# Oscilloscopes for debugging automotive Ethernet networks


ROHDE&SCHWARZ

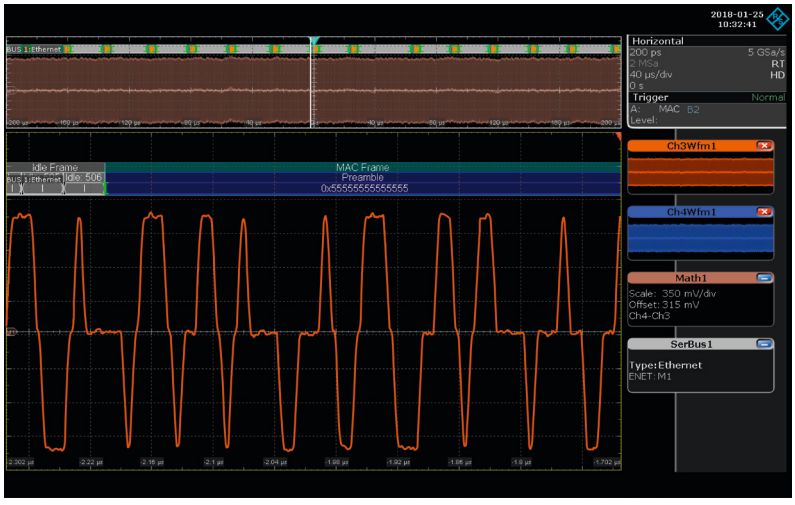
Application Brochure | Version 01.00

# Comprehensive analysis allows faster debugging

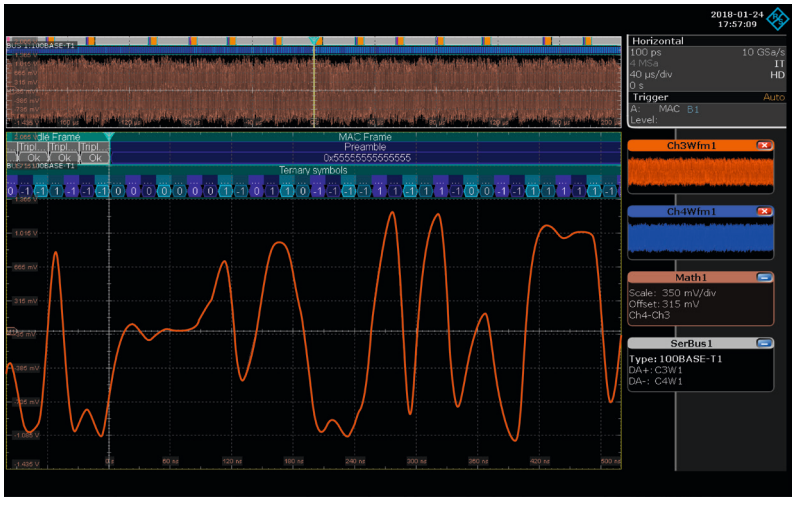
Developers of electronic control units (ECUs) with an automotive Ethernet interface must perform tests to ensure that their devices work properly. However, if problems occur during signal transmission, plain Ethernet protocol analysis is not adequate in most cases. The trigger and decode bundle for Rohde&Schwarz oscilloscopes provides a good workaround for this problem. The bundle allows developers to trigger on the transmitted Ethernet protocol content, decode the content and correlate its timing to the electrical bus signals. During debugging work, this helps to significantly accelerate the problem analysis.

Automotive Ethernet is becoming increasingly popular as a fast bus system for in-vehicle applications such as driver assistance and infotainment systems. The automotive industry developed the 100BASE-T1 Ethernet interface for this purpose. It is based on BroadR-Reach® technology and has been standardized by the IEEE 802.3bw working group. 100BASE-T1 uses full duplex Ethernet communications via an unshielded Ethernet twisted pair. The 100BASE-T1 signals have PAM-3 modulation and the levels of the differential signal are between –1 V and +1 V. At 100 Mbit/s, the data rate is significantly faster than traditional bus systems such as the CAN bus.

The transmitter modifies the frequency response of the 100BASE-T1 signals in order to ensure reliable transmission with minimal RF leakage from the unshielded cable. The 100BASE-T1 standard requires the presence of an equalizer in the transmitter. When establishing the connection, the 100BASE-T1 PHY chips measure the cable's frequency response. The equalizers predistort the signals for subsequent data transmission in the aim of ensuring reliable signal transmission while simultaneously minimizing RF leakage from the cable.




Differential 100BASE-TX signal: The three levels and the steep edges at the transitions are clearly visible.




Automotive 100BASE-T1 signal: The three levels of the PAM-3 signal are not always clearly visible due to the predistortion produced by the equalizer.

Compared to the Ethernet 100BASE-TX standard (without equalizers), signals in the 100BASE-T1 system are highly distorted due to the predistortion. As a result, developers can no longer judge the signal quality solely by analyzing the levels of the electrical bus signals.

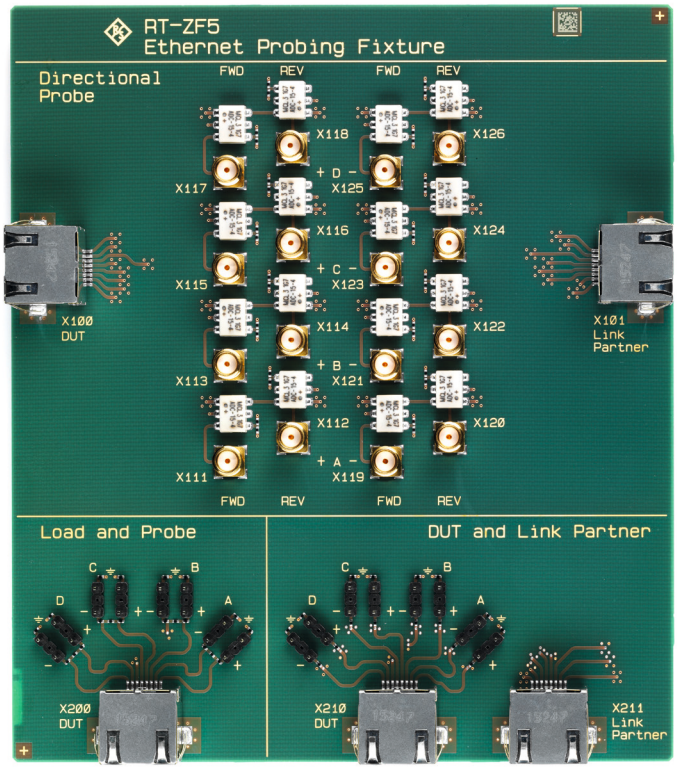
## Testing automotive Ethernet interfaces

The IEEE has specified the characteristics of 100BASE-T1 interfaces. Using the standardized compliance test, developers can measure the electrical characteristics of the interface using an oscilloscope and network analyzer in a laboratory. An Ethernet protocol analysis tool such as Vector CANoe or Wireshark is normally used to verify that the electronic control unit (ECU) correctly handles communications. Tools of this kind record all of the Ethernet data traffic and provide comprehensive analysis capabilities. However, transmission errors appear only in the form of telegram errors and in-depth analysis of the root cause is not possible. An oscilloscope with a suitable trigger and decode bundle is generally required for this purpose.

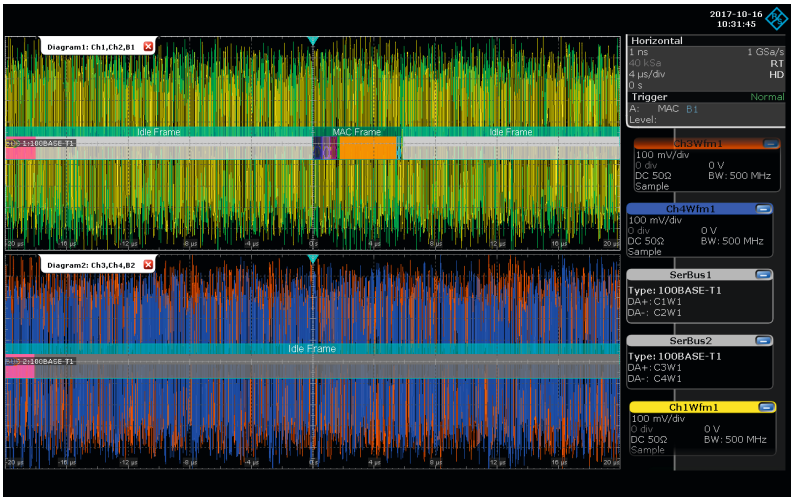
Using the trigger and decode bundle for the Rohde&Schwarz 100BASE-T1 bus, ECU developers can directly correlate the electrical signals with the transmitted telegram content as part of their analysis work. For example, problems that occur on the bus in automotive Ethernet applications can be debugged just as easily as conventional CAN buses (for which powerful trigger and decode bundle options also exist).

## Special features of the automotive Ethernet trigger and decode bundle

In 100BASE-T1 communications, both data streams are transmitted simultaneously via a twisted pair. If the developer records the bus level with an oscilloscope, then the superimposed data streams for both bus developers are measured. Without separating these data streams, there is no way to perform the required analysis. The R&S®RT-ZF5 Ethernet probing fixture is equipped with suitable directional couplers. After insertion into the Ethernet line section, it separates the data streams to allow noninstrusive recording of 100BASE-T1 communications with an oscilloscope.




The R&S®RT-ZF5 Ethernet probing fixture allows nonintrusive recording of both data streams in full duplex 100BASE-T1 communications.




100BASE-T1 decoding of both data streams in full duplex communications. The MAC frame is highlighted in color while the continuously transmitted idle frames are gray.

However, the recorded signals have been highly distorted by the equalizer used in the 100BASE-T1 transmitter. Prior to further processing, the signals are first equalized using complex algorithms and then decoded. The oscilloscope unscrambles the telegrams in the decoding process and displays all of the transmitted data telegrams and idle frames. The decoded telegrams are shown as color-coded bus signals and in tabular format. This allows developers to correlate the live 100BASE-T1 signals with the transmitted protocol content in order to perform highly detailed analysis.

The extensive triggering capabilities also allow developers, for example, to display isolated telegrams with specific source or destination addresses.

## Analyzing telegram errors

The timing relationship between bus communications and other signals can be revealed based on 100BASE-T1 decoding. For example, developers can determine the start time of an ECU for debugging purposes by triggering the oscilloscope on the 12 V supply voltage and measuring the time elapsed until the first valid telegram arrives. The stability of bus communications can also be verified just as easily: The developer configures the triggering specifically for short-term interruptions of the supply voltage and then analyzes the resulting interruptions in the bus communications. If many interruptions occur, then the stability is significantly impaired.

Sporadic bus errors due to coupling from interference sources can be difficult to debug without additional analysis capabilities. By decoding the 100BASE-T1 communications, developers can analyze bus communications across all of the protocol layers with proper timing correlation in order to identify coupling from interference sources.


Decoding of the electrical 100BASE-T1 bus levels. The two levels of the differential 100BASE-T1 signal are clearly visible along with the decoded telegram content.

## Using the oscilloscope with a trigger and decode bundle option

| OSI | Automotive Ethernet |
|---|---|
| 7 Application | Applications: FTP, SOME/IP, HTTP, SMTP...) |
| 6 Presentation | |
| 5 Session | |
| 4 Transport | TCP, UDP |
| 3 Network | IP |
| 2 Data link | 100BASE-T1 1000BASE-T1 |
| 1 Physical | |

- Error free communications
- Validate sleep/wake-up cycles
- Resistant to EMI
- Correct latency
- Correct boot time

Measurements can be made across all seven OSI layers, thereby enabling a wide range of test and analysis possibilities.

For example, in the measurement in screenshot below, the MAC frame and idle frames are correctly transmitted at the start of the recording. However, the data stream is abruptly interrupted in the middle of the recording. In the lower signal, the frequency spectrum of the interfering signal (area marked in gray) is plotted. A peak is clearly visible at 2 MHz. Obviously, this interfering signal caused the bus interruption. The combination of decoding capabilities with other analysis tools provided by the oscilloscope (e.g. frequency analysis) makes this type of debugging much easier. For example, the oscilloscope allows interference, that would be very difficult to isolate using other methods, to be detected at a glance.

## Summary

For developers of electronic control units (ECUs) with automotive Ethernet interfaces, Rohde&Schwarz has a complete 100BASE-T1 trigger and decode bundle option including a probing fixture for nonintrusive signal access. During debugging work, developers are supported by the comprehensive triggering and display functions for transmitted telegrams. The displayed decoding information is correlated in time with the electrical signal. This allows developers to analyze the protocol content during debugging and identify the causes of any bus errors that occur.

Besides the 100BASE-T1 trigger and decode bundle option, Rohde&Schwarz has complete test solutions for 100BASE-T1 and 1000BASE-T1 automotive Ethernet compliance tests and link segment tests using an oscilloscope and network analyzer.

## Oscilloscope configuration requirements

- Oscilloscope:
  R&S®RTO2004 (4 channels, ≥ 600 MHz bandwidth) or
  R&S®RTE1054 (4 channels, ≥ 500 MHz bandwidth)
- R&S®RTE-TDBNDL for serial trigger and decode functionality
- R&S®RTO-K57 or R&S®RTE-K57 for 100BASE-T1 support
- R&S®RT-ZF5 Ethernet probing fixture for channel separation

## Also important

- R&S®RTO-K24 BroadR-Reach® compliance test option
- R&S®RTO-K87 1000BASE-T1 Ethernet compliance test option


Analysis of a sporadic interruption in bus communications using a combination of protocol analysis and frequency analysis.

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**Regional contact**

- Europe, Africa, Middle East | +49 89 4129 12345
  customersupport@rohde-schwarz.com
- North America | 1 888 TEST RSA (1 888 837 87 72)
  customer.support@rsa.rohde-schwarz.com
- Latin America | +1 410 910 79 88
  customersupport.la@rohde-schwarz.com
- Asia Pacific | +65 65 13 04 88
  customersupport.asia@rohde-schwarz.com
- China | +86 800 810 82 28 | +86 400 650 58 96
  customersupport.china@rohde-schwarz.com


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Comprehensive analysis allows faster debugging
Data without tolerance limits is not binding | Subject to change


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