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Design and Implementation of Portable Health Monitoring system using PSoC Mixed Signal Array chip

D.J.R.Kiran Kumar, Nalini Kotnana

Abstract*— Health monitoring systems become a hot topic and important research field today. Research on health monitoring were developed for many applications such as military, home care unit, hospital, sports training and emergency monitoring system. In this work, a portable real-time wireless health monitoring system is implemented using Programmable System on Chip (PSoC) and developed. The developed acquisition system is used for remote monitoring of patients’ temperature, heart rate and oxygen saturation in blood i.e. pulse oximetry, pH level of blood, ECG. This system allows the physician able to understand patient's scenario on the computer screen by wireless module. Here low cost, low power consumption and flexible network topology ZigBee wireless module is used to sense the remote patient data. All sensor data are transferred within a group of ZigBee wireless module. The goal is to demonstrate the possibilities offered by system-on-chip programmable devices in specific processing systems, where the costs make the use of specific integrated circuits unaffordable. The sensor unit consists of (1) temperature sensor; (2)two types of LEDs and photodiode packed in Velcro strip that is facing to a patient’s fingertip for pulse oximetry and heart beat; (3) three color LED with LDR for pH level;(4) ECG; (5) Microcontroller unit for interfacing with wireless module, processing all biomedical sensor data sending to base PC;

PSoC circuits built by Cypress Microsystems which represents a new concept in embedded systems design that replaces multiple traditional MCU-based system components with one, low cost single-chip programmable device. PSoC designer tool will be used for implementing the application and building the software.

***Keywords*— temperature sensor, heartbeat, pulse oximetry, pH level, ECG, PSoC.**

I. INTRODUCTION

Health monitoring systems become a hot topic and important research field today. Research on the monitoring were developed for many applications such as military, homecare unit, hospital, sports training and emergency monitoring system. In this paper, we developed the wearable and real-time monitoring system of some critical vital signs for elderly people, because the people who ages over 60 years old encounter accidental incidents over 60 percent. That system may help doctor or people in family monitor the emergency alarm from patient or elderly people. The vital signs of health status that are the important parameter in health monitoring system consists of blood pressure, heart rate, oxygen saturation, body temperature and respiratory rate. In this work, we consider five parameter of the vital signs which are temperature, heart rate and oxygen saturation in blood, ph level, ECG. The pulse oximetry data helps to prevent and protect the oxygen lack in monitored patient’s blood stream. This condition will occurs when the brain does not receive enough oxygen is called cerebral hypoxia [4]. Moreover, pulse oximetry data can predict the patient’s disease and accident situation. Wireless technology was developed in many applications that becoming a part of human activities such as agriculture, military, medical care, smart home system etc. Distinctly, wireless sensor networks (WSN) play a crucial role in such a monitoring system application, for the reason that WSN can offer some advantages over other types of wireless systems, especially its scalability, power management and flexibility of architecture. As a matter of fact, there are two popular standards in the wireless personal area network (WPAN), namely, Bluetooth and ZigBee. This work was focused on the capability of wireless sensor networks as an efficient tool to monitor health in term of all the sensor data for demonstration. This situation makes it difficult to develop and challenge because many applications in WSNs developed for fixing the position of member in wireless personal area network (WPAN). We adopted the wireless sensor ZigBee for using as a real-time health monitoring system on a patient. The rest of the paper is organized as followed. Section 2, we describe our approach to understand the system model. In section 3, we describe various sensors principles. Section 4 and section 5 provide the software details and wireless sensor network details to sense the remote patient data. In section 6, the device and experimental result from that device was shown. The last section is discussion and conclusion.

II. HEALTH MONITORING SYSTEM DESIGN IN PSOC

Bio-medical Sensor networks have the potential to help reduce the workload of medical care. By introducing Body area Networks of wireless vital sign sensors the collection of physiological data can be greatly simplified. The Body Area Network will be worn by patients who need 24 hours surveillance due to a chronic illness, and it will report any abnormalities to a physician. A good quality of life can be maintained for patients who can function in their everyday activities while being monitored. Using PSoC provides adaptable, flexible design platform for more efficient designs.

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Short time is required to develop the application and introduce it to the market. PSoC is a configurable mixed signal array integrated a proven 8bit microcontroller. Figure 1 shows a PSoC family device developed by Cypress. PSoC has three separate memory spaces: SRAM for data, flash memory for instructions and fixed data, and I/O Registers for controlling and accessing the configurable logic blocks and functions.

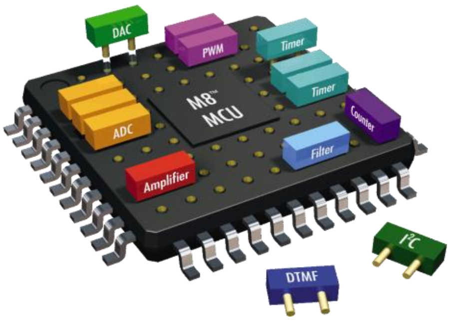

Fig. 1 Cypress's PSoC device

A. Conventional method

The classical system consists of a microcontroller unit, two series of Li-Ion cells, power supply circuit, photo-detector module, ZigBee module, digital to analog converter IC, operating amplifier IC, driver circuit for red LED and infrared LED, couple of light-emitting diode (LEDs) to measure Heartbeat and oxygen concentration in blood as shown in figure 2. The amplifier and DAC are externally connected to the PCB and using the external circuitry is complex in nature thereby increasing the cost and size in implementation. The distortion can also be introduced due to the non-linearity effect of the transistors which are used externally on a PCB.

B. Advanced system design using PSoC

While having the benefits of traditional programmable devices, this approach is significantly less expensive in terms of die area and overall product cost, making it cost competitive with traditional microcontroller implementations.

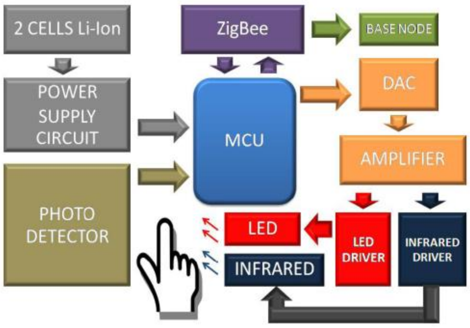

Fig. 2 Block diagram conventional system architecture

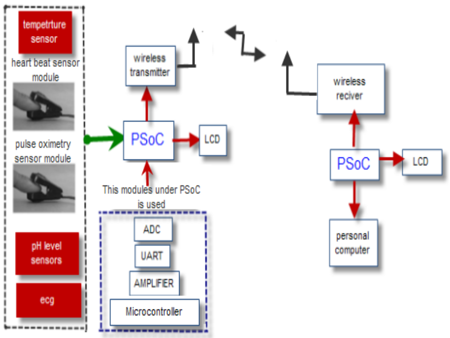

Fig. 3 Block diagram showed system architecture using PSoC

Figure 3 depicts block diagram of sensor module unit. Interfacing PSoC unit to store the monitored data and results are displayed using personal computer node and as well as these results transmitted using wireless sensor, at transmitter end. These all blocks we were found at remote patient. At receiver end one more PSoC unit is used to store the received results from wireless sensor and last the results displayed using personal computer node.

III. SENSORS

A. Temperature sensor

Temperature sensor DS18B30 is used to measure the body temperature. The single track numeral temperature sensor DS18B20 was produced by the American DALLAS Corporation. It can transform the temperature signal into the serial digital signal supply the microcomputer processing directly. Compares with the traditional thermostat, it can directly readout the measure temperature, and according to the actual it can actualize 9~12 numerical value readout way through simple programming. Figure 4 shows block diagram of DS18B20. The information read or write to the DS18B20 only need a single line. The temperature transformation power originates from the main line, and the main line itself can supply power to the DS18B20, does not need the extra power source. So, if use the DS18B20, the structure of the system will be simpler, and more reliable. Because each DS18B20 contains a unique silicon serial number, multiple DS18B20s can exist on the same 1-Wire bus. This allows for placing temperature sensors in many different places. Applications where this feature is useful include HVAC environmental controls, sensing temperatures inside buildings, equipment or machinery, and process monitoring and control.

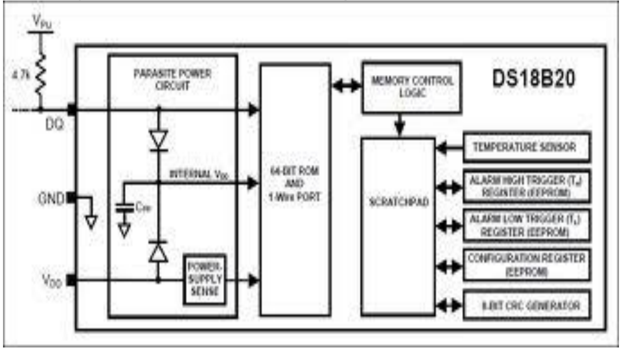

Fig. 4 Block diagram of DS18B20

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B. Heart beat

Heart rate measurement is one of the very important parameters of the human cardiovascular system. The heart rate of a healthy adult at rest is around 72 beats per minute (bpm). Athletes normally have lower heart rates than less active people. Babies have a much higher heart rate at around 120 bpm, while older children have heart rates at around 90 bpm. The heart rate rises gradually during exercises and returns slowly to the rest value after exercise. The rate when the pulse returns to normal is an indication of the fitness of the person. Lower than normal heart rates are usually an indication of a condition known as bradycardia, while higher than normal heart rates are known as tachycardia.

AVERAGE HEARTBEAT RATE

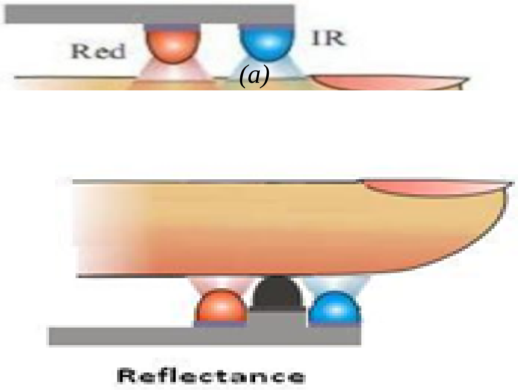
AGE	RANGE	AVERAGE RATE
0-1 Month	100-180	140
2-3 Month	110-180	145
4-12 Month	80-180	130
1-3 Years	80-160	120
4-5 Years	80-120	100
6-8 Years	70-115	92.5
9-11 Years	60-110	85
12-16 Years	60-110	85
>16 Years	60-100	80

Heartbeat is sensed by using a high intensity type LED and photo diode it is shown in figure 5. The change in volume caused by the pressure pulse is detected by illuminating the fingertip's skin with the light from an LED using a photodiode sensor. With each heart beat, a surge of blood is forced through the vascular system, expanding the capillaries in the finger, and changing the amount of light returning to the photo detector [3]. Very small changes in reflectivity or in transmittance caused by the varying blood content of human tissue are almost invisible. Valid pulse measurement therefore requires extensive preprocessing of the raw signal. A suitable operational amplifier is needed to amplify the heartbeat signal, due to its very low amplitude compare to the surrounding noise. A super bright LED is suggested in the circuit as it can also perform well as light sensor. A photodiode, whose resistance changes in response to the amount of light shining on it.

Fig. 5 Fingertip placement over the sensor unit

C. Pulse oximetry

The pulse oximetry data are important for doctor to monitor patient's health condition. Pulse Oximetry has traditionally be done in two methods: transmittance and reflectance of light. In transmittance pulse oximetry, light is shone through the tissue using an LED and is detected on the other end using a photo detector. In contrast, reflectance pulse oximetry uses a photo detector on the same side as the LED to detect the light reflected by the tissue as shown in figure 6.



(a)

(b)

Fig. 6(a) Transmittance and (b) Reflectance configure rations of transducer

The data helps to prevent and protect the oxygen lack in monitored patient's blood stream. This condition will occurs when the brain does not receive enough oxygen is called cerebral hypoxia. Moreover, pulse oximetry data can predict the patient's disease and accident situation. Modern pulse oximetry was born with the realization that pulsatile changes in light transmission through living tissues are due to alteration of the arterial blood volume the tissue. Measurement of the pulsatile component would eliminate the variable absorption of light by bone, tissue, skin, pigment, etc from analysis. The most important premise of pulse oximetry therefore, is that the only pulsatile absorbance between the light source and the photo detector is that of arterial blood.

Two wavelengths of light are used; 660 nanometers (red) and 940 nanometers (near infrared). At 660nm, reduced hemoglobin absorbs about ten times as much light as oxyhemoglobin. At the infrared wavelength, (940nm), the absorption coefficient of oxyhemoglobin is greater than that of reduced hemoglobin as shown in figure 7. The pulse oximeter directly senses the absorption of red and infra red light and the ratio of pulsatile to nonpulsatile light at the red and infrared wavelengths are translated through complex signal processing to a function of the arterial oxygen saturation.

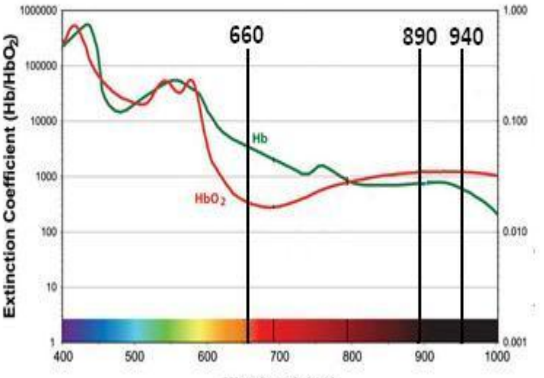


Fig.7 Light absorption characteristics of HbO_2 and Hb at different wavelengths

The fundamental pulse oximetry ratio of ratios concept was invented by [4, 5] and further refined by and Dual-wavelength illumination of arterial blood results in an absorption contrast that depends upon the proportion of hemoglobin that is chemically combined with oxygen. The color of blood varies depending on the oxygen content and in particular the hemoglobin molecules reflect more oxygenated hemoglobin molecules.

Precise measurements of the arterial oxygen saturation can be carried out invasively with co-oximeters. The estimation of SpO_2, commonly referred as SpO_2, is a function of the measured magnitude at the systolic and diastolic states on the two photo plethysmo grams (PPG).

$$\text{Ratio of ratios} \approx \frac{\ln\left(\frac{red_{systole}}{red_{diastole}}\right)}{\ln\left(\frac{infrared_{systole}}{infrared_{diastole}}\right)}$$

Where Red systole and Red diastole are the magnitudes of the red light measured at the systolic and diastolic states respectively, and likewise for IR systole and IR diastole.

However, it is essential to note that the “Ratio of Ratios" (R-curve) has to be empirically calibrated for the specific device in order to produce SpO2 in percentage.

D. pH level

Almost all processes containing water have a need for pH measurement. Most living things depend on a proper pH level to sustain life. All human beings and animals rely on internal mechanisms to maintain the pH level of their blood.

The blood flowing through our veins must have a pH between 7.35 and 7.45. Exceeding this range by as little as one-tenth of a pH unit could prove fatal. These ph levels measured using three colors LED with LDR. For ph sensor we are using three Led’s red, green and blue, one LDR.

LDR color sensor: A Color sensor using a standard LDR and the RGB Color Model. One way of building an active color sensor is to use the RGB color model, which defines all colors as an additive combination of the primary colors: Red, Green and Blue. The sensor consists of a normal Light Dependent Resistor (LDR), surrounded by Red, Green and Blue Led’s.

The exterior of the sensor is covered in black insulating tape, to cut out all ambient light from interfering with the LDR. This is important, as ambient light can wreak havoc on the readings. The LDR is connected with an appropriate resistance, so as to divide the reference voltage (5V) between itself and the fixed resistor. As the light intensity varies, so does the voltage across the LDR. The key idea is to record the voltage across the LDR when the object is illuminated by one of the three colors, and use that to figure out the color of the object.

Fig. 8 Sensor unit design to measure pH level

E. ECG

The Electrocardiogram (ECG) is an essential diagnostic tool that measure and record the electrical activity of the heart. A wide range of heart conditions can be detected when interpreting the recorded ECG signals. These qualities make the ECG a perfect instrument for patient monitoring and supervision. ECG is measured by analog front end instrumentation amplifier.

The electrocardiogram ECG is considered a highly valuable diagnostic aid and clinical tool in modern medicine. This is primarily because a visual inspection of the recorded ECG wave form is critical to the correct diagnosis and treatment of cardiovascular diseases.1 Measuring the surface of the body, the ECG wave form conveys vital physiological information of the condition of the patient’s heart and cardiovascular system.2,3 As a result, it is highly crucial that a patient’s ECG wave form is faithfully captured and pre-served as it passes through the electrocardiograph equipment in order to avoid any misinterpretations of the patient’s condition. It is therefore important that in testing, evaluating, critiquing, and calibrating electrocardiograph equipment, a test ECG signal that represents realistically the actual electrocardiogram is obtained. This is an essential feature in the performance evaluation and commissioning of ECG equipment. It must be noted that many signal sources act as patient simulators that synthesize electronically a signal representing the ECG, yet frequently these signals do not change over the full range of the heart rate in a manner that reflects their true behavior. In this article, we report on the development of an accurate and programmable ECG generator that will provide ECG wave forms of different kinds of heart disease for the testing and calibration of electrocardiograph equipment.

A single sinus (normal) cycle of the ECG, corresponding to one heartbeat, is traditionally labeled with the letters P, Q, R, S, and T on each of its turning points fig .The P wave is followed by a QRS complex. The QRS complex represents the depolarization of the ventricular myocardium. A normal P wave has duration of less than 0.11 s, while a normal QRS complex greater than 0.1 s. The normal T -wave duration is greater than 0.13 s, and the duration of a Q wave is more than one fifth the height of an R wave. A normal PR interval is 0.12 – 0.20 s. The normal QT interval is greater than 0.4 s. The normal heart rate HR is 60 – 100 beats per minute (BPM) with variations of less 10%.

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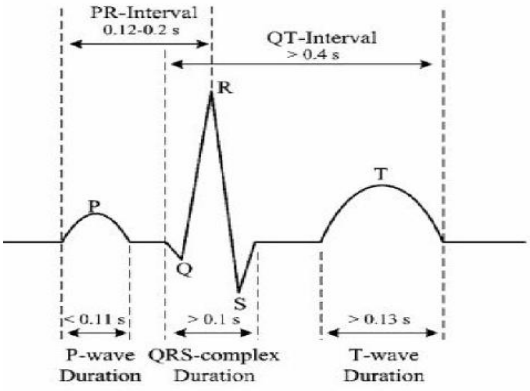


This article suggests some ideas for a low-cost implementation of an ECG monitor. Its configuration is envisaged for use with a personal computer (PC). Although this article is written with patient safety in mind, any ideas presented are not by themselves necessarily compatible with all system safety requirements; anyone using these ideas must ensure that, in a particular design, the design as a whole meets required safety criteria.

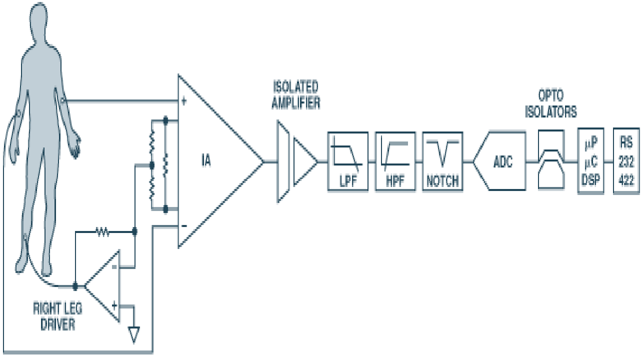


Fig. 9 Typical single-channel electrocardiograph

First we provide an overview of typical analog ECG topology. Then a circuit is proposed which performs analog-to-digital conversion, digital filtering, and digital amplification an integrated “system on a chip” that combines an A/D converter, microcontroller, and flash memory. Various types of “ECG electrodes” are available in market, but the most simplest and common one is CLAMP ELECTRODES which we have used in our project. The ECG clamp electrodes pack contains three reusable clamp electrodes which can be attached to wrists or ankles. The electrode is 3 x 8 centimeters providing a 24 cm^2 area to maximize contact. The ECG clamp electrodes connect to any Bio Amp Cable with snap-connect Lead Wires. The basic function of electrodes is to pick up the signals (bio-potentials) from the body.

We are using lead II configuration in which the electrodes are connected to the two hand and one legs. The signals are very small in amplitude, so they are given to the amplifier for getting proper measurable amplitude as shown in figure 10.

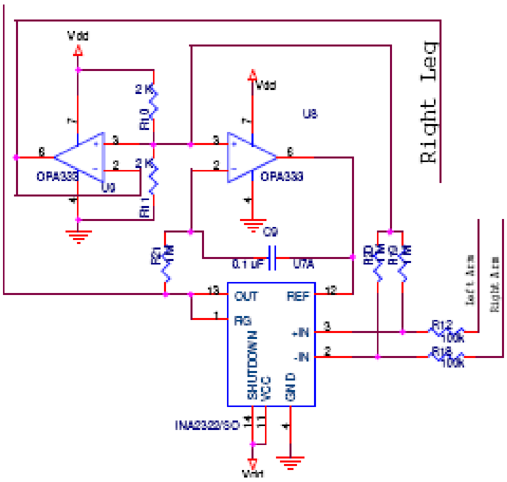
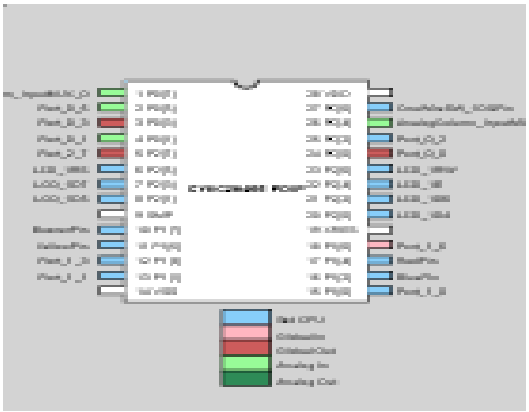


Fig. 10 ECG amplifier circuit

IV. PSOC SOWTWARE DETAILS

PSoC Designer is the software interface for configuring and programming analog- and digital-peripheral functionality into a Cypress PSoC device. Inside the interface, you can select and place user modules, write C and/or Assembly source, and debug and program the project/part. When used with associated hardware, this dynamic hardware-software combination allows you to test the project in a hardware environment while viewing and debugging device activity in a software environment.

PSoC Designer contains three subsystems: Device Editor, Application Editor and Debugger. The interface is split into several active windows that differ depending on which subsystem you are in. As you move between subsystems, you will notice different options being enabled or disabled in the toolbar and menus depending on the functionality of your PSoC device. The process of debugging is employed to load this complete integrated process into CY8C27443-24PXI PSoC device chip consisting of 8 Digital Blocks and 12 Analog Blocks.



The digital value Data can be observed by connecting the port2_6 to the LCD.

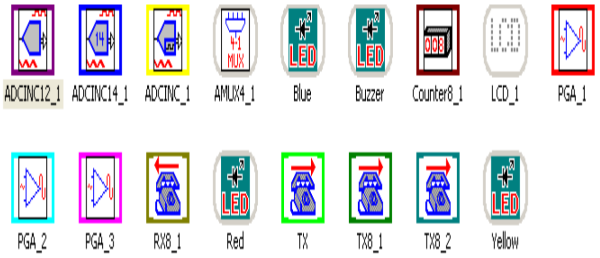


Fig. 11 Selected user modules in PSoC designer

After selecting user modules the below figure shows the highlighted analog and digital blocks, here the figure 12 it self shows that 12 highlighted digital blocks out of 16 digital blocks and 6 highlighted analog blocks out of 12 analog blocks. The inter connections between the modules is possible by setting Global parameters in PSoC designer.

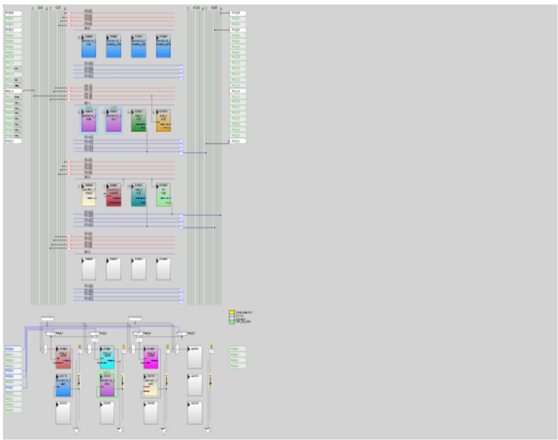


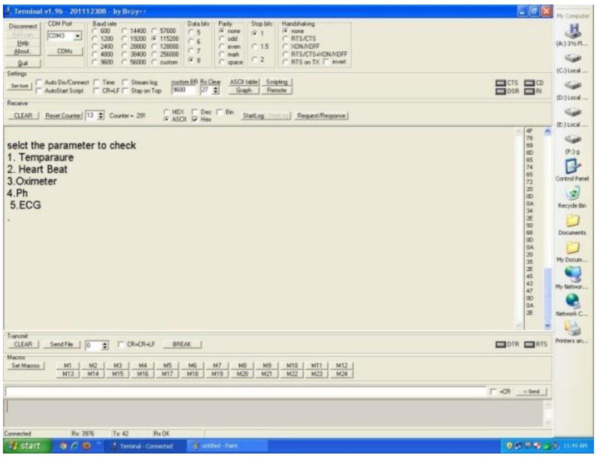
Fig. 12 Used analog and digital blocks in PSoC designer

V. WIRELESS SENSOR NETWORK

Various wireless network technologies have been used in health monitoring system; however, the purpose of this research is the communication between sensor and other sensors in the group. We developed and implemented Wireless Sensor Networks (WSNs) for communication in health monitoring system, the entire wireless system should be able to re-route and change network architecture when patient move to any position immediately. The system is based on ZigBee wireless standard. ZigBee is famous for low cost, low power consumption and flexible network topology. The power of ZigBee module is about 2 mW when running operation and lower than 1 micro-watt when is in sleep operation modes. After power on the total monitoring system the program is loaded in to the microcontroller. Using hyper link terminal in the PC the data from each sensor is perceived. And the received data of a patient at rest room is transmitted to the doctor using ZigBee.

VI. EXPERIMENTAL RESULTS

By the implementation of portable wireless health monitoring PSoC system these are the results we can find using hyper terminal in PC. The ZigBee wire less module is used to retrieve data from the remote patient. The first window we can find in the PC is s shown in figure 13(a). Select parameter to check the health condition of a patient i.e temperature, heartbeat, oxygen concentration in blood, pH level, ECG as shown in figure 13(b), 13(c), 13(d), 13(e), 13(f). There by the instant action to be taken by a doctor and the patient life is extended to some period.



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selct the parameter to check
1. Temparaure
2. Heart Beat
3.Oximeter
4.Ph
 5.ECG
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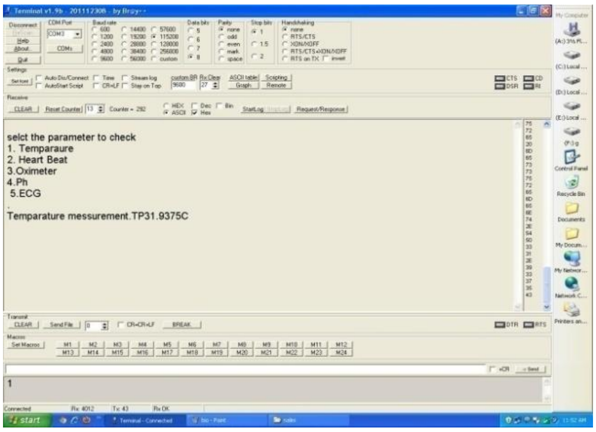
(a)



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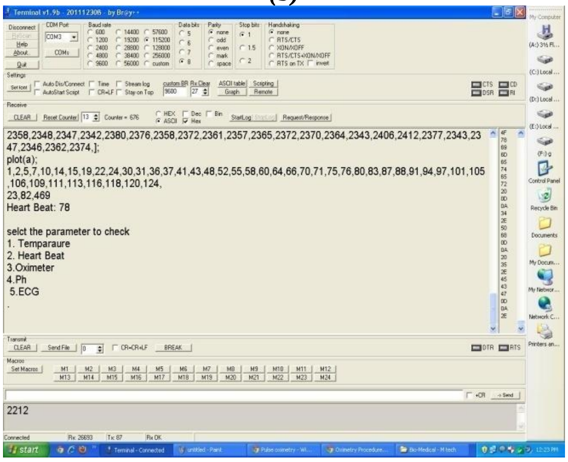
(b)



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47,2346,2362,2374,];
plot(a);
1,2,5,7,10,14,15,19,22,24,30,31,36,37,41,43,48,52,55,58,60,64,66,70,71,75,76,80,83,87,88,91,94,97,101,105
,106,109,111,113,116,118,120,124,
23,82,469
Heart Beat: 78

selct the parameter to check
1. Temparaure
2. Heart Beat
3.Oximeter
4.Ph
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(c)

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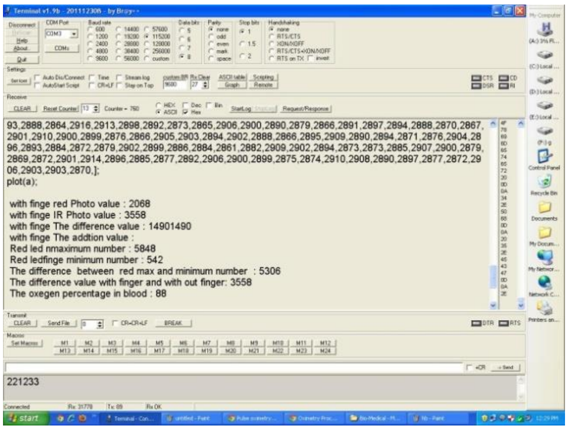

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06,2903,2903,2870,];
plot(a);

 with finge red Photo value : 2068
 with finge IR Photo value : 3558
 with finge The difference value : 14901490
 with finge The addtion value :
 Red led nmaximum number : 5848
 Red ledfinge minimum number : 542
 The difference  between  red max and minimum number  : 5306
 The difference value with finger and with out finger: 3558
 The oxegen percentage in blood : 88
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221233
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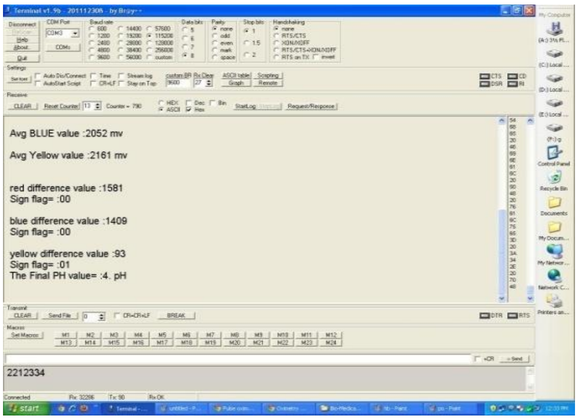
(d)



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Avg BLUE value :2052 mv

Avg Yellow value :2161 mv


red difference value :1581
Sign flag= :00

blue difference value :1409
Sign flag= :00

yellow difference value :93
Sign flag= :01
The Final PH value= :4. pH
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2212334
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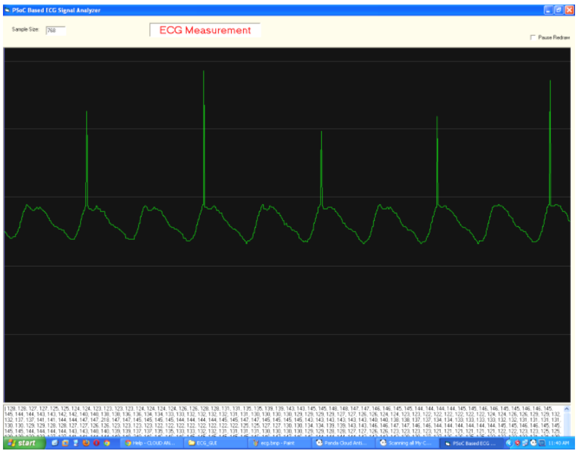
(e)



(f)

Fig. 13*(a)* Parameters ready to sense data perceived in PC. *(b)* Sensed data from temperature sensor DS18b20. *(c)* Sensed data from heart beat sensor unit. *(d)* Sensed data from pulse oximetry sensor unit. *(e)* pH level and *(f)* ECG waveform.

VII. CONCLUSION

This paper presents implementation and design of wireless sensor network for real-time health monitoring system by using ZigBee wireless standard. So finally we conclude that Programmable System on Chip (PSoC) has been the cost effective implementation used for wireless recording and transmission system of bio-medical signals. And it is very useful to the remote patients. The use of a microcontroller as the building block of the wireless recorder has the benefits of intelligence, compact size, and reliability. By the aid of this highly integrated microcontroller, external components, and hence wirings are kept to a minimum. The intelligence of this device is due to the processor itself, which could handle simple pre- processing tasks. The maximal throughput of the A/D conversion and the data transmission is about 40 Kbits per second, thus, limiting the applications to low-frequency signals, such as ECG, EMG, and EEG. Further advantage of this device is its low-power consumption, which is attractive for portable applications. Moreover, this part was also layout on a motherboard to increase its mechanical strength. The change of different front-end modules is thus speeded up. We hope that the system should be adapted for minimizing the device's size and allow for daily life usage. We also plan to include other health monitoring module such as; EMG, EEG for completing the system, and we hope that the system should be adapted for minimizing the device's size and allow for daily life usage.

REFERENCES

1. Elder care Thailand association, http://eldercarethailand.com.
2. http://en.wikipedia.org/wiki/1-Wire. R. E.
3. Cady, Fredrick. Software and Hardware Engineering Free scale HCS12. Oxford University Press. 2008. http://www.freescale.com.
4. http://www.oximetry.org/pulseox/principles.htm.
5. http://www.howequipmentworks.com/physics/respi_measurements/oxygen/oximeter/pulse_oximeter.html.
6. C.Otto, Milenkovic, A., Sanders, C., Jovanov, E., "System architecture of a wireless body area sensor network for ubiquitous.
7. Cypress Microsystems.
8. PSoC User Module Data Sheets.
9. T.Martin,E.Jovanov,D.Raskovic,Issuesinwearablecomputingformedicalmonitoringapplications:acasestudyofawearableECGmonitoringdevice,in:*InternationalSymposiumonWearableComputersISWC2000,*Atlanta,October2000.
10. "What is PSoC,"David Tomanek, DAT Consulting Cons, Pasadena, Applied Electronics (AE), 2010 International Conference on California, USA.
11. Bronzino, Joseph D. (Editor). The Biomedical Engineering Handbook. Boca Raton: CRC Press, Inc., 1995.
12. B.B. Flick & R. Orglmeister, A Portable Microsystem-Based Telemetric Pressure & Temperature Measurement Unit, *IEEE Tr on Biomedical Engg.,* **47**(1), 2000, 12-16.
13. Arif C.,"Embedded Cardiac Rhythm Analysis and Wireless Transmission (Wi-CARE)," *MS Thesis*, School of Computing and Software Engineering, Southern Polytechnic State University, Marietta, Georgia, USA, 2004.
14. Congestion-Aware, Loss-Resilient Bio-Monitoring Sensor Networking for Mobile Health Applications Fei Hu, Yang Xiao, *Senior Member, IEEE*, and Qi Hao, *Member, IEEE*, IEEE Journal on selected areas in communications, vol. 27, no. 4, may 2009.

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