International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 6 | Issue: 1 | Jan – Feb 2025 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v6i1.26

Design of Smart Bracelet Based on STM32 MCU

Depeng Xu*, Lina Zhou, Mengshan Li

College of Physics and Electronic Information, Gannan Normal University,
Ganzhou, Jiangxi, China,341000

*Corresponding author detail: Depeng Xu; dpxu@gnnu.edu.cn

ABSTRACT
With the enhancement of living standards, individuals are placing a growing emphasis on health and are increasingly interested in gaining a comprehensive understanding of their physical and mental well-being. This thesis presents the design of a multifunctional smart bracelet that integrates step counting, heart rate monitoring, temperature detection, and time display. The bracelet is equipped with features such as sports step counting statistics, health monitoring, and wireless Bluetooth communication. Initially, an accelerometer is utilized to achieve precise step counting, while a heart rate sensor collects heart rate data in real time. A temperature sensor monitors the ambient temperature, and a clock module provides accurate timekeeping. All information is intuitively displayed on an OLED screen, facilitating users to readily access their health status information at any given moment. By establishing thresholds for health indices, the bracelet's buzzer is employed for early warning and alert notifications. This design effectively addresses the limitations of traditional bracelets, including their singular functionality, high cost, and excessive power consumption. It is highly practical, user-friendly, and offers a novel approach to the advancement of intelligent technology.

Keywords: smart bracelet; STM32 microcontroller; temperature detection; heart rate detection; pedometer.

INTRODUCTION
With the continuous advancement and evolution of society, the psychological and material needs of the public are better met, and the quality of life is also improved accordingly. Therefore, the public's attention to health is increasing. Smart bracelets have now become a widely used health monitoring tool. They can record daily activity data, and after analysis, they can reflect the health status of the human body. This paper designs a multifunctional smart bracelet that integrates step counting, heart rate monitoring, temperature detection, and time display [1]. It achieves precise step counting through the ADXL345 accelerometer, real-time heart rate data collection through the MAX30102 heart rate sensor, environmental temperature monitoring through the DS18B20 temperature sensor, and accurate time provision through the DS1302 clock module. All information is intuitively displayed on the OLED LCD screen, making it convenient for users to grasp their health status at any time. This smart bracelet integrates multiple functions, is practical, low-cost, simple, and convenient, and provides strong support for sports training and health management, with a good market prospect.

OVERALL STRUCTURE OF THE SMART BRACELET SYSTEM
The overall structure of the smart bracelet system based on the STM32 microcontroller consists of two parts: hardware and software. The hardware part includes the STM32 microcontroller and modules such as the step counter, heart rate sensor, OLED display, temperature sensor, button, clock, and buzzer. According to the design schematic, the hardware of each module is soldered to implement the basic functions of the bracelet. The circuit design of this project also includes power supply circuits, reset circuits, and crystal oscillator circuits to ensure the stable operation of the system. The Bluetooth module (HC-05) is connected to the microcontroller via a serial port, and data is transmitted to the mobile client software via Bluetooth to achieve storage, analysis, and processing of user data. The overall structure diagram of the system modules is shown in Figure 1 [3].

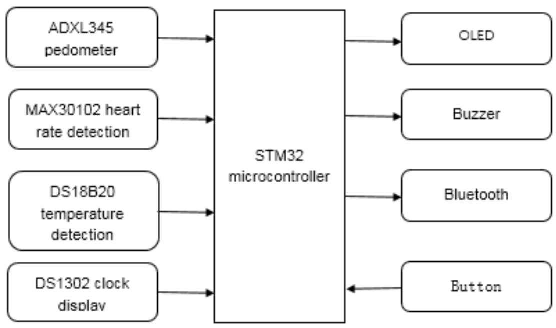

FIGURE 1: Overall Structure Diagram of System Modules.

The software part is completed in the Keil5 platform using C for software code writing and system debugging and operation. First, the written system program code is written into the microcontroller's memory, then the CPU executes each instruction according to the program, and finally, the execution results are output through the I/O interface.

HARDWARE DESIGN OF THE SMART BRACELET SYSTEM

The hardware of this system consists of six main functional modules, which are the motion step counting module, clock module, heart rate and blood oxygen module, OLED display module, button module, Bluetooth module, and the STM32F103C8T6 main control chip [4]. The main control chip works in coordination with each module to realize the various functions of the smart bracelet system.

The STM32 main control chip used in this paper is the core of data processing in this design. It controls the operation of each module through its excellent computing performance and diverse external interfaces. The system module design includes a power supply design, step counter design, heart rate detection design, OLED display design, temperature detection design, clock design, button design, and buzzer design. The following figure is the system module structure diagram.

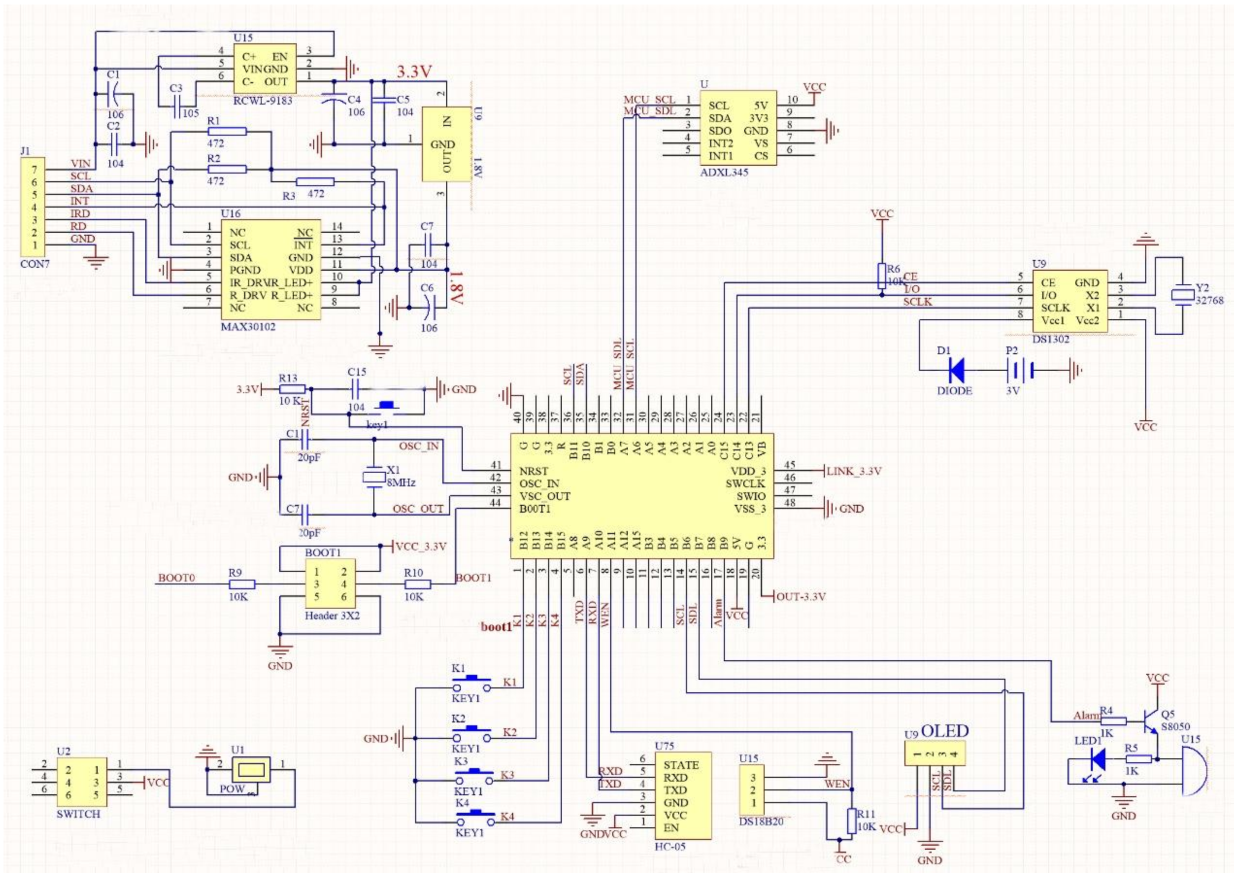

FIGURE 2: System Module Structure Diagram.

1. Power Supply Design

The smart bracelet is powered by an internal lithium battery for long-term operation and uses a 5V 1A DC USB interface to charge the system battery. The working voltage of the STM32 main control chip is 2.0 to 3.6V, while the working voltage of each module is usually 3.3V. The system consists of a three-hole power supply interface and a six-contact power control device. The three-hole socket is used to connect to the external power supply, while the six-contact switch is responsible for controlling the power on and off of the microcontroller circuit. The power supply design is shown in Figure 3.

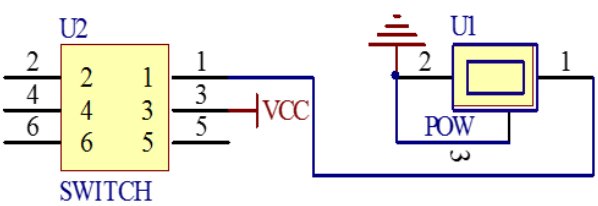

FIGURE 3: Power Circuit Design Diagram.

2. Pedometer Design

The pedometer design employs the ADXL345 three-axis accelerometer, which is characterized by its compact design, extremely low power consumption, and high cost-effectiveness, making it widely used in portable devices [5]. The ADXL345 can accurately measure in tilt detection applications and capture dynamic acceleration changes caused by impacts. With its excellent resolution (3.9mg/LSB), the ADXL345 can detect tiny tilt changes of less than 1.0°. The principle behind it is that when a user walks, their arm swings back and forth in rhythm with the steps. This swinging motion generates acceleration, and the sensor saves the data produced. The chip then automatically processes the data, converting the original analog signals into digital signals [6], and performs filtering and calculations on the digital signals. Filtering is done to reduce noise and interference, thereby making the data more accurate. An algorithm is then used to convert the acceleration data into step count data (peak detection algorithm).

The algorithm identifies the peaks in the acceleration data, with the peaks corresponding to the start and end of each step. By calculating the time difference between the peaks, the bracelet can estimate the distance traveled by the wearer. The circuit diagram of the pedometer is shown in Figure 3. This sensor outputs data in a 16-bit two's complement binary format and supports data reading through 3-wire SPI, 4-wire SPI, and I2C interfaces, making it particularly suitable for applications in portable devices.

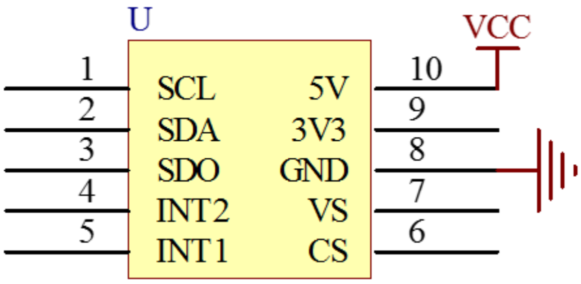

FIGURE 3: ADXL345 Circuit Diagram.

3. Heart Rate Monitoring Module Design

The MAX30102 module integrates pulse oximetry and heart rate monitoring functions. It incorporates red and infrared LEDs, a photodetector, and low-noise electronic circuits, and it also has a strong ability to resist interference from ambient light [7].

The MAX30102 operates at a 1.8V power supply and also features an independent 5V power supply, making it suitable for various wearable devices. Pulse and blood oxygen saturation monitoring uses the photoplethysmography method. The sensor mainly consists of light-emitting devices and photoelectric converters, and it is usually fixed on the patient's finger, wrist, or earlobe by means of a strap or clamp. The light-emitting diodes (LEDs) of specific wavelengths inside the sensor play a key role. They have selective absorption characteristics for oxygenated hemoglobin (HbO2) and reduced hemoglobin (Hb) in the blood. Red light around 660nm and infrared light around 900nm are commonly used wavelengths. When light penetrates the patient's peripheral blood vessels, the intensity of the transmitted light changes due to the changes in blood vessel volume caused by the pulse. The photoelectric sensor is responsible for capturing these reflected light rays and converting them into electrical signals. The pulse signal shows periodic changes, and the changes in blood vessel volume are also periodic. Therefore, the periodic changes in the electrical signal can indirectly reflect the pulse rate. The MAX30102 integrates LEDs, LED driver circuits, photodetectors, analog-to-digital converters, and digital filtering modules [8]. This design enables the MAX30102 to provide accurate heart rate and blood oxygen data for health monitoring devices while simplifying the integration and development process. The heart rate monitoring module is shown in Figure 4.

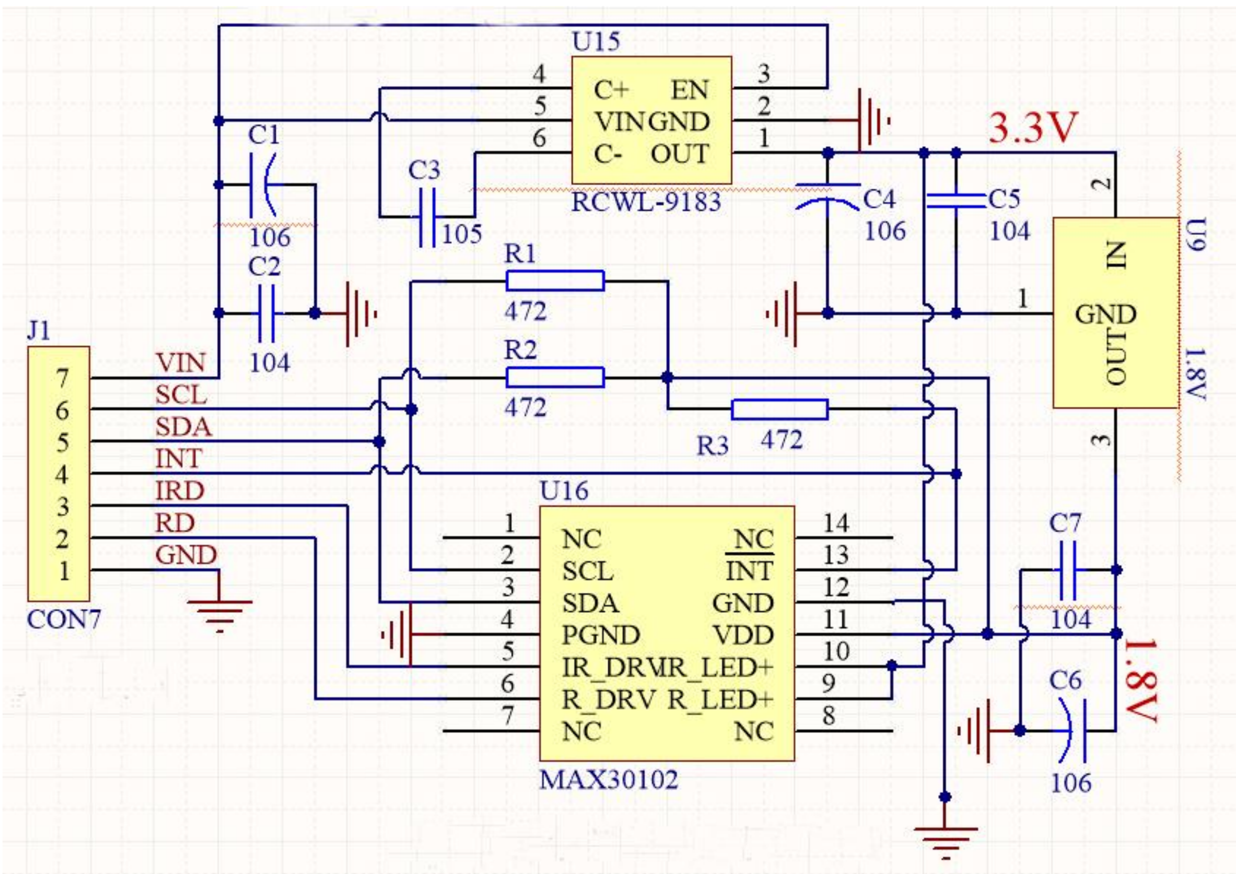

FIGURE 4: Heart Rate Monitoring Module Diagram.

4. OLED Display Module Design

OLED screens use organic light-emitting diodes as display elements, which have the advantages of self-luminescence, ultra-thin and lightweight, high response speed, and low power consumption. Its function is to receive and display the data from various modules transmitted by the STM32 microcontroller. The OLED display module is a device with a display capability of 128 columns by 64 rows of dot matrix, suitable for graphic and character display. The circuit design of the liquid crystal display module features a four-pin header interface P5, specifically designed for connecting to the OLED screen. This interface provides a 5V power supply for the display screen. The SCL (clock line) of the screen is connected to the B6 pin of the microcontroller, ensuring the smooth transmission of serial clock signals. At the same time, the data transmission line SDA is connected to the B7 pin of the microcontroller, guaranteeing the smooth flow of serial data. This connection method allows the microcontroller to interact with the OLED screen through the I2C communication protocol, thereby enabling the control of screen content and information display.

5. Temperature Module Design

The DS18B20 is a digital temperature sensor that can provide Celsius temperature readings with a resolution of 9 to 12 bits. It can accurately measure temperatures within the range of -55°C to +125°C, with an accuracy of ±0.5°C (between -10°C and +85°C). The DS18B20 sensor uses the single-wire communication protocol to exchange analog-to-digital data with the STM microcontroller [9], requiring only one wire for both data transmission and power supply. It includes components such as a temperature sensor, 64-bit ROM, temperature register, configuration register, and CRC generator. Upon receiving a temperature conversion command, the DS18B20 sensor begins to measure the ambient temperature. Once the measurement is complete, the result is stored in the temperature register. After the temperature conversion is finished, the content of the temperature register can be read through a single wire. The DS18B20 is widely used in various temperature monitoring systems due to its simple interface, high precision, and wide temperature range. In this design, particular attention is given to the situation where the temperature value measured by the smart bracelet exceeds the preset threshold. The alarm system inside the DS18B20 will be activated, thereby alerting the user to an abnormal temperature health indicator.

6. Clock Module Design

The DS1302 is a low-power, serial-interface real-time clock (RTC) chip. It can provide information on seconds, minutes, hours, dates, months, and years, including leap year compensation valid up to the year 2100 [10]. It has an internal oscillator circuit, typically driven by an external 32.768kHz crystal, which provides a very stable reference frequency. The RTC chip tracks time-based on this reference frequency and saves the time information in registers.

The circuit principle of the clock module is shown in Figure 5. The DS1302 communicates with the STM32 using a three-wire serial interface. The RST signal is used to select whether the DS1302 enters command mode or data transfer mode; SCLK is used for synchronizing data transfer; and the I/O line is the actual data input/output channel. The DS1302 has a wide operating voltage range of 2.5 to 5.5V and also provides a pin for backup power [11]. The DS1302 is characterized by its low power consumption, designed with an extremely low operating current, making it very suitable for portable devices and applications that require accurate timekeeping over long periods.

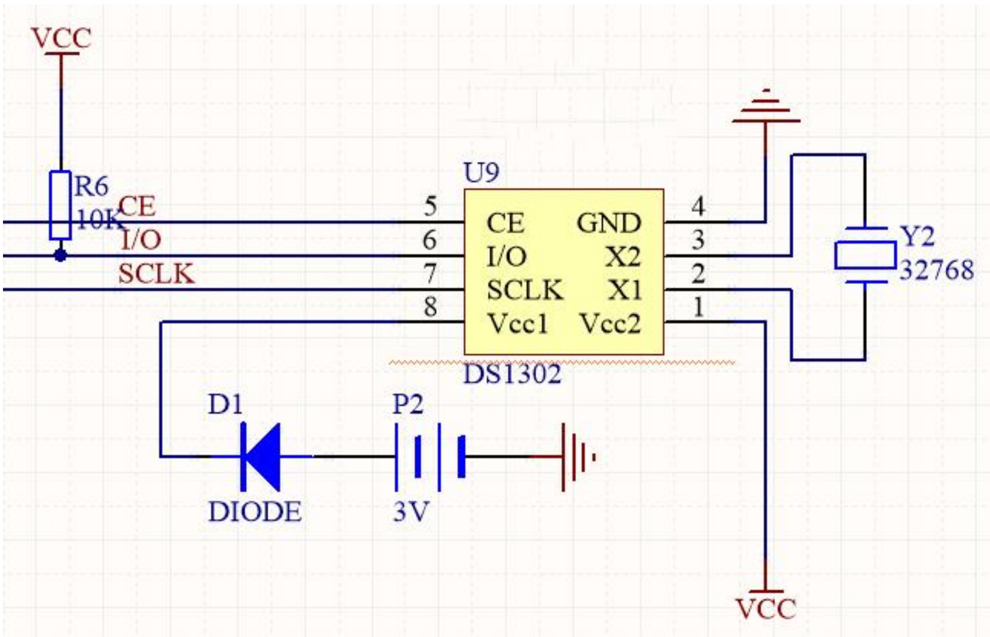

FIGURE 5: Circuit Schematic of the Clock Module.

7. Button Design

In this design, four independent control command buttons are equipped, which are used for parameter settings, increasing setting values, decreasing setting values, and clearing the current step count and mileage data, respectively. One end of each independent button is connected to the ground line (GND), and the working mode is low-level effective, that is, when the button is pressed, a low-level signal will be generated on the I/O line.

To address the issue of keyboard jitter, a software debouncing method is employed. This method is economical and easy to implement. The basic principle of software keyboard debouncing is that when a button closure event is detected, a specific subroutine is first called. This subroutine causes the system to pause for a brief period (usually a few milliseconds), thereby ignoring the short-term unstable signals caused by the mechanical movement of the button. Similarly, when the button is released, this delay program is also triggered. In this way, the instantaneous unstable signals caused by the physical characteristics of the button can be effectively filtered out, ensuring the stability and reliability of the button signal.

8. Buzzer Design

The upper and lower limits of heart rate and body temperature can be set through buttons, and the buzzer will sound and light alarm when the parameters exceed the range. There are many specifications of buzzers on the market, and choosing a buzzer that provides a 5V power supply is more practical here (the circuit is powered by 5V without the need for additional voltage reduction). In the design, when a high temperature is detected, the buzzer will be activated. The buzzer circuit is shown in Figure 6, consisting of three parts: the first part is a 1k resistor, the second part is a PNP transistor, and the last part is the buzzer. The main function of the transistor is to amplify the current to make the buzzer alarm.

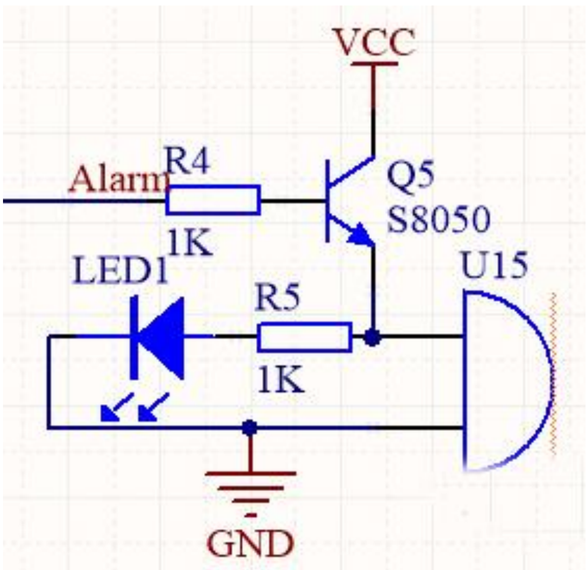

FIGURE 6: Buzzer Design Diagram.

9. Bluetooth Design

Bluetooth is mainly responsible for the connection between the bracelet and the smartphone. The HC-05 module is equipped with a complete Bluetooth RF transceiver and baseband processor, using CMOS technology and featuring Adaptive Frequency Hopping (AFH). It also supports the Serial Port Protocol (SPP) and Enhanced Data Rate (EDR) technology, with a maximum transmission rate of up to 3 Mbps. The working principle of Bluetooth is based on the Bluetooth 2.0 + EDR protocol standard to achieve serial communication between the STM32 and the Bluetooth module, enabling devices such as the STM32 microcontroller to have Bluetooth functionality once connected to this module. The role of Bluetooth is to operate in automatic connection mode, performing transparent data transmission through the Bluetooth protocol, characterized by its simplicity, ease of use, and high performance.

SOFTWARE DESIGN OF THE SMART BRACELET

The software design of the smart bracelet in this paper mainly involves writing program codes for each module. After successful compilation and execution, the programs are burned into the microcontroller. These programs are stored in the memory, awaiting execution by the CPU. Once all programs have run, the output is sent through the I/O ports, and the output data is displayed on the OLED electronic screen.

System main program operation flow: After the system is powered on, it initializes the pins of each sensor, and then initializes the IIC protocol to display relevant information on the OLED screen. Subsequently, the ADXL345 module measures gait data, the DS18B20 measures temperature, the heart rate sensor measures the current heart rate value, and the clock returns the current time. Once all data is returned to the main controller, it is displayed on the OLED screen. At this point, the data is also sent to the mobile phone via Bluetooth. Finally, it checks whether any button has been pressed; if so, it proceeds to the button function to handle the corresponding event.

CONCLUSION

This paper conducts market research and analysis on the public's continuous pursuit of health needs, and in combination with the characteristics of the STM32 microcontroller, designs a multifunctional smart bracelet that integrates step counting, heart rate monitoring, temperature detection, and time display. The focus is on the design of the hardware circuit system of the smart bracelet. At the same time, through experiments, the accuracy and reliability of the temperature detection, heart rate monitoring, and step counting statistics of the smart bracelet are verified. Communication between the bracelet's Bluetooth and smartphones allows users to monitor their health data in real time. During the design process, low-power design techniques are used to effectively extend the battery life of the smart bracelet.

Advanced sensor fusion algorithms are introduced to optimize CPU task scheduling, power management, and software data processing, resulting in a device with high performance and low power consumption.

REFERENCES

[1] Fu Jingfei. Research and Development of Health Monitoring and Service System [D]. Xi'an: Xi'an University of Technology, 2018, 8.

[2] Li Mingpei. Design and Research of Smart Bracelet [J]. Scientific and Technological Innovation, 2021 (28): 194.

[3] Zeng Guiling. Design of Smart Bracelet Based on STM32 Microcontroller [J]. Journal of Xi'an University of Arts and Science, 2023, 26 (3): 72-73.

[4] Hui Pengfei. Bluetooth Wireless Multi-function Smart Bracelet Based on STM32 [J]. Journal of Science of Teachers' College, 2023, 43 (11): 27-28, 38.

[5] Qin Yuyang. Research and Design of Fall Detection and Alarm Device for the Elderly [D]. Dalian: Dalian Maritime University, 2013, 40.

[6] Zhao Huafeng. Design and Implementation of Three-axis Accelerometer Pedometer Based on Microcontroller [J]. Information and Computer, 2017 (20): 115-116.

[7] Ji Jun, Wang Jinghua, Zeng Yidong, et al. Research on Pulse Oximetry Based on MAX30101 Chip [J]. Chinese Medical Equipment, 2020, 17 (10): 27-31.

[8] Sun Wei, Tang Ning, Jiang Guiping. Research on Feature Point Recognition and Preprocessing of Pulse Wave Signal [J]. Journal of Biomedical Engineering, 2015, 32 (1): 197-201.

[9] Huang Wenjing. Design of Elderly Health Bracelet System Based on STM32 [J]. Shanxi Electronic Technology, 2023 (6): 5-6, 60.

[10] Liu Weidong, Zeng Shaojie, Li Chao, et al. Analysis of the Design of Digital Clock and Temperature Display System Based on Microcontroller [J]. Shandong Industrial Technology, 2018 (14): 163.

[11] Zhang Jifeng. Research and Application of Real-time Clock Chip DS1302 in Teaching [J]. Heilongjiang Science and Technology Information, 2017 (5): 12.