WHITE PAPER

POWER-OVER-ETHERNET (POE)
REMOTE POWER VIA STRUCTURED CABLING

Power-over-Ethernet – PoE for short – describes a concept which supplies consumers connected over a (copper) data cable with the electrical power required to operate the device. Today active devices can already be used to supply power of up to 100 watts to a data line. If a structured cabling system is to be used in this way, however, there are a few points which need to be borne in mind when planning, installing and operating it. This White Paper tells you about them.

Development of the PoE standard up to the transmission of 100 watts of power was carried out in three standardisation phases:

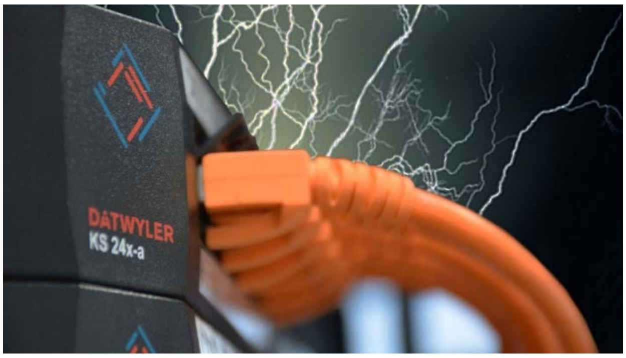
PoE: Power supply over 10Base-T / 100Base-TX

The first standard for the supply of power over data cable – IEEE 802.3af – was ratified in 2003. While the conductor pairs 1/2 and 3/6 are used for data transmission, the two free pairs are available for the supply of power to end devices such as webcams, IP telephones or WLAN access points. Alternatively, however, provision is also made for the conductors engaged in data transmission to be used in parallel for the power supply. With a defined power output of 15.4 watts per port at the active components (switch port), end devices with a lower power consumption can be operated safely.

PoE Plus: Power supply for 1000Base-T as well

The remote supply of power to end devices was further developed by 2009. With PoE+ Standard IEEE 802.3at the maximum power at the transmitter end was increased to 30 watts on the one hand, releasing power transmission for faster Ethernet protocols such as 1000Base-T on the other. This made it possible to run other applications with a higher power requirement.

In the case of 1000Base-T, data transmission takes place in parallel over all four pairs. Power transmission is effected over two pairs and overlays data transmission. The available



power at the consumer end is a maximum of 25.5 watts. This still severely restricts the choice of consumer.

4PPoE: Power transmission up to 100 watts

With standard IEEE 802.3bt, published in the 1st quarter of 2018, all the conductors in the data cable are used for power transmission for the first time. With “Four-Pair Power over Ethernet“ (4PPoE) the power at the transmitter end increases to 60 and 100 watts (IEEE 802.3bt Type 3 / Type 4 respectively).

This means that the supply of power to high-performance consumers in the workplace now becomes a reality. At the same time the standard makes RJ45 the globally standardised connection technology for supplying electrical power to end devices over data cabling. Standard 4PPoE is backward compatible with PoE and PoE+. It is also compatible with 10, 100 and 1000BASE-T as well as with 2.5, 5 and

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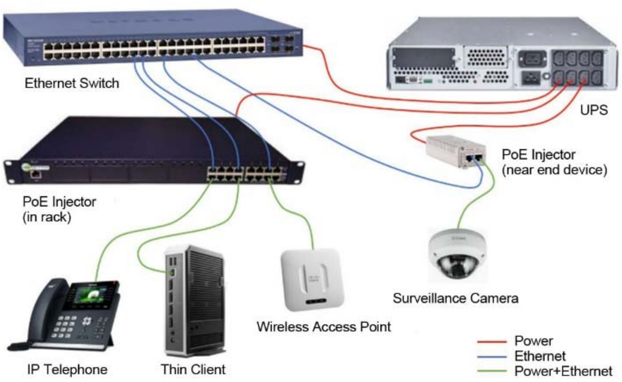
Service	Standard	Max. current	Pairs with current	Max. power: Source (PSE)	Max. power: Component (PD)	Standard ratified
PoE	IEEE 802.3af (802.3at Type 1)	350 mA	2	15.4 W	12.95 W	2003
PoE+	IEEE 802.3at Type 2	600 mA	2	30 W	25.5 W	2009
4PPoE	IEEE 802.3bt Type 3	600 mA	4	60 W	51 W	2018 (expected)
4PPoE	IEEE 802.3bt Type 4	860 mA	4	90 (100) W	72 W	2018 (expected)
Non-PoE Standard based	Cisco UPOE	600 mA	4	60 W		No official standard
Non-PoE Standard based	HDBase-T™	1000 mA	4	96 W		No official standard

Table 1: Overview of PoE protocols - 2003 to 2018

10GBASE-T. The minimum supported cabling standard is Class D (Category 5e components), with the budget for loop resistance being 25 ohms. The maximum input voltage for PoE is 57 volts.

Application: Endspan PoE or midspan PoE
Basically there are two ways to integrate PoE into a communication network. One space-saving and highly integrated solution is to use a PoE compatible switch (endspan PoE). Factors to be borne in mind here are increased power consumption and greater heat generation in the rack.

If, however, only a few PoE devices are to be connected, a PoE injector can be introduced between switch and end device.



Top image: Endspan PoE solution.
Bottom image: Midspan PoE solution.

A PoE injector is a current injection device introduced into the transmission link downstream of the switch. This means that the PoE injector can be installed in a rack, or in the local vicinity of the end device.

Checklist
Whether and how the power input is used depends on many factors. As a guide, here are some important questions relevant to the use of PoE:

- Is the end device PoE-compatible?
- Does the switch / injector cover the power requirement?
- Enough space in the rack / at the location of the end device?
- Is consideration given to heat management along the transmission channel?
- Is there access to the end devices?
- Has the power supply of the end devices been clarified, e.g. of the surveillance cameras, motion and light sensors?
- Is integration into the building management planned?
- Internet of Things: Are the devices for the stationary installation PoE compatible, e.g. the sensors?

Keeping the heating of cables under control
Data cables in structured premises cabling are primarily optimised to transmit digital signals as efficiently as possible. Their design is not optimal for the transmission of electric power.

A few things must therefore be borne in mind when they are used for PoE. For example, the conductor cross-sections of data cables are small compared to those of low-voltage power cables. At a maximum of 57V, PoE voltage also tends to be low for power transmission. Consequently the current in the conductor is relatively high, and hence the power loss (P) along the cable increases. Power loss can be calculated as follows:

$$P = I^2 \times R$$

I stands for the current in the conductor,
R is the DC (total) resistance of the conductor.

This indicates that power loss increases
a) the higher the current is,
b) the longer the transmission link is,
c) the greater the conductor resistance is.

This power loss takes the form of heat loss. This means that when PoE is used the communication cabling system turns into a little heating system.

One should also be aware that as a general rule electrical insulators are also good thermal insulators. This has a negative effect on heat dissipation.

Number of cables	Temperature rise (°C)											
	0.4 mm cords		Cat 5 cables		Cat 6 cables		Cat 6_A cables		Cat 7 cables		Cat 7_A cables	
	air	conduit	air	conduit	air	conduit	air	conduit	air	conduit	air	conduit
1	1.9	3.1	1.1	1.7	0.8	1.3	0.7	1.1	0,7	1.1	0.6	0.9
7	5.7	9.1	3.5	5.2	2.6	4.0	2.3	3.3	2.3	3.3	1.7	2.6
19	10.5	16.5	6.7	9.7	5.1	7.4	4.4	6.1	4.4	6.1	3.1	4.7
24	12.2	19.1	7.9	11.3	6.0	8.7	5.1	7.1	5.1	7.1	3.6	5.5
37	16.2	25.1	10.7	15.2	8.2	11.6	7.0	9.5	7.0	9.5	4.7	7.2
48	19.3	29.8	13.0	18.2	10.0	14.0	8.5	11.4	8.5	11.4	5.7	8.5
52	20.3	31.4	13.8	19.3	10.6	14.8	9.0	12.0	9.0	12.0	6.0	9.0
61	22.7	34.9	15.5	21.6	12.0	16.6	10.1	13.4	10.1	13.4	6.7	10.0
64	23.5	36.1	16.1	22.4	12.4	17.1	10.5	13.9	10.5	13.9	6.9	10.3
74	26.0	39.8	17.9	24.9	13.9	19.1	11.7	15.4	11.7	15.4	7.7	11.3
91	30.1	45.9	21.0	29.0	16.4	22.2	13.8	17.9	13.8	17.9	8.9	13.1

Temperature rise above 10 °C (grey backgroun): not recommended

The values in this table are based on the implicit DC resistance derived from the insertion loss (IL) of the various categories of cable. Manufacturers' and/or suppliers' specifications give information relating to a specific cable.

NOTE 1: The temperature rise (°C) is based upon a current of 500 mA per conductor, for all pairs in all cables in a bundle.
NOTE 2: The current per conductor for each category is dependent on the cable construction.

Problems hardly ever occur in practice, as long as only part of the cables in a data network are used for power transmission, and then only for PoE or PoE+. Heat dissipation in such an installation is good enough to cause no significant heating of the cables.

When 4PPoE (up to 100 watts) is used, however, cable heating becomes a phenomenon to be taken seriously. Experiments have shown that, when the installation rules are ignored and in the worst-case scenario, cable conductor temperature can rise to a level where the thermoplastic insulation materials melt. This can ultimately cause a short circuit.

For years experts have been addressing the issue of how the installation of high-performance communication networks incorporating PoE can be designed to be safe on the one hand, but straightforward, simple and economical on the other. Currently the second edition of ISO/IEC TS 29125 (2017) is dealing, among other things, with the safe installation practice of data networks in which large-scale PoE applications are to be employed.

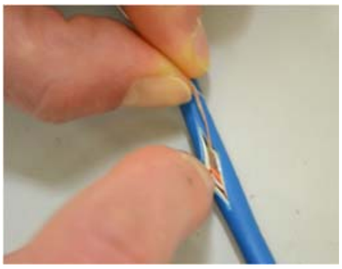
ISO/IEC findings and recommendations

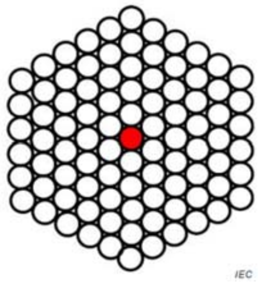
The ISO/IEC have measured the heating of a cable in a cable bundle "in the air" and "in the duct" (photos top right).

To do this a thermocouple was introduced into each cable and this was placed in the centre of the bundle (right-hand photo and drawing).

In Table 2 (top, source: ISO/IEC) the conductor temperature of the cable in the centre of the cable bundle is shown as a function of the conductor cross-section (= cable category), the number of cables in the bundle and the installation environment. Here all the pairs in all the cables of the bundle carry a current of 500mA per conductor.

In order to simplify installation practice as much as possible, the standard recommends a maximum of 37 cables per bundle throughout. If the cable properties, the installation environment and the effective PoE landscape are included in the planning process, however, other bundle sizes are also acceptable.





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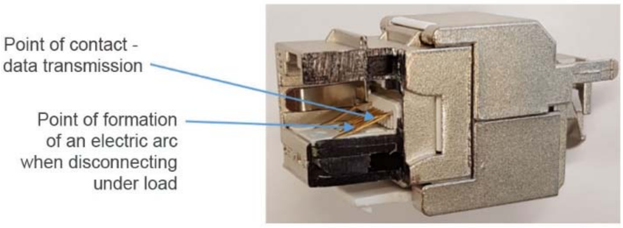
Connections disconnect under load

Like the RJ45 module, the RJ45 connector was originally developed for the transmission of electrical data signals. The RJ45 connection technology was only used for power transmission in a second phase. This means that it is not designed for power transmission.

As far as was technically possible the power transmission capacity was improved over the years. Despite this, the RJ45 connector reveals weaknesses in contact design, particularly when the link is connected or disconnected under load.

Simply complying with the component standards of the IEC 60603-7 family does not ensure that PoE applications are supported. In the meantime IEC 60512-99-001 established a test regime specifically for this purpose, in which the insertion and removal of the RJ45 connection is tested under load. Only products with this seal of approval guarantee suitability for PoE applications and the trouble-free operation of remotely powered end devices.

IEC 60512-99-001 recommends switching off the power source each time prior to connecting or disconnecting the RJ45 link.



Section of an RJ45 module in the region of the contact springs

When disconnecting the remotely powered RJ45 connection an electric arc from the connector contacts to the contact springs in the module can occur at the detachment point. The higher the electrical power transmitted, the more marked is this effect. The burn marks on the contacts caused thereby result in an increase in transfer resistance. In order to be able to guarantee data transmission in spite of this, the design is such that the detachment points when disconnecting and the data transmission position when plugged in are geographically separated in the module.

Conclusion and product recommendation

In terms of PoE the following key statements may be made:

- S/FTP cables have better heat dissipation than UTP cables
- AWG22 is more suitable for PoE than AWG24
- Small cable bundles conduct heat better than large ones
- Insulated and enclosed installation spaces (e.g. ducts) hinder heat dissipation
- Only modules certified to IEC 60512-99-001 guarantee the fail-safe operation of PoE applications.

As a result we recommend the following products from the Datwyler portfolio for PoE applications:

Copper data cables:	Article number
CU 7150 4P - FRNC/LS0H - Cat 7$_{A}$	18292500DK*
CU 7702 4P - FRNC/LS0H - Cat 7$_{A}$	17740000DK*

RJ45 modules:	Article number
KS-TC Plus - Cat 6$_{A}$	418069
KS-T Plus 1/8 - Cat 6$_{A}$	418061
MS-C6$_{A}$ 1/8 Cat 6$_{A}$ (Keystone)	309249

Copper patch cables:	Article number
RJ45-Patchkabel - Cat 6$_{A}$	653xxx (various colours)

***** *These cables are also available in fire resistance classes C_{ca} and $B2_{ca}$.*

