

# Power over Ethernet

## IEEE 802.3af

### Introduction

The networking of industrial plants is an important topic in the world of automation and is constantly increasing. Based on the role model of the office networks, Ethernet networking is now moving into the industrial environment and beginning to replace other standards such as Profibus. Various companies now offer networking solutions under the name of Industrial Ethernet. These range from the small entry level switch and modular gigabit switches to Wireless LAN (WLAN) Access Points. To save installation costs and for added flexibility in the networking, the IEEE 802.3af standard was introduced which enables common transmission of data and energy over a network. This means that a single LAN cable will be sufficient in future instead of one cable each for the data network, energy network and telephone network (VoIP). Devices such as IP telephones and access points with PoE functionality are already used successfully in the office environment. Unlike the office network with its star-shaped network structure, industry usually uses a linear network structure. Since the Power over Ethernet (PoE) standard only describes a point-to-point connection, the use of PoE in industry is restricted.

## **Basic principles of PoE**

To save costs in the planning, wiring and installation of networks, the Power over Ethernet (PoE) process was developed and standardized under IEEE 802.3af. The devices are supplied with power directly via the data cable (e.g. via a CAT 5/5e cable up to 100m). PoE makes the network planning flexible and independent of switch cabinets and sockets. There are no extra costs for the electricity and telephone network (VoIP) wiring. The main advantage of Power over Ethernet is that you can save the power supply cable and install devices with Ethernet interface in places of difficult access or in areas in which a lot of cables would be an interference. This saves drastic installation costs on the one hand and increases the fail safety of the connected devices by the use of an uninterruptible power supply (UPS) on the other hand. PoE is mainly used by terminating equipment which consumes little power. The technology is used typically in IP telephones, cameras or wireless transmission devices such as WLAN Access Points or Bluetooth Access Points. But PoE can also be used as a redundant power supply for switches to improve the fail safety of a network. For example the energy supply can be maintained by PoE when the supply voltage to a switch fails so that the network availability is increased considerably. PoE can be used in four-wire and eight-wire networks. Only the phantom power can be used in four-wire networks, both phantom and spare-pair power can be used in eight-wire networks. Power over Ethernet is defined and standardized by the IEEE in the 802.3af standard. Two groups of devices are defined:

1. Power over Ethernet PSE (Power Sourcing Equipment) device acts as a voltage source and supplies PoE PD devices with electricity via the data cable.
  
2. Power over Ethernet PD (Powered Device) device is supplied with current by PoE PSE device via the data cable.

## PD detection and classification

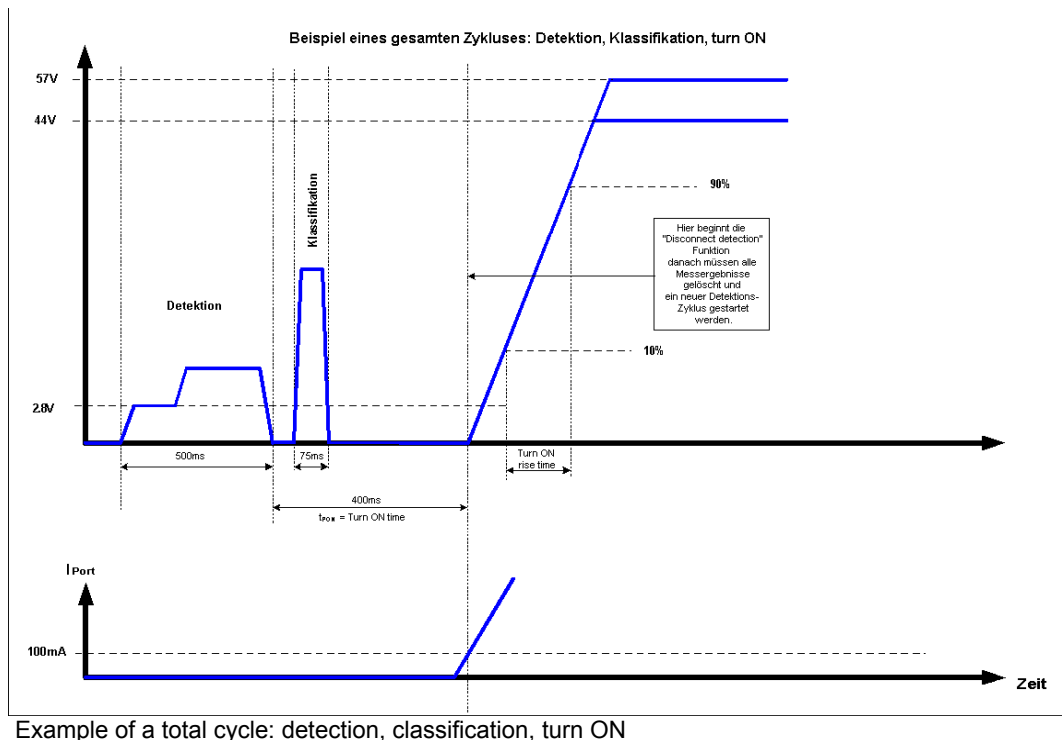
IEEE 802.3af PSE devices have a test mechanism to protect connected incompatible devices from being damaged. Only devices which have an authenticating characteristic based on the IEEE 802.3af standard receive current via the data cable. To determine whether a PD is connected, the following input parameters are checked:

- characteristic resistance =  $R_{GOOD}$  (19k – 26, 5k),
- typical resistance value =  $R_{TYP}$  (25k),
- characteristic capacitance =  $C_{GOOD}$  (max.150nF).

This method is called "Resistive Power Discovery". The detection voltage  $V_{detect}$  must be in the valid range  $V_{valid}$ . The PSE measures the current at two different  $V_{detect}$  voltages at the am Power Interface (PI) of the PD and generates a  $\Delta V_{test}$  and a  $\Delta I_{test}$  from it. The differential input resistance of the PD is then calculated from this. The value of the input resistance is decisive for the decision of the PSE for activating the external feed:

- $R = R_{GOOD} \rightarrow$  PD available
- $R = R_{BAD} \rightarrow$  no PD available.

If the PSE detects a PD it starts classification, i.e. determination of the power requirement of the connected device. For this the PSE applies a defined voltage  $V_{class}$  to the PI of the PD's and measures the resulting current  $I_{class}$ . The PD is assigned to a power class based on the value of the current. Only now the total voltage  $V_{port}$  is supplied to the PI.



pos.	parameters	character	unit	min.	max.	addition information
1	idle - clamping	$V_{OC}$	V		30	just in detections mode
2	short - power	$I_{SC}$	mA		5	just in detections mode
3	valid test clamping	$V_{valid}$	V	2.8	10	
4	classification- clamping	$V_{class}$	V	15.5	20.5	
5	clamping balance between test points	$\Delta V_{test}$	V	1		
6	time between two measurements	$T_{BP}$	Ms	2		at max. f= 500Hz
7	slew rate	$V_{slew}$	V / $\mu s$		0.1	
8	valid signature- resistance	$R_{GOOD}$	K $\Omega$	19	26.5	
9	invalid Signature- resistance	$R_{BAD}$	K $\Omega$	15	33	
10	idle-resistance	$R_{open}$	K $\Omega$	500		
11	valid signature- capacitance	$C_{GOOD}$	nF		150	
12	invalid signature- capacitance	$C_{BAD}$	$\mu F$	10		
13	signature offset voltage tolerance	$V_{OS}$	V	0	2.0	
14	signature offset power tolerance	$I_{OS}$	$\mu A$	0	12	

Table 2.1: PSE PI detection requirements

### PD rejection criteria

- resistance less than or equal  $R_{BAD_{min}}$  ( $\leq 15k$ ) or
- resistance greater than or equal  $R_{BAD_{max}}$  ( $\geq 33k$ ) or
- capacitance greater than or equal  $C_{BAD_{min}}$  ( $\geq 10\mu F$ )

### PoE power classes

In the IEEE 802.3af the power of the voltage supply on the PSE side (see table 2.2) and the current consumption of the PD on the PSE side (see table 2.3) is divided into five different classes. Due to power losses (see fig.: 2.5) the complete power is no longer available at the PD (see table 2.4).

class	purpose	minimum act level at the exit of PSE
0	default	15.4 watt
1	optional	4.0 watt
2	optional	7.0 watt
3	optional	15.4 watt
4	reserved for future applications	handle as class 0

Table 2.2: PoE PSE power classes

Measured classification power $I_{CLASS}$	classification
0mA bis 5mA	class 0
>5mA and <8mA	class 0 or 1
8mA to 13mA	class 1
>13mA and <16mA	class 0, 1 or 2
16mA to 21mA	class 2
>21mA and <25mA	class 0, 2 oder 3
25mA to 31mA	class 3
>31mA and <35mA	class 0, 3 or 4
35mA to 45mA	class 4
>45mA and <51mA	class 0 or 4
$\geq 51mA$	class 0

Table 2.3: PD classification

Class	purpose	minimum act level at the entry of PD's
0	default	0.44 to 12.95 watt
1	optional	0.44 to 3.84 watt
2	optional	3.84 to 6.49 watt
3	optional	6.49 to 12.95 watt
4	not allowed	reserved for future applications

Table 2.4: PD power classes

parameters	condition	min.	max.	unit
power for class 0	14.5V to 20.5V	0	4	mA
power for class 1	14.5V to 20.5V	9	12	mA
power for class 2	14.5V to 20.5V	17	20	mA
power for class 3	14.5V to 20.5V	26	30	mA
power for class 4	14.5V to 20.5V	36	44	mA

Table 2.5: PoE PD classification, measured at the PD input

### Power losses

The PSE sends a maximum power of 15.4W with 350mA at a minimum voltage of 44V to the PD. A standard Cat5 cable with a length of 100m attains a resistance of approx. 20Ω giving a power loss of approx. 2.45W.

$$R_{CABLE} = (20\Omega || 20\Omega) + (20\Omega || 20\Omega) = 20\Omega$$

$$P_{CABLE} = (350mA)^2 * 20\Omega = 2.45W$$

$$P_{PD} = 15.4W - 2.45W = 12.95W$$

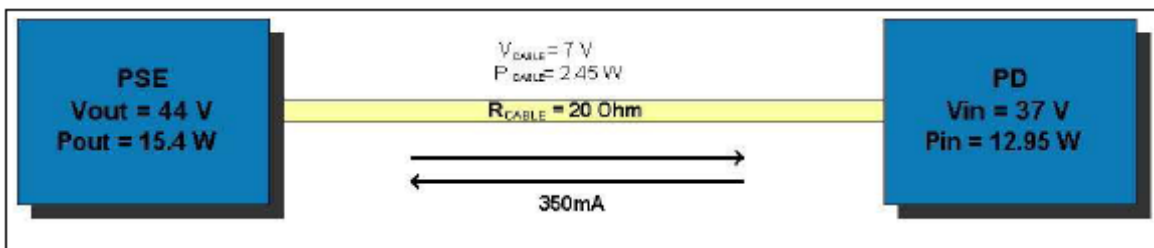


Figure 2.5: Power losses

## Feed locations

When using PoE a distinction must be made between Midspan and Endspan supply.

### Midspan

A Midspan module is a device which can be integrated into an existing network to provide energy on the data lines. A PoE Powered Device (PD) can then be integrated relatively simply into a non-PoE network. This enables easy upgrading of existing networks.

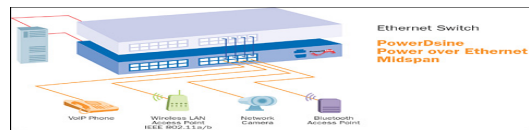


Figure 2.6: PoE Midspan supply

### Endspan

The PSE is already integrated in the switch. This means that the switch can provide PoE at its Ethernet ports so that no Midspan module and no further power supply is necessary.

## Feeding methods

There are two different ways of feeding the voltage to the data cable:

1. Phantom power
2. Spare-pair power

The Power Device has to support both versions, Phantom- and Spare pair power. With the Power Sourcing Equipment it is different, the manufacturer has the choice which version he wants to support.

### Phantom power

In the phantom power the voltage is coupled to the wire pairs 1/2 (-) and 3/6 (+). This method can be used in networks with four-wire or eight-wire wiring.

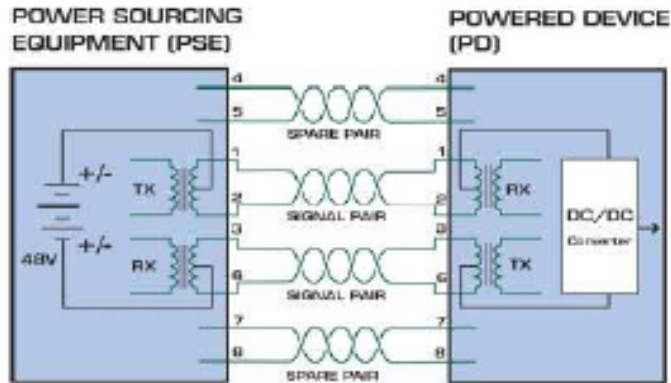


Figure 2.7: Phantom feed

### Spare-pair power

The spare-pair power uses the free wire pairs. The voltage is fed directly to the free wire pairs 4/5 (+) and 7/8 (-). This method can be applied exclusively in networks with eight-wire wiring. This does not apply for Gigabit Ethernet because here all eight wires are used for signal transmission and no spare-pairs are available.

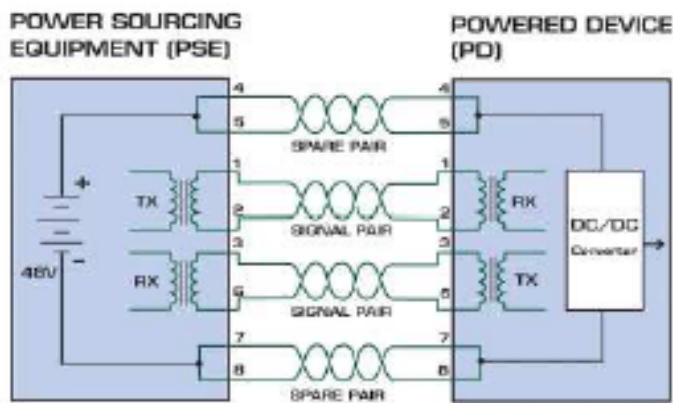


Figure 2.8: Spare-pair feed



## Detection and classification by the example of the PoE Controller MAX5945

The MAX5945 is a four-port Port Power Management Controller made by Maxim. It contains all the necessary circuits (PD detection, classification ...) for setting up a standard-conformant Power Sourcing Equipment.

The MAX5945 can be operated in three different modes.

1. fully automatic
2. semi-automatic
3. manual

The MAX5945 takes over complete control in the fully automatic mode, from detection and classification to connection of the PoE voltage to the respective port.

The semi automatic mode is designed so that the PoE controller takes over the detection and classification but the activation of the PoE voltage must be effected by another controller.

In manual mode the MAX5945 gives the complete control over to another controller.

The wiring and functional principle of the MAX5945 can be described by the example of one PoE-capable RJ45 port.

The detection voltages are applied via the OUT pin and the flowing current is measured via the detection pin (DET). If a valid PD is detected, the classification voltage is applied via OUT and the flowing classification current is measured again at the DET input. The power transistor is only switched on via the GATE output and the full -57 Volts applied to the PD when the power class is determined and is in a valid range.

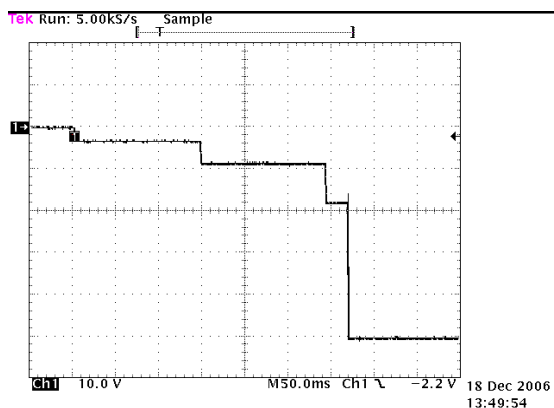


Figure 3.6: Signature of a valid PD's

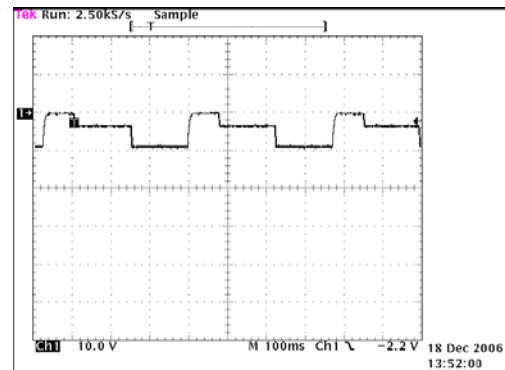


Figure 3.7: Signature of invalid PD's

Fig. 3.6 shows the signature of a valid PD, the two detection phases and the classification are well visible. Fig. 3.7 shows the signature of invalid PD's, it switches off after the detection and a new detection is triggered.

The SENSE pin is linked to a comparator circuit which takes over the control of the port during operation of a PD (DC disconnect). If the connection to the PD is interrupted, i.e. the voltage at the SENSE pin drops below the DC-disconnect threshold for longer than a max. 400ms, the controller switches off the port. The overcurrent switch-off is also controlled with the SENSE pin.

Figure 3.8 shows the wiring of a port of the MAX5945.

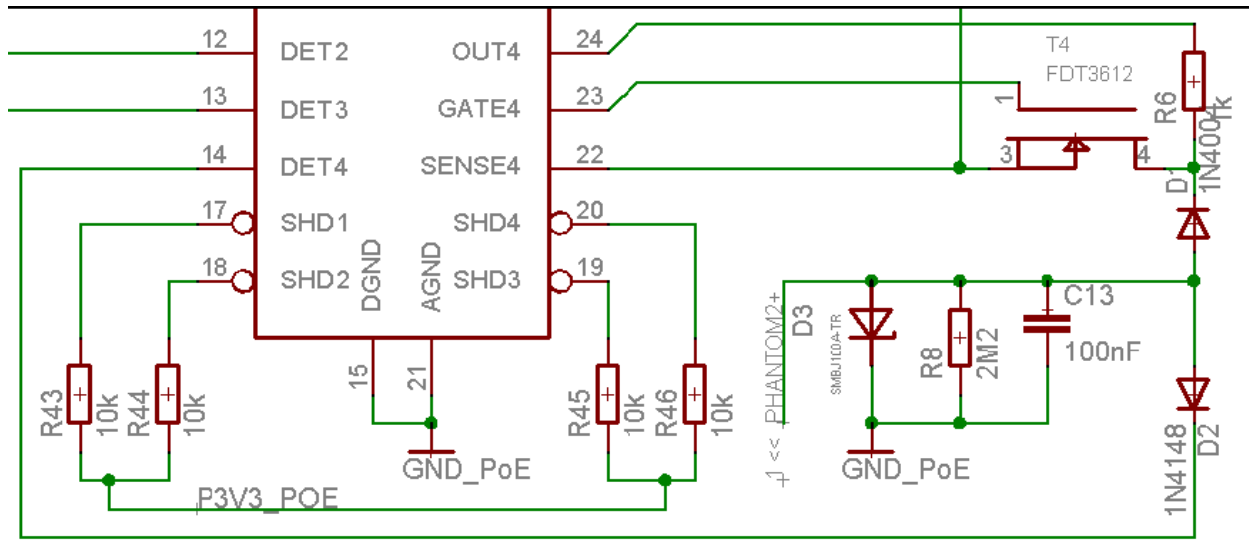


Figure 3.8: Wiring of a PoE port at the MAX5945

## PoE Solutions from Hirschmann

Hirschmann Automation and Control GmbH offers Power over Ethernet solutions from the DIN rail to the backbone. Starting with the MICE modular system which offers a four-port PoE media module, then the PoE compact devices of the OpenRail family which will be launched at the end of 2008. Continuing with Hirschmann's latest series, the MACH1000 PoE switches in the 19" format which are particularly suitable for harsh environments. Our MACH4000 backbone switches can also be fitted with a PoE module and can therefore support up to 32 PoE ports (max. 100W).

Since Power over Ethernet will become increasingly important in the future, our Wireless Lan Access Points of the BAT family can already be supplied via PoE today.