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Application Research of Domestic Digital Quantity Acquisition Controller Under the Background of Innovation

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Abstract: Based on the background of information innovation, the development of intelligent sensing technology science is studied to provide agricultural modernization and intelligent transformation technologies with high quality, strong reliability, high cost performance and rich applicable scenarios for the national agricultural Internet of Things control, industrial automation, instrumentation and other industries. This project uses domestic components as the structural basis and domestic single-chip microcomputer chips as the main control carrier. It innovatively integrates autonomous controllable technology and uses the MODBUS protocol to achieve reliable data exchange between the controller and other devices. It designs a domestic digital quantity acquisition controller that can support 6-way isolated digital input interface, 12-way isolated digital output interface and 1-way 485 isolated communication, and is compatible with the standard MODBUS protocol, variant MODBUS protocol and protocol switching in different scenarios. It can not only meet the domestic and foreign market's demand for safety and reliability, but also greatly contribute to the autonomous controllability and technological innovation in my country's information technology field, and realize the sustainable development of autonomous controllable systems.

Keywords: Digital Quantity Acquisition Controller; Hardware Design; MODBUS Protocol.

1. Introduction

The information innovation industry, or the industry of information technology application innovation, places great emphasis on network infrastructure and data security, with digital acquisition being a key component. Currently, in the share of intellectual property of China's innovation products, independent intellectual property in infrastructure, underlying hardware, and solutions remains low, posing an urgent problem to address. Digital acquisition is widely applied in fan control systems(Fang et al,2023), agricultural robot control(Zheng Zhiliang,2022), and industrial automation products(Wang Bin, Zhang Guoqiang,2021). However, there are few digital acquisition systems with independent intellectual property rights, creating an increasingly urgent demand for the development of digital acquisition controllers. This project develops a domestically-produced digital acquisition controller that supports a 6-way isolated digital input interface, a 12-way isolated digital output interface, and a 1-way 485 isolated communication. The controller is compatible with the standard MODBUS protocol, variant MODBUS protocol, and protocol switching in various scenarios. Using domestic components as its structural foundation and a domestic single-chip microcontroller chip as the main control carrier, it innovatively incorporates autonomous controllable technology and employs the MODBUS protocol for reliable data exchange with other devices. With its rich peripheral interfaces and powerful communication capabilities, it enables flexible software programming, digital signal acquisition, data processing, and control logic implementation.

Under the framework of China's Information Technology Application Innovation (Xinchuang) initiative, the development and application of domestically produced digital data acquisition controllers have garnered significant attention. These devices are integral to achieving technological independence in areas such as scientific research, industrial automation, and national security.

Recent research has focused on addressing the challenges posed by heavy reliance on foreign core technologies like analog-to-digital converters (ADCs) and field-programmable gate arrays (FPGAs). For example, Zhang et al. (2023) analyzed the performance of domestically produced ADCs, highlighting the progress made in reducing the performance gap with international counterparts. Similarly, Li and Wang (2022) explored the integration of domestic FPGAs into digital acquisition systems, demonstrating their viability for precision measurement tasks. Furthermore, research efforts have emphasized the importance of collaboration between academia and industry to accelerate innovation in this field. Studies by Chen et al. (2021) underline the role of government policies and funding in fostering a competitive ecosystem for developing high-quality, domestically produced components. Benchmarking studies, such as those conducted by Liu et al. (2023), have compared domestic digital acquisition systems against imported models, identifying key areas for optimization.

While progress has been substantial, challenges remain in improving the precision, stability, and cost-efficiency of domestic controllers. Ongoing research aims to overcome these barriers, ensuring robust applications across diverse sectors.

2. Hardware Design

2.1. System Structure and Working Principle

In hardware design, this project includes circuit board design and interface circuit design. Based on requirements, a digital interface circuit with 12 output ports and 6 input ports is designed for controlling external devices and collecting external input signals. Additionally, an isolation circuit is

designed to protect the 485 communication interface from electrical interference and to improve communication stability.

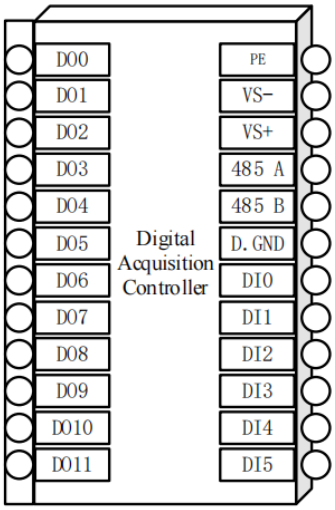

Figure 1. Digital Acquisition Controller

The digital interface circuit with 12 output ports and 6 input ports ensures circuit stability and anti-interference capability. To enhance power stability, necessary protection and isolation measures are added to the hardware design to ensure the equipment can pass the electromagnetic compatibility (EMC) test.

To protect the device's control interface from external interference and damage, necessary protection circuits are added. These include short-circuit overcurrent protection, self-resetting overcurrent fuses, a varistor circuit for overvoltage protection, and suitable ESD tubes for static protection, ensuring component integrity. Additionally, filtering circuits are added to filter out high-frequency noise and interference, ensuring stable and reliable operation of the input signals.

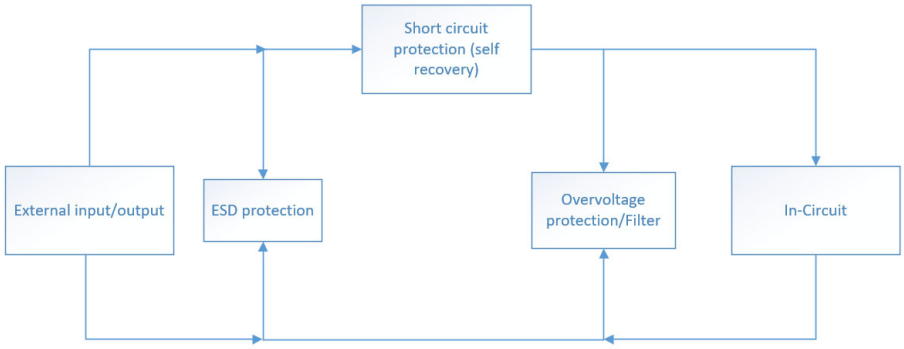

Figure 2. Interface Protection Circuit

For the power circuit design, stability is ensured by adding common-mode inductors to suppress common-mode interference and X and Y capacitors to reduce noise. Overvoltage and overcurrent situations are also considered by adding fuses and varistors.

Heat dissipation is addressed through reasonable PCB layout to ensure heat is efficiently dissipated into the air, allowing stable circuit operation.

2.2. Isolation Circuit Design

An isolation circuit is designed for the 485 communication interface to protect the device from electrical interference and to improve communication stability.

The 485 circuit may face various external interferences, and the device could be damaged by external factors, especially as 485 communication is a crucial part of this product, being the sole communication channel with external devices. To ensure data communication stability, the design includes filtering and grounding.

3. Software Design

3.1. Multi-Protocol Support Design

The controller supports the standard MODBUS protocol as well as switching between multiple variant MODBUS protocols, allowing compatibility with general-purpose gateway devices on the market. This includes data frame format analysis, communication command generation, and response to facilitate reliable communication with other devices.

Besides default support for the standard MODBUS protocol, the device can be configured to switch to other variant MODBUS protocols based on market research. Through analysis and study, these variants are incorporated into the software design, enabling the device to switch between protocols and maintain seamless communication with other devices.

4. Project Case

Using the domestically-produced digital quantity acquisition controller, an automatic smoke alarm is developed, as shown in Figure 3, with the circuit diagram shown in Figure 2.

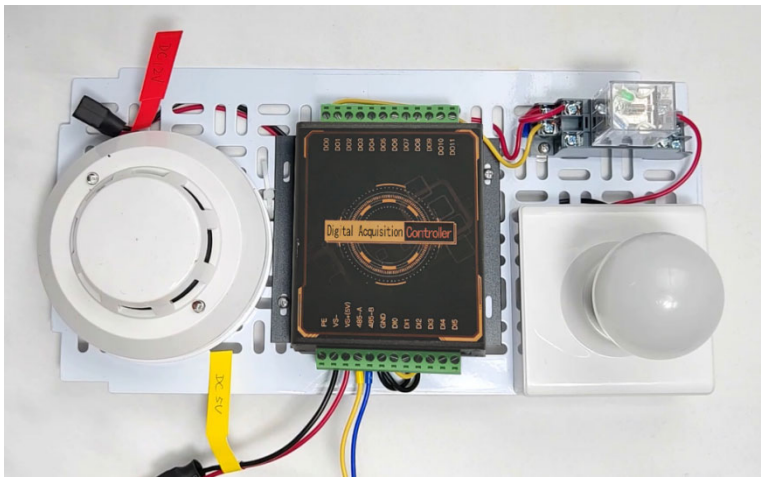

Figure 3. Physical Automatic Smoke Alarm

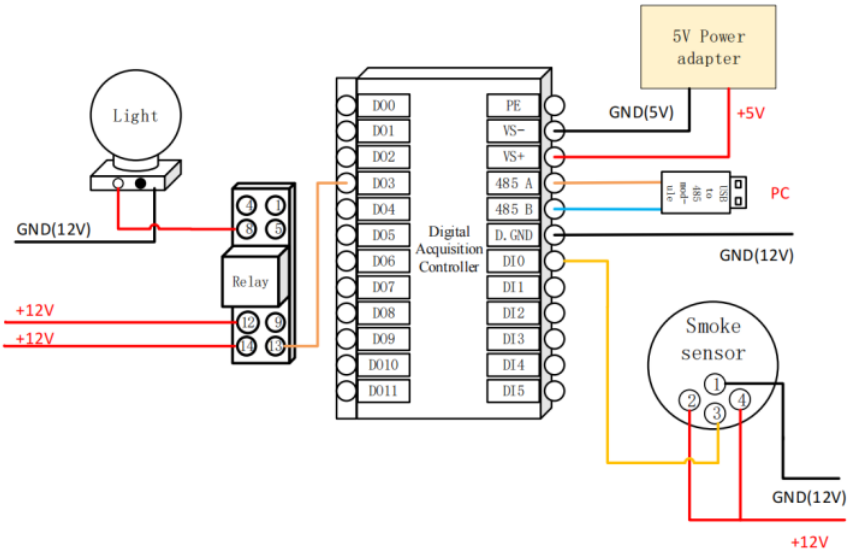

Figure 4. Circuit Diagram of Automatic Smoke Alarm

The smoke alarm uses the domestic digital acquisition controller, supporting a 6-way isolated digital input interface, a 12-way isolated digital output interface, and a 1-way 485 isolated communication. It is compatible with both standard MODBUS and variant MODBUS protocols. The circuit includes interface protection, power supply, and isolation circuits to enhance stability. The software, as shown in Figure 5, features an EXC application program and uses multiple serial ports, with COM18 selected for automatic mode. When the detected smoke concentration reaches the warning level, the smoke alarm is triggered, as shown in Figure 6.

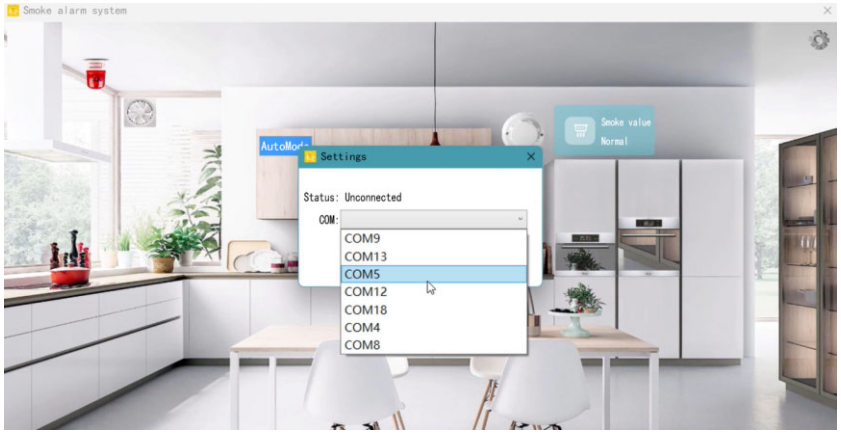

Figure 5. Smoke Alarm Software Interface

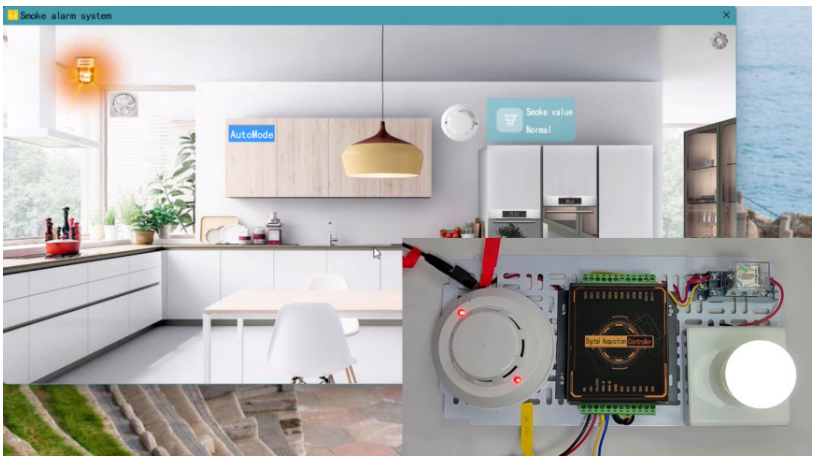

Figure 6. Smoke Alarm Working Principle

5. Scheme Advantages

5.1. Adoption of Domestic Chips

The main control chip of the digital acquisition controller is a domestic single-chip microcontroller, maximizing the advantages of domestic chips, such as cost control, supply stability, and local technical support. This selection reduces manufacturing costs and increases the domestic component ratio. Emphasizing independent intellectual property in design and development during the controller's R&D process aids in achieving full domestic production and reduces dependency on foreign technologies.

5.2. Multi-Protocol Compatibility

The controller not only supports standard MODBUS protocol communication but also enables switching between multiple variant MODBUS protocols, making it compatible with widely used gateway devices on the market. This compatibility includes data frame format analysis, command generation, and response for reliable communication.

6. Conclusion

Through this project, autonomous research on digital acquisition has been realized, contributing to the development of intelligent sensing technology for agriculture in China. It provides high-quality, reliable, cost-effective, and versatile solutions for agricultural IoT control, industrial automation, and instrumentation in various sectors.

7. Funding

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