Health Monitoring System using Pulse Oximeter with Remote Alert

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Abstract*—This A remote patient monitoring system is implemented which is used for real time monitoring of various heath parameters of a remotely based patient. Oxygen saturation and body temperature are the two parameters calculated and transmitted via a server to a remote client. The main purpose of this paper is to present a remote Pulse Oximetry System for health monitoring purposes. The framework lays on the idea that the vital health signs, can be collected from the patient and passed to a processer, where these signs will be processed, compared and monitored in order to alert important personnel in the case of an emergency. The blood oxygen saturation is the biometric sign which is monitored by this device .The technique used in this work is called "Photoplethysmography" which is based on the change in the intensity of light transmitted through the tissue due to arterial blood pulse. This technique converts the intensity of light into a voltage signal which is used to calculate the oxygen saturation of the patient. This is due to the fact that oxygenated blood has such characteristics in absorbing the Red and Infrared wavelengths which differs from the deoxygenated blood. Comparison of the two absorptions produces an estimation of the oxygen saturation in the patient's blood.

Keywords: SpO2, LM35 Sensor, Pulse Oximeter Sensor, HbO2.

I. Introduction

This Monitoring patient's vital health signs at home are very important to save the patient's precious life. The advancement in technology made it a simple task for both the patients with critical heart diseases and another critical health conditions along with their respective doctors to monitor the important health signs at home instead of being at the hospital the whole time[1][2]. An important health sign for patients with such conditions is the blood oxygen saturation known as SpO_2. The pulse oximeter continuously and non-invasively monitors the level of the oxygen saturation in the blood of the patient. The collected data from the pulse oximeter is then sent to the doctors in their PCs. Also, with the aid of software, it send alarm message whenever it detects an abnormal condition such as "SpO_2 level drop, the sensor being detached weak signal and etc. Many studies where done and they highlighted the advantages of using the pulse oximetry in monitoring the blood saturation levels for patient with critical heart diseases. For example, Simon and Clark reported that the use of pulse oximetry decreased the need to use arterial blood gas analysis by 37%. Additionally, they reported that the use of the pulse oximetry caused significant changes in the medical treatment of disorders in the emergency rooms.

II. Overview of the Oximeter

Looking back at the history of the oximeter, the first device to measure the oxygen saturation by transilluminating it with colored light " red and green filters", was invented in 1935 by a German physician called Karl Matthes (1905-1962). The device was unable of distinguishing between the arterial, venous and capillary blood. To include both the venous and capillary blood, an attempt was made in the period of the Second World War as a part of a project to investigate the problem of the loss of consciousness by the American physiologist Glenn Allan Milikan (1906-1947). However, the transmitted light through the ear is not attenuated by the arterial, venous and capillary blood only, it is also attenuated by the skin whose pigmentation and because of that the absorption properties varies from one person to another. Also, the absorption properties will vary with respect to the thickness of the tissue (muscle, bone and etc). In 1949, Wood added a pressure capsule in order to squeeze the blood out of the ear to obtain the zero setting in an effort to get the absolute oxygen saturation value and that is when the blood was readmitted. In 1964, Shaw was able to assemble the world's first absolute reading ear oximeter. The device uses eight wavelength of light to obtain the absolute O_2 saturation level in the blood. The device was commercialized by Hewlett-Packard. The device's use was limited to pulmonary functions and to the sleep laboratories because of its cost and size. The first pulse oximetry was developed in 1972 by two Japanese Bioengineers, Takuo Aoyagi and Michio Kishi who were working at Nihon Kohden Corporation. The device used the ratio of red to infrared light absorption of the pulsating the components in the measuring site. The device was tested on patients by surgeon Susumu who was working at Sapporo Minami National Sanatorium along with his associates which led the device to be reported in 1975. After that, the device was commercialized by Biox and Nellcor (which is now part of Corvidien Ltd.) in 1981 and 1983 respectively. The invention of the pulse oximeter was a breakthrough which helped doctors and especially surgeons to get quick but yet an accurate reading to the patient's oxygen saturation levels. Before the invention of the pulse oximeter, the patients' oxygenation could only be determined by arterial blood gas

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which is a single – point – measurement that takes several minutes for the sample collection which can be only processed by the laboratory and that made it inconvenient in the operating rooms. Due to its quick and accurate readings, the pulse oximeter was directly used in the operating rooms to monitor the patient's oxygen level. This encouraged Biox to shift their attention from initially being concerned with respiratory care towards expanding their marketing resources to focus on operating rooms market in late 1982. In 1983, Nellcon started to compete with Biox for the U.S operating room market. By 1987, the standard of care in the administration of anesthetic decided to include the pulse oximeter in all the operating rooms across the U.S. After the operating room, the use of the device spared into being used in the recovery rooms and then into the intensive care units.

In 2009, Nonin Medical Inc. introduced the world's first fingertip pulse oximeter with Bluetooth technology [3][4][5]. The main purpose for that was to help with the increasing need for the remote disease management. Onyx II 9560, provided a solution that helps in simplifying the exchange of information between both the patients and their clinicians to monitor the vital health signs [6][7][8]. The company says that the integration of interoperable, Bluetooth technology helps in monitoring the health signs in environments never before possible [9][10][11].

III. Methodology And System Components

The system is divided into two major parts namely:

1- Hardware components
2- Software components

These two parts work side by side in order to achieve the desired results. Also, in this section, the main flowchart is presented alongside its explanation.

A. Hardware components

The main aim of the hardware part of this system is to generate, process and compare the results of data. The software part enables the system user to get the logic which helps in calculating the oxygen saturation from the transmitted and received wavelengths of light. This process is going to be based on the transmission mode of the pulse oximetry. In this mode, the test side is going to be sandwiched between the transmitters which are placed on one side and the receivers on the opposite side. This allows the sensors to collect the two incidents of light at the same time.

After that, the received data is going to be processed in order to get the actual SO_2 level by using Equation (1). The equation used for obtaining the oxygen saturation is giving by:

$$\frac{R}{IR} = \frac{I_{Rmax}/I_{Rmin}}{I_{IRmax}/I_{IRmin}} \quad (1)$$

This equation is a normalization equation that gives the actual oxygen saturation within the blood. The parameters in this equation represent the AC and the DC current obtained from the infrared and the red LEDs respectively. The hardware part of this project is divided into two main parts which are:

1- Oximeter circuit.
2- Arduino MEGA and GSM shield.

B. Software components

This part of the of the system is responsible of providing the logic needed to compute and initialize the communication between the oximeter circuit and the Arduino board as well as initializing the communication between the Arduino and the GSM shield. The main equation used to compute the oxygen saturation presented in Equation (1) was first introduced by the Japanese scientist, Takuo Aoygi in 1970s. He was able to reach this equation observing that when he holds his breath, the ratio of the density of the red and the infrared wavelengths changes. Using this equation, the code needed for setting up the computation and the comparison between the absorption of the two wavelengths were able to be achieved. The flowchart is shown in Figure 2. It was written using the Arduino compiler that uses special and modified instruction set built to be compatible with the Arduino. The compiler also supports most of the C++ instruction set.

IV. Results and Discussion

The pulse oximeter is able to measure the SO_2 saturation based on the fact that the blood changes colour as the hemoglobin absorbs two spectrum of light depending on its saturation with oxygen. The two wavelengths used are red light with a wavelength of 660nm and infrared light with a wavelength of 940nm. The oxyhomoglobin absorbs more infrared light than it does with the red light. However, when the oxygen saturation decreases, the absorption of the red light increases as a result to that the colour of the blood becomes darker.

The pulse oximeter combines two technologies namely:

i. Spectrophotometry:

This technology measures the oxygen saturation within the blood. The calculation of the oxygen saturation within the blood is based on Beer-Lambet law which links the intensity of the light transmitted through a given solution to the concentration of the solution.

ii. Optical Plethysmograph:

This technology measures the pulsatile changes in the arterial blood volume.

A. The developing of the oximeter circuit

Any pulse oximeter circuit is build based on one of the two common modes:

a. Transmittance mode:

As previously explained, in this mode the light emitting diodes are place on one side of the test site while the sensors are placed on the opposite side in order to collect the passed through light.

b. Reflectance mode:

In this mode of the oximetry, both the light emitting diodes as well as the sensors are placed alongside each other on one side of the test site. This method is intended to be used in body locations where the transmittance mode cannot be used such as on the check, legs, and the forehead.

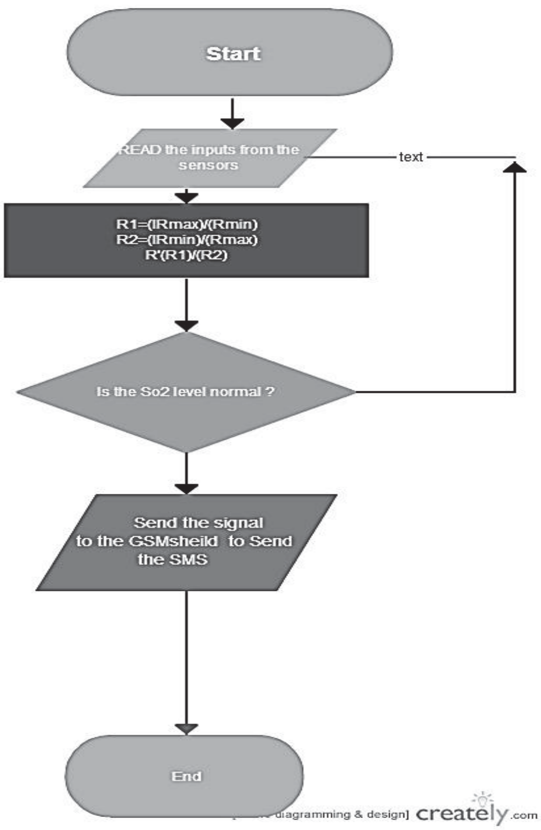

Figure 2 Computation and the comparison between the absorption of the two wavelengths

In this system development, the transmitted mode of oximetry was used due to convenience and the advantages it gives. The advantages of using this mode can be listed as the following:

1. The separation between the outcomes of the two transmitted wavelengths.
2. The resulting signal from the two sensors will be less effected by the noise that would occur in the case of reflectance mode.
3. In this mode, the infrared absorption can be used as the base at which the absorption of the red light would be compared.

After choosing the oximetry mode, the circuit was developed using the components shown in Figure 3.

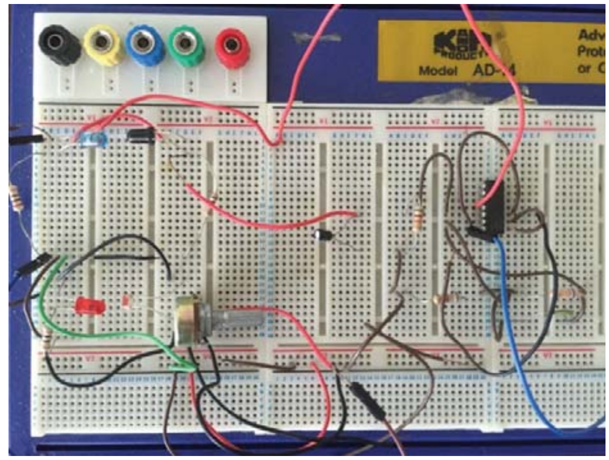

Figure IV1: Pulse Oximeter circuit

After constructing this circuit, the infrared sensor was attached to a filter that helps to reduce the noise effect and obtain a much better signal form. The filter has a cutoff frequency of almost 2Hz. The aforementioned is depicted in Figure 4.

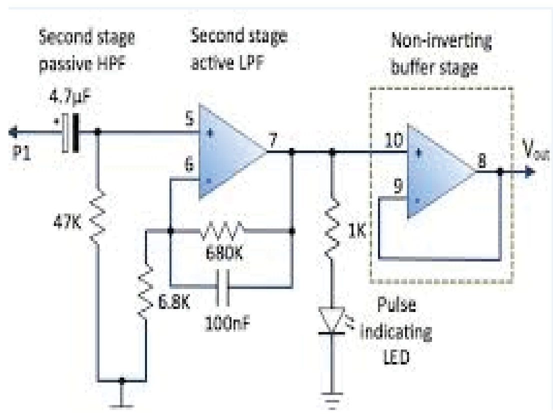

Figure IV. High pass/low pass filter

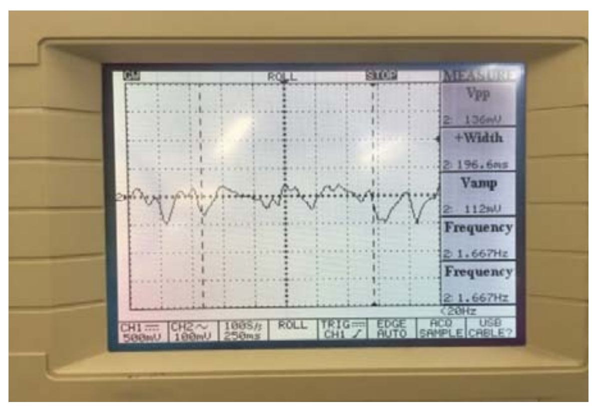

Figure 5: The outcome signal from the IR LED before adding the filter

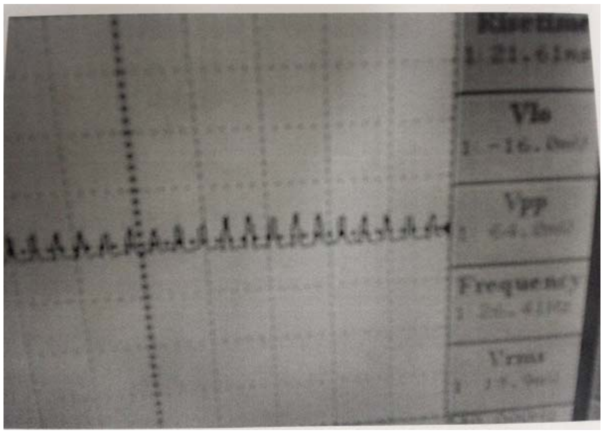

Figure 6: The outcome signal after the implementation of the filter

V. SOFTWARE DEVELOPMENT AND RESULTS

The software that supports this system was written using the Arduino C++ libraries. This software is responsible of computing the SpO_2 within the blood from the collected signal from the two sensors. The software computes this result by using the normalization equation presented earlier in Section 3. The outcome is then compared to the normal level of oxygen saturation and the condition is set to detect any level of SpO_2 which is below 95%. When the value of the oxygen saturation is below this condition, the software will initiate the GSM shield in order to send a SMS message to the physician mobile device. The results are shown in Figure 7.

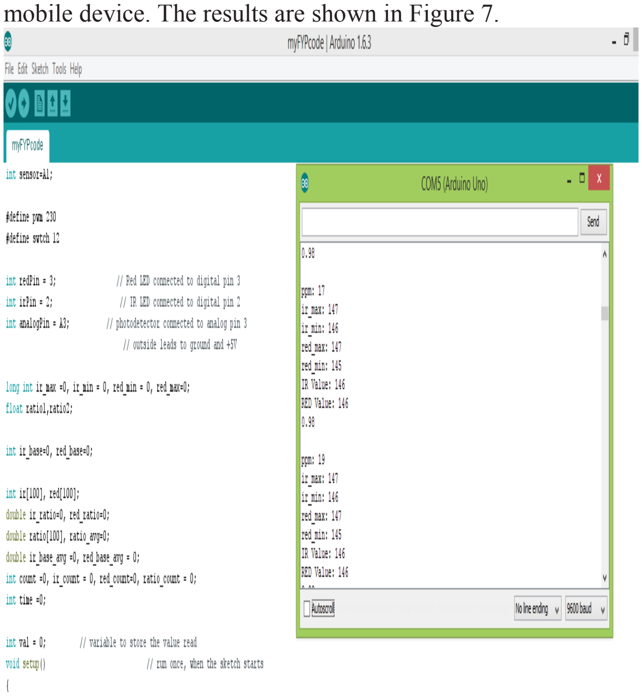

Figure 7 Calculation of the Oxygen saturation

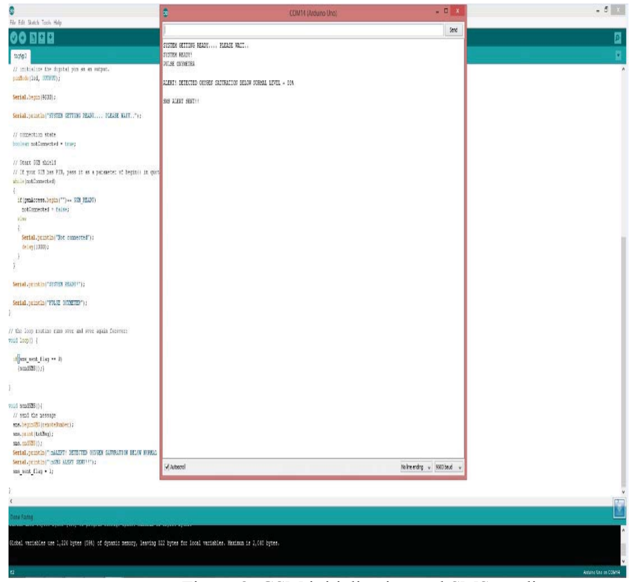

Figure 8: GSM initialization and SMS sending

The system was tested on few volunteers. Some samples were taken when the volunteers were asked to breathe normally. The oximeter was placed on the index finger of the volunteers and the serial monitor command of the Arduino compiler was used to display the parameters of the IR and red sensors as well as the percentage of the oxygen saturation which is calculated with the normalization equation. In the last sample, the volunteer was asked to hold her breath for 45 seconds and the same procedure was followed. This sample was intended to test the condition in order to ensure that the GSM shield was working properly. The oximeter recorded a severe level of drop in the oxygen saturation which is in the range of moderate hypoxia (86-90%). When the software detected this condition, it initiated the GSM shield and sent text message as shown in Figure 9.

VI CONCLUSION

The Arduino-based pulse oximeter was successfully built. The pulse oximeter is a very important device that helps in the continuous monitoring of one of the most important health parameters namely the oxygen saturation. The absorption of light by the blood shows the significance of the implementation of this form of energy in monitoring the wellbeing of the human being. After finishing this project, the difficulties faced can be listed as the following:

1. The significant effect of the noise on the outcome waveforms obtained from the sensors because of the surrounding sources of light.
2. The high sensitivity of the LEDs as well as their sensors which may lead to the permanent damage of these devices.
3. The transformation of the analog signal form into the digital signal form yields in some invalid outcomes which cannot be verified because most of the related works are under copyright.

4. The development of the code to calculate the SpO_2 was a little bit complicated.

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