Research and Implementation of A Portable Heart Rate Detection Device Based on STM32

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Abstract

To achieve the detection of vital sign parameters, designed a portable and low power consumption of the heart rate detection device. Using electrodes, heart-wires and ECG acquisition chip ADS1292R acquired original electrocardiogram (ECG) signal. And low power consumption chip STM32 completed original signal denoising and processing, taking the difference threshold method for location of ECG's R wave, to achieve calculated heart rate of sign parameters. Using the bluetooth wireless transmission module to push ECG signal, and heart rate value to the mobile terminal, and achieved display of sign parameters in real-time. The detection device is powered by a soft-pack lithium battery to meet the needs of the portable. The experiments showed that the difference threshold method positioning R wave's accurate can reach above 98.76%. Compared with Mindray pm-9000 ECG monitor, and the error of heart rate is within 4%,can meet the real-time of heart rate's testing standard.

Keywords

Portable,STM32,ADS1292R,ECG signal,difference thresold method,heart rate.

1. Introduction

The Heart rate as a basic physiological parameters of the human body [1], it said heart beats per minute, contains a wealth of physiological information. Mechanical contraction of the heart before the first electrical excitation, atrial and ventricular electrical stimulation can be transmitted to the body surface tissue [2]. Normal cardiac activity began in the sinus node, excited atrial at the same time through the bundle conduction to the atrioventricular node, the last excited ventricle. This sequential, electrically activated transmission causes a series of potential changes that form the corresponding bands on the ECG (Electrocardiograph) [3].

In view of the importance of physical health, the monitoring of ECG and heart rate not only provides an important basis for the diagnosis and treatment of patients with cardiovascular diseases [4], but also helps the healthy users to timely adjust the physiological mode and lifestyle according to the monitored physiological parameters To reduce the prevalence of such diseases. Currently, the market test heart rate equipment is divided into two categories. One is the hospital-specific heart rate monitoring instruments, which are complicated to operate, high cost of monitoring, fixed monitoring sites and require professional medical personnel's guidance to use; the other is the market some portable signs parameter detection device, for example based on ZigBee technology Non-lead wire Holter monitor design [5], and wrist-ring heart rate monitor, but such products can not display ECG signals in real time, is not conducive to the doctor's analysis of the patient's condition. Therefore, the development of a real-time display of ECG and heart rate sign parameters detection device is of great significance.

Based on this, a portable heart rate detection device is designed, which can accurately measure the heart rate value and display ECG signals and heart rate sign parameters in real time. Hardware part of the data acquisition, processing and calculation, and transmission, mobile APP-side data to complete the real-time display.

2. System Design

In this paper, the design of the physical parameters of the detection device, the electrode chip, ECG as the sensor unit, with the bioelectric potential measurement chip ADS1292R through bipolar lead CM5 way [6], the acquisition of the original ECG signal; microprocessor STM32 as a signal processing unit , The processed data is sent to the mobile APP through the wireless transmission module, so as to realize the intelligent display of the ECG signal waveform and the heart rate value.

System design block diagram shown in Figure 1, consists of the following units: sensor unit, ECG signal acquisition unit, signal processing unit, wireless transmission unit and terminal display unit.

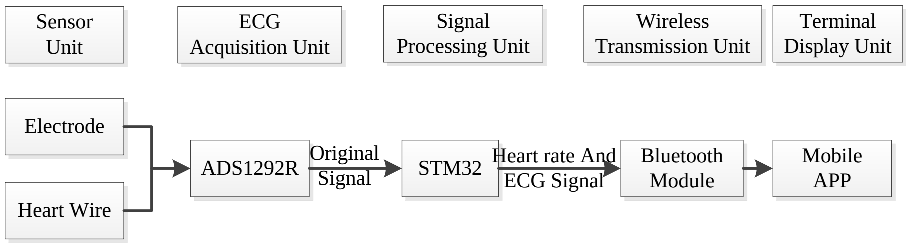

Fig. 1 The diagram of system design.

3. Hardware Design

The device hardware circuit design, including the following modules: microcontroller control module, signal acquisition module, Bluetooth transmission module and power management unit. The signal acquisition module sends the collected raw ECG signals to the singlechip control module for filtering and heart rate calculation. The Bluetooth transmission module then pushes the data to the mobile phone APP for displaying, and the power management unit provides the front-end hardware unit with working voltage and current.

Circuit design, in order to achieve the portable device, low power consumption and performance stability. Therefore, the device PCB layout, the circuit layout size reduced to 20 mm * 40mm, the implementation of the top, bottom double-sided components, and components are SMD package, to meet the portable requirements,Figure 2 is a physical diagram of the hardware device.

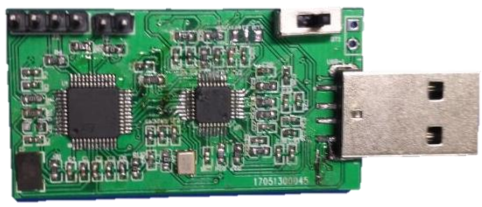

Fig. 2 The physical map of device hardware

3.1 Microcontroller Control Module

Taking into account the device's low-power characteristics, MCU processing unit controller using chip STM32F103CBT6, 32-bit microprocessor and 128kb of embedded Flash memory space for fast data processing and storage [7]. Crystal 8M passive crystal oscillator as a high-speed external clock source to provide system clock.

In the consideration of optimizing the hardware circuit, the SWD four-wire download method is used to program the main chip, and the BOOT pins are set as BOOT0 and BOOT1 respectively. Therefore, the STM32F103CBT6 microcontroller starts to be imported from the user flash area. The microcontroller uses seven pins: ADS_DRDY, ADS_START, ADS_RESET, SPI_CS, SPI_CLK, SPI_MISO, SPI_MOSI, connected to the ECG signal acquisition module.

Use SPI interface communication protocol to provide the correct timing for the ADS1292R, as the host to the ECG acquisition chip to send the start (high begin to collect data), reset signal (low reset), external interrupt response pin ADS_DRDY low, Enter the interrupt to receive the original ECG signal, the serial port leads to UART_TX through 0 ohm resistor, UART_RX respectively connected with the receiving and sending data pin of the Bluetooth module, and sends the de-noised ECG signal and heart rate value to the mobile phone APP for display. In addition, the serial port pins TX, RX lead through two pin, to facilitate the debugging process.

3.2 ECG Signal Acquisition Module

ECG signal acquisition module mainly consists of ADS1292R and its peripheral circuits, do not use analog front-end circuit module acquisition, can improve the collection efficiency and stability. The ADS1292 is a specialized biosensitive collection chip, which can realize multi-channel signal acquisition. Channel 1 is dedicated to 3-byte respiratory signal access, 2-channel is used to extract 3-byte ECG signals, and its internal integrates specialized 32Khz square wave modulation unit, through IN3P, IN3N pin output modulation of respiratory signals [8]. Data output format for the 3-byte frame header, 3-byte respiration signal, 3-byte ECG signal, because this article only collected ECG signal, channel 1 can be set to the default state, to reduce power consumption when collecting raw data Set the sampling rate to 250hz.

Acquired by the ECG acquisition unit, the electrode and the ECG using two leads from the human chest to obtain the original ECG signal, waiting for the microcontroller instruction, the collected 9-byte data sent to the microcontroller through the SPI interface for processing.

3.3 Bluetooth Transmission Module and Power Management Unit

Bluetooth transmission module using low-power BLE4.0 module [9], the module contains DSP processing unit, and UART serial protocol data communication with the microcontroller to facilitate data transmission. The device will set the Bluetooth transfer rate of 115200bit / s, and the same serial port microcontroller baud rate.

The power management unit is composed of a rechargeable battery, a power supply module and a charging module. The battery adopts a soft battery with a capacity of 330 milliamps, with a typical voltage of 3.7 volts and a voltage of 4.2 volts when the battery is fully charged. The power supply module uses a voltage regulator chip The TLV70033DCK converts the battery voltage into a stable voltage of 3.3V, provides the operating voltage for the entire hardware device, and controls the supply of the battery voltage through the toggle switch. The charging module uses CN3052A as the charging chip, charges the battery through an external 5V DC power supply, Charge current 250 mA.

4. Software Design

Software part of the main signal acquisition, calculation, processing and transmission, the main program flow chart shown in Figure 3(a).

The main program will first use the external crystal as the system clock and enable the peripherals (UART1, SPI1, SYS_EXTI, and GPIOB) to configure the UART1, SPI1, and GPIOB ports. To achieve fast data transfer, UART1 is transmitted as a DMA Therefore, the DMA1 clock needs to be enabled to further reduce the power consumption.

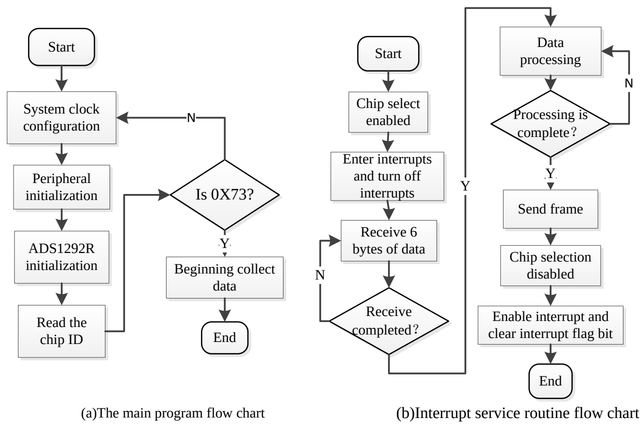

Fig. 3 The program flow chart

The ADS1292R is initialized to provide a reset signal to the chip. SPI1 sets its internal 11 registers. The ADS1292R is set to capture the ECG signal, the sampling rate, and the format of the frame header. The chip ID is read. If it is 0X73, data acquisition starts. Microcontroller in the interrupt service routine to read 9 bytes of data to complete denoising and heart rate calculation, and then the ECG signal, the physical parameters of the frame sent to the Bluetooth module. Interrupt service routine shown in Figure 3(b).

SCM 4ms scan an interrupt, the data processing time of 2ms, the microcontroller does not process data, make it into low power mode, to further optimize the code.

5. Data Processing And Calculation

5.1 ECG Signal Processing

Electrocardiogram is used to collect ECG signal from the chest region of human body. It is very weak and easily affected by various random high-frequency noise and power frequency noise in the environment. Motion artifact interference caused by human body movement is also an influencing factor. Resulting in baseline ECG signal drift [10].

Due to the interference of these common noises, the acquired ECG signal needs to be denoised, and the anti-jamming algorithm is studied to extract the active components in the original signal to calculate the value of the sign parameter.

The collected raw ECG signal, which has a large number of glitches and a significant baseline drift, these burrs are caused by high-frequency, frequency interference in the environment, and useful information carried by ECG signals are mainly distributed between 0.5 ~ 35Hz. Therefore, a 20-order FIR low-pass filter with a cut-off frequency of 35 Hz is designed to perform high-frequency filtering on the original signal [11]. As shown in Figure4, high-frequency noise can be effectively suppressed.

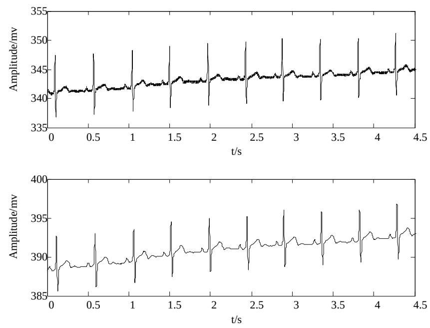

Fig. 4 ECG signal low-pass filter before and after contrast

After the previous FIR digital low-pass filter, the original ECG signal noise in the high-frequency components are effectively suppressed, but there is still a baseline drift. Baseline drift is caused by changes in the electrode position caused by breathing or other causes during the test. The frequency is below 0.5 Hz, which is a periodic fluctuation of the signal. Therefore, using morphological filtering [12] to remove, as shown in Figure 5, ECG baseline can be corrected.

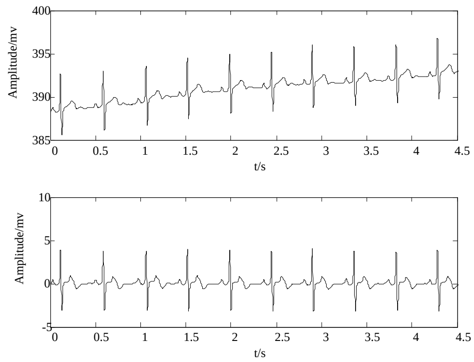

Fig. 5 Before and after the baseline drift ECG signal contrast

5.2 Qw Heart Rate Calculation

The calculation of heart rate needs to locate the R wave of ECG signal. The R wave is the most violent part of the ECG signal. In this paper, differential threshold method is used to make the latter difference of ECG signal sequence. Combined with the dynamic threshold, , Drop branch. The flow chart shown in Figure 6.

Differential Threshold R-wave detection can be achieved in many forms. The first-order differential sequence of ECG signals can be used to detect R-wave in QRS complex, which can obviously highlight the fastest changing position of R-wave velocity and can accurately Estimate the width of R wave. According to the characteristics of R wave signal, we can see that the descending branch is the position of maximum derivative. Therefore, when the difference is calculated, the maximum value of the derivative is positive with the former value subtracted.

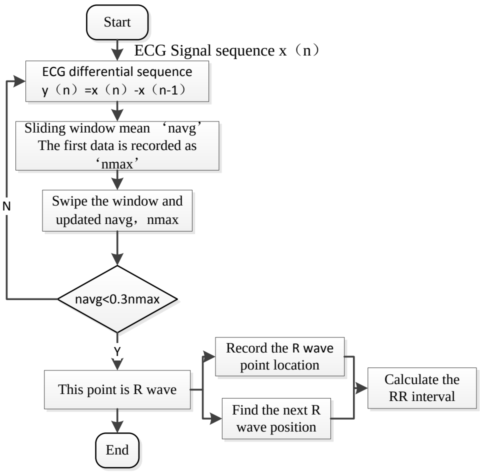

Fig. 6 Positioning R wave flow chart

The first R wave position is found by using the first order difference and the sliding window with the time width of 3. The R interval is found by sliding the window and the RR interval R-R is calculated. Using the formula:

$$HR = 60fs / R\text{-}R \quad (1)$$

Where HR is the heart rate, fs is sampling rate.

5.3 R Wave Positioning

The design of MATLAB simulation algorithm for the ECG signal after denoising, R-wave positioning in the MATLAB simulation code on the specific performance: data import, the first R wave position determination, RR interval and dynamic threshold comparison and subsequent adjacent R wave of the decision.

Identify the R-wave spikes, marked with an asterisk, as shown in Figure 7 below. From the simulation results, the differential threshold method can accurately locate the R-wave position. Therefore, by adding this algorithm within the singlechip program and finding the RR interval, the heart rate can be accurately calculated.

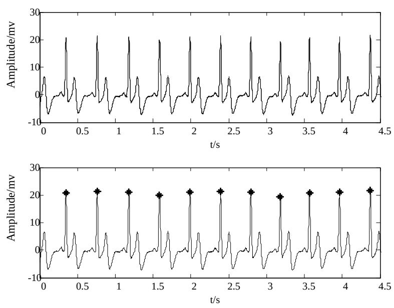

Fig. 7 R wave positioning map

6. System Testing

6.1 Heart Rate Test

The heart rate values collected by Mindray PM-9000 ECG monitor were used as a control group to test 8 people and synchronously record the measured values of the portable heart rate detection device, as shown in Table 1.

Table 1 Heart rate test control

Numble	Mindray PM-9000	Heart rate detection device	Relative error rate (%)
1	72	70	2.78
2	69	68	1.45
4	77	78	1.30
5	79	76	3.80
6	80	81	1.25
7	73	75	2.74
8	78	76	2.56

It can be seen from the test results in Table 1 that the error rate of the heart rate value measured by the device is controlled within 4%, so the detection standard of the real-time heart rate can be met.

6.2 APP Terminal Interface Display Test

As shown in Figure 8, the APP receives a piece of ECG waveforms and heart rate values transmitted by the Bluetooth module. It can be seen from the figure that the characteristic points of the QRS complex displayed are clear and the waveform is clear and stable. Therefore, this design of the detection device can complete the ECG signal acquisition, processing and transmission.

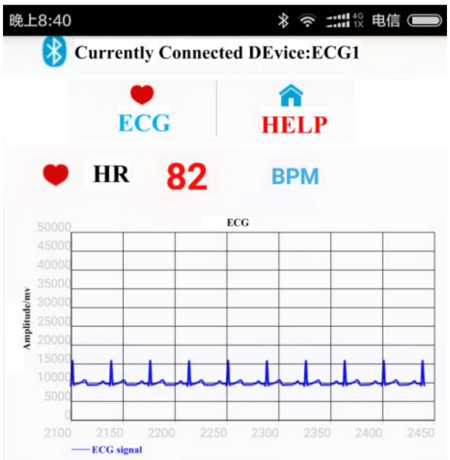

Fig. 8 ECG signal waveform and heart rate display

6.3 Power Test

Test device using 330 mAh lithium battery power supply, Table 2 for the microcontroller operating mode and low-power mode power consumption.

Table 2 operating mode and low power mode

Mode	Voltage / V	Current / mA	Power Dissipation / mW
Operating	3.7	20.21	74.78
Low power consumption	3.7	12.30	45.51

From the test results we can see that the device under normal use, the device can work continuously for about 16 hours.

7. Conclusion

The heart rate detection device designed in this paper has been optimized in both hardware and software to meet the needs of portable and low power consumption. The singlechip has been designed to eliminate the noise according to different noise. The experimental results show that the noise reduction effect Good, calculated signs more accurate parameters to meet real-time measurement requirements. At the same time facilitate the use of exercise, real-time and effective monitoring of cardiovascular patients with ECG, will help reduce the possibility of patients with paroxysm death. The device has a wide range of applications in the field of mobile medical care.

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