



# EtherCAT®

## Highlights

- Ethernet up to the terminal – complete continuity
- Ethernet process interface scalable from 1 bit to 64 kbyte
- Ethernet solution for the field level
- Exact timing and adapted to synchronisation

# EtherCAT

The real-time Ethernet fieldbus

► [www.beckhoff.com/EtherCAT](http://www.beckhoff.com/EtherCAT)

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# Product overview EtherCAT components

EtherCAT components							
PC-based Control		EtherCAT Terminal		EtherCAT Box		EtherCAT P Box	
Industrial PCs	CPxxxx Panel PCs (EtherCAT masters)	Couplers	EK1xxx EtherCAT Coupler E-bus	Digital I/O	EP1xxx, ER1xxx, EQ1xxx* digital input	Digital I/O	EPP1xxx digital input
	Cxxxx control cabinet PCs (EtherCAT masters)		BK1xxx EtherCAT Coupler K-bus		EP2xxx, ER2xxx, EQ2xxx* digital output		EPP2xxx digital output
			EKxxxx Bus Coupler for EtherCAT Terminals		EP23xx, ER23xx, EQ23xx* digital combi		EPP23xx digital combi
Embedded PCs	CXxxxx Embedded PCs (EtherCAT masters)	Digital I/O	EL1xxx digital input	Analog I/O	EP3xxx, ER3xxx, EQ3xxx* analog input	Analog I/O	EPP3xxx analog input
			EL2xxx digital output		EP4xxx, ER4xxx* analog output		EPP4xxx analog output
Software PLC/Motion Control	TwinCAT EtherCAT masters and development environment	Analog I/O	EL3xxx analog input	Special functions	EP43xx analog combi	Special functions	EPP5xxx position measurement
			EL4xxx analog output		EP5xxx, ER5xxx* position measurement		EPP6xxx communication
Safety	TwinSAFE open and scalable control technology	Special functions	EL5xxx position measurement		EP6xxx, ER6xxx* communication		EPP7xxx motion
			EL6xxx communication		EP7xxx, ER7xxx* motion		
Redun- dancy	TwinCAT EtherCAT Redundancy extension of the EtherCAT master with cable redundancy capability	System	EL7xxx motion	System	EP8xxx, ER8xxx* multi-functional I/O box	System	EPP1111 EtherCAT P Box with ID switch
			EL9xxx system terminals		EP1111 EtherCAT Box with ID switch		EPP9001 EtherCAT P/EtherCAT connector with power transmission
					EP1122 2-port EtherCAT junction		EPP9022 4 x diagnostics (Us, Ur, Is, Ir)
					EP9214, EP9224 7/8" plug, 7/8" socket		EPP1322 3 ports, with feed-in
							EPP1332 3 ports, with refresh
							EPP1342 3 ports

\*EPxxxx: industrial housing in IP 67, ERxxxx: zinc die-cast housing in IP 67, EQxxxx: stainless steel housing in IP 69K

EtherCAT Plug-in Modules		Fieldbus Box	Infrastructure Components		Drive Technology
<b>Couplers</b>	<b>EJ1100</b> 371 EtherCAT Coupler E-bus	<b>Fieldbus Box</b>	<b>PCI Ethernet</b>	<b>FC9xxx</b> 630 PCI, Mini PCI, PCIe cards 1 Gbit/s	<b>Servo Drives</b>
<b>Digital I/O</b>	<b>EJ1xxx</b> 372 digital input	<b>Fieldbus Modules</b>	<b>PCI EthernetCAT</b>	<b>FC9xxx</b> 631 PCI, Mini PCI, PCIe cards 100 Mbit/s	
	<b>EJ2xxx</b> 376 digital output				
<b>Analog I/O</b>	<b>EJ3xxx</b> 380 analog input			<b>FC1100</b> 622 PCI EtherCAT slave card	
	<b>EJ4xxx</b> 384 analog output			<b>FC1121</b> 622 PCI Express EtherCAT slave card	
<b>Special functions</b>	<b>EJ5xxx</b> 386 position measurement			<b>CU2508</b> 617 1 x RJ45 (+ 8 x RJ45: 100 Mbit/s)	
	<b>EJ6xxx</b> 388 communication			<b>CU1128</b> 619 8 x RJ45, IP 20	
	<b>EJ7xxx</b> 391 motion			<b>EP9128-0021</b> 619 8 x M8, IP 67	
				<b>CU1521-0000</b> 620 multimode, IP 20	
<b>System</b>	<b>EJ9xxx</b> 394 system modules			<b>EP9521-0020</b> 621 multimode, IP 67	
					<b>AX5000</b> 1 344 Digital Compact Servo Drive
					<b>AX8000</b> 1 336 multi-axis servo system for OCT motors
					<b>EL72xx</b> 228 servomotor terminal, $I_{ms} = 4.5 \text{ A}$ , 50 V DC
					<b>EP7211-9034</b> 311 servomotor box, $I_{ms} = 4.5 \text{ A}$ , 50 V DC, OCT, STO
					<b>EJ7211-xxxx</b> 392 servomotor module, $I_{ms} = 4.5 \text{ A}$ , 50 V DC, OCT
					<b>Distributed Servo Drive system</b>
					<b>AMP8000</b> 1 356 Synchronous Servomotors with integrated servo drive
					<b>Servo-motors</b>
					<b>AM80xx</b> 1 366 Synchronous Servomotors with One Cable Technology (OCT)
					<b>AM85xx</b> 1 378 Synchronous Servomotors with increased rotor moment of inertia and One Cable Technology (OCT)
					<b>AM88xx</b> 1 392 stainless steel Synchronous Servomotors with One Cable Technology (OCT)
					<b>ALxxxx</b> 1 400 Linear Servomotors
					<b>Compact Drive Technology</b>
					<b>AM81xx</b> 1 414 Synchronous Servomotors with One Cable Technology (OCT) for the servo I/Os
					<b>AA1121</b> 1 412 linear actuator
					<b>Transport system</b>
					<b>XTS</b> 1 428 eXtended Transport System

# EtherCAT – Ultra high-speed for automation

## Highlights

- Ethernet up to the terminal – complete continuity
- Ethernet process interface scalable from 1 bit to 64 kbyte
- first true Ethernet solution for the field level
- exact timing and adapted to synchronisation

## Performance

- 256 digital I/Os in 12  $\mu$ s
- 1000 digital I/Os in 30  $\mu$ s
- 200 analog I/Os (16 bit) in 50  $\mu$ s, corresponding to 20 kHz sampling rates
- 100 servo axes every 100  $\mu$ s
- 12,000 digital I/Os in 350  $\mu$ s

## Topology

- line, tree or star topology
- up to 65,535 devices within one network
- network size: almost unlimited ( $> 500$  km)
- operation with or without switches
- cost-effective cabling: Industrial Ethernet patch cable (Cat. 5)
- physical layer:
  - Ethernet 100BASE-TX via twisted pair, up to 100 m between 2 slaves
  - Ethernet 100BASE-FX via fibre optic cable, up to 20 km between 2 slaves
- hot connect of bus segments

## Address space

- network-wide process image: 4 Gbyte
- device process image: 1 bit to 64 kbyte
- address allocation: freely configurable
- device address selection: automatically via software

## 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 down to the I/O terminal: no complex Bus Couplers
- low interface costs due to highly integrated EtherCAT Slave Controller

## Protocol

- optimised protocol directly within the Ethernet frame
- fully hardware-implemented
- for routing and socket interface: UDP datagram
- processing while passing
- distributed clocks for accurate synchronisation
- timestamp data types for resolution in the nanosecond range
- oversampling data types for high-resolution measurements

## Diagnostics

- breaking point detection
- continuous “quality of line” measurement enables accurate localisation of transmission faults
- Topology View

## Interfaces

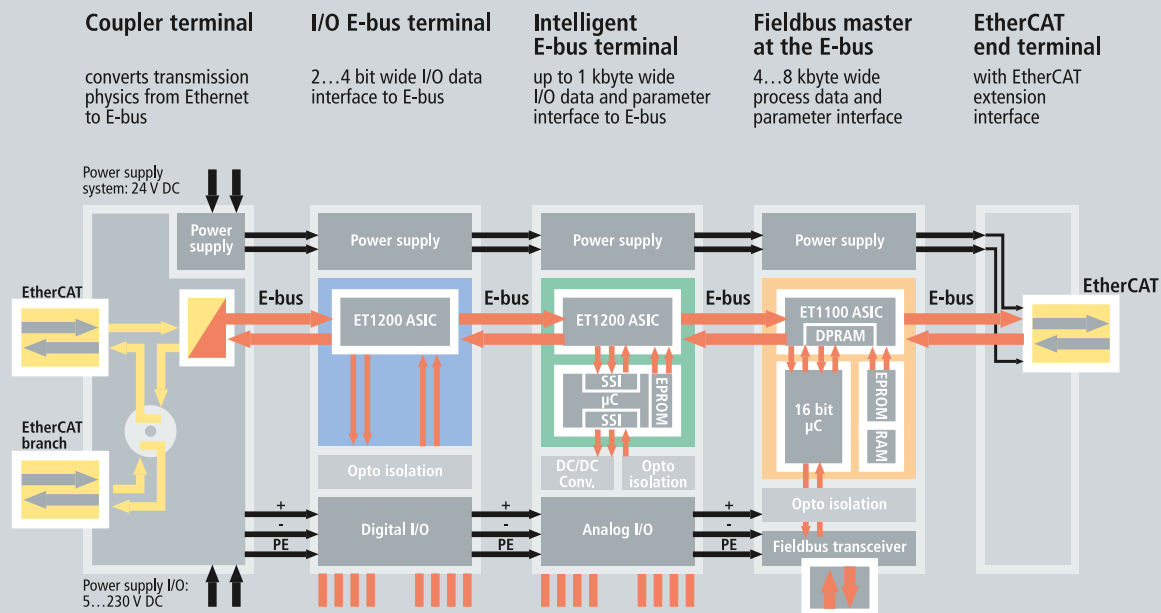
- switch port terminal for standard Ethernet devices
- fieldbus terminals for fieldbus devices
- decentralised serial interfaces
- communication gateways
- gateway to other EtherCAT systems

## Openness

- fully Ethernet-compatible
- operation with switches and routers possible
- mixed operation with other protocols also possible
- internet technologies (Web server, FTP, etc.)
- compatible with the existing Bus Terminal range
- protocol is published completely
- EtherCAT is IEC, ISO and SEMI standard.

## EtherCAT Technology Group

- international pool of companies
- includes users and manufactures
- supports technology development
- ensures interoperability
- integration and development of device profiles



**Protocol processing completely in hardware** | Protocol ASICs flexibly configurable. Process interface from 1 bit to 64 kbyte.

## Ethernet for Control Automation Technology

### 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 standards where conventional fieldbus systems reach their limits: 1000 distributed I/Os in 30  $\mu$ s, 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 port.

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

### Principle of operation

There are many different approaches that try to provide real-time capability for Ethernet: for example, the CSMA/CD access procedure is disabled via higher level protocol layers and replaced by time slicing or polling. Other propositions use special switches that distribute Ethernet telegrams in a precisely controlled timely manner. While these solutions are able to transport data packets more or less quickly and

accurately to the connected Ethernet node, bandwidth utilisation is very poor, particularly for typical automation devices, since even for very small data quantities a complete Ethernet frame has to be sent. Moreover, the times required for the redirection to the outputs or drive controllers and for reading the input data strongly depend on the implementation. A sub-bus is usually also required, particularly in modular I/O systems, which, like the Beckhoff K-bus, may be synchronised and fast, but nevertheless always adds small delays to the communication that cannot be avoided.

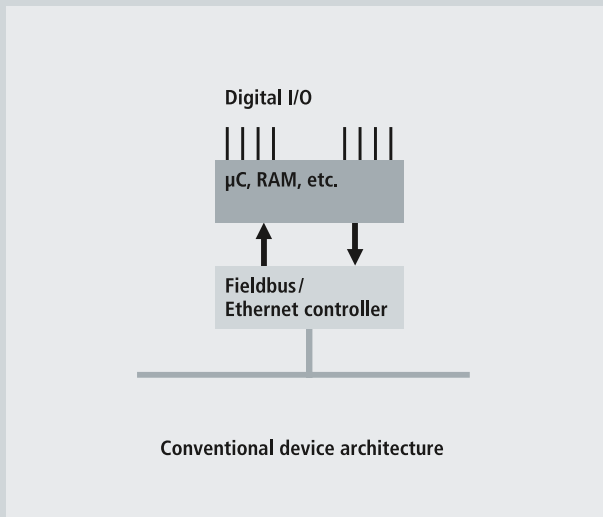
With EtherCAT technology, Beckhoff overcomes these system limitations of other Ethernet solutions: the process no longer involves consecutive steps for receiving and interpreting telegrams and copying the process data. In each device (down to the individual terminals) the EtherCAT Slave Controller reads 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 runtimes 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.

From an Ethernet point of view, an EtherCAT bus segment is simply a single large Ethernet device that receives and sends Ethernet frames. However, the “device” does not contain a single Ethernet controller with downstream microprocessor, but a large number of EtherCAT slaves. Like for any other Ethernet device, direct communication may be established without a switch, thereby creating a pure EtherCAT system.

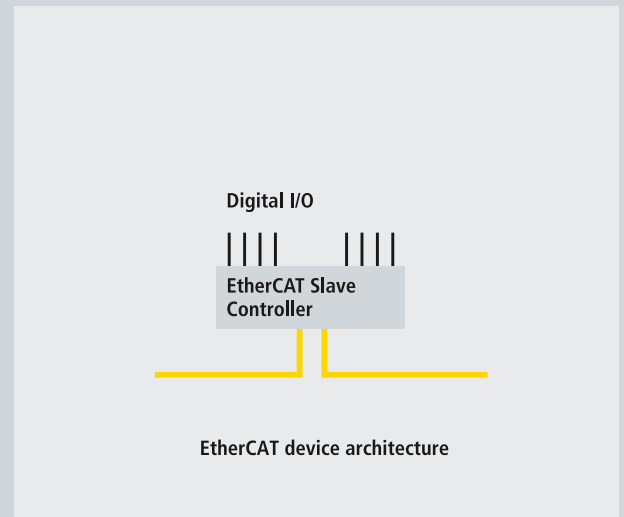
### Ethernet down to the terminal

The Ethernet protocol remains intact right down to the individual devices, i.e. down to the individual 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 multiport cards, which bundle up to four Ethernet channels on one PCI slot.



Conventional device architecture



EtherCAT device architecture

**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.

### Protocol

The EtherCAT protocol is optimised for process data and is either transported directly in the Ethernet frame or packed into UDP/IP datagrams. The UDP version is used in situations where EtherCAT segments in other subnets are addressed via routers. Ethernet frames may contain several EtherCAT telegrams, with each telegram serving a particular memory area of the logical process image with an addressable size of up to 4 GB. The data sequence is independent of the physical order of the EtherCAT Terminals in the network; addressing can be in any order. Broadcast, Multicast and communication between slaves are possible.

The protocol can also handle parameter communication, which typically is acyclical. The structure and meaning of the parameters is specified via CANopen device profiles, which are available for a wide range of device classes and applications. EtherCAT also supports the SERCOS servo profile according to IEC 61800-7-204.

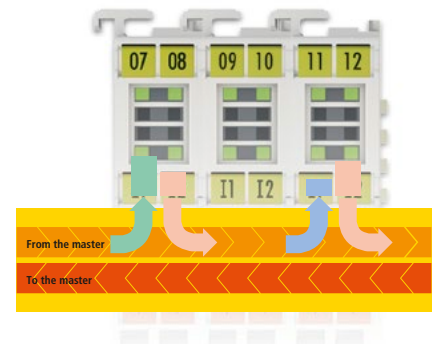
In addition to data exchange according to the master/slave principle, EtherCAT is also very suitable for communication between controllers (master/master). Freely addressable network variables for process data and a variety of services for parameterisation, diagnosis, programming and remote control cover a wide range of requirements. The data interfaces for master/slave and master/master communication are identical.

### Performance

EtherCAT reaches new dimensions in network performance. The update time for the data from 1000 distributed inputs/outputs is only 30 µs – including terminal cycle time. Up to 1486 byte of process data can be exchanged with a single Ethernet frame – this is equivalent to almost 12,000 digital inputs and outputs. The transfer of this data quantity only takes 300 µs.

The communication with 100 servo axes takes place every 100 µs. With this cycle time, all axes are provided with set values and control data and report their actual position and status. The distributed clocks technique enables the axes to be synchronised with a jitter of significantly less than 1 microsecond.

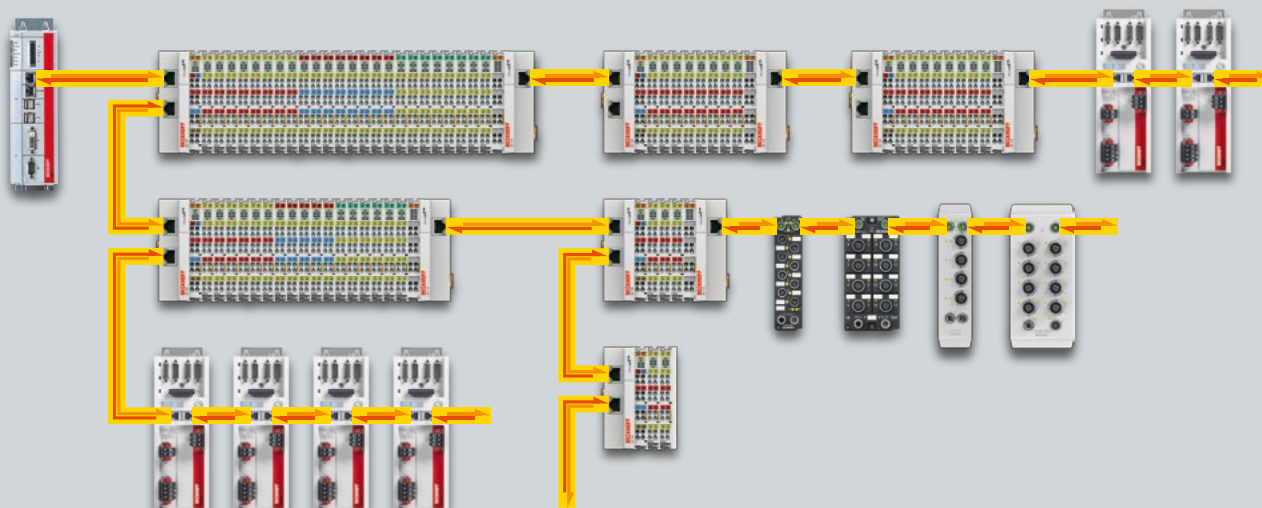
The extremely high performance of the EtherCAT technology enables control concepts that could not be realised with classic fieldbus systems. Very fast control loops can thus also be closed via the bus. Functions that previously required dedicated local hardware support can now be mapped in software. The tremendous bandwidth enables status information to be transferred with each data item. With EtherCAT, a communication technology is available that matches the superior computing capacity of modern Industrial PCs. The bus system is no longer the “bottleneck” of the control concept. Distributed I/Os are recorded faster than is possible with most local I/O interfaces.



FMMU: telegram processing completely in hardware

The benefits of this network performance also become apparent in smaller controllers with comparatively moderate computing capacity. The EtherCAT cycle is so fast that it can be executed between two control cycles. The controller thus always has the latest input data available; the outputs are addressed with minimum delay. The response behaviour of the controller is improved significantly without increasing the computing capacity itself.

The EtherCAT technology principle is scalable and not bound to the baud rate of 100 Mbaud – extension to Gbit Ethernet is possible.



**Freedom in the choice of topology** | Maximum flexibility for wiring: with or without switch, line or tree topologies can be freely selected and combined. Address assignment is automatic; no IP address setting is required.

### EtherCAT instead of PCI

With increasing miniaturisation of the PC components, the physical size of Industrial PCs is increasingly determined by the number of required slots. The bandwidth of Fast Ethernet, together with the data width of the EtherCAT communication hardware (EtherCAT Slave Controller) enables the transfer of PC interfaces to intelligent interface terminals at the EtherCAT system. Apart from the decentralised I/Os, axes and control units, complex systems such as fieldbus masters, fast serial interfaces, gateways and other communication interfaces can be addressed via a single Ethernet port in the PC. Even further Ethernet devices without restriction on protocol variants can be connected via decentralised switch port terminals. The central IPC becomes smaller and therefore more cost-effective, one Ethernet interface is sufficient for the complete communication with the periphery.

### Topology

Line, tree or star: EtherCAT supports almost any topology. The bus or line structure known from the fieldbuses thus also becomes available for Ethernet. Particularly useful for system wiring is the combination of lines and branches or stubs. The required interfaces exist on the couplers; no additional switches are required. Naturally, the classic Ethernet star topology with junction terminals can also be used.

Wiring flexibility is further maximised through the choice of different cables. Flexible and inexpensive shielded Industrial Ethernet fieldbus cables transfer the signals in Ethernet mode (100BASE-TX) up to a cable length of 100 m between two devices. The complete bandwidth of the Ethernet network – such as different optical fibres and copper cables – can be used in combination with switches or media converters. For each cable distance, the signal variant can be selected individually. Since up to 65,535 devices can be connected, the size of the network is almost unlimited.

### Distributed clocks

Accurate synchronisation is particularly important in cases where spatially distributed processes require simultaneous actions. This may be the case, for example, in applications where several servo axes carry out coordinated movements simultaneously.

The most powerful approach for synchronisation is the accurate alignment of distributed clocks. In contrast to fully synchronous communication, where synchronisation quality suffers immediately in the event of a communication fault, distributed aligned clocks have a high degree of tolerance vis-à-vis possible fault-related delays within the communication system. 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 reference clock can determine the runtime offset to the individual local clocks simply and accurately – and vice versa. The distributed clocks are adjusted based on this value, which means that a very precise network-wide timebase with a jitter of significantly less than 1 microsecond is available.

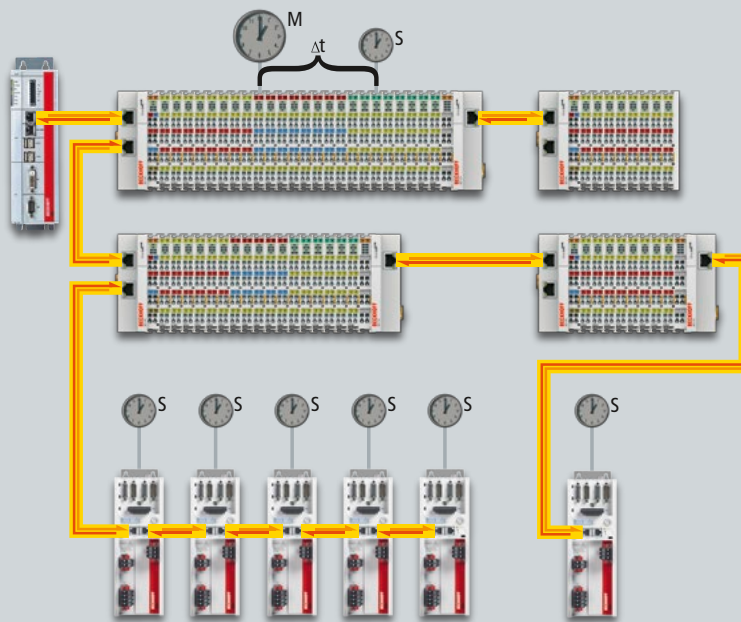
However, high-resolution distributed clocks are not only used for synchronisation, but can also provide accurate information about the local timing of the data acquisition. Thanks to extended data types, very precise timestamps can be assigned to measured values.

### Hot Connect

Many applications require a change in I/O configuration during operation. Examples are machining centres with changing, sensor-equipped tool systems or transfer systems with intelligent, flexible workpiece carriers, or printing machines in which individual printing units are switched off. The protocol structure of the EtherCAT system takes account of these requirements: the Hot Connect function enables parts of the network to be linked and decoupled or reconfigured "on the fly", offering flexible response capability for changing configurations.

### High availability

Increasing demands in terms of system availability are catered for with optional



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

cable redundancy that enables devices to be changed without having to shut down the network. EtherCAT also supports redundant masters with hot standby functionality. Since the EtherCAT Slave Controllers immediately return the frame automatically if an interruption is encountered, failure of a device does not lead to the complete network being shut down. Dragchain applications, for example, can thus be specifically configured as stubs in order to be prepared for cable break.

#### 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 and IEC 61784-3, 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.

#### Diagnostics

The diagnostic capability of a network is a crucial factor for availability and commissioning times – and therefore overall costs. Only faults that are detected quickly and accurately and located unambiguously can be rectified quickly. Therefore, special attention was paid to comprehensive diagnostic features during the development of EtherCAT.

During commissioning, the actual configuration of the I/O terminals should be checked for consistency with the specified configuration. The topology should also match the configuration. Due to the built-in topology recognition down to the individual terminals, the verification can not only take place during system start-up, automatic reading in of the network is also possible (configuration upload).

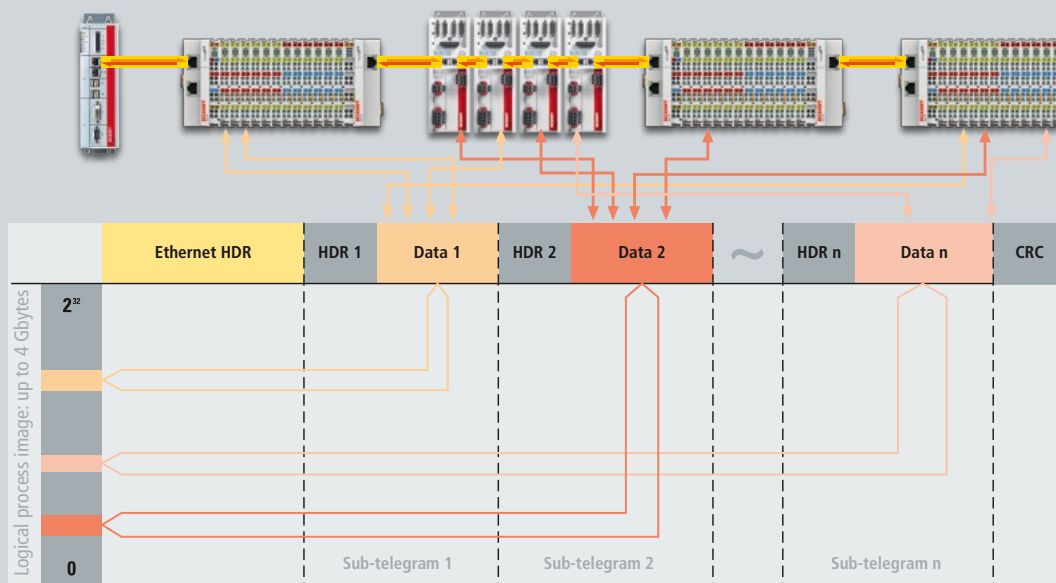
Bit faults during the transfer are reliably detected through evaluation of the CRC checksum in each device. Apart from breaking point detection and localisation, the protocol, transfer physics and topology of the EtherCAT system enable individual quality monitoring of each individual transmission segment. The automatic evaluation of the associated error counters enables precise localisation of critical network sections. Gradual or changing sources of error such as EMC influences, defective connectors or cable damage are detected and located.

#### EtherCAT components

On the hardware side, EtherCAT technology is located in EtherCAT Terminals, for example. The I/O system in protection class IP 20 is based on the housing of the tried and tested Beckhoff Bus Terminal system. In contrast to Bus Terminals, where the fieldbus protocol data is converted within the Bus Coupler to the internal, fieldbus-independent terminal bus, the EtherCAT protocol remains fully intact down to the individual terminal. In addition to EtherCAT Terminals with E-bus connection, the proven standard Bus Terminals with K-bus connection can also be connected via the BK1120 EtherCAT Bus Coupler. This ensures compatibility and continuity with the prevalent system. Existing and future investments are protected.

EtherCAT is fully integrated into the Beckhoff control architecture. The EtherCAT Box modules feature an integrated EtherCAT interface and can be connected directly to an EtherCAT network without an additional Coupler Box. The EPxxxx series with industrial housing and protection class IP 67 is suitable for application directly at the machine in harsh industrial environments. The EQxxxx series with stainless steel housing and protection class IP 69K is suitable for applications with high hygienic standards, such as in the food, chemical or pharmaceutical industries.

The Beckhoff Industrial PCs, the Embedded PCs of the CX series, the Control Panels



**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 address space of 4 Gbytes.

with control functionality, and the Ethernet PCI cards already offer inherent EtherCAT capability. The Beckhoff Servo Drives are also available with EtherCAT interface.

### Openness

The EtherCAT technology is not only fully Ethernet-compatible, but also characterised by particular openness “by design”: the protocol tolerates other Ethernet-based services and protocols on the same physical network – usually only with minimum loss of performance. Any Ethernet device can be connected within the EtherCAT segment via a switch port terminal without influencing the cycle time. Devices with fieldbus interface are integrated via EtherCAT fieldbus master terminals. The UDP protocol variant can be implemented on each socket interface. EtherCAT is a fully open protocol. It is recognised and available as an official IEC specification (IEC 61158, type 12).

cost-effectively integrated in all kinds of automation devices, while ensuring interoperability of these implementations. The EtherCAT Technology Group is the official IEC partner organisation for fieldbus standardisation. Membership is open to all companies.

For further information see

► [www.ethercat.org](http://www.ethercat.org)

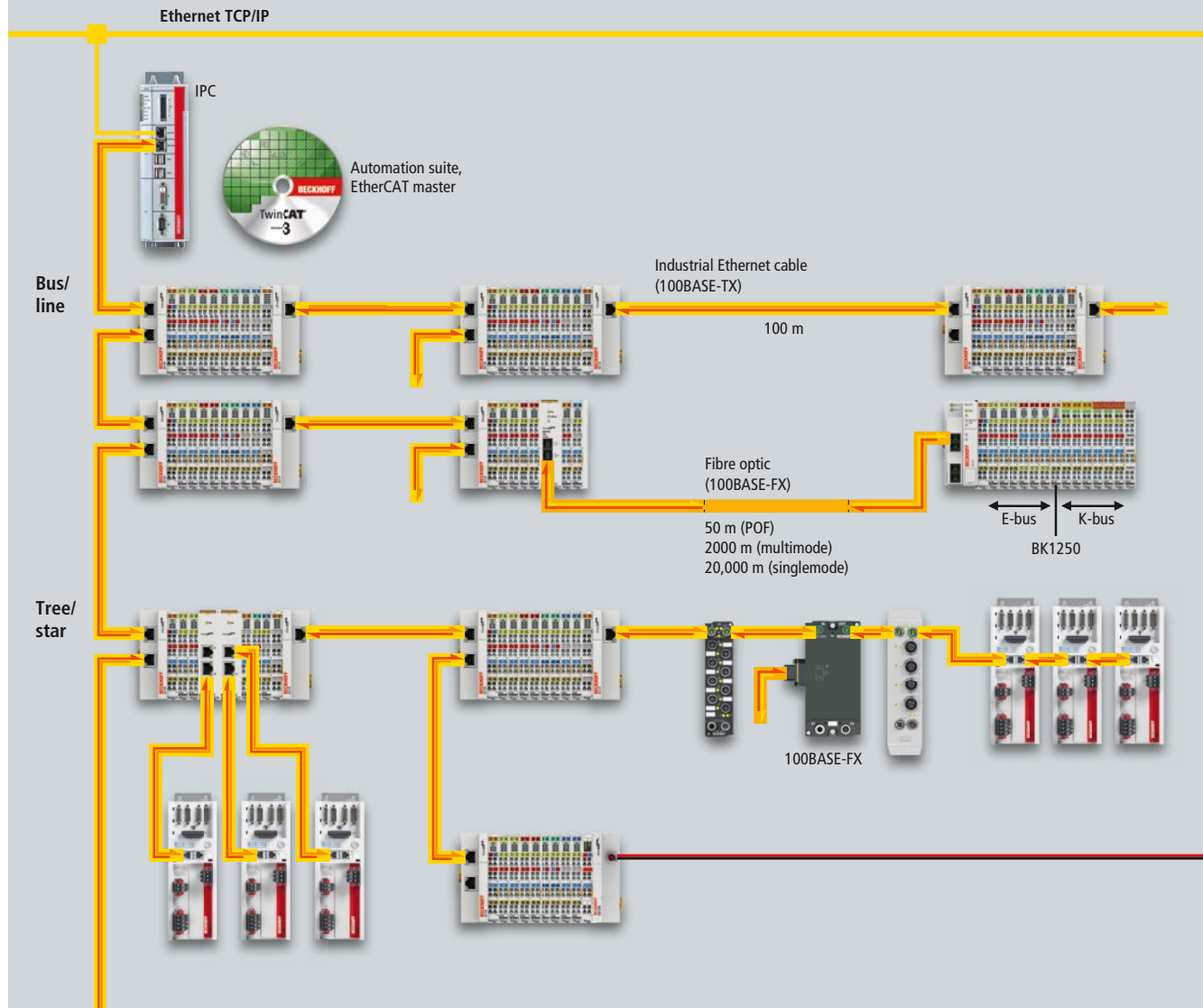
**EtherCAT**  
Technology Group

### EtherCAT Technology Group

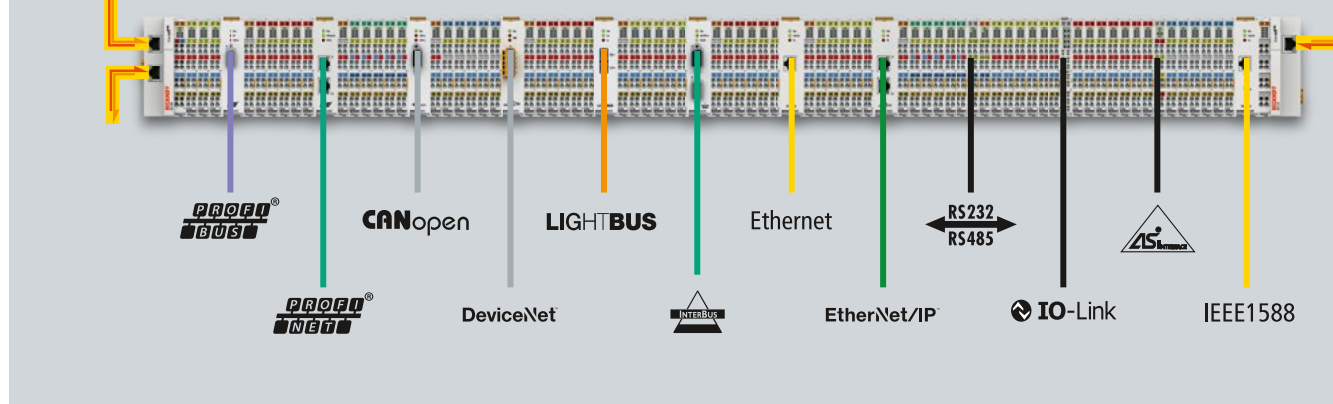
The EtherCAT Technology Group (ETG) is an association of automation users and manufacturers with a mission to support the development of EtherCAT technology. The group represents a variety of industry sectors and application areas. This ensures that the EtherCAT technology functions and interfaces are ideally prepared for the widest range of applications. The organisation ensures that EtherCAT can be easily and

# EtherCAT system overview

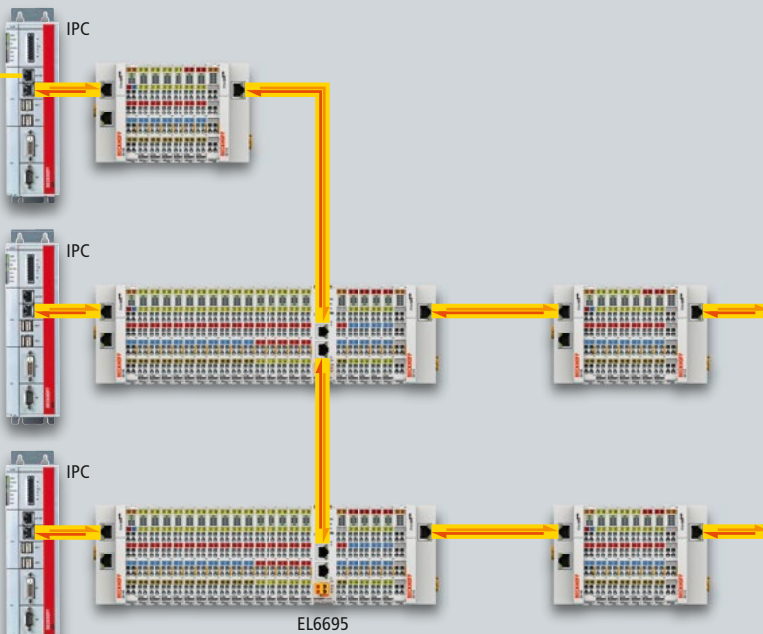
## Flexible topology



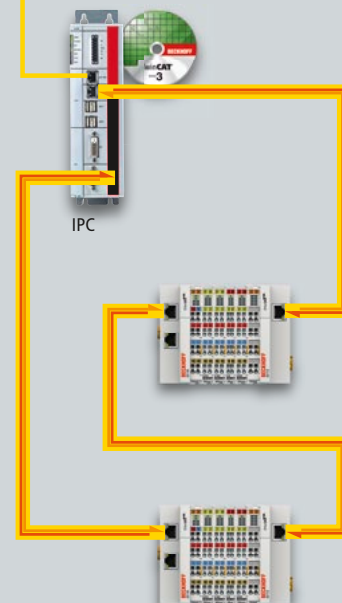
## Fieldbus integration



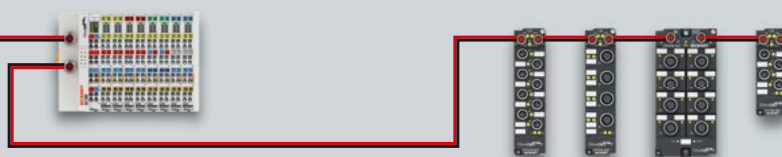
## EtherCAT bridge



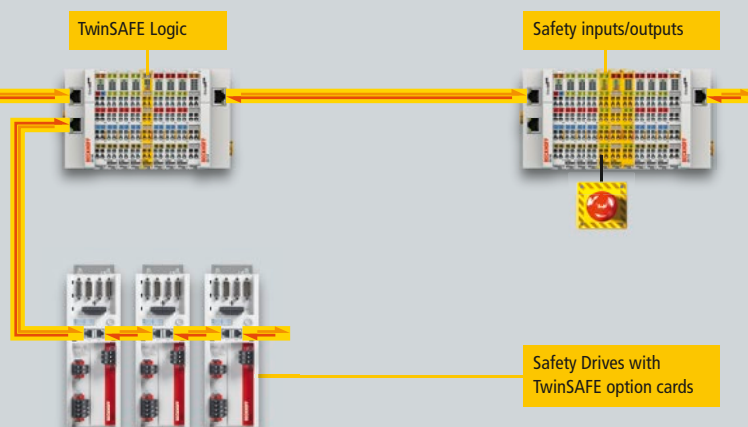
## Cable redundancy



## EtherCAT P



## Safety



# EtherCAT P | Ultra-fast communication and power in one cable

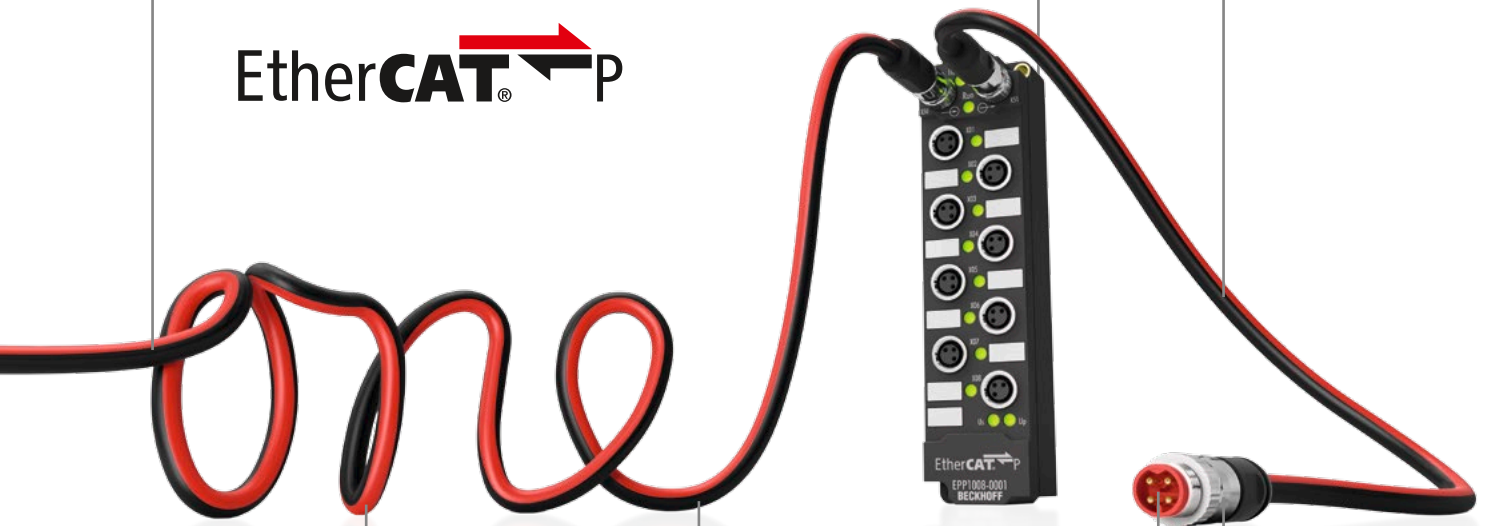
► [www.beckhoff.com/EtherCATP](http://www.beckhoff.com/EtherCATP)

The same free and flexible choice of topology well-known from EtherCAT is also available with EtherCAT P.

Minimised installation space in drag chains, control cabinets and machines

Forwarding of power supply in the devices

Ether**CAT**<sup>®</sup> P



Outstanding EtherCAT performance at low connection costs

Reduced material and assembly costs

One Cable Connection:  
EtherCAT + 2 x 24 V DC  
(U<sub>P</sub>, U<sub>S</sub>) on just 4 wires

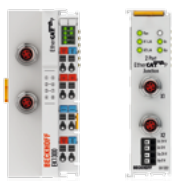
Highly scalable connector family from 24 V DC to 630 V AC/850 V DC



EPPxxxx | EtherCAT P  
products in IP 67



EPPxxxx-006x | Compact  
EtherCAT P products in IP 67



EK13xx | EtherCAT P  
products in IP 20



ENP/ECP | Connector family  
for all applications

EtherCAT P from Beckhoff extends the EtherCAT technology, which has become an established global standard. The solution combines ultra-fast EtherCAT communication with the 24 V system and peripheral voltage in a single cable, optionally with additional power supply capabilities. This means that with EtherCAT P, One Cable Automation (OCA) can be implemented across the entire field level, enabling plug-and-play connection of machines and other equipment ranging from sensors to drives without the need for control cabinets.

An EtherCAT P line combines 24 V DC supply for connected EtherCAT P slaves, sensors and actuators in a single 4-wire standard Ethernet cable.  $U_S$  (system and sensor supply) and  $U_P$  (peripheral voltage for actuators) are electrically isolated from each other and can supply current of up to 3 A to the connected components.

### **EtherCAT P: From 24 V DC sensor to 630 V AC/850 V DC drive**

EtherCAT P offers benefits both for connecting remote, smaller I/O stations in terminal boxes and I/O components distributed in the process. A complete connector family was developed, so that the One Cable Automation concept can also be used for connecting components with higher voltage and/or current requirements. The ENP/ECP connector family is designed to cover all applications up to drives with 650 V AC or 850 V DC and up to 64 A.

For higher loads, a compact EtherCAT P element with the same pin assignment as the M8 connector was equipped with additional power pins, resulting in the ENP/ECP connectors B12, B17, B23 and B40 for different performance classes. Featuring a bayonet fitting and IP 67 protection rating, they enable simple, fast and reliable connection directly

at the machine and optimised scalability of EtherCAT for the following applications:

- B12 for connecting compact motors with integrated output stages, for up to 48 V DC and 10 A
- B17 for asynchronous motors with frequency converter, for up to 230 V DC and 14 A
- B23 for complete control cabinets, for up to 400 V AC and 30 A
- B40 for the supply of robot stations, for up to 64 A

Technical data	EtherCAT P
Voltages	2 x 24 V DC according to IEC 61131 (-15 %/+20 %), max. 3 A each per $U_S$ and $U_P$
Connectors	Incorrect connections are ruled out with the new EtherCAT-P-coded M8 connector.
Topology	cascadable in all topology variants
Network planning	tool-based calculation of currents and voltages, resulting in optimum design and distribution of feed-in points
Process data	EtherCAT process data scalable from 1 bit...64 kbyte per device
Devices	up to 65,535 devices in one network
Performance	cycle times of < 100 $\mu$ s, distributed clocks synchronisation << 1 $\mu$ s, signal sampling with oversampling << 1 $\mu$ s with $n = 1 \dots 1000$

# EtherCAT P simplifies system cabling

The fundamental idea of EtherCAT P is to simplify system wiring by reducing the number of connectors on automation components and devices. The single-cable solution, which is highly scalable according to individual power requirements, can be deployed on the entire field level: A conventional standard Ethernet cable is used for the 24 V range. For higher voltages and currents, EtherCAT P is integrated into the corresponding power cable. For this purpose, Beckhoff offers the ENP/ECP connector family, which includes a comprehensive range of cables and connectors.

Eliminating the need for separate supply cables reduces material costs, installation effort and time, as well as the risks of installation errors. In addition, the installation space required in drag chains, control cabinets and in the machine itself is minimised. Moreover, cable routes become smaller and less cluttered, and the size of sensors and actuators can be reduced. Overall, this opens up significantly more freedom in system design, while minimising material or system costs, which can be further reduced using specific tools for system planning.

## EtherCAT P – the ideal sensor, actuator and measurement bus

With EtherCAT P, the  $U_S$  and  $U_P$  currents are directly fed into the wires of the 100 Mbit/s line, resulting in a very cost-effective and compact connection. This makes EtherCAT P the ideal sensor, actuator and measurement bus, offering benefits for connecting smaller remote I/O stations in terminal boxes as well as I/O components distributed in the process environment. A special M8 connector was developed for this purpose, with mechanical coding that reliably protects against mismatching with standard EtherCAT slaves.

To be able to connect components with higher voltage and/or current supply needs, a complete EtherCAT P connector family has been designed: the ECP/ENP connector family covers all applications up to drives with 630 V AC or 850 V DC and 64 A ratings and enables efficient connection of all field level components. For I/O connection, interfaces in IP 20 and IP 67 ratings are available. The system is also suitable for actuators such as AC and

DC motors, valve terminals, and sensors, such as proximity switches, light barriers or rotary encoders. Cameras, bar code scanners and 3D scanners can be integrated for machine vision applications.

## EtherCAT P Box modules for all data acquisition requirements

For the 24 V I/O level, a complete range of system and I/O components is already available with IP 67 rating. The entire variety of tried and tested EP Box modules is also available in EPP format with EtherCAT P technology for connecting sensors and actuators. These include different 4-, 8- and 16-channel digital input modules (3.0 ms or 10  $\mu$ s filter), 4-, 8-, 16- and 24-channel digital output modules (0.5 A or 2 A output current), a wide range of 4-, 8- and 16-channel IP 67 I/Os with combined digital inputs/outputs, as well as serial RS232 and RS422/RS485 interfaces. In addition, there are EPP box modules for analog input and output parameters, e.g.  $\pm 10$  V/0 to 20 mA, differential/absolute pressure, and data from resistance sensors, thermocouples and incremental encoders.

EtherCAT P topologies are just as freely selectable and customisable as with EtherCAT. The current carrying capacity of 3 A per EtherCAT P segment enables a wide range of sensors/actuators to be used. The following IP 67 infrastructure components can be used for creating the required network structure directly in the field:

- EtherCAT P Box with ID switch (EPP1111)
- EtherCAT P junction with power feed-in (EPP1322), with or without refresh (EPP1332/EPP1342)
- EtherCAT P power distribution box (EP9224-0037), with B17-ENP feed-in
- EtherCAT P junction from EtherCAT Box system (EP1312)
- EtherCAT P/EtherCAT connector with power transmission (EPP9001)
- EtherCAT P/EtherCAT connector without power transmission (ZS7000-0005)
- EtherCAT P Box for diagnosing  $U_S$  (system and sensor supply) and  $U_P$  (peripheral voltage for actuators) (EPP9022)

## EtherCAT P Couplers for connecting to the IP 20 world

The IP 20 EK13xx EtherCAT P Couplers enable EtherCAT P to be used all the way through, from the control cabinet right to the machine. The EK1300 Coupler integrates EtherCAT Terminals (ELxxxx) with an EtherCAT P network. The upper EtherCAT P interface is used to connect the coupler to the network, while the lower EtherCAT-P-coded M8 socket is used for optimal continuation of the EtherCAT P topology. Since EtherCAT P integrates power supply and communication on a single line, an additional power supply for the coupler via the terminal points is not required. Depending on the application, the system and sensor supply  $U_S$  or the peripheral voltage for actuators  $U_P$  can be bridged to the power contacts.

The 2-port EK1322 EtherCAT P junction enables the configuration of EtherCAT P star topologies. The ports can be used to connect individual EtherCAT P devices or whole EtherCAT P segments. The EK1322 can be installed at any point in an EtherCAT segment between the EtherCAT Terminals (ELxxxx). The front terminal points are used for the system and sensor supply  $U_S$ , and the peripheral voltage for actuators  $U_P$  for the EtherCAT P outputs.

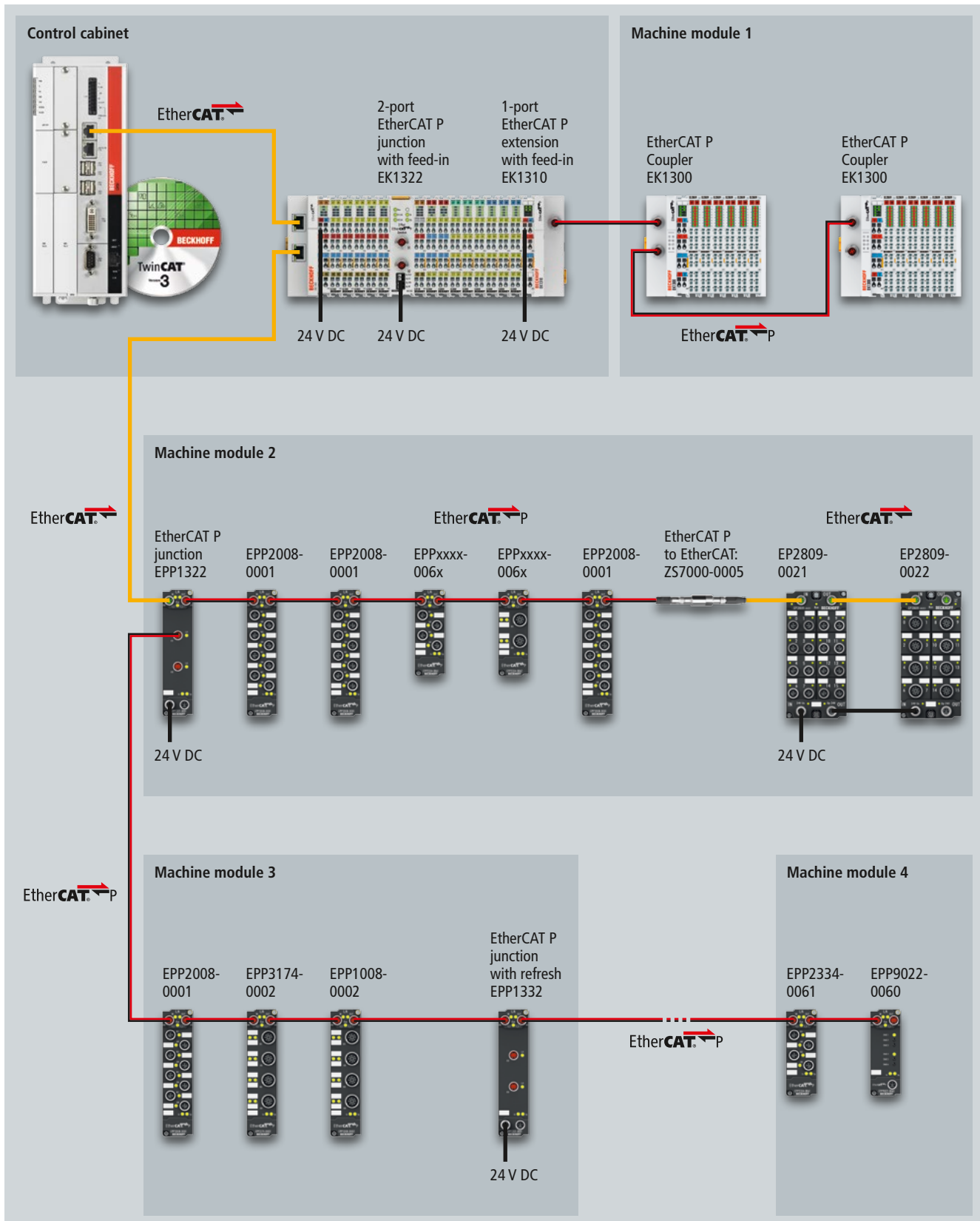
The EK1310 EtherCAT P extension enables conversion from EtherCAT to EtherCAT P or extension of an EtherCAT P network. Terminal points are used for system and sensor supply  $U_S$  and the peripheral voltage for actuators  $U_P$  for the EtherCAT P output.

EtherCAT P products in IP 67  
see page **322**

EtherCAT P products in IP 20  
see page **106**

EtherCAT P accessories  
see page **661**

# EtherCAT P components

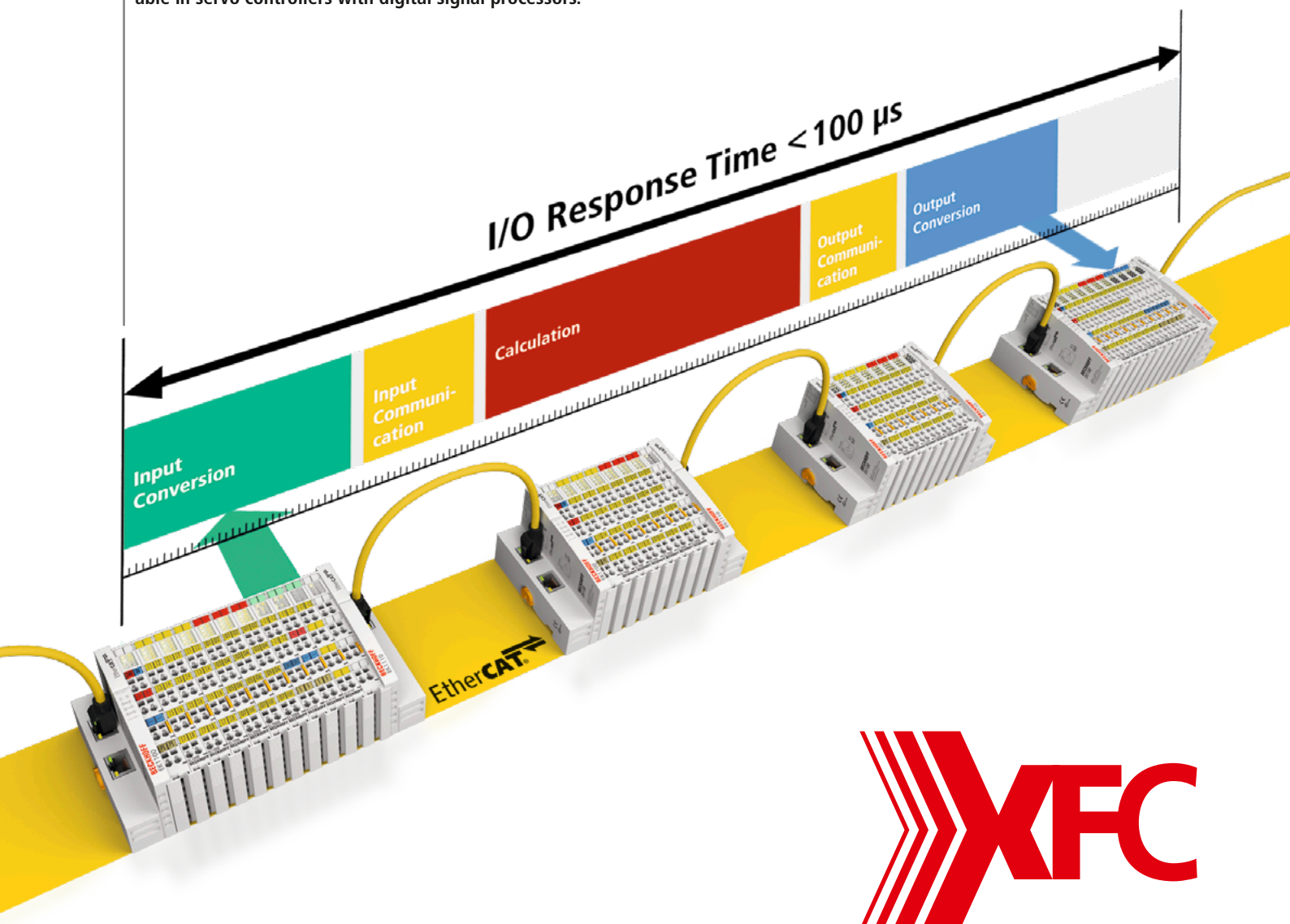


EtherCAT P directly connects different machine modules with power and ultra-fast communication in one cable.

# XFC | Higher production efficiency with extremely fast control technology

► [www.beckhoff.com/XFC](http://www.beckhoff.com/XFC)

The I/O response time includes all hardware processing times (IPC, EtherCAT and I/O system), ranging from physical input event to output response. With an I/O response time of  $< 100 \mu\text{s}$ , PLC programmers have access to performance that in the past was only available in servo controllers with digital signal processors.

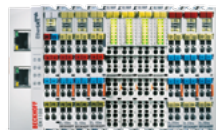




TwinCAT



Industrial PC



Fast I/O



Drive Technology

### EtherCAT | Even faster with XFC

With XFC technology (eXtreme Fast Control) Beckhoff presents an ultra fast control solution: XFC is based on optimised control and communication architectures comprising an advanced Industrial PC, ultra-fast I/O terminals with extended real-time characteristics, the EtherCAT high-speed Ethernet system, and the TwinCAT automation software. With XFC it is possible to achieve I/O response times  $< 100 \mu\text{s}$ . This technology opens up new process optimisation opportunities for the user that were not possible in the past due to technical limitations.

XFC represents a control technology that enables very fast and highly deterministic responses. It includes all hardware and software components involved in control applications: optimised input and output components that can detect signals with high accuracy or initiate tasks; EtherCAT as very fast communication network; high-performance Industrial PCs; and TwinCAT, the automation software that links all system components.

Not long ago, control cycle times around 10 to 20 ms were normal. The communications interface was free-running, with corresponding inaccuracy of the determinism associated with responses to process signals. The increased availability of high-performance Industrial PC controllers enabled

a reduction in cycle times down to 1–2 ms, i.e. by about a factor of 10. Many special control loops could thus be moved to the central machine controller, resulting in cost savings and greater flexibility in the application of intelligent algorithms.

XFC offers a further reduction of response times by a factor of 10, and enables cycle times of  $100 \mu\text{s}$  and below, without having to give up central intelligence and associated high-performance algorithms. XFC also includes additional technologies that not only improve cycle times, but also temporal accuracy and resolution.

Users benefit from options for enhancing the quality of their machines and reducing response times. Measuring tasks such as preventive maintenance measures, monitoring of idle times or documentation of parts quality can simply be integrated in the machine control without additional, costly special devices.

In a practical automation solution, not everything has to be extremely fast and accurate – many tasks can still be handled with “normal” solutions. XFC technology is therefore fully compatible with existing solutions and can be used simultaneously with the same hardware and software.

### TwinCAT – The extreme fast real-time control software

- real-time under Microsoft Windows down to  $12.5 \mu\text{s}$  cycle time
- standard IEC 61131-3 programming in XFC real-time tasks
- Standard features of Windows and TwinCAT are XFC-compliant.

### EtherCAT – The extreme fast control communication technology

- 1000 distributed digital I/Os in  $30 \mu\text{s}$
- EtherCAT down to the individual I/O terminals, no sub bus required
- optimised use of standard Ethernet Controllers, e.g. Intel® PC chipset architecture in the EtherCAT master
- advanced real-time feature based on distributed clocks
  - synchronisation
  - timestamping
  - oversampling

### EtherCAT Terminals – The extreme fast I/O technology

- full range I/O line for all signal types
- high-speed digital and analog I/Os
- Timestamping and oversampling features allow extreme high timing resolution (down to 10 ns).

### IPC – The extreme fast control CPU

- Industrial PC based on high-performance real-time motherboards
- compact form factors optimised for control applications

# XFC technologies

## Distributed clocks

In a normal, discrete control loop, actual value acquisition occurs at a certain time (input component), the result is transferred to the control system (communication component), the response is calculated (control component), the result is communicated to the set value output module (output component) and issued to the process (controlled system).

The crucial factors for the control process are: minimum response time, deterministic actual value acquisition (i.e. exact temporal calculation must be possible), and corresponding deterministic set value output. At what point in time the communication and calculation occurs in the meantime is irrelevant, as long as the results are available in the output unit in time for the next output, i.e. temporal precision is required in the I/O components, but not in the communication or the calculation unit.

The distributed EtherCAT clocks therefore represent a basic XFC technology and are a general component of EtherCAT communication. All EtherCAT devices have their own local clocks, which are automatically and continuously synchronised with all other clocks via the EtherCAT communication. Different communication runtimes are compensated, so that the maximum deviation between all clocks is generally less than 100 nanoseconds. The current time of the distributed clocks is therefore also referred to as system time, because it is always available across the whole system.

### Distributed clocks

- distributed absolute system synchronisation for CPU, I/O and drive devices
- internal sampling 10 ns
- distributed clock precision  $\ll 1 \mu\text{s}$

## Timestamp/multi-timestamp

Process data is usually transferred in its respective data format (e.g. one bit for a digital value or one word for an analog value). The temporal relevance of the process record is therefore inherent in the communication cycle during which the record is transferred. However, this also means that the temporal resolution and accuracy is limited to the communication cycle.

Timestamped data types contain a timestamp in addition to their user data. This timestamp – naturally expressed in the ubiquitous system time – enables provision of temporal information with significantly higher precision for the process record. Timestamps can be used for inputs (e.g. to identify the time of an event occurred) and outputs (e.g. timing of a response). This way it is possible to determine, for example, the precise point in time when an output is to be switched. The switching task is executed independently of the bus cycle.

While timestamp terminals can execute one switching task or switching event per bus cycle, multi-timestamp terminals can execute up to 32 switching tasks or switching events per cycle.

### Signal technology for terminals with timestamping (64 bit time resolution)

- extremely precise time measurement for digital single shot events per cycle: resolution 1 ns, internal sampling 10 ns, accuracy with distributed clocks  $\ll 1 \mu\text{s}$  (+ input delay)
- exact time measurement of rising or falling edges of distributed digital inputs
- exact timing of distributed output signals, independent of control cycle
- absolute distributed clocks time with 64 bit resolution, easy time handling over > 580 years

### Signal technology for terminals with multi-timestamping (32 bit time resolution)

- precise time measurement of up to 32 events per cycle: resolution 1 ns, internal sampling 10 to 40  $\mu\text{s}$  dependent on the configuration
- exact time measurement of rising or falling edges of distributed digital inputs
- exact timing of distributed output signals, independent of control cycle
- distributed clocks time with 32 bit resolution, sufficient for actions in a  $\pm 4$ -second time frame

## Oversampling

Process data is usually transferred exactly once per communication cycle. Conversely, the temporal resolution of a process record directly depends on the communication cycle time. Higher temporal resolution is only possible through a reduction in cycle time – with associated practical limits.

Oversampling data types enable multiple sampling of a process record within a communication cycle and subsequent (inputs) or prior (outputs) transfer of all data contained in an array. The oversampling factor describes the number of samples within a communication cycle and is therefore a multiple of one. Sampling rates of 200 kHz can easily be achieved, even with moderate communication cycle times.

Triggering of the sampling within the I/O components is controlled by the local clock (or the global system time), which enables associated temporal relationships between distributed signals across the whole network.

### Signal oversampling

- multiple signal conversion within one control cycle
- hard time synchronisation through distributed clocks
- for digital input/output signals
- for analog input/output signals
- support of analog I/O EtherCAT Terminals
  - up to 100 kHz signal conversion
  - down to 10  $\mu$ s time resolution
- support of digital I/O EtherCAT Terminals
  - up to 1 MHz
  - up to 1  $\mu$ s time resolution
- application
  - fast signal monitoring
  - fast function generator output
  - signal sampling independent of cycle time
  - fast loop control

## Fast I/Os

Very fast physical responses require suitably short control cycle times in the associated control system. A response can only take place once the control system has detected and processed an event.

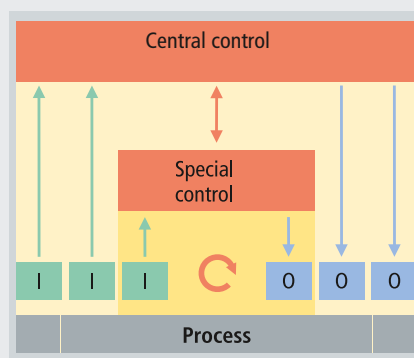
The traditional approach for achieving cycle times in the 100  $\mu$ s range relies on special separate controllers with their own, directly controlled I/Os. This approach has clear disadvantages, because the separate controller has only very limited information about the overall system and therefore cannot make higher-level decisions. Reparameterisation options (e.g. for new workpieces) are also limited. Another significant disadvantage is the fixed I/O configuration, which generally cannot be expanded.

### Extreme fast I/O response time

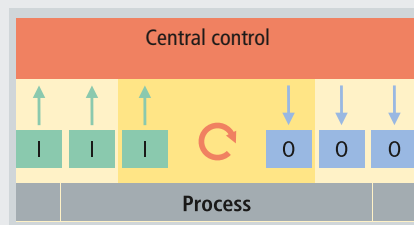
- from 85  $\mu$ s
- Deterministic synchronised input and output signal conversion leads to low process timing jitter.
- Process timing jitter is independent of communication and CPU jitter.

### Extreme short control cycle time

- 100  $\mu$ s (min. 12.5  $\mu$ s)
- new performance class for PLC application: control loops with 100  $\mu$ s



Subordinate special control (limited process image)



Fast central control (complete process image)

# XFC components

Implementation of the XFC technologies described above requires full support for all hardware and software components involved in the control system, including fast, deterministic communication and I/O and control hardware. A significant part of XFC are the software components responsible for fast processing of the control algorithms and optimised configuration of the overall system.

Beckhoff offers a special XFC product range based primarily on four categories: EtherCAT as fieldbus, EtherCAT Terminals as I/O system, IPCs as hardware platform, and TwinCAT as higher-level software. All components are based on open standards, which means that any engineer or programmer can develop very fast control solutions with high performance based on standard components (i.e. without special hardware).

## I/O component with XFC technology

Standard EtherCAT Terminals already offer full support for XFC technology. Synchronisation of the I/O conversion with the communication or – more precisely – with the distributed clocks is already standard in EtherCAT and is therefore supported by the corresponding terminals.

XFC terminals offer additional special features that make them particularly suitable for fast or high-precision applications:

- digital EtherCAT Terminals with very short  $T_{ON}/T_{OFF}$  times, or analog terminals with particularly short conversion times
- EtherCAT Terminals and EtherCAT Box modules with timestamp/multi-timestamping latching at the exact system time at which digital or analog events occur. Output of digital or analog values can occur at exactly predefined times.
- Terminals with oversampling enable actual value acquisition or set value output with significantly higher resolution than the communication cycle time.

## Communication component – EtherCAT fully utilised

With high communication speed and usable data rates EtherCAT offers the basic prerequisites for XFC. However, speed is not everything. The option of using the bus to exchange several independent process images arranged according to the control application enables parallel application of XFC and standard control technology. The central

control system is relieved of time-consuming copying and mapping tasks and can fully utilise the available computing power for the control algorithms.

The distributed EtherCAT clocks that form the temporal backbone of the XFC technologies are available in all communication devices without significant additional effort.

The crucial point of XFC is the option of integrating all I/O components directly in the EtherCAT communication, so that no subordinate communication systems (sub bus) are required. In many XFC terminals the AD or DA converter is connected directly to the EtherCAT chip, so that delays are avoided.

## Control component – High-performance Industrial PCs

Central control technology can be particularly advantageous if it can run faster and more powerful control algorithms than would be the case with many distributed small controllers.

Fast multi-core processors are ideal for running the operator interface of the machine in parallel with the control tasks. Large caches available with modern CPUs are ideal for XFC technology, because fast algorithms run in the cache and can therefore be processed even faster.

An important factor for short XFC cycle times is the fact that the CPU is not burdened with complex process data copying tasks needed by traditional fieldbuses with their DPRAM-based central boards. EtherCAT process data communication can be handled entirely by the integrated Ethernet controller (NIC with bus master DMA).

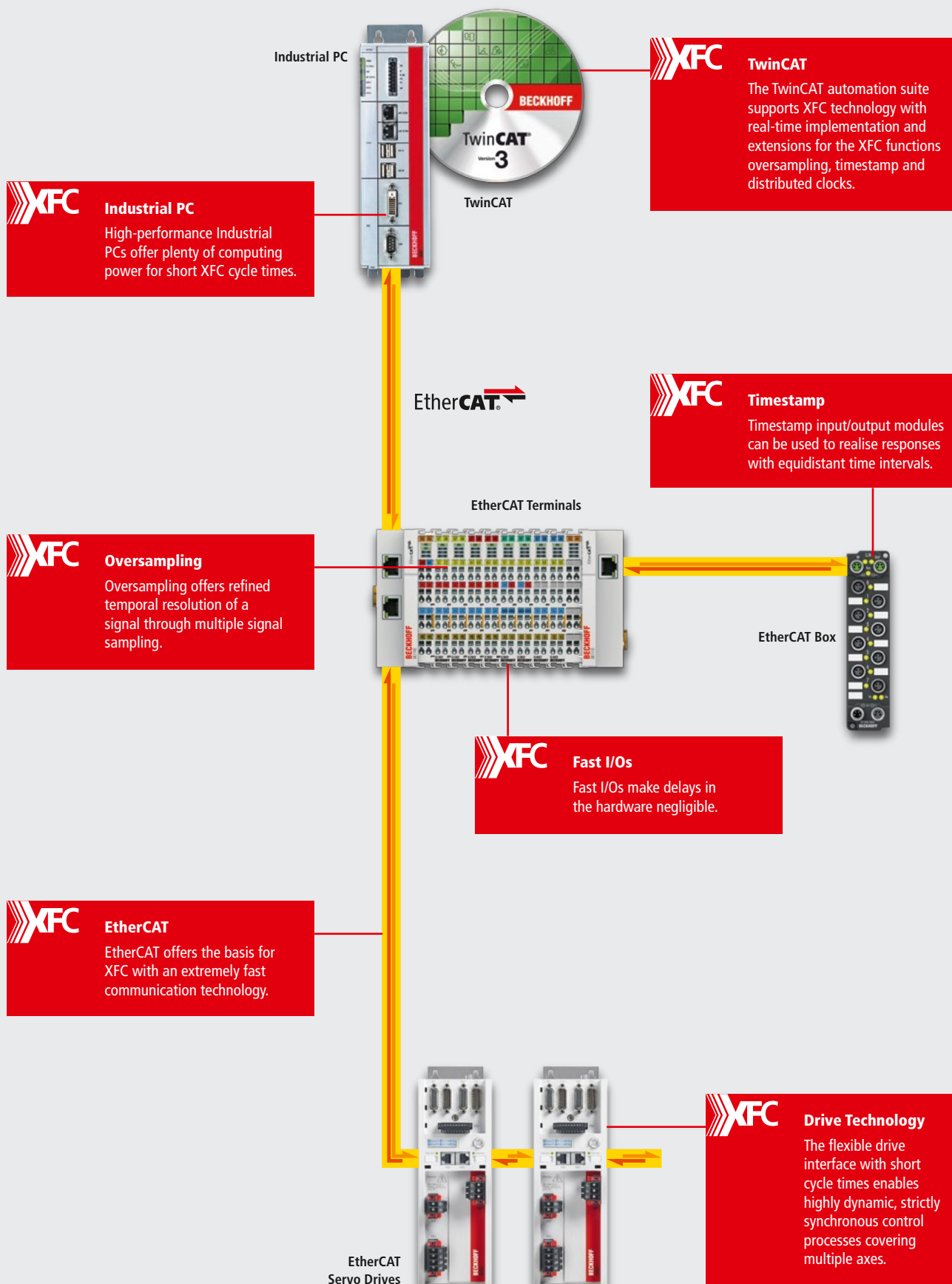
## Software component – TwinCAT automation suite

TwinCAT as high-performance automation suite fully supports the XFC technologies while retaining all the familiar features. The real-time implementation of TwinCAT supports different tasks with different cycle times. Modern Industrial PCs can achieve cycle times of 100 µs or less without problem. Several (different) fieldbuses can be mixed. The associated allocations and communication cycles are optimised according to the fieldbus capabilities. The EtherCAT implementation in TwinCAT makes full use of the communication system and enables application of several independent time

levels. It uses distributed clocks. Different time levels enable coexistence of XFC and normal control tasks in the same system, without the XFC requirements becoming a “bottleneck”.

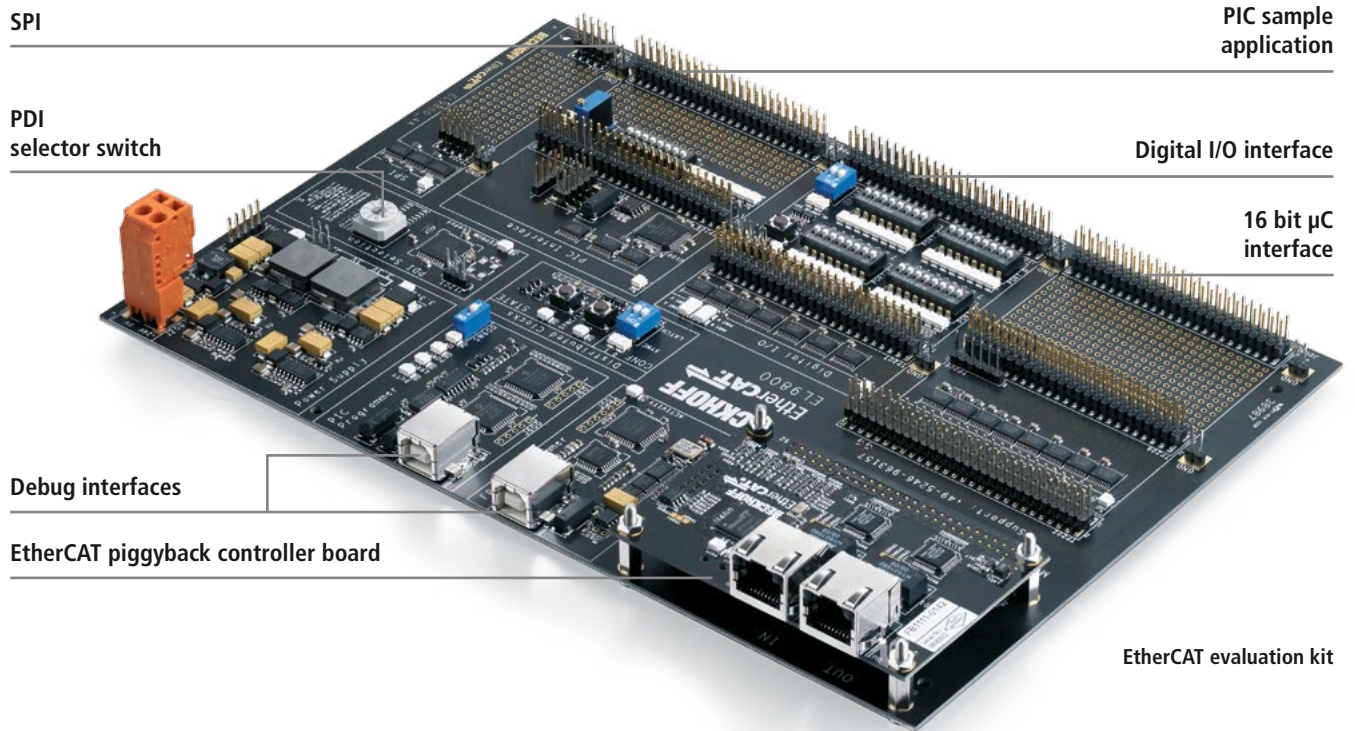
An option specially designed for XFC enables inputs to be read during independent communication calls and outputs to be sent directly after the calculation. Due to the speed offered by EtherCAT the inputs are read and processed “just” before the start of the control tasks, followed by immediate distribution of the outputs with a second fieldbus cycle. The resulting response times are faster than the fieldbus cycle time in some cases.

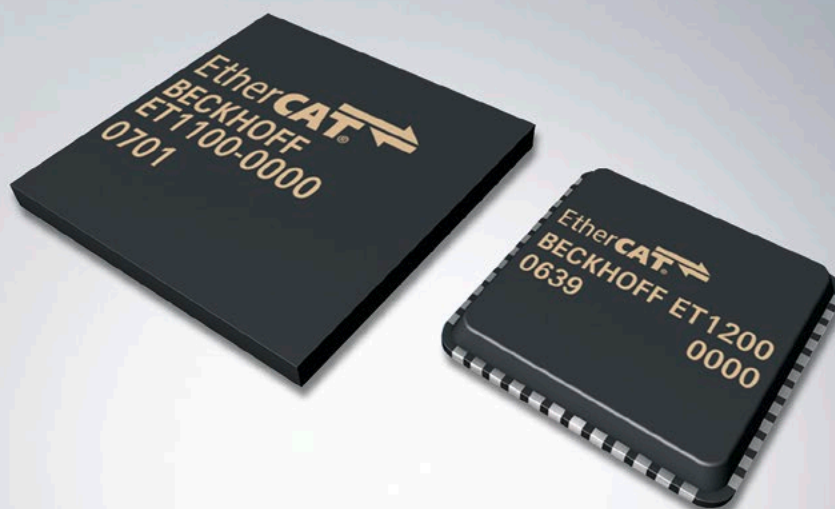
Special TwinCAT extensions facilitate handling of the XFC data types (timestamp and oversampling). PLC blocks enable simple analysis and calculation of the timestamps. The TwinCAT scope can display the data picked up via oversampling according to the allocated oversampling factor and enables precise data analyses.



# EtherCAT | Development Products

► [www.beckhoff.com/EtherCAT-development-products](http://www.beckhoff.com/EtherCAT-development-products)





## ET1100, ET1200 | EtherCAT ASICs

The ET1100 and ET1200 EtherCAT ASICs offer a cost-effective and compact solution for realising EtherCAT slaves. They process the EtherCAT protocol in the hardware and therefore ensure high-performance and real-time capability, independent of any downstream slave microcontrollers and associated software. Through their three process data interfaces – digital I/O, SPI and 8/16 bit  $\mu$ C (not for ET1200) – the EtherCAT ASICs enable realisation of simple digital modules without microcontrollers and development of intelligent devices with own processor. Both ASICs feature distributed clocks that enable high-precision

synchronisation ( $\ll 1 \mu$ s) of the EtherCAT slaves. The supply voltage is 3.3 V or 5 V; the core voltage of 2.5 V is generated by the integrated in-phase regulator or can be supplied directly. The ET1100 is suitable as a universal solution for all types of EtherCAT devices; the ET1200 is optimised for modular devices using E-bus/LVDS (Low Voltage Differential Signalling) as internal interface. Due to their compact design and small number of external components, both ASICs only require minimum space on the board.

The ET1100 ASIC housing (BGA128) only measures 10 x 10 mm. The chip can

support up to four EtherCAT ports. The 8 kB internal memory (DPRAM) for access to process and parameter data is optionally addressed via parallel or serial data bus. Alternatively, the ASICs can also be used without controller. In this case up to 32 digital signals can be connected directly.

The ET1200 ASIC is the “small” variant of the ET1100; with its QFN48 housing measuring only 7 x 7 mm, the chip is even more compact. The device offers 16 digital I/O interfaces and distributed clock hardware for high-precision synchronisation. The 1 kB internal DPRAM is addressed via a fast (20 Mbit/s)

serial interface. The “small ASIC” offers up to three EtherCAT ports, one of which can be used as MII for connecting a standard PHY. The other ports are used for LVDS, which makes the ET1200 the right choice for modular devices using LVDS as internal bus physics.

Technical data	ET1100	ET1200
Number of EtherCAT ports	4 (max. 4 x MII)	3 (max. 1 x MII)
FMMUs	8	3
SYNC manager	8	4
DPRAM	8 kbyte	1 kbyte
Distributed clocks	yes (64 bit)	yes (64 bit)
Process data interfaces	32 bit digital I/O SPI 8/16 bit $\mu$ C	16 bit digital I/O SPI –
Housing	BGA128, 10 x 10 mm	QFN48, 7 x 7 mm
Further information	<a href="http://www.beckhoff.com/ET1100">www.beckhoff.com/ET1100</a>	<a href="http://www.beckhoff.com/ET1200">www.beckhoff.com/ET1200</a>

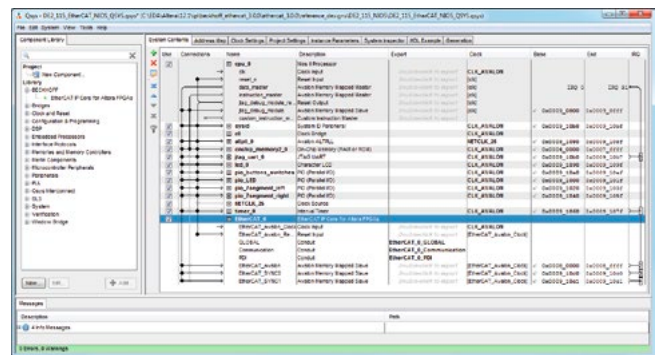
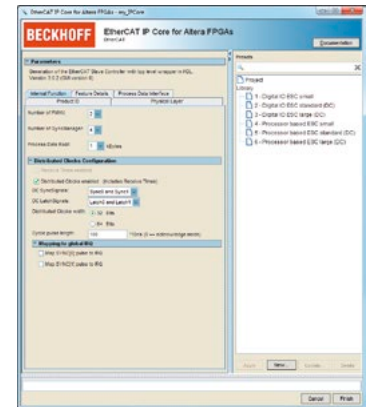
# ET1810, ET1811, ET1812 | EtherCAT IP core for Altera® FPGAs

The EtherCAT IP core enables the EtherCAT communication function and application-specific functions to be implemented on an FPGA (Field Programmable Gate Array – i.e. a device containing programmable logical components). The EtherCAT functionality is freely configurable. The IP core can be combined with own FPGA designs, and it can be integrated in System-on-Chips (SoCs) with soft core processors or hard processor systems via the Avalon® or AMBA® AXI™ interfaces. The physical interfaces and internal functions, such as the number of FMMUs and SYNC managers, the size of the DPRAM, etc., are adjustable. The process data interface (PDI) and the distributed clocks are also configurable. The functions are compatible with the EtherCAT specification and

the EtherCAT ASICs (ET1100, ET1200).

The ET1811 quantity-based license for Altera® FPGAs offers manufacturers of small lots and development service providers the possibility of entering the world of EtherCAT development with low initial investment. For the development of an EtherCAT device, the ET1811 one-time kick-off charge is required, plus the ET1811-1000 royalty for 1000 devices. The royalties for 1000 devices must be paid in advance each time.

For development service providers only the ET1811 one-time kick-off charge will be required; the ET1811-0030 system integrator OEM license will be required for each customer implementation. The end customer will be required to pay the royalty license (ET1811-1000).



Configurable features	ET1810, ET1811, ET1812
PHY interface	1...3 ports MII, 1...3 ports RGMII or 1...2 ports RMII
FMMUs	0...8
SYNC manager	0...8
DPRAM	0...60 KB
Distributed clocks	0...2 SYNC outputs, 0...2 latch inputs (32/64 bit)
Process data interfaces	32 bit digital I/O, SPI, 8/16 bit asynchronous µC interface, Avalon interface, AMBA AXI3 interface, 64 bit general purpose I/O
Further information	<a href="http://www.beckhoff.com/ET1810">www.beckhoff.com/ET1810</a>

Ordering information	
Node-locked buy out license	
ET1810	Node-locked license for using the EtherCAT IP core on one workstation. The license includes 1 year of maintenance and updates.
ET1810-0010	Extension of the node-locked Altera license (ET1810) for one additional workstation
ET1810-0020	One-year maintenance extension for node-locked license (ET1810)
Node-locked quantity-based license	
ET1811	One-time kick-off charge for the node-locked quantity-based license for using the freely configurable EtherCAT IP cores on one workstation
ET1811-1000	Royalty for 1000 devices, ET1811 required
ET1811-0020	One-year maintenance extension, ET1811 required
ET1811-0030	System integrator OEM license
Floating buy out license	
ET1812	Floating buy out license for Altera FPGAs
ET1812-0010	Extension of the floating license (ET1812) for one additional workstation
ET1812-0020	One-year maintenance extension for floating license (ET1812)

## Evaluation license (Open Core Plus IP)

Full-featured, time-limited version available. ► [www.beckhoff.com/ET1810](http://www.beckhoff.com/ET1810)

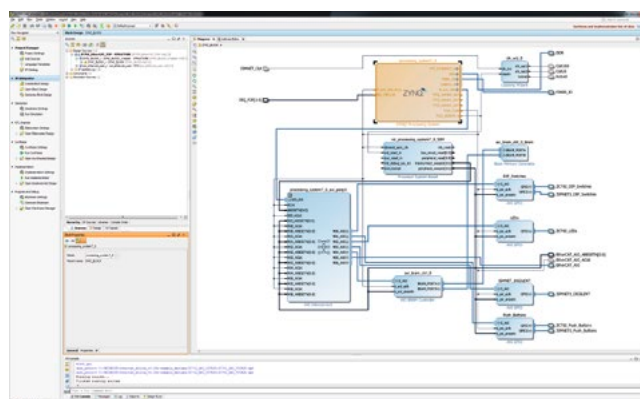
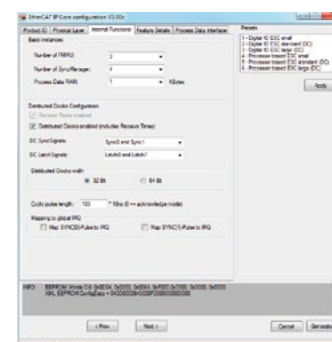
# ET1815, ET1816 | EtherCAT IP core for Xilinx® FPGAs

The EtherCAT IP core enables the EtherCAT communication function and application-specific functions to be implemented on an FPGA (Field Programmable Gate Array – i.e. a device containing programmable logical components). The EtherCAT functionality is freely configurable. The IP core can be combined with own FPGA designs, and it can be integrated in System-on-Chips (SoCs) with soft core processors or hard processing systems via the AMBA® AXI™ interfaces. The physical interfaces and internal functions, such as the number of FMMUs and SYNC managers, the size of the DPRAM, etc., are adjustable. The process data interface (PDI) and the distributed clocks are also configurable. The functions are compatible with the EtherCAT specification

and the EtherCAT ASICs (ET1100, ET1200).

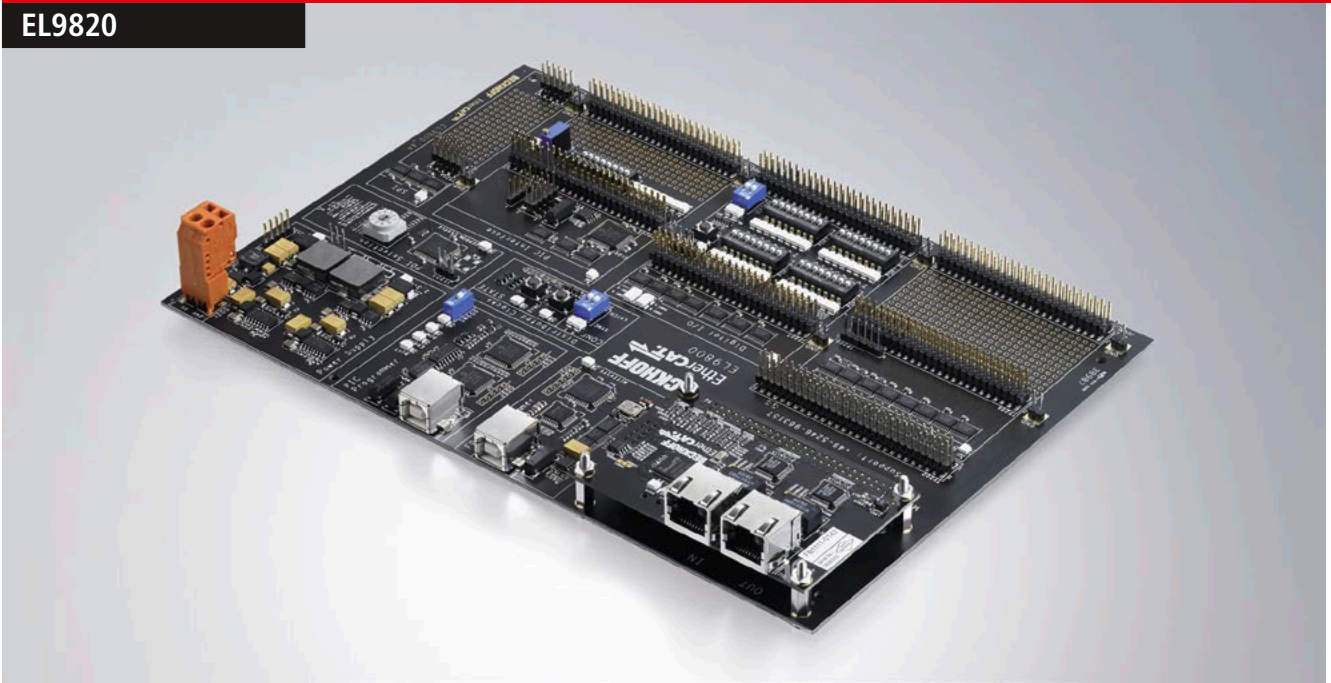
The ET1816 quantity-based license offers manufacturers of small lots and development service providers the possibility of entering the world of EtherCAT development with low initial investment. For the development of an EtherCAT device, the ET1816 one-time kick-off charge is required, plus ET1816-1000 royalty for 1000 devices. The royalties for 1000 devices must be paid in advance each time.

Development service providers only require ET1816 one-time kick-off charge; the ET1811-0030 system integrator OEM license is required for each customer implementation. The end customer requires the royalty license (ET1816-1000).



Configurable features	ET1815, ET1816
PHY interface	1...3 ports MII, 1...3 ports RGMII or 1...2 ports RMII
FMMUs	0...8
SYNC manager	0...8
DPRAM	0...60 KB
Distributed clocks	0...2 SYNC outputs, 0...2 latch inputs (32/64 bit)
Process data interfaces	32 bit digital I/O, SPI, 8/16 bit asynchronous µC interface, AMBA AXI4/AXI4 LITE interface, 64 bit general purpose I/O
Further information	<a href="http://www.beckhoff.com/ET1815">www.beckhoff.com/ET1815</a>

Ordering information	
Node-locked buy out license	
ET1815	Node-locked license for using the EtherCAT IP core on one workstation. The license includes 1 year of maintenance and updates.
ET1815-0010	Extension of the node-locked Xilinx license (ET1815) for one additional workstation
ET1815-0020	One-year maintenance extension for node-locked license (ET1815)
Node-locked quantity-based license	
ET1816	One-time kick-off charge for the node-locked quantity-based license for using the freely configurable EtherCAT IP cores on one workstation; target hardware: selected Xilinx devices
ET1816-1000	Royalty for 1000 devices, ET1816 required
ET1816-0020	One-year maintenance extension, ET1816 required
ET1811-0030	System integrator OEM license



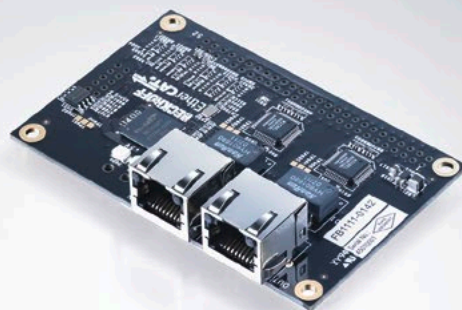
## EL9820 | EtherCAT evaluation kit

The evaluation kit serves as platform for the development of EtherCAT slaves. The piggyback controller board supplied with the kit realises the complete EtherCAT connection with the ASIC ET1100. All digital I/O, SPI and asynchronous  $\mu$ Controller

process data interfaces (PDIs) are connected to pin strips and can be selected via PDI selector switch. The SPI interface can optionally be connected with a PIC microcontroller included with the kit or directly to the pin strip. A programming and debugging

interface for the controller is also provided. The EL9820 can therefore also be used as platform for the ET9300 EtherCAT Slave Stack Code provided with the evaluation kits.

Technical data	EL9820
Evaluation kit	base board
EtherCAT Slave Controller	ASIC ET1100
EtherCAT piggyback controller board	FB1111-0142 with ASIC ET1100
Software	EtherCAT Slave Stack Code ET9300
Accessories	cables, documentation
Workshop	optionally available as TR8100
Further information	<a href="http://www.beckhoff.com/EL9820">www.beckhoff.com/EL9820</a>



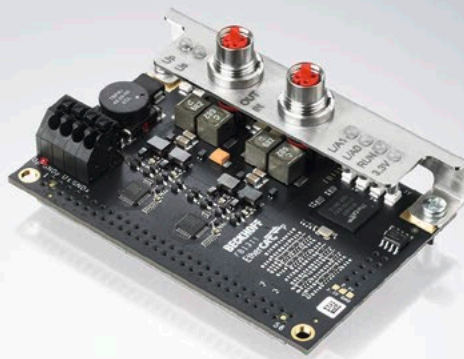
## FB1111 | EtherCAT piggyback controller board

The FB1111 EtherCAT piggyback controller board offers a complete EtherCAT connection based on the ET1100 EtherCAT ASIC. All variants of the FB1111 have

the same form factor and can be used with the EtherCAT evaluation kit. They can be integrated as EtherCAT interfaces in devices.

Ordering information	
FB1111-0140	EtherCAT piggyback controller board with ET1100 and $\mu$ C interface; can be integrated as EtherCAT interface in devices.
FB1111-0141	EtherCAT piggyback controller board with ET1100 and SPI interface; can be integrated as EtherCAT interface in devices.
FB1111-0142	EtherCAT piggyback controller board with ET1100 and digital I/O interface; can be integrated as EtherCAT interface in devices; included in the EL9820 evaluation kit.

► [www.beckhoff.com/FB1111](http://www.beckhoff.com/FB1111)



## FB1311 | EtherCAT P piggyback controller board

With the FB1311 piggyback controller board, the EL9820 evaluation kit can now be used as a fully fledged EtherCAT P slave (powered device). Based on the ET1100 EtherCAT ASIC,

the FB1311 piggyback controller board offers a complete EtherCAT P connection.  $U_S$  is used for power supply of the evaluation board and is additionally available for input connec-

tions and for supplying sensors.  $U_P$  can be used to supply electrically isolated actuator supplies.

### Ordering information

FB1311-0140	EtherCAT P piggyback controller board with ET1100 and $\mu C$ interface
FB1311-0141	EtherCAT P piggyback controller board with ET1100 and SP interface
FB1311-0142	EtherCAT P piggyback controller board with ET1100 and digital I/O interface

► [www.beckhoff.com/FB1311](http://www.beckhoff.com/FB1311)



## ZS7002-9990 | EtherCAT P M8 Flange Sample Box

The EtherCAT P M8 Flange Sample Box contains various flanges, housings, contact carriers and counter nuts.

Content	
ZS7002-0001	EtherCAT P flange, M8, female, straight, 4-pin, rear assembly, print contact, IP 67, EtherCAT-P-coded, 12.5 mm, with counter nut
ZS7002-0002	EtherCAT P flange, M8, female, straight, 4-pin, rear assembly, print contact/contact carrier glued into housing, IP 67, EtherCAT-P-coded, 6.0 mm, with counter nut
ZS7002-0003	EtherCAT P flange, M8, female, straight, 4-pin, rear assembly, print contact, IP 67, EtherCAT-P-coded, 6.0 mm, with counter nut
ZS7002-0004	EtherCAT P flange, M8, female, straight, 4-pin, rear assembly, print contact, IP 67, EtherCAT-P-coded, 10.0 mm, with counter nut
ZS7002-0005	EtherCAT P flange, M8, female, angled, 4-pin, rear assembly, print contact, IP 67, EtherCAT-P-coded, 8.2 mm, with counter nut
ZS7002-0006	EtherCAT P flange, M8, female, angled, 4-pin, rear assembly, print contact, IP 67, EtherCAT-P-coded, 12.2 mm, with counter nut
ZS7002-0007	EtherCAT P flange, M8, female, straight, 4-pin, rear assembly, print contact, IP 67, EtherCAT-P-coded, 9.0 mm
ZS7002-0008	EtherCAT P flange, M8, female, straight, 4-pin, rear assembly, print contact, IP 67, EtherCAT-P-coded, 13.0 mm
ZS7002-1001	M8 contact carrier, straight, EtherCAT-P-coded for ZS7002-0003, ZS7002-0004, ZS7002-0007 and ZS7002-0008
ZS7002-1002	M8 contact carrier, angled, EtherCAT-P-coded for ZS7002-0005 and ZS7002-0006
ZS7002-2001	M10 counter nut, EtherCAT-P-coded, hexagonal
ZS7002-2002	M12 counter nut, EtherCAT-P-coded, hexagonal
ZS7002-2003	M8 housing, EtherCAT-P-coded for ZS7002-0003
ZS7002-2004	M8 housing, EtherCAT-P-coded for ZS7002-0004
ZS7002-2005	M8 housing, EtherCAT-P-coded for ZS7002-0005
ZS7002-2006	M8 housing, EtherCAT-P-coded for ZS7002-0006
ZS7002-2007	M8 housing, EtherCAT-P-coded for ZS7002-0007
ZS7002-2008	M8 housing, EtherCAT-P-coded for ZS7002-0008

Ordering information	
ZS7002-9990	EtherCAT P M8 Flange Sample Box

► [www.beckhoff.com/ZS7002-9990](http://www.beckhoff.com/ZS7002-9990)



## ET2000 | Industrial Ethernet multi-channel probe

The ET2000 multi-channel probe from Beckhoff is a versatile piece of hardware for analysing any Industrial Ethernet solution. With eight ports this device enables unlimited synchronised recording of up to four independent channels at a speed of 100 Mbit/s. All real-time Ethernet standards such as EtherCAT, PROFINET, etc. and conventional office Ethernet networks are supported.

Through its compact and rugged design the ET2000 is ideal both for the local application at

machines or in the laboratory. The four channels enable recording and analysis of separate networks or different points within the same network. All frames in transit – in both directions – are furnished with a high-precision timestamp in the probe hardware and copied to the Gbit uplink port. The high timestamp resolution of 1 ns enables very precise timing analysis of the connected network segments. The ET2000 probe is transparent for the connected buses. Thanks

to the low cycle delay of 1  $\mu$ s the influence on the system is very small.

The device can be connected to any Gbit Ethernet interfaces on the PC side. A plug-in for the free Wireshark network monitor enables this network monitor to be used for analysing recordings and high-precision timestamps.

Technical data	ET2000
Number of ports/channels	8/4
Uplink port	1 Gbit/s
Delay	approx. 1 $\mu$ s
Resolution timestamp	1 ns (channel 0/1)
Software interface	WinPcap
Data transfer rates	probe ports: 100 Mbit/s, uplink port: 1 Gbit/s
Hardware diagnosis	link/activity LED per channel, 1 power LED
Power supply	24 (18...30) V DC, 500 mA, 3-pin connection (+, -, PE)
Dimensions (W x H x D)	approx. 100 mm x 150 mm x 40 mm
Operating temperature	0...+55 °C
Further information	<a href="http://www.beckhoff.com/ET2000">www.beckhoff.com/ET2000</a>



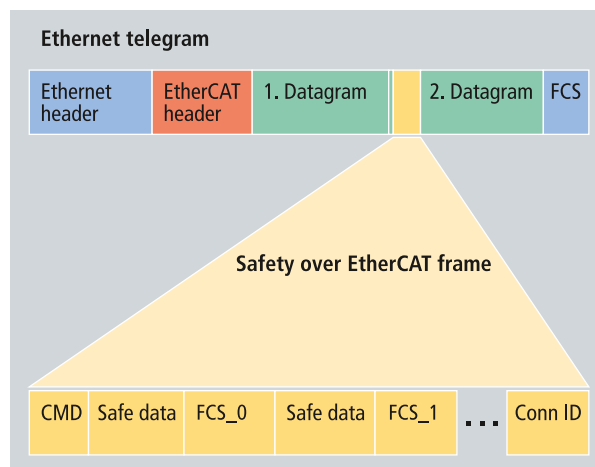
## Safety over EtherCAT

In the interest of realising safe data communication for EtherCAT, the Safety over EtherCAT protocol has been disclosed. The protocol meets the requirements of IEC 61508 up to Safety Integrity Level (SIL) 3 and of IEC 61784-3, as approved by the TÜV.

EtherCAT is used as a single-channel communication system. The transport medium is regarded as a “black channel” and not included in the safety considera-

tions. Thus, the protocol can also be transmitted by other communication systems, backplanes, WLAN. 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.

The license for implementation of the Safety over EtherCAT master and slave technology in a device is free of charge.



## ET9402 | Safety over EtherCAT Conformance Test Tool

The FSoE Conformance Test Tool (FSoE CTT) enables in-house testing of Safety over EtherCAT (FSoE) slave devices with EtherCAT interface. The utilisation of the ET9402 tool during the development of Safety over EtherCAT devices helps to ensure the conformity and to prepare

the device for the official, independent FSoE Conformance Test in an ETG accredited EtherCAT Test Center.

The tool is based on the EtherCAT Conformance Test Tool (ET9400) with extensions regarding to Safety over EtherCAT functionality. A valid subscription of

the ET9400 is a prerequisite for the FSoE CTT.

The test includes a complete test set for testing the conformance of FSoE slave devices. The test set is approved by TÜV. According to the Safety over EtherCAT Conformance Test Policy of the EtherCAT Technol-

ogy Group (ETG), every manufacturer of EtherCAT devices with Safety over EtherCAT is obliged to prove the compatibility of the Safety over EtherCAT implementation by means of the current version of the FSoE tests and the required FSoE Conformance Test Tools.

### Ordering information

#### ET9402

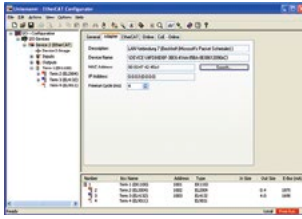
Safety over EtherCAT Conformance Test Tool

- includes a complete test set for testing the conformance of FSoE slave devices
- The test set is approved by TÜV.
- A valid subscription of the ET9400 is a prerequisite for the FSoE CTT.

► [www.beckhoff.com/ET9402](http://www.beckhoff.com/ET9402)

# ET9000, ET9200, ET9300 | EtherCAT development software

## ET9000 | EtherCAT configurator



Through clear definition of the interfaces in the EtherCAT specification an EtherCAT master can be developed without having to develop a configurator at the same time. The EtherCAT configurator is aimed at EtherCAT

master developers who want to use it or integrate and distribute it with their software package.

The Windows software for configuring an EtherCAT network includes a configurator for:

- reading XML device descriptions (ESI)
- generating XML configuration descriptions (ENI)

### Features

- online features
  - scanning of EtherCAT networks
  - diagnostics
  - free-run online mode for commissioning
- topology representation
- Automation software interface starts the configurator as COM server.
  - COM interface
  - XML interface for parameter exchange between client and server

- Safety configuration, EL69xx Safety PLC (Safety over EtherCAT)
- including embedded graphical user interface
- EXE file, executable under Windows XP, Vista and Windows 7

The EtherCAT configurator is not required if the TwinCAT software from Beckhoff is used.

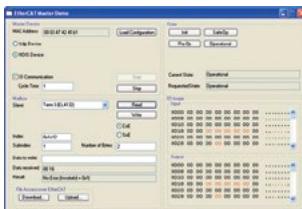
### Ordering information

ET9000

license for using the EtherCAT configurator

► [www.beckhoff.com/ET9000](http://www.beckhoff.com/ET9000)

## ET9200 | EtherCAT Master Sample Code



The EtherCAT Master Sample Code is a user mode Windows application that demonstrates implementation of the EtherCAT master. The TR8200 workshop for EtherCAT master developers is based on the ET9200.

### Features

- boot-up and configuration
- sending and receiving of "raw" EtherCAT frames to/from a network adapter
- management of EtherCAT slave states
- reading of XML configuration descriptions
- sending of the initialisation commands that are defined for the different state changes to the slave device
- mailbox communication
- CoE (CAN Application protocol over EtherCAT)
- SoE (Servodrive Profile over EtherCAT)
- EoE (Ethernet over EtherCAT)
- FoE (File Access over EtherCAT)
- AoE (ADS over EtherCAT)
- integrated virtual switch functionality
- cyclical process data communication
- distributed clocks state machine

The software is sent as source code and can be adapted to the hardware environment (Ethernet controller) and integrated in a real-time environment.

### Ordering information

ET9200

license for using the EtherCAT Master Sample Code

► [www.beckhoff.com/ET9200](http://www.beckhoff.com/ET9200)

## ET9300 | EtherCAT Slave Stack Code

The EtherCAT Slave Stack Code (SSC) is a code written in ANSI C. Its modular and simple structure enables fast entry into slave development.

A large number of EtherCAT slaves can be realised with the SSC, from the I/Os to the drives. The stack can be easily adapted to different platforms since it provides a defined hardware access layer and also supports different controller architectures.

The SSC, which has been available since 2004 and has been continuously maintained and enhanced in collaboration with the EtherCAT Technology Group, is considered to a certain extent to be the reference for an

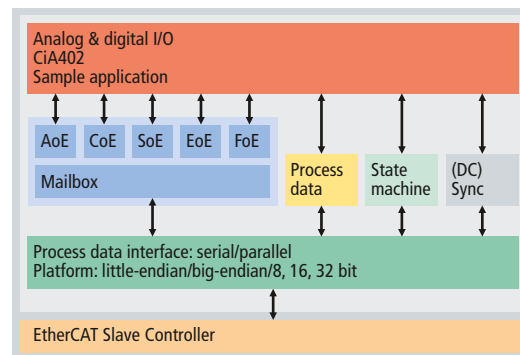
EtherCAT slave device implementation. Particular attention was paid to the conformity with the protocol specification.

The slave stack code tool provided offers the possibility to generate a slave stack code, device description files (ESI) and individual source code documentation to suit the developer's own needs.

### Functionality (excerpt)

- ESM (EtherCAT State Machine)
- mailbox protocols:
  - CoE (CAN application protocol over EtherCAT)
  - AoE (ADS over EtherCAT)

- EoE (Ethernet over EtherCAT)
- FoE (File Transfer over EtherCAT)
- preparation for SoE (Servo drive profile over EtherCAT)
- preparation for boot loader support
- various synchronisations (e.g. DC), including Sync Watchdog
- example implementation of the CiA402 drive profile according to ETG.6010 specification



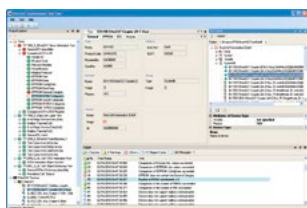
### Ordering information

ET9300

license for using the EtherCAT Slave Stack Code  
(free download from Beckhoff website via Member Area of the EtherCAT Technology Group web page)

► [www.beckhoff.com/ET9300](http://www.beckhoff.com/ET9300)

## ET9400 | EtherCAT Conformance Test Tool



The Conformance Test Tool (CTT) enables in-house testing of EtherCAT slave devices. Use of the CTT supports EtherCAT device development, helps to ensure conformance prior to device release and to prepare the device for the official, independent Conformance Test in an EtherCAT Test Center (ETC) accredited by the EtherCAT Technology Group.

The CTT simplifies the development work with many helpful functionalities. Error detection and troubleshooting are supported by comprehensive test log information. The CTT supports the generation of different device configurations (e.g. synchronisation modes or PDO configuration) and their automated tests. Tests can be conducted as long-term tests and thus as communication stress tests, too. Each test is identified individually to enable the assignment of the telegrams in a network capture. All test results can be saved in Excel or CSV for personal documentation.

With the external CU2508 real-time Ethernet port multiplier, any computer can be used for real-time tests, too. That is also the case for tests of devices supporting synchronisation modes with DC.

In addition to many comfortable device configuration functions, the CTT supports an editor for the ESI as well as the EEPROM content (SII) and enables the control of the state machine.

Among others, the delivered tests check:

- consistency and plausibility of the information from CoE object dictionary, SII and ESI
- test of the EtherCAT State Machine (ESM) and Explicit

Device Identification methods

- mailbox communication with SoE and CoE
- object dictionary description for different profiles, including CiA402
- FSoE protocol (with existing ET9204 license)

System prerequisites:

Standard PC, Windows XP/Windows 7/Windows 10 (32 or 64 bit), network interface card (100 Mbit/s, together with CU2508: 1000 Mbit/s), CU2508 if applicable.

Further information and download of the CTT at ► [www.ethercat.org](http://www.ethercat.org) (members only).

### Ordering information

ET9400

1-year license for using the EtherCAT Conformance Test Tool

► [www.beckhoff.com/ET9400](http://www.beckhoff.com/ET9400)