



SENSOR+TEST 2017

DIE MESSTECHNIK-MESSE

The Measurement Fair

30 May – 1 June 2017, Nürnberg, Germany

PRESS RELEASE

SENSOR+TEST 2017

Europe's Biggest Measurement Fair – End of May in Nürnberg

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Editors please note:

Using the subheadings you can find those components for your reports that are most suited for your readership. You will also find more information about the exponents described here as well as other product novelties in the ever increasing overall offerings at: <http://www.sensor-test.de/presse/news>

The 24th international measurement fair, the SENSOR+TEST, will be held from the 30th of May to the 1st of June, 2017, on the fair grounds of the Nürnberg Exhibition Center. This is the communication platform across all branches of industry for developers, design engineers, and users in the area of sensor, measuring, and testing technology. It is also a must for students of natural sciences and engineering. State-of-the-art sensors and measurement technology are crucial for future advances in technical devices, machines, systems, and processes. And without the latest testing equipment, the continuously increasing requirements for reliability of products and processes cannot be met. Particularly, the digital world of Industry 4.0, the Industrial Internet, and the Internet of Things requires more and more precise data from real processes to derive added value from this information.

There is no comparable platform in all of Europe, where users can meet so many innovative suppliers of sensor, measuring, and testing technology from all over the globe. The AMA Association for Sensors and Measurement, the major supporter, and the AMA Service GmbH, the organizer, are counting this year on approximately 600 exhibitors and about 9,000 visitors.

Special Topic 2017: Networked Measuring for Mobile Applications

The SENSOR+TEST stays abreast of the growing importance of sensor, measuring, and testing systems for today's networked world. The range of products and services will cover mobile systems for measurement on humans to instrumented vehicles, mobile machines, and aerospace technologies. The data is supplied by autonomous measuring sensors or sensor networks comprising

numerous sensors. The essential advance in tomorrow’s networked world is the availability of local measuring results. Thus, the benefits derived from the data by the user and the context of their use is decisive for the efficiency of such systems. Many such applications can be seen live at the Action Area – including secure data transfer to the respective stand of the exhibitor. The focus of the special topic of the SENSOR+TEST 2017 at the forum in Hall 5 will deal with new solutions and concepts as well as questions regarding data security and worldwide networks, distributed and continuous data acquisition, user-friendly software for mobile applications, networking of test tasks in the Internet of Things, or data management with sensor technology.

The AMA Innovation Award will be bestowed for the seventeenth time at the SENSOR+TEST. The renown 10,000-Euro award is presented annually by the AMA Association for Sensors and Measurement. The award goes directly to the winning developer team, not the enterprise or institute. There is also an award for the best young enterprise in the competition. The jury, comprising representatives from universities, institutes, and enterprises, especially consider the degree of innovation and the clear usability in applications. All accepted submissions will be published with a brief description of the project in the brochure “AMA Innovation Award 2017 – the Competitors.” It can be downloaded free of charge.

Product Overview at the SENSOR+TEST 2017

The following text is based on the preliminary information given by the exhibitors to AMA Service, the fair organizers, up to mid-February 2017. It comprises a preview of products, services, and trends presented at this year’s SENSOR+TEST from 30 May to 1 June, 2017. The structure follows the trade fair’s nomenclature.

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Geometric Parameters

Distance, gap, position, angle, inclination, attitude, and fill level determinations are among the most common measurement tasks in a plethora of applications from smartphones and automotive engineering at test rigs and with driver assistance systems to tooling equipment and robots. The great variety of sensor principles

can be found under the broad offerings at the SENSOR+TEST. Here you can also find standard strain gauges, encapsulated in Constantan grid material with modified phenol backing just as easily as specialized strain gauges with Karma foil gauges and fiber-optic enhanced polyimide film backing for underwater and high-altitude measurements.

A fiberglass-based temperature and strain gauge measuring system monitors up to 50 km measuring distances at a resolution of up to 20 cm. The system works with an accuracy of 2 microstrain at a maximum expansion of $\pm 3\%$. The strain gauge measuring system is suited for fatigue and structural health monitoring of bridges, tunnels, dams, pipelines, power lines, and railroad tracks.¹

Fiber Bragg gratings (FBGs) are optical interference filters in optical conductors that reflect wavelengths within the bandwidths of the filters. A Belgian supplier offers special FBGs with a number of independent optical fiber cores in a multiplexed array to monitor curvature and shape. This combination enables the measurement of multiaxial strains.² A research institute developed a spectrally sensitive detector for special applications on the basis of FBGs using two stacked silicon photodiodes and optical thinfilm filters. The narrow-band filters can accurately detect wavelength shifts in the picometer range.³

Non-contact, wear-free laser triangulation sensors measure displacement, distance and position. Thanks to the additional measuring ranges of 100 and 200 mm, they can be used in applications in which greater measuring ranges are required.⁴ Triple-beam interferometers are suited for simultaneous determination of position and inclination with an exactitude in the nanometer range. They have an extremely compact design and can be easily adapted to the most varied measuring tasks, such as on guides, microscopes, measurement and positioning stages, high precision pitch and yaw corrections during biaxial or multiaxial length measurements, calibration of machine tools, and differential measurements.⁵ A Romanian supplier at the SENSOR+TEST is showing a laser interferometer with coherent lighting providing a high-contrast speckle pattern. The angular displacement of the light field can be mapped linearly to a sensor array. The shifting of the image is used to measure the angular displacement in one or two directions (1D or 2D) of randomly shaped machine parts, micro- or nano-components.⁶ New sensors based on the tunnel magnetoresistive (TMR) effect maintain a high temperature stability and have 100-times lower energy consumption as comparable sensors. A German supplier developed two TMR product families for distance, position, and angle measurement.⁷

Inductive displacement transducers have a hollow coil body with a strictly symmetrical coil and a magnetic shield with high permeability. A nickel-iron core moves linearly within the coil form. The displacement of the core leads to an inductance variation in both coil halves. The measuring range extends up to 20 mm. The inductive transducers can be strung together with push-pull connectors.⁸ Other linear transducers detect the absolute position of the plunger using an inductive resonator measuring system. It consists of an excitation coil which causes an oscillating resonance circuit. This in turn excites the receiver coils on a printed circuit board. The integrated electronics transform these signals proportionately to the linear travel. The measuring range extends from 7 to 500 mm at an accuracy of 0.05%.⁹

Simple motion sensors can be implemented by using a compact Doppler radar module with two antennas. The Doppler signal processor computes the FFT from the Doppler signal and evaluates the results for the direction of the motion and its speed. A slim construction of 25x25x6 mm³ allows the module to be integrated in lamps or automatic door openers. Speed measurement is also available for industrial applications.¹⁰

Certified inclinometers detect the inclination of ships, rotating tower cranes, wind power turbines, power-plant chimneys, or drawbridges in the gravitational field by means of MEMS sensors. Digitalization and linearization is performed by an integrated controller. The sensors meet SIL2 requirements (performance level d) and communicate via Profisave per Profinet interface.¹¹ This enterprise also provides an SIL2-certified rotary encoder. The two-chamber design is highly shock and vibration resistant thanks to its robust construction. It also offers protection class IP69K. The encoder provides reliable position values as well as speed signals.¹²

New Hall sensors enable precise and redundant angular and position measurements for safety-critical automotive and industrial applications, such as the detection of clutch positions, motor air management during exhaust gas recirculation, or throttle positions and turbocharger actuator control. Each sensor comprises two silicon dies in a stacked SOIC8 package, measuring the same magnetic field independently.¹³ Originally developed for motor-sport applications, the highly vibration resistant angle sensors of a British enterprise can also be used in an industrial environment in particularly rough ambient conditions. The extremely accurate, non-contact Hall sensor is packaged in an only 8 mm high IP68 housing and functions with a separately equipped magnet.¹⁴

A French manufacturer is showing linear actuators designed for zero maintenance and years of continuous operation during a long service life. This is achieved by fixed coil and magnet designs, without electric flying leads and a non-contact bearing design. An aluminum heat sink dissipates the heat to the housing interfaces.¹⁵ This manufacturer also offers non-contact, inductive, magnetic sensors for position measurement in the centimeter range. Depending on various parameters, such as available power, sensor accuracy, and dimension, various sensor structures can attain detection ranges of up to 40 mm. Such sensors are used in vehicle tires to measure wear and tear at the gap between the steel and rubber structures.¹⁶

A measuring head for magnetic position measurement is based on a pole pitch of 80 µm. At a reading distance up to 240 µm it attains an accuracy of 5 µm and better. Thus magnetic encoders are almost at the level of optical measuring solutions, but have the advantage of better soiling resistance.¹⁷ New magnetic position encoders for power drives have a resolution of 17 bits and are very robust. A special magnetic wire made in the USA functions as an energy harvesting system by providing high-energy pulses from the angular motion. It thus constantly activates the rotation counter and the corresponding electronics.¹⁸

A Chinese supplier offers an optically modulated level sensor with a pulse rate of 5 or 20 µs and a temperature range of -40 to 125 °C.¹⁹ A portable load indicator has

a 2.4" LCD that shows detected signals numerically or graphically. At a sampling rate of 1 kHz it is especially suited for dynamic applications.²⁰ An Italian supplier provides an industrial assembly in a 19" rack for programming magnetoresistive NXP sensors.²¹ Piezoresistive, non-hysteretic level probes measure hydrostatic pressure proportionally to the level of a liquid column in dependence of ambient pressure. A Swiss enterprise supplies these with a digital or analog output, including a datalogger or GSM module.²² A Chinese supplier offers an intelligent two-wire level meter with a 4 to 20 mA or an RS485 / HART output.²³

Users can gain experience with magneto-resistive sensor technology to implement positioning tasks with a novel evaluation kit. The set contains the necessary electronics for signal processing, pole rings, and linear scales in various pole divisions as well as the corresponding free-pitch and fixed-pitch sensors. Various measuring setups can be realized at the end of the drive shaft, at its circumference, or for linear measurements.²⁴

Mechanical Parameters

This section gives you an overview of the initial reports from exhibitors dealing with parameters, such as pressure / differential pressure, force / weight, mechanical stress and torque to density and viscosity. On the one hand, the SENSOR+TEST is the right fair to find a great variety of standard transducers, on the other hand it is also the place to discover specialized equipment, not found in every-day applications.

Pressure, Differential Pressure

The technologies applied extend from piezoresistive silicon sensors for pressure measurement in liquid and gaseous media to thinfilm strain gauges. Some sensor systems are equipped with integrated temperature sensors.

An American supplier provides Bluetooth-capable MEMS pressure sensors for automotives, industrial, consumer applications, and prefabricated sensor modules and ceramic sensors as well as sensors for air-compressor and water-purification applications.²⁵ Sensors for absolute pressures with an edge length of one millimeter is offered by another supplier. The embedded piezoresistors have a sensitivity of 20 $\mu\text{V}/\text{hPa}$ at a measuring accuracy of up to 0.001 hPa. Thanks to their high resolution, they are suited for indoor navigating or assuming monitoring tasks, such as for injury prevention by detection of patients that fall down.²⁶ A pressure transmitter based on microfused technology measures liquid or gas pressures in difficult media, such as polluted water, steam, etc. The transducer pressure cavity is made out of a single massive piece of stainless steel.²⁷ The pressure transmitter from a Chinese supplier has an accuracy of 0.25 and 0.5%, 4 to 20 mA outputs, and provided in protection class IP65 and stainless steel.²⁸

Miniaturized pressure transmitters in a compact metal package measure various kinds of pressures, such as absolute, relative, and differential pressure in a range from 50 mbar to 10 bar. In their robust metal housing, these sensors can measure small differential pressure changes at a high system pressure. These 35x25x25 mm³ sensors are used in medical technology for gas-flow monitoring, as level indicators for liquids, or for pressure measurement in clean rooms.²⁹ The world's smallest differential pressure sensor has a size of only 5x8x5 mm³ and thus allows

new application possibilities, such as for measuring mass flow in medical technology or in the consumer industry.³⁰ A pressure transmitter, the smallest according to the supplier, is suited for simple integration into microcontroller-based systems via its I²C interface. With its extremely low power consumption and RFID interface, it is cut out for battery-operated devices.³¹ Another maker is offering the smallest programmable 2-wire pressure sensor with a HART interface. Completely welded, it is used to monitor relative pressure for gas, steam, liquid, and dust.³²

Custom-tailored pressure sensors for test beds, special equipment, and test driving is manufactured by a British enterprise. Thanks to the hermetically welded, oil-free stainless-steel membranes, the pressure transmitters are compatible to practically all media.³³ They make internal sealing superfluous.³⁴ Piezoresistive sensor cells can also be integrated in existing applications, such as pressure switches or pressure controllers. Depending on the space requirements, a number of mechanical attachment means, such as bolting, welding, plugging, and clamping, are available.³⁵ A Chinese supplier provides piezoresistive MEMS pressure sensors for a range of -100 kPa to 60 MPa.³⁶ New heavy-duty pressure transducers with low power consumption are designed for use in HVAC and cooling systems. They are resistant against many HFC and GWP refrigerants. They operate in a pressure range of 1 to 50 bar and have a high electromagnetic compatibility as well as shock and vibration resistance.³⁷ This supplier also offers very precise pressure sensors for low air flows to measure the barometric height of drones and weather balloons, air flow in HVAC channels, or respiratory air flow in medical systems. The pressure ranges extend from 1.6 mbar to 10 bar.³⁸

Developers in automotive, aerospace, and the mechanical engineering industry focus on unaltered measuring results. A Swiss precision specialist has developed a pocket measuring instrument that can reliably measure pressures up to 100 bar with an accuracy of 0.5 percent end scale over a temperature range of -40 to 125 °C. The robust stainless-steel housing and the overpressure resistance can withstand rough ambient conditions.³⁹ Pressure transmitters in a splash-water protected polycarbonate enclosure (IP65) convert a detected pressure into a standard analog electrical signal, linearize the measuring curve, and compensate the temperature fluctuations. The devices can be configured via an integrated USB interface at which the measuring values can also be output.⁴⁰ The manufacturer also produces a pressure measurement device with two measuring ranges and an auto-range function especially designed for mobile applications.⁴¹ New CMOS differential pressure sensors are characterized by their very good repeat accuracy and a measuring speed of up to 2 kHz. The fully calibrated and temperature compensated sensors differ not only in regard to their pressure ranges, pneumatic connections, and output signals.⁴²

An Italian sensor manufacturer has developed a ratiometric pressure transducer, originally made of the automotive sector, aimed at unadulterated results. This sensor is now offered for the industrial and biomedical sectors as well. The pressure transducer makes use of a piezoresistive, chemically etched ceramic membrane. It measures the changes in a specific resistance with a Wheatstone bridge.⁴³ A Rumanian supplier is showing differential pressure sensors with piezoresistive silicon membranes of 1 mm², while the entire chip has a size of 3x3 mm². Pressurization takes place on both sides of the membrane. This allows the

sensor to function as a measuring probe as well as a differential pressure instrument.⁴⁴

PCB-based pressure sensors have an extremely low-noise, analog output signal, a high resolution, and a fast sampling rate. This is enabled by a two-chip system comprising a MEMS sensor chip and a signal-conditioning chip. The areas of application are high-end measuring devices for non-invasive blood-pressure measurement. The standard measuring range of the sensors is from 0 to 250 mbar or 0 and 12 bar. With the single-point pressure threshold value detection, a small-sized, low-cost pressure switch can be obtained here.⁴⁵ Leakages in gas lines can be detected with a 100-mbar pressure transmitter. It is equipped with a high-capacity battery, a SIM card, and an integrated antenna. The measurements take place every five minutes and are transmitted every day to a central station.⁴⁶ Any material can be subject to magnetostriction. With an inverse magnetostrictive effect, the magnetic permeability of a ferromagnetic material changes in dependence of its internal mechanical stress. Based on this measuring principle, a sensor is able to measure the mechanical strain in the cables of a harness bridge.⁴⁷

IO-link is a future-oriented communication system for the attachment of intelligent sensors and actuators to automation systems. Their standardization comprehends not only the electrical connection data, but also a digital protocol over which the sensors and actuators communicate with an automation system. A German enterprise has now started to equip its pressure and temperature sensors with this interface.⁴⁸

Force, Weight, Torque

Miniature load cells in a stainless-steel enclosure with integrated cables have an accuracy of 0.15 to 0.25% and measure compression as well as tension. Thanks to their compact size, they can be easily integrated in maintenance ducts on machine test systems to measure forces on a drive shaft, for instance.⁴⁹ In a research project, highly sensitive strain gauges were developed using functional thin-film material that is resistant to temperature changes. They are well suited for force, tension, torque, and weight measurement.⁵⁰

Rotating digital torque sensors make it easier for users of torque measuring technology to perform a quick electrical measurement setup. The sensor already has all the necessary calibration data on board and can be read out by the measuring software. A commercially available PC or laptop with a USB connection can be used as a display and evaluation unit. The measurement rate goes up to 2,500 revolutions per second.⁵¹ A German supplier makes torque flanges for highly precise, dynamic torque detection. A sensor signal amplifier compensates zero-point drift in dependence of the ambient temperature at the point of measurement and thus achieves precise torque measurements for drive-train serial components.⁵² Sensors with 6 axes measure force and torque in three spatial directions. This allows the determination of grasping force of robot tongs and many other applications in robotics and production engineering. The values are evaluated by an eight-channel measuring amplifier that records various channels via a time axis (y-t diagram) or an x-axis (x-y diagram).⁵³ A Rumanian supplier has developed a robotic micro-manipulation system with MEMS micro-

tongs for cell manipulations in which the microsensors are integrated for position measurement and force feedback.⁵⁴

Silicon-based MEMS sensors can control safety-relevant bolted joints in machine engineering, extraction technology, and wind turbines. The new sensor is applied to the bolt head and measures its deformation depending on the preload force between the workpiece and the bolt head. Four piezoresistive, strain sensitive measuring resistors are integrated via a Wheatstone bridge. The active surface without the electrical connections has an area of only 200x200 μm^2 at a thickness of 10 μm .⁵⁵

Dynamic Parameters

The SENSOR+TEST is the most prominent platform for vehicle developers thanks its plethora of accelerometers, vibration, oscillation, and acoustic analysis systems – not to forget the development of the many speed and flow sensors driven by microsystem technology (MEMS).

Speed, Acceleration, Vibration

The light detection and ranging method is very similar to optical gap and speed measuring. A Lidar-based sensor determines the position and speed of the vehicle ahead by means of runtime measurements. Integrated in modern vehicles systems, adaptive speed control or laser pistols for police speed control are made viable. The emitters consist of pulsed laser diodes with a peak power of 650 W at 905 nm. The reflected signal is captured by Si-PINs or Si-avalanche photo-diodes.⁵⁶

Triaxial accelerometer sensors are ideal for industrial environments, where vibrations need to be measured in all three spatial axes. Such environments are often found in the aerospace and automotive industries as well as in agriculture, mining, and road construction. Submersible, triaxial miniature accelerometer sensors are hermetically sealed and have an overmolded bushing at the cable exit. This puts the sensors in a waterproof protection class as per IP68, which can withstand water pressures of up to 12 bar. The 500-g sensor has a sensitivity of 10 mV/g and the 50-g sensor of 100 mV/g.⁵⁷ This supplier also provides a triaxial vibration sensor in a robust, waterproof stainless-steel housing as per IP66 with a mounting aperture in the middle. Internal electronics minimize noise and increase the stability of the preload.⁵⁸ Electrically insulated IEPE miniature accelerometer sensors can also be found with an interior of black anodized aluminum.⁵⁹ Box-shaped accelerometers can easily be attached with an M3 thread or a plastic clip and are particularly suited for modal analysis thanks to their measuring characteristics. They have a sensitivity of 10 and 100 mV/g.⁶⁰ MEMS-based SIL2 vibration sensors detect the effects of dynamic acceleration. The data are digitized and made available for many functions. By means of 11th-order filters, preferred frequency bands can be filtered out, for instance the 0.1 to 2 Hz for mast-head vibrations on wind power plants.⁶¹ Laser vibrometers are able to determine material properties, errors, or characteristics very exactly for the most varied test pieces based on their vibration behavior. They allow non-contact vibration measurements on surfaces of any roughness in a range of 0 to 5 MHz at a resolution in the subnano range. The working distance can be continuously adjusted with an integrated lens from a few centimeters to a few meters.^{62 63}

A new generation of vibration analyzers can be used for various highly dynamic pulse measurements and angular evaluations to examine rotary vibrations on power trains or to monitor torsion vibrations on turbines. The trigger threshold value is easy to adapt and allows automatic tracking for changing measuring conditions.⁶⁴ A mobile measuring system for vibration analysis as per VDI 3834 works at a measuring range of 0 to 10 Hz for natural frequency detection, gondola oscillations, rotational imbalances, or wing misalignments on wind power plants or very low frequency vibrations on machines and constructions. If limit-value thresholds are exceeded, automatic alarms are sent by various communication means.⁶⁵ A Belgian supplier develops vibration, tilt, and pressure sensors for wind power plants that monitor gears, housing, towers, and rotor blades and detect seismic activities. Pore-water pressure sensors monitor the anchorage of tower foundations on the seabed.⁶⁶

High-resolution inclination sensors are based on a very exact and robust pendulum system made of high-purity silicon. Through an acceleration, tilt, or vibration in the direction of measurement causes the pendulum to move with the test mass. The two-color tilt sensors measure the displacement with a resolution of up to 0.002 and the acceleration sensors measure accelerations of ± 2 g to ± 18 g at resolutions of 0,002%.⁶⁷ With a multichannel system, large structures can be reliably monitored and protected regardless of the measuring data by vibration test. The channels measure the response signals during and after the vibration test independently of the oscillation system in real-time and compare these with the user-defined alarm and stop limit thresholds.⁶⁸

Flow

An new inline flow metering device uses surface acoustic waves (SAW) that only have a planar propagation. The patented technology has no built-in components or constrictions in the measuring tube. Measurements are performed without contact of the sensor elements to the medium. Thus, the inside of the tube can be produced in the same surface quality as the other tubes. Besides flow and temperature, the sensor can also measure density and mass flow.⁶⁹ A flexible flow meter measures standard volumes and mass flow in air, nitrogen, oxygen, argon, carbon-dioxide, methane, or hydrogen. Different process connections allow flow measurements of DN 15 to DN 1000 and media temperatures of up to 185 °C.⁷⁰ A mobile flow meter has a USB connection for bidirectional communication and power supply. A processor-controlled linearization allows for five selectable units, a nine-step attenuation, and measurement of six different gas standards.⁷¹ This manufacturer also supplies a portable mass flow meter based on the calorimetric measuring principle with all these feature in a robust aluminum case.⁷²

Thermal Parameters

There are approximately 600 temperature sensor elements to choose from at the SENSOR+TEST 2017, particularly Pt, NTC, or KTY types. The market for temperature sensors and measuring devices seems endless in regard to size and variety. You can get this impression of the SENSOR+TEST every year. Besides standard sensor elements, such as NTC, Pt100/Pt100, or the numerous types of thermoelements, non-contact temperature measurement is strongly represented. Shown are custom-tailored designs for medical technology, car racing, energy

harvesting, or more general models for measurement and control engineering as well as building automation. Pyroelectric infrared sensors are designed for non-contact temperature measurement, gas analysis, spectroscopy, environmental measuring technology, as well as for safety and security applications. Modern ion-beam etching methods now attain very high specific detectivity (D^*) values.

Temperature Probes

From China we have drawn and rolled thermocouple wires in the most varied temperature ranges for measuring tasks, temperature sensors, as well as extension or compensating wire.⁷³ Platinum-based resistance temperature detectors (RTDs) are designed for stable, fast linear outputs and available in wide range of resistance values and in a variety of packages and sizes.⁷⁴ In a Pt temperature sensor for temperatures of up to 250 °C, the platinum structure of the measuring shunt is covered by an annealed high-temperature glass layer. This optimally protects the sensor from ambient effects and makes it suited for applications such as heaters, infrared radiators, or calorimetric measurements.⁷⁵ A compact infrared sensor can withstand operating temperatures of up to 180 °C, and can thus measure the temperature of carbon brake discs. A PT1000 output ensures a high accuracy of the internal sensor temperature measurement. Thus, target temperatures are obtained in dependence of the signal output and the ambient temperature.⁷⁶ This supplier also provides a shock-protected infrared sensor for measuring brake disc temperature in rough environments at a temperature range of 50 to 800 °C.⁷⁷

Classical methods of online temperature detection by means of a plunger coil and an NTC as a temperature probe (Essert method) fails during high loads, such as those in car engine pistons. That is why a German manufacturer developed a robust eight-channel temperature detection system to measure temperature on pistons online at important points. A sensor telemetry amplifier in the piston, that can withstand 200 °C, scans the temperature measuring points at each stroke of the piston and transmits the measured data to a stationary evaluation unit.⁷⁸

A Taiwanese manufacturer supplies non-contact measuring infrared temperature probes on MEMS basis with a temperature sensitive area of 8x8 or 16x16 pixels. The modules have a small footprint and are suited for intelligent HVAC control, presence detection for building security, and gesture control for interactive devices.⁷⁹ To limit Johnson noise, one sensor has a thermistor referencing the ambient temperature. Its 116 thermal elements are arrayed on a floating micro-membrane and measure in a spectral range of 5 μm to 14 μm . They are used in electromedical applications as forehead or ear thermometers.⁸⁰ The first thermopile array sensor in SMD design worldwide comprises 64 thermopile elements arrayed in an 8x8 matrix with an integrated silicon lens. The highly precise measuring values can be read out via the I2C interface once per second. The sensor can measure the actual temperature as well as the temperature gradient and can produce thermal images and identify the direction of motions.⁸¹ Aluminum connecting heads with terminal nuts made of nickel-plated steel and rubber or silicon sealants as well as measuring transducers and clamping sockets are supplied by a German manufacturer.⁸²

Temperature Measurement Devices and Cameras

Industrial processes can be monitored with a camera at a resolution of 640x480 pixels for longwave infrared applications.⁸³ A high-temperature camera in a compact aluminum case (IP54) or a robust stainless steel industrial housing (IP65) with provisions for air purge, protective windows, and water cooling. At 512 x 384 pixels and a frame rate of 60 images per second, it has a large, continuous measurement range of 600 °C to 1500 °C, or optionally 1400 °C to 3000 °C. It operates in the near infrared range (NIR) at wavelengths of 0.8 µm to 1.1 µm.⁸⁴ Besides these stationary cameras, this maker also offers the worldwide first portable and robust infrared camera for shortwave measurement of high temperatures. The device measures online thermal images with a resolution of 480x360 pixels, a frame rate of 25 Hz, and a continuous measuring range of 600 to 1500 °C.⁸⁵

Besides a very extensive temperature range, a new digital pyrometer also boasts a special operating mode that enables a smooth and automatic transition from one-color to two-color measurements. It covers the measuring ranges from 100 and 2,000 °C. In a lower range of up to 250 °C the device operates in one-color mode, at 250 to 280 °C it finds an automatic and continuous transition from one-color to two-color measurement, while temperature ranges from 280 and 2,000 °C are measured in a two-color ratio mode. According to the manufacturer's specifications, this extensive measuring range enables the monitoring of processes, such as inductive heating, hardening, tempering/annealing, brazing, sintering, vacuum processes, coating, and laser heat treatment.⁸⁶ A robust thermal imaging camera for combustion chambers has an extensive and continuous measuring range of 600 °C to 1,800 °C. It has a motor-focused borescope lens with a sapphire protection window. They are installed in a watercooled stainless steel probe cooling jacket. The camera operates in the near infrared range at a wavelength of approximately 1 µm. In glass melting or in rotary kilns the IR camera is used for online temperature monitoring and must withstand the high ambient temperatures, operating in a narrow-band spectral range.⁸⁷

A supplier provides a system for automated, continuous thermal and visual monitoring of electric grid substations and critical industrial assets for early fault detection. It comprises a 640x480 pixel infrared camera with a telephoto lens in a stainless steel enclosure and can be upgraded with optional fixed thermal imagers and fixed single point infrared pyrometers to also monitor assets beyond the infrared camera's field of vision.⁸⁸ New portable high-temperature pyrometers designed for the glass and metal industry can also be easily used with protective clothing such as thick gloves. They measure temperatures between 200 and 2,500 °C, operating at short wavelengths. All pyrometers have standard vario optics with a distance ratio of up to 200:1 and measuring distances between 0.65 and 12 m.⁸⁹

A German supplier offers various x-InGaAs photo diodes. The standard product has a peak wavelength at 1.75 µm and idea for applications that cannot be performed with the usual InGaAs spectral. It has a chip diameter of one millimeter in a TO-46 housing. A heterostructure photodiode on an InAs substrate has a relative wide peak at 2.8 µm. Another detector with a 0.5 mm chip is designed for uncooled operation and a spectral range of up to 3.5 µm.⁹⁰ Assistance with the selection of IR detectors is provided by a development kit with pyroelectric

detectors and uncooled PbSe detectors including the required radiation sources. The development kit contains a monoboard computer as well as the corresponding transmitter and receiver modules.⁹¹

Uncooled microbolometer cameras primarily target price-conscious users with universal measuring and testing tasks. Thanks to powerful detectors in the format of 640x480 IR pixels and high-luminosity interchangeable lenses, users can obtain measuring equipment suited for controlling technical assets, construction thermography, and R&D applications.⁹²

Climatic Parameters

This section is mainly about a combination of humidity and temperature measurements. There are also plenty of sensors for barometric air pressure, atmospheric gas concentrations, smoke, dust, or solar radiation, for that matter, all of which can be found at the SENSOR+TEST 2017.

A high-sensitivity gas sensor selectively detects a number of volatile organic compounds, including formaldehyde and ethanol. A 3.0x3.0x0.7 mm³ silicon micro-heating plate with nanostructured sensor material allows for highly sensitive gas measurements. With the corresponding ASIC, one can integrate the chip into various end devices, such as mobile telephones, wearables, or terminals.⁹³ A new multichannel analyzer for at least three different sample-gas components allows connection of WLD, NDIR, and YSZ gas sensors. Internal computations based on thermodynamics offer a great number of variations.⁹⁴

Nondispersive infrared gas-measurement components based on a two-channel thermopile measure CO₂, CH₄, and CO at the same time. Two infrared narrow-band pass filters provide the sensor's gas-absorption and reference signal. The output signal voltage is directly proportional to the incident infrared radiation.⁹⁵ Gas moisture is examined with pyroelectric sensors at wavelengths of 1.94 μm and 2.9 μm. The absorption wavelengths of CO₂, however, overlap the signal. Though with the right narrow band filters and a suitable light source, a reliable measurement can be performed by simple NDIR devices. The central wavelengths for the new filters are selected for measurements of methane (CH₄) at 7.91 μm, alcohol mixtures at 9.50 μm, and moisture (water vapor) at 5.78 μm.⁹⁶ Filters for the near (NIR), middle (MWIR), and far (FIR) infrared range, including IR edge, long-pass (LP), and IR anti-reflection (AR) filters are supplied by a Chinese maker.⁹⁷

The days when one had to run from one measuring site to the next regardless of the weather to read off fill levels or datalogger values are definitely over. With an easy-to-install GSM-2 module, measuring data can be sent per email or SMS right back to the office. The data transmitted from the measuring sites are continuously read, stored, and displayed by a data manager for permanent monitoring of the measuring devices.⁹⁸ Environmental monitoring systems with a range of three kilometers between the wireless sensors and the gateway can monitor temperature and humidity. Up to 100 wireless sensors can be integrated into a network. When threshold values are exceeded, alerts are sent per SMS or email.⁹⁹ A Finnish manufacturer has developed a fully automatic measuring system based on a self-organizing wireless network. The measuring and monitoring system can be

used with a browser or a mobile app. Available physical parameters include temperature, humidity, and room-air carbon-dioxide levels.¹⁰⁰

A complete sensor system comprising capacitive humidity and bandgap temperature probes as well as analog and digital signal-processing means are contained in a 1,3x0,7x0,5 mm³ flip-chip package. On/off body detection determines whether a device is worn on a person's body. This allows for smarter battery management corresponding to the individual's needs for battery-driven devices, such as headphones, fitness trackers, smart medical devices, or VR goggles.¹⁰¹

To attain highly precise laser-interferometer measurements, the laser wavelengths in the air must be corrected. A prerequisite for this method are exact environment data for temperature and air pressure. One supplier offers a precision climate measuring station for calibration interferometers. It can also be used a separate climate station for other applications. The measuring system detects temperature, air pressure, and humidity with the greatest accuracy, using digitally calibrated sensors that communicate per wire or wireless. A high-resolution air pressure sensor and a relative humidity probe are also available.¹⁰²

Optical Sensors / Acoustic Measurement

There are plenty of application fields for optical sensors: gas and particle measurement, fluorescence and analysis techniques, spectroscopy, temperature measurement, motion detectors, high-resolution positioning systems, etc. Among the major parameters besides sensitivity relative to wavelength is always the signal-to-noise ratio. Not only sensors are used in these applications, but special light sources as well.

A supplier offers a wide choice of pyro-electrical infrared detectors for digital motion and presence detection. With a large detection range at a sensitivity of only 1.8 V, they are used in IP cameras and systems for wireless intrusion alarms.¹⁰³ Another supplier of optical measuring solutions offers systems in the UV, VIS, NIR, and MIR ranges for industrial process control and analytical lab applications.¹⁰⁴ An NIR or SWIR process spectrometer can be used in multi-channel mode with up to nine parallel measuring sensors. Major areas of application are the measurement of moisture, protein, and fat content, the analysis of product yield and quality in the agriculture, feed, and food industries as well as in the chemical industry and plastics production.¹⁰⁵

To measure gases in particularly low concentration quickly, the detectors must have an extremely high sensitivity. Thus, PbSe detectors are often used here. The resistance value of polycrystalline lead selenide detectors is dependent on incident light. When infrared light irradiates a PbSe or PbS detector, its resistance is lowered. To obtain a higher performance and a greater spectral range of 1 to 5.2 μm, they are cooled in one or two steps.¹⁰⁶ For gas measurement there are versions with four PbSe chips and a filter in a TO-8 or TO-39 can.¹⁰⁷ These are now also available in a multichannel variant.¹⁰⁸

FTIR spectral sensors for the near infrared range can be seen at the SENSOR+TEST. With 70x50x25 mm³ they are hardly larger than a matchbox. Such a design is made possible by coupling a Michelson interferometer in MEMS

technology with an IR detector.¹⁰⁹ Photomultiplier tubes (PMTs) have very low noise and a sensitivity greater by a number of magnitudes than detectors in the UV or VIS range. A British manufacturer offers end-window PMTs with blue-green sensitive bi-alkali photocathode and 10 high-gain, high-stability, SbCs dynodes of linear focused design. The compact PMTs are particularly suited for use in scintillation applications.¹¹⁰ This manufacturer also offers compact photodiode modules with a diameter of 25 or 30 mm in rectangular or cylindrical form. High-speed electronics combined with a PMT boasting very low dark counts enables a wide dynamic range.¹¹¹ Corresponding high-voltage power supplies of up to 2,000 V and HV plugs with different diameters are also available.¹¹²

Shortwave UV LEDs are used in phototherapy, analytics, printing technology, and catalysis as well as for water, air, and surface sterilization. A Japanese manufacturer has developed a high-power LED for the UV-B range with an optical power of 45 mW at a drive current of 350 mA and a wavelength of 285 nm. The LED chip and a protective diode are packaged in a 3.5x3.5 mm² SMD housing and hermetically sealed with quartz glass.¹¹³ From Germany we have a powerful UV-C LED with a narrow bandwidth of 278 nm and an optical power output of 30 mW at a drive current of 350 mA in a 6x5 mm² SMD housing.¹¹⁴ A research institute has developed new multispectral UV light sources for fluorescent and absorbance measurements. Manufacturers of measuring devices for bioanalytics and medical technology can use these to make significantly smaller systems. Examples are constant-light illumination modules with three UV LEDs in wavelengths of 245, 265, and 280 nm for absorbance measurement of DNA samples. For tumor diagnostics, the researchers developed a miniaturized short pulse UV module with a pulse rate of 1 ns for fluorescent excitation at 370 nm.¹¹⁵

A monolithic microchip based on four integrated photo diodes in a 3D structured silicon substrate can accurately determine the direction of incident light within a few degrees. The areas of application include the control of modern lighting systems, beam guidance in laser technology, or smart displays.¹¹⁶ A new, universally applicable, high-speed optical sensor evaluates surface impressions. Thus optical-sensor adaptations required for batch changes can be carried out directly on the computer in the process monitoring center as well as on a tablet or smartphone by the operator.¹¹⁷

Narrowband external cavity laser (ECL) diodes have a very narrow line width, good wavelength stability, and low noise. They are used in optical communications or fiber sensor technology with an integrated Bragg grating for detection of sound or seismic waves.¹¹⁸ An interferometric sensor enables simultaneous detection of position variations of up to three targets with a stunning position resolution of 10 to 12 m at a 10-MHz bandwidth. The sensor attains working distances of more than 20 meters and target velocities of up to 2 m/s. Thanks to its three-axes design, it can measure angular variations and tilt effects of a target. A webserver and various interfaces enable industrial network integration.¹¹⁹

Laser diodes based on the phase-shift principle have been used to date in laser distance measurement devices in the red spectral range. These laser diodes are operated with a very high modulation bandwidth, which is why DPSS lasers in the green spectral range are not suitable even if the human eye can see green light much better than red light. One supplier now offers a 515-nm laser diode for

distance and levelling measuring devices.¹²⁰ Laser beams are usually focused with spherical lenses. The shorter the focal length, the stronger the influence of the spherical aberration. Relief is found in aspherical lenses with at least one free-form surface made using CNC polishing techniques.¹²¹ Linearly variable filters in the infrared range are used by many line detectors and other applications, such as for portable mini-spectrophotometers, multi-gas detectors, or various scientific analyzers, often requiring measuring values in the range of 0.9 to 5 μm .¹²² This British manufacturer also offers optical filters for sensor systems in the visible spectral range of 0.3 to 1 μm and infrared filters in the spectral range of 1 to 6 μm , for gas sensors, for instance.¹²³ A Chinese supplier is showing IR filters for gas analysis and thermography as well as AR/VR polarization filters as beam splitters.¹²⁴

The trend towards high-speed processing and miniaturization also applies to optical sensors. Thus, metal semiconductor field-effect transistors (MESFETs) and transistors with a high electron mobility (HEMTs) are able to respond within pico- or nanoseconds to the incoming light signal. Potential applications include ultra-fast optical switch and passive component applications. The laser synthesizing products use new organometallic compounds with dual-photon absorption based on azo compounds, ferrocene, and acridine, which can be integrated in optical high-speed switching devices.¹²⁵ Doped borophosphate vitreous materials are available as nano-powders and nano-structured thin films with high optical and magnetic properties for the production of opto-magnetic switches and Faraday rotators. Their operating range extends from 603 to 663 nm.¹²⁶

A French manufacturer developed a human-activity sensing module for applications in smart-buildings. An infrared array transforms the heat emitted by humans into electric signals, which are then provided in real-time for a building's automation, while ensuring people's privacy.¹²⁷ This manufacturer also offers a demo-kit to detect the presence/absence, count people, and determine their positions and trajectories. The kit contains a prototype of the product in a plastic casing for ceiling attachment as well as a power supply and a WiFi communication module. The sensor can be combined with a visible camera that can be used to check the accuracy of the measured data via a dedicated Web interface.¹²⁸

Industrial image processing technology also needs sensors and systems as shown at the SENSOR+TEST. To emphasize their significance, a special stand called "Vision Sensors and Systems" will again be set up at the SENSOR+TEST 2017, where enterprises and institutes can present their products and solutions.

Acoustic Measurement

3D ultrasound sensors detect and track individuals and objects in real-time. These sensors are small, energy efficient and robust. They protect the individuals' privacy, since they are not identified. The sensors can be used to monitor various environments, such as offices, conference rooms, retail businesses, public transportation, etc. They can also be used to prevent collisions of autonomous vehicles in automobiles, logistics, and robotics. With gesture control smartphones, TVs, and robots can be controlled. An evaluation kit for this product is offered by a German supplier. It includes a 3D ultrasound sensor and a graphic plug-and-play interface.¹²⁹

Acoustic emission (AE) can be used in rotating machinery for preventing cyclic fatigue cracks, friction, turbulence, material loss, cavitation, leakage, etc. to optimize predictive maintenance means. Smart AE sensors are capable of storing data for preprocessing, threshold comparisons, and pre-diagnosis algorithms.¹³⁰ A sound level meter for occupational and environmental safety applications is available with the frequency weightings A and C and the time weightings Fast (125ms) and Slow (1s). Despite its high functionality, it is easy to operate.¹³¹ This manufacturer is also showing a vibro-acoustic measuring system in the size of a USB hard drive with up to 16 measuring channels. An extremely low power consumption enables operation with a tablet PC.¹³² A software program measures, analyzes, and stores vibration and sound data. At the core of the analyzer is a powerful SQL database that reliably stores large quantities of data and allows various data and report management functions.¹³³

Chemical Sensors

Sensors for determining the concentration of combustible, explosive, toxic, or other gases have been in the focus of the SENSOR+TEST for years. In the reports submitted by the exhibitors this year, optical processes are again emphasized. Alongside catalytic sensors, there is a wide offering of wet chemical sensors for pH value, oxygen concentration, or conductivity.

A modular online analysis system automatically monitors the main parameters in drinking water purification. The basic version provides sensor cubes for five measuring values: pH-value, redox potential, conductivity, chlorine, and turbidity. The chlorine dioxide sensor cube contains a membrane covered amperometric MEMS sensor and can be used wherever oxidants are used for water purification.¹³⁴

Sensors that are used in space applications are subject to high vacuum conditions and must therefore be low outgassing. The patented "Silver Window" for high temperature seals sensors at room temperature and allows the sensors to breathe oxygen at high temperatures to prevent oxygen loss in the ceramics or crystal.¹³⁵ This supplier also has a multichannel monitoring system for hot oils at up to 150 °C. The debris sensor continuously detects magnetic abrasion as an indicator of wear and particles to prevent failure in hydraulic and lubrication systems and it also removes the debris.¹³⁶

Air Quality

A Rumanian supplier has developed a noninvasive breath test for early diagnosis of tropical diseases, such as hydatidosis, leishmaniasis, and dengue. A pool of gold nanoparticles, carbon nanotubes, and semiconducting nano-wires with high affinity towards the identified VOCs is selected and investigated by complementary chemical sensing techniques, such as mid-Infrared quantum cascade laser spectroscopy and different types of chemical gas sensors.¹³⁷

Every gas has a selective absorption in the UV and IR spectral range. This allows gas measuring systems to detect gases in the lower ppm range. Typical applications are the measurement of SO₂ and NO₂ in exhaust gas monitoring, SO₂ and CO₂ in stack gas detection, as well as CO and NO in combustion-engine and gas-generator control. The modules have a low power consumption, small

size, and fail-safe data communication via CANopen.¹³⁸ A compact NDIR-CO₂ sensor module makes use of two detectors for absolute measurements. As opposed to recent low-cost single element CO₂ sensor modules that measure relative CO₂ levels, this module can be used in an environment where the baseline CO₂ concentration is high, such as in hospitals, libraries, and other public facilities. Every sensor module is individually calibrated and provided with both a UART and I2C digital interface.¹³⁹ A smart carbon dioxide IR probe measures CO₂ concentrations in bio-incubators, cold-storage warehouses, greenhouses, and swimming pools, where reliable and exact measurements of the CO₂ concentration is required.¹⁴⁰ Smart NDIR gas sensors detect gas concentrations of CO₂, CO, CH₄, CH₂O, and volatile organic compounds (VOC).¹⁴¹ MEMS sensors for carbon dioxide and methane determine the conductivity of gas molecules by chemisorption and calorimetric effects at the sensitive layer surface. An integrated heating element under the active sensor surface consists of a polysilicon layer. Thanks to a sensitivity in the ppm range and their stability, these sensors are suited for measurements in air-pollution applications¹⁴² and gas leakage on mobile phones, computers, and other consumer electronics.¹⁴³

A market leader in the area of particle measurement has expanded its range of aerosol monitors with three new models. These are certified by European emission standards, such as MCERTS, and are designed for high quality requirements. All systems are packaged in a compact, weather-resistant housing. A heated inlet enables longer runtimes and a reliable measuring accuracy at different temperatures and changing humidity.¹⁴⁴ A laser-based sensor uses the light-scattering method to detect and count particles in the concentration range of 1 to 1.000 µg/m³ in real-time. The particle sensor provides information on the particle concentration for given particle concentration range.¹⁴⁵ A Chinese manufacturer is showing a laser-based particle sensor that can detect PM10, PM2.5, and PM1.0 particle concentrations as well as temperature and humidity in real-time.¹⁴⁶ The detection and identification of engineered nanoparticles (ENPs) in cosmetic products, food, and beverages require an efficient sample preparation and extraction from these complex materials. Analytical instrumentation combines two complementary transduction principles, one optical and one electrochemical. The signal patterns are then evaluated with chemometrical processes.¹⁴⁷

A module can monitor pollutants, oil residues, combustible gasses, as well as the water content in the air simultaneously. Thus it can monitor compressors for filling respiratory gas cylinders as well as the room air. Up to eight gas components as well as oil and water can be measured at the same time.¹⁴⁸ An oxygen measuring system determines the absolute oxygen content, i.e. the oxygen partial pressure, directly in the exhaust gas mixture. The obtained data can be used to optimize furnace combustion and to increase the efficiency as well as to monitor inert or enriched processes.¹⁴⁹ A Swiss manufacturer is showing an extremely resistant oxygen sensor and universal measuring electronics for electrochemical gas sensors.¹⁵⁰

A monitoring system based on photoacoustic spectroscopy measures the overall concentration of SF₆ gases in an enclosed area of a GIS substation to determine the leak rate. It is flexible and automatically compensates fluctuations in temperature, pressure, and water vapor concentrations. The system can be expanded to an area-monitoring system of up to 24 measuring locations.¹⁵¹ An

NDIR gas sensing bench from the same supplier detects the concentrations of all common refrigerants in the ambient air of refrigeration plants. It can be adapted easily and at low cost to all F-gases, without modifying the hardware. The system is based on the time-tested multi-gas sensor technology and is able to measure up to three gases in the infrared range and two with electrochemical sensors simultaneously.¹⁵² Two-channel detectors in a TO46 housing with an aperture opening of around 6 mm² are designed for gas analysis and leakage detection that can be used in stationary and mobile devices ranging from medicine to safety technology. The IR filters are located directly over the pyroelectric material in the center of the detector. This ensures that the optical channels are close together, increasing the optical performance and signal-to-noise distance.¹⁵³ A moisture, hydrogen, and temperature transmitter continuously monitors changes in the high-voltage transformer insulating oil and thus provides accurate real-time measurements and online trend data to quickly diagnose transformer errors to prevent damage.¹⁵⁴

A Japanese supplier at the SENSOR+TEST is showing an ultra-compact electrochemical carbon-monoxide sensor with a diameter of 13.9 mm and a thickness of 5.0 mm.¹⁵⁵ This enterprise has also developed an air-quality sensor that it claims has the worldwide lowest energy consumption of 15 mW. The small metal-oxide indoor air-quality sensor has a size of 3.2x2.5x0.99 mm³ and an increased sensitivity to gaseous air pollutants and can be used in air filters, air conditioners, and fire-detection alarm devices. Thanks to the miniaturization of the sensor chip, the device can be fitted in a standard surface-mounted box and is suited for mass production.¹⁵⁶

Measurement and Test Technology

The spectrum of products to be exhibited extends from complex measuring systems for test rigs, decentralized monitoring of constructions, machines, and plants to handheld measuring devices and equipment for process instrumentation – not to forget mobile measuring technology mainly used in automotive development. Visitors can experience this live during outdoor test drives on the fair grounds.

A digital, bus-capable measuring system can be used to connect electrochemical measuring cells, pellistors, and optical infrared cells as well as sensors for temperature, humidity, and pressure. These sensors are interchangeable and digitally pre-calibrated. An analysis module detects the connected sensor type and reads the data according to the respective measuring principle. An output module supports analog as well as digital outputs and various bus connections.¹⁵⁷

Magnetic field cameras are used for quality control and development of high-end permanent magnets and magnet systems for motors and generators as well as for medical and biotech applications. With an integrated MiniCube1D or MiniCube3D magnetic field camera, the high speed portal scanners measure and analyze the 3D magnetic field distribution of respectively flat magnets and magnet assemblies up to 300mm x 300mm and permanent magnet rotors.¹⁵⁸ A magnet measurement system measures magnets and magnetic components fully automatically and with high precision. The system can be individually adapted to the geometry of the magnetic elements. Supplementary components are used to measure weight and

geometry. The measuring range extends from 0.1 to 5 Am² at an exactitude of $\pm 0.5^\circ$.¹⁵⁹

Lock-in amplifiers can carry out more exact and quicker measurements over a large impedance range than is possible with conventional impedance analyzers. Another advantage is the brief measuring time of 20 ms per measuring point at a typical accuracy of 0.05%. Areas of application are the characterization of semiconductor components and materials, solar cells, dielectric spectroscopy, bioimpedance tasks, and microfluidic systems.¹⁶⁰

The smallest power analyzer for networked, distributed, and mobile applications opens new possibilities for online power computation, analysis of multiphase power systems, and test-bed links. The system continuously monitors electrical parameters, such as effective, idle, and apparent power, as well as power factors and efficiency, mechanical parameters, such as rotational speed, torque, etc., and also environmental parameters, such as interior, exterior, coil, and temperature. This is a solution for complex measuring tasks in the area of automotive development, lab tests, and test driving.¹⁶¹

A multitude of probes and signal cables can be connected to a mobile data logger with up to 16 input channels. These robust data loggers are characterized by a very low power consumption, so that battery-operated long-term measurements can be made over several years. Besides touchscreen operation, the device also provides powerful software for data collection and evaluation.¹⁶² A new 16-channel analog-to-CAN converter with a 16-bit resolution and a CAN output offers seamless integration in existing or new electrical systems. Four different factory configurations are available: an 8-channel Wheatstone bridge, 16-channel analog inputs, 6-channel analog inputs, or 8-channel analog and 8-channel PT1000 inputs.¹⁶³ A mobile, robust data logger is especially suited for noise, vibration, and harshness (NVH) measurements. It records four analog measuring channels with up to 40 kHz bandwidth as well as the signals from two video cameras, CAN and GPS data, as well as rotary speed. CFast or SDHC memory cards are used for data storage.¹⁶⁴

A two-channel Ethernet sensor interface can be used to connect sensors with mV/V, ± 5 V, ± 10 V, and 0/4-20 mA output signals. At a sampling rate of up to 2,500/s, highly dynamic measurements can be realized. A robust aluminum die-cast housing makes it suitable for heavy industrial applications.¹⁶⁵ A compact PCI multifunction card offers custom-tailored layout variants with a simultaneously sampling 18-bit analog input and up to 32 digital I/Os. Depending on the number of actively used channels, up to 200 kS/s and 1 MS/s can be sampled synchronously. Besides the predefined standard signals forms, arbitrary signals for hardware-in-the-loop applications can be generated.¹⁶⁶ An online spectral analysis of broadband sensor signals with integrated preamplifiers for voltage, current, strain gauge, piezoelectric ICP, inductive LVDT, and capacitive sensors is suited for all measuring tasks for which high precision and/or high signal bandwidths are required. The 24-bit converted data can be continuously sampled at a rate of 4 MHz per channel, stored, and transmitted to a PC.¹⁶⁷

Valuable insights can be gained out of huge amounts of measuring data. A software program for data indexing searches such data masses and puts the

results in an indexed database from which it can be queried.¹⁶⁸ An easy-to-operate analysis tool for data loggers displays measured data as a time diagram, frequency spectrum, power spectrum, power spectral density, frequency response function, cross spectrum, spectral density, autocorrelation, cross correlation, spectrogram, and octave analysis as well as functioning as a digital multimeter with a numeric display. It also has various trigger options.¹⁶⁹ A new version of a data-analysis and graphic program was improved for greater user friendliness and support for an HTML dialog with JavaScript. External applications, such as map services, LIMS systems, or Web-based database systems can be integrated using standard technologies.¹⁷⁰

Developers are faced with the challenge to integrate smaller and smaller components and circuits on smaller and smaller PCB areas. An alternative to conventional copper circuitry is offered by a new silver-ink technology in conjunction with a state-of-the-art printing process without the use of aggressive chemicals. It enables extremely fine conductors to be printed on PET, allows the attachment of fine-pitch (0.50mm) IC based components on PET via a proprietary bonding process using traditional SMT equipment. A UV-cured encapsulant is used to protect the solder joints to enable them to withstand vibration and mechanical shock.¹⁷¹ Highly miniaturized and energy-autarkic wireless sensor nodes can soon be embedded in the most diverse assemblies to be networked among each other or with the production and application environment. The smart sensor nodes support production processes, store operating parameters for intelligent maintenance concepts, provide effective protection against plagiarism, as well as secure networking with the periphery for the required data.¹⁷² A gateway is available with a preinstalled SIM card and optional data flat rate to integrate heterogeneous measuring systems and sensors simply and quickly in a common network. An MQTT broker enables individual data processing. Data export modules, feeds, views, and user management software complement the cloud platform.¹⁷³

Quality assurance in running production processes or in test labs can be diverse, specialized, complex, and flexible. Measuring and testing tasks play a central role here. A German manufacturer offers a sector-independent software platform for measurement, evaluation, and management of measuring tasks. A broad spectrum of functional components simplifies the optimization of the quality-assurance process.¹⁷⁴ The demand for competent product qualification according to DIN EN ISO 17025 is also increasing in the automotive industry. A German manufacturer's test center offers manifold environmental simulations, such as climate testing, vibration and mechanical shock testing, salt spray mist and condensation tests, electrical testing, as well as diverse system and function tests. The equipment is complemented by a dust chamber and a 160-kN shock vibration bench with a temperature overlay.¹⁷⁵

Monitoring Tasks

Measuring and testing technology is increasingly becoming a control instrument for production processes. Rather than just detect errors, measurement technology is applied more and more to prevent them from occurring at all. In this context, digitization and the inherent data acquisition and evaluation as well as the integration of measuring and testing data in superordinate systems, such as ERP and production planning, are already very advanced. If all parameter requirements

are met, enterprises can fully exploit the safety margin in the production process, which can possibly save making investments in more precise machinery.¹⁷⁶ For coordinate measuring equipment to attain its highest precision, temperature, temperature fluctuations, and humidity must be within certain limits. A temperature monitoring system of a big measuring system manufacturer not only detects the temperature to within 25 mK, but also provides a room temperature profile and outputs various temperature gradients in real-time.¹⁷⁷

GSM-2 is a combination of an autonomous data logger and a remote data transmission unit in one device. When linked to a pressure transmitter or water level sensor, GSM-2 can autonomously collect up-to-date measurement values for pressure and temperature (and optionally for conductivity), and then transmit this data via SMS, e-mail or FTP using the GSM wireless network (GPRS connection). The GSM-2 remote data transmission unit is normally used in hydrology and hydrogeology applications as a means of recording water levels or used in construction for pressure measurements.¹⁷⁸ Gateways with globally operational SIM-cards play a huge role in monitoring and maintenance applications of installed machines worldwide and build the foundation of brand-new business models. This gateway is able to transfer signals worldwide in adjustable time cycles to the own portal from data sources of all sorts like diagnostic messages of big machines or water levels of waters by mobile communications or Ethernet. The data can be called up by registered users with gateways which are identical in construction or directly by internet-ready devices or are being send automatically to a defined group of recipients.¹⁷⁹

A portable data acquisition system with 8 to 32 channels and two module slots for signal input cards offers all functions for recording, transmitting, and analysis of data in a single measuring device. It is suited for time and location independent logging tasks.¹⁸⁰ This manufacturer also offers a data acquisition system with smartphone compatibility, wireless Internet connectivity, stackable, networkable, and powerful data acquisition functionality. It can be used as a single stand-alone unit for troubleshooting and maintenance, stacked for high channel count jobs, or networked with multiple units for synchronized data recording in distributed data applications.¹⁸¹

Special Forum: Networked Measuring Technology for Mobile Applications

Modern cloud technologies can be used to store, evaluate, display, and integrate data. This applies especially for mobile work and processing machines demanding robustness, reliability, and long-term availability. Networking and data management via mobile wireless or WLAN technology are the prerequisites for recording the data from sensors and measuring systems, for preparation and transmission to servers and databases via Internet connections. The continuous availability of sensor data from machines and systems lets user draw conclusions in regard to their status and efficiency. The information can be called up on PCs, tables, or smartphones.

At the special forum "Networked Measuring for Mobile Applications" in Hall 5, visitors can obtain specific information on new products and development in the area of networked, mobile measuring technology. One supplier, for instance, is showing mobile vibration sensor and measuring systems. They detect changes in the vibration behavior before damage occurs. The sensors measure acceleration,

inclination, angle, or magnetic field in three axes. At a measuring frequency of 6.6 kHz and an integrated 16-bit A/D converter, they attain a resolution of up to 0.00002 g and thus analyze the smallest vibrations.¹⁸² Self-configuring wireless nodes are completely based on standards and require no manual configuration. They use SmartMesh wireless technology to automatically detect sensors and actuators per plug-and-play and integrate them in the low-power wireless network.¹⁸³ The SmartMesh IP network compliant to the 6LoWPAN standard offers the same reliability as wired networks and enables mesh wireless networks with an ultra-low energy consumption. This allows safe use in battery-operated IoT sensors with a batter life of over ten years.^{184 185}

Measuring technology in mobile hydraulics is subjected to particularly harsh environments. One manufacturer is presenting a pressure transducer especially designed for application in agricultural and forestry machines, construction machines, and injection molding plants. It has an ECE type approval for road use and is available in protection types up to IP69K. Extreme vibration and shock resistance combined with the high insulation voltage of AC 500 V guarantee reliable operation even in difficult conditions. The device is available in variable measuring ranges from 100 to 1,000 bar relative pressure and medium temperatures from -40 to +125 °C.¹⁸⁶

A mobile front-end measures multi-channel noise, performs vibration measurements, dynamic signal analysis, as well as data acquisition and monitoring tasks for noise and vibration, modal analysis, experimental strain and stress analysis, engine testing, and functional testing. Various analog I/O boards can be used for high-speed data acquisition, simultaneous sampling, signal conditioning for voltage inputs, and integration of IEPE sensor electronics, and bridge measurements.¹⁸⁷

Energy saving sensors, based on an open WiFi standard as per IEEE 802.11 b/g/n, for vibration, inclination, and shock, and an integrated data logger for up to 5 million data points are shown by another manufacturer at the SENSOR+TEST. The sensors meet all requirements for IoT (Internet of Things) applications and transmit the data by means of MQTT (message queuing telemetry transport) protocol.¹⁸⁸ An app-box detects, analyzes, alerts, and transmits data directly from an equipment cabinet into a business process on mobile devices or existing sensor clouds. This dramatically reduces the paths from machines or sensor data. Programming knowledge or sensor knowhow is no longer required.¹⁸⁹

A high-precision GNSS receiver can be used by driver assistance systems to detect and track vulnerable road users (VRU), such as pedestrians or cyclists, as well as to identify fixed objects, such as parking spaces. The achievable position accuracy is ± 2 cm. The 240-channel system makes use of all six GNSS systems, such as GPS, GLONASS, BeiDou, Galileo, QZSS, and SBAS, tracking and processing their signals.¹⁹⁰

Lidar systems for atmospheric measurements emit laser pulses and detects backscattered light from the atmosphere. The runtime of the signals is used to compute the distance to the measured object, such as clouds or aerosol strata. A Chinese supplier offers a lidar system for drones and the smart-device industry. Particularly attractive are the applications in altitude determination, drone terrain

tracking, and distance measurement. Unlike traditional altitude measurement solutions, such as GPS, barometers, and ultrasound, the module can detect and refresh the distance between a flying drone and crops on the ground in real time at a frequency of 500 times per second. It also ensures that the drone can fly at a stable height with an error of centimeters only. The module, which is free from the interference of temperature, ambient light change, and airflow.¹⁹¹

A French supplier offers a roll angle device based on an integrated 6-axes movement unit. It was originally developed for angle measurement for motorbike applications. Its light weight and its very compact housing help for an easiest installation. It has a 6-axes inertia sensor with high accuracy, an integrated roll-angle computation means, as well as a CAN interface with a programmable baud rate. The system can be mounted on the motorcycle axle, but with adapted kinematic models also for other angle, yaw, or pitch measurements on ground vehicles, cable cars, or UAVs (unmanned aerial vehicles).¹⁹²

Components for Sensors and Measurement

Calibration Systems

Complementing the vast spectrum of sensor, measuring, and testing technology, a broad range of calibration devices are also to be found at the SENSOR+TEST.

A data management solution for calibration and test labs standardizes the calibration process and generates calibration certificates at the press of a button. The software meets the requirements of DIN EN ISO/IEC 17025, ILAC, and DAkkS.¹⁹³ A German measuring device manufacturer has now received accreditation from Germany's National Accreditation Body (DAkkS) for the on-site calibration of temperature sensors. As an external calibration service provider, the enterprise meets the stringent requirements of CQI-9 for the automotive industry and AMS 2750 for the aerospace industry. The accredited temperature range for the calibration of temperature display devices extends from -270 °C to +2,500 °C. The smallest specifiable measurement uncertainty is between 0.25 and 2.5 K, depending on the simulated sensor type.¹⁹⁴

A solution for automatic calibration and functional end-of-line testing for linear magnetic position sensors is offered by an Italian manufacturer.¹⁹⁵ Modular pressure controllers are a simple and maintenance-free solution for the calibration of pressure gauges, pressure switches, and sensors. One supplier is now showing the first fully automatic, battery-powered pressure calibrator with an integrated pump and an automatic pressure control unit for on-site calibrations. The handheld device has a high accuracy, low weight, and a touchscreen.¹⁹⁶ A stand-alone device from the same supplier can manage from two to five pressure modules simultaneously and offers a quick and stable pressure control with an accuracy of 0.001%.¹⁹⁷

Products sold in the EU per length must be measured on calibrated machines that meet the European measuring device directive 2014/32/EU. This standard defines the requirements for measuring devices and data retention in regard to measuring accuracy, safety, and data integrity. Manufacturers that produce according to this standard can now obtain a system that measures length and speed with laser

precision and is capable of detecting changes in direction and standstill conditions.¹⁹⁸

Please note that this is only a small excerpt of the overall offerings at the SENSOR+TEST, as every specification of product properties implies the calibration of standards.

Conclusion

With about 600 exhibitors, the SENSOR+TEST is the most important measuring fair in Europe. From 30 May to 1 June, 2017, the AMA conferences SENSOR 2017 and the IRS² 2017 will be held parallel to the trade fair. Two expert forums in Halls 1 and 5, a Forum Innovative Testing and on 30 May in Hall 5 the special topic Networked Measuring for Mobile Applications. Live demonstrations are to be provided on all three days of the fair, including test driving by suppliers of mobile measuring technology at the outdoor Action Area. For research by topics, products, applications as well as an overview of the many programs, there are offers on the Internet (www.sensor-test.com), for mobile handhelds (m.sensor-test.com) and the social media (www.facebook.com/sensorplustest, www.twitter.com/sensorplustest). Follow the up-to-date information posted by the organizers and exhibitors during the fair with the hash tag #sensortest on Twitter.

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Press information incl. images on the SENSOR+TEST can be downloaded free of charge for journalists at www.sensor-test.com/press.

¹ Polytec GmbH, Waldbronn, Germany

² FBGS International N.V., Belgium

³ CiS Forschungsinstitut für Mikrosensorik GmbH, Erfurt, Germany

⁴ Micro-Epsilon Messtechnik GmbH & Co.KG, Ortenburg, Germany

⁵ SIOS Messtechnik GmbH, Ilmenau, Germany

⁶ Sitex 45 SRL, Bucharest, Rumania

⁷ Sensitec GmbH, Lahnau, Germany

⁸ a.b.jödden HmbH, Krefeld, Germany

⁹ TWK-Elektronik GmbH, Düsseldorf, Germany

¹⁰ Endrich Bauelemente Vertriebs GmbH, Nagold, Germany

¹¹ TWK-Elektronik GmbH, Düsseldorf, Germany

¹² TWK-Elektronik GmbH, Düsseldorf, Germany

¹³ Endrich Bauelemente Vertriebs GmbH, Nagold, Germany

¹⁴ Variohm EuroSensor Ltd.. Towcester, Northhamptonshire, Great Britain

¹⁵ Cedrat Technologies S.A., Meylan Cedex, France

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- ¹⁶ Cedrat Technologies S.A., Meylan Cedex, France
 - ¹⁷ BOGEN Electronic GmbH, Berlin, Germany
 - ¹⁸ Posital Fraba, Köln, Germany
 - ¹⁹ Intellisense (Xiamen) Microelectronics, Xiamen, China
 - ²⁰ TEAC Europe GmbH, Wiesbaden-Erbenheim, Germany
 - ²¹ Testing Technologies s.r.l., Torino, Italy
 - ²² KELLER Gesellschaft für Druckmesstechnik mbH, Jestetten, Germany
 - ²³ Micro Sensor Co., Ltd., Baoji, Shaanxi, China
 - ²⁴ Sensitec GmbH, Lahnau, Germany
 - ²⁵ Pressure-Sensor.com, Newport News, Virginia, USA
 - ²⁶ CiS Forschungsinstitut für Mikrosensorik GmbH, Erfurt, Germany
 - ²⁷ Shanghai Zhaohui Pressure Apparatus Co. Ltd, Shanghai, China
 - ²⁸ Micro Sensor Co., Ltd., Baoji, Shaanxi, China
 - ²⁹ Analog Microelectronics GmbH, Mainz, Germany
 - ³⁰ Sensirion AG, Stäfa ZH, Switzerland
 - ³¹ KELLER Gesellschaft für Druckmesstechnik GmbH, Jestetten, Germany
 - ³² ACS-Control-System GmbH, Eggenfelden, Germany
 - ³³ Variohm EuroSensor Ltd., Towcester, Northhamptonshire NN, Great Britain
 - ³⁴ H.Heinz Meßwiderstände GmbH, Elgersburg, Germany
 - ³⁵ STS Sensoren Transmitter Systeme GmbH, Sindelfingen, Germany
 - ³⁶ Nanjing Gaohua Technology Co. Ltd., Nanjing, China
 - ³⁷ Honeywell, Newhouse, Motherwell ML1 5SB, Great Britain
 - ³⁸ Honeywell, Newhouse, Motherwell ML1 5SB, Great Britain
 - ³⁹ STS Sensoren Transmitter Systeme GmbH, Sindelfingen
 - ⁴⁰ Mensaura, Oettingen, Germany
 - ⁴¹ Mensaura, Oettingen, Germany
 - ⁴² Sensirion AG, Stäfa ZH, Switzerland
 - ⁴³ Sensaggio S.r.l., Milano, Italy
 - ⁴⁴ Sitex 45 SRL, Bucharest, Rumania
 - ⁴⁵ Pewatron, Zürich, Switzerland
 - ⁴⁶ STS Sensoren Transmitter Systeme GmbH, Sindelfingen, Germany
 - ⁴⁷ Cedrat Technologies S.A., Meylan Cedex, France
 - ⁴⁸ Jumo GmbH & Co.KG, Fulda, Germany
 - ⁴⁹ Honeywell, Newhouse, Motherwell ML1 5SB, Great Britain
 - ⁵⁰ HTW des Saarlandes, Saarbrücken, Germany
 - ⁵¹ Lorenz Messtechnik GmbH, Alfdorf, Germany
 - ⁵² Manner Sensortelemetrie GmbH, Spaichingen, Germany
 - ⁵³ ME-Meßsysteme GmbH, Hennigsdorf, Germany
 - ⁵⁴ SITEX 45 SRL, Bucharest, Rumania
 - ⁵⁵ CiS Forschungsinstitut für Mikrosensorik GmbH, Erfurt, Germany
 - ⁵⁶ Laser Components GmbH, Olching, Germany
 - ⁵⁷ disynet GmbH, Brüggen, Germany
 - ⁵⁸ disynet GmbH, Brüggen, Germany
 - ⁵⁹ disynet GmbH, Brüggen, Germany
 - ⁶⁰ Metra Meß- und Frequenztechnik in Radebeul e. K., Radebeul, Germany
 - ⁶¹ TWK-Elektronik GmbH, Düsseldorf, Germany
 - ⁶² SIOS Meßtechnik GmbH, Ilmenau, Germany
 - ⁶³ Polytec GmbH, Waldbronn, Germany

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- 64 IfTA GmbH, Gröbenzell, Germany
 - 65 GEPA GmbH, Grünwald, Germany
 - 66 disynet GmbH, Brüggen, Germany
 - 67 a.b.jödden gmbh, Krefeld, Germany
 - 68 m+p international Mess- und Rechnertechnik GmbH, Hannover, Germany
 - 69 Bürkert GmbH & Co. KG, Ingelfingen, Germany
 - 70 FlowVision GmbH, Altdorf, Germany
 - 71 Mensaura, Oettingen, Germany
 - 72 Mensaura, Oettingen, Germany
 - 73 Shanghai JNL Industry Co., Ltd., Shanghai, China
 - 74 Honeywell, Newhouse, Motherwell ML1 5SB, Great Britain
 - 75 JUMO GmbH & Co. KG, Fulda, Germany
 - 76 Texys International, Varennes-Vauzelles, France
 - 77 Texys International, Varennes-Vauzelles, France
 - 78 Manner Sensortelemetrie GmbH, Spaichingen, Germany
 - 79 Oriental System Technology Inc., Hsinchu, Taiwan
 - 80 Oriental System Technology Inc., Hsinchu, Taiwan
 - 81 Endrich Bauelemente Vertriebs GmbH, Nagold, Germany
 - 82 Delta-R GmbH, Mannheim, Germany
 - 83 LumaSense Technologies GmbH, Frankfurt / Main, Germany
 - 84 DIAS Infrared GmbH, Dresden, Germany
 - 85 DIAS Infrared GmbH, Dresden, Germany
 - 86 LumaSense Technologies GmbH, Frankfurt / Main, Germany
 - 87 DIAS Infrared GmbH, Dresden, Germany
 - 88 LumaSense Technologies GmbH, Frankfurt / Main, Germany
 - 89 DIAS Infrared GmbH, Dresden, Germany
 - 90 Laser Components GmbH, Olching, Germany
 - 91 Laser Components GmbH, Olching, Germany
 - 92 InfraTec GmbH, Infrarotsensorik und Messtechnik, Dresden, Germany
 - 93 IDT Integrated Device Technology, Vimercate, Italy
 - 94 ZIROX Sensoren & Elektronik GmbH, Greifswald, Germany
 - 95 Oriental System Technology Inc., Hsinchu, Taiwan
 - 96 Laser Components GmbH, Olching, Germany
 - 97 Hangzhou Multi IR Technology Co, Ltd., Hangzhou, China
 - 98 KELLER Gesellschaft für Druckmesstechnik mbH, Jestetten, Germany
 - 99 SAF Tehnika JSC, Riga, Lettland
 - 100 Nokeval Oy, Nokia, Finland
 - 101 Sensirion AG, Stäfa ZH, Switzerland
 - 102 SIOS Meßtechnik GmbH, Ilmenau, Germany
 - 103 Excelitas Technologies GmbH & Co. KG, Wiesbaden, Germany
 - 104 inno-spec GmbH, Nürnberg, Germany
 - 105 Polytec GmbH, Waldbronn, Germany
 - 106 Laser Components GmbH, Olching, Germany
 - 107 Laser Components GmbH, Olching, Germany
 - 108 Laser Components GmbH, Olching, Germany
 - 109 Mountain Photonics GmbH, Landsberg am Lech, Germany
 - 110 ET Enterprises Limited, Uxbridge UB8 2YF, Great Britain
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- 112 ET Enterprises Limited, Uxbridge UB8 2YF, Great Britain
 - 113 EQ Photonics GmbH, Eching, Germany
 - 114 Laser Components GmbH, Olching, Germany
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 - 116 CiS Forschungsinstitut für Mikrosensorik GmbH, Erfurt, Germany
 - 117 Silicann Systems GmbH, Rostock, Germany
 - 118 Laser Components GmbH, Olching, Germany
 - 119 Attocube Systems AG, Munich, Germany
 - 120 Laser Components GmbH, Olching, Germany
 - 121 Laser Components GmbH, Olching, Germany
 - 122 Vortex Optical Coatings Ltd., Hinckley, Leicestershire LE10 1BB, Great Britain
 - 123 Vortex Optical Coatings Ltd., Hinckley, Leicestershire LE10 1BB, Great Britain
 - 124 Daheng New Epoch Technology, Inc., Beijing, China
 - 125 Sitex 45 SRL, Bucharest, Rumania
 - 126 Sitex 45 SRL, Bucharest, Rumania
 - 127 IRLYNX, Montbonnot, France
 - 128 IRLYNX, Montbonnot, France
 - 129 Toposens GmbH, Munich, Germany
 - 130 SITEX 45 SRL, Bucharest, Rumania
 - 131 SINUS Messtechnik GmbH, Leipzig, Germany
 - 132 SINUS Messtechnik GmbH, Leipzig, Germany
 - 133 m+p international Mess- und Rechnertechnik GmbH, Hannover, Germany
 - 134 Bürkert GmbH & Co. KG, Ingelfingen, Germany
 - 135 disynet GmbH, Brüggen, Germany
 - 136 disynet GmbH, Brüggen, Germany
 - 137 Sitex 45 SRL, Bucharest, Rumania
 - 138 Wi.Tec-Sensorik GmbH, Wesel, Germany
 - 139 Figaro Engineering Inc., Mino, Osaka, Japan
 - 140 Vaisala Oyj, Vantaa, Finland
 - 141 Hangzhou Multi IR Technology Co., Ltd., Hangzhou, China
 - 142 Sitex 45 SRL, Bucharest, Rumania
 - 143 Zhengzhou Winsen Electronics Technology Co., Ltd., Zhengzhou, China
 - 144 Driesen+Kern GmbH, Bad Bramstedt, Germany
 - 145 Honeywell, Newhouse, Motherwell ML1 5SB, Great Britain
 - 146 Hangzhou Multi IR Technology Co, Ltd., Hangzhou, China
 - 147 Sitex 45 SRL, Bucharest, Rumania
 - 148 Knestel Technologie & Elektronik GmbH, Hopferbach, Germany
 - 149 LogiDataTech Systems GmbH & Co. KG, Baden-Baden, Germany
 - 150 Membrapor AG, Wallisellen, Switzerland
 - 151 LumaSense Technologies GmbH, Frankfurt, Germany
 - 152 LumaSense Technologies GmbH, Frankfurt, Germany
 - 153 InfraTec GmbH, Infrarotsensorik und Messtechnik, Dresden, Germany
 - 154 Vaisala Oyj, Vantaa, Finland
 - 155 Figaro Engineering Inc., Mino, Osaka, Japan
 - 156 Figaro Engineering Inc., Mino, Osaka, Japan
 - 157 LogiDataTech Systems GmbH & Co. KG, Baden-Baden, Germany
 - 158 Magcam NV, Leuven, Belgium
 - 159 Matesy GmbH, Jena, Germany

- ¹⁶⁰ Zurich Instruments AG, Zürich, Switzerland
- ¹⁶¹ Dewetron GmbH, Ostfildern, Germany
- ¹⁶² Driesen+Kern GmbH, Bad Bramstedt, Germany
- ¹⁶³ Texys International, Varennes-Vauzelles, France
- ¹⁶⁴ TEAC Europe GmbH, Wiesbaden-Erbenheim, Germany
- ¹⁶⁵ Lorenz Messtechnik GmbH, Alfdorf, Germany
- ¹⁶⁶ Alldaq - a division of Allnet GmbH, Germering, Germany
- ¹⁶⁷ LTT Labortechnik Tasler GmbH, Würzburg, Germany
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- ¹⁷⁰ Additive Soft- und Hardware für Technik und Wissenschaft GmbH, Friedrichsdorf, Germany
- ¹⁷¹ Molex Deutschland GmbH, Walldorf, Germany
- ¹⁷² Strategische Partnerschaft Sensorik e.V., Regensburg, Germany
- ¹⁷³ Measure2go, A brand of taskit GmbH, Berlin, Germany
- ¹⁷⁴ NEST Electronics GmbH, Bruckmühl, Germany
- ¹⁷⁵ Weber GmbH, Aschaffenburg, Germany
- ¹⁷⁶ Carl Zeiss 3D Automation GmbH, Aalen, Germany
- ¹⁷⁷ Carl Zeiss 3D Automation GmbH, Aalen, Germany
- ¹⁷⁸ KELLER Gesellschaft für Druckmesstechnik mbH, Jestetten, Germany
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- ¹⁸² GEPA mbH, Grünwald, Germany
- ¹⁸³ Linear Technology GmbH, Ismaning, Germany
- ¹⁸⁴ Linear Technology GmbH, Ismaning, Germany
- ¹⁸⁵ Schildknecht AG, Murr, Germany
- ¹⁸⁶ Jumo GmbH & Co.KG, Fulda, Germany
- ¹⁸⁷ m+p international Mess- und Rechnerntechnik GmbH, Hannover, Germany
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