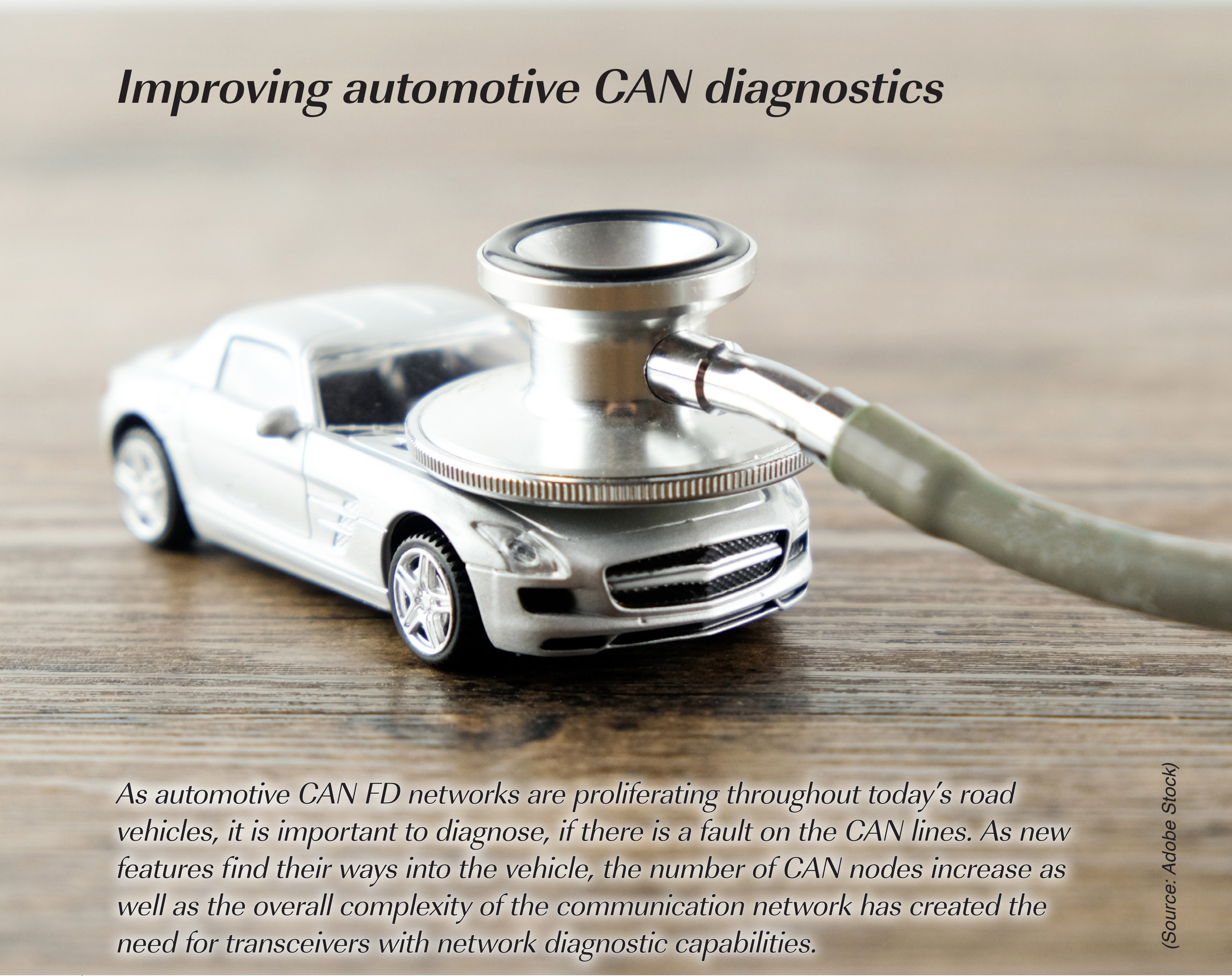
Improving automotive CAN diagnostics



(Source: Adobe Stock)

As automotive CAN FD networks are proliferating throughout today's road vehicles, it is important to diagnose, if there is a fault on the CAN lines. As new features find their ways into the vehicle, the number of CAN nodes increase as well as the overall complexity of the communication network has created the need for transceivers with network diagnostic capabilities.

Legacy CAN high-speed transceivers compliant with ISO 11898-2 served their purpose in delivering robust CAN communication throughout the vehicle, but lack the ability to communicate network fault conditions when they occur. Transceivers have, over time, migrated from an 8-pin component to more complex components by adding pins. These more complex components come in 14-pin packages, but are still basically the 8-pin components with an added nFault pin that marginally addresses a network fault condition. System-basis chips (SBCs) are also rapidly being adopted across numerous applications throughout the vehicle. As such, CAN FD transceivers and CAN FD SBCs must become smarter and need more capable interface with the MCU (microcontroller unit) than a general purpose pin control. This interface could be Serial Peripheral Interface (SPI), which offers high bandwidth for communicating the latest features of a smarter transceiver or SBC. Some of these components include fail-safe modes, which can intervene if a CAN node is otherwise stuck in a higher power state. This prevents the transceiver from needlessly draining the battery or allowing invalid data frames on the CAN network during certain fault cases. This article considers methods to avoid invalid data and how TI's CAN transceivers and SBCs can help a node's local processor determine if an issue exists on the CAN network.

By understanding the amount and complexity of electronics is increasing each year, transceiver architecture improvements are needed. These new complexities need more useful information and control in order to enable the most robust CAN node architectures. Improved network diagnostics is one area that has been lacking. Electronic control units (ECUs) tend to follow a general architecture. It will consist of a local MCU, communication ports (CAN FD, LIN, Ethernet), and power. There will often be other specialized interfaces such as motor drivers, LED drivers, and cameras. The ECU's primary function could be for advanced driver assistance system (ADAS), body electronics and lighting, infotainment and cluster, or even electric vehicle/hybrid electric vehicle (EV/HEV) applications. For such systems, CAN FD is an appropriate interface, because of its higher data throughput and robustness, when compared to other automotive communication options. ▷

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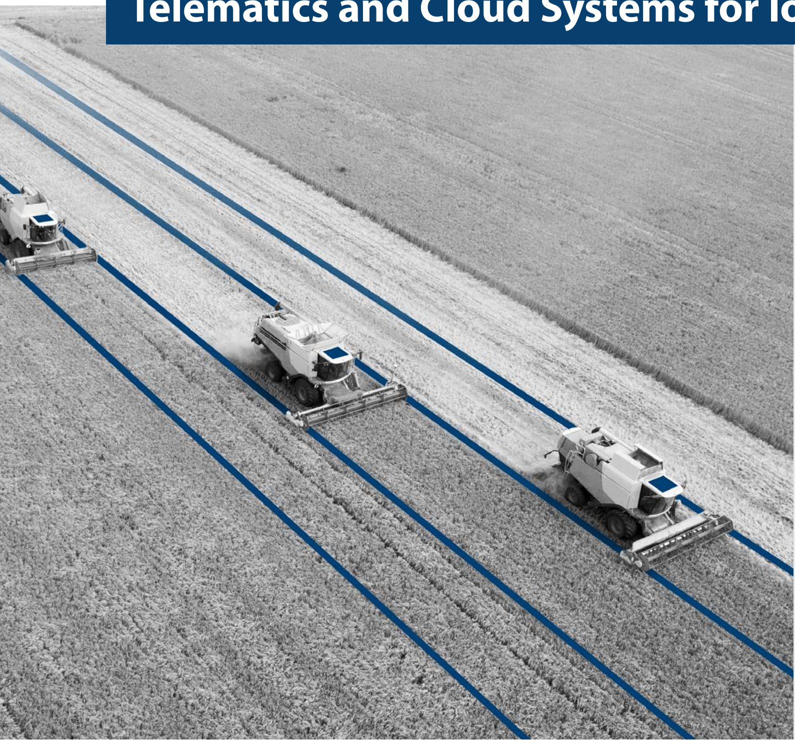

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In applications like ADAS or radar, knowing if the CAN network has some common faults would be beneficial to the system designer or vehicle repair technicians. Understanding if there is a network fault and not just a faulty ECU and possibly general location could reduce help reduce down time. Knowing this difference allows services to avoid un-needed warranty component replacements. If the network has a fault that prevents communication between one or more of the nodes on the CAN network, diagnostics can be difficult. In comparison, in a scenario where only one ECU has an issue, communications may not be blocked, but some other action is required for resolution.

In many CAN FD networks, the CAN high (CAN_H) and CAN low (CAN_L) lines are used in a line topology with 120-Ω termination resistors at each end. Another CAN network configuration is a star topology with a central 60-Ω termination resistor. For our examples, we will consider a mostly linear, non-star topology.

Figure 1 depicts a simplified three-node CAN network. The CAN FD transceiver must be able to handle certain network fault voltages that can swing between -42 V and +42 V for 12-V battery systems and between -58 V and +58 V for 24-V battery systems.

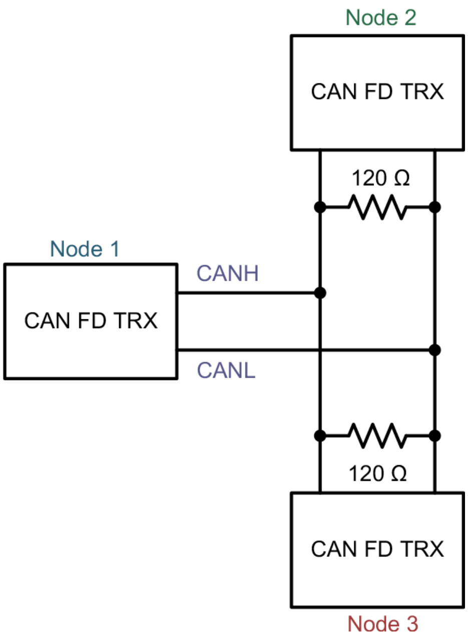

Figure 1: Three-node CAN FD network example (Source: Texas Instruments)

Legacy CAN transceivers from 8-pin to more capable 14-pin components have limited capability to communicate back to the MCU. 8-pin transceivers need all pins just for control, while 14-pin transceivers have added extra pins that can communicate limited information back to the MCU. Some 14-pin components have added the capability to detect certain network fault conditions such as CAN_H or CAN_L shorted to battery (Vbat), shorted to ground or being open (no termination between CAN_H and CAN_L). Communicating this fault information back to the MCU is challenging due to the single GPIO pin only communicating a high (logical 1) or low (logical 0) status. An example could be a nFault pin; a low indicates that a fault has occurred, but no real information is shared on what the fault was. Many SBC's include Serial Peripheral Interface (SPI) communication, yet the network condition communication between the transceiver and MCU has progressed very little.

Though it is possible to determine the presence and type of network fault, the location of the fault on the CAN network can influence how it appears to a connected transceiver. Let's start our analysis by considering the three-node configuration in Figure 1 and applying different network faults. Network faults typically manifest as opens and shorts. Figure 2 and Figure 3 show different scenarios of CAN_H and CAN_L being open. The location of the open lines can determine whether the fault is detectable.

In Figure 2, the opening occurs at Node 2 or Node 3. The whole network could detect this fault condition because one or both terminations are missing. When the fault happens at Node 1, only Node 1 will detect the fault. Node 2 and Node 3 will detect a "good" network, because the end-point termination is intact and therefore cannot report that an opening has occurred at Node 1. Figure 3 provides further examples, where either CAN_H or CAN_L is open, but these may not hamper network communication.

Network faults that are the result of a short have their own set of challenges. The short can be either CAN_H or CAN_L shorted to Vbat, Vcc, or ground, as well as CAN_H and CAN_L being shorted together. When shorted together, CAN_H and CAN_L could also be shorted to Vbat, Vcc, or ground. Figure 4 and Figure 5 show different cases for the short condition.

The faults shown in Figure 4 show cases where only one CAN line is shorted. In these cases, CAN data may be degraded, but communication might still be possible. With network fault detection, the issue can be identified confidently as a network short condition rather than seemingly random occasional communication failures. The issue arises when considering faults 10 and 11 shown in Figure 5. To understand the issue requires considering both Figure 4 and Figure 5 with the fault conditions shown. Faults 7 and 8 are distinct faults that a system would be able to identify as different. The issue is the ability to distinguish between fault 7 and fault 10 or between fault 8 and fault 11. A system may have both faults indicated when it is one or the other.

The faults shown in Figure 5 show cases, where both CAN_H and CAN_L are experiencing a short. During such conditions, it is unlikely that CAN data frames can be transmitted on the network. With clever design of a network fault detection circuit, each of these cases can be identified as unique fault conditions and ease suspicions of other hardware problems. Knowing which of these disruptive faults is occurring can help pinpoint which section of the CAN network needs service or repair to get the CAN network back online.

When a transceiver can determine a network fault has taken place, the system designer can decide the best method for communicating a fault condition. This communication could be a service light on the dashboard or stop communication with the nodes. Table 1 lists the fault conditions and whether the location of the fault can be determined. The information provided on a fault condition along with the CAN network architecture understanding ▷

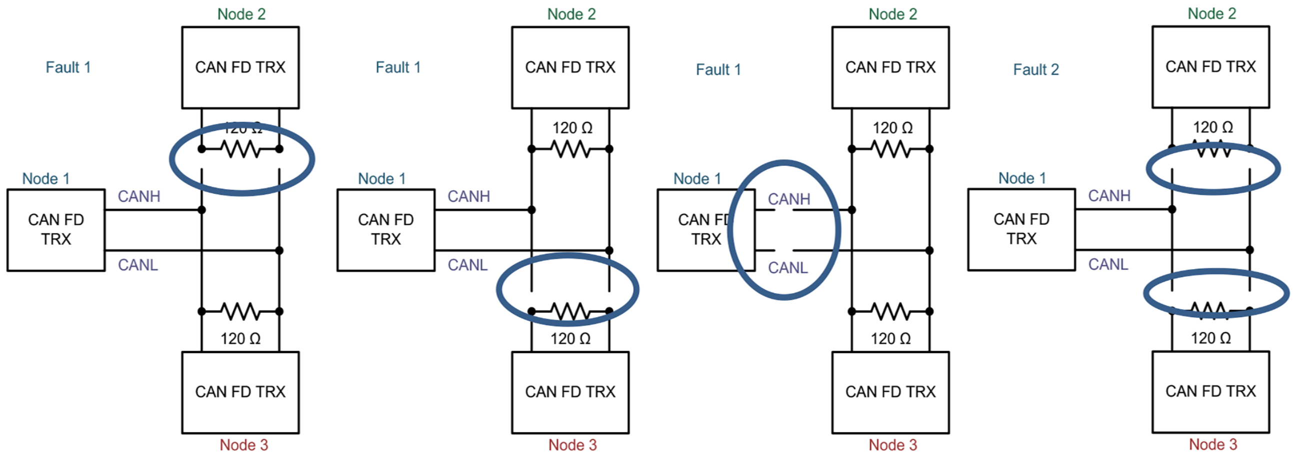

Figure 2: CAN_H and CAN_L both are open at same time (Source: Texas Instruments)

could be used by a service department to help narrow down possible locations of a fault.

As CAN FD communication and functional safety continue to grow in importance, network-fault diagnostics should be a consideration during the CAN network development process. Considering only the network fault tolerances of a CAN transceiver is becoming insufficient for today's robust networks. When autonomous vehicles become more ubiquitous, network fault tolerances will no longer be enough and smarter transceivers with advanced network diagnostic capability will be required.

Original equipment manufacturers (OEMs) are requesting more detailed information on network faults in transceiver solutions. In the future, CAN networks will need to be designed in a manner that will utilize smarter transceivers to help determine network faults and their locations. The ability to communicate with the MCU by providing diagnostic information will enable the future CAN network to be more robust. Such transceivers will provide reliable information to the system diagnostic methodologies that can help resolve network failures. To accomplish this, the transceiver functionality needs to go beyond network faults and a close collaboration between the CAN network designer and CAN transceiver manufacturer is required. Future smart transceivers can provide network diagnostic information back to the MCU, which can enhance the ▷

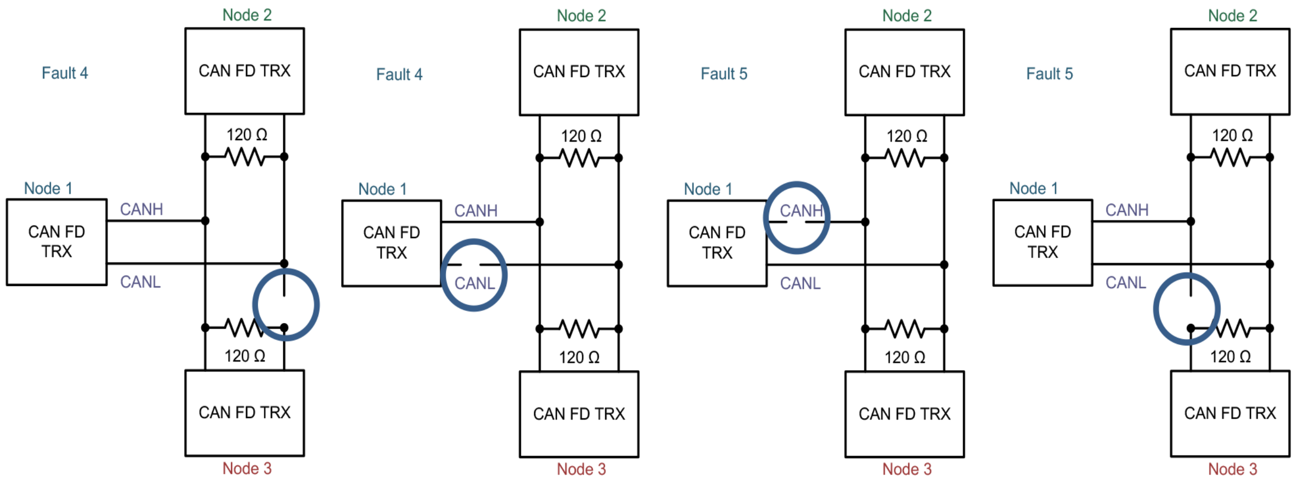

Figure 3: CAN_H or CAN_L are opened individually (Source: Texas Instruments)

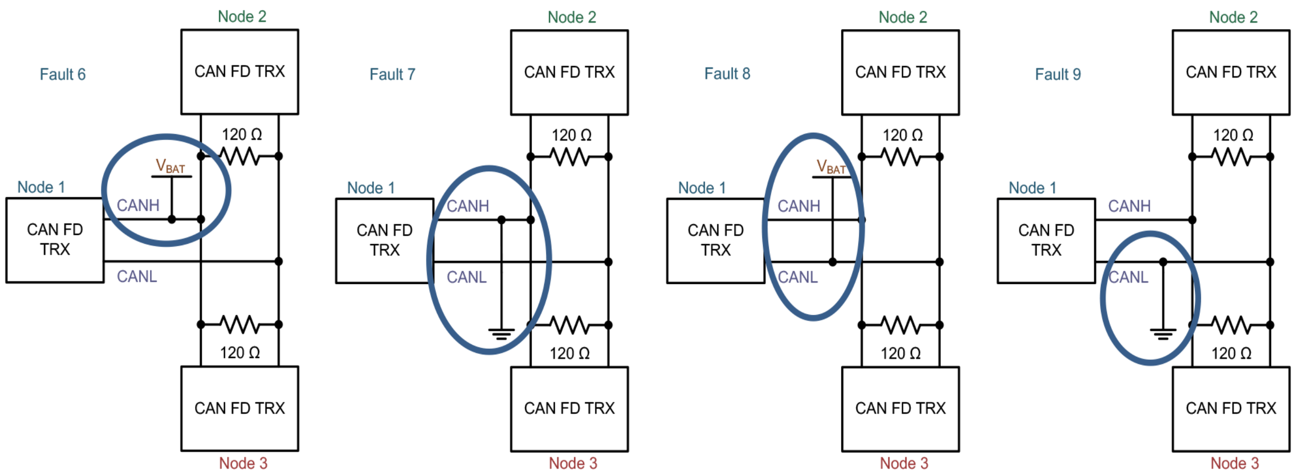

Figure 4: CAN_H or CAN_L shorted to Vbat or ground (Source: Texas Instruments)

robustness of a CAN network. Network fault diagnostics needs to be a system level design effort that includes a smart transceiver such as TCANxxxxx. If a critical fault is occurring at the electronic control unit, then the general communication of the network can be compromised. For complete coverage of a node, a system-level diagnostic solution is needed for each node and the ability to communicate this information back to a central controller.

Future CAN transceivers

What if an open fault condition takes place at Node 1 before a sleep command? The node may stay in a high- ▷

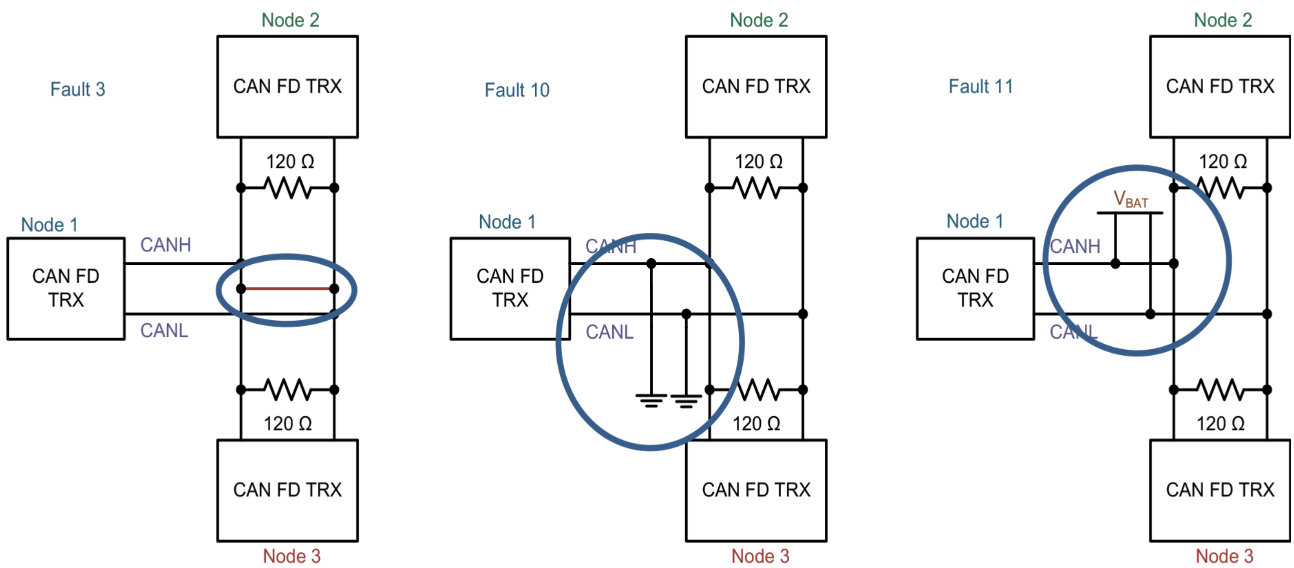

Figure 5: CAN_H shorted to CAN_L examples (Source: Texas Instruments)

Table 1: Network fault conditions and fault-location capabilities (Source: Texas Instruments)

Fault No.	CAN_H	CAN_L	Fault detected
1	Open	Open	All smart transceivers see this fault as missing termination, whether seeing no termination or seeing 120 Ω instead of the expected 60-Ω termination
2	Open	Open	Depending upon the open location, the smart transceiver can diagnose this fault as no termination
3	Shorted to CAN_L	Shorted to CAN_H	Yes, but not the location
4	Normal	Open	• Transceiver 1 can detect this fault but cannot tell the difference between it and fault 2 or 5 • Transceiver 2 and Transceiver 3 do not see this as a fault
5	Open	Normal	• Yes, but cannot tell the difference between this fault and fault 2 and fault 4 • Transceiver 2 and Transceiver 3 do not see this fault
6	Shorted to Vbat	Normal	Yes, but not location
7	Shorted to GND	Normal	Yes, but cannot tell the difference between this and fault 10
8	Normal	Shorted to Vbat	Yes, but cannot tell the difference between this and fault 11
9	Normal	Shorted to GND	Yes, but not the location
10	Shorted to GND	Shorted to GND	Yes, but cannot tell the difference between this and fault 7
11	Shorted to Vbat	Shorted to Vbat	Yes, but cannot tell the difference between this and fault 8

power state which could drain the battery. An example of this could be a car parked at the airport for a couple weeks. Smart transceivers that have advanced network diagnostics and a network designed to utilize the transceiver could mitigate the situation where the owner of the car returns home to a dead battery at the airport and thus avoiding a bad day. Texas Instruments has two transceivers today that support this advanced bus fault diagnostic capability, TCAN1144-Q1 and TCAN1146-Q1. ◀

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