Design of Electromagnetic Compatibility Performance of Multi-Node CAN-Bus System

Lei Zhang
(The 713th Research Institute of CSIC, Zhengzhou, Henan, 450015, China)
e-mail: zl_zh1007@163.com

Abstract: In order to improve the electromagnetic compatibility of multi-node CAN-Bus, this paper designs a filter circuit based on the elimination of system conduction noise, and analyzes the noise separation part and filter in the filter circuit in detail, and verifies the validity of the design in the multi-node bus system.

1. Introduction
Controller Area Network (CAN) is a bus protocol that has been widely used in various industrial fields. Compared with other network control systems, the bus system can realize more real-time and reliable data transmission between nodes in the distributed control system. At present, a unified international standard has been formed, but the bus system is susceptible to electromagnetic interference, which seriously affects the reliability of operation. Therefore, it must be reasonably analyzed and designed according to the actual situation of the system to improve the electromagnetic compatibility of bus communication.

Based on the multi-node CAN-Bus system, this paper proposes a set of design and optimization schemes for electromagnetic compatibility performance, which realizes the stable operation of multi-node CAN-Bus system in strong electromagnetic interference environment.

2. Introduction to CAN-Bus
CAN-Bus belongs to bus serial communication network. Its transmission medium adopts common twisted pair and adopts differential non-return-to-zero coding technology. Compared with general communication bus, CAN-Bus data communication has the outstanding advantages of reliability, timeliness and flexibility.

The CAN protocol itself has no limit on the number of nodes, and the number of nodes on the bus can be dynamically changed. The broadcast message is transmitted, and the message can be received by all nodes at the same time, which improves the real-time performance of the bus. With multi-master structure, each node has equal status regardless of master-slave. The priority of the node is determined by the identifier (ID) of the transmitted message. The content of the CAN message is identified by the message identifier, and each message is identified. The identifier is unique in the network. The CAN network topology is shown in Figure 1.
CAN network adopts bus topology, which has many advantages, and it has been widely used in many fields to meet the application requirements of most fields. However, with the expansion of application fields, some defects of bus topology are gradually found. The CAN-Bus is susceptible to electromagnetic interference, and the data transmission is unstable under the environment of strong electromagnetic radiation. Therefore, the electromagnetic compatibility performance has a great influence on the operational reliability of the bus system. Therefore, electromagnetic compatibility has become an important product performance index.

Electromagnetic compatibility includes: electromagnetic interference radiation emitted by electronic products to the external environment, and the influence of electromagnetic signals on electronic products in the external environment. The magnitude of this influence generally depends on the sensitivity of the product itself to external electromagnetic signals.

3. **Common measures to improve the electromagnetic compatibility of CAN-Bus**

Commonly used measures to improve the electromagnetic compatibility of the bus are mainly focused on the design of the system hardware and the laying of the circuit, including [2]:

1. Select components with good electromagnetic compatibility;
2. Reasonably lay out the PCB board, the interconnected components are arranged as much as possible, and the leads are as short as possible; the digital circuit is effectively separated from the analog circuit to prevent mutual signal interference; the ground wire is reasonably distributed, and the double layer board or a multi-layer board is used to reduce the ground impedance, and at the same time try to make all the ground wires on the board equipotential.
3. Cable laying as specifications, the power cable, control cable and CAN-Bus cable as far as possible to classification arrangement, and avoid different types of cables laid in parallel to reduce radiation interference.
4. Use electromagnetic shielding to reduce radiated interference, and use electromagnetic shielding device to shield the electromagnetic emission and electromagnetic absorption of bus communication.

However, in a multi-node CAN-Bus system, there may be high-power switches and high-power components, switch opening and closing, driver enable and other transient surges caused by transient and transient processes, which will be transmitted through the cable and brought to the bus and cause huge electromagnetism harm to the bus. In order to eliminate these transient pulses and surges and ensure reliable CAN-Bus communication, when design the system, filtering technology should be used to eliminate the electromagnetic interference caused by conduction coupling. In this paper, the system hardware design is used to achieve filtering, eliminating conducted interference and ensuring stable transmission of the CAN-Bus.

4. **Filter system design**

The interference signal on the general power supply line is a mixed interference signal including common mode (CM) and differential mode (DM) superposition. Since different modal signals determine different filter performance, topology and parameter selection, it is necessary to separate the noise first. In this paper, the high-power driver system is used as the reference object, which mainly contains the common-mode interference signal. Therefore, the common-mode signal is the main
research object in the noise separation and filter design.

The design of the noise separation network, considering the noise separation performance and the spurious effect at high frequency, consider the use of a full-resistance noise separation network\[^{[3]}\]. The network has high separation performance for common mode noise and low spurious effect at high frequencies. The resistive network structure is shown in Figure 2. A resistive network of resistors \( R_x \) can increase noise by 15 to 20 dB over a transformer-based separation network.

![Fig.2 Pure resistive noise separation network diagram](image)

On the basis of conductive noise modes effective separation, the filter design can effectively control the noise to meet the electromagnetic compatibility standard. For the characteristics of common mode noise, the filter designing principle is shown in Figure 3.

![Fig.3 Filter schematic](image)

In the figure, \( L_x \) is a common mode choke. Since the two coils of \( L_x \) are wound in the same direction, when the power input current flows, the generated magnetic fields can cancel each other, which is equivalent to no inductive effect. Therefore, it is necessary to use a high magnetic permeability. The core, \( L_x \) is equivalent to a large inductance for common mode noise, so it can effectively suppress common mode conducted noise. The capacitor \( C_y \) connected to the ground at the input end of the switching power supply bypasses the common mode noise. The capacitor \( C_x \) connected in parallel at both ends of the common mode choke coil can suppress the differential mode noise, and \( R \) is the discharge resistance of \( C_x \).

5. Test verification

In order to verify the design effect, in a multi-node CAN-Bus system, the system before and after the filter circuit was tested, and the conduction noise and CAN communication signal quality in the system were compared. The power conduction emission curve before adding the filter circuit is shown in Figure 4. The column diagram of the CAN-Bus data transmission quality is shown in Figure 5.
Fig. 4 Test curve of system power conduction emission before filtering (a) positive electrode (b) negative electrode

Fig. 5 Voltage histogram of each node of CAN bus before filtering

It can be seen from Figure 4 and Figure 5 that before the filter circuit is added, the positive and negative poles of the power supply exceed the allowable range of the system conduction noise in the range of 100 kHz to 2 MHz. Therefore, after the power is turned on, all the node voltages of the CAN-Bus fluctuate greatly. The node voltage fluctuates greatly and the frequency is high, which seriously affects the data transmission quality, resulting in data loss and even CAN communication interruption. In the system, if the filter circuit is tested, the system conduction noise curve and the bus node voltage diagram are shown in Figure 6, Figure 7.

Fig. 6 Test curve of system power conduction emission after filtering (a) positive electrode (b) negative electrode
Comparing the curve before and after adding the filter circuit, it can be seen that after adding the filter circuit, the conduction noise of the positive and negative poles of the power supply drops significantly to the allowable range of the system, which satisfies the noise requirement of CAN-Bus. After the power is turned on, the voltage of all nodes of the CAN-Bus is stable and does not appear. The voltage jumps sharply. After the power is turned on, the bus data transmission is normal, and no frame loss or network interruption occurs. It is proved that the filter circuit designed in this paper is effective in eliminating the conduction noise of the system, improving the electromagnetic compatibility of the multi-node CAN-Bus system and ensuring the reliability of bus transmission.

6. Conclusion
In order to improve the electromagnetic compatibility of multi-node CAN-Bus, this paper designs a filter circuit based on the elimination of system conduction noise, and analyzes the noise separation part and filter in the filter circuit in detail. In order to verify the effectiveness of the design, a filter circuit is applied to a multi-node CAN-Bus system with high conduction interference in a power supply. The transmission curve before and after adding the filter and the voltage of each node of the CAN-Bus are compared. It is proved that the filter circuit effectively eliminates the conduction noise of the system. The fluctuation of the voltage of each node is improved, and the electromagnetic compatibility performance of the bus system is improved.

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