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Design and Development of a portable Pulse Oximetry system

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Abstract

Heart is the most important part in human body. Thus, it is important to follow-up and monitor its condition. Heart rate (HR) and blood oxygen saturation (SpO_2) are important indicators directly related to heart-pulmonary system. Monitoring of HR and SpO_2 offers us a good indication of heart functionality. Therefore, it is crucial to design and develop a homemade inexpensive device for measuring HR and SpO_2. Pulse Oximeter (PO) is an opto-electronic non-invasive medical instrument capable of measuring and recording the changes of HR and SpO_2 at the finger tip. In this paper we will demonstrate the overall process involved in the development of a portable (PO) system which can be used for health condition monitoring or for educational and research purposes.

Keywords: Pulse Oximetry, Optical Sensor, Heart Rate level.

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1. INTRODUCTION

Pulse oximetry systems are based on two principles related to the characteristic of blood flow rate in the context of the oxy-hemoglobin and deoxy-hemoglobin status. Both oxy-hemoglobin and deoxy-hemoglobin are different in their absorption of red and infrared light, and that the volume of the arterial blood in tissue changes as the pulse changes. With each heartbeat, the volume of the arteries becomes larger before the blood enters the capillaries. This change makes possible for the oximetry system to differentiate the arterial blood from all other absorbing substances [1]. Usually, in a pulse oximeter, two lights with different wavelengths are transmitted through the tissue [1]. Since both oxygenated and deoxygenated hemoglobin have different absorbance and reflectance properties, two different light sources are used. Oxygenated hemoglobin has the highest absorbance in the infrared band (850nm-1000nm), while deoxygenated hemoglobin (Hb) has a high absorbance in the red band (600 nm to 750 nm). This is why most present pulse oximeters use 940 nm infrared and 660 nm red light emitting diodes [1]. Figure 1 shows the absorption levels of oxygenated and deoxygenated blood at different wavelengths.

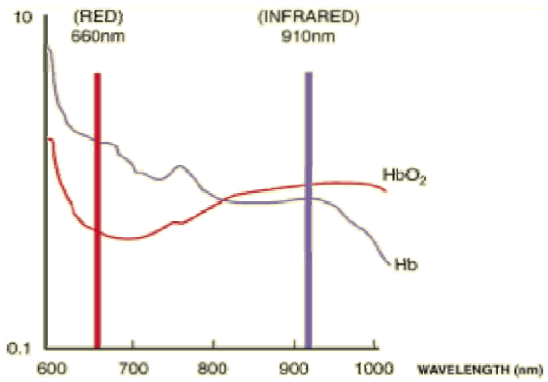


Fig 1. The absorption levels of oxygenated and deoxygenated blood at different wavelengths [2]

When light is emitted into the body tissue, some light will be absorbed by the skin, bones, and muscle tissue. This represents the static direct current (DC) component of the signal received at the photo detector receiver. The pulsatile flow in arteries and arterioles during diastole and systole will create some variation in light intensity. This will produce the AC part of the signal [3]. Both AC and DC components are shown in Figure 2.

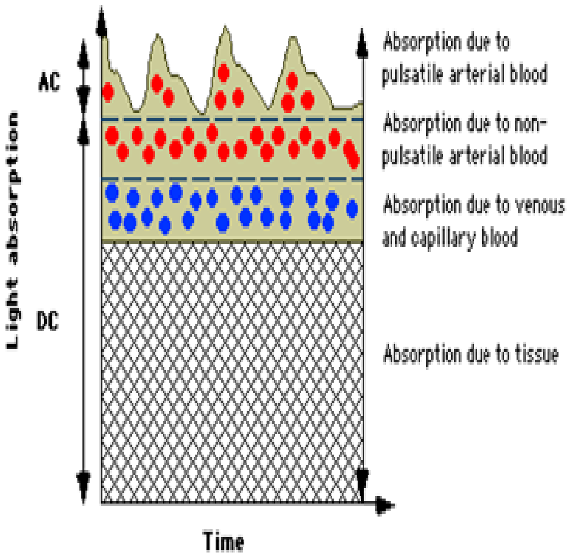


Fig 2. Diagram showing light absorption through living tissue [3]

2. MATERIALS AND METHODS

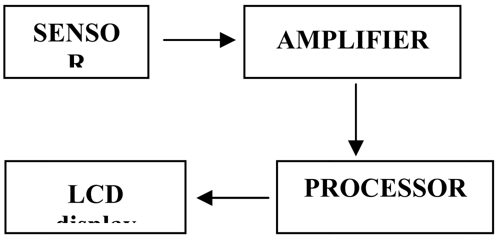


Fig 3. Block diagram showing the flow of operation for the Pulse Oximetry system

Pulse Oximeter system consists of a probe (sensor), signal-processing unit (main device) and also a results displaying unit.

2.1 Sensor of Pulse Oximetry

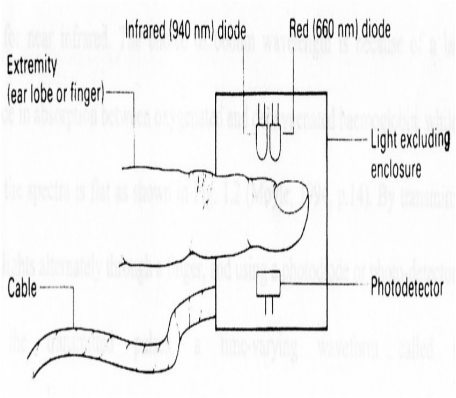


Fig 4. Sensor orientation for light transmittance in the designed pulse oximeter [4]

The newly designed low-cost Pulse Oximetry system consists of a probe (sensor); the sensing probe consists of two LEDs, and a photo-detector. The two LEDs used in the sensor part are the red (660nm) and infrared (940nm) (refer Figure 4). The signal collected from the photo-detector (Light Dependant Resistor (LDR) & Infrared Receiver (IR)) will be supplied to a dual operational amplifier (LM358) and then further conveyed to PIC16F877A so that the signal could be processed easily [4].

2.2 Computing of Pulse Oximetry

The output signal from the dual amplifier will be further supplied to a Programmable Interface Controller (PIC16F877A) which will be converted from analogue signal into digital signal through the built-in Analogue to Digital Converter (ADC). However, this converting process will require MICRO C programming software to generate the Hexadecimal file of the PIC before one can display the value of detected pulse rate and oxygen saturation in the blood. The schematic drawing of PIC 16F877A was presented in Figure 5.

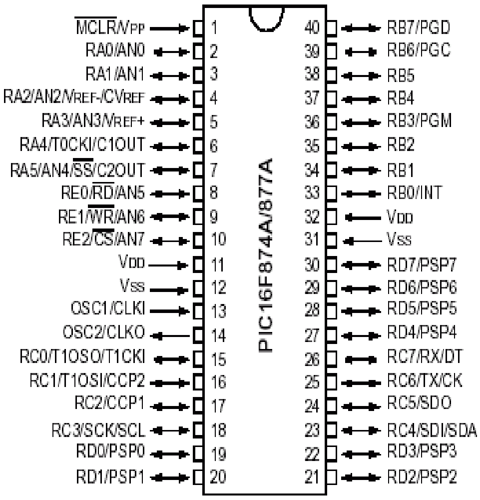


Fig 5. Details of PIC16F877A connections [5]

2.3 Display of Pulse Oximetry

For the device to be user friendly as in showing the recorded values, the output produced by the PO will be displayed via a Liquid Crystal Display (LCD) screen. This also shows that the newly developed PO system has extra capabilities in collecting the measured data such as the HR and SpO_2 which could be further analyzed and stored inside a computer as shown in Figure 6.

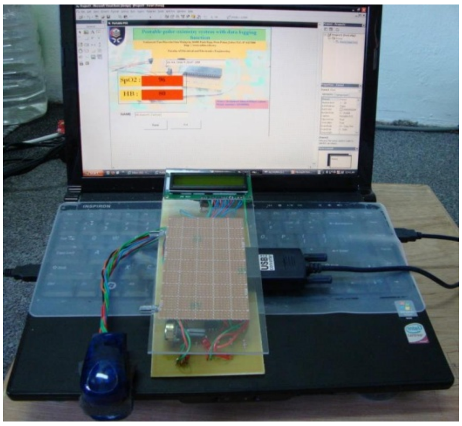


Fig 6: The complete device of the designed Pulse Oximetry system connected to a computer

3. RESULTS AND DISCUSSIONS

From this study a portable PO system has been designed and developed. The system was able to produce highly reliable results for both HR and also SpO_2. In developing the sensor part the use of super bright LED was useful since its capability to penetrate the skin layer with different color. Next, the LDR positioned near the LED were able to detect the light reflected at the fingertip during blood circulation and from this detection the output signal from LDR were in resistance and very small in value.

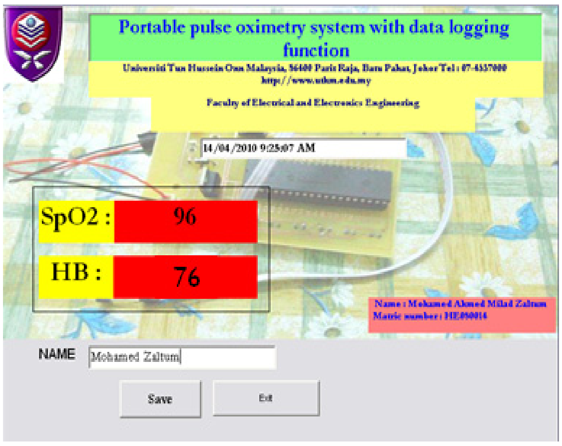
Thus, there is a need for the signal to be amplified. The signal were then fed into the amplifier and further processed by the PIC.

The next stage was to program the selected PIC. This required more efforts than the previous stage as the PIC needed boot loading then the micro C code was loaded into it. The PIC were programmed in order to functionalize the ADC converter thus, converted the analogue signal into digital.

Finally, the device was completed by the attachment of an LC, as well as demonstrating the output reading from the device through the computer. From this, the user of this PO device could read their test results via an LCD as shown in Figure 7.

In addition, the test results were also recorded and displayed on a computer by Visual Basic as show in Figure 8.

Fig 7. The Liquid Crystal Display (LCD) screen showing an example results


Portable pulse oximetry system with data logging function

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SpO2 : 96

HB : 76

Name : Mohamed Ahmed Milad Zaltum
Matric number : HE090014

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Fig 8. Display of the recorded test results via Visual Basic software

3.1 Comparison between standard System (DOLPHIN MEDICAL 2100 PULSE OXIMETER) with the proposed System

Once the PO device has been designed and developed, it is crucial to conduct a comparative analysis between the designed and the standard PO device.

Thus, the analysis will prove the reliability of the test results produced by the designed PO device. For this purpose three people with different skin color were selected such as (bright skin, fair skin and also dark skin). Therefore, in this section, Mr. Wan Suhaimizan, Mr. Mohamed Alarqaa and finally, the author himself (Mr. Mohamed Zaltum) were selected for the HB and SpO_2 comparative test procedure.

The test results were obtained via the Standard System and Proposed System at the same time under five different conditions such as (soon after arriving at the lab, after rest, after exercise, rest after exercise and then finally, before leaving the lab). The conditions were kept the same for the three persons who participated in this PO device testing. The results were then plotted in the following Figure 9, 10 and 11.

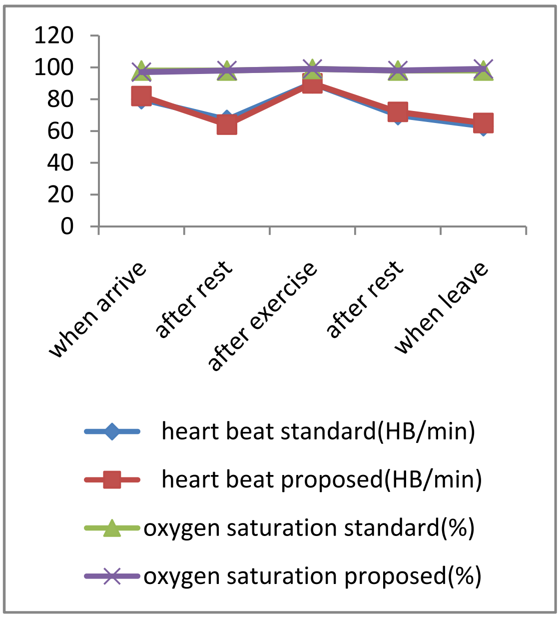

Fig 9. Results showing the output reading for pulse/oxygen level of (Mr. Mohamed Alarqaa)

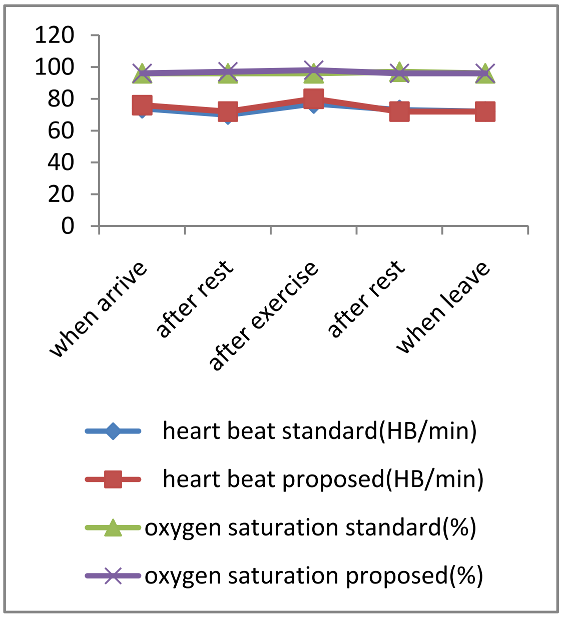

Fig 10. Results showing the output reading for pulse/oxygen level of (Mr. Wan Suhaimizan)

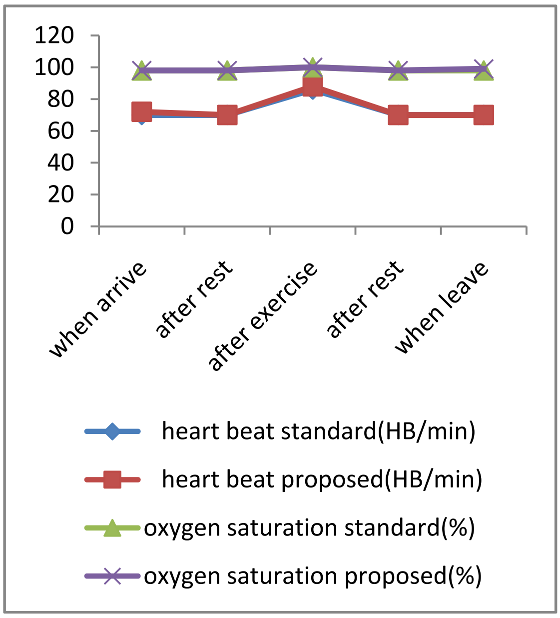

Fig 11. Results showing the output reading for pulse/oxygen level of (Mr. Mohamed Zaltum)

From the results obtained for the three candidates as shown in the graphs (Figure 9, 10 and 11) the developed PO device were capable of producing test result with very close to the standard device. In another words, it could be summarized that the newly developed PO device were able to produce the test results with a difference of 5% error state, which demonstrated that the device has a high level of accuracy in comparison to the standard device. Next, the designed PO device was further tested for its reliability via a standard SpO_2 simulator. The tests were conducted for both HR and SpO_2 readings. The outcome of this test will be discussed in the next section.

3.2 Test Proposed System by SpO_2 Simulator (Index 2)

The results obtained from the standard system were compared with the SpO_2 simulator under two setting which are (70 heart beat per minute (HB/min) and 75 HB/min). These standard values were set with the SpO_2 device and compared with the standard system. From the tests performed, it was discovered that the results produced by the PO device through the standard system were also having less than 5% errors, as shown in Figure 12. This again demonstrated the accuracy and reliability of the results as in the readings for the HB and SpO_2 that were being produced by the PO device designed in this study.

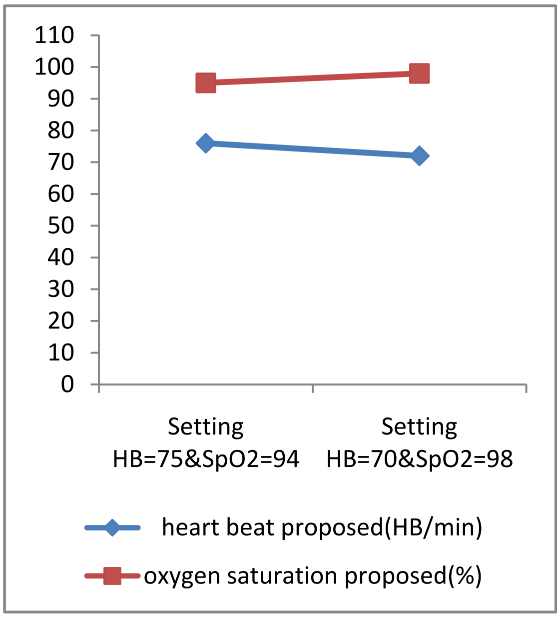

Fig 12. Results produced by the SpO_2 Simulator (Index 2) and the Proposed System

4. CONCLUSIONS

Overall, the objective of this research has been achieved, since the result obtained from the developed PO device has less than 5% errors state in comparison to the standard device. Therefore it is assured that the device were able to produce highly reliable test results for both the HR and SpO_2. Considering the high cost of the standard equipment, local ones as in this study the home-built PO device demonstrated the proof of concept, where by a much cheaper device can be produced. In addition, this PO device has the extra function of recording the test result for the user to come back later to analyze and observe their test result again. Finally, these PO devices are highly suitable for personal usage, technical school and university level for educational and research purposes.

5. ACKNOWLEDGEMENT

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