BECKHOFF New Automation Technology

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

ELM3704-0001

RUN
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X004

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< 1 µs synchronization
100 ppm at 23 °C
24 bit
up to 50,000 samples/s

Extremely accurate, fast and robust: system-integrated measurement technology

Machine building

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

Test stands

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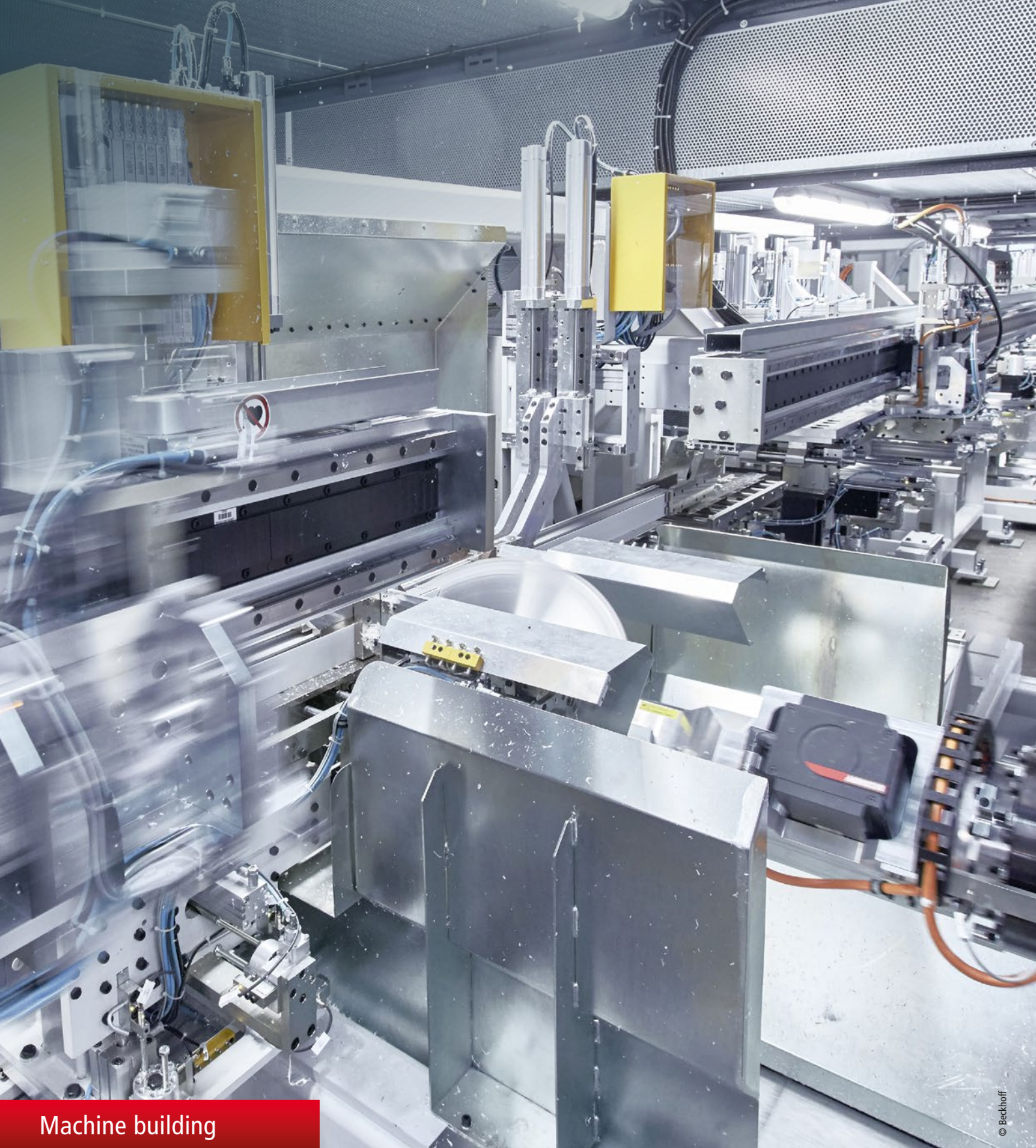
Lab and research facilities

Direct integration into the control system of:

- machinery for optimized production, resource savings, and predictive maintenance
- test stands for exceptionally precise results
- lab and research facilities for reliable measurement data acquisition and 24/7 operation

Increased system efficiency:
the benefits in 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 the processing quality of your production.
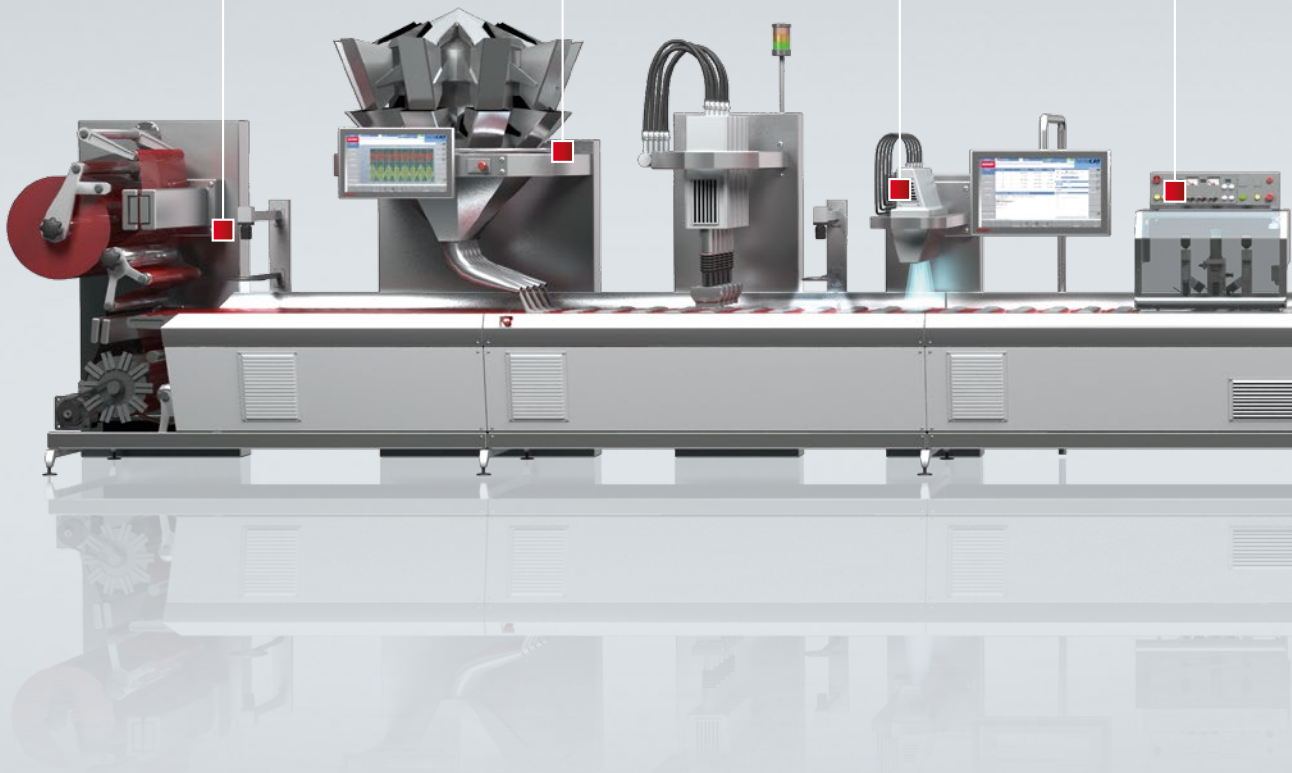
Measurement technology at high speed
Faster measurements with sampling rates exceeding 10 ksps can scan even highly dynamic processes and provide valuable data for subsequent analyses.

Measurement technology provides insight
Precise measurement technologies with an accuracy of better than 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 across long machine runs for improved product quality and less 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.

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 rate of rejects.

Ideal for Industrie 4.0 applications:

System-integrated measurement technology manages high data volumes for power and condition monitoring.

Measurement technology adds value

Proactive measurement technology checks its own functionality and the status of the cabling to produce reliable data 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 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

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
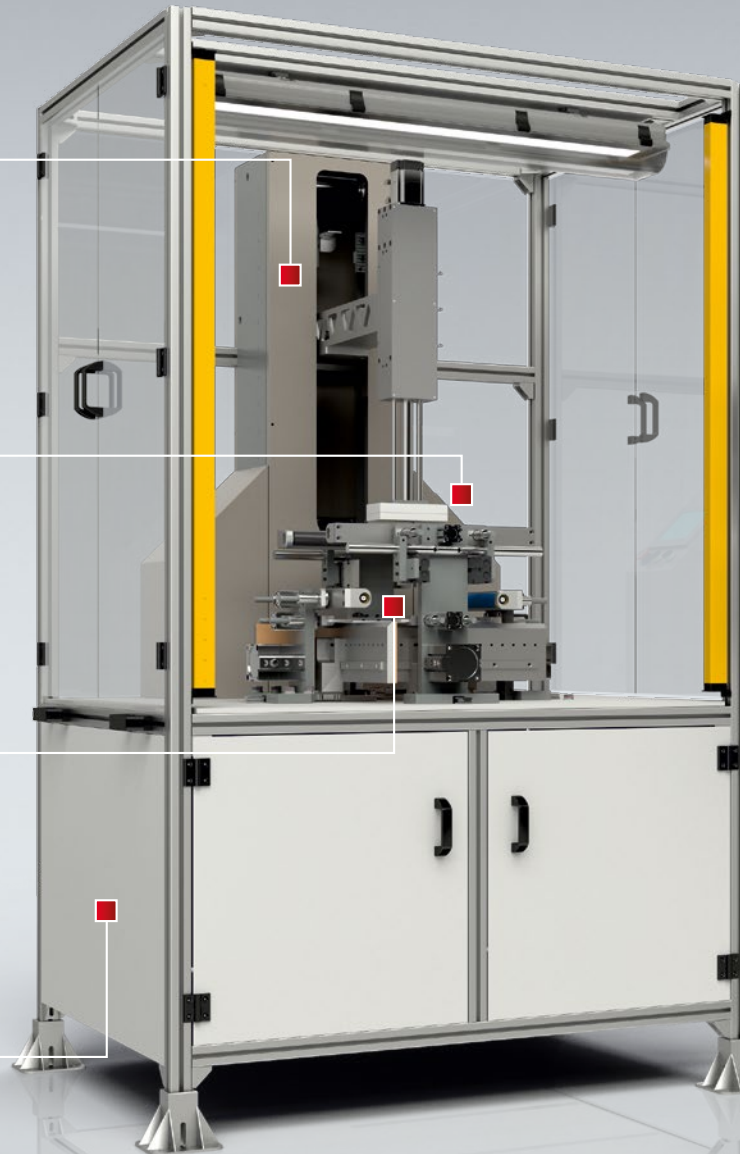
Reduce complexities:

EtherCAT communication connects sensors, actuators, and control system seamlessly

Measure accurately, take instant action:

less uncertainty and short test times with industrial measurement technology

Reduce costs:

with affordable mass-market components and a highly scalable product portfolio

Beckhoff measurement technology in a test stand for automotive parts

© Integrated DNA Technologies, Inc.

Proven industrial volume production
Beckhoff has produced industrial automation technology for more than 30 years. Designed for 24/7 operation inside or outside of control cabinets and featuring long-term availability, the Beckhoff components are ideally suited for measurement and testing applications. Besides sophisticated analog technology, our portfolio features digital, analog and feedback inputs for fundamental signal acquisition at exceptionally low prices per channel. Monitoring analog outputs and actuators in a test stand is easily implemented as well, because TwinCAT supports up to 255 axes simultaneously. And Gigabit

Easily integrate any software:

TwinCAT uses various technologies to communicate with other software

Leverage universal connectivity with TwinCAT:

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

Utilise device variety:

EtherCAT components from more than 5,000 members of ETG, the EtherCAT user organisation

Talk Automotive with us:

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

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EtherCAT ensures the fastest real-time communication with sensors and actuators.

Highly accurate, dynamic, and stable over the long term

The feature list of measurement technology from Beckhoff is long: small measurement uncertainties of up to 25 ppm, detection of dynamic signals with up to 1 Msps, time-synchronised measurement and control with a time error of $<< 1$ µs, synchronisation 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. And with up to 65,535 subscribers, it has no limitations on the hardware side either.

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

Complete your control system: with simple measurement technology integration

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.

High-precision measurement technology for automation applications

With its new ELM-series EtherCAT device family, Beckhoff is adding high-precision and high-speed technologies to its portfolio of measurement technology devices. These powerful EtherCAT modules open new doors in terms of time and measurement precision, synchronisation and especially long-term reliability that previously were only possible with cost-intensive specialised equipment introduced into integrated automation systems. As a result, Beckhoff offers a platform-wide measurement solution for existing PC- and EtherCAT-based control applications without performance losses through platform or system breaks.

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

High-end measurement technology with attractive pricing through series production, seamlessly integrated into the automation system.

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. High-precision measurement technology

measurement technology modules instantly recognise potentially faulty measurements that could otherwise have been considered valid in the past. 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 recognise overloads. Features like 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 long years of experience in series production of automation components.

Bringing precision measurement technologies into the industrial environment enables makers of traditional manufacturing, testing and inspection equipment to further advance their applications.

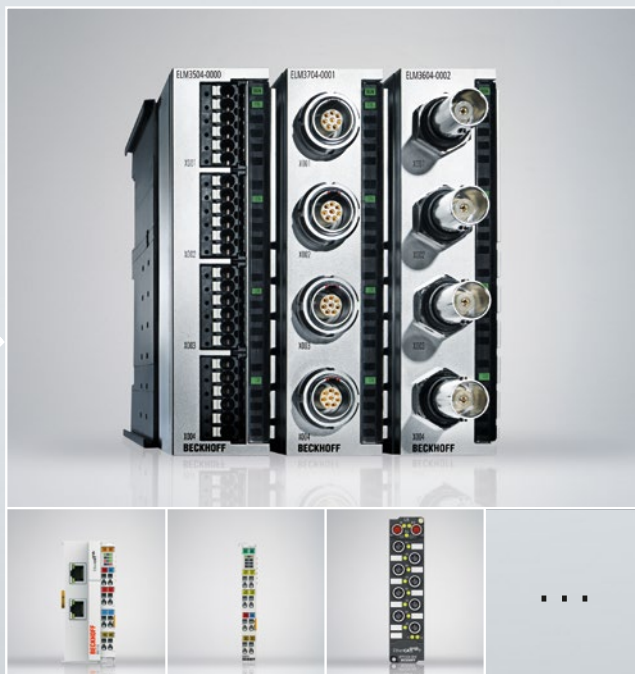**Beckhoff – automation and measurement technology from a single source:**

- complete automation toolbox with IPC, I/O, motion control and automation
- comprehensive toolbox for centralised and distributed measurement technology concepts
- systems based on standard components
- easy integration into existing control environments
- innovative, well-established vendor with global reach

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

The sensors
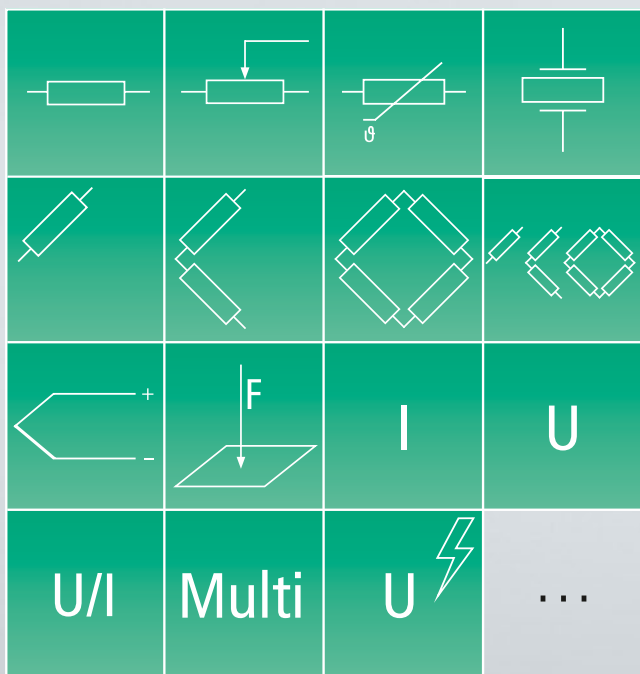
The measurement modules

Measurement sensors

Beckhoff I/O modules accommodate most common sensors:

- force
- pressure
- temperature
- speed (rpm)
- frequency
- torque
- measurement bridges
- vibration
- current
- voltage
- …

Measurement technology hardware

Beckhoff offers I/O modules in various protection ratings for common sensors:

- DIN rail-mountable IP20 modules
  - Bus Terminals
  - EtherCAT Terminals
  - EtherCAT measurement modules in connector-compatible metal housings
- flexibly installed IP67 modules
  - Fieldbus Box
  - EtherCAT Box, also available in stainless steel and die-cast zinc housings

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 as the compatible technology EtherCAT G with 1 Gbit/s data rates ready to support even more data-intensive applications.
- PROFIBUS, PROFINET, EtherNet/IP, etc.: All measurement data can alternatively be collected via many other Beckhoff-supported fieldbus systems.

The measurement software in the cloud
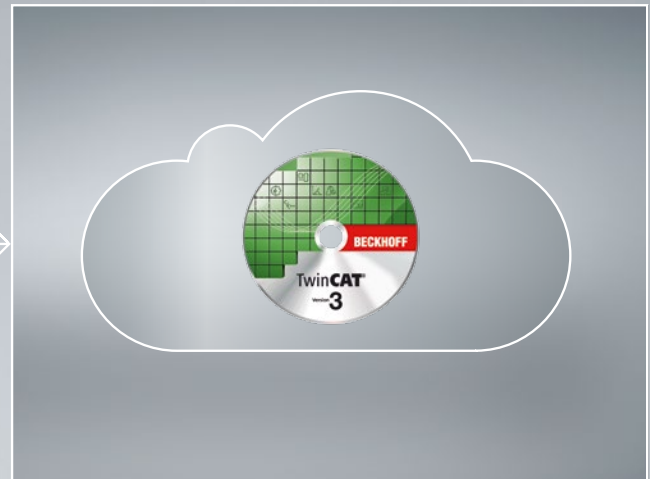
The measurement technology bus

The measurement software on premise

Measurement software "on premise"
"On premise" describes the use of TwinCAT 3 on a local control IPC with engineering, PLC, motion control, safety, visualisation, 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 not only locally in the machine controller, but also 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

The EtherCAT measurement modules: extremely accurate, fast and robust

ELM3604-0002

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How valuable is your data?

Do you know whether your machines and systems (still) produce correct measurements? Or do you trust on 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 new 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 calibrations

We reserve the right to make technical changes.

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

in the production facilities at Beckhoff ensure reliable and precise measurement functionality.

High-end measurement technology in metal housings
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 housings. Effective heat dissipation and shielding deliver technological improvements over the tried-and-tested EL series. Robust and well protected, the Beckhoff metal

modules implement sophisticated measurement technology on 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 technologies that can self-check and validate as effectively as technically feasible. Integrated connection diagnostics in the EtherCAT measurement modules 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 100 ppm at 23 °C
- metal housings 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

High flexibility, high process stability: the Beckhoff measurement technology hardware
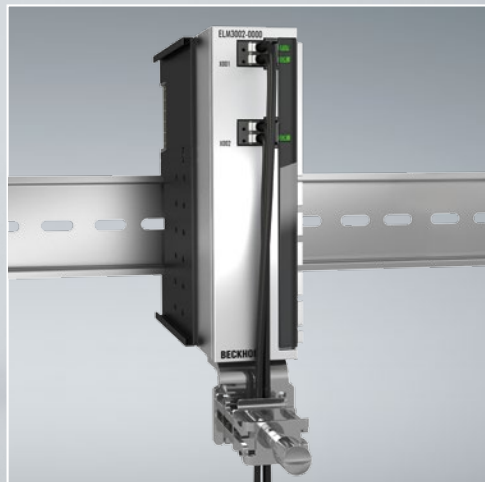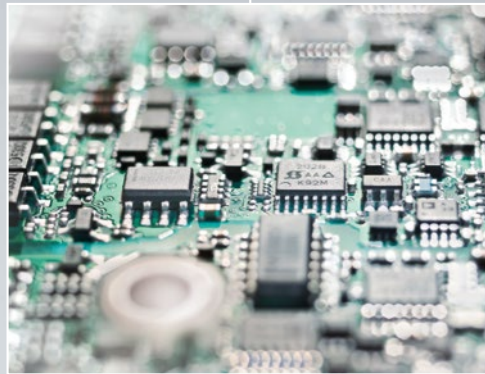

New measurement technology approach

The ELM-series EtherCAT measurement modules reflect the successful packaging 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 attractively priced industrial measurement technology in different versions available to fulfill challenging requirements. It provides multifunction channels with many integrated and online switchable measurement ranges as well as price-optimised variants for varying channel quantities.

DIN rail-mountable modules in metal housings

- use on the DIN rail 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 discharge of 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, and long-term reliable.
- BNC technology for vibration analysis, quick-and-easy bayonet connection, well-shielded through coax cable for quick wiring modifications.
- High-quality LEMO connectors for high-end applications. Slightly more difficult to assemble, but offers consistent shielding and is usable as a power plug; easily removable for maintenance or other purposes.

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 for each analog cable enable clean crimping. Ultimately, high-quality analog measurement technology always starts with the cable connection.

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

High process stability
Process stability is especially 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 diagnostics immediately detect short-circuits, cable breaks and shunts to the extent technically possible.
- comprehensive self-test and repeat internal checks

- continuous monitoring of temperature and inputs to detect overloads and prevent critical failures
- 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, via the Beckhoff recalibration service, ELM devices can be checked, aligned and recalibrated at the factory in Verl, Germany.

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

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

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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

Newly developed for highest demands
The "intrinsic values" of the EtherCAT measurement modules open up entirely new opportunities for the use of measurement technology in automation as well as 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. Over 20 years of experience integrating electronics in modular I/O terminal housings have been incorporated in the development, testing and production of the ELM series.

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

High-quality input electronics
- Carefully selected components with high stability, robust EMC protection circuitry and proven design from previously-designed terminals have been combined to provide reliable inputs for high quality demands.
- In the multifunction models, which also sport a switching feature, the variants are equipped

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
- synchronised scanning with delta-sigma conversion across multiple channels and terminals via EtherCAT distributed clocks

| | Decimation unit | TrueRMS integrator/ differentiator | Scaler | PDO transport via EtherCAT |
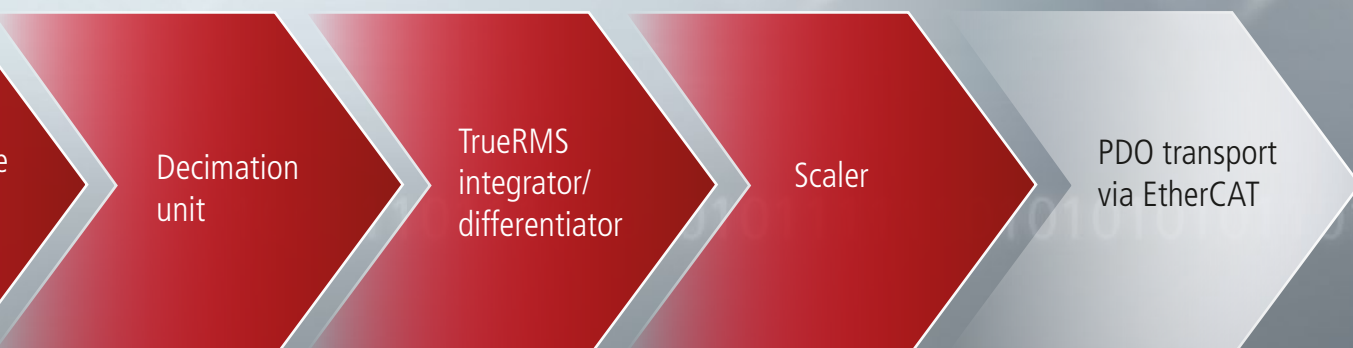
- 10 ksps sampling rates with the standard terminal version; over 20 ksps in 2-channel models; up to ultra-fast 50 ksps 24-bit IEPE scanning with the ELM360x

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

Decimation unit
- channel sampling rate changeable at runtime
- uses oversampling to transmit measured data over 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 totally free supporting point table up to linearisation

EtherCAT – the measurement technology fieldbus
- 100 µs minimum EtherCAT cycle time
- oversampling for transmitting larger data packets per cycle
- synchronised via distributed clocks to ensure < 1 µs deviations from each other

Fast and open, the ideal fieldbus for measurement technology: EtherCAT and EtherCAT G


Firmly established: EtherCAT from Beckhoff
As the inventor of EtherCAT, Beckhoff continues to play a leading role in the advancement of the protocol and in the development of innovative products for EtherCAT, especially the modular EtherCAT Terminal I/O system. Additionally, EtherCAT has become firmly established in the measurement technology world. With its high data rate of 100 Mbit/s, EtherCAT meets many measurement technology requirements in lab and production environments. For especially data-intensive applications, EtherCAT G provides communication bandwidths of up to 10 Gbit/s. Other benefits include the ease with which equipment manufacturers can integrate EtherCAT into their products. After 14 years, the EtherCAT Technology Group (ETG) provides an almost unlimited variety of devices via more than 5,000 member companies and 100 master device manufacturers. Almost every sensor type is now available with an EtherCAT interface. With its EtherCAT-based modular I/O terminal system and TwinCAT PC-based control software, Beckhoff provides the automation infrastructure for many machines, which is why the company's ultra-precise, DIN rail-mounted measurement technology is such a valuable addition. It simplifies control cabinet design, saves space and streamlines

Optimized accuracy: up to << 1 µs with timestamp functionality in nanosecond resolution

EtherCAT enhances the value of your data by maximising time and value precision.
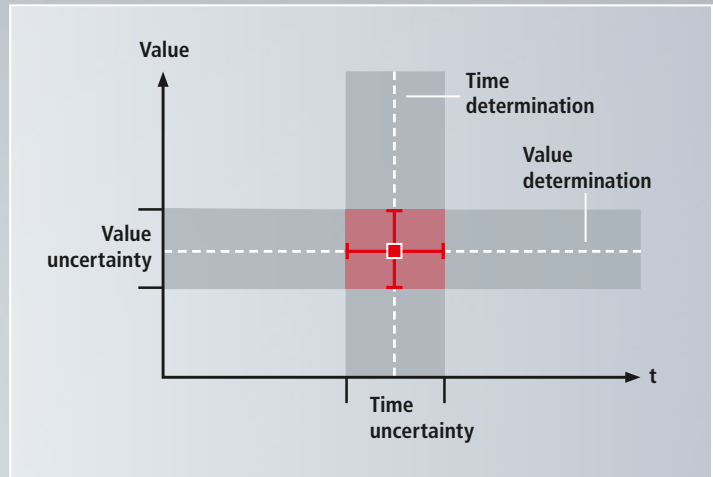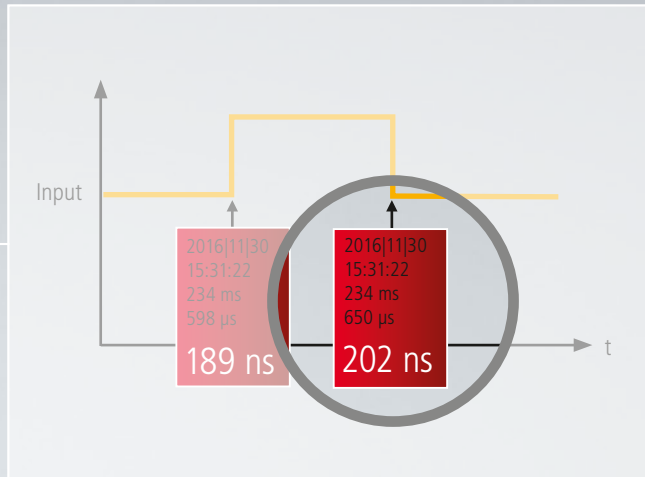
procurement processes, because all the automation, control and measurement technologies are available from a single equipment manufacturer. The direct integration of precise measurement technology into the control platform via EtherCAT promotes simpler system architectures and reduces complexity. It also delivers fieldbus technology capabilities such as easy configuration based on EtherCAT standards, synchronised scanning via distributed clocks (including external synchronisation with PTP/IEEE 1588-based and other time sources) and consistent diagnostics from the controller to the I/O level.

Ultra-precise time synchronisation
A measurement value is defined by two essential characteristics: the value itself (and its uncertainty) as well as the exact time at which the measurement was taken. With its distributed clocks, EtherCAT enables highly accurate synchronisation of all inputs and outputs with an uncertainty factor that is typically well below 1 µs between the devices on the network and also relative to a global reference time. On the other hand, the precision of the EtherCAT measurement modules significantly improves the reading of the values. As a result, times and values are now determined much more accurately than with standard automation technologies.

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

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

CX20xx
Embedded PC

EtherCAT G Master

EtherCAT® G

EtherCAT®

100 Mbit/s

Segment 1

EK1400
EtherCAT G
Coupler

EK1100

EtherCAT® G

EtherCAT segment – 100 Mbit/s

EtherCAT® G

Segment 2

1 Gbit/s

CU1403
EtherCAT G
Branch Controller

CU1423
EtherCAT G
Junction

EtherCAT segment – 1 Gbit/s
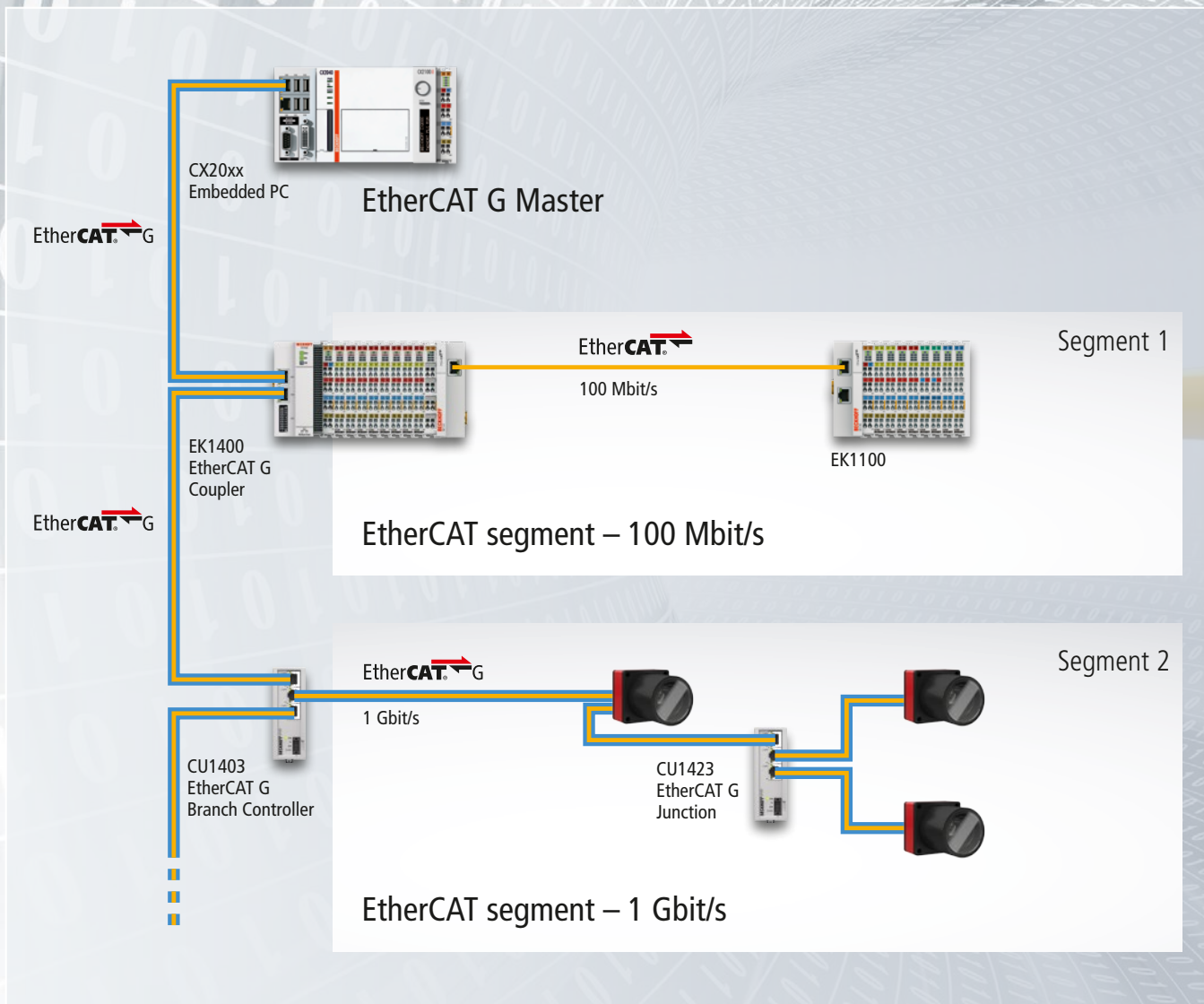
EtherCAT G builds on the principles of the successful EtherCAT technology but moves the available data rates up to 1 Gbit/s and 10 Gbit/s. The EtherCAT protocol itself remains unchanged. As before, all of the devices on a network receive the telegrams sent by the EtherCAT master. Each EtherCAT slave 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 delaying telegram processing. The last device in a segment or stub line identifies an open port

and utilises the full duplex feature of Ethernet network 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 and unplugged via the Hot Connect feature. Network-wide diagnostics are available to help minimise machine downtime and increase availability. And the built-in system of distributed clocks still ensures devices are
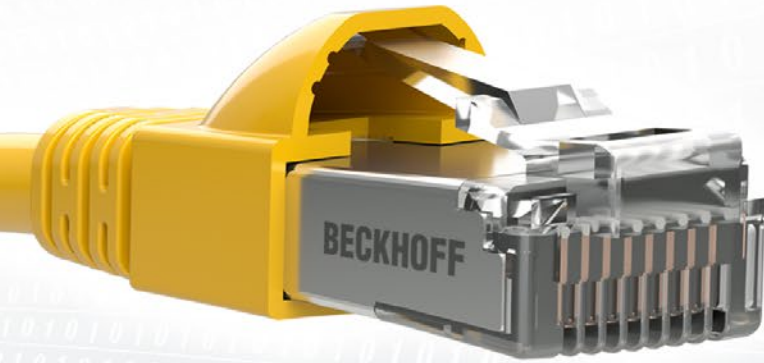
EtherCAT ® G

10 Gbit/s
1 Gbit/s
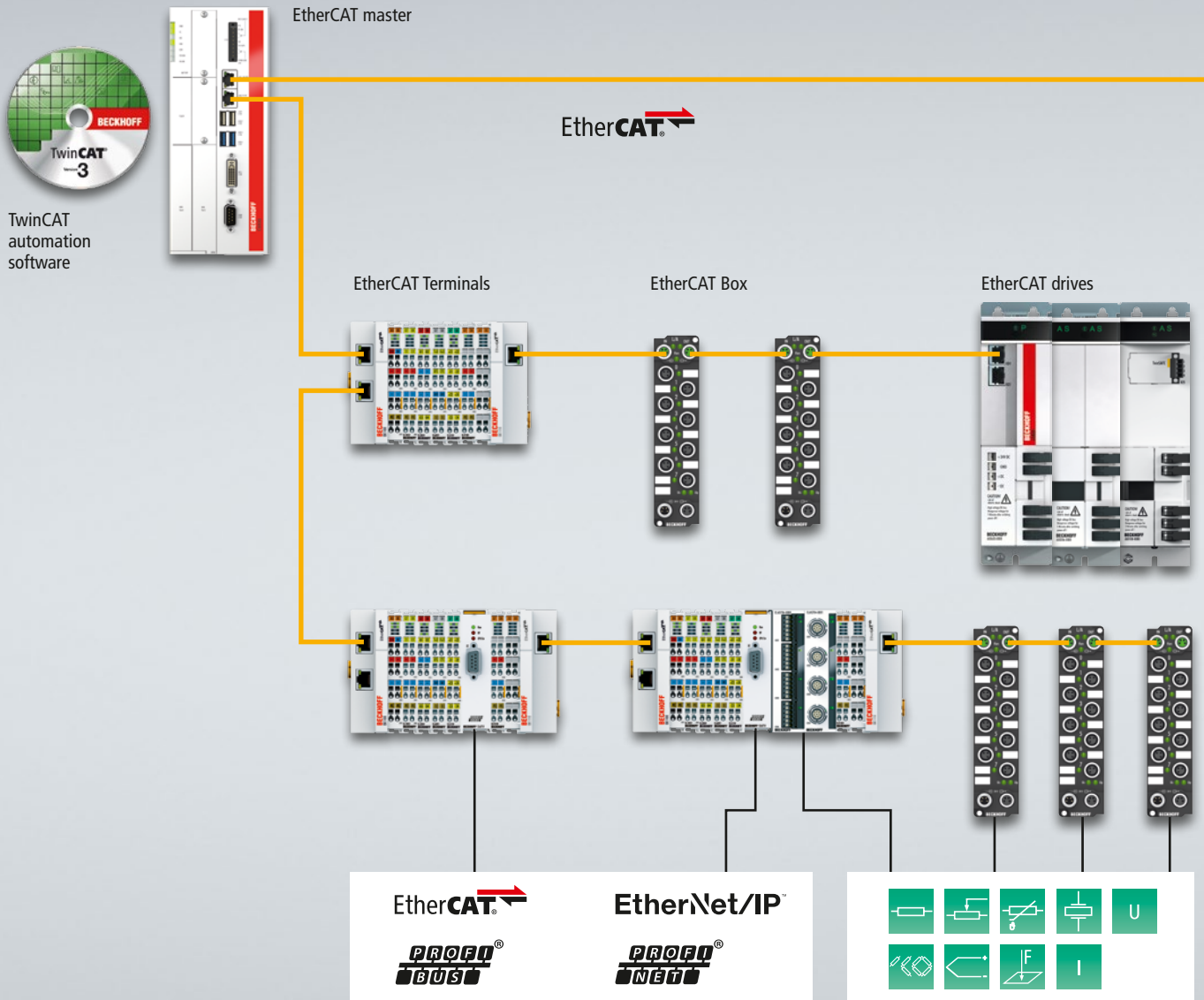# 100 Mbit/s

synchronised precisely in better than 100 ns.

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

Consistent features

- real-time Ethernet down to the I/O level
- flexible topology
- outstanding diagnostics
- synchronisation accuracy better 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

TwinCAT automation software

EtherCAT master

EtherCAT

EtherCAT Terminals

EtherCAT Box

EtherCAT drives

EtherCAT

EtherNet/IP

PROFIBUS®

PROFINET®

U

F

I

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 utilisation, telegram processing on-the-fly, high-precision synchronisation, extensive diagnostics functionality and more are fully retained.

EtherCAT P
Coupler
EK1300

EtherCAT P
Coupler
EK1300

EtherCAT® ➤ P

Junction with
feed-in

24 V DC

Junction

EPPxxxx

EPPxxxx-006x

Proximity
switches

Camera

Barcode
scanner
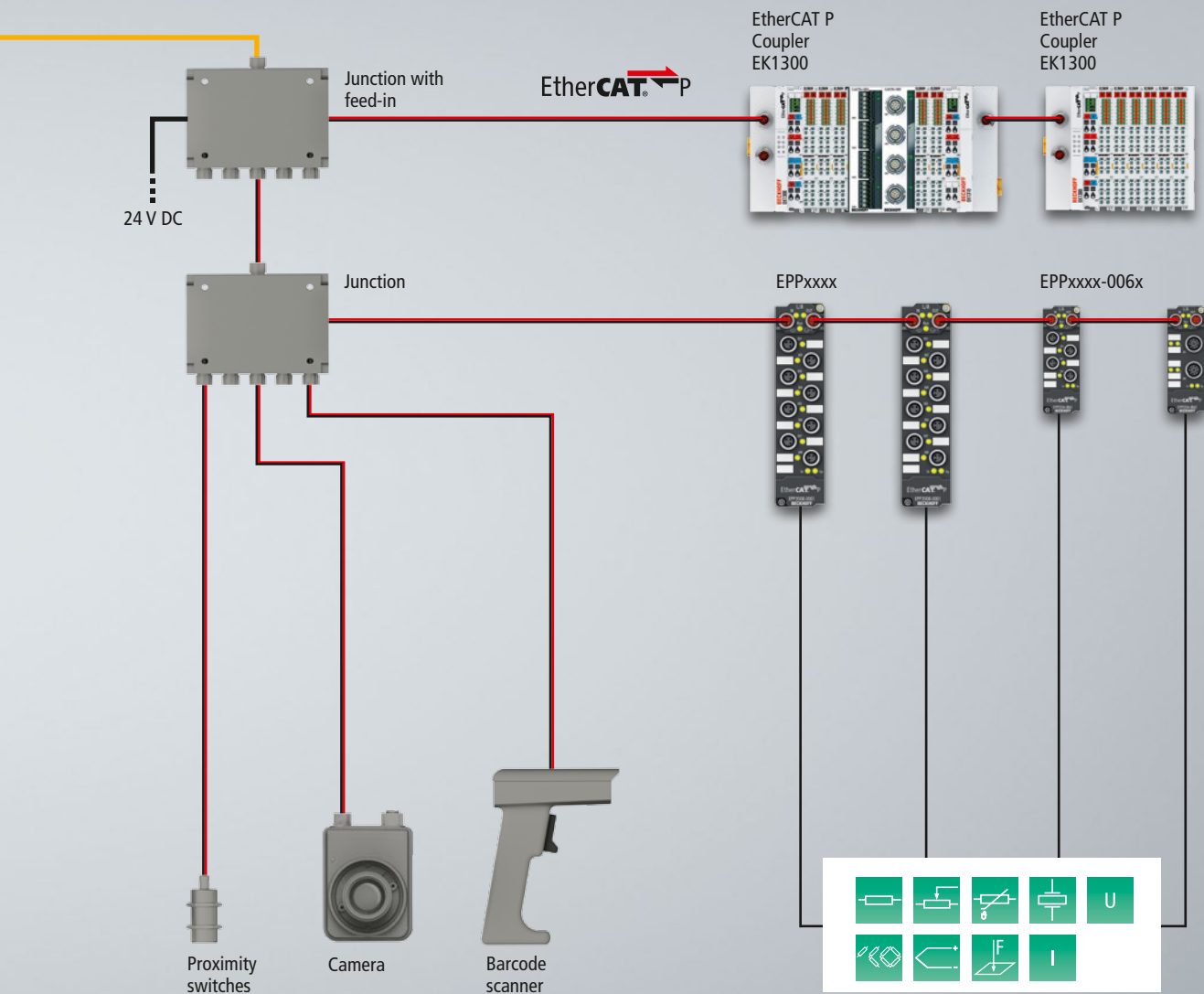
The currents of U_S and U_P are directly injected into the wires of the 100 Mbit/s line, enabling the realisation of highly cost-effective, space-saving connections. EtherCAT P offers benefits both for the connection of smaller remote I/O stations in terminal boxes and for decentralised I/O components 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 decentralised measurement technology creates an entirely new set of synergies in every machine. High-quality measurements can now be collected from each section of a line with relative little wiring effort. The concept also applies to temporary or 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 technology modules. 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: a suitable device category for any application

Basic line ELM3x0x
24 bit
10 ksps per channel
simultaneous
25 resp. 100 ppm @ 23 °C

Economy line ELM3x4x
24 bit
1 ksps per channel
multiplexed
100 ppm @ 0...50 °C

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ELM3148-0000

With its continuously expanded 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 those process-critical measurement channels for which the standard EL/KL analog terminal technology is not suited. The basic line is designed for acquiring signals of highly dynamic processes with a high measurement accuracy across all channels and modules, 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 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 operation.

Economy line: robust and precise measurement technology in the control cabinet

System components

Economy line

EKM1101	ELM9410
EtherCAT Coupler with diagnostics	Power supply terminal with diagnostics

The Coupler and the power supply terminal are designed especially for use with measurement terminals. They provide E-bus 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 2-channel current/voltage measurement	ELM3144 4-channel current/voltage measurement	ELM3146 6-channel current/voltage measurement	ELM3148 8-channel current/voltage measurement
Channels	2	4	6	8
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, 4-pin	Push-in, 4-pin	Push-in, 6-pin	Push-in, 6-pin
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)				

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

Basic Line

	ELM3704-0001	ELM3704	ELM3702	ELM3004	ELM3002	ELM3104
	4-channel multifunctional input	4-channel multifunctional input	2-channel multifunctional input	4-channel voltage measurement	2-channel voltage measurement	4-channel current measurement
Channels	4	4	2	4	2	4
Resolution	24 bit	24 bit	24 bit	24 bit	24 bit	24 bit
Max. sampling rate per channel	10 ksps	10 ksps	10 ksps	10 ksps	20 ksps	10 ksps
Connection technology	LEMO, 8-pin	Push-in, 6-pin	Push-in, 6-pin	Push-in, 2-pin	Push-in, 2-pin	Push-in, 2-pin
U (0…10/30 V, ±10 V) U	■	■	■	■	■	
I (-10/0/+4…+10/+20 mA) I	■	■	■			■
Measurement bridge (SG)	■	■	■			
IEPE	■	■	■			
Resistance measurement	■	■	■			
Potentiometer	■	■	■			
Temperature (RTD)	■	■	■			
Temperature (Thermocouple)	■	■	■			

* These two measurement technology modules are also available with push-in as ELM3602-0000 and ELM3604-0000

ELM3102	ELM3504	ELM3502	ELM3604-0002	EL3604-0000	ELM3602-0002	EL3602-0000
2-channel current measurement	4-channel strain gauge (SG) evaluation	2-channel strain gauge (SG) evaluation	4-channel analog input IEPE	4-channel analog input IEPE	2-channel analog input IEPE	2-channel analog input IEPE
2	4	2	4	4	2	2
24 bit	24 bit	24 bit	24 bit	24 bit	24 bit	24 bit
20 ksps	10 ksps	20 ksps	20 ksps	20 ksps	50 ksps	50 ksps
Push-in, 2-pin	Push-in, 6-pin	Push-in, 6-pin	BNC	Push-in, 2-pin	BNC	Push-in, 2-pin
			■	■	■	■
■						
	■	■				
			■	■	■	■
	■	■				

Measurement modules for any application

Performance Class

Analog Input	Precision		Standard
Multi Multi	EL3751 | 24 bit, 10 ksps	ELM 370x | Differential input, 24 bit	EL3681 | Digital multimeter
U U (0…10/30 V, ±10 V)	EL3602-0010 | Differential input, 24 bit EL3602 | Differential input, 24 bit KL336x | Oscilloscope terminal, 10 µs ELM314x | 24 bit, 1 ksps	EL3602-0002 | Differential input, 24 bit KL31x2 | Differential input, 16 bit, 0.05 % ELM300x | Differential input, 24 bit	EL300x | Single-ended, 12 bit EL316x | Single-ended, 16 bit KL306x | Single-ended, 12 bit KL3468 | Single-ended, 12 bit
I -10/0/+4…+10/+20 mA	EL3612 | Differential input, 24 bit ELM314x | 24 bit, 1 ksps	ELM310x | Differential input, 24 bit	EL301x | Differential input, 12 bit EL305x | Single-ended, 12 bit EL314x | Single-ended, 16 bit KL301x | Differential input, 12 bit KL305x | Single-ended, 12 bit
U/I -10/0…+10 V, -20/0/+4…+20 mA	ELM314x | 24 bit, 1 ksps		EL3174 | 16 bit
230/690 V AC, 410 V DC, 1/5A			EL3403 | 3-phase, 500 V, 1 A KL3403 | 3-phase, 500 V, 1 A
Temperature (Thermocouple)	EL3314-0010 | Types J, K, L,…U, 24 bit		EL331x | Types J, K, L,…U, 16 bit
Temperature (RTD)	EL320x-0010 | Pt100, 16 bit		EL320x | Pt100/1000, Ni100, 16 bit EP3204 | Pt100/1000, Ni100, 16 bit (also EPP, EQ, ER)
Resistance measurement			EL3692 | 10 mΩ…10 MΩ, 24 bit
Potentiometer			EL3255 | With sensor supply, 16 bit
Resistor bridge Strain gauge (SG)	EL3356-0010 | 24 bit, with self-calibration, EP3356 | 24 bit, with self-calibration ELM 350x | 24 bit, with power supply		EL3356 | 16 bit, with self-calibration
IEPE	ELM360x | 25 ksps, 24 bit		EL3632 | 50 ksps, 16 bit
LVDT (inductive meas. bridge)			EL5072 | 24 bit, 2 channels
Pressure measurement			EM3701 | Differential pressure, -100…+100 EP3744 | Differential/relative pressure 1/7 ba (also EPP, EQ, ER)

Please note: For some of the above series, factory calibration certificates are available. Please contact Beckhoff if you are interested. All EL/KL terminals (with a few exceptions) are available as ES/KS versions featuring a pluggable wiring level.

Beckhoff – the measurement technology expert

The high-precision modules in the ELM series are not the first products for measurement applications offered by Beckhoff. Previously introduced devices for special measurement tasks include the EL series EtherCAT Terminals as well as Bus Terminals in the KL series and the IP67 box module series from Beckhoff. They fulfil the promise made by Beckhoff to be present in specialty fields like weighing technology or vibration measurement with technologically leading automation components. Examples include the EL3692 resistance measurement terminal, which mea-

KL3681 | Digital multimeter		
EL306x | Single-ended, 12 bit	EL310x | Differential input, 16 bit	
EL3702 | Differential input, 16 bit, 100 ksps	KL300x | Single-ended, 12 bit	
KL310x | Differential input, 16 bit		
	KL340x | Single-ended, 12/16 bit	
EL302x | Differential input, 12 bit	EL304x | Single-ended, 12 bit	
EL311x | Differential input, 16 bit	EL312x | Differential input, 16 bit	
EL315x | Single-ended, 16 bit	EL3742 | Differential input, 16 bit, 100 ksps	
KL302x | Differential input, 12 bit	KL304x | Single-ended, 12 bit	
KL344x | Single-ended, 12 bit	KL345x | Single-ended, 12 bit	
EL3174-0002 | 16 bit, electrically isolated	EP31xx | 16 bit (also EPP, EQ, ER)	
EL3413 | 3-phase, 690 V, 5 A	EL3433 | 3-phase, 500 V/10 A	**Application example power monitoring (Energy)**
EL3453 | 3-phase, 690 V, 5 A	EL3783 | 3-phase, 690 V, 5 A, oversampling terminal	
EP3314 | Types J, K, L,…U, 16 bit (also EPP, EQ, ER)	KL331x | Types J, K, L…U, 16 bit	
EL3204-0200 | up to 240 kΩ, 16 bit	EL3214 | Pt100/1000, Ni100, 16 bit	
KL32xx | Pt100…1000, Ni100, 16 bit	KL3208-0010 | NTC 1.8…100 k, 16 bit	
EL32xx | up to 5 kΩ, 16 bit		
KL3351 | 16 bit	KL3356 | 16 bit, with self-calibration	**Application example condition monitoring (Vibration)**
EM3702 | Relative pressure, 0…7500 hPa	EM3712 | Relative pressure, -1000…+1000 hPa	
KM3701 | Differential pressure -100…+100 hPa	KM3702 | Absolute pressure 7500 hPa	

sures 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 measurements. With the BK/BC or EL67xx Bus Couplers, measurement technology terminals and IP67 modules can be operated not only on EtherCAT systems, but on 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 such application example is condition monitoring, where not only the dedicated EL3632 is used to measure vibrations, but current, power and hydraulics are monitored with sensors via standard terminals with 10 V or 20 mA connectors.

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 bed measurement technology to condition monitoring and power monitoring

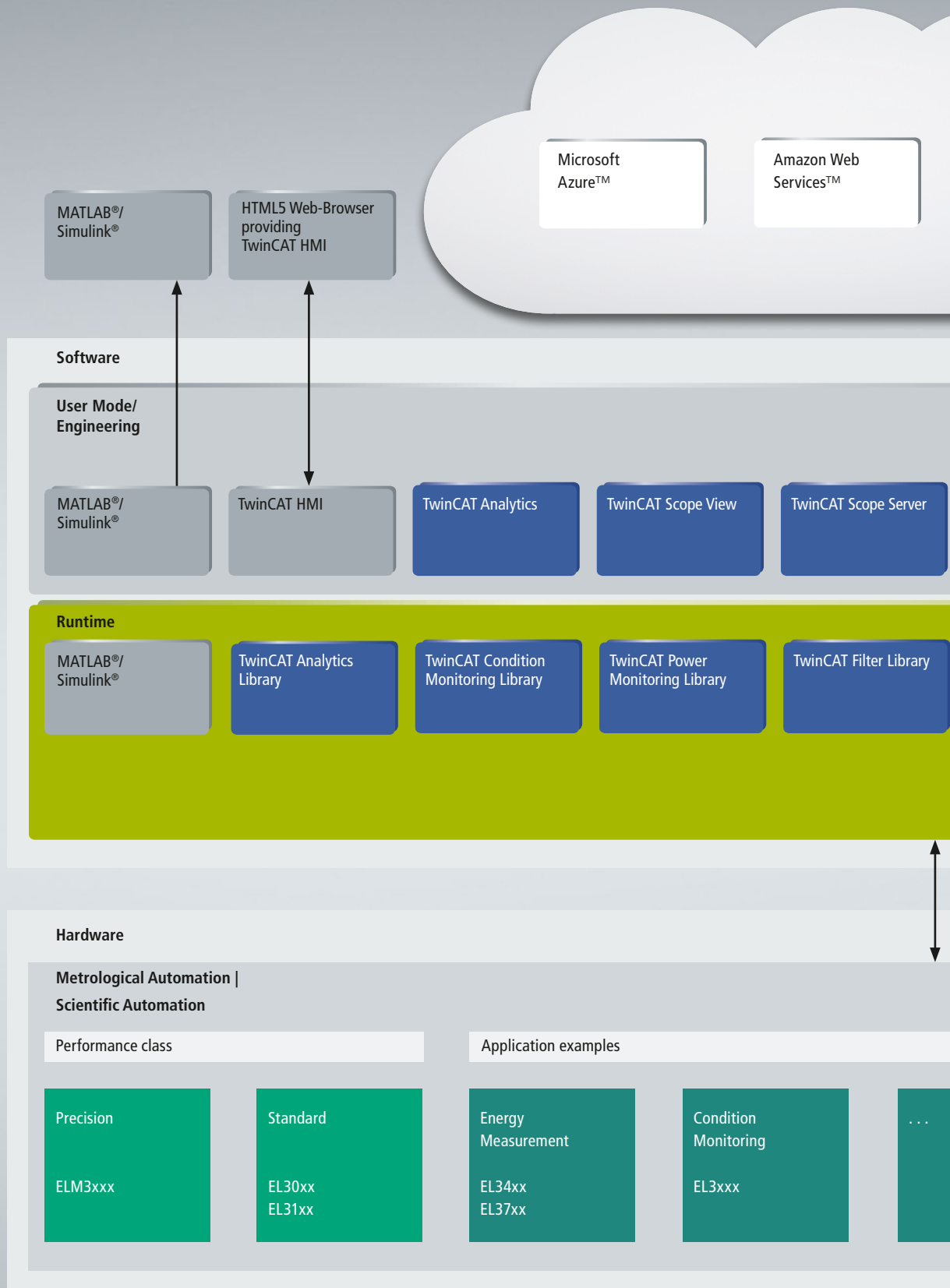# TwinCAT 3: highly modular backbone of PC-based control technology
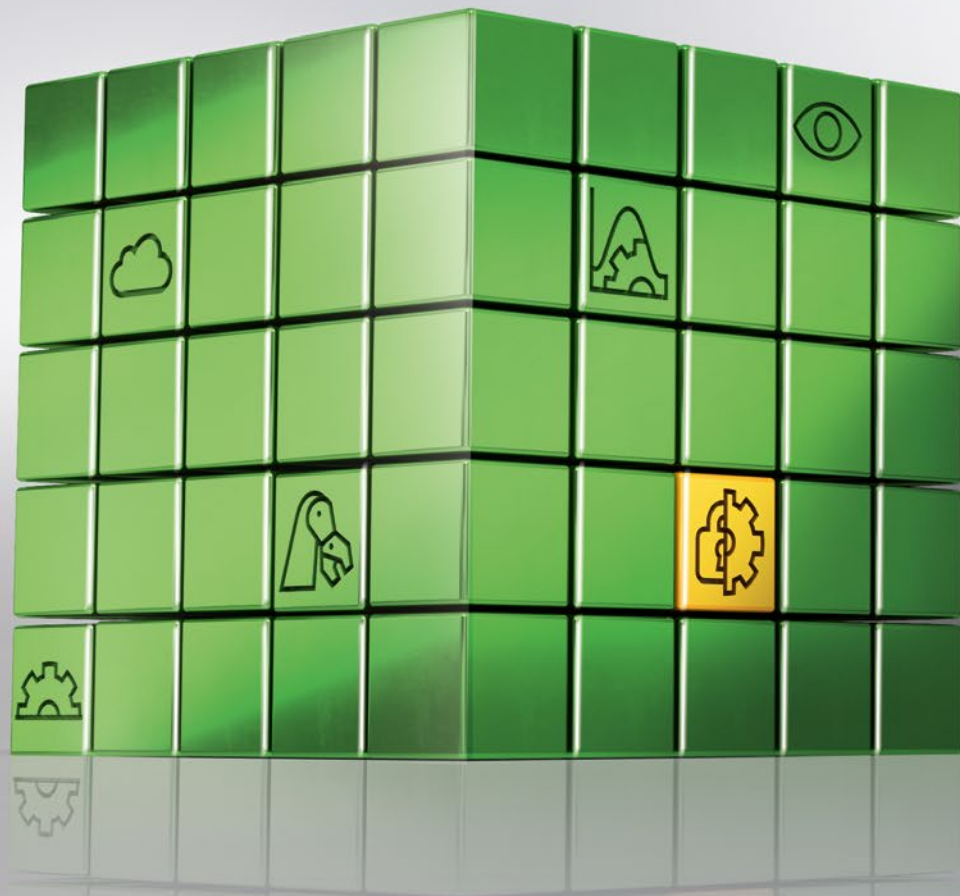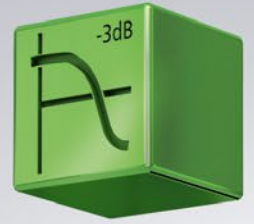
Beckhoff offers system solutions in various performance classes for all areas of automation. The control and drive technology is highly scalable and thus optimally adaptable for different applications. The TwinCAT engineering and control software combines all required machine functions such as PLC, HMI, motion, robotics, measurement technology, vision, but also 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.
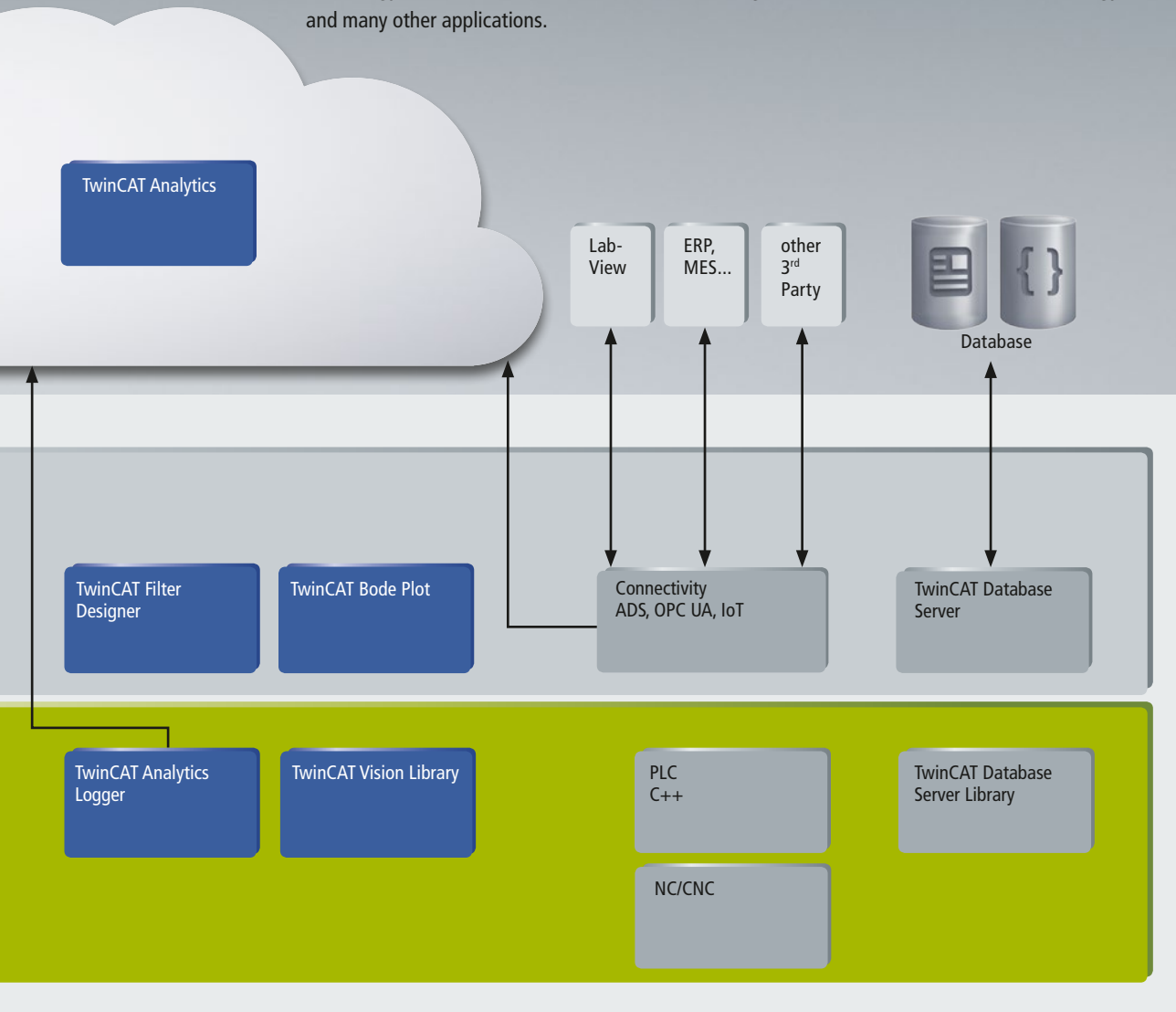
Flexibility through modularity
- The modular solution is scalable and expandable according to the user's needs.
- highly scalable computing platforms for all performance requirements
- All data storage and analysis options: locally in the machine, in the corporate network, or in the cloud.
- simplified code generation using templates
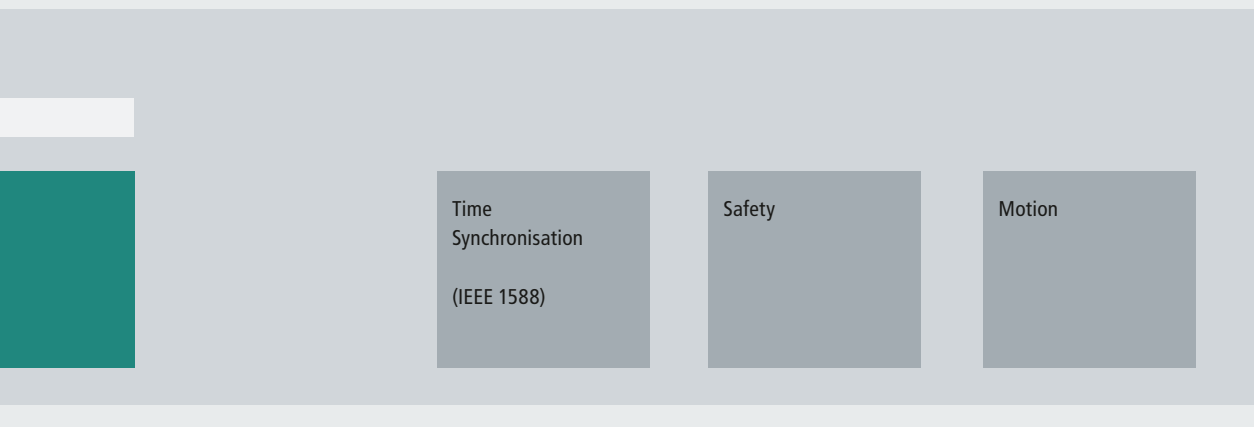- easy code replication for volume production

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

Microsoft Azure™	Amazon Web Services™

MATLAB®/ Simulink®	HTML5 Web-Browser providing TwinCAT HMI

Software

User Mode/ Engineering

MATLAB®/ Simulink®	TwinCAT HMI	TwinCAT Analytics	TwinCAT Scope View	TwinCAT Scope Server

Runtime

MATLAB®/ Simulink®	TwinCAT Analytics Library	TwinCAT Condition Monitoring Library	TwinCAT Power Monitoring Library	TwinCAT Filter Library

Hardware

Metrological Automation | Scientific Automation

Performance class		Application examples		
Precision	Standard	Energy Measurement	Condition Monitoring	. . .
ELM3xxx	EL30xx EL31xx	EL34xx EL37xx	EL3xxx	

The integrated Beckhoff system processes and transports data across all levels of modern machine control from the lowest I/O level, directly or via sensor buses and various established fieldbuses 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 that can reside in the machine, 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.

TwinCAT Analytics

Lab-View

ERP, MES...

other 3rd Party

Database

TwinCAT Filter Designer

TwinCAT Bode Plot

Connectivity ADS, OPC UA, IoT

TwinCAT Database Server

TwinCAT Analytics Logger

TwinCAT Vision Library

PLC C++

TwinCAT Database Server Library

NC/CNC

Fieldbus: EtherCAT

Time Synchronisation

(IEEE 1588)

Safety

Motion

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

MATLAB®/Simulink®
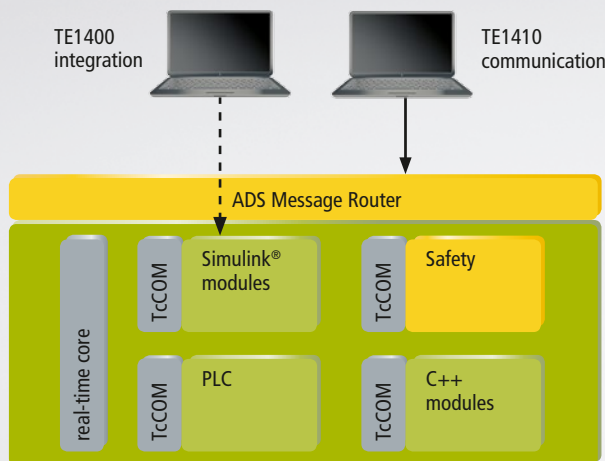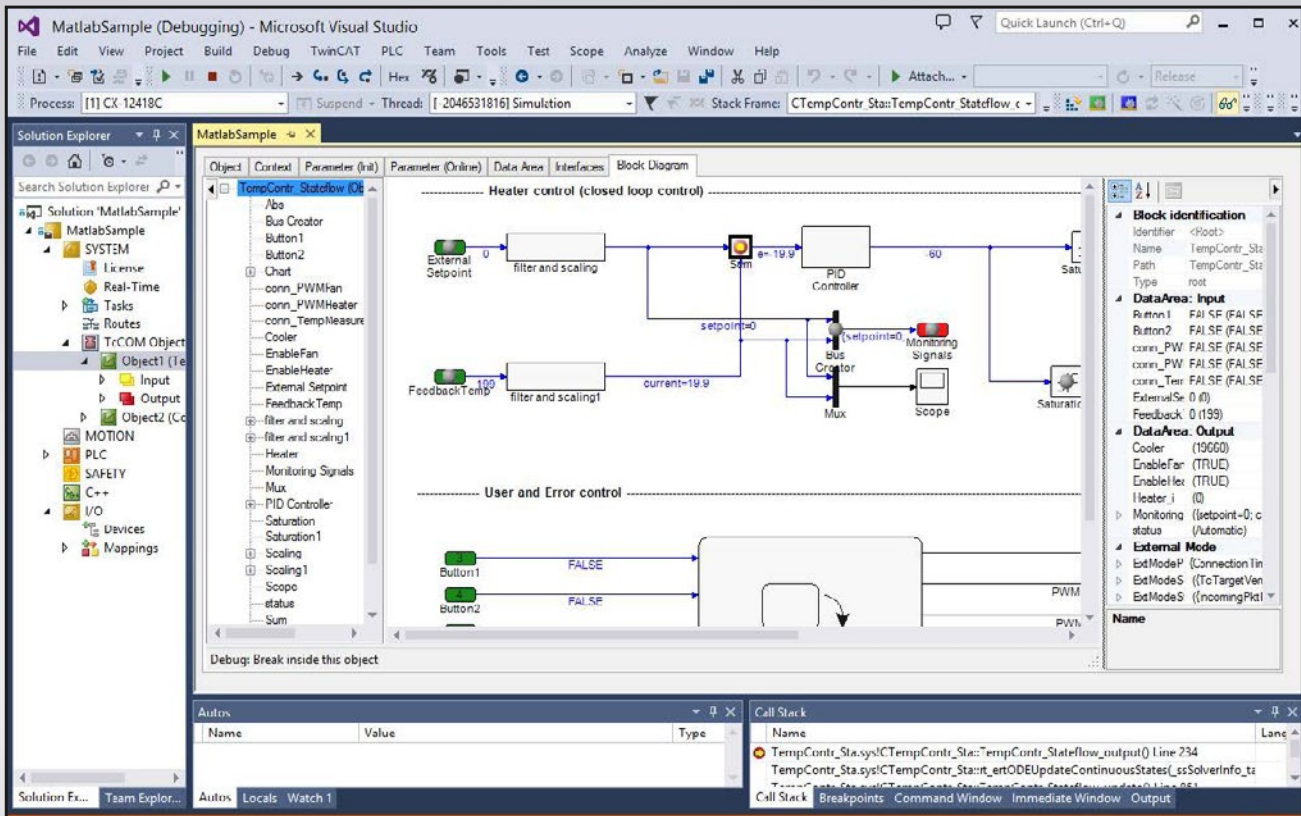
MATLAB® and Simulink® set standards in measurement data analysis as well as in system modeling and simulation. Both tools from MathWorks are widely accepted in many industries.

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 objects (TcCOM models) in TwinCAT 3.

In TwinCAT, these modules can be triggered directly via a real-time task or via other TcCOM models. Embedded as a control in TwinCAT Engineering, the block diagram allows you to parameterise such a model in TwinCAT and monitor signals. You can use this product to develop, for example, monitors that can be executed in real time or virtual sensors for deducing measurement values that cannot be read directly, or to simulate in real time the behavior of non-existing components (hardware-in-the-loop).

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 module calls (read/write). You can also use this product to make MATLAB®-based analyses available as functions that can be called 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
- parameterisation and charting of (internal) model signals
- debugging in XAE possible

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

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

TwinCAT Scope
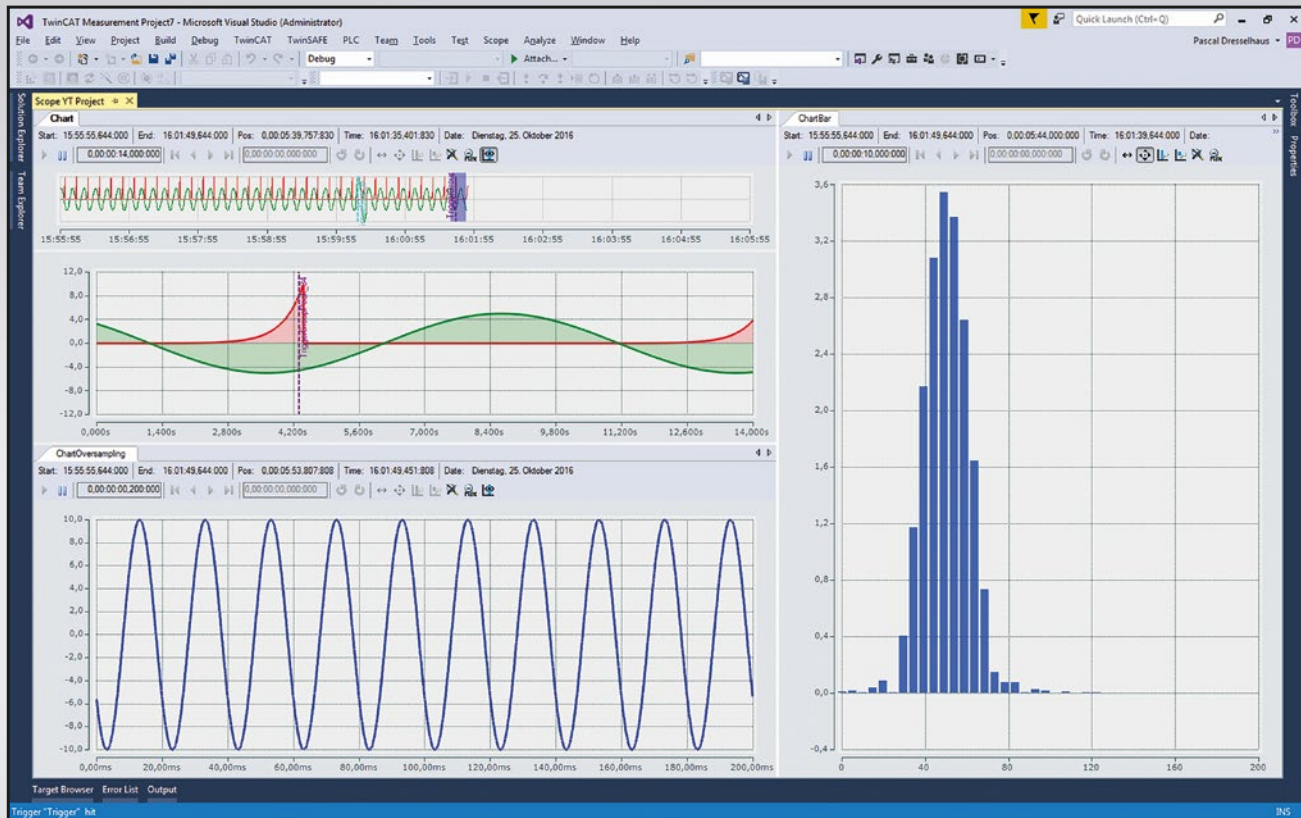
TwinCAT Scope is a state-of-the-art charting tool for visualising signals from the TwinCAT system. It records high-resolution data and displays it in the form of line or bar charts with outstanding performance. Significant events can be marked and easily spotted on overview charts.
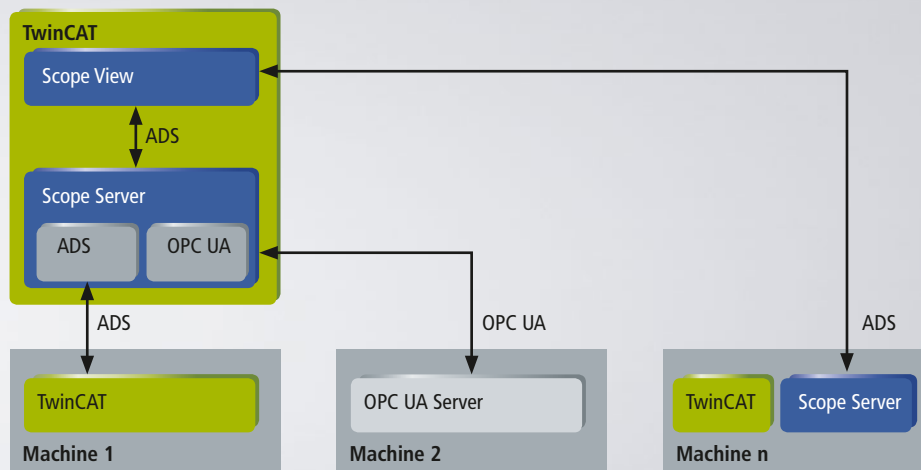
This extremely powerful software scope is the highlight of the TwinCAT Measurement portfolio. Integrated into Visual Studio® as an independent project, it is able to visualise measurement signals in the single-digit microsecond range. In addition to established functions like trigger, chart synchro-nisation and cursor, TwinCAT Scope View also features DirectX and multi-core support to fully utilise the computing power of each individual hardware system to display high-frequency signals, even from oversampling values.

TwinCAT Filter Designer

The Filter Designer has been designed and integrated into TwinCAT Engineering so that users are able to 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 modules. Alternatively, the coefficients can be copied into function blocks of the TwinCAT Filter Designer PLC library, enabling users to easily configure digital filters such as Butterworth or Chebyshev as lowpass, bandpass or highpass 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 ideal for this purpose. With it, the user can transmit nominal values to the drive and graphically display its frequency response and phase in order to optimise the drive parameter settings.

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

The developers of TwinCAT Scope paid special attention to its seamless interaction 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 to display 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 makes it possible to pool all essential data from testing and measurement tasks.

**Software oscilloscope with multi-core processor performance**
- high-end charting tool for high-resolution
- 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

Simplified database connection for efficient measurement applications

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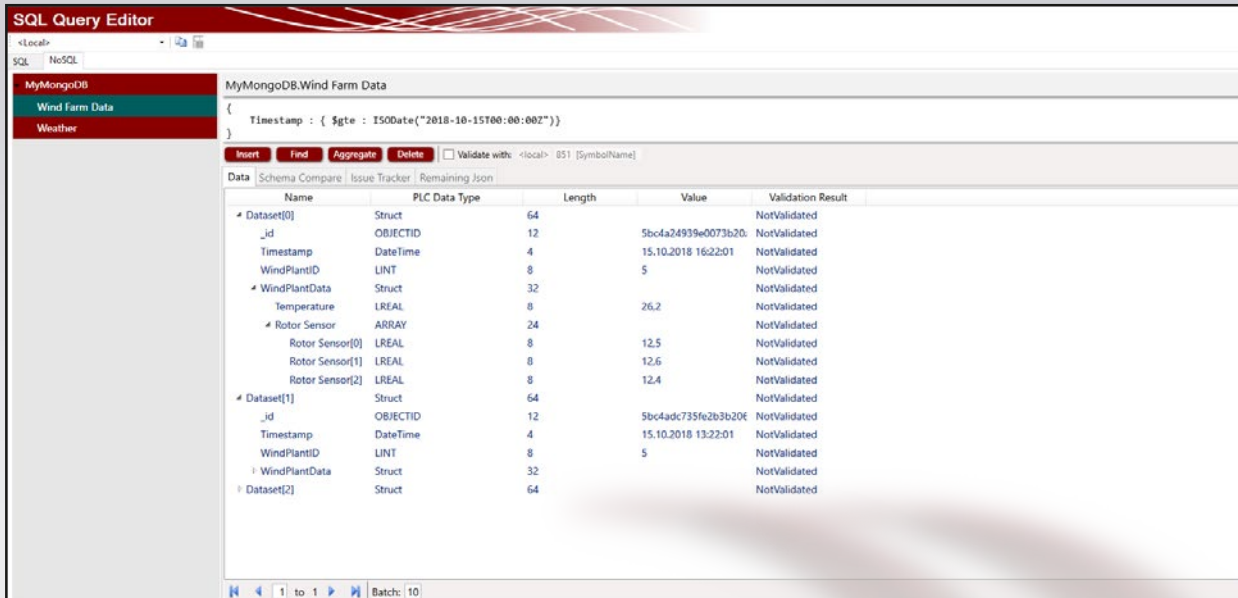
Testing the SQL or NoSQL database communication in the SQL Query Editor takes only a few clicks. The process uses the target system's TwinCAT Database Server. In combination with the automated code generation, the resulting programmed links from the controller are failure-proof.

SQL   NoSQL
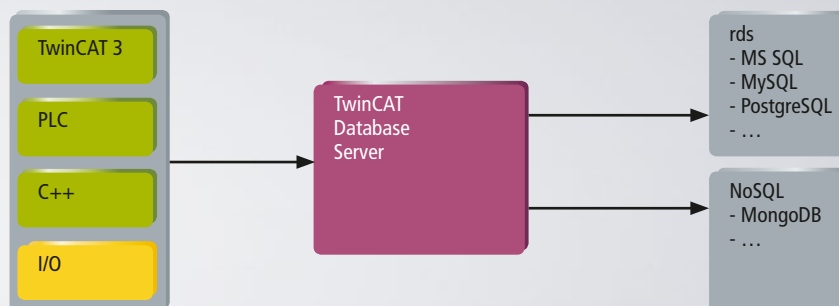
Data is a valuable asset these days. The same is true for data from machines, systems or test stands, it has a lot of value and must be protected. The TwinCAT Database Server does precisely that by handling the data traffic between TwinCAT and various database systems. It can write or read values during this process.

The Database Server offers four functional modes. The Configure Mode allows for fast and easy configuration of a database connection without requiring any programming. 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 features total flexibility, because user can combine their commands themselves and even trigger Stored Procedures on the database side. 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 offers support for classic relational databases like Microsoft SQL, Oracle, MySQL or SQLite, and in addition a NoSQL Expert Mode for connection to so-called NoSQL databases such as

MongoDB in addition. 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 for all user groups available

Seamless and consistent data analysis with TwinCAT Analytics

TwinCAT Analytics
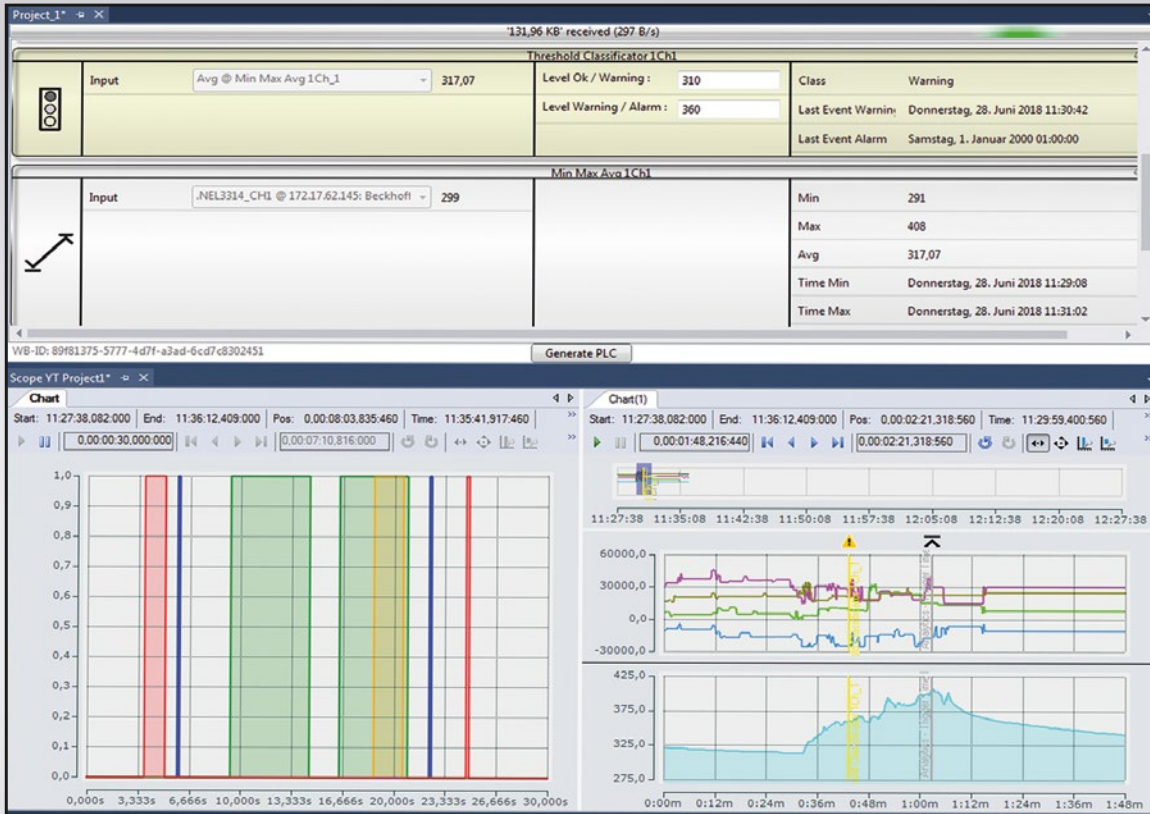
Configurator and Scope View in an Analytics project. The data is streamed into the analytics software directly from the machine or via a database via MQTT. Significant events can be dragged and dropped from the analysis into the charting tool and marked in the data.
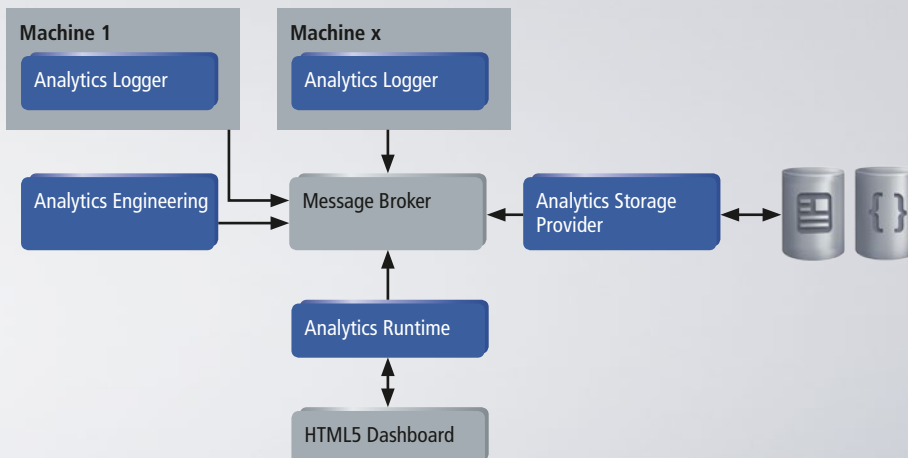
As the acquisition and analysis of relevant data is a means of generating competitive advantages, an increasing number of data analysis tools are available on the market. Yet for the most part these do not speak the language of the machine builders and are limited to a small number of application scenarios. TwinCAT Analytics, in contrast, has been developed specially for this purpose. The TwinCAT Analytics engineering tools are seamlessly integrated into the Microsoft Visual Studio® environment that is already familiar from machine applications. That means considerable time savings are possible in the engineering process. Moreover, many algorithms are available, which have been specially developed in a language that allows

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 control computer deliver the desired analysis results. It is perfect in combination with TwinCAT Scope, for example, for representing a frequency spectrum as a bar chart, and also with TwinCAT Analytics for a centralised analysis of multiple control systems.

direct reference to mechanical 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 located in a network. The path to 24/7 monitoring is fairly simple: 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 also on a virtual machine in parallel with machine operation. Once generated, the code can also be further customised to create individual analyses in a programming language that is familiar to the machine builder. Existing code can be transferred one-to-one as well. Finally, an individual analysis dashboard can be designed on the basis of TwinCAT 3 HMI, which can be provided to the end user as added value. It goes without saying that TwinCAT Analytics not only works with live data, but also with historical machine data. Database access is possible via the Analytics Storage Provider. On the bottom line, TwinCAT Analytics is not just a product, it is rather an entire workflow, which supports flexible usage of the latest technologies such as IoT tools and on that basis enables users to implement true Industrie 4.0 applications.

Data analysis as added value for the mechanical engineer

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

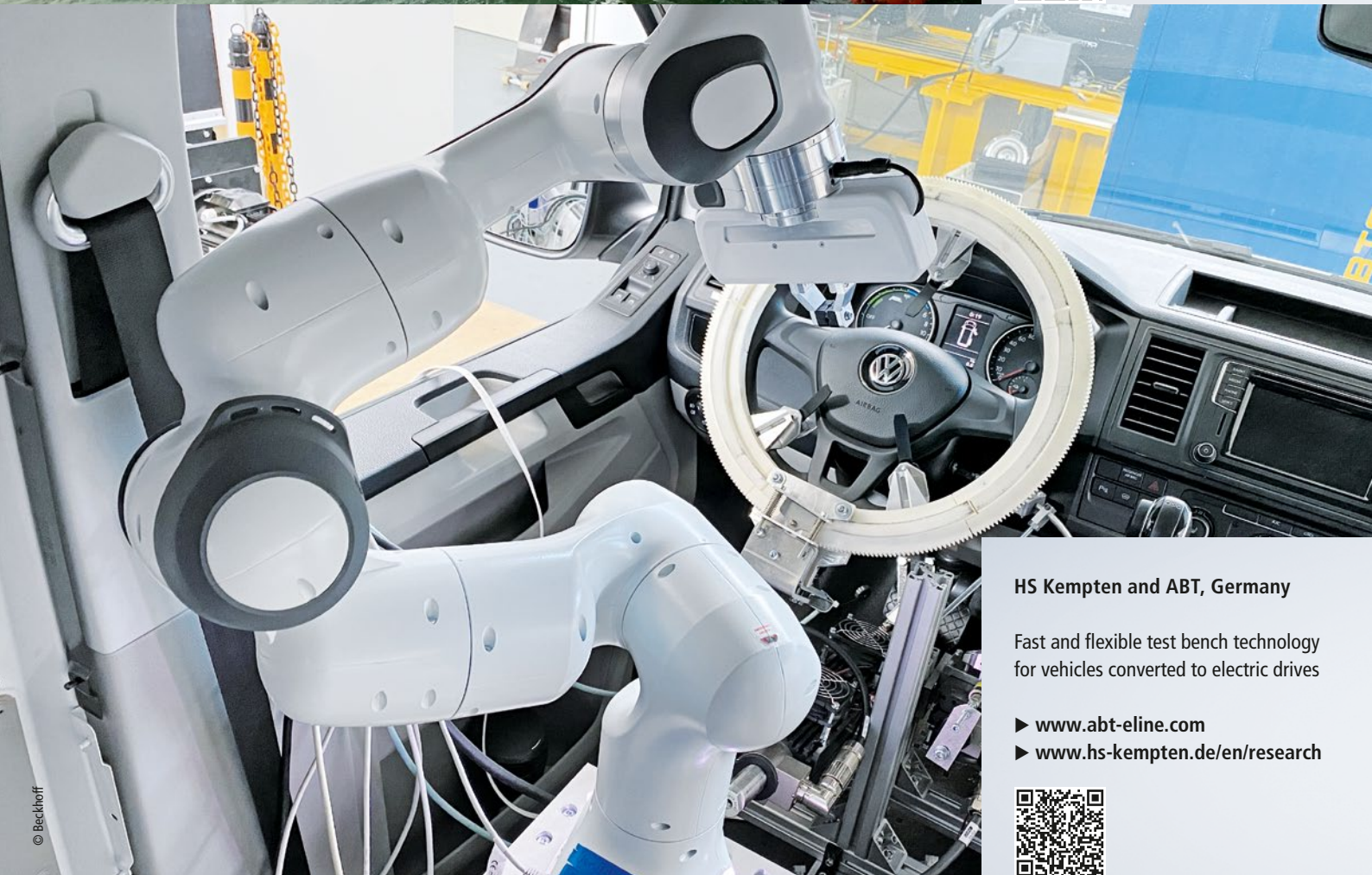# References: Beckhoff measurement technology in use worldwide

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Aoling and CNOOC, China

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

▶ **www.cnooc.com.cn**

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HS Kempten and ABT, Germany

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

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Pensar Otra Vez, USA

PC Control and EtherCAT in
high-temperature PCB test handler

▶ **https://pensar2.com**

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Romande Energie, Switzerland

Integrated measurement technology
ensures reliable grid management
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Integrate PC-based control for a leading edge in measurement technology:

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