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# Design of an Intelligent Water-Saving Shower System Device

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## Abstract

**Currently, most shower equipment needs to discharge a portion of the remaining cold water from the inlet pipe before use, resulting in a considerable amount of water being wasted and the existing functions are not perfect. In order to effectively save water resources, improve the comfort and emotional experience of showers, an intelligent water-saving shower home robot has been designed. This robot is centered around STM32 control and utilizes a cloud platform to achieve remote monitoring and real-time control of intelligent water-saving shower robots. At the same time, a water-saving function of "storing cold water and discharging hot water" has been designed, which can store and utilize residual cold water and save water resources. In addition, it also has functions such as voice control, heart rate monitoring, film and television playback, and entertainment interaction, which can monitor the human heart rate status in real-time and meet the emotional experience needs. This shower robot has the characteristics of intelligence, water-saving, convenience, and humanization, which can achieve a win-win situation in social, economic, and environmental benefits, and has broad market prospects.**

## Keywords

**Intelligent shower; Emotional experience; Water-saving shower; Cloud control.**

## 1. Development Background and Significance

With the fast-paced pace of life, people's demand for showers is not just to simply clean themselves, but has shifted towards a pursuit of stress release and comfort. Through a survey of user shower behavior experience, it can be concluded that users' needs for shower rooms are primarily emotional, including aesthetic and entertainment needs. Therefore, this robot has designed voice control and video playback capabilities. Secondly, the functional requirements include constant temperature, water saving, and other functions. This robot has undergone structural modifications and functional upgrades to the current shower equipment, inventing a water-saving device with the function of "storing cold water and hot water", which can effectively utilize the cold water that is often overlooked and wasted before hot water is discharged during bathing. There are also usability requirements, including interactive guidance and maintenance cleaning. This robot has a multifunctional touch screen that can provide data such as residual water volume, body temperature, recycled water volume, shaving cost, and human heart rate.

Figure 1: Shower Scene

Figure 2: Shower Modeling Figure

## 2. Product Design and Working Principle

This product is equipped with an STM32 processor, DS18B20 water temperature sensor, infrared human body sensing probe, infrared human body temperature sensor, heart rate sensor, and servo mixing valve on top of existing showers. It can detect human body temperature, automatically set the optimal water temperature according to the season, automatically sense whether there is anyone under the shower, accurately control the temperature through PID algorithm, and display it on a touch screen. And a cloud platform based intelligent control system was designed, which is controlled through a waterproof touch screen or voice control to achieve intelligent constant temperature, and users can also interact with entertainment such as video and audio through the screen, as well as monitor healthy heart rate[1].

After selecting the fully automatic sensing mode, the hot water flows out at the preset temperature after 5 seconds, which can achieve the goal of cutting off the flow of people and water. At the same time, individuals can set the water temperature according to their own needs through a touch screen or cloud. In addition, the system adopts gradient billing and dynamically displays cost changes to urge users to save water. In addition, in order to meet the comfort needs of young people, this system integrates the design and installation of speakers and display screens, allowing people to enjoy Bluetooth music playback function while not installing complex electrical products in the bathroom, resulting in a more concise and spacious bathroom space. The results show that the system has significant water-saving effects after application, and is easy to promote, achieving intelligent control and resource conservation on a low-cost basis.

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## 2.1. Overall Design

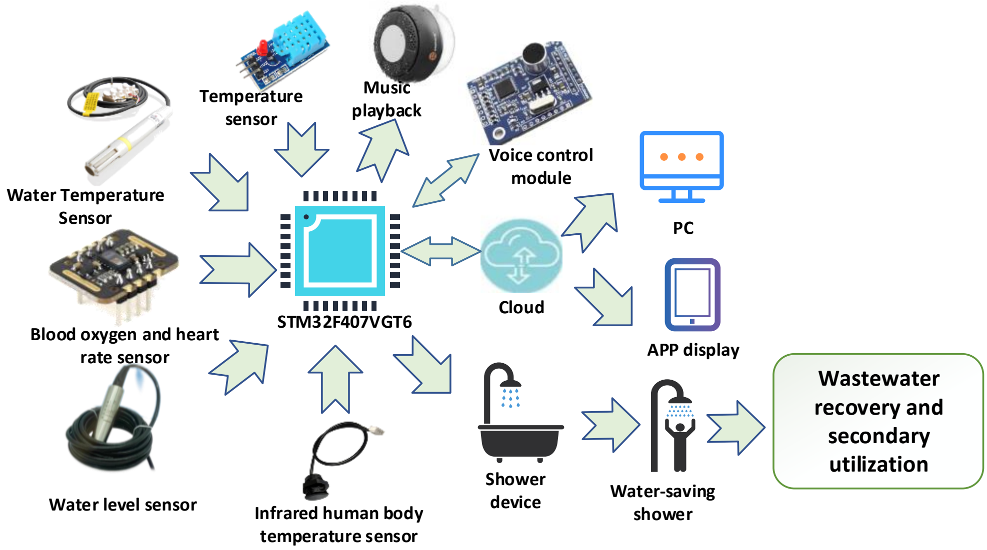



Figure 3: Overall System Design Diagram

The overall system includes an STM32 processor loaded on the shower, and the shower and its sensor modules work together. Firstly, the infrared body temperature sensor captures the body temperature and automatically sets the most comfortable bathing temperature based on the current season; DS18B20 water temperature sensor detects water temperature in real-time; The rotation button of the mixing valve is controlled by the servo motor, and the PID algorithm is used to quickly and accurately control the angle of the servo motor to control the mixing degree of cold and hot water in the mixing valve, achieving the effect of quickly adjusting the mixing valve to keep the water temperature constant. When the water temperature reaches a certain temperature and the infrared human body sensing probe senses someone below the shower, the electromagnetic valve is immediately controlled to discharge water. During the bathing process, the water temperature can also be manually set and controlled.

## 2.2. Design of Water-Saving Devices

The water-saving shower device is designed as a circular shape, divided into upper and lower layers. To achieve waterproofing, the lower layer is divided into left and right compartments. The left compartment is the channel through which shower water flows out of the shower when it reaches 38 ℃, controlled by solenoid valve B. The right compartment is the integration area of STM32 control board and S3003 steering gear and other electrical components. The side wall near the bottom in the upper layer is equipped with electromagnetic valve A, which directly determines the opening and closing of the channel connected to the water storage container. Physiological studies have shown that the human body does not feel cold and the relatively comfortable water temperature throughout the year is between 38 and 40 ℃. Therefore, the device in this article uses 38 ℃ as the temperature value to determine whether to turn off solenoid valve A and turn on solenoid valve B[3]. The DS18B20 digital temperature sensor is equipped at the bottom directly below the upper inlet pipe, which can convert the collected temperature data into electrical signals in real-time and transmit them to the control board. In the 3D front view, the inlet pipe, temperature sensor, and solenoid valve A are in a straight line, while solenoid valve B is in the opposite direction of the thermocouple sensor. The integration area of the electrical components is directly below the DS18B20 temperature sensor. The control board determines whether the water temperature reaches 38 ℃ to control the opening and closing of solenoid valves A and B. The design of the water storage container is transparent, with a volume of 20L. The outer wall of the container has a water level line, making it convenient for users to pay attention to the water storage situation at any time and promptly reuse the water in the water storage container.

## 2.3. Heart Rate Monitoring Design

During work, the pulse sensor first detects the human pulse and converts it into an analog electrical signal. The chip on the Bluetooth module continuously samples and quantizes the signal through an internally integrated ADC. Then, a series of data values are processed using pulse signal edge detection method and improved median filtering method to obtain the pulse cycle. Then, an integrated RF transceiver is used to wirelessly send the data to the host. After receiving the data, the Bluetooth module on the host directly forwards it to the microcontroller through the serial port. The microcontroller then converts it to obtain the heart rate value and compares it with the threshold. If it exceeds the range, an alarm will be triggered[2]. This design belongs to wearable devices. In addition to monitoring pulse signals, the system also monitors the battery level of the slave during operation. The real-time heart rate information display and setting of the system can be achieved through the touch screen, and remote monitoring can be carried out on the cloud platform.

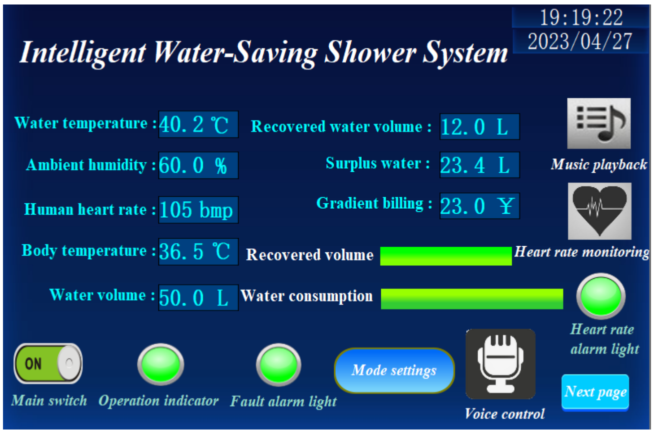
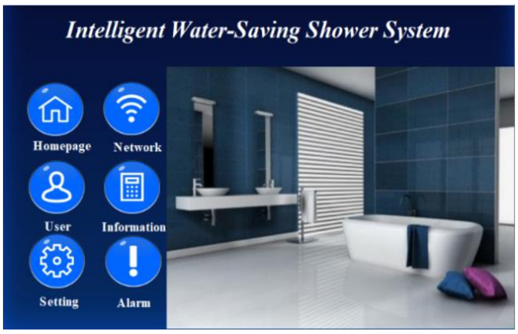



Figure 4: Heart Rate Monitoring and Parameter Display Interface

## 2.4. Cloud Based Remote Monitoring Design

DHT11 temperature and humidity module is selected to collect temperature and air humidity in the environment, non-contact infrared temperature measurement module to collect human body temperature, water level sensor to collect shower water volume, digital temperature sensor DS18B20 to collect shower water temperature, and pulse sensor module to collect human pulse. The microcontroller transmits the above collected parameters to the cloud server through a 4G module. In network transmission mode, it can monitor real-time parameters such as human heart rate, shower water temperature, shower water volume, gradient billing, and robot operation on the cloud configuration interface. Heating time and shower temperature can also be remotely set in the cloud to meet the needs of different users for shower water temperature [5].



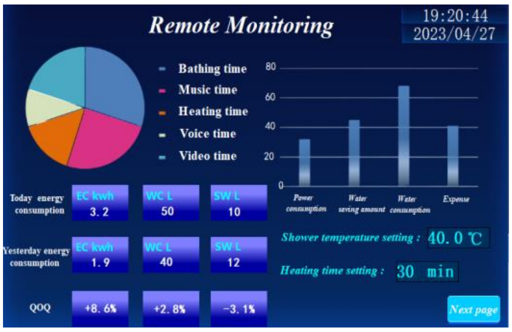




Figure 5: Intelligent Interaction Main Interface Figure 6: Cloud Monitoring Interface

### 2.5. Waterproof Design

The raw material of the waterproof and breathable film is EPTFE, which has excellent waterproof, breathable, dustproof, and heat dissipation properties, and can achieve IP67 and IP68 dustproof and waterproof protection levels. IPX-7 can soak for 30 minutes at 1 meter underwater; IPX-8 is completely waterproof and can be used continuously in water for a long time.

### 2.6. Video playback design

The intelligent audio control system selects STM32 and LD3320 as the system control core chips and voice control modules, and the LD3320 recognizes the sound signal. The intelligent audio control system effectively achieves functions such as song playback and pause playback through voice control. This design implements speech recognition for simple words to control the MP3 module to play music, while the Bluetooth module connects to the phone to play music [4]. It constructs a voice control function for intelligent audio, with speaker openings set at the bottom of the screen display, as shown in Figure 7.

Figure 7: Audio player amplifier

## 3. Theoretical design calculation

### 3.1. PID control algorithm

Due to the closed-loop control system using PID control algorithm, the cooling part uses PWM as the control variable, and the heating part uses the effective value of voltage as the control variable. Therefore, a digital PID incremental control algorithm is adopted.

$$\Delta u(k) = K_p[e(k) - e(k-1)] + K_I e(k) + K_D[e(k) - 2e(k-1) + e(k-2)] \qquad (1)$$

In equation (1), $K_p$ is the proportional coefficient; $K_I = K_p \frac{T}{T_I}$ is the integration coefficient; $K_D = K_p \frac{T_D}{T}$ adjust the coefficient.

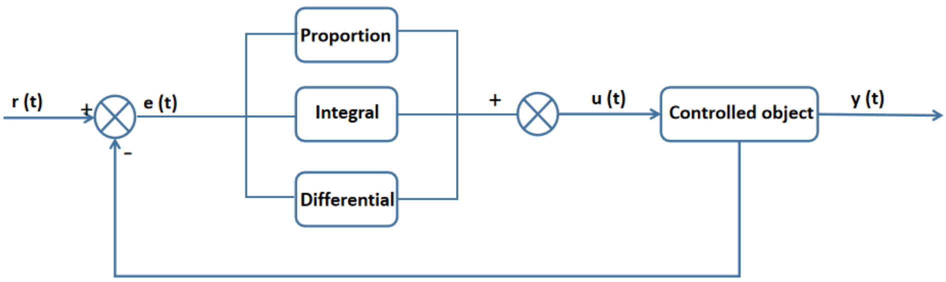



Figure 8: PID Control Principle Diagram

This design aims to achieve a static error of the water temperature to be measured within the range of 0.2℃, with a temperature setting range of 0-70℃ and a minimum division of 0.1℃. Adopting segmented PID algorithm with different PID coefficients in different intervals, achieving more accurate temperature control. At the same time, compensation measures should be added to compensate for the loss of heat during the process of hot water flowing through the shower and reaching the surface of the human body. After the shower is over, the water remaining in the water pipe will flow through a fixed path to the cold water pipe, thus avoiding the waste of the first section of cold water during the next shower.

## 4. Innovation points

(1) Accurate temperature control. Real time monitoring of water temperature can be carried out to improve the anti-interference of system temperature measurement, and stable temperature measurement can also be achieved in environments with large temperature differences. Users can also set the temperature according to their personal needs and accurately control the temperature.

(2) Gradient billing promotes water conservation. This system adopts gradient billing, dynamically displaying changing fees to urge users to save water. Meet the functions of energy conservation, water conservation, and electricity conservation, elevate bath products to a new level and keep up with the times.

(3) Intelligent and user-friendly interaction. By optimizing methods such as voice control and touch control, it is convenient for users to shower, enhancing the visual, tactile, and auditory experience of shower users, thereby improving the psychological comfort of bathing.

(4) Cloud based remote monitoring. You can remotely monitor the operating parameters of the shower robot through the cloud, such as shower water temperature, shower water volume, remaining water volume, environmental humidity, etc., to obtain the equipment operation status in the first time.

(5) Monitor heart rate to ensure safety. In order to prevent accidents during the shower process, especially for the elderly, a shower bracelet that can effectively monitor heart rate has been designed, with remote setting, query, and alarm functions.

(6) Video playback entertainment. The entertainment function of video and audio playback on the screen meets user needs, enhancing the user experience from unique design concepts, rich and diverse functions, and interesting aspects, making the bathing process a natural journey of body and mind.

## 5. Application Prospects

The following table takes a total of four showers per day for a family of four as an example for calculation. It can be seen that the minimum daily economic cost savings are 0.039 yuan, which adds up. If promoted to households and various public places for use, the economic cost savings and the total amount of water resources are very considerable. The most important thing is to save a considerable amount of unpolluted water, creating potential huge environmental and economic benefits.

Table 1: Savings based on a total of four integrated showers per household of four in Beijing

| Taking the shower in beijing as an example | | | | | |
|---|---|---|---|---|---|
| | water saving/L | water cost savings/yuan | Power consumption/kw • h | electricity fee/yuan | can save economic costs/yuan |

| | | | | | |
|---|---|---|---|---|---|
| average per day | 10 | 0.04 | $5 \times 10^{-4}$ | $2.44 \times 10^{-4}$ | 0.039 |
| monthly average | 300 | 1.20 | $1.5 \times 10^{-2}$ | $7.32 \times 10^{-3}$ | 1.192 |
| Annual average | 3600 | 14.4 | $1.8 \times 10^{-1}$ | $8.784 \times 10^{-2}$ | |

This cloud smart intelligent water-saving shower robot has added the function of "storing cold water and discharging hot water" - storing and utilizing residual cold water, as well as gradient billing to supervise water-saving, while meeting the basic functional needs of users for shower cleaning, effectively saving water resources. Combined with an intelligent cloud monitoring system, it can remotely set the water temperature and heating time, making it convenient for users. It can also monitor the human heart rate during bathing in real-time, reducing safety hazards for the elderly while showering. In addition, the designed functions such as voice control, film and television playback, and entertainment interaction can enhance the comfort and emotional experience of users when showering. The significant advantages of intelligence, water-saving, convenience, and humanization make this robot have a very broad market prospect.

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