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DESIGN OF MULTI-PARAMETER WATER QUALITY DETECTION SYSTEM BASED ON ATMEGA128

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Abstract. In order to build an efficient multi-parameter system of water quality detection, this paper proposes a system with ATMEGA128 as the processor and each sensor selected according to the actual needs. The designed system can solve the problems including single measurement parameter and poor accuracy of the current water quality measurement, which is of great significance to the coal mine, hydrogeology and water environment monitoring.

Keywords: water quality; multiple parameters; ATMEGA128; sensors.

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Problem statement. With the development of economy, the utilization of water resources and water environment has been paid more and more attention, and the online detection system of water quality parameters has been widely used. The water quality detection system is indispensable to the monitoring of water pollution in coal mines, the exploration research of hydrogeology, or the regular water environment monitoring. However, at the present stage, the water quality detection system is mostly single measurement, which means that only one water parameter is monitored. The number of multi-parameter measuring equipment is small, and their accuracy is poor.

In this paper, a multi-parameter detection system based on ATMEGA128 is proposed, which can effectively carry out multi-parameter water quality detection. The system detects water temperature, pH value and conductivity at the same time, can provide convenience for various studies, and will be an important part of development of the water parameters measuring equipment in the future.

Basic material

1. General structure

In this paper, ATMEGA128 Single Chip Microcomputer is used to detect multiple parameters of water quality, such as the temperature, pH and conductivity, at the same time. The system consists of the temperature sensor circuit, the pH sensor circuit, the conductivity sensor circuit, the amplification circuit, and ATMEGA128 single chip microcomputer. The water parameters are detected by the corresponding sensor, and the fine current is produced, which is amplified by the amplification circuit and sent to ATMEGA128 for processing, so that corresponding value is obtained. The general structure diagram of the system is shown in Fig. 1.

2. Selection of microprocessor

In order to provide information more quickly, the ATMEGA128 developed by ATMEL is used as the core processor in this system. It has the characteristic of 1 MIPS/MHz processing speed due to the RISC instruction set. Inside the ATMEGA128 chip, there are 8 channel ADC modules integrated. The precision can be up to 10 bits, and 4-way differential input increases the stability of the input signal. Furthermore, its internal timer has not only the function of timing and counting, but also other powerful functions of capturing interrupts, PWM waveform output, etc. These characteristics are not comparable to other processors.

3. Circuit design of sensor

3.1. Design of temperature module

Temperature is the most common and important parameter of a water source, moreover, other parameters are directly or indirectly affected by it, so a fast and accurate temperature module is indispensable. Considering the influence of the water pH, the waterproof, rust-proof and corrosion-resistant DS18B20 temperature sensor is selected in this module. DS18B20 produced by DALLAS is a fully digital temperature conversion and output sensor, and its advanced single bus communication can greatly reduce the number of microprocessor pins used. The conversion accuracy can reach ±0.5°C due to its 12 bits data resolution. DS18B20 has two kinds of power supply: parasitic and external. Under parasitic power supply, the circuit will "steal" energy when the I/O or VDD pins are at a high level, so a strong pull to the I/O line should be provided, and the complexity of circuit design will be increased. Therefore, external power supply is used in the design, as shown in Fig. 2. The advantage of this mode is that it does not require a strong pull to the I/O line, and the bus controller does not have to always maintain a high level during temperature conversion. In this case, other data can be allowed to be exchanged on the single bus during the transition.

3.2. Design of pH sensor module

When a glass electrode is immersed in the tested solution, both sides of the glass membrane contact with internal constant pH buffer solution and the tested solution, respectively. Hydration on the interactional surface can form a hydration layer, and H^+ of the solution exchanges ions with it, so the interfacial potentials φ_1 and φ_2 are generated. According to the nienster formula, the membrane potential is set to $\Delta\varphi M$, and the formula is as follows:

$$\Delta\varphi M = \varphi_1 - \varphi_2 = 0.059\lg(\alpha H^+_{test}/\alpha H^+_{inside})$$

Since the pH value of the internal buffer solution of the glass electrode is fixed, the pH value of the tested solution can be determined by using the reference electrode to measure $\Delta\varphi M$. In fact, due to the influence of glass material, thickness and conditions of the process (heat treatment), $\Delta\varphi M$ is not equal to zero when $\alpha H^+_{test} = \alpha H^+_{inside}$. There are still several mV, which we call asymmetric potential. The actual conversion formula is:

$$\Delta\varphi M = E_a + 0.059\lg(\alpha H^+_{test}/\alpha H^+_{inside})$$

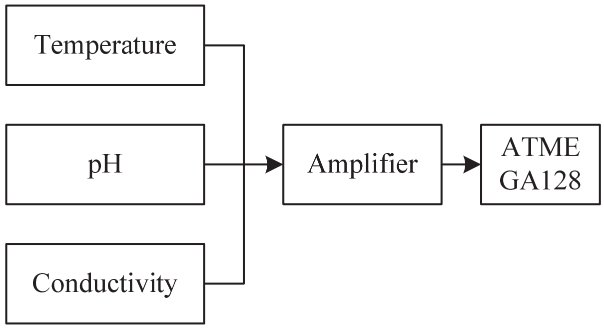

Fig. 1. General structure diagram

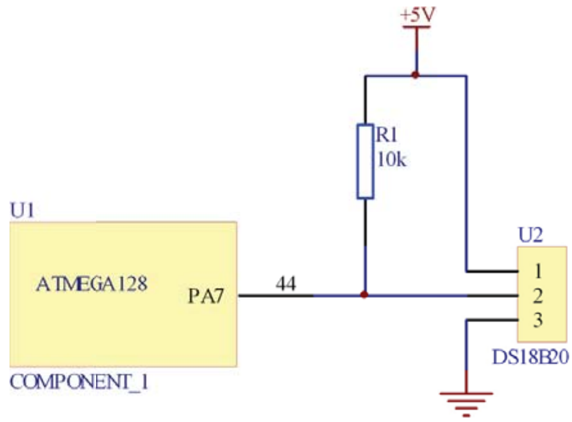

Fig. 2. Temperature measurement circuit

The E-201-C composite electrode pH sensor produced by Shanghai Leici is selected for this system. The electrode of the sensor has two output pins: PH^+ and PH^-. When pH value of the tested water is less than 7, the sensor output signal is negative, and it can not be sampled by MCU. PH^- is the reference electrode, the value of which is expected to be half of power supply voltage in the actual circuit, and PH^+ is the measuring electrode, the pin of which is a sampling pin of MCU for AD sampling. The design requirement of this module is that when pH value of the tested water is 7, the output voltage of circuit should be around 2.5V, when pH value of the tested water is less than 7, the output voltage of circuit should be 0~2.5 V, and when pH value of the tested water is greater than 7, the output voltage of circuit should be 2.5~5 V, so that MCU can identify the sampling signal. In Fig. 3, the first amplifier is proportional follower, noninverting input of which is connected to the voltage regulator module by a potentiometer. The voltage regulator module consists of resistance R28 and regulator chip TL431C. By adjusting the potentiometer R29, the output voltage of pin 7 of LM324 can be set between 0~5V. The output voltage is expected to be set around 2.5V in the practical measurement, so that the PH^+ relative to PH^- voltage can be guaranteed to be not negative. The second amplifier is

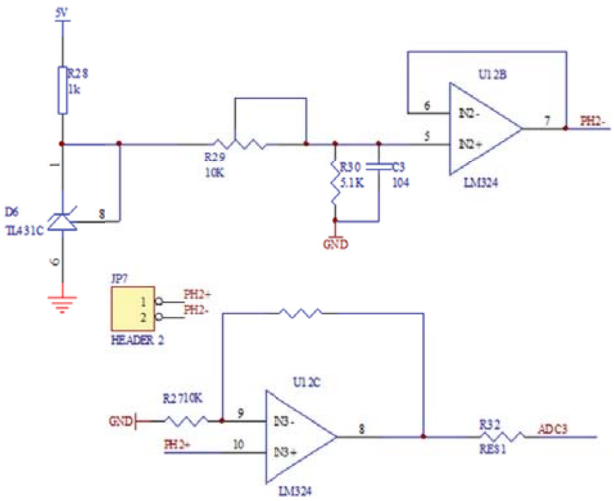

Fig. 3. pH sensor circuit

a proportional one, amplifying the millivolt voltage signal coming from the PH+. After amplification, the signal is transmitted to the ADC3 sampling channel of MCU.

Through the relevant information, we can learn that the electrical conductivity of the mine water inrush quality is in the range of 0～20000 μs/cm. Thus, the CM-230 conductivity sensor produced by Shanghai Chengci Electronics Co. is chosen in this module to meet its requirements.

3.3. Design of conductivity module

The design of the conductivity meter includes four aspects:

1. Design of the instrument interface circuit. The CM-230 conductivity sensor has four lead wires. Pin 1 (CELL1) and pin 2 (CELL2) are used to measure the input and output voltage. Pin 3 and pin 4 are the power pin and the ground pin. In general, the interface circuit is designed as shown in Fig. 4.

2. The measuring principle of the conductivity sensor indicates that the sensor electrode measures the quantity of charge in the solution, i.e. the amount of current. The operation resides in applying a certain voltage on both ends of the electrode, and then measuring the output current. In order to make the positive and negative charge in the solution accumulate on the electrode for not a long time and avoid affecting the measuring precision, the voltage applied to both ends of the electrode must be PWM wave, the frequency of which is around 100 Hz. The PWM circuit diagram is designed as shown in Fig. 5.

In Fig. 5, CD4051 is the multichannel selective switch chip, which can select from X0~X7 to connect to pin X according to the different combination of A, B, C pins. The high/low level of PWM waveform output is required to lie within ±5V in this module, so pin X0 and pin X1 are connected to the +5V zener diode and the -5V zener diode, respectively. Pin B and pin C are connected to the ground, and pin PE5 of the MCU can control pin A of CD4051. When pin PE5 is at the low level, X is connected with X0 channel, and the output level is +5V. When pin PE5 is at a high level, X is connected with X1 channel, and the output level is -5V. Therefore, the corresponding PWM waveform can be obtained at pin X, just requiring a periodic high/low level output of pin PE5.

3. In order to meet the demand of different ranges and improve the measuring precision of the instrument, a switch range circuit is designed in this module as shown in Fig. 6. Pin CELL2 is the output voltage signal of the conductivity sensor; it is connected to pin X0~X3 of CD4052 through four different resistances. CD4052 and CD4051 have the same function, and the difference between them is just that CD4052 has a two-channel signal (X and Y). Only the X channel is used in this design through setting A and B ports in CD4052. The latter are connected to pin PC2 and PC3 of the MCU, so anyone of the X0~X3 channels can be selected by pin PC2 and PC3.

In Fig. 6, pin CELL2 of CD4052 is also connected to the LM324 amplifier's pin 2, which is the reverse input

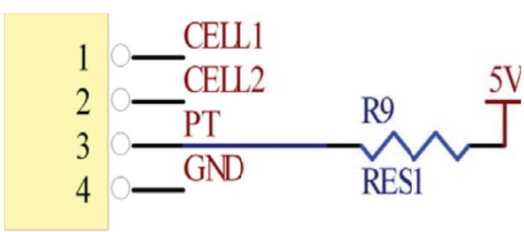

Fig. 4. Sensor and control board interface circuit

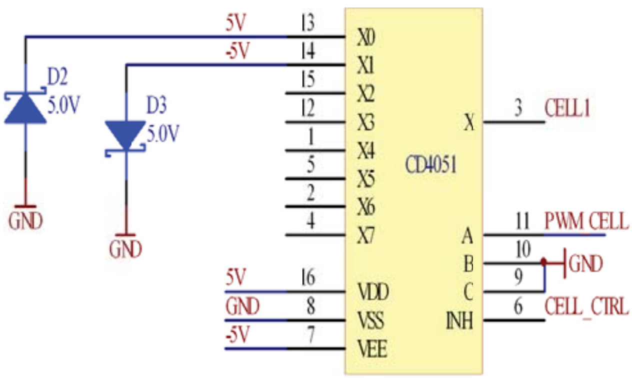

Fig. 5. PWM waveform output circuit

pin of the first amplifier in the chip. Meanwhile, pin X of CD4052 is connected to the LM324 amplifier's pin 1, which is the output pin of the first amplifier in the chip. According to the amplifier's working principle, the output voltage of the amplifier's pin 1 is different, as the resistance value of R10~R13 is selected differently. In the light of electrical conductivity range of the tested solution, different resistances are selected to avoid the amplified voltage saturation and to achieve the goal of widening the switch range.

4. Waveform shaping and signal amplification. This part is the core of the conductivity module design. As stated above, the X channel of CD4051 outputs the PWM waveform; its frequency is around 100 Hz, and the fluctuation amplitude is ±5V. After this waveform goes through the conductivity sensor, pin CELL2 can get an output voltage, which is also the PWM waveform around 100 Hz. Only the amplitude of the waveform drops to the millivolt level. As is generally known, the ADC sampling pin of MCU only can sample the positive voltage signal. Therefore, one impact of the circuit is amplifying the output voltage of the conductivity sensor on pin CELL2. The amplification factor is determined by the resistance value of R10~R13 in Fig. 6. Another function of the circuit is shaping the output PWM waveform on pin CELL2 and filtering the negative voltage signal to bring convenience for MCU sampling.

The first amplifier in Fig. 7 only serves as signal amplification. The second amplifier is combined with the D4 and D5 diodes to constitute the precision rectifying circuit, so that negative half-cycle signal of PWM waveform can not pass through this circuit. Finally, the reconstructive signal is sent to the pin ADC1 sampling.

5. Software design

The software flow diagram is shown in Fig. 8. After the system is powered on, the initialization is performed first, and then the temperature, pH value and conductivity are collected; the data are then stored and processed.

CONCLUSIONS This paper provides a brief description of the design of ATMEGA128 used in the multi-parameter water quality measurement system for the first time. The main processor, as well as each sensor, is selected according to the practical needs. Then the circuit is designed, and its parameters are calculated. The system based on ATMEGA128 designed in this paper manages to solve the problems of current water quality measurement (single parameter measurement, low precision, etc.) very well.

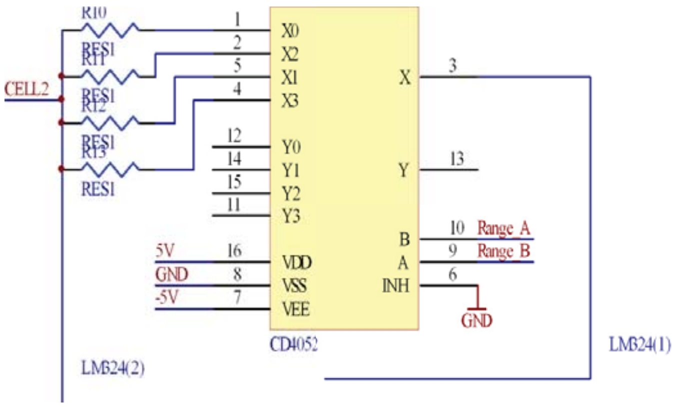

Fig. 6. PWM waveform output circuit

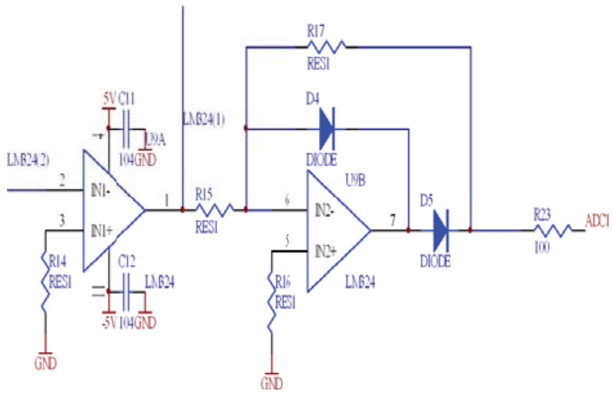

Fig. 7. Signal amplification and shaping circuit

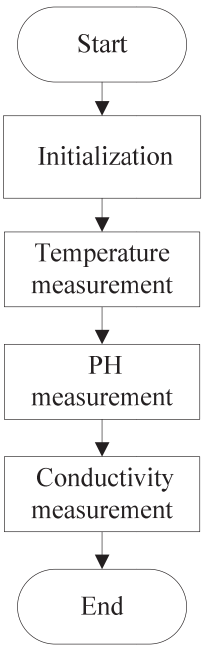

Fig. 8. Software flow diagram

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