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Design of a drinking water quality monitoring and evaluation system

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Abstract

With the rapid development of industry and agriculture, water pollution is found everywhere, and the protection of water resources has attracted increasing attention. For a long time, drinking water pollution was measured manually, which is time-consuming and laborious. To effectively detect and evaluate drinking water pollution, a drinking water quality monitoring and evaluation system is designed. The system can perform real-time measurements of water temperature, conductivity, turbidity and other parameters. The measurement results can be displayed on an LCD screen and can be transmitted remotely. The system can be used to detect the contamination of drinking water resources, such as surface water and groundwater, and to judge whether the water quality is qualified according to the set threshold parameters. The test results demonstrate that the system can realize dynamic monitoring and evaluation of drinking water resources. In addition, the system can provide effective data for water resource environmental protection.

Key words: evaluation, monitoring, water resources

INTRODUCTION

Drinking water is essential to life. Water is necessary for cooking and drinking. The amount of water that is required per day varies according to physical activity, age, health problems and environmental conditions (Kotlarz *et al.* 2018). People around the world currently drink at least one liter of water per day according to research, and more than 5% drink three liters of water per day. For those working in hot climates, 16 liters of water may be needed per day. Hence, drinking water is important (Ameer *et al.* 2017).

Drinking water resources are extremely scarce. Globally, only 89% of the population has access to adequate drinking water from a source that is suitable for drinking (Van Nevel *et al.* 2017). In some regions, such as sub-Saharan Africa, only 40–80 percent of the population can obtain clean drinking water. From the sources of drinking water, nearly 4.2 billion people worldwide can obtain tap water, while another 2.4 billion can obtain spring or public tap water. The World Health Organization considers having safe drinking water to be a fundamental human right, but approximately 12 billion people lack safe drinking water.

Drinking water is a highly important water resource and a basic requirement for human survival. Drinking water is important to daily life and plays a vital role in the development of society (Moriasi *et al.* 2015). Therefore, people should always be aware of the pollution and safety of drinking water resources (Seth *et al.* 2016). Through a reasonable assessment of drinking water safety and health risks, reasonable plans and solutions can be developed for the management of water resources (Bilgin & Konanç 2016). With rapid industrial and economic development, varying degrees of harm to drinking water have been caused, and water pollution, water shortages, and the pollution of rivers and lakes are becoming increasingly severe (Wang *et al.* 2017). Therefore, the protection of drinking water is of high significance.

With the increasingly severe pollution of drinking water resources, people's awareness of the protection of drinking water gradually strengthened, and management departments increased the intensity of water resource detection (Abyaneh 2014). However, in the traditional water quality detection system there are many shortcomings, such as high cost, large volume, inability to realize the remote transmission of parameters, and single measurement parameters. In view of the scenario that is described above, a drinking water quality monitoring and evaluation system is designed. Through this system, tap water and surface water can be detected automatically, the quality of drinking water can be estimated, and the remote dynamic monitoring of water quality and water conditions can effectively reduce the human, material and financial resources that are invested in water resource protection. At the same time, the system can conduct on-line water quality assessment. The assessment is based on threshold parameters that are set by experienced managers. When a value is uploaded to the cloud assessment system, the system can automatically determine whether the water quality in the region is qualified according to the threshold (Wang *et al.* 2018).

METHODOLOGY

The overall design of the system is as follows: First, the parameters of conductivity, temperature and turbidity are collected, and network signals such as WIFI and 4G are uploaded to the cloud platform. The cloud platform evaluates the water quality according to the cloud platform evaluation parameters that have been set by users. Since the technologies of WIFI and 4G are relatively mature, we will focus on collection and evaluation. The hardware sensor acquisition circuit and the software part of the system are designed in the following subsections.

Hardware design

WIFI, 4G and other communication methods are relatively mature. For this system, the most important hardware design circuit is the sensor acquisition circuit. Hence, we introduce the hardware design of the conductivity, temperature, and turbidity detection circuit. First, the design of conductivity testing circuit is illustrated in Figure 1. The conductivity of drinking water is measured by measuring the R2 value. The value of the R2 conductivity varies, thereby causing 555 unsteady-state timer flip-flop, which produces a rectangular wave frequency that also varies. The single-chip microcomputer receives the waveform frequency. Using a formula for converting frequency into resistivity, the conductivity can be calculated from the resistivity, which is cheaper than using a

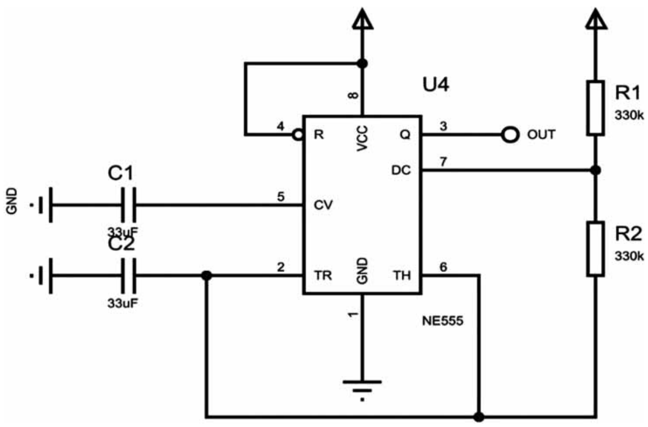

Figure 1 | Conductivity test circuit.

finished conductivity sensor.

$$\mathrm{f} = \frac{1}{T} = \frac{1}{[(R_1 + 2R_2) * c * \ln 2]} \tag{1}$$

The formula for the unknown resistance R2 can be obtained from Equation (1):

$$R_2 = \frac{1}{2}\left[\frac{1}{(f * c * \ln 2)} - R_1\right] \tag{2}$$

The temperature monitoring circuit, as illustrated in Figure 2, consists of a temperature sensor that uses 18B20 and a single-chip microcomputer, which use a line to communicate. To provide the sensor 18B20 with sufficient current supply during temperature acquisition, we adopt the improved parasitic power supply mode. The output DQ of the sensor Q1 is connected to the microcontroller. To avoid the temperature error that is caused by insufficient current supply, a 10 K resistor, namely, R8, is added to the line and connected to the parasitic power supply.

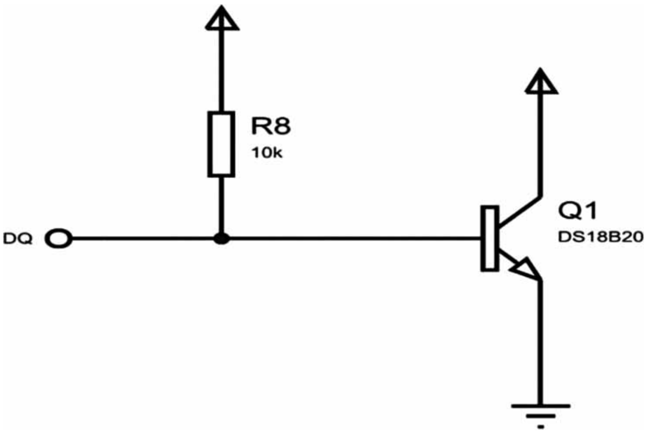

Figure 2 | Temperature monitoring circuit.

Finally, we introduce the design of the turbidity detection circuit. The turbidity sensor uses photosensitive resistance. In the sensor, the resistance changes dramatically in the following scenario: When the liquid turbidity increases, the light that is emitted by a diode and reaches the photosensitive resistor is substantially weakened, and the resistance of the photosensitive resistor increases. When the fluid turbidity drops, the light from the diode will reach the photoresistor smoothly. When the diode light signal intensity is constant, the measured substance turbidity changes, and the resistance of the photoresistor also changes. Hence, the photoresistor resistance changes can reflect the measured changes in the turbidity. The A/D converter digitizes the electrical signals that are read by the turbidity sensor. As illustrated in Figure 3 of the A/D conversion circuit, an ADC0832 8-pin VCC is connected to the microcontroller power supply terminal, with a 7-pin ADC0832 as a reset termination unused P3 port, to simplify the circuit, and DI and DO are connected in parallel by a data line that is connected with the P3 port.

Software design

The overall process of the system is to collect water quality parameters through various sensors and to determine whether there is a network signal. When the network signal exists, the parameters are uploaded in real time. This section mainly introduces the software flow of parameter acquisition.

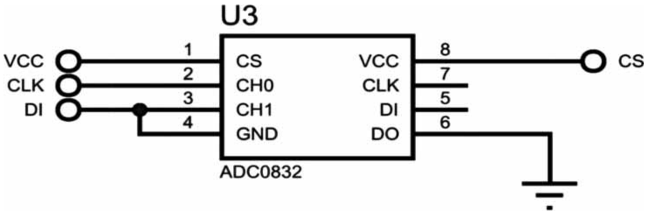

Figure 3 | Turbidity detection circuit.

First, we introduce the design of the temperature detection module software. The temperature monitoring program is illustrated in Figure 4. After the system has been powered on and initialized, the DS18B20 is initialized and reads the temperature value of data processing, and a code for displaying the temperature is generated.

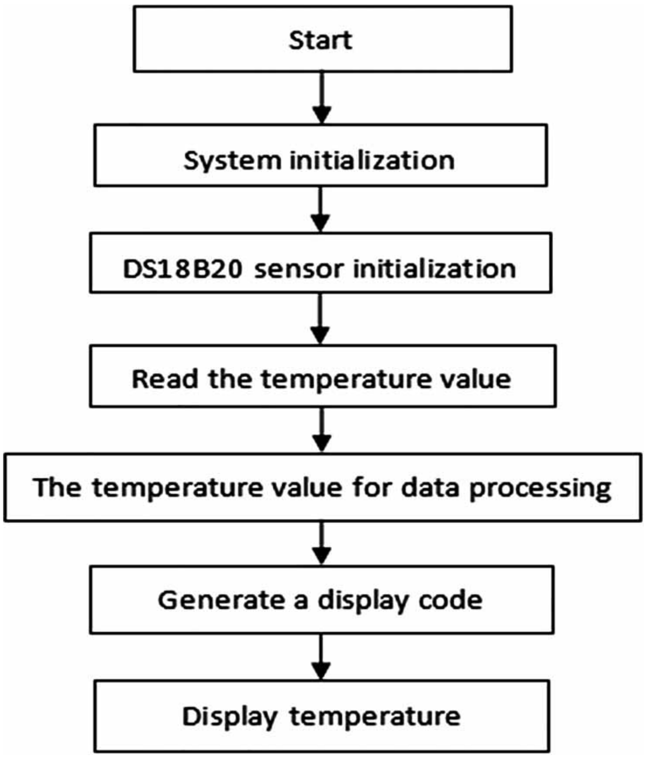

Figure 4 | Temperature monitoring flow chart.

An electrical conductivity measurement flow chart is presented in Figure 5. After the system is electrified, the system is initialized. The microcontroller measures the period of 555 oscillation by a timer counter, calculates the resistance value that corresponds to R2 from the period, and calculates the electrical conductivity of the measured water resources from the resistance value. The whole process is completed by interruption.

Finally, we present a turbidity detection flow chart. The detection flow chart is shown in Figure 6. After the system is powered on, the turbidity information is initialized and read from the sensor. The turbidity information comes from the AD converter. After reading the AD converter, the data are processed to calculate the turbidity value and the turbidity value is sent to the host computer communication interface.

RESULTS AND DISCUSSION

A picture of the device is shown in Figure 7. Compared with the traditional device, this device is small and easy to carry, and the designed conductivity sensor circuit is of low cost. The most important

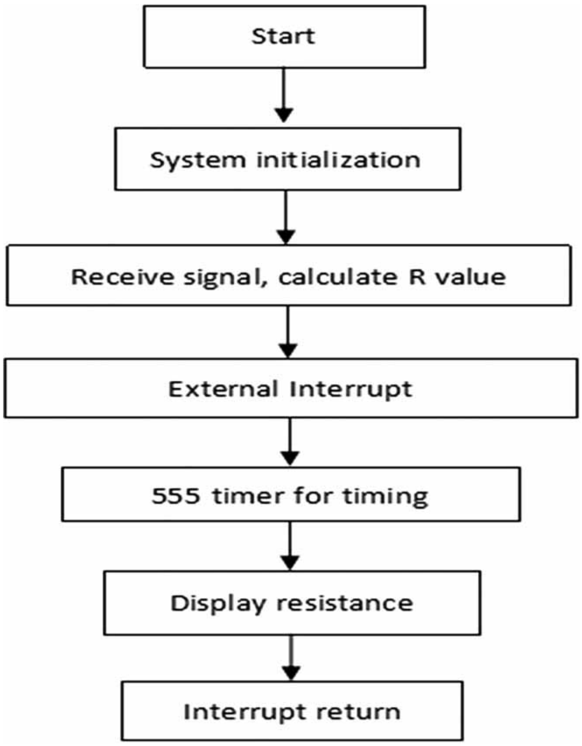

Figure 5 | Conductivity monitoring flow chart.

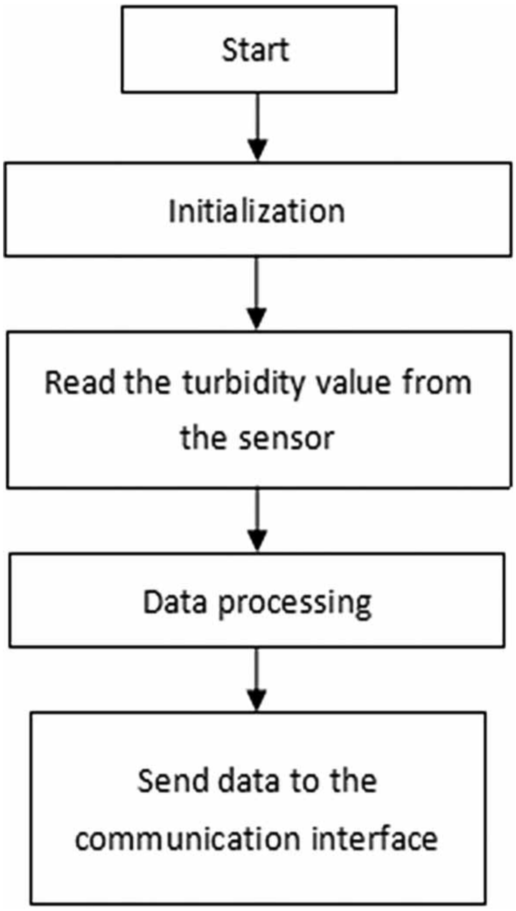

Figure 6 | Turbidity monitoring flow chart.

Figure 7 | Water quality monitoring device.

property is that the equipment uploads the observation information to the cloud platform through WIFI, 4G and other networks, which is convenient for networking for regional monitoring. The equipment adopts a low-power design, and a 18,650 battery can enable the equipment to stand by for a whole year, with a standby current of approximately 100 μa. Due to the use of a liquid crystal display, the operation is simple and the display is clear.

In this paper, the drinking water source of Qingdao City, China was systematically tested using the device. The drinking water source includes an urban water supply, rural tap water, a source reservoir, groundwater and other sources. The results are shown in Table 1. Comparing our system with the standard instrument, the measurement results are almost the same. After uploading the measured data to the cloud platform, the water quality can be evaluated automatically according to parameters such as conductivity and turbidity that are stipulated by the national drinking water standard. The test results demonstrate that the system can display the temperature, turbidity and conductivity normally. According to investigation and testing, the overall water quality of Qingdao is satisfactory, and the water quality level is among the highest in the country. According to the set standards, 100 points of urban tap water are tested and all 100 points are qualified; hence, the qualification rate is 100%. For rural tap water, 100 points are tested, of which 97 are qualified; hence, the qualification rate is 97%. Since the overall water supply is a pipeline, the pollution should be in the user's home pipeline. Twenty points are tested in the water source reservoir test and in the groundwater test, and both pass rates exceed 90%.

Table 1 | Test results for drinking water

Place	Number of test points	Number of qualified points	Qualification rate
Urban water supply	100	100	100%
Rural tap water	100	97	97%
Water source reservoir	20	18	90%
Groundwater	20	19	95%

CONCLUSIONS

Aiming at overcoming the difficulty, high time consumption, and high power consumption in the monitoring of drinking water pollution, a new scheme for measuring conductivity with a 555 timing circuit, temperature with a digital temperature sensor 18B20, and turbidity with a photoresistor is presented. The measurement results can be uploaded to the cloud platform in real time through WIFI, 4G and other network signals. The cloud platform is set according to the specified settings. The threshold parameters are used to determine whether the water quality is qualified. This system has effectively improved the monitoring efficiency of drinking water pollution and has reduced the volume of the testing equipment. The system is simple in design, convenient to use and of low cost. The system can be used to monitor and evaluate the supply of water resources by the government and can also be used as an on-line monitoring tool for the protection of water resources. The system can realize the detection of various parameters by collocating various sensors, which has high application value.

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