Cable into the Future:
Industrial Ethernet with 10 Gbps

A White Paper presented by:
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Today's machines and plants generally communicate using Ethernet with 100 megabits per second (Mbps). However, many applications, such as cameras for quality inspection, servers to document quality data and scanners that identify components, demand higher data rates. Frequently, communications also must be established with the factory control system. While data transmission rates of 1 gigabit per second (Gbps) are standard, 10 Gbps will be necessary in the near future (Fig. 1).

Classic fieldbuses and generic cabling can no longer meet the requirements of these networks. Automation-related applications are subject to the same demanding environmental conditions as fieldbus communication. To reliably transmit data in this environment, the components must be able to cope with the mechanical effects as well as the high electromagnetic load.

Figure 1. Today, Cat6$_A$ components allow 10 Gb Ethernet to be reliably used in an industrial environment.

CAT6A is not the same as Cat6$_A$

Different standards exist to implement a channel for 10 Gb Ethernet. The American TIA (Telecommunications Industry Association) 568B standard describes a CAT6A channel that is achieved with category CAT6A components. Cable configurations according to CAT6 should still be used if at all possible.

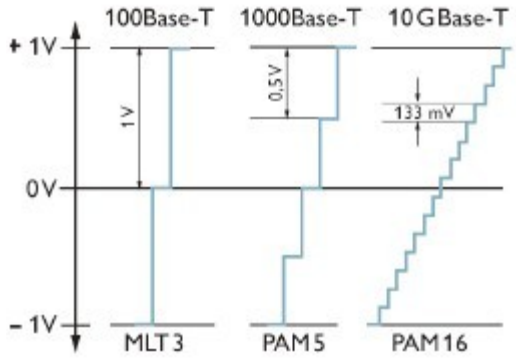

Figure 2. Lower signal clearances for Gigabit Ethernet with PAM (Pulse Amplitude Modulation) increase the danger of disturbances when compared to Fast Ethernet with MLT (Multi Link Trunk).

Because CAT6 is defined only up to 250 MHz, only a reduced transmission-related quality is defined for the frequency range from 250 to 500 MHz (Fig. 3). The incorrect interpretation of a signal occurs far more frequently. This means that it is necessary to repeat the Ethernet packet. Office applications can tolerate this, since the only effect is slower data transmission. However, this is not acceptable in the industrial area, with its real-time

requirements. Each signal must be reliably transmitted to avoid having to repeat packets. As a consequence, designing a channel according to standard TIA 568B is insufficient for the industrial environment.

Standard ISO/IEC TR24750 shows how an existing network can be qualified for 10 Gb Ethernet. This standard can be used for existing cable sections where measurements can prove that it is suitable for 10 Gb Ethernet transmission. This can often be achieved with good CAT6 components, careful cable routing and short channel lengths.

However, it is not possible to configure new channel types. Several components on the market, with attributes such as "suitable for 10 Gb Ethernet," refer to the standard, but they are not CAT6A or Cat6$_A$ components.

An additional standard to consider is ISO/IEC 11801. Amendment 1 defines the requirements placed on a channel. Class E$_A$ is specified for 1 to 500 MHz without reducing the quality (Fig. 3). This avoids the risk of a high-frequency signal transmission error and the resulting repetition of the Ethernet frame packet. Real-time systems as well as systems with a high data rate can also be reliably configured. Amendment 2 describes the requirements of Cat6$_A$ components used in the Class E$_A$ channel.

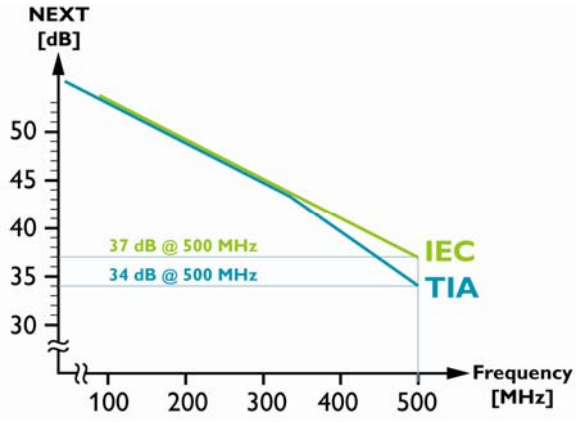

Figure 3. The TIA and IEC committees assume different NEXT values (near end crosstalk) across the frequency range.

The planned configuration of a new channel—without incurring the risk of a data transmission error—is possible only when Cat6$_A$ components are used. Only this channel—signified by the "A" as subscript—permits reliable data transmission in the industrial environment, with its wide range of disturbance sources.

Cabling Standards

The communication-related infrastructure of buildings—with their ISDN telephone communication and Ethernet applications—is based on generic cabling. ISO/IEC 11801 describes the structure and quality of the components.

ISO/IEC 24702 is a supplemental standard for industrial buildings. It considers the specific conditions, such as temperature and the environment, which can affect an industrial application.

Category, Channel and Class

Under the ISO/IEC 11801 and 24702 standards, the channel includes all of the cabling between two active devices. The various quality stages are designated with the Class and the associated component qualities with the Category. The table shows these interrelationships and, therefore, the maximum number of possible Ethernet versions.

Table 1. Class and Category

Class	D	D	E	E_A	F	F_A
Category	5	5	6	6_A	7	7A
Frequency (MHz)	100	100	250	500	600	1000
Ethernet	100Base-TX	1000Base-T	1000Base-T	10GBase-T	-	-
Data rate (Mbps)	100	1000	1000	10000	-	-
Pairs	2	4	4	4	-	-

Standard Cable Cross Section

The voltage differences between signals for 1 Gb and 10 Gb Ethernet are minimal, according to IEEE 802.3, and even slight disturbances can reduce the information content (Fig. 2). IEEE assumes disturbances that are applicable for the office environment. Disturbances in an industrial environment are generally more extreme and demand the appropriate protective measures.

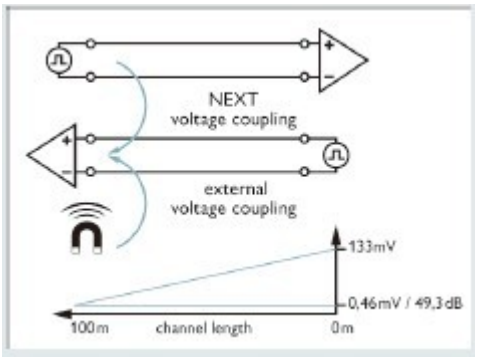

Figure 4. Low NEXT values increase the level of disturbance coupled in from adjacent pairs and are added to external disturbances.

This means that shielded components, which correspond to standard $Cat6_A$, are that much more important. The coupling attenuation (a measure of the shield quality) should reach 80 dB. This results in a rating of separating class d according to EN 50174-2, which allows communication cables to be routed with almost no clearance to power cables (Fig. 4).

For generic cabling with its reference implementation, a channel length of 100 m is achieved with a rigid system of horizontal and patch cables. In the industrial environment, for the various subsections, cables with varying quality and cross sections are used. The reference implementation model is not sufficient here. Using the appropriate formulas, a check must be made as to whether the transmission section maintains the values required for the channel. This method is complex and inflexible. If this method is not to be applied, then a horizontal cable with AWG 24 must be routed in the complete channel.

These considerations apply for up to 20 degrees Celsius. Higher temperatures—typical for industrial applications—can also be taken into consideration from a theoretical perspective. As a consequence, the user can calculate a channel with several subsections with different temperature profiles. This calculation is not required if a cross section of AWG 22 is used throughout the system being considered.

Plug Connectors Must Remain User-Friendly

The plug connectors are just as important as the cables. Cables with cross sections of AWG 24 or AWG 22 require special versions. Cables sold by the meter are generally used in industry. This requires simple connection of plug connectors without the use of special tools. Cables must be routed so that the data transmission quality is automatically maintained. Quick connection technologies (such as Phoenix Contact's Quickon and Piercecon) allow a high-quality connection in compliance with the requirements of $Cat6_A$. The assembly of plug connectors in the field generally used in industry is therefore now also possible for 10 Gb Ethernet. This means it is no longer necessary to rethink planning and installation—a decisive advantage.

Plug connectors can be roughly classified according to their use in the control cabinet or in the field. In the first case, the usual RJ45 mating face can be used up to $Cat6_A$. An especially good 360-degree shielding is necessary to minimize the EMC effects of neighboring devices such as frequency converters. High-quality surfaces will prevent gases from causing contact corrosion—thereby preventing a creeping aging process, which can result in the connection failing due to higher transition resistances. Over the long term, the usual patch cables from the office environment do not fulfill the reliability requirements that industrial applications call for.

For use in the field, RJ45 plug connectors with a special protective housing and M12 plug connectors have established themselves on the market. Also in this case, $Cat6_A$ is already possible with the new M12 plug connectors according to IEC 61076-2-109 (International Electrotechnical Commission). The same is true for RJ45 connectors.

Conclusion

Sophisticated and demanding tasks that require the extended use of automation technology can now use cabling solutions that are fit for the future. 10 Gb Ethernet can be transmitted via a class E_A channel in line with industrial requirements using $Cat6_A$ components. With well-designed, industrial-grade components, planning and installation can become routine.

About Phoenix Contact

Phoenix Contact develops and manufactures industrial electrical and electronic technology products that power, protect, connect and automate systems and equipment for a wide range of industries. Phoenix Contact GmbH & Co. KG, Blomberg, Germany, operates 47 international subsidiaries, including Phoenix Contact USA in Middletown, Pa. Phoenix Contact's formal Integrated Management System is registered to ISO quality, environmental and safety standards (ISO 9001:2008, 14001:2004 and OHSAS 18001:2007).

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