



Scientific Automation: High-precision temperature measurement and signal acquisition in climatic chambers

PC-based measurement technology for Miele quality assurance

Quality, strength of innovation, tradition – these are values to which Miele & Cie. KG has been committed to since the business was founded in 1899. True to the guiding principle of “Forever better,” the name Miele stands for the development and production of domestic appliances and commercial equipment that meet the highest quality standards. The quality assurance system and the feedback of test and measurement data in all relevant processes are among the key factors in the success of the Miele brand. “Scientific Automation” from Beckhoff has been a part of these sub-processes for about two years now.

For several generations, the family-owned Miele company, with headquarters in Gütersloh, Germany, has produced premium household appliances and first-class commercial equipment that are designed for high quality, long service life and sustainable resource conservation. Each year, more than 7 % of the company’s sales is invested in research and development. Miele has production facilities in eight plants in Germany and one plant each in Austria, the Czech Republic, Romania and China. The extensive product range includes washing machines, clothes dryers, built-in cookers and ovens, dishwashers, fridges and freezers, fully automatic coffee

machines, microwave ovens and much more. The entire product range undergoes constant, intensive quality tests and checks.

Automated test and measurement

The central division in Miele’s Gütersloh plant is also responsible for basic research for the “Cooling & Coffee International” (CCI) business unit. “The CCI Test and Development Center includes 11 climatic chambers with a total of 14 stand-alone measuring systems, in which fridges and freezers, fully automatic coffee machines,

A climatic chamber usually contains a measuring system with four measuring stations; some climatic chambers were equipped as dual chambers that incorporate eight measuring stations. CCI's Basic Research has a total of 56 measuring stations at its disposal for testing fridges and freezers, fully automatic coffee machines, and microwave ovens.

Testing a built-in fully automatic coffee machine:

For each measuring system, 80 channels for high-precision temperature measurement with PT100 sensors are available.



In a total of 11 climatic chambers, fridges and freezers, fully automatic coffee machines, and microwave ovens are put through a rigorous testing program to meet Miele's exacting quality standards.



and microwave ovens are put through a rigorous testing program," reports Benjamin Held, Development Engineer in CCI Basic Research. A climatic chamber usually contains a measuring system with four measuring stations. Some climatic chambers were equipped with double the number, however, so that a total of 56 measuring stations are available for CCI's basic research.

All measuring stations are equipped with automation and measurement technology from Beckhoff. For each measuring system, 80 measuring channels for high-precision temperature measurement with PT100 sensors are therefore available. There are also connections for 80 thermocouples, 20 analog inputs and outputs, and 20 digital inputs and outputs. All connection points take the form of Beckhoff EtherCAT terminals. Each climatic chamber is equipped with a C6650 industrial PC from Beckhoff that provides the central control functions for the chamber. A Beckhoff CP6903 Control Panel is built into the control panel door and facilitates visualization of the application and the dialog with the PLC.

The software-PLC used in the application is TwinCAT PLC. For programming, Miele focuses on IEC 61131-3. On this subject, Benjamin Held commented that: "The test applications are programmed in the Structured Text programming language."

High-precision temperature measurement through certified accuracy

Climatic tests are accorded a very high priority at Miele, because refrigeration technology is extremely sensitive to climatic conditions. Since the refrigerators are used worldwide and have to run 24/7, year after year without interruption, all operation conditions must be evaluated. As Benjamin Held continued: "Our fridges and freezers are not just used in European households. Depending on the location, and considering countries in Asia or the Middle East as examples, temperatures up to 43 °C (109 °F) and air humidity up to 90 % RH can exist. We have therefore defined 'climate categories,' and we test in conformance with standards that category conditions are maintained. Other factors such as transportation condi-



Michael Jost, Product Manager for EtherCAT and Beckhoff I/O systems: "The EL3201-0020 high-accuracy temperature terminals are metrology modules that undergo a special setup procedure by Beckhoff during manufacturing. If climate categories are to be tested very accurately, the control technology must always be one step better to ensure that the tolerances will be maintained."

Benjamin Held, Development Engineer in the Basic Research department of Miele's "Cooling & Coffee International" (CCI) business unit: "Painstaking environmental tests to evaluate all operating conditions guarantee that Miele refrigeration units can also be used in extremes of climates and will run around the clock, year after year, and without interruption."

The stated aim is the highly accurate measurement and control of the temperature in the appliances and climatic chambers during the entire test period.

tions are also simulated, where appliances are exposed to a temperature range of -20 °C (-4 °F) to +60 °C (140 °F)."

As well as the adaptable test and measurement capabilities, precise temperature measurement is particularly important for Miele. The stated aims are highly accurate temperature measurement in the appliances and precise control of temperature in the climatic chambers. Fundamentally, temperature is a critical process variable that is continuously acquired and evaluated throughout the one- to three-week testing periods.

Based on the "Scientific Automation" solution, the integration of automation technology with measuring tasks, Beckhoff has developed special fieldbus terminals for highly accurate temperature measurement. The usual accuracy of PT100 terminals in industrial applications is around ± 1 °C. The Beckhoff EtherCAT temperature measuring terminals used by Miele deliver an accuracy of ± 0.1 °C, which is an impressive improvement by a factor of 10. Michael Jost, Product Manager for EtherCAT and Beckhoff I/O systems, describes the interrelationship as follows: "The EL3201-0020 high-accuracy temperature terminals are measuring modules that undergo a special setup procedure during manufacturing. The factory calibration is recorded in an individual certificate, as required for high-precision measuring equipment. Such dedicated measurement technology is the basis for the integration of high-performance and high-precision measurement technology without special components. If climate categories are to be tested very accurately, then the tolerances must be maintained as well. To ensure this, the control technology must always be one step better. In our view, the measuring device must be better by a factor of 10 than the equipment that it will be used with."

High-accuracy signal acquisition with scalable precision

The second climatic parameter that is acquired in Miele's application is air humidity. "We use external measuring equipment for this purpose i.e. we use humidity sensors that likewise operate in the high-precision range. Their analog output signals are connected to analog input terminals," says Benjamin Held. For this application,

too, there is an ultra-accurate 2-channel analog input terminal in the form of the EL3602 EtherCAT Terminal, as Michael Jost reports: "The EL3602 analog EtherCAT input terminal processes signals in the ranges: ± 10 V, ± 5 V, ± 2.5 V and ± 1.25 V. The voltage is digitized with a 24-bit resolution and transmitted as a measured value to the parent controller in an electrically isolated manner. The input channels have differential inputs and possess a common, internal ground potential."

The capabilities of the EtherCAT terminals extend beyond high-precision signal acquisition, because the terminals have a very high potential frequency for sampling measured values. "Our test procedures are mainly carried out at relatively low clock rates ranging from 30 seconds to a minute," explained Benjamin Held. "Consequently, we mainly use the precision of the measuring terminals, less so for their speed. On the other hand, we have to implement widely differing test conditions and requirements, especially for standards-regulated tests and for energy consumption measurements, and in the process guarantee an absolutely reliable and precise results graph." The experts at Miele therefore focus on basic functions and, as and when required, on specialized functions. Basically, standard tests are carried out with extensive preparation, with test-process verification, and with extensive measurement technology. "In operations of this type, from 20 to 30 temperature sensors are quickly distributed and positioned in the device to be tested. We also carry out dynamic tests," explains Benjamin Held. "For example, during commissioning, we also introduce disturbances into test procedures. We use warm or frozen food, for example, or standardized test packets, or the fridge is opened and closed. These are random variations that must be reproduced and tested."

Automated test level

It is generally known that the sensor level is just one part of a test and control task; the control of actuators or controllers is another part. "The actuators are not standardized. This means that simple actuators, such as fans, can be directly controlled. Other actuators, such as amplifiers or controllers, are controlled via analog output terminals," says Benjamin Held, while pointing out that today's refrigerators

Fridge/freezer undergoing testing in the climatic chamber. To ensure that the appliances can be used worldwide, they are specified by 'climate categories,' and Miele checks in conformance with standards that category conditions are maintained.



are equipped not just with one compressor cycle or a chiller or compressor, but sometimes have two combined compressors. Moreover, Miele also uses variable-speed compressors, which create extensive opportunities for work and research. In addition - and depending on the climate category and appliance - arrangements known as 'winter circuits' may also be implemented. Fans can also be incorporated in an appliance to enable dynamic cooling with a precise temperature distribution. Benjamin Held assesses this interrelationship as follows: "We have a great many parameters at our disposal for controlling the test and measurement tasks. It is important to us that the automated test and measurement technology makes us as flexible as possible, so that we can vary the control variables quickly and accurately. The Beckhoff platform we have implemented means that we can

incorporate these requirements in programming and thus quasi-automate the measurement procedures. This is particularly significant in the area of quality checks, because the program procedures enable us to achieve a high throughput of tested appliances."

The sensor data from the test and measurement functions of the climatic chambers are transmitted from TwinCAT via the standardized OPC interface to Miele's parent test-data acquisition system. "This way, we can connect other, external instruments, such as our portable energy meters without any problems," says Benjamin Held.

Miele & Cie. KG www.miele.com

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Reproducible measurements through certified precision

Thanks to the high fundamental accuracy of the EL3201-0020 temperature measurement terminal, the measuring error is reduced to ± 0.1 K of the temperature measurement range. The EtherCAT Terminal enables direct connection of a resistance sensor (PT100) using 4-wire technology. The characteristic curves of the sensors are implemented over their complete measuring range and are made available to the higher-level control system in a suitably linearized form.

Reliable reproducibility of results is becoming increasingly important in a wide range of automation applications, in order to optimize parameters and ensure verifiability, for example for online quality monitoring in running processes. Beckhoff meets these requirements with a calibration certificate that authenticates the measuring accuracy of the terminal and the exact measuring error. Online download of the certificate based on the serial number and terminal handling similar to common analog terminals make the application of high-precision measurement technology very convenient.

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