Reducing Maintenance Costs With Cable Diagnosis and Micrel's LinkMD™

Micrel's LinkMD™ Cable Diagnostic Technology Significantly Reduces Cost of Ownership for Industrial Ethernet networks

By Mike Jones

It has been fully 30 years since the birth of Ethernet. Recently, today's de-facto networking standard found its way onto the factory floor. This is an interesting turn of events, considering Ethernet was never originally intended to be deployed in such extreme environments. However, its low cost, simplicity and field-proven open standardisation has proven too good to resist. As the industry looks to the next generation of total managed networks and seeks to replace the current physical layer field bus domination. An emerging trend of 'intelligent' (Ethernet) industrial devices, sensors and actuators and has begun and is rapidly gaining momentum, especially in Europe and in the more advanced industrial arena in Germany. Just imagine the ability of a local production engineer to be able to quickly and accurately remotely diagnose a faulty sensor or cable on the factory floor and then enable protection switchover, avoiding any factory down time. It is easy to realise the benefits when one considers that €100s billion are spent each year on maintenance in Germany alone.

Many new industrial Ethernet standards are available to provide device layer solutions. For example, ProfiNet, Powerlink and EtherCAT, but will they ultimately be robust enough? Traditionally, the weakest link for all Ethernet networks, industrial or not, has been the physical interface, i.e., the connectors and cabling.

Issues with installation and maintenance will continue to have a major impact on overall network costs. Micrel's LinkMD™ Cable Diagnostic technology solution goes well beyond Ethernet-defined standards to provide a comprehensive solution to such problems, significantly reducing the cost-of-ownership of an industrial Ethernet network.

Common Cabling Issues

The standard physical interface for a Fast Ethernet network consists of a CAT 5 Unshielded Twisted Pair (UTP) cable and RJ45 connector. Harsh environmental conditions, including excess vibration, dirt and moisture, have led to M12 and 'rugged' RJ45 type connectors to be occasionally utilised. However, no alternative industrial solution has yet to be agreed upon although the standard RJ45 connector remains most popular.

Open or short circuit is still by far the most common cabling problem that can occur in a network, caused by a multitude of different events. An open circuit may simply be the result of someone inadvertently removing or forgetting to connect a cable. It might also be the result of a damaged cable or connector, highly possible in factory floor or remote outdoor applications.

The ability to diagnose such cabling faults is essential in a typical industrial redundant ring topology. A simple example of a redundant ring network is shown in Figure 1. This graphic illustrates where the Master node will detect any link-down condition and manage the local redundant link.

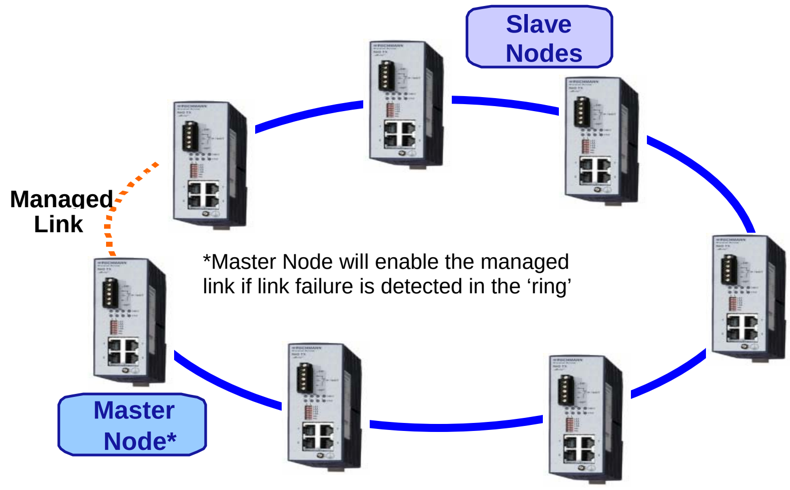


Figure 1. Simple Redundant Ring Network

LinkMD™ Cable Diagnostics Technology

Micrel's LinkMD™ cable diagnostics utilises time domain reflectometry (TDR) to analyze the cabling plant for these common cable problems, such as open circuits, short circuits and impedance mismatches.

When a pulse of known amplitude and duration is injected down a cable pair, a reflected pulse will be returned. The reflection is caused by the impedance mismatch at the fault or load termination. The amplitude of the reflection can be analyzed to calculate the impedance mismatch and hence identify if a fault exists down the cable. Figures 2 and 3 show examples of the reflected waveform, for various fault conditions.

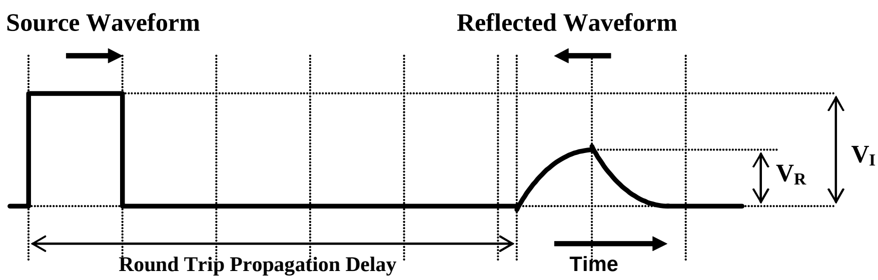


Figure 2. Source and Reflected Waveforms of an incorrectly terminated cable.

The Reflection Coefficient, ρ_L, defined as the ratio of the amplitude of the reflected wave and the amplitude of the incident wave is calculated thusly:

$$\rho_L = \frac{V_R \text{ (reflected wave)}}{V_I \text{ (incident wave)}} = \frac{Z_L - Z_o}{Z_L + Z_o}$$

Where Z_L is the load impedance and Z_o is the cable impedance, which is 100 ohms for a CAT5 cable.

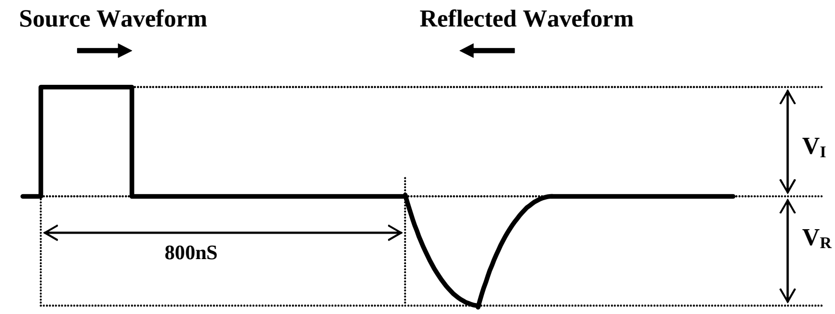
By applying this formula, a fault can easily be identified:

a) If $Z_L = 0$, then $\rho_L = -1$ (short)
b) If $Z_L < 100$, then $-1 < \rho_L < 0$ (incorrect termination)
c) If $Z_L = 100$, then $\rho_L = 0$ (correct termination)
d) If $Z_L > 100$, then $0 < \rho_L < +1$ (incorrect termination)
e) If $Z_L >> 100$, then $\rho_L = +1$ (open)

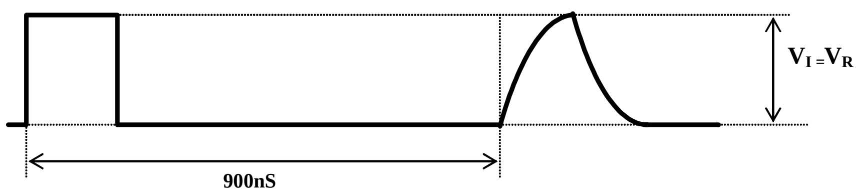
Hence, for a perfect terminated cable, then $\rho_L = 0$ and hence, no reflection occurs. In reality however, there will always be some slight imperfections that occur so an attenuated reflection will always be seen.

The significance of the negative unity reflection coefficient, for a short-circuit condition, is that the reflection will be reverse polarity and equal amplitude relative to the incident pulse, as shown in Figure 3a.

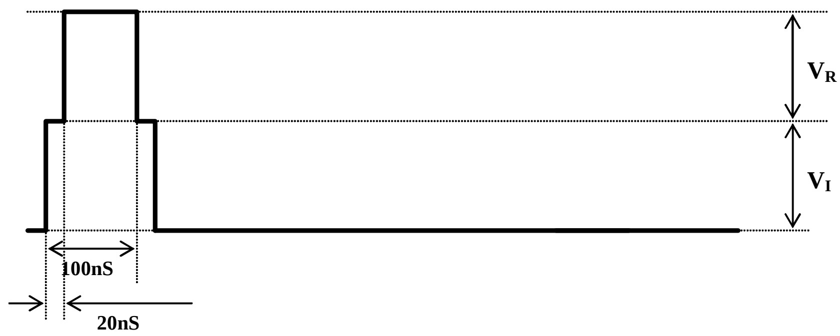
Likewise, for an open-circuit condition, the reflected waveform is of equal amplitude and polarity to the incident waveform (Figure 3b), resulting in a $\rho_L = +1$.



a) 80m cable, short-circuit



b) 90m cable, open-circuit



c) 2m cable, open-circuit

Figure 3. Examples of Source and Reflected Waveforms for open and short-circuit cables of various lengths.

Calculating Fault Distance

Velocity of Propagation (VOP) is a specification that provides the speed of a signal, down a given cable, relative to the speed of light in a vacuum (3.0×10^8 m/s). The VOP specification will not only vary dependent upon the type of cable, but also the manufacturer. The VOP of a CAT5 cable is usually around 0.66. This means that a signal will travel down a CAT5 cable at a speed of $0.66 \times 3.0 \times 10^8$ m/s = 2×10^8 m/s.

Using this specification, we can easily calculate the length of cable, or distance to fault, by measuring the propagation delay of the reflected waveform. From the previous calculation, we can see that a useful rule of thumb for cable length is 5nS propagation delay per metre of cable (remembering to halve the round trip propagation delay when calculating distance).

For example, Figure 3b shows the propagation delay of a reflected waveform for a 90m CAT5 cable (open-circuit). Hence, to calculate the distance to fault:

$$\text{Distance} = \frac{\text{(Propagation Delay in nS)}}{2 \times 5\text{nS/m}}$$

with a propagation delay ≈ 900nS, then distance to fault ≈ 90m.

Micrel's LinkMD cable diagnostics will provide fault diagnostics up to a maximum of 200m. Calibration of the VOP for a specific cabling plant can result in accuracy of: +/- 1m.

For short cables, as shown in Figure 3c, the reflected wave will be superimposed onto the original incident waveform. This is a result of the propagation round trip delay being less than the incident pulse period:

$$\text{Incident Waveform Period (100nS)} \geq \text{Cable length} \times 5\text{nS/m} \times 2$$

Hence, this condition will arise for cable lengths or fault distances less than 10m.
Micrel's development kits provide LinkMD™ software enabling faster time to market. The LinkMD™ GUI, shown in Figure 4, provides full access to the Ethernet device's internal register map and cable diagnostic support.

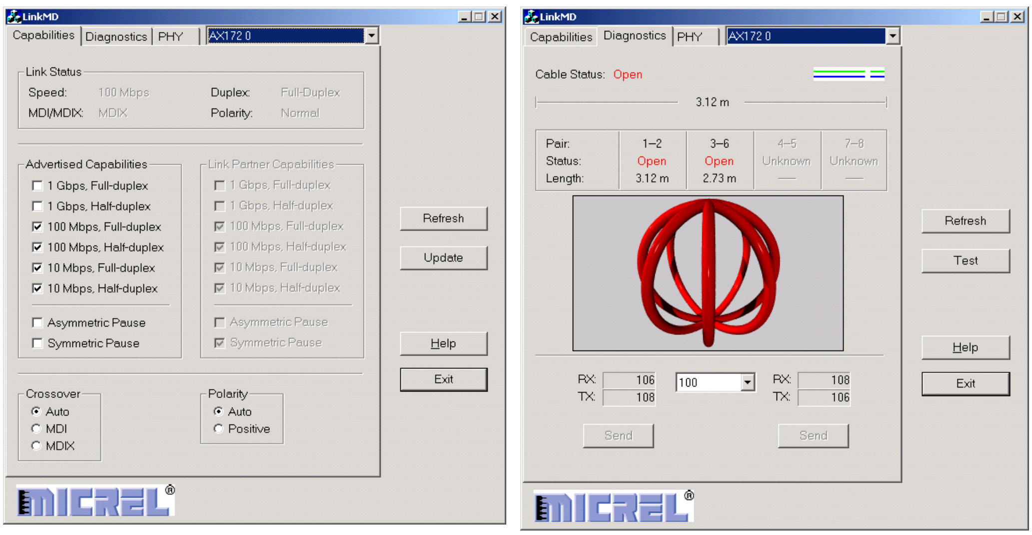


Figure 4. Micrel's LinkMD™ Software GUI.

As Ethernet continues to grow in the industrial market, the need for 'smarter' devices are essential for low cost installation and maintenance. Traditionally, a network's weakest link has always been the physical interface. With the advent of LinkMD™ cable diagnostics, Micrel's new generation of Ethernet devices can significantly reduce the cost of ownership for industrial applications, particularly in the German industrial arena where advanced diagnostic techniques are being deployed.

LinkMD™ technology has been successfully integrated in all of Micrel's latest generation of Ethernet devices, including the KS8001 Single-Port PHY, KS884x family of Single and 2-Port Controllers and KS8893ML 3-Port switch.

The KS8001 PHY offers ultra low power consumption, HP Auto MDI/MDI-X Crossover and LinkMD™ cable diagnostics in a tiny 48-Pin LQFP package. Support for Serial MII (SMII) is another industry first, as well as the common Reduced MII (RMII) and standard MII.

The KS884x family offers designers the largest selection of 8-bit, 16-bit and 32-bit Generic Bus Ethernet Controllers, specifically targeted for embedded and industrial applications. LinkMD™ diagnostics are complimented by Hewlett Packard's (HP) Auto MDI/MDI-X Crossover, loop-back modes and 34 MIB counters per port for full compliant performance monitoring statistics. The KS8842ML is the industry's only 2-Port Ethernet controller and offers pin compatibility with the Single Port KS8841ML, for dual PCB layout and simple upgrading, as shown in Figure 5.

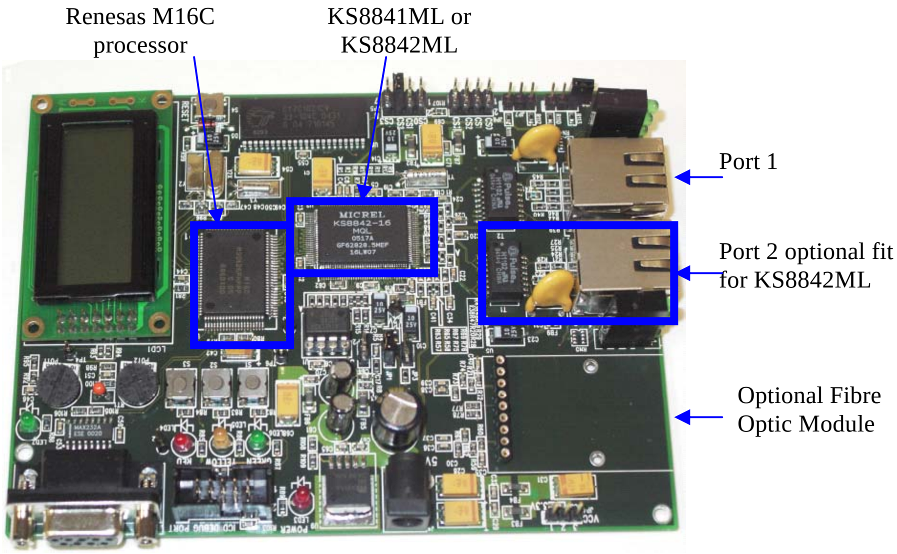


Figure 5. KS8841/2ML Dual Layout Evaluation Board.

The KS8842ML and KS8893ML share a unique 'three-in-one' flexi-engine which provides 'store and forward' switch, two-port isolation and repeater modes of configuration. In repeater mode, the maximum latency is 310nS, ideal for real time critical industrial applications, such as Powerlink.

All of the above devices will be made available in both industrial temperature range and RoHS compliant lead-free packages. Evaluation boards, hardware design package and software driver support are also available. For further information please contact your local Micrel Sales Representative or FAE (www.micrel.com)

Note: LinkMD is a trademark of Micrel, Inc.