Rosenberger

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Connectors and Cables for Ethernet:

# Certified Performance

**When developing a new contact system, strict requirements for the electrical and mechanical properties as well as the assembly and implementation into an Ethernet transmission system for 100BASE-T1 (OABR) and 1000BASE-T1 must be considered. Comprehensive tests demonstrate just how well these targets were achieved.**

By Thomas Müller, Dr. Gunnar Armbrecht and Martin Zebhauser

Although the large-scale introduction of Ethernet systems experienced a slight delay compared to initial forecasts, OEMs and analysts agree on one thing: an increasing number of Ethernet systems will be installed in the coming vehicle generations. Additional innovations in vehicle assistance systems as well as infotainment can only be implemented by networking control units and sensors. Assembly, connector and cable manufacturers are fully committed to the market for automotive Ethernet solutions, thus giving it similar promise.

### Current status of standardization

The initial work carried out in the context of the OPEN Alliance to meet the automotive requirements for Ethernet systems has now evolved into two official IEEE standards 100BASE-T1 (100 MBit/s based on BroadR-Reach® technology) and 1000BASE-T1 (1 GBit/s).

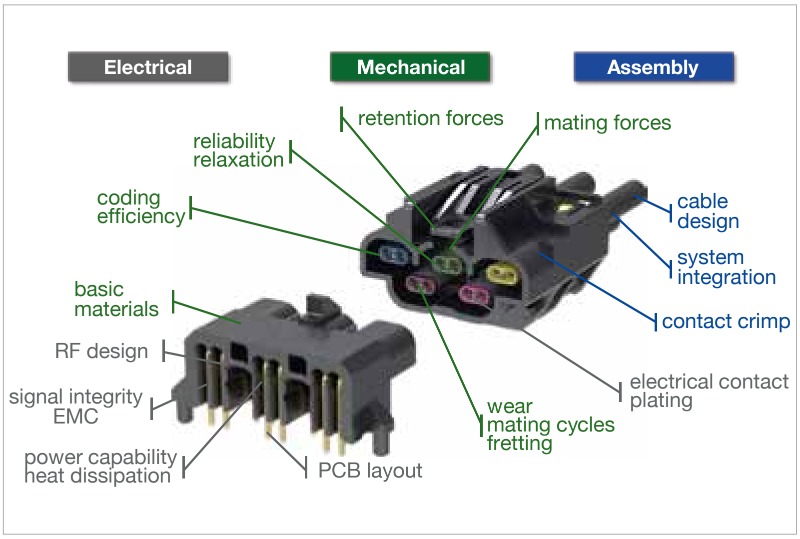


*Figure 1. Requirements from several areas were taken into consideration for the MTD system* (Picture: Rosenberger)

After requirements were already defined for the entire channel as well as individual components for 100Mbit/s Ethernet, the same step for 1000BASE-T1 is now being pursued as part of OPEN Alliance TC9. The basic objective is to define the electrical requirements on connectors and cables as well as the corresponding measurement procedures derived from the requirements for the entire channel, which was defined in the IEEE. Rosenberger is actively involved in the standardization processes in both committees, where it contributes its expertise in the fields of automotive connector design, signal integrity and EMC. First laboratory measurements are taken and then an evaluation phase follows, which is intended to test the components at vehicle level as installed in real vehicles in conjunction with the available 1000BASE-T1-PHYs and in order to ensure the coexistence of different systems.

### Growing demand in bandwidth

In addition to the advantages offered by in-car networking based on the Ethernet protocol, the further aims are to use unshielded twisted pair cables (UTP) for both data rates in order to achieve advantages in installed space, weight and perhaps even costs over established shielded systems, such as HSD and FAKRA. Since both protocols 100BASE-T1 and 1000BASE-T1 are based on multi-level PAM-3 transmission, the increase in data rate goes along with a tenfold increase of bandwith to approx. 600 MHz.

As a result, the frequency ranges that are used for Ethernet data transmission increasingly overlap with the receive and transmit frequency ranges of other radio services in the vehicle. An example of this is the frequency range for FM radio reception, which is also used by Gigabit Ethernet. Here, the EMC behavior is the key element that determines whether unshielded systems can be used in the vehicle. This is primarily determined by the electrical properties of the transmission channel and the used components, such as connectors and cables.

### From single contacts to a system solution

The industry already largely agrees that systems based on single contacts in conjunction with twisted wires do not meet the quality requirements for a transfer system up to 600 MHz. This is why Rosenberger developed the MTD (modular twisted-pair data) contact system for unshielded Ethernet transmission, which is both suitable for use with 100 Mbit/s as well as 1 Gbit/s and covers the whole transmission channel, including connectors, cables, and the transition to the printed circuit board.

The electrical and mechanical properties as well as assembly requirements were defined and implemented in the MTD in close collaboration with OEMs, leading cable manufacturers and assemblers. The aspects to be considered here include the electrical and mechanical properties and assembly (figure 1).

### Mechanical properties

MTD is a connector system for unshielded twisted pair cables (UTP) that meets the electrical channel requirements both for 100Mbit/s as well as Gigabit Ethernet. It saves space, is lightweight and durable and also meets the applicable mechanical and environmental requirements for automotive connector systems (e.g. USCAR or LV214). Furthermore, it offers a scalable number of ports that can be mechanically coded as well as color coded. The MTD connector system is optimized for 0.14 mm² jacketed cables and does not require any special copper alloys,

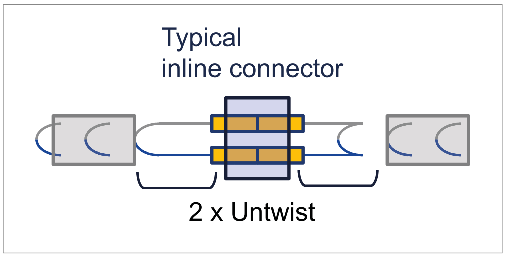


*Figure 2. Schematic diagram of an inline connector* (Picture: Rosenberger)

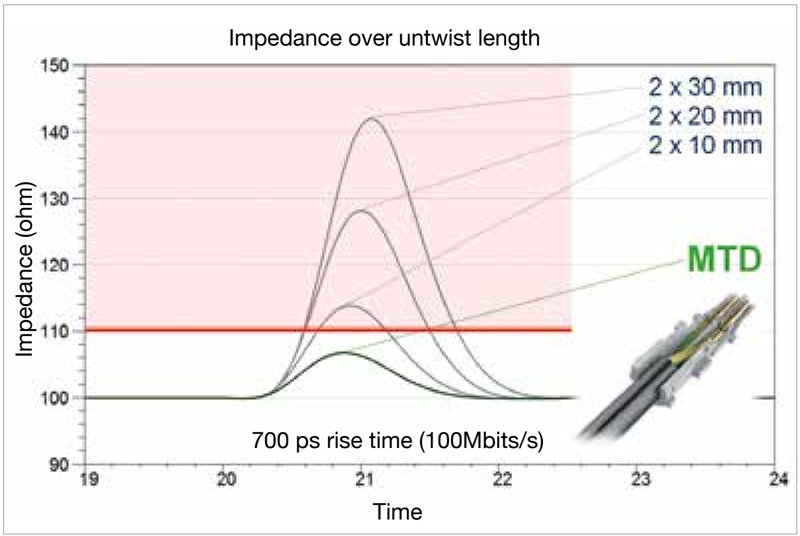


*Figure 3. Optimized cable transition with the MTD system* *(Picture: Rosenberger)i*

which provides integrated strain relief from the cable jacket to the connector housing.

## Electrical properties

The electrical design was optimized with respect to return loss, balance, insertion loss and crosstalk to acieve the best electrical properties within a limited assembly space.

During bi-directional transmission over a single differential pair, each Ethernet chip simultaneously operates as a transmitter and receiver. Areas along the transmission channel that are not impedance matched represent electrical discontinuities that cause unwanted reflections. A well-known example of this is the transition area from a connector's contact to the cable: the jacket must be removed and the  wires of the differential pair must be untwisted.

Figure 2 shows the systematic representation of a typical inline connector in which two of these untwisted areas are occur consecutively in a small space.

Figure 3 shows the impedance of this arrangement depending on the untwisted length with a rise time of 700 ps, which corresponds to a bandwidth of approximately 500 MHz. With just an untwist length of 2 x 10 mm, the required maximum impedance of 110 Ohm for 100 Mbit/s Ethernet is exceeded. To achieve the best performance for MTD, the length of the cable transition was minimized and integrated into the connector housing in a reproducible manner, as displayed in figure 3.

## Demanding Measurements

Performing measurements on automotive Ethernet components requires high-quality measurement technology as well as knowledge in handling vector network analyzers (VNA). Precise calibration, phase-stable cables as well designed measurement fixtures providing an adaptation to a coaxial interface (e.g. SMA) are necessary to achieve conclusive and reproducible results. Rosenberger engineers use a complex measurement setup that consists of 15 m cable with four inline connectors as well as PCB connectors that are used both for 100BASE-T1 as well as for 1000BASE-T1 to measure the overall channel. Here, the device under test is placed at 10 mm distance over conductive groundplane

The return loss of the overall channel fulfills the requirements for 100BASE-T1 and 1000BASE-T1 at the maximum transmission frequency of 600 MHz as given in the 1000BASE-T1 channel specification.

Balance is the key element for good EMC behavior of unshielded transmission systems. It is determined by the mode conversion behavior, i.e. the conversion of a differential signal that is necessary for the data transmission into a common-mode signal. Unwanted common-mode signals lead to increased emissions as well as lower immunity against disturbing external signals.

Figure 4 shows that the mode conversion of the overall channel based on the MTD system is better than the required channel limit. LCL refers to the mode conversion in reverse direction on the same end of the channel where the signal is fed in and LCTL refers to the mode conversion in a forward direction to the other end of the channel. These very low

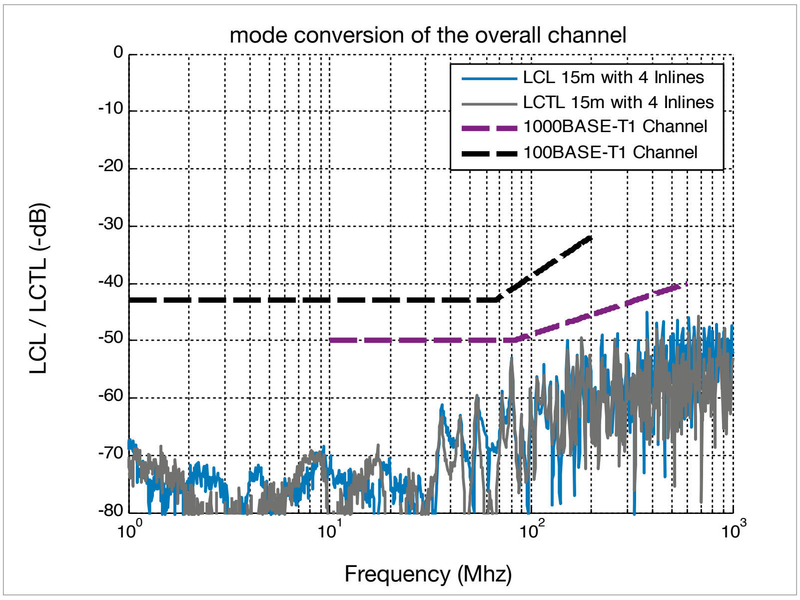


*Figure 4. Very low mode conversion ensures the best EMC behavior* *(Picture: Rosenberger)i*

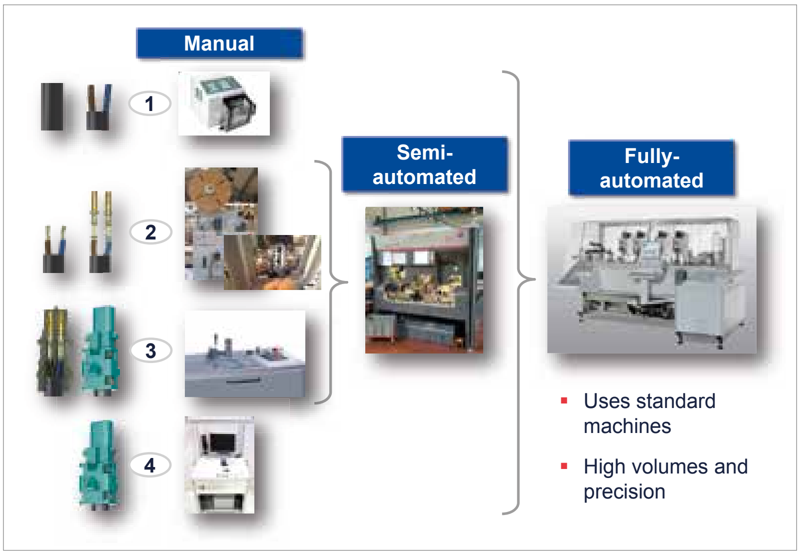


*Figure 5. The MTD system enables various levels of automation* *(Picture: Rosenberger)*

mode conversion values can only be achieved with MTD connectors in combination with optimized jacketed cable.
The insertion loss of the entire channel is essentially determined by the characteristics of the cable. Compared to conventional FlexRay 2 x 0.35 mm² UTP cables, the outer diameter was significantly reduced going along with a decrease in cable cross-section to only 2 x 0.14 mm². The amount of copper savings compensates the costs for using high-quality jacket material. Due to increase of attenuation with rising temperatures, PVC is generally not suitable. Measuring the insertion loss of the entire channel at room temperature revealed a sufficient margin for higher temperatures up to 105°C and aging effects.

## Assembly: Various levels of automation

In addition to the connector system's electrical and mechanical properties, assembly is also a crucial factor. MTD allows various levels of automation to meet the requirements of OEMs and assembly manufacturers.

Figure 5 shows how assemblies can be reliably manufactured in only a few steps using simple tools, such as stripping and crimping machines. In the first step, the cable is cut to the desired length and the cable jacket is removed. In the second step, the wires are stripped and the contacts are crimped. A double crimp process minimizes differences in length and ensures short processing times. In the third step, the contacts are placed into the lower half of the connector housing and the housing cover is closed. Round contacts eliminate the need for any additional alignment. In the final step, the fully assembled connector is visually and electrically inspected using spring-loaded contact pins, thus ensuring the best quality even in manual assembly. Marking good parts and sorting out bad parts ensures that only flawless components are released from the assembly process for further use.

Steps two and three can be consolidated into a semi-automated process. The transition to a fully automated process, which can be implemented on standard machines, is an effective solution for meeting continuously growing volume requirements. All three manufacturing processes ensure high-quality assembled cables with low investment and assembly costs.

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