BECKHOFF New Automation Technology

High-end measurement technology:
For test stand and machine building

ELM3704-0001

RUN
OK

X001

OK

X002

OK

X003

< 1 µs synchronization
25 ppm
24 bit
up to 50,000 samples/s

OK

X004

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Extremely accurate, fast and robust:
System-integrated measurement technology
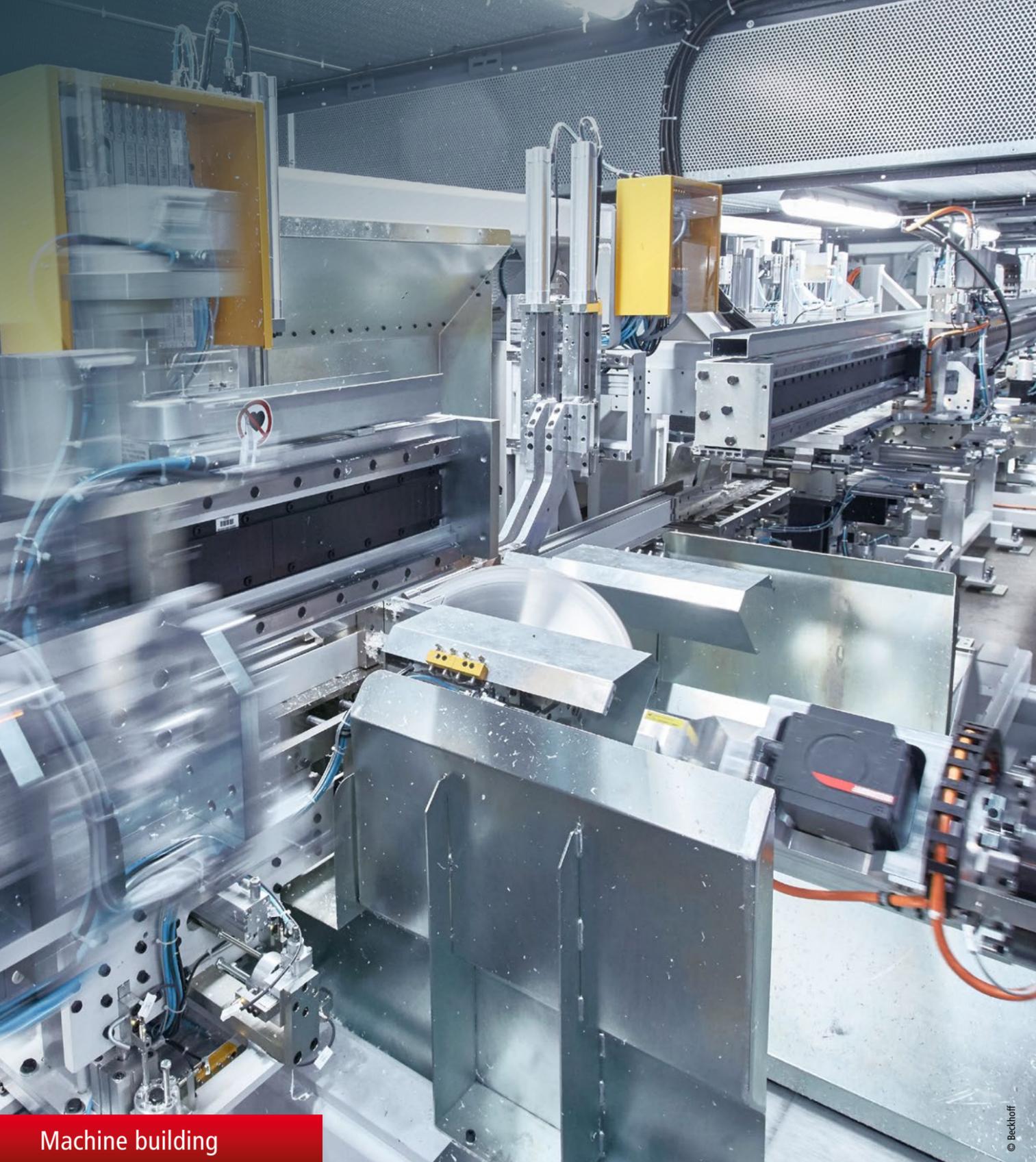
© Beckhoff

Machine building

© Akka DNO GmbH und ZF Friedrichshafen AG / TRW Automotive GmbH

Test stands

© Lionel Flusin / stock.adobe.com

Lab and research facilities

Direct integration into the control system of:
- machinery and systems for optimized production, resource conservation and predictive maintenance
- test stands for exceptionally precise results
- lab and research facilities for reliable measurement data acquisition and 24/7 operation

▶ www.beckhoff.com/measurement

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Increased system efficiency:
The benefits for machine building

Reduced production costs:

High-precision measurement technology reduces the consumption of raw materials and energy in production.

Increased availability:

Reliable measurement technology forms the foundation for advanced predictive maintenance solutions.

Optimized product quality:

Highly precise measurement technology increases processing quality in your production.

Accelerated product development:

Continuously measured production data help developers improve their products.

Enhanced process quality:

High-speed measurement technology reduces cycle times and accelerates production processes – while dramatically reducing the reject rate.

Ideal for Industrie 4.0 applications:

System-integrated measurement technology supplies data for power and condition monitoring.

Measurement technology at high speed
Faster measurement at sampling rates exceeding 10 ksps can scan even highly dynamic processes and provide a large amount of valuable data for subsequent analyses.

Measurement technology provides insight
Precise measurement technology with an accuracy of over 100 ppm and a 24-bit resolution creates true added value because it can detect even the smallest deviations and enable corrective action. Low temperature drift ensures predictable error limits even for long machine runs, thus improving product quality and lowering production variations.

Measurement technology provides a complete overview
Synchronous measurement technology scans multiple channels simultaneously – even for multiple machines. This comprehensive synchronised process image overview can help you implement a high-quality measurement infrastructure across a wide range of systems.

Measurement technology adds value
Proactive measurement technology checks its own functionality and the status of the cabling to produce reliable data from measurement sections in operations that run unattended over long periods. This improves the overall quality and availability of your processes and enables more informed decisions, because you receive valid and traceable quality data for each part produced.

Measurement technology saves money
Measurement technology for automated applications creates an impressive return on investment very quickly. It makes tight fault tolerances possible, and since faulty parts are identified right away, they won't negatively impact downstream production.

Measurement technology supplies data to the cloud
Analog and digital inputs gather all data and status information, which can then be processed and stored locally or remotely in databases or in the cloud via TwinCAT Connectivity functions. This promotes data insight – generated by Beckhoff measurement technology.

System-integrated measurement technology increases competitiveness
- increased productivity
- increased availability through predictive maintenance
- reduced material consumption
- improved process quality
- improved product quality
- direct connectivity enables Industrie 4.0 solutions

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More reliable results: Benefits for test stands in research, test and lab facilities

Draw on the automation toolbox:

Drive technology, machine vision, machine learning/AI, robotics

Reduce complexity:

Integrated EtherCAT communication connects sensors, actuators, and control systems seamlessly

Measure accurately, act immediately:

Less uncertainty and short test times with industrial measurement technology

Reduce costs:

With affordable volume production components and a highly scalable product portfolio

Easily integrate any software:

TwinCAT uses various forms of technology to communicate with other software

Leverage universal connectivity with TwinCAT:

Cloud, IoT, OPC UA, EtherCAT, fieldbus and database systems

Utilize device variety:

EtherCAT components from more than 6,900 members of ETG, the EtherCAT user organisation

Fluent in Automotive:

Standard-compatible solutions available for SENT, LIN, CAN, RAW CAN, SAE J1939, and dbc

© Integrated DNA Technologies, Inc.

Beckhoff measurement technology in a test stand for automotive parts

Tried-and-tested industrial volume production

Beckhoff has been producing industrial automation technology for over 40 years. Designed for 24/7 operation inside or outside of control cabinets and available long-term Beckhoff components are ideally suited for measurement and testing applications. In addition to sophisticated analog technology, our portfolio features digital, analog and feedback inputs for simpler signal acquisition at exceptionally low prices per channel. Monitoring analog outputs and actuators on a test stand is easy too, because TwinCAT supports up to 255 axes simultaneously. Gigabit EtherCAT ensures the fastest real-time communication with sensors and actuators.

Highly accurate, dynamic, and stable over the long term

The list of features for measurement technology from Beckhoff is long: small measurement uncertainties of up to 25 ppm, detection of dynamic signals at up to 1 Msps time-synchronized measurement and control with a time error of << 1 µs, synchronization with any external time source – and everything is stable over the long term and can be recalibrated while still being affordable and expandable.

Universal in terms of hardware and software

TwinCAT software has many benefits as a basis for your test stand. With its exceptional flexibility, it can be easily adapted to all requirements with existing or customer-specific functions. With or without a real-time integration with the TwinCAT real-time controller, it offers cycle times of up to 50 µs (20,000 control cycles per second), and with functions for data storage and analysis it supports even demanding HiL applications and closed-loop control circuits. It can be easily connected to specific control software such as LabView. With up to 65,535 subscribers, it has no limitations in terms of hardware either.

Industrial measurement technology with integrated automation technology:

- simplifies test stand design
- streamlines the engineering process
- reduces communication complexity
- supports modern technology such as cloud, IoT, OPC UA, machine learning, etc.
- significantly reduces costs

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Complete your control system: With easy measurement technology integration

High-end measurement technology with attractive pricing thanks to volume production, seamlessly integrated into the automation system.

Integrate measurement technology into your overall control system: TwinCAT integrates PLC, motion control, measurement technology as well as I/O and cloud connectivity on a single, universal software platform.

Beckhoff measurement technology combines established I/O technology standards with the latest advances in high-precision measurement technology:

1. Standard 12/16-bit analog measurement
2. Energy monitoring in power grids
3. Condition monitoring (vibration measurement technology)
4. 24-bit precision measurement technology

High-precision measurement technology for automation applications
With its new ELM series EtherCAT device family, Beckhoff is adding high-precision and high-speed technology to its portfolio of measurement technology devices. These powerful EtherCAT modules open new doors in terms of accuracy, time and value precision, synchronization and in particular long-term measurement precision that were previously only made possible by adding cost-intensive specialized equipment to integrated automation systems. As a result, Beckhoff offers a universal measurement solution for existing PC- and EtherCAT-based control

applications without performance losses through platform or system breaks.

A milestone in automation
The new ELM series measurement device family represents a milestone in the world of automation. It features powerful, robust and user-friendly measurement technology that was designed especially for use in industry-standard control cabinets with short installation deadlines. Other features include extensive self-diagnostics to ensure reliable long-term operation even in unattended environments without frequent

maintenance routines. For example, the EtherCAT measurement technology modules instantly recognize potentially faulty measurements that may otherwise have erroneously been considered valid for long periods of time. This feature is implemented via extensive connection diagnostics, self-tests and continuous internal checks as well as the constant monitoring of temperature and inputs to detect overload. Features such as high resolution, high measurement accuracy and a high sampling rate – all of which have long been common in lab environments – are now made available by Beckhoff for conventional industrial automation applications. This is done by

leveraging Beckhoff's many years of experience in volume production of automation components. Bringing precision measurement technology into the industrial environment enables makers of classic manufacturing, testing and inspection equipment to further advance their applications.

Beckhoff – automation and measurement technology from a single source:
- complete automation toolbox with IPC, I/O, motion control and automation
- comprehensive toolbox for centralized and distributed measurement technology concepts
- all products are based on standard components
- easy integration into existing control environments
- innovative, well-established vendor with global reach

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Seamless integration from data acquisition to analysis: The Beckhoff measurement chain

The measurement software in the cloud
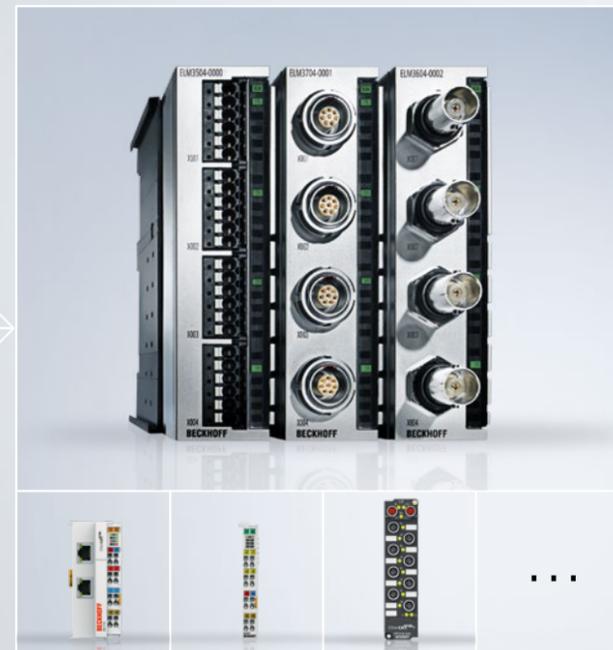
The sensors

		F	
U/I	Multi	U	...

The measurement terminals

...

The measurement technology bus

EtherCAT G
EtherCAT

PROFINET   PROFIBUS   EtherNet/IP   ...
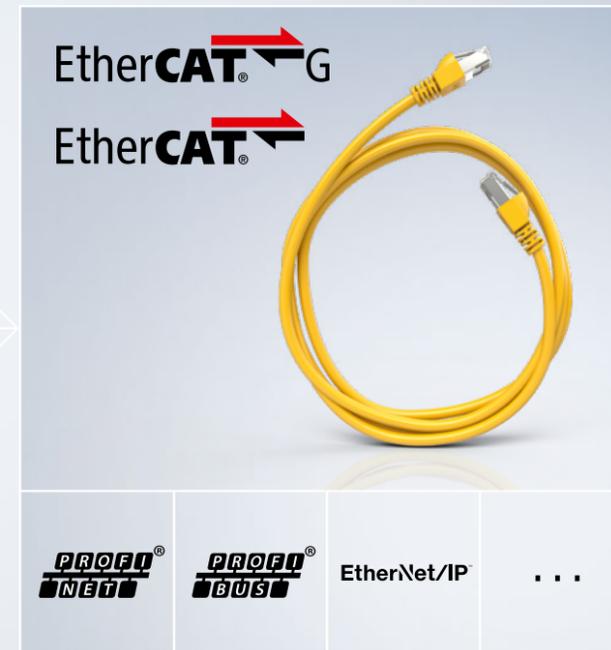
The measurement software on premises

...

Measurement sensors
Beckhoff I/O modules can connect most common sensors electrically:
- force
- pressure
- temperature
- speed (rpm)
- frequency
- torque
- measurement bridges
- vibration
- current
- voltage
- ...

Measurement technology hardware
Beckhoff offers I/O modules in various protection classes for common sensors:
- DIN rail-mountable IP20 Terminals
  - Bus Terminals
  - EtherCAT Terminals
  - EtherCAT measurement terminals in connector-compatible metal housing
- Flexibly installed IP67 modules
  - Fieldbus Box
  - EtherCAT Box, also available in stainless steel and die-cast zinc housing
- Calibration is available as an option
  - Factory calibrated

- ISO 17025
- DAkkS
  (The National German Accreditation Body)

Measurement technology bus
Performance counts, which is why EtherCAT has become established as a major measurement technology bus:
- With a usable data rate of 100 Mbit, EtherCAT can accommodate hundreds of channels with 24-bit resolution and oversampling, synchronous scanning, cable redundancy, and time stamps with ns resolutions, and is ready to support even more data-intensive applications

in the form of the compatible EtherCAT G with a 1 Gbit/s data rate.
- PROFIBUS, PROFINET, EtherNet/IP, etc.: All measurement data can alternatively be collected via many other Beckhoff-supported fieldbus systems.

Measurement software "on premises"
"On premises" describes the use of TwinCAT 3 on a local control IPC with engineering, PLC, motion control, safety, visualization, communication and measurement technology on a single software platform:

- TwinCAT Analytics for in-process and post-process analytics
- TwinCAT Power Monitoring for power grid analytics
- TwinCAT Condition Monitoring for signal analytics
- TwinCAT MATLAB®/Simulink®: Integrates MATLAB®/Simulink® models and algorithms into standard automation applications
- TwinCAT Connectivity to implement cloud computing, data storage and third-party measurement software, such as LabView, based on open interfaces in TwinCAT

Measurement software in the cloud
Many TwinCAT features can be used both locally in the machine controller, and in the cloud:
- TwinCAT IoT: Communication with various cloud systems via protocols like OPC UA Pub/Sub, AMQP or MQTT
- TwinCAT Analytics: Analysis of the complete process image of multiple machines in a central system for perfect data aggregation
- TwinCAT Analytics Cloud Storage Provider: Easy connection to storage services on various public cloud platforms

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The EtherCAT measurement modules:
Extremely accurate, fast and robust

ELM3604-0002

Fast: Basic models feature up to 50,000 samples per second with 24-bit resolution

Precise timing: Exact < 1 µs synchronisation with EtherCAT distributed clocks, both internally and externally with a superordinate clock

Precise values: Measurement accuracy of 100 ppm and better with high temperature stability, depending on the measurement range

Proactive: Integrated connectivity and functional diagnostics ensure long-term operating reliability

How valuable is your data?
Do you know whether your machines and systems (still) produce correct measurements? Or do you place your trust in a successful commissioning process? Are the final test results all that's needed to confirm that everything is working as it should? Whether in a production line, power distribution system, packaging line or lab, reliable measurement values are the reward for your investment. Only customers who trust your systems will award you new orders. Integrated high-end measurement technology shines with its lean architecture and accurate and reliable data. Thorough preliminary tests and stringent calibrations in the production facilities at

Beckhoff ensure reliable and precise measurement functionality.

High-end measurement technology in metal housing
Long-term reliability, adjustability in the field, self-diagnostics and high temperature stability are core requirements for any industrial measurement device. That's why the ELM series of high-end measurement devices from Beckhoff is available in metal housing. Effective heat dissipation and shielding deliver technological improvements over the tried-and-tested EL series. Robust and well protected, the Beckhoff metal modules bring sophisticated measurement technology

to the DIN rail. Beckhoff measurement technology is often employed in unattended environments where no one inspects the wiring or checks the plausibility of measurement results on a daily basis. That's why industrial users expect measurement technology that can check and validate at a state-of-the-art level. Integrated connection diagnostics in the EtherCAT measurement terminals check for cable breaks and short circuits, and an internal self-test function provides improved operating and measurement reliability. Both are new ways of combating the unknown quantity of measurement uncertainty.

Reliable measurement technology meets industrial requirements:
- up to 50,000 samples per second
- measurement accuracy of 25 ppm at 23°C
- metal housing for optimum heat dissipation
- extremely robust – ideal for harsh environments
- flexible connector front-end: LEMO, BNC, push-in
- pretreated in the factory for high-quality measurement results
- integrated connection and functional diagnostics
- optional factory calibration certificate, ISO17025 or DAkkS

High flexibility, high process stability:
The Beckhoff measurement technology hardware
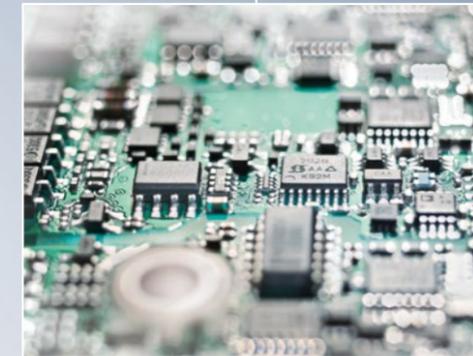
Benefit from extensive in-house expertise in measurement technology: Beckhoff has the necessary knowledge not only for development and consulting, but also for production and quality assurance.

Optionally integrated shield connectors cleanly crimp each analog cable. Ultimately, high-quality analog measurement technology always starts with the cable connection.

New measurement technology approach
The ELM series EtherCAT measurement terminals reflect the successful combination of established precision measurement technology for machine design and engineering with robust, long-term usability in mind. This approach also benefits test bench and lab applications by making different versions of attractively priced industrial measurement technology available to fulfill challenging requirements. It provides multifunctional channels with many integrated measurement ranges that can be switched online as well as price-optimized variants for varying channel quantities.

DIN rail-mountable modules in metal housing
- Plug-in compatible with well-known EtherCAT Terminals
- can accept cable shield and ground (PE) as the conductor and fastens mechanically
- provides effective heat dissipation for analog electronics and discharges heat to rear wall of control cabinets
- suitable for use in demanding, low-maintenance environments
- provides a protective barrier around the high-quality electronic components
- reduces the impact of electromagnetic interference (EMI)

Flexible connector front-end
- Push-in connector with maintenance quick-release – the standard solution for typical requirements. Easy to assemble with or without wire end ferrule, designed for long-term use.
- BNC technology for vibration analysis, quick-and-easy bayonet fitting, well-shielded through coax cable for quick wiring modifications.
- High-quality LEMO connectors for high-end applications. Offers consistent shielding and is usable as a power plug; easily removable for maintenance or other purposes.

- High-quality look and feel that matches the high-end measurement precision.

High process stability
Process stability is particularly important in mostly unattended installations with infrequent maintenance. The devices must autonomously determine whether they can still measure correctly, because no test engineer can check them for irregularities on a daily basis:
- Extensive connection diagnostics immediately detect short circuits, cable breaks and shunts as far as is technically possible.
- comprehensive self-test and repeat internal checks

- continuous monitoring of temperature and inputs to detect overloads and prevent them from affecting operation
- diagnostic reports continuously available via EtherCAT

Traceability and recalibration
Each Beckhoff measurement technology terminal has its own unique ID for which a factory certificate can be issued. Also, ELM devices can be checked, aligned and recalibrated by the Beckhoff recalibration service at the factory in Verl, Germany.

Beckhoff offers extensive measurement technology expertise:
- deep in-house measurement technology knowledge
- development, design and production processes are closely linked
- superior manufacturing skills
- comprehensive expertise in measurement terminal calibration, alignment and adjustment
- sophisticated terminal tuning enhances measurement precision

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High-end measurement technology requires high -end technology: signal processing in the EtherCAT measurement modules

ELM3704-0001

X001
X002
X003
X004

RUN OK
OK
OK

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Analog electrical signal → **High-quality, stable and robust input electronics** → **Analog-to-digital conversion in 24-bit resolution** → **2 freely parameterisable filters up to the 39th order** → **Decimation unit** → **TrueRMS integrator/ differentiator** → **Scaler** → **PDO transport via EtherCAT**

Newly developed for the toughest demands
The intrinsic values of the EtherCAT measurement terminals open up completely new opportunities for the use of measurement technology in automation as well as in testing and inspection applications. The entire data acquisition process has been redeveloped and rebuilt by Beckhoff – from the analog electrical signal to the handover of the digitised values, all enhanced with data that improve reliability and time resolution, to meet the tougher demands on measurement technology. Over 20 years of experience in integrating electronics into modular I/O terminal housing have been incorporated into development, testing and production.

High-quality input electronics
- Carefully selected components with high stability, robust EMC protection circuitry and tried-and-tested design from previous terminals have been combined to provide reliable input circuitry for high quality parameters.
- In the multifunctional models, which also sport a switching feature, the variants are equipped

Channel-oriented thinking
- each channel can be parameterized separately
- separate CoE directory and process data
- Consecutive or synchronous scanning, depending on module series

with individual feature upgrades. For example, the ELM360x IEPE modules feature different supply currents, and the ELM350x measurement bridge modules can supply a wider voltage range.
- Since the units are pre-aged by Beckhoff before they are calibrated, they deliver outstanding application stability from the start.

State-of-the-art analog/digital converters
- 24-bit resolution for high signal detail
- synchronized scanning with delta-sigma conversion across multiple channels and terminals via EtherCAT distributed clocks

- 10 ksps sampling rates with the standard terminal version; over 20 ksps in 2-channel models; up to ultra-fast 50 ksps 24-bit IEPE scanning with the ELM360x

The filtering machine
- powerful and efficient local calculation in the terminal
- CoE-selectable Butterworth filters or pre-defined filters using coefficients
- resolves aliasing problems and creates room for selective filters or band-stop filters that can be changed during runtime

Decimation unit
- channel sampling rate can be changed during runtime
- uses oversampling to transmit measured data via EtherCAT

Special functions
- Special functions can be activated optionally.
- A TrueRMS algorithm converts the data stream accordingly.
- optional 2-stage decimation/integration unit

Free scaling
- After being changed to fit the electrical measurement range (e.g. 0…+10 V),

the measurement value can be converted.
- classic gain/offset with y = mx + b, with internal correction table or with any supporting point table up to linearisation

EtherCAT – the measurement technology fieldbus
- up to 100 µs minimum EtherCAT cycle time
- oversampling to transmit larger data packets per cycle
- synchronized via distributed clocks to ensure < 1 µs deviation from each other

Fast and open, the ideal fieldbus for measurement technology: EtherCAT and EtherCAT G
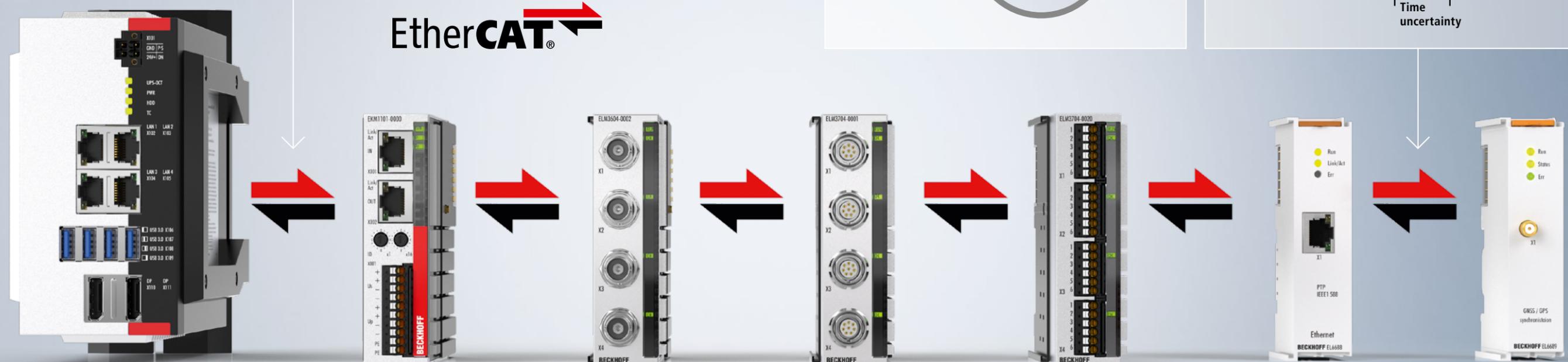
Optimized accuracy: up to << 1 µs with timestamp functionality in nanosecond resolution
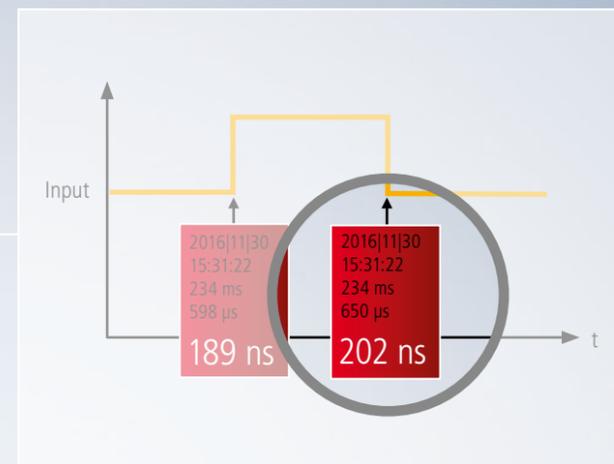
EtherCAT enhances the value of your data by maximizing time and value precision.

Input

2016|11|30 15:31:22 234 ms 598 µs
189 ns

2016|11|30 15:31:22 234 ms 650 µs
202 ns

t

Value

Time determination

Value determination

Value uncertainty

Time uncertainty

t
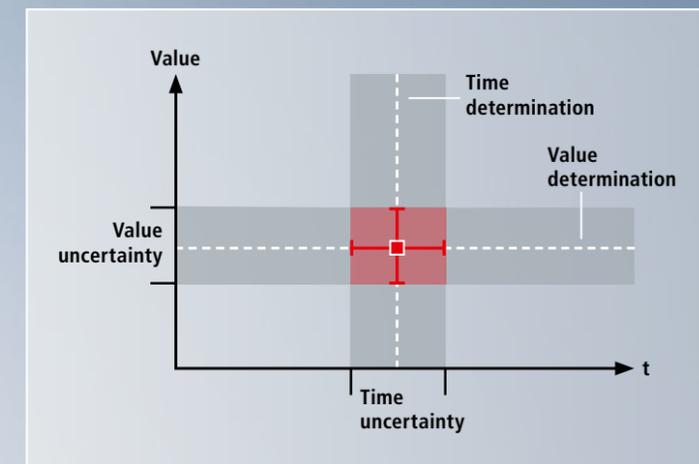
Firmly established: EtherCAT from Beckhoff
As the inventor of EtherCAT, Beckhoff still plays a leading role in the further development of this pioneering industrial technology, and continues to strive to develop innovative products for EtherCAT – notably including the modular EtherCAT Terminal system. EtherCAT is now widely established in the measurement technology sector. With its 100 Mbit data rate, EtherCAT covers many of the requirements for measurement technology in laboratory and production environments. EtherCAT G provides bandwidths of up to 10 Gbit/s for particularly data-intensive applications. Additional benefits for device manufacturers include easy integration and an unbelievable range of suppor-

ters in the ETG, which has been active for over 20 years and now boasts more than 6,900 members, 100 of which are master manufacturers. What's more, EtherCAT integration is now available for virtually any sensor. With its EtherCAT-based modular terminal bus system and IPC-based TwinCAT, Beckhoff provides the automation backbone in many machines and is now enriching this system with precise measurement technology on the mounting rail. This makes cabinet design more integrated than ever, saves installation space, and simplifies procurement, since all components are supplied from a single source. Optimized accuracy: up to << 1 µs with the timestamp function in ns resolution. EtherCAT allows you to

increase the value of data by maximizing time and value precision. The direct integration of precise measurement technology into the controller via EtherCAT makes for a simple system design that serves to reduce complexity. It also offers a number of technological fieldbus highlights, such as easy parameterization according to EtherCAT standards, synchronous scanning through distributed clocks (extending to external synchronization to any time source via GNSS, PTP/IEEE 1588, and many more), and continuous diagnostics from the control to I/O level.

Highly accurate time synchronization
A measured value has two essential properties:

the measurement uncertainty (value amount) and the exact time determination (time of the measurement). EtherCAT enables high-precision time synchronization of all inputs and outputs based on distributed clocks, typically with time uncertainties of significantly less than 1 µs, both relatively between the devices in the network, and absolutely to a superordinate global reference time. On the other hand, the EtherCAT measurement terminals significantly improve the process of determining values thanks to their high-precision measurements. Overall, a measured value can be determined much more accurately in terms of time and value using this method.

EtherCAT optimizes measurement technology architectures:
- just one communication technology for machine control and measurements
- optimally coordinated products and technology
- the world's fastest Ethernet fieldbus
- 500 compatible EtherCAT I/O Terminals
- open protocol for easy integration of third-party products
- timestamping for maximized measurement quality
- investment protection: no versioning

EtherCAT G: System scalability from 100 to 10,000 Mbit/s

EtherCAT**®** G

CX20xx Embedded PC

EtherCAT**®** G

EtherCAT G Master

EK1400 EtherCAT G Coupler

EtherCAT**®** G

EtherCAT**®**

100 Mbit/s

Segment 1

EK1100

EtherCAT segment – 100 Mbit/s

CU1403 EtherCAT G Branch Controller

EtherCAT**®** G

1 Gbit/s

Segment 2

CU1423 EtherCAT G Junction

EtherCAT segment – 1 Gbit/s
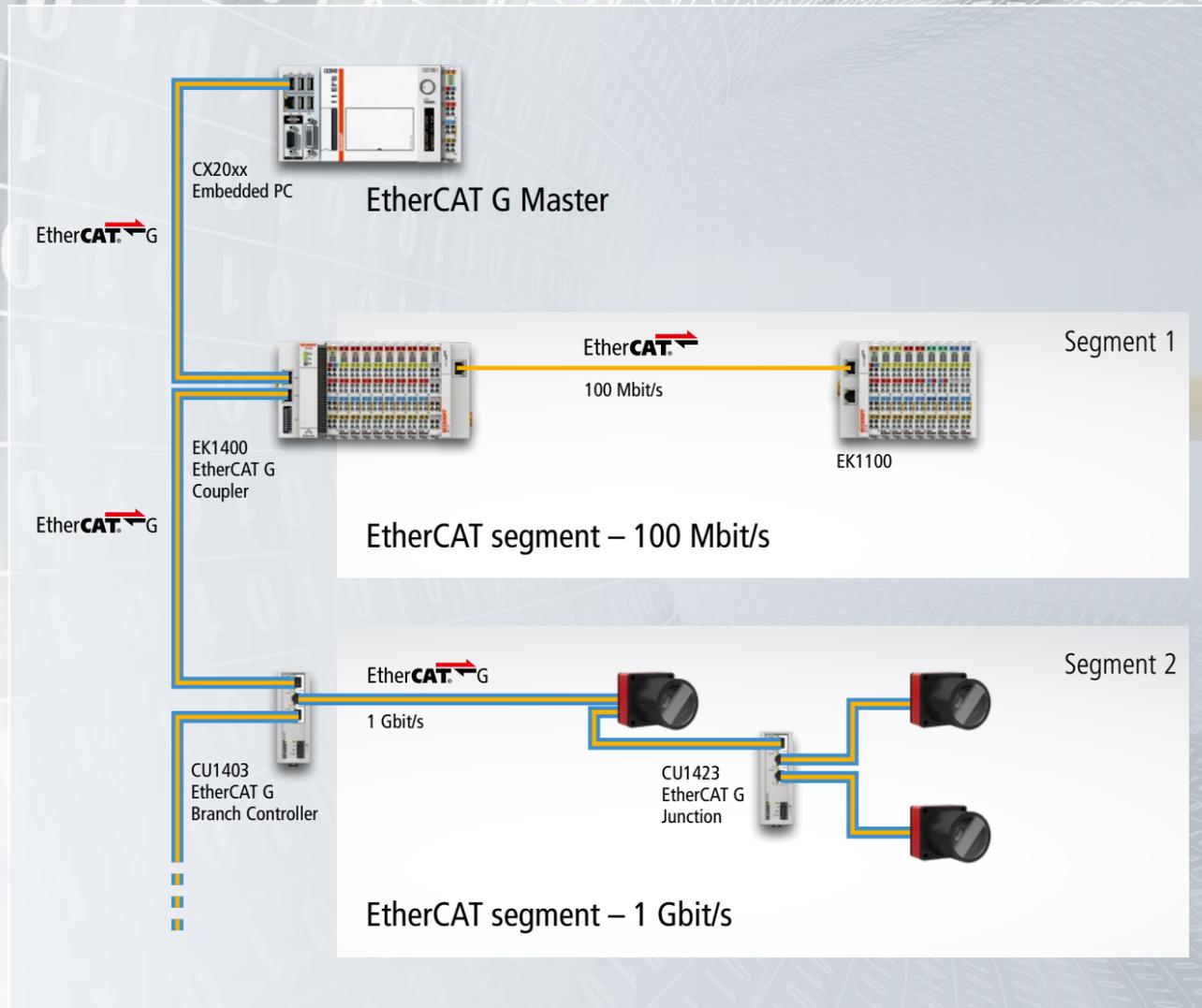
10 Gbit/s
1 Gbit/s
100 Mbit/s

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EtherCAT G builds on the principles of the successful EtherCAT technology but moves the available data rates up to 1 Gbit/s and 10 Gbit/s. The EtherCAT protocol itself remains unchanged. As before, all of the devices on a network receive the telegrams sent by the EtherCAT master. Each EtherCAT slave still reads the data addressed to it on the fly and inserts its own data into the frame as the frame moves downstream; now, though, it does this at 1 Gbit/s or 10 Gbit/s. Hardware propagation times are the only factor that can delay telegram processing. The last device in a segment or stub line identifies an open port and utilizes the full

duplex feature of Ethernet physics to send the telegram back to the master.

EtherCAT G and EtherCAT G10 also retain all other capabilities of EtherCAT. Devices with three or four ports (junctions) enable users to flexibly configure network topologies that suit the exact requirements of their machine architecture. Optional machine modules can still be plugged in and unplugged via the Hot Connect feature. Network-wide diagnostics are available to help minimize machine downtime and increase availability. The built-in system of

distributed clocks still ensures devices are synchronized precisely with a delay of less than than 100 ns between devices..

Measurement applications in particular benefit from the enhanced capabilities of EtherCAT G/G10, because high sampling rates of > 100 ksps with 24-bit resolution can now be implemented with ease for more than 100 channels.

Consistent features

- real-time Ethernet down to the I/O level
- flexible topology
- outstanding diagnostics
- synchronization accuracy of less than 100 ns
- exceptionally simple configuration
- low system costs
- maximum performance
- ability to integrate functional safety
- IEEE-802.3 compliant

▶ **www.beckhoff.com/ethercat-g**

EtherCAT P: The sensor, actuator and measurement technology bus

EtherCAT master

TwinCAT automation software

EtherCAT Terminals

EtherCAT Box

EtherCAT drives

Junction with feed-in

24 V DC

EtherCAT P Coupler EK1300

EtherCAT P Coupler EK1300

Junction

EPPxxxx

EPPxxxx-006x

Proximity switches

Camera

Barcode scanner
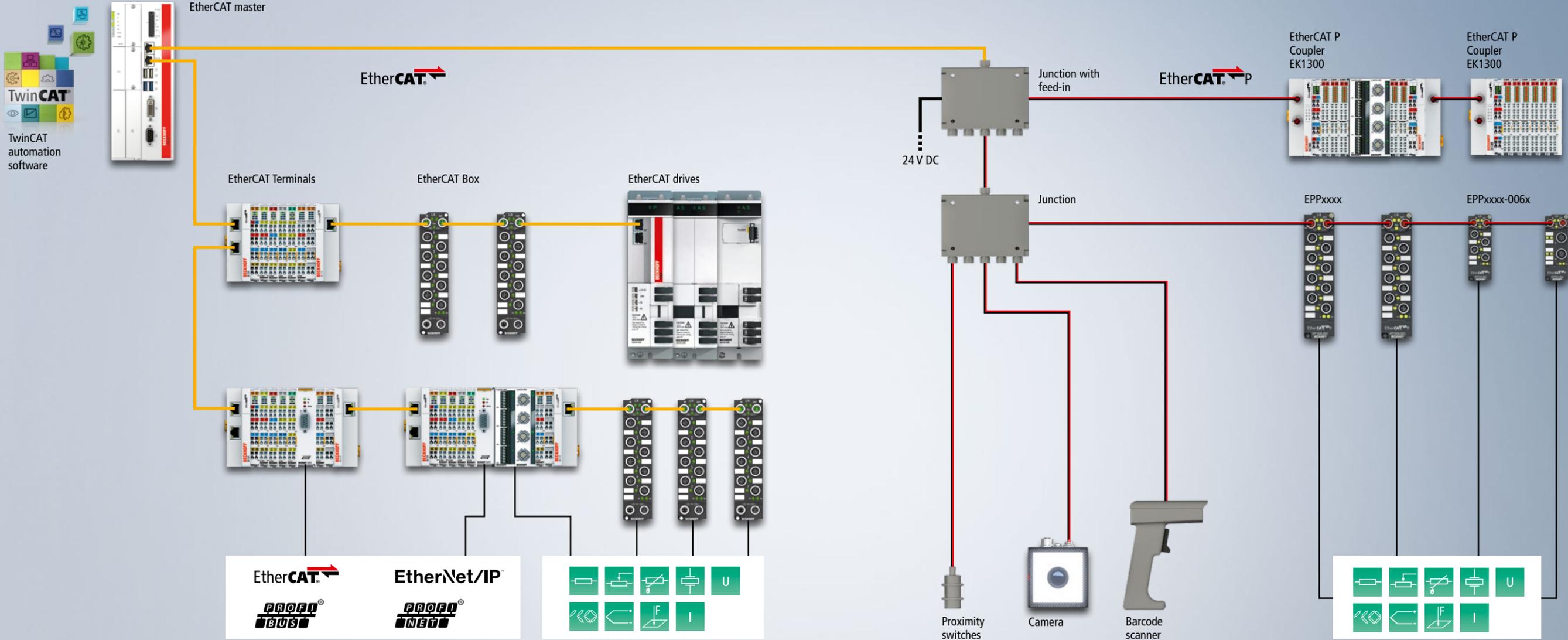
The One Cable Automation fieldbus

With EtherCAT P, Beckhoff combines communication and power supply in a single standard 4-wire Ethernet cable. The 24 V DC supply of the EtherCAT P slaves and of the connected sensors and actuators is integrated: U_S (system and sensor supply) and U_P (peripheral voltage for actuators) are electrically isolated from each other and can each supply a current of up to 3 A to the connected components. At the same time, all the benefits of EtherCAT, such as freedom in topology design, high speed, optimum bandwidth utilization, telegram processing on the fly, high-precision synchronization, extensive diagnostics functionality and more are fully retained.

The currents of U_S and U_P are directly injected into the wires of the 100 Mbit/s line, enabling very cost-effective, space-saving connections. EtherCAT P offers benefits both for the connection of smaller remote I/O stations in terminal boxes and for decentralized I/O components on-site throughout the process. A connector family was developed especially for EtherCAT P in order to prevent potential damage caused by confusion with standard EtherCAT slave connectors. It covers all applications from the 24 V I/O level up to drives with 400 V AC or 600 V DC and a current of up to 64 A.

Combining EtherCAT P with decentralized measurement technology creates a completely new set of synergies in every machine. High-quality measurements can now be collected from each section of a line with relatively little wiring work. This concept can even be used for temporary and even portable measurement stations which can be positioned wherever they are needed. For control cabinet installations, the EK1300 EtherCAT P Coupler must be used to connect EtherCAT measurement terminals. Since the EtherCAT P specification has been disclosed by the ETG, any equipment manufacturer can implement it. EtherCAT P brings industrial measurement technology and non-cabinet IP67 environments together.

The high-speed fieldbus with One Cable Advantage:
- optimized for direct connection of EtherCAT P devices in the field
- reduced wiring effort saves time
- fewer sources of error
- smaller sensors and actuators through elimination of separate supply cables
- easy connection of components

▶ www.beckhoff.com/ethercat-p

Beckhoff measurement technology: The right device category for any application

Economy line: Robust, precise measurement technology in the control cabinet

Basic line ELM3x0x
24 bit
10 ksps per channel
Simultaneous
Up to 25 ppm @ 23°C

Economy line ELM3x4x
24 bit
1 ksps per channel
Multiplex
Up to 100 ppm @ 0…50°C

ELM3704-0001

ELM3148-0000

System components

Economy line

With its continuously expanding portfolio of measurement technology components, Beckhoff covers the full range of industrial measurement requirements, from one to thousands of measurements per second, and from voltage and current measurement to oscillation and force measurement. IP20 components read the sensors from inside the control cabinet.

Seamlessly integrated into the EtherCAT I/O system, the high-end measurement technology incorporated in the basic line reads even process-critical measurement channels that the standard EL/KL analog terminal technology is not suitable for. The basic line is designed for acquiring signals for highly dynamic processes with a high measurement accuracy across all channels and modules simultaneously, while the economy line is

targeted at less dynamic processes. Integrated 24 V sensor supplies and 24 V power contacts reduce the amount of wiring in the control cabinet. The economy line's outstanding temperature stability of 100 ppm in typical control cabinet temperature conditions exceeds even that of the basic line.

Both product lines support tried-and-tested EtherCAT features such as distributed clock time-stamping in ns-format and bus diagnostics. The modules ideally receive their power from system components such as the EKM1101 Coupler. Integrated diagnostic functions ensure reliable measurement.

EKM1101 — EtherCAT Coupler with diagnostics

ELM9410 — Power supply terminal with diagnostics

The Coupler and the power supply terminal are designed especially for use with measurement terminals. They provide an E-bus-based and contact-based power supply of up to 2 A, filtered and electronically isolated to shield the measurement terminals from interferences caused by the power supply and other bus users. They also deliver a wide range of diagnostic values (temperature, vibration, voltage) for system condition monitoring.

	ELM3142 ELM3144 ELM3146 ELM3148 — Current/voltage measurement	ELM3244 ELM3246 — RTD temperature measurement	ELM3344 ELM3344-0003 ELM3348 ELM3348-0003 — TC temperature measurement	ELM3542 ELM3544 — Measurement bridge analysis (SG)
Channels	2/4/6/8	4/6	4/8	2/4
Resolution	24 bit	24 bit	24 bit	24 bit
Max. sampling rate per channel	1 ksps	1 ksps	1 ksps	1 ksps
Connection technology	Push-in	Push-in	Push-in	Push-in
U (0…10/30 V, ±10 V)	■			
I (-10/0/+4…+10/+20 mA)	■			
Measurement bridge (SG)				■
IEPE				
Resistance measurement		■		
Potentiometer				
Temperature (RTD)		■		
Temperature (Thermocouple)			■	

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Basic line: Fast high-end measurement technology for industrial 24/7 operation

Basic line

	ELM3002 ELM3004 Voltage measurement	ELM3002-0205 High-voltage measurement	ELM3102 ELM3104 Current measurement	ELM3102-0100 Current/voltage measurement, isolated	ELM3502 ELM3504 Measurement bridge analysis (SG)	EPP3504 Measurement bridge analysis (SG)
Channels	2/4	2	2/4	2	2/4	4
Resolution	24 bit	24 bit	24 bit	24 bit	24 bit	24 bit
Max. sampling rate per channel	20/10 ksps	50 ksps	20/10 ksps	20 ksps	20/10 ksps	10 ksps
Connection technology	Push-in	4 mm	Push-in	Push-in	Push-in	Push-in
U (1200 V)		■				
U (0…10/30/60 V, ±10 V)	■			■	■	■
I (-10/0/+4…+10/+20 mA)			■	■		
Measurement bridge (SG)					■	■
IEPE						
Resistance measurement						
Potentiometer					■	■
Temperature (RTD)					■	■
Temperature (Thermocouple)						

	ELM3602 ELM3604 IEPE Input	ELM3602-0002 ELM3604-0002 IEPE Input	ELM3702 ELM3704 Multifunctional input	ELM3704-0001 Multifunctional input	ELM3702-0101 Multifunctional input, isolated	ELM2642 ELM2644 Reed multiplexer 1:4	ELM2742 ELM2744 Solid state multiplexer 1:4
Channels	2/4	2/4	2/4	2/4	2/4		
Resolution	24 bit	24 bit	24 bit	24 bit	24 bit		
Max. sampling rate per channel	50/20 ksps	50/20 ksps	10 ksps	10 ksps	10 ksps		
Connection technology	Push-in	BNC	Push-in	LEMO	LEMO		
U (1200 V)							
U (0…10/30/60 V, ±10 V)	■	■	■	■	■		
I (-10/0/+4…+10/+20 mA)			■	■	■		
Measurement bridge (SG)			■	■	■		
IEPE	■	■	■	■	■		
Resistance measurement			■	■	■		
Potentiometer			■	■	■		
Temperature (RTD)			■	■	■		
Temperature (Thermocouple)			■	■	■		

The application options for the integrated measurement technology in the ELM3xxx series, along with normal analog EL3xxx/EL4xxx inputs and outputs, is extended significantly with these multiplexers. Now, more sensors or sources can simultaneously be connected to an analog input channel. The switching elements are also designed specifically for small analog signals. They also enable multi-channel acquisition of analog singals and make it easier to switch between different test conditions in test stations that are integrated into production facilities without an externally connected switching element.

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Measurement modules for any application

Performance class

Analog input	Precision		Standard			
Multi — Multi	ELM370x | 24 bit, 10 ksps	EL3751 | 24 bit, 10 ksps	EL3681 | Digital multimeter		KL3681 | Digital multimeter	
U — U (±5 mV…±60 V)	ELM300x | 24 bit, 20 ksps EL3602 | 24 bit, 1 ksps EL3602-0002 | 24 bit, ±200 mV EL3602-0010 | 24 bit, ±75 mV	KL31x2 | 16 bit, 0,05 % KL336x | Oscilloscope terminal, 10 µs	EL300x | 12 bit EL306x | 12 bit EL310x | 16 bit EL316x | 16 bit EL3174-0042 | 16 bit, electrically isolated		KL300x | 12 bit KL306x | 12 bit KL3468 | 12 bit KL310x | 16 bit KL340x | 12/16 bit	EL3702 | 16 bit, 100 ksps
I — -10/0/4…10/20 mA	ELM310x | 24 bit, 20 ksps EL3612 | 24 bit, 1 ksps		EL301x | 12 bit EL302x | 12 bit EL304x | 12 bit EL305x | 12 bit	EL311x | 16 bit EL312x | 16 bit EL314x | 16 bit EL315x | 16 bit	KL301x | 12 bit KL302x | 12 bit KL304x | 12 bit KL305x | 12 bit KL344x | 12 bit KL345x | 12 bit	EL3742 | 16 bit, 100 ksps
U/I — -10/0…+10 V, -20/0/+4…+20 mA	ELM314x | 24 bit, 1 ksps		EL3072 | 12 bit EL3074 | 12 bit	EL3172 | 16 bit EL3174 | 16 bit	EL3174-0002 | 16 bit, electrically isolated	EP31xx | 16 bit (also EPP, EQ, ER)
U/I HV — 230/690 V AC, 410 V DC, 1/5A	ELM3002-0205 | 24 bit, 1200 V, 10 ksps electrically isolated		**Management** EL3483 | 3-phase mains monitor EL3483-0060 | 3-channel 480 V AC/DC EL3423 | 3-phase, 480 V, 1 A, AC/DC, eco	**Measurement** KL3403 | 3-phase, 500 V, 1 A, AC/DC KL3453 | 3-phase, 690 V AC/DC, 1/5 A AC EL3443 | 3-phase, 480 V, 1 A, AC/DC	EL3446 | 6-channel current 1 A AC/DC EL3453 | 3-phase, 690 V AC/DC, 1/5 A AC EL3444 | 4-channel current 10 A AC/DC	**Monitoring** EL3773 | 3-phase, 500 V, 1 A, AC/DC EL3783 | 3-phase, 690 V AC/DC, 1/5 A AC
Temperature (thermocouple)	EL3314-0010 | Types J, K, L, ... U, 24 bit ELM3344 | Types J, K, L, ... U, 24 bit ELM3348 | Types J, K, L, ... U, 24 bit		EL331x | Types J, K, L, ... U, 16 bit EL3314-0002 | Electrically isolated		EP3314 | Types J, K, L, ... U, 16 bit (also EPP, EQ, ER)	KL331x | Types J, K, L, ... U, 16 bit
Temperature (RTD)	EL320x-0010 | Pt100, 16 bit	ELM3244 | RTD, 24 bit ELM3246 | RTD, 24 bit	EL320x | Pt100/1000,Ni100, 16 bit	EP3204 | Pt100/1000, Ni100, 16 bit (also EPP, EQ, ER)	EL3204-0200 | Up to 240 kΩ, 16 bit KL32xx | Pt100/1000, Ni100, 16 bit	EL321x | Pt100/1000, Ni100, 16 bit, 3-wire KL3208-0010 | NTC 1,8…100 kΩ, 16 bit
Resistance measurement	ELM350x | 24 bit, with power supply, 20 ksps		EL3692 | 10 mΩ…10 MΩ, 24 bit			
Potentiometer	ELM350x | 24 bit, with power supply, 20 ksps		EL3255 | 16 bit, with sensor supply			
Resistor bridge (SG)	ELM350x | 24 bit, with power supply, 20 ksps EPP3504-0023 | 24 bit, with power supply, 10 ksps	ELM354x | 24 bit, with power supply, 1 ksps EP3356 | 24 bit, with self-calibration EL3356-0010 | 24 bit, with self-calibration	EL3356 | 16 bit, with self-calibration		KL3351 | 16 bit	KL3356 | 16 bit, with self-calibration
IEPE (ICP, CCLD, …)	ELM360x | 50 ksps, 24 bit, 0/2/4 mA, AC/DC coupling		EL3632 | 50 ksps, 16 bit, 2/4/8 mA			
Pressure measurement			EM3701 | Differential pressure, -100…+100 hPa	EP3744-1041 | Differential-/relative pressure 1…7 bar (also EPP, EQ, ER)	EM3702 | Rel. pressure, 0…7.500 hPa KM3701 | Diff. pressure -100…+100 hPa	EM3712 | Rel. pressure, -1.000…+1.000 hPa KM3702 | Abs. pressure 7500 hPa
LVDT (inductive bridge)			EL5072 | Inductive sensor interface	(LVDT, half bridge, RVDT)		

Application example: power monitoring (energy)

Application example: condition monitoring (vibration)

Please note: For some of the above series, factory calibration certificates or external calibration certificates (ISO 17025, DAkkS) are available.

Beckhoff – the measurement technology expert

The high-precision measurement terminals in the ELM series are not the first products to demonstrate measurement applications by Beckhoff. Previously introduced devices for special measurement tasks include the EL series EtherCAT Terminals as well as Bus Terminals from the KL series and the IP67 series. They fulfil Beckhoff's promise to provide state-of-the-art automated components for specialty fields such as weighing technology or vibration measurement. Examples include the EL3692 resistance measurement terminal, which measures across nine decades in 4-wire mode, the EP1816-3008 for position detection (for example, for a robot arm), or the KL3403 for 3-phase power measurement. With the BK/BC Bus Coupler or EL67xx Fieldbus Couplers, measurement technology terminals and IP67 modules can be used to operate not only EtherCAT systems, but other bus systems as well (PROFIBUS, PROFINET, EtherNet/IP, etc.).

To accommodate a wide range of applications, Beckhoff offers various performance classes from 12-bit to 24-bit resolution, from slower sampling rates of 100 samples per second to 100 ksps oversampling terminals, and from 0.5 to 0.01 % measurement accuracy ratings. One application example is condition monitoring, where the dedicated EL3632 is used to measure vibrations, and also to monitor current, power and hydraulics with sensors via standard terminals with 10 V or 20 mA standard signal input.

Beckhoff has the right measurement modules:
- for all industries, ranging from wood processing to metal processing to wind turbines
- for all applications, ranging from industrial and test bench measurement technology to condition monitoring and power monitoring

# TwinCAT 3: The highly modular backbone of PC-based control technology
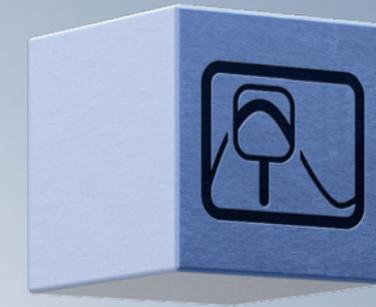
Beckhoff offers system solutions in various performance classes for all areas of automation. The control and drive technology is highly scalable and thus optimally adaptable for different applications. The TwinCAT engineering and control software combines all required machine functions such as PLC, HMI, motion, robotics, measurement technology, vision, along with IoT and data analysis in one package. TwinCAT IoT supports all standard protocols for cloud communication and push messages to smart devices. TwinCAT Analytics provides the basis for comprehensive process data storage and analysis.

Flexibility through modularity

- this modular solution is scalable and expandable according to the user's needs.
- highly scalable computing platforms for all performance requirements
- all data storage and analysis options: locally in the machine, in the corporate network, or in the cloud.
- simplified code generation using templates
- easy code replication for volume production

All modules for system-integrated measurement technology on one universal platform

The integrated Beckhoff system processes and transports data directly or via sensor buses and various established fieldbuses across all levels of modern machine control from the lowest I/O level to the PC-based control system. Once the data has been processed by a wide range of software modules, it is stored in database systems and sent to analytics stations which either reside in the machine on-premises, a central factory location, or the cloud. The flexibility, expandability and scalability of the universal control technology from Beckhoff are features that deliver huge user benefits in measurement technology and many other applications.

MATLAB®/ Simulink®	HTML5 web browser providing TwinCAT HMI					

Cloud:
- Microsoft Azure™
- Amazon Web Services™
- TwinCAT Analytics

- LabVIEW
- ERP, MES…
- Other 3rd Party solution
- Database

Software

User mode/ engineering

MATLAB®/ Simulink®	TwinCAT HMI	TwinCAT Analytics	TwinCAT Scope View	TwinCAT Scope Server	TwinCAT Filter Designer	TwinCAT Bode Plot	Connectivity ADS, OPC UA, IoT	TwinCAT Database Server

Runtime

MATLAB®/ Simulink®	TwinCAT Analytics Library	TwinCAT Condition Monitoring Library	TwinCAT Power Monitoring Library	TwinCAT Filter Library	TwinCAT Analytics Logger	TwinCAT Vision Library	PLC C++	TwinCAT Database Server Library

NC/CNC

Fieldbus: EtherCAT

Hardware

Metrological automation | Scientific automation

Performance class		Application examples		
Precision ELM3xxx	Standard EL30xx EL31xx	Energy measurement EL34xx EL37xx	Condition monitoring EL3xxx	…

Time synchronization (IEEE 1588)	Safety	Motion

MATLAB® and Simulink® – strong partners in measurement and testing technology

MATLAB®/Simulink®

MATLAB®/Simulink®

TE1400
integration

TE1410
communication

ADS message router

Real-time core

| TcCOM | Simulink® Module | TcCOM | Safety |
| TcCOM | PLC | TcCOM | C++ Module |
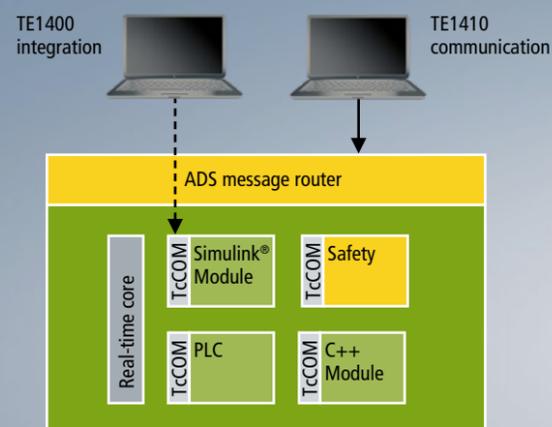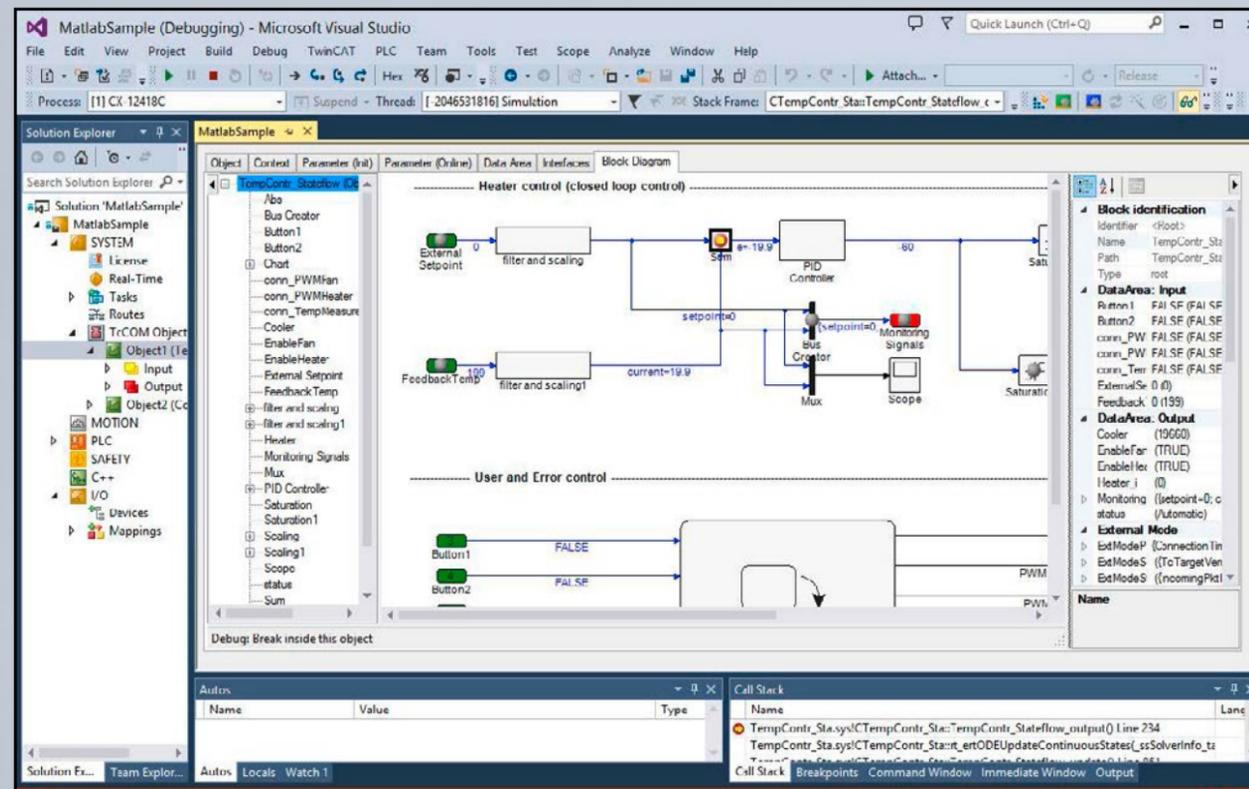
MATLAB® and Simulink® set standards in measurement data analysis as well as in system modeling and simulation. Both of these tools from MathWorks are widely accepted in many industries.

Beckhoff supports the integration of both tools into its TwinCAT 3 engineering system with two products: Target for MATLAB®/Simulink® (TE1400) and Interface for MATLAB®/Simulink® (TE1410).

When using Simulink® engineering, you can use TE1400 to generate instances of TwinCAT object models (TcCOM) in TwinCAT 3.

In TwinCAT, these modules can be triggered directly via a real-time task or via other TcCOM models. The block diagram, which is embedded as a control in TwinCAT Engineering, allows you to parameterize a model in TwinCAT and monitor signals. You can use this product to develop, monitors that can be executed in real time or virtual sensors for deducing measurement values that cannot be read directly, or to simulate the behavior of non-present components (hard-ware-in-the-loop) in real time, to give a few examples.

TE1410 supplies an ADS-based communication interface for exchanging data between TwinCAT and MATLAB®/Simulink®. It supports synchronous and asynchronous read/write procedures as well as method calls (read/write). You can also use this product to make MATLAB®-based analyses that have been processed once available as functions that can be called up from within TwinCAT. Or you can use the product in connection with Simulink® for software-in-the-loop simulation as part of model-based software development.

TE1400
- one-click TcCOM generation from within Simulink®
- multiply instantiable modules in TwinCAT
- block diagram as a control in XAE
- parameterization and charting of (internal) model signals
- debugging in XAE is possible

TE1410
- ADS client in Simulink®
- embedded target browser in the Simulink® block
- ADS client/server in MATLAB®

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# The multi-core oscilloscope for high-end measurement technology: TwinCAT Scope

TwinCAT Scope
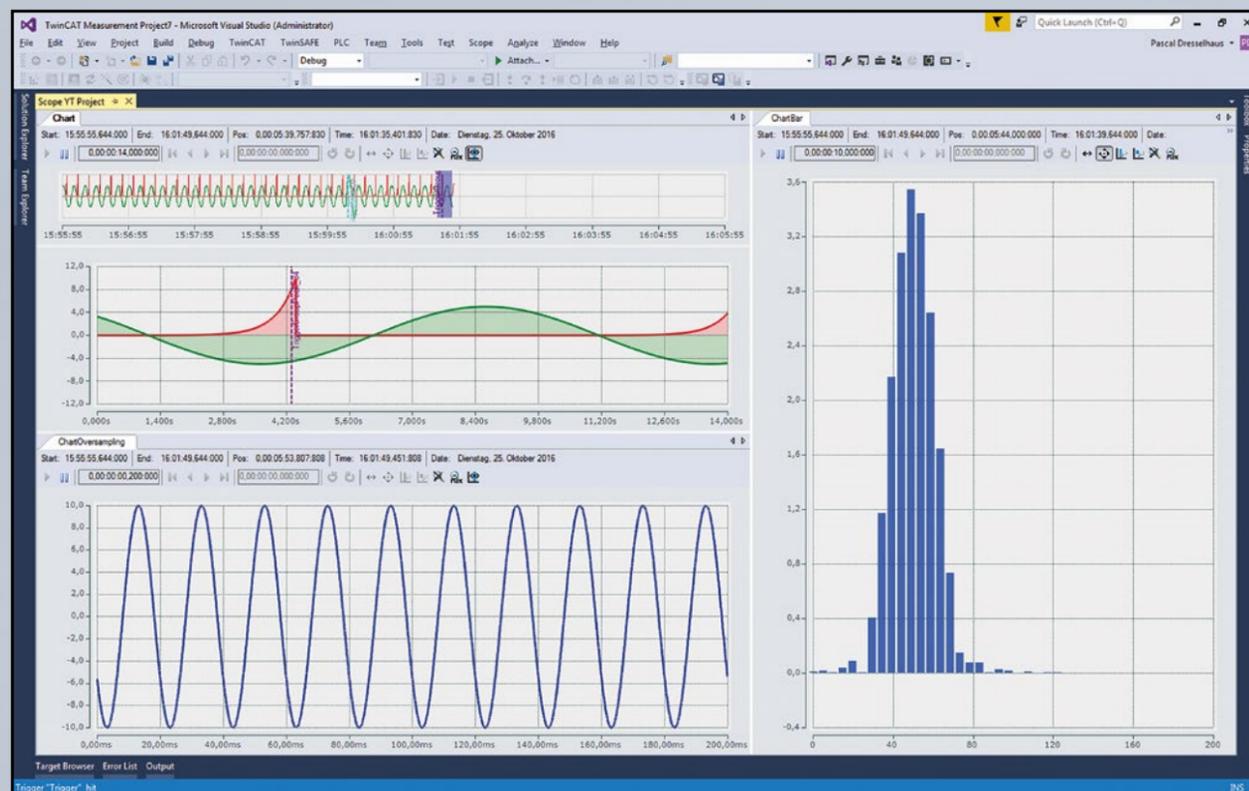
TwinCAT Scope is a state-of-the-art charting tool for visualizing signals from the TwinCAT system. It constantly records high-resolution data and displays it in the form of line or bar charts with outstanding performance. Significant events can be marked and easily spotted on overview charts.

TwinCAT Filter Designer

The Filter Designer has been designed and integrated into TwinCAT Engineering so that users can adapt filters to specific measurement tasks. It makes it possible to edit filter curves graphically or in tables and to drag-and-drop the resulting filter coefficients into the new ELM measurement terminals. Alternatively, the coefficients can be copied into the function blocks of the TwinCAT Filter Designer PLC library, enabling users to easily configure digital filters such as Butterworth or Chebyshev as low-pass, band-pass or high-pass filters.
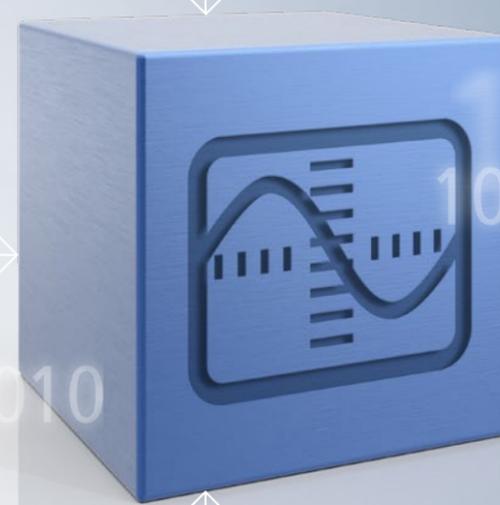
TwinCAT Bode Plot

As a major part of an automation system, drive technology generates lots of process and measurement data. Before this data can be used for condition monitoring and analytics, however, it must be properly adjusted. Bode Plot, which is based on TwinCAT Scope, is perfect for this. It allows user to transmit nominal values to the drive and graphically display its response in terms of frequency and phase in order to optimize the drive parameter settings.
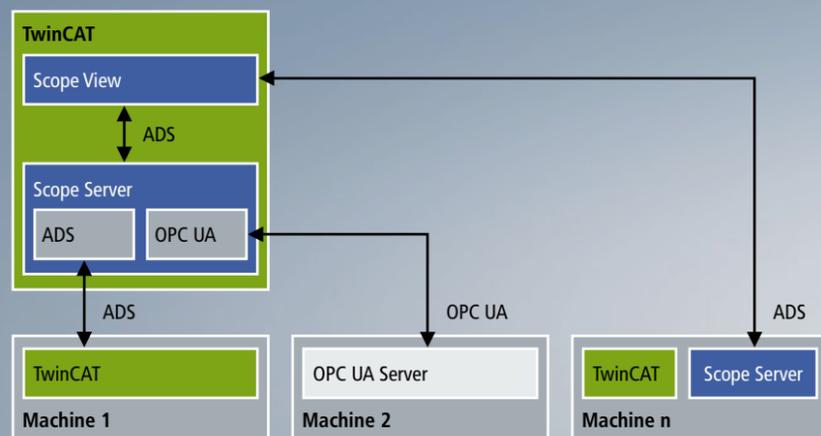
This extremely powerful software oscilloscope is the highlight of the TwinCAT Measurement portfolio. Integrated into Visual Studio® as an independent project, this charting tool is able to visualize measurement signals in the single-digit microsecond range. In addition to established functions like trigger, chart synchronization and cursor, TwinCAT Scope View also features DirectX and multi-core support to fully utilize the computing power of each individual system to display high-frequency signals, even from oversampling values.

Multiple integrated wizards simplify the intuitive operation of TwinCAT Scope View even further. In addition to a project wizard, it features a wizard for selecting and transforming physical units and one for converting data into other file formats such as csv or tdms. The latter makes it possible to cut out unneeded data and specify a time period for exporting. In addition, data imports and exports can be fully automated via the PLC.

The developers of TwinCAT Scope ensured that it interacts seamlessly with other TwinCAT products. Besides templates for motion applications, for example, it features bar charts that are very useful in connection with the TwinCAT Condition Monitoring library, i.e. for displaying frequency curves of power or magnitude spectra. Even images produced by vision systems can be integrated into the data stream via their time stamp and displayed in Scope. With all these features, Scope allows you to pool all essential data from testing and measurement tasks.

Software oscilloscope with multi-core processor power

- high-end charting tool for high-resolution data
- free basic version integrated into TwinCAT XAE
- long-term and trigger-driven recordings
- communication via ADS or OPC UA standard
- scope control for integration into the user's own .NET-based HMI

Machine 1 | Machine 2 | Machine n

Simplified database connection for efficient applications

TwinCAT Database
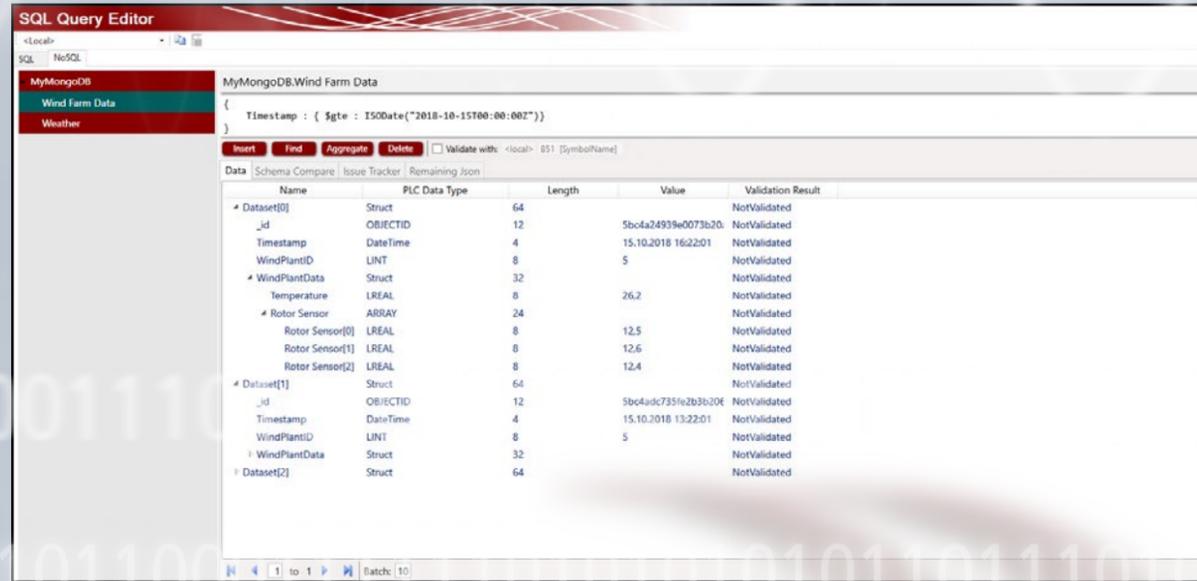
Testing the SQL or NoSQL database communication in the SQL Query Editor can be done with just a few clicks. The process uses the target system's TwinCAT Database Server. In combination with the automated code generation, the resulting programmed links from the controller are failure-proof.

SQL   NoSQL

TwinCAT 3
PLC
C++
I/O

→ **TwinCAT Database Server** →

rds
- MS SQL
- MySQL
- PostgreSQL
- …

NoSQL
- MongoDB
- …
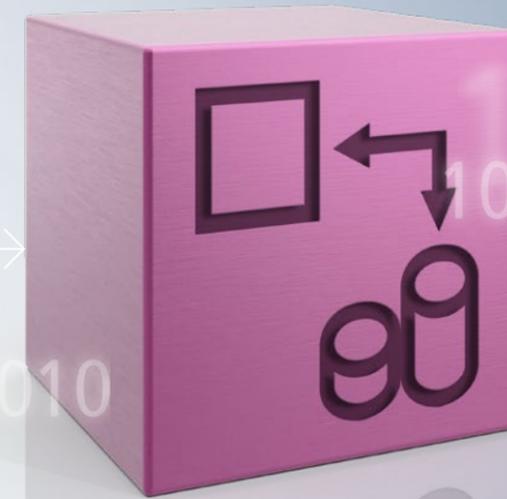
Data is a valuable asset these days. This is true for data from machines, systems or test stands; it is very important and must be protected. The TwinCAT Database Server does precisely that by handling the data traffic between TwinCAT and various database systems. It can write or read values during this process.

The Database Server offers four functional modes. The Configure mode enables fast and easy configuration of a database connection without requiring any program code. The PLC Expert mode was designed for PLC programmers who do not want to create their own SQL commands in the

PLC; the Database Server does this automatically. The SQL Expert mode offers total flexibility, because users can combine their commands themselves and even trigger stored procedures on the database. This mode is also available for C++. In environments with frequently changing measurement campaigns, a rigid table structure in a relational database is particularly difficult to manage, which is why the Database Server supports classic relational databases like Microsoft SQL, Oracle, MySQL or SQLite and also offers the option to connect to NoSQL databases such as MongoDB in NoSQL Expert mode. For this purpose, no pre-

defined scheme is required, which increases the flexibility of the application significantly.

Convenient database integration without programming
- direct link from the real-time context to the database
- supports relational and NoSQL databases
- easy configuration in TwinCAT Engineering
- PLC code generation for easy implementation in the controller
- various PLC function blocks available for all user groups

# Seamless and consistent data analysis with TwinCAT Analytics

TwinCAT Analytics
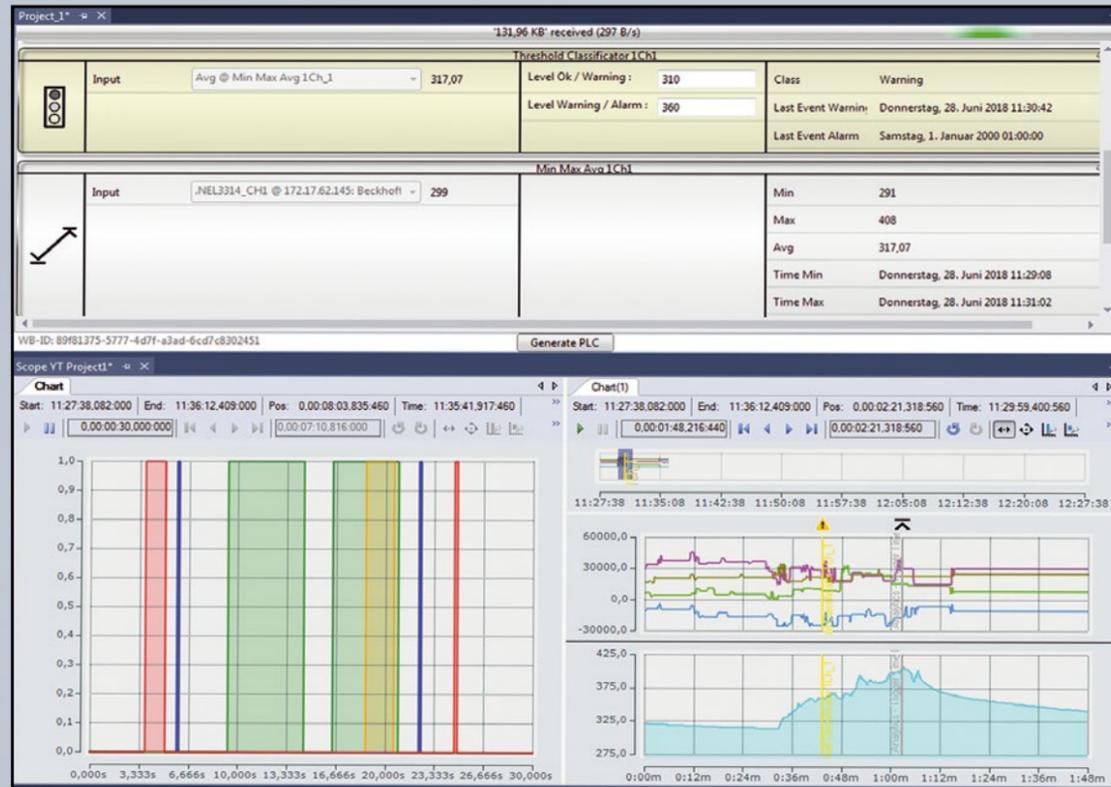
Configurator and Scope View in an Analytics project. The data is streamed into the analytics software directly from the machine or via a database using MQTT. Significant events can be dragged and dropped into the charting tool from the analysis and marked in the data.

TwinCAT Condition Monitoring

In order to implement condition-based machine maintenance, measured values must be evaluated. Evaluation is simplifed by the TwinCAT Condition Monitoring PLC library: Complex but easy-to-handle mathematical algorithms that are run on the local control computer deliver the desired analysis results. It is the ideal partner for TwinCAT Scope, for example, when representing a frequency spectrum as a bar chart, and also for TwinCAT Analytics when performing centralized analysis of multiple control systems.
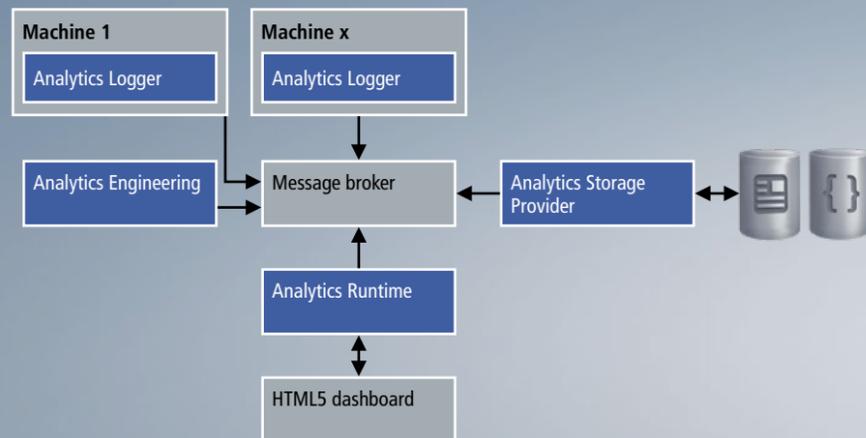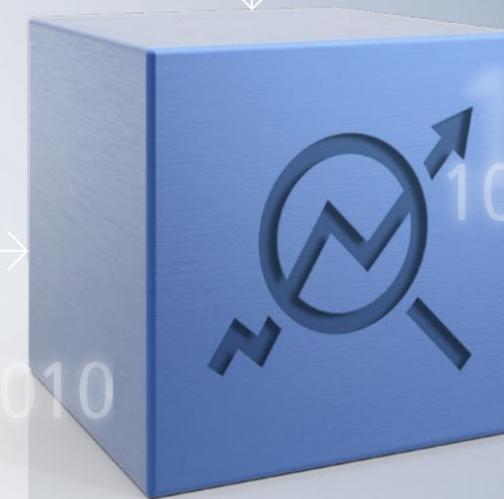
As the acquisition and analysis of relevant data generates competitive advantages, an increasing number of data analysis tools are available on the market. Yet for the most part, these do not speak the language of the machine builders and are limited to a small number of application scenarios. In contrast, TwinCAT Analytics has been developed specially for machine building. The TwinCAT Analytics engineering tools are seamlessly integrated into the Microsoft Visual Studio® environment that is already familiar from machine applications. Considerable time can thus be saved in the engineering process. Moreover, many algorithms are available, which have been specially developed so that linguistically, they directly reference mechani-

cal engineering and the specific functions. Familiar tools from the TwinCAT product world, such as the TwinCAT Scope charting tool, simplify the use of TwinCAT Analytics and the opportunities it offers. TwinCAT Analytics not only allows troubleshooting on machines, it also enables permanent monitoring of one or more machines in a network. 24/7 monitoring is fairly simple to implement: from an analysis performed in the configuration tool, readable PLC code can be generated at the touch of a button. The resulting code can be run on an analysis IPC or on a virtual machine in parallel with machine operation. Once generated, the code can also be further customized to create individal analyses in a programming language that

is familiar to the machine builder. Existing code can be transferred exactly as it is as well. Finally, an individual analysis dashboard can be designed using of TwinCAT 3 HMI, which adds value for the end user. It goes without saying that TwinCAT Analytics not only works with live data, but also with historical machine data. Access to the database can be obtained via the Analytics Storage Provider. Ultimately TwinCAT Analytics is not just a product, it is an entire workflow that supports flexible use of IoT technology and thus enables users to implement real Industry 4.0 applications.

Data analysis gives added value for the mechanical engineer

- new business models based on data analysis
- quick and easy fault analysis
- machine optimization
- easy engineering integrated into TwinCAT XAE
- cost reduction through automatic PLC code generation for 24/7 monitoring
- almost automatic data management
- maximum flexibility with IoT technology

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References: Beckhoff measurement technology in use worldwide

Aoling and CNOOC, China

Offshore oil platforms feature condition monitoring and vibration analysis in real time with PC-based control

▶ www.cnooc.com.cn

Pensar Otra Vez, USA

PC Control and EtherCAT in high-temperature PCB test handler

▶ https://pensar2.com
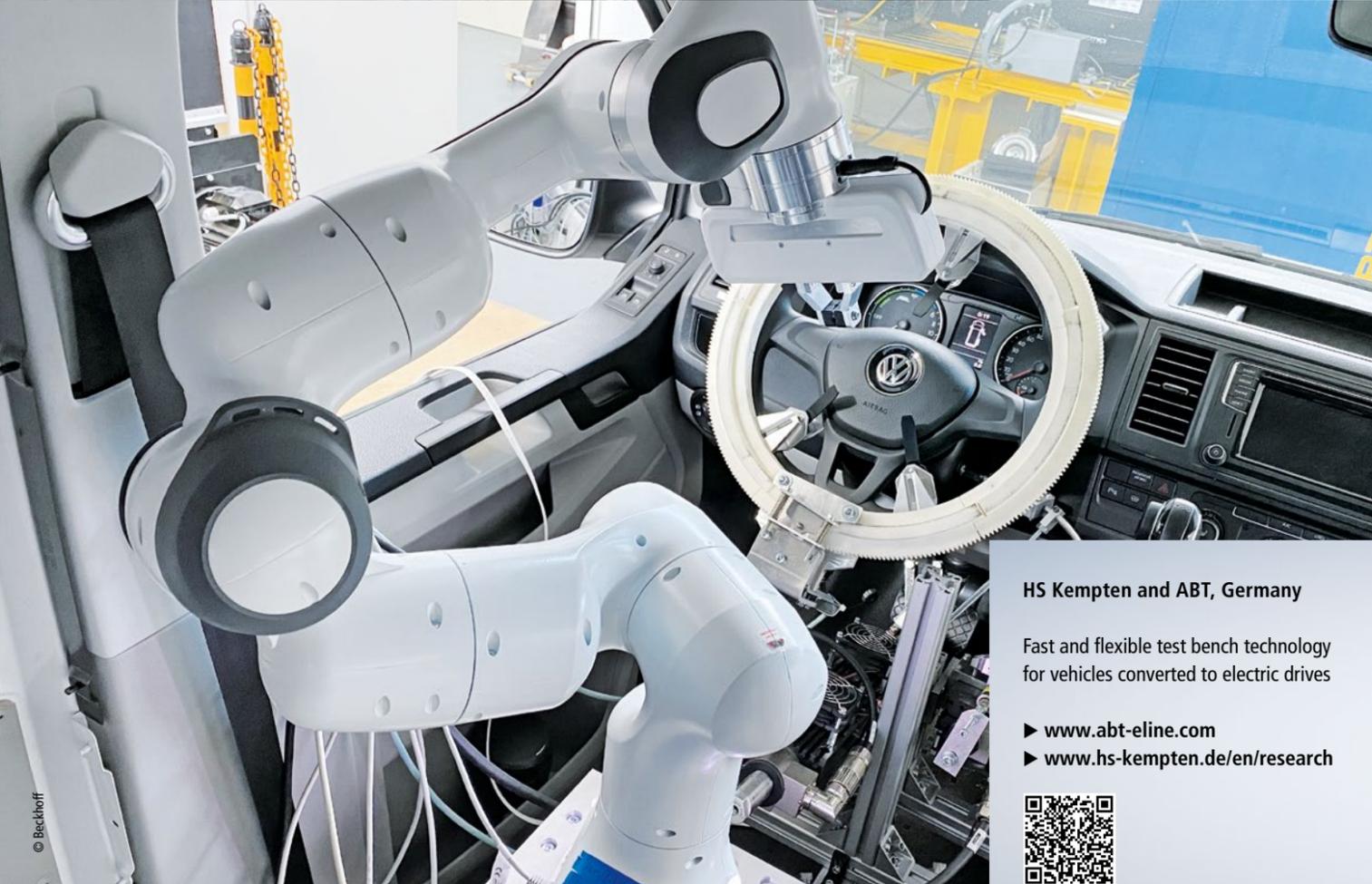
HS Kempten and ABT, Germany

Fast and flexible test bench technology for vehicles converted to electric drives

▶ www.abt-eline.com
▶ www.hs-kempten.de/en/research

Romande Energie, Switzerland

Integrated measurement technology ensures reliable grid management for power utility.

▶ www.romande-energie.ch

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Beckhoff Automation GmbH & Co. KG
Hülshorstweg 20
33415 Verl
Germany
Phone: + 49 5246 963-0
info@beckhoff.com
www.beckhoff.com