

Physical diagnostics of CAN networks

With increasing connectivity and rising data rates, the physical quality of signal transmission has become a key focus. The CAN Bus Tester GT3 from Gemac Chemnitz (Saxony, Germany) is available for physical diagnostics and signal quality assessment in practical applications.

(Source: Adobe Stock)

The controller area network (CAN) has been an established and reliable communication system in vehicles, mobile machinery, and industrial applications for decades. With increasing connectivity and rising data rates – particularly due to the use of CAN FD (flexible data rate) – the physical quality of signal transmission has become a key focus.

Traditional diagnostic approaches focus primarily on the protocol level and analyze frames, error counters, or bus load. While these methods provide important information about logical communication, they do not capture the state of the physical transmission. In practice, many communication problems arise not from protocol errors but from deviations in electrical signal transmission. These often go undetected at first but compromise the stability and robustness of the overall system.

Physical CAN signal transmission

CAN operates as a differential two-wire system in which information is transmitted via a voltage difference between the CAN_H and CAN_L lines. Active states correspond to a differential voltage of approximately 2 V, while inactive states are characterized by a voltage difference that is virtually zero. This transmission principle ensures high immunity to electromagnetic interference.

Signal transmission follows the principles of transmission line theory. CAN lines have a characteristic impedance of approximately 120 Ω and require proper termination at both ends of the bus. Typically, two terminating resistors, each with a value of 120 Ω , are used, resulting in a total impedance of 60 Ω .

Mismatches directly cause reflections. These manifest as overshoot, ringing, and distorted signal edges. Typical

causes include improper termination, inappropriate cable lengths, branch lines, or impedance steps within the cabling.

Impact of increasing data rates on signal integrity

With the introduction of CAN FD, the requirements for physical signal quality have increased significantly. Higher bit rates shorten the bit times and reduce the permissible tolerances for signal transmission. The system behavior increasingly resembles that of a high-frequency transmission system.

Particularly during the data phase of CAN FD, the following factors have a direct impact on signal quality:

- ◆ Slope of the signal transitions;
- ◆ Signal propagation times along the line;
- ◆ Temporal stability of the signal (jitter);
- ◆ Electromagnetic interference.

Even slight deviations shift the receiver's effective sampling time out of the stable signal range. This results in bit errors or reduced signal-to-noise ratios, without immediately causing protocol errors.

Limitations of conventional diagnostic methods

Analyzing only the protocol layer is not sufficient for a comprehensive assessment of the system's state. Error counters and status information reveal the behavior of the communication, but do not provide any insight into the physical causes.

A reliable diagnosis requires the simultaneous consideration of several physical parameters:

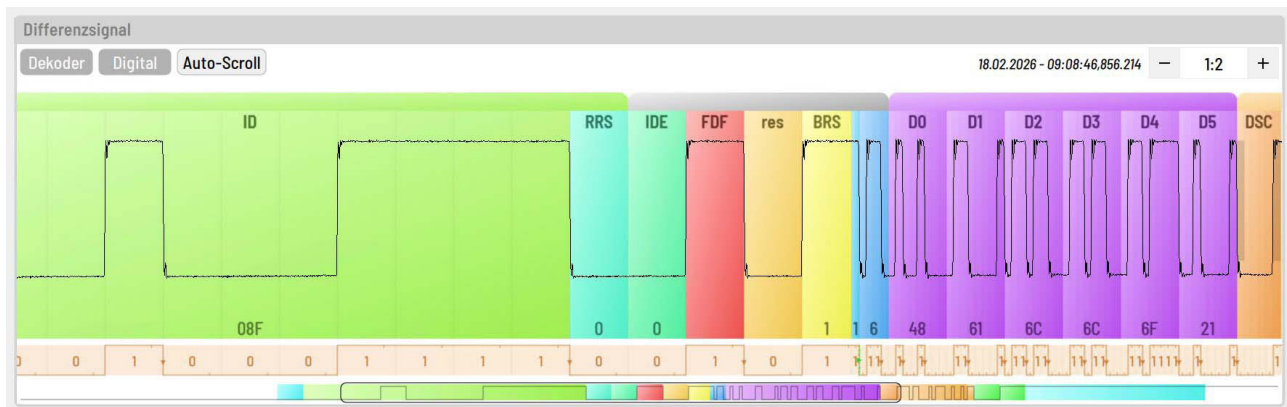


Figure 1: Display of a CAN-FD frame in the CAN Bus Tester GT3 (Source: Gemac Chemnitz)

- ◆ Differential signal amplitude;
- ◆ Rise and fall times;
- ◆ Overshoot and ringing;
- ◆ Jitter and temporal signal variation;
- ◆ Signal-to-noise ratio;
- ◆ Effective termination resistance.

Interpreting these parameters is complex and requires a solid understanding of signal processing and measurement technology.

Evaluation of signal quality

To simplify diagnosis, methods are used that combine multiple physical measurement parameters into a single signal quality value. This involves normalizing and weighting the relevant parameters to produce a dimensionless metric. This signal quality value is typically expressed as a percentage and directly indicates the extent to which the physical signal transmission falls within the specified limits.

The advantage lies in the significant reduction in complexity: instead of evaluating individual metrics in isolation, users are provided with an overall assessment that can be interpreted immediately. At the same time, access to detailed individual parameters for further analysis is retained.

CAN bus tester

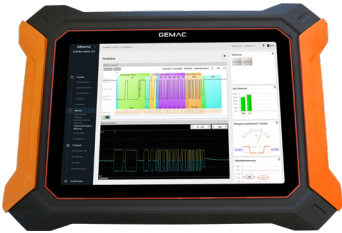


Figure 2: CAN Bus Tester GT3
(Source: Gemac Chemnitz)

In complex networks with multiple control units, long cable runs, or high levels of electromagnetic interference, a combined analysis of the protocol and physical layers is essential.

The CAN Bus Tester GT3 is developed and manufactured by Gemac and is available for physical diagnostics and signal quality assessment in practical applications. The system records both physical signal parameters and logical communication, and automatically calculates a signal quality value based on this data. This provides users with a quick and transparent assessment of the network's condition and a targeted identification of fault causes.

The tester supports not only CAN CC (classic) networks but also CAN FD applications. By combining physical measurements with signal quality assessment, it simplifies commissioning, maintenance, and troubleshooting in complex networks without requiring in-depth knowledge to interpret the physical measurement data.

Conclusion

Physical signal integrity plays a decisive role in determining the reliability of CAN CC and CAN FD networks. As data rates increase and system complexity grows, purely protocol-based diagnostics become less meaningful. Only the combination of physical measurements, in-depth

Open-source CANopen tool

Chanchal Dhiman has released the open-source CANviz browser-based CANopen analyzer. The tool (version 0.3.1) passively decodes CiA 301 and CiA 402 messages from the COB-ID (communication object identifier) structure, tracks NMT (network management) state per node, decodes CiA 402 drive states from TPDO1 (transmit process data object) without an EDS (electronic data sheet) file, and pairs SDO (service data object) transactions against a built-in 180-entry object dictionary. It installs via pip and requires no native application; a CAN CC (classic) hardware interface is sufficient. The tool is available at <https://github.com/Chanchaldhiman/CANviz>.
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signal analysis, and a structured evaluation methodology provides a comprehensive and reliable assessment of the network system. Aggregated signal quality metrics serve as an effective tool for presenting complex relationships in an understandable way while ensuring high diagnostic accuracy. The CAN-Bus Tester GT3 from Gemac Chemnitz provides a practical solution for this purpose. ◀



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