International Journal of Computer Science and Information Technology
ISSN: 3005-9690 (Print), ISSN: 3005-7140 (Online) | Volume 2, Number 2, Year 2024
DOI: https://doi.org/10.62051/ijcsit.v2n2.06
Journal homepage: https://wepub.org/index.php/IJCSIT/index

Wearable Health Monitoring Terminal Supporting Edge Cloud Computing Collaboration

Mengzhuo Liu, Xinyu Gao, Shiyi Wang, Ziwei Du, Rong Xing, Xiuyuan Yang, Yangyang Zheng

School of Information Engineering, Henan University of Science and Technology, Luoyang, 471023, China

ABSTRACT

In view of the problems of data accuracy and reliability, health data processing and interpretation that exist in current wearable health monitoring devices, this paper designs a wearable measurement device based on the STM32F103VCT6 that can collect a variety of physiological signals in real time, such as electrocardiography, blood oxygenation and so on. Based on the consideration of data accuracy and reliability, the STM32F103VCT6 processor with high performance, low power consumption and high reliability is used as the main control chip, and at the same time, suitable FIR filter parameters are designed to filter out the electromyographic signals and the industrial frequency interference noise, so as to effectively remove the noise and the redundant frequency components, and make the waveforms more clear and intuitive, and the data more accurate and reliable. For the processing and interpretation of health data, the signal spectrum is analysed by FFT transform, and the data is sent to the cloud system through wireless WiFi module, and the cloud platform checks, parses, plots and stores the data in real time, which has been proved the effectiveness of the design scheme by testing it in the real environment and making samples.

KEYWORDS

STM32, Physiological Signals, Edge-Cloud Collaboration

1. INTRODUCTION

In recent years, people's attention to health is getting higher and higher, modern social medical care is gradually changing from disease treatment to the mode of early prevention and treatment, and remote real-time health monitoring has become the focus of people's increasing attention, and wearable human health monitoring system has become an important tool for health monitoring because of its portability and real-time nature. The research and design of portable ECG monitoring devices for home use is not only of important research significance, but also of practical application value [1].

At present, much progress has been made in the direction of wearable human multi-physiological parameter monitoring systems at home and abroad. Specifically, Wang Tao et al [2] proposed to design a wearable embedded health monitoring system for real-time monitoring of heart rate and body temperature,

which improves the accuracy of physiological parameters through filtering circuits and signal processing algorithms, but the volume of the single-chip multi-parameter physiological parameter system is not small enough to be practical; Wang Zhao et al [3] explored a new mode of clinical monitoring of wearables based on the SensEcho monitoring system, which can provide richer diagnostic and therapeutic information, but lack of research on the alarm timeliness and false alarm rate of the monitoring system; Li Lixuan et al [4] based on wearable monitoring devices, incorporating the concept of the Internet of Things platform, which can satisfy the real-time monitoring of multiple patients in the ward, the effective application of the system relies on the network environment of the ward, and the real-time and validity of the data collection will be greatly affected when the network environment is unstable.

From the perspective of the development trend of wearable human multi-physiological parameter monitoring system at home and abroad, the detection technology for all kinds of physiological parameters of the human body has been more mature, but most of the wearable multi-physiological parameter monitoring system still stays in the stage of the prototype, with a single function, and most of them have higher requirements for the network. Therefore.

Designing a wearable human health monitoring terminal for dynamic environments has great significance and broad application prospects. In this project, a human physiological signal health monitoring system with cloud-edge-end architecture is designed, including a user-side device subsystem, an edge-side subsystem and a cloud subsystem. The user's characteristic information such as heart activity, pulse, body temperature and blood oxygen are collected in real time using wearable physiological signal acquisition devices, and the user's physical health is analysed by artificial intelligence technology, the surrounding environment is always kept in view using temperature and humidity acquisition, and the daily healthy gait status is counted by pedometer module. The design adopts end-cloud computing power synergy technology, which can speed up data processing and reduce the energy consumption of the device by distributing the computation and processing tasks of data to the edge end and the cloud end. The application of this technology helps to improve the real-time and accuracy of data transmission and processing, and enhances security and reliability.

2. OVERALL PROGRAMME DESIGN

This design is based on STM32F103VCT6 to design and fabricate a multi-physiological signal acquisition and processing system, which is powered by 5V power supply. Different physiological signals are collected using multiple sensors, and the raw signals collected are processed to obtain the time domain and frequency domain characteristics of the signals, so as to realise the monitoring of various physical and physiological parameters of the subject.Figure 1 shows the overall scheme design diagram of the system.

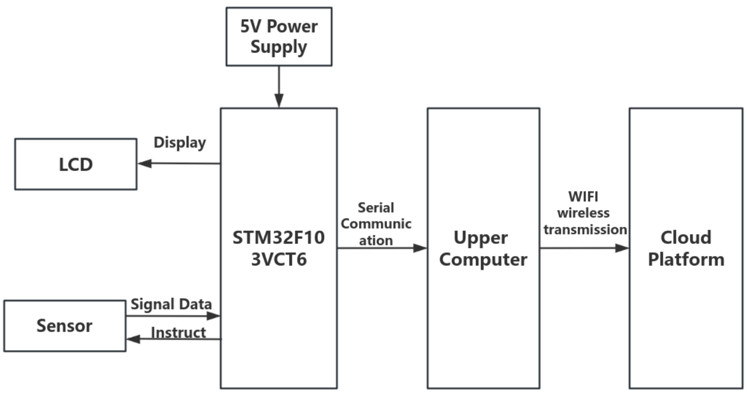

Figure 1 Overall system scheme design

The acquisition end is divided into two parts: the information acquisition unit and the main control unit. The information acquisition unit consists of electrocardiogram acquisition module, oximetry acquisition module, temperature measurement module and pedometer, which are in direct contact with the measured parts of the human body to obtain the physiological signals of the human body, and after amplifying and filtering the signals, the acquired information will be stored in the internal RAM, and then be transmitted to the main control unit through the built-in communication protocol.

STM32, as the main control chip, reads and writes the sensors, receives the data from the sensors, processes them to obtain the monitoring values of each physiological signal, and transmits the signal waveforms and data to the LCD screen for display through the SPI interface to realise real-time monitoring of the data. At the same time, STM32 directly imports the data into the host computer through the serial port and draws a diagram, and further adopts the FFT transform to analyse the signal spectrum and other filtering processes, so as to express the signal more intuitively and accurately. The data can also be sent to the cloud system through the wireless WiFi module, and the cloud platform checks, analyses, draws and stores the data in real time.

3. HARDWARE MODULE DESIGN

3.1. Main control circuit

The STM32F103VCT6 processor is used as the main controller for data acquisition and data processing in this solution.The STM32F103VCT6 features a 32-bit RISC core with a high performance M3, high-speed embedded memory, and a wide range of enhanced Io's and peripherals that are connected to two APB buses. The operating temperature range is from -40°C to +105°C and the power supply is 2.0 to 3.6 V. This chip has the advantages of high performance, low power consumption, and high reliability to meet the design of this programme.

3.2. ECG measurement module

TI's integrated chip ADS1292 is used, which is a suitable chip for bioelectrical signal acquisition with multi-channel, high resolution and low noise. Figure 2 shows the schematic diagram of the ECG measurement module,with proper electrode placement, the ADS1292 captures ECG signals and transmits the data to the STM32 via an SPI interface, which induces a small electrical change on the surface of the skin during depolarisation of the cardiomyocytes in each heartbeat, which is captured and amplified by the ECG recording device to depict the ECG.

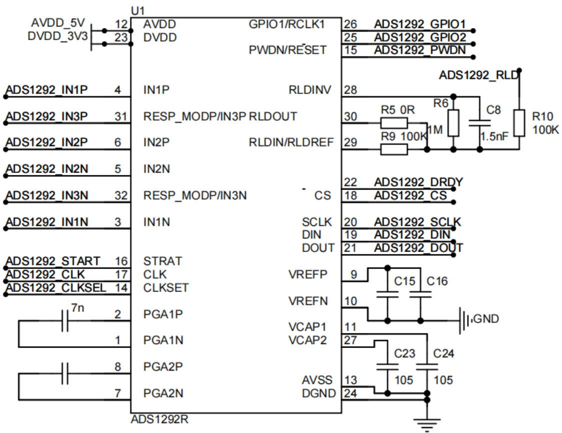

Figure 2 Schematic diagram of ECG measurement module

Figure 3 shows the ECG signal acquisition circuit system framework diagram.After the ECG signal is acquired by the electrodes, it is preliminarily amplified by a differential amplifier circuit and the common mode interference signal is suppressed. At the same time, the signal acquisition quality is improved by suppressing the common mode interference and lifting the measurement voltage through the right leg driving circuit. Next, a clear waveform is obtained through the filtering circuit. The filtered signal is then quantised to convert the continuous analogue signal into a discrete digital signal, which is done by an analogue-to-digital converter (ADC), which converts the sampled analogue signal into a digital form of ECG data. Finally, the digital ECG signals obtained are further processed and analysed by digital signal processing algorithms and techniques, including filtering, rhythm analysis, heart rate calculation, R-wave detection, etc., so as to extract relevant information about the heart's motion and function.

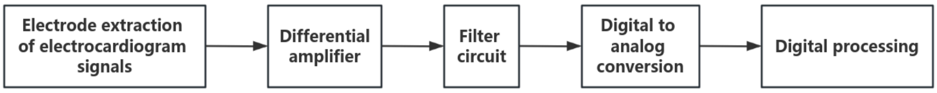

Figure 3 ECG signal acquisition circuit system framework diagram

3.3. Blood oxygen module

The MAX30102 chip is used in this module design. The chip can be divided into two parts, one part is the analogue signal acquisition circuit, in the detection, the measurer will place the wrist or finger on the RED and IR lamps do not move, through the RED and IR lamps emit a specific wavelength of light, the collection of human body reflected back to the light, through the PD tube will be converted into an electrical signal light signal, and ultimately converted into a digital signal through the 18bit ADC converter. The second part is the digital processing circuit, the raw data converted by ADC is filtered and placed in the buffer; the microcontroller reads and writes the internal registers of the chip through the IIC interface to read out the corresponding data. The design of the blood oxygen module is shown in Figure 4.

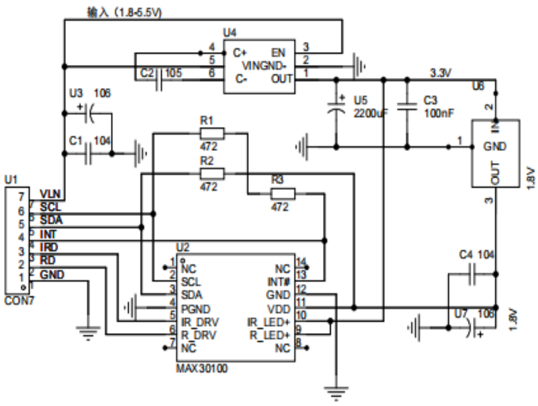

Figure 4 Blood Oxygen Module Schematic

3.4. Temperature and humidity acquisition module

A digital temperature and humidity sensor, the DHT11, is used in the design of this module. it integrates a resistive humidity sensor and an NTC (negative temperature coefficient) thermistor sensor, and is connected to a high-performance 8-bit microcontroller. The sensor draws an air sample in the measured environment, at which point a pick style temperature and humidity stream is generated. The air sample passes through two bridge sensors located within the sensor, and the amplified and A/D converted digital signals are sent to the microprocessor for data processing. The microprocessor calculates the actual temperature and humidity values from these signals. The design of the temperature measurement module is shown in Figure 5.

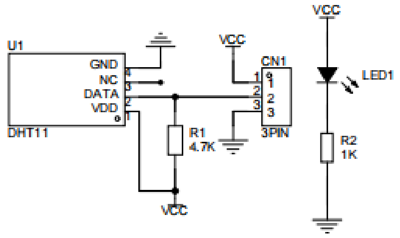

Figure 5 Temperature measurement module design schematic diagram

3.5. Pedometer module

The MPU6050 sensor is used in this module design. It is a six-axis sensor module that can simultaneously detect three-axis acceleration, three-axis gyroscope (three-axis angular velocity) motion data and temperature data. Using the DMP module (Digital Motion Processor) inside the MPU6050 chip, the sensor data can be filtered and fused, and it directly outputs the attitude data after attitude solving to the main controller through the I2C interface, which reduces the computation capacity of the main controller. The MPU6050 sensor measures the acceleration of the human body when walking. The MPU6050 sensor measures the acceleration generated by the human body when walking, and the number of steps can be obtained by reading the MPU6050 acceleration data register and the bias angle data register, and further data filtering and processing. The design of the pedometer module is shown in Figure 6.

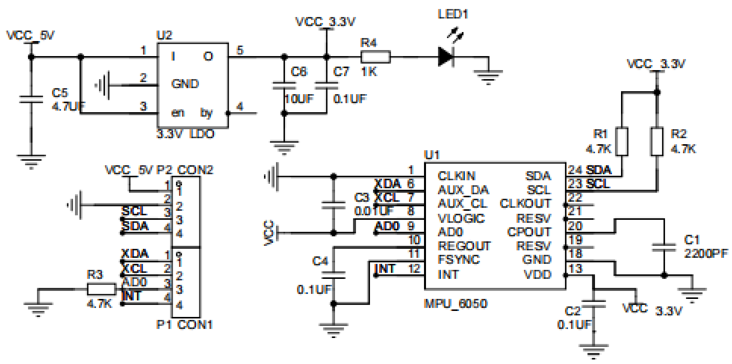

Figure 6 Step counting module design schematic diagram

3.6. LCD Display Module

The LCD display module is used to display information such as filtered ECG signal waveform and heart rate value. The instrument detects the user's heart rate blood oxygen and other data through sensors and transmits the data to the internal processor. The internal processor processes and calculates the detected data to arrive at the final heart rate value. The processor sends the calculated data to the LCD module, which converts it into images and text to be displayed on the LCD screen.

4. SOFTWARE IMPLEMENTATION AND ALGORITHM ANALYSIS

4.1. Software design

Figure 7 shows the system software design flow chart.The MDK5 development environment is used and C language is used to initialise the peripherals such as UART, SPI, ADC, DMA, etc., as well as to configure the system clock to 72 MHz. at the same time, the baud rate of the serial port is set to 115200 to ensure the efficiency of data transmission[5].During the initialisation process, you can judge whether the data conversion completion pins of each signal are low by turning on the external interrupt. If it is judged to be low, the interrupt service procedure transmits the converted multi-signal data to the upper computer. The lower computer and the upper computer are coordinated to achieve real-time and efficient data transmission.

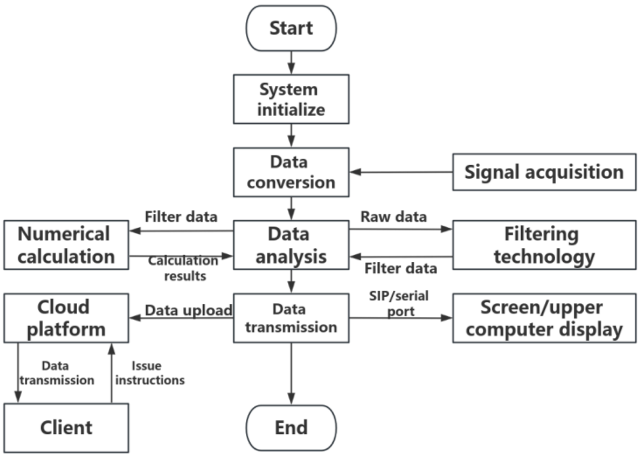

Figure 7 System Software Design

Due to the limitations of the system hardware equipment, there are inevitable systematic errors in the acquisition of physiological signals, such as limb movement during the test, power interference in the surrounding environment and human respiration, etc. In the case of ECG signal acquisition, for example, the above interferences can lead to bias in the reading of ECG data, and it is therefore necessary to filter the data in order to obtain more intuitive and accurate signal data[6].

4.2. Cloud-based systems

The above procedure is used to configure the peripherals such as UART, SPI, ADC and DMA, and the corresponding interrupt service routines. These peripherals and interrupt service procedures can connect to a remote server after data interaction with the sensor. Use the network communication module to upload the data to the cloud server, and at the same time synchronise the client with the cloud server to achieve data synchronization, and the user can independently choose to upload data.

Cloud-based systems enable the processing, analysis, storage and transmission of data:

-Data analysis: data needs to be analysed in order to provide guidance and assistance to users or doctors.

-Compute offloading: offloading a portion of compute-intensive tasks from the device to the cloud for processing, reducing the speed burden and power consumption of the endpoints.

-Cloud storage and communication: cloud services can store, process and communicate information uploaded by devices.

4.3. Heart rate detection algorithm

The speed of the heart rate can be characterised by the number of QRS wave clusters on the ECG in a given period of time. The heart rate calculated from the ECG is the number of electrical excitations of the heart per minute. Under normal circumstances each QRS wave on the ECG represents a heartbeat. The number of heartbeats in a certain period of time is converted into the number of heartbeats per minute, which is the heart rate. The flow of heart rate algorithm design in this programme is shown in Figure 8.

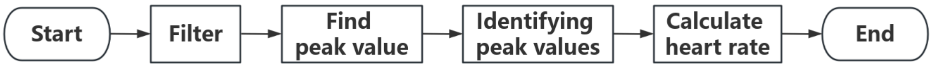

Figure 8 Heart rate detection algorithm design

(1)ECG Signal Filtering Processing

The ECG waveform data of channel 2 is processed by a FIR bandpass filter to perform FIR filtering on the acquired raw data.

(2)search for peaks

The minimum and maximum values of the ECG waveforms were recorded by continuously updating the min and max arrays. Three consecutive data points (BPM_LH[0], BPM_LH[1], BPM_LH[2]) were then used to identify a peak (i.e., the R-wave in the QRS complex).

(3)Identifying Waveforms

Waveforms are identified by examining the waveform of the ECG signal. If the current data point (BPM_LH[1]) is higher than both the previous (BPM_LH[0]) and the next (BPM_LH[2]), and the data at that point is greater than 1/3 of the minimum (max[0]) plus the peak (Peak), the point is determined to be a wave peak.

(4)Calculate heart rate

Heart rate is calculated using the formula:

$$HR = 60 * (1/RR) \text{ (times/minute)} \quad (1)$$

where HR is the heart rate and RR is the time to beat once, i.e. the distance between R-waves (distance between adjacent wave crests).

5. SIMULATION ANALYSIS

As mentioned above, the acquisition of ECG signals is susceptible to interference, which can be classified as EMG noise, IF interference and baseline drift depending on the causative agent. A Butterworth low-pass filter filters out EMG signals, a band-pass filter handles industrial frequency interference and an IIR zero-phase shift digital filter corrects baseline drift, resulting in better ECG waveforms through filtering techniques.

In order to exclude the influence of the error caused by the contact between the system and the human body during the acquisition of the signal, the ECG dataset of MIT-BIH is selected as the original data in the simulation process. Firstly, the signal is converted from the time domain to the frequency domain by FFT processing, and then the corresponding filter is designed to filter out the interference signal in a certain frequency range. As Figure 9 visualises the signal characteristics of the signal after the filtering process.

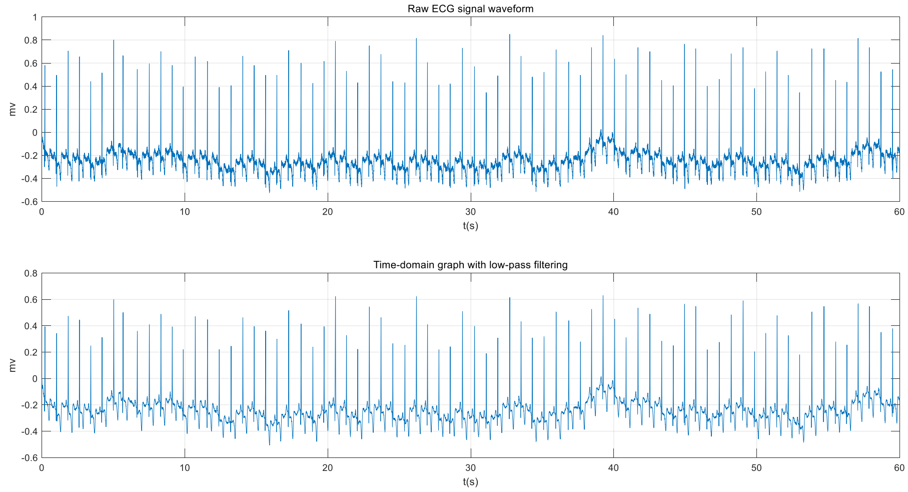

Figure 9a Comparison of signals before and after low-pass filtering

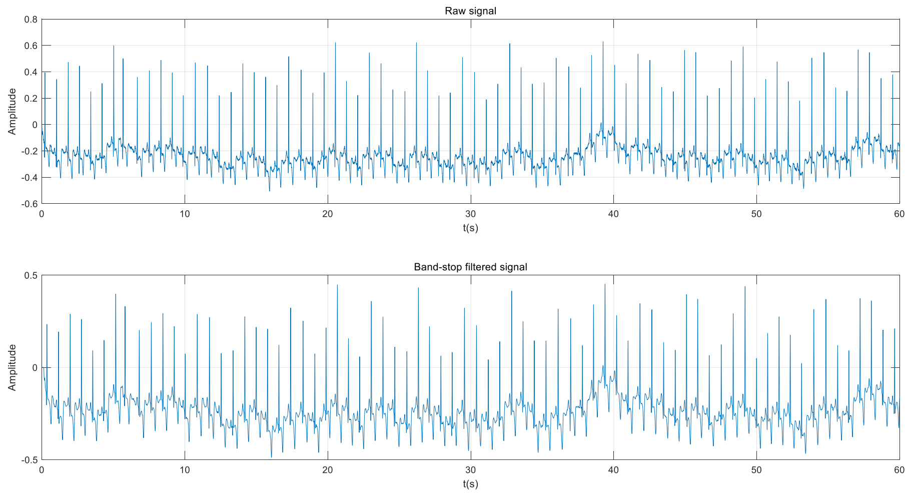

Figure 9b Comparison of signals before and after bandstop filtering

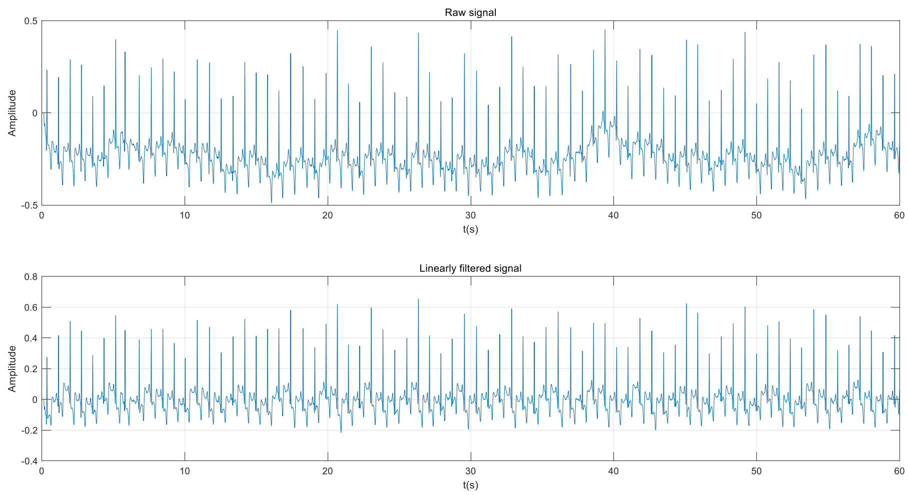

Figure 9c Comparison of signals before and after linear filtering

6. CONCLUSION

This paper proposes a human physiological signal health monitoring system based on cloud-edge-end architecture, which collects data through ECG module, blood oxygen module, temperature and humidity acquisition module, and pedometer module and sends them to STM32F103VCT6 for processing to achieve the collection and measurement of human physiological signals so as to analyse the physiological health status of the human body through intelligent data processing, and process abnormal signals in a timely manner, so as to protect the human body. health. This system innovatively adopts the collaborative approach of edge-end and cloud computing power, which divides the collected data into edge-end and cloud processing, with higher precision and faster time, ensuring the effective processing of data. At a time when people are paying more and more attention to health, this project has important research significance and broad application prospects.

ACKNOWLEDGEMENTS

This paper was supported by the 2023 Henan Provincial Undergraduate College Student Innovation and Entrepreneurship Training Program (202310464022) and the 2023 College Student Innovation and Entrepreneurship Training Program (2023095) of Henan University of Science and Technology.

AUTHOR INTRODUCTION

Mengzhuo Liu，Student ID：211404160214; Xinyu Gao, Student ID: 211404160205; Shiyi Wang, Student ID: 221404160321; Ziwei Du, Student ID: 221404160204; Xiuyuan Yang, Student ID: 221404160127; Rong Xing， Student ID: 221404160126; Yangyang Zheng, Student ID: 221415010127. All of the above authors are undergraduates majoring in communication engineering.

REFERENCE

[1] Ding Youde, Wang Qian , Liu Yang , Gong Pingping , She Jinxiong. Design of a portable ECG monitor for home use [J]. Medical Preparation ,2019,32(18):17-18.

[2] WANG Tao,TIAN Ruizhi,ZHAO Youming et al. Multi-point monitoring system and circuit design of physiological parameters based on STM32 and filtering algorithm[J]. Experimental Technology and Management,2021,38(11):77-83,95.

[3] WANG Zhao,LIANG Hong,WANG Jiachen et al. Exploratory study on new model of clinical monitoring based on wearable technology[J]. Journal of Biomedical Engineering,2021,38(4):753-763.

[4] LI Lixuan,LIANG Hong,FAN Yong et al. Research and development of intelligent monitoring system based on internet of things and wearable technology and its application mode exploration[J]. Journal of Biomedical Engineering,2023,40(6):1053-1061.

[5] HUANG Maocheng,CHEN Lan,LU Chao. Design of mobile ECG detection system with motion artefact elimination[J]. Sensors and Microsystems,2017,36(4):94-96,99.

[6] ZHU Chunxiang,GAO Mingyu,WANG Binrui. Design of a wearable ECG monitoring system based on Wi-Fi[J]. Experimental Technology and Management,2022,39(4):120-126.

[7] LI Hongli,WANG Yun,XIU Chunbo,et al. Development of wearable multi-physiological parameter monitoring device[J]. Sensors and Microsystems,2022,41(11):73-76,80.

[8] Rao Kemeng. Design of wireless ECG signal monitoring system based on GPRS and Zigbee[J]. Computer Measurement and Control,2021,29(2):20-24,29.

[9] WANG Dongqing,DONG Yuyang. Design of portable EEG acquisition system based on ADS1299[J]. Communication Technology,2022,55(8):1090-1098.