

Design of an Online Water Quality Detection System Based on STM32

Wei Jin

Suzhou Vocational Institute of Industrial Technology, Suzhou, Jiangsu, 215104, China

Abstract

To address the problems of traditional water quality detection, such as reliance on manual sampling, long detection cycles, and insufficient real-time monitoring capability, a multi-parameter online water quality detection system based on the STM32F103C8T6 microcontroller is designed. The system integrates a DS18B20 temperature sensor, a turbidity sensor, and a pH detection module, together with an OLED local display module and an ESP8266 wireless communication unit, to realize real-time multi-parameter acquisition of water temperature, turbidity, and pH value. The alarm thresholds can be customized via push buttons; when a detected parameter exceeds the set range, an audible and visual alarm is triggered, and the water quality data are uploaded to terminal devices via WiFi. Physical test results show that the system features stable data acquisition and timely alarm response, and realizes both on-site monitoring and remote data viewing. With the advantages of low cost and convenient deployment, the system is suitable for simple water quality monitoring of small- and medium-sized water bodies and drinking water sources.

Keywords

Water Quality Detection; STM32F103C8T6; Wireless Monitoring.

1. Introduction

Water resources are the fundamental natural resource for human survival and social development. With the rapid advancement of industrialization and urbanization, industrial wastewater, agricultural non-point source pollution, and domestic sewage are continuously discharged into the aquatic environment. The risk of water pollution keeps increasing, which makes water quality and safety monitoring increasingly important. Traditional water quality detection mostly adopts the mode of manual sampling followed by laboratory analysis. Although its detection accuracy is relatively high, the sampling process is cumbersome and the detection cycle is long, making it difficult to achieve continuous in-situ monitoring or to respond quickly to sudden abnormal water quality events.

The rapid development of embedded and Internet of Things (IoT) sensing technologies is driving water quality monitoring toward automation and intelligence. Owing to their compact size, low power consumption, and outstanding cost-effectiveness, microcontroller-based water quality monitoring devices have become an important solution for small water bodies. However, some existing monitoring systems suffer from insufficient sensor integration, weak resistance to environmental interference, and relatively high remote transmission costs. To address these problems, this paper designs a multi-parameter water quality detection system based on the STM32F103C8T6, which acquires three core water quality parameters, namely temperature, turbidity, and pH, provides local screen display and an audible-visual alarm when thresholds are exceeded, and uploads data wirelessly via WiFi through the ESP8266 module. The system meets the needs of both on-site use and remote monitoring, and provides a low-cost technical solution for the online monitoring of small- and medium-sized water bodies.

2. Overall System Design

The system uses the STM32F103C8T6 as the main control unit and adopts a modular design approach. The hardware is divided into the main control unit, the sensor acquisition module, the human-machine interaction module, the audible-visual alarm module, and the wireless communication module[1]. The system block diagram is shown in Fig.1.

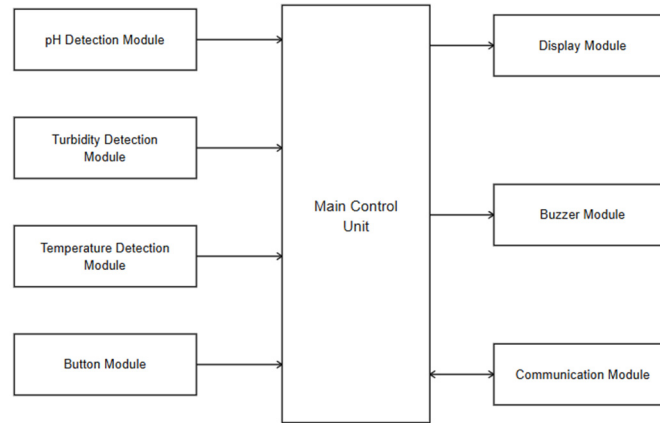


Fig 1. System block diagram

The main control unit is responsible for receiving the output signals of each sensor and performing data computation and logic judgment. The DS18B20 sensor acquires the water temperature, the turbidity sensor obtains the turbidity of the water based on the optical scattering principle, and the pH electrode module completes the acidity/alkalinity detection of the water. The push-button module is used to set the upper and lower alarm thresholds for temperature, turbidity, and pH. The OLED display shows the measured water quality values locally in real time. When any detected parameter exceeds the preset threshold, the audible-visual alarm unit composed of a buzzer and LEDs is activated. The ESP8266-01S WiFi module transmits the processed water quality data through the serial port, and a network debugging tool on a mobile terminal receives the monitoring data, realizing remote monitoring.

3. Hardware Circuit Design of the System

3.1. STM32F103C8T6 Minimum Control System

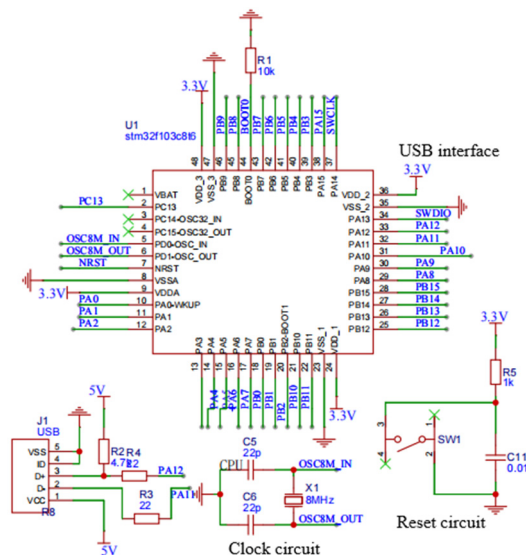


Fig 2. Circuit diagram of the MCU minimum system

The main control chip selected is the STM32F103C8T6, whose core is the Cortex-M3 with a maximum operating frequency of 72 MHz. The chip integrates multiple on-chip ADC, GPIO, and USART peripherals, which can satisfy the hardware resource requirements of multi-sensor acquisition and serial wireless communication. The circuit diagram of the STM32F103C8T6 minimum system is shown in Fig. 2.

The clock circuit adopts an 8 MHz external high-speed crystal (HSE) scheme. A parallel resonant circuit composed of crystal X1 and 22 pF load capacitors C5 and C6 provides the MCU with an accurate 8 MHz reference clock signal; after frequency multiplication by the internal PLL, a 72 MHz system clock is output, providing a synchronized timing basis for the CPU core and peripherals.

The reset circuit combines power-on automatic reset with manual push-button reset, and is implemented through a 1 k Ω pull-up resistor R5, a 0.01 μ F capacitor C11, and a tactile switch SW1. At power-on, the RC charge/discharge characteristic completes the initialization, and pressing the button forces a reset, ensuring that the system reliably returns to its initial state at startup or under abnormal conditions.

The hardware pin allocation of the MCU is as follows: the DS18B20 temperature sensor is connected to pin PC14; the analog signals of the turbidity and pH sensors are connected to the ADC acquisition pins; the OLED display uses I2C communication with PB8 as SCL and PB9 as SDA; the three function buttons are connected to ordinary GPIO pins; and the TXD and RXD pins of the ESP8266 module are connected to PA10 and PA9 of the MCU respectively, realizing TTL serial data exchange[2].

3.2. Sensor Acquisition Module Circuits

1) Temperature detection module: The temperature sensor uses a DS18B20 digital sensor with single-bus communication, a measurement range of -55 to +125 $^{\circ}$ C, and a measurement accuracy of ± 0.5 $^{\circ}$ C. Communication is completed over a single data line, and the peripheral circuit is simple. VDD is connected to the 5 V power supply and GND is grounded; the DQ data pin is connected to an I/O port of the MCU through a pull-up resistor, realizing bidirectional digital signal transmission without additional signal conditioning circuits, which makes it suitable for on-site water temperature acquisition[3]. The temperature detection circuit is shown in Fig.3. The sensor communicates with the main control chip through the single-bus protocol: the main control chip sends commands to control the DS18B20 to start temperature measurement and receives the returned measurement result.

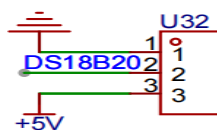


Fig 3. Temperature detection circuit

2) Turbidity detection module: The turbidity sensor works based on the optical scattering principle. The transmitter emits light into the water sample, the suspended particles in the water produce a scattering effect, and the receiving unit detects the change in light intensity and converts it into an analog voltage output. The more suspended impurities there are in the water, the stronger the scattered light intensity is, and the output voltage changes accordingly. The turbidity detection circuit is shown in Fig.4. Pin 1 of the module is connected to the 5 V supply voltage, pin 3 is grounded, and the analog output pin 2 is connected to the ADC channel (A02) of the STM32; the main controller reads the voltage signal and converts it into the turbidity value. R16 and R17 are current-limiting resistors, which prevent sensor damage or signal distortion caused by excessive current.

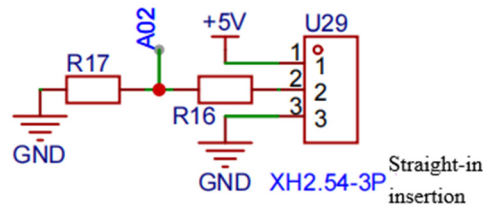


Fig 4. Turbidity detection circuit

3) pH detection module: The sensor of this module measures the hydrogen ion concentration in the water through the electrode and outputs a voltage signal proportional to the pH value. The change of the pH value causes a potential change at the electrode, and this potential change, after conversion, can reflect the acidity/alkalinity of the water quality in real time. The pH detection circuit is shown in Fig.5. Pin 1 of the module is connected to the 5V power supply; pin 2 is grounded; pin 3 is the digital output pin, which can provide a high or low signal and is suitable for simple threshold judgment, but it is not used in this circuit; pin 4 is the analog output pin, which is responsible for outputting the processed voltage signal to the ADC module of the STM32 microcontroller. The main controller converts the acquired voltage into the pH value, thereby realizing the detection of the acidity/alkalinity of the water.

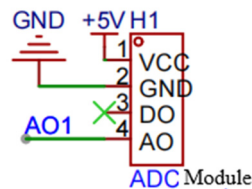


Fig 5. pH detection circuit

3.3. Human-Machine Interaction and Alarm Circuits

The human-machine interaction unit consists of a push-button module and an OLED display module. The button module has three independent tactile buttons: KEY1 switches the setting interface, KEY2 increases the parameter, and KEY3 decreases the parameter, completing the modification of the upper and lower alarm limits for temperature, turbidity, and pH. The button circuit is shown in Fig.6.

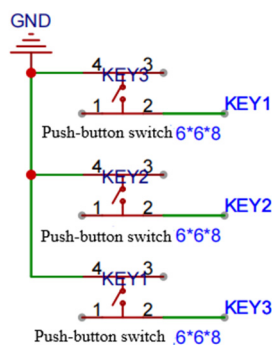


Fig 6. Button circuit

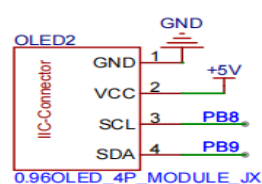


Fig 7. Display circuit

A 0.96-inch OLED display with an I2C interface is used. VCC is connected to 5 V, GND is grounded, and SCL and SDA realize the communication. It is used to display the measured water quality parameters and the threshold setting interface. The display circuit is shown in Fig.7.

The audible-visual alarm circuit is composed of a buzzer and LED indicators, as shown in Fig.8. When the main control I/O outputs a low level, the transistor is turned on, the buzzer sounds, and the LEDs light up; after the parameters return to the normal range, the I/O outputs a high level and the alarm is released.

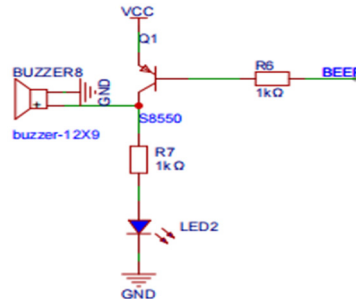


Fig 8. Audible-visual alarm circuit

3.4. ESP8266 Wireless Communication Module

The ESP8266-01S WiFi module realizes wireless transparent transmission, and its circuit is shown in Fig.9. Pin 1 of the module is connected to the 3.3 V power supply, and TXD and RXD are cross-connected to the serial port of the STM32. The EN pin is the enable pin of the module, and the RST pin realizes the hardware reset. The microcontroller sends the temperature, turbidity, pH, and abnormal status information to the ESP8266 through the serial port. After the module connects to the WiFi of the local area network, it sends the data to the TCP client, and the network debugging tool on the mobile phone receives the monitoring data, thus completing the remote monitoring[4].

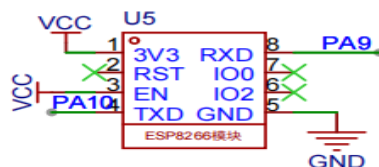


Fig 9. Communication circuit

4. Software Design of the System

The software is developed based on the STM32 standard peripheral library. The software program mainly includes system initialization, the sensor acquisition subroutine, the key scanning subroutine, the OLED display subroutine, the ESP8266 data transmission, and the threshold-judgment alarm program.

4.1. Main Program Flow

The Main Program Flow is shown in Fig.10. After power-on, the system completes the initialization of the system clock, GPIO, ADC, serial port, DS18B20, and OLED peripherals in sequence, and then enters the main loop: scan the key states and determine whether to enter the threshold setting mode; read the DS18B20 temperature data; read the ADC sampling values and convert them into turbidity and pH; output the data to the OLED; compare the measured values with the alarm thresholds, and trigger the audible-visual alarm if any parameter exceeds the limit; call the serial port sending function to deliver the water quality data to the ESP8266 for uploading to the terminal. The above process is executed cyclically[5].

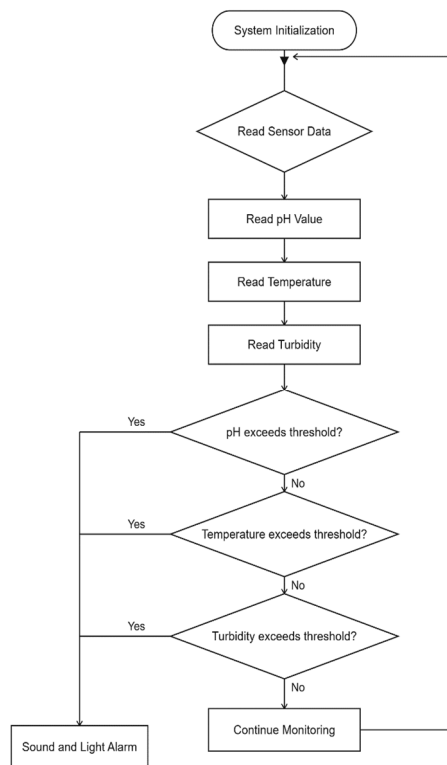


Fig 10. Main Program Flow

4.2. Functional Subroutines

1) DS18B20 temperature acquisition subroutine: completes the single-bus initialization, sensor reset, and presence detection, issues the temperature conversion command, reads the raw temperature data, and parses and converts it into the actual temperature.

2) Key scanning subroutine: cyclically reads the GPIO levels of the buttons with software debouncing. KEY1 cyclically switches among the setting interfaces of the temperature upper limit, the turbidity upper limit, and the upper and lower pH limits; KEY2 increases the parameter; KEY3 decreases the parameter, thereby completing the alarm threshold configuration.

3) OLED display subroutine: sends commands and display data based on the I2C protocol, realizing screen initialization, screen clearing, and character and number display; it distinguishes between the main monitoring interface and the threshold setting interface and switches the corresponding display content.

4) Data processing and alarm subroutine: performs average filtering on multiple groups of ADC samples to suppress noise, and converts the voltage sampling values into the physical quantities of turbidity and pH. When any of the following conditions is met, the temperature is higher than the upper limit, the turbidity is higher than the upper limit, or the pH exceeds the upper or lower limit, the audible-visual alarm is triggered.

5) ESP8266 communication subroutine: the microcontroller outputs the temperature, turbidity, pH, and the "normal/abnormal" status string through the serial port; the ESP8266 completes the WiFi transparent transmission and pushes the monitoring data to the TCP client.

5. Conclusion

This paper designs a multi-parameter water quality detection system based on the STM32F103C8T6 microcontroller, which realizes the acquisition of three water quality

parameters, namely temperature, turbidity, and pH, and provides an OLED local display, button-based threshold configuration, an audible-visual alarm on threshold exceedance, and ESP8266 wireless data upload. With the modular hardware design and clear software logic, the test of the complete machine shows that each module works stably and that the system can accomplish on-site water quality monitoring and remote data viewing.

The system has the advantages of low cost and convenient assembly and debugging, and is suitable for small ponds and simple drinking water monitoring scenarios. In the future, more water quality detection parameters such as dissolved oxygen can be added; the digital filtering algorithm can be optimized to reduce the interference of the environment on sensor sampling; a cloud platform can be connected to realize data storage and historical curve viewing; and a low-power design can be added to adapt to field battery power supply, so as to further expand the application scenarios of the system.

References

- [1] Wu, W. B. (2025). Design and research of an embedded water quality detection system. *Office Automation*, 30(24), 20–22.
- [2] Wang, J. N., & Hao, C. Z. (2024). Research on an intelligent water quality detection system based on STM32. *Equipment Management and Maintenance*, (20), 170–172.
- [3] Liu, Z. P. (2024). Design of a water quality detection system based on single-chip microcomputer technology. *Electronic Technology*, 53(10), 30–31.
- [4] Huang, T., Fang, Q., & Sun, Q. Y. (2024). Design of a multi-parameter water quality detection system based on single-chip microcomputer technology. *Application of Integrated Circuits*, 41(9), 22–25.
- [5] Ma, H. T. (2025). Design of an agricultural water quality detection system based on a single-chip microcomputer. *Hebei Agricultural Machinery*, (10), 24–26.