Development of a Low-Cost Pulse Oximeter

Basma Binte Azma, Mohidul Hasan Rahad, Nowroz Bin Nasim

Abstract— **Pulse oximetry is a non-invasive sensor that measures the blood's oxygen saturation using light at particular wavelengths (most commonly the fingernail bed). The pulse oximeter uses a unique algorithm to analyze the absorbed light and display a saturation value. Hemoglobin with and without oxygen absorbs light at various wavelengths (660 nm and 940 nm, respectively). It is used in emergency rooms, hospital wards, and ambulances to measure blood oxygenation in patients with respiratory issues or to monitor the respiratory depressant effects of pain medications. It is a standard monitor for all anesthetic cases in most industrialized nations. This project aims to create a pulse oximeter without requiring specialized sensors, using only essential electronic components.**

Introduction

A pulse oximetry technique determines the blood's oxygen saturation level. It is a simple, painless test to determine how well oxygen is being delivered to the body parts farthest from the heart, such as the arms and legs. A probe, which resembles a clip, is applied to a body part, like an ear lobe or finger. The probe measures the amount of oxygen in the blood using light. This knowledge aids the medical professional in determining whether a patient requires additional oxygen. Pulse oximetry may be employed to determine whether there is enough oxygen in the blood. Numerous circumstances call for this information. It may be used - During or following sedation-involved procedures or surgery, to assess the effectiveness of lung medications, to determine a person's capacity to handle more activity, to determine whether a ventilator is required to aid in breathing, or to assess how well it is doing, determining if someone experiences sleep-related breathing pauses (sleep apnea). A person with any condition that impacts blood oxygen levels, such as a heart attack, heart failure, chronic obstructive pulmonary disease (COPD), anemia, lung cancer, asthma, or pneumonia, can also have their health evaluated using pulse oximetry. Other factors may have led the doctor to suggest pulse oximetry.

System Overview

A. Working on the Pulse Oximeter

We have used Arduino pro mini as it is convenient and can be carried anywhere. The Arduino pro mini is powered by a 9V battery attached to a MOSFET which acts as a voltage regulator to convert the voltage from 9V to 5V. The sensors of our circuits are the Red Led, IR Led, and Photodiodes, as shown in fig-1.2. The sensors are attached to the analog ports of the Arduino pro mini. We have attached 4.7K ohm resistors and transistors to the Red Led, the IR Led, and a 10K ohm resistor to the photodiode. We used an OLED display that is attached to the digital ports of the Arduino pro mini. When we insert a finger between the sensors, the photodiode receives the signals one by one from the Red and IR led that have passed through the finger and sends the signal report to the Arduino, where the programs in Arduino compare the results and find out the oxygen level in the blood and pulse rate, the block diagram in fig-1.1 shows the process.

B. Block Diagram showing the system

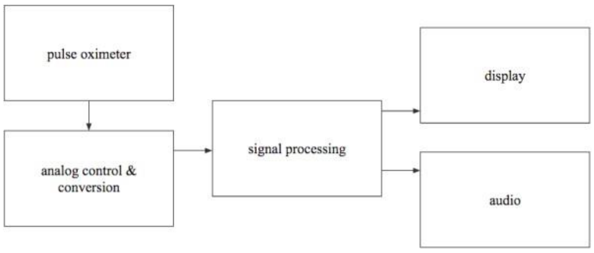

Fig-1.1(Block diagram of the system)

II. PRINCIPLE OF OPERATION

The pulse oximeter sensor is a finger clip that consists of a red, infrared, and photodiode-emitting LED, as shown in fig-1.2. The LEDs will shine light through the user's finger with the proper driving circuitry, and a photodiode will measure the amount of light absorbed. Because oxygenated hemoglobin absorbs less light than pure hemoglobin, the amount of oxygen saturation in the user's blood can be determined by the amount of light absorbed.

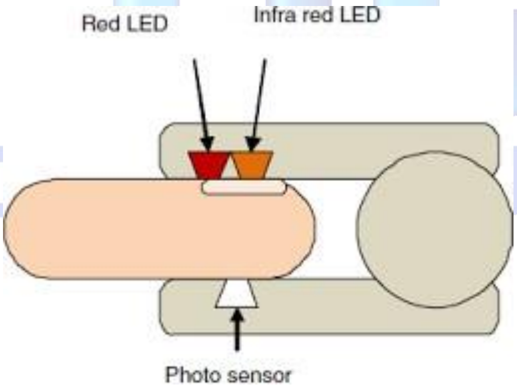

Fig-1.2 (Sensor LEDs)

A. Analog Control and Conversion

The pulse oximeter will be connected to an analog driving circuit to translate light pulses into a rough oxygen saturation signal. This initial signal will then be processed through the Arduino pro mini, where the input readings from the analog sensors will be gone through the code and calculated with proper calibration to give us the blood oxygen level and pulse level that is then displayed in an OLED display connected to the digital ports of the Arduino pro mini.

The sensor's oxygen saturation signal will be analyzed to calculate the patient heart rate in real-time. The R wave, representing ventricular depolarization of the heart, signifies the most substantial peak in the oxygen saturation signal for each heartbeat. The elapsed time between successive R waves will be calculated using an algorithm for real-time detection developed by Pan and Tompkins [4]. This RR interval will be converted to the current heart rate value. The noise-reduced signal and the current heart rate calculation will be passed to the display and audio modules for presentation to the user.

B. Circuit Diagram

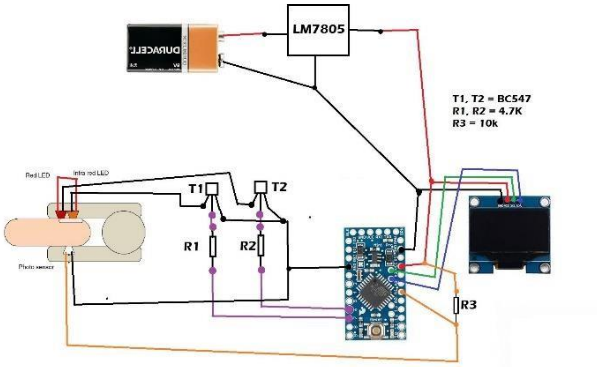

Fig-1.3 (Circuit diagram)

C. Ports and Connections

- Anodes of the Red and IR led are connected to the VCC
- The cathode of the Red led is connected to a transistor, the emitter of a transistor. The collector of the transistor is grounded, and the base of the transistor is connected to a 4.7K ohm resistor, which is connected to pin 6 of the Arduino.
- The cathode of the IR led is connected to a transistor, the emitter of a transistor. The collector of the transistor is grounded, and the base of the transistor is connected to a 4.7K ohm resistor, which is connected to pin 7 of the Arduino.
- The anode of the photoresistor is connected to a 10K ohm resistor and then to the A1 pin of the Arduino.
- The cathode of the photoresistor is grounded.
- The VCC pin of the display is connected to the MOSFET, and the ground pin is connected to the ground. The SCL pin is connected to the A4 pin, and the SDA pin is connected to the A5 pin.
- The circuit is powered by a 9V battery connected to a MOSFET that regulates the voltage to 5V.

D. Programming

The Arduino pro mini used in the project cannot be directly connected to the laptop for programming, so we have used an Arduino UNO and removed the chip, connecting the Tx and Rx port with the Arduino pro mini, and successfully connected the pro mini to the laptop. We have used the Arduino IDE software for the programming and compiled the software, and uploaded it to the Arduino pro mini.

As the code was successfully uploaded, we disconnected the Arduino pro mini from the Arduino Uno and connected it to our circuit.

III. PROJECT DEMONSTRATION

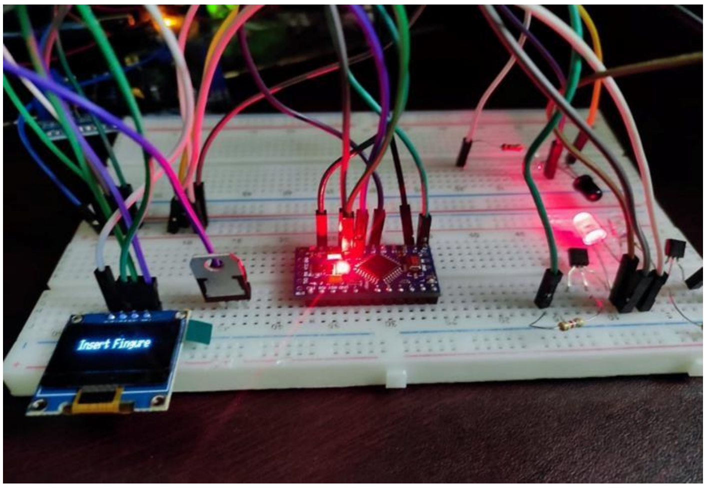

Fig-1.4 (Front view of the circuit with display)

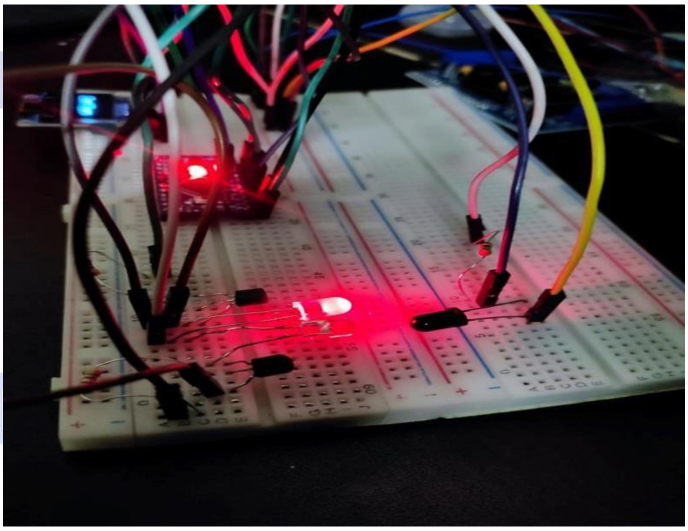

Fig-1.5 (Side view of the circuit showing the sensors)

A. Result Analysis

After the project was finished in fig1.4, we collected a few readings from the pulse oximeter and compared them to readings from a pulse oximeter readily accessible in stores. In our initial tests, the values differed from 6 to 11 percent when compared to a pulse oximeter readily accessible on the market. The results currently differ by 3 to 6 percent compared to a commercially available oximeter due to our continued effort in calibrating our program. We ensured the sensors were covered from external lights and very close to the finger.

B. Discussion

The objective of the project was to design a pulse oximeter with essential electronic components that are readily available at an affordable price. With proper discussion among our group mated, we have tried to achieve our goal. We tried not to use any complex components or circuits. Initially, we designed a circuit in online CAD software to look into the possibilities of the circuit. We used various components but finally reached a circuit design that seemed to work fine and is quite simple.

The programming of this project was lengthy part. We initialized the program with every piece of equipment we were using and started to add calculations step by step. Several times the programming had faults in it, which required our effort and time to make it properly functioning again. Finally, as everything was ready, we calibrated the formulas used in the program to make the reading accurate compared to a commercially available oximeter.

In the hardware section, we faced a few problems as many of our components failed to work at the initial stage; while soldering, we even needed to replace an OLED display. The sensors were replaced with new ones time by time. However, finally, we could reach a point where all the hardware seemed to function correctly, and we were able to take readings.

C. Conclusion

The primary purpose of this study was to create a device that could measure SpO2 in a non-invasive, comfortable, and continuous manner. The results reveal that the device works using a pulse oximeter or a visual approach with two diodes fig1.5. This research proved to be a good beginning point for developing a gadget that, with a few tweaks, will become a medical device. Our goal of making the system accessible and portable has been thoroughly proven and tested.

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