Design and Research of Water Quality Monitoring System Based on nRF24L01 Wireless Communication

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Abstract. To ensure health and safety, and understand the heavy metal content, residual chlorine content and pH value in water real-time, we designed a new intelligent water quality monitoring system based on STM32F103 micro control embedded system and nRF24L01 wireless communication module. The system uses a mode of master and slave station system program. As the master chip of the slave station, STM32F103 realizes the collection and data processing of heavy metal, chlorine, organic matter and microorganisms in the water through various sensors. At the same time, the nRF24L01 wireless communication module not only sends the data to the master station for displaying real-time, can also send the master station as a gateway to the mobile client.

1. Introduction
In recent years, with the rapid development of heavy industry and science technology, the problem of water pollution has become more and more serious. Health and safety problems caused by water pollution also occur frequently, so national water quality monitoring needs higher requirements and standards [1]. In the past, water quality monitoring systems have the disadvantages of complicated wiring, high cost, poor real-time performance, and contingency, which are difficult to widely use. Therefore, we designed a new intelligent water quality monitoring system to assist the original monitoring system to achieve more comprehensive water quality monitoring. The system includes the characteristics of automation, intelligence and network. It uses sensors to form distributed nodes, which can perform real-time multi-point water quality monitoring on reservoirs, rivers and lakes [2].

2. Overall system design
The water quality monitoring system we designed includes two parts: the master station and the slave station. The slave station mainly uses STM32F103 embedded system as the main control chip, and uses various common sensors such as residual chlorine sensor, TOC sensor, conductivity sensor, ORP sensor, turbidity sensor, PH sensor, etc. to detect residual chlorine and heavy metal, organic pollutant content and pH value in water, and collect and process these data. The slave transmits data to the master station device through the nRF24L01 wireless communication module [3], and the nRF24L01 wireless communication module of the master station is configured to accept the mode, and the data of the slave station is received and transmitted to the control device. The control system of the master station can also use STM32F103 as the main control chip, or use other types of control chips such as...
STC15F2K60S2. The master station can not only display the received data by using the display device, but also send it to the mobile phone client through the gateway to realize online real-time monitoring [4]. The system structure is shown in Fig.1.

![System Structure Diagram](image)

**Figure 1.** Overall structure of the system structure.

### 3. Basic design

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#### 3.1. Sensor module

As the sensing component of this intelligent system, the sensor is the primary device for automatic water quality detection and automatic control. This system uses various types of sensors to detect harmful components in water. For example, CLE3-DMT residual chlorine sensor is used to detect free chlorine and monochloramine, the US Global Water PH sensor is used to detect water PH, TCS3000 ring conductivity sensor is used to detect heavy metal ions, SE-564-ORP sensor is used to detect organic pollutants, etc. The analog signal collected by the sensor is transmitted to the STM32F103 MCU in the form of a digital signal after passing through the ADC0809 analog-to-digital conversion chip. The STM32F103 MCU controls the wireless communication module in the form of commands based on the signals collected by the sensor.

#### 3.2. NRF24L01 wireless communication module

NRF24L01 is a wireless transceiver chip for global wireless communication produced by NORDIC. Its working frequency range is 2.400-2.525GHz. This band is a global open frequency band, which can avoid low frequency signals and various household appliances interference [5]. The nRF24L01 has a
fast transfer rate of up to 8Mbps. In addition, the nRF24L01 includes a frequency synthesizer, power amplifier, crystal oscillator, demodulator, modulator, and enhanced Shock Burst(TM) mode controller. It also includes 126 communication channels and 6 data channels, which can meet the needs of multi-point communication and frequency modulation. The output power, frequency channel and protocol can be set through SPI interface programming, and can be connected and operated with almost any single chip microcomputer. Furthermore, its current consumption is also extremely low. When the transmit power of the selected transmit mode is 0dBm, its current consumption is 11.3mA, and in the receive mode is 12.3mA. The current consumption in the power-down mode and standby mode will be lower, only 900nA. After the nRF24L01 receives the data, it introduces the core module's program into the interrupt through the interrupt pin IRQ, and then reads the data from the wireless module RXFIFO register. The application circuit of the specific nRF24L01 chip is shown in Fig.2.

Figure 2. NRF24L01 chip practical application schematic.

3.3. STM32F103 microcontroller

Microcontrollers play an important role in controlling the processing operations, communication protocols, power consumption management, etc. of the entire system. As the main control chip, its model selection is crucial in the overall system design. Considering the advantages of low operating voltage, low power consumption, fast computing speed and simple programming, the STM32F103 microcontroller is selected in this design. The STM32F103 microcontroller is produced by STMicroelectronics. Its core is ARM's new generation of 32-bit low-cost, high-performance general-purpose microcontroller Cortex-M3, which is fast, up to 72MHZ. Besides, the power consumption is low, and there are three modes of sleep, standby, and shutdown. Moreover, self-contained NRF24L01 interface, SPI interface, on-chip flash512k, 80 GPIOs, 8 timers, 2 12-bit digital-to-analog converters and 3 12-bit analog-to-digital converters make it easy to achieve wireless communication and parameter conversion, and processing. Data acquisition can choose SD card storage, GPS receiver module, and other various types of sensing modules. The wireless module can automatically generate the preamble
and perform CRC check. After sending the data, the IRQ notifies the STM32 to jump out of the interrupt routine. Furthermore, in the case of different modes, the STM32 can access the FIFO memory, store the data first, and then transfer the data to the STM32 for processing by the SPI. In addition to the above functions, STM32F103 can be compiled by KEIL environment, and can be programmed by serial port, JLINK and STLINK. It is simple and easy to implement program design and programming.

3.4. Transmission mode

The system we designed uses STM32F103 chip to control the nRF24L01 wireless communication module [6]. The specific steps are as follows: (1) Give the CE pin a low level and CSN high level to enter the configuration mode. (2) The transmit address is accepted to be written to the local register at intervals. (3) Select channel 0 to enable ACK response. (4) Set the working frequency, transmission data length and transmission speed. The selected working frequency is 2.400 GHz, the data length is 32 bytes, and the speed is 2 Mbit/s. (5) Configure registers to set parameters such as operating mode and interrupt. (6) Configure CE to a high level to put it into transmit mode. The principle of the data acceptance mode is basically the same as the principle of the transmission mode, and the acceptance mode is also selected by giving the pin a level entry mode configuration. The specific process can be seen in Fig.3 and Fig.4.

Figure 3. Transmission mode.

Figure 4. Acceptance mode.
4. Text System debugging results
Debugging is an integral part of the overall system development and design process and an important step in ensuring system quality and performance. This time, the drinking water was monitored in a certain area of Hainan Province, China, and the results of the water quality monitoring system were shown in the Fig5. After the system is powered on, the liquid crystal display will show the detection results of various parameters. Based on the results shown, we can clearly see the safety of the water quality. In addition to viewing through the display, it can also be sent to the mobile client for online monitoring.

![Figure 5. The results of water quality monitoring system.](image)

5. Conclusion
Water quality monitoring system is an important part of national drinking water safety management and a major factor affecting human health and safety. In a big social environment where material needs are gradually being met, more people are pursuing a healthy life, and the requirements for water quality are getting higher and higher. We designed this intelligent water quality monitoring system based on the high-performance STM32F103 embedded system and the low-power nRF24L01 wireless communication module. Users can use the mobile phone to realize online real-time monitoring of various parameters in water quality. The system does not require wiring, and has the advantages of good versatility, strong practicability, and stable performance. It can also achieve wireless communication, and in the case of an external antenna, wireless communication within a range of 200 meters can be achieved [7]. The system has been successful in water quality monitoring experiments. If it is further researched and developed, it is likely to be widely used in water plants, food, chemical, metallurgy, environmental protection and pharmaceutical industries.

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