Smart Phone Based SpO2 Monitoring System

Omkar Satav, Shubham Shinde, Sushant Kamble
Department of Electronics & Telecommunication Engineering, Vishwakarma Institute of Information Technology, Pune, India.

Abstract- Smart phone is one of the most globally high powered device with which one can do almost anything for basic use. So as to make regular health checkup an habit with android programmable device which can be handy for any person & also cost effective. The goal is to provide a portable and low powered device for SpO2 measurement and detection of PPG wave to display its result on any android device. The discussion covers light absorption, sensor calibration, signal conversion, transmission media and power device. Open source pure JAVA API, android plot is used to create a dynamic PPG chart. Its library is added to our android application then the plot view can be added to layout main file.

I. INTRODUCTION

A Smart phone based SpO2 measurement system is a eccentric method used to calculate the oxygen saturation of human body. The fundamental of expanding this method is to spread the custom of constant health assessment. Standard devices are huge so patients needs to go to hospital even for small checkup which is wastage of time and money. While there are technology in some mobiles for health monitoring but they are not medical devices used for diagnose & are also costly. Our main aim is to make device wireless, less bulky, smaller & much more cost effective.

Smart phone based SpO2 monitoring system is named because of its ability to show the value of SpO2 on any Smart phone device. It uses smart phone’s display to indicate SpO2 value on android application which is been developed specially for this device. It also stores this detected value in database format which can be used for further monitoring. This gives user an autonomy to monitor there regular health without invasive method. It will also save the time and heavy fees spend on doctor.

World health Organization (WHO) stated that 17.5 million death were caused in 2012 due to CVD’s (cardiovascular diseases) that was almost 31% death overall in a year. To take precaution against CVD’s which include congenital heart diseases, heart attack, heart muscle diseases, coronary artery diseases etc. There are many technique to detect CVD’s by several means which includes ECG monitoring but there is a requirement of portable device which can supervise the CVD patient. Monitoring ECG signal is sophisticated for normal person but PPG can be accepted by general public as it uses only single detection without any Invasive method. PPG (photoplethysmogram) is a volumetric measurement of an organ. PPG can be used for monitoring of heart rate, Respiration, Depth of anesthesia and Hypervolemia.

II. System Overview

In this paper a portable SpO2 detector which uses PPG is designed and also implemented to communicate, monitor & control different components are being used. This device consist of 6 different parts: Pulse Oximeter, AFE4490, Arduino, Bluetooth module, Power device, and Android device. The Block diagram of system is shown in fig.(1). The system uses pulse oximeter to detect the signal from Infrared & red led which transmit to photo-detector. The signal obtained from the pulse oximeter is transmitted to AFE4490 which is signal conditioner IC which amplifies, removes noise & converts the data in digital form. This digital data is send to Arduino to calibrate & calculate value of SpO2 by formula. This SpO2 signal is send to the android device through Bluetooth (HC-05) as Bluetooth module is point to point for communication.
III. Methodology

A. Pulse Oximeter (Nellcor Oximax 100A)

Nellcor Oximax DS100A sensor are designed in such a way that it should provide best measurement of SpO2. This sensors have high accuracy, lightweight, reliable & reusable with wide range of single patient use sensor. It uses non-invasive method with Oximax technology which is placed on fingertip to any size of person & infant, signal has a DB-9 connector to output. It consist of Infrared & Red led with photo-detector which are necessary component to determine peripheral capillary oxygen saturation. Two wavelength are passed to photo-detector which are Infrared & red led with a wavelength of 940nm & 660nm. Absorption of light at these wavelength differentiate between pure oxygen & impure oxygen in blood. Fig (a) shows absorption of light while fig(b) is Nellcor Oximax DS100A sensor. Impure oxygen allows more infrared light to pass through and absorb more red light. The amount of light transmitted is measured & differentiated with normalized signal that are produced. It measures percentage hemoglobin that shows the percentage of blood which is loaded with oxygen. The produced signal contains noise and needs amplification and conversion to digital form.

B. AFE4490 (Signal Conditioner)

The signal obtain from the Nellcor oximeter sensor is noisy & weak. To have more accurate signal TI’s AFE4490 IC is used. We use the AFE4490 shield kit so that it can fit on Arduino to make it easier for communication without any wire. AFE4490 shield shown in fig.2 (a). This module amplifies the signal eliminating the noisy components. Also this module uses 22 bit ADC to convert the signal into digital form. The AFE4490 is a fully integrated analog front end that is ideally suited for pulse oximeter application. The device is very configurable timing controller. This flexibility allows the user to have complete control of device timing characteristic. To ease clocking requirement and provide low jitter clock to the device, an oscillator is also integrated that functions from an external crystal. The device has n DB-9 connector at the input end so that pulse oximeter sensor can be easily inserted in it. The device communicate to external device using SPI interface. The device is complete AFE solution packaged in a single, compact VQFN-40 package shown in fig.2 (b) (6mm x 6mm) and is specified over temperature range of -40°C to 85°C.
C. Arduino Uno

The signal generated by AFE4490 is given to Arduino Uno for calculation and calibration of SpO2 value. Arduino Uno is a microcontroller board which uses ATmega328P. Arduino Uno is 1st board to have USB connector which can be connected to the PC for communication of software & hardware of Arduino. Fig. 3 (a) shows Arduino uno. Arduino software are used to write program in basic language like C. The calculation of SpO2 is done by the formula as

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\text{SpO2} = \frac{\text{REDac}/\text{REDdc}}{1\text{Rac}/1\text{Rdc}}
\]

Then we calibrated this value to get a proper signal without any error by formula \(\%\text{Spo2} = 110 - 25 \times R\). We use Arduino for serial communication which is available on digital pins 0(RX) & 1(TX) which does not require any external drivers. A software serial library allows serial communication.

D. Algorithm for Calculation of SpO2

We included all header files required like string.h, SPI.h, math.h, FIR.h. Initialized & defined serial port communicating with Bluetooth module HC-05. Define SPI pins along with clock driver data mode and set bit order type. Set baud rate for serial communication. Initialize the AFE4490, set all its registers for timing synchronization and data synchronization. Write various functions required for communication. Read IR & RED Led digital values through LED2VAL register & LED1VAL register respectively. Taking reading of 2000 samples and find out mean square value of RED & IR ADC. Obtain SpO2 value dividing RED ADC value with IR ADC value. Determine whether the probe is connected to finger or inserted to get SpO2 value. Using Bluetooth module send data to android application.
E. Bluetooth (HC-05)

Connection between HC-05 & Arduino is serial communication with transmitter and receiver signal pins connected to each other. We developed a shield for HC-05 so that it can be mounted on Arduino kit so to make connection easier & reduce the size of the device. Fig.4 (a) shows HC-05 shield. HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband.
F. Algorithm for Android Application

Bluetooth device sends the value of SpO2 which is displayed on this application. Include the graph view library in the android app gradle file & synchronize the project. Include all buttons Textview, Listview, Imageview, and Graphview in the XML layout file. Use relative layout for proper display and set the background image. In main activity java code, set the XML layout file. In manifest file write the code for permission to use Bluetooth. If Bluetooth is not available request user to enable Bluetooth. Scan various Bluetooth devices. Set OnItem ClickListener for selection of Bluetooth device. Use connect thread to establish RF channel for serial communication. Use connect thread for receiving and sending the data. Handler should be define for communication process. Once the handler is received send it to target handler. In message handler, first create a graph using graphview library. Create a new data point, every time message is received. Through the help of data points, update the graph. If there is any error received value due to probe not connected or finger not inserted then alert the user through toast or textview.

G. Power Supply (Adafruit Powerboost Shield)

Adafruit Powerboost shield is mounted on the Arduino and provides a slim rechargeable power pack with a built in battery charger as well as DC to DC converter. It consist of TPS61090 DC to DC converter chip which generates a stable output voltage. It provides high efficient power conversion and is capable of delivering output current upto 0.5A to 5V at a supply voltage downto 1.8V. It has power save mode for improved efficiency at low output power. During shutdown load is completely disconnected from battery. It also have over-temperature protection. The output has a USB connector for ease of use. MCP73831 is also in built in adafruit powerboost so as to charge the battery. It is a linear charge management controller which has high accuracy preset voltage regulation of 0.75%. MCP73831 limits the charge current based on die temperature during high power or high ambient conditions. We use lithium polymer battery of 3.2V to 1200mAH capacity which fits in the shield easily. The battery used is rechargeable which has over charging protection and discharging protection with over voltage protection.
IV. Conclusion

We have successfully developed a Smart phone based SpO2 measurement system with use of PPG to calculate SpO2 for regular health assessment of people. This device is light weight, smaller in size and wireless. This system is compatible with any android base device so that waveform of PPG & SpO2 value can be displayed to the user. Further this Data is stored in the device and can be send to the physician to analyze it.

V. Additional Development

In future we would use Raspberry pi to reduce the component and get the wireless data signal through wifi system which is in built in Raspberry pi. As we are now just monitoring SpO2 and PPG but further we would implement Heart rate, Temperature in one single mobile application. Also for support of every Smart phone Operating system like windows & IOS we would make an application.

REFERENCES