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A Wireless Physiological Monitoring System for Hyperbaric Oxygen Chamber

Chengcheng Lu, Wushan Cheng

(College of Mechanical Engineering, Shanghai University of Engineering Science, Shanghai 201620,China)

Abstract:This paper introduces a system which can monitor multi-physiological parameters in the hyperbaric oxygen chamber. The monitoring system was designed as a star wireless sensor network and the system's transmission protocol based on the IEEE802.15.4 were programmed. The signals can be collected with the sensor network working under network synchronization. The system can be used to monitor physiological parameters such as blood pressure, pulse rate and temperature. A prototype of the monitoring system has been fabricated and extensively tested with very good results.

Keywords:physiological parameters, wireless sensor network, hyperbaric oxygen chamber, Zigbee.

I. INTRODUCTION

With the development of wireless sensors and sensor networks, the method and technology of medical monitoring will fundamentally change. Hyperbaric oxygen chamber has been widely used in clinical disease treatment. The physiological monitoring system in the chamber is an important equipment which can be used to monitor physiological parameters of the patient during the therapy of hyperbaric oxygen. Due to the special environment of hyperbaric oxygen chamber, the existing monitoring equipment have some limitations which are mainly shown in three aspects:

(1)Multiply sensors are connected with the processor through the wired way.(2) Multiply sensors are independent of each other and lack of an integrate system.(3) The equipment does not support continuous acquisition of the signal and real-time processing of the data [1].

The major idea of this paper is to develop a wearable physiological parameters equipment based on wireless sensor technology, which can be better adapt to the special environment of hyperbaric oxygen chamber and the need of clinical treatment. The system can be used to monitor physiological parameters such as blood pressure, temperature and pulse rate. Because of the power-saving mode of the hardware and software, the end device in the hyperbaric oxygen chamber can be powered by battery. After collection and conversion, the signal will be displayed on the screen which in the chamber, and at the same time the signal can be transmitted to the central monitoring terminal (host computer) which outside the chamber through the Zigbee wireless transmission technology, so the monitoring system can realize synchronous monitoring inside and outside the chamber.

II. SYSTEM STRUCTURE AND HARDWARE DESIGN

Small package, low power consumption, wireless communication, security and interoperability are the basic requirements of medical wearable monitoring equipment. Fig. 1 shows the functional block diagram of the system hardware. The system is mainly composed of monitoring terminal (host computer), coordinator node outside the hyperbaric oxygen chamber and multi-parameter acquisition sensor nodes inside the chamber. The inputs from sensors are integrated and processed. The results are sent wirelessly through the Zigbee Module to the host computer. The values can then be displayed on the Graphical User Interface (GUI) running on a computer.

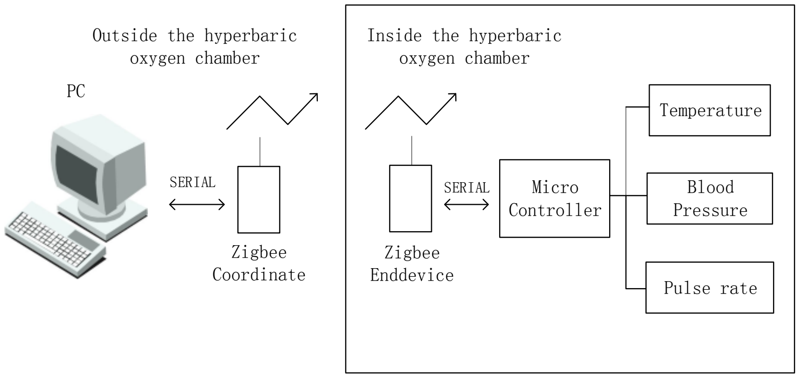

Fig. 1 Functional block diagram of system hardware

A. Blood pressure sensor

Pressure sensor is one of the most important parts in electronic sphygmomanometer, for it is the key factor that influence the detection precision. In this paper, we choose resistance pressure sensor MPS2107. It can detect small changes of pressure in the cuff [2], [3].

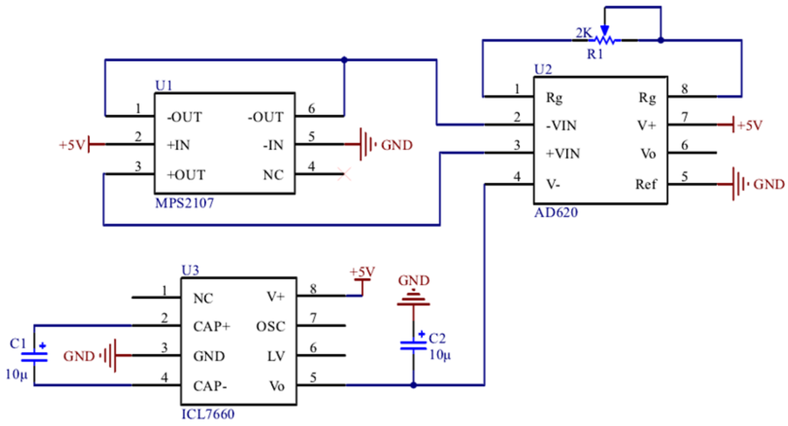

Fig. 2 The main circuit schematic of blood pressure measurement circuit

Due to the output of pressure sensor is a differential and weak signal, we use instrumentation amplifier AD620 to amplify the pressure signal. The gain equation is then

$$G = \frac{49.4k\Omega}{R1} + 1 \tag{1}$$

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000. Furthermore, the AD620 features 8-lead SOIC and DIP packaging that is smaller than discrete designs and offers lower power (only 1.3 mA max supply current), making it a good fit for battery-powered, portable (or remote) applications. Its working voltage is ±2.3V to ± 18V but the working voltage of microcontroller is +5V, so we use ICL7660 to get -5V. We can adjust the resistance value of R1 to get different magnification. Fig.2 shows the main circuit schematic.

B. Pulse rate sensor

We choose the TCRT5000 as the pulse rate sensor. The TCRT 5000 has a compact construction where the emitting-light source and the detector are arranged in the same direction to sense the presence of an object by using the reflective IR beam from the object. The operating wavelength is 950 nm. The detector consists of a phototransistor [4].

Fig. 3 shows the pulse rate sensing principle.When the heart pumps a pulse of blood through the blood vessels, the finger becomes slightly more opaque and so less light reached the detector. With each heart pulse the signal varies. This variation is converted to electrical pulse.

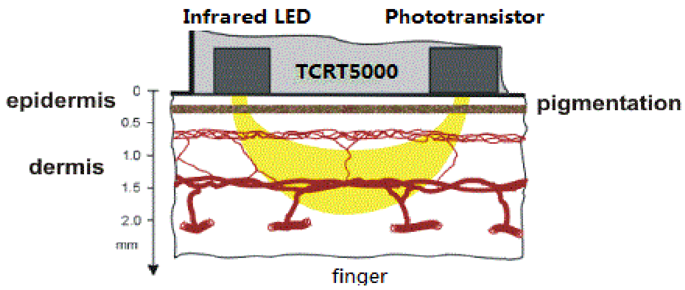

Fig.3 The pulse rate sensing principle

Fig. 4 is the pulse signal acquisition circuit. U1 is infrared transmitting and receiving device. R1 choose 270 Ω is based on the infrared light sensitivity of phototransistor. When the finger away from the sensor or detected strong interference of light, DC voltage of the input will be greatly changed. So we use the bipolar coupling capacitor which made of C1 and C2 to constitute a simple photoelectric isolation circuit. The frequency of the output signal is very low, and therefore we first use R2, C3 to filter out high frequency interference, and then integrated operational amplifier LM324, R5 and C4 constitute a low-pass filter to further filter out the residual interference. It's cut-off frequency

$$f_0 = \frac{1}{2\pi R_5 C_4} \approx 3.39 \tag{2}$$

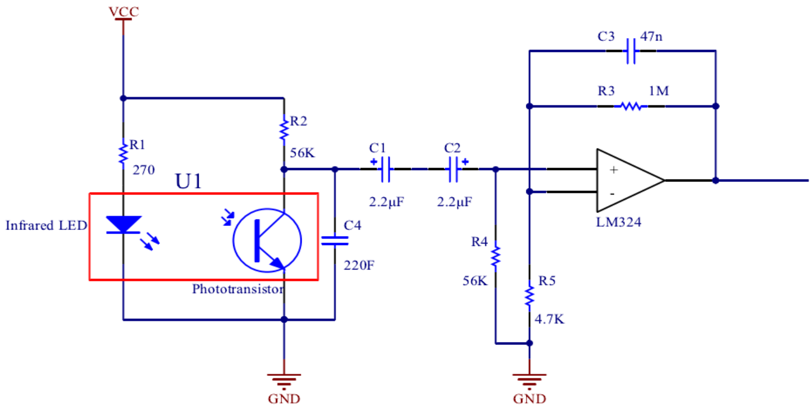

Fig.4 The pulse signal acquisition circuit

C. Temperature Sensor

The measurement of temperature is one of the fundamental requirements for body condition detection. The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. It has an operating temperature range of -55℃ to $+125$℃ and is accurate to± 0.5°Cover the range of-10℃to $+85$℃. Fig. 5 shows the circuit application of DS18B20. The sensor is mounted on the upper arm to measure skin temperature. From the temperature of the skin, the body temperature is estimated. There can be different methods to estimate the exact body temperature from skin temperature, but with a rough estimation usually the body temperature is 5.1℃ higher than skin temperature when the body temperature is measured at the ear. The changes in body temperature would indicate whether the patient is undergoing any following condition such as trauma, injury, heart attack, stroke and burns [5], [6].

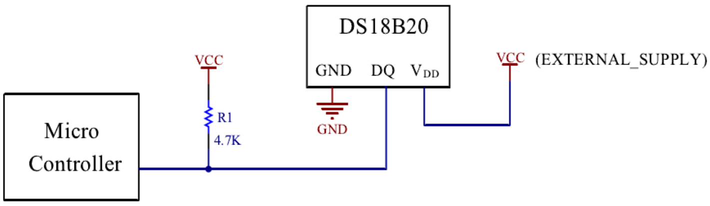

Fig. 5 Circuit application of DS18B20 temperature sensor

Fig. 6 shows the comparison of temperature measured by the developed temperature sensor with respect to a glass thermometer (reference temperature).

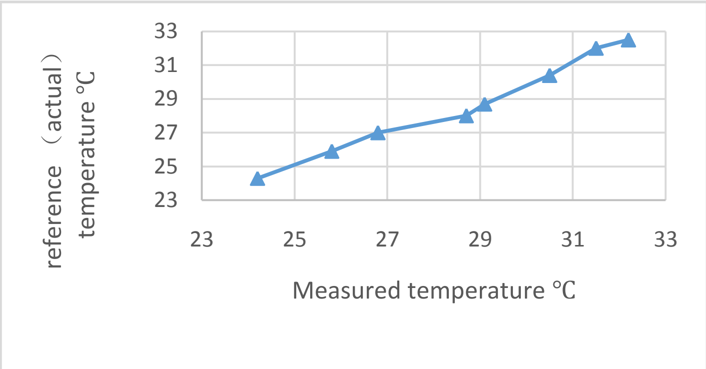

Fig.6 Measured versus Reference temperature

D. Microcontroller Interfacing and Communication

The microcontroller used is STC89C52. The Microcontroller is programmed using "C" language for the operation of the above mentioned tasks in this project [7]. Inputs from the blood pressure sensor and pulse rate sensor are fed to ADC channel. The digital signal from temperature sensor is given to port. Each sensor's signal is sampled at a predefined rate through interrupt-driven algorithms. Fig. 7 shows the prototype of the monitoring system.

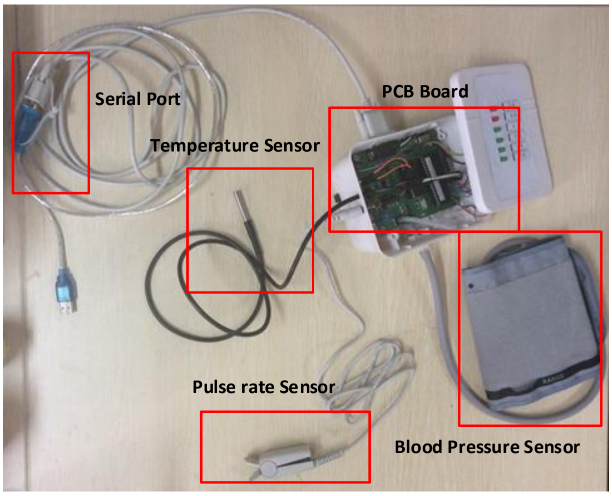

Fig. 7 The prototype of the monitoring system

Communication between sensing unit and receiving unit is done wirelessly using Zigbee protocol. Texas Instruments networking protocol Zigbee 2007 is based on the MAC and PHY layers of the IEEE 802.15.4 specification, and is tailored for simple network development in the 2.4 GHz frequency band. The protocol provides the features to find form and join a network, as well as discovering nodes on the network and route to them [8], [9]. To connect the CC2530 module to the Microcontroller is done using three wires. The GND, RXD and TXD of the Microcontroller are connected to GND, TX and RX of the CC2530 module (Fig.8).

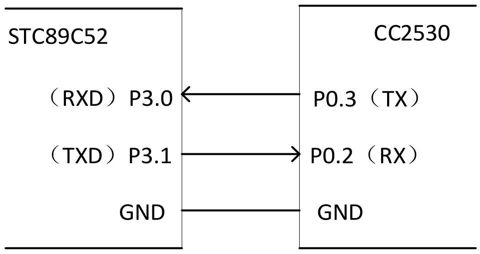

Fig.8 CC2530 module electrical connection with microcontroller

The GUI was programmed in C# and captures the serial communication, as shown in Fig. 9. Through the GUI, we can receive the data from the coordinator node and use the processing ability of the host computer to record, save and operate the date. The Coordinator node can set the WSN's parameters through the GUI.

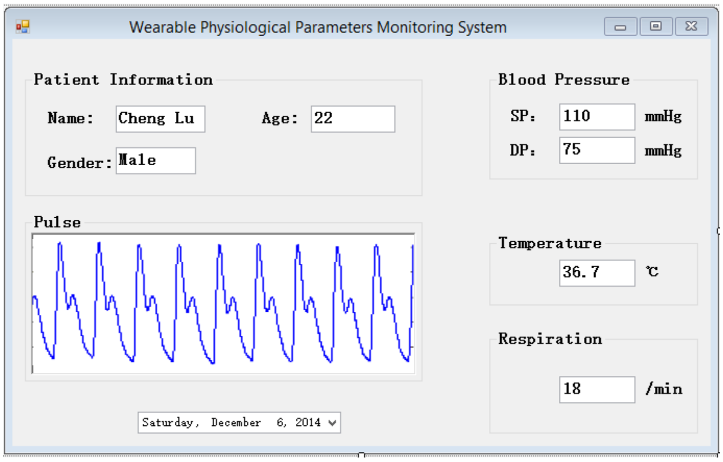

Fig. 9 The graphical user interface

III. EXPERIMENNT RESULTS AND ANALYSIS

The proto type of wearable physiological parameters monitoring system has been developed.We use this prototype for a clinical analysis of 10 cases under 2.0 ATA cabin pressure and compared test results with Heal Force PC-3000 patient monitor. Table.1 shows the comparison of blood pressure measured by the prototype with respect to PC-3000. Through linear regression analysis, the correlation coefficient of the systolic pressure is 0.9673 and the correlation coefficient of the diastolic pressure is 0.8685. A good identity of results has been reached.

Table. 1 The comparison of blood pressure by the prototype with respect to PC-3000.

Case		1	2	3	4	5	6	7	8	9	10
Systolic	Prototype	119	128	117	113	121	107	119	131	120	111
Pressure	PC-3000	121	125	118	114	119	109	117	129	122	110
Diastolic	Prototype	79	84	75	73	81	68	77	85	73	71
pressure	PC-3000	76	83	73	75	84	70	74	82	77	68

IV. CONCLUSION

In this paper, we discussed wireless embedded device for monitoring physiological parameters such as blood pressure, temperature and pulse rate. The Zigbee module is used for wireless transmission of physiological parameters from transmitting unit to the receiving unit where they will be monitored. The physiological parameters are seen on graphical user interface using C# which will help the medical professionals to monitor the fluctuations in parameters easily.

Clinical test results show that monitoring equipment has been meet the demands of system design and test parameters are accurate and reliable, has good clinical application performance. Beyond the application for hyperbaric oxygen chamber, it can be used for anyone who is at-risk, with a mental or physical disability. Monitoring of soldiers in the war would be possible if the sensitivity to movement was decreased.

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