

Ethernet compliance testing with the R&S®RTO oscilloscope

In industry, IT and the private sector, it is difficult to imagine a world without Ethernet data exchange. An automated test solution that supports compliance tests on Ethernet interfaces is now available for the R&S®RTO digital oscilloscopes. A test wizard guides the user through the measurements to deliver precise measurement results.

Ethernet originated in the world of computer networking but is now well-established as the communications interface for countless electronic devices and systems. For example, this standard is used in the automotive industry to

control robots in production systems. Developers must ensure the interoperability of Ethernet interfaces. The necessary tests must be determined along with acceptance criteria and how to quickly detect any possible design

flaws. Ethernet compliance tests allow comprehensive verification of interfaces based on standardized test sequences, thereby providing support to hardware developers as they work to debug and release their designs.



Fig. 1: Ethernet compliance testing with the R&S®RTO: Just load the test software, connect the test fixture set and follow the test wizard through the configuration process for the tests.

	10BaseT	100BaseTX	1000BaseT	10GBaseT
Standard	IEEE 802.3 clause 14	IEEE 802.3 clause 25	IEEE 802.3 clause 40	IEEE 802.3an
Coding	Manchester coding, unidirectional, 2 twisted pairs	4B5B, MLT-3, unidirectional, 2 twisted pairs	8B10B, PAM-5, bidirectional, 4 twisted pairs	128-DSQ, PAM-16, bidirectional, 4 twisted pairs
Signal levels	Manchester level change	3 levels	5 levels	16 levels
Transmission bandwidth	10 MHz	32.5 MHz	62.5 MHz	500 MHz

Fig. 2: Protocol characteristics of various Ethernet standards.

Standardized Ethernet compliance tests

Ethernet was developed in the 1970s by Robert Metcalfe for use as a communications protocol. Beginning in 1980, Ethernet was standardized by the IEEE 802 working group and then continually developed. 10BaseT, 100BaseTX and 1000BaseT are the most popular electrical Ethernet standards (Fig. 2). For switches and servers, interfaces with 10GBaseT Ethernet are also being developed to allow higher data throughput. All of these interfaces use two or four twisted pairs typically with RJ-45 connectors.

The Ethernet standard with the lowest data rate (10BaseT) is based on a signal with Manchester coding. The other standards considered here with higher data rates use more complex coding schemes for data transmission along with up to 16 electrical signal levels.

IEEE has specified compliance tests for the electrical characteristics of Ethernet interfaces. The documentation describes comprehensive tests of transmitter signal quality and some tests of receiver signal quality. The specification defines test setups, test sequences

and special test modes. The user is expected to manually activate the test modes when performing the compliance tests, e.g. by setting the appropriate register entries. Details can be found in the documentation for the Ethernet

chip that is used. Fig. 3 shows an example of test mode 1 for the 100BaseT transmitter test used to measure the quality of the 1000BaseT signal (peak voltage, maximum droop, differential output template).

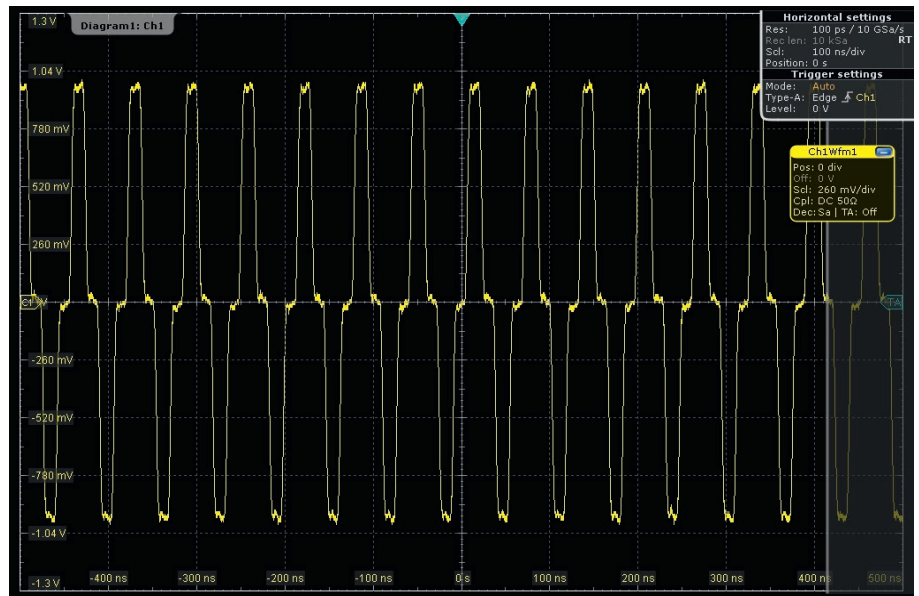
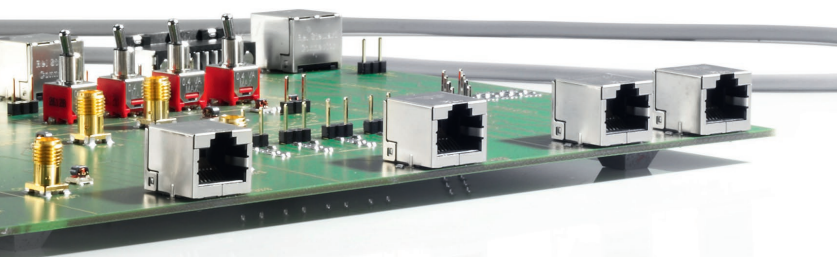


Fig. 3: Signal acquired by oscilloscope from Ethernet chip in mode for 100BaseTX tests for peak-to-peak jitter measurements.

The University of New Hampshire InterOperability Laboratory (UNH-IOL) is industry-recognized worldwide for Ethernet compliance testing. For this reason, Rohde & Schwarz requested the UNH-IOL to validate the R&S®RTO oscilloscope and R&S®ScopeSuite software for compliance testing in line with the 10BaseT, 100BaseTX and 1000BaseT Ethernet standards. The UNH-IOL confirmed that “the R&S®RTO oscilloscope and R&S®ScopeSuite correlate with the UNH-IOL’s time tested techniques and methodologies.”



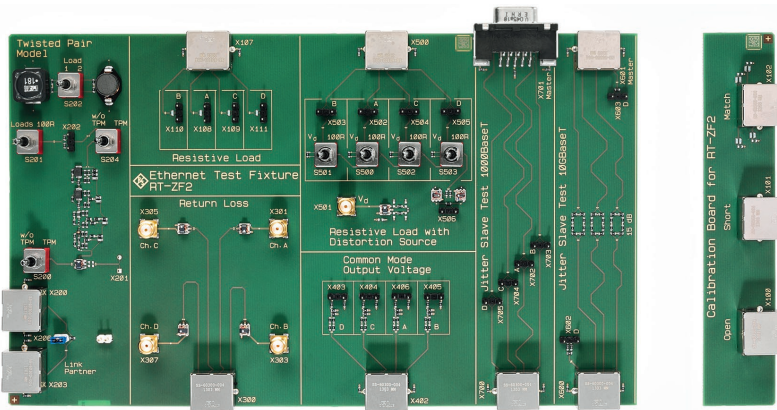


Fig. 4: R&S®RT-ZF2 Ethernet test fixture set for 10BaseT, 100BaseTX, 1000BaseT and 10GBaseT Ethernet compliance tests.

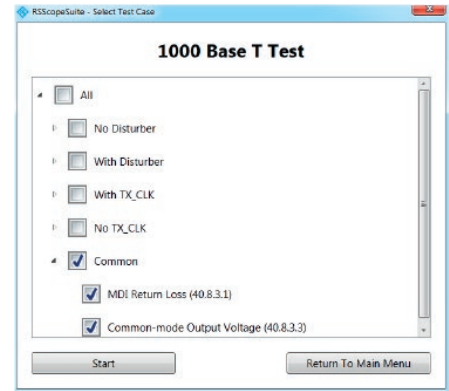


Fig. 6: Test selection for 1000BaseT Ethernet compliance testing.

Complete test equipment for Ethernet compliance tests

Developers need to perform Ethernet compliance tests on components or devices as part of basic R&D or when debugging their designs during integration. For analysis and verification applications, Rohde&Schwarz offers a complete solution based on the R&S®RTO oscilloscopes (Fig. 1) as well as appropriate software options and test accessories:

- R&S®RTO-K22: Ethernet compliance test software for 10BaseT, 100BaseTX and 1000BaseT
- R&S®RTO-K23: Ethernet compliance test software for 10GBaseT
- R&S®RT-ZF2: Ethernet test fixture set for 10 / 100 / 1000BaseT and 10GBaseT
- R&S®RT-ZF2C: 1000BaseT jitter test cable

Ethernet compliance tests are very demanding on the oscilloscope. During transmitter distortion tests, for example, the transmitter signal distortion must not exceed a value of 10 mV even with an unwanted signal of 5.4 V (V_{pp}) and 20.833 MHz. The outstanding dynamic range provided by the R&S®RTO oscilloscopes ensures exact results in this critical test.

The R&S®RT-ZF2 test fixture set (Fig. 4) is equipped with all interfaces from 10BaseT to 10GBaseT, making it simple to connect the oscilloscope probes to the DUT signal lines. Fig. 5 shows the test equipment required for compliance tests in line with the applicable Ethernet standards.

Fast results with the R&S®ScopeSuite test software

When putting new hardware designs into operation, developers tend to be under significant time pressure, making it important to perform the relevant tests as quickly as possible. Easy-to-operate test software such as R&S®ScopeSuite with its high level of automation can make a huge difference. The integrated test wizard guides the user through the test setup, automatically configuring the oscilloscope as well as the connected signal generator and spectrum or network analyzer. Depending on the user's preference, R&S®ScopeSuite can be installed on a separate PC or on the oscilloscope itself. For operation on the

Test equipment	10 / 100 / 1000BaseT	10GBaseT
Oscilloscope	10 / 100BaseT: at least R&S®RTO1002, 1000BaseT: at least R&S®RTO1012	at least R&S®RTO1022
R&S®ScopeSuite software	R&S®RTO-K22 Ethernet compliance test	R&S®RTO-K23 10G Ethernet compliance test
Test fixture	R&S®RT-ZF2 Ethernet test fixture set	R&S®RT-ZF2 Ethernet test fixture set
Probes	10 / 100BaseT: 1 differential probe, at least R&S®RT-ZD10 1000BaseT: 2 differential probes, at least R&S®RT-ZD10	1 differential probe, at least R&S®RT-ZD30
Recommended extras	1000BaseT: – R&S®RT-ZF2C jitter test cable – HAMEG HMF2550 or Tabor WX2182B function generator for 1000BaseT signal distortion tests – R&S®ZVL vector network analyzer for return loss measurements	– spectrum analyzer for transmitter linearity measurements with start frequency < 1 MHz (e.g. R&S®FSL3) – vector network analyzer for return loss measurements with start frequency < 1 MHz (e.g. R&S®ZVL3)

Fig. 5: Test equipment required for Ethernet compliance tests.

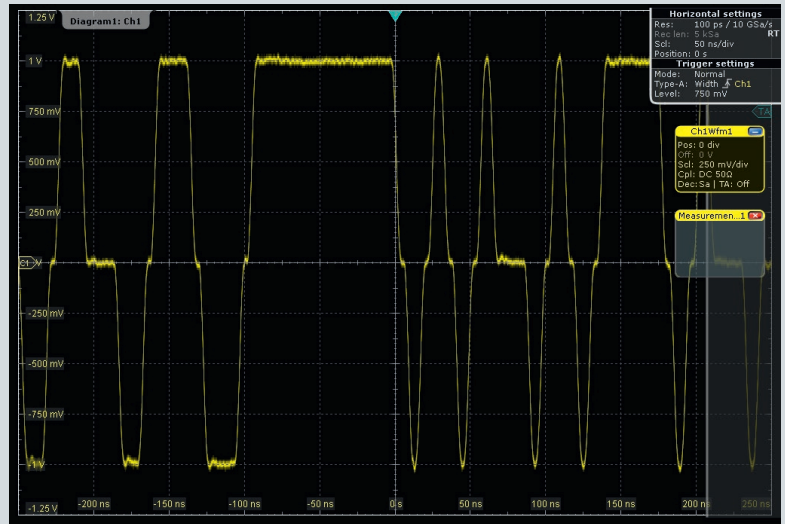
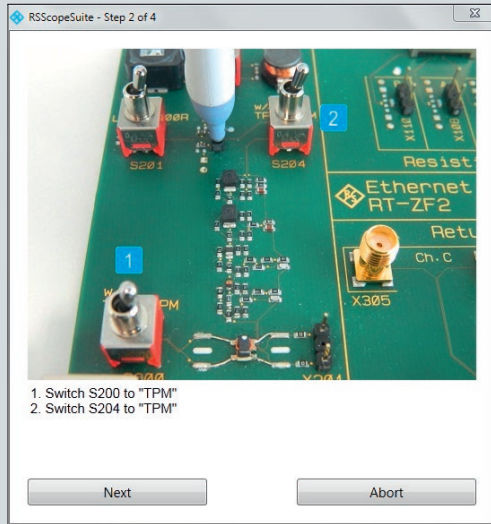


Fig. 7: Instructions for an Ethernet compliance test case. The configuration on the test fixture is explained on the left while the signal acquired by the oscilloscope from the Ethernet chip in the configured test mode is visible on the right.

R&S®RTO oscilloscope, it is convenient to use an additional monitor where R&S®ScopeSuite can be controlled with a mouse while the oscilloscope screen simultaneously displays waveforms and results.

R&S®ScopeSuite includes all of the established test cases for the different Ethernet standards. Individual tests or complete test groups can be selected (Fig. 6). After the software has been launched, it automatically configures the R&S®RTO. Then, the test wizard conveniently guides the user through the configuration steps using graphics (Fig. 7).

Once all the steps are complete, the measurements are executed automatically. R&S®ScopeSuite shows the test results with a traffic light display to provide a fast overview (Fig. 8). Here too, the flexibility of the R&S®ScopeSuite software is apparent: For example, a test can be repeated at the push of a button if signal errors occur. Upon completion of the measurements, the user can compile the relevant results into a test report to obtain clear, complete documentation with figures and tables (Fig. 9).

Fig. 8: Test result with traffic light display and option to repeat test.

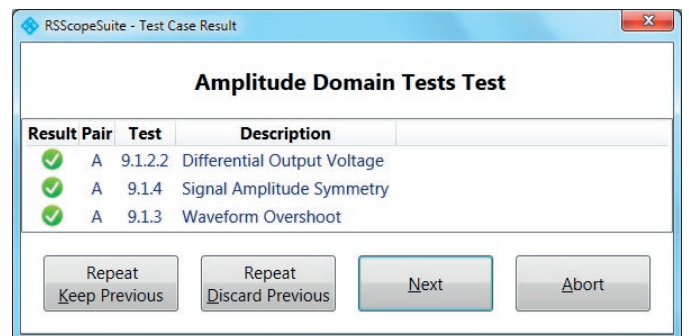
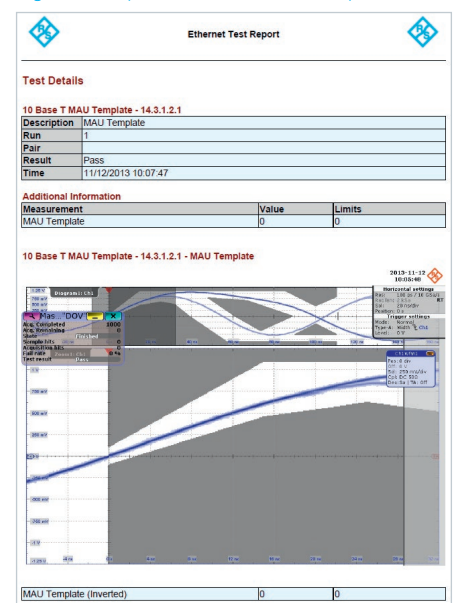


Fig. 9: Excerpt from a detailed test report.



Summary

Based on the R&S®RTO oscilloscope, the R&S®RT-ZF2 test fixture set and the options R&S®RTO-K22 for 10 / 100 / 1000BaseT and R&S®RTO-K23 for 10GBaseT, Rohde&Schwarz is now offering a complete solution for compliance testing of the most popular Ethernet protocols. The outstanding dynamic range and the low-noise frontends of the R&S®RTO ensure accurate results even in the critical transmitter distortion tests. The complete solution works quickly to deliver precise results that can be fully documented to meet the user's requirements.

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