HARTING

Pushing Performance

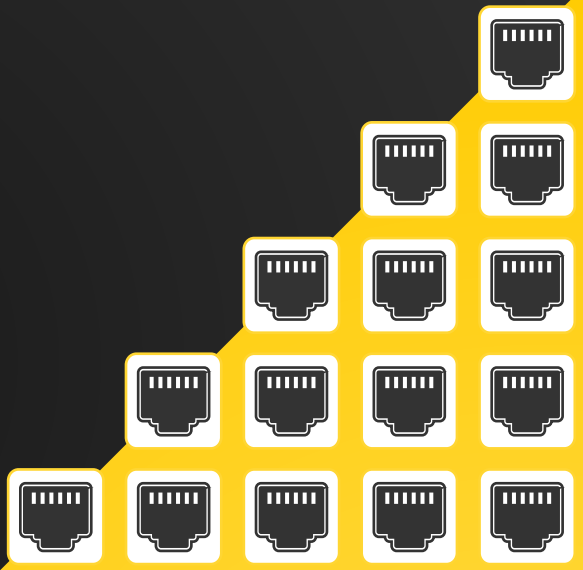
HARTING E-BOOK

SMALLER, FASTER, SMARTER

Ethernet Connectivity
for Industrial Transformation

FOREWORD

DIGITALIZATION IN INDUSTRIAL AUTOMATION IS ADVANCING WITH **GREAT STRIDES.**



Ethernet is taking on the job of the universal communication protocol in more and more areas. And because of this, the vision of a uniform protocol standard for communication from the cloud right down to every sensor is manifesting - and IIoT is becoming more and more of a reality. However, an industrial transformation with Ethernet cannot occur without the right infrastructure.

In this eBook, We show you how to choose the right Ethernet interface for each application and which newcomers you should definitely keep an eye on. We wish you a good read!

CONTENT

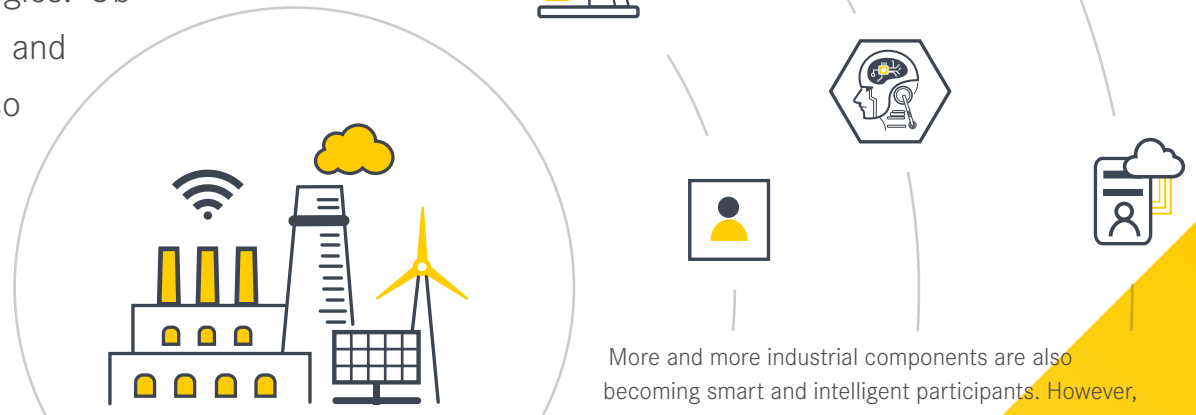
THE BEGINNING – FROM HAWAII TO THE WHOLE WORLD

In the early 1970s, ALOHAnet, the world's first radio data network, began in the Hawaiian Islands. In 1970, University of Honolulu professor Norman Abramson was looking for a cheap communication solution for the university's various locations on neighbouring islands.

This first protocol, which fired data packets over two frequency bands at random in order to avoid collisions, comprised the basis for what would later become Ethernet. At that time, few people could have imagined how this development, dubbed ALOHAnet, would one day form the basis of communication for international industrial production. Today, industrial production is no longer conceivable without the ubiquitous Ethernet. The requirements for data transmission in automation environments are steadily increasing and are quantitatively reflected in the number of installed Ethernet nodes. Today, Ethernet with its Industrial Ethernet variants has become the most widely used communication standard in industrial plants - and the trend continues to rise. This makes the reliable infrastructure of interfaces and cabling even more important.

ETHERNET IS TURNING INTO THE IIOT

IoT – the Internet of Things – describes the networking of virtual and real physical objects in order to make them interact using information and communication technologies. Objects in our daily lives acquire digital capabilities, and hence become real physical objects that can also participate in digital networks. This process also takes place in industrial applications, where it is called the Industrial Internet of Things (IIoT).



More and more industrial components are also becoming smart and intelligent participants. However, they are no longer limited to the upper levels of internal company networks as they once were. Ethernet protocols have been increasingly connected to cloud systems in recent years, while something is also starting to happen at the field level. Here, Single Pair Ethernet (SPE for short) is the new "physical layer" that covers the last mile to bring Ethernet right to the sensors.

The increased collection, evaluation and use of data creates the need for more powerful infrastructure. At the same time, this infrastructure is expected to take up less space and use less resources. Efficiency is the key word here, as more and more sensors with their increasing bandwidth requirements become network participants. New hardware technologies are required.

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AUTOMATION AND IT MERGE INTO AUTOMATION IT

Automation environments continue to join together with the previously separate IT world. The thrust is to process increased data rates from all areas of the company in a practical manner and use these in algorithms.

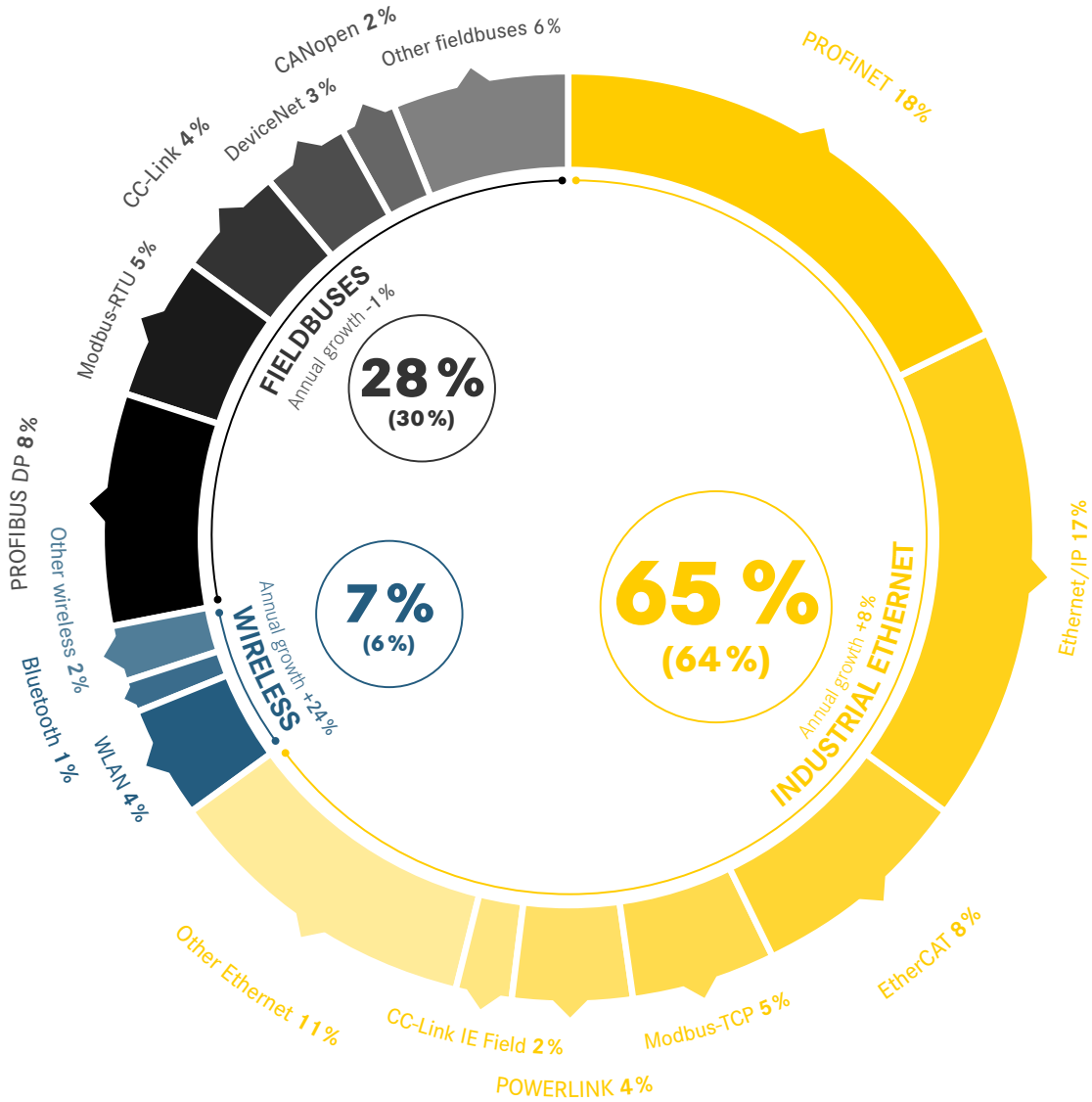
The aim of automation has always been to increase **flexibility and productivity**. Connecting all industrial machines with each other and with IT enables the data obtained from the machines to be visualized while also enabling predictions to be made. Where do I need to tweak my process? Where is optimization potential hidden? IT-supported data evaluation opens up completely new possibilities for optimization. The digitalization of the field level also brings about completely new business models or services that were previously unthinkable. Pay-per-part models or the software-based activation of additional functions in machinery are just two examples.

Above and beyond this, the operators of plants can keep an eye on their processes worldwide.
For all of these developments, Ethernet protocol is the unifying language that enables this convergence. It also becomes clear just how important it is to carry out this fusion consistently in every detail. Ethernet from the cloud to the sensor - this is how to implement real IIoT.

The shift away from analogue systems and fieldbuses towards Ethernet protocols comes up regularly in the annually published studies of the HMS Industrial Network. These studies show the market distribution of new communi-cation nodes in industrial networks. While Ethernet protocols had an overall share of 38% in 2016, just five years ago, this has now grown to 65% in 2021. Meanwhile, the total share of fieldbus systems has shrunk by 30 %.

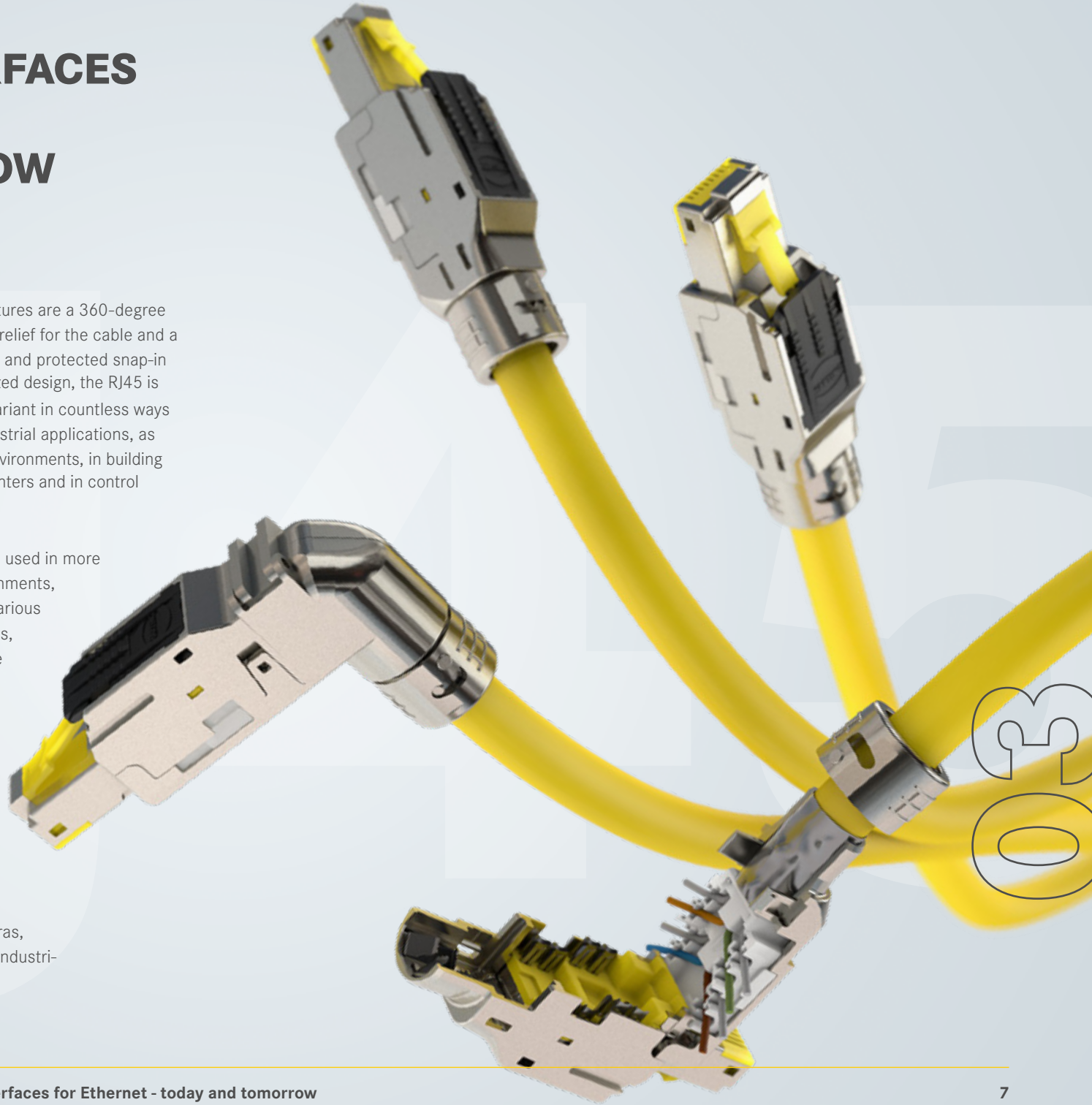
The trend towards a uniform protocol for all business areas continues unabated. But opens questions like how has this affected your choice of infrastructure and interfaces? Or which connector is suitable for which application? When is an industry-grade solution necessary? Which solutions are perfect today but could be obsolete tomorrow?

These are the questions we will address in the coming pages.



Source: HMS Industrial Networks

THE ESSENTIAL INTERFACES FOR ETHERNET – TODAY AND TOMORROW



RJ45

Probably the best known and most frequently used Ethernet connector worldwide is the Registered Jack 45 - RJ45. Many people know it from the office environment as the LAN connector. Originally developed for telecommunications, the RJ45 has become an absolute high runner for the transmission of TCP/IP and, less frequently, for PROFINET and other Industrial Ethernet protocols. This mating face is without a doubt an internationally well-known and widely used standard due to its unmistakable shape. Nevertheless, that the design was never intended for applications in an industrial environment. The fragile plastic locking tab breaks easily, and the contacts are not particularly well designed for stress under shock and vibration. The data rate and transmission reliability is limited because the contacts of the individual wire pairs of the cable are not shielded against each other in the mating face. With the RJ Industrial®, HARTING was one of the first suppliers to develop a variant for automation that is suitable for industrial use and can be assembled without special tools. Its main features are a 360-degree shielding, a strain relief for the cable and a much more robust and protected snap-in clip. In this optimized design, the RJ45 is used as an IP20 variant in countless ways in demanding industrial applications, as well as in office environments, in building cabling, in data centers and in control cabinets.

If the RJ45 is to be used in more demanding environments, it is packaged in various protective housings, appropriate for the application. The interface itself is always identical. Typical examples are the variant 4 connectors, which are used for mobile phone base stations, surveillance cameras, outdoor WLAN or industrial building cabling.

It is protected to IP 65/67 just like its larger counterpart, variant 14, has a zinc die-cast housing and is frequently used in the field of automotive production, particularly in robotics applications. Moreover, this RJ45 housing also complies with the AIDA specifications in order to ensure cable packets can be changed quickly.

For the area of machine and plant construction, the RJ-based connection is called Han® 3A, Han® 3A Hybrid (variant 5) with power supply, Han-Modular® as a component of an overall supply or Han® F+B for the food industry. Here, in this area, even higher requirements for IP degree of protection 69K for cleaning with high-pressure cleaners apply.

When should I use RJ45?
Both in IP20 as a solution or in IP65/67 protective housings? The RJ45 connector is one of the most common connectors in the world and is the symbol for Ethernet. Wherever the environmental conditions are moderate, such as in the office, data center and also in the control cabinet, and no high mechanical loads occur, this is where you find this interface. There is a whole range of RJ45 versions with robust protective housings for use in harsh industrial environments. The RJ45 has been hardened for these environmental conditions and is successfully used in many cases.

Mating face	**RJ45**	**RJ45 PushPull variant 4**	**RJ45 PushPull variant 14**	**RJ45 Han® 3A (variant 5)**	**RJ45 Han® 3A Hybrid (data + power) (variant 5)**	**M12, D- and X-coded**	**M8 D-coded**
Degree of protection acc. to IP class	IP20	IP 65/67	IP 65/67	IP 65/67	IP 65/67	IP 65/67	IP 65/67
Application field	Office, building, data centre, control cabinet	Robust infrastructure such as: mobile phone base stations, surveillance cameras, outdoor WLAN, industrial building cabling.	PROFINET interface for automobile manufacturing, especially robots (fast change of cable packages)	PROFINET interface for robust infrastructure such as: industrial building cabling, machine and plant construction	PROFINET interface for robust infrastructure where a single-cable solution is beneficial: toll bridges, WLAN production halls, decentralised drives, etc.	Robust infrastructure such as: industrial building cabling, mechanical and plant construction, railways, etc.	Robust infrastructure such as: industrial building cabling, machine and plant construction, distribution boxes, railway, etc. with small installation space

Mating face	**RJ45 Han® F+B**	**RJ45 Han-Modular®**	**Inserts M12, D- and X-coded for Han-Modular®**	**ix Industrial® IP20**	**ix Industrial® Mini PushPull**	**har-port RJ45**	**T1 Industrial Style (SPE)**
Degree of protection acc. to IP class	IP 65/67/x9K	IP 65/67	IP 65/67	IP20	IP 65/67	IP20 or IP 65/67 (depending on protective cap)	IP 20 or IP 65/67
Application area	Food and beverage industry	Robust infrastructure such as: industrial building cabling, mechanical and plant construction, railways, etc.	Robust infrastructure such as: industrial building cabling, mechanical and plant construction, railways, etc.	Small, robust device interface, control cabinet and vision sensor technology	Space-saving use in mobile radio base stations, surveillance cameras, outdoor WLAN, industrial building cabling	Service interface for control cabinets, machines and systems and similar.	Single-pair IIoT infrastructure, Ethernet connection technology for connecting the field level (sensor-to-cloud or sensor-to-IIoT platform)

M8 AND M12 CIRCULAR CONNECTORS

The second most well-known shape used for Ethernet under demanding conditions is the circular connector. Here, the sizes M8 and M12 in particular are very widespread. Traditionally they have been used wherever liquids, dusts, vibration, electromagnetic interference fields or other disturbing influences are present. D-coded M8 as well as D- and X-coded M12 connectors are used in industrial building cabling, machinery and plant construction, but also find a particularly large market in railway applications. Equipped with connection systems for on-site assembly in the field and PushPull quick locking mechanisms, M12 connectors are becoming increasingly popular as a robust and space-saving interface. Compared to RJ45 connectors, they have a very robust male/female contact system and the proven screw connection as well as the robust metal housing ensure reliable function in harsh industrial environments.

When should I use M8 or M12 connectors?

M8 and M12 interfaces combine three important advantages over the familiar RJ interface: a high IP degree of protection without an additional protective housing, very low space requirements and thereby a high packing density, and a vibration-proof male/female contact system. This makes them the preferred interface in all applications where you find vibration, contamination or small installation spaces. Generally speaking, these are production environments, and production environments near machines.

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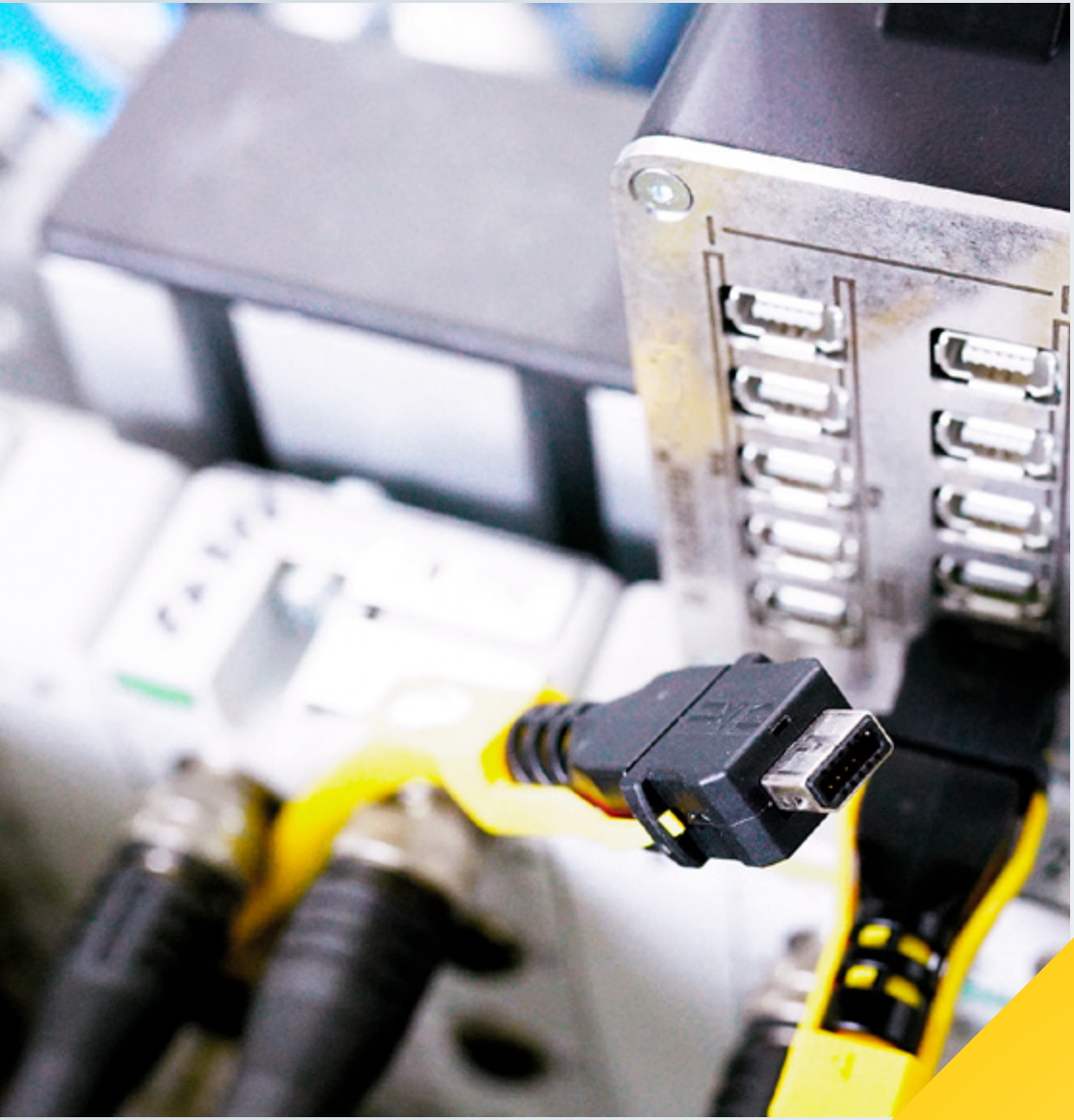

IX INDUSTRIAL®

The third typical Ethernet mating face on the market is the comparatively new ix Industrial® interface. It was just standardized in IEC 61076-3-124 in 2016 and offers a miniaturized and high-performance al-ternative with an industrial-grade contact system to the familiar RJ45 solution.

Because of miniaturization, the trend towards ever smaller devices and component sizes does not stop with interfaces. Today, the RJ45 mating face is still a common interface, but in some devices it is simply too big. When the socket is the largest component in a modern industrial camera and takes up the most space in the entire application, adjustments have to be made. ix Industrial® miniaturized Ethernet interface takes this development into account. The ix interface requires 70% less space in the device than RJ45 sockets, while at the same time offering even better transmission performance of up to 10 Gbit/s thanks to shielding, while offering superior robustness thanks to a metallic locking mechanism. It is an investment-safe alternative to the well-known RJ45. Soon, the ix Industrial®, like the RJ before it, will be available as a PushPull variant with IP 65/67 protection.

When should I use the HARTING ix Industrial® Ethernet interface

Due to the 70% smaller device socket compared to the well-known RJ45, the ix Industrial® offers the perfect interface for Gigabit Ethernet in combination with a normalized standard, excellent shielding and robustness with the easiest handling. They can be found in office environments as IP20 and in production and in outdoor use as the IP65/67 PushPull variant. This makes the ix Industrial® the interface of choice for all small and compact devices with Gigabit Ethernet and helps to save valuable installation space in the control cabinet.

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PRACTICAL EXAMPLE

FOURFOLD PERFORMANCE FOR THE BECKHOFF XTS SYSTEM WITH THE HARTING IX INDUSTRIAL®

The challenge

With the XTS linear transport system, Beckhoff cleverly combines the advantages of linear and rotary drives and creates completely new possibilities for material transport in automation applications. The three main components are the static linear motor, a parallel guide rail and the passive mover itself.

When the movers move along the track and follow their scheduled movement pattern, such as unlocking, clamping, releasing, braking, etc., a computer must continually calculate the switching and current supply to the responsible motor modules. For this to happen, a total of three computer cards can be combined in the XTS system, each of which previously had four RJ45 sockets as ports. One mover can be controlled per port, which results in a maximum possible quantity of twelve movers.

The challenge: Beckhoff's goal for the latest generations of the XTS system was to increase the number of movers, but without having to change the compact dimensions of the system.

The solution

The ix Industrial® interface from HARTING can replace the outdated RJ45 interfaces of the computer cards in the latest generations of the XTS system. It is now at least 70% smaller in the unit, significantly more robust and equipped with a stable metal locking mechanism. Power transmission via PoE/PoE+ is just as secure as the reliable hold to the PCB provided by multiple THR shield contacts. Standardized according to IEC 61076-3-124, the ix interface is an open standard and therefore meets the requirement profile of the XTS system for a standardized solution. In the case of the XTS system, reliable shielding and excellent data transmission rates were essential, which the ix Industrial® connector fulfills through a clever shielding concept.

Two 100 Mbit Ethernet connections are possible for each HARTING ix Industrial® connector. A solution like this is not possible with an RJ45 connector. In this way, a total of eight instead of four ports could be installed on the same PCB and two instead of one Ethernet channel could be run per port.

The result

48 instead of 12 ports on three computer cards and thus the possibility to use 48 XTS strands instead of 12 per unit, a performance increase of 400%. This illustrates the enormous potential of miniaturised and powerful Ethernet interfaces for IIoT and I4.0 applications.

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T1 INDUSTRIAL STLYE FOR SINGLE PAIR ETHERNET (SPE): THE LAST METERS

The next milestone in the development of Ethernet in automation goes by the acronym SPE - Single Pair Ethernet. This denotes the transmission of Ethernet via just a single pair of copper wires and offers the necessary infrastructure for Ethernet to enter into the field level. This means that the last mile to the field is finally connected economically via Ethernet. While cables with four or eight cores are too large and too expensive, slim SPE cables provide a high-performance alternative to familiar BUS cabling. This enables smart sensors to communicate directly via a uniform Ethernet network right to the cloud without a system break. Single Pair Ethernet (SPE) has made the much-stressed buzzword IIoT a reality. Sensor-actuator networks are connected directly to the cloud in real time. Transmission rates of 10 Mbit/s to 10 Gbit/s are possible and standardized, as are transmission lengths of up to 1,000 meters. In addition, devices can be supplied with up to 50 watts of final power via the Power over Data Line (PoDL) standard.

In order to set a uniform standard for interfaces here as well, HARTING has successfully standardized the T1 industrial connector in IEC 63171-6 and designed it for 10 Gbit/s in a future-proof manner. The design focus for this solution was on the high shielding requirements and the transmission of high frequencies of up to 600 MHz. The entire interface was newly developed and, with contacts arranged in parallel next to each other on the PCB, ensures absolutely identical running times in both signal paths. And thus a future-proof solution for SPE capable of meeting future requirements was achieved.

These new possibilities, from space-saving Gigabit Ethernet to the smallest sensor, will only gradually reveal their potential and show how such condensed data collection in individual machine components can powerfully revolutionize all of factory automation.

When should I use the HARTING T1 Industrial interface?
Single-pair wires are fast, space-saving, cost-efficient and convenient to implement. The equipping of simple sensors, cameras and more with Ethernet interfaces positions SPE as the driver of topics like Integrated Industry and IIoT. This makes the field level smart and reduces the effort required for parameterization, initialization and programming.

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EVERYTHING FOR ETHERNET

HARTING has more than just a wide range of different data interfaces adapted to industrial application areas. It is our goal to offer engineers a complete and coordinated solution from device integration right through to cabling infrastructure. These products range from the device interfaces on PCBs to the matching lower parts, connectors and system cables and encompass the panel feed-through in the control cabinet, couplers, junction boxes and patch panels. Customized and ready-to-use cable assemblies tailored to the application also complete the product range. But even if you want to assemble your cable yourself, we supply the right connection technology - with the matching raw cables and tools. True to our motto "Everything for Ethernet", Ethernet switches for industrial use are also available.

Four pairs, two pairs or one pair - what will it be?

There are different approaches to infrastructure for the transmission of Ethernet in industrial environments.
They depend on the required transmission rate. Fast Ethernet (10/100 Mbit/s) for use in many Industrial Ethernet protocols requires two wire pairs. These cables often have a star quad structure and the transmission category Cat. 5. The connection technology normally used for these applications is RJ45 with only four contacts or M8/M12 with D-coding. Gigabit Ethernet requires four wire pairs. The minimum requirement here is Cat. 5, but today Cat. 6A cables are predominantly used in order to be future-proof for data rates of up to 10 GBit/s. Suitable interfaces include RJ45 with eight contacts, M12 with X-coding or ix-Industrial connectors.

SPE as a new, space-saving solution that does not require a medium disruption to previous BUS protocols, is a new, emerging infrastructure solution for the digitalization of the field level. This is a technology that users should definitely keep in mind.

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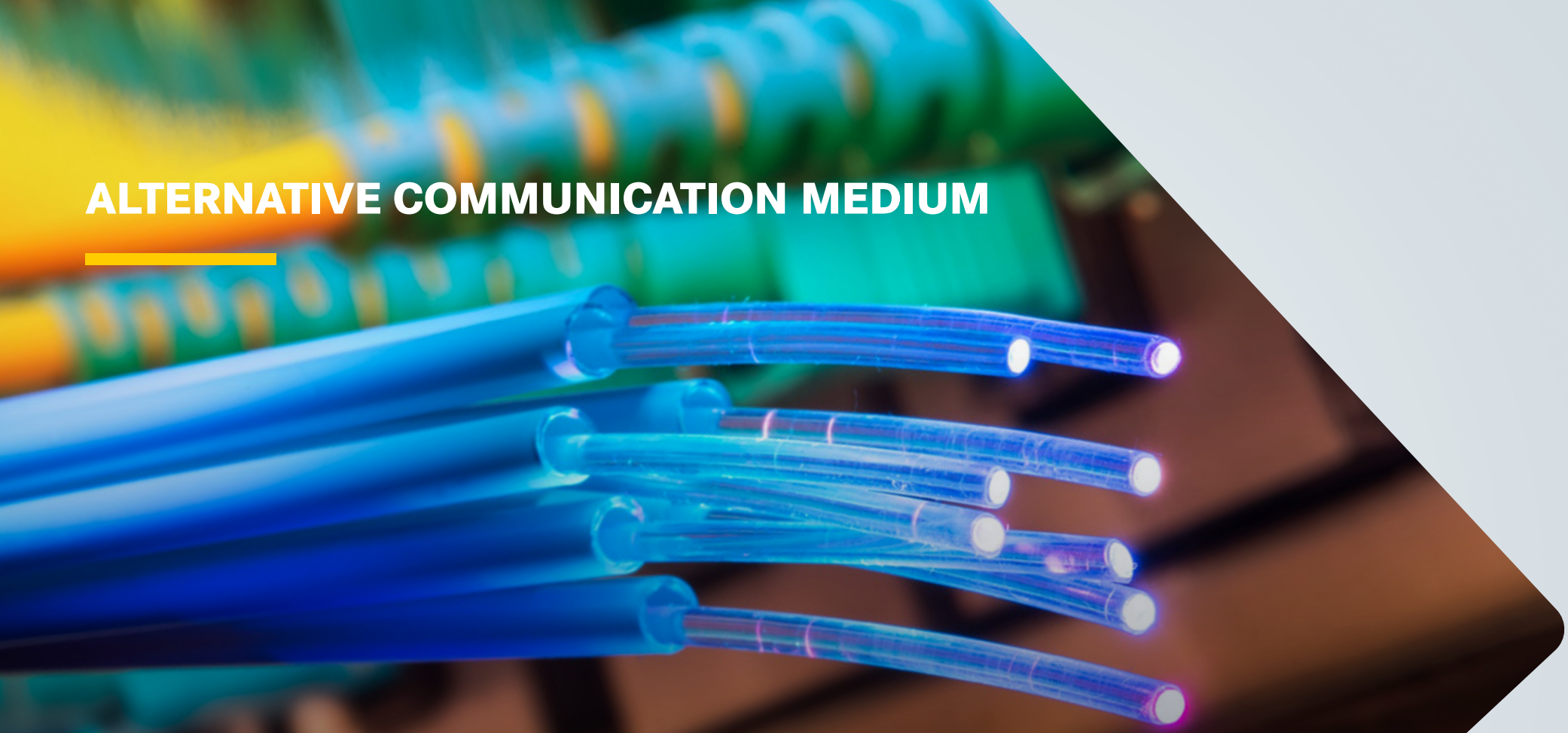
THE KEY MEDIUM – CUPRUM (COPPER)

Cuprum is derived from the Greek word Cyprium and means something like "ore from the Greek island of Cyprus". According to tradition, this is where it was first extracted and where it got its name. As an excellent electrical conductor available in sufficiently quantities, it is the set standard for the transmission of currents of all kinds. This is also the case in data cables for Ethernet networks. Over the decades, new standards have been set in transmission rates that were previously considered impossible. Twisting of wire pairs and efficient shielding concepts currently make transmission rates of up to 40 Gbit/s possible, which corresponds to the Cat.8.1/8.2 standard. What you find here are four pairs of stranded copper wires, which add up to a total of eight wires that transmit data. This divides the data stream into several paths. The previously mentioned stranding and shielding make high frequencies possible, however the frequencies currently possible are or were exhausted. The latest developments in single-pair Ethernet are breaking new ground in this area, but more on that later.

ALTERNATIVE COMMUNICATION MEDIUM



It has been repeatedly said that copper as a communication medium will be replaced by alternative transmission options in the foreseeable future. But is copper really loosing its position or rather set to become the basis for all IIoT plans? Electrical transmission is the common factor to all copper-based solutions. This sets physical limits on the usable frequencies and the transmission length. 1/10/25/40 Gbit/s over 100 metres is the known limit for Ethernet via copper cable. To circumvent this limitation with respect to both transmission rate and transmission length, and also to connect mobile systems with Ethernet, fiber-optic conductors are now used just as much as wireless radio systems.

For some years now, **fiber optics and WLAN** have been considered to be the future communication medium that will overtake the traditional cable. But is this really the case?

Admittedly: With fiber optic cables, high data rates can be transmitted over distances of many kilometers, and that without complex shielding to control EMC. WLAN combines gigabit transmission with being able to move independent of fixed cabling. If I have already installed a WLAN access point, new devices are quickly connected wirelessly. Until then, however, installation of the access point is costly and this also must have a cable connection. Unfortunately, the user must accept a few decisive disadvantages when using these technologies. Optical fibers must be connected under very clean conditions to avoid signal attenuation due to contamination. Likewise, no supply voltages can be transmitted in addition to the data. A device still needs additional copper cabling for the power supply.

The same applies to WLAN devices. Mobile solutions often rely on rechargeable batteries or a power supply connected by copper cable, which ultimately negates the mobility advantage. Another issue is the environmental impact of rechargeable batteries, which is increasingly coming into focus today. Furthermore, a number of further issues must be considered: real-time transmission is not guaranteed and the data rate is reduced depending on the location and number of recipients. Other questions include gow secure is my data when sent wirelessly and how high is the radiation exposure in sensitive areas? These are issues that can be safely neglected with classic copper cable.

Ethernet over four or eight wires offers up to 100 watts of supply power at the device via Power over Ethernet (PoE) and in many cases makes an additional power supply unnecessary. If the application allows it, a single-cable solution is always preferred. This feature comes into its own especially in the cramped conditions of the field level. During the course of development of IIoT, more and more smart sensors and other participants are being relocated into machines and require the space-saving supply of data and power here. One new development in this regard is particularly noteworthy.

THREE STEPS TO THE RIGHT ETHERNET INTERFACE

1

What speed is required?
What data rate does the application require. Is Fast Ethernet sufficient or is Gigabit Ethernet required? This makes it necessary to design the connection technology and cabling either in two pairs for Fast Ethernet (up to 100 Mbit/s) or in four pairs for Gigabit Ethernet.

2

What are the environmental requirements?
In which environment should the application be used? The environmental requirements below are relevant for the selection of the design and these requirements should be considered:

- Degree of protection (IP20 or IP65/67)
- Temperature range
- Vibration and shock resistance
- Climatic and possibly also chemical resistance

3

What are the required specifications?
Which applications will the unit be used with? Are there specifications from user organizations such as the PNO for PROFINET, ODVA for Ethernet/IP, ETG for EtherCAT, VNO for Varan, to name a few? These considerations often also lead to the selection of a standardized Ethernet interface. The available size of the unit and the available installation space in the application also play a role.

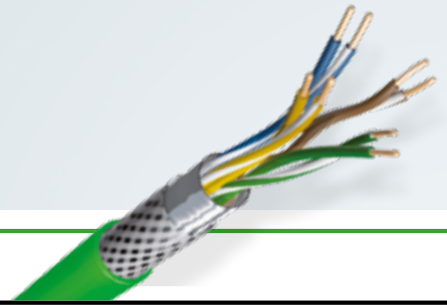
EXAMPLES

Compact vision sensor with PROFINET conformity
These vision sensors deliver high-resolution images and therefore the data interface must be designed for Gigabit Ethernet. Robustness and a small installation space are further requirements. The ix Industrial® interface is suitable for simple IP20 applications or the M12 X-coded as a waterproof and dustproof IP65/67 interface. Both interfaces are also PROFINET-compliant.

Data interfaces on robots in automobile manufacturing
Very robust and easily replaceable interfaces are required in this environment, as the cable packages wear out over their service life due to the permanent bending and torsional stress caused by the rapid movement of the robots. The Han® PushPull variant 14 in the metal version is perfect for this. Thanks to the PushPull locking mechanism, the cable packages can be replaced very quickly, minimizing the downtimes. In addition, this design is available with RJ45 or optical data containers as well as with signals and power. In other words, this makes it the ideal interface for the lifelines of data, power & signals. Moreover, the interface is AIDA and PROFINET compliant.

Mechanical and plant engineering
In this area, the extremely robust Han® connectors are the measure of all things and whether as Han® 3A, Han-Modular® or also in other designs such as the Han® F&B for the food and beverage industry, there are RJ45 or M12 D- or X-coded designs available that can also be used for different Industrial Ethernet protocols.

ETHERNET CONNECTIVITY – OVERVIEW OF ALL CONNECTORS FOR ETHERNET IN INDUSTRIAL APPLICATIONS



IP20 IP65/67	F	D G H A D E H I	C D							B C D	D A D E H J
IX INDUSTRIAL	RJ45 8 POLES	M12 X CODED	1 GBASE-T 2.5 GBASE-T 5 GBASE-T 10 GBASE-T	EIA/TIA T 568 A	EIA/TIA T 568 EN B	ETHERNET/IP (2 PAIRS)	PROFINET	10BASE-T 100BASE-TX	M12 D CODED M8 D CODED	RJ45 4 POLES	
1	1	1	BI_DA+	WHITE/GREEN	WHITE/ORANGE	WHITE/ORANGE	YELLOW	TX+	1	1	
2	2	2	BI_DA-	GREEN	ORANGE	ORANGE	ORANGE	TX-	3	2	
6	3	3	BI_DB+	WHITE/ORANGE	WHITE/GREEN	WHITE/GREEN	WHITE	RX+	2	3	
4	4	8	BI_DC+	BLUE	BLUE						
5	5	7	BI_DC-	WHITE/BLUE	WHITE/BLUE						
7	6	4	BI_DB-	ORANGE	GREEN	GREEN	BLUE	RX-	4	6	
9	7	5	BI_DD+	WHITE/BROWN	WHITE/BROWN						
10	8	6	BI_DD-	BROWN	BROWN						

*3.8 = GND

ADDITIONAL INFORMATION

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www.HARTING.com
All solutions, products and support materials on our website

INDUSTRIAL-ETHERNET-TRENDS
www.HARTING.com/Industrial-Ethernet-Trends
Live and on-demand digital events on the topic of Industrial Ethernet

SPE INDUSTRIAL PARTNER NETWORK
www.single-pair-ethernet.com
Co-founded by HARTING, this global network of companies has set itself the goal of establishing Single Pair Ethernet as an infrastructure in the sense of a holistic ecosystem.

HARTING Americas
1370 Bowes Rd.
Elgin, IL 60123
More.Info@HARTING.com
+1(866) 278-0306