EtherCAT |
Cutting Costs with High-speed Ethernet

High performance Motion Control
Open interfaces
Fieldbus integration

EtherCAT | Industrial Ethernet

Modular automation Flexible topologies
Safety Condition monitoring Redundancy
Small and medium control technology Scientific Automation

Redundancy

Measuring te
High-speed co
Modular a

EtherCAT®

The real-time Ethernet fieldbus for automati

➔ **Real-time Ethernet down to the I/O level**

➔ **Low system costs**

➔ **Flexible topology**

➔ **Maximum performance**

➔ **Easy configuration**

➔ **Legacy fieldbus integration supported**

➔ **Integrated safety devices**

➔ **Large selection of components**
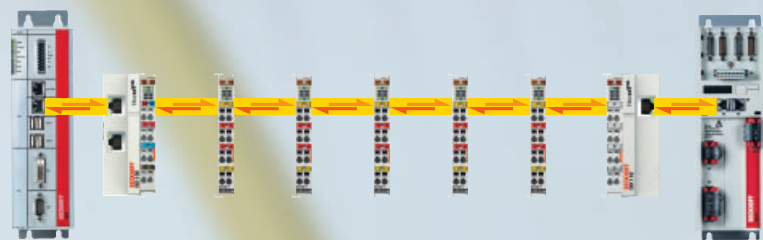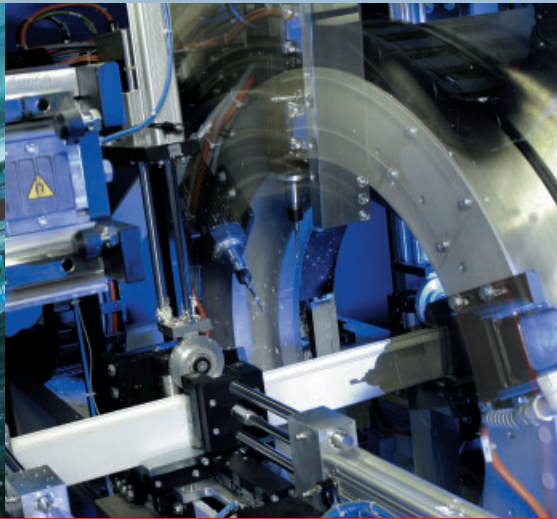
➔ **Outstanding diagnostics**
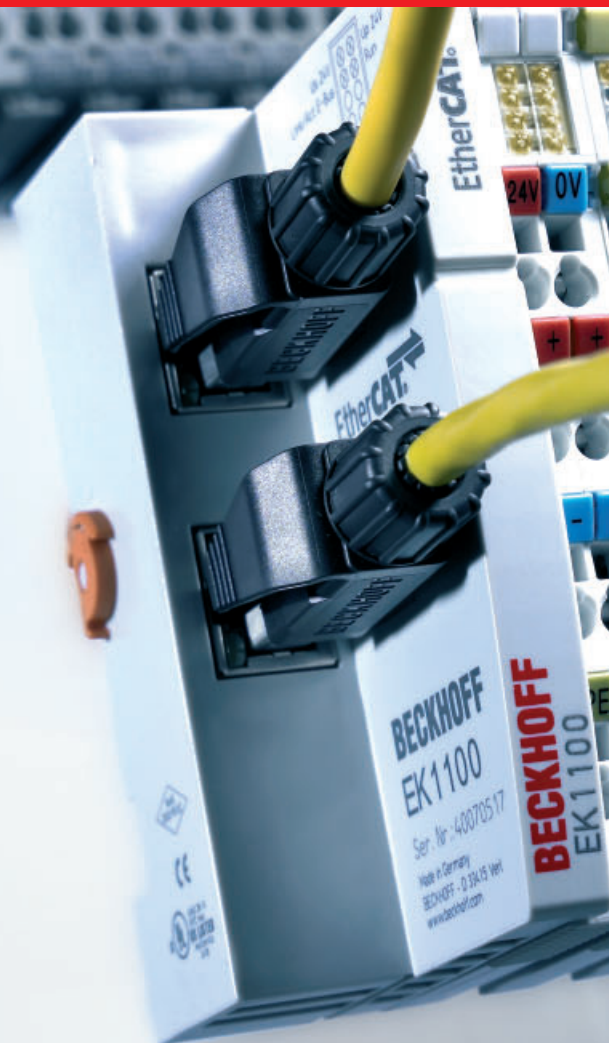
EtherCAT®
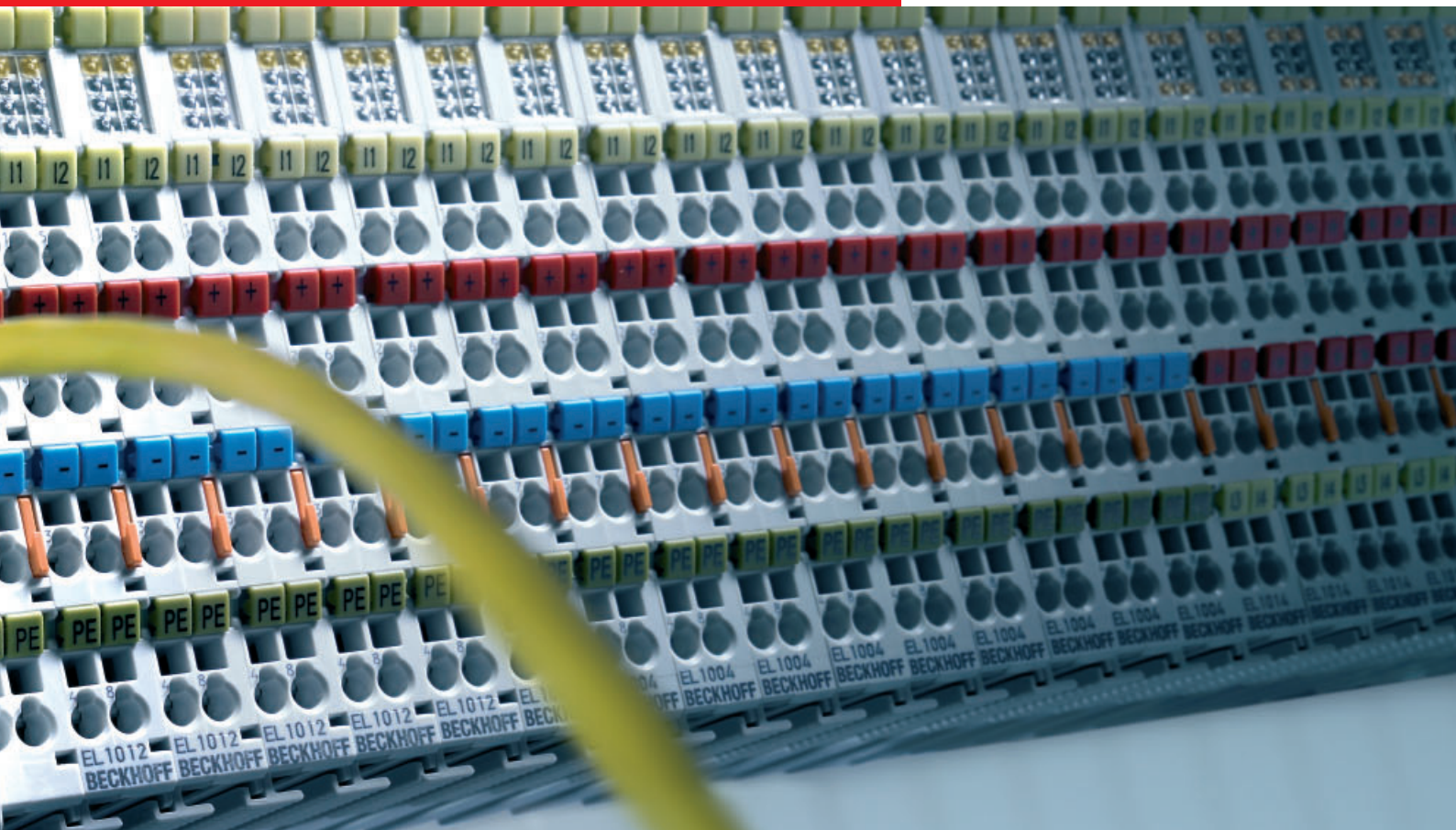
Ethernet down to the terminal | Full duplex Ethernet in the ring, one telegram for many devices, connection directly at the standard Ethernet port.
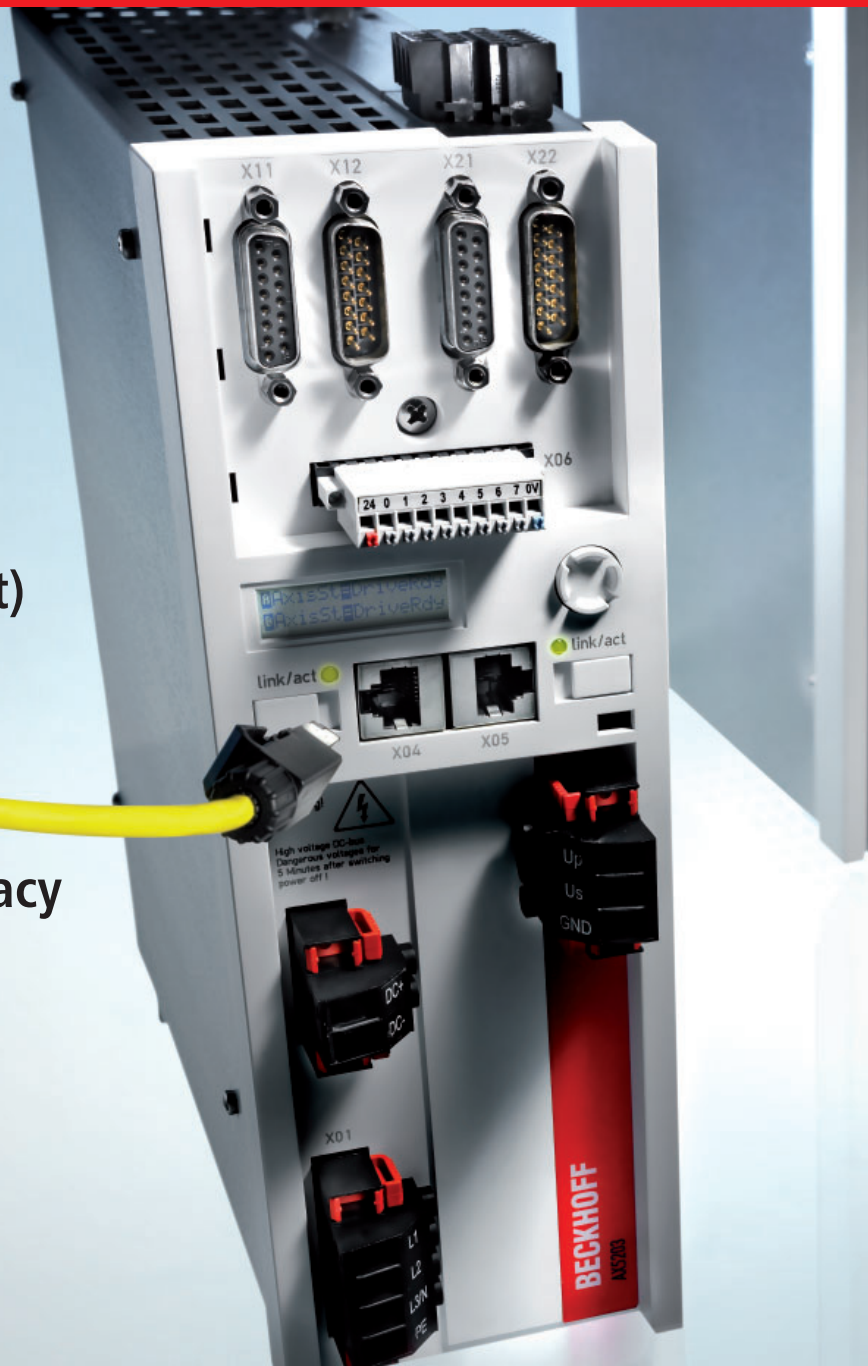
BECKHOFF New Automation Technology

Fast, flexible, precise, cost-optimised | Ideal

➜ **1,000 digital I/Os every 30 μs**

➜ **200 analog I/Os (16 bit) every 50 μs**

➜ **100 servo axes every 100 μs**

➜ **Synchronisation accuracy better than 1 μs**

➜ **Straightforward parameterisation**

WWW. **beckhoff.com/EtherCAT**

EtherCAT (Ethernet for Control Automation Technology) is the ideal Ethernet solution for industrial automation, characterised by outstanding performance and particularly simple handling.

for any application

EtherCAT®

Highlights
– Ethernet down to the terminal – complete continuity
– Ethernet process interface, scalable between 1 bit and 60 kbyte

Topology
– line, tree or star topology, up to 65,535 devices
– network size: almost unlimited (> 500 km)
– hot connect/disconnect of bus segments

Cost benefits
– no more network tuning: lower engineering costs
– Hard real-time with software master: no plug-in cards required
– no active infrastructure components (switches, etc.) required
– Ethernet cable and connector costs lower than for traditional fieldbuses
– EtherCAT right down to the I/O terminal: no complex Bus Couplers required
– low interface costs due to highly integrated EtherCAT Slave Controller

Protocol
– optimised protocol directly within the Ethernet frame, dynamic processing
– fully hardware-implemented, independent of stack performance
– distributed clock for accurate synchronisation
– time stamping and oversampling for high-resolution measurements

Interfaces
– switch port terminal for standard Ethernet devices
– fieldbus terminals for fieldbus devices
– communication gateways

Openness
– fully Ethernet-compatible
– operation with switches and routers possible, but not required
– mixed operation with other protocols also possible
– Internet technologies (Web server, FTP, etc.)
– EtherCAT is IEC, ISO and SEMI standard.
– supported by the EtherCAT Technology Group, the world's largest organisation devoted solely to Industrial Ethernet

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Real-time Ethernet: Ultra high-speed right up to the terminal

Outstanding performance, flexible topology and simple configuration characterise EtherCAT (Ethernet for Control Automation Technology), the real-time Ethernet technology from Beckhoff. EtherCAT sets new standards where conventional fieldbus systems reach their limits: 1,000 distributed I/Os in 30 µs, almost unlimited network size, and optimum vertical integration thanks to Ethernet and Internet technologies. With EtherCAT, the costly Ethernet star topology can be replaced with a simple line or tree structure – no expensive infrastructure components are required. All types of Ethernet devices can be integrated via a switch or switch port.

Where other real-time Ethernet approaches require special master or scanner cards, EtherCAT manages with very cost-effective standard Ethernet interface cards.

Principle of operation

With EtherCAT technology, Beckhoff overcomes the system limitations of other Ethernet solutions: The process no longer involves consecutive steps for receiving and interpreting telegrams and copying the process data. In each device (down to the I/O terminals) the EtherCAT Slave Controller reads the data relevant for the device while the frame passes through it. Similarly, input data is inserted into the data stream on the fly. While the frames (delayed by only a few bit times) are already passed on, the slave recognises relevant commands and executes them accordingly. The process is hardware-implemented in the slave controller and is therefore independent of the protocol stack software run-times or the processor power. The last EtherCAT slave in the segment returns the fully processed frame, so that the first slave device forwards it to the master as a kind of response telegram.

Ethernet down to the terminal

The Ethernet protocol remains intact right down to the individual devices, i.e. down to the individual I/O terminals; no sub bus is required. Only the physical layer is converted in the coupler from 100BASE-TX or -FX to E-bus, in order to meet the requirements of the electronic terminal block. The E-bus signal type (LVDS) within the terminal block is nothing proprietary, it is also used for 10 Gbit Ethernet. At the end of the terminal block, the physical bus characteristics are converted back to the 100BASE-TX standard.

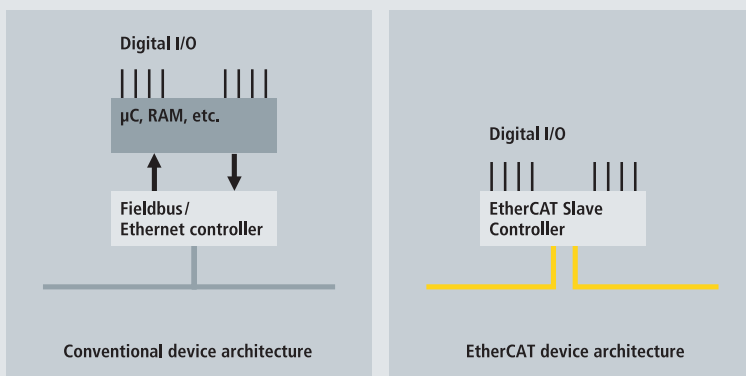The on-board Ethernet MAC is sufficient as hardware in the master device. DMA (direct memory access) is used for data transfer to the main memory. That means that the network data access burden is lifted from the CPU. The same principle is also used in the Beckhoff multi-port cards, which bundle up to four Ethernet channels on one PCI slot.
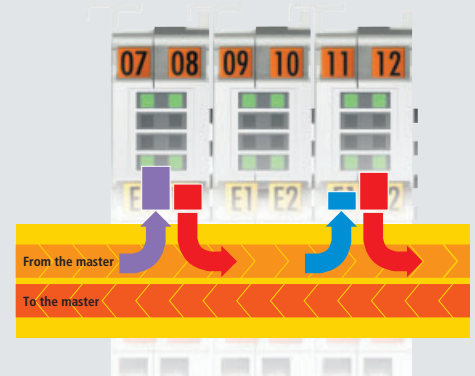
Distributed clocks

Accurate synchronisation is particularly important in cases where spatially distributed processes require simultaneous actions.

The most powerful approach for synchronisation is the accurate alignment of distributed clocks. With EtherCAT, the data exchange is fully based on a pure hardware machine. Since the communication utilises a logical (and thanks to full-duplex Fast Ethernet also physical) ring structure, the "master clock" can determine

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EtherCAT Slave Controller (ESC) | EtherCAT is not only faster outside the I/O device, but also inside. Digital I/Os are directly operated by the EtherCAT Slave Controller, without delays through local firmware and independent of the installed µC performance.

Optimised protocol | Telegram processing completely in hardware

Digital I/O

µC, RAM, etc.

Fieldbus / Ethernet controller

Conventional device architecture

Digital I/O

EtherCAT Slave Controller

EtherCAT device architecture

07 08 09 10 11 12

From the master

To the master

the run-time offset to the individual "slave clocks" simply and accurately. The distributed clocks are adjusted based on this value, which means that a very precise network-wide timebase with a jitter of significantly less then 1 microsecond is available.

However, high-resolution distributed clocks are not only used for synchronisation, but can also provide accurate information about the local timing of the data acquisition. Thanks to new, extended data types, very precise time stamps can be assigned to measured values.

Safety over EtherCAT
In the interest of achieving safe data communication with EtherCAT, the Safety over EtherCAT protocol has been created. The protocol meets the requirements of IEC 61508 up to Safety Integrity Level (SIL) 3, as approved by the
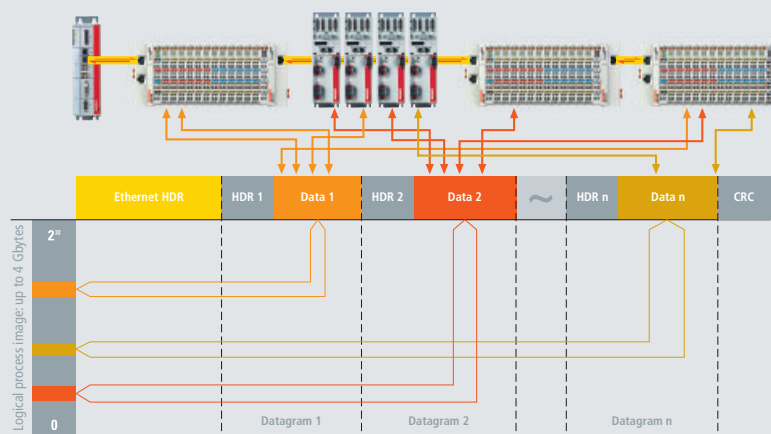
German Technical Inspection Agency (TÜV).

EtherCAT is used as a single-channel communication system. The transport medium is regarded as a "black channel" and is not included in the safety considerations. Thus, the protocol can also be transmitted by other communication systems, backplanes, WLAN, etc. The transfer cycle can be as short as required without affecting residual error probability. The cyclic exchange of safe data between a Safety over EtherCAT master and a Safety over EtherCAT slave is referred to as a connection that is monitored via a watchdog timer. A master can establish and monitor several connections to different slaves.
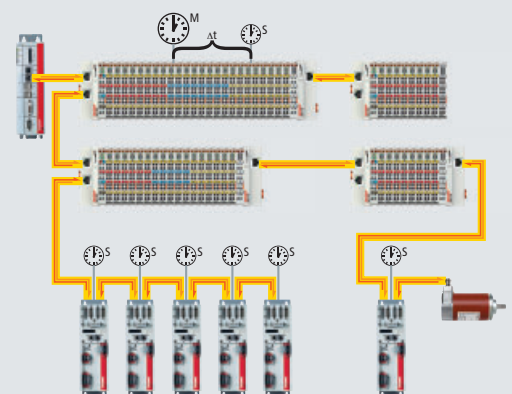
Costs
EtherCAT has considerable cost benefits, especially when compared with conventional fieldbus systems. Special hardware in

the master or a communication coprocessor is not necessary. A cost-effective EtherCAT Slave Controller handles all time-critical tasks in the slave, so that there are no demands for processor power from the communication side, resulting in low connection costs. Industrial Ethernet cables and connectors, which are available at a lower cost than comparable fieldbus components, are sufficient. No active infrastructure devices such as switches are required. This also applies to associated power supply units, installation and parameterisation. Due to the high speed of EtherCAT, no network tuning (often required for fieldbuses) is needed. Address selection can be automatic, saving associated costs.

Protocol structure | The process image allocation is freely configurable. Data are copied directly in the I/O terminal to the desired location within the process image: no additional mapping is required. There is a very large logical address space of 4 GB.

| Ethernet HDR | HDR 1 | Data 1 | HDR 2 | Data 2 | ~ | HDR n | Data n | CRC |

Logical process image: up to 4 Gbytes 2^{32} ... 0

Datagram 1   Datagram 2   Datagram n

Distributed clocks | Local absolute system synchronisation for CPU, I/O and drive units

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Automation

IPC

TwinCAT
– control software (PLC, Motion Control,
   EtherCAT master)
– real-time under Microsoft Windows with
   cycle times down to 50 µs
– programming according to IEC 61131-3

www. beckhoff.com/TwinCAT

Industrial PCs
– Industrial PCs with
   real-time motherboards
– compact form factors,
   optimised for control
   applications

Embedded PCs
– Embedded PC for DIN rail
   mounting
– direct I/O interface
   for EtherCAT and
   Bus Terminals

www. beckhoff.com/Embedded-PC

www. beckhoff.com/IPC

EtherCAT®

I/O

Motion

EtherCAT Terminals
– EtherCAT up to the I/O terminal
– full range I/O line for all signal types

Bus Terminals/Fieldbus Box
– open I/O systems in IP 20 and IP 67 ratings
– fieldbus interface for EtherCAT
– wide range of I/O signal types

AX5000 Servo Drives
– 1- and 2-channel Servo Drives with fast control technology
– high-speed EtherCAT system communication
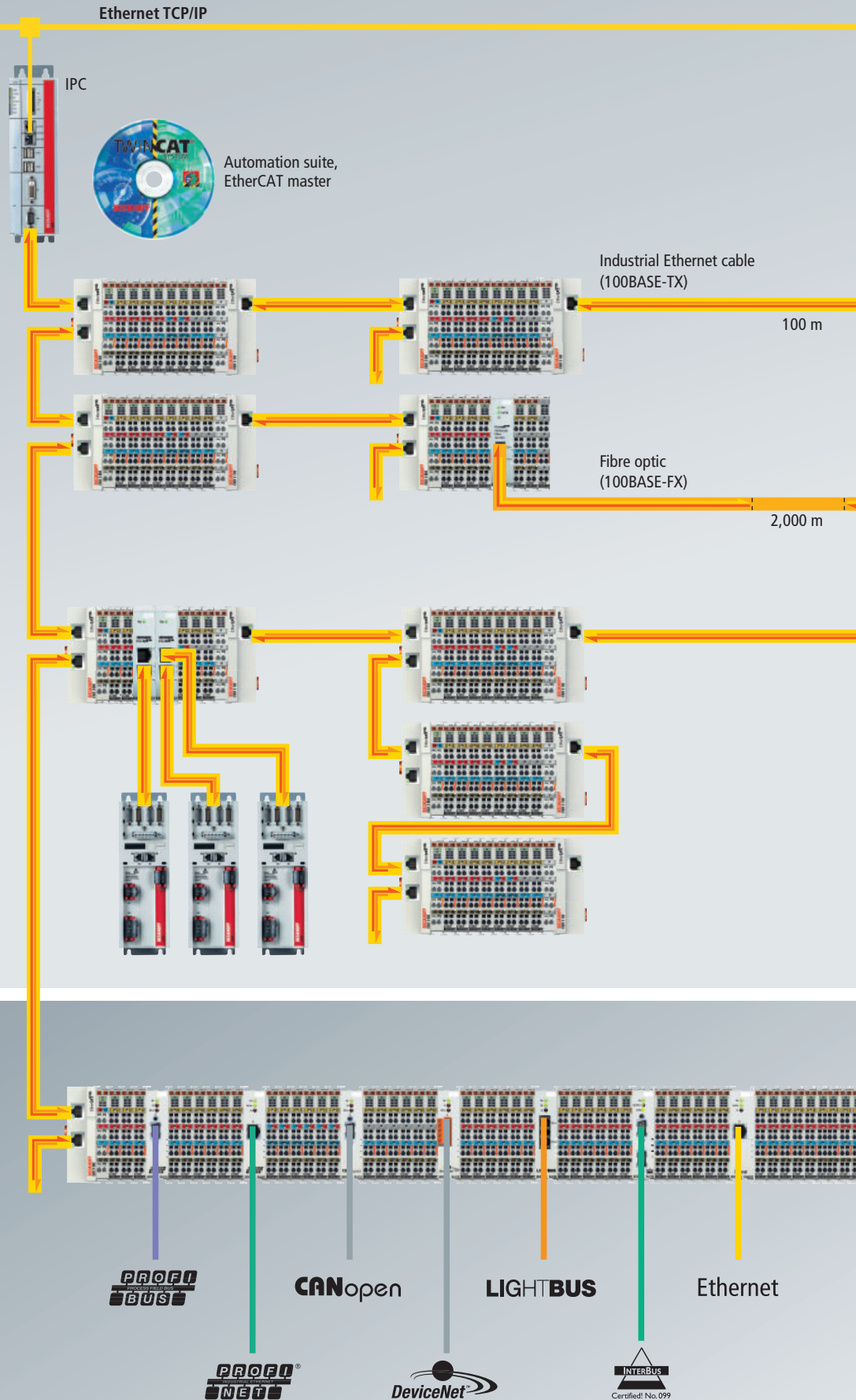– variable motor interface/wide voltage range

www. beckhoff.com/EtherCAT-IO

www. beckhoff.com/AX5000

www. beckhoff.com/FieldbusBox

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Ethernet TCP/IP

Flexible topology

IPC

Automation suite,
EtherCAT master

Industrial Ethernet cable
(100BASE-TX)

Bus/line

100 m

Fibre optic
(100BASE-FX)

2,000 m

Tree/star

Fieldbus integration

PROFI BUS
PROCESS FIELD BUS

CANopen

LIGHTBUS

Ethernet

PROFI NET
INDUSTRIAL ETHERNET

DeviceNet

INTERBUS
Certified! No. 099

EtherCAT bridge

IPC

IPC

IPC

Redundancy

IPC

Safety

E-bus   K-bus

IO-Link   IEEE1588

RS232
RS485

ASi INTERFACE

Safety logic   Safety input/output

Safety over
EtherCAT

Safety drives

We reserve the right to make technical changes.

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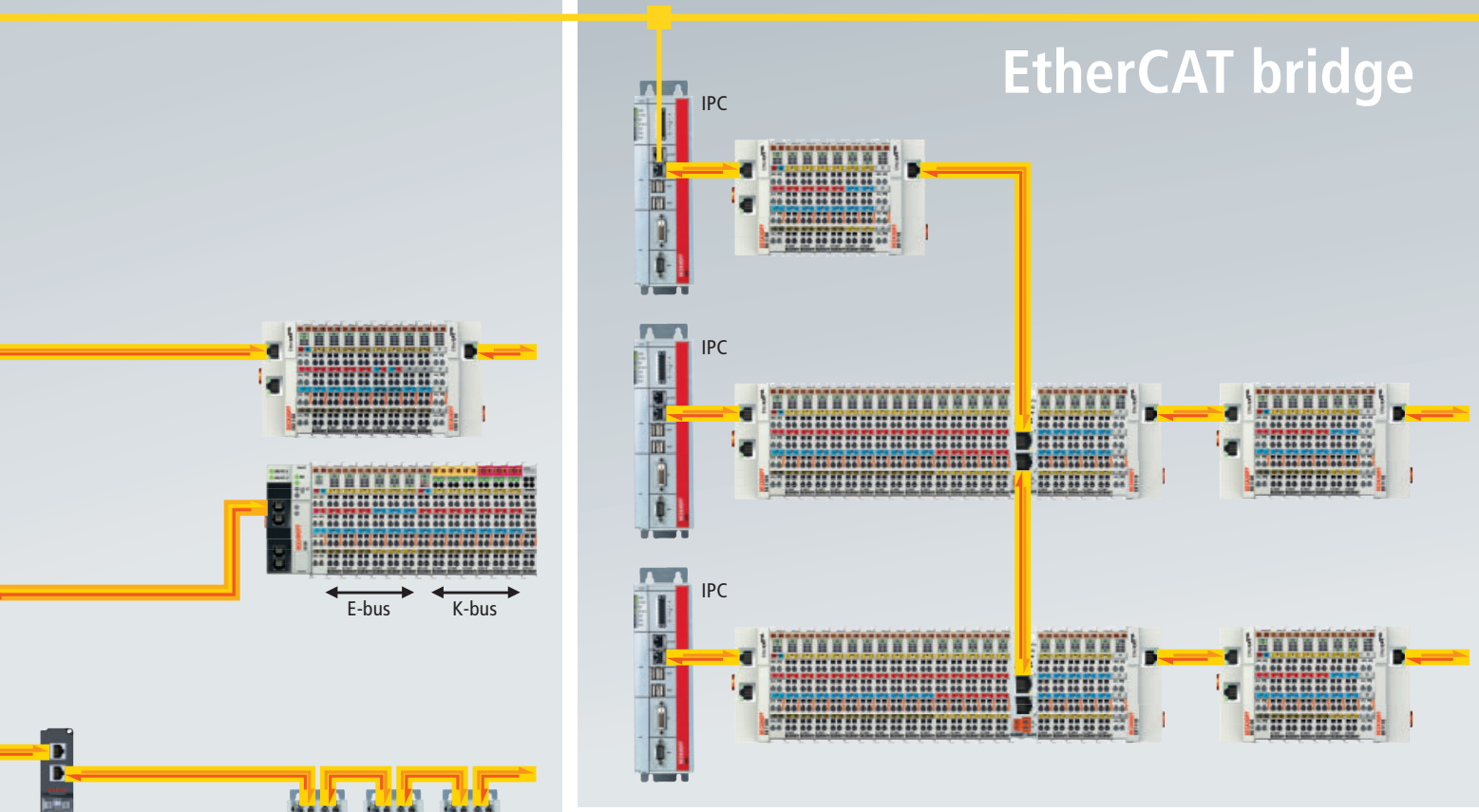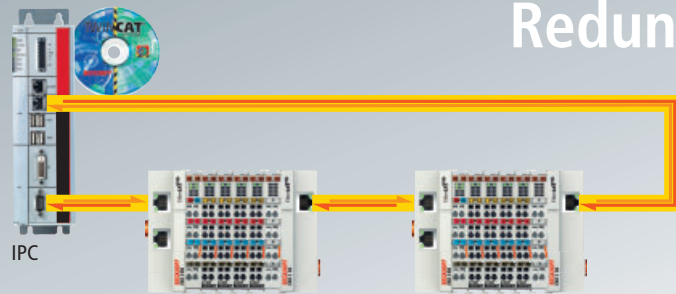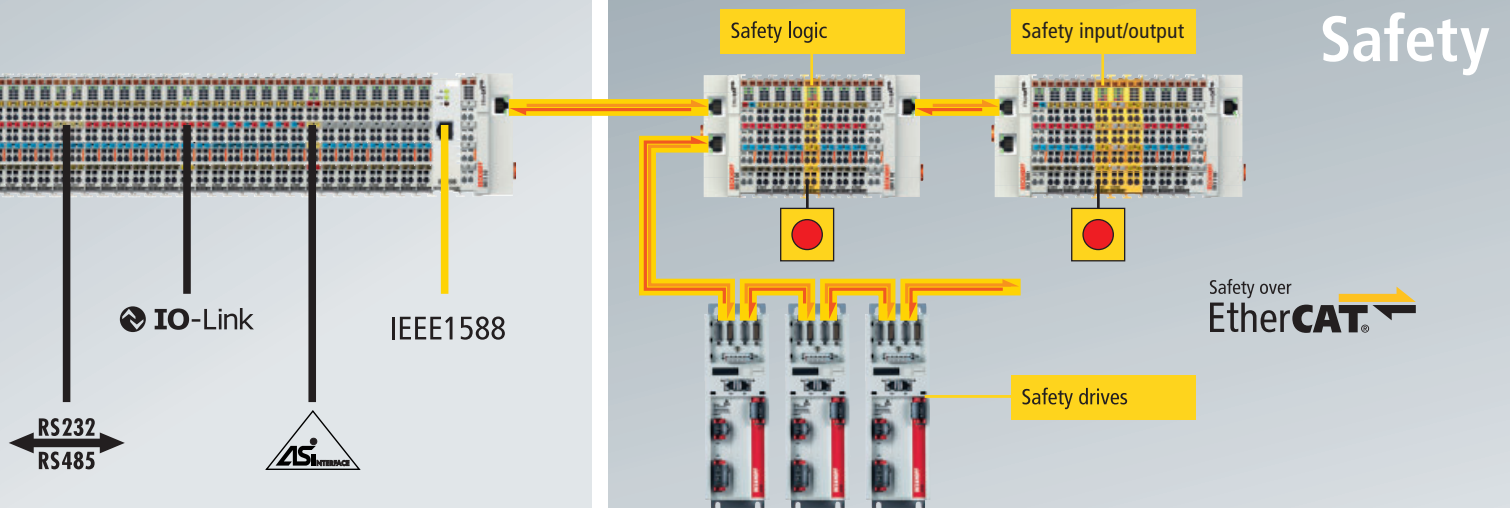
EtherCAT down to the terminal: the EtherCAT protocol is maintained down to each device; no sub bus is required.

Status LED for secure commissioning

EtherCAT Terminals

Terminal block design W x H x D (mm): 12 x 100 x 68
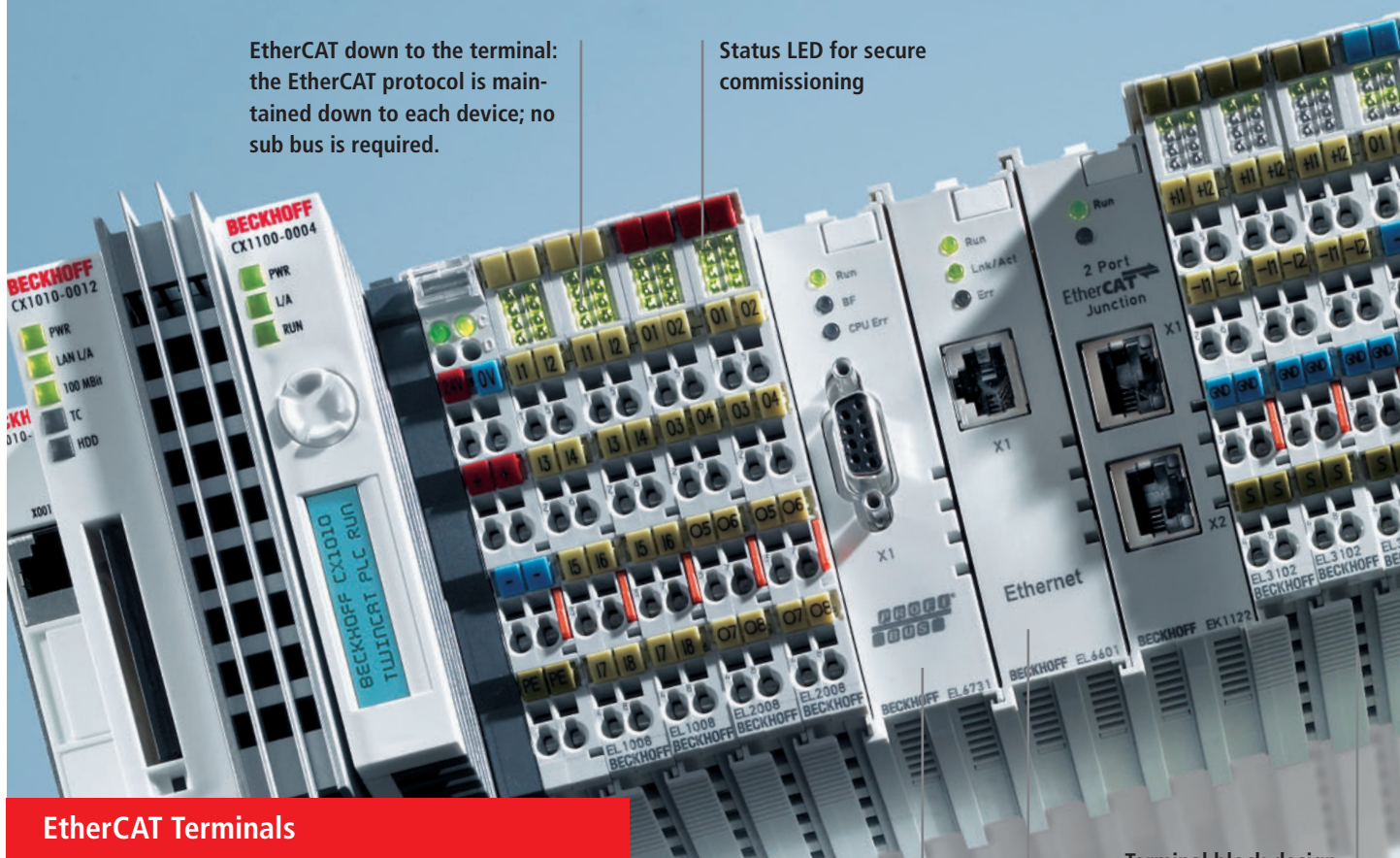
Embedded PC with direct E-bus interface

Protection of investment: fieldbus devices are integrated via decentralised fieldbus master/slave terminals.

Any Ethernet device can be integrated locally via switch port terminals.

Compatibility and integration: in addition to EtherCAT Terminals, the tried and tested Bus Terminals can also be connected via the BK1120 EtherCAT Bus Coupler.

EtherCAT®

Cost-effective cabling: Industrial Ethernet cable (min. CAT5), distance between I/O stations up to 100 m

Since up to 65,535 devices can be connected, the size of the network is almost unlimited.

The ES type EtherCAT Terminals feature a pluggable wiring option.

Flexible wiring: line or tree topologies can be freely selected and combined. Addresses are assigned automatically.

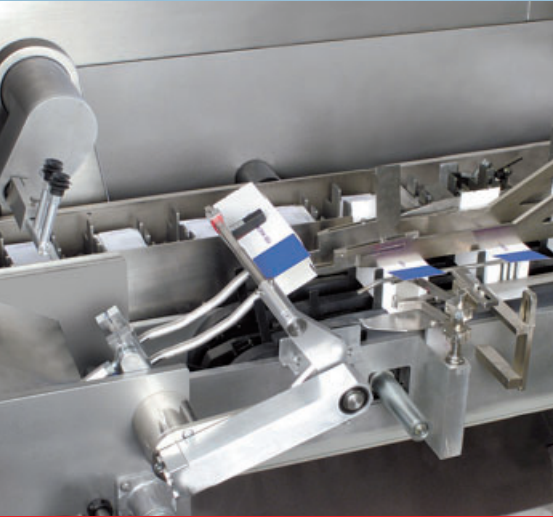The EtherCAT Coupler converts the transfer behaviour from twisted pair (100BASE-TX) to E-bus.

Safety integrated: TwinSAFE terminals permit the connection of safety sensors and actuators.

Bus Terminals

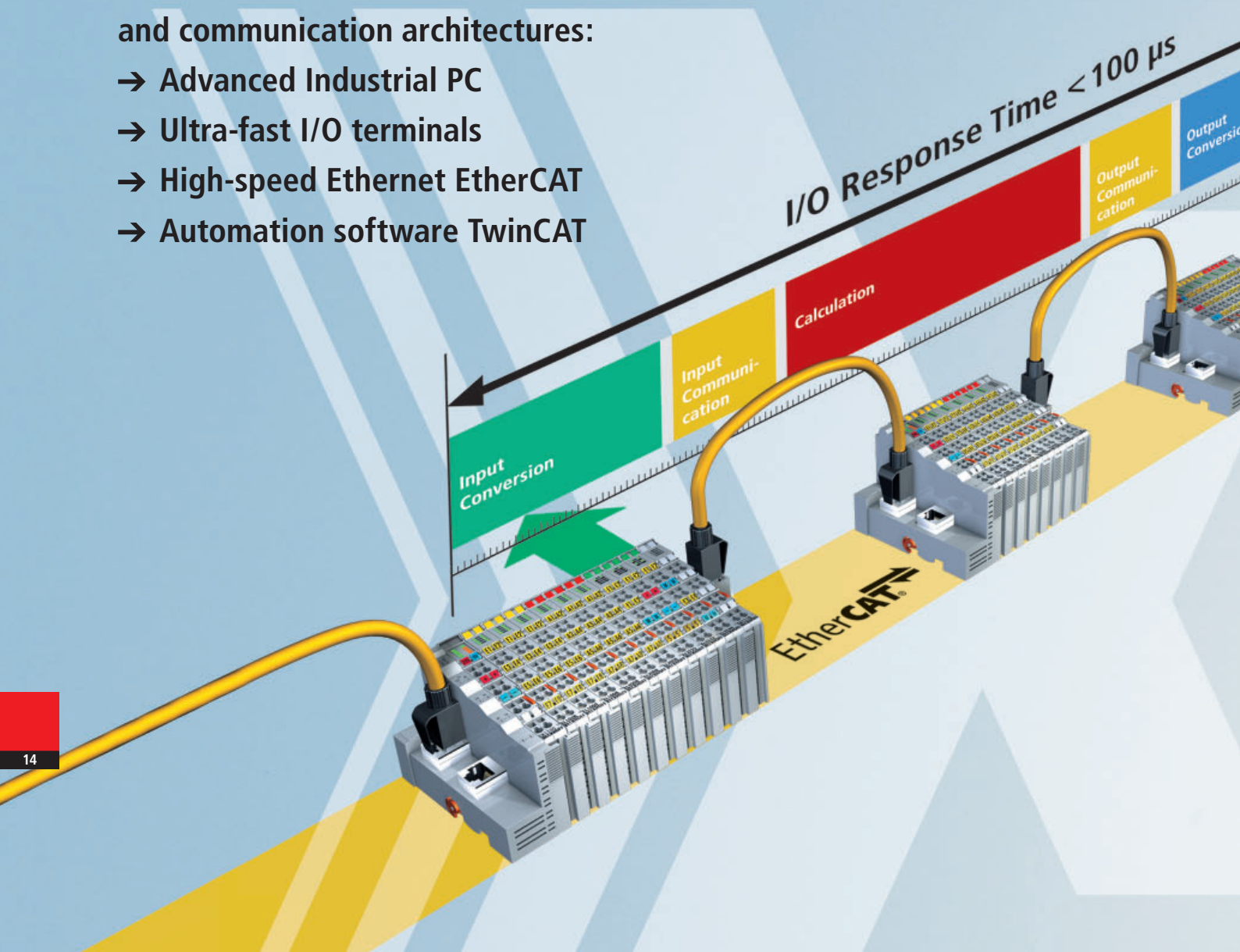**BECKHOFF** New Automation Technology

EtherCAT | Even faster with XFC

XFC is based on optimised control and communication architectures:

→ **Advanced Industrial PC**
→ **Ultra-fast I/O terminals**
→ **High-speed Ethernet EtherCAT**
→ **Automation software TwinCAT**

I/O Response Time < 100 µs

Input Conversion

Input Communication

Calculation

Output Communication

Output Conversion

EtherCAT

Cost reduction

With XFC technology (eXtreme Fast Control Technology) Beckhoff presents an ultra fast control solution: With XFC it is possible to achieve I/O response times < 100 µs. This technology opens up new process optimisation opportunities that were not possible in the past due to technical limitations.

XFC
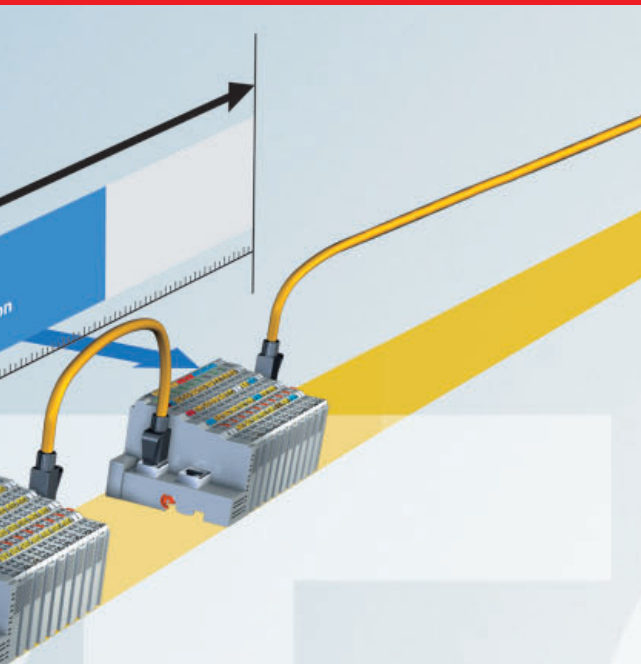
Cost benefits from using XFC
– increased machine and system throughput due to significantly reduced signal delays
– achieves faster sequences of motions
– condition monitoring with standard control system
– standard I/O instead of expensive special local controllers
– standard I/O instead of expensive instrumentation interfaces
– measurement technology in integrated control system, no separate system required

Very short controller cycle time
– new performance class for PLC applications: from 50 µs

Very fast I/O response time
– from 85 µs
– Deterministically synchronised conversion of the input and output signal leads to reduced process timing jitter, independent of the communication and CPU jitter.

Distributed clocks
– local absolute system synchronisation for CPU, I/O and drive units
– resolution: 10 ns, accuracy < 100 ns

Signal oversampling
– multiplex signal conversion within one control cycle
– hard time synchronisation through distributed clocks
– for digital/analog input/output signals
– sampling rates up to 100 kHz (analog) and 500 kHz (digital)
– application
    – fast signal monitoring, fast signal generator output
    – signal sampling independent of cycle time
    – fast controllers

Signal time stamp (resolution 10 ns)
– exact edge time measurement for local digital inputs
– exact timing of local output signals, independent of the control cycle

WWW. beckhoff.com/XFC

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EtherCAT Technology Group

The EtherCAT Technology Group (ETG) is an association of automation users and manufacturers with a mission to support the development of EtherCAT technology. The group represents a variety of industry sectors and application areas. This ensures that the EtherCAT technology functions and interfaces are ideally prepared for the widest range of applications. The organisation ensures that EtherCAT can be easily and cost-effectively integrated in all kinds of automation devices, while ensuring interoperability of the implementations. The EtherCAT Technology Group was founded in November 2003 and today has more than 850 member companies from 44 countries.

For further information see **www.ethercat.org**