INDUSTRIAL PARTNER NETWORK

APPLICATION NOTE

# SINGLE PAIR ETHERNET – T1 INDUSTRIAL CONNECTIVITY

## INTRODUCTION

Individual connector designs are inextricably linked to a specific application and are internationally standardized. Well-known examples are the RJ45 connectors for Ethernet, the HDMI or DVI connectors for video transmission or the USB connectors. Standardized interface connectors are an important prerequisite for the successful market launch of new network technologies such as Single Pair Ethernet (SPE). Only with standardized interfaces is it possible to connect different devices in a uniform data network. Using the example of the "Industrial Style" SPE connectors according to the international standard IEC 63171-6, the design according to the specifications of the associated IEEE 802.3 standards and the market requirements of the industry are described here.

## SPECIFICATION OF THE ELECTRICAL CHARACTERISTICS

### Rated voltage:

For the pure Ethernet transmission usually a differential voltage signal of +/- 1V is used. For the definition of the nominal voltage of a SPE connector, however, the parallel use of the two wires for the remote power supply must also be considered. The method used for this with SPE is called Power over Data Line (PoDL). Similar to Power over Ethernet (PoE), the maximum nominal voltage is 48 V DC, resulting in a max. supply voltage of the Power Sourcing Equipment (PSE) of 60 V DC. Unlike PoE, PoDL defines other typical on-board voltages of 12 V and 24 V DC, as used in vehicles.

### Insulation voltage:

According to the standard IEEE 802.3cr Annex J, the insulation requirements for network components are defined. In terms of connection technology, an insulation strength between the contacts and the shield of 1.5 kV (rms), 2250 V DC or ten 1.2/50 pulses 2.4 kV is required. As with other data connectors for common applications in building and industrial cabling, the dielectric strength from contact to contact is 1.0 kV (rms).

### Rated current:

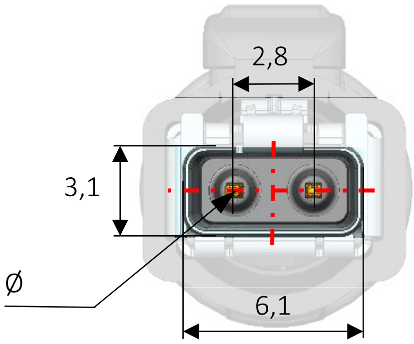
The PoDL requirements are also decisive for the design of the nominal current. In the current IEEE802.3bu standard, the maximum feed-in power is specified in Table 104-1 as 63.3 W, which corresponds to a max. supply power at the powered device (PD) of 50 W. This results in a current of 1.36 A at a minimum permissible supply voltage of 48 V. In order to specify a future-proof interface, a nominal current of 4 A was selected.

Background: According to the National Electric Code (NEC) for the North American market, the maximum power for NEC Class 2 devices is limited to 100 W and this is also the maximum remote power for the PoE standard IEEE802.3bt [bt]. This means that future PoDL expansions will also remain below 100 W and for the 24 V supply voltage used in industrial automation, the rounded max. rated current of 4 A.

### HF transmission parameters

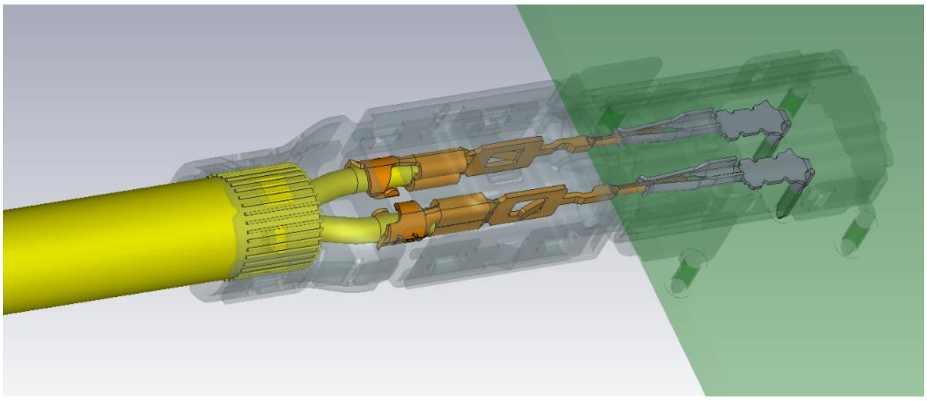
SPE uses a full duplex connection over a differential wire pair with an impedance of 100 Ohm for data transmission. In order to realize a lower susceptibility to interference, especially for use in electric vehicles, a lower coding with PAM3 up to 1000BASE-T1 and PAM4 for 2.5/5/10GBASE-T1 was selected for SPE. This increases the bandwidth requirement enormously compared to "multipair Ethernet standards" (MPE). For example, a bandwidth of 4 GHz is required for 10GBASE-T1 (compared to only 500 MHz for 10GBASE-T). This increases the HF requirements for cables and connection technology.

This requires a very symmetrical design of the connectors as well as the cables in order to reliably meet the HF requirements. For this reason, the contacts of the T1 industrial connector are arranged symmetrically in the fully enclosed shield housing. Thus, the coupling capacitances and inductances of both conductors to the shielding or the PCB are identical and the differential data transmission is not disturbed.




**Picture 1: Symmetrical design of the mating face according to IEC 63171-6 (Source: HARTING)**

Likewise, both contacts are arranged parallel to the PCB and next to each other. This means that the propagation times in both signal paths are identical and propagation time differences are minimized (see Picture 2).

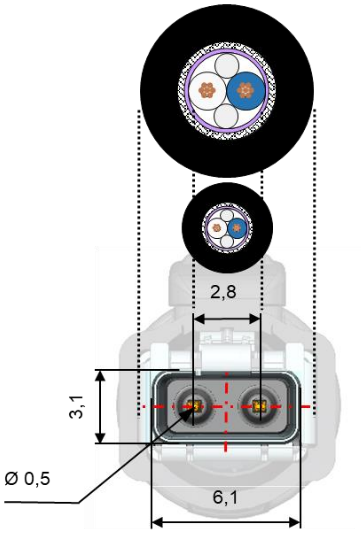


**Picture 2: Simulation model with symmetrical structure of the mating face according to IEC 63171-6 (Source: HARTING)**

## Technical design of the SPE connection technology according to IEC 63171-6

The SPE interface according to IEC 63171-6 was designed with sufficient reserve for future higher bandwidths and requirements regarding remote power supply via PoDL considering the described electrical parameters. For industrial use, the M8 and M12 IP65/67 housing designs accepted and widely used in the market were used. Great importance was also attached to a balanced relationship between the market trend for miniaturized interfaces and high robustness. The focus was clearly on good usability and the optimum design of the connection area to fit the various wire and cable diameters.

In line with these design objectives, 0.5 mm contacts with a contact spacing of 2.8 mm were selected as the contact system. The contact spacing is coordinated with the necessary cable cross sections. For the short transmission distances for 100BASE-T1 and 1000BASE-T1, AWG 28/26 and AWG 22 conductors with wire diameters of approx. 1 mm and approx. 1.6 mm respectively are used. However, for the 10BASE-T1L with a range of 1000 m, AWG 16/18 conductors with a core diameter of approx. 2 mm are required and therefore the 2.8 mm contact spacing is optimal. According to IEEE 802.3, the greater ranges are only possible with shielded transmission lines.




**Picture 3: Size comparison mating face and SPE cable AWG 26 (bottom) resp. AWG 18 (top)**

For this reason, and in order to ensure safe transmission even in harsh industrial environments, a shielded design was consistently implemented. The shielding elements of the IP20 version also serve as a robust mechanical locking mechanism. The metal latching lever avoids the avoids the often criticized problem of defective latches with the RJ45.

M8 and M12 circular connectors have become established in industrial applications. Accordingly, the new SPE mating face has been integrated as a uniform "data container" in the M8 designs with screw, SnapIn and PushPull locking. Furthermore, M12 designs with screw and PushPull locking are also standardized, in particular to accommodate the large cable cross-sections for the 1,000 m 10BASE-T1L transmission. The same mating face is thus used in all designs. This means that IP20 connectors can also be connected to the IP65/67 interfaces for parameterization or testing. The use of this standardized SPE data container also makes it easy to integrate this IEC 63171-6 mating face into other designs.


**Picture 5: T1 Industrial SPE Connector according to IEC 63171-6 as IP20 version (Source: HARTING)**

Shown below is a selection of the different designs in protection class IP65/67 and IP20. This product portfolio will be further expanded in the future on the basis of IEC 63171-6 to include a complete range of solutions with PCB sockets, connectors, panel feed-throughs and system cables.

**Picture 6: T1 Industrial SPE Connector versions according to IEC 63171-6 as IP65/67 as well as IP20 versions (top row from left to right: M12 PushPull Stvb., M8 PushPull Stvb., M8 SnapIn Stvb. and IP20 Stvb. / bottom row from left to right: M12 socket with screw and PushPull locking, M8 socket with SnapIn and PushPull locking, angled IP20 PCB socket) (Source: HARTING)**

Since remote power supply via PoDL only works as a point-to-point connection and requires a number of additional components and costs, it makes sense, especially for devices with IP65/67 protection, such as sensors, to simply implement the power supply via a separate circuit. Hybrid connectors such as the M8 hybrid connector shown below are used for this purpose. In addition to the two SPE data contacts, there are 2 power contacts for 8 A / 60 V DC for power supply. So the cabling can also be realized in line, because the power supply can be looped through from device to device.

**Picture 7: Hybrid M8 SPE connector according to IEC 63171-6 (Source: HARTING)**

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## OVERVIEW OF THE CONSTRUCTION TYPES AND TYPICAL AREAS OF APPLICATION

IEC 63171-6 describes a whole range of different designs. With this practical solution portfolio, the wide range of industrial applications can be realized and suitable interfaces are also available for other fields of application from building automation to data centre use.

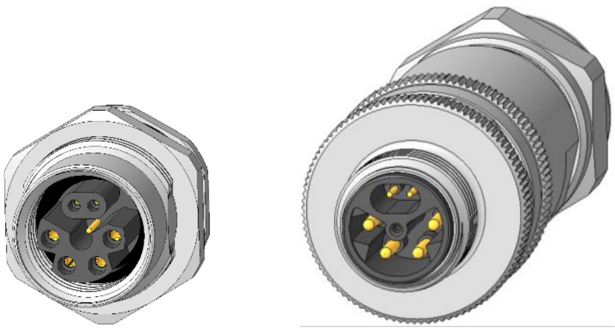
| Type | Typical application fields |
|---|---|
|  **T1 Industrial IP20** | In the control cabinet and everywhere where high requirements for the protection class are not necessary. |
|  **T1 Industrial M8 SnapIn Locking** | mall and cost-optimized devices in IP65/67 environments, such as sensors, LED lighting or similar. |
|  **T1 Industrial M8 PushPull Locking** | Small devices in IP65/67 environments that can be quickly and easily connected and changed through PushPull locking, such as sensors or similar. |
|  **T1 Industrial M8 Screw Locking** | Small devices in IP65/67 environments, such as sensors or similar. |

| | |
|---|---|
|  **T1 Industrial M12 Screw Locking** | Classic field devices in IP65/67 environments, such as sensors, IO distributors and actuators or similar. |
|  **T1 Industrial M12 PushPull Locking** | Classic field devices in IP65/67 environments that can be quickly and easily connected and changed using PushPull locking, such as sensors, IO distributors and actuators or similar. |
|  **T1 Industrial M8 Hybrid Screw Locking** | Small devices in IP65/67 environments with higher power requirements, such as sensors and actuators or similar. |

**Table 1: Overview of IEC 63171-6 designs and typical application fields**

## FURTHER HYBRID M12 CONNECTORS

Especially for the connection of devices in industrial applications, connection solutions are required that enable both data communication and power supply with only one cable and only one interface. Hybrid interfaces with a separate SPE insert and additional contacts for the power supply in the well-proven M12 design are the ideal solution here.



**Picture 8: Hybrid M12 SPE connector according to IEC 63171-7 (Source: TE)**

In order to meet the requirement for different voltage requirements of the devices, different coding types are defined in IEC 63171-7.

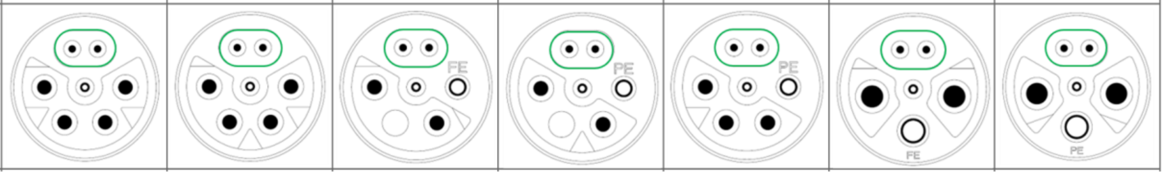
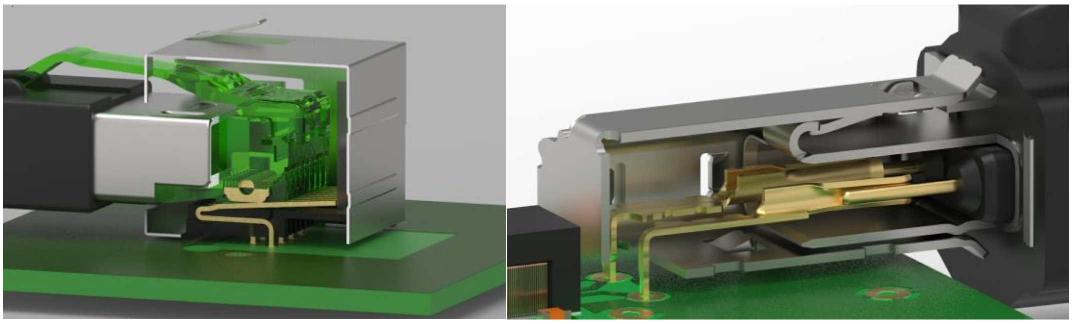
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POWER | 2-Phase | | | | 3-Phase | 2-Phase | |
| | < 50 VAC<br>≤ 63 VDC | | | ≤ 600V AC<br>≤ 600V DC | ≤ 480V AC. | ≤ 50 VAC<br>≤ 63 VDC | ≤ 600V AC<br>≤ 600V DC |
| | 12A Max. | 2x 8A Max. | 8A Max. | 8A Max. | 8A Max. | 16A Max. | 16A Max. |
| | Type 1 | Type 2 | Type 3 | Type 4 | Type 5 | Type 6 | Type 7 |
| MALE |  | | | | | | |

**Table 2: Overview of the IEC 63171-7 coding types**

This makes the M12 hybrid interfaces ideal for DC drives and servo motors, for example, as well as small three-phase drives and many other devices.

## COMPARISON T1 INDUSTRIAL WITH THE CLASSIC RJ45

The most frequently used interface for 2- or 4-pair Ethernet systems (MultiPair Ethernet = MPE) worldwide is the RJ45. Widely known weaknesses of the RJ45 are the contact system, which is susceptible to contact interruptions, and the often fragile plastic latching lever. Accordingly, special attention was paid to these features in the design of the T1 Industrial. A classic pin-socket contact system was used, which means that two contact points are always realized per contact. The locking is part of the 360° shield housing and robustly made of metal.



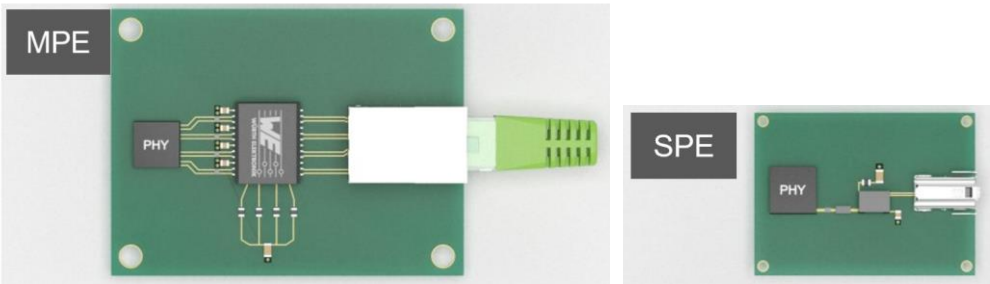
**Picture 9: Detailed views of locking and contact system RJ45 and T1 Industrial (Source: WE)**

## Size comparison of RJ45 and T1 Industrial

The size of the T1 Industrial IP20 interface is about 50% smaller than that of the RJ45 and thus the port density can be doubled, for example in switches.

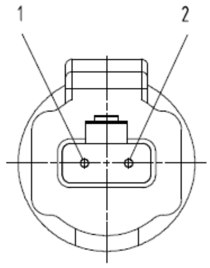
**Picture 10: Design study multiport SPE jack**

The space requirement on the PCB is also reduced with SPE compared to MPE. Not only the reduced space requirement for the pure socket is relevant here, but also the magnetic components, which are only required once compared to MPE. Thus, the space requirement can be reduced to approx. 30%.



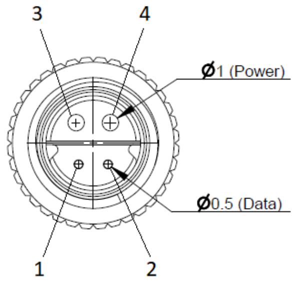

**Picture 11: Size comparison MPE and SPE on the printed circuit board (Source WE)**

## APPENDIX 1: WIRE COLORS AND PIN ASSIGNMENT




| Contact | PMA Signal | PoDL | Wire Color |
|---|---|---|---|
| 1 | BI_DA+ | PoDL+ | Blue |
| 2 | BI_DA- | PoDL- | White |

**Table 3: Pin assignment SPE connectors according to IEC 63171-6**




| Contact | Signal | PoDL | Wire Color |
|---|---|---|---|
| 1 | BI_DA+ | PoDL+ | Blue |
| 2 | BI_DA- | PoDL- | White |
| 3 | $V_{CC}$ (+) | - | Red |
| 4 | $V_{EE}$ (GND/-) | - | Black |

**Table 4: Pin assignment hybrid M8 SPE connector according to IEC 63171-6**

## DOKUMENT INFORMATION

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## COPYRIGHT NOTICE



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