Research on CAN bus consistency test method

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Abstract: As a mature industrial field bus, the CAN bus has been widely used in industrial field control. In the application of multi-node CAN bus, how to ensure the reliable operation of the CAN bus has been widely concerned. The main items, purpose and test methods of sex testing are elaborated in detail, aiming to provide some ideas for how to promote the reliability application research of CAN bus.

1. Introduction

The CAN bus[1,2] was developed by the German BOSCH company, which is famous for the development and production of automotive electronic products, and eventually became an international standard (ISO 11898). It is currently one of the most widely used field buses in the world. CAN bus has the advantages of reliable error handling and error detection mechanism, strong anti-electromagnetic interference ability, low cost and so on. It has been widely used in aerospace, rail transportation and other fields. Generally, each CAN node that constitutes the bus network is provided by different manufacturers. Each manufacturer uses different equipment when designing the CAN node, and the quality of the products is also uneven. Usually, the entire node is affected by the error of one of the nodes. The normal operation of the bus network may sometimes lead to the paralysis of the entire CAN network. In severe cases, it may endanger personal safety. In order to ensure the reliable application of the CAN bus, it is necessary to perform reliability tests on the physical layer, link layer, and application layer after the CAN node networking is completed, testing parameters such as voltage threshold, signal edge, bit time, baud rate tolerance, etc. Whether it meets the corresponding international standards, so as to minimize the probability of failure.

Conformance testing can solve the problem of differences in product performance due to different developers' understanding of the bus protocol text and the different design methods of CAN nodes. It can give a relatively objective evaluation of product interconnectivity [3]. This article mainly describes the main items, test objectives and test methods of the CAN bus consistency test, and aims to provide some ideas for how to promote the reliability application research of the CAN bus.

2. CAN bus compliance test program

At present, many domestic professional companies (such as Guangzhou Zhiyuan Technology Co., Ltd.) have developed CAN bus test instruments, which have been gradually applied to CAN node design and development and networking testing, thus providing reliability design and development of CAN bus Technical support. This article will use the CAScope analyzer of Guangzhou Zhiyuan Electronics Co., Ltd. to conduct a consistency test on the CAN bus. The specific test plan is shown in Figure 1.
3. CAN bus commonly used test content and method

3.1. Signal edge time test

The signal edge time refers to the total time between the recessive level to dominant level time and the dominant level to recessive level change. The edge includes the rising and falling edge time. Ideally, the edge time tends to 0 is the best, but the smaller the edge, the instantaneous voltage change rate is too high, which leads to electromagnetic radiation and EMI test exceeds the standard. Therefore, the appropriate edge time needs to be able to not only meet the time requirements of the bit signal, but also solve the problem of EMI exceeding the standard [4]. If the signal edge time does not meet the specified time, it may cause inaccurate sampling points and erroneous data frames. In severe cases, the bus may be paralyzed.

The edge time directly reflects the size of the parasitic capacitance of the CAN circuit and the cable. According to the principle of zero-input response of the first-order circuit and zero-state response of the first-order circuit, the signal edge time increases with the increase of the parasitic capacitance, and with the parasitic capacitance decreases as the capacitance decreases. When the edge time is fixed, the rising slope of the signal edge reflects the ability of the transceiver chip to control the slope of the signal edge. From the structural principle of the CAN transceiver, the falling slope of the signal can indirectly reflect the size of the bus resistance. The decreasing slope decreases as the bus resistance increases, and increases as the bus resistance decreases.

The default edge interval refers to the edge time when the bit voltage of the standard Bosch automotive electronics specification changes by 20% to 80%. The CAN-DIFF bit time of the tested CAN system, the edge time (rising edge and falling edge) is less than 10% of the bit time, and the bandwidth is not less than 5 times the baud rate. When the edge is too slow, the terminal resistance value and amplitude can be reduced to speed up the discharge and reduce the impact of distributed capacitance. Secondly, replace the cable and use a dedicated CAN standard cable.
Figure 2. Signal edge time test results

Figure 2 shows that the edge time (rising edge and falling edge) is less than 10% of the bit time, and the bandwidth is greater than 5 times the baud rate, which meets the technical requirements of relevant standards.

3.2. Sampling point test

The signal bit sampling point refers to the time point at which the sampling is obtained and the bus status is read and interpreted in the CAN bit time interval, and is the position where the CAN node recognizes a level logic. In the CAN protocol, the bit time is divided into a synchronization segment, a propagation time segment, a phase buffer segment 1 and a phase buffer segment 2, and the sampling point is between the phase buffer segment 1 and the phase buffer segment 2. The CAN bus can be sampled once or three times at the sampling point, depending on the CAN baud rate configuration register. Sampling points are extremely important to the CAN bus, especially when networking, multiple nodes try to keep the same sampling point. If the sampling points of the nodes in the network are inconsistent, it will lead to sampling errors at the same sampling frequency, which will make the entire network error occurred.

In the CAN signal transmission process, when the characteristic impedance changes, it will cause signal reflection, which will easily cause signal distortion; when the capacitive reactance on the bus is large, it will easily cause the signal edge to be too slow. Therefore, in order to ensure the accuracy of the signal sampling at the receiving end, the sampling points are located in the area after 50% of a bit. When the bit level becomes flatter, the error rate of the sampling logic value also decreases. Under normal circumstances, the later the sampling point, the more stable the waveform, and the CAN transmission distance will be farther. But the sampling point is not the later, the better. When it exceeds 95%, if there is a bit width deviation between nodes, that is, a baud rate deviation, it is easy to make mistakes. According to the CIA CANopen specification, the sampling point range is 70%-90%, as long as the sampling point falls within this range, it means that it meets the technical requirements, but the value is not static, and needs to be adjusted according to the actual situation.

Figure 3. Test results of sampling points
The tested baud rate sampling point adapts to the range of 60%-80%, and the characteristic value is 70%.

3.3. Signal delay test

When the CAN node sends a message, it will send a 2-bit ACK segment (composed of ACK response gap bits and ACK delimiter) after sending the CRC check field. The CAN sending end will monitor the data on the bus while sending the data. If the received data is inconsistent with the sent data, it means that the transmission has failed. Since the sending end continuously writes two recessive bits to the ACK segment while sending data, the CAN receiving node will change the bus level from "recessive" to "dominant" during the response gap after receiving the data correctly. If the sending node monitors the ACK response gap bit as "dominant" during the readback process, it means that the receiving end has correctly received the data; if affected by the transmission delay, the sending end monitors the ACK response gap during the readback process. If the bit is "recessive" or it is monitored that the ACK delimiter bit changes from "recessive" to "dominant", it means that no node has correctly received the message, and the sender will know that the transmission has failed.

Due to the influence of the transmission distance between nodes and the characteristics of the isolation devices in the circuit, there is a relatively large data transmission delay. If CAN resynchronization is not enough to compensate for this delay, it will cause data sampling errors and eventually CRC check errors. Therefore, the signal delay parameters need to be tested after the CAN node is networked to ensure that the CAN bus network can be used normally. Under normal circumstances, the ideal bus maximum delay time is less than. According to the research results of reference [5], in order to reduce the delay, when designing the circuit, try to avoid the use of optocoupler isolation devices with large delays. Magnetically isolated integrated circuits or high-speed optocoupler devices can be used. Due to the different signal transmission speed of cables of different materials, in order to reduce the signal transmission delay in the cable, try to use standard CAN communication cables.

The signal delay time is limited to less than 20%. The signal delay measurement results show that the actual test result is 6.5%. Between the limit value of 0 and 20%, the test passes.

3.4. Bus utilization test

In the general industry, the bus utilization rate is defined as the ratio of the actual data transmission rate to the theoretical data transmission rate. When the bus is idle, the sending node can send a message to the bus. The bus determines which node can obtain the bus control right according to the priority of the message sent by the CAN node. When the high and low priority nodes send messages to the bus at the same time, only the high priority node with the highest level can win the control of the bus. The low-priority node with the failure of the president can only give up the control of the bus, waiting to continue to try to grab the control of the bus when the next bus is idle. If the high-priority node has been preempting the bus, it will directly cause the low-priority node to fail to send data normally, and the low-priority message will be severely blocked, resulting in the low-priority message being unrestrictedly delayed, or even frame loss [6]. In extreme cases, it may cause the appearance of erroneous frames, which seriously affects the normal communication of the bus.
Under normal circumstances, the recommended bus utilization rate is 30%, and its essence is to allow low-priority CAN nodes to communicate normally in real time. The bus utilization rate is not static. If the CAN bus management strategy is optimized to ensure that each CAN node can complete the bus data transmission within the specified time period, the bus utilization rate can be appropriately increased.

![Bus utilization test](image)

**Figure 5. bus utilization test results**

The average utilization rate of the obtained CAN bus is 23.8703%, less than 30%; the utilization rate of the burst bus is 38.0147%, less than 70%, so the probability of bus competition arbitration is relatively low, and the bus is highly scalable.

4. Conclusion

It can be seen from the CAN standard that in order to ensure the reliable operation of the CAN bus, it is necessary to test the CAN bus at the physical layer, data link layer and application layer. However, in different applications, the test content is different according to different actual conditions. The trade-off, this article mainly explains the main items of the most commonly used and basic CAN bus conformance test from the perspective of engineering application, and describes the test purpose and test method in detail, in order to achieve the purpose of throwing bricks and jade. How to promote CAN bus reliability application research provides some ideas. At the end of the article, according to the actual application scenario, the CAN bus is simply tested, and the test results are briefly explained.

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