Key technology of distributed temperature field monitoring system based on single bus

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Abstract. In the artificial stratum freezing method construction, the stratum temperature is an important basis for judging the thickness, strength and stability of the frozen wall. The temperature of the circulating return brine is an important indicator reflecting the state of heat exchange between low-temperature brine and the stratum. Due to the large number of temperature measurement points, long measurement distances, and relatively scattered positions in the freezing project, this paper uses a single-bus temperature measurement technology to develop a monitoring system based on high-performance microcontrollers and distributed digital temperature measurement cables on the hardware. Combined with LabVIEW software, the real-time collection and monitoring of temperature data is realized.

1. Introduction
The artificial freezing method is one of the stratum improvement construction methods in my country. Since it was first successfully applied in China in 1955, it has been widely promoted in mine construction, urban underground engineering and traffic tunnels. The temperature field is an important basis for judging the thickness of the frozen wall and an important indicator reflecting the strength and stability of the frozen wall[1], so several temperature measurement holes were drilled in the weak position of the frozen wall to monitor the development of the frozen wall in real time[2]. In the past, temperature measuring devices such as glass thermometers, thermocouples, and thermal resistors were placed in temperature measuring holes and the main pipeline of brine to analyze the cooling trend of the formation and the working state of freezing equipment. However, the large number of measurement points and dispersion caused a large number of wires to be laid, Disadvantages such as large collection workload and incorrect data reading. In recent years, the single-bus temperature measurement technology[3-5] has been widely used in freezing projects. Multiple digital temperature sensors can be mounted on a bus, with a measurement accuracy of ±0.5°C. It has the advantages of rapid networking of discrete temperature measurement points in the whole field[6]. This article introduces a temperature acquisition system based on a single chip microcomputer with STM32F4 series microcontroller as the core and distributed temperature measurement cable. The system uses RS485 serial communication to establish the connection between the acquisition instrument and the PC, and the monitoring interface is designed using LabVIEW software.

2. Single bus discrete point networking temperature measurement technology

2.1. Design of temperature acquisition hardware
2.1.1. Wired temperature measuring instrument.
Considering the circuit design of the single-chip microcomputer and the number of temperature sensors used, the core of the single-chip microcomputer uses STM32F4 series microcontrollers, combined with the corresponding embedded software to achieve data acquisition control and communication functions. The prototype is shown in figure 1. The system hardware has designed a driving circuit with strong pull-up capability, the transmission distance can reach 1000m, and 55 temperature measurement points can be identified. Equipped with a 2.8-inch TFT LCD screen to display the running status information of the monitoring module, which facilitates the interactive operation of on-site debugging and human-machine interface. In addition, the module also designed a program with automatic ID number recognition function, ID identification, location information recognition and information storage recognition completed by the established ID number information database.

Figure 1. Prototype of temperature measuring instrument

2.1.2. Wireless temperature measuring instrument.
The freezing temperature field wireless monitoring module adopts ZigBee technology, integrating temperature acquisition, routing node and coordination functions. The meters are distributed in different areas of the frozen project, perform temperature collection and transmission, and build a network topology. Single-bus digital temperature sensor is used for temperature acquisition, and the parasitic power supply mode is used (the working power of DS18B20 is 3–5V). For construction sites with no power supply or unstable power supply, the collection instrument can be powered by 18650 lithium battery, which is not limited by the complex construction sites to complete the space networking monitoring. After the instrument collects all the data on the subordinate lines, it executes the router function to package and forward the data to the coordinator, and the coordinator uploads it to the host computer for data display and management. The working principle is shown in figure 2.
2.1.3. Distributed digital temperature measurement cable.

Usually the sensors of the temperature measurement cable are connected to the temperature measurement cable, which needs to be made manually on site, but the quality of the hand-made is random, plus the low temperature and humidity environment in the drill hole, groundwater penetration and water vapor condensation in the hole, the sensor on the cable and the cable connector are prone to short circuit due to water ingress. In addition, as the drilling depth increases to hundreds of meters or even kilometers, the construction and safety of the lowering and hanging of the temperature measurement cable increases, and the traditional processing and installation methods are not conducive to the inspection, maintenance and reuse of the temperature measurement system. In order to ensure the factory standardized production and quality inspection of the sensor and cable connection, and at the same time facilitate on-site installation, maintenance and reuse, an integrated and continuous temperature measurement cable with DS18B20 embedded in the cable was developed, as shown in figure 3.
2.2. LabVIEW configuration monitoring software
LabVIEW is a graphical programming language and standard data acquisition software. It has powerful information processing capabilities and hardware device driver functions. Therefore, the software design of the host computer mainly uses LabVIEW to complete the real-time display of temperature values[7]. The instrument control of LabVIEW includes sending commands directly to the instrument and calling instrument driver programming. The operation of the instrument can be realized by calling the VISA WRITE and VISA READ functions in LabVIEW. Figure 4 shows the temperature monitoring display on the front panel of the host computer LabVIEW. The accuracy is ±0.01°C. The software implements functions such as database management, early warning, data graphic display, and report production, laying a foundation for data analysis and processing.

![Figure 4. Upper computer monitoring software](image)

3. Calibration of temperature measurement value
In order to verify the acquisition accuracy of temperature measurement, the DS18B20 sensor was calibrated. First of all, number all DS18B20 one by one, and then use the standard thermometer of class 0.1 as a reference to conduct high, low temperature and normal pressure environmental tests in a constant temperature water tank and a low temperature test box. The temperature recorded by the DS18B20 and the temperature set by the thermometer are defined as variable X and variable Y, respectively. Use linear regression analysis to determine the closeness between the sensor recording temperature and the thermometer design temperature, as shown in figure 5.
4. Conclusion
The temperature field monitoring system based on the single-bus technology is widely popularized and applied in the freezing project due to its outstanding wiring advantages, ultra-long-distance transmission, and rapid network connection of discrete points. The monitoring module as the core part of the system must have the characteristics of anti-interference, good stability and high collection accuracy. Through experimental testing and on-site application, certain improvements have been made in the functional design and performance quality of the module, which has made a beneficial exploration for the realization of information construction of freezing method, and achieved good results.

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