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# DESIGN AND IMPLEMENTATION OF A WEARABLE HEALTH DEVICE

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## Abstract

Many situations arise every day where humans have to worry about their health and fitness. Further monitoring critical human body parameters in reliable and regular manner helps clinical practitioners and common person to take critical decisions and improve life quality. With advancements in microelectronics and sensor technology, it has become possible to design and develop small size wearable devices for clinical and home usage that give and record regular health related data. The current work presents design and development of a small wearable device that measures pulse rate, oxygen saturation, skin and body temperature using high-accuracy pulse Oximeter sensor and temperature sensors. The Pulse/Oxygen saturation and skin/body temperature data from sensors is fed to Analog Front End (AFE) devices AFE 4490 and LMP 90100 by Texas Instruments respectively. The data is further processed at an ultra low-power Mixed Signal Micro-Controller, MSP430F5338 of Texas Instruments and fed to Bluetooth transceiver. The processed data giving the requisite health parameters is further displayed on the hand held device and can be periodically send to PDAs or to a central server through Bluetooth transceiver.

**Keywords:** Oximeter, Wearable Devices, Health Devices, Micro-controller, Bluetooth Transceiver

## 1. Introduction

Oxygen is most important elements needed by humans to sustain life. It is core element which turns sugar into usable energy. The protein haemoglobin {Oxyhaemoglobin (HbO2)} found in red blood cells are bounded to O2, its mandatory function is to deliver 98% of oxygen to body cells. To measure percentage of HbO2 in blood vessels is called oxygen saturation (SpO2) [1]. Human body contentiously require oxygen supply for correct functioning of various organs. Though some body parts can function without oxygen for some duration, but some cannot tolerate its absence even for a short period. Therefore, it is critically necessary to measure amount of oxygen presence in the blood to assess functioning of body parts.

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For this purpose, the non-invasive approach (Photoplethysmogram (PPG)) is used for measuring oxygen in the blood. Haemoglobin has certain property of light absorption, so in this approach the skin is illuminated and changes in light absorption is measured [2]. Device used to obtain PPG is called Pulse Oximeter and it measures SpO2 (Peripheral capillary oxygen saturation) and pulse rate. In oximeter, human skin is illuminated by Red and Infrared wavelengths (easily transmitted through tissues) and light absorption is measured using photo detector. The SpO2 is calculated from the ratio of the absorption of the red and infrared light [2]. Typically light emitters /detectors are attached to finger, toe and ear lobes etc as shown in Figure 1.

**Figure 1. Ear and Finger Oximeter Sensors [**Pictures Curtsey Wikipedia**]**

*1.1. Principles of Oximetry:*

Emitter is attaching on one side and detector is on the other side of the finger and signal received through detector is called photoplethysmogram (PPG). The PPG signal carries minute AC component on a considerable DC level [3]. The DC level is dependent upon light absorption by individual depending upon physiological characteristic like tissue etc. The AC component in turn is due to absorption of light in arterial blood.

Pulse Oximeter analyses changes in blood colour on the basis of spectro-photometric measurements via photo detector. Blood contains 100% oxygen is distinctively red, whereas blood with no oxygen has a characteristic dark blue coloration. The principle of pulse oximeter is based on the red and infrared light absorption characteristics of haemoglobin with bounded and unbounded oxygen. Oxygen bounded haemoglobin absorbs more infrared light and allows more red light to pass through and oxygen unbounded haemoglobin absorbs more red light and allows more infrared light to pass through. Red light is in the 600-750 nm wavelength light band and Infrared light is in the 850-1000nm wavelength band. Oxygen bounded versus unbounded blood light absorption of IR and Red light is as shown in Figure 2.

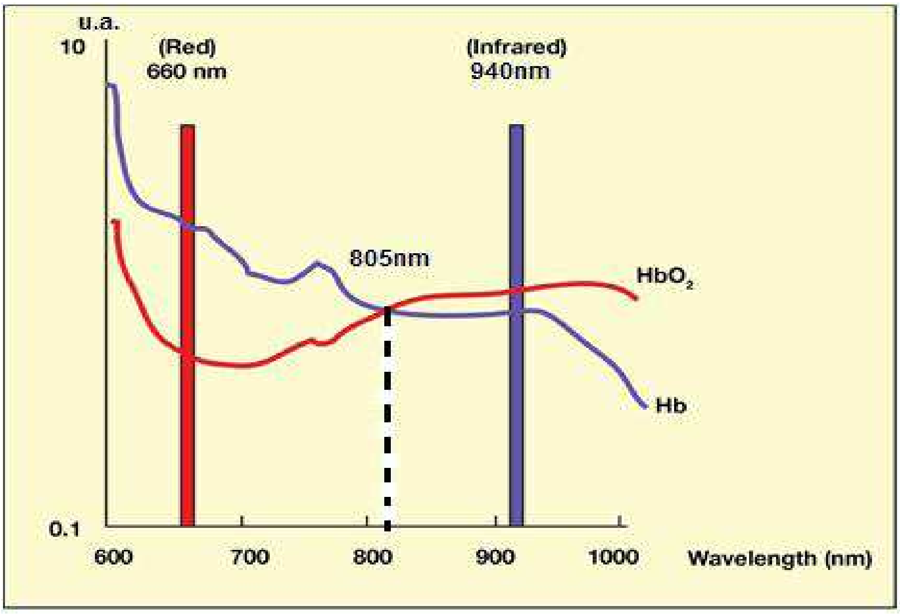


***Figure 2. Oxygen bounded versus unbounded blood light absorption of IR and RED lights [3]***

There are two types of haemoglobin in the blood namely Saturated Arterial Haemoglobin (also named as Oxyhaemoglobin), HbO2, and Unsaturated or reduced haemoglobin, Hb. Pulse Oximeter measures the ratio of these two quantities. The arterial oxygen saturation, SaO2, is the ratio of the concentration of Oxyhemoglobin (cHbO2) to the concentration of the summation of concentration of both haemoglobin types and is represented as a percentage as given by the formula below:

$$SaO2 = \frac{cHbO2}{cHbO2 + cHb} \times 100\% \qquad (1)$$

*1.2. Principles of Human Body/Skin Temperature Measurements:*

Human body temperature can be measured using various invasive and non-invasive methods. In this regard various types of sensors are used to measure temperature by measuring different characteristics of human body. These sensors include resistive sensors, IR sensors and conventional thermometers [4]. In present work resistive sensors are used. These sensors are non-invasive and attached with body. With variation in temperature, resistance of material attached with body varies in deterministic manner which correspond to specific temperature accordingly.

## 2. Hardware

The block diagram of the model is depicted in Figure 3. It consists of the following units:-

1. Pulse Oximeter sensor probe
2. Pulse Oximeter Signal Conditioning Unit AFE 4490 of Texas Instruments

3. Body and Skin Temperature Sensor Probe and Signal Conditioning Unit, LMP 90100
4. Bluetooth Device manufactured by Blue Radio
5. Power/battery management
6. Organic Light Emitting Diode (OLED) Display
7. Ultra low-power Mixed Signal Micro-Controller, MSP 430F5338 of Texas Instrument

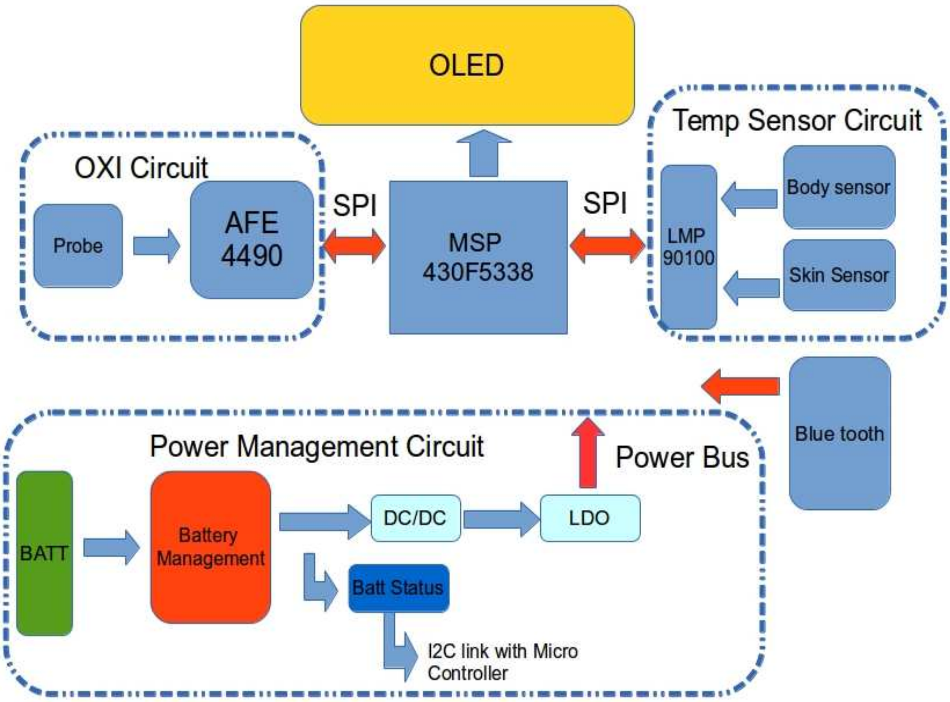


***Figure 2. Pulse Oximeter Block Diagram***

*2.1. Pulse Oximeter Sensor Probe:*

Pulse oximeter Sensor probe contains light source and a photo detector. The light is transmitted through the tissue on the finger and detected on the other side. When blood flows through finger capillaries, it causes blood volume variations which affect passing light and detected by the phototransistor. In the present work, Red LED and Infrared LED are used, one transmits at wavelength approximately 660 nm and the other transmits at wavelength from 900-940nm, respectively. Detected variation by photo transistor reveals amount of light absorbed by oxygen bounded and unbounded haemoglobin. The Nellcor DS100A [5] compatible SPO2 finger clip pulse oximeter probe is used in this project.

*2.2. Pulse Oximeter Signal Conditioning:*

In this work major components for signal acquiring and signal-conditioning of the PPG signals are the LED, photo-detector and AFE4490. The AFE4490 is a complete Analog front-end (AFE) solution targeted for pulse-oximeter applications. It is integrated with both the LED driver circuitry and the photodiode signal conditioning circuitry. It consists of 22-bit Analog-to-Digital converter (ADC) with noise rejection at receiver channel, an LED transmit section, and diagnostics for sensor and LED fault detection. The AFE have flexibility to complete control of the device timing characteristics. The AFE communicate with the micro-controller using a Serial Peripheral Interface, SPI interface. Figure No 4 shows a detailed block diagram for the AFE4490 [6].

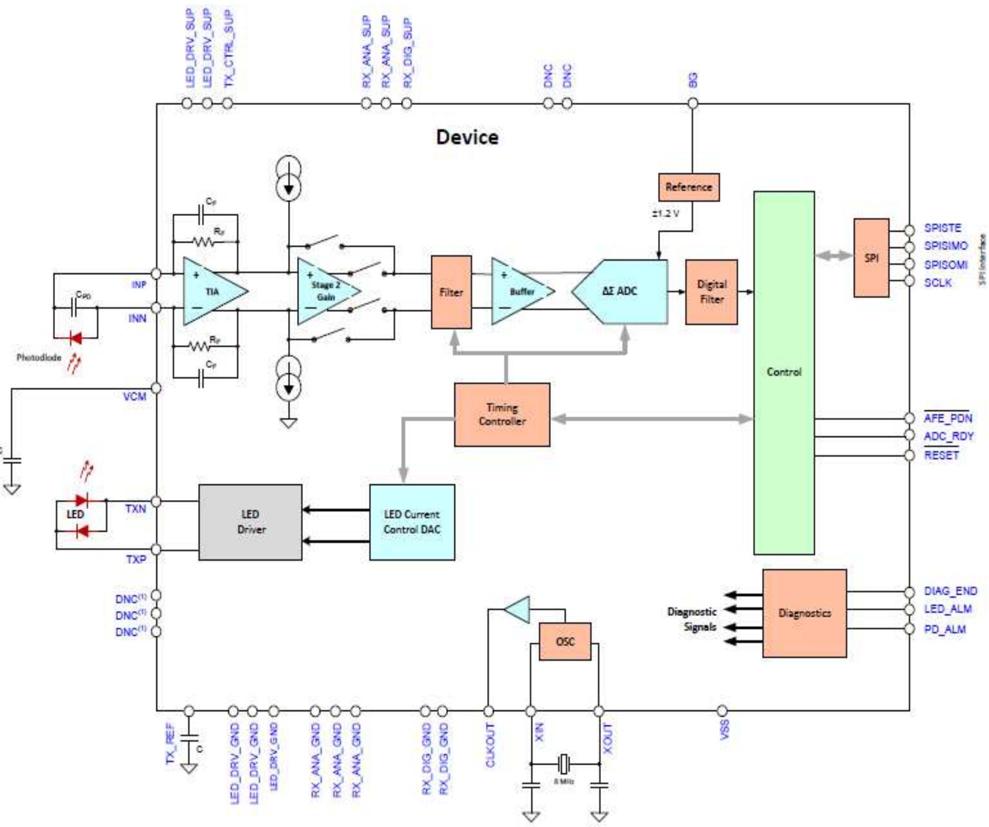


***Figure 4. Detailed block diagram for the AFE449 [6]***

*2.3 Body and Skin Temperature Sensor Probe and Signal Conditioning:*

Hyperthermia can cause rise in body temperature and may lead to multiple body organ failure. In this situation continuous observation of body temperature is necessary. In the present work, two sensors LM-35 and highly accurate/reliable NTC sensor are used for skin and body temperature measurements. LM-35 is integrated with Micro Controller directly on an Analog port with 12 bit resolution. LM-35 is a sensitive and considerably reliable sensor that requires no additional drive and signal conditioning circuitry. The NTC sensor used is medically graded and has accuracy upto $0.1^{o}$ C between $25^{o}$ C to $45^{o}$ C. However, NTC sensor required accurate current source drive and signal conditioning unit. For this purpose in our work Analog Front End (AFE) LMP 90100 by Texas Instruments is used. LMP 90100 is a 24-Bit Low Power Sigma Delta ADC with built in 50/60 Hz rejection [7]. Further LMP 90100 is interfaced with Micro-controller via SPI.

### *2.4. Micro-Controller MSP430F5338:*

The Texas Instruments MSP430F5338 is an ultra low-power Micro-controller, integrated with four 16-bit timers, a high-performance 12-bit Analog-to-Digital converter (ADC), two universal serial communication interfaces (USCI), hardware multiplier, DMA, real-time clock module with alarm capabilities, and 83 I/O pins [8]. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The algorithm is developed and written on the micro-controller to periodically transmit the health data using attached Bluetooth device. The information is also stored in the inbuilt memory and displayed on the OLED display of the wearable device.

### *2.5. Bluetooth Transmission:*

In this hardware no wired communication with the external world is used. Blue Tooth device manufactured by Blue Radios is installed to transmit PPG and temperature information to home user or medical staff at the hospital on their PDAs /Tablets. This device communicates with micro-controller on a UART using manufacturer defined AT command set. Android application has been made to receive and evaluate the information. Android 18 Kitkat is used for this purpose.

## 3. Conclusions

The current work presents design and development of a small wearable device that measures pulse rate, oxygen saturation, skin and body temperature using high-accuracy pulse Oximeter sensor and temperature sensors. The measurements carried out on the designed architecture and prototype hardware is showing good results and within the tolerance range of the system. A multilayer PCB of compact size of 2.5 inch x 3.5 inch is prepared. Due to compact device architecture and easy to use, it can be by easily used by individual at home and health professionals.

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