STM32-based Health Monitoring System for Infants and Toddlers

ZHUANG Jianjun, DONG Jianing

(*Nanjing University of Information Science & Technology*, *Nanjing 210044*, *China*)

Abstract: In order to allow the guardians to monitor the physiological parameters of the infant more intuitively and to be able to respond to sudden irregularities in the pulse rate, abnormal blood oxygen, high or low body temperature and other conditions, and to facilitate communication with the medical staff or to request assistance in treatment, an STM32 microcontroller-based infant health monitoring system is designed. The digital signal acquisition module for pulse, blood oxygen and body temperature acquire the raw data, and the microcontroller performs algorithmic processing to display the physiological parameters such as pulse, blood oxygen and body temperature of the infant, and configures the threshold alarms for the physiological parameters by means of a keypad module. Finally, the test results are compared and tested against the standard physiological parameters of infants and children to verify that the system meets the requirements of medical precision and accuracy.

Keywords: Infants and Children, Microcontrollers, Health Monitoring Systems, Physiological Parameters

1 Introduction

With the progress and development of the Internet and sensor technology, it is also widely used in daily life, and nowadays medical health problems cover all age groups, especially the health monitoring of infants and children has always been the focus and difficulty of research in the medical field.

Premature babies and infants are small, susceptible to infections and environmental influences, and they are very active, with frequent and rapid changes in their physiological parameters, which can have serious consequences if they are not careful[1]. It is therefore important to keep an eye on the physiological parameters and health status of infants and young children and to adjust their diet and lifestyle according to these health indicators or to seek medical attention in a timely manner in order to avoid the development of more serious diseases.

2 General System Framework

The general framework of the system is shown in Fig.1. The infant health monitoring system uses the STM32 microcontroller with ARM Cortex-M3 as the core as the system processing unit, which transmits the temperature signal, pulse signal and blood oxygen signal collected by the temperature module and pulse and blood oxygen module respectively to the microcontroller processing unit through the IIC communication protocol, and calculates and processes them through the corresponding algorithm to be able to These parameters are then displayed on the display and updated in real time. The user can also configure the standard physiological parameter range thresholds by pressing a button, and the user's actual physiological parameters are compared with the standard range thresholds to remind the user of his or her health condition.

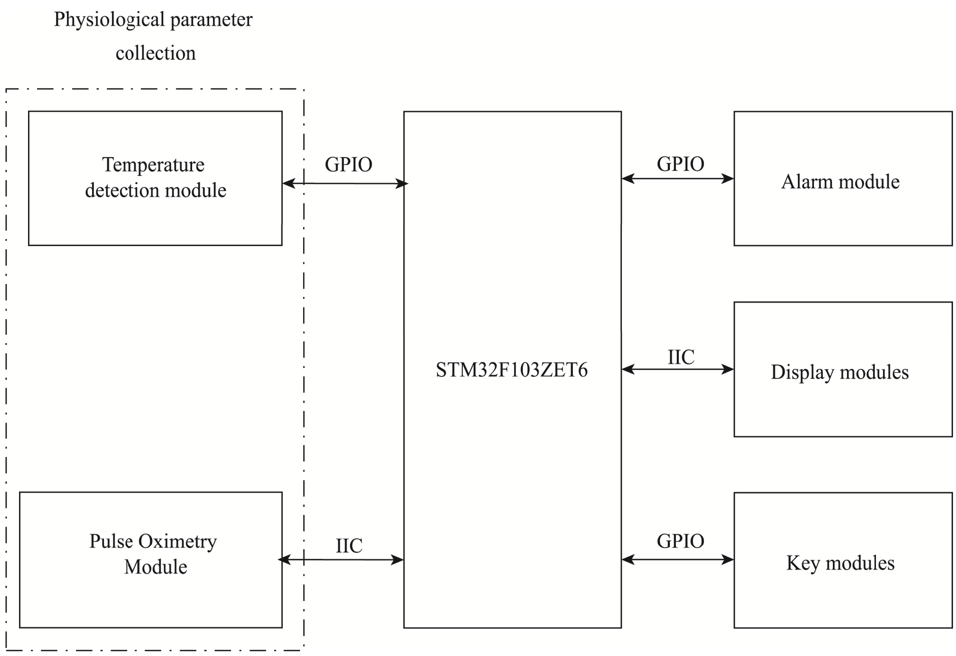


Fig.1 General Framework Diagram of the System

2.1 Processor Unit

The micro control unit used in this system is the STM32F103ZET6 main control chip, the physical diagram of the chip is shown in Fig.2, the chip core is Cortex-M3. Cortex-M3 is a 32-bit processor core, this core's internal data path, registers, memory interface are 32-bit, it has independent instruction and data bus, that is, data access does not occupy the instruction bus, which greatly improves performance[2].

Fig.2 STM32F103ZET6 Chip Physical Drawing

2.2 Oximetry Pulse Sensor

This system uses the MAX30102 chip from Maxim, a module that has both an oximeter and pulse detector biosensor.The internal structure of the MAX30102 is shown in Fig.2, which integrates a red LED with a wavelength of 660nm and an infrared LED with a wavelength of 880nm, an opto receiver, an ADC channel, a digital filter, and a low-noise electronic circuit with ambient light suppression. The module can be switched off by software with zero standby current, allowing the power rail to remain powered at all times.

It also comes with an 18-bit digital-to-analogue converter that converts the PPG analogue signal captured by the opto receiver into a PPG digital signal. The converted PPG data is stored in a cyclic FIFO of 32 depth, and the microcontroller sets each of the MAX30102's control registers, as well as reads the PPG data stored in the cyclic FIFO, via the IIC interface [3-5], while MAX30102 uses a single 1.8V power supply and a separate 5.0V supply for the internal LEDs on the operation, Fig.3 shows the MAX30102 internal structure diagram.

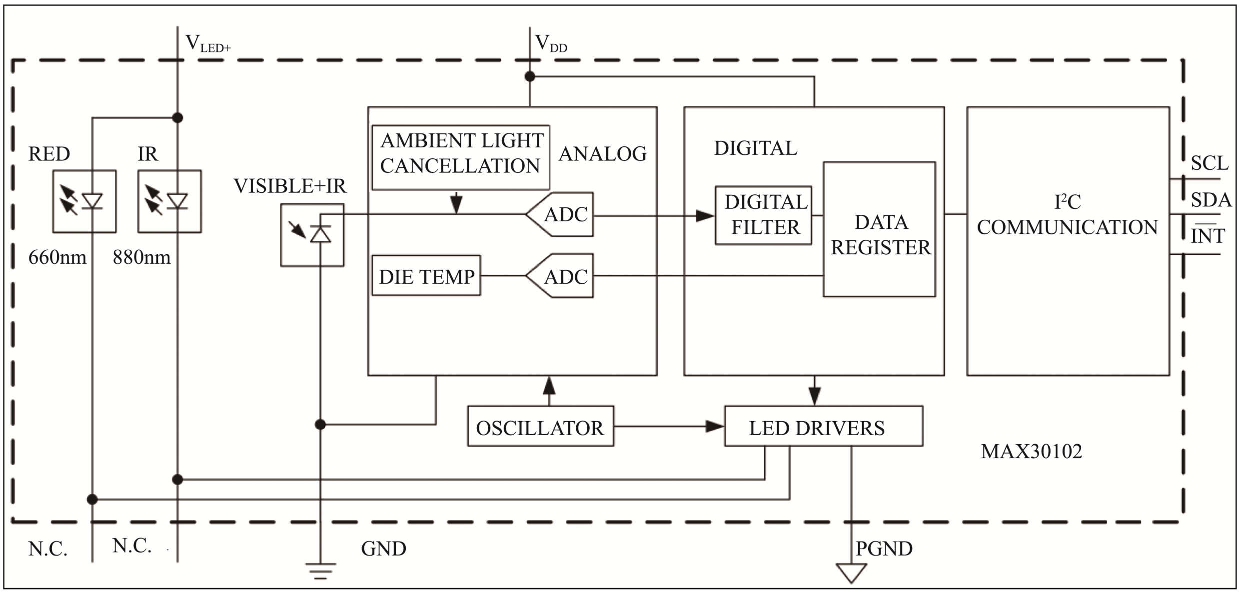


Fig.3 MAX30102 Internal Structure Diagram

2.3 MLX90614 Temperature Sensor

The MLX90614 sensor is a digital sensor and the conversion of the analogue signal to the temperature of the object to be measured is done by the on-chip ADC and DSP， the physical drawing is shown in Fig.4

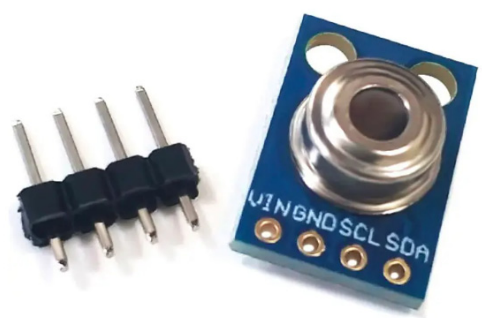


Fig.4 Physical View of MLX90614

The MLX90614 sensor is available in a medical standard model with the measurement accuracy shown in Fig.5, where Ta, To are the ambient temperature and the measured object temperature respectively. It can be seen that at room temperature, when the measured human body temperature is between 36 degrees Celsius and 38 degrees Celsius, the test accuracy can reach ±0.2 degrees Celsius.

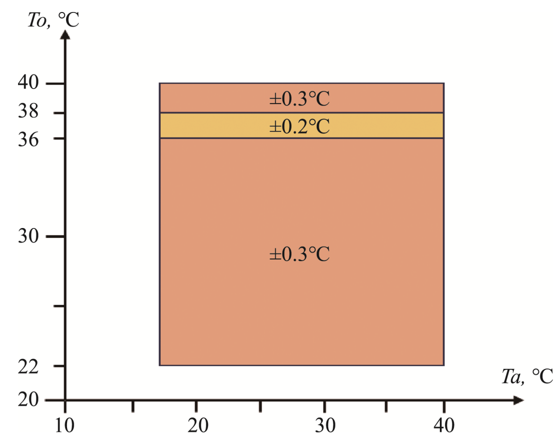


Fig.5 MLX90614ESF-DCC Detection Accuracy Curve

3 Principles of Physiological Parameter Acquisition

3.1 Principle of PPG Signal Pulse Oximetry Acquisition

The system measures the pulse and other physiological parameters of the human body by means of the photoelectric volumetric method, through which the PPG signal is obtained as a waveform signal, based on Lambert's law. Bill's law. As a non-invasive technique for the detection of physiological signals, PPG uses the pulsating component of the arterial blood to vary the absorbance of infrared light periodically in response to the beating of the heart, and the reflected infrared light is photoelectrically PPG is a non-invasive monitoring method for monitoring blood volume changes in human tissue by means of photoelectric means, as shown in Fig.6.

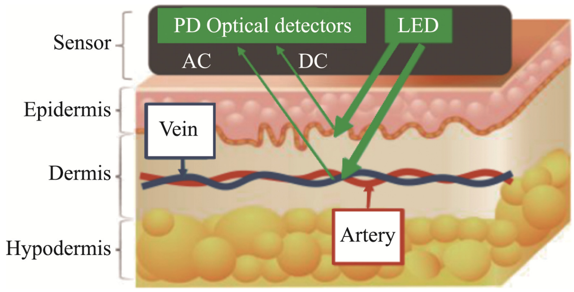


Fig.6 Basic Principle Diagram of the Photo Volumetric Method

When a beam of light of a certain wavelength is shone on the fingertip, each time the heart beats, the contraction and dilation of the blood vessels affects the transmission or reflection of the light, and as the beam passes through the fingertip and is reflected back to the photosensitive sensor, the beam is attenuated by a certain amount, while the degree of light absorption in muscle, bone, veins and other tissues is largely unchanged, but changes occur in the arteries, where there is blood flow, so that the PPG signal can be separated into a DC component and an AC component, as shown in Fig.7. The PPG signal can be separated into a DC signal and an AC signal, as shown in Fig.7. The DC component is derived from the light signal reflected or transmitted by the tissue and is determined by the tissue structure as well as the venous and arterial content, and generally shows small changes with respiration, while the AC component corresponds to changes in blood volume synchronised with the heartbeat[6-8].

3.2 PPG Signal Filtering

When acquiring the PPG signal through the sensor, the PPG signal is susceptible to noise, which mainly includes: ambient light, baseline drift, etc. These noises will seriously affect the accuracy of pulse oximetry monitoring. As there is no linear relationship between the PPG signal and the noise signal, the acquired PPG signal needs to be processed for noise reduction to extract a good quality PPG signal. The effects of ambient light can be addressed at the hardware level, while baseline drift generally refers to human respiration and low frequency noise less than 1Hz generated mainly by respiratory fluctuations and amplifier circuit instability, so it can be effectively removed by a low-pass filter [12].

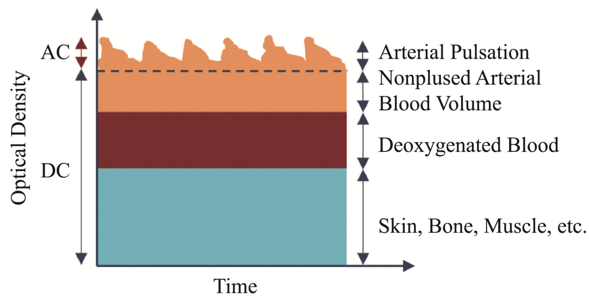


Fig.7 PPG Signal in Skin Tissue

The actual measurement results in Fig 7, it is known that irradiation instability degree of the solar simulator is ±0.7%.

Using the Filter Designer & Analysis Toolbox in Matlab to design the bandpass filter, the 61st order FIR filter with Kaiser window in the simulation has a good suppression effect on the baseline drift of the PPG signal, and also has a good smoothing effect on the high frequency noise, as shown in Fig.8.

4 Software Programming

4.1 General Flow Diagram of the Software

The software part of the system mainly consists of the main program, pulse measurement subroutine, blood oxygen measurement subroutine, temperature measurement subroutine, communication program, etc., as shown in Fig.9. The main program function connects the pulse oximetry sensor, temperature sensor, display module, alarm module and other components together. After the program starts, it first executes the initialization program of communication I/O ports, timers, interrupts, etc. required by each module, then

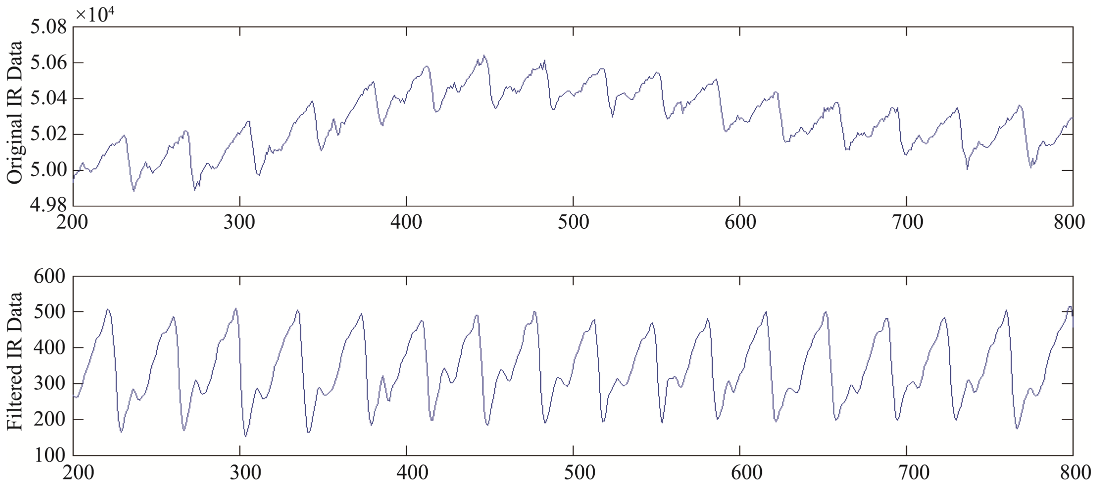


Fig.8 Raw PPG Signal and FIR Filtering

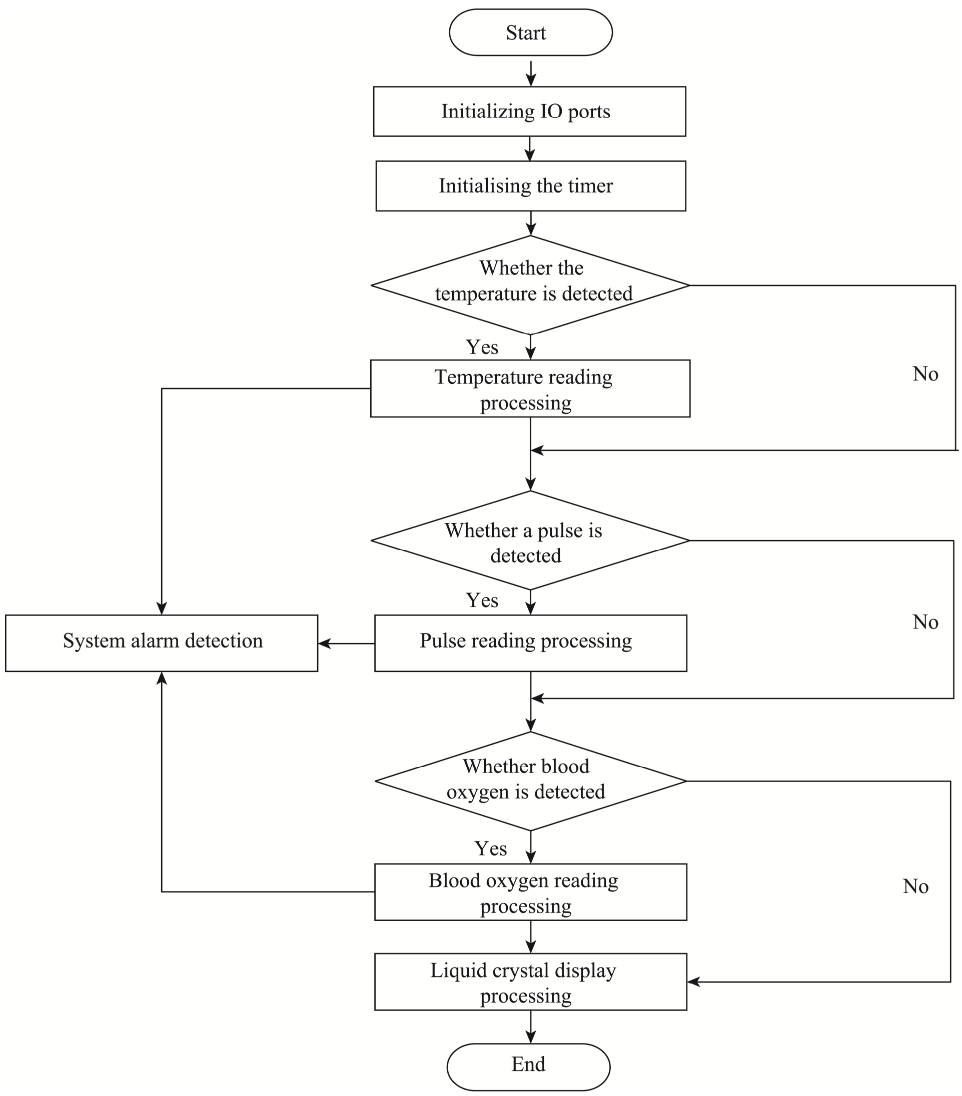


Fig.9 System Software Flow Chart

the temperature detection subroutine starts measuring the temperature to see if the temperature is detected and read, the system starts calling the pulse oximetry monitoring subroutine to monitor whether the pulse and blood oxygen, and once the data has been read, the alarm program is called and fed back to the display circuit, i.e. the temperature, blood oxygen and pulse of the infant. The system's alarm circuit warns when the measured pulse, oxygen and temperature are below or above the thresholds.

4.2 Pulse Oximetry Algorithm Design

The MAX30102 has two different LEDs for red light (660nm) and infrared light (880nm), we measure the pulse first by waiting for the interrupt signal to be generated, determine whether the detection threshold is reached, after testing to reach the threshold, wait for the waveform to stabilise, FIR filter the PPG signal and store the data in the buffer while calculating the threshold, detect whether the PPG signal passes the threshold curveThe pulse is then calculated.

Blood oxygen acquisition is based on the fact that reduced haemoglobin (Hb) and oxyhaemoglobin (HbO2) in blood have a large difference in absorption of red light with a wavelength of 660nm and a small difference in absorption of infrared light with a wavelength of 880nm. Based on the principle of light absorption in blood, we separate red red and infrared light hired into DC and AC signals by equation (1) to derive R and finally substitute into Equation (2) is calculated to obtain.

$$R = \frac{AC_{\text{red}} / DC_{red}}{AC_{\text{ired}} / DC_{ired}} \tag{1}$$

$$SpO_2 = \mathrm{a}R^2 + bR + c \tag{2}$$

4.3 Temperature Measurement Algorithm Design

Infrared temperature sensor MLX90614 is IIC communication protocol connected to STM32, the SCL, SDA, VIN, GND pins directly linked to the microcontroller's I/O port, through a series of operations to convert the human infrared radiation into digital signals and transmitted to the microcontroller processing and display, reading process as shown in Fig.10.

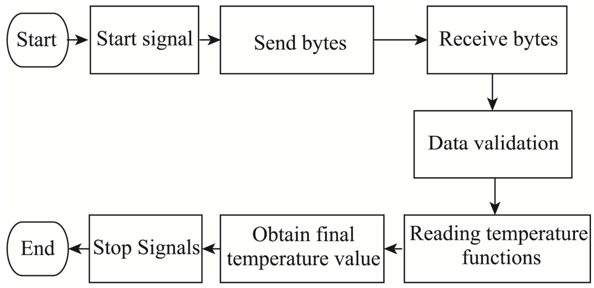


Fig.10 MLX90614 Reading Temperature Flow

5 Analysis of Test Results

5.1 Criteria for Physiological Parameters of Infants and Children

The physiological parameters of infants and young children need to be accurately understood because of the rapid changes in their body responses compared to adults.

Table 1 Criteria for Physiological Parameters in Infants and Young Children

Physiological Parameters	Parameter Criteria
Body Temperature	36.5~37.5℃
Pulse	120-140bpm
Oximetry	95~99%

5.2 Body Temperature Test

According to the collection principle described in the previous section, after completing the system design, four healthy adults were selected as volunteers to collect body temperature instead of infants and children, using commercially purchased infrared thermometers to conduct comparison experiments with the system in this paper, Table 2 shows the parameters of market infrared thermometers.

Table 2 Parameters of Infrared Thermometers on the Market

Content	Parameters
Name	Infrared Thermometer
Number	CK-T1503
Range/°C	32.5~42.5
Accuracy/°C	±0.2

Comparing the two measurements, the results of the temperature measurements are shown in Table 3.

Table 3 Comparison of Body Temperature Test Data

Testers	Market Infrared Thermometer/°C	MLX90614 Temperature Measurement/°C
A	36.0	36.33
B	36.3	36.23
C	36.7	36.34
D	36.3	36.23

The comparison error rates were 0.009%, 0.002%, 0.01% and 0.004% respectively, with a mean error of 0.00625%.

From the results of this test, the mean temperature comparison error rate was only 0.00625%, which meets the medical requirement for high accuracy and precision in temperature measurement.

5.3 Pulse Oximetry

A CMS50D pulse oximeter was prepared and four healthy adults, A, B, C and D, were used as volunteers to replace infants and children to measure their oxygen saturation, and a commercially available CMS50D pulse oximeter was used to compare the system with this paper.

Table 4 CMS50D Pulse Oximeter Parameters

Parameters	Oxygen Saturation/%	Pulse Rate/ bpm
Range	0~100	30~250
Accuracy	±2	±2
Resolution	1	1

Comparison of the two measurements, pulse, and oxygen measurements are shown in Table 5 and Table 6.

Table 5 Comparison of CMS50D Pulse Oximetry and Pulse Data from This System

Testers	CMS50D Pulse Oximeter/bpm	MAX30102 Pulse Measurement/bpm
A	92	93
B	95	95
C	81	80
D	83	84

The comparison error rates were 0.011%, 0, 0.012% and 0.012% respectively, with a mean error of 0.00875%.

Table 6 Comparison of the CMS50D Pulse Oximeter with the Blood Oxygen Data from This System

Testers	CMS50D Oxygen/%	MAX30102 Oxygen/%
A	94	95.26
B	98	97.12
C	98	98.93
D	97	99.85

The error rates for the comparisons were 0.013%, 0.011%, 0.009% and 0.028% respectively, with an average error of 0.01525%.

The analysis of the above data shows that the system is able to operate stably and accurately detect the user's pulse and blood oxygen with a mean error of 0.00875% and 0.01525% respectively, which is in line with the requirements for medical use.

6 Conclusion

The system is simple to implement, easy to operate and use, with pulse, blood oxygen and body temperature detection functions, the data detected and the actual data for comparison, the results are almost the same at the same time the design has a display function, the display can accurately display temperature, pulse, blood oxygen and other information. In order to complete the medical device inspection and clinical testing as soon as possible, the system needs to be scaled down in the next work, adding mobile terminal connections, measuring more physiological parameters, improving software algorithms, realising wearable and other functions, and striving to put the results into real life as soon as possible.

References

[1] Wu, Z L. and Chen, Y Y. (2020). Design of heart rate detection system for infants and children. Science and Technology, 34, PP. 101-102.

[2] Cui, T. (2021). Design and development of STM32-based wearable health parameter monitoring system. Foshan Institute of Science and Technology.

[3] Li, J H. Pan, T. Xu, Y H. et al. (2022). Real-time monitoring of blood oxygen saturation based on pulse wave tracing method. Information Technology and Informatization, 11, PP: 78-81.

[4] Wang S H. Zang Y L. Zhu S G. (2022). Intelligent clothing design with heart rate and blood oxygen detection function. Woolen Technology, 50(11), PP: 38-44.

[5] Wang X. (2022). Design and implementation of portable cardiopulmonary monitoring system. Nanjing University of Posts and Telecommunications.

[6] Zhen C P. Zeng S M. (2022). Intelligent remote multi-physiological parameters health monitor. Electronic Technology Applications, 48(04), PP: 86-89.

[7] Hu C W. (2020). Multi-sensor-based wireless medical monitoring system. Hangzhou University of Electronic Science and Technology.

[8] Uyinga. (2018). Home medical monitoring system. Inner Mongolia University.

[9] Koukou, Z. Theodoridou, A. Taousani, E. et al. (2022). Effectiveness of Non-Pharmacological Methods, Such as Breastfeeding, to Mitigate Pain in NICU Infants. Children, 9, PP: 1568.

[10] Saba, F M. Mohsin, M. Sania, B. (2020). Wearable technology for infant health monitoring: a survey. IET Circuits, Devices & Systems, 14(2), PP: 101-102.

[11] Liu, Y P. Yu, X X. Luo, X. et al. (2021). Improved Qsofa Algorithm Based on PPG Wearable Device. Journal of Physics: Conference Series, 1848(1), PP: 25-26.

[12] Li, J D. Ma, Q. Chan, A H. et al. (2019). Health monitoring through wearable technologies for older adults: Smart wearables acceptance model. Applied Ergonomics, 75, PP: 12-13.

[13] Rooks and Joshua. (2016). System Design and Implementation of a Wearable Posture and Health Monitoring Device. University of California Los Angeles.

[14] Lv. WH. (2013). Research on Performance Testing of Pyrheliometers. Chinese Journal of Scientific Instrument. 34(12). PP. 19-24.

[15] Ge, H Y. (2021). Status and technology analysis of wearable health monitoring devices. Information Technology Construction, 000(005), PP: 64-64.

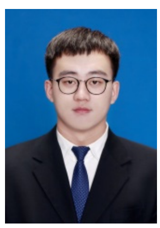
[16] Oliver, N. Flores-Mangas, F. (2006). HealthGear: a real-time wearable system for monitoring and analyzing physiological signals.

[17] Li, J W. Peng, Z. Gao, S. et al. (2017). Smartphone-assisted energy efficient data communication for wearable device. Computer Communications, 105(JUNa1), PP: 33-43.

Author Biographies

ZHUANG Jianjun received Ph.D. from Nanjing University in 2008. He is now a professor and master's supervisor at Nanjing University of Information Engineering. His main research interests include medical signal acquisition and processing, embedded medical instrument development, etc.

E-mail: jjzhuang@nuist.edu.cn



DONG Jianing received B.Sc. degree from Dalian University for Nationalities in 2019. Now he is a M.Sc. candidate in Nanjing University of Information Engineering. His main research interest includes the development of embedded medical instruments.

E-mail: 719527496@qq.com