System-level testing of CAN FD transceivers

For multi-node CAN FD networks, the author recommends to apply a system-level testing of CAN transceivers and CAN protocol controllers.

(Source: Adobe Stock)

A CAN FD interface is mainly comprising a CAN FD protocol controller (often integrated in the micro-controller) and a CAN transceiver. CAN FD is scalable regarding the bit time. CAN FD transceivers use arbitration bit rates of up to 1 Mbit/s as CAN CC (classic) is doing. In the data phase, the bit rate can be higher depending on the physical network design. In multi-node networks, you can achieve 2 Mbit/s. Using in some nodes CAN SIC (signal improvement capability) transceivers can enable bit rates above 2 Mbit/s, but this is not the topic of this article.

CAN FD transceivers are connected to the CAN-H and CAN-L network lines. The bit values are represented by differential voltages. A nominal 2-V differential voltage represents a dominant bit and a nominal 0-V differential voltage is regarded as a recessive bit. Differential voltages greater than 1,5 V are interpreted as dominant bits. Whereas, differential voltages less than 200 mV are regarded as recessive bits.

Evaluating a multi-node CAN FD network and the achievable bit rates in the arbitration as well as the data phase requires a proper selection of transceiver chips and other electromechanical components, especially the cable. Also used network topology has an important impact. A daisy-chain bus-line topology or a bus-line topology with very short (not terminated) stubs fit best. The CiA 601-6 specification contains requirements for cables to be used for CAN FD networks.

Why to perform system-level testing?

Most of the time, while choosing CAN transceivers, customers evaluate the CAN transceiver by sending a bit stream on the TXD pin of the CAN transceiver through the function generator. Although this method is perfectly suitable for the evaluation of a single-node CAN, it seems to be flawed while developing a multi-node, far-spaced CAN FD network. Hence, a system-level testing of CAN controllers and CAN transceivers is necessary to select the right CAN transceiver.

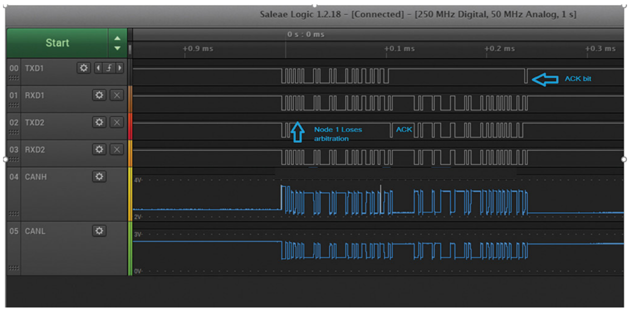

Figure 1: CAN arbitration in a two-node network (Source: Analog Devices)

The primary reason for this system-level testing approach is the arbitration feature of the CAN protocol. If two nodes try to occupy the bus simultaneously, access is implemented with a non-destructive, bit-wise arbitration. The node that sends a first CAN-Identifier bit as a "zero" (dominant), while the other nodes send this bit as a "one" (recessive), retains control of the CAN network and goes on to complete its data frame.

As shown in the Figure 1, node 1 and node 2 are connected to each other over the CAN network. So, CAN-H and CAN-L lines are common to both nodes. TXD1 and RXD1 pins provide the physical layer symbols (NRZ-coded bits; NRZ: non-return-to-zero) to the node-1 protocol controller, whereas TXD2 and RXD2 pins do this for node 2. As it can be seen, the first three bits of node 1 and node 2 are the same: 1, 0, and 1, respectively. The fourth bit of node 2 is 1, whereas this bit of node 1 is 0. As node 1 has a dominant bit, it wins the arbitration and continues sending the complete data frame. The date frame is acknowledged by node 2. Once node 1 finishes the transmission, node 2 can start the sending of its data frame. Node 1 acknowledges this data frame by means of the ACK slot bit.

Each node should use a unique CAN-Identifier (CAN-ID), in order to avoid arbitration deadlocks. They can lead to situations, in which one node goes bus-off. In CAN FD communication, the arbitration (nominal) bit rate can be ▷

kept the same or different from the data phase bit rate. In CAN CC (classic), both the arbitration and data phase bit rate are the same.

CAN nodes synchronize on observed edges within the NRZ-coded bits, but the signal propagation time on the bus line introduces phase shifts between the nodes. CAN's non-destructive arbitration mechanism for media access control requires that the phase shift between any two nodes is less than half of one bit time. This lower boundary for the nominal (arbitration phase) bit time defines an upper boundary for the nominal bit rate as well as for the network length. Thus, the rise time and fall time of the RXD, the loop delay of the CAN transceiver as well as the cable come into the picture. At a higher bit rate, for example, 10 Mbit/s, the propagation delay, and rise time/fall time need to be less than 50 ns.

Example transceiver testing

Let's take an example of the MAX33012E CAN transceiver, which has been tested up to 13,3 Mbit/s with a 20-m cable. As shown in Figure 2, the TXD2 bit width is 75 ns (corresponding to 13,3 Mbit/s) and the RXD2 bit width is 72 ns. As the controller samples at 80 percent of the TXD bit width, the minimum RXD bit width including rise time/fall time and loop delay of the RXD required is 60 ns. It can be seen that the received bit width is 72 ns. Thus, the MAX33012E satisfies the condition and is robust enough to work at higher bit rates. In this situation, the CAN controller doesn't detect any error and continues to perform data communication.

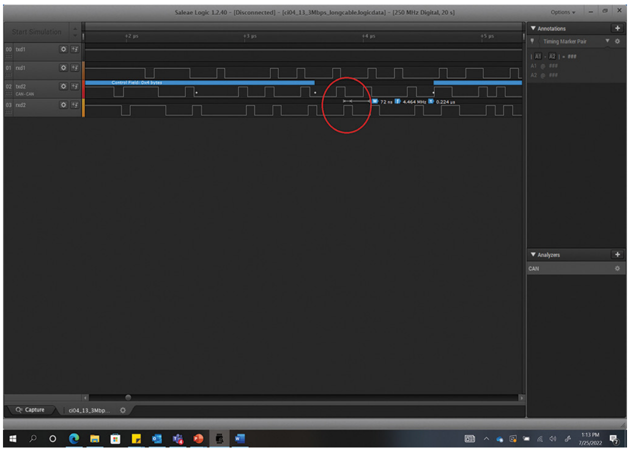

Figure 2: CAN transmission using a MAX33012E (Source: Analog Devices)

The shown oscilloscope shot of a competitor transceiver (see Figure 3), which was also tested at 13,3 Mbit/s, demonstrates the transmitted bit width of 75 ns (corresponding to 13,3 Mbit/s) and the received bit width of less than 80 % of the transmitted bit width (48 ns). Thus, the arbitration phase bit transmission failed, leading to an error in communication, and finally the system stopped working.

These kinds of data transmission errors can only be uncovered by performing complete system-level testing, which includes multiple CAN controllers, CAN transceivers, and a long cable.

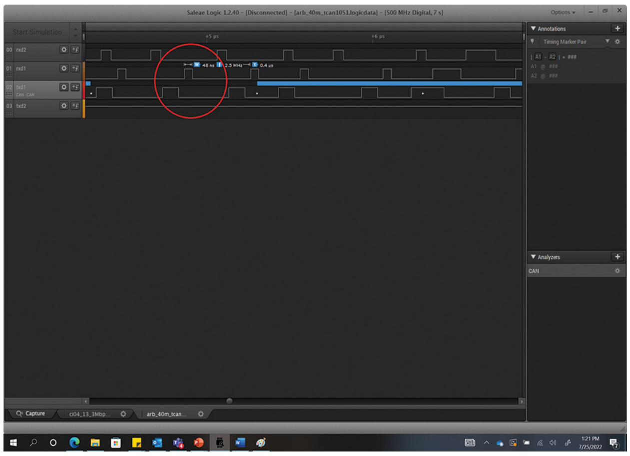

Figure 3: CAN transmission using a CAN transceiver from a competitor (Source: Analog Devices)

Conclusion

System-level testing of the CAN transceiver helps to unveil the possible future data transmission problems in your system. These problems can be avoided by evaluating a CAN transceiver with a CAN protocol controller and a cable that satisfy the required timing and voltage specifications. Robustness of the CAN system is a cumulative performance of each component in the CAN network. Evaluating only one component, or CAN transceiver, does not provide an accurate measure of system functionality. Performing a prior validation of the system is much more cost-effective than replacing a faulty one. Thus, we highly recommend system-level testing before choosing your CAN transceiver. ◀

According to documentation from Analog Devices.
For further questions, please contact *adi-germany@analog.com*