ISSN: 2664-9640

# Intelligent Aquaculture System Based on STM32 MCU

Tala
Department of automation, North China Electric Power University, Baoding 071066, China
2819434551@qq.com

## Abstract

**In order to accurately detect water quality in real time and improve the level of automated production. Therefore, an intelligent aquaculture system is designed based on STM32 . The system performs A/D sampling on the temperature sensor, water turbidity sensor, pH sensor, oxygen sensor, etc.,And after filtering and converting the collected data, STM32 uploads the data to the farmer's mobile phone through the wireless communication module. Exceptions are issued with a warning. In addition, the system uses ultrasonic sensors as the water level measuring device, and uses the PID controller to control the operation of the water pump so that the actual water level reaches the set water level.**

## Keywords

**Sensor, STM32, PID controller,A/D conversion,circuit,automation.**

## 1. Introduction

The overall scale of my country's fishery industry is huge, and it has grown rapidly in recent years. At present, the output of aquatic products in my country is still dominated by artificial aquaculture, and the output of wild fishing is relatively low. In the process of aquaculture, there will be a large number of fish deaths in a short period of time, which is mainly directly related to the quality of water quality. Moreover, in freshwater fishery aquaculture , it is also necessary to detect the health status of fish in real time.Because the disease occurs in a very short time , its spread is very fast, and the resistance to aquatic biological diseases is relatively weak, farmers tend to suffer from serious economic losses to production. At the same time, the process of feeding and changing water on time is cumbersome and takes a lot of time and manpower for farmers. Therefore, a set of intelligent aquaculture system is particularly important to promote the development of aquaculture.

Intelligent aquaculture system needs to combine embedded technology, circuit design technology, sensor detection technology, automatic control technology and communication technology to realize real-time detection and remote detection of water quality parameters and fish health status, and realize remotely the processes of automatic water change and timing feeding. This will improve the automation level , detection efficiency of water quality testing and production processes to reduce manpower and material resources, and achieve intelligent and networked aquaculture.

## 2. The overall framework of a smart aquaculture system

The intelligent aquaculture system mainly uses the STM32F103RCT6 as the main control core of the system. The system is formed through the effective combination of the self-designed main circuit,the communication module, water quality sensor module, camera, keyboard, LCD, water pump, steering gear and other peripherals. As the main control unit, the STM32 needs to continuously perform A/D conversion on various sensors, and digitally filter the collected data, then display the relevant parameters on the LCD, and transmit the data to the user's mobile phone program through the wireless communication module,which is convenient for the staff to grasp the water quality of the current waters in real time. If the current water quality changes greatly or a certain index exceeds the standard, the buzzer on site will alarm and let the on-site personnel check the relevant situation. At the same time, the communication module will transmit the alarm information to the application program in time for remote monitoring. In order to realize remote monitoring of fish health and prevent large-scale outbreak of fish diseases, the system is also equipped with a camera, and the real-time collected images are uploaded to the application program through the single-chip microcompute so that users can view it in real time. This system uses external actuators such as water pumps and steering gears to realize regular water changes and feeding, and also supports remote operation of production equipment (water pumps and feeders), saving time and manpower and improving production efficiency. The intelligent aquaculture system framework is shown in Figure 1.

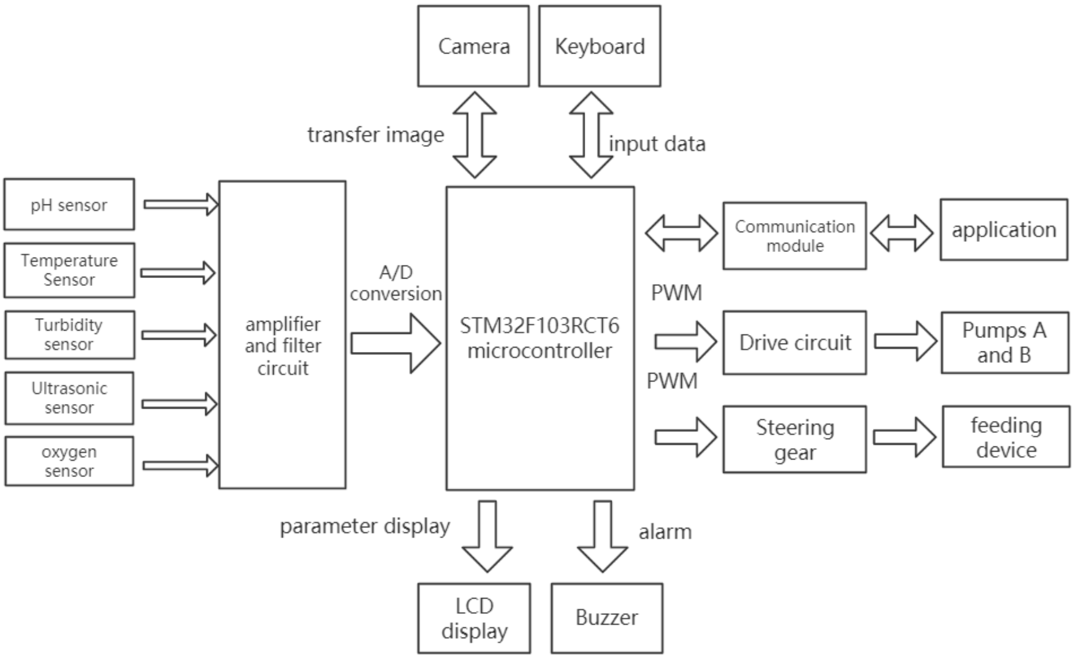


Fig. 1 The intelligent aquaculture system framework

The intelligent aquaculture system is mainly divided into three parts. The first part is the parameter detection part. They are composed of pH sensor, oxygen content sensor, temperature sensor, ultrasonic sensor, turbidity sensor and their amplifying and filtering circuits. These sensors transmit electrical signals to the A/D port of the microcomputer through the amplifying and filtering circuits . The second part takes the STM32F103RCT6 microcomputer as the core, and integrates the main circuit with voltage regulator, driver and communication circuits. Among them, the voltage regulator circuit provides appropriate stable voltage to each module, the drive circuit receives the PWM of the single-chip microcomputer to drive the actuator, and the communication module is responsible for communicating with the application program and transmitting data.As the most core in this part, single-chip microcomputer is responsible for parameter processing, transmission, analysis, alarm prompt and automatic execution of related tasks. The third part is the display and operation part, which consists of LCD and matrix keyboard.They are mainly responsible for displaying the parameters of the current water area and the state of the fish body and inputting some data. At the same time, the keyboard can be used to set alarm thresholds of related parameters, automatic water change, and feeding time, and to operate on-site production equipment.

## 3. Main circuit design of system

The system takes STM32F103RCT6 microcomputer as the core, uses 7.2V standard power source to supply power to the whole system, which provides stable working voltage to single-chip microcomputer and various external devices through voltage regulator chips AMS1117-3.3 and AMS1117-5V. The communication of the WIFI module and the user's mobile phone is used to accomplish the networking of the system. The overall circuit is shown in Figure 2:

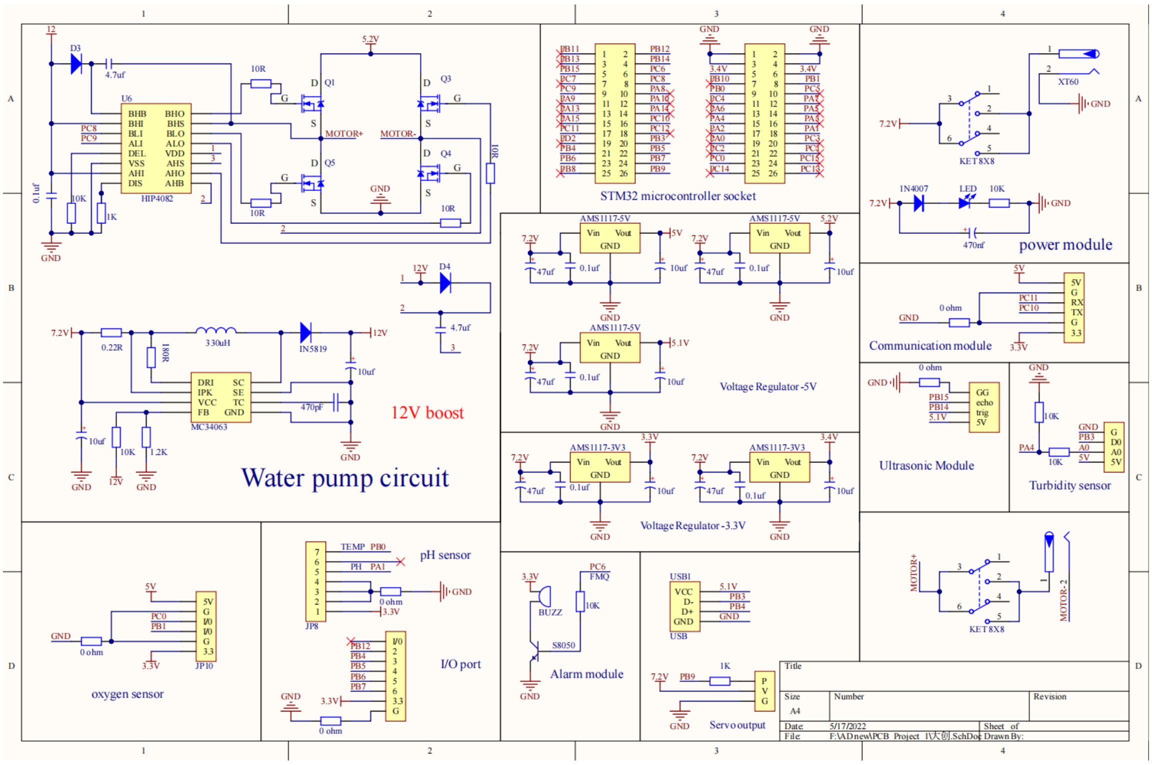


Fig. 2 Overall circuit

## 4. Sensor section of System

### 4.1. pH detector module

Because the module requires lower power consumption and smaller volume, the "E-201-C" pH composite electrode sensor is used. Through the TLC4502 dual operational amplifier circuit as shown in Figure 3, the weak detection of the internal and external reference electrodes the potential difference signal is collected and amplified so that the STM32 microcomputer can collect the voltage signal, and perform digital filtering to convert the pH of the corresponding voltage value. The configured standard buffer solution is used to calibrate the voltage value corresponding to PH. The ADC module of the STM32 microcomputer performs data conversion to obtain the relationship between the detected signal value and the pH as shown in Figure 4:

Their relationship was found to be approximately as the following formula by the least squares method.

pH=-6.1031*V+22.156

Therefore, if we use the median filter algorithm for filtering, we can obtain an ideal pH parameter.

ISSN: 2664-9640

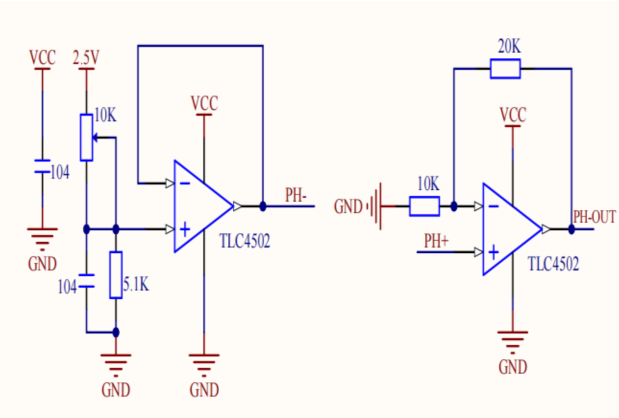


Fig. 3 Amplifying circuit

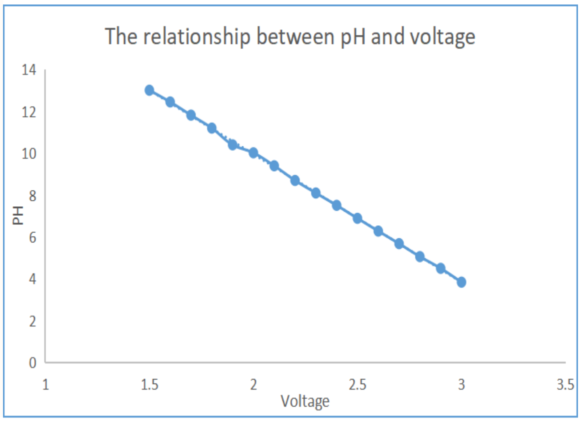


Fig. 4 The relationship between pH and voltage

## 4.2. Temperature sensor module

The digital temperature sensor DS18B20 with a single bus interface has a temperature conversion accuracy of ±0.5 °C and a wide measurement temperature range, generally -55 ~ +125 °C. temperature measurement system.

The VDD pin of the temperature sensor DS18B20 is connected to a 5V external power source, the GND pin is connected to ground, and the DQ pin is connected to the PB0 pin of the microcomputer . In this way, the data transmission can be realized in a single bus way. When the microcomputer performs various operations on the DS18B20, it must be carried out according to the protocol. The operation protocol is: initialize DS18B20 (send reset pulse) → send ROM function command → send memory operation command → process data.

## 4.3. Turbidity Sensor Module

The turbidity sensor (as shown in Figure 7) uses the optical principle to comprehensively judge the turbidity through the light transmittance and scattering rate in the liquid solution. Inside the sensor is an infrared pair tube. When light passes through a certain amount of water, the amount of light transmitted depends on the degree of pollution of the water. The more polluted the water, the less light is transmitted. The light receiving end converts the transmitted light intensity into the corresponding current size. The more light that passes through,and the current is large. On the contrary, the less light that passes through and the smaller the current is, and then the current that flows is converted into a voltage signal through a resistor. The turbidity of the current waters can be obtained by sending the voltage signal of the single-chip microcomputer into the A/D conversion port of the single-chip microcomputer. The relationship between turbidity and voltage value through field calibration is shown in Figure 5.

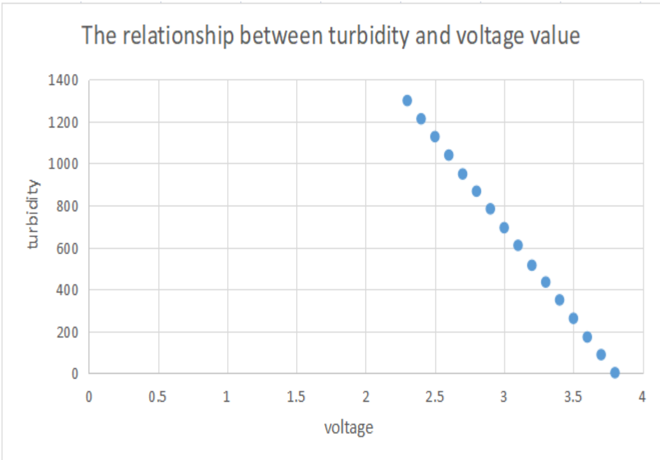


Fig. 5 The relationship between turbidity and voltage

ISSN: 2664-9640

## 4.4. Ultrasonic Sensor Module

This system uses HC-SR04 ultrasonic module (as shown in Figure 8) as the sensor for measuring water level. This ranging module can provide non-contact distance sensing function of 2cm-400cm, and the ranging accuracy can reach as high as 3mm.The module includes an ultrasonic transmitter , receiver and control circuit. The basic principle is: use the TRIG port to trigger ranging, and give a high level of at least 10us. At this time, the module automatically sends 8 square waves of 40khz, and automatically detects whether there is a signal return. Once a signal returns, a high level is output through the ECHO port, and the duration of the high level is the time from the launch to the return of the ultrasonic wave. The specific timing is shown in Figure 6. The measurement period is generally more than 60ms to prevent the influence of the transmitted signal on the echo signal.

Water level = water tank height - (high level time * speed of sound (340M/S))/2;

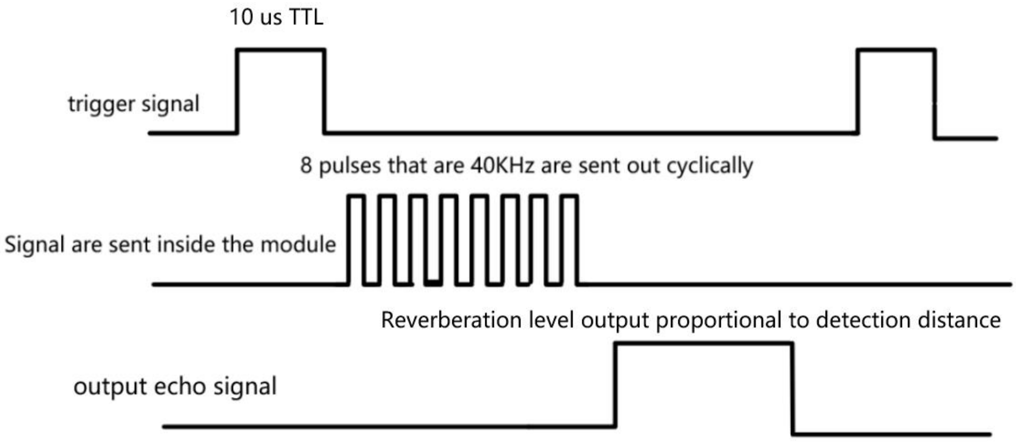


Fig. 6 Sequence diagram of ultrasonic working process

Fig. 7 Turbidity sensor

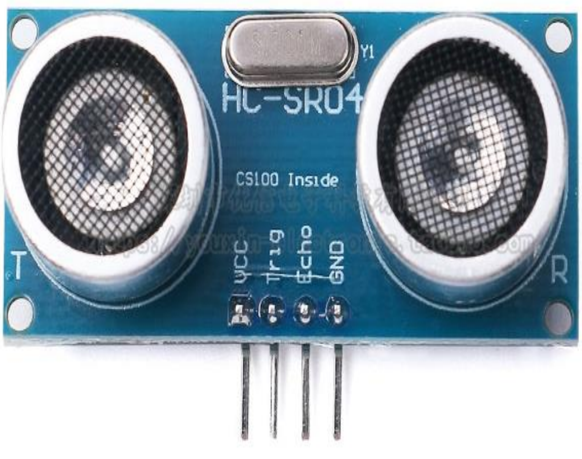


Fig. 8 Ultrasonic sensor

## 5. System driver circuit

First of all, the STM32 can output DC signals, but its driving ability is also limited, so the single-chip microcomputer generally acts as a driving signal, driving large power tubes such as positive channel Metal Oxide Semiconductor to generate large currents to drive the motor.And the conduction time of the MOSFET in one week determines the speed of the motor. The motor drive mainly uses N-channel MOSFET to construct the H-bridge drive circuit, and the H-bridge is a typical DC motor control circuit.

In this circuit, the HIP4082 chip is used to control the turn-on and turn-off of four Mos tubes. When the input pin PC8 of the chip inputs the corresponding PWM, which will control the state that MOSFET Q1 and Q4 are turned on or off, so that the water pump is forwarded. When the input pin PC9 of the chip inputs the corresponding PWM, it controls the MOSFET Q2 and Q3 to be turned on and off, so that the water pump is transmitted back. By adjusting the output duty ratio of the single-chip microcomputer to adjust the conduction time of the MOSFET in one cycle, the pumping speed of the water pump can be adjusted.

Because the operating voltage of the HIP4082 chip is 12V, the MC34063 boost chip can be used to boost the 7.2 power supply voltage to 15V. The overall circuit for driving the water pump is as shown in Figure 9:

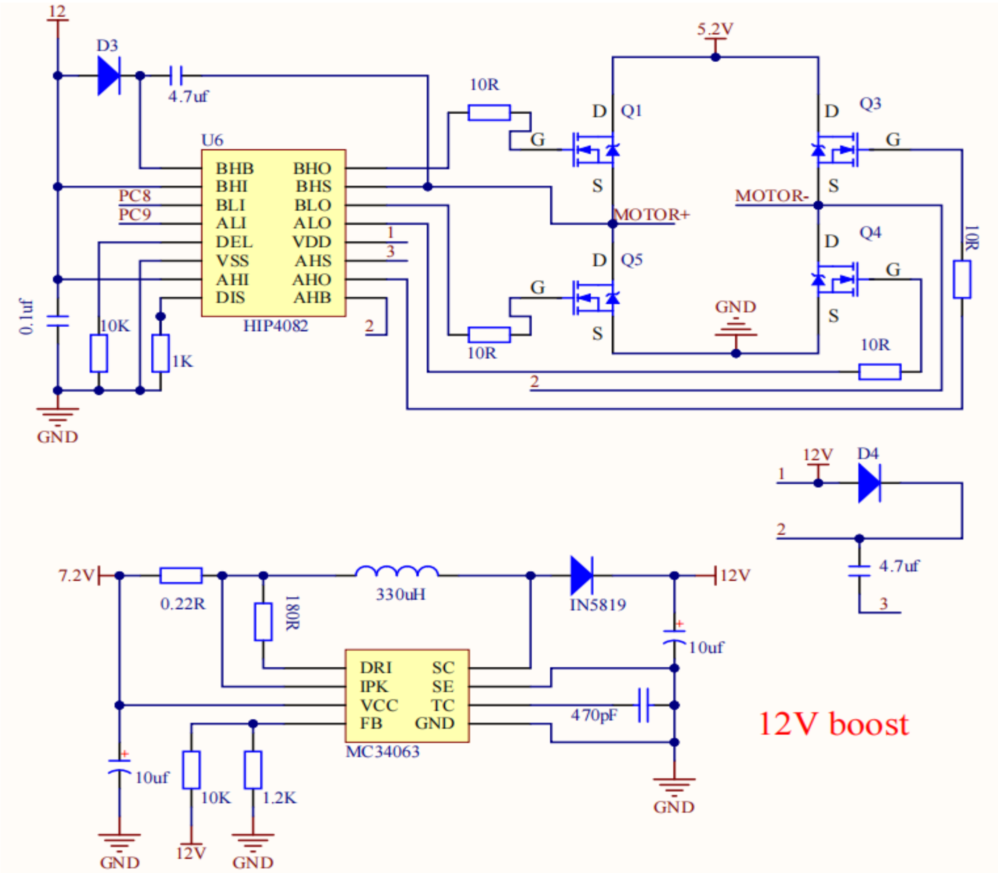


Fig. 9 circuit of driving the water pump

## 6. Core control technology of system

### 6.1. Automatic water change at regular intervals

When the system is in the automatic state,the STM32 sends an instruction to drive the water pump to pump water once the timing of the system is up, so that the water level of the water tank reaches the lower limit, and then starts another water pump to add water to the water level to reach the predetermined value to realize the automatic water exchange process.

Therefore, the most important thing in this process is to control the water level of the water tank, otherwise the water in the water tank will be drained or overflowed, resulting in production loss. The liquid level control device of the water tank uses the ultrasonic module as the measuring device, the single-chip microcomputer as the controller, and the water pump as

ISSN: 2664-9640

the actuator. It can measure the water level changes in the range of 3cm ~ 200cm, the acquisition period is 60ms, and then weighted filtering.

$$\overline{\mathrm{H}} = \sum_{i=0}^{5} a_i H_i$$

When it is detected that there is a deviation between the actual water level of the water tank and the set water level, the pump motor will work to replenish or add water to the water tank until the set water level is reached. Its principle block is shown in Figure 10. Once the system fails, the single-chip microcomputer can drive the buzzer to issue a warning to the user according to the upper and lower limits of the set water level.

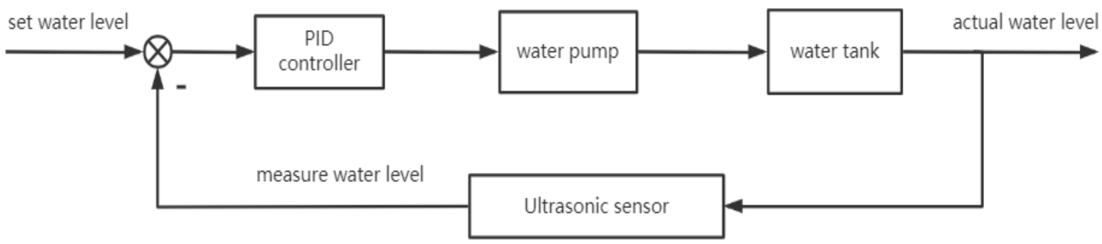


Fig. 10 Schematic block diagram

PID control consists of proportional, integral and derivative. The control law of PID control system:

$$\mathrm{u}(t) = K_p (e(t) + \frac{1}{T_1} \int_0^t e(t)dt + T_D \frac{\mathrm{d}e(t)}{dt})$$

The proportional control can quickly respond to the error, and the proportional coefficient Kp determines the size of the control effect. The larger the proportional coefficient, the smaller the static error in the control process. But the smaller the proportional coefficient, the stronger the stability of the system. The integral control will continue to superimpose until the error in the system disappears, but the integral control will increase the maximum deviation of the system. The differential control can reduce the maximum error of the system, thus it improve the stability of the system. Set a target value, and the actual value of the output will be sent back through the monitoring transmission device. If the actual value of the output is different from the target value, the difference between the target value and the actual value of the output is called an error, and the PID controller will keep making this error. The error is reduced, and finally the error tends to 0 infinitely.

## 6.2. Automatic feeding

Its timing principle is based on STM32 timing interrupt 4. If the timing interrupt is set to be interrupted once every 500ms, we can write a counting program in the interrupt service subroutine. Once the number of times exceeds a certain threshold, it means that the timing time has come. Timing time = 500ms * total number of interrupt executions. For example, one hour = 500ms * 7200 interrupts. The general flow of the program operation is shown in Figure 11.

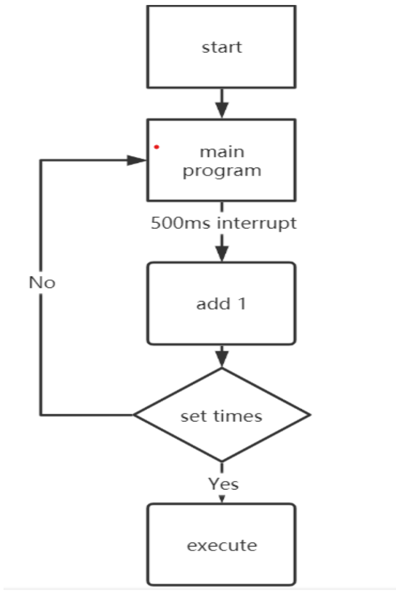


Fig. 11 The basic idea of program running

When the feeding time is up, the STM32 will send out the corresponding PWM , forcing the 270° steering gear to turn a certain angle and opening the feeding valve. The opening of the valve is proportional to the duty of the PWM , and the larger the duty cycle make the opening of the valve more greater.

## 6.3. Communication and Alarm

UART is a universal serial data bus used for asynchronous communication. The bus has bidirectional communication, which can realize full-duplex transmission and reception. In embedded design, UART is used for host to communicate with auxiliary device. When the STM32 at each site collects the data of water quality , it is packaged into frames and sent to the user's mobile phone or computer through the Bluetooth or WiFi module. The UART communication protocol is mainly used in this process. UART data consists of 1 start bit, 5 to 9 data bits (depending on the UART), an optional parity bit and 1 or 2 stop bits, in the form of Figure 12:

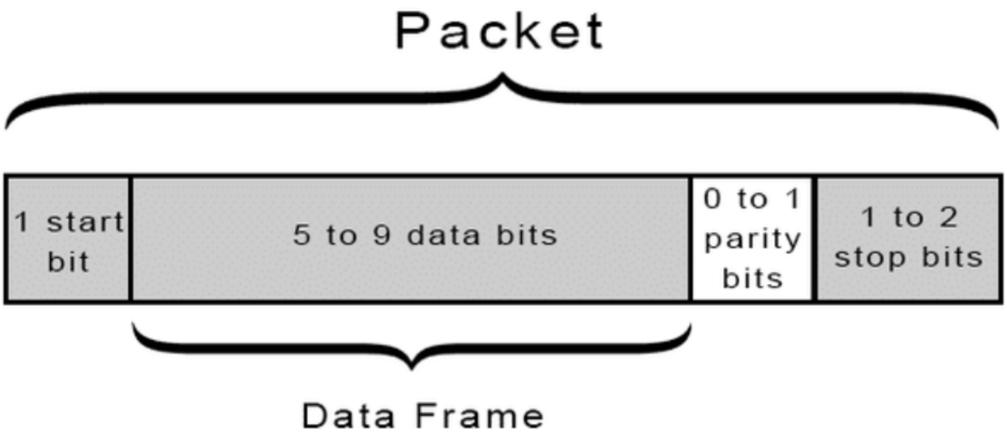


Fig. 12 Form of the UART frame

When the water quality parameters are abnormal, the PC6 port of the STM32 is set to a high level, and the transistor S8050 is turned on to drive the buzzer to issue a warning. The circuit is shown in Figure 13.

ISSN: 2664-9640

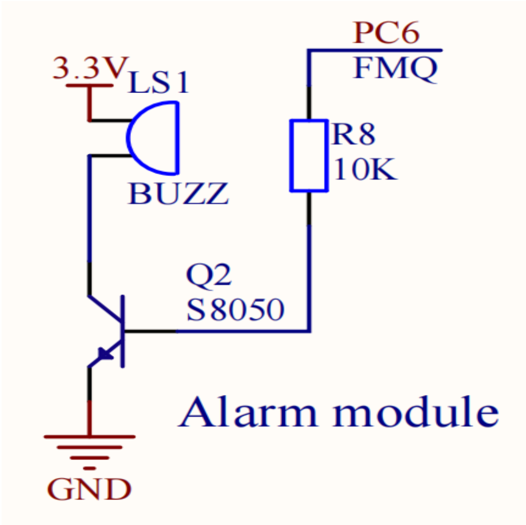


Fig. 13 Alarm circuit

## 7. Conclusion

Designing a system that can monitor parameters of the current waters in real time can facilitate farmers to grasp the water quality of the waters at any time. When the parameters are abnormal, the farmers can be reminded to find out the situation in real time to avoid major economic losses. At the same time, the automatic timed water change and feeding functions provide great convenience for breeding, saving a lot of manpower and time. Even if no one is in the situation, the system runs automatically 24 hours a day, which greatly promotes production efficiency. The devices selected for this system design are low power consumption, cheap and less investment. And farmers can remotely view the situation of relevant waters in real time through the WIFI module, which realizes the networking of the farm. Therefore, with the application of this system will promote the aquaculture industry.

## References

[1] Jiao Xiongke, Liu Xiaxia, Liu Meiqi, et al. Wireless Fish Pond Water Quality pH Detection System Based on CC3200 Microcontroller [J]. Zhejiang Agricultural Science, 2020, 61(4): 783-785.

[2] Wang Shujuan, Cai Weizheng, Qi Ming. The Basis of Analog Electronic Technology [M].Beijing, Higher Education Press, 2009.

[3] Chen Haixiu, Li Zhishuai, Liu Jie,Design of Turbidity Sensor Based on STM32[J]. Instrumentation Technology,2019,10:44-47.

[4] Zhang Lin, Chang Yuancheng, Zhao Beiyu. Intelligent Garbage Collection Based on STM32 [J].Journal of Fujian Computer, 2021, 37(2): 114-115.

[5] SHI Linglong,SUN Shanshan ,An Ultrasonic Ranging System Based on Single-chip[J].Journal of Fujian Computer,2022,38(2).

[6] Li Xinqi. Application and Development of Single-chip Microcomputer. Electronic World, 2017, 63(15): 92

[7] Li Dazhe,Li Huiling,Shen Hai.Research and Design of Water Tank Level Control System[J]. Information Systems Engineering,2021,11:61-64.