SPE | INDUSTRIAL PARTNER NETWORK®

APPLICATION NOTE

SINGLE PAIR ETHERNET – M12 HYBRID SYSTEM

Picture 1: M12 Hybrid connector, coding Type II *(source: TE Connectivity)*

M12 SPE HYBRID SOLUTION FOR HIGH POWER APPLICATIONS

With IIoT, the industry is placing ever tougher demands on network technology. In the future, even small devices should be connected to the company network as simply as possible. The trend towards miniaturisation ensures that ever smaller space is available for network technology and the cables used. At the same time, the demands on the possible data transmission rates are increasing.

Single Pair Ethernet (SPE) is the technology that excellently meets these requirements. It uses only one signal pair compared to four signal pairs used in conventional Ethernet. This reduces the weight and diameter of the cables and it also miniaturise the connectors. The requirements for the connectors are standardized in the IEC 63171 series. The requirements for the cables are standardized in the IEC 61156 series.

Comparable with Power over Ethernet (PoE) used for conventional Ethernet, it is possible to transfer power over the SPE signal pair by using Power over Data Line (PoDL). With PoDL, a maximum power of around 50W can be transferred. For industrial applications this might not always be sufficient. Therefore the SPE Industrial Partner Network proposes the use of a hybrid connectivity solution. Here the cables and connectors have one signal pair for SPE and separate power lines to transfer power.

One variant is the M8 Hybrid connector, standardized in IEC 63171-6 and capable of handling over 300 W over 40 m transmission length. More details on the M8 Hybrid connector can be found in the application note "Single Pair Ethernet - M8 Hybrid System". Another variant is the M12 Hybrid connector, currently standardized in IEC 63171-7 with several connector codings, it can handle even higher power levels than with the M8 Hybrid connector. Its capabilities will be explained in the following sections.

METHODS TO TRANSFER POWER

PoDL

PoDL is a remote powering technology, which supplies power up to 50 W @ 48 VDC to an SPE device over the data cable pair. The technology is standardized in IEEE 802.3bu and inside the IEEE 802.3cg with the additional power classes 10 to 15. PoDL can be used in conjunction with all SPE data transfer standards. The origin of PoDL is inside the automotive industry where you need to connect many small and energy-efficient devices with data communication and power. On this application, PoDL is highly reliable from a performance point of view for low power devices. But in the industrial environment, you find applications which need much more power than the 50 W, may operate at higher (hazardous) voltage levels and may require longer cable lengths. Other major disadvantages of PoDL are the required electronics to implement it. This leads to additional cost and PCB space in the small devices and is consuming extra energy. Also powering remote devices with PoDL in a multidrop configuration is not possible.

Direct Power Supply

The common way to supply devices is the direct supply over the power grid. For the direct supply, usually the device is connected to two separated cables one for power and another one for communication. The transmittable power is not limited but the cabling effort and the necessary cable space is high. This technology is not very efficient in terms of cable space and cost but for higher-powered devices, this is the only possibility next to hybrid power solutions.

Hybrid Signal/Power System

The hybrid system combines advantages of power supply and communication over one cable. This configuration significantly reduces the need for a separate power network and is still able to power higher power devices beyond the maximum power of 50 W with PoDL. The basis of the solution is to add two or more power lines next to the SPE pair. With this combination, you get a small diameter cable, which enables 1 Gbit/s data transmission combined with high power supply capabilities.

Other advantages are the cost and space efficient cabling and the significantly improved EMC characteristics with the separate data and power pairs, compared to PoDL. Also it has the ability to power multiple devices in a multidrop network layout.

M12 HYBRID INTERFACES

Within the IEC 63171-7 standard seven different connector interfaces are defined, see Picture 1 and 2. The different interfaces can be categorized into three different groups.

The first group refers to type I, II, III and VI and is defined for the non-hazardous voltages (≤ 63 V DC or < 50 V AC). The types can vary in maximum currents they can handle and the power pin layout. The power contact for type I, II and III can handle currents up to 8 A and are connected to wires of 16 AWG. In type I the two left power contacts are shorted with each other and the two right power contacts are shorted with each other. This enables the interface to handle higher currents up to 12 A. Here, each power contact is connected to wires of 17 AWG. Type VI supports 16 A by utilizing two larger power contacts that are connected to 14 AWG wires. This variation in different wire gauges is important for the amount of power it will transfer over distance. This is elaborated on in a later section. Lastly, type III and VI include a functional earth.

The second group refers to type IV and VII and is defined for hazardous voltage (≤ 600 V DC or ≤ 600 V AC). Type IV and VII can handle 8 A and 16 A on their power contacts and are connected to wires of 16 AWG and 14 AWG, respectively. Due to the high voltage level they include a protective earth (PE) contact.

The third group is represented by type V and is meant for three-phase applications. It is able to be used for voltages up to 480 V AC and current up to 8 A. Also here, due to the high voltages a protective earth contact is included.

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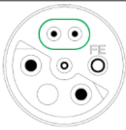
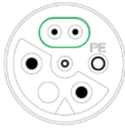
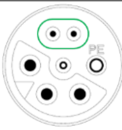
POWER	Single / Dual Phase / DC				3-Phase	Single / Dual Phase / DC	
	< 50 V AC ≤ 63 V DC			≤ 600 V AC ≤ 600 V DC	≤ 480V AC.	< 50 V AC ≤ 63 V DC	≤ 600 V AC ≤ 600 V DC
	12A Max.	2x 8A Max.	8A Max.	8A Max.	8A Max.	16A Max.	16A Max.
CODE	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII
MALE MATING FACE							

Picture 2: Interface types per IEC 63171-7

COMPARISION OF THE POWERING VIA PoDL WITH THE M12 HYBRID SYSTEM

With PoDL the highest power level that can be transmitted is 50 W with a maximum current of 1.36 A for a data rate of 1 Gbps and 52 W with a maximum current up to 1.579 A for a data rate of 10 Mbps as defined in IEEE802.3bu and IEEE802.3cg, respectively. For this the highest voltages on the wire pair from the Power Supplying Equipment (PSE) side is 60 V DC.

The M12 Hybrid connector supports higher currents and, depending on the interface type, higher voltages. Therefore, significant higher power levels above 52 W are possible. To understand the amount of power the M12 Hybrid connector can support, we have to understand the voltage drop that occurs over the cable to the powered device. This voltage drop is related to the resistance of the cables. Therefore the design and length of the cable are crucial here. To get insight in the amount of power that can be transmitted we assume the circuitry shown in picture 3.

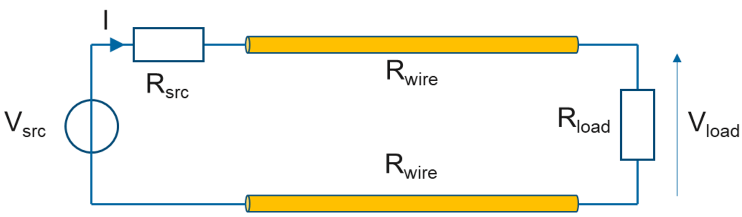
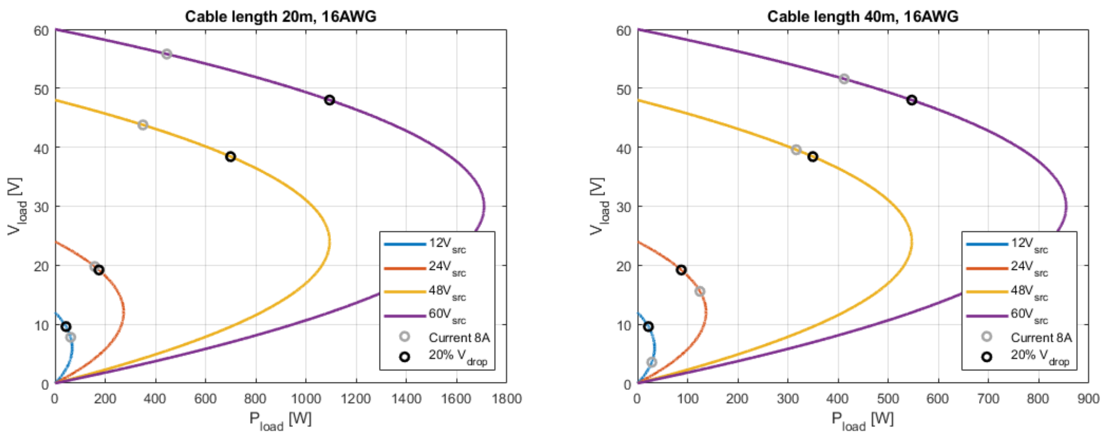


Bild 3: Basic circuitry for power transfer

On the left we have the Power Sourcing Equipment (PSE) that include a voltage source with internal resistance. The second part is the cable with losses and on the right, we have the Powered Device (PD) containing a load resistance that requires a specific voltage range. With this simplified model we can see the amount of power will be transferred at what current over a specific length of cable. In the following, this is carried out for some representative interfaces (types) of the M12 hybrid connector in order to show the possible power transmissions. In all these examples we neglect the source resistance for simplificiation and the amount of power is determined by the wire gauge of the cables and the maximum allowed working voltage. Furthermore, for every interface a cable distance of 40 m is taken into account which is the same distance that can be covered with 1 Gbps SPE.

CONNECTOR TYPES II AND III (Voltages up to 50 V AC rms)

If we take the losses of an 16 AWG copper wire and for simplification neglect the source resistance we will obtain the results of a cable length of 20 m and 40 m as shown in Picture 4.

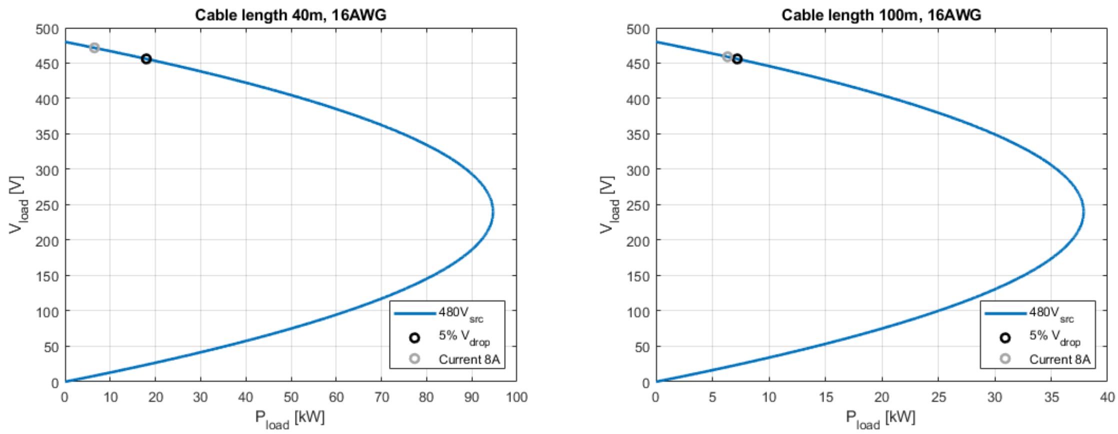


Picture 4: Transferred power for M12 hybrid interfaces type II and III.

On the left side of these graphs we can see that if the power increases, the voltage of the load will drop, which is caused by the increase of current through the power pair. When the voltage drop is 50% we see that the amount of transferred power is maximal, but typically this maximum is not used due to instability issues it causes for the PDs. Most electrical devices in this voltage range accept a maximum voltage drop of 10% of the source voltage which results in a power efficiency of approximately 80%. However, we compare the powers at a voltage drop of 20% which is comparable with PoDL and field busses. This 20% voltage drop is indicated by the small black circle. With a source voltage of 60 V we see that a power of more than 400 W can be transferred over both 20 m as well as 40 m cable distance. In the type II interface we have two power circuits, meaning that 2 times 400 W of power can be transferred. Here the maximum power is limited by the amount of current. If we check the amount of transferred power for a source voltage of 24 V, the transferred power is close to 100 and 200 W for 40 m and 20 m cable length, respectively. Note that for the 20 m the power is limited by the maximum amount of current the connector can handle. However, for 40 m the power is limited by the voltage.

CONNECTOR TYPE V (Hazardous Voltage and Three-phase)

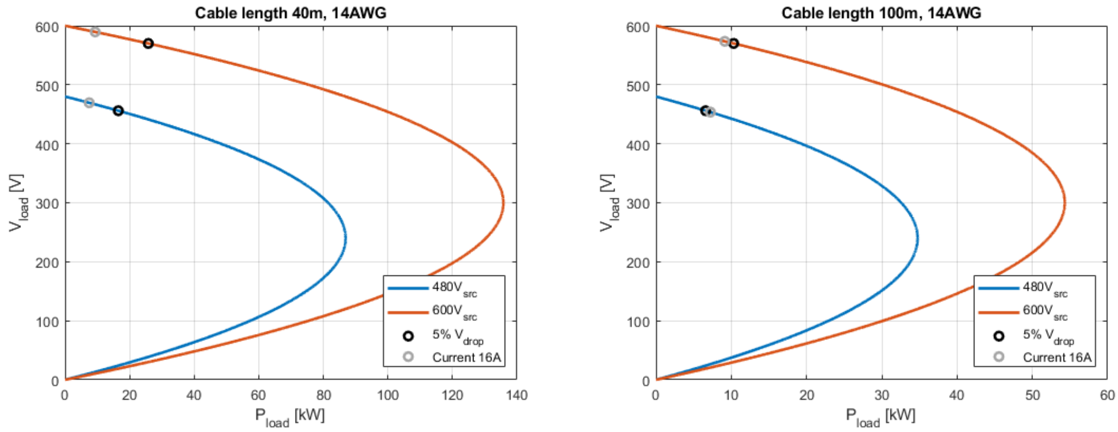
For a three-phase system with 16 AWG wires and a phase voltage of 480 V_{rms}, we can transfer power levels above 6 kW over 40 m. With a maximum voltage drop of 5% we see that the maximum current of 8 A is limiting the power level here. If the power is limited due to the maximum current it also means that over longer length high power levels can be transferred. On the right we see the graph for a cable length of 100 m where we still can handle more than 6 kW of power.



Picture 5: Transferred power for M12 hybrid interface type V.

POWER TRANSFER WITH CONNECTOR TYPE VII (Hazardous Voltage)

If we assume a 14 AWG copper wire and for simplification neglect the source resistance we will obtain the results shown in Picture 4. With a source voltage of 600 V and assuming a maximum 5% voltage drop we can see that a power of more than 9 kW can be transferred even up to 100 m cable distance.



Picture 6: Transferred power for M12 hybrid interfaces type VII.

The following table summarizes the features and advantages/disavantages of the different usable SPE remote powering solutions.

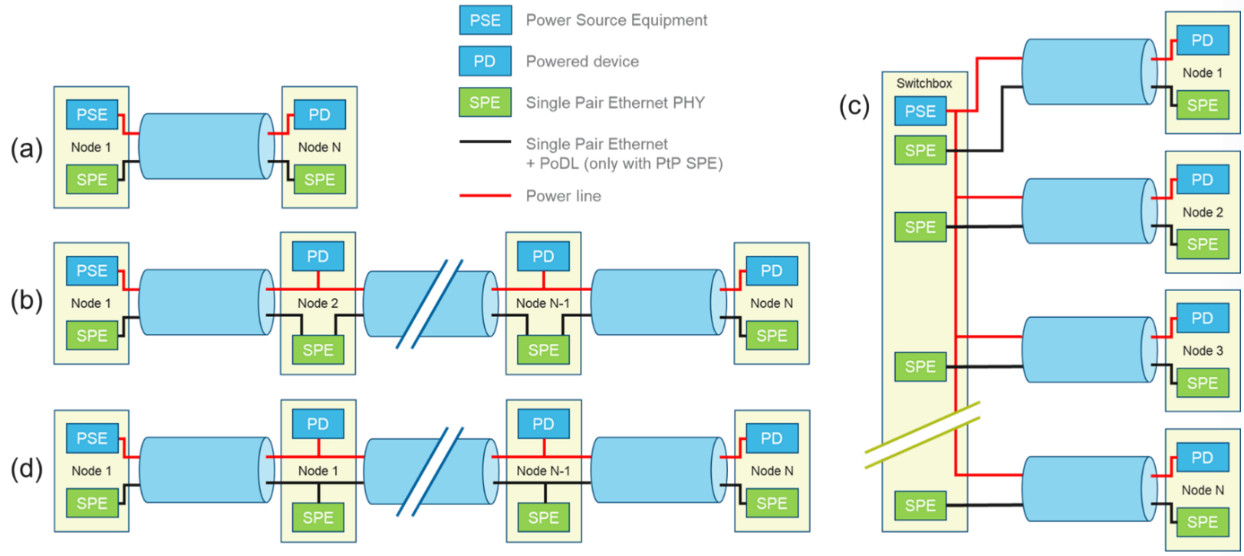
Feature	PoDL (40 m)	M12 Hybrid system (40 m)	Direct power supply
Power at PD for given source voltage	up to 50W @ 60V	around 150 W (2x) @24 V around 350 W @ 48 V around 400 W (2x) @ 60 V around 7 kW @ 480 V around 9 kW @ 600 V	not limited
Cable Dimensions	one small cable	one (hybrid) cable	two separate cables
Connector size	small	medium	big
Connection type	only P2P	P2P and PTMP	P2P and PTMP
EMC	power and data in one wire pair	galvanic isolation	galvanic isolation

Table 1: Comparision of the different powering methods

POWER DISTRIBUTION STRUCTURE

With PoDL designs, only a point-to-point connection is possible. Within the working group IEEE 802.3da investigations are ongoing to extend PoDL to power several PDs with one PSE. Here the focus is on 10 Mbs speeds only. By splitting the signal lines and power lines by using the hybrid cabling solution we obtain more freedom in implementing the power network. With the additional power lines of the

M12 Hybrid connector more than one PD can be powered and, of course alternatively, PoDL can be used simultaneously as well. Examples of possible topologies to power devices (represented by nodes in the Picture) in a network are shown in Picture 7.



Picture 7: Network topologies Hybrid connector system: (a) Point to point, (b) SPE daisy chained and power on a bus, (c) Switch with hybrid power source, (d) SPE and power on a bus, *(source: TE Connectivity)*

- **Point to point (PtP) cabling solution (a)**
  This is similar to most Ethernet communication setups. Here, the power over the separate power lines is applied point-to-point in case we need to have a high amount of power for one PD. In case PoDL is used in addition, we can use the power lines to power devices like actuators that generate EMC noise and supply power to noise sensitive devices like the SPE PHY chips seperatly via PoDL.
- **SPE daisy chained and power on a bus (b)**
  Often in automation networks the devices are installed in a daisy change topology where every device contains a network switch. With the M12 Hybrid cabling solution the power can be supplied directly to all devices via one power source.
- **Hybrid Ethernet switching solution (c)**
  From a switch with a hybrid power source the power to multiple devices can be delivered via one power source.
- **SPE and power on a bus (d)**
  Multidrop SPE does not have the possibility to add PoDL. With the M12 hybrid solution the power can be supplied via the extra power lines. This allows options like checking the power consumption of the connected devices or sending not needed devices to sleep mode and wake up the devices if needed.

The M12 Hybrid SPE solution is an excellent cable and connector solution for a large variety of harsh industrial use cases. In comparision to PoDL more variants of power networks are possible.

Technical Overview of M12 Hybrid Connector Type II and cable

Hybrid System Properties:

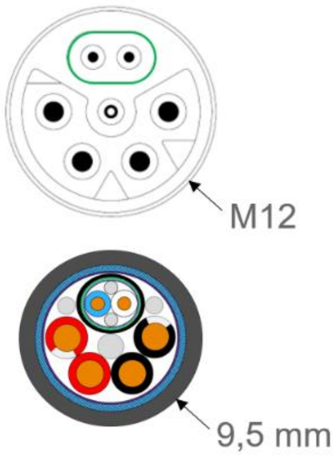
- Transfer rates up to 1 Gbit/s at 600 MHz bandwidth
- Up to 40 m distance with 1 Gbit/s (1000BASE-T1)
- Power over separate wire pair up to 2 x 400 W
- Optionally: Power over Data Line (PoDL) with up to 50 W @ 48 V DC

The compatibility of the cables with the M12 Hybrid connectors must be taken into account when designing the cables. The currently developed connector pair with mating face per IEC 63171-7 type II, supports 26 AWG wires for the SPE, and 16 AWG wires for power.

Current cable parameter values for connector type II:

Function	Wire cross section	Conductor diameter (mm)	Cable outside diameter (mm)
SPE	26 AWG	0,5 max.	9,5 max.
Power	16 AWG	1,5 max.	

Table 2: Proposed cable parameter for Hybrid M12 SPE connector type II according to IEC 63171-7



Future cable parameters (all connector types)

Function	Wire cross section	Conductor diameter (mm)	Cable outside diameter (mm)
SPE	22 ~ 26 AWG	0,8 max.	11,5 max.
Power	14 ~ 16 AWG	1,8 max.	

Table 3: Proposed general cable parameter for Hybrid M12 SPE connectors according to IEC 63171-7

The cable sheath colour can be selected in green RAL 6018 according to DESINA specifications. Outdoor cables are usually provided with a black cable sheath due to the technical conditions.

Pin assignment type 2 and preferred wire colours:

Contact	Signal	Optional PoDL	Wire Color
1	BI_DA+	PoDL+	Blue
2	BI_DA-	PoDL-	White
3	U1	-	Red
4	GND1	-	Black
5	U2	-	Red/white
6	GND2	-	Black/white
7	Shield	-	N/A (SPE braid)

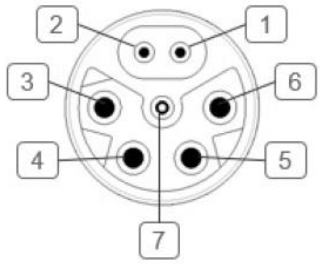


Table 4: Pin assignment Hybrid M12 SPE connector according to IEC 63171-7

List of abbreviations

- IIoT Industrial Internet of Things
- PoDL Power over Data Line
- P2P Point to point
- PTMP Point to multi point
- PD Powered device
- PSE Power sourcing equipment

DOKUMENT INFORMATION

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