Design of a Wireless ECG Monitoring System using Android and Bluetooth Low Energy Technology

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***Abstract* - The incidence of cardio-cerebrovascular disease is high, if the abnormal heart rate can be detected in time, the patients can be quickly rescued at the time of onset. Based on Bluetooth Low Energy (BLE) technology, this paper develops a portable, low-power heart rate meter. The heart rate monitoring system contains two parts: the heart rate data collection end and the mobile phone App. After the heart rate is acquired by the sensor, processed through the hardware filter and software filter, it is sent to the Android mobile phone by Bluetooth 4.0 wireless transmission technology. The App displays the heart rate value in real-time. The heart rate meter can collect data at 40～120 times per minute, when the beats per minute are less than 60 or higher than 100, the alarm will emit an emergency sound.**

Keywords - heart rate meter; Bluetooth Low Energy; Bluetooth 4.0; CC2540; Android

I. INTRODUCTION

Heart rate monitor is a commonly used medical equipment, which provides heart rate measurement real-timely and it has a wide range of applications [1]in patient monitoring, clinical treatment and sports competition and other fields , With the rapid development of mobile Internet and integrated circuit technology, it is possible to complete the human health detection by using of smart phones. Compared with the traditional heart rate meter [2], this method is more flexible, software design is convenient and the function is easy to add, which meets the needs of the public.

At present, there are two kinds of heart rate detection device on the market. The first is used in hospital, which has the advantages of high precision, but has the disadvantages of large volume, and it is expensive, so it is not suitable for public use; the second is portable heart rate meter, it comes with a display module and its volume is small, but standby time is short. To solve the above issues, this paper designs a portable heart rate meter with low power consumption, low cost and easy carrying. this meter measures heart rate data，and send to a smart phone wirelessly through Bluetooth 4.0[3] protocol, the mobile phone APP display the value of heart rate real-timely.

II. SYSTEM STRUCTURE DESIGN

The system is composed of the heart rate collecting end and the mobile phone APP, and the collecting end consists of heart rate sensor [4], signal conditioning circuit, CC2540 controller and power management circuit. After acquired by the heart rate sensor, the heart rate signal is amplified by the signal amplifier circuit, filtered by the hardware filter, then the CC2540 microcontroller complete the software filter and heart rate calculation, and data is sent to the mobile phone via Bluetooth low Energy technology.

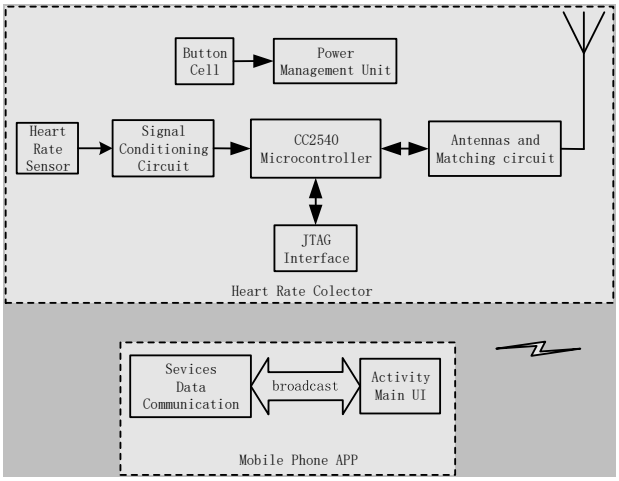

Figure1. Structure of wireless heart rate meter

III. DESIGN OF HARDWARE CIRCUIT

A. Heart Rate Sensor

This design uses pulse sensor based on the principle of photoplethymograph.it is mainly composed of green light source and photoelectric detector[5-8]. Because of the difference of the blood vessel transmittance caused by the pulse beating, the light intensity of the reflected light is detected by the photoelectric detector after the human blood .vessel is irradiated by the green light source, therefore the optical signal is converted into electric signal. Because the pulse signal is weak, its band isbetween 0.05 and 200Hz,and it'sinfluenced by external interference easily, so the function of low-pass filtering and amplification is completed by signal conditioning circuit.Finallythe AD converter in cc2540 controller converts the analog signal to digital signal.

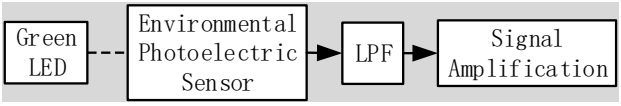

Figure2. Structure of heart rate sensor.

B. Main Control Circuit

Bluetooth low energy technology is developed based on standard Bluetooth technology, with low operation and standby power consumption, usually a button cell can work for several years continuously, it is very suitable for the application of short distance and low data rate wireless communication. CC2540 is a single mode Bluetooth low energy chip produced by TI company. It has the characteristics of low cost, low power consumption and so on. It is built in an enhanced 8051 microcontroller core, with the addition ofAD, USB, USART, I2C, SPI, Timer, DMA common peripherals, it is a true system on chip(SOC),and has two chip version: CC2540F128 with 128KB flash and CC2540F256 with 256Kb flash. In addition CC2540 supports five kinds of low power mode to meet different applications requirements [9].

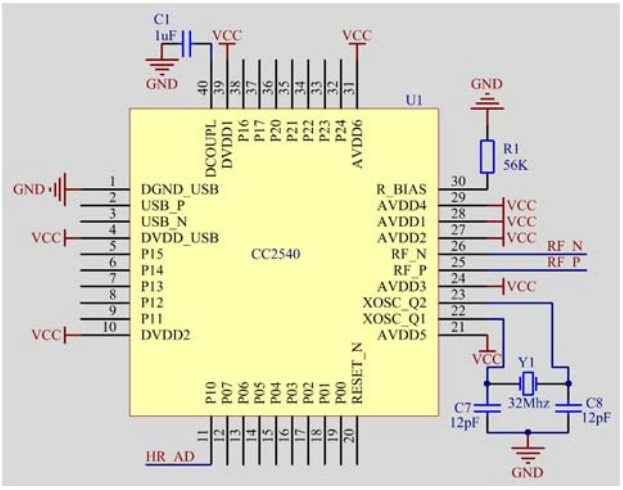

Figure 3. CC2540 core circuit

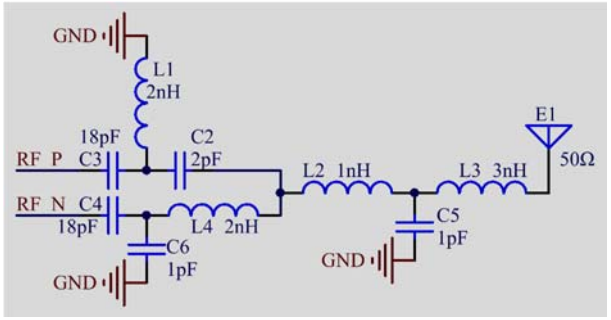

Figure 4. Antenna matching circuit.

C. Antenna matching circuit

CC2540 chip has integrated 2.4GHz Bluetooth low power RF transceiver, external pins are pin RF_N and pin RF_P. Figure 4 is antenna impedance matching circuit, the end of the circuit connects antennas with characteristic impedance of 50 Ohms, to reach the best effect of radio frequency. figure 5 is graph ofS11 parameter vs frequency figure 6 is Smith Chart of PIFA.

D. Printed circuit board design

As shown in figure 7, system uses inverted F antenna, which has the impedance of 50 ohms. In order to improve the efficiency of radio frequency signal transmission and reduce the energy loss, the impedance matching between the RF source and the antenna is completed by using balun matching circuit.Formula (1) and (2)[10] is Calculating formula of Γ_0 and SWR(Standing Wave Ratio) respectively. Γ_0 is the reflection coefficient of antenna, $Z_0$is the characteristic impedance，Z_L is load impedance. The ideal value of Γ_0 is zero, and the goal of design is making value of SWR approach 1:1 asfar as possible. figure 8 is 3D figure of printed circuit board.

$$\Gamma_0 = \frac{Z_L - Z_0}{Z_L + Z_0} \quad (1) \qquad SWR = \frac{1+|\Gamma_0|}{1-|\Gamma_0|} \quad (2)$$

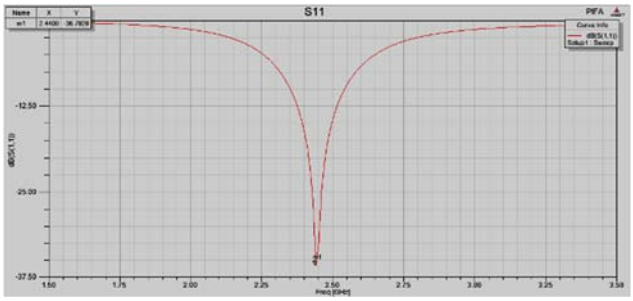

Figure 5. S11 parameter vs frequency

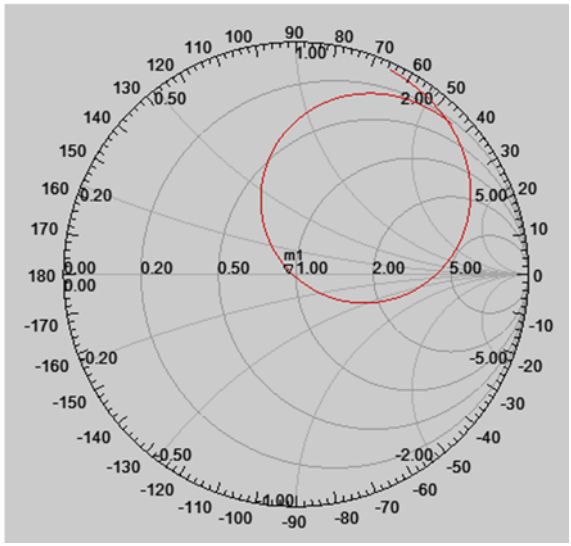

Figure 6. Smith Chart of PIFA.

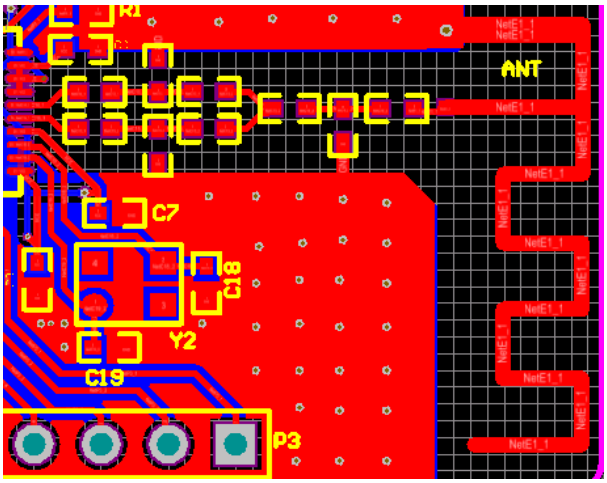

Figure 7. PCB layout of antenna

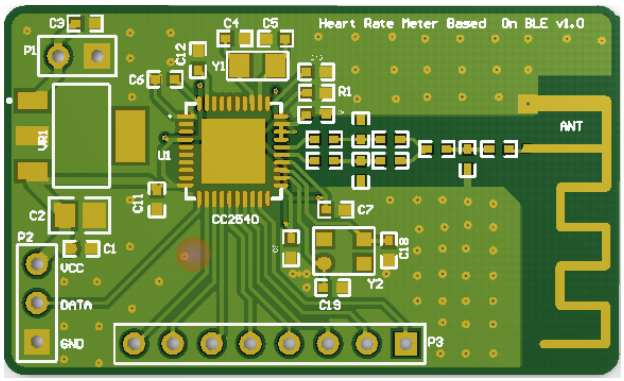

Figure 8. 3D figure of printed circuit board

IV. SOFTWARE DESIGN

System software includes embedded software of heart rate collector and Android mobile APP software, the software of heart rate collector is developed based on BLE protocol stack BLE-STACK, which is free protocol stack for developers to use,and it'sprovided by TI company , the stack includes lower communication protocols and provides many API function, software developers can call these API function flexibly[11].

A. Overall software design

As illustrated in Figure 9, the system first initialize the clock, IO port, hardware abstraction layer (HAL), nonvolatile memory (NV) and Analog to Digital (AD) module after system power on, then call osal_start_task ( )function to start the OSAL, in turns to perform each task. in task initialization function osal_init_task( ), system start heart rate collection task every 5ms, and finallyfinished wireless transmission of heart rate after completion of the acquisition.

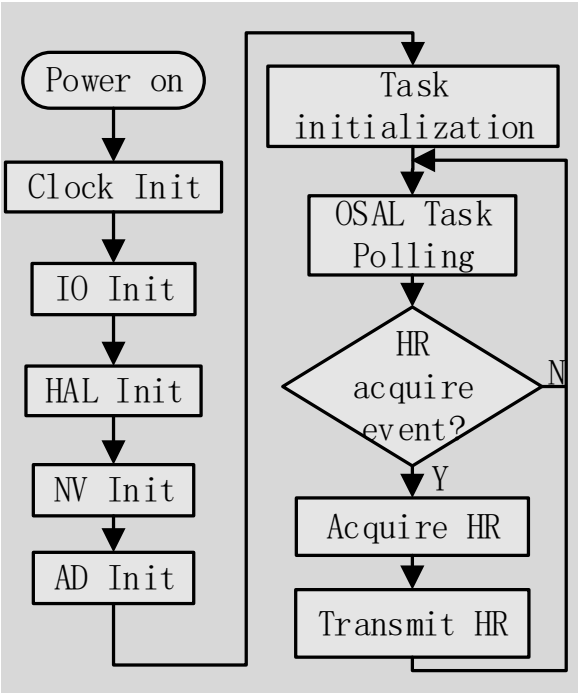

Figure 9. CC2540 software flow chart

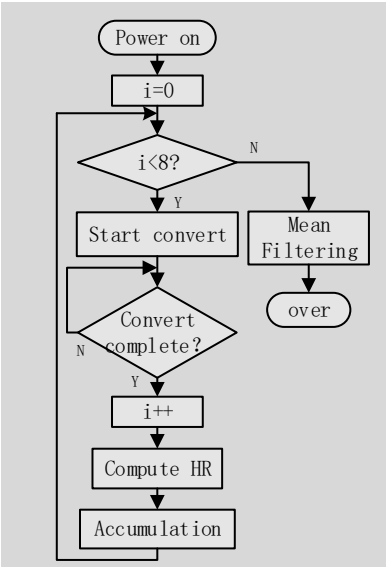

Figure 10. Heart rate acquisition flow chart.

B. heart rate acquisition program

The heart rate acquisition program is shown in Figure 10, the CC2540 controller is integrated with 12 bit precision AD converter. Eight times mean filtering is used in order to reduce the interference and enhance the stability.

C. Data transmitting

After the heart rate is acquired, it is required to send to the Android mobile phone through Bluetooth low energy protocol wirelessly. After the collector is connected with the mobile phone normally, it will notify the phone via the GATT_Notification function.

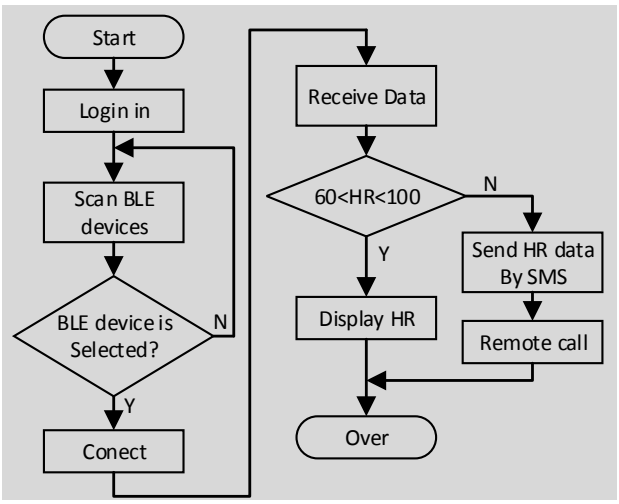

Figure 11. Android software flow chart

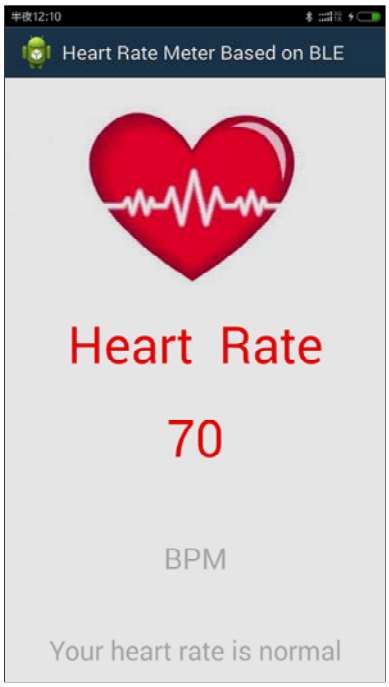

Figure 12. User interface diagram of APP.

D. Android software design

Android APP software is developed based on Eclipse development environment, using JDK version 7.2. As Android 4.0 or more support Bluetooth low energy protocol, the design uses SDK of Android 4.1. Figure 11 is software flow chart of Android APP. The process of receiving data is ongoing and it will occupies system resources, this design receives data in the background using services components. Because the services component does not have a corresponding user interface, so data is transmitted to the activity components through broadcast receiver components, thus APP completes receiving and display value of the heart rate. In addition, Bluetooth permissions should be opened in the Androidmanifest.xml file, <uses-permission android: name = "android.permission. BLUETOOTH"/> <uses-permission android: name= "android.permission. BLUETOOTH_ADMIN"/>.

V. SYSTEM DEBUG

Test mobile phone must support BLE in hardware, we use Samsung S4 phone which installs Android 4.1 system.Connected by phone through the USB data cable, the computer needs install corresponding driver, and phone need enter the USB debug mode. Figure 12 is user interface diagram of Android APP.

VI. CONCLUSION AND SUMMARY

This paper proposed a design of heart rate meter, by means of optical capacitance product method to collect heart rate data, using TI company's chip CC2540 supporting Bluetooth low energy as the main control chip to complete the signal processing and transmission. In the display side, we use Android smart phones to receive, store and display heart rate data. This system can measure heart rate of the earlobe or the tip.The testing results indicates the system can work steadily.

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