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Application Design of Bluetooth 5.0 Low Power Technology in Smart Bracelet

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Abstract: *With the rapid development of smart wearable devices, smart bracelets, as a wearable device integrating health monitoring, sports tracking, information reminders and other functions, are becoming more and more popular among consumers. This paper elaborates on the application design of Bluetooth 5.0 low-power technology in smart bracelets, including product overview, functional design, hardware selection, software development, production and manufacturing. Special attention is paid to the role of Bluetooth 5.0 low-power technology in improving the battery life of smart bracelets, enhancing data transmission stability and expanding the connection range. By adopting low-power Bluetooth 5.0 chips such as PHY6202/PHY6212 designed for smart wearable devices, low power consumption, high performance and versatility of smart bracelets are achieved. This paper aims to provide users with comprehensive and convenient health management and sports tracking services while ensuring the comfort and user experience of the device.*

Keywords: *Bluetooth 5.0; Low-Power Technology; Smart Bracelet; Health Monitoring; Sports Tracking; PHY6202/PHY6212 Chip*

1. Introduction

Smart bracelets combine modern technology with health concepts and have developed rapidly in the market in recent years, becoming personal health monitoring and daily life assistants. Their portability, practicality and fashion sense attract many consumers, especially young people and health seekers. The market potential is huge due to technological progress and cost reduction.

The introduction of Bluetooth 5.0 low-power technology brings new opportunities for smart bracelets. This technology not only has wide coverage, fast transmission, and strong anti-interference, but more importantly, its low power consumption can significantly extend the battery life and meet the needs of all-weather health monitoring and sports tracking.

This paper aims to deeply explore the application design of Bluetooth 5.0 low-power technology in smart bracelets and analyze its role in improving device performance, battery life and user experience. Through this study, it provides a reference for the design and development of smart bracelets and promotes the sustainable development of the smart wearable device industry. In the future, smart bracelets will be more intelligent and personalized, providing users with richer and more convenient health management and life experience [1] .

2. Overview of Bluetooth 5.0 Low Energy Technology

Bluetooth 5.0, the latest version of Bluetooth technology, was released by the Bluetooth Special Interest Group (SIG) in 2016, marking another major advancement in Bluetooth technology. Compared with its predecessor, Bluetooth 5.0 has significantly improved transmission speed, coverage, power consumption and compatibility.

The core advantages of Bluetooth 5.0 low-power technology include wider coverage, faster transmission speed and lower power consumption. Its maximum transmission distance can reach 300 meters, which is four times that of Bluetooth 4.2, allowing Bluetooth devices to maintain a stable connection at a longer distance. At the same time, the maximum transmission rate of Bluetooth 5.0 can reach 2Mbps, and even 24Mbps in some cases, greatly improving data transmission efficiency. More importantly, Bluetooth 5.0 significantly reduces device power consumption and extends battery life by

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introducing low-power broadcast and connection functions, which is particularly critical for smart wearable devices and IoT devices [2-3] .

In addition, Bluetooth 5.0 also has an indoor positioning assistance function. Combined with Wi-Fi, it can achieve indoor positioning with an accuracy of less than 1 meter, providing more personalized services and experiences for application scenarios such as smart homes and health monitoring.

In the field of Internet of Things, the application prospects of Bluetooth 5.0 low-power technology are broad. From smart home to wearable devices, from medical health to industrial control, Bluetooth 5.0 is promoting profound changes in all walks of life. In the field of smart home, Bluetooth 5.0 can achieve seamless connection and intelligent control between smart home devices, improving the convenience and comfort of users' lives. In the field of medical health, Bluetooth 5.0 supports remote medical monitoring and health management, providing strong support for users' health protection [4] .

In short, Bluetooth 5.0 low-power technology, with its significant advantages and broad application prospects, is becoming an important force in promoting the development of smart wearable devices and the Internet of Things.

3. Overview of Smart Bracelet Design

Smart bracelet design is a complex process that comprehensively considers technology, functions and user experience. First of all, it is key to clarify product positioning. Smart bracelets should focus on providing comprehensive health management and sports tracking services. Target user analysis shows that different groups, such as young people with strong health awareness, fitness enthusiasts and working professionals, have different needs for smart bracelets, and these differences need to be fully considered during design [5] .

In terms of core function design, smart bracelets need to integrate functions such as health monitoring (heart rate, blood oxygen, sleep), exercise tracking (number of steps, running distance, calorie consumption, exercise pattern recognition) and daily life management (notification reminders, music control, mobile payment, smart home control) to meet the diverse needs of users.

In terms of comfort, aesthetics and user experience, smart bracelets should be made of soft, skin-friendly materials and ergonomically designed to ensure comfortable and stable wearing. The appearance design should pursue fashion trends and conform to diverse aesthetics. The dial interface and icon design should be intuitive and easy to operate to enhance the visual experience [6] .

User experience design is equally important. Smart bracelets should provide multiple operation modes such as touch or button to adapt to different user habits. The APP side is rich in functions and supports personalized customization, such as exercise goal setting, health data synchronization, social sharing, etc., to enhance user participation and stickiness.

4. Hardware selection and design

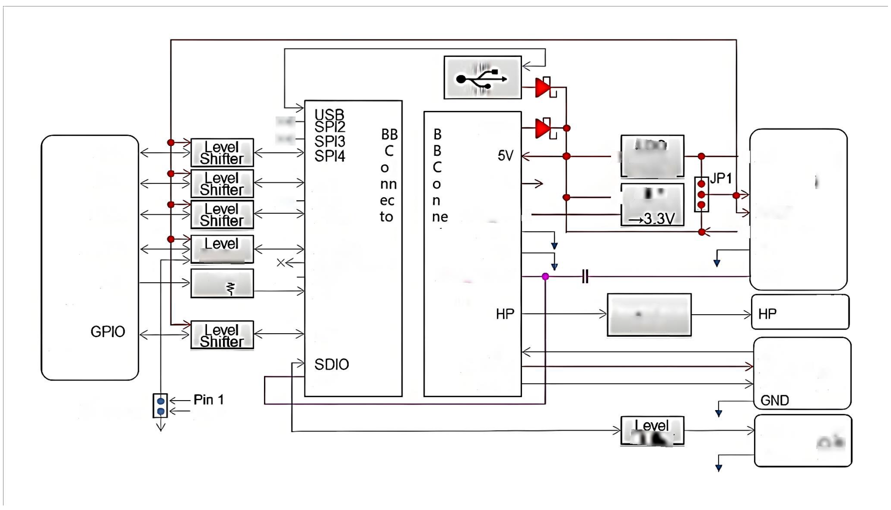

Figure 1 Hardware design schematic diagram of smart bracelet

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The hardware design of a smart bracelet is the basis for its function realization. Reasonable hardware selection and design can not only improve the performance of the device, but also optimize the user experience. Figure 1 Schematic diagram of the hardware design of a smart bracelet. The following is a detailed discussion of the hardware selection and design of a smart bracelet [7-8] .

4.1 Main control chip selection (PHY6202/PHY6212)

4.1.1 Chip Overview and Low Power Consumption Characteristics

PHY6202/PHY6212 are low-power Bluetooth 5.0 chips designed for smart wearable devices. They integrate powerful processing capabilities and rich peripheral interfaces to meet the needs of smart bracelets in health monitoring, sports tracking, and daily life management. Both chips use advanced low-power design to maximize the battery life of the device while ensuring performance. By optimizing the power management strategy, PHY6202/PHY6212 can maintain a stable connection with the smartphone in low-power mode and receive and send data in a timely manner.

4.1.2 Multi-protocol support and high-performance processing

PHY6202/PHY6212 supports the Bluetooth 5.0 standard, with wider coverage, faster transmission speed and stronger anti-interference ability. In addition, these two chips also support multiple communication protocols, such as ANT+, Wi-Fi, etc., and can seamlessly connect and exchange data with other smart devices. In terms of performance, PHY6202/PHY6212 uses a high-performance processor and memory architecture, which can efficiently process complex algorithms and large amounts of data, ensuring the accuracy and real-time performance of smart bracelets in real-time monitoring, data analysis, etc. [9-10] .

4.1.3 Flexible hardware interface and easy-to-use software development

PHY6202/PHY6212 provides a rich hardware interface, such as UART, SPI, I2C, etc., which can easily connect various sensors and actuators. In addition, these two chips also support a variety of peripheral expansions, such as SD card, camera, etc., which provides more possibilities for the function expansion of smart bracelets. In terms of software development, PHY6202/PHY6212 provides complete development tools and documents, including SDK, driver and sample code, which can reduce the difficulty of development and improve development efficiency.

4.2 Sensor Selection

4.2.1 Heart Rate Sensor

The heart rate sensor is one of the most important sensors in a smart bracelet. It can monitor the user's heart rate changes in real time and provide health advice and exercise guidance to the user. When choosing a heart rate sensor, we need to consider factors such as its accuracy, response speed, and power consumption. At present, the mainstream heart rate sensors on the market usually use photoplethysmography (PPG) or electrocardiogram (ECG) technology to accurately measure the user's heart rate.

4.2.2 Blood oxygen sensor

Blood oxygen sensors can measure the oxygen content in the user's blood and provide users with a reference to the health status of the respiratory and cardiovascular systems. When choosing a blood oxygen sensor, we need to pay attention to its measurement accuracy, response speed, and anti-interference ability. Some high-end smart bracelets are already equipped with blood oxygen sensors, which can provide users with more comprehensive health monitoring services.

4.2.3 Accelerometer and Gyroscope

Accelerometers and gyroscopes are important sensors used for motion tracking in smart bracelets. Accelerometers can measure the acceleration changes of the bracelet in three axes, thereby calculating the user's steps, running distance and other motion data. Gyroscopes can measure the angular velocity changes of the bracelet, providing users with more accurate motion posture and trajectory information. When choosing accelerometers and gyroscopes, we need to consider factors such as their accuracy, power consumption and stability.

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4.3 Display and Battery Design

4.3.1 High-definition, low-power OLED or LCD screen

The display screen of a smart bracelet is an important interface for users to interact with the device. When choosing a display screen, we need to pay attention to factors such as its resolution, brightness, contrast, and power consumption. OLED and LCD are two common display screen technologies, each with its own advantages and disadvantages. OLED screens have the characteristics of self-luminescence and can display more vivid and clear images, but their power consumption is relatively high. LCD screens have the advantages of low power consumption and low cost, but their display effect may be slightly inferior to that of OLED screens. According to the positioning and needs of the smart bracelet, we can choose the appropriate display screen technology.

4.3.2 High Energy Density Batteries and Charging Methods

The battery is the key to the battery life of a smart bracelet. When choosing a battery, we need to pay attention to its capacity, energy density and safety. Batteries with high energy density can provide a longer battery life for smart bracelets while ensuring safety. In addition, the charging method is also an important factor affecting the user experience. Wireless charging and magnetic charging are two common charging methods, which can simplify the charging process and improve user convenience. When choosing a charging method, we need to consider factors such as compatibility, charging speed and cost.

4.4 Other Hardware Components

4.4.1 NFC module

The NFC module is a key component in smart bracelets to realize functions such as mobile payment and smart home control. Through the NFC module, the smart bracelet can communicate with various NFC tags and card readers to simulate and copy functions such as access cards, bus cards, and bank cards. When choosing an NFC module, we need to pay attention to its compatibility, security, and performance.

4.4.2 Buttons and Vibration Motors

Buttons and vibration motors are important components for user interaction in smart bracelets. Buttons can provide users with a more intuitive and convenient operation method, while vibration motors can provide users with reminders and feedback. When choosing buttons and vibration motors, we need to consider factors such as their feel, response speed, and power consumption.

5. Software Development and Design

The software development and design process of smart bracelets covers several key links, including operating system selection and custom development, application development, firmware upgrade mechanism design, etc. The following is a detailed discussion of these aspects.

1) Operating system selection and customized development (FreeRTOS or RT-Thread) As the core of the entire device, the operating system of the smart bracelet is crucial to its selection and customized development. FreeRTOS and RT-Thread are two popular open source operating systems. They each have unique advantages and are suitable for the development of different types of smart bracelets. FreeRTOS: FreeRTOS is a lightweight real-time operating system suitable for resource-constrained embedded systems. Its design is simple, easy to understand and use, and has high reliability and real-time performance. In the development of smart bracelets, FreeRTOS can be tailored and optimized to meet the special requirements of the bracelet in terms of power consumption, performance, and storage. At the same time, the modular design of FreeRTOS allows developers to flexibly add or delete functional modules according to the functional requirements of the bracelet, thereby reducing development costs and improving development efficiency. RT-Thread: RT-Thread is a feature-rich real-time operating system that provides a wealth of components and libraries, such as file systems, network protocol stacks, graphical interfaces, etc. These components and libraries can greatly simplify the development process of smart bracelets and improve development efficiency. In addition, RT-Thread also supports multi-tasking and priority scheduling, allowing the bracelet to handle multiple tasks at the same time and ensure the real-time performance of key tasks. In the development of smart bracelets, RT-Thread can be customized to meet the requirements of the bracelet in terms of function,

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performance and stability. Both FreeRTOS and RT-Thread need to be tailored and optimized to adapt to the hardware resources and application scenarios of smart bracelets. Tailoring includes removing unnecessary modules and functions to reduce system complexity and power consumption; optimization includes adjustments to improve system performance, reduce memory usage and power consumption. At the same time, modular design is also an important aspect of customized development of operating systems, which makes the system more flexible, easy to maintain and expand. In terms of real-time guarantee, the operating system needs to ensure timely response and processing of key tasks. This can be achieved by optimizing task scheduling algorithms, improving interrupt response speed, and reducing system latency. In addition, the real-time performance of the system can also be ensured by using technical means such as hardware timers and interrupt priority management.

2) Application Development The application development of smart bracelets is a key part of their software development and design.By developing various applications, smart bracelets can achieve comprehensive monitoring and management of users' health, exercise, life, etc. Health monitoring applications: including heart rate monitoring, blood oxygen monitoring, sleep monitoring, etc. These applications collect users' physiological data through sensors, and process and analyze them through algorithms to provide accurate health information. For example, the heart rate monitoring application can monitor the user's heart rate changes in real time through the heart rate sensor and issue an alarm when the heart rate is abnormal; the blood oxygen monitoring application can measure the user's blood oxygen saturation through the blood oxygen sensor to evaluate the user's respiratory function and oxygenation capacity; the sleep monitoring application can monitor the user's sleep status and quality through acceleration sensors and light sensors, and provide corresponding sleep suggestions.Exercise tracking applications: including exercise pattern recognition and tracking algorithms. These applications provide comprehensive exercise analysis and suggestions by identifying the user's exercise status and recording exercise data. For example, the sports mode recognition application can identify the user's running, cycling, swimming and other sports status through the accelerometer and gyroscope, and record the corresponding sports data; the sports tracking algorithm can analyze the user's sports trajectory, speed, distance and other parameters based on these data, and provide corresponding sports suggestions and improvement plans. Notification reminder application: Receive various notifications by synchronizing with the smartphone. These applications allow users to receive and view important information even when it is inconvenient to check their phones. For example, the call reminder application can display the incoming call information on the bracelet and remind the user to answer the call through vibration; the SMS reminder application can display the SMS content on the bracelet, which is convenient for users to quickly view and reply. Music control application: Control the music playback of the mobile phone. These applications allow users to directly control the music playback of the mobile phone on the bracelet, such as switching songs and adjusting the volume. This not only improves the convenience of users, but also allows users to focus more on music enjoyment when exercising or walking. Smart home control application: Control smart home devices through Bluetooth Mesh or other protocols. These applications allow users to directly control smart home devices at home through the bracelet, such as turning on and off lights and adjusting the air conditioning temperature. This not only improves the user's comfort, but also makes it easier for users to manage their home devices. In the process of application development, it is necessary to focus on user experience and practicality of functions. Through reasonable interface design and interaction design, the application can be easier to use and understand; through accurate data analysis and processing algorithms, the application can provide more accurate and useful information. At the same time, it is also necessary to focus on the stability and security of the application to ensure the security and privacy protection of user data.

3) Firmware upgrade mechanism design The firmware upgrade mechanism is an important part of the software development and design of smart bracelets.Through firmware upgrades, known errors can be fixed, new functions can be added, or existing functions can be improved, thereby improving the performance and user experience of the bracelet. The design of the firmware upgrade mechanism needs to consider multiple aspects, including the selection of upgrade methods, the production and management of upgrade packages, and the control and verification of the upgrade process. Common upgrade methods include online upgrades and offline upgrades. Online upgrades are to download and upgrade the upgrade package through a network connection; offline upgrades are to manually transfer the upgrade package to the bracelet and upgrade it. In terms of the production and management of upgrade packages, it is necessary to ensure the correctness and integrity of the upgrade package. This can be achieved by using technical means such as digital signatures and checksums. Digital signatures can ensure that the upgrade package has not been tampered with during transmission; checksums can be used to detect whether errors occur during the transmission of the upgrade package. In terms of the

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control and verification of the upgrade process, it is necessary to ensure the reliability and security of the upgrade process. This can be achieved by using technical means such as multi-stage upgrades and rollback mechanisms. Multi-stage upgrade can divide the upgrade process into multiple stages, and each stage is verified and confirmed to ensure the correctness of the upgrade process; the rollback mechanism can automatically restore to the original firmware version when the upgrade fails to avoid adverse effects on users. In addition, in the design of the firmware upgrade mechanism, user convenience and user experience must also be considered. For example, a one-click upgrade function can be provided so that users can easily complete the firmware upgrade; at the same time, functions such as upgrade progress display and upgrade result prompts can also be provided to facilitate users to understand the upgrade process and results.

6. Core Algorithms and Implementation

The core algorithms of smart bracelets are the key to their functional realization. These algorithms cover many aspects such as step counting, heart rate monitoring, sleep monitoring, exercise pattern recognition, calorie consumption estimation, etc. The following is a detailed discussion of these core algorithms and their implementation.

1) Step Counting Algorithm Step counting is one of the most basic functions of smart bracelets, and its implementation mainly depends on the accelerometer.The accelerometer can sense the acceleration changes of the bracelet and convert them into steps through the algorithm. Algorithm principle: The accelerometer monitors the acceleration and deceleration movements of the wrist and combines the three-axis data to determine the user's walking gait. When a specific gait pattern is detected, the algorithm will identify it as a step. Implementation method: First, the raw data of the accelerometer is filtered to reduce noise interference. Then, the processed data is processed using the pedometer algorithm to identify the gait pattern and calculate the number of steps. Finally, the step count data is transmitted to the mobile phone APP through communication methods such as Bluetooth for users to view.

2) Heart rate monitoring algorithm Heart rate monitoring is one of the important health monitoring functions of smart bracelets, and its implementation mainly relies on optical heart rate sensors.Algorithm principle: The optical heart rate sensor uses light (usually green light) to illuminate the skin and monitors the heart rate by measuring the changes in the light absorbed by the blood. When the heart beats, the blood flows and changes the absorption rate of light, which is captured by the sensor. Implementation method: First, light is emitted to the skin through an LED light, and the reflected light is received by a photosensitive element. Then, the received light signal is processed and analyzed to extract the heart rate information. Finally, the heart rate data is transmitted to the mobile phone APP through communication methods such as Bluetooth for users to view and analyze.

3) Sleep Monitoring Algorithm Sleep monitoring is another important health monitoring function of smart bracelets, and its implementation mainly relies on accelerometers and heart rate sensors.Algorithm principle: The accelerometer can monitor the user's body movements during sleep, while the heart rate sensor can monitor the changes in the user's heart rate during sleep. By combining the data of these two sensors, the user's sleep state and quality can be judged. Implementation method: First, the data of the accelerometer is processed and analyzed to identify the user's body movements during sleep. Then, combined with the data of the heart rate sensor, the user's sleep stage (such as light sleep, deep sleep, etc.) is judged. Finally, the sleep data is transmitted to the mobile phone APP through communication methods such as Bluetooth for users to view and analyze.

4) Motion Pattern Recognition Algorithm Motion pattern recognition is one of the advanced functions of smart bracelets.Its implementation mainly relies on sensors such as accelerometers and gyroscopes. Algorithm principle: By monitoring the acceleration, angular velocity and other parameters of the user during exercise, and combining machine learning algorithms or pattern recognition algorithms, the user's motion pattern (such as running, cycling, swimming, etc.) can be identified. Implementation method: First, preprocess and extract features from the raw data of the sensor. Then, use machine learning algorithms or pattern recognition algorithms to train and learn the feature data to establish a motion pattern recognition model. Finally, input the real-time sensor data into the model to identify and judge the motion pattern.

5) Calorie Consumption Estimation Algorithm Calorie consumption estimation is another important function of smart bracelets.Its implementation mainly depends on the acceleration sensor, heart rate sensor and the user's personal information (such as age, gender, weight, etc.). Algorithm principle: By

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monitoring the changes in the acceleration and heart rate of the user during exercise, and combining the user's personal information, the calories consumed by the user during exercise can be estimated. This usually involves the application of kinematic algorithms and energy consumption models. Implementation method: First, the data of the acceleration sensor and heart rate sensor are processed and analyzed to extract the exercise intensity and heart rate information. Then, the user's personal information and energy consumption model are combined to estimate the calories consumed by the user during exercise. Finally, the calorie consumption data is transmitted to the mobile phone APP through communication methods such as Bluetooth for users to view and analyze.

6) Data Processing and Transmission Algorithms The data processing and transmission algorithms of smart bracelets are important supports for the realization of their functions.These algorithms include data filtering, data compression, data synchronization, etc. Data filtering: used to reduce noise and interference in sensor data and improve data accuracy and reliability. Data compression: used to reduce the amount of data transmission, improve data transmission efficiency and save energy. Data synchronization: used to ensure data synchronization and consistency between the bracelet and the mobile phone APP. The implementation of these algorithms usually relies on embedded system programming and communication technologies, such as C language programming, Bluetooth communication, etc. Through reasonable algorithm design and optimization, efficient and accurate data processing and transmission can be achieved. In summary, the core algorithms of smart bracelets cover multiple aspects such as step counting, heart rate monitoring, sleep monitoring, exercise pattern recognition, and calorie consumption estimation. The implementation of these algorithms relies on expertise in multiple fields such as sensor technology, machine learning algorithms, embedded system programming, and communication technology. Through reasonable algorithm design and optimization, various functions of smart bracelets can be realized, and users can be provided with more accurate, reliable and convenient health monitoring and exercise tracking services.

7. Conclusion

Smart bracelets, as multifunctional smart wearable devices such as health monitoring and sports tracking, have penetrated into people's lives. This paper deeply explores the key technologies of smart bracelets, such as software development and design, core algorithms and implementation. In software development, reasonable operating system tailoring, modular design and real-time guarantee ensure the special requirements of smart bracelets in power consumption, performance and storage. Rich application functions, such as health monitoring and sports tracking, provide convenient services for users. The firmware upgrade mechanism ensures the continuous update and optimization of the bracelet.

In terms of core algorithms, algorithms such as step counting, heart rate monitoring, and sleep monitoring rely on sensor technology, machine learning, and other fields of knowledge to ensure that the data is accurate, reliable, and real-time. With the advancement of sensor technology and the optimization of algorithms, smart bracelets will provide more accurate health monitoring and sports tracking services.

Looking into the future, smart bracelets will be more intelligent, personalized and convenient. As an important part of the smart home ecosystem, smart bracelets will bring users a more convenient and intelligent life experience. In short, smart bracelets have shown great market potential and application value, and we expect them to bring people a healthier, more convenient and intelligent lifestyle in the future.

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