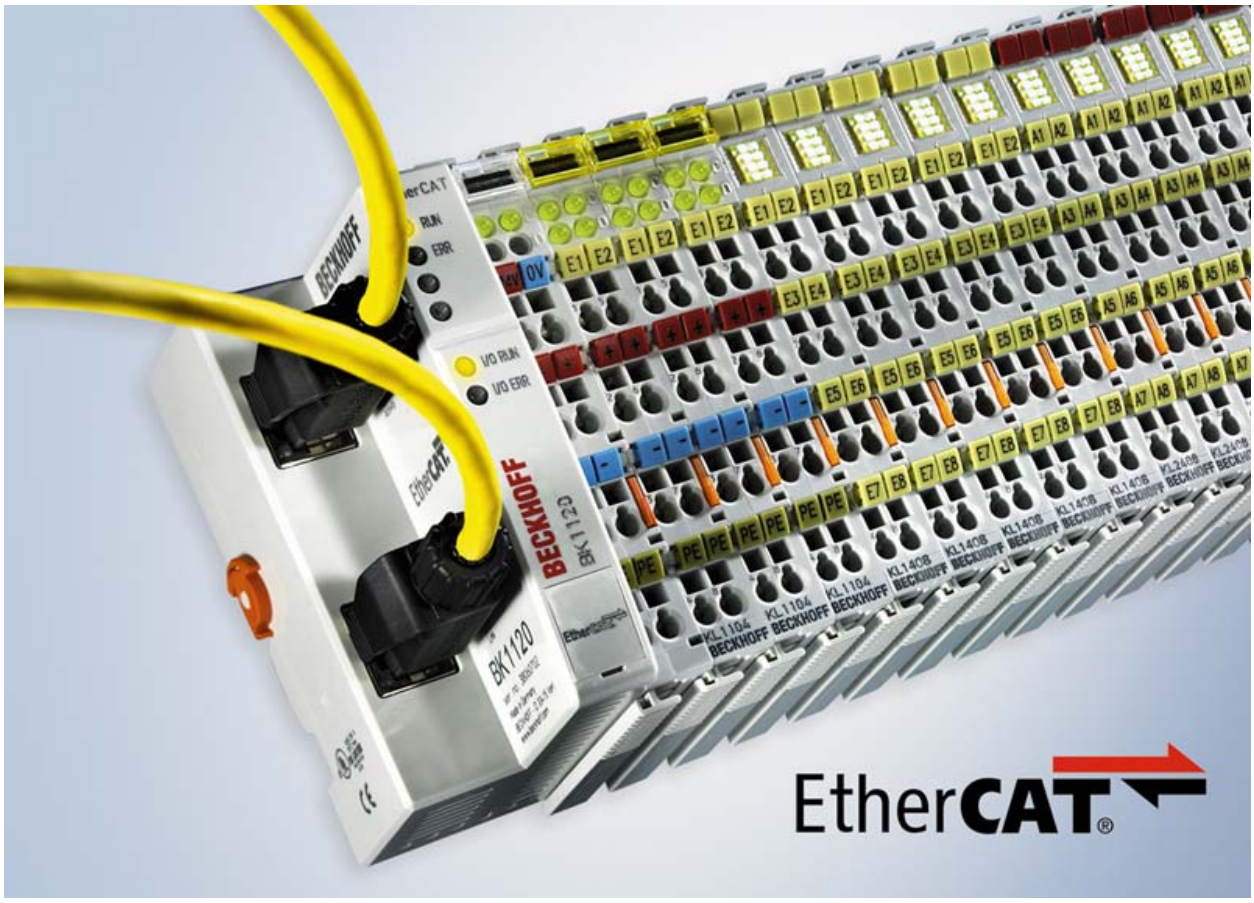


Recommendations for the design of the

Infrastructure for EtherCAT/Ethernet

Version: 1.0.0
Date: 2009-12-23

BECKHOFF

Table of contents

1 Foreword

1.1 Notes on the documentation

1.1.1 Liability conditions

This documentation has been prepared with care. The products described are, however, constantly under development. For this reason, the documentation may not always have been fully checked for consistency with the performance data, standards or other characteristics described. If it should contain technical or editorial errors, we reserve the right to make changes at any time and without notice. No claims for the modification of products that have already been supplied may be made on the basis of the data, diagrams and descriptions in this documentation.

1.1.2 Delivery conditions

In addition, the general delivery conditions of the company Beckhoff Automation GmbH apply.

1.1.3 Brands

Beckhoff®, TwinCAT®, EtherCAT®, Safety over EtherCAT®, TwinSAFE® and XFC® are registered and licensed brand names of Beckhoff Automation GmbH. The use by third parties of other brand names or trademarks contained in this documentation may lead to an infringement of the rights of the respective trademark owner.

1.1.4 Patents

The EtherCAT technology is patent protected, in particular by the following patent applications and patents: DE10304637, DE102004044764, DE102005009224, and DE102007017835 with the corresponding applications and registrations in various other countries.

1.1.5 Copyright

1.2 Safety instructions

This description is only intended for the use of trained specialists in control and automation technology who are familiar with the applicable national standards. It is essential that the following notes and explanations are followed when installing and commissioning these components. The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations, guidelines and standards.

1.2.1 Delivery state

All the components are supplied in particular hardware and software configurations appropriate for the application. Modifications to hardware or software configurations other than those described in the documentation are not permitted, and nullify the liability of Beckhoff Automation GmbH.

1.2.2 Operator's obligation to exercise diligence

The operator must ensure that
- the EtherCAT components are used only for the intended purpose.
- the EtherCAT components are only operated if they are in perfect working order.
- only sufficiently qualified and authorized personnel operate the EtherCAT components.
- none of the safety and warning notes attached to the EtherCAT products are removed, and all notes remain legible.

1.2.3 Description of safety symbols

The following safety symbols are used in this documentation. They are intended to alert the reader to the associated safety instructions.

 **DANGER**	**Serious risk of injury!** **Failure** to follow the safety instructions associated with this symbol directly endangers the life and health of persons.
 **WARNING**	**Risk of injury!** **Failure** to follow the safety instructions associated with this symbol endangers the life and health of persons.
 **CAUTION**	**Personal injuries!** **Failure** to follow the safety instructions associated with this symbol can lead to injuries to persons.
Warning	**Damage to the environment or devices** **Failure** to follow the instructions associated with this symbol can lead to damage to the environment or equipment.
 **Note**	**Tip or pointer** This symbol indicates information that contributes to better understanding.

2 Overview

2.1 Intention

The market is growing for Ethernet as a physical medium for the transport of real time fieldbus protocols in the industrial environment. So that basic network principles from the office area are not applied unreflected to industrial concerns, it is necessary to sensitize planners and users to the technological aspects.

As a real-time protocol, EtherCAT relies on Ethernet as a physical carrier, and is dependent on the long-term stable operation of the Ethernet connection. The underlying high frequency technology was mastered many years ago and is described in the relevant standards. Certified components provide for commissioning without problem and for compatibility.

As with other fast transmission systems, disruptive effects can also occur with the high frequency Ethernet technology in operation or during commissioning if it is used inappropriately. These disruptions are simple to locate or avoid completely if a few basic principles are followed. This documentation is intended to provide users with a guideline, without any obligatory character or legally binding effect, to enable them to plan and design reproducibly reliable Ethernet cabling for the industrial environment.

The topics of installation and testing/acceptance are dealt with in separate documents.

This document makes no claim to be complete and, in particular, does not replace normative installation directives such as ISO/IEC 61784, fundamental communication directives such as ISO/IEC11801/EN50173 or specific installation directives. This document is mainly intended for the European market.

2.2 Summary of the information

Based on the following chapters, the fundamental information is summarized as follows:

Standardized performance classes
These performance classes are defined for Europe in the EN50173-1 standard, e.g. ‘Class D’. If a transmission link verifiably corresponds to a performance class, then it conforms to EN50173. A component manufacturer (cable, connector) can certify its products according to the limit values from EN50173 et al. The exclusive use of components certified to EN50173 may be sufficient to ensure the conformity of the transmission link; in individual cases it must be verified by means of suitable measuring methods according to EN50346.

European and US standards
Distinction must be made between Ethernet components certified according to

- the European standard series: EN50173 (similar to ISO/IEC11801)
- US standard series EIA/TIA 568

The two standards differ slightly and also still use the same terms, such as Cat 5 or Class D. But: components certified in accordance with TIA568 may not be used in cabling installed according to EN50173 – although it will work (in all probability), the cabling or the entire permanent link respectively no longer meets the EN standard [EN50173-3, chapter 1].

Standard series for industrial concerns
Extended standard series (ISO24702, EN51918 et al.) have been drawn up especially for industrial concerns and deal with environmental conditions or with protocol-specific regulations, for example. However, they do not affect the basic electro-technical principles according to EN50173.

Definition of the Ethernet transmission link (channel)
An Ethernet transmission link (channel) is characterized by a (technically related) capability to reliably

guarantee a defined data throughput [Mbit/s] under all defined operating conditions and, hence, high service quality.

Structure of the connecting link
According to EN50173-1, the maximum permissible configuration for an Ethernet link is 90 meters of permanently laid cable plus 2 device connecting cables of 5 meters each, with a maximum of four intermediate connectors. Hence, a total channel length of 100 meters. Other configurations, such as a direct 100 meter long connection, are to be designed in accordance with EN50173-3, appendix B and tested in the field for conformity to the performance class.

Required connection performance
In the EtherCAT application area, only the connection performance of Fast Ethernet (100 Mbit/s) according to EN50173 Class D [up to100 MHz] is required and is dealt with below. It is permissible for the user to demand connection classes with a higher performance (classes E [up to 250 MHz], E_A, F [up to 600 MHz], F_A), but this is not technically justified.

Application-specific cabling
A transmission link for the transmission of Ethernet telegrams can be implemented according to the requirements of these application-neutral standards; however, it does not have to be. It is then considered to be application-specific cabling. Experience has shown that cabling that lies far outside the normative specification also (sometimes) works. If necessary, specifications and restrictions imposed by the component manufacturer are to be observed. Hence, for example, length limitations may typically be defined with regard to certain types of cable. In particular, there are now many industrial Ethernet cables on the market that go beyond the normative specifications and therefore represent application-specific cabling according to the manufacturer's specification. A certification test is to be carried out for the conformity of such a cable section to the connection class.

Reaching agreement
It is recommended that agreement be reached between suppliers and users on the properties and acceptance procedures with regard to the Ethernet cabling used.

Avoidance of borderline cabling
Borderline Ethernet cabling can work reliably under acceptance conditions, but fail under operating conditions (aging, EMC, temperature, movement/impact).

Factors influencing the performance
The performance (i.e. the reliable transmission of 10/100/1000 Mbit/s) of Ethernet cabling generally depends on the following factors:

- the cable quality (attenuation, cross-section, cable structure, screening) of the individual subsections
- the plug quality (fit, screening, cable suitability)
- the number of connectors
- the ambient temperature (20 to 60 °C, specified with derating according to EN50173)
- Environmental influences (e.g. MICE classification according to EN50173-1, chapter 5: Mechanical/Ingress/Climatic/Electromagnetic rating)

Fewest possible connectors
The number of connectors between the end points is to be reduced to the necessary minimum.

Permissible categories
In order to achieve this performance class, only Ethernet components conforming to EN50173 Cat. 5 and higher are permissible (see EN50173-3, chapter 1.2, among others). Components conforming to EN50173 Cat. 5 are thus adequate. When using wall bushings/double couplers, these must conform to EN50173 Cat. 6 in order to achieve performance class D for the entire link.

Use of four-core/two-pair cables
Four-core/two-pair cables are frequently used for industrial Fast Ethernet, as opposed to the fully configured eight-core/four-pair cables normally used in office communication. This is to be considered during the acceptance test.

Cable structure
A paired cable structure is usual in general networking, i.e. each 2 cores used as an electrically differential pair are twisted together as a pair. The pairs created are twisted again and sheathed by a screen if necessary.
Since the electrical characteristic values and mechanical stability are more difficult to guarantee in particular in moving cables (e.g. drag chain operation) when twisting in pairs, total twisting as a star quad with a four-core configuration is preferred in the industrial environment. Cords or separation stars are used as core elements/cores.

Recommended color coding
Color coding based on TIA-568B is recommended for the signals TD+, TD-, RD+, RD- and the screen for a four-core/two-pair industrial Ethernet cable (see chapter 4.2.5).

Recommended cable cross-sections
The following cable cross-sections are recommended for general use:

- Wire structure: stranded or rigid core
- Cross-section: AWG26/7 to AWG22/1 accordingly 7 cores 0.14 mm² (stranded) up to 0.34 mm² rigid. Up to AWG26/19 is in use for highly flexible cables.

Use exclusively screened Ethernet cables
It is recommended to use exclusively screened Ethernet cables according to EN50288-2 (STP, SF/UTP). The screen should contact the connectors over a circumference of 360°.

Avoidance of excessively long ‘patch cables’
Be careful when using so-called ‘patch cables’ with lengths of over 5 meters! Commercially available patch cables are subject to considerably more generous limit values according to EN50173-1, chapter 9 than cables that are intended for fixed installation in accordance with EN50288. Series connection or an over-length configuration is to be avoided and, if necessary, checked at least by verification. A simple continuity test is **not** sufficient!
Application-specific patch cables manufactured from goods sold by the meter are also to be checked for their suitability. In this context, take into consideration any length limitations on the part of the component supplier.

Rigid Ethernet cables are preferable
If possible, it is recommended to employ rigid Ethernet cables instead of stranded cables, because rigid Ethernet cables have the better electrical characteristics ($Attenuation_{stranded}$ > $Attenuation_{rigid}$).

Larger core cross-sections are preferable
If possible, it is recommended to employ larger core cross-sections (e.g. AWG22 instead of AWG26), because larger core cross-sections have the better electrical characteristics ($Attenuation_{thin\ core}$ > $Attenuation_{thick\ core}$). If the length exceeds 50 meters, too small a cross-section (AWG26) can prevent conformity to the performance class!

Check Ethernet cabling before commissioning
It is recommended to check the installed Ethernet cabling before commissioning.

Monitor Ethernet cabling during operation
It is recommended to monitor installed Ethernet cabling during operation using software diagnostic tools (e.g. Beckhoff TwinCAT).

In consideration of the specified standards, a verification decision on a cable section can thus be made as follows:

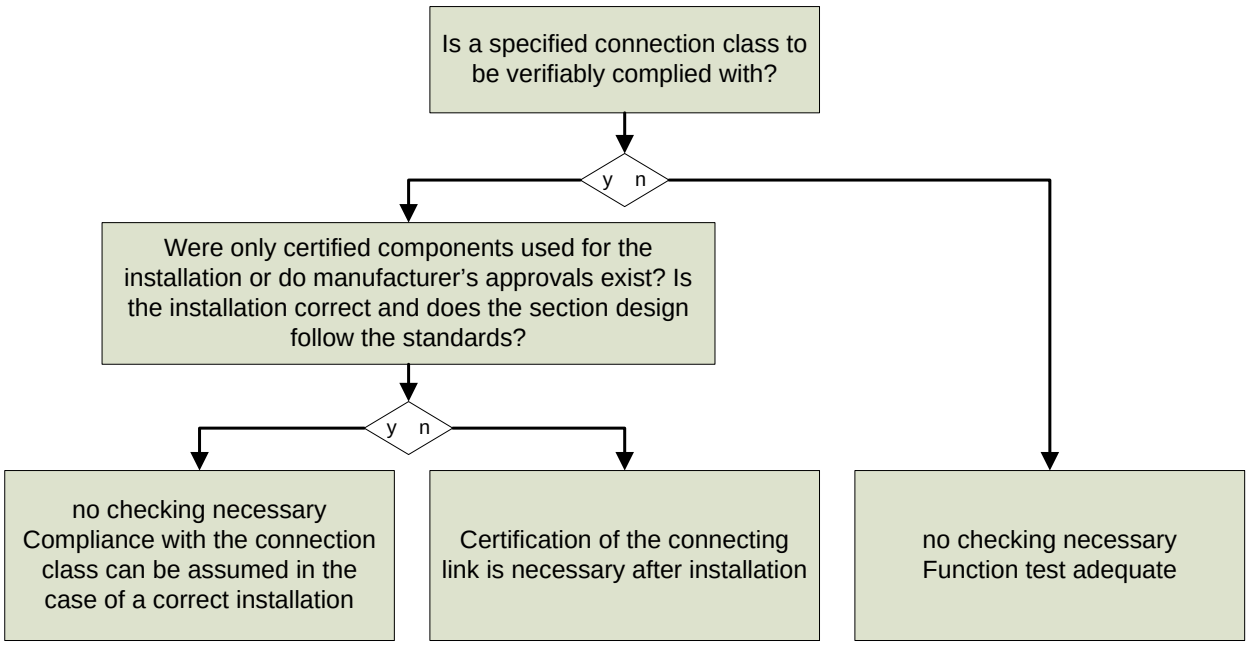


Figure 2-1: Verification decision

3 Basic principles

3.1 Basic Ethernet principles

Ethernet is used at present in different performance classes, depending on the data transfer rate: 10, 100 or 1000 Mbit/s. The Fast Ethernet (100 Mbit/s) dealt with exclusively here as a physical transmission method according to ISO/IEC 8802-3 is characterized as

- type 100Base-TX
- full duplex, hence collision avoidance according to CSMA/CD is not necessary
- use of only 2 of the 4 possible core pairs (cores 1/2 and 3/6). A four-core cable is therefore adequate.
- point-to-point connection between 2 intelligent devices, which dynamically negotiate parts of the connection establishment via the connection ICs

The 100 Mbit/s usable data stream is triple-encoded:

1. 4Bit/5Bit encoding (ISO9314, for clock recovery), results in 125 Mbit/s gross data stream
2. NRZI (Non Return to Zero Inverted) encoding for frequency reduction (a level change means 1_{bin}), results in a maximum frequency of 62.5 MHz.
3. MLT-3 encoding (for frequency reduction, 3 voltage states instead of 2), results in a maximum signal frequency of 31.25 MHz on the cable. The actual frequency depends on the data stream and is thus variable.

Taking into account arising harmonics, a connection performance of the total section is sufficient according to EN50173-1 Class D for signals up to 100 MHz and thus for Fast Ethernet (EtherCAT).

Conversely, Gigabit Ethernet works with a mean signal frequency of 62.25 MHz and needs all 4 core pairs. In principle a fully-configured Class D link is suitable for transmission. However, since all four core pairs are used in Gigabit Ethernet, and in fact bi-directionally at the same time, it is recommended to obtain link certification in accordance with the tightened limit values (crosstalk, return loss) according to ANSI/TIA/EIA-TSB-6 (TIA Cat. 5e).

3.1.1 Establishment of a connection

The simplest way of diagnosing an Ethernet connection is to observe the link display at both end points: if an Ethernet cable is connected at each end to a device, both terminals begin to synchronize themselves or to maintain synchronization by the continuous transmission/reception of a special bit sequence (the idle symbol). This idle symbol consists of the maximum possible number of level changes, since the ‘1’ is transmitted 5 times – the transmission of a ‘1’ means a level change in the NRZI process.

Hence, due to the constant exchange of idle symbols, an Ethernet device that is not operative has a higher current consumption than during normal data traffic!

3.2 Overview of the standard environment

A large number of standards are relevant to Ethernet technology. These standards are concerned with:

- Installation
- Communication protocols
- Mechanical/electrical limit values
- Component definitions:

This document deals with the subsection: which components in which constellation result in the desired performance class for the cable section?

Three normative committees are considered in this introduction:

- ISO: International Organization for Standardization http://www.iso.org
- EN/DIN: Committee for European standards or their German editions through DIN http://www.cenelec.eu
- TIA/EIA: US standards committee http://www.tiaonline.org/

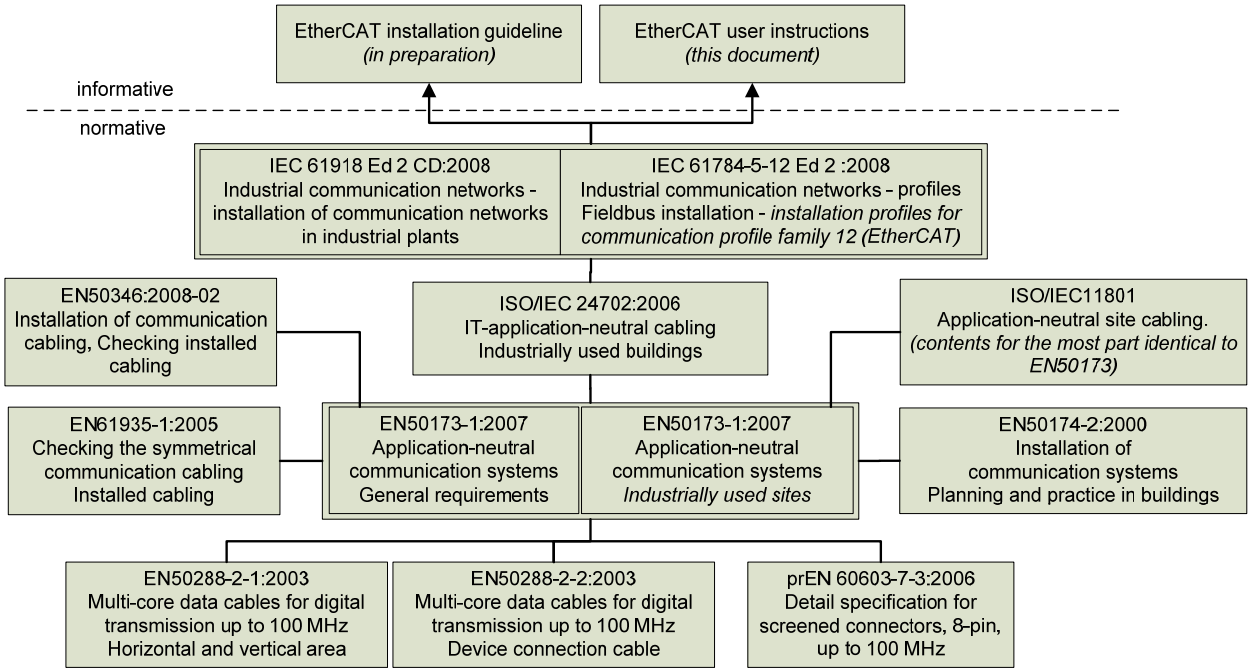


Figure 3-1: Overview of standards (does not claim to be complete)

Table 3-1: References

Standards	Comment
EN50174-2:2000 prEN50174-2:2007	Information technology: installation of communication cabling • Part 2: Installation planning and installation practices in buildings
EN50288-2-1:2003 EN50288-2-2:2003	Multi-core metallic data and control cables for analogue and digital transmission • Part 2-1: Framework specification for screened cables up to 100 MHz Cables for the horizontal and vertical areas • Part 2-2: Device connection cables and switchboard cables
EN60603-7-2 EN60603-7-3	Connectors for electronic facilities • Part 7-2: Detail specification for unscreened free and fixed connectors, eight-pin, for data transmissions up to 100 MHz • Part 7-3: Detail specification for screened free and fixed connectors, eight-pin, for data transmissions up to 100 MHz
EN50173-1:2007 EN50173-3:2007	Information technology; application-neutral communication cable systems • Part 1: General Requirements
IEC24702:2006	Information technology • Application-neutral cabling, industrially used buildings
IEC61784-5-12/WD	Industrial communication networks • Fieldbus installation profiles • Installation profiles for communication profile family 12 (EtherCAT)
IEC61918 Ed.2.0	Industrial communication networks • Installation of communication networks in industrial plants

3.3 Transmission link

General Ethernet cabling (twisted pair) according to DIN EN 50173 is characterized by:

- Maximum 90 meters of permanently laid cable (as per EN50288-x-1) plus two device connection cables, each maximum 5 meters long (as per EN50288-x-2). Results in a maximum total of 100 meters.
- A maximum of four connectors between the end points plus two terminal connectors
- Cable according to EN50288
- Double couplers (for the connection of two RJ45-plugs) are treated separately and normally count as 2 connectors.
- All cables must exhibit the same nominal characteristic impedance: 100 ±5 Ω or 120 ±5 Ω @ 100 MHz

The following illustration shows three models for the sections of a transmission link (channel):

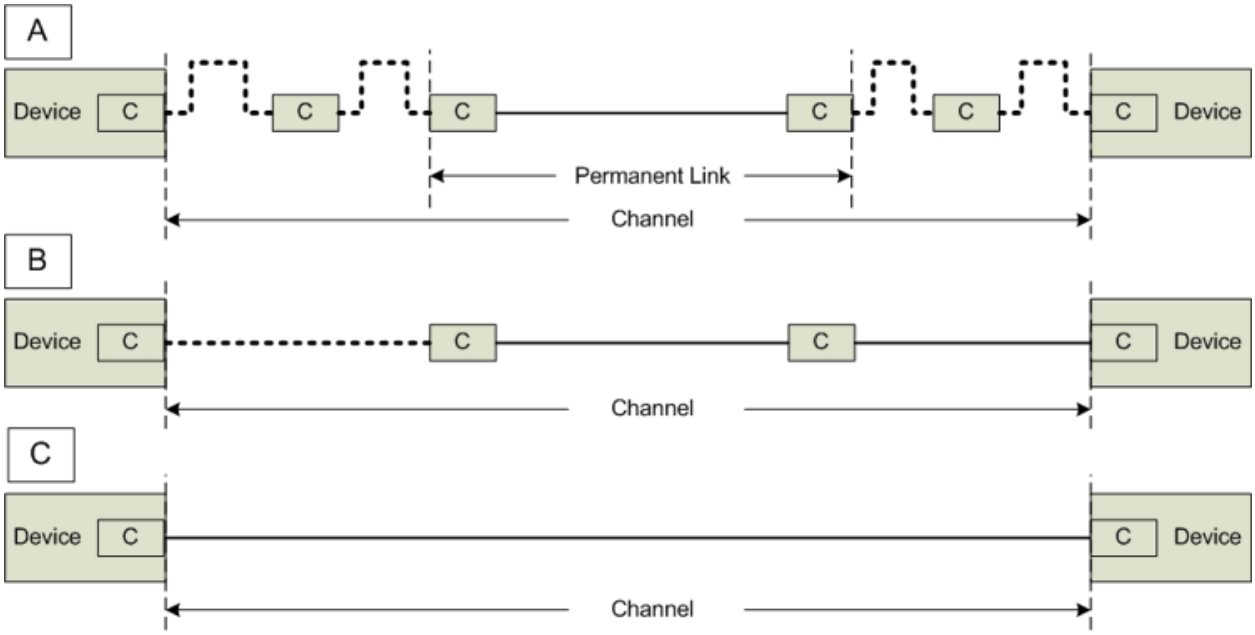


Figure 3-2: Models for the sections of a transmission link (channel):

Model A
Model A illustrates the maximum permissible model according to EN50173-1, consisting of

- maximum 90 m permanent link: permanent link with cable according to EN50288-2-1
- Total of 6 connectors **C**, including the terminal connection points
- Maximum 2 device connection cables (patch cables) according to EN50288-2-2,

Decisive for acceptance tests is that

- a measurement of the permanent link according to EN50173-1, appendix A includes the two connection points
- a measurement of the channel according to EN50173-1, chapter 5 **does not** include the two connection points

The target market of ISO11801/EN50173 ‘Building services-orientated network cabling’ becomes clear from the structure (patch bays, intermediate distributors, floor distributors). The maximum of four connectors can also be distributed in other ways over the cable section, for example in patch bays; see Model B.

Models B and C
Models B and C represent more typical transmission links for the industrial area; they are discussed in EN50173-1 or ISO24702.

3.3.1 Performance of a transmission link

Table 3-2: EN50173-1:2007, chapter 5 defines 8 classes according to the permissible frequency range

Class	SRGK	A	B	C	D	E	F	RuK-S
Frequency range up to	0.1 MHz	100 kHz	1 MHz	16 MHz	100 MHz	250 MHz	600 MHz	1 GHz

Equations according to which the frequency-dependent limit curves (e.g. within the range 1 to 100 MHz, class D) can be calculated are specified for the Ethernet-relevant performance classes D, E and F. Depending on the parameter, the measured value must, if necessary as f(f), remain under or above the limit value curve.

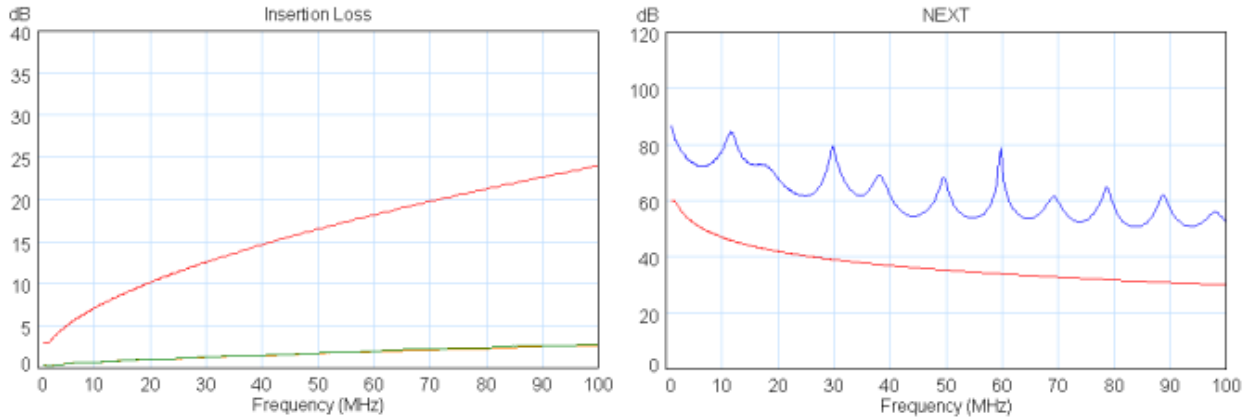


Figure 3-3: Examples of measurements

The illustrations show examples of measurements of insertion losses and crosstalk at the near end of the cable (NEXT, Near End Cross Talk) in comparison to the respective frequency-dependent limit curve (red). The following parameters are defined:

Table 3-3: Overview of parameters according to EN50173-1:2007

German	English	Abbreviation
Rückflussdämpfung	Return Loss	RL
Einfügedämpfung	Insertion Loss, Coupling Attenuation	
Nahnebensprechdämpfung	near end crosstalk loss	NEXT
leistungssummierte Nahnebensprechdämpfung	power sum NEXT	PSNEXT
Dämpfungs-Nebensprechdämpfungs-Verhältnis, nahes/fernes Ende	Attenuation to crosstalk ratio near/far	ACR-N ACR-F
Leistungssummiertes ACR	power sum ACR	PSACR
Ausgangsseitige Fernnebensprechdämpfung	equal level far end crosstalk ratio	ELFEXT
Leistungssummiertes ELFEXT	power sum ELFEXT	PSELFEXT
Gleichstrom Schleifenwiderstand	Resistance	-
Gleichstrom Widerstandsunterschied	Resistance Difference	-
Laufzeit	Propagation Delay	-
Laufzeitunterschied	Delay skew	-
TCL Unsymmetriedämpfung	Transverse Conversion Loss	TCL
Kopplungsdämpfung	Coupling Attenuation	-

3.3.1.1 Extract from characteristic values EN50173 Class D

Table 3-4: selected characteristic values for transmission links according to EN50173-1 class D

Characteristic value	Channel	Permanent Link
Length	max. 100 m	max. 90 m
max. insertion loss [dB @ 100 MHz, 100m]	24 dB	20.4 dB
NEXT [dB @ 100 MHz, 100m]	30.1 dB	32.3 dB
max. propagation delay [ns @ 100MHz]	548 ns	491 ns

Comments

- In the (informative) calculations of the max. limit values in EN50173-1, chapter 5.2, the max. permissible 4 connectors within the channel are assumed.
- A max. signal propagation delay of 548 ns is permitted for EN50173 Class D at 100 MHz. This limits the use of excessively long cables. Even at an assumed NVP_{cable} of 60%, only a channel length of 100 m is still possible.
- All limit values are based on the assumption of an ambient temperature of 20°C. A derating of 0.2%/°C is defined in EN50173 up to the region of 60°C. Hence, cable and connector characteristics worsen as the ambient temperature rises. The maximum permissible channel length therefore reduces as the temperature rises.

Note	**Deviation from the specifications** The specifications of ISO11801/EN50173 quoted above can be deviated from, e.g. by more connectors or cable sections than permissible or by non-conforming cable material. In this case the transmission link must be calculated according to ISO11801/EN50173 and verification/certification is recommended after the installation.

4 Components

4.1 Cable

EN50173-1, chapter 7 requires the use of cables according to EN50288, twisted pairs, for conformity. This includes both screened and unscreened cables. Since screened cables are recommended for EtherCAT cable connections, these will be dealt with exclusively below.

The relevant EN50288-2 standard contains sub-chapters on rigid and flexible cables. Twisted pairs or star quads are allowed as cable structures for both cables. The star quad is more advantageous: mechanically more stable (moving application, transverse compressive strength), lower space requirement, better NEXT values.

Since cable development has undergone technological progress since the creation of these standards, there are now numerous cables suitable for Ethernet communication on the market which

- have the required electrical characteristics as per EN50173ff as a specification, but which
- do not meet or exceed individual (mechanical) specifications according to EN50288.

Such cables are identified, for example, by the remark ‘Similar to Cat.5’ in the data sheet and can be used according to the manufacturer’s specifications – this is then a case of application-specific cabling, which can be subjected to a certification test after the installation if necessary.

These standards contain, for example, the following data:

EN50288-2-1:

- Purpose: screened cables -100 MHz, permanently installed for horizontal/vertical areas
- ‘Rigid wire structure’, solid copper conductors
- Cross-section corresponds approx. to AWG24 to 21
- Insertion loss max. **21.3 dB** /100 m at 100 MHz
- DC loop resistance < 19 Ω / 100 m

EN50288-2-2:

- Purpose: screened cables -100 MHz, device connection cable
- ‘Flexible wire structure’, stranded wire – single or multi-strand conductors
- Insertion loss max. **32 dB** /100 m at 100 MHz
- DC loop resistance < 29 Ω / 100 m

The data are valid for 20°C. Correction calculations can be performed for other ambient temperatures according to the standard specification.

In addition, cables can be approved by the manufacturer according to the MICE classification as per EN50173-1, chapter 5 or appendix G for the ambient conditions specified therein.

Note	**Patch cables and attenuation** As can be seen from the technical data above, it is not possible to achieve an EN50173 Class D channel with its permissible insertion loss of 24 dB / 100 m at 100 MHz using a patch cable certified according to EN50288-2-2. The use of patch cables (according to EN50288-2-2) with a length of over 10 meters or the series connection of such cables is to be provided for only in acknowledgment of the technological restrictions.

For the combination of cable and plug, the class of the fully assembled patch cables with permissible limit values is defined in EN50173-1, chapter 9.

Note	**Screening** An existing screen may increase the insertion loss of a cable among other things. This effect will only be noticeable in the case of great lengths. If the acceptance of a cable section fails for this reason, it is preferable, for example, to use larger core cross-sections rather than dispensing with screened cables. A screen also improves the return loss RL.

IEC61784-5-12 refers to this in its 'Installation profile for EtherCAT networks' by specifying a max. connection length of 100 m using AWG22 cable (note: type EN50288-2-1).

4.1.1 Cable structure

Cable cross-sections measured according to AWG (American Wire Gage) are specified in the form AWGxx/y, where xx stands for the cross-section and y for the number of cores. Examples:

- AWG22/1 means cross-section AWG22, one core
- AWG22/7 means total cross-section AWG22, seven cores

The cable structure according to ISO/IEC11801 is specified as follows:

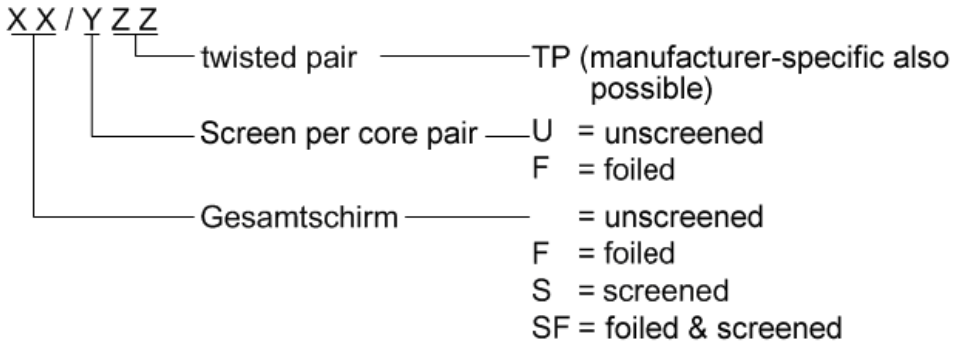


Figure 4-1: Cable structure according to ISO/IEC11801

Note	**Screening recommendation** The exclusive use of overall screened transmission links is recommended, e.g. SF/FTP, S/FTP or SF/UTP. Ensure the correct connection of the screen in the terminal devices!

Note	**Auto-crossing** Due to automatic cable detection (auto-crossing) symmetric (1:1) or cross-over cables can be used between EtherCAT devices from BECKHOFF.

4.1.2 Recommended cables

Beckhoff recommends the following cables for use in EtherCAT systems.

Note	**Data sheets and documentation on cables** Please refer to the associated data sheets and documentation for the technical data of the cables recommended here; these are available for download on our website (www.beckhoff.com).

4.1.2.1 Sold by meter

Table 4-1: Sold by meter

Designation	Cable
ZB9010	Industrial Ethernet/EtherCAT cable, fixed installation, CAT 5e, 4-wires
ZB9020	Industrial Ethernet/EtherCAT cable, suitable for drag chains, CAT 5e, 4-core
ZB9030	EtherCAT/Ethernet cable, PVC, screened
ZB9031	EtherCAT/Ethernet cable, PUR, suitable for drag chains, screened
ZB9032	EtherCAT/Ethernet cable, PUR, suitable for drag chains, Highflex

4.1.2.2 EtherCAT patch cable

ZK1090-9191-xxxx

Table 4-2: EtherCAT patch cable, 2 x RJ45 plug

Designation	Length
ZK1090-9191-0001	0.17 m
ZK1090-9191-0002	0.26 m
ZK1090-9191-0005	0.5 m
ZK1090-9191-0010	1.0 m
ZK1090-9191-0020	2.0 m
ZK1090-9191-0030	3.0 m
ZK1090-9191-0050	5.0 m
ZK1090-9191-0100	10.0 m

Please refer to the catalogue, the price list or our website (www.beckhoff.com) for the available lengths.

4.1.2.3 EtherCAT cable with M12 connectors

Table 4-3: EtherCAT cable, 2 x M12 connectors (D-coded), fully assembled

Designation	Length
ZK1090-6161-0005	0.5 m
ZK1090-6161-0010	1.0 m
ZK1090-6161-0020	2.0 m
ZK1090-6161-0025	2.5 m
ZK1090-6161-0050	5.0 m
ZK1090-6161-0100	10 m

Please refer to the catalogue, the price list or our website (www.beckhoff.com) for the available lengths.

Table 4-4: EtherCAT cable, M12 flange – RJ45 plug, fully assembled

Designation	Length
ZK1090-6292-0005	0.5 m
ZK1090-6292-0020	2.0 m
ZK1090-6292-0050	5.0 m
ZK1090-6292-0100	10 m

Please refer to the catalogue, the price list or our website (www.beckhoff.com) for the available lengths.

4.1.2.4 EtherCAT cable, PVC, with M8 connectors

Table 4-5: EtherCAT cable, PVC, fully assembled, 2 x M8 connector

Designation	Length
ZK1090-3131-0020	2.0 m
ZK1090-3131-0030	3.0 m
ZK1090-3131-0040	4.0 m
ZK1090-3131-0050	5.0 m
ZK1090-3131-0075	7.5 m
ZK1090-3131-0100	10 m
ZK1090-3131-0150	15 m
ZK1090-3131-0200	20 m
ZK1090-3131-0250	25 m
ZK1090-3131-0300	30 m
ZK1090-3131-0350	35 m
ZK1090-3131-0400	40 m
ZK1090-3131-0450	45 m
ZK1090-3131-0500	50 m

Please refer to the catalogue, the price list or our website (www.beckhoff.com) for the available lengths.

Table 4-6: EtherCAT cable, PVC, 1 x M8 connector, 1 x RJ45, fully assembled

Designation	Length
ZK1090-3191-3020	2.0 m
ZK1090-3191-3050	5.0 m

Table 4-7: EtherCAT cable, PVC, 1 x M8 connector, 1 x open end

Designation	Length
ZK1090-3100-3020	2.0 m
ZK1090-3100-3050	5.0 m

Please refer to the catalogue, the price list or our website (www.beckhoff.com) for the available lengths.

4.1.2.5 EtherCAT cable, PUR, Highflex, with M8 connectors

Table 4-8: EtherCAT cable, PUR, Highflex, 2 x M8 connector, fully assembled

Designation	Length
ZK1090-3131-0001	0.15 m
ZK1090-3131-0003	0.3 m
ZK1090-3131-0005	0.5 m
ZK1090-3131-0010	1.0 m
ZK1090-3131-0020	2.0 m
ZK1090-3131-0030	3.0 m
ZK1090-3131-0040	4.0 m
ZK1090-3131-0050	5.0 m
ZK1090-3131-0075	7.5 m
ZK1090-3131-0100	10 m
ZK1090-3131-0150	15 m
ZK1090-3131-0200	20 m
ZK1090-3131-0250	25 m
ZK1090-3131-0300	30 m
ZK1090-3131-0350	35 m
ZK1090-3131-0400	40 m
ZK1090-3131-0450	45 m
ZK1090-3131-0500	50 m

Please refer to the catalogue, the price list or our website (www.beckhoff.com) for the available lengths.

Table 4-9: EtherCAT cable, PUR, Highflex, 1 x M8 connector, 1 x RJ45, fully assembled

Designation	Length
ZK1090-3191-0020	2.0 m
ZK1090-3191-0050	5.0 m

Please refer to the catalogue, the price list or our website (www.beckhoff.com) for the available lengths.

Table 4-10: EtherCAT cable, PUR, Highflex, 1 x M8 connector, 1 x open end

Designation	Length
ZK1090-3100-0020	2.0 m
ZK1090-3100-0050	5.0 m

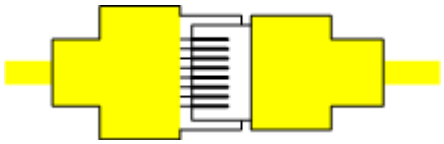
Please refer to the catalogue, the price list or our website (www.beckhoff.com) for the available lengths.

Note	**Further cables** Information about further versions and lengths can be found on our website (www.beckhoff.com) and in the price list.

4.2 Plug connector

4.2.1 Transition points

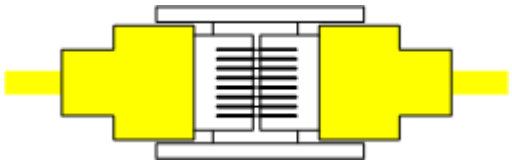
Each transition point negatively affects the entire transmission link due to attenuation, reflection and crosstalk between the cable pairs. Therefore the number of permissible transition points for a channel conforming to EN50173 is limited to six.



A simple plug/socket transition has **one** transition point between the two cables.

Figure 4-2: simple plug/socket transition

Figure 4-3: simple plug/socket transition



A double coupler has **two** transition points between the two cables.

Figure 4-4: Double coupler

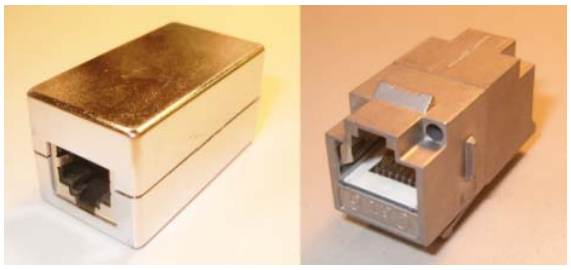


Figure 4-5: Double couplers; left Cat. 5, plastic; right: Cat. 6, all metal

Note	**Use double couplers in accordance with Cat. 6** In order for the performance of a transmission link to conform to EN50173 Class D, for which only Cat. 5 components are normally required, double couplers, if used, must be Cat. 6 compliant (see EN50173-3, appendix B).

4.2.2 Designs

The connection equipment for Fast Ethernet must meet the electrical and mechanical requirements of EN50173 Class D. Backwards compatibility thereby exists. Higher class connection equipment can also be used for achieving Class D.
The plug components can be approved by the manufacturer according to the MICE classification as per EN50173-1, chapter 5 or appendix G for the ambient conditions specified therein.

The connector substantially affects the electrical characteristics of the transmission link, in particular the parameters screening effect, attenuation, cross talk and return loss. For transmission link design, an insertion loss of 0.4 dB (EN50173-1, appendix A) is roughly assumed for a single connector.

The following mating faces are in use for Class D:

EN60607: RJ45

Figure 4-6: Connector according to EN60603-7, for field assembly,
left: four-pin, compatible with Fast-Ethernet*,
right: eight-pin, suitable for Gigabit Ethernet

*) A four-core configuration according to TIA-568B is adequate for Fast Ethernet (100 Mbit/s).

EN61076-2-101: M12

Figure 4-7: Connector EN61076-2-101, type D, four-pin, screened

EN61076-2-101: M8

Figure 4-8: Connector EN61076-2-101, four-pin, screened

4.2.3 Recommended connectors

Beckhoff recommends the following connectors for use in EtherCAT systems.

Table 4-11: Recommended connectors, overview

Designation	Connector
ZS1090-0003	RJ45 connector, 4-pin, IP 20, for field-assembly
ZS1090-0005	RJ45 connector, 8-pin, IP 20, for field-assembly, suitable for Gigabit Ethernet
ZS1090-0004	M12 connector, 4-pin, IP67, for field-assembly, d-coded
ZS1090-0006	M8 connector, 4-pin, IP67, for field-assembly

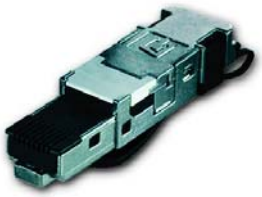
Note	**Data sheets and documentation on connectors** Please refer to the associated data sheets and documentation for the technical data of the connectors recommended here; these are available for download on our website (www.beckhoff.com).

ZS1090-0003

RJ45 connector, 4-pin, IP 20,
for field-assembly

ZS1090-0005

RJ45 connector, 8-pin, IP 20,
for field-assembly, suitable for Gigabit Ethernet



ZS1090-0004

M12 connector, 4-pin, IP67,
for field-assembly, d-coded

ZS1090-0006

M8 connector, 4-pin, IP67,
for field-assembly

4.2.4 Recommended control cabinet feed-throughs

ZK1090-6292-0000

M12 socket on RJ45 socket,
straight outlet

ZK1090-6294-0000

M12 socket on RJ45 socket,
90° angled outlet

Note	**Fewest possible transition points** Give preference to control cabinet feed-throughs with only one transition point, i.e. simple plug/socket transition (see ZK1090-6292, page 19)!

4.2.5 Other connectors

Connectors other than those specified above can also be used. These must then meet the electrical and mechanical requirements according to EN50173-1:2007, appendix D.

Table 4-12: Assignment

Signal	Comment	RJ45	M12	Cable colour as per TIA-568B	Cable colour as per EN61918
TD+	Transmit data +	1	1	WH/OG	YE
TD-	Transmit data -	2	2	OG	OG
RD+	Receive data +	3	3	WH/GN	WH
RD-	Receive data -	6	4	GN	BU
-	3rd pair +	4	-	BU	-
-	3rd pair -	5	-	WH/BU	-
-	4th pair +	7	-	WH/BN	-
-	4th pair -	8	-	BN	-
Screen	Screening	Housing	Housing	n.def.	n.def.

WH=white, OG=orange, GN=green, BU=blue, BN=brown, YE=yellow

5 Appendix

5.1 Support and Service

Beckhoff and their partners around the world offer comprehensive support and service, making available fast and competent assistance with all questions related to Beckhoff products and system solutions.

5.1.1 Beckhoff's branch offices and representatives

Please contact your Beckhoff branch office or representative for local support and service on Beckhoff products!
The addresses of Beckhoff's branch offices and representatives round the world can be found on her internet pages: http://www.beckhoff.com
You will also find further documentation for Beckhoff components there.

5.1.2 Beckhoff company headquarters

Beckhoff Automation GmbH
Eiserstr. 5
33415 Verl
Germany

Phone: + 49 (0) 5246/963-0
Fax: + 49 (0) 5246/963-198
E-mail: info@beckhoff.com
Web: www.beckhoff.com

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