Servo control system based on optical fiber CAN communication

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Abstract. Aiming at the problem that the long-distance transmission of CAN bus in the servo control system is susceptible to electromagnetic interference, a servo control scheme based on optical fiber CAN bus was proposed to solve the problem of stable and reliable communication of CAN bus. Firstly, the paper introduced the architecture of the distributed servo control system and the existing problems; After that, the working principles of the twisted-pair CAN bus interface and the optical fiber CAN bus interface were analyzed; Then the servo control system and control strategy based on the optical fiber CAN bus were designed; Finally, a field experiment was carried out, and the experimental results indicated that the scheme had good real-time communication and reliability.

1. Introduction

Faced with the pressure of rising labor costs and the demand for industrial upgrading, the demand for intelligent device systems and services in China's manufacturing industry has increased year by year, and relevant planning and preferential policies have also been introduced at the national level, clearly pointing out that the industry of intelligent manufacturing equipment is one of the industries in urgent need of development. As a key implementation link of the intelligent manufacturing equipment industry, the service control system is widely used in automation fields such as automatic machine tools, industrial robots, artillery control, and rudder control.

A naval pre-research project used a distributed servo drive system based on a two-level CAN bus to control the logical motion of multiple mechanisms, and had realized the linkage function of the mechanism. Since many mechanisms of the system adopted high-power servo drive to control, pulse width modulation generated strong electromagnetic interference when multiple servo devices worked, and long-distance data communication between multiple mechanisms sometimes caused unnormal operation of the CAN. Therefore, higher requirements were imposed on CAN data transmission media with high power and multiple servo nodes. CAN bus is a serial data communication protocol for multiple master stations. Due to its real-time communication, flexibility and reliability, the twisted-pair CAN (Wire-CAN) bus distributed system has been widely used, but in some places with strong interference, high-speed requirements and long-distance requirements, it is not suitable to use twisted pair to transmit data.

In modern communication networks, optical fibers are widely used due to their high speed and large capacity. Compared with twisted pair and other media, optical fiber has lower transmission loss, which greatly expands the transmission distance. In addition, optical cable also has the characteristics of energy non-radiation, non-conductivity, no inductance, corrosion resistance, high communication reliability, good confidentiality, low maintenance cost, etc. And when the information is transmitted in the optical cable, there is no crosstalk and mutual interference between the signals, and no coupling problem between the lines. Therefore, in some CAN bus systems with harsh environments, wide geographical distribution, and high speed requirements, optical fiber transmission can be used on the corresponding branches to ensure the performance of the entire CAN network. This paper combined the characteristics of optical fiber and proposed a servo control scheme based on optical fiber CAN (Fiber-CAN) bus, which can effectively solve the difficulty of long-distance, real-time, stable and reliable communication in the environment with complex electromagnetic interference [1].

2. Architecture of distributed servo control system

In large-scale distributed real-time systems, each CAN bus network accommodates a limited number of nodes, so in order to realize the real-time performance and reliability of data communication, it is necessary to expand the CAN bus network to meet the requirements of systematic data communication. The more common method is to adopt the strategy of hierarchical CAN bus network expansion, and the number of levels can be determined according to the number of system nodes [2].

The control system of a naval pre-research project adopted the distributed control mode of bus interconnection, and its structure is shown in Figure 1. The system is of two-level CAN structure. As the main control computer, The scheduling module is responsible for function decision-making and task scheduling, and forms the first-level CAN communication network with multiple communication modules; The communication module completes the motion control of each actuator, and forms the second-level CAN communication network with a plurality of drivers and encoders.

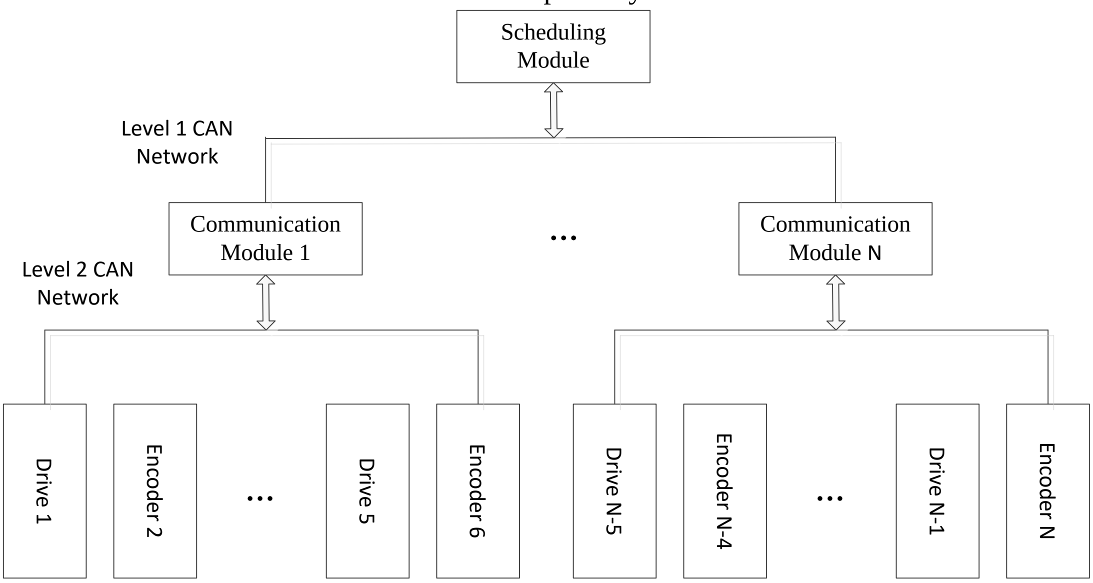

Figure 1. Distributed system structure of two-level CAN bus.

Due to the large number of motion mechanisms controlled by the servo drive system, the number of nodes in the CAN network is large and the distance between them is relatively long. The length of the cable in the physical layer of the first-level CAN network reaches 100 meters. The increase in the number of nodes in the bus and the increase in the distance cause the baud rate to be reduced when communicating on the CAN bus and susceptible to external electromagnetic interference. When multiple servo devices are linked and enabled at the same time, although the CAN bus has taken measures to isolate electromagnetic interference such as twisted-pair shielded cable and single-ended node, the electromagnetic interference generated by pulse width modulation during servo operation still affects the communication quality of the twisted-pair CAN network, resulting in the frequent frame loss and increasing error frames on the bus.

3. Analysis of the interfaces of Wire-CAN bus and Fiber-CAN bus

Wire-CAN bus and Fiber-CAN bus satisfy the same interface protocol and are analyzed from these two aspects.

3.1. Wire-CAN bus interface

The design schematic diagram of the twisted pair communication interface of CAN bus is shown in Figure 2. The PCA82C250 is a transceiver of CAN bus, serving as the interface between the CAN controller SJA1000 and the physical bus. It provides the transmission ability of differential motion to the bus and reception capability of differential motion to the CAN controller. Based on the interface principle of the Wire-CAN bus, when the TX0 terminal of a SJA1000 outputs a 0 level, the bus is dominant, and all SJA1000s on the bus will receive dominant bits; Conversely, if the TX0 terminal outputs 1 level, the bus is invisible, and other SJA1000s will also receive invisible bits.

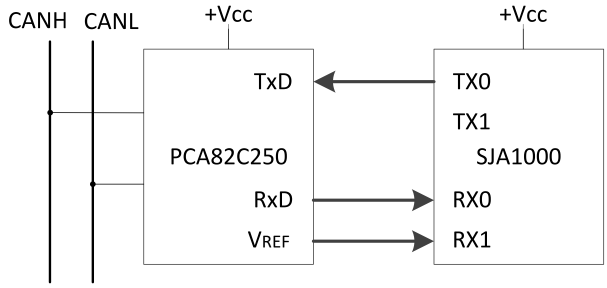

Figure 2. Interface structure of Wire-CAN bus.

3.2. Fiber-CAN bus interface

The design schematic diagram of the optical fiber communication interface of CAN bus is shown in Figure 3. The electrical signal of Fiber-CAN bus is TTL level, and the electrical signal of Wire-CAN bus is differential signal. PCA82C250 can complete the conversion between differential signal and TTL level.

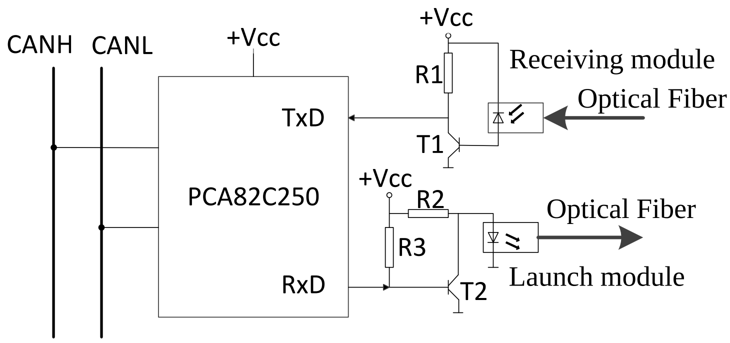

Figure 3. Interface structure of Fiber-CAN bus.

First, the process of completing the optical/electrical conversion of the light receiving module is analyzed. Assuming that the Fiber-CAN bus is dominant, that is, there is optical transmission on the optical fiber, the current generated by the photodiode in the optical receiving module drives T1 to conduct. Making the input of the terminal TxD as 0 level, Wire-CAN bus is also dominant. On the contrary, when Fiber-CAN bus is recessive, that is, there is no optical transmission in the optical fiber, the photodiode in the optical receiving module has no current, and the transistor T1 is turned off. Making the input of the terminal TxD as 1 level, Wire-CAN bus is also recessive.

The process of completing the electric/optical conversion of the light emitting module is analyzed. Assuming that Wire-CAN bus is dominant and the output of terminal RxD is 0 level, the audion T2 cuts off the lighting of the light emitting diode, and there is optical transmission on the optical fiber, that is, the Fiber-CAN bus is also dominant. Conversely, when Wire-CAN bus is recessive and the output of terminal RxD is 1 level, the audion T2 is turned on and the light emitting diode does not emit light, without optical transmission on the optical fiber, that is, Fiber-CAN bus is also recessive [3][4].

4. Scheme design of servo control system based on Fiber-CAN bus

At present, the first-level CAN network based on Wire-CAN bus servo control system has problems such as too long transmission distance and susceptibility to electromagnetic interference affecting normal operation, and the optical fiber has the advantages of high transmission rate, high reliability, strong anti-interference ability, etc., a distributed servo control scheme based on the Fiber-CAN bus is proposed.

Considering that when optical fiber is used as the communication medium for transmission, the optical signal can only be transmitted from the transmitting terminal to the receiving terminal, so the general bus link topological structure is not applicable; Considering the lack of reliability of the unidirectional ring network, a ring redundant structure is designed. Even if individual nodes break down, the system can still run stably [3]. Therefore, the system adopts a bidirectional ring network topology, and the system structure is shown in Figure 4.

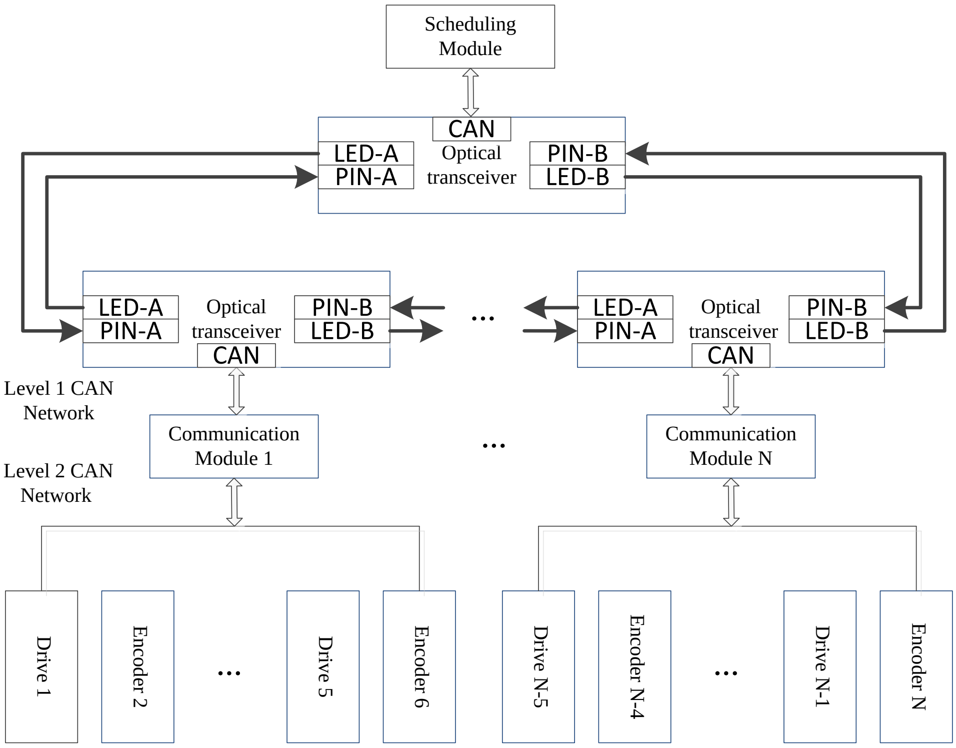

Figure 4. System structure based on Fiber-CAN bus.

The optical transceiver is a optical fiber communication device that takes advantage of optical transmission characteristics to achieve remote transmission through the technologies such as signal modulation and photoelectric conversion. The optical transceiver includes two light emitting modules LED-A and LED-B, two light receiving modules PIN-A and PIN-B, a CAN transceiver module and a programmable logic control module. In Figure 4, the scheduling module and each communication module form a first-level CAN communication network. After being subjected to protocol analysis by the optical transceiver and the photovoltaic conversion, the data of any node on the CAN bus are transmitted between the optical transceivers through optical fiber. Each node is connected through a dual-ring fiber network and can conduct bidirectional communication. When the scheduling module is required to transmit data, the optical signal is transmitted clockwise from LED-A to PIN-A of the optical transceiver N, or counterclockwise from the LED-B to PIN-B of the optical transceiver 1. This communication mode ensures that each node has two transmission options. When a certain optical cable fails, it is only necessary to avoid the abnormal line and realize the loopback transmission of information, so as to maintain normal communication. Since there is no crosstalk and mutual interference between the signals when the information is transmitted in the optical cable, and no coupling problem between the lines, the problem that the CAN bus is susceptible to electromagnetic interference during long-distance transmission is solved, improving the reliability of data communication.

Since CAN bus utilizes the multi-master mode, any node can acquire the control of the bus and transmit data out, so each node on the bus has a unique identifier. Each node sends data to the bus, and the data is converted into an optical signal by the optical transceiver to realize loopback transmission of the information; The optical transceiver receives the optical signal and converts it into electrical signal, and then the communication module performs filtering. The data of the same identifiers are reserved, while that of the different are discarded. The optical transceiver can control the data transmission and reception of the Fiber-CAN network: when an optical transceiver transmits data, the remaining optical transceivers will not forward the data on the communication module to the optical transmission module; when an optical transceiver receives the data, it determines whether the data are looped back through the fiber. If they are, then they will be removed and the next communication cycle is entered into, otherwise the optical transceiver will forward them. Each node also reads the level on the bus while sending a level to the bus, and compares it with the level sent by itself. If the levels are the same, the next one is transmitted, and if they are not the same, the transmission is stopped and the bus contention is exited. The remaining nodes continue the above process. Until only one level transmitted by one node is left on the bus, the bus contention terminates, and node with the highest priority obtains control right of the bus [5][6].

5. Experiments

In order to verify the feasibility of the servo control scheme based on Fiber-CAN bus and the data transmission and reception strategy of optical transceiver, this paper built an experimental platform, connected five communication modules and one scheduling module with corresponding optical transceivers, and then connected the modules in a loop by optical fibers. The drivers in each communication module were enabled to create a complex electromagnetic environment, and field tests were performed. During the test, the CAN box was installed in the CAN network of the scheduling module to read and receive the data. The scheduling module sent a group of data by means of broadcast. After receiving the data, each communication module returned a group of data where the first byte had a corresponding node number and the other bytes were 0. A number of groups of tests were performed, one of which is shown in Table 1.

Table 1. Experimental data.

CAN Node	Frame ID	Transmission direction	Receive time mark(second)	Data
Scheduling Module	0X601	Send	594.9743	01 02 03 04 05 06 07 08
Communication Module 1	0X701	Receive	594.9766	01 00 00 00 00 00 00 00
Communication Module 2	0X702	Receive	594.9795	02 00 00 00 00 00 00 00
Communication Module 3	0X703	Receive	594.9829	03 00 00 00 00 00 00 00
Communication Module 4	0X704	Receive	594.9853	04 00 00 00 00 00 00 00
Communication Module 5	0X705	Receive	594.9886	05 00 00 00 00 00 00 00

Through the analysis of multiple groups of test data, the communication reliability of the servo control system based on Fiber-CAN bus was high, and the feasibility of the system scheme was verified. However, the identification of the receiving time of each node indicated that the communication time was delayed for about 2ms~3ms after the data were subjected to electro-optical conversion and photoelectric conversion by optical transceivers. With the increase of the nodes, communication delay also grew.

6. Conclusions

This paper adopted the servo control system scheme based on optical fiber CAN bus, which had good real-time communication and reliability, better solved the problem that long-distance transmission of CAN bus was susceptible to electromagnetic interference, and satisfied the requirements of the servo control system for communication technology. Therefore, the scheme can serve as an effective supplement and an alternative mean of existing communication methods. However, when the optical fiber CAN bus was used to communicate, the electric/optical conversion and optical/electrical conversion of the signal led to delay in communication time, so it is not suitable to be applied in the case where the high requirement for real-time communication. In the next stage, the servo control system based on the optical fiber CAN bus will be further improved to solve the problems faced currently.

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