Design and Prototyping of PSoC based Pulse Oximeter

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Abstract- Pulse Oximeter is a non invasive medical device which measures the percentage of oxygenated blood in patient's haemoglobin. This percentage is important for providing anesthesia, detecting cardiac and respiratory problems and helps in diagnosis of sleeping ailments. It is built on PSoC which comprises of various sub-systems like LCD driver (which can drive LCD at different voltages), UART (for broadcasting messages), analog filter, capacitive sense, Analog to Digital Convertor, Pulse Width Modulation, etc. PSoC integrates all basic and advance requirements of a pulse oximeter into a small scale chip performing all these operation hence increasing its efficiency. PSoC includes the 8-bit (8051) or 32-bit (Arm Cortex M3) microprocessor, which integrates three to four functions to become the control chip of the physiological monitor of pulse oximeter. It helps it achieve portability, high functionality and low cost thus making it available to common people.

This paper attempts to understand the designing of a pulse oximeter and the application of PSoC in the same. Later it highlights the applications of both to produce a more efficient medical device.

Keywords- PSoC, Pulse Oximeter

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1 INTRODUCTION

Pulse oximeter has gained wide spread clinical acceptance in the latter part of the 21st century. It is a medical device used for monitoring the oxygen content of the arterial blood. It measures the absorption of light passing through the body, which varies as blood pulses into the tissue with each beat of the heart. It made its first appearance in 1995 but gained recognition in 2000 [1].

PSoC based Pulse oximeter is built on a single chip i.e. Programmable system on chip, hence increasing its efficiency as well as its portability. PSoC features digital and analog programmable blocks, which themselves allow implementation of large number of peripherals. It combines the programmable digital and analog components, indicating that it is able to provide the signal amplifier, analog-to-digital converter/digital to analog converter, filter and PWMs required for pulse oximeter. PSoC was commercialised by Cypress Semiconductors in 2002 [2].

Our present technology using Atmel's Atmega 16 microcontroller has an analog environment, separate from a digital core whereas the pulse oximeter on PSoC is a single chip mixed signal design. Pulse oximetry is a useful method of monitoring patients in many circumstances, in the face of limited resources and allows for the assessment of several different patient parameters. It is a standard method for monitoring preoperative and noninvasive conditions [3]. Due to its simplicity and speed, pulse oximeter is of critical importance in emergency medicine [4]. Moreover due to the low prices, an economical product can be manufactured which would benefit the poor.

2 SYSTEM ARCHITECTURE

In this section, we will illustrate the design of our proposed PSoC based Pulse Oximeter. Figure 1 shows our overall system architecture. It depicts the basic module of PSoC, which is a reconfigurable mixed signal system on chip. It comprises of two parts – configurable digital blocks and configurable analog blocks. These blocks enable implementation and placement of predefined user configurable modules [5].

2.1 PSoC Modules-

2.1.1 Configurable Digital Blocks-

The digital blocks are state machines that are configured using the blocks registers. There are two types of digital blocks, Digital Building Blocks (DBBxx) and Digital Communication Blocks (DCBxx). Only the communication blocks can contain serial I/O user modules, such as SPI, UART etc. Each digital block is considered 8-bit resources that designers can configure using pre-built digital functions or user modules (UM), or, by combining blocks, turn them into 16-, 24-, or 32-bit resources. Concatenating UMs together is how 16bit PWMs and timers are created. The digital block here comprises of PWM, timer, counter and UART.[6]

PWM- Pulse Width Modulator is a device which controls the power of DC devices which draw up to few amperes of current.

UART- Universal Asynchronous Receiver/Transmitter is an individual (or part of an) integrated circuit used for serial communications over a computer or peripheral device serial port.

In our system it is responsible for the wireless transmission of data via IEEE 802.15.4 (zigbee - specification for a suite of high level communication protocols).

One more module used here is SPO2 logic block. It receives its input in form of PPG signals (photoplethysmographic signal) which is amplified, filtered and then fed to an ADC. It is coded with the logic of finding the SPO2 content of the blood [7].

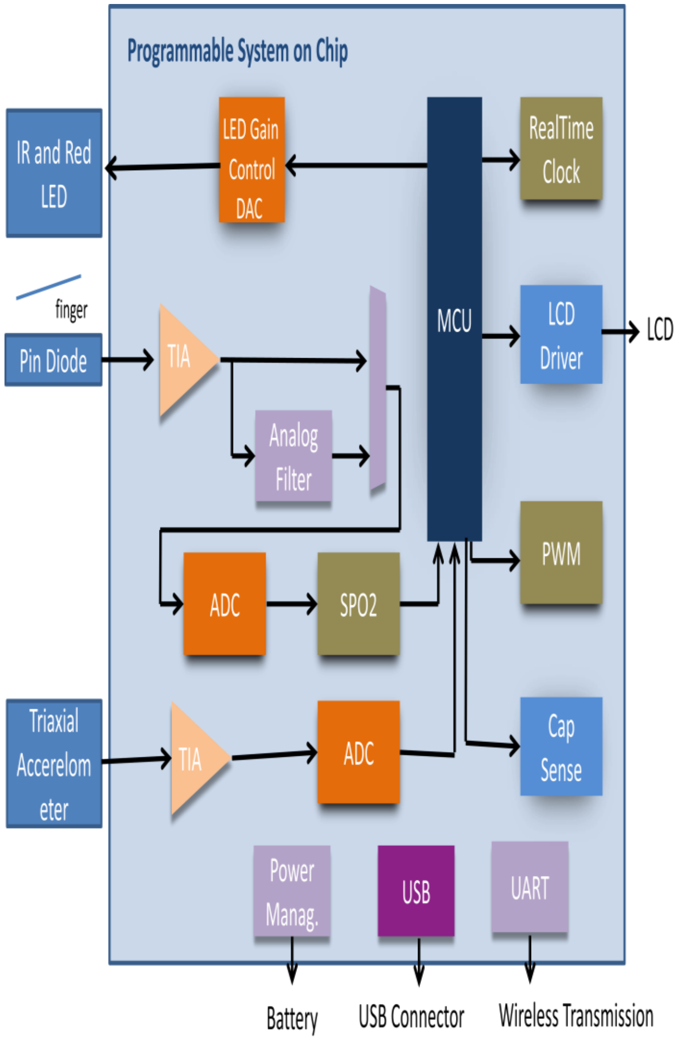

Figure 1

2.1.2 Configurable Analog Blocks-

There are two types of analog blocks: Continuous time (CT) blocks and Switch cap (SC) blocks. The continuous time (CT) blocks are composed of an op-amp circuit and designated as ACBxx where xx is 00-03. The other type is the switch cap (SC) blocks, which allow complex analog signal flows and are designated by ASCxy where x is the row and y is the column of the analog block. Designers can modify and personalize each module to any design [8]. The analog block here comprises of ADCs, DACs, filters, cap sense and amplifiers.

ADC- Analog to Digital Converter is a device that converts a continuous quantity to a discrete time digital representation. Here we have used a 12 bit resolution ADC- because we need the best accuracy possible in order to give correct and accurate results. DAC - digital-to-analog converter (DAC or D-to-A) is a device that converts a digital (usually binary) code to an analog signal. Filters are the basic building blocks of signal processing used for separation of signals depending on definite criteria. TIA – amplifier-is a device for increasing the power of a signal by use of an external energy source. Cap sense- capacitive sensing is a technology based on capacitive coupling used in different types of sensors.
Figure 2 depicts the few basic modules of PSoC.

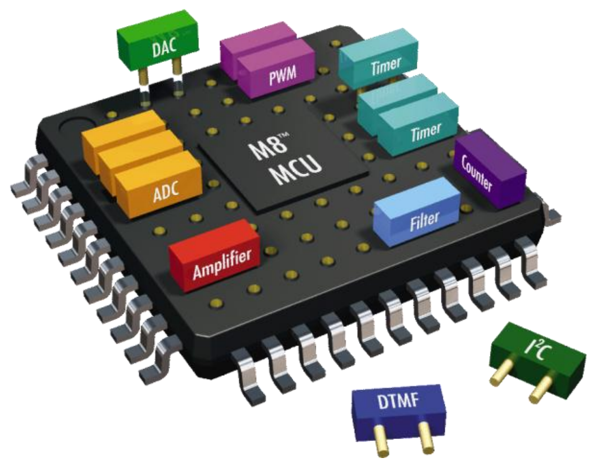

Figure 2

2.2 Modules of Pulse Oximeter-

Pulse Oximetry is based on spectrophotometric measurements of changes in blood color. The optical property of blood in the visible (between 500 and 700nm) and near-infrared (between 700 and 1000nm) spectral regions depends strongly on the amount of oxygen carried by the blood [9]. For this purpose a Pulse Oximeter consists of two LEDs: 660nm (Red LED) and 820nm (Infrared LED) and a photodiode chips mounted on a single substrate. Four LED chips for each wavelength are placed at equal distance around the photodiode to enhance the signal level as well as to minimize inhomogeneous effects of tissue [10]. Figure 3 shows a finger held wearable pulse oximeter.

2.3 Additional Feature-

PSoC based Pulse oximeter is itself a very efficient device but to enable ambulatory monitoring we need to add a triaxial accelerometer. It is designed with three orthogonal internal sensing elements to enable simultaneous multi-axis measurements (x, y, and z-axis). Its exact application will be explained in the later section (sec 4).

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Figure 4

3 IMPORTANCE OF PSoC

The Electronic architecture of the PSoC based Pulse Oximeter is based on the Programmable System on Chip which helps in reducing the number of discrete components. In health care technology, it is important to miniaturize the devices to make them convenient to carry or wear and thus suitable for ambulatory monitoring applications.

PSoC's user configurable modules and their API ("Application Programming Interface") routines facilitate faster system development and programming, this is one of the main reasons for using PSoC . Indeed, it can carry out all the steps from signal conditioning to transmission of formatted data, including analog to digital conversion and data processing, all within a single part component. This increases the functionality and portability of the device at low cost thus making it available to common people.
The RF (radio frequency) module of the PSoC is a very useful low cost device which can increase its functionality to a large extent, helping in wireless communication [11].

4 APPLICATION

A PSoC based Pulse Oximeter has the potential to revolutionise the field of automated healthcare. This device can further be developed to monitor the ambulatory motions, using a triaxial accelerometer sensor and a wireless sensor node. This could be called as ambulatory PSoC based pulse oximeter.

The proposed ambulatory PSoC based pulse oximeter monitoring system consists of two parts: wearable sensor devices part and server part. The wearable sensor devices are wearable sensor node with ECG and accelerometer sensor and a PPG module (the PSoC pulse oximeter); these are connected to a base-station and measure physiological data from human body [12]. The measured physiological data are transmitted to a base station via IEEE 802.15.4 using a Zigbee. The output waveforms of accelerometer and PPG sensor are shown at the server side.

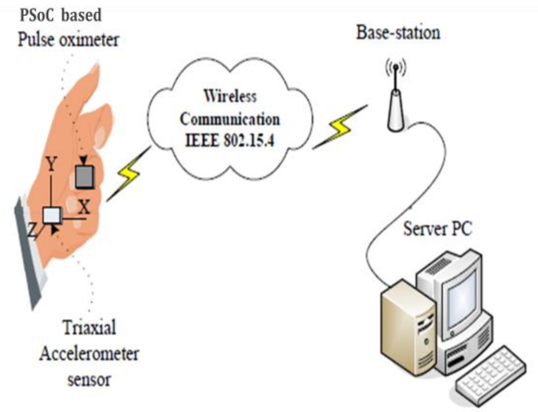

Figure 4 shows overall system architecture of the ambulatory PSoC based pulse oximeter for ubiquitous-healthcare monitoring system [13].

Ambulatory data is helpful in determining the various physiological states of the human body. For example the data obtained for a man while he is sleeping or resting is different from the data obtained while he is walking, standing or performing any other action. This data, hence obtained through the PSoC based Pulse Oximeter can be used to monitor people who are highly susceptible to various health disorders. For example old people or people with serious ailments like AIDS or cancer.

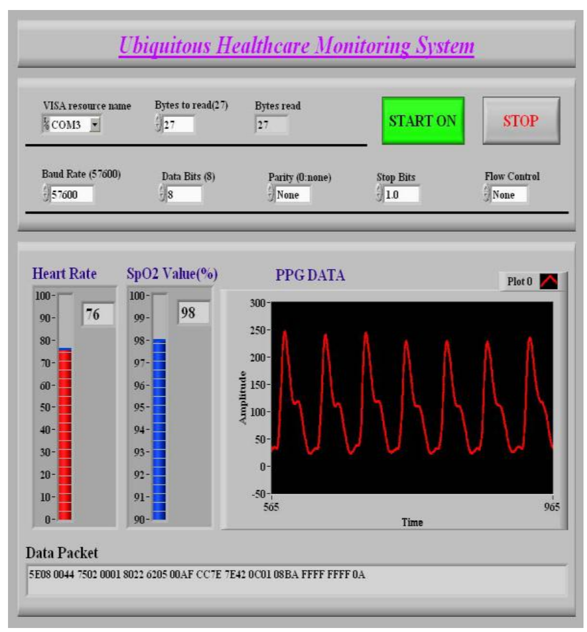

Figure 5

Figure 5 shows the screen capture of the SpO2 monitoring program. This program was designed with Lab VIEW. It monitors the PPG signal by drawing the pulse waveform at server PC connected base-station as soon as it receives the SpO2 value (%) and heart rate from the ambulatory pulse oximeter. This system acts as a continuous event recorder, which can be used to follow up patients at home. ECG, acceleration and SpO2 value can be measured on the wearable sensors, and all measured data are saved in server wirelessly. It can make correct diagnosis even under situations where the patient is unconscious and does not have the ability to carry out daily activity and hence we can detect these conditions and inform the concerned or related people of the patient.

This application can also provide continuous breathing rate information by examining how a PPG signal is used by a pulse oximeter to determine arterial oxygen saturation and heart rate [14]. This can help combat medics and field commanders to better predict a soldier's health condition and enhance their ability to perform remote triage procedures. By combining non-invasive physiological sensors with innovative microelectronics, mathematical models and equations, a wireless communication link, and global positioning, we can extract breathing rate information of the soldiers [15].

5 CONCLUSION

The PSoC based Pulse Oximeter is one of those modern medical devices which have reduced dimensions, increased durability and efficiency, and are less expensive as the electronic technology evolves to maturity. Further the development of its ambulatory system can help in advancement of the Ubiquitous Healthcare Monitoring system.

A comparative analysis between Microcontroller based Pulse Oximeter and PSoC based Pulse Oximeter definitely approves the latter. It owes to the fact that with PSoC the system results in a much smaller footprint and has more efficient functionality. PSoC enables wide range of integrated analog and digital circuits in a single chip.

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7 REFRENCES

1. R.C. Chpta, S.S. Ahluwalia, S.S. Ranthawa," Development and Design of Pulse Oximeter", Central Scientific Instruments Organisation (Chandigarh)
2. History of PSoC, http://cypress.com
3. Impact of pulse oximetry screening on the detection of duct dependent congenital heart disease: a Swedish Prospective screening study in 39821 newborns, BMJ, 8 January 2009.
4. An Ultra-Low-Power Pulse Oximeter Implemented with an Energy-Efficient Transimpedance Amplifier, IEEE Transactions on Biomedical circuits and systems, VOL 4 NO 1, February 2010.
5. David Tomanek," What is PSoC", DAT Consulting Cons, Pasadena, California, USA
6. Mario Hrgeti, Igor Krois and Mario Cifrek,"Accuracy Analysis of Dissolved Oxygen Measurement System Realized with Cypress PSoC Configurable Mixed Signal Array", Faculty of Electrical Engineering and Computing, University of Zagreb
7. Dareen Toumi, Claudine Gehin, Andre Dittmar and Eric McAdams," Design and validation of an ambulatory system for the measurement of microcirculation in the capillaries: Hematron device", 31st Annual International Conference of the IEEE EMBS Minneapolis, Minnesota
8. Wallace_psocpres, http://psocprec.com
9. W. S. Johnston, Y. Mendelson," Extracting Breathing Rate Information from a Wearable Reflectance Pulse Oximeter Sensor", Proceedings of the 26th Annual International Conference of the IEEE EMBS San Francisco, CA, USA
10. S. Takatani, C.Davies, G.P. Noon, Y. Nose, M.E. DeBakey, "A Noninvasive Reflectance Pulse Oximeter Sensor", Dept. of Surgery, Houston
11. Rakhee Mohiddin, Manoj Kumar, Shashi Kumar Palakurty, Surabhi Bothra, Sai Phaneendra P, M.B. Srinivas ," Building a Sensor Network with PSoC", 2011 Fifth International Conference on Sensing Technology
12. Curt Schurgers and Mani B Shrivastava, "Energy Efficient Routing in Wireless Sensor Network", MILCOM,2001
13. Young-Dong Lee, Sang-Joong Jung, Yong-Su Seo ,Wan-Young Chung, "Measurement of Motion Activity during Ambulatory Using Pulse Oximeter and Triaxial Accelerometer
14. W. S. Johnston, Y. Mendelson," Extracting Breathing Rate Information from a Wearable Reflectance Pulse Oximeter Sensor", Proceedings of the 26th Annual International Conference of the IEEE EMBS San Francisco, CA, USA
15. A. Johansson and P. A. Oberg, "Estimation of Respiratory Volumes from the Photoplethysmographic Signal. Part I: Experimental Results," Medical and Biological Engineering and Computing., vol.37, pp. 42–47, 1999.
16. N. Watthanawisuth, T. Lomas, A. Wisitsoraat, A.Tuantranont," Wireless Wearable Pulse Oximeter for Health Monitoring using Zigbee Wireless Sensor Network" , National Electronics and Computer Technology Centre (NECTEC), Thailand.
17. Juan M. Lopera, Juan Diaz, Miguel J. Pneto and Fernando Nu50, "PULSE OXIMETER FOR HOMECARE", Universidad de Oviedo SPAIN
18. Paul F. Stetson," Determining Heart Rate from Noisy Pulse Oximeter Signals Using Fuzzy Logic", Advanced Development Group, Pleasanton
19. G. Comtois, Y. Mendelson," A Wearable Wireless Reflectance Pulse Oximeter for Remote Triage Applications", Worcester Polytechnic Institute, Worcester
20. Guowei Di, Xiaoying Tang, Weifeng Liu ,"A Reflectance Pulse Oximeter Design Using the MSP430OF149", Beijing Institute of Technology, Beijing
21. Bertrand Massot, Claudine Gehin, Ronald Nocua, Andre Dittmar, Eric McAdams, "A wearable, low-power, health-monitoring instrumentation based on a Programmable System-on-Chip", 31st Annual International Conference of the IEEE EMBS Minneapolis, Minnesota
22. N.Sriraam, T.S.Bharath Balaji, M.Elshin Joel., S.Prasanna, "An Ubiquitous Healthcare system using a wearable shirt for smart home", 2010 IEEE EMBS Conference on Biomedical Engineering & Sciences (IECBES 2010), Kuala Lumpur, Malaysia

23. Michael Healy, Thomas Newe , Elfed Lewis, "Wireless Sensor Node Hardware: A Review", University of Limerick, Ireland
24. Paolo Pivato, Stefano Dalpez, David Macii , Dario Petri," A Wearable Wireless Sensor Node for Body Fall Detection", University of Trento

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