INDUSTRIAL
PARTNER
NETWORK

APPLICATION NOTE

SINGLE PAIR ETHERNET – M8 HYBRID SYSTEM

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 is the technology that perfectly meets these requirements. Central elements of

the standard are the Single Pair Ethernet cables and connectors. In the IEC 61156 series of standards, the International Electrotechnical Commission has defined and standardized the structure and the electrical properties. The IEC 61156 standard divides the Single Pair Ethernet cables into the following categories: type of installation, maximum length and data transmission rate. In the IEC 63171-6 the IEC has standardized the connectors to be used for SPE together with the various cable types.

For a transmission rate of 1 Gbit/s over a transmission distance of 40 m the standards IEC 61156-11 (fixed installation) and IEC 61156-12 (flexible application) define the cable

requirements. To realize the high transmission rate over a single pair, particularly demanding electrical properties are required. In the past, this transmission was realized with four pairs as standard. To support the standardized data rates, it is necessary to increase the bandwidth considerably compared to

conventional Industrial Ethernet Cat.5e data lines. For this reason, the SPE cables are specified for a frequency of up to 600 MHz.

With the use of a two wire SPE cable, Power over Data Line (PoDL) can be used to supply the network's end devices with power of up to 50 W @ 48 V DC. The cable cross-section can be AWG 22 or AWG 26. For the hybrid SPE solution, the M8 Hybrid connectors and the hybrid cables are supporting a configuration build up out of a SPE data pair for data transmission purposes (AWG 22 to AWG 26) combined with a separate power pair (AWG 18) for powering the remote equipment. Main usage of this hybrid SPE solution would be for applications requiring flexible shielded cables used at distances up to 40 meters and high-power levels at the remote powered device. The inner shielding of the data pair is connected to the outer shielding of the cable. The screened data pair is mandatory. The outer screen is optional depending on the application and active equipment.

POWER OVER DATA LINE (PODL)

Power over Data Lines (PoDL) is an Ethernet technology, which supplies power up to 50 W @ 48 V DC to an Ethernet device. 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 perfect but in the industrial environment, you find application, which needs much more power than the 50 W. Therefore, we developed a hybrid cable solution.

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 space is high. This technology is not very efficient in terms of cable space and costs but for higher-powered devices, this is the only suitable type of connection.

HYBRID SYSTEM

The hybrid system combines advantages of a direct supply with the small form factor of one cable. The solution adds two or more power cores to an SPE data pair. In this combination, you get a small diameter cable, which enables 1 Gbit/s data transmission combined with a power supply of up to 200 W @ 24 V DC and 400 W @ 48 V DC. Other advantages are the cost and space efficient cabling and the great EMC characteristics with the separate data and power pair.

PODL VS. M8 HYBRID SYSTEM VS. DIRECT SUPPLY

After the description of all three possible connection types. The following table summarizes the features of each solution.

Merkmal	PoDL	M8 Hybridsystem	Direktversorgung
Power	up to 50 W @ 48 V	up to 200 W @ 24 V up to 400 W @ 48 V	not limited
Cable Dimensions	one small cable	one 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 line	galvanic isolation	galvanic isolation

POWER TRANSFER

With PoDL the highest power level that can be transmitted is 50 W @ 48 V DC what requires a maximum current of 1.36 A. For this the highest voltages from the Power Supplying Equipment (PSE) side is 60 V DC what is the limit. The increase of current in the hybrid connector would provide higher power levels. In the end the received power depends on the maximum allowed voltage drop of the load, which 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 Figure 1.

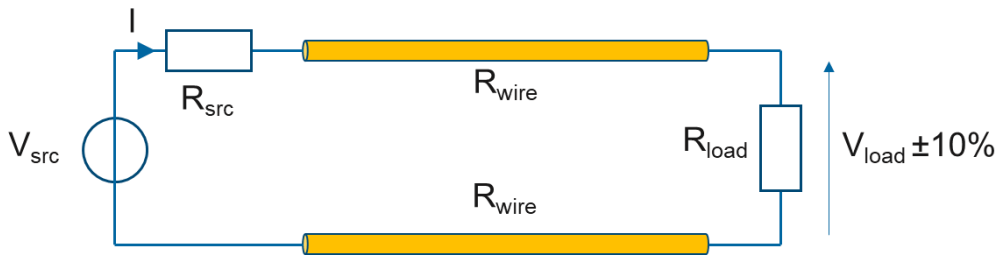
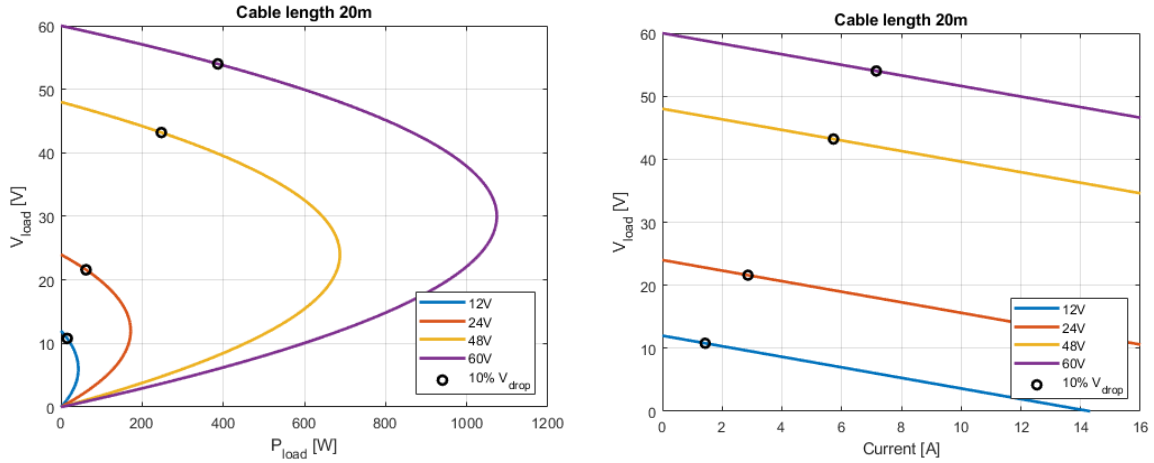


Figure 1: Basic circuitry for power transfer

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) that contains a load resistance that requires a specific voltage range. With this setup we can see what power will be transferred with what current over a specific length of cable. If we assume an AWG 18 copper wire and for simplification neglect the source resistance we will obtain the results given in Figure 2.



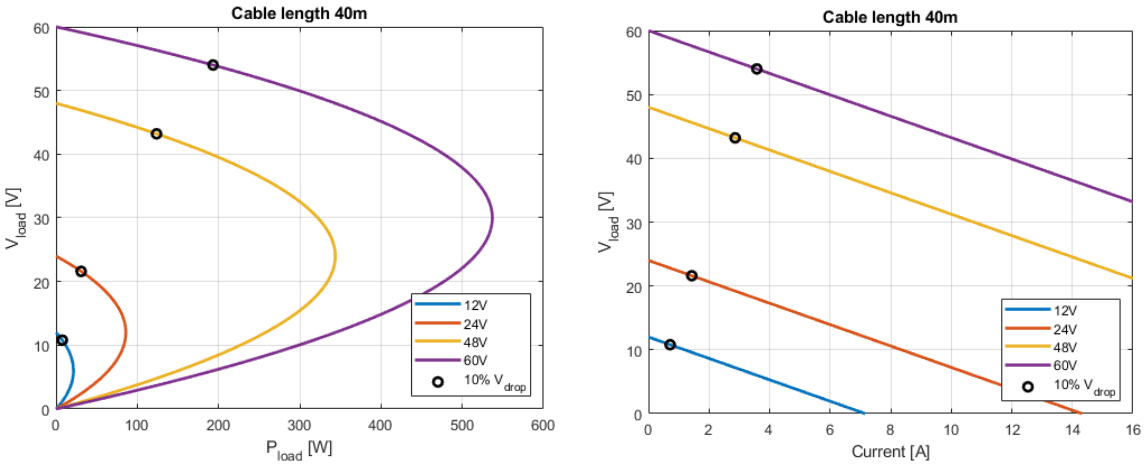


Figure 2: Voltage drop over the AWG 18 copper wire as function of transmitted power and current. (Note: The points at the curves represent the workig point with 10% voltage drop.)

On the left side we can see that if the power increases, the voltage of the load will drop, what 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 can provide for the PDs. Most electrical devices accept a maximum voltage drop of 10% of the source voltage what is a power efficiency of approximately 80%. This voltage drop is shown by the small black circle. Note that for PoDL the voltage drop can go up to 20%. With a source voltage of 60 V and assuming a maximum 10% voltage drop we can see that a power of close to 200 W can be transferred over 40 m cable distance.

POWER DISTRIBUTION

With PoDL designs, only a point-to-point connection is possible. With the project IEEE 802.3da are investigations ongoing to extend PoDL to power several PDs with one PSE, although those are focused on 10 Mbit/s speeds only. By splitting the signal lines and power lines by using the Hybrid cabling solution we get more freedom in implement the power network. With the additional power lines of the M8 Hybrid connector more than one PD can be powered and, of course, PoDL can be used as well. Examples of possible topologies to power nodes in a network are shown in Figure 3.

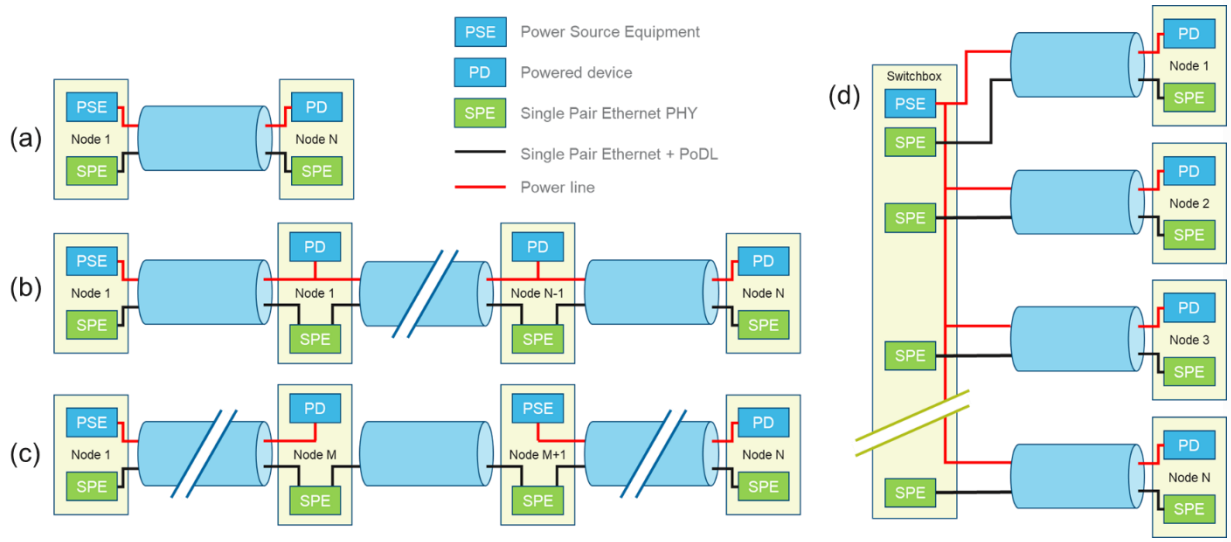


Figure 3: Network topologies hybrid connector: (a) Point to point, (b) Bus powered, (c) Bus powered with additional resupply points, (d) Switch with hybid power source

- **Point to point (PtP) cabling solution (a)**

  This is the classical way with the typical Ethernet star topologie. The power distribution 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, the network for power distribution can be splitted in a network that can handle EMC noise from all kind of actuators on the separate power lines and in a network for that provides less noise like powering the SPE PHY chips themselves.

- **Line topology cabling solution with central power supply (b)**

  Often in automation networks machines or network devices are installed similar like a typical bus topology with integrated network switches. With the M8 Hybrid cabling slution such installation concept are possible, because PoDL not support such daisy chain network structures.

- **Point to point (PtP) cabling solution with distributed power supplies (c)**
  If the line length ar to high to cover the maximum specified voltage drop more power supplies can be added and in this way long line length are possible.

- **Hybrid Ethernet switching solution (d)**
  Also a Hybrid Ethernet switch with the M8 Hybrid interface is a useful solution. In this way the switch can also offer a power delivery and control system. Such a power control system can check the power consumtion of the connected devices. Can send not needed device to sleep mode and wake up the devices if needed and so on.

The M8 Hybrid SPE solution is a perfect one cable and connector solution for all harsh industial use cases. In comparision to PoDL a lot of different network structures are possible.

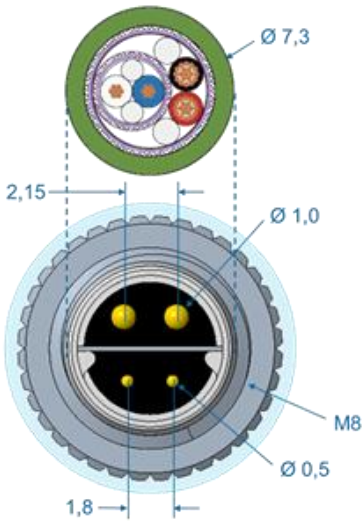
In the future, the range of hybrid connection technology will be expanded to include an M12 version, which will provide higher power and allow larger wire cross-sections to be connected.

TECHNICAL OVERVIEW OF M8 HYBRID CONNECTOR AND CABLE SYSTEM

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 200 W @ 24 V DC
  and 400 W @ 48 V DC
- Optionally: Power over Data Line (PoDL) with up to 50 W @ 48 V DC

The compatibility of the cables with the M8 Hybrid connectors must be taken into account when designing the cables. During the development of the SPE mating face according to IEC 63171-6, thinner AWG 22 and AWG 26 wires for the SPE signals and AWG 18 wires for the power wires need to be supported. The adjacent figure shows the size ratios between mating face and cable construction.



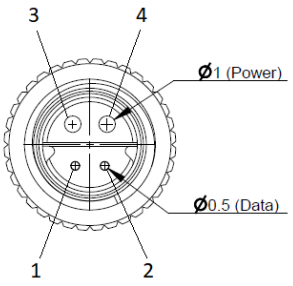
PREFERRED VALUES FOR THE ESSENTIAL CABLE PARAMETER

Wire cross section	Wire diameter	Cable diameter
AWG 26/22 (Data)	1,4 – 1,7 mm	7,5 mm max.
AWG 18 (Power)	1,6 mm	

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.

WIRE COLOURS AND PIN ASSIGNMENT

Contact	PMA signal	Wire colour
1	BI_DA+	Blue
2	BI_DA-	White
3	U	Red
4	GND	Black



M8 HYBRID CONNECTOR SPECIFICATION

- Rated voltage 60 V DC
- Current rating data pair 1.5 A (4 A)
- Current rating power pair 8 A
- Fully shielded 360°
- Bandwidth up to 600 MHz
- Cable diameter range 7.5 mm max
- Conductor area signal 0.32 mm^2 - 0.13 mm^2 (AWG 22 – AWG 26)
- Conductor area power 0.81 mm^2 (AWG 18)

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

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DOKUMENTEN INFORMATIONEN

Dokument: 2020-09_SPE-APPLICATIONNOTE_SPE-HYBRID_V10EN.DOCX

Datum: 2020-09-09 **Version:** 1.0

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