# Design and Development of Miniaturized Pulse Oximeter for Continuous Spo2 and HR Monitoring with Wireless Technology

**Rekha Chandra R, Safeer K P, Srividya P**

***Abstract*—This paper demonstrates the design of a Pulse Oximeter using 8 bit Atmel Microcontroller .The Oxygen Saturation of blood (SpO2) and Pulse Rate are the two important parameters for monitoring patient's health condition. The method that has been used to measure pulse rate is widely known as photo-plethysmo-graphy (PPG). The Pulse Oximeter is one of the medical device used to measure SpO2 and pulse rate of a person and its readings is analyzed using developed algorithm. The proposed system consists of Finger tip sensor, Analog device, 8 bit Atmel Microcontroller circuit and display unit (PC). The oxygen saturation of blood can be calculated by measuring different intensities of red and infrared lights operating at different wavelengths of 660nm and 940nm. The pulse rate can be calculated by measuring the peaks of IR signal between the elapsed time. All these parameters are measured and then transferred to PC via Bluetooth for displaying the results. Practically, any body part can be used to measure pulse rate through the sensor, although fingertips and earlobes are commonly targeted.**

***Index Terms*—SpO2,Pulse rate, PPG, Microcontroller.**

## I. Introduction

Continuous measurement of arterial blood oxygen saturation level and pulse rate are the very important parameters for old people, pregnant women and in several critical situations. This is continuously monitored by a pulse oximeter device. A pulse oximeter is one of the medical device which indirectly monitors the patient's oxygen saturation level in the blood noninvasively and continuously (as it is opposed to measure oxygen saturation (Spo2) directly from a blood sample) and changes in the blood volume due to arteries in the skin, produces photo-plethysmo-graph (PPG). The PPG signal consists of different components like AC and DC due to arteries, blood volume, skin, tissues, muscles, blood vessels etc and noise which are caused by motion artifacts, respiration rate, thickness of the skin etc. This project presents a miniaturized and a low cost pulse oximeter to continuously measure patient's oxygen saturation level in the blood (SpO2) and pulse rate. Pulse oximeter works on the principle of absorption of light and transmittance/reflectance of light characteristics. Absorption of light takes place due to oxygenated blood and deoxygenated blood, where oxygenated blood contains different light absorption characteristics due to arterial blood vessels (called AC component) than deoxygenated blood, because light absorption characteristics due to skin, tissue or muscle remains constant under red and infrared wavelengths of deoxygenated blood (called DC component). Oxygenated blood absorbs more infrared light than red light due to this the blood volume at high saturation has very low impact on the detected red signal than infrared signal. Thus AC component of red signal is less than infrared signal. Deoxygenated blood absorbs more red light than infrared light, due to this the blood volume at low saturation has very low impact on the detected infrared signal than red signal. Thus AC component of infrared signal is less than red signal. The change in the light intensity due to arterial blood pulse, transmitted through tissue called the photo-plethysmo-graph (PPG), which can be measured as a voltage signal. PPG signal can be obtained by taking the ratio of ratios of light absorption characteristics of red and infrared light that is., AC component and DC component from each of the two Led's. So an hardware implementation is included by placing a finger in between two light sources (red and infra red) and a photo detector placed on the opposite side of the two LEDs to obtain corresponding PPG signals, which can be used to estimate the oxygen saturation level (SpO2) by comparing the light absorption characteristics of the two different LED's. As the PPG signal is corrupted by motion artifacts, it is given to the Microcontroller for further signal processing. Thus SpO2 can be calculated by computing both the AC and DC components of red and infrared LEDs corresponding to PPG signals.

## II. Background

Cristian Rotariu et al. [11] proposed an efficient long time continuous patient monitoring system, which includes determination of oxygen saturation level in blood and heart rate and provides a better medical assistance for patients. This system includes SpO2 and heart rate acquisition by using wireless network in support of microcontroller firmware and provides the results in central monitoring system using graphical user interface. To determine the precision of SpO2 and HR, they have considered METRON simulator through which better accuracy has been maintained. The major advantage of this methodology is that, it is used for remote monitoring of patients suffering from chronic diseases.

A survey was done by Alexandros pantelopoulos et al. [9] which made study of wearable sensor based system for health monitoring. The study was on different biosignal like ECG,

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BP, RR, SPO2, HR, Glucose level, EMG and EEG. The wearable sensors used for determination of these bio signals are chest electrodes, piezoelectric sensor, pulse oximeter, strip base glucose meter, skin electrodes and scalp placed electrodes respectively. In this survey pulse oximeter is defined as "a device which indicates the oxygenation or the amount of oxygen that is being carried in a patient's blood".

An online based graphical display system was developed in determination of Spo2 and heart rate by Dilpreet Kaur et al. [5]. This system consists of a photo-plethysmo-graph probes that senses PPG signal and converts it into electrical signal which is then passed onto driver circuit. This circuit corresponds to the controlling of led switching with monitoring of ac & dc components. Further, this data is passed onto amplifier which improvises the signal strength and converts the data into digital signal by the use of ADC. This signal is further processed by microcontroller and displayed.

Sangeeta Bagha et al. [1] made a real time analysis of photoplethysmography signal for determination of oxygen saturation level and pulse rate. This system involves development of the pulse oximeter system in support of labview software. The hardware system includes sensor unit followed by transimpedence amplifier and sample hold circuit to obtain red and infrared PPG. This data is passed onto Labview through DAC. This system is real time feasible which would reduce the performance of conventional pulse oximeter.

Gayathri.R et al. [2] developed a pulse oximeter using MSP microcontroller. This system majorly classified into transmitter and receiver section. In transmitter section, the Spo2 signal from the sensor module is amplified by op-amps followed by ADC conversion. This digital data is transmitted to the receiver section by the support of Zigbee module. In the receiver section, Zigbee module supports in reception of transmitted data which is further stored in ATmega controller and displayed in PC. The main advantage of this system is to reduce the power consumption.

M. Laghrouche et al. [13] designed a low cost embedded oximeter for the purpose of diagnosing and treatment of diseases using medical devices. In this method, a wearable pulse oximeter systemis used for continuously monitoring physiological signals which is difficult for the advancement of diagnosing and treatment of diseases. The device used to measure heart rate and SpO2 can be measured by non professionals at homes. This system measures real time data for the analysis of arterial SpO2 and heart rate using wireless transmission.

Raksha Iyer et al. [10] proposed an advanced low cost system for the determination and calculation of physiological parameters of human subjects. In this system the heart rate is measured by heart beat sensors. Oxygen saturation level, heart rate is determined by pulse oximeter. Temperature determination is done by LM34 and the weight is determined by weight sensor. These sensors are monitored and the signals are processed by passing through signal conditioning and microcontroller and its results are displayed in display unit.

Kiran Kumar et al. [15] using a programmable system on chip, they developed portable health monitoring system. The main objective is to design a low cost, low power consumption and use of flexible network for determination of heart rate, oxygen rate, PH level and ECG. In this method, the sensor signal is passed on to PSoC circuit which is processed by using the inbuilt ADC, UART, Amplifier and microcontroller whose results are displayed on LCD with the support of transreceiver units. The major feature of this technique is use of PSoC circuits in replacement of microcontroller. However the system is yet to be properly implemented as the device size is larger and is not feasible for daily life usage.

Abhishek Ekhare et al. [7] developed an efficient pulse oximetry technique which quickly determines the decrease in patient's blood oxygen saturation levels and pulse rate. This system uses a wireless technique to transfer the results to a remote location like computer or mobile phones in emergency conditions. The datas from the pulse oximeter probe is passed onto photo detector from which is given to signal conditioning circuit that consists of multiple filters and amplifiers and is given to the microcontroller unit for monitoring applications and transmitted via GSM module. The information regarding reduction of Spo2 rate falling below 90% or pulse rates below 60 or above 150 is immediately noticed and passed onto health care consultant. It is tested on real time patients and proved to be efficient

## III. WORKING PRINCIPLE

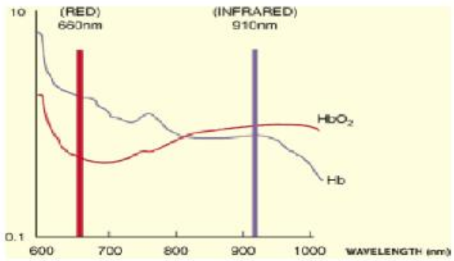


Fig1: Absorption of oxygenated hemoglobin and deoxygenated hemoglobin at different wavelengths

The developed real time pulse oximeter system consists of pair of LEDs operating at different wavelengths, one is the visible red spectrum of 660 nm and the other is the infrared spectrum of 940nm as shown in fig 1. There are two methods of light absorption characteristics, they are transmission and the reflectance of light. In the transmission method, the light sources (emitter) consists of red and infrared LEDs and the light detector consist of photo detector which are opposite to each other with the finger in between, where the lights can pass through. In the reflectance method, the light sources (emitter) and the light detector are placed on top of the measuring site (finger) that is., next to each other. The light is emitted from the emitter to the skin which results with a small fraction of changes in the light intensity, that is received by the photo detector across the site which are related to blood flow, tissue, blood volume, muscles. The signal from the sensor is sent to the analog device to convert it into digital data and then sent to the microcontroller for measuring the levels. The data from the microcontroller unit is being sent to display unit ie., PC via Bluetooth module as shown in fig 2 below. By placing the finger in between light sources and detectors, the ratio (R) between two different light intensities are measured that is, an AC and DC component from each of the LED can be calculated in the measurement. It is assumed that, the AC component results from the absorption by the arteries due to changes in the blood volume, similarly DC component results from the absorption by the body tissue, skin, bone and veins which remains constant. Thus the transmission of light can be calculated through the arteries and tissue by taking ratio of ratios(Ros) from each of the led's using Equation.(1), where R is ratio between AC component and DC component of red and infrared light.

$$\text{Ratio of ratios} = \frac{(AC/DC)Red}{(AC/DC)IR} \qquad (1)$$

Once the ratio of ratios (ROS) is calculated, the oxygen saturation (SpO2) can be calculated from the calibrated Equation (2) as follows:

$$SpO2 = 110 - (25 * R)\% \qquad (2)$$

Therefore by using a single medical device both oxygen saturation and Pulse rate of a volunteer can be measured.

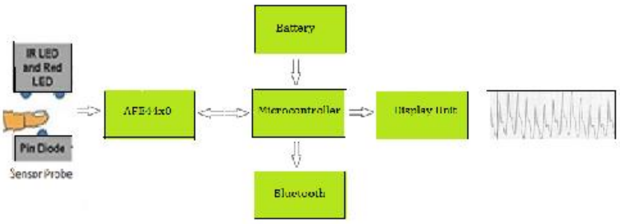


Fig 2: Block diagram of Spo2 and Pulse rate measurement

### A. *Sensor module*

The finger tip sensor consists of two LED's on transmission side and photodiode on reception side in which a finger is placed in between. The physical signal is captured from the human body (the index finger or the earlobe) through the pair of LED's with 660 nm (red) and photodiode with 940 nm (infrared). The photo detector detects the signal emitted by the emitter and converts it into electrical signal (voltage). The resulted signal has to be processed for the levels of conversion, amplification and filtration for which it has to be given to the AFE circuit.

### B. *Analog Circuit*

The AFE44x0 is an analog front end (AFE) circuit, designed for pulse oximeter applications, which consists of a low noise receiver channel integrated with an analog to digital converter (ADC), an LED transmission section, diagnostics module for sensor and LED fault detection. In this circuit, an analog signal obtained from the photo diode must be amplified, filtered, conditioned, scaled and has to be converted to digital form for further processing which has a voltage of 1.2V with a 22 bit resolution in order to pass it to the microcontroller. It is configurable timing controller and it communicates with an external microcontroller using an serial peripheral interface (SPI).

### C. *Microcontroller*

The microcontroller is used to configure and process the AFE44x0 analog front end (AFE) information. This 32 bit microcontroller from the Texas Instruments family is used for counting the pulse rate, calculation of SpO2 using an appropriate algorithm and controlling LED display using available pulse oximeters. It is of low power consumption, which is optimized to achieve extensive battery life in portable applications and it is used to separate red and infrared components before sending to a display unit.

### D. *Bluetooth Module*

Bluetooth technology used in this system communicates with a microcontroller unit (MCU) using Bluetooth module (HC05). It transmits the reading of continuously measured blood oxygen saturation and pulse rate to the PC for displaying the results.

### E. *Display Unit*

The results of SpO2 and pulse rate coming out from the controller are displayed on a PC via Bluetooth.

## IV. EXPERIMENTAL SETUP

The measured values of SpO2 and Pulse rate calculated for 6 different subjects using the above proposed pulse oximeter is shown in Table 1. This experiment is done offline using Matlab simulation. The noisy signal shown in fig 3, can be eliminated using band pass filter with the cutoff frequency of 0.8 to 3hz and sampling frequency of 50hz. The filtered signal of Red and IR is shown in fig 4. Later on online simulation is done and the results are displayed on PC via Bluetooth

Table 1: Experimental values calculated for different subjects

| Subjects | SpO2% | Pulse Rate |
|---|---|---|
| Subject A | 97.92 | 98 |
| Subject B | 98.54 | 98 |
| Subject C | 97.37 | 95 |
| Subject D | 96.12 | 90 |
| Subject E | 99.07 | 110 |
| Subject F | 97.75 | 87 |

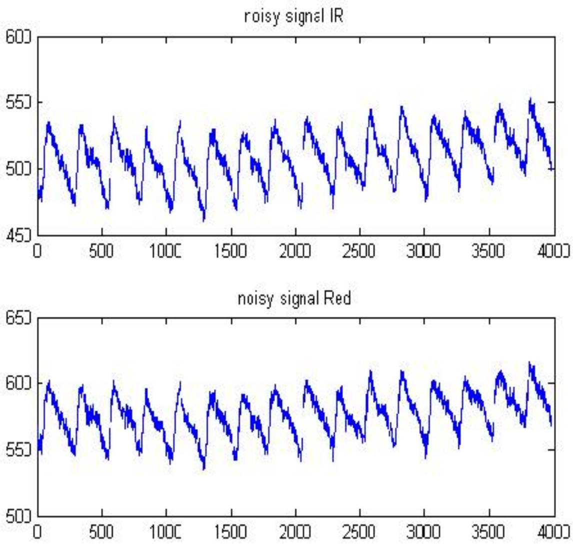


Fig 3: Noisy Infrared signal and Red signal and signal

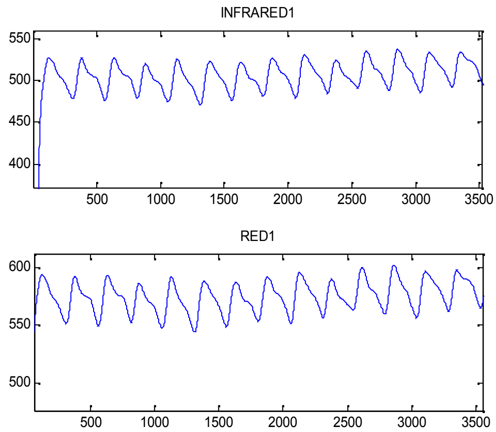


Fig 4: Filtered Infrared and Red signal

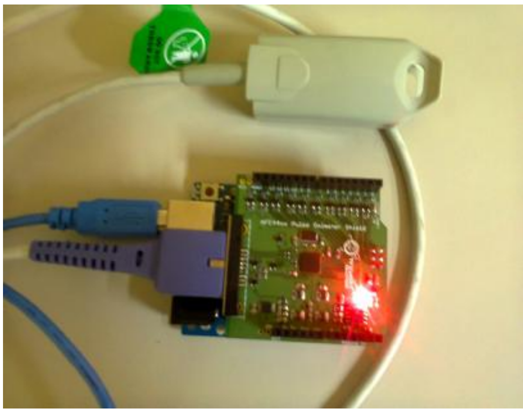

Fig 5: Analog device interfaced with microcontroller

## V. CONCLUSION

In this paper, we developed a process of a wireless Pulse Oximeter system for monitoring of SpO2 and pulse rate using a PPG technique, interfaced with 8-bit Microcontroller. The SpO2 and pulse rate can be measured non invasively for long time period using the developed algorithm. The value obtained from the controller is in digital form and the result is analysed using Matlab and AVR studio which is then displayed on PC via Bluetooth. While collecting the data for the measurements of SpO2 and pulse rate, generates noise and disturbance in certain conditions due to motion artifacts, skin pigmentation, venous blood etc. So an higher order filtering is required to detect PPG waveforms obtained from reflective sensors which is weaker than PPG waveforms obtained from transmission sensor. A better accuracy can be achieved in this system by reducing the motion artifacts.

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