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Wetland Water Quality Detection System Based on STM32

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Abstract

The wetland water quality real-time detection system designed in this article can detect pollution data in nature reserves such as wetlands in real time, solving the problems of difficult data statistics and slow update speed in pollution detection systems, enabling relevant departments to respond more quickly and conveniently to pollution problems. The design adopted STM32 MCU, combined with pH value sensor, turbidity sensor, TDS sensor, liquid level sensor and so on to achieve real-time collection of various water quality data in the test area. And then, the system can send monitoring data to cloud servers such as Alibaba Cloud through IoT chips such as ESP32 or ESP8266 for remote real-time monitoring. From the above design, it can solve the current problems, including heavy workload, cumbersome steps, time-consuming and labor-intensive testing, inability to achieve uninterrupted access to water quality information, and poor timeliness of manual testing, improving the poor connection between data at different detection points at different times and the inability to intuitively see the changes in water quality over time and location. The modular design of the system not only ensures the stability and reliability of the system, but also achieves flexible application and on-demand customization, which has broad promotion prospects.

Keywords

STM32; pH value; TDS; ESP32; Internet of Things.

1. INTRODUCTION

With the continuous deterioration of the global environment, water quality issues in wetlands and nature reserves are increasingly causing concern. Wetlands are one of the most abundant ecosystems on Earth. They are not only the home of numerous wild animals and plants, but also play a crucial role in purifying water resources and maintaining ecological balance. However, wetland ecosystems face a series of threats, including factors such as urbanization, pollution, climate change, and excessive development, which have led to serious damage to wetland water quality. In order to better protect the water quality of wetlands and nature reserves, we need advanced monitoring systems to monitor and evaluate the health status of water bodies in real-time. To address this challenge, we have designed a wetland water quality detection system based on the STM32 main control chip. This system utilizes various sensor technologies, including pH sensors, temperature sensors, humidity sensors, turbidity sensors, and liquid level sensors, to comprehensively measure various parameters of wetland water bodies. In addition, we have also adopted Internet of Things technology to upload data to the cloud through modules such as ESP32, enabling remote access and real-time analysis of monitoring data, providing more powerful support for environmental protection work. This wetland water quality detection system not only represents an innovative technological achievement, but also an active exploration in the environmental protection industry. Through

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our efforts, we hope to provide more reliable and efficient tools for water quality protection in wetlands and nature reserves.

2. THE WORKING PRINCIPLE OF THE SYSTEM

The system uses STM32 as the main control chip, and uses communication buses such as IIC and SPI to measure water quality data in natural reserves such as wetlands, along with pH sensors, temperature sensors, humidity sensors, turbidity sensors, and liquid level sensors. It also uses ESP32 IoT chips to upload monitoring data to the cloud and save it on the server. The upper computer accesses the server to obtain historical monitoring data for analysis, Display the analysis results and original monitoring data in a graphical GUI interface.

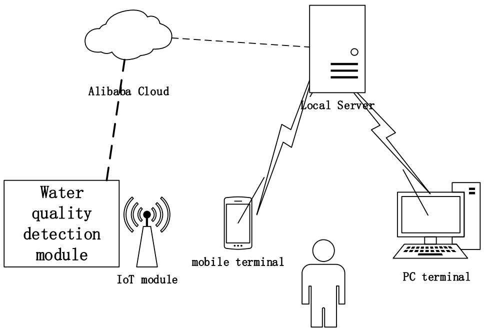

Figure 1. Working principle of the system

3. HARDWARE DESIGN

The hardware of the detection device consists of a CPU module, pH value acquisition module, turbidity acquisition module, SHT30 module, liquid level acquisition module, DCDC power supply module, communication module, display module, etc. The hardware block diagram is shown in Figure 2.

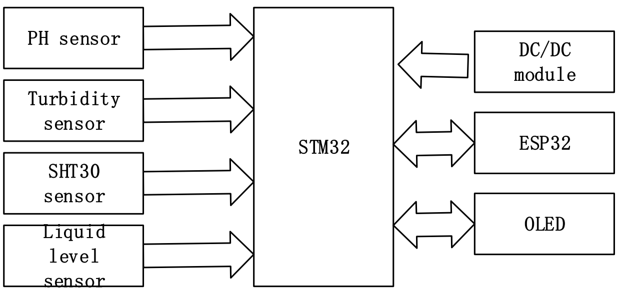

Figure 2. Hardware Block Diagram

3.1. CPU Module

STM32F103C8T6, A 32-bit microcontroller chip produced by STMicroelectronics based on the ARM Cortex-M3 core. It has high performance and low power consumption characteristics. This makes it suitable for handling complex tasks while maintaining energy efficiency. This chip provides a variety of peripherals, including general-purpose input/output pins (GPIO), analog-to-digital converters (ADC), timers, serial communication interfaces (SPI, I2C, USART, etc.), etc. These peripherals can be used to connect and interact with various sensors and communication modules. It is a cost-effective microcontroller suitable for various budgets. As a powerful microcontroller chip, it provides the necessary performance, memory, and peripherals to support data collection, processing, and communication while maintaining energy efficiency, which is crucial for applications that run in natural environments for a long time.

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3.2. PH value acquisition module

The circuit of the pH value acquisition module is shown in the following figure. This module is connected to the PH composite electrode through BNC connectors, and has an extended DS18B20 temperature sensor interface, making it convenient for software temperature compensation design. Adjusting the knob of the 10K blue potentiometer can adjust the magnification (clockwise adjustment to increase, counterclockwise adjustment to decrease). An analog voltage with an output voltage of 0-5V is converted into a pH value through AD acquisition. The signal output from both ends of the signal electrode and reference electrode of the composite pH electrode is voltage. At a fixed temperature, as long as the voltage value is known, the pH value of the solution can be calculated. The measurement of pH value is actually the measurement of voltage signal, and the signal acquisition circuit is the foundation of other work. Due to the high internal resistance of the composite pH electrode, the key to the measurement circuit is to achieve high impedance input. The operational amplifier is required to have high input impedance. Generally, the internal resistance of the glass electrode can reach up to 102, which means that the correct voltage signal can only be obtained when the input impedance of the operational amplifier is higher than the internal resistance of the sensor, The selection of TLC4502 high-performance high impedance operational amplifier (with an input impedance of 10'Q at room temperature of 25C and powered by a single power supply) greatly reduces the requirements for the power supply and provides the possibility for portable products.[1]

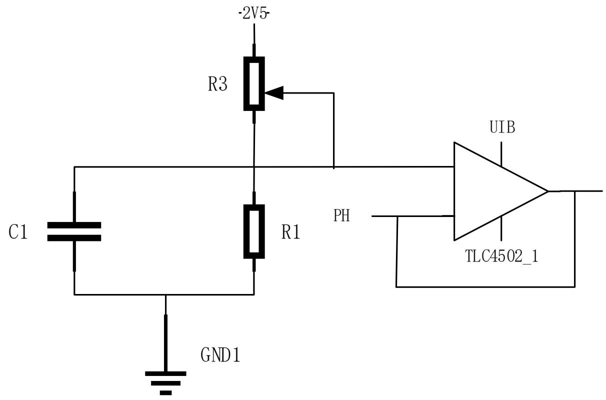

Figure 3. Voltage following circuit

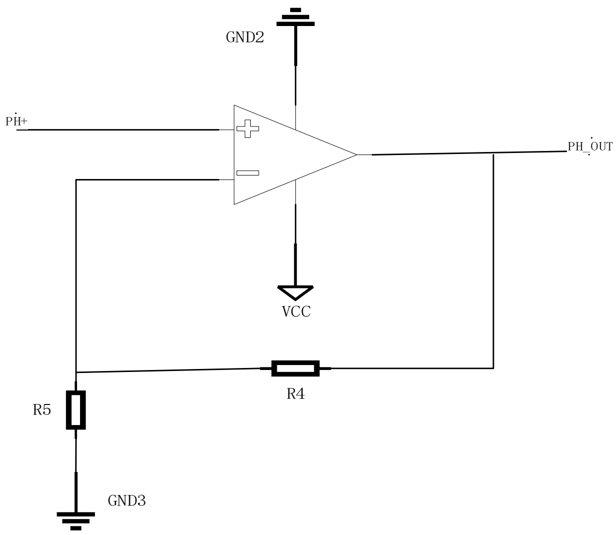

Figure 4. Signal amplification circuit

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3.3. Turbidity Collection Module

The turbidity sensor module converts the current signal output by the sensor into a voltage signal, and processes the AD conversion data through a microcontroller. The modified module has analog and digital output interfaces. The analog quantity can be sampled and processed through a microcontroller A/D converter to obtain the current water turbidity. [2] The digital quantity can be adjusted by the potentiometer on the module to trigger the threshold. When the turbidity reaches the set threshold, the D1 indicator light will be turned on, and the sensor module output will change from high level to low level. The microcontroller monitors the changes in the level to determine whether the turbidity of the water exceeds the standard, thereby warning or linking other devices. This module is connected to the turbidity sensor through a 3Pin XH-2.54 connector. Adjusting the knob of the 10K blue potentiometer can adjust the triggering threshold of the digital output.

The turbidity value meets the following relationship with the module output voltage:

$$TU = -865.68 \times U + K$$

In the above equation, TU is the current turbidity value, U is the output voltage value of the module under the current temperature conditions, and K is the intercept value, which needs to be obtained through calibration methods.

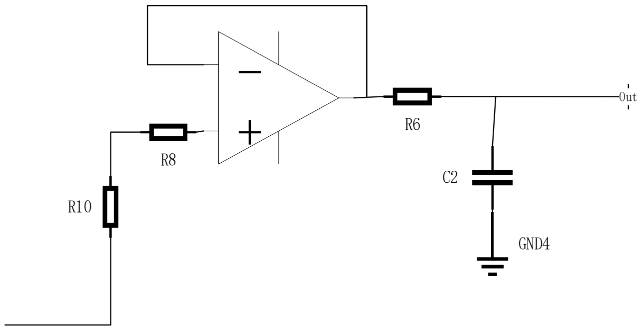

Figure 5. Output circuit

3.4. SHT30 temperature sensor

The SHT30 temperature and humidity sensor in this module is a digital temperature and humidity sensor. It is a part of the SHT series of sensors specifically designed to measure temperature and humidity in the environment.

Temperature measurement range: -40 ° C to+125 ° C, humidity measurement range: 0% to 100%.

Accuracy: Temperature accuracy: usually ± 0.3 ° C, humidity accuracy: usually ± 2% relative humidity.

SHT30 uses the I2C (Inter Integrated Circuit) communication protocol and can be easily integrated into various digital circuits. Provide digital temperature and humidity values for easy reading and processing by microcontrollers or microprocessors. Moreover, SHT30 has excellent anti-interference performance and can work under harsh environmental conditions, including high humidity and pollution. Sensors have fast response time and are suitable for applications that require real-time temperature and humidity measurement. The SHT30 sensor has low power consumption characteristics and is suitable for portable devices and battery powered applications.

SHT30 temperature and humidity sensors are widely used in various application fields, including meteorological stations, indoor air quality monitoring, greenhouse environment

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monitoring, industrial automation, medical equipment, and Internet of Things (IoT) equipment. Its high accuracy, digital output, and reliability make it a wide choice for temperature and humidity sensors, especially in systems that require precision and performance.

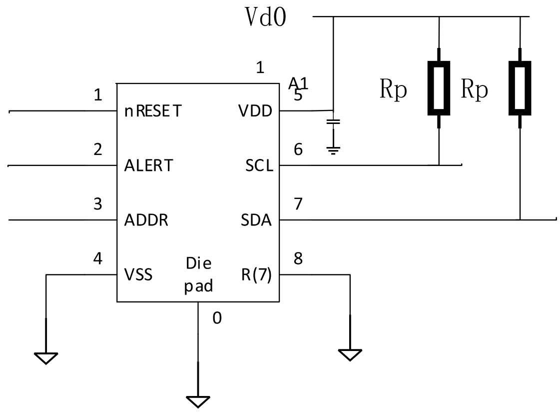

Figure 6. SHT30 circuit

3.5. Liquid level sensor

This module uses ultrasonic ranging to collect liquid level information. The ultrasonic ranging module is a sensor used to measure distance, which determines the distance between objects and sensors by sending ultrasonic pulses and measuring their echoes. Its principle is similar to that of bats or dolphins sending ultrasonic signals and locating targets by receiving echoes. The ultrasonic transmitter emits an ultrasonic signal in a certain direction of space, and when encountering obstacles on the way, the ultrasonic signal will be reflected, and the sound wave will immediately return along the original path. If the timing starts at the moment the ultrasonic signal is transmitted and stops immediately at the moment the ultrasonic receiver receives the reflected signal, taking half of the time difference can obtain the actual distance between the ultrasonic passing through the emission point and the obstacle. [3] At the same time as the launch, the timing starts. When the ultrasonic waves propagate in the air and encounter obstacles, they immediately return, and the ultrasonic receiving end stops the timing immediately upon receiving the reflected waves. The propagation speed of ultrasound in the air is v, which is 344 m/s at room temperature. According to the time difference recorded by the timer between the ultrasonic transmitter and receiver can determine the distance. [4] The ultrasonic distance measurement module can perform non-contact distance measurement and is suitable for various objects, including liquids, solids, and objects with different surfaces. These sensors typically have good distance measurement accuracy and can be used for precise measurements. The ultrasonic ranging module usually has an adjustable ranging range, and users can set the maximum and minimum distance for ranging according to their needs. Ultrasonic sensors can provide real-time distance measurement and are suitable for applications that require rapid feedback. These sensors are widely used for measuring liquid levels, object positions, and distances, as well as for automatic control systems.

3.6. DCDC Power module

The DC-DC power module is used to convert the input DC voltage into the required output voltage. This voltage can be higher, lower, or equal to the input voltage. This voltage conversion is usually achieved through a switching power supply circuit. This module has high efficiency and can minimize energy loss, which is crucial for battery powered equipment and energy sensitive applications. And it has adjustable output voltage, which can be set by adjusting some parameters.

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This module provides stable output voltage and can maintain consistent voltage output during input voltage fluctuations or load changes. The design includes: DC/DC module, power supply circuit, heat dissipation processing, power supply indication circuit, decoupling circuit, test point network, SMA oscilloscope detection port, power output, electronic load, and mechanical positioning hole for environmental adaptation testing. [5] Protection functions are achieved through external circuits, including overvoltage protection, overcurrent protection, and overheating protection, to prevent damage to modules or connected circuits. The DC-DC power module has a wide range of applications in the electronic field, which can achieve effective conversion between different voltage requirements and provide stable power supply. This is crucial for the design and operation of the detection system.

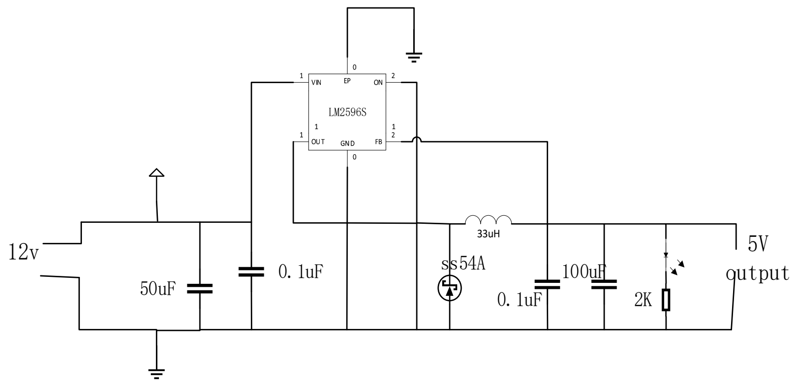

Figure 7. DCDC Power module

3.7. Communication module

The communication module adopts ESP32 as the main chip and uploads data through wireless network connection to the cloud. ESP32 is a dual core 32-bit microcontroller developed by Espressf Systems, designed specifically for Internet of Things (IoT) applications. With powerful performance and more features. ESP32 has two 32-bit Tensilica LX6 processor cores, enabling it to handle multitasking and multithreaded operations in parallel. This improves processing performance and efficiency.

Wi Fi and Bluetooth: The ESP32 supports the 802.11 b/g/n Wi Fi standard, as well as Bluetooth 4.2 and Bluetooth Low Power (BLE) capabilities. This makes it suitable for connecting to wireless networks and Bluetooth peripherals.

Low power mode: The ESP32 has multiple low power modes, including deep sleep mode, which can minimize power consumption when needed and help extend battery life.

Rich peripheral devices: ESP32 is equipped with various peripheral interfaces, including SPI, I2C, UART, PWM, ADC, etc., suitable for connecting various sensors and devices.

Highly integration: ESP32 integrates flash memory, memory, and various peripherals, reducing the need for external components, making it highly suitable for compact IoT devices.

Security features: ESP32 provides encryption engine, SSL/TLS support, and other security features to protect communication and devices.

Multipurpose applications: ESP32 is widely used in various IoT applications, including smart homes, sensor networks, IoT devices, robots, industrial automation, and many other fields.

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4. SOFTWARE DESIGN

C Programming Language was used, compiled and debugged in Keil5 MDK environment, with techniques such as interrupt, timer, I2C, SPI, and multi-CPU communication, to finish software design. The process is shown in Figure 8.

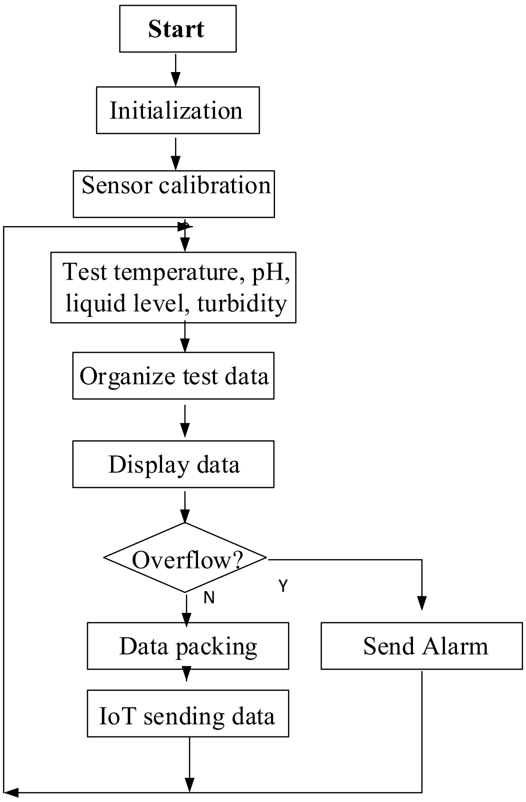

Figure 8. Main program flowchart

5. CONCLUSION

In this project, a low-cost STM32F1 series microcontroller is used as the main controller, fully utilizing the peripheral resources of the microcontroller and paired with different sensors to greatly improve the flexibility of measurement. The OLED display screen can also visually see test data at monitoring points, while the use of IoT chips such as ESP32 can achieve remote network viewing of data. Coupled with the upper computer, users can visually see various data through the GUI interface.

ACKNOWLEDGMENTS

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