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Design & Test of Radio Communication and Control System for Aquaculture

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Abstract: Aiming at low automation degree and backward aquatic product management of current aquaculture in China, this paper designed a set of radio communication and control system which consists of 3 parts of information collection module, control module and radio communication module. This system both realizes wireless monitoring of quality parameters of water for aquaculture and realizes wireless control of water level and dissolved oxygen value through radio communication. Test results show that data transfer is more accurate and reliable after adding customized protocol and answer signals in radio communication. The highest error and missing rate within 1000 m is 0.36, the lowest error and missing rate is 0.05 and the longest response time is 49 ms. The dissolved oxygen value detection system designed in this paper is close to the testing value of existing dissolved oxygen value transmitter DO6309. With wireless data transfer mode, it has higher practicality. The wireless control of dissolved oxygen value and water level can be controlled within the appropriate range with stable and precise control. The study results can provide intelligent aquaculture model with simple operation and precise control for enormous aquatic breeders. *Copyright © 2013 IFSA.*

Keywords: Aquaculture, Radio communication, Water level, SCM.

1. Introduction

China is a large agricultural country, while fishery is one of important industries of Chinese agriculture. In despite of Chinese fishery has gone through stable and fast development with considerable increase of total production [1], it is also confronted to challenges in respect of resource, environment, market, S&T and system etc. All of these factors restrict the development of fishery at certain degree. At present, the management of Chinese aquaculture is mainly guided by culture experience such that the production and the safety are hard to be ensured. China's present aquaculture modes are mainly concentrated on two fields that are industrial culture [2] and cage culture [3]. Chinese aquaculture integrally shows following features [4]: decentralized aquaculture operation with unreasonable structure; backward aquaculture facilities with low intelligent degree; and the aquaculture safety needs to be improved.

With people's increasing demand to aquatic products, scaled aquaculture has become a necessary development trend of aquaculture. At present, most of existing scaled culture monitoring systems adopt wired mode for realizing the data communication between the monitoring terminal and the computers of control center [5]. Most of aqua-farms rely on artificial culture experience [6], so the monitoring technology is low and there will be a lot of

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monitoring points and complex wiring when the culture area is larger. Nowadays, some culture monitoring systems have introduced the wireless sensor network technology and partially solved above problems [7]. There are now aquaculture monitoring systems realized automatic monitoring [8] to water level, temperature, pH and dissolved oxygen, which has important significance of scientific culture to farmers, but its cost is high and the intelligent degree and scientific management need to be promoted.

This paper therefore designed a set of radio communication and control system for aquaculture. This design adopts radio communication and sensor networking technology, which has lower cost and easier expansibility than wired, GPRS and GSM data transfer as well as realizes wireless intelligent control to water level and dissolved oxygen value so as to realize more precise and scientific control and reduce energy consumption. This system is mainly suitable for middle and large aquaculture farmers.

2. System Structure

The radio communication control system designed in this paper mainly consists of radio communication module, information collection module and control module. Its structure drawing is shown as Fig. 1. The information collection module collects parameters of the water quality of culture pond in real time and sends the collected information such as water level, dissolved oxygen value, temperature and pH value to the host computer through APC220 after such information are pretreated by single chip micro (SCM) STC89C52; and the host computer will display the collected data on human-machine interface after processing such as temperature compensation and error correction. In the event that the collected parameters are outside the preset range, it will alarm through the alarm promoting circuit; meanwhile, the host computer will send the control information to SCM STC89C52 through APC220 in order to utilize the SCM to control the aerator and the pond's water level and so on.

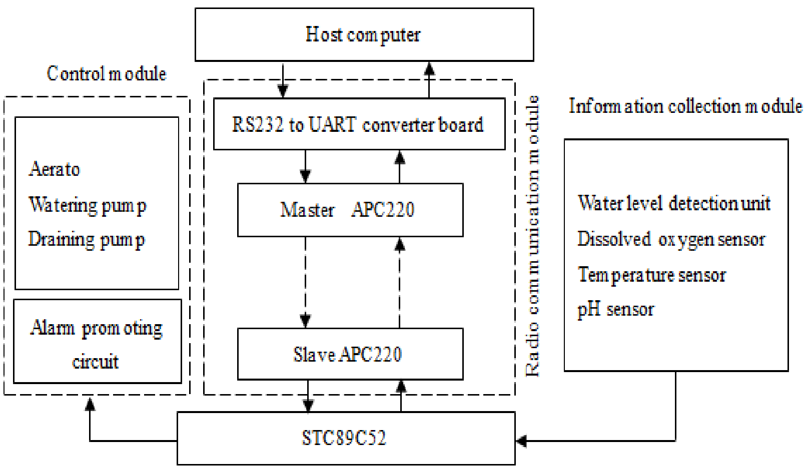

Fig. 1. System structure drawing.

3. Design of Radio Communication

This system adopts APC220-43 multichannel micro-power embedded wireless data transmission module whose communication channel is half-duplex and the module is embedded with high-speed SCM and high-performance radio chip with 1200 m radio transfer range and strong interference rejection. The host computer has to be connected with APC220-43 by RS232 to UART/TTL interface converter board as shown in Fig. 1. The serial port is initialized as 9600 Baud rate, 8 data bits and 0 check bit.

The design of this system demands not less than 2 APC220-43 modules and comprises a master station APC220-43 and multiple slave stations APC220. When the host computer gives information, the master station APC220 will send a set of binary code i.e. a frame of data. According to the function of each part, they are divided into 3 parts that are address code, data code and stop signal code. As a communication station, each APC220 module has a unique address code. When the master station sends signals, all of slave stations unconditionally receives that and compares the received address code with local address code. If the address codes are different from each other, the data will be rejected without response; if the address codes are identical, the data code will be matched with defined ones. When the stop signal code is received after successful matching, it will set corresponding flag bit and simultaneously implement corresponding program and reset flag bit. The flow chart of the slave station receives control command is shown as Fig. 2.

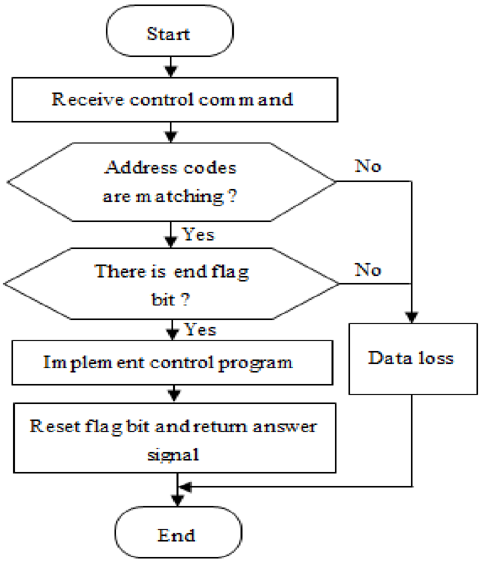

Fig. 2. Flow chart of the slave station receives control command.

In order to strengthen the reliability of the system, answer signal will be returned after all flag bits set by slave stations enter implementation program. The host computer will send the same signal once at 1s interval until it receives the answer signal. If there is no answer signal after sending 3 times, it will give alarm. There are two methods for SCM STC89C52 to send the collected data, of which one is sending collected data once at certain time interval (the time can be customized) to the host computer and display e.g. pH value, dissolved oxygen value and temperature value etc., the other is sending signal when collected signal changes. Taking the water level information for instance, at the beginning of change, it sends normal signal to the host computer for displaying normal water level information, when higher or lower water level is detected, it will send corresponding signal to the host computer for displaying alarm signal until normal signal is received. The mode that the host computer receives collected data is similar to the mode that the lower computer receives control signal. But their difference is that the host computer, upon receiving data, firstly detects the flag bits in data information before reading and displaying data (main functions of flag bit are marking start bit and end bit of data as well as explaining what data value is collected).

4. Design of Control System

4.1. Design & Principle of Water Level Control Hardware

The water control unit consists of watering equipment, draining equipment, water level detection circuit and SCM (STC89C52). The control principle of water level detection is shown as Fig. 3.

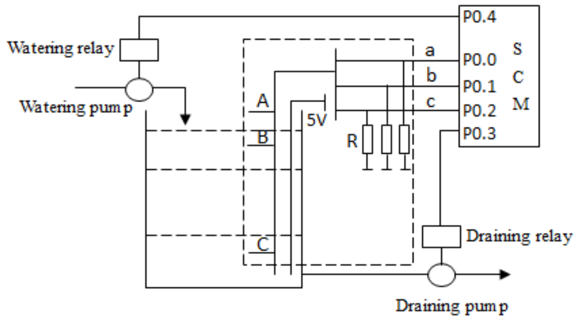

Fig. 3. Schematic of control of water level detection.

The watering equipment comprises of watering relay and watering pump; the draining equipment comprises of draining relay and draining pump; the water level detection circuit is used for detecting the water level of pond; and the SCM is used for implementing water level adjusting commands, controlling open and close of watering relay and draining relay, and then controlling the start and stop of watering pump and draining pump. The water level information obtained is sent to the host computer via APC220-43 module, and then the host computer generates draining command or watering command according to such information.

The water level detection circuit comprises a piece of detecting bar with insulated shell, on which there are detecting points A, B and C that are composed of metal conductor. The three detecting points are respectively connected with ports P0.0, P0.1 and P0.2 of SCM through three conductors a, b and c; the three conductors a, b and c are respectively grounded through a 4 kΩ resistance; SCM respectively exports high and low electrical level to draining relay and watering relay through ports of P0.3 and P0.4 in order to control closing and opening of corresponding pump. When water level is detected, vertically immerse the detecting bar into water and make positions of three detecting points A, B and C respectively on dividing points of high level, normal level and low level. The water to be detected is applied 5 V voltage; utilizing the conducting property of water, when the detecting point is immersed into water, it will be powered by 5 V voltages, and then the port of the SCM connected with such detecting point will input high electrical level, otherwise it will input low electrical level. Therefore, which detecting point is immersed into water can be determined according to high or low of input electrical level of SCM port so as to get the information of water level, and then SCM's P0.3 and P0.4 ports export corresponding high or low electrical level to control actions of two relays in order to control opening or closing of corresponding water pump for adjusting the water level. The relationship between water level detection signals of SCM's P0.0~P0.4 ports and output control is shown as Table 1, of which 0 refers to low electrical level and 1 refers to high electrical level.

Table 1. The relationship between water level detection signals of SCM's P0.0~P0.4 ports and output control.

P0.0(a)	P0.1(b)	P0.2(c)	Water level	P0.3 (Draining relay)	P0.4 (Watering relay)	Function
1	1	1	High water level	0	1	Draining
0	1	1	Normal water level	1	1	No operation
0	0	1	Low water level	1	0	Watering

4.2. Design of Water Level Control Program

The water level control command can be sent by the host computer and the SCM can also self control according to the detected water level information, but the host computer control is preferential. When SCM detects the signal of normal water level, it will send signal of normal water level to the host computer through APC220-43; in case of high water level, it will send signal of high water level to the host computer, meanwhile P0.3 exports low electrical level and P0.4 exports high electrical level to perform drainage operation. When the water level returns to normal, it will send signal of normal water level and stop draining. The control principle for low water level is similar. Water of normal fish pond is changed once per 10~15 days, about 1/3 of pond water amount will be changed each time and massive drainage and irrigation is prohibited [9]. The host computer sends water changing command and the SCM returns water changing answer signal to the host computer and performs drawing action upon receiving such command; when the water level is lower than point C, SCM stops draining and performs watering operation until water level is normal, and then it sends water changing completion information to the host computer; if the host computer receives no water changing answer signal after sending command for 3 times, it will send alarm signal. The flow chart of host computer controls water changing is shown as Fig. 4. The principle that host computer controls draining and watering is similar to that of control of water changing.

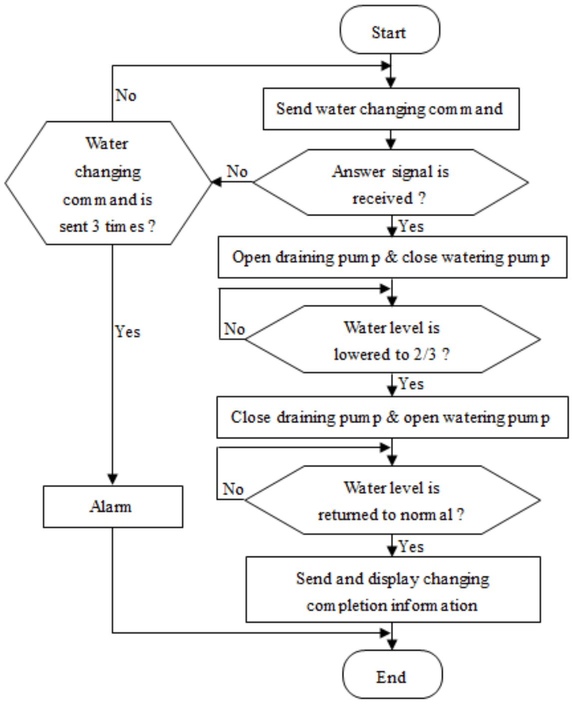

Fig. 4. Flow chart of host computer controls water changing.

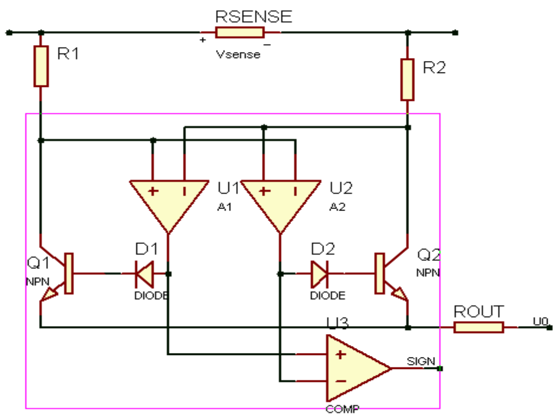

Fig. 5. Current-voltage conversion circuit.

4.3. Realization of Detection of Dissolved Oxygen Value

The dissolved oxygen sensor adopted in design of this paper is polarographic oxygen electrode that utilizes galvanometry to determine dissolved oxygen amount. The current value determined on the electrode of dissolved oxygen sensor is at μA level which cannot be directly input into analog-digital conversion (A/D) conversion circuit, but has to be converted into voltage signal by conversion circuit and amplified to 0~5 V voltage before entering A/D conversion. This paper designed a current-voltage conversion circuit by adopting precise amplifier MAX472. The current-voltage conversion circuit is shown as Fig. 5.

There is internal structure of MAX472 inside the solid line box, of which A1 and A2 are operational amplifiers that forms differential input and can strengthen interference rejection and increase measurement accuracy of low current signal; both Q1 and Q2 are transistors; COMP is comparator; on the outside of the solid box, there is external resistance circuit designed according to system requirements, of which RSENSE is the current sampling resistance. Due to the impedance of the measuring electrode is very high (normally above meg-ohm) and ordinary amplifying circuit cannot meet requirements of high input impedance, this design uses INA118 to increase the input impedance of amplifying circuit. There is an amplifying structure made up of three operational amplifiers inside INA118 and gain at different levels can be realized through external regulating resistance. The voltage amplifying circuit is shown as Fig. 6. Pins 1 and 8 in the figure externally connect resistance RG for changing gain G of amplifier INA118; pins 2 and 3 respectively connect the cathode and the anode of amplified electric potential signal; pins 4 and 7 respectively connect -5 V and +5 V power source and ground via decoupling capacitors C5 and C4; and pin 5 connects bias voltage. The electric potential signals from pins 2 and 3 can be converted into potential signals within 0~5 V after they are amplified to G times by INA118 and combined with the bias voltage from pin 5; this converted electric potential signal is finally exported by pin 6, and then A/D conversion is performed by ADC0809.

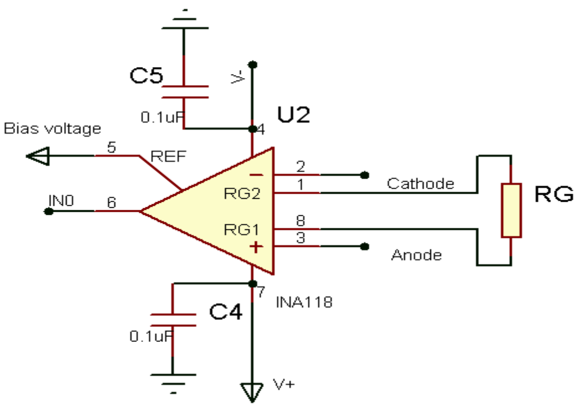

Fig. 6. Voltage amplifying circuit.

4.4. Detection of Dissolved Oxygen Value and Design of Control Program

The electric current signal collected by dissolved oxygen sensor is amplified to 0~5 V voltage signal after passing current-voltage conversion circuit and then passing signal amplifying circuit. The voltage signal enters A/D conversion circuit and preliminarily processed by SCM, and then it is sent to the host computer by APC220-43. The host computer will carry out temperature compensation and error correction to dissolved oxygen value according to the temperature value currently collected. The host computer displays the obtained dissolved oxygen value on human-machine interface and makes comparison with the lower limit set by the system. If the value is smaller than the lower limit, the host computer will send aerator starting command and alarm. Upon correctly receiving such command, the SCM will close the normally open contact terminal of relay to make the aerator operate; when the dissolved oxygen value of pond reaches to the upper limit set by the system, the host computer will automatically give aerator shutting command and SCM will control the aerator to stop working. Dissolved oxygen value detection and control flow chart is shown as Fig. 7.

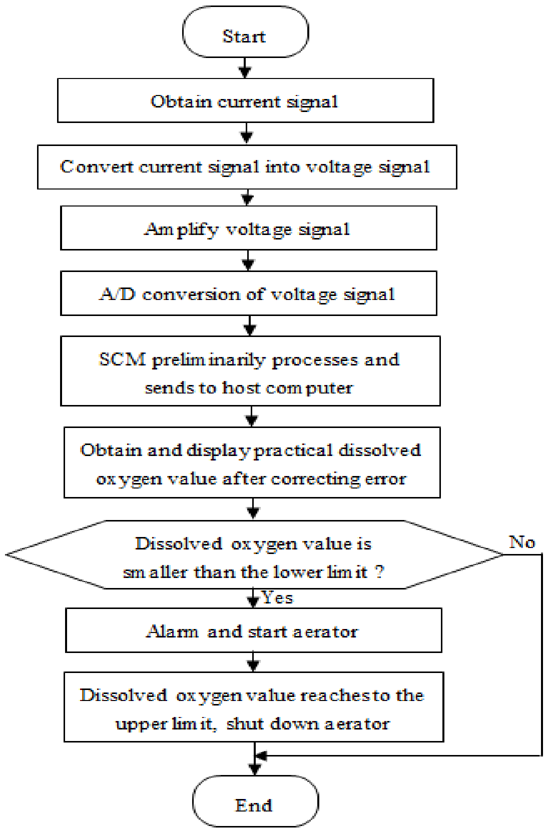

Fig. 7. Dissolved oxygen value detection and control flow chart.

5. Testing & Measurement

5.1. Test Conditions

This system was applied in the fishery experimental park of Sichuan Agricultural University upon completion of design. A 10 m×8 m area and 1.5 m depth pond within the park was taken and 15 kg carp fry was put into the pond. By field survey, the distance between the monitoring room and the fishpond is about 900 m. The radio communication system was tested before testing the system. The test was performed during 1 Jan. 2012 to 2 Jan. 2012 and mainly on missing and error rate of data transfer, response time and transfer distance. The whole system was tested during 1 Mar. 2012 to 30 Sep. 2012 and mainly on system's water quality detection precision and controlling effect of each controlled value.

5.2. Result & Analysis

The performance test of radio communication is shown as Table 2. With respect to data in table under each monitoring distance, each kind of control command was sent 100 times and record the times of sending failure and finally take an average, i.e. the error and missing rate of data transfer in table is the times of error in data transfer of 100 times. It is known from table 2 that the transfer distance of this radio communication system can reach 1000m with short control response time, low and stable data transfer error and missing rate such that the controlling and information communication requirements of this system can be satisfied.

Table 2. Table of performance test of radio communication system.

Monitoring distance /m	Oxygenation response time /ms	Water level control response time /ms	Error and missing rate of data transfer /%
100	16	15	0.05
300	18	19	0.08
500	22	22	0.12
700	27	25	0.18
800	33	35	0.25
900	38	39	0.30
1000	48	49	0.36
1100	53	56	0.52

Dissolved oxygen values under different temperature were tested and the results are shown in Table 3. It can know from data of this table that the test value of dissolved oxygen value detection system is similar to the test value of dissolved oxygen value transmitter DO6309, but the cost of polarographic oxygen electrode adopted is lower and existing dissolved oxygen value transmitter normally collects data by wired method that cannot meet requirements of this system.

Table 3. Test table of dissolved oxygen value detection system.

Temperature	Test value of DO6309 /ppm	Test value of this system /ppm
0 °C	13.55	13.52
5 °C	11.81	11.77
10 °C	10.50	10.51
15 °C	9.52	9.40
20 °C	8.71	8.77
25 °C	7.70	7.82
30 °C	7.00	7.10
35 °C	6.48	6.51

For carp, the suitable temperature is 25°C ~32°C and the optimal dissolved oxygen value is 6.5 mg/L. During continuous 24 h, the dissolved oxygen in water must be above 5 mg/l in more than 16 h and it cannot be under 3 mg/l at any time [10], the water depth is 1.2~1.5 m. Data at 0:00, 8:00, 12:00, 16:00 and 20:00 per day were recorded during the experiment period in order to get average value at each time point for carrying out analysis. Dissolved oxygen value and condition of water level control is shown as table 4. It can be seen from table 5 that the control results of this system during 180 days of experiment were accurate and stable.

Table 4. Dissolved oxygen value and water level control test.

Time	Dissolved oxygen value (mg/L)	Water level (m)
0:00	5.6	1.2
8:00	6.5	1.29
12:00	6.4	1.33
16:00	6.6	1.30
20:00	6.7	1.32

6. Conclusions

Aiming at disadvantages of onsite wired monitoring system that is massively applied at present, the radio communication and control system for aquaculture designed in this paper realized wireless communication and control so as to avoid disadvantages of hard to network, uneasy to expand and high cost. Data transfer is more accurate and reliable after adding customized protocol and answer signal in radio communication. The highest error and missing rate within 1000 m is merely 0.36, the lowest error and missing rate is 0.05 and the longest response time is 49 ms. After temperature compensation and error correction is added to dissolved oxygen value detection system designed in this paper, its measured value is close to the testing value of existing dissolved oxygen value transmitter DO6309 and it adopts wireless data transfer mode that meets the requirement of this system. The wireless control of dissolved oxygen value and water level can be controlled within the appropriate range with stable and precise control.

Acknowledgements

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