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Design of Distributed Multi-Parameter Measurement Control System Based On CAN Bus

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Abstract. This paper introduces a multi-parameter distributed measurement control system based on CAN bus network and uses C8051F040 MCU as measurement control node, and corresponding hardware and software design to realize simultaneous detection of multiple measurement nodes. This paper described the overall structure of the system, introduced the hardware design and system software design of the data acquisition and control processing module based on C8051F040 microcontroller, and verified the correctness and feasibility of the system design by experimental tests.

1. Introduction

Modern distributed measurement and control networks use RS-485 as the fieldbus. However, RS-485 is generally not suitable for using as a fieldbus in the case of a long distance and a harsh working environment.

Compared with RS-485, CAN bus is an effective serial communication network which supports distributed and it has good real-time performance, high reliability and strong anti-interference ability. When the transmission distance is less than 40m, the CAN bus can reach a maximum transmission rate of 1Mb/s. When the transmission distance is 10km, it can still provide a transmission rate of up to 50kbit/s. The CAN bus works in a multi-master control mode. Each node in the network can obtain the bus usage right according to the bus access priority (depending on the message ID) and using the non-destructive bitwise arbitration method [1].

The CAN bus encodes the data block, which can complete point-to-multipoint data communication at one time, enhances the real-time performance of data communication between nodes in the network, and easily forms a redundant structure, which improves the reliability and flexibility of the system. The early CAN bus was mainly used in automotive electronic systems. Due to its powerful fault-tolerant control and fault handling capabilities, as well as low cost, the CAN bus has been widely used in industrial sites where has critical standards for real-time and anti-interference capabilities.

In order to meet the needs of distributed real-time measurement of multiple drilling parameters during drilling, this paper designs and implements a distributed multi-parameter measurement control network with high applicability, reliability and scalability based on CAN bus, and the correctness and feasibility of the design were verified by experiments.

2. The overall structural design of the distributed measurement system

The system adopts a distributed structure based on CAN bus. The system consists of a measurement control host and the distributed control data acquisition and control processing module (slave) of multiple measurement nodes. The system connects the measurement control host and each measurement slave through the CAN bus to form a distributed measurement system, which realizes the functions of rapid detection, fault location, parameter setting and check back of the measurement node. Its system structure is shown in Figure 1. The measurement control host adopts a PC, and is connected to the CAN bus through the CAN communication adapter card HK-CAN30B. The measurement node (slave) is a self-designed distributed data acquisition and control processing module, and each measurement module is connected on the CAN bus. The HK-CAN30B interface card communicates with the measurement control host and is controlled by the measurement control host. The data acquisition and control processing module consist of C8051F040 microcontroller with CAN core, CAN bus transceiver PCA82C250, input and output interface and other peripherals.

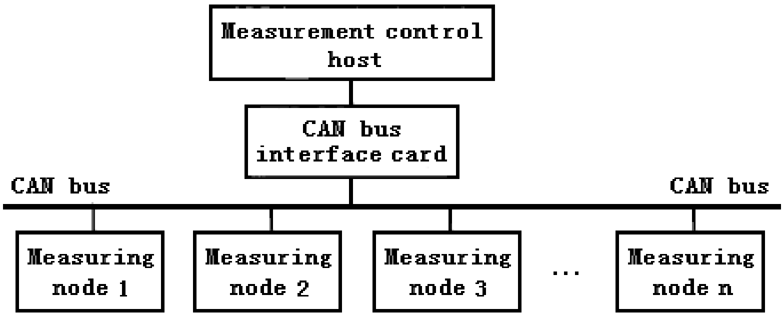

Figure 1. Structure of the distributed measurement system

3. Design of distributed data acquisition and control processing module

3.1. Introduction to C8051 Microcontroller and On-Chip CAN Controller

The distributed data acquisition and control processing module is composed of C8051F040 microcontroller integrated with CAN core. The C8051F040 microcontroller is an 8-bit highly integrated mixed-signal SoC-level microcontroller produced by Cygnal Company of the United States. It is fully compatible with the 8051-microcontroller instruction set. The CIP-51 core has a maximum operating frequency of 25MHz and an execution speed of up to 25MIPS. It has a built-in 64KB system programmable Flash program memory and 4KB internal data memory. It integrates almost all external device modules and other functional components needed to form a single-chip data acquisition and control system on a single chip. Includes CAN controller, 2 serial interfaces, 5 16-bit timers, 8-bit and 12-bit A/D converters, and 12-bit D/A converters. On-chip JTAG emulation circuitry provides full speed, non-intrusive Circuit simulation (without on-chip resources), support for breakpoints, single-step debugging commands, support for memory and register checksum modification, making programming and debugging very convenient [2].

The C8051F040's integrated CAN controller complies with Bosch CAN2.0A and Bosch CAN2.0B specifications, allowing serial communication using the CAN protocol. The C8051F040's CAN controller consists mainly of the CAN core, message RAM (independent of the C8051 RAM), the message processor, and the CAN internal control registers. The maximum operating speed of the CAN bus is up to 1 Mbps, and the actual rate is limited by the physical layer of the selected transmission data on the CAN bus. The CAN processor has 32 message objects that can be configured to send or receive data. The input data, the message object and its identification mask are stored in the CAN message RAM. All protocol functions for transmission of data and acceptance filtering is performed by the CAN controller, without the intervention of the microcontroller core, so that the overhead of the CPU for CAN communication is minimized. Its structure is shown in Figure 2 [3].

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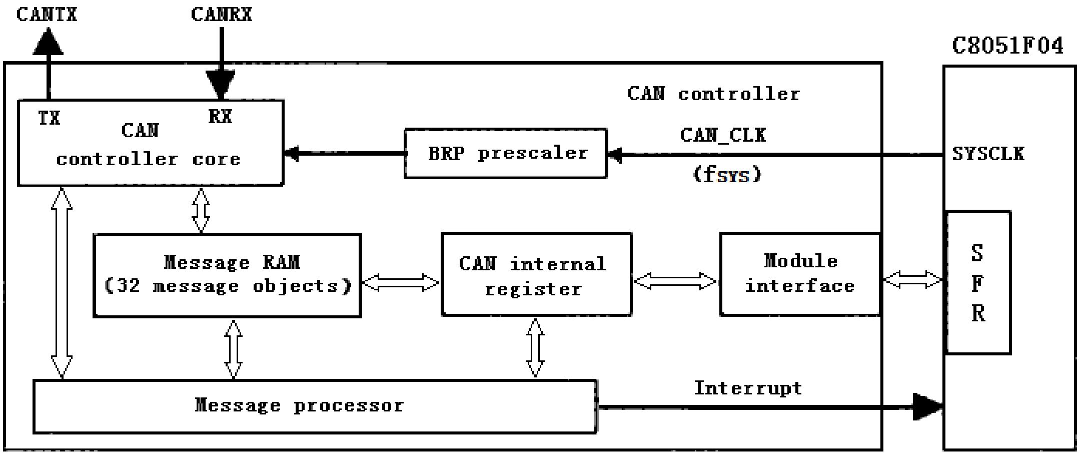

Figure 2. C8051F040 integrated CAN controller structure

The CAN core provides shifting (CANTX and CANRX), serial/parallel conversion of messages, and other protocol-related tasks (such as transmission of data and acceptance filtering). The message RAM can store 32 message objects and arbitration masks received and transmitted on the CAN network, and each message object has its own identifier mask. The CAN internal registers and message processor provide an interface for data transfer and status notification between the CAN controller and the C8051F040 microcontroller core.

3.2. Hardware circuit design

Since the C8051F040 microcontroller integrates almost all external device modules and other functional components required to form a single-chip data acquisition and control system on one chip, the hardware design of the distributed data acquisition and control processing module is greatly simplified. The circuit structure of the distributed data acquisition and control processing module is shown in Figure 3. It consists of a power supply circuit, a crystal oscillator circuit, a JTAG interface circuit, a reset circuit, a CAN drive circuit, and an input/output interface.

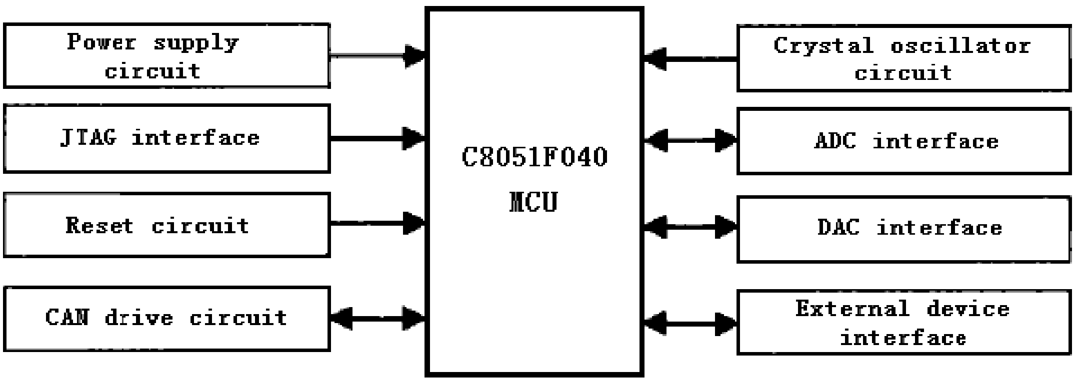

Figure 3. Circuit structure diagram of distributed data acquisition and control processing module

The CAN module inside the C8051F040 MCU is just a protocol controller. It does not provide a physical layer driver. Therefore, an external CAN bus transceiver is required to provide the physical layer driver when using it. Here, the more popular CAN bus transceiver PCA82C250 of Philips is used [4]. Considering that there are many interference signals in the measurement of drilling parameters, the relevant signals must be properly isolated. Therefore, an optoelectronic isolation layer is set between

C8051F040 and PCA82C250. The CAN bus signals CANTX and CANRX are electrically isolated from the C8051F040 through the high-speed optocoupler 6N137, then driven by the CAN bus controller interface chip PCA82C250, and then connected to the CAN data line. The optocoupler 6N137 realizes electrical isolation between the data acquisition and control module and the CAN bus, which not only improves the reliability of the module, but also protects the bus and other modules on the bus. A 110Ω resistor is connected in series with each of the CAN_H and CAN_L pins to connect to the bus for current limiting. The circuit schematic of the distributed data acquisition and control processing module is shown in Figure 4.

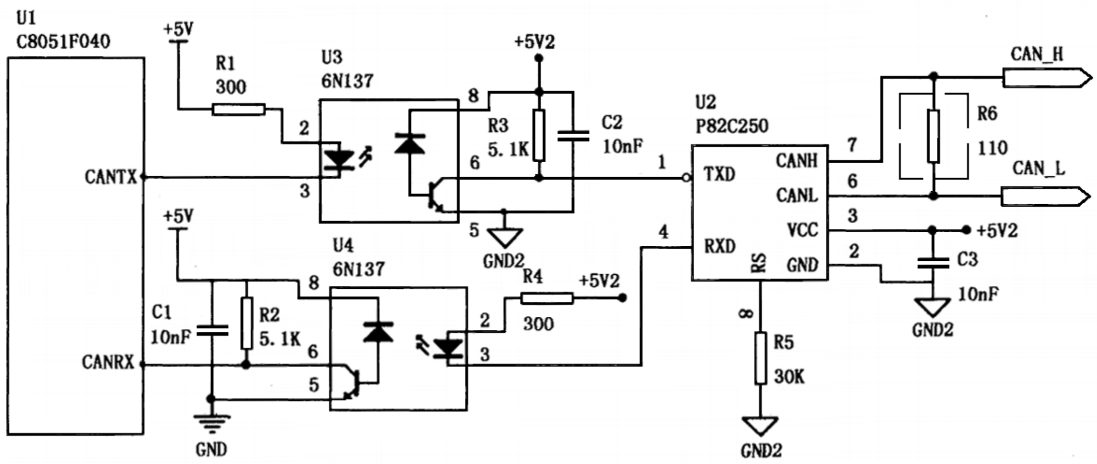

Figure 4. Schematic diagram of distributed data acquisition and control processing module

4. System software design

System software design includes host control software design and measurement node software design [5-6].

4.1. Host control software design

Host control software design is written in VC++. Features include: system initialization, measurement node parameter settings, monitoring node online status, receiving remote commands on the Ethernet, storing historical data, maintaining a monitoring database, and other related functions. Its software flow chart is shown in Figure 5.

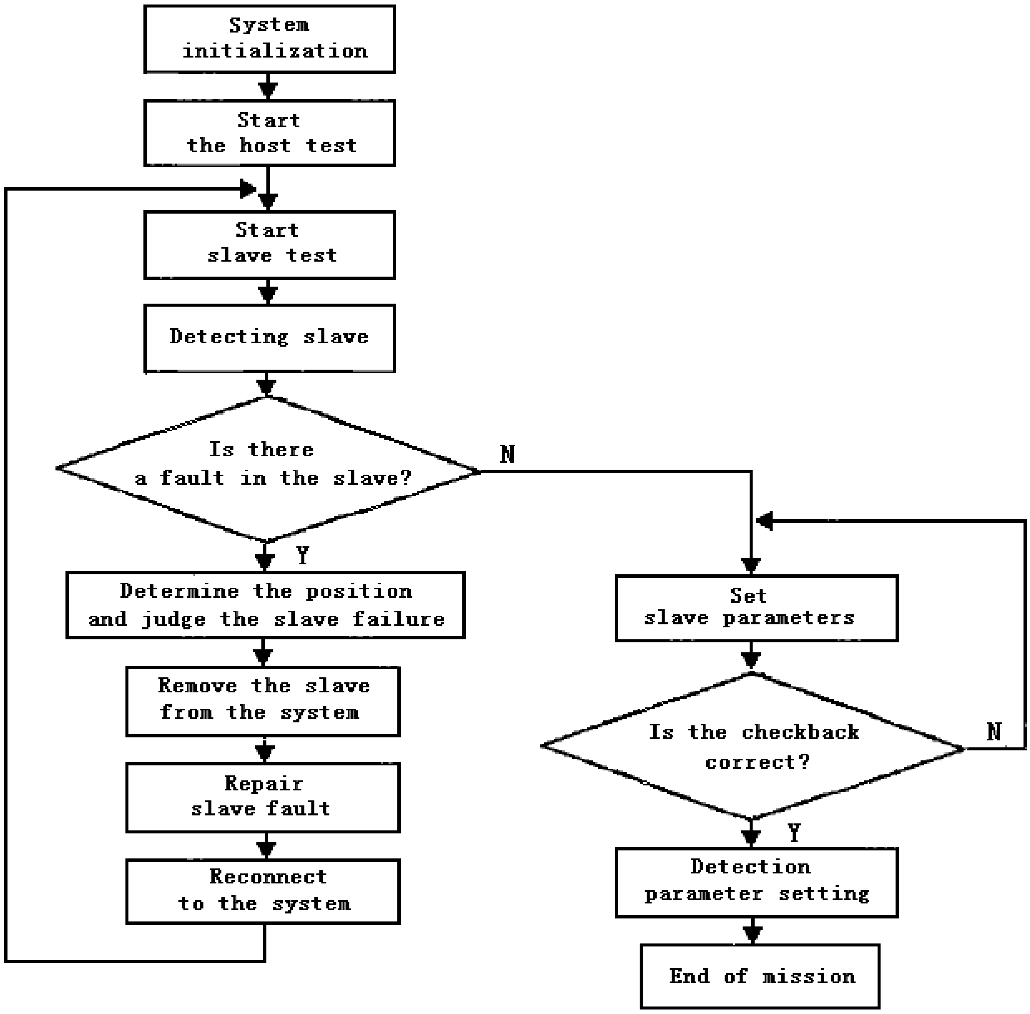

Figure 5. Host software flow chart

4.2. *Measurement node software design*

The measurement node software is relatively simple. The measurement node transmits data through the CAN bus, and at the same time, according to the remote command action transmitted by the host, the measurement and control tasks are completed, and the software flow chart is shown in Figure 6.

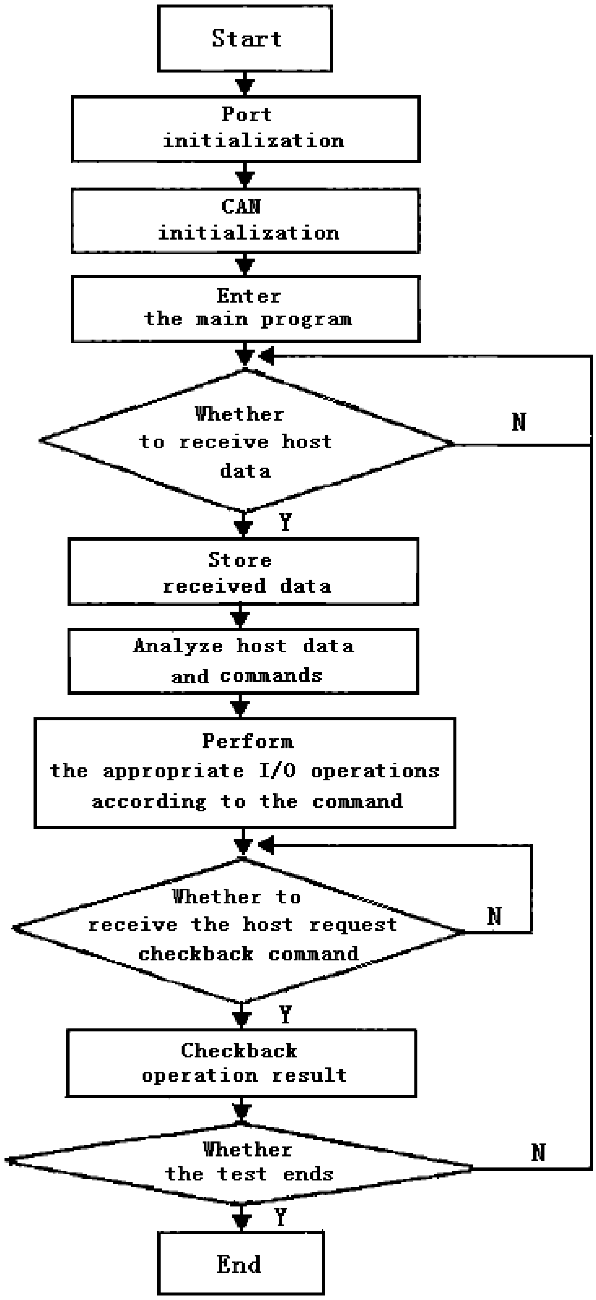

Figure 6. Slave software flow chart

5. Experimental testing and analysis

In order to verify the designed distributed multi-parameter measurement system, the system was tested experimentally on the test platform. The measurement module collects the data of the A/D channel, receives the control parameters transmitted from the host for PID control, and outputs through the D/A channel to form a PID control loop. The host completes the setting of the PID control parameter, receives the data of the A/D channel transmitted from the measurement module, performs fault diagnosis, and performs a check back of the control parameters. The transfer function of the control object is approximated 220/ (S2+12.5S+100). The program uses the structure of interrupt and query. The sampling period is 40ms, the control period is 40ms, the CAN communication rate is 1Mbps, and the overflow of timer T2 starts A/D sampling, overflow interrupt of timer T3 starts PID calculation, D/A channel output, CAN message transmission, CAN communication interrupt realizes standard message reception. The experimental test results show that the CAN bus network communication has good real-time performance, stable and reliable operation, and the measurement module can set parameters according to the commands and data sent by the host, which satisfies the design requirements of the distributed multi-parameter measurement system.

6. Conclusion

The C8051F040 microcontroller with internal integrated CAN controller is designed to be a fractional data acquisition and control processing module. It is not only simple and reliable in hardware design, but also more convenient and concise when compiling the corresponding software. This paper designs a multi-parameter distributed measurement system based on CAN bus network with this design scheme, and introduces the hardware design which based on the data acquisition and control processing module of C8051F040 microcontroller and CAN communication software design. Finally, the design of the system is proved to be correct and feasible through experiments, which provides theoretical and experimental basis for the use and promotion of distributed measurement systems based on CAN bus.

Acknowledgments

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