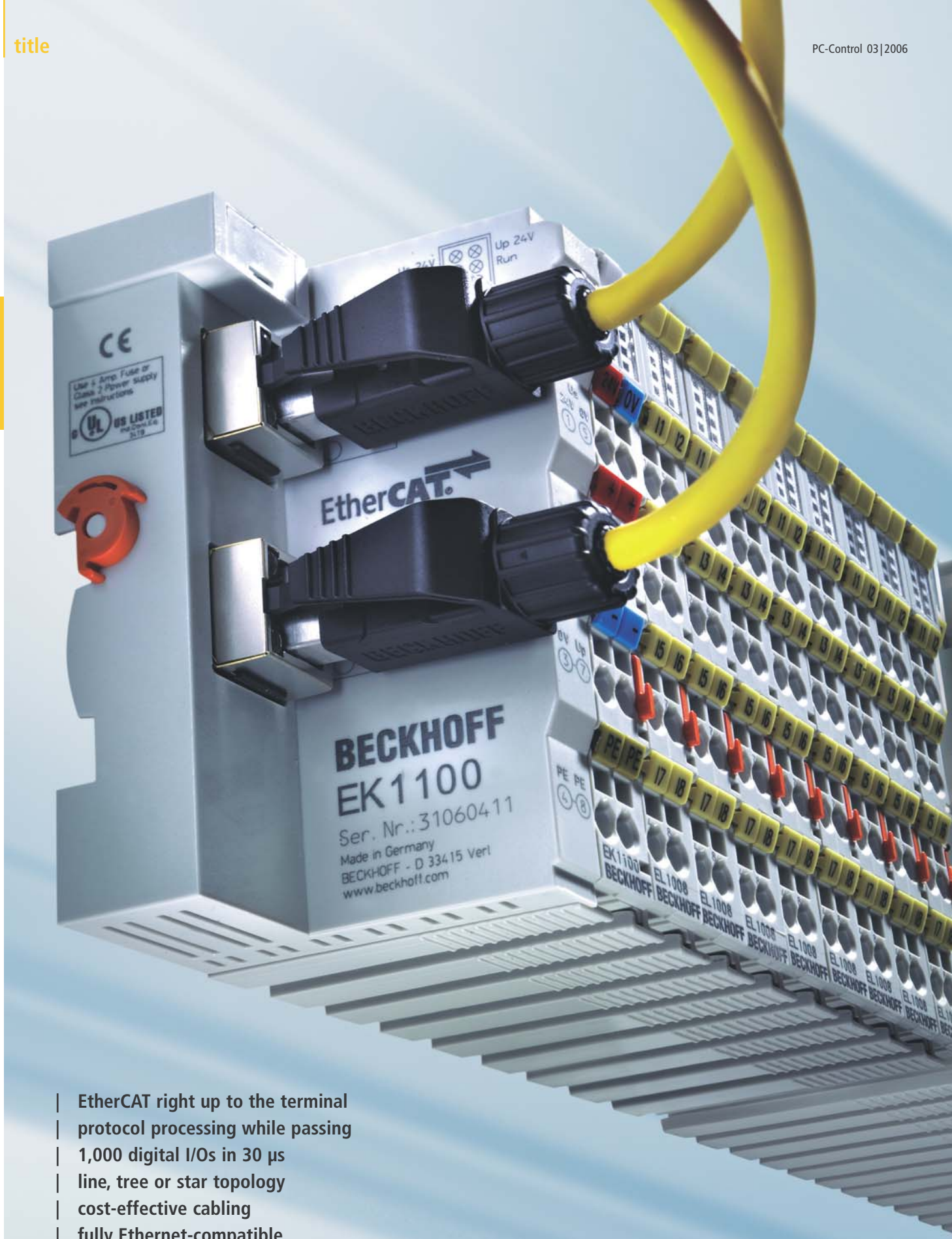


- EtherCAT right up to the terminal
- protocol processing while passing
- 1,000 digital I/Os in 30 µs
- line, tree or star topology
- cost-effective cabling
- fully Ethernet-compatible
- convenient diagnostics

EtherCAT in dynamic, electronic terminal blocks

Industrial Ethernet has also arrived in electronic terminal blocks. Full Ethernet compatibility, maximum utilization of the large bandwidth offered by Ethernet and remarkable real-time characteristics at low costs – these are the outstanding features of the EtherCAT I/O system from Beckhoff.

Bus Terminal I/O – the electronic terminal block – was developed by Beckhoff and introduced 12 years ago. It has embarked on an unparalleled, triumphant advance in automation technology. The Bus Terminal system is a technology that has shaped automation engineering over the last few years and has become a worldwide standard that has continuously developed since its introduction. While Bus Terminals were limited to standard signals back in 1995, an almost seamless product range comprising more than 200 terminals and 60 Bus Couplers or controllers is now available.

The entry of Ethernet into the industrial environment has also had an impact on Bus Terminal technology. Beckhoff uses EtherCAT (Ethernet for Control Automation Technology), a real-time Ethernet technology that overcomes the limits of conventional fieldbuses and is designed for the next generation of control technology – both in terms of transfer speed and with regard to topology flexibility and size.

Beckhoff offers the user two I/O systems, i.e. the Bus Terminal and the EtherCAT Terminal system. From the outside and in terms of mechanical configuration, they are almost identical. The differences are internal, i.e. in the signal and protocol processing.

The EtherCAT Terminals are specially designed for the high performance and flexible topology of the EtherCAT protocol. On the hardware side, the modular EtherCAT I/O system with IP 20 protection is based on the housings of the reliable Bus Terminal system. In contrast to Bus Terminals, where the fieldbus signal is converted within the Bus Coupler to the internal, fieldbus-independent Terminal Bus (K-bus), the EtherCAT protocol is fully maintained right up to the individual terminals.

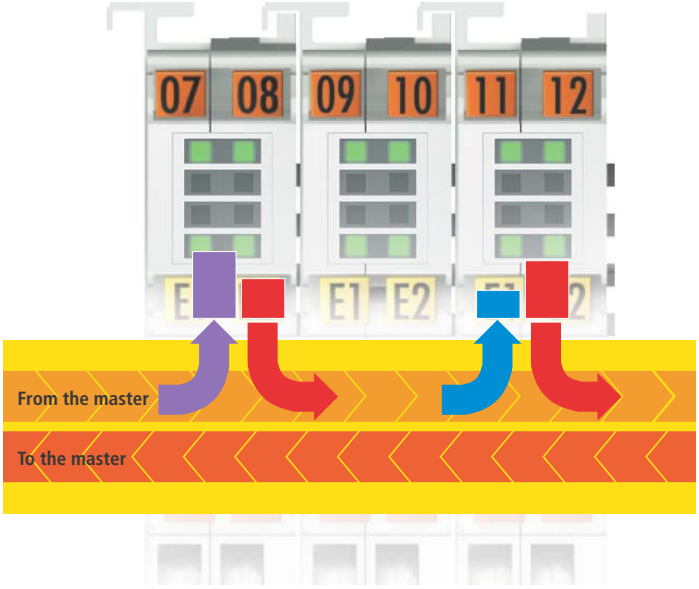
In addition to EtherCAT Terminals, standard Bus Terminals can also be connected via the BK1120 EtherCAT Bus Coupler, so that compatibility and continuity are ensured. Thus, existing and future investments are protected. Beckhoff continues to develop both I/O systems further.

Fast analog and digital terminals: The high speed of the communication system is also reflected in the newly developed EtherCAT I/O Terminals. For example, conversion times in the new 16-bit analog terminals have become 40 times faster so that the devices can be used in fast controllers. In digital terminals, the fast digital inputs/outputs with T_{on}/T_{off} times of 1 µs offer response times of 100 µs.

Ethernet "on the fly"

Each individual EtherCAT Terminal is equipped with an EtherCAT slave controller for protocol processing. To achieve high-speed processing beyond other Ethernet solutions, EtherCAT processing occurs directly during the pass. The Ethernet packet is no longer received and interpreted, followed by copying of process data to every connection. The EtherCAT slave devices read the data addressed to them while the frame passes through the node (chart below). Similarly, input data are inserted while the telegram passes through. The telegrams are only delayed by a few nanoseconds. Since an Ethernet frame comprises the data of many devices both in send and receive direction, the user data rate increases to over 90 %. The full-duplex features of 100BASE-TX are fully utilized, so that effective data rates of > 100 Mbit/s (> 90 % of 2 x 100 Mbit/s) can be achieved.

The Ethernet protocol according to IEEE 802.3 is fully maintained right up to the individual terminals. Only the physical transfer behavior is converted from twisted pair to E-bus inside the coupler. E-bus technology is based on LVDS (low-voltage differential signaling) transfer, which satisfies the requirements of electronic terminal blocks. LVDS is a fast and cost-effective, alternative physical Ethernet layer that can also be used for 10 Gigabit Ethernet (IEEE802.3ae). At the end of the modular device, the system is simply switched back to 100 BASE-TX.



Telegram processing completely in hardware

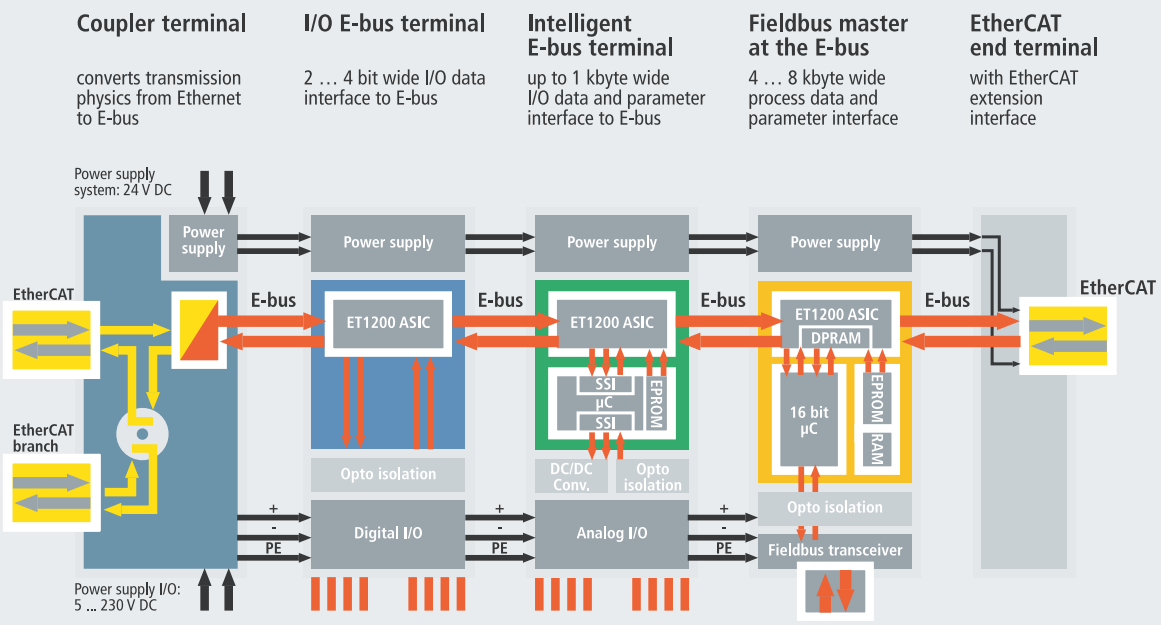
Openness and flexibility inside

The EtherCAT protocol can transport other Ethernet-based services and protocols in the same physical network – usually 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 a fieldbus interface are integrated via EtherCAT fieldbus master terminals. The UDP protocol variant can be implemented on each socket interface.

The EtherCAT function of Hot Connect/Disconnect of bus segments offers significant benefits in terms of system flexibility in practical applications because many systems – e.g. in processing centers with multiple, sensor-equipped tool systems – require a modification of the I/O configuration during operation. The EtherCAT protocol structure meets these requirements since Hot Connect enables parts of the network to be activated/deactivated or reconfigured during operation so that the system can respond flexibly to different configurations.

Flexible topology and distributed applications

The EtherCAT Terminal system supports almost any topology. The bus or line structure known from traditional fieldbuses is also available for Ethernet now.



Protocol processing completely in hardware – protocol ASICs flexibly configurable.
Process interface from 2 bit to 64 kbyte.

Particularly useful for system wiring is the combination of line and branches or stubs: The required interfaces exist on the EtherCAT Couplers; no additional switches are required. The traditional switch-based Ethernet star topology can also be used. Wiring flexibility is completed through the choice of different cables. Flexible and cost-effective, standard Ethernet patch cables meet the 100BASE-TX transfer requirements in the control cabinet. A wide range of industry-standard cables and plug connectors are available for networking outside the control cabinet. Fiber optic connections can be realized with standard media converters and transitions to rotating machine components with standard Ethernet slip rings.
The 100BASE-TX hardware enables a cable length of 100 m between two EtherCAT I/O stations and is particularly suitable for distributed applications such as material handling systems. Since up to 65,535 devices can be connected to an EtherCAT segment, the size of the network is practically unlimited.

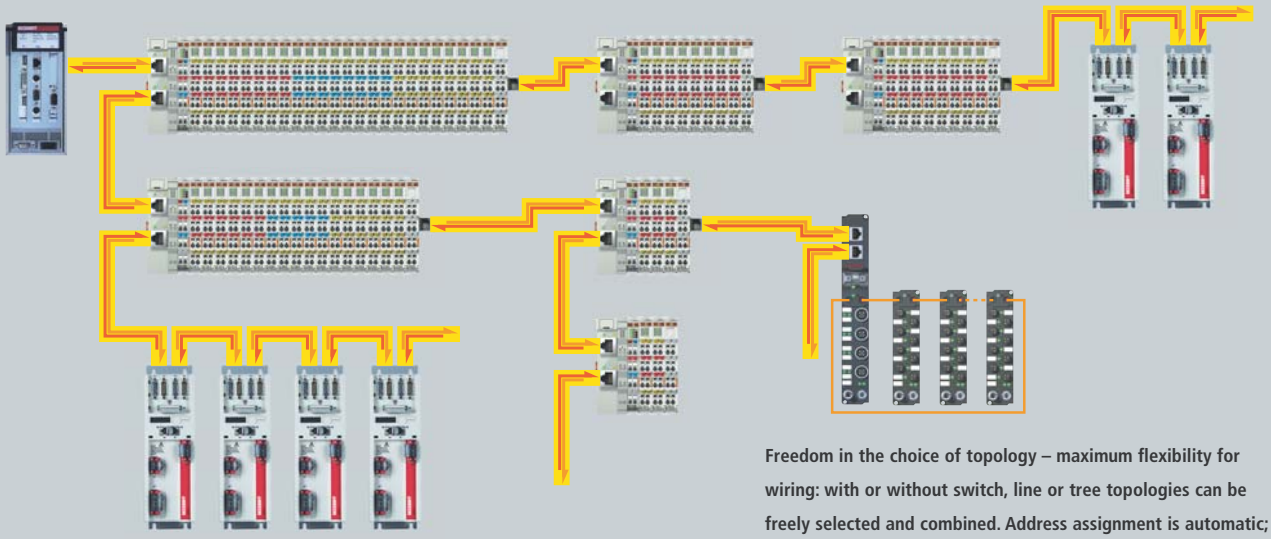
Low infrastructure costs

Since no hubs or switches are required for EtherCAT, costs associated with these devices, including power supply, installation etc., are completely avoided. Standard cables (minimum CAT5) and standard plug connectors can be used if environmental conditions permit.
EtherCAT is also suitable for lower and medium range control applications where it enables high-performance, cost-effective control solutions. The EtherCAT master requires no special plug-in card and can be easily implemented on any existing Ethernet controller. Control and regulation concepts can be easily made, even using simple CPUs, due to the extremely high performance of EtherCAT.

Among other things, EtherCAT improves system performance without changing the CPU by shifting the mapping task from the control CPU into the EtherCAT system. Pre-sorted data are transferred to the control computer's RAM via Direct Memory Access (DMA). With traditional fieldbuses, a physical process image is generated that typically does not match the control variables. The process of re-sorting ("mapping") is handled by the controller CPU and requires up to 30 % of its capacity.
Valuable CPU time is used to look for individual bits in the data and copy them into variables. The work must be carried out again in reverse order before issuing the data. With EtherCAT, mapping is shifted to the fieldbus slaves. This takes load off the master. The CPU can carry out the complete data exchange while requiring only a few accesses to the Ethernet controller, since it is only necessary to send one EtherCAT frame for small to medium sized system parameters.

Simple diagnostics and high availability

Experience with fieldbus systems shows that availability and commissioning times crucially depend on the diagnostic capability. Only faults that are detected quickly and accurately and are precisely located can be corrected at short notice. Therefore, special attention was paid to exemplary 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, this verification can not only take place during system start-



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.

System structure

In analogy to the Beckhoff Bus Terminals, the EtherCAT Terminal family is a modular I/O system consisting of electronic terminal blocks. An I/O station consists of an EtherCAT Coupler and almost any number of terminals. Since up to 65,535 devices can be connected, the size of the network is practically unlimited.

EtherCAT is designed for operation without switch. In this case, the EK1100 coupler is used. For applications requiring a switch, Beckhoff will shortly provide a solution in the form of the EK1000 that can process the EtherCAT UDP protocol in passing.

The electronic terminal blocks are attached to the EtherCAT Coupler. The contacts are made as the terminal clicks into place, without any other manipulation. This means that each electronic terminal block can be individually exchanged and is mounted on standard DIN rail.

Suitable EtherCAT Terminals are available for common digital and analog signal types used in the world of automation. Fieldbus devices, e.g. for PROFIBUS, CANopen or DeviceNet, are integrated via local fieldbus master/slave terminals. Removal of the fieldbus master saves PCI slots in the PC. Any Ethernet device can be integrated locally via switch terminals.

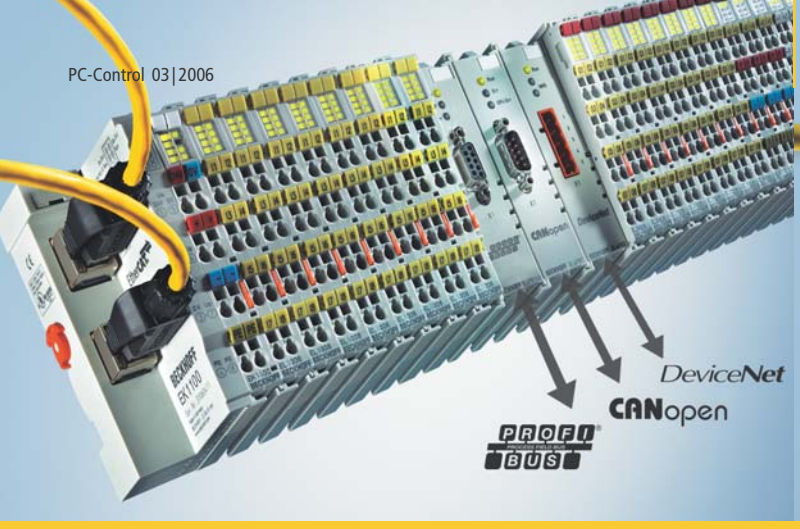
The fine granularity of the EtherCAT Terminals enables bit-precise composition of the required I/O channels. The digital EtherCAT Terminals are designed as 2-, 4-, or 8-channel terminals. The standard analog signals of ± 10 V, 0 ... 10 V, 0 ... 20 mA and 4 ... 20 mA are all available as 1-, 2-, 4-, and 8-channel variants within a standard housing.

The EtherCAT Terminal system offers different connection options for optimum adaptation to the respective application. The ELxxxx EtherCAT Terminals include electronics and connection level in a single enclosure. The ESxxxx type EtherCAT Terminals provide a pluggable connection feature. The ES series Bus Terminals enable the complete wiring to be removed as a plug connector from the top of the housing for servicing.

up, automatic reading in of the network is also possible (configuration upload). Apart from breaking point detection and localization, the protocol, physical transfer behavior 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 localization of critical network sections. Gradual or changing sources of errors such as EMC influences, defective connectors or cable damage are detected and located before they lead to malfunctions. Increasing demands in terms of system availability are met with optional line redundancy that enables devices to be changed without having to shut down the network. This offers scope for new automation applications in machine construction and can be realized with standard components. EtherCAT also supports redundant masters with hot standby functionality. Since the 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. Drag chain applications, for example, can be specifically configured as stubs in order to be prepared for cable fracture.

Benefits for the user

Talking about transfer times in microseconds and synchronicity in nanoseconds may create the impression of high complexity. Quite to the contrary. The technical limits of EtherCAT are so far ahead of today's typical requirements that network dimensioning and optimization are generally no longer an issue. EtherCAT I/Os offer unprecedented design convenience for system integrators.
EtherCAT Terminals provide a comprehensive range of signals: Complemented by a large number of special terminal developments, EtherCAT covers a wide range of applications, from simple, cost-sensitive standard applications to special high-end applications. Market experience with Bus Terminals enables the signal mix to be tailored to the application during the product introduction. EtherCAT Terminals are being developed further, particularly with regard to applications that open up new functionality through added technical features. New signal types are being integrated on an ongoing basis. Control cabinets become smaller since many aux-



Fieldbus devices (PROFIBUS, CANopen, DeviceNet, AS-interface etc.) are integrated via decentralized fieldbus master/slave terminals. The removal of the fieldbus master saves PCI slots in the PC.

The BK1120 EtherCAT Bus Coupler offers Bus Terminals with more than 200 different signal types for the fast real-time Ethernet system, including safety functions. The Bus Terminal has become an automation technology standard within the last few years with millions of terminals in use worldwide.

iliary boxes disappear. This also reduces the wiring effort, and the number of different interfaces is reduced to the new standard EtherCAT interface. Fast, synchronous process images and clearly structured parameter interfaces standardize and simplify access to the control periphery.

The synchronicity offered by EtherCAT in the EtherCAT Terminals is available in two stages: better than 0.1 ms for all components, better than 1 µs for special terminals with a distributed clock. Synchronicity is not an academic gimmick. In practice, synchronous I/Os behave like parallel wiring. It is important that logical links always experience a constant delay, particularly for the optimization of processes with a temporal correlation.

Even more important is high temporal precision in control applications. Oversampling enables process values to be read, processed and issued. The jitter introduced by the whole control system does not exceed ±5 µs. With a high-performance control system, the whole signal propagation delay from input to output of the calculated analog value can be reduced to 200 µs.

A comparison between an EtherCAT system and an advanced digital drive controller clearly illustrates the performance capability. Such a device uses a computation kernel that is optimized for this purpose: a digital signal processor with a typical clock frequency of 120 MHz. Today, a drive controller can achieve a cycle time of 62.5 µs. While this means a new value every 62.5 µs, under unfavourable conditions, the response to a fast change in current may take 125 µs. The jitter in this application is 62.5 µs. By comparison, the signal route via an analog EtherCAT input terminal with oversampling, a PC with TwinCAT and output via an analog EtherCAT output terminal takes 200 µs with a jitter of only ±5 µs. This illustrates that even demanding technical processes can be controlled with standard control components. The realization effort remains comparatively low. Programming takes place in IEC 61131-3 under Windows. Programs can be created very conveniently with standard TwinCAT software.

The high data rate of EtherCAT also enables fast up- and downloading of parameter sets. In practice, one can afford the luxury of sending current datasets to all parameterizable devices during the start-up phase of the system. This only takes a few seconds. The benefits are simple data management and backup in a single device. If required, components can simply be exchanged without requiring adjustment. During troubleshooting, identical parts can be replaced even if the parameters are different. Data are stored centrally, which facilitates archiving. The system also offers benefits for series production: there is a single image for the control system with all programs and settings. The image is loaded and the test can commence. Individual components no longer have to be parameterized individually during commissioning. Intermixing of different version releases is also easier to avoid.

The freedom to mix topologies and the fact that there are virtually no practical restrictions in the number of devices offer further arguments for the utilization of EtherCAT I/O Terminals. Here too, the design effort is reduced while diagnostics are improved. Each Bus Terminal is known to the master in the topology and can be located exactly in the event of a fault.

Diagnostics in TwinCAT

TwinCAT, the automation software from Beckhoff, supports EtherCAT Terminals from version 2.10 on. TwinCAT simplifies commissioning and offers the convenient diagnostic functions of EtherCAT. For example, it provides access to information about all I/O terminals listed in the object dictionary. This object dictionary can be accessed via Automation Device Specification (ADS) from visualization or from the PLC. The TcEtherCAT.lib library was developed for EtherCAT diagnostics via PLC code. All diagnostic messages and displays can thus be determined via PLC code.

→ EtherCAT Terminals **www.beckhoff.com/ethercat**
→ EtherCAT Technology Group **www.ethercat.org**