CHEMICAL ENGINEERING TRANSACTIONS

VOL. 71, 2018

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Xiantang Zhang, Songrong Qian, Jianmin Xu

ISBN 978-88-95608-68-6; **ISSN** 2283-9216

DOI: 10.3303/CET1871052

Design of Acid Rain pH Detector Based on STC Single Chip Microcomputer

Tingting Dong[a], Meijiu Lu[b], Liwei Geng[a,*]

[a] Hebei Agriculture University, Baoding 071051, China
[b] Baoding Agriculture School, Baoding 071001, China
47104180@qq.com

With the development of industrialization, environmental pollution has become a great challenge for mankind. Acid rain, as a common environmental pollution factor, has caused great damage to agricultural production, human health, building safety and so on. In view of the problems caused by acid rain, a detection system of acid rain pH value based on STC single chip microcomputer is designed in this paper. By detecting the pH value, it can better judge the damage degree of acid rain, and do a good job of prevention as soon as possible. Firstly, the principle of pH measurement is introduced. Then, according to the characteristics of pH measuring electrode, the design of acid rain measurement amplifying and conditioning circuit is designed. Because the temperature is the important factor that affects the accuracy of pH value, the temperature compensation circuit is designed by using the temperature sensor. Finally, through the GPRS wireless transmission system, the collected acid rain signal value is sent to the PC. The experimental results show that the data collected by the measurement system can meet the requirements of the system design. Each module has normal function and the software program control is in line with the design requirements. The acid rain measurement in the experiment is verified by a standard pH meter, with a deviation of between 0.04pH. The system has the characteristics of low cost, small size, low power consumption and high accuracy. After testing, the acid rain detection system has higher pH value measurement accuracy and temperature measurement accuracy, and the measuring end can accurately measure data and send it reliably and stably to the data management platform of PC.

1. Introduction

Acid rain is a kind of pollution phenomenon caused by human activities or natural disasters resulting in regional precipitation acidification. It usually refers to atmospheric precipitation with pH value less than 5.60. The forms of precipitation include rain, snow and hail. Since 1980s, with the rapid development of economy, acid rain pollution is becoming more and more serious in China. It has become the third largest acid rain disaster area in the world (Yang et al., 1999; Hua and Li, 1998). With the rapid development of industry, acid rain pollution is becoming one of the most important factors of global ecological disaster. The formation of acid rain is mainly caused by the burning of large amounts of fossil fuels such as coal (Cao, 2007). These fossil fuels are used in human life and produce many acidic substances, such as SO_2, nitrogen oxides and so on. After that, these acidic substances are released into the atmosphere, and when rain, snow and other natural phenomena occur, they combine with acidic substances to form acid precipitation (Zhang et al., 2009)). The acid substances in acid rain are mainly sulfuric acid and nitric acid. Among them, sulfuric acid is usually produced by coal combustion of nitrogen oxides, while nitric acid comes from nitrogen oxides produced by oil combustion. These acid compounds and rain produce complex atmospheric chemical reactions and atmospheric physics processes, eventually forming acid rain and falling down. The formation of acid rain is shown in Figure 1.
In the middle of last century, because of the rapid development of industry in developed countries, a lot of environmental pollution (Sun, 2008) accidents occurred, so people begin to chemical detection and analysis of rainwater samples gradually. In recent years, with the rapid increase of social demand, the application of acid rain observation data has been expanded (Ding et al., 2004; Tang et al., 2007; Ba et al., 2007). The analysis

Please cite this article as: Dong T., Lu M., Geng L., 2018, Design of acid rain ph detector based on stc single chip microcomputer, Chemical Engineering Transactions, 71, 307-312 DOI:10.3303/CET1871052

and evaluation of the quality of acid rain observation data are also in progress (Tang et al., 2008; Tang et al., 2008). The measurement of acid rain generally refers to the measurement of the pH value of acid precipitation such as rain water (Zhang et al., 2010). The concept of "pH" was first proposed by Danish scientist Solonsen in 1909. The measurement of pH is mainly composed of four kinds, which are chemical analysis, virtual contrast, potentiometric analysis and test paper comparison. Potentiometric analysis has been widely used in some pH liquid detection methods. Compared with other measuring methods, potentiometric analysis has the advantages of continuous monitoring, high accuracy, and low cost of human resources and so on. Generally, glass electrode is used as sensor, which is a widely used method for measuring pH value (Guo and Cai, 2006; Li, 2003).

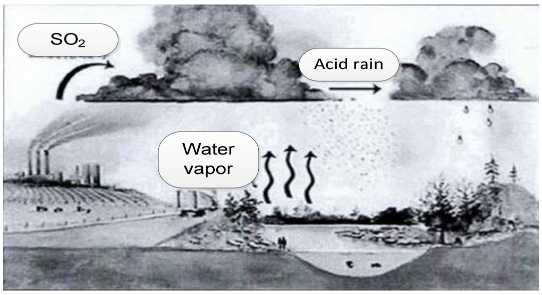

Figure 1: Formation process of acid rain.

2. Principle of pH value measurement

The pH value of atmospheric precipitation is expressed by the pH value. The pH value is defined as the negative logarithm of the hydrogen ion concentration. It is a dimensionless quantity. Among them, [H+] is the molar concentration of hydrogen ion and the unit is mol/L. Generally speaking, the pH value refers to the value of the hydrogen ion concentration at the normal temperature of 25degrees Celsius.

$$pH = -\lg[H^+] \tag{1}$$

There are three methods for measuring pH value, which are potentiometric method, test paper method and acid-base potentiometric titration method. Automatic measurement of pH value is mainly based on potentiometric method. The potentiometric method, also called the direct potentiometric analysis, is a quantitative analysis of the measured solution by measuring the electromotive force of the primary cell. A galvanic cell is a system that converts the energy of a chemical reaction into electrical energy. The voltage of the primary cell is called electromotive force (EMF). The electromotive force (EMF) is composed of two electrodes, and the voltage between the two electrodes follows the Nernst equation:

$$E = E_0 + KT(PH_x - PH_0) \tag{2}$$

In formula (2), E is measured electrode potential (mV), Eo is reference electrode potential (mV), K is Nernst coefficient (constant), T is absolute temperature (K), pHx is the measured solution pH value, and pHo is reference solution pH value (constant). The composite glass electrode used in this design is the potentiometric method. The pH sensor is inserted into the solution to be tested so that the composite glass electrode and the solution to be tested form a galvanic cell. The two output leads of the composite glass electrode are the positive and negative electrodes of the primary cell. The voltage is recorded as V (mV), and the solution temperature is recorded as t (Centigrade). When we take parameters and variables into formula (2), we can get:

$$V = K(273.15 + t)(PH_x - PH_0) \tag{3}$$

It can be seen from formula (3) that the pH value of rain water can be calculated as long as the voltage value of the composite glass electrode and the temperature value of rain water are measured.

3. System design

According to the functional requirements, the system design can be divided into 7 parts, which are acid rain signal collection, temperature signal acquisition, signal conditioning, STC microcontroller control board, power supply, data transmission and data management units. Signal acquisition and conditioning is the conversion of chemical or physical signals into electrical signals that can be recognized by the control panel. After the signal has been filtered and amplified to ensure its accuracy, it is sent to the STC control panel. The STC control board carries out A/D conversion, temperature measurement, temperature compensation and data packaging for the processed electrical signals, and transmits the collected data in GPRS mode. The implementation of data management is to automatically and continuously parse the data on the PC, and finally realize the display, storage and sharing. The system structure diagram is shown in Figure 2.

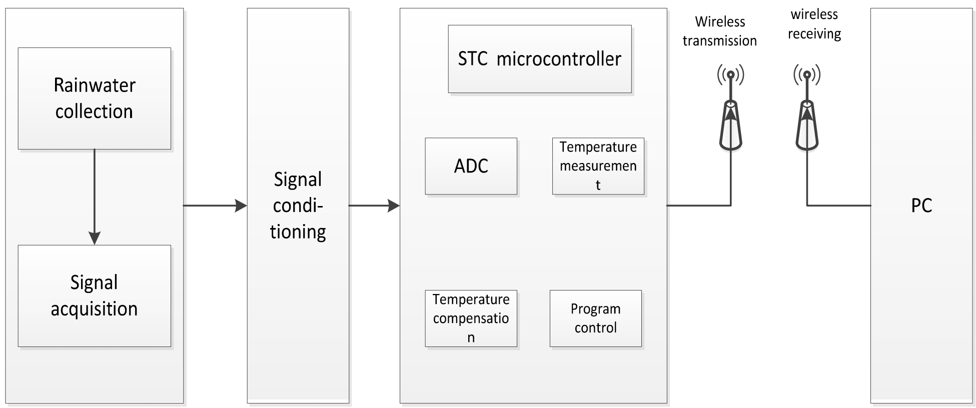

Figure 2: System structure diagram.

3.1 Hardware circuit design

3.1.1 Design of pH electrode signal measuring circuit

The primary cell of the composite glass electrode in the solution is a high internal resistance signal source, so the pH electrode signal measurement amplifier circuit can only get the correct electrode voltage signal only when the input impedance is high enough. The design uses high input impedance, low input current operational amplifier CA3140 to form a measuring signal amplification circuit. The amplifier has very fast response speed and self- compensation capability to achieve stable amplification gain. The pH electrode signal amplification circuit is shown in Figure 3. U1 and U2 are phase ratio operational circuits. When the parameters are symmetrical, the differential operational amplifier has very high input impedance. Among them, R=R2, R3=R4, we can get:

$$AIN1_{+} - AIN_{-} = \left(1 + 2\frac{R_3}{R_5}\right)(V_t - V_r) \quad (4)$$

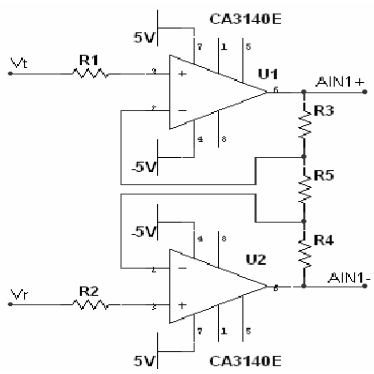

Figure 3: Amplifying circuit for pH electrode signal.

3.1.2 Design of temperature measuring circuit

The temperature is measured by four wire platinum resistance PT100, and its temperature range is -200 ~+850 degrees centigrade. In addition, the utility model has the advantages of shock resistance, good stability, high precision, etc. Four wire platinum resistance can counteract the error caused by lead resistance. The platinum resistance connection is shown in Figure 4. The voltages at the ends of the precision resistor are V_RES+ and V_RES- (the same as ground). There are:

$$V\_RTP_{+} - V\_RTP_{-} = I \times R_{tp} \quad (5)$$

$$V\_RES_{+} - V\_RES_{-} = I \times R_{rs} \quad (6)$$

Therefore, the formula for calculating the resistance value of platinum can be obtained, as shown in equation (7), and the interference caused by current fluctuation can be counteracted in calculation.

$$Rtp = \frac{V\_RTP_{+} - V\_RTP_{-}}{V\_RES_{+} - V\_RES_{-}} R_{rs} \quad (7)$$

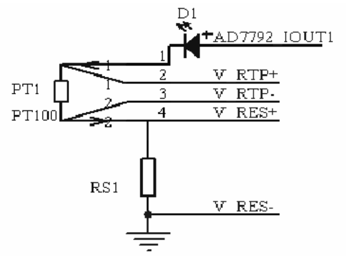

Figure 4: Four wire platinum resistance connection diagram.

3.2 Software programming

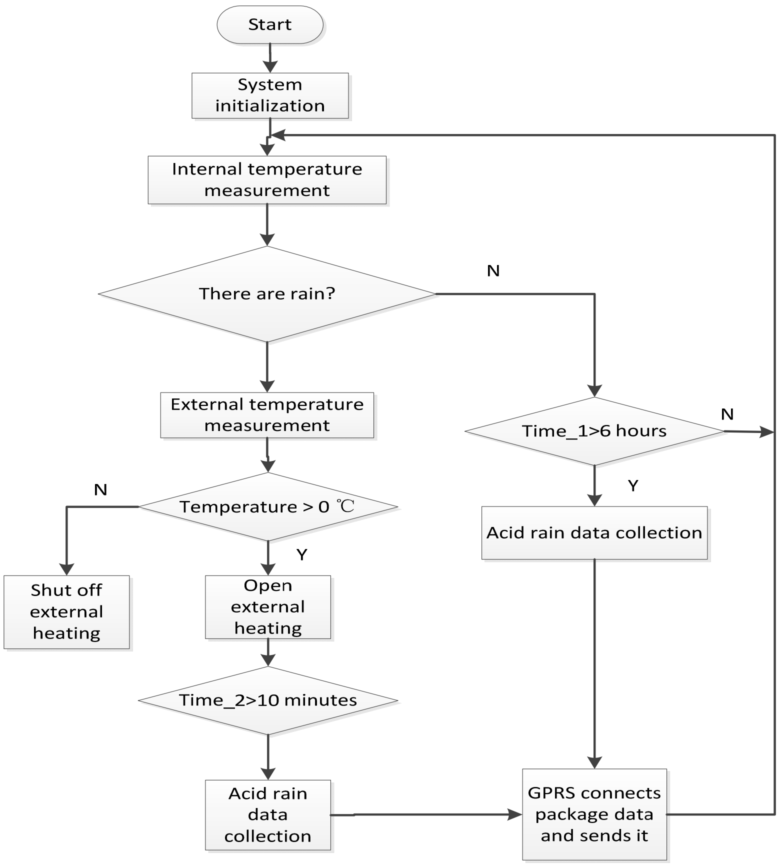

Figure 5: Flow chart of STC single chip control program.

The main function of STC MCU control program is to measure the acid rain, measure the temperature inside and outside, control the inside and outside weather protection system, and control the data receiving and sending regularly. The data sending includes 3 processes which are initialization of GPRS module, establishment of connection and sending of data. First, after power on or reset, the program initializes the internal resources of the control panel. Then set the system variables required initial value, related memory content and serial communication parameters and so on. Finally, the program enters the main part to complete the set function. STC microcontroller control program flow as shown in Figure 5.
The control panel controls the time by timer. When the set time arrives, the control board sends instructions through the serial port to connect the GPRS module with the server, and then sends the collected data to the server. The GPRS program flow is shown in Figure 6.

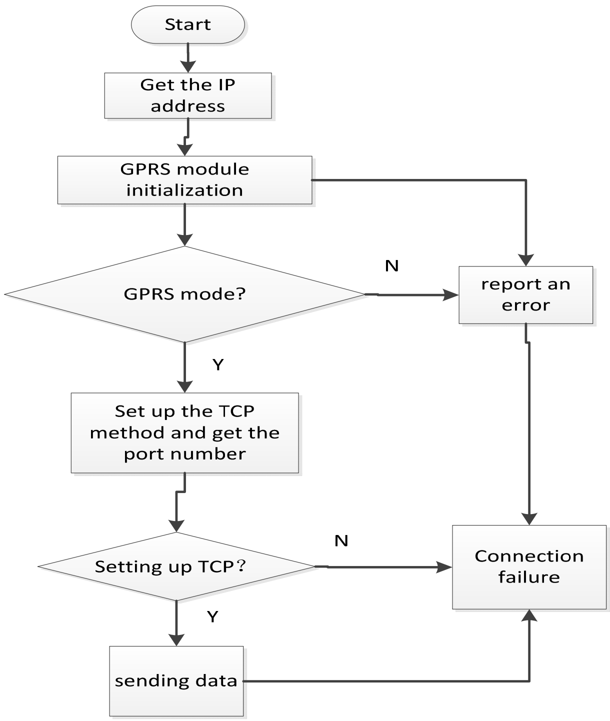

Figure 6: GPRS program flow chart.

4. Simulation experiment and result analysis

Table 1: Experimental data on the un-rainfall

Data type	Acid rain	Internal temperature	External temperature	Rainfall condition	standard liquid
10 minutes apart	6.86	24 °C	23 °C	1	pH6.8
10 minutes apart	4.04	24 °C	23 °C	1	Ph4.1
6 hours apart	6.83	23 °C	22 °C	1	pH6.8
6 hours apart	4.03	19 °C	18 °C	1	pH4.1

Table 2: Experimental data on rainfall status

Data type	Acid rain	Internal temperature	External temperature	Rainfall condition	standard liquid
10 minutes apart	6.85	25 °C	23 °C	0	pH6.8
10 minutes apart	4.06	24 °C	22 °C	0	Ph4.1
6 hours apart	6.82	21 °C	19 °C	0	pH6.8
6 hours apart	4.01	19 °C	17 °C	0	pH4.1

In the laboratory, the system test is mainly to verify whether the measurement of the sensor is accurate or not, whether the control functions is positive or not, and whether the data transmission can work or not. In the laboratory environment, the two scenarios of rainfall and no rainfall are simulated, and the related parameters of the two situations are measured continuously for 12 hours. The standard liquid pH is 6.8 and 4.1 for the target of acid rain measurement. The data are shown in Table 1 and Table 2.

From the analysis of the test results in the laboratory environment, the data collected at the measuring end meets the technical specifications of the system design, and the functions of each module are normal, and the program control meets the design requirements. The standard deviation of acid rain measured by standard pH meter is between 0.04pH, and the accuracy of system design target can be satisfied completely.

5. Conclusion

The design of acid rain pH value detection system based on STC microcontroller has the advantages of low cost, small size, high precision and stable performance. The system realizes the real-time monitoring of the pH value of acid rain in the environment. In this paper, firstly, the pH value of acid rain was collected by composite glass electrode, and the acid rain measurement, amplification and conditioning circuit and temperature compensation circuit are designed. Then, the acid rain signal is sampled and transformed by the AD converter. Finally, the collected acid rain signal is sent to the PC through the GPRS wireless transmission system. The experimental results show that the data collected at the end of the acid rain measurement system can meet the technical specifications of the system design, and the functions of each module are normal, and the program control meets the design requirements.・

Acknowledgments

Project name: Research on information management system for environmental parameters of livestock and poultry houses; Subject of Baoding Science, Technology and intellectual property Office. (No. 18ZN004).

References

Ba J., Tang J., Wang S.F., 2007, Analysis of temporal and spatial distribution and seasonal variation of acid rain in Chongqing area in recent ten years. Meteorology, 34(9), 81-88.

Cao D.Y., 2007, Study on Influence of Acid Rain on Ancient Buildings in Suzhou. Pollution Control Technology, 20(1), 8-11.

Ding G.A., Xu X.B., Wang S.F., 2004, Basic data set and preliminary analysis of acid rain network of China Meteorological Administration. Journal of Applied Meteorology, 15, 85-94.

Guo H.P., Cai P., 2006, Quality control technology in the manufacture of high precision acidity meter. Measurement technology, 3, 69-72.

Hua R.M., Li X.Q., 1998, Research progress of acid rain in China (J). Journal of Anhui Agriculture University, 25(2), 206-210.

Li W.B., 2003, Simplified pH detector. Analysis and monitoring, 24(11), 61-62.

Sun Y., 2018, Evaluation method of odor pollution in urban sewage treatment plants based on electronic nose technology, Chemical Engineering Transactions, 68, 253-258, DOI: 10.3303/CET1868043

253Tang J., Cheng H.B., Yu X.L., 2007, Statistical analysis of the acid rain observation network of unknown samples. The assessment results of meteorology, 33(12), 75-83.

Tang J., Xu X.B., Ba J., 2007, Analysis of the characteristics of acid rain changes in Beijing Tianjin area in recent years - Discussion on aerosol effects. Journal of Graduate University of Chinese Academy of Sciences, 24(5), 667-673.

Tang J., Xu X.B., Ba J., 2008, Electrical conductivity addition property and its application in quality evaluation of acid rain observation data. Applied meteorological journal, 19(4), 1-8.

Yang A., Sun B., Zhao G., 1999, The distribution and origin of acid rain and its influence on soil environment in China. Soil, 1, 13-18.

Zhang H.Y., Liu P., Wang J.F., Wang X.D., 2009, Generation and detachment of surface crust on ancient earthen architectures, Rock and Soil Mechanics, 7, 81-83.・

Zhang X.M., Chai F.H., Wang S.L., 2010, Research status of acid rain in China. Environmental science research, 5, 527-532.