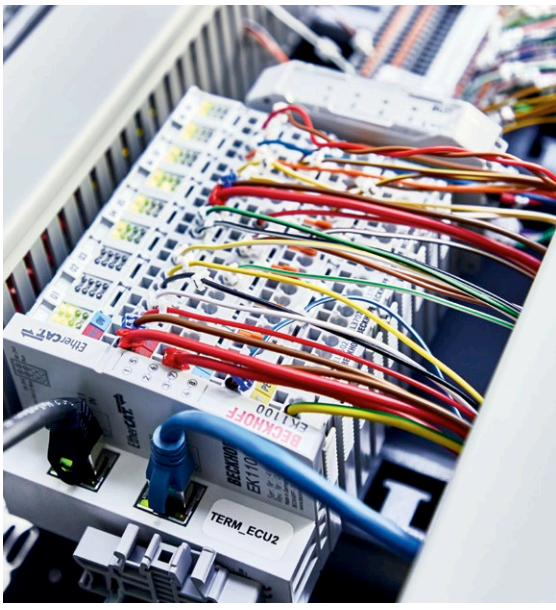
System-integrated measurement technology used in automotive Hardware-in-the-Loop test system

# Efficient acquisition of measurement data via EtherCAT analog terminals in steering unit testing

Reliable steering is one of any vehicle's most important safety-relevant elements. Correspondingly high demands are placed on system testing that accompanies the development process. Together with ZF Friedrichshafen AG, the Cologne, Germany-based Akka DNO GmbH has therefore developed a high-performance Hardware-in-the-Loop test system that acquires necessary data via high-end measurement technology directly integrated in PC-based control technology from Beckhoff.

**The combination of electric power steering on the front axle and active rear axle kinematics increases car safety.**

With 230 locations around the world, ZF Friedrichshafen AG is a global leader in driveline and chassis technology as well as active and passive safety technology. Akka DNO GmbH (formerly Gigatronik Köln GmbH) specializes as an engineering partner for the automotive industry and develops modern Hardware-in-the-Loop (HiL) test systems with ZF, among others. Sören Ole Kuklau, Team Management Function Development at Akka DNO, explains: "We provide support with our long-standing expertise in the creation of test specifications, test automation and in the construction of the test infrastructure in particular. A good example of this is the HiL test system for the electronic power pack (EPP) in a vehicle steering unit, which was developed in close cooperation with ZF. We began development in 2016 and even at that time we were already using measurement I/O terminals from Beckhoff, such as the EL3751 EtherCAT input terminal. With oversampling, additional filters and the adjustable measuring range, this multi-function terminal offered




**Measurement technology integrated in standard EtherCAT Terminals is an integral component of PC-based control from Beckhoff.**


**Sören Ole Kuklau from Akka DNO, Dr. Michael Moczala from ZF and Wilm Schadach, Beckhoff Sales Office Monheim, Germany, with the Hardware-in-the-Loop test system for the control unit and electric motor of an electric car steering system (left to right).**

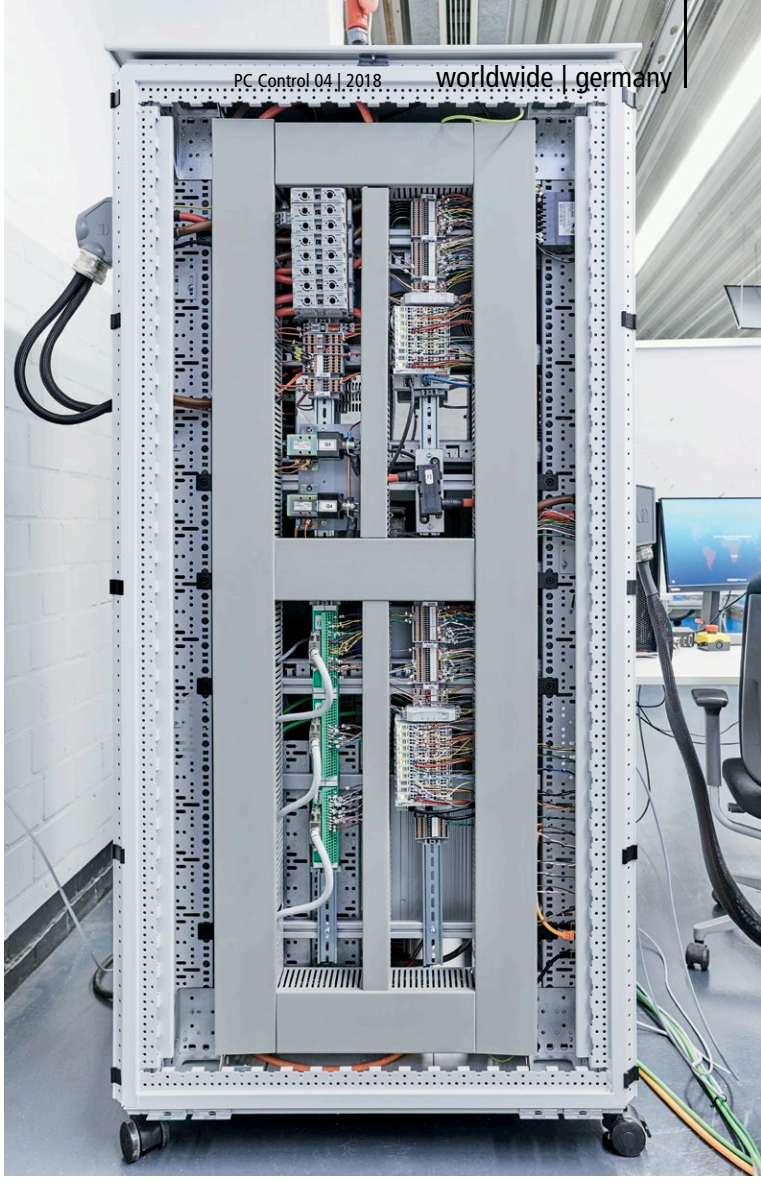
us many options to reliably acquire certain analog values that are particularly critical in our industry."

Dr. Michael Moczala, Team Leader Software/System Test Tooling in the area of Active & Passive Safety Technology, Steering from ZF in Düsseldorf, outlines further details of this HiL test system: "In the EPP-in-the-Loop (EPPiL) testing, the EPP – in other words, the combination of the electronic control unit and the electric motor that it controls to drive a car's electric steering system – is tested in a simulation environment. In practice this means that all components that interact with these two hardware elements in the vehicle are mapped as virtual models and simulated on a special real-time system."

**PC-based control is universal, open and scalable**

Test systems in the HiL area can also be automated completely and universally with PC-based control – extending to seamlessly integrated measurement and safety technology. Sören Ole Kuklau outlines the specific benefits for the EPPiL test equipment: "In the EPPiL system, the PC-based control technology from Beckhoff provides the complete I/O infrastructure. The actual simulation runs on the separate real-time system. With regard to computing power, the CX5140 Embedded PC has proven to be ideal for data handling. Not only that, the Beckhoff hardware can, if necessary, be scaled very easily according to individual application requirements – even up to high-performance multi-core systems."

According to Sören Ole Kuklau, the impressive depth of the I/O range and openness through the globally established EtherCAT standard offers further key advantages: "We placed very high demands on the I/Os with regard to the resolution of time and values and we paid attention to additional functions available in EtherCAT, such as oversampling. The EtherCAT measurement terminals from Beckhoff offer the ideal solution here, especially as the widespread use of EtherCAT allows the simple integration of third-party components in order to use automotive-specific bus systems, for example. Furthermore, we benefit in the test benches from the useful diagnostic options with EtherCAT, among other things, for monitoring the data connection between the test console and the control cabinet. In addition to that, there is the high reliability and performance of the data transmission that we



**Above: The EtherCAT I/O system is implemented in an extremely compact space on the side of the control cabinet.**


**Below: The test console with the electronic power pack (right), the torque measurement shaft (center) and the load motor (left)**

rely on." Dr. Michael Moczala adds a further aspect: "With the very high data quantities, it helps that we can acquire and transmit the information at two different sampling rates – the critical signals such as position specification and torque measurement at 4 ksamples, in other words, with a 250 µs cycle, and the rest of the data at 1 ksamples or with a 1 ms cycle. In this way, the typical bottleneck can be avoided in data transmission to the separate real-time simulation system, which is connected to the Embedded PC as an EtherCAT slave."

**Analog I/Os form backbone of the EPPiL test system architecture**

Dr. Michael Moczala explains the operating principle of the test system: "The hardware interface of the EPPiL simulator – the so-called test console – includes a load motor and a torque sensor for detecting the state of the connecting shaft. Connected to that is the actual test specimen, i.e. the electronic power pack consisting of a control unit and support motor. The EtherCAT I/O system forms the connection to the simulation technology, to the models representing the real-world mechanical steering components, different types of vehicles and roads through to the vehicle communication, among others. Communication between the modeling technology and the load motor as well as the torque measurement shaft is also implemented via the EtherCAT I/Os. From the simulation technology we obtain the angle of the shaft of the EPP motor and transmit it to the converter of the load motor. The torque sensor of the measurement shaft supplies the resulting torque. With this information, the movement equations are in turn solved in the simulation, from which we obtain the new position value to be transmitted to the load motor to close the HiL loop."

The EtherCAT I/O system encompasses five EK1100 EtherCAT Couplers as well as 57 different EtherCAT Terminals. For the analog value processing, these include three EL4732 eXtreme Fast Control (XFC) output terminals, seven EL3702 XFC input terminals and 18 EL3104 input terminals. Sören Ole Kuklau explains their specific tasks: "The EL4732 output terminals transmit the setpoints to the programmable power supply units of the test system, and the EL3702s read their actual values back. The 64 channels of the so-called Fault Insertion Unit (FIU) for the interspersing of electrical faults, such as short-circuit or open circuit, are checked for plausibility via the 18 EL3104 terminals." Dr. Michael Moczala adds: "The correct FIU function is thus monitored and the time of the respective switching procedure determined. The speed of the data acquisition is particularly important here, as switching times in the millisecond range are typical."


**With the EtherCAT measurement modules, Beckhoff offers a new generation of high-precision measurement I/Os with a robust metal housing.**

# System-integrated measurement technology – also for high-end requirements

PC-based control provides measurement technology that can be integrated seamlessly into the control technology. In this interview, Product Manager Martin Podrouschek explains its advantages and wide range of uses extending up to high-end applications.

**What characterizes measurement technology from Beckhoff that is integrated directly in the control technology and what benefits does it offer in the field of testing technology?**

**Martin Podrouschek:** Two areas of application should be mentioned here. First of all, there are the conventional production machines, where developers, design engineers, programmers and users wish to know more details about running processes. These include the quality of the manufactured parts, consumption of operating resources and cycle times. Control technology usually already exists in such machines, and the addition of a separate measurement and data logging system often fails due to financial or organizational hurdles. Conversely, with PC-based control or at least an EtherCAT-based I/O system, the EtherCAT measurement terminals from Beckhoff offer a simple way to supplement the control system with measurement technology that even supports the fast and highly precise acquisition of analog values, as well as the transmission of large analog data quantities over 100 Mbit/s EtherCAT. The big advantage of this is that the additional process knowledge gained makes it possible for the post-process measurement technician to carry out extensive rework. In fact, the control system programmer can now influence a machine's control loop better on the basis of high-quality data and can optimize the control process. The second area of application primarily concerns measurement applications in testing technology. Through the Beckhoff-typical combination of measurement and control technology, users are also capable of actively intervening and automating test applications. And it is precisely the extensive range of drives and switches, input and output modules, analog and digital technology, position-detecting and feedback terminals from the industrial environment combined with the unlimited programming flexibility of TwinCAT software – with libraries, wizards and data connectivity options – that makes completely new concepts for automated

Three EL3751 multi-function input terminals are additionally implemented. The torque sensor is read via one of the terminals. The other two inputs read the voltages of the power supply units. Sören Ole Kuklau comments: "Their flexibility with regard to the voltage range considerably simplifies our work, because the terminals can set to +/-10 V for the torque sensor or to +/-30 V for the power supply units." For Dr. Michael Moczala, the quality of the measured data acquisition via the EL3751 is of crucial importance: "The torque sensor signal is fundamentally important to achieve stable system behavior in conjunction with the simulation model. Therefore, the values from the torque sensor must be transmitted with the smallest possible delay, very low noise and the greatest possible accuracy."

### PC-based control offers exciting future potential

Since the start in 2016, the third generation of EPPiL test systems equipped with Beckhoff technology is now available, as Dr. Michael Moczala explains: "Our experiences with Beckhoff technology have been very good, so we will be retaining it in coming test system generations and we will also use new developments in the EtherCAT Terminals wherever possible." Sören Ole Kuklau also sees

test benches possible for these users. Due to the openness of PC-based control technology, users still remain flexible in the integration of special devices and industry-specific software.

**What special properties benefit users of the ELM3xxx analog measurement modules?**

**Martin Podrouschek:** Users who integrate measurement technology in their 24/7 production machines expect that the measuring components will work just as smoothly and as long as the control system itself. In particular, the measurement technology must do what it is supposed to do over the entire period and even under adverse conditions if necessary: it must measure precisely. And that is exactly where the focal point of Beckhoff measurement technology resides. Due to a wide range of internal functions and a correspondingly aligned production approach, the measurement solutions fulfill these customer expectations. Examples of this are extensive integrated self-tests, which ensure that the measurement modules work perfectly, as well as thorough pre-treatment of the modules during production and optional factory and DakkS-compliant certificates, through to Beckhoff recalibration services.

**What are the typical fields of application for the system-integrated Beckhoff measurement technology and how has this range been extended over the years?**

**Martin Podrouschek:** Traditional production machines are increasingly equipped with integrated measurement technology. User interest is increasing not only in energy measurement and consumption data acquisition, but also in inline parts measurement on the manufactured object. In this environment, the 12/16/24-bit analog inputs in the 12-mm plastic housings have long since become accepted. These include the EL3751 EtherCAT Terminal presented in the application report as the first precision measurement terminal from the new generation with 100 ppm accuracy. The ELM3xxx measurement modules with 30-mm metal housings introduced in 2016 open up an even wider range of applications, especially in the high-end segment. Above all the testing market in general is reacting very positively to these developments and the EtherCAT modules can be used not only via TwinCAT, but also operated on every EtherCAT master. The increasing requirement for automation in test applications benefits in ideal fashion from the system-integrated Beckhoff approach, which also enables the integration of safety, vision, cloud connectivity and motion control on a single platform.

**What characterizes the new EtherCAT measurement modules for high-end applications?**

**Martin Podrouschek:** From a technical point of view, the processing of analog data can take place either locally in the measurement module or centrally in the TwinCAT-based controller in the I&C world. Depending on the system concept, one or the other will be more useful and the Beckhoff analog inputs have always supported both. Temperature-stable, precise measurements with an oversampling function with currently up to 50 ksamples/s are advantageous for both applications. In particular for local processing, the modules offer a wide range of analog functions such as multi-stage, freely preset filtering, true RMS calculation and drag indicator. In addition, some terminals feature special technologies for sensor connection: specialties such as tare, bridge extensions and shunt calibration are integrated in the ELM350x measurement modules for weighing and strain applications, while TEDS and AC/DC coupling are usable in the ELM360x IEPE terminals for vibration measurement. The integrated measurement technology from Beckhoff imposes virtually no limits on technically oriented users in the installation of established measurement technology methods in production and test machines and market-leading applications.

Further information:
www.beckhoff.com/measurement-modules

**Martin Podrouschek, Product Manager Fieldbus Systems, Beckhoff**

further development potential: "We already have pre-development projects for automotive-specific test systems that are based completely on Beckhoff technology. These also include the servo drive technology, which is advantageous due to high performance and speed as well as the convenient configuration in TwinCAT software. Another pre-development project is concerned with the integration of MATLAB®/Simulink® in TwinCAT to be able to relocate the real-time simulation to the Embedded PC and reduce costs as a result. Apart from that, we are working on using the ASAM standard XiL-API to decouple test cases, test automation tools and HiL test hardware with TwinCAT."

Further information:
www.akka-technologies.com
www.zf.com