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The Design and Implementation of an Intelligent Water Cup

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Abstract: Leveraging advancements in science and technology, particularly the extensive use of embedded technology, everyday items such as water cups have been transformed into intelligent devices. This paper proposes the design of an intelligent cup powered by the STM32F103 Microcontroller Unit (MCU). The device employs the DS18B20 temperature sensor and the Water Sensor water level sensor to monitor the temperature and water level in the cup. It allows users to set reminders for regular hydration and to specify a heating temperature for the water. Once the desired temperature is reached, the device automatically maintains it. All these features are displayed on an OLED screen, enabling users to hydrate regularly and quantitatively. This intelligent cup thus marries convenience with health consciousness, revolutionizing the simple act of drinking water.

Keywords: Microcontroller, Temperature sensor, OLED, Health consciousness

I. Introduction

Water, a vital resource for humans, is increasingly gaining attention for its health benefits. The intelligent water cup, an everyday item closely associated with us, not only enhances the quality of life but also promotes physical and mental well-being. Regular and quantitative water intake, along with controlled water temperature, are essential for healthy and scientific hydration.

To cater to these needs, this paper presents the design of aintelligent water cup. This innovative device not only reminds users to hydrate regularly and quantitatively but also features heating and insulation capabilities. Thus, the intelligent water cup serves as a practical solution for maintaining healthy hydration habits.

This article primarily focuses on the design of an intelligent water cup, powered by the STM32F103 microcontroller. The system leverages microcomputer control and sensor technology to facilitate various functionalities. These include display modes, water level and temperature monitoring, and time setting, all of which are presented through an OLED display module. This intelligent water cup represents a significant advancement in daily necessities, enhancing user experience with its intelligent features.

II. Overall system design

The system's hardware modules encompass the STM32F103C8T6 microcomputer, a DS18B20 temperature sensor, a water sensor for water level detection, a heating module, an OLED display module, and a buzzer alarm module, among others. The system's hardware design is executed using Altium Designer software for PCB design, while the KEIL5 program is employed for software design. The overall system design is depicted in Figure 1.

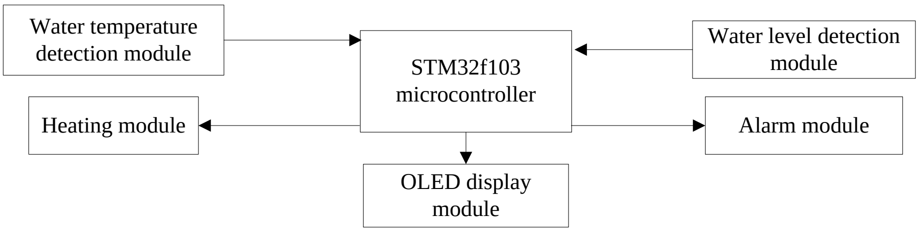

Figure 1: The overall design of Intelligent water cup

III. System hardware design

The hardware of the system includes these components:

STM32F103C8T6 Microcontroller: This serves as the central processing unit of the system, controlling the operations of other modules.

DS18B20 Temperature Sensor: This sensor is used to detect and monitor the temperature of the water in the cup.

Water Sensor: This sensor is responsible for detecting the water level in the cup.

OLED Display Module: This module displays the various functionalities of the intelligent cup, such as water level, temperature, and set time.

Alarm Module: This module serves to remind the user to drink water at regular intervals.

Heating Module: This module is used to heat the water to a desired temperature.

Button Module: This module allows the user to interact with the intelligent cup, setting the time and temperature.

Each of these modules plays a crucial role in the functionality of the intelligent water cup, contributing to a seamless user experience.

3.1 STM32F103C8T6 MCU

The STM32F103C8T6 is indeed a medium-density performance line microcontroller, featuring an ARM Cortex-M3 32-bit RISC core that can run at up to 72MHz. It's housed in a 48-channel LQFP package and offers high-speed embedded memory, enhanced I/O, and connectivity to two APB buses. Notably, the STM32F103C8T6 is equipped with a 12-bit analog-to-digital converter and a PWM timer, providing excellent performance and powerful features at a very affordable price.

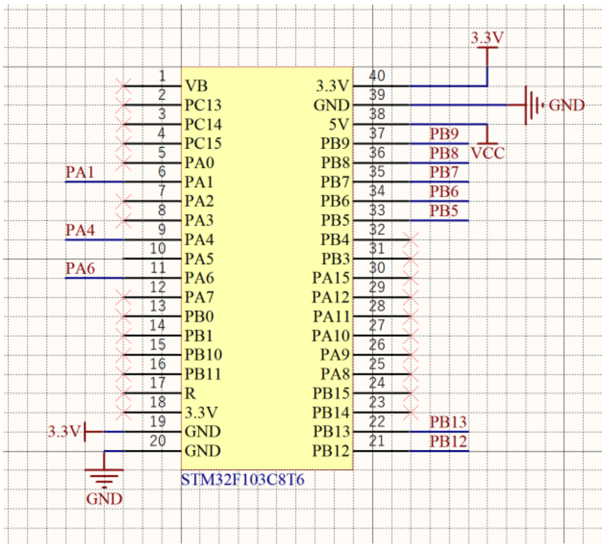

Figure 2 The mini system circuit diagram of microcontroller

3.2 DS18B20 temperature sensor

The DS18B20 is indeed a compact, cost-effective, and reliable single-wire device, making it superior to traditional thermistors. It communicates via a single pin, receiving high-level input signals and transmitting open-drain outputs. A pull-up resistor is necessary for power activation. Its ease of wiring and availability in various package types make it suitable for a wide range of applications. In the context of the intelligent water cup, the DS18B20 serves as the temperature detection module. It measures the temperature of the water in the cup and displays it on the screen, thereby informing the user about the current water temperature. This feature plays a crucial role in ensuring that the water is at an optimal temperature for consumption. The circuit diagram of Temperature sensor is shown in Figure 3

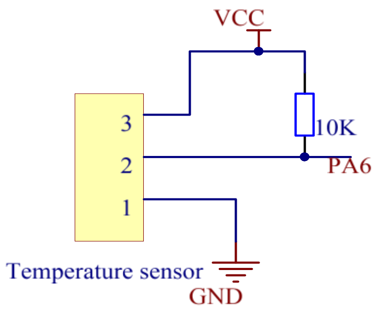

Figure 3 The circuit diagram of Temperature sensor

3.3 OLED display module

Indeed, OLED (Organic Light Emitting Diodes) displays have gained significant popularity in electronic design in recent years. As a self-illuminating technology, OLEDs are based on the phenomenon of electroluminescence, where light is emitted from a material when an electric current is applied. The advantages of OLED displays are numerous. They offer high contrast levels, resulting in clearer and more vibrant images. The self-illumination property eliminates the need for backlighting, allowing for thinner screens compared to traditional LCD displays. This makes OLED displays an excellent choice for a wide range of applications, including the intelligent water cup design discussed in this context. The OLED display module in the intelligent cup provides a clear and efficient way to communicate information to the user, enhancing the overall user experience. The circuit diagram of OLED is shown in Figure 4.

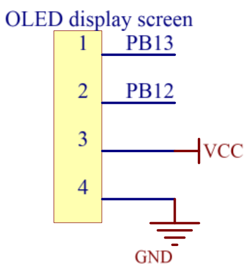

Figure 4 The circuit diagram of OLED

3.4 Water level detection module design

The Water Sensor, a water level sensor, is indeed an integral part of the intelligent water cup design. It operates with three pins: GND, VCC, and an analog signal output pin. The sensor measures the water level by gauging the amount of water through ten exposed parallel wire traces. This process converts the water level into an analog signal, which can be directly read as an output analog value.

The module primarily utilizes the current amplification principle of the transistor. When the liquid level height enables the transistor's base and the power supply's positive electrode, a certain amount of current is generated between the transistor's base and emitter. This current is amplified between the transistor's collector and emitter, producing a characteristic voltage through the emitter's resistance. This voltage is then collected by the AD converter.

The Water Sensor thus measures the amount of water in the cup and displays it on the OLED screen, providing the user with real-time information about their water consumption. This feature enhances the functionality of the intelligent water cup, making it a practical tool for maintaining healthy hydration habits. The circuit diagram of water level detection is shown in Figure 5.

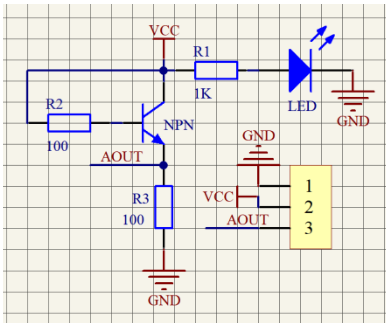

Figure 5 The circuit diagram of water level detection

3.5 Alarm module design

The alarm module in the intelligent water cup design utilizes a high-level trigger active buzzer. This type of buzzer doesn't require an external excitation source. It only needs to be connected to a DC power supply to automatically emit sound at a relatively fixed frequency. The driving method commonly used for this type of buzzer is direct drive through a transistor. In this design, an NPN type transistor is used. The transistor serves a crucial role in driving the buzzer. It amplifies the driving current, enabling the buzzer to produce sound. This feature is essential for the intelligent water cup, as it provides audible reminders for the user to hydrate regularly, enhancing the overall functionality of the device. The circuit diagram of alarm module is shown in Figure 6.

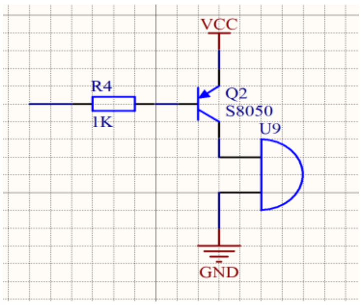

Figure 6 The circuit diagram of alarm module

3.6 Heating module design

The heating module, comprising a motor drive module and a heating plate, plays a crucial role in the intelligent water cup design. The system reads the water temperature via the temperature sensor. If the user has set a desired water temperature, the main controller compares this set temperature with the current temperature. It then controls the heating effect of the heating plate to regulate the water temperature.

This feature ensures that the water is always at the user's preferred temperature, enhancing the overall user experience. The intelligent water cup thus not only reminds users to hydrate regularly but also ensures that the water is at an optimal temperature for consumption. This makes it a practical tool for maintaining healthy hydration habits. The circuit diagram of heating module is shown in Figure 7.

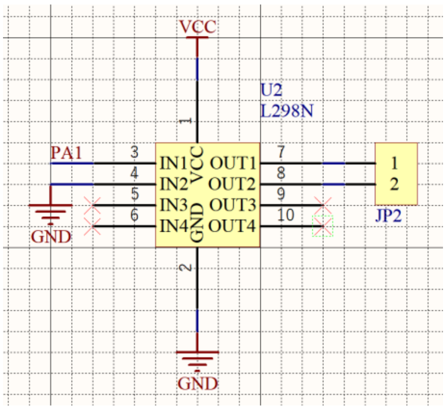

Figure 7 The circuit diagram of heating module

3.5 Key module design

The key system of the intelligent water cup comprises four buttons, each with a distinct function:

Key1: SW1 is used for setting parameters.

Key2: SW2 is used to switch between different modes.

Key3: SW3 is used to add functions or stop the buzzer beep.

Key4: SW4 is used for subtraction or decrementing values.

These keys provide an interactive interface for users to customize the functionalities of the intelligent water cup according to their preferences, thereby enhancing the overall user experience. The circuit diagram of key module is shown in Figure 8.

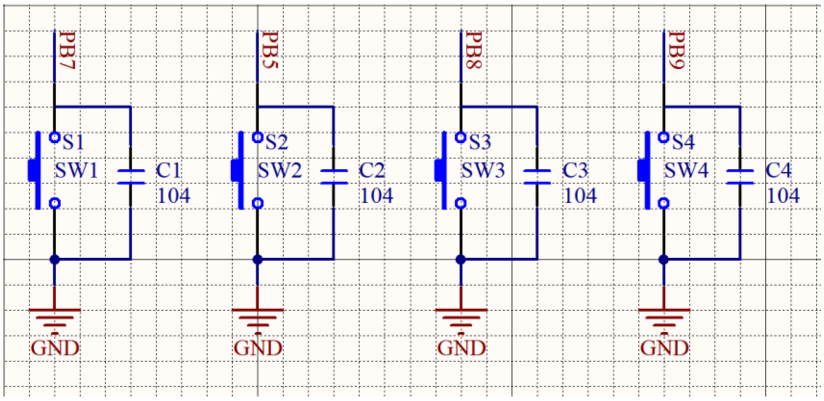

Figure 8 The circuit diagram ofkey module

IV. System software design

In this design, the C language is used to develop the program within the KEIL5 environment. This allows for efficient coding and debugging, ensuring the smooth operation of the intelligent water cup's various functionalities. The use of C language and KEIL5 software thus contributes significantly to the overall performance and reliability of the intelligent water cup.

4.1 Overall program design

Upon starting the intelligent cup system program, the program side is initialized first. Following this, the hardware components are initialized according to the preset state of the program, with a slight delay for hardware initialization. Once the hardware is initialized, the system enters the intelligent mode. The intelligent cup system operates in two modes: Intelligent Mode and Heating Mode. You can switch between these modes by pressing key2.

Intelligent Mode: In this mode, you can press key1 to enter the settings. You can then adjust the time by pressing key3 (for addition) and key4 (for reduction). When the set time is reached, the MCU sends commands to the buzzer, which automatically alerts the user to drink water. You can stop the alarm by pressing key3.

Heating Mode: In this mode, you can press key1 to enter the settings. You can then adjust the temperature by pressing key3 (for increase) and key4 (for decrease). Once the set temperature is reached, it is automatically maintained. The PID algorithm controls the PWM output, ensuring a control accuracy within ±1 degree.

This design allows the intelligent cup to provide timely reminders for hydration and maintain the desired water temperature, enhancing the user's hydration experience. The software flow of the design is shown in Figure 9.

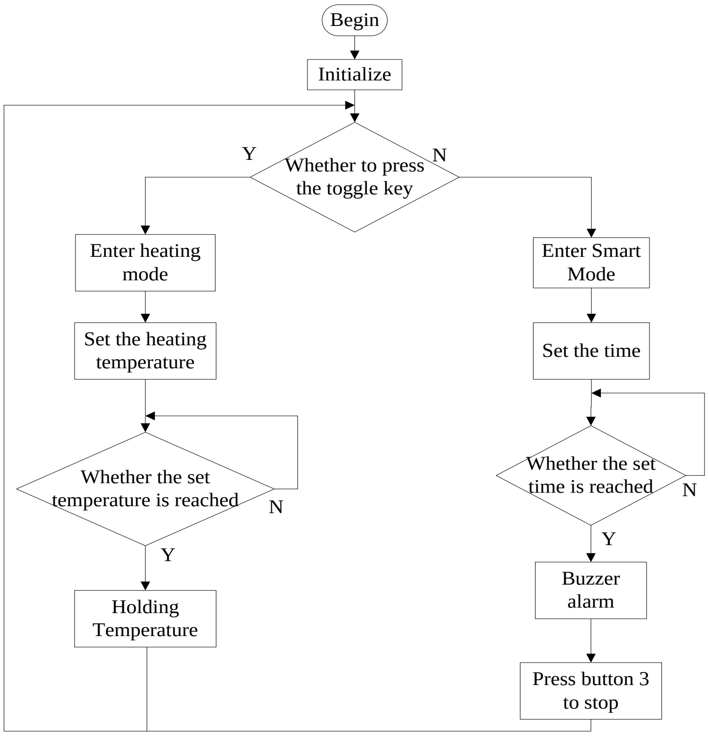

Figure 9 The software flow of the design

4.2 Temperature detection program design

Indeed, the sensor module requires initialization before it can start detecting water temperature data. Here's a step-by-step breakdown of the process:

1. Initialization: The temperature sensor is initialized through the program. This prepares the sensor for data detection.
2. Data Detection: Once initialized, the sensor begins to detect the water temperature data.
3. Data Transmission: The detected data is then sent to the MCU (Microcontroller Unit) for comparison and processing.
4. Data Writing: The temperature data is written to the DS18B20 temperature sensor through a specific function.
5. Data Reading: The temperature data is then read from the DS18B20 through another function.

6. Display: Finally, the data is written to the display screen, allowing the current temperature value to be displayed.
This process ensures accurate temperature detection and display, contributing to the intelligent functionality of the intelligent water cup. The software flow of temperature sensor module is shown in Figure 10.

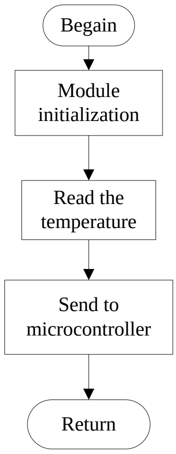

Figure 10 The software flow of temperature sensor module

4.3 Water level detection program design

Indeed, the Water Sensor water level sensor plays a crucial role in measuring the water level in the intelligent water cup. Here's a step-by-step breakdown of the process. The Water Sensor is initialized, preparing it for water level detection. Once initialized, the Water Sensor detects changes in the water level. This occurs when water comes into contact with the parallel wires of the sensor. The analog voltage value is collected through Analog-to-Digital Conversion (ADC). The analog voltage value is then converted into a water level measurement through an A/D conversion function.
This process ensures accurate water level detection, contributing to the intelligent functionality of the intelligent water cup. It allows the cup to monitor the amount of water and display it on the OLED screen, providing the user with real-time information about their water consumption. The software flow of water level detection is shown in Figure 11.

4.4 Key programming

Absolutely, the use of a debounce method is essential in key programs to prevent false triggering due to mechanical and electrical noise. Here's a step-by-step breakdown of the process. The program first determines whether the button is pressed for the first time. If it is pressed, the program calls a delay of about 10ms. If it is not pressed, the program returns. A delay of about 10ms is implemented to ensure that the button press is intentional and not due to noise or a quick, accidental press. After the delay, the program checks again whether the button is pressed. If it is not pressed, the program returns. If it is pressed, the program proceeds to the next step. The current key value is obtained, and the corresponding subprogram is called. The process ends after the subprogram is called.

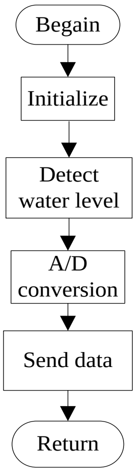

Figure 11 The software flow of water level detection program

In the software design of this intelligent water cup, the delay function is used as the debounce function. This ensures that the button presses are accurately detected and processed, contributing to the overall functionality and user experience of the device.The software flow of Key is shown in Figure 12.

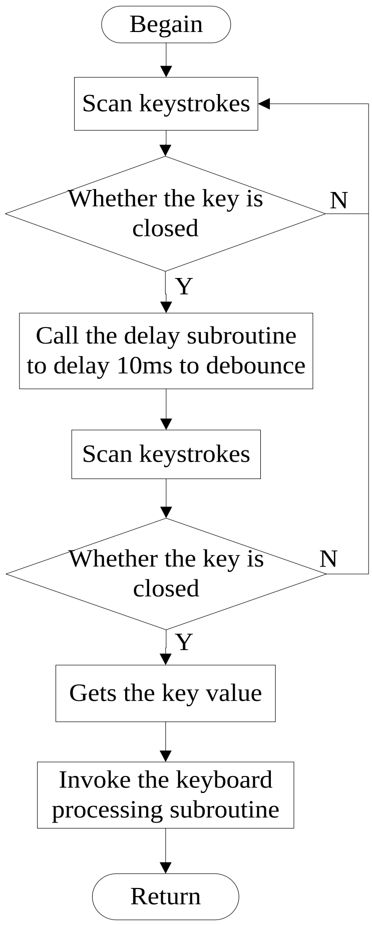

Figure 12The software flow of key

V. Conclusion

This article presents the design of an intelligent water cup based on the STM32 single-chip microcomputer. The intelligent cup can detect the current water temperature and volume, heat the water, and send reminders. It features an intelligent reminder mode and a heating mode, which can be switched using buttons. The water temperature, volume, and mode can be displayed on the screen, and a timer alarm can also remind users to drink water. The system's feasibility has been verified through testing, and it successfully achieves the goal of promoting regular and quantitative healthy water consumption. However, there is still room for improvement in this system. Future enhancements could include adding water quality detection functions to remind users to change the water when the quality is poor. Incorporating human body sensing functions, such as using pyroelectric induction sensors like the HC-SR505 to detect if someone is near the cup, could help determine whether to remind users to drink water. Replacing the buzzer with a voice broadcast module could also enhance the reminder effect. These improvements could further enhance the functionality and user experience of the intelligent water cup.

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