depends on a person's gender, age, smoking behaviour, different stages of pregnancy and residential the

MEASUREMENT PRINCIPLES

The method to measure Hb concentration is based on multi-spectral spectrophotometry. Blood consists primarily by water and hemoglobin that have different absorption coefficient across different wavelength [13]. Absorption coefficient of

transmitted light through the finger tissue is different in every wavelength and is relatively low in range 600-1300 nm [18]. The presence of deoxyhemoglobin and oxyhemoglobin in blood are detected by light emitting diode (LED) - red (670 nm) and infrared (940 nm), respectively [18]. Hemoglobin also contain other component such as Meth-hemoglobin and carboxy-hemoglobin, but have minor constituents so it can be ignored [19]. The fundamental laws that leads quantitative analysis.

spectroscopy is based on The Beer Lambert Law describes the relation between extinction coefficient, thickness and concentration of the absorbing medium. When the light goes through the medium, only part of the light is transmitted and the remaining is absorbed or reflected. It depends on the wavelength which is measured and concentration of the medium. OD is non-dimensional parameter that represents the optical density of the absorption the molar extinction coefficient at a specific wavelength, is the concentration and is the optical path length along the medium 0 and are the intensities of the incident and transmitted light, respectively In the case of more than one substance absorbing, the Beer Lambert's Law is still valid and defined that each absorber affect to the total absorbance or optical density .

The hardware system consists of two LEDs, sensor (photodiode) signal with conditioning circuit, and microcontroller. LED is used to illuminate light with specific wavelength which is transmitted through optical path length (finger tissues, bone and vein). Transmitted light that carries information about the concentration of hemoglobin in the blood is detected by sensor. Sensor changes transmitted light intensities to voltage output. PPG signal can be divided into AC and DC components. The magnitude of the AC component is very small as compared to the DC offset, so a signal conditioning circuit is needed to extract the AC component. Diagram block of the system hardware is given in Fig. 1. It controls LEDs through a microcontroller displaying and processing the signal. The LED driver connects microcontroller I/O pin to LED. With this driver, the LED's current is not taken from microcontroller pin but directly from the power supply

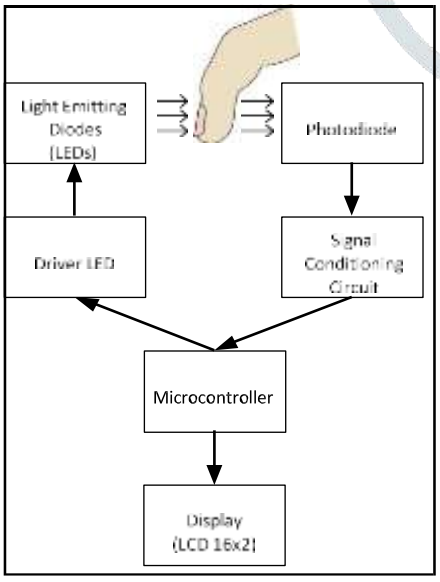


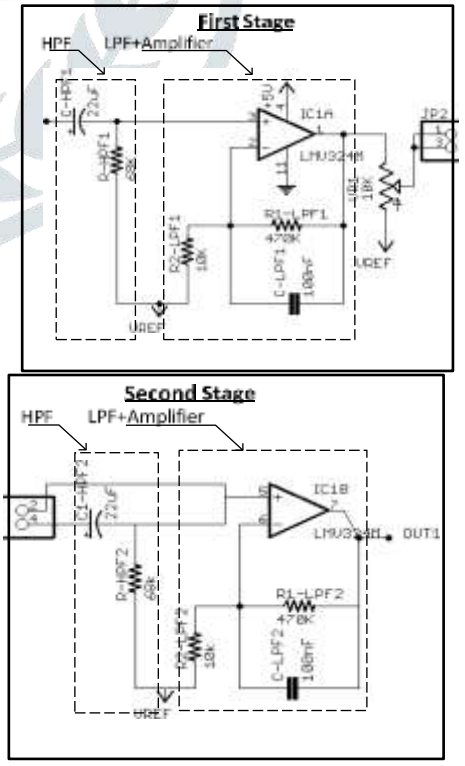
Fig.1 Block Diagram of Hardware System

II. PROPOSED METHODOLOGYThe design of the Signal Conditioning circuit is given in fig.

2. The output of the signal conditioning circuit was in voltage. This output needs to be changed into digital data using an Analog to Digital Converter (ADC) for processing by the microcontroller. One feature of the microcontroller which was used in the system was ADC. Microcontroller processes PPG signal to calculate the hemoglobin concentration and anemia status. The microcontroller works based on the program downloaded to the microcontroller. The flow chart for the programming of the microcontroller is given in fig. 3. Peak and valley detection algorithm was used for calculation of the AC component of the signal. The Hb concentration was calculated based on a ratio of AC to DC component of red and infrared signals.

This system measures the PPG signal with a red and infrared light source. The signal result from this system with red and IR LED is given in fig.3 There were 78 subjects of pregnant women with good health condition. Data from 21 subjects used for training while the remaining 57 subjects used for testing. Sysmex KN-21, one of the most popular automated hematology analyzer to measure Hb, was use for invasive methods (gold standard). Blood sample was extracted from the subject veins. The Hb concentration compared to the normal level to determine the status of anemia of subjects.

Fig. 2 Design of Signal Conditioning Circuit



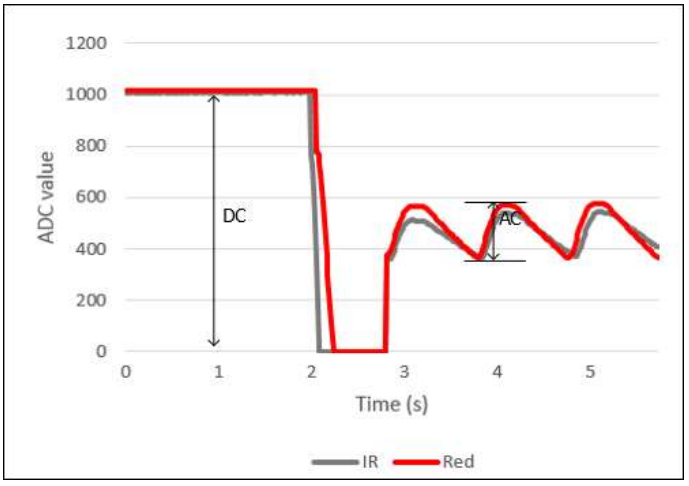


Fig. 3. PPG wavelength from RED and IR LED

Linear regression was used to obtain the conversion formula from training data to Hb concentration value see Fig.4.
The concentration of Hb is given by the formula 1 below:
Hb = -3.3912x + 14.937
where x represented the ratio of (AC/DC)IR/(AC/DC)R. Table I provided the paired t-test from the Hb concentration, which was measured by the developed non-invasive device and the standard method.

III

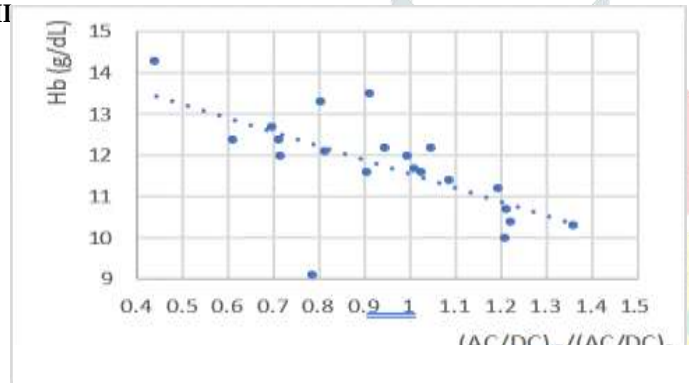


Fig 4. Linear regression

Paired *t*-test from Hb concentration measured by developed non-invasive device and standard method is given in Table I. Table I showed that both methods gave similar quantitative results although the non-invasive method gave slightly less accurate results. The accuracy of the non-invasive device was low. The low accuracy was probably caused by many factors such as the movement of subject when measurement was taken, unfit fingertip position, influence from other substances, and false in peak and valley detection because of signal noises. To improve the accuracy of the system, more LEDs can be used. Proper grounding can also be used to

CONCLUSION

The non-invasive anemia diagnostic device is developed using a spectroscopy method with two LEDs at 670 nm and 940 nm wavelengths. Photodiode is used as a sensor to detect transmitted light through the finger. The signal conditioning circuit is used to get the AC component of the signal. The microprocessor-based system is used to control the operation of LEDs, process data from sensors, calculate hemoglobin concentration, and determine anemia status. ADC in the microcontroller is used to convert analog sensor data in voltage to digital data so that it can be further processed by a microcontroller. After calculating the hemoglobin concentration, anemia status can be determined. This developed system still has relatively low accuracy.
The design of a non-invasive optical sensor for anemia detection effectively demonstrated the potential for a painless, rapid, and portable screening method to complement or reduce reliance on traditional invasive blood tests. The core conclusion is that the device can provide acceptably accurate hemoglobin (Hb) estimations using photoplethysmography (PPG) and the modified Beer-Lambert law, making it a viable tool for widespread initial screening and continuous monitoring.

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