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Design of an Online Water Quality Monitoring System for Aquaculture

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Abstract: This article introduces an online water quality monitoring system for aquaculture. Its data acquisition module collects water quality data through dissolved oxygen, temperature, turbidity, conductivity, and pH sensors. The data processing module uses specific algorithms to process the data, such as applying temperature compensation to conductivity readings to improve accuracy, and also filters, classifies, and stores the data. The data communication module employs the ESP8266 wireless communication module to achieve remote transmission. The monitoring center, through an APP, enables real-time remote monitoring and analysis of the data, and sends alerts when values exceed thresholds, thereby facilitating intelligent aquaculture for farmers.

Keywords: online water quality monitoring for aquaculture; water quality sensors; wireless communication module; mobile APP

INTRODUCTION

The aquaculture industry, as a key pillar industry of the national economic system, holds significant strategic value in its vigorous development. As the limitations of traditional aquaculture models become increasingly evident—such as relatively low production efficiency and difficulties in operation and management [1].traditional farming methods are gradually fading from the historical stage, and the development of modern aquaculture is moving towards intelligent farming [2].

Environmental factors play a crucial role in aquaculture. If a certain growth index exceeds a specific value, it can lead to negative consequences for aquatic organisms, such as significantly slowed growth rates or even mass mortality [3]. Therefore, water quality parameters are of great importance in aquaculture. Among these parameters, key indicators such as dissolved oxygen, water temperature, turbidity, conductivity, and pH must all have strict thresholds.

This system is an online water quality monitoring system for aquaculture, constructed by integrating temperature, dissolved oxygen, pH, turbidity, and conductivity sensors, along with a wireless communication module, a main control unit, and real-time monitoring via a mobile APP. It enables real-time collection and transmission of water quality parameters, achieves data visualization, and preliminarily realizes intelligent aquaculture.

1. Overall System Design Scheme

The system mainly consists of an STM32F103C8T6 micro controller, various water quality sensor modules, an OLED display module, a power module, and a wireless communication module. By programming the STM32 micro controller, each module is enabled to perform its respective functions. Among these, the main control module is the core part of the entire online water quality monitoring system for aquaculture, controlling all other parts except the power supply. The water quality sensor modules include a dissolved oxygen sensor module, a DS18B20 temperature sensor module, a pH sensor module, a conductivity sensor module, and a turbidity sensor module. The display module is an OLED screen, used for data visualization. The power module provides a stable power supply for this online water quality monitoring system for aquaculture. The ESP8266, serving as the wireless communication module, connects to the mobile APP, thereby fulfilling the function of remote monitoring of water quality parameters.

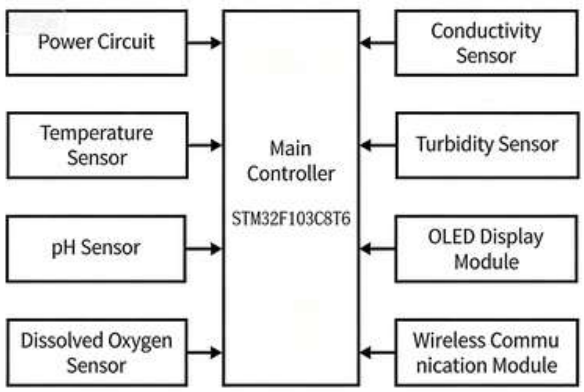

Figure 1-1 Overall System Framework Diagram

2. System Hardware Circuit Design

2.1 Micro processor

A micro processor is essentially a micro controller unit (MCU). Since the micro controller is the core component of the online water quality monitoring system for aquaculture, selecting an appropriate micro controller is particularly important. Currently, the main micro controllers available on the market are the STC series (belonging to the 51 series) and the ARM series (STM32). Therefore, when making a selection, it is necessary to compare the performance of these four types of micro controllers from multiple aspects to choose the one suitable for this system. The following table compares the four models of micro controllers. Based on the design requirements of this online water quality monitoring system for aquaculture, this study systematically evaluates the technical selection criteria from five dimensions: first, the richness of resources is examined, as it directly affects functional development; second, the system's scalability is assessed, because strong expandability facilitates flexible integration of peripheral resources; third, the completeness of open-source resources is analyzed, as sufficient open-source materials can significantly shorten the development cycle; fourth, cost control factors are considered, since lower implementation costs are beneficial for subsequent market promotion of the product; finally, system stability is verified, as excellent stability can effectively reduce the equipment failure rate.

Table 2-1 Micro controller Comparison

Type	51	ARM	ARM
Model	STC89C52	STM32F407	STM32F103
Frequency	8MHz	168MHz	8MHz
Bit	8-bit	32-bit	32-bit
Flash	2K	1024K	128K
RAM	512B	192K	64K
Pin	40	144	48
ADC	2	3	2
PWM	0	2	2

After a comprehensive comparison, this system selects the STM32F103C8T6 micro controller produced by STMicroelectronics. It features rich resources, strong expandability, abundant open-source resources, relatively low cost, and high stability. Due to its abundant on-chip resources, the STM32F103C8T6 micro controller can also provide interfaces for peripheral devices and ample on-chip resources for subsequent functional design. This micro controller also possesses numerous built-in peripherals and relatively high processing capabilities, including multiple communication interfaces (such as UART, I²C, USB, CAN, SPI), a 12-bit ADC, timers, and a CPU with an operating frequency of up to 72 MHz [4].

2.2 Micro controller Peripheral Circuit Design

This paper designs an online water quality monitoring system for aquaculture based on the STM32F103RCT6 micro controller. Figure 2-1 shows the circuit diagram of its CPU minimum system. This circuit mainly consists of the STM32F103C8T6 and also includes peripheral circuits required for the micro controller's operation, such as the crystal oscillator and filter circuit.

(1)Crystal Oscillator Circuit: The crystal oscillator circuit is composed of an 8 MHz crystal oscillator and two 20pF capacitors. The function of the crystal oscillator is to provide a stable operating signal for the STM32 micro controller to enable control of its various functions. The pulses of this operating signal represent the speed at which the micro controller operates. By controlling the various external modules and enabling their interaction, it facilitates the realization of the entire system's functions. The crystal oscillator forms an oscillation circuit with the STM32's OSC_IN pin and OSC_OUT pin. During its oscillation process, a certain amount of inductance is generated, which can decrease the stability of the clock oscillator. Therefore, two 20pF capacitors are connected across the crystal oscillator to eliminate the interference of this inductance on the micro controller's operation.

(2)Filter Circuit: The filter circuit consists of capacitor elements C13, C14, and C15. The filter circuit effectively suppresses high-frequency noise components and interference signals.

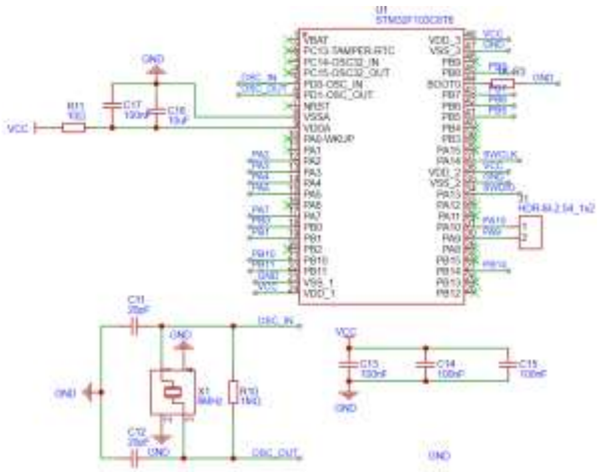

Figure 2-1 CPU Minimum System Circuit Schematic Diagram

2.3 Power Supply Module Design

The power supply module circuit is shown in Figure 2-2. The input power is converted to the main power supply. The system input power is 5V, which is then regulated to output a voltage of 3.3V to power the micro controller and low-power peripherals. First, through the USB Type-C interface, the 5V external power supply is connected to the system via the VBUS interface. Then, the voltage conversion is completed through the AMS1117-3.3 voltage conversion circuit, obtaining a stable 3.3V voltage value. Finally, a power indicator circuit, constructed with a current-limiting resistor R1 and an LED, is integrated to form the power supply module for the micro controller.

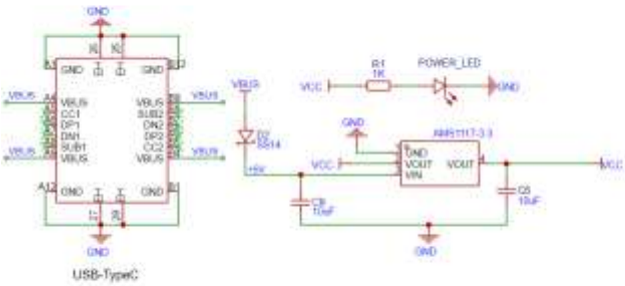

Figure 2-2 Power Supply Module

2.4 Buzzer Module Circuit Design

The buzzer module is a key part of this design. This module can respond promptly when water quality parameters are abnormal. The circuit schematic diagram of the buzzer module is shown in Figure 2-3. Its VCC pin is connected to the power supply, the GND pin is connected to ground, and the input/output port is connected to PB1.

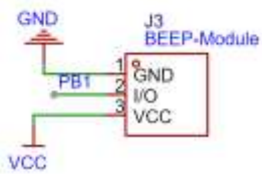

Figure 2-3 Buzzer Module

2.5 Display Module Circuit Design

The display module is a key part of this design. The OLED display module is selected for this design, which enables the visualization of water quality parameters. The circuit schematic diagram of the OLED display module is shown in Figure 2-4. Its VCC pin is connected to the power supply, the GND pin is connected to ground, the serial clock line SCL is connected to PB8, and the serial data line SDA is connected to PB5.

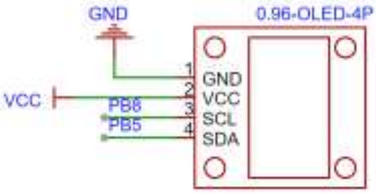

Figure 2-4 OLED Display Circuit Schematic Diagram

2.6 Wireless Communication Module Design

The wireless communication module is also a key component of this design. The ESP8266 wireless communication module is selected for this design, which enables the remote communication function for water quality parameters. The circuit schematic diagram of the ESP8266 wireless communication module is shown in Figure 2-5. The 3V3 pin is connected to the VCC power supply, the GND pin is connected to ground, the RX receive pin is connected to PA2, and the TX transmit pin is connected to PA3.

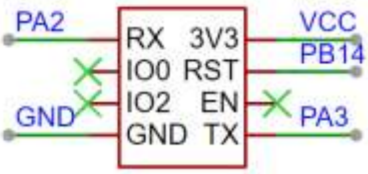

Figure 2-5 ESP8266 Module Circuit Schematic Diagram

2.7 Multi-Channel Sensor Module Circuit Design

2.7.1 DS18B20 Temperature Sensor Module Circuit Design

The temperature sensor module is an important component of the multi-channel sensor module, and its performance directly affects water quality detection. This design selects the DS18B20 digital temperature sensor to achieve accurate water temperature measurement. The DS18B20 temperature sensor has unique advantages and operating principles. The circuit schematic diagram of the DS18B20 temperature sensor module is shown in Figure 2-6. The VCC pin is connected to the +5V power supply, the GND pin is connected to ground, and the TEMP pin I/O port is connected to PB7.

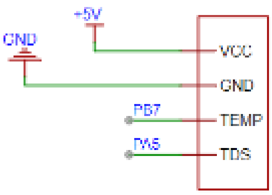

Figure 2-6 DS18B20 Module Circuit Diagram

2.7.2 Dissolved Oxygen Sensor Module Circuit Design

The dissolved oxygen sensor module is also an important component of the multi-channel sensor module. The concentration and saturation level of dissolved oxygen detected by this module directly affect aquaculture production. This design adopts the fluorescence method dissolved oxygen sensor to achieve accurate detection of dissolved oxygen concentration and saturation. The circuit schematic diagram of the fluorescence method dissolved oxygen sensor is shown in Figure 2-7 (the left side controls transmission and reception, while the right side is responsible for serial communication). The VCC pin is connected to the +5V power supply, the GND pin is connected to ground, the 485-A pin is connected to PB10, and the 485-B pin is connected to PB11.

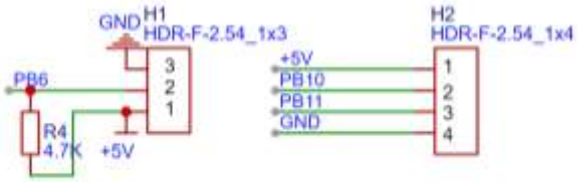

Figure 2-7 Dissolved Oxygen Module Circuit Diagram

2.7.3 PH Sensor Module Circuit Design

The pH sensor module is also an important component of the multi-channel sensor module. In this design, the E-201-C pH sensor is selected to achieve accurate pH value detection. This sensor has unique advantages and operating principles. The circuit schematic diagram of the E-201-C pH sensor is shown in Figure 2-8. Its VCC pin is connected to the +5V power supply, its GND pin is connected to ground, and its PO pin is connected to PA4.

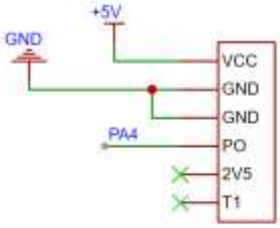

Figure 2-8 PH Module Circuit Diagram

2.7.4 Conductivity Sensor Module Circuit Design

The conductivity sensor module is also an important component of the multi-channel sensor module. In this design, the TDS conductivity sensor is selected to achieve accurate detection of electrical conductivity. The circuit schematic diagram of the TDS conductivity sensor is shown in Figure 2-9. Its VCC pin is connected to the +5V power supply, its GND pin is connected to ground, and its TDS pin is connected to PA5.

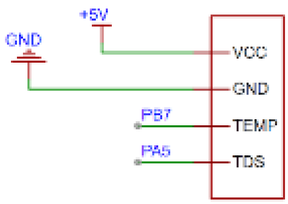

Figure 2-9 TDS Module Circuit Diagram

2.7.5 Turbidity Sensor Module Circuit Design

The turbidity sensor module is also an important component of the multi-channel sensor module. In this design, the TS-300B turbidity sensor is selected to achieve accurate detection of turbidity. The circuit schematic diagram of the TS-300B turbidity sensor is shown in Figure 2-10. Its VCC pin is connected to the +5V power supply, its GND pin is connected to ground, and its AO pin (which outputs an analog signal) is connected to PA7.

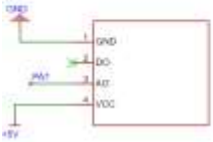

Figure 2-10 Turbidity Module Circuit Diagram

2.8 Chapter Summary

This chapter focuses on the hardware design implementation of the online water quality monitoring system for aquaculture. The system adopts the STM32F103C8T6 as its core controller and has maximized the utilization of the chip's I/O port resources, essentially covering all available pins of the micro controller. Subsequently, appropriate sensor modules were selected based on system requirements to detect critical water quality parameters in aquaculture, such as dissolved oxygen, pH, temperature, conductivity, and turbidity, along with a wireless communication module to enable remote monitoring of these water quality parameters.

3. Software Design

3.1 Main Program Design

The flowchart of the micro controller main control program designed in this paper is shown in Figure 3-1. The system primarily collects water quality parameters through various sensors, which are then processed and displayed on the OLED, and subsequently uploaded to the cloud server via the ESP8266 module. The software design encompasses the overall system flow as well as the program logic for each sensor and the ESP8266 module. The various modules of the system work collaboratively, with each sensor responsible for data acquisition and the ESP8266 module handling data upload. Based on the collected water quality parameters—dissolved oxygen, pH, turbidity, water temperature, and conductivity—the display data on the OLED is updated in real-time. Furthermore, data interaction with the mobile APP is achieved, presenting various water quality parameter information in a data visualization format.

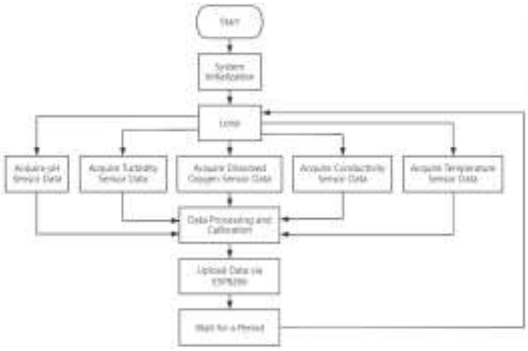

Figure 3-1 Turbidity Module Circuit Diagram

3.2 MQTT Transmission Protocol Program Design

As shown in Figure 3-2, the wireless network module connects to the client cloud APP via MQTT, with its main function being data collection and publication. The terminal first needs to transmit data to the broker server on the cloud platform. Before sending messages, it must establish a connection with the broker server. Once established, it sends connection requests to the Alibaba Cloud platform and the cloud APP. After authorization verification, the terminal encapsulates the message topic, message content, and QoS value according to the MQTT format [5]. It then sends the data to the message broker, awaits acknowledgment of this message, and feeds it back to the message broker, thus completing the data publication.

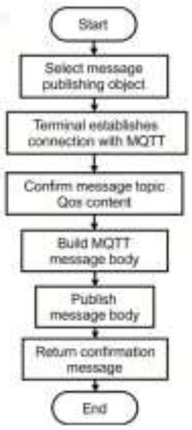

Figure 3-2 MQTT Communication Establishment Program Flowchart

3.3 Alibaba Cloud Platform Development

This online water quality monitoring project for aquaculture was created on the Alibaba Cloud IoT Platform. Through the Alibaba Cloud platform, the creation of products and devices, as well as the development of the APP interface, were completed. The specific implementation steps include: product creation, function definition, human-machine interaction, and device debugging.

4. Experimental Results

4.1 System Testing Results

During the hardware and software debugging of the online water quality monitoring system for aquaculture, all hardware devices must first be checked, including the micro controller, sensors, buzzer, display screen, wireless communication module, and power supply. Inspect the solder joints on the PCB board to ensure they are secure and verify the correctness of the wiring. Before turning on the power, confirm that all interfaces are properly connected and that there is no risk of short circuits. Then, turn on the power switch and check whether the power indicator and other relevant indicator lights are operating normally, as shown in Figure 4-1.

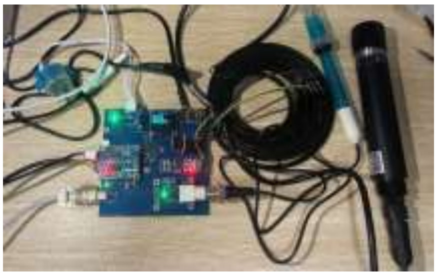

Figure 4-1 System Hardware Testing Diagram

4.1.1 OLED Screen

The content displayed on the screen is shown in Figure 4-2. The first line of the screen displays the actual pH value, the second line displays the actual conductivity value, the third line displays the actual turbidity value, the fourth line displays the actual temperature value, the fifth line displays the actual dissolved oxygen saturation value, and the sixth line displays the actual dissolved oxygen concentration value.

Figure 4-2 OLED Screen Display Diagram

4.2 System Software Testing Results

The software part of the online water quality monitoring system for aquaculture is presented in the form of a mobile APP. It has two functions: online water quality monitoring and setting thresholds for each sensor, meeting users' needs for remote monitoring of water quality information in aquaculture. First, connect the mobile APP to the wireless communication module of the hardware. After successful pairing, enter the page to directly view dynamic, changing data of pH value, TDS value, NTU value, water temperature, dissolved oxygen saturation, and concentration. The software interface implementation is shown in Figure 4-3.

Figure 4-3 System Software Testing Diagram

5. Conclusion

This research primarily focuses on developing an online water quality monitoring system for aquaculture. The function of online monitoring of water quality parameters in aquaculture has been achieved. Through debugging and practical use of the system, its performance has basically met the expected indicators. Meanwhile, the system has proven to be stable and reliable during long-term operation, offering certain practical value in production practice. The key results include:

(1)This research designed a set of online water quality monitoring devices for aquaculture based on the STM32 microcontroller. Through the collaborative work of the DS18B20 temperature sensor, TDS conductivity sensor, pH sensor, dissolved oxygen sensor, and NTU turbidity sensor, real-time synchronous acquisition of several key indicators—water temperature, conductivity, pH, dissolved oxygen, and turbidity—was achieved, addressing the issues of insufficient coverage and data lag associated with traditional sampling methods.

(2)In this study, through the application of the ESP8266 wireless communication module, water quality parameters in aquaculture can be transmitted in real-time to a mobile APP via mobile data, enabling remote real-time monitoring of water quality parameters. The threshold warning function of the monitoring center can automatically trigger local audible and visual alarms when water quality anomalies occur.

6. ACKNOWLEDGMENTS

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