

**Flexible
test systems
for maximum
efficiency**

Test stand systems

Test stands for electrical drive systems and components
in development, production and quality assurance



About the Kistler Group

Kistler is the global market leader for dynamic pressure, force, torque and acceleration measurement technology. Customers benefit from Kistler's experience as a development partner, and our unique sensor technology enables them to optimize their products and processes so as to secure sustainable competitive edge. With some 1 860 employees at 61 locations worldwide, the Kistler Group posted sales of CHF 422 million in 2017.



Kistler: the byword for advances in engine monitoring, vehicle safety and vehicle dynamics. Our products deliver data that plays a key part in developing efficient vehicles for tomorrow's world.



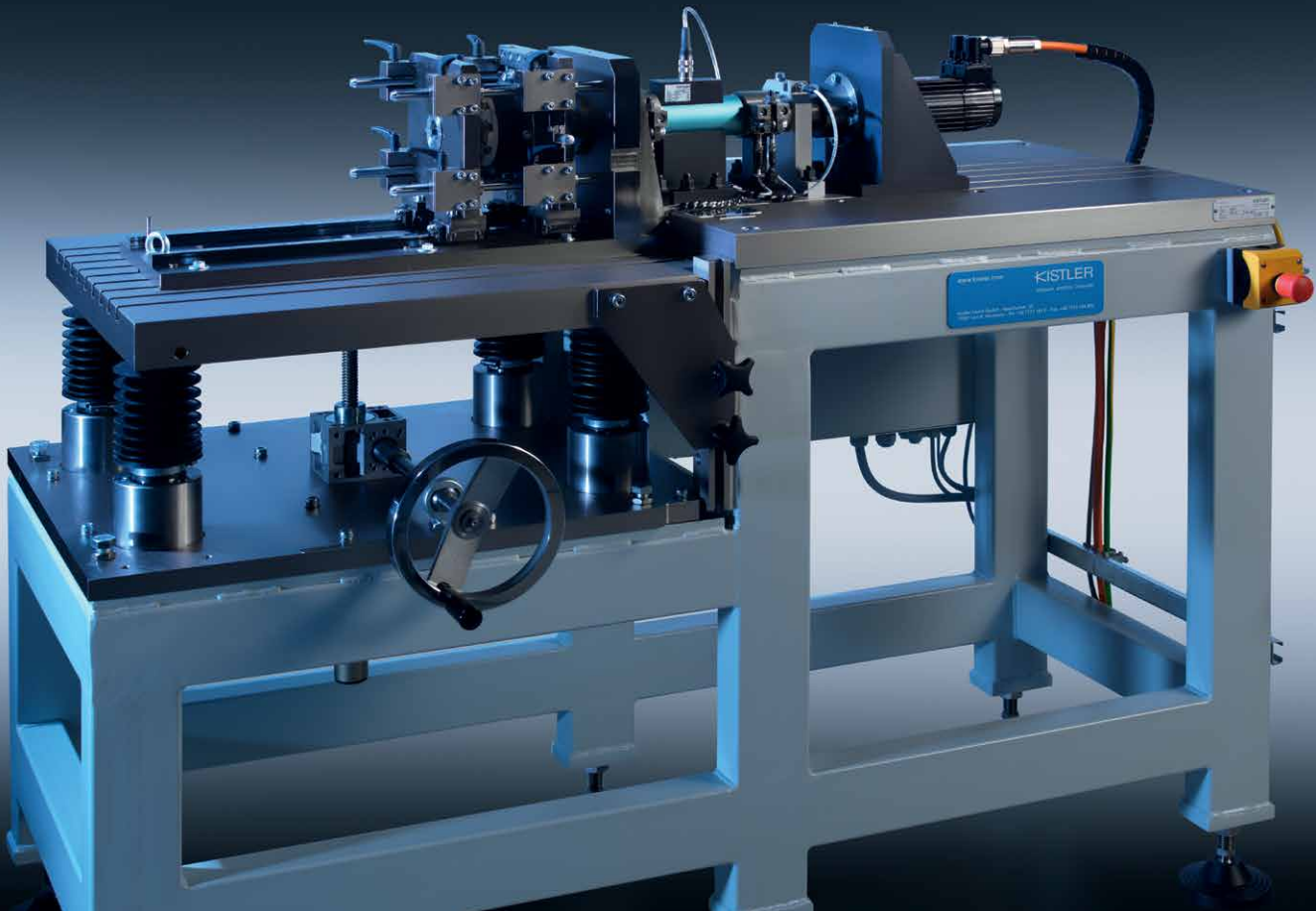
Measurement technology from Kistler ensures top performance in sport diagnostics, traffic data acquisition, cutting force analysis and many other applications where absolutely reliable measurements are required despite extreme conditions.



By supporting all the stages in networked, digitized production, Kistler's systems maximize process efficiency and cost-effectiveness in the smart factories of the next generation.

Contents

| | |
|--|-----------|
| Customized test stand technology from one single source | 4 |
| Precise measurement values: the basis for performance and quality | 6 |
| Individual requirements for test processes | 8 |
| Electromobility | 10 |
| Power tools | 12 |
| Minimum Energy Performance Standards (MEPS) | 13 |
| Measurement technology and test stand system components | 14 |
| Modular system technology to meet wide-ranging test requirements | 16 |
| Kistler's system components – for optimum integration of specimen | 16 |
| Service: customized solutions from A to Z | 18 |
| At our customers' service across the globe | 19 |



Customized test stand technology from one single source

Electrical drive systems and applications call for test and measurement technology that is both flexible and scalable. With automated test stand systems by Kistler, you can significantly boost the efficiency of your test procedures – paving the way for you to develop high-caliber products that deliver excellent performance.

Kistler's test stand systems are used in development, quality control and production – and the goals are always the same: to optimize the efficiency of test equipment and ensure that innovation can continue to advance. Our systems are precisely tailored to each customer's requirements. Because their measuring chains are calibrated, the results they deliver are reproducible as well as precise. Kistler's portfolio comprises test stand systems for electrical machines, generators and drive systems. When you choose Kistler, you get everything from one single source: from individual components through to complete solutions.

Electromobility

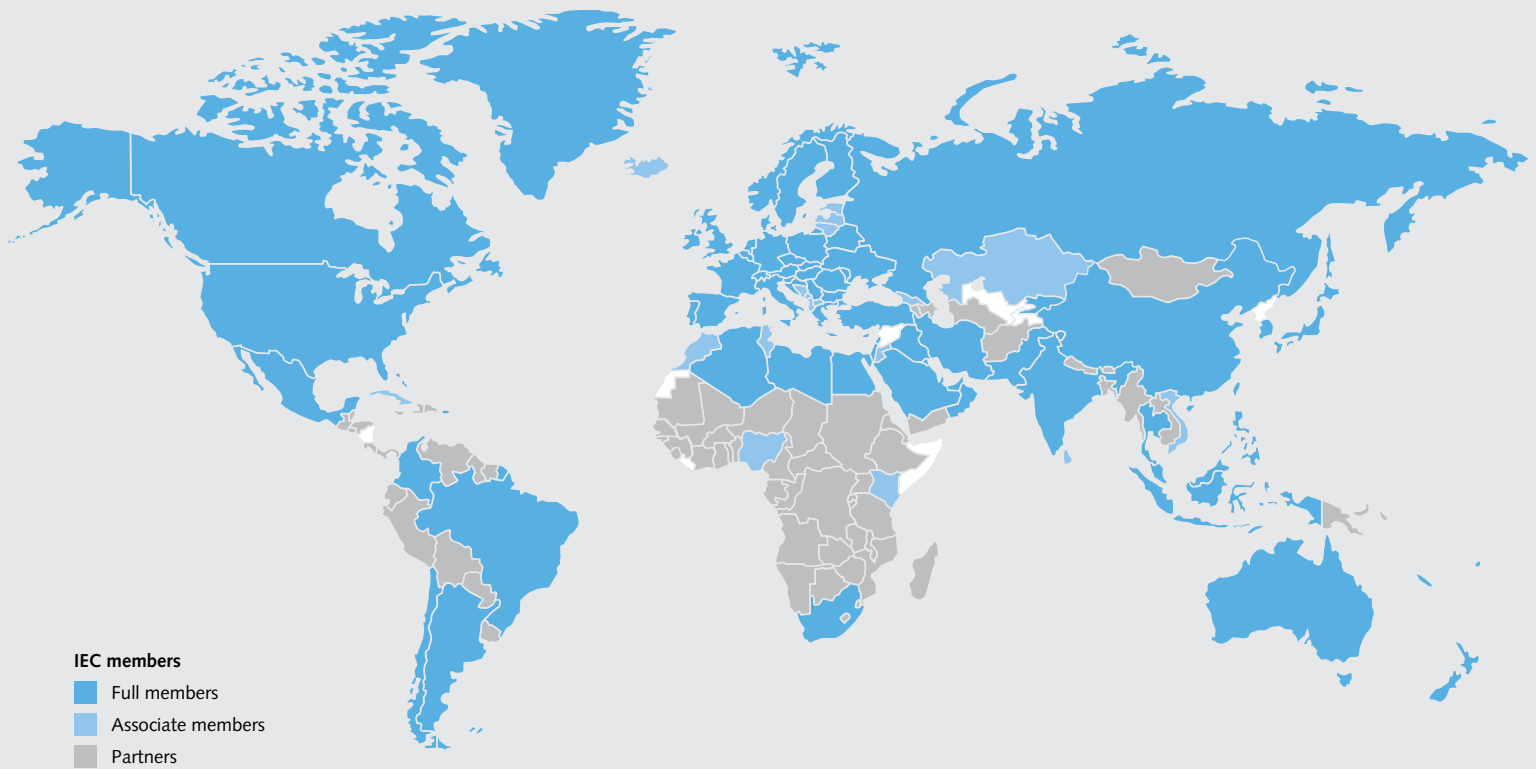
In the past, testing was mainly restricted to individual electrical components such as generators, starters, auxiliary drives and transmissions. As electromobility continues to gain ground, the emphasis nowadays is increasingly on technologies that can test complex drive systems. Kistler already identified this trend many years ago: so today, our measurement technology experts supply highly efficient automated system solutions that open the way for product solutions to meet the challenges of the future.

Automotive drive systems and components

Electromobility spans a vast application area, ranging from external starter/generator solutions for optimized automatic starting and stopping through to all-electric drive systems. Kistler offers system solutions that cover all these requirements: products tailored to each application deliver high-precision, efficient testing of electric drive components and the related power electronics.

Minimum Energy Performance Standards (MEPS)

Electric motors have to meet certain minimum efficiency requirements if they are to achieve the environmental targets set by many industrialized countries. These requirements are defined in the standard for energy-efficient motors (IEC 60034-30-1), which specifies International Efficiency classes IE1 to IE4. For this kind of tests, Kistler offers standardized test stand solutions with fully automated testing for IEC motors from 0.75 to 375 kW.



IEC member states

Power tools

Brushless DC motors (BLDC) are now being used more often in power tools, instead of universal motors. This is a field where Kistler can look back on years of experience with many renowned customers. As your reliable, professional partner, we work with you to develop individually adapted test stand concepts to measure, optimize and continue developing your BLDC motors – and we offer speed ranges that other providers are unable to cover.

Further applications

As well as the core areas described above, Kistler also meets a vast range of different requirements for power, speed and torque. Our modular test stand concepts are ideally adaptable to large numbers of applications – as regards the adaptation of the DUT (Device under test) themselves, and also in terms of measurement and functional processes for specific applications.

Benefits of Kistler test stand systems

- Efficient quality control
- Process reliability
- The basis for developing high-quality products and boosting productivity
- Enhanced efficiency and performance for electrical drive systems
- Reduced testing costs
- Flexible and modular customizable components, or complete systems from one single source
- Extensive range of services
- Products that are simple to integrate



Precise measurement values: the basis for performance and quality

Test systems from Kistler deliver reproducible, precise measurement results to support the development of efficient, high-performance products that can cope with the challenges of the future.

The basis: measurement of mechanical and electrical characteristics, thermal design, overload capacity and other application-specific measurands. Our systems cover a wide spectrum: examples include mechanical components such as drive measurement setups with torque sensors, small test stands with torque/speed measurement and manual or external control, as well as complete solutions with automation software to analyze and document electrical machines. And for all of these applications, our systems come equipped with variable interfaces to connect the DUT – a feature that gives them maximum flexibility during use.

Effective evaluation, optimization and ongoing development call for a flexible, high-performance testing system that opens up scope for a vast range of measurement assignments in research, development, quality assurance and production.

Benefits:

- Extensive range of high-precision measurements to meet the most demanding test requirements
- Calibrated measuring chains
- Modular concept
- Variable interface connection
- Intuitively operated test system
- Lower costs thanks to automated test procedures
- Control and analysis with individual software solutions
- Sensor technology and test stand systems from one single source

| Application | Power (typical)* | Torque (typical)* | Speed range* |
|--|------------------|---------------------|---------------------------------|
| Automotive auxiliary drives (motors for pumps, fans, actuators and windshield wipers, generators, electric turbochargers) | up to 40 kW | up to 100 N·m | up to 150 000 min ⁻¹ |
| Main drives for electric vehicles (synchronous, asynchronous and hybrid motors, transmission-motor combinations) | up to 500 kW | up to 20 000 N·m | up to 30 000 min ⁻¹ |
| Standard motors (1+3ph AC drives) | up to 400 kW | up to 40 000 N·m | up to 3 600 min ⁻¹ |
| Electric power tools | 10 W ... 25 kW | 0.05 ... 150 N·m | 0 ... 50 000 min ⁻¹ |
| Electric drives, general | 10 W ... 150 kW | 0.05 ... 500 N·m | 0 ... 150 000 min ⁻¹ |
| Maximum values | 2 W ... 800 kW | 0.01 ... 25 000 N·m | 0 ... 150 000 min ⁻¹ |

*Special adaptations are possible for variants

Measurement of electrical parameters

- Power analyzer with the required number of channels to measure:
 - current
 - voltage
 - power
 - with harmonic transients as an option
- Winding resistances are measured with a micro-ohmmeter

Measurement of mechanical parameters

- Torque measurement by high-precision Kistler torque sensors with supply module
- Speed measurement
- Measurements via the dynamometer's encoder, pulses will be forwarded to the measurement system
- Rotation angle measurement

Vibration analysis

Electronic system (compliant with ISO 10816) to detect system errors such as bearing damage, imbalance, etc., in order to prevent subsequent damage that could occur during measurements.

Temperature measurement

Multi-channel temperature measurement to determine temperatures of DUT (motor/controller/bearing area, etc.) during heat run measurement, for freely definable load cycles or in various test modules.



Individual requirements for test processes

Every test stand solution has its own individual requirements and objectives. Maximum flexibility is essential to tap the full potential of a test system.

Drawing on more than half a century of experience in test stand design, Kistler realized long ago that successful test system developments depend on involving the customer in the project process right from the outset. Our test stand systems can handle a vast spectrum of measurements – thanks to maximum flexibility based on modular components and extensive add-on options. Knowledge of the customer's exact requirements and objectives is the fundamental prerequisite for offering optimum individual solutions. This is why Kistler believes in intensive dialog with customers as the key to developing solution concepts that ensure maximum flexibility and performance potential.

Comprehensive project management is another aspect that is given special priority at Kistler. From development and production through to on-site setup – our customers are integrated into the entire process. We pay particular attention to commissioning, and we provide individual customer training to ensure that our systems will operate efficiently. And as an added benefit, Kistler is on hand to offer its vast range of services once your equipment has been successfully commissioned.

Project workflow:

1. Requirements analysis

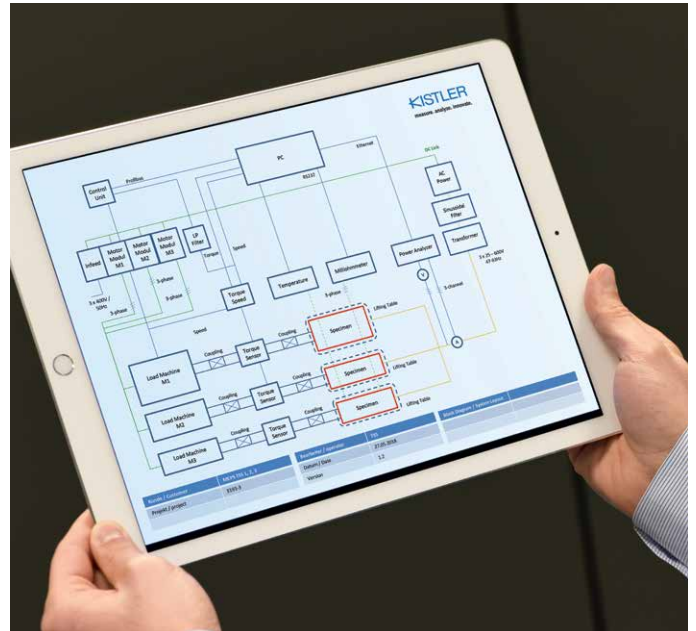
The first step is to determine what is needed. We work with our customers to coordinate the technical requirements (mechanical and electrical limits, test modules, etc.). This work can be undertaken on the basis of performance specifications already drawn up by the customer; alternatively, we can work together to develop the performance specifications.

2. Concept phase

In close liaison with our customers, we develop an appropriate test stand concept based on the available data. This usually includes a technical description together with a budget price and a block diagram that illustrates the system in detail.

3. Concept optimization

As a next step, the concept will be modified and fine tuned in close cooperation with the customer. The goal: approval of a finalized concept that provides the basis for the purchase decision.



4. Order placement

Once the final concept has been approved and the order is placed, we start to work out all the details. Our customers are fully integrated into this stage of the process too, and they can intervene actively in the development process. On conclusion of this phase, all the documents generated are approved jointly by the customer and ourselves.

5. Procurement phase

Once the customer has approved the system specification, the process moves into the operative phase. This involves ordering the relevant components and starting the assembly procedure.

6. Initial start-up

Once the test stand is completed, we carry out the system test and the internal pre-acceptance procedure, whereby the test stand is being tested in regard of its technical properties.

7. Factory acceptance

The next step is the Factory acceptance Test. For this stage, customers come to Kistler's premises, so they can see for themselves whether the test stand meets the technical and contractual specifications. As a result, the Factory acceptance is being approved by the customer. This is followed by delivery of the system, as agreed by contract.

8. Final acceptance

Installation, commissioning and training are carried out at the customer's site by an experienced member of Kistler's staff. After a defined test phase – the Final Acceptance Test – our technician officially hands the project over to the customer.

9. After-sales

Once the project has been successfully handed over, you can rest assured that Kistler is standing by to provide after-sales service if you have any technical issues: we will implement upgrades for various components, extend your test stand, and carry out maintenance.

Benefits:

- Turnkey solution from one single source
- Development process coordinated with the customer
- Measurable quality
- One central point of contact
- Planning security
- Short response times



Electromobility

In the past, testing was restricted to individual electrical components such as generators, starters and transmissions. With electrification gaining ground in the automotive sector and e-mobility growing its market share, more and more auxiliary drives have been added: nowadays, testing is required for seat height adjusters, electrical window regulators and electric tailgate openers, to name only a few examples. These auxiliary drives are important components of a vehicle that set a variety of requirements: so audit and testing of these peripheral and ancillary devices also has to meet increasingly strict standards.

Kistler responded to this challenge years ago by developing system solutions that can handle a vast range of different applications. These drives are often exposed to different ambient conditions, for instance the simulations have to cover both extremely low and extremely high temperatures. This requirement is met by specially adapted temperature and climate chambers that can be individually adjusted to each test stand. Depending on the drive's function, moreover, axial and radial forces also have to be simulated, often in the form of a hardness test. For cases such as these, Kistler offers mechanical adaptations that exert the relevant forces on the test motors.

If there are special requirements for noise and noise reduction, Kistler can draw on its experience of various projects involving different noise protection concepts that have yielded successful results in the past.

Increasing attention is being focused on the main electric drive in vehicles. A main electric drive is also the key feature in many of the models under discussion in political circles: examples include battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), range-extended electric vehicles (REEV) as well as vehicles with fuel cells. In terms of efficiency and local emissions, electric motors are far superior to pure combustion engines, and they are regarded as the model for the future.

Vehicle development cycles are becoming shorter all the time, placing heavy demands on everyone involved – so a flexible test environment that is easy to adapt is an essential requirement. Kistler draws on its decades of experience in testing electric motors to respond to the new challenges posed by electromobility. We have already met requirements for high speeds (of up to 50 000 min⁻¹) or torques in the range of several kilonewton meters. The infrastructure for the test stand, comprising media supply and



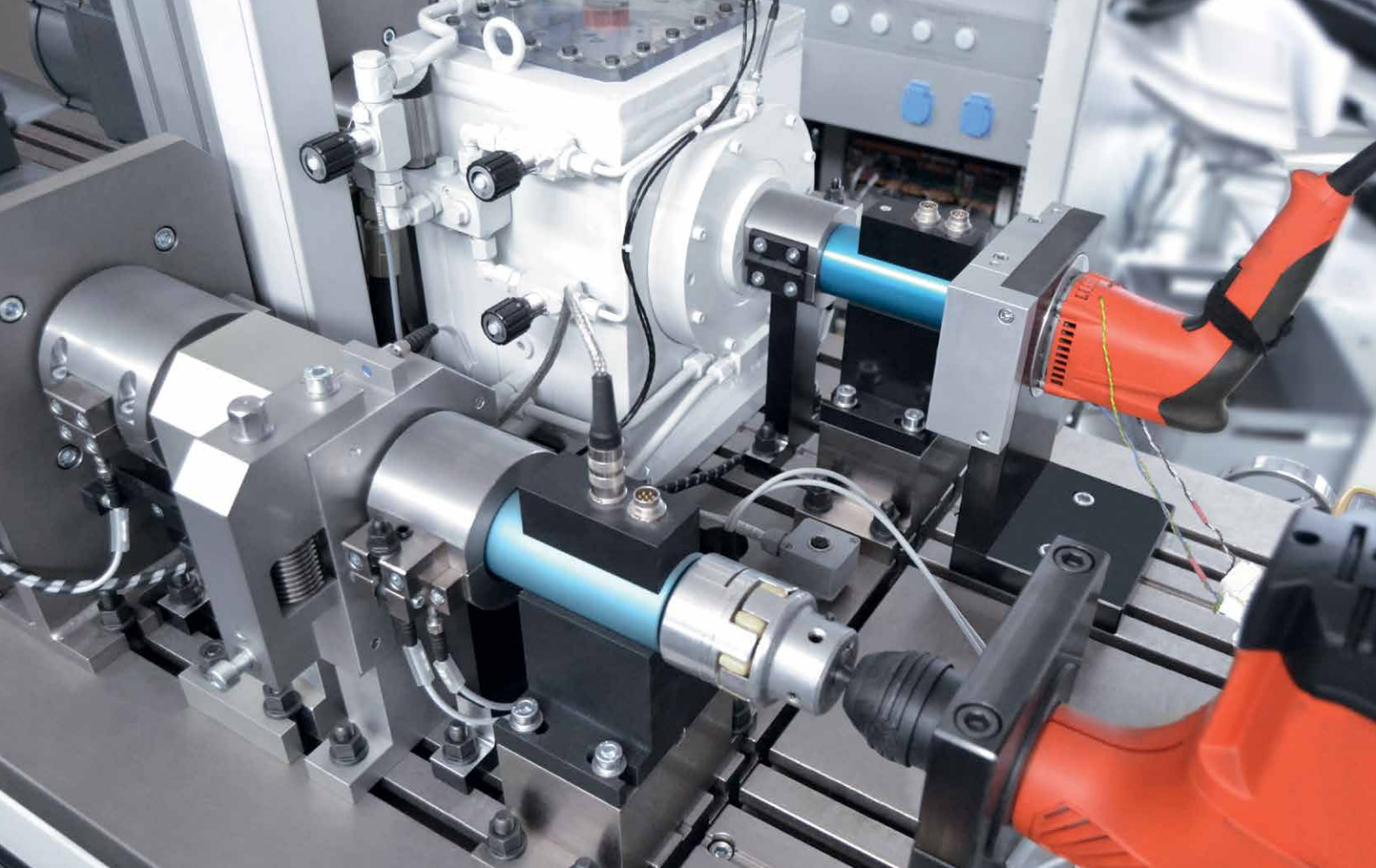
environmental simulation, can be set up according to customers' wishes. Supply options for the DUT, for instance, include battery simulators, LV (Low-Voltage) feeds and coolant conditioning.

A climate chamber can be added to the test stand to simulate environmental conditions. Test stands by Kistler are already in successful operation for research and development purposes, and for auditing main electric drives.

Battery simulation:

- Modular scalability in the typical power range from 50 to 500 kW
- Modular scalability in the typical current range from +/- 100 to 1 200 A
- 2 voltage ranges (10 to 680 V or 10 to 1 000 V) that can be adapted to the specific application
- Fast voltage control (typically: 450 μ s)
- Fast current control (typically: 2 μ s)
- Fast load transient response (typically: 100 μ s for a load step of 10 % to 90 % of output current)
- High control accuracy – typically 0.3 % for current and voltage
- Real-time simulation via C-Code or MATLAB® Simulink®
- Protection against short circuits
- Galvanic isolated with insulation monitoring
- Standalone or integrated on the intermediate circuit (DC)

Battery simulation can be supplied as a standalone solution, or can be integrated into the test system prior to delivery.



Power tools

Development work never stops in the power tools sector. Power drills, angle grinders and electric saws – wherever these and other motor-driven tools are used, the focus is always on the same objectives: ongoing development, quality improvements, and tools that deliver enhanced performance and efficiency.

When the aim is to prolong battery life, new motor concepts need to be tested – Kistler provides the proper solution. Test stand technology with an active dynamometer in four-quadrant mode allows adjustment and tracking in numerous test scenarios. Very small or critical specimen (such as those with integrated electronics) can be optimally tested across the entire speed range starting from zero – because compensation of mass inertia is possible in addition to torque control. The direction of rotation can be chosen freely.

By driving with a load machine, drag measurements are possible to determine the electromotive force; other possibilities include synchronous and oversynchronous modes as well as skid tests. A climate chamber can also be used to actively influence the ambient conditions.

There are often vast differences between the drives to be tested – so the requirements for adapting them are just as varied. To meet these challenges, Kistler offers a diverse range of specimen fixtures and appliances matched to your specific application.



Minimum Energy Performance Standards (MEPS)

To achieve the environmental goals that have been defined, many countries have committed to cut industrial energy consumption by using more efficient motors. Global energy standards such as IEC 60034-30-1, NEMA MG1 and others define the efficiency classes and minimum requirements for electric motors in the 0.75 to 375 kW power range.

In many industrialized nations, about 70 % of total electrical energy consumption is needed for electrical drives, so there is plenty of potential for boosting efficiency here. For almost 30 years, Kistler has been offering test stand solutions that are supportive to achieve this goal. These modular systems meet the legal requirements for accuracy. Customers receive a complete turnkey solution.

Automated test stand software from Kistler enables to determine the energy efficiency of electric motors according to IEC 60034-2-1 with little expenditure of time.

The procedure is as follows: measurement data from the S1 heat run, the load characteristic and the no-load characteristic are determined automatically according to the test sequence described above, and the results are then presented in an Excel table. The automatic calculation is performed with the stored formulas. Based on the determined efficiency factor (expressed as a percentage), motors can be assigned to an International Efficiency class IE-1, IE-2, IE-3 or IE-4.

Measurement technology and test stand system components

Test stand systems from Kistler deliver precise measurement results that are reproducible and meaningful – thanks to perfect coordination of their mechanical and electrical components.

Everything from one single source: Always focusing on each customer's specific needs, Kistler develops complete turnkey solutions that meet professional standards. The basis: a test stand concept that is both modular and scalable.

Measurement technology

The measurement technology in our solutions is tailored to each test assignment, to capture electrical parameters such as voltage, current and power. At the same time, winding resistances are measured by micro-ohmmeters, and customized probe types are used to record temperatures. Parameters acquired by mechanical means include torque and speed. All data is stored centrally for further processing.



Test stand system components

As well as a regenerative drive system with an active dynamometer in 4-quadrant mode and a variable supply for the specimen (AC, DC), Kistler offers customers the option of connecting specimen motors precisely to the drive axle. This is achieved thanks to an adjustable lifting table, a flexible specimen holder or a linear guide track.



Test stand system components

- 1 Test stand control and measurement equipment
- 2 Flexible PC operating workstation
- 3 Multi-range torque sensor
- 4 Converter Cabinet and variable voltage supply
- 5 Precisely aligned and balanced dynamometer
- 6 Lifting table for fast and accurate axle height adjustment

Measurement technology (example of a setup)

- A Resistance measuring device to record cooling curve and winding resistance
- B Power analyzer for high-precision measurement of voltages, currents, power, phase angle, etc.
- C 19" industrial PC for the control function, and evaluation with automation software
- D Mains ON-OFF and EMERGENCY STOP circuit
- E Connection panel for voltage paths, temperature sensors, analog signal outputs and controlled 3-AC and DC power supply for specimen

Modular system technology to meet wide-ranging test requirements

Every testing process sets its own individual requirements – and Kistler offers a vast range of components and detailed solutions to complement your test stand to ensure that every requirement can be met. The benefits: users can extend their range of tests and boost the effectiveness of their test procedures.

Our modular component concept is the ideal way to adapt a test system precisely to each customer's needs. Modular components guarantee maximum flexibility allowing users to cope with constantly evolving requirements over the long term.

Kistler also offers an upgrading and extension service for existing test systems – so systems already in place can be adapted to handle changes and additions to test assignments.

Benefits of Kistler test stand systems

- Wide range of add-on options
- More effective test procedures
- Flexibility thanks to options for adaptation and add-ons
- Modular components

Kistler's system components – for optimum integration of specimen



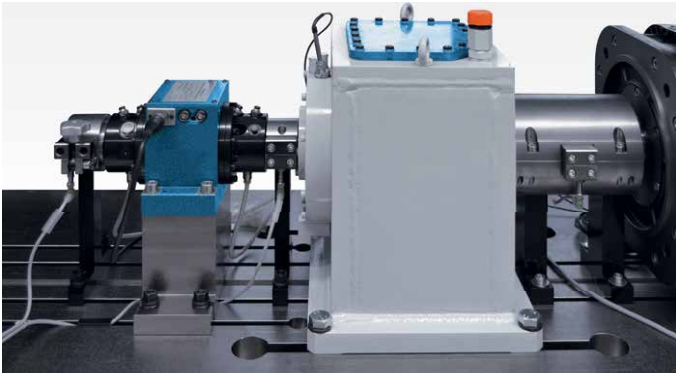
Height adjustment

The axle height for each specimen can be adapted precisely thanks to a lifting table with a choice of motor driven or mechanical adjustment (using a handwheel). Optimal axial alignment of the specimen is also ensured thanks to a grooved clamping plate.



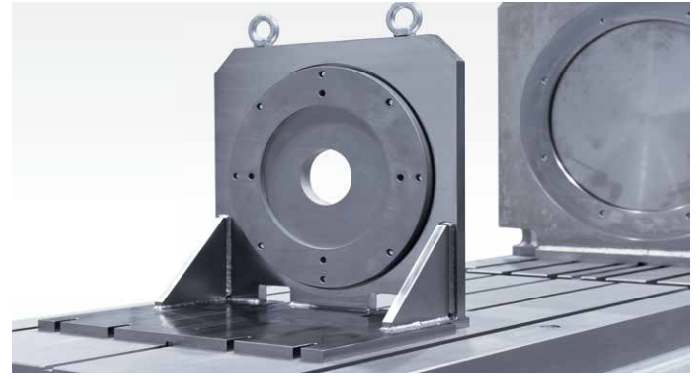
Conditioning of specimen

Precise conditioning parameters for the specimen are ensured by external cooling and temperature conditioning units. These devices allow variation of specimen temperatures, with integration into the test procedure as appropriate.



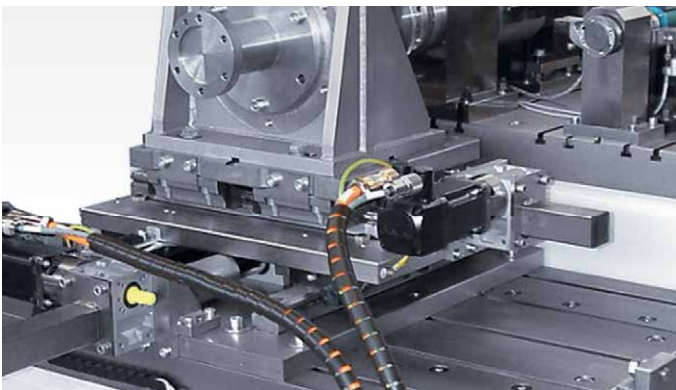
High speed and high torque requirements

Suitable transmissions can be integrated into the power train to attain high torques with low speeds or high speeds with low torques.



Variable specimen mounting bracket

The two-section specimen mounting bracket comprises a welded bracket to fasten the specimen to the test bench, and a flange ring. This flexible fixture makes it easy to accommodate specimen with different geometries. Specimen can be exchanged quickly – and time spent on adaptation is minimal.



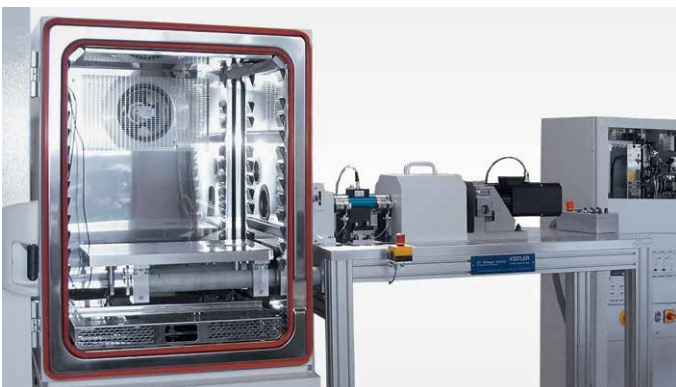
Force on bearings

An XY spindle crosstable can be used for rapid and precise alignment of a fixed specimen. This table also allows axial and radial application of forces, either mechanically (using a handwheel) or by motor driven means.



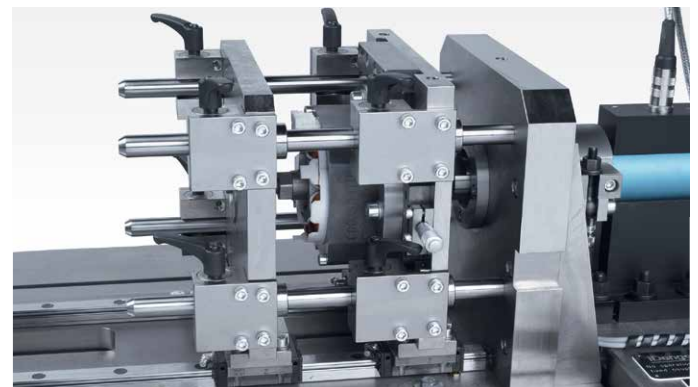
Calibration equipment

With our calibration equipment, calibration of torque sensors can be done by the customer without involving Kistler. In addition, calibration certificate for the lever arm and test weights – to guarantee accurate calibration – will be provided.



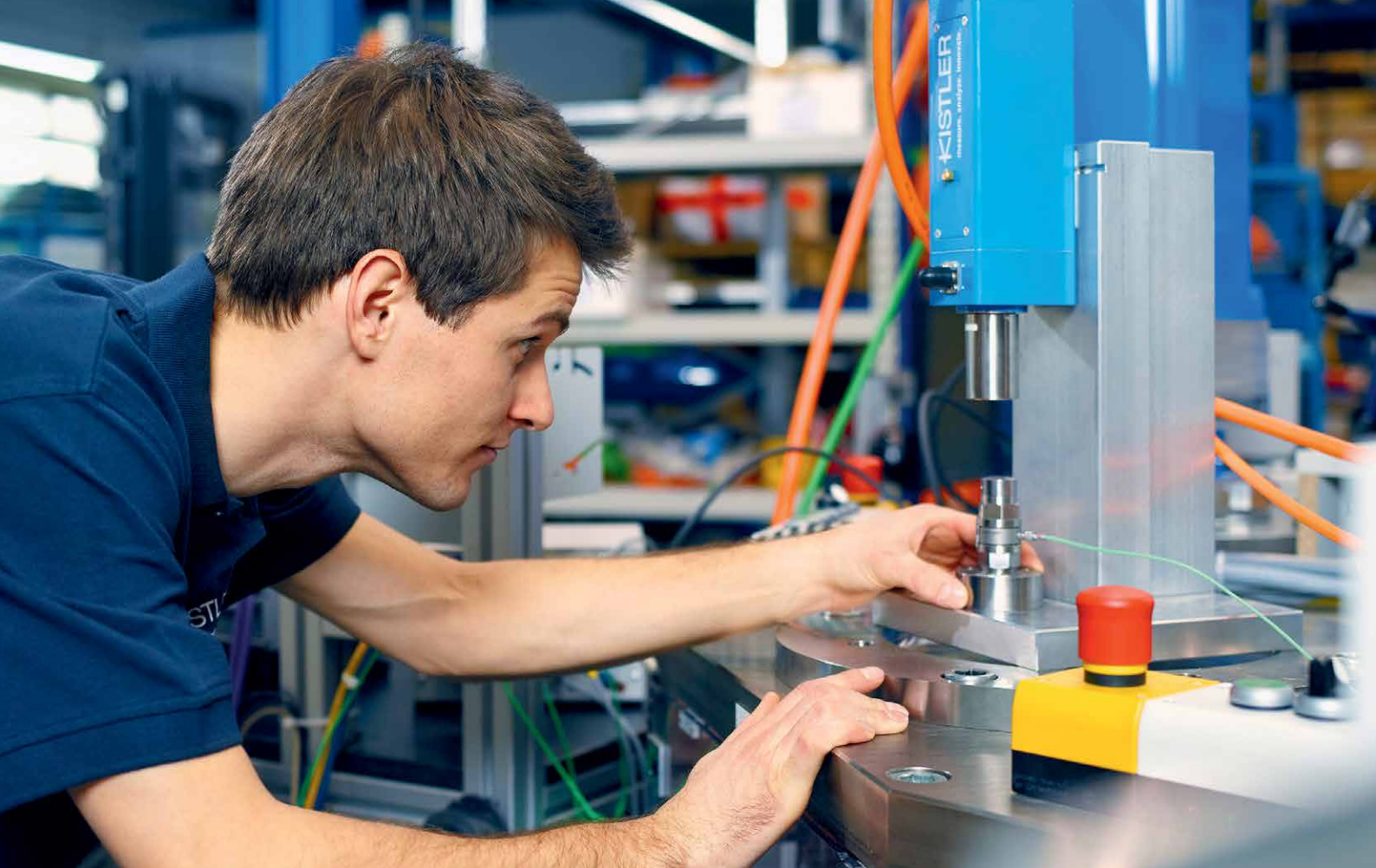
Environmental simulation

A climate chamber is integrated into the drive train for tests under different climate conditions. This allows simulation of temperatures from -70 °C to +180 °C and humidity ranges from 10 % to 95 % (relative humidity), according to requirements.



Specimen motors without bearings

For rotor-stator combinations without housings, Kistler's portfolio includes suitable specimen holders that allow clamping and testing of different rotors and stators with various exchangeable parts.



From professional advice on installation to speedy deliveries of spare parts: Kistler's comprehensive range of services and training is at your disposal across the globe.

Service: customized solutions from A to Z

In addition to sensors and systems, Kistler offers a host of services – from professional advice on installation to speedy worldwide deliveries of spare parts. For an overview of the services we offer, visit: www.kistler.com. For detailed information on our training courses, please contact our local distribution partners (see page 19).

Kistler service at a glance

- Advisory
- Support with system commissioning
- Process optimization
- Periodic on-site calibration of sensors in use at customers' premises
- Education and training events
- Development services

At our customers' service across the globe

Thanks to our global sales and service network, Kistler is close to our customers – wherever they are. Some 1 860 employees at 61 facilities are dedicated to the development of new measurement solutions, and they offer individual application-specific support at the local level.



Who to contact

No matter whether you come to us for advice, or support with an installation – on our website, you'll find the contact details for your personal partner anywhere in the world.



Data sheets and documents

Use our search engine to download data sheets, brochures or CAD data.



Education and training events

Education and training courses – when our sensors and measuring systems are explained by experienced Kistler trainers – are the most efficient way for you to acquire the expertise you need.

KISTLER
measure. analyze. innovate.

Increased Cost Efficiency with Cavity Pressure-Based Systems

Process monitoring and control
Efficiency in reinforced injection molding production

Plastics Processing
Optimized Process Efficiency for Injection Molding

Composites
Process homogeneity and quality assurance in the production of fiber-reinforced composite structural elements

Find out more about our applications:
www.kistler.com/applications

Kistler Group
Eulachstrasse 22
8408 Winterthur
Switzerland
Tel. +41 52 224 11 11

Kistler Group products are protected by several intellectual property rights. For more details, see www.kistler.com. The Kistler Group includes Kistler Holding AG and all its subsidiaries in Europe, Asia, the Americas and Australia.

Find your local contact at
www.kistler.com

KISTLER
measure. analyze. innovate.