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Pulse Oximeter using PSoC

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Abstract*: *A pulse oximeter to measure the oxygen saturation in blood as well as heart rate was developed using PSoC. The method proposed here is to transmit light of two different wavelength through the finger and tissues and to measure the change in absorption intensities. The signals are obtained as photoplethysmograph (PPG) waveforms. The pulse oximeter finds the variations in both the waveforms and calculates the SpO2 and heart rate of an individual. The system developed has a wide clinical application and can be used for patient monitoring and for doing vascular assessment. It also helps us to explore the use of SOC in medical care devices. An adult SpO2 finger probe nellcor DS100A sensor was used for this project.

Index Terms*: *SpO2, oxygen saturation, pulse rate, PPG, PSoC development kit.

I. INTRODUCTION

Non invasive technique for measuring blood oxygen saturation is now well accepted in health monitoring systems. Earlier invasive techniques were used such as co-oximeter and arterial blood oxygen analyzer which required artery blood from to be drawn at regular intervals [11]. Oxygen depletion can cause serious health problems such as brain damage and respiratory problems. This is very useful for finding sleep apnea, breathing problems, administering anesthesia, hypoxemia and vascular assessment. The system developed can be used as an emergency module for monitoring patients. It is very simple and requires fewer resources.

PSoCs from Cypress Semiconductor stands for Programmable System On Chip. Similar to an FPGA a PSoC has a processor core, configurable analog and digital blocks, and has programmable interconnects. So signal can acquired and processed on the same chip. The blocks are not fixed as in other chip which gives the programmer more flexibility in designing. In our cardiovascular system heart takes deoxygenated blood from veins and pumps out oxygenated blood to arteries. The blood from artery is bright red in colour and absorbs IR light and blood from veins is darker and absorbs RED light. In pulse oximeter we take advantage of this property of blood. Photoplethysmography is a non-invasive method which uses opto-electric method to measure blood volume flowing through a particular site and a photoplethysmograph (PPG) can be obtained .PPG sensors can be of two types ,reflectance type and transmission type.

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II. WORKING PRINCIPLE

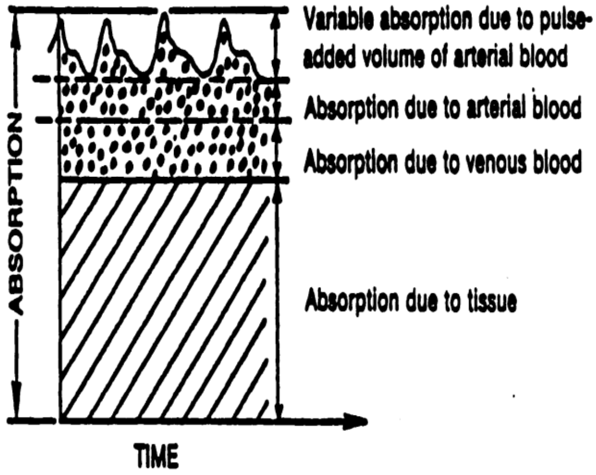

Figure 1. Rhythmic effect due to pulsatie property of blood and absorption due to tissue

The name pulse oximeter is itself because they function depending on the pulsatile property of the PPG signals. They all work based on Beer-Lambart Law, which allows as to find the concentration of the absorbing substance. If the incident light intensity is I_N and the transmitted light intensity is I_O then,

$$I_O = I_N e^{-\varepsilon_\lambda c L} \tag{1}$$

Where ε_λ is the extinction coefficient at a specific wavelength. L is the optical path length and c is the concentration of the absorbing substance. Here light of two wavelengths 660nm (RED) and 940nm (IR) are used[8]. Both haemoglobin (Hb) and oxyhaemoglobin (HbO_2) have different attenuation characteristics and the wavelength is choosen such that at one wavelength they have different attenuation property and at the other they have same attenuation property.

In order to find the oxygen saturation the AC and DC values of the pulsating RED and IR PPG are extracted and the ratio R is found[10][8].

$$R = \frac{AC/DC_{red}}{AC/DC_{ir}} \tag{2}$$

The SpO2 value can then be calculated from the R value either by using a look-up table or by using the clinical empirical formula,

$$SpO_2 = 110 - 25R\ \% \tag{3}$$

The sensor should have a monochromatic light source and not a scattered source of light and also the alignment of sensor is also very important.

Since IR light is absorbed by oxygenated blood it is used to find the heart rate. The heart rate is calculated by finding the number of samples between two beats.

III. SYSTEM DESCRIPTION

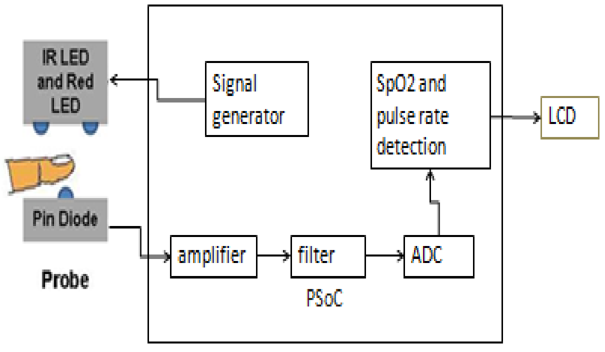

Figure 2. Block diagram

The pulse oximeter was developed using PSoC development kit CY8C-001 and was developed with PSoC 1. Pulsatile input was generated from the signal generator. The different pulse oximeter modules are;

A. SpO_2 Sensor

The sensor used here is nellcor DS100A , it has a 7-pin D-type male connector. It consists of two LEDs and a photodiode. The connections are made to ,2,3,5,7 and 9 which are ir ,red ,photodiode anode, ground and photodiode cathode respectively. The sensor requires an input of 5V.

B. Amplifier

The amplifier part consists of transimpedance amplifier for converting photodiode output current to voltage signal and a programmable gain amplifier (PGA) for further signal amplification.

C. Filter

The required PPG signal is in the range of 0.5Hz to 5Hz for this the corresponding filter circuit consisting of LPF and HPF are configured for the required cut-off range. An inital stage of filtering is done before the ADC module.

D. ADC

The signal is then fed to a analog to digital converter having a resolution of 13 bit. Since PSoC 1 has only one ADC both signals were fed through a multiplexer.

E. SpO_2 and pulse detection

The IR and RED signals are then differentiated two find the peaks. The peaks of both PPGs are found and the ratio R is found and calibrated and SpO_2 is calculated using the clinical empirical formula. The IR peaks are used for heart rate calculation

F. LCD

The result is displayed on the on-board LCD which has a 16x2 alphanumeric display and 1.8 to 5V I/O pin. The displays such as SpO2, pulse rate, pulse error and please wait are displayed on the LCD.

G. Signal generator

The timing signals are generated in the signal generator block. Each led is switched ON and OFF for a time limit of 250µs such that within 1ms both LEDs are activated. The signal generator module consists of PWM generator block using dead band.

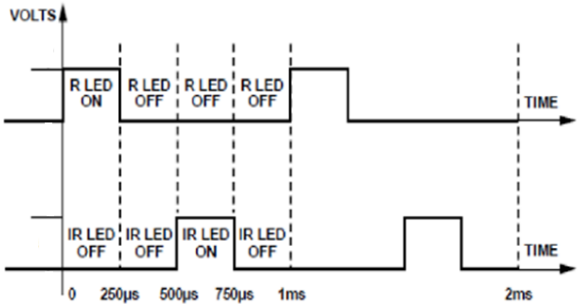

Figure 3. Timing signals for RED and IR LEDs

Figure 4. RED and IR timing signals viewed using CRO**.**

The realized prototype is as shown below it consists of sensor module, electronic interfaces and PSoC designer designed and configured modules and APIs.

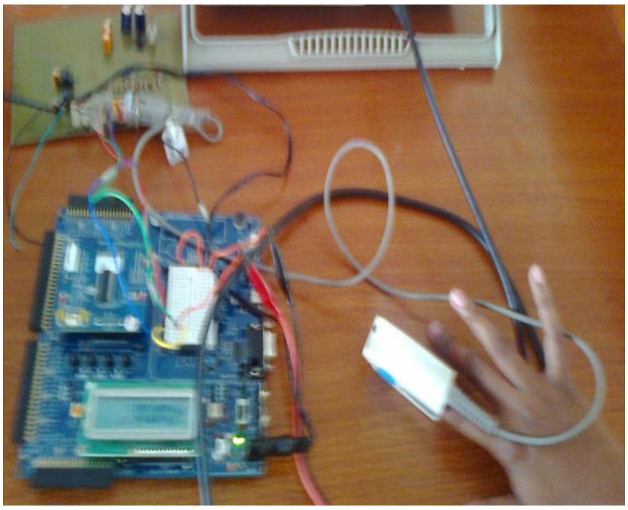

Figure 5. Realized setup of pulse oximeter.

IV. PSOC SOFTWARE

In PSoC software structure the program was written to initialize all the user modules. The RED and IR timing signals were generated and the photodetector output was fed to a transimpedance amplifier. The corresponding voltage signal was then pre-amplified and fed to a low pass filter and then to ADC. The ADC output was then fed to appropriate low pass and high pass digital filters of the corresponding cut off frequencies. The PPG frequency range of interest is from 0.5Hz to 5Hz.

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The peaks of both RED and IR PPGs were detected and pulse rate and SpO_2 content were calculated. To reduce fluctuations moving average filtering was done .The flowchart is as follows,

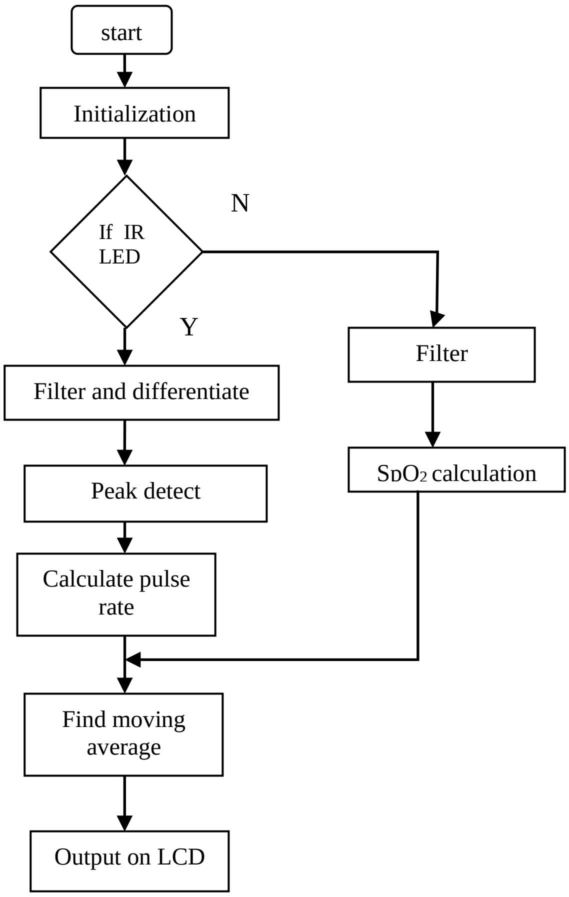

Fig 5: flowchart

V. INTERNAL MODULE STRUCTURE

The internal user modules were configured using PSoC Designer software version 5.3 and the corresponding API's were written. The top array of rows are the digital blocks and the bottom array of rows are the analog blocks. The designer 5.3 has auto routing by which it highlights the available connections thereby making it easier to route to the pins.

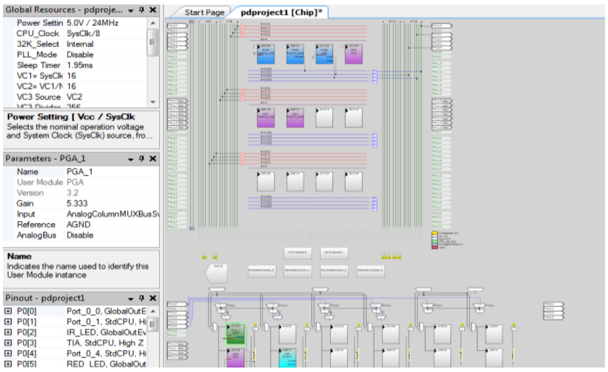

Figure 5. PSoC user module configuration

VI. CONCLUSION ACKNOWLEDGEMENTS

A pulse oximeter was developed using PSoC and the heart rate and oxygen saturation was displayed on the LCD module. The main advantage of this system is that it is cheaper and durable compared to other microprocessor systems. It can used as a modern ambulatory device and has reduced dimensions.

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