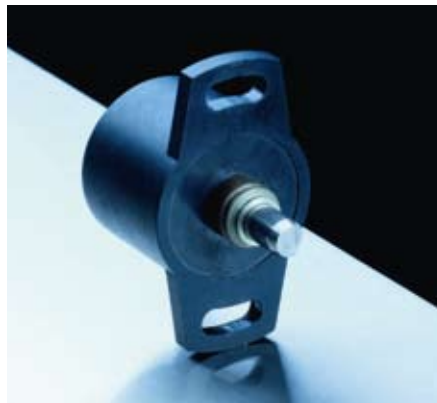


TECHNIK



Position Transducers and Rotary Sensors

- non-contacting
- touchless
- potentiometric



novotechnik
Siedle Group

Contents

4



Position Transducers and Angle Sensors for Off Road Vehicles

The automation trend in off road vehicles continues. Examples can be seen in road construction, agricultural, forestry and railroad equipment. Automation makes it possible to produce inexpensively with consistent quality in the long run. Working equipment with increased performance also places increasingly demanding requirements on the components used.

17



Signal Processing in many Variations

Sensor elements often supply a relatively low level signal. It is advisable to convert these signals or process them further directly on or at least near the sensor to be able to transmit them interference-free over longer distances. Potentiometric position transducers matched to signal processors are a typical example of this approach. With decentralized system structures, it is also advisable to display the measured value and to immediately process it further directly on site.

20



On the Road with London Taxis

Today the operating principles frequently used for contactless angle detection include magnetic methods. They supply absolute measured values, operate reliably even under harsh environmental conditions and, due to the low costs compared to other measuring methods, are suitable not only for countless measurements mechanical and process plant engineering, but also for use in mobile applications.

22



Segway Human Transporter – A Vehicle that's Fun to Drive

The Segway Human Transporter (HT) is a single-axle, self-stabilising scooter, which has gained many fans over the past several years. Fitness is unnecessary, as the scooters are electrically driven and healthy people won't have any problems with coordination, either. The vehicle keeps itself and the drive in balance; braking, acceleration and steering are controlled by the operator shifting his weight or tilting his body.

26



Linear and Rotary Position Transducers in Transportation Technology

Transportation technology is an important topic in the construction of the Airbus A380 jumbo jet. Many different assemblies are transported from development and production plants in England, Spain, France and Germany to Hamburg (Germany) or Toulouse (France) for final production. Component parts are often extremely large, and transport of such components is very demanding. Airbus wing assemblies, for example, are produced at the English plant in Broughton. They are more than 45 m long and 11 m wide.

Rugged, Reliable and Inexpensive Solutions are in Demand: Position Transducers and Angle Sensors for Off Road Vehicles	4
From Single-Turn to Multiturn: Contactless Rotary Sensor Technology also for Mass Markets	6
Broad Range of Interfaces, High Speeds, Rugged and Measuring Lengths up to 4,500 mm: Magnetostrictive Transducers – Ideal for Long Measurement Distances	8
Gearless Multiturn Sensors now without External Power Supply for the first Time: Rotation Counter uses GMR Effect	10
Advancing New Technologies: Position and Angle Measuring Technology for the Automotive Industry	12
Individual and Simple: Inexpensive Angle Sensors with a Broad Range of Uses	15
From Measuring Transducer to Programmable On-Site Display: Signal Processing in many Variations	17
Rugged, Reliable and, if necessary, also Redundant: Precision Rotary Transducers for the Heavy-Duty Segment	19
Magnetic Rotary Sensor in Use: On the Road with London Taxis	20
Sensor Potentiometers ensure Safe Cornering: Segway Human Transporter – A Vehicle that's Fun to Drive	22
Improved Engine Performance with Increased Environmental Protection: Potentiometers Accelerate	24
The Right Sensor for any Position Detection: Linear and Rotary Position Transducers in Transportation Technology	26
Potentiometers as Unmatched Problem-Solvers: Position Measurement under Extreme Conditions	28
Contactless, Magnetostrictive Position Transducers with a Measuring Path of up to 2,500 mm: For Direct Integration in Pneumatic and Hydraulic Cylinders	30

Imprint

Publisher

HW-Verlag
P.O.Box 60
86407 Mering
GERMANY
Tel. +49 8233 3276 1
Fax +49 8233 3276 2

Text

Dipl.-Ing. (FH) Dietrich Homburg
Ellen-Christine Reiff, M.A.

both Redaktionsbüro Stutensee
Am Hasenbiel
76297 Stutensee
GERMANY
www.rbsonline.de

Layout

close-cut multimedia design
Kiefernweg 10
76356 Weingarten
GERMANY
www.close-cut.de

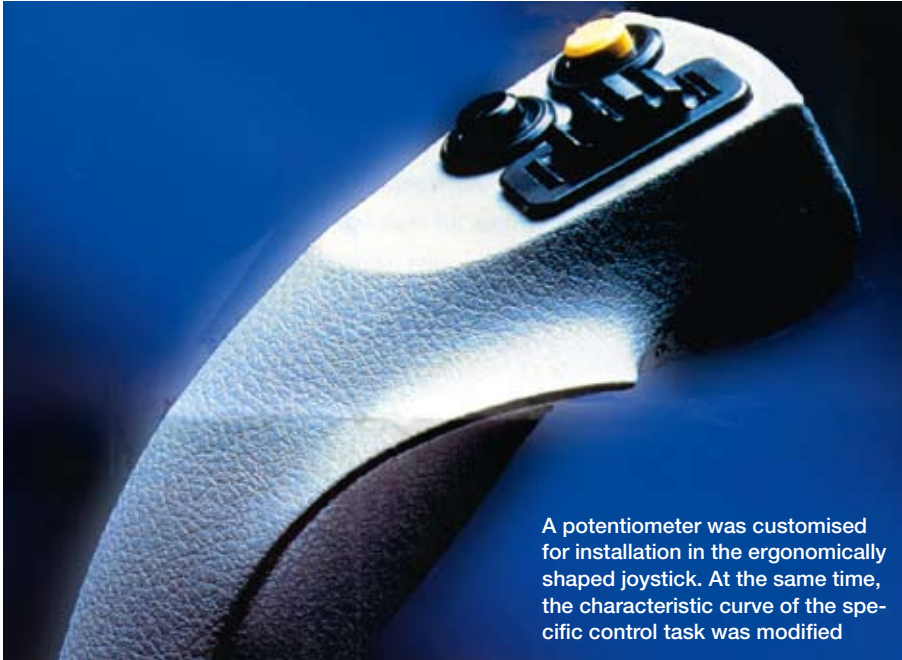
Production

VeBu Druck + Medien GmbH
Am Reutele 18
88427 Bad Schussenried
GERMANY
Tel. +49 7583 9406 0
Fax +49 7583 9406 35

For technical documentation and
information on the described systems
and products, please contact:

Novotechnik
Messwertaufnehmer OHG
P.O.Box 4220
73745 Ostfildern (Ruit)
GERMANY
Tel. +49 711 4489 0
Fax +49 711 4489 118
info@novotechnik.de
www.novotechnik.de

Rugged, Reliable and Inexpensive Solutions are in Demand: Position Transducers and Angle Sensors for Off Road Vehicles



A potentiometer was customised for installation in the ergonomically shaped joystick. At the same time, the characteristic curve of the specific control task was modified

Position transducers and angle sensors in mobile applications must not only be precise, they are also required to work as reliably and maintenance-free when subjected to heavy vibrations, moisture and extreme temperature fluctuations. In addition, desire for affordable technology also plays a major role. Current development work focuses on simple connection technology, features matched to the application and a rugged design.

The right operating principle for every task

In the process it becomes apparent that the conductive plastic potentiometers are still important systems in many applications in

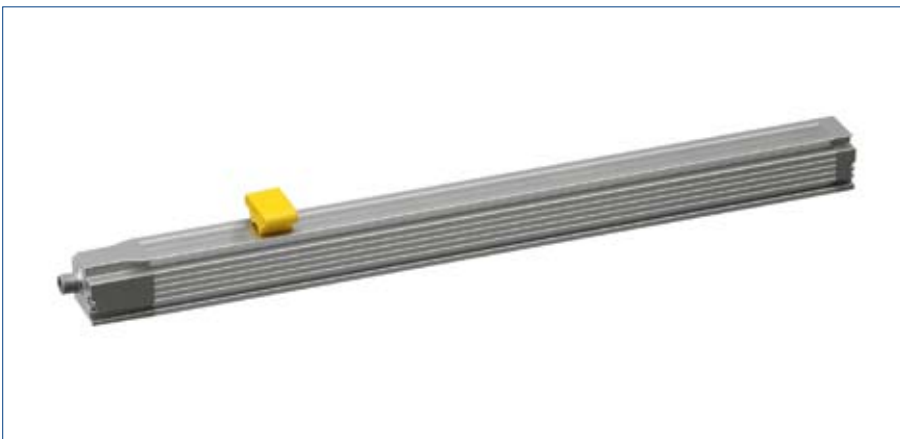
the field of off road mobile machines. However, in highly dynamic applications, during continuously rotating or high-frequency actuation, contactless processes, which operate virtually wear-free, are increasingly more interesting. Depending on the application case, different operating principles are used in the process, e.g. inductive or magnetic processes. This means that instead of initially implementing paths or angles via levers, hinges or cables subject to wearing and debris in order to detect them at a suitable location, it is considerably simpler to pick up the measured value directly with a rugged sensor. The wearing of the mechanical design is avoided, dirt and debris become less critical, even if the machine cannot be cleaned at short intervals and even in the

The automation trend in off road vehicles continues. Examples can be seen in road construction, agricultural, forestry and railroad equipment. Automation makes it possible to produce inexpensively with consistent quality in the long run. Working equipment with increased performance also places increasingly demanding requirements on the components used. These components must provide increased working speeds, higher machine utilization levels and a larger range of functions. These requirements have had effects on the development of the sensor technology used in these special markets.

case of more demanding requirements on the throughput or speed. Position detection does not become a problem.

Potentiometer for toughest environmental conditions: Railway track-laying system

Linear conductive plastic potentiometers also often contribute to design simplifications. The LWX position transducer was developed especially for applications under tough environmental conditions. Thanks to a replaceable gasket on the push rod and a patented volume compensation which reliably prevents the penetration of dust, water and oil, the sensor meets the requirements of the protection type IP67.



Magnetostrictive position transducers, with their reliability and accuracy in mobile applications, also play an important role among the durable transducers. These sensors are especially well-suited when it is difficult to provide a mechanical connection between the sensor and the moving part

The conductive plastic potentiometer was able to prove its durability in practical use. In case of the railway track-laying system, the sensor detects the penetration depth of the spikes with which the rails are secured. The spikes are pounded in pneumatically and the conductive plastic potentiometer is directly mounted on the outside of the hammer cylinder. The heavy vibrations and moisture, dust and extreme temperature differences in outside use, do not impair the sensors operation. Other interesting applications for linear potentiometers can also be found in agricultural machines including sprayer arm positioning, and plow plate alignment. The position transducer can be attached on the outside of the cylinder and can, for example, therefore replace mechanical indicators.

Conductive plastic potentiometers in control and operating units

Potentiometers are also used as a versatile problem-solver on off road vehicles in other areas. They can easily be integrated in control and operating units of cranes, farm tractors and forestry machines and are easily

The LWX position transducer was developed especially for applications under tough environmental conditions. Thanks to a replaceable gasket on the push rod and patented volume compensation, the sensor meets the requirements of the protection class IP67



modified if necessary. An increased torque on the potentiometer shaft protects against accidental misadjustment. Other features include the addition of integrated switch functions which often eliminate the need for separate external microswitches.

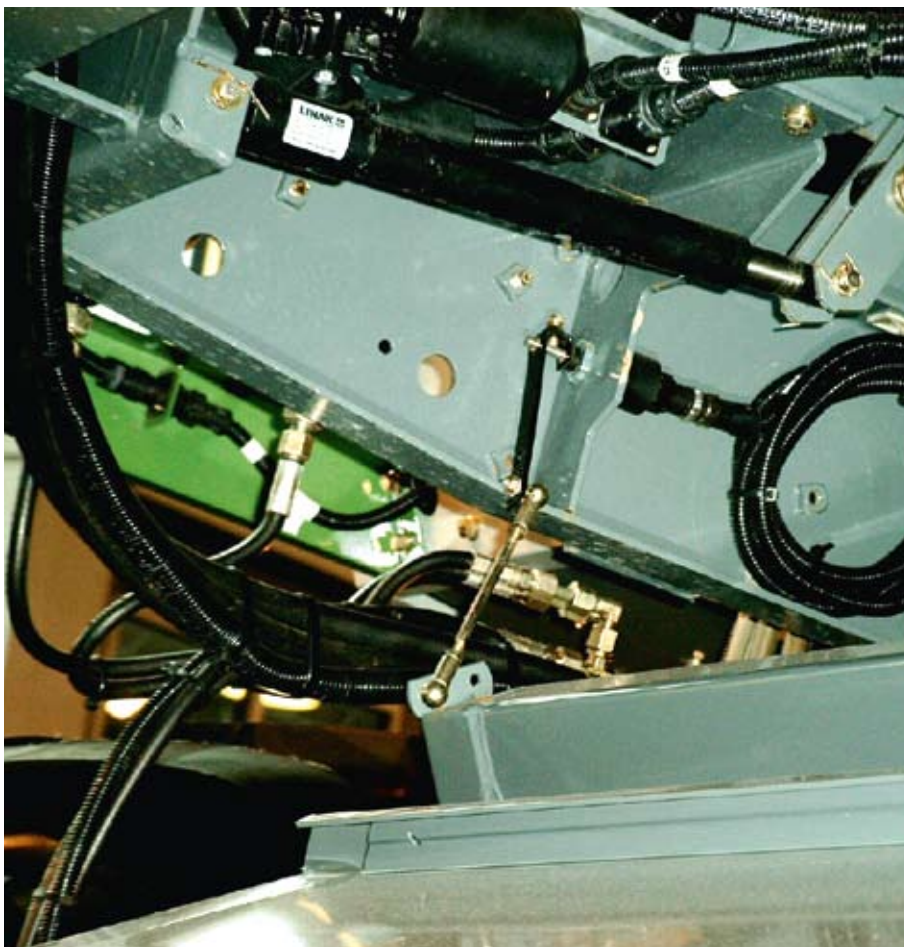
With joysticks on off road forestry machines for example, it was possible to integrate a thumbwheel controller as an option. With a standard potentiometer, it would not have been possible to solve

the problem due to the strictly specified dimensions. The potentiometer used was customised for installation in the ergonomically shaped joystick, and at the same time, the characteristic curve of the specific control task was also modified.

Magnetostrictive position transducers: broad range of applications

Magnetostrictive position transducers, with their reliability and accuracy in mobile applications, also play an important role among the durable transducers. These sensors are especially well-suited when it is difficult to provide a mechanical connection between the sensor and the moving part, for example on mobile saws, or lifting devices. Magnetostrictive position transducers of the latest generation not only have the monitoring and linearization of the measured values integrated, they also guarantee a high degree of safety and dynamics during the measured value transmission.

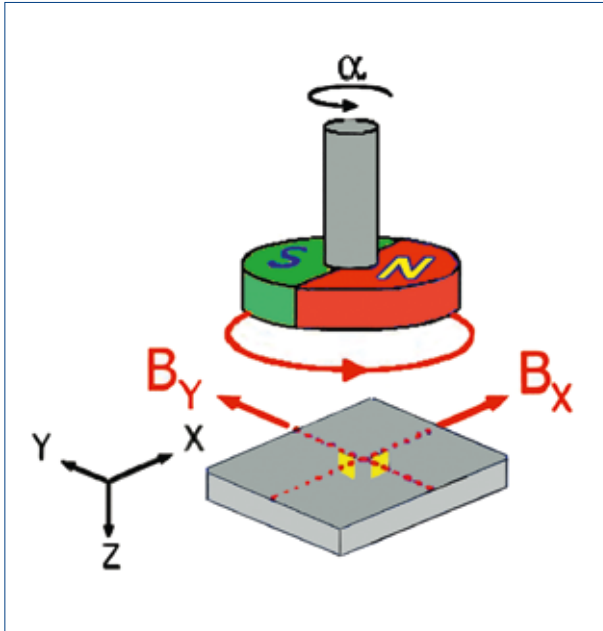
The magnetostrictive position transducers of the TLM and TMI series are offered with effective lengths up to 4.5 m with a resolution independent of their length of 5 μm . The magnetostrictive position transducers of the TIM series are especially designed for the mobile segment and are offered with effective lengths of up to 2.5 m. The TLM, TMI and TIM series are insensitive to shocks and vibrations and comply with the protection class IP67. Any desired adjustment speed of the position sensor can be set. It does not have any mechanical connection to the position transducer and can be integrated directly to the moving machine part. These systems are tolerant to misalignment in both vertical and horizontal directions. If required, the position transducer of the TLM and TMI series can also operate with several position markers.



Instead of implementing paths or angles via a mechanism subject to wearing and debris in order to detect them at a suitable location; it is considerably easier to pick up the measured value directly with a rugged sensor

From Single-Turn to Multiturn:

Non-Contact Rotary Sensor Technology Moving into High-Volume Applications



Operating principles used frequently in today's non-contact angle detection include magnetic systems. They operate non-contacting, i.e. without mechanical wear and provide absolute measurement values. Non-contacting magnetic principles are reliable even under harsh environmental conditions and, due to their low cost compared to other measurement principles, are an excellent choice for high-volume applications. The typical markets include countless applications in mechanical and process plant engineering, but also mobile applications, e.g. in vehicle engineering or on naval vessels and pleasure boats. Thanks to their form fit compatibility, they can often replace conventional potentiometer technology, which tends to be susceptible to wear in high vibration environments.

A magnet is mounted on the rotating shaft. Depending on the angle of rotation, the orientation of the magnetic field changes, and with it the signal voltage of the sensor element, which basically consists of two Hall sensors arranged vertically to each other

The necessity for measuring angles has long played a major part in technology. Angle measurement has long played a major part in technology. A basic distinction can be made between the measurement of up to a full rotation or multiple rotations. Basically, one can distinguish between the single-turn sensors with measurements of up to a full rotation and multi-turn sensor with the ability to detect multiple rotations. In both cases non-contacting principles provide potential users with excellent pricing.

Magnetic angle sensors for 360°

There are various methods for mechanical angular measurement, however the basic design initially appears to be almost identical. A magnet is attached to a rotating axis. The different shape of the field lines dependent on the angle of rotation is detected by a sensor element. The selection of this sensor element is decisive for the detection range of the angle sensor. With the optimization of Hall sensor elements (see text in box) and evaluation electronics matched to them, Novotechnik has succeeded in developing extremely rugged, reliable and high-precision sensors in this area.

A magnet is also attached to the rotating axis with the NOVO Hall sensors. Depending on the angle of rotation the orientation of the magnetic field and the signal voltage of the sensor element changes. The element

consists of two Hall elements arranged vertically to each other. This enables a clear assignment of each angular position over a full rotation. The respective voltage change is converted into an analogue signal proportional to the angle of rotation within the sensor IC. The sensors operate internally with a resolution of 14 bits and an independent linearity of typically $\pm 0.3\%$. They are insensitive to contamination or moisture (IP54 or IP65) and are designed so that play-free connection is easily possible. Oblong holes on the housing simplify adjustment.

There are suitable versions for both industrial and mobile applications. The RFC 4800, for example, complies with all EMC specifications required for mobile applications, meets the requirements for



The RFC 4800 complies with all EMC specifications required in mobile applications

The Hall effect for single-turns

The Hall effect was discovered in 1879 by the physicist Edwin Hall. A magnetic field arranged vertically to a conductor with current flowing through the conductor deflects the current. Electric motors, for example, operate according to this principle. Within the conductor, there is an analogous feature. The current lines are displaced to one side. The displacement effect results in a displacement voltage laterally to the current flow. This effect is especially pronounced in the Hall Generators. However, as the signal change in the sensor elements based on the Hall effect which function according to this principle is not linear to the angle of rotation, only restricted detection of angles was possible in the past. By optimising the sensor elements and the evaluation electronics, sensors are available on the market today which are suitable for detecting measurement angles of up to a full 360°.

ingression protection up to IP69 and, with various mechanisms and plug modules, can easily be integrated in various applications. Different interfaces are also available for the miniature version RFC 4000. With an overall height of 7 mm, this sensor is extremely flat and can easily be integrated even under tight installation conditions.

New-generation contactless rotation counters

Many applications require angle measurements beyond a full rotation. Depending on the application, today's common multi-turn sensors have functional limitations. For example, the typical low-cost 10-turn potentiometers frequently do not meet the requirements for resolution and reliability. Some optical encoder solutions are too expensive for many applications. A new patented rotation counter principle based on Giant Magnetoresistance solves the problem.

The new sensor system supplies absolute position values and is well-suited, for example, for use in true-power-on systems, as it requires no reference signals of any kind. The maintenance-free and cost efficient design opens up new possibilities in the automotive sector, for example in electronic steering systems. The ability to magnetically detect up to 16 rotations is also of interest for industrial applications.

The design principle of the magnetic rotation counter is easy to understand and is described in detail in the technical article "Rotation counter uses GMR effect" on Page 10. In addition to the angle of rotation signal, the magnetic multiturn sensor can also count and permanently store up to 16 rotations in the powerless state without a buffer battery and without a gear unit. Concepts for higher rotation counts (up to 12 bits, which is equivalent to 4,096 rotations) are already available and will be realized in the next two to three years. The advantages of the new multiturn technology can already be used in a large number of industrial and automotive applications today.

The multi turn technology was implemented first in the RSM2800 series, which uses the extremely compact 28 mm diameter design of the familiar RSC 2800 single-turn potentiometer. The angular range of the series can be selected by the customer, covers between 2 and 16 rotations and maps the measured angle as a constant, analogue characteristic curve. Various supply voltage and output voltage ranges are being currently realized.

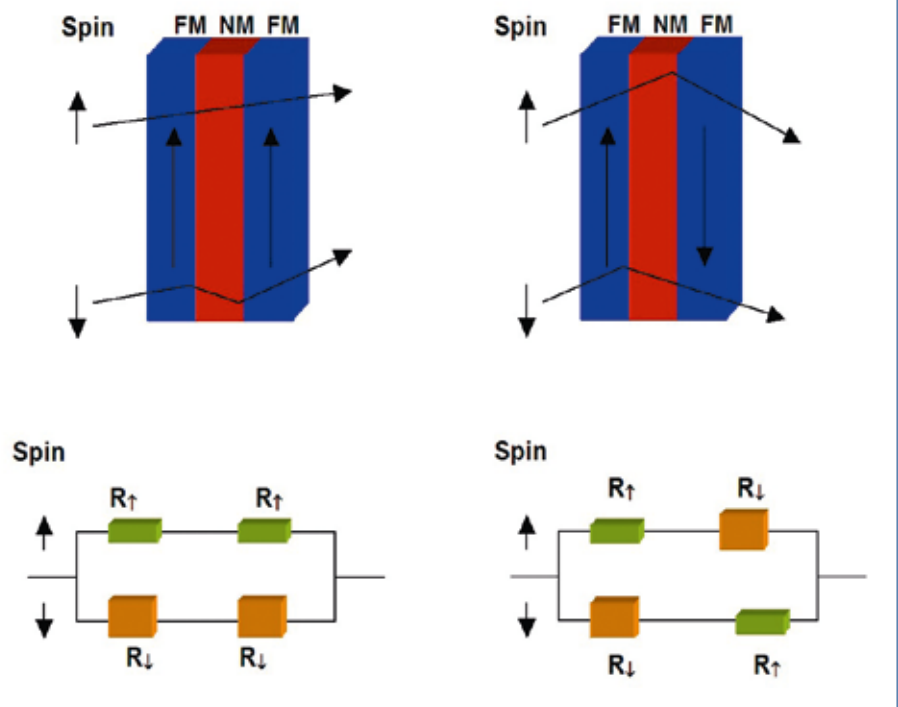
The advantages of the new multiturn can be used in a large number of industrial and automotive applications. In automobiles or off-road vehicles the steering angle can be detected over several rotations of the steering wheel. The multi-turn sensors are also suitable for commercial door systems, linear or rotary actuators and drives for fittings, flaps or valves



The GMR effect for multiturns

The GMR (Giant Magnetoresistance) effect is a phenomenon in quantum mechanics that is observed in thin film structures of ferromagnetic and non-ferromagnetic layers. In a heterogeneous structure consisting of two magnetic layers (sensor layer and reference layer), which are separated by a non-magnetic only a few atom layers thick, the magnetic torques of the two layers take up a position relative to each other as soon as they are subjected to an external magnetic field. The reference layer orientation is held in place by an artificial antiferromagnet (AAF). As a result, the sensor layer aligns either parallel or anti-parallel to it. The electrical resistance changes dramatically when the magnetic torques fold over in this "sandwich". The resistance drops to a minimal value, when they are positioned parallel to each other, with an anti-parallel alignment it reaches its maximum. The magnetization state of this kind of structure can easily be determined with a resistive measurement.

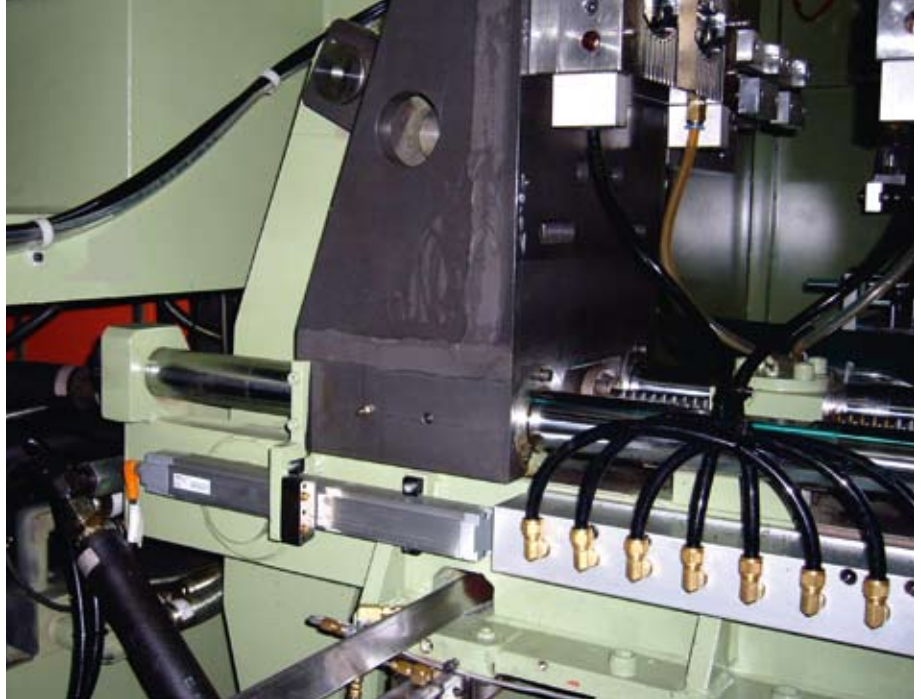
Layer structure of the GMR element.



Broad Range of Interfaces, High Speeds, Rugged and Measuring Lengths up to 4,500 mm:

Magnetostrictive Transducers – Ideal for Long Measurement Distances

For some linear measuring applications it is difficult or impossible to mechanically connect the component to be measured to the linear transducer, especially over long measurement distances. In these cases, magnetostrictive position transducers are often an appropriate solution. Position is transmitted by a magnetic field from a magnet mounted on the moving component. There is no mechanical connection of any type, making this a fully contactless, or “touchless” sensing technology.



This contactless relationship between the magnetic position marker and the magnetostrictive position transducer itself opens up great freedom in design and installation. For example, the transducer unit might be installed in a machine bed with the position marker mounted on the moving part. Because of the magnetic field linkage, the physical relationship between position marker and transducer is easy to maintain, with a tolerance +/- 2 mm. The measuring method is insensitive to environmental influences such as temperature, moisture, shocks, vibration, or interference fields.

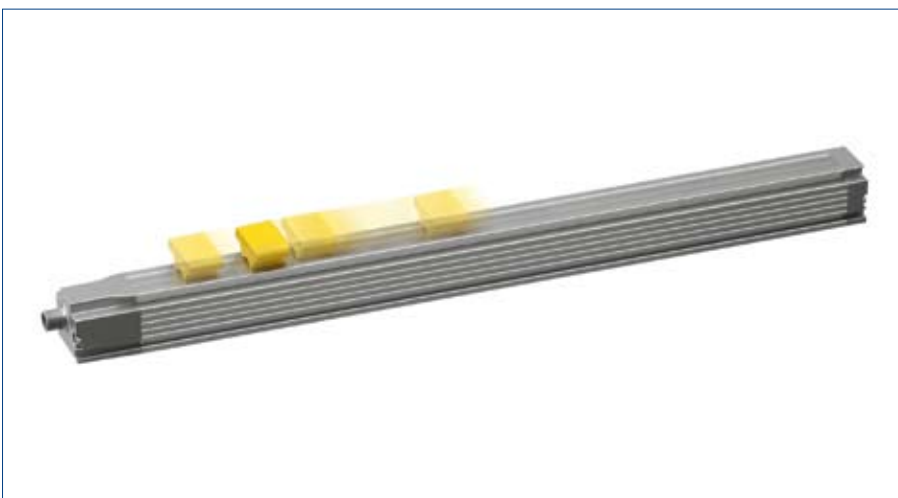
Magnetostrictive technology provides an immediate absolute position measurement on startup, an important advantage when starting or restarting machinery. Compared to other sensor technologies, even long distance can be measured inexpensively with excellent precision.

Accuracy even over great measuring distances

The rugged TLM and TMI series linear transducers from Novotechnik utilize Novostriptive technology. TLM and TMI are of-

fered in several shapes and with effective measuring strokes from lengths from 50 mm to 4.5 meters. All are rated to IP67 environmental sealing, and their operating range is from -40 to +85 °C. The TMI series is designed for integration into high pressure air or hydraulic cylinders with working pressures of up to 350 bar and peaks of up to 600 bar.

Novostriptive technology provides very high dynamic response, and wear-free operation, even under extreme conditions. Consequently, they are well suited for a broad range of industrial and mobile



Novotechnik magnetostrictive transducers with measurement length of 3.5 meters are installed directly into the moving part of the lateral positioning structure of this transport device for Airbus A380 wings

applications, such as precision handling of heavy parts. Electrical linearization and fault detection are included in the on-board electronics. The resolution of 0.001 mm is independent of the measuring length, which can be extremely important when a long measuring distance is required.

Broad range of interfaces

After calculating position using the magnetostrictive principle the calculated position is checked for plausibility and then translated by an application-specific IC (ASIC) into one of several output interface formats, with an output update rate of up to 16 kHz (62.5 μs).

Output formats include Start/Stop, Synchronous Serial Interface (SSI), CANOpen, analog voltage, 4-20 mA, or Novotechnik's DyMoS interface. DyMoS also provides a separate velocity value, which eliminates the need for a second sensor in some applications. With CANOpen, the transducers become plug-and-play devices, which are easily integrated in an existing automation environment. Manual calibration of the application is no longer required, as calibration data is supplied by the transducer itself.

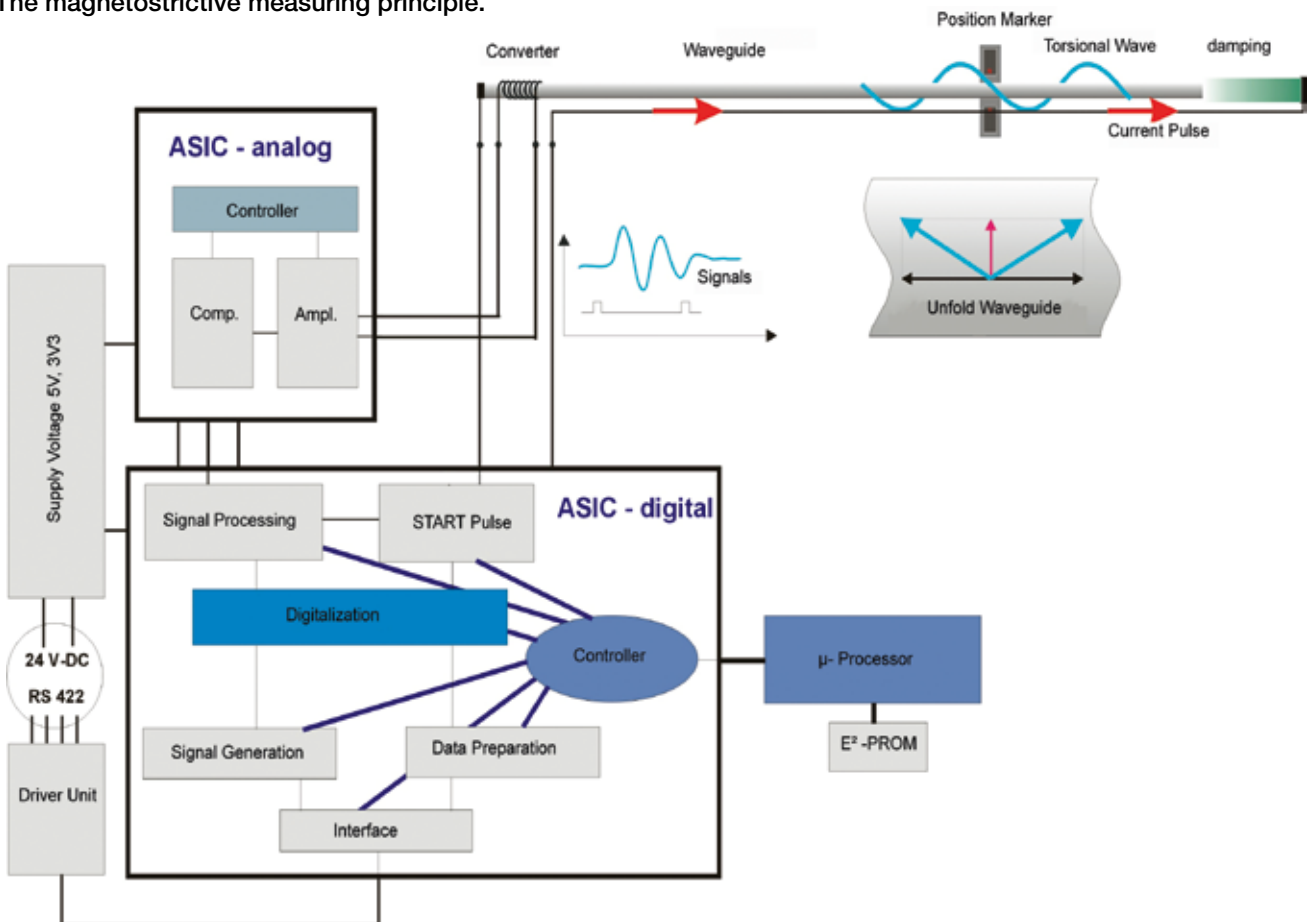


Rugged TLM and TMI series linear transducers from Novotechnik utilize magnetostrictive technology and offer effective measurement lengths from 50 mm to 4.5 meters

The magnetostrictive measuring principle

The measuring process of the contactless magnetostrictive method is triggered by a short current pulse, which generates a circular magnetic field around the waveguide. The magnetic position marker has a magnetic field with lines running perpendicular to the circular field on the waveguide. At the point where the two magnetic fields meet, an elastic deformation of the waveguide (a magnetostriction) occurs. This deformation creates a magnetic pulse in the waveguide, which propagates as a torsional wave with a speed of approximately 2,800 m/s. This pulse is converted to an electrical signal at one end of the waveguide and damped at the other. The time-of-flight between the location where the pulse was generated and the signal converter is directly proportional to the distance between the position marker and the transducer's signal converter.

The magnetostrictive measuring principle.



Gearless Multiturn Sensors for the First Time without External Power Supply: Rotation Counter uses GMR Effect

Many applications require measurement angles larger than 360°. Quite a large number of rotation counters can perform this task in conjunction with a 360° sensor. However, the operating principles common in the past have properties which sometimes have negative effects: They require either a continuous power supply, are based on mechanical principles and are therefore subject to wear, or they are complex and therefore often too expensive for the specific application. A patented rotation counter principle based on Giant Magnetoresistance solves the problem.

The GMR (Giant Magnetoresistance) effect is a phenomenon in quantum mechanics, which is observed in thin film structures of ferromagnetic and non-ferromagnetic layers. In a heterogeneous structure consisting of two magnetic layers separated by a thin non-magnetic layer, the magnetic torques of the two outer layers take up a position relative to each other as soon as they are subjected to an external magnetic field. They align parallel or anti-parallel. If the magnetic torques fold over in this “sandwich”, the electrical resistance changes dramatically. When they are positioned parallel to each other, the resistance drops to

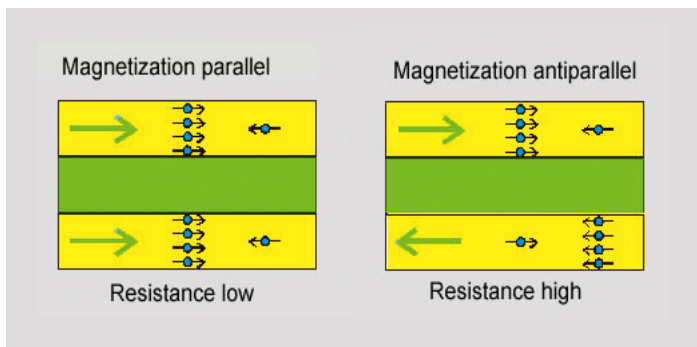
a minimal value, and with an anti-parallel alignment it reaches its maximum. The name Giant Magnetoresistance effect is derived from this behaviour.

“Sandwich structure” made of different layers

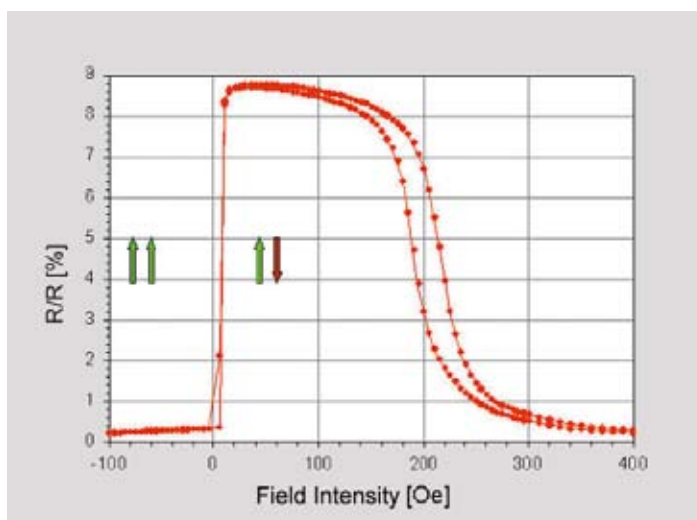
The magnetoresistance effects were discovered almost twenty years ago. It is remarkable that the giant magnetoresistance (GMR) discovered independently by Peter Grünberg and Albert Fert very quickly created the transition to specific applications. In hard disks, for example, the GMR effect

has already been used to precisely read out data since approximately the mid-90's. In addition, it is used around the world in CD and DVD drives. Now it can also be used to realise inexpensive, reliable multiturn sensors.

In addition to the angle of rotation signal, this kind of multiturn sensor using the giant magnetoresistance (GMR) effect, can also currently count and permanently store up to 16 rotations in the deenergized state without a buffer battery and without a gear unit. It operates contactlessly using the magnetic principle, and is therefore wear-free. In the process, it supplies absolute position values



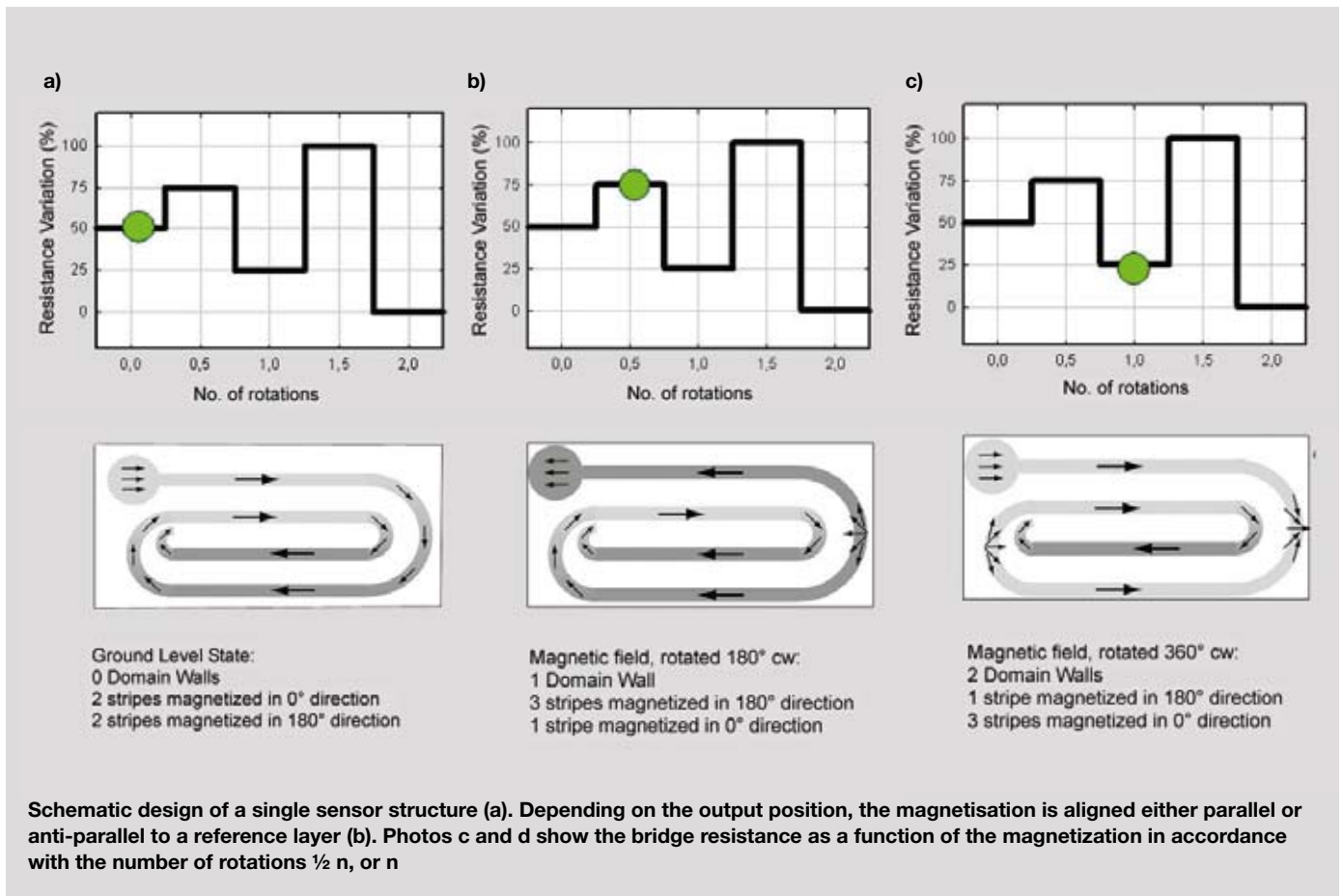
Behaviour of a GMR layer system



Characteristic line of the GMR layer system used for the multiturn sensor



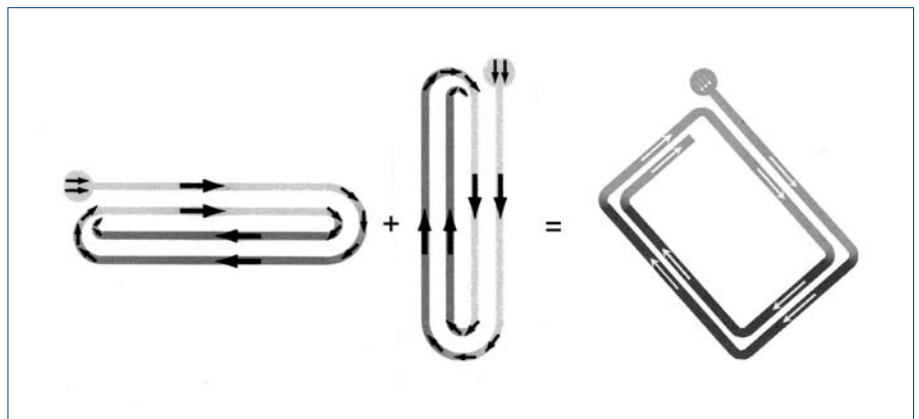
The patented rotation counter operates with a supply voltage of 5 V. Its housing consists of high-quality, temperature-resistant plastic. The requirements for the ingress protection IP65 are achieved



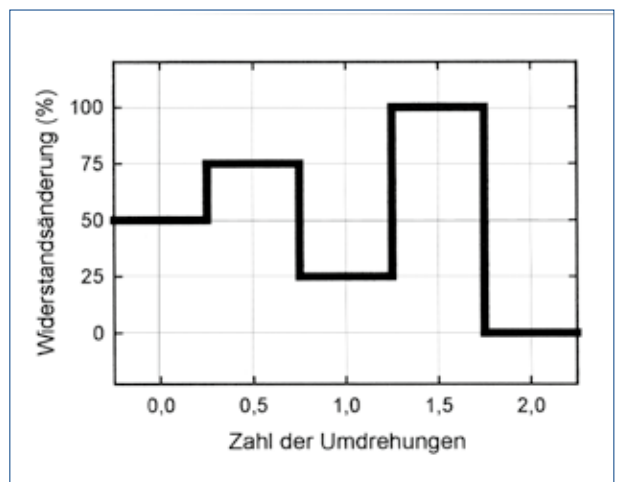
and provides the measured value as a real “true power on” system immediately following start-up.

The structure of the magnetic rotation counter is easy to understand with regard to the principle it is based on. Exactly one spiral arm is required for each rotation to be counted. An important part of the sensor element is the relatively large area at the start of the spiral, the domain wall generator. Due to the large geometric expansion, the magnetisation can easily follow the outer magnetic field in this area. By rotating an external magnetic field with a suitable strength, 180° domains are generated in the domain wall generator and injected into the spiral structure or deleted again during reverse rotation. In the process, the magnetisation of the sensor layer in the spiral arms is directed either parallel or anti-parallel to the reference layer.

A distinctive resistance value of the spiral structure results from the number of rotations, respectively the number of magnetized spirals. When this kind of sensor is combined with a 360° sensor (e.g. Hall), $n \times 360^\circ$ ($n =$ number of spiral arms) can be measured. As the number of rotations is stored magnetically, the sensor detects the rotations even without a power supply. Even long lasting power outages are of no concern.

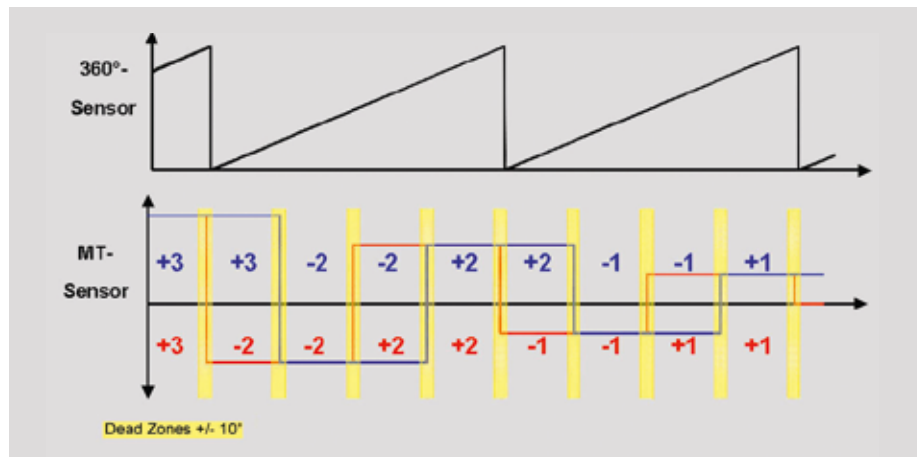


Implementation of two multiturn elements offset by 90° forming a diamond structure



Detecting absolute angle up to 16 rotations

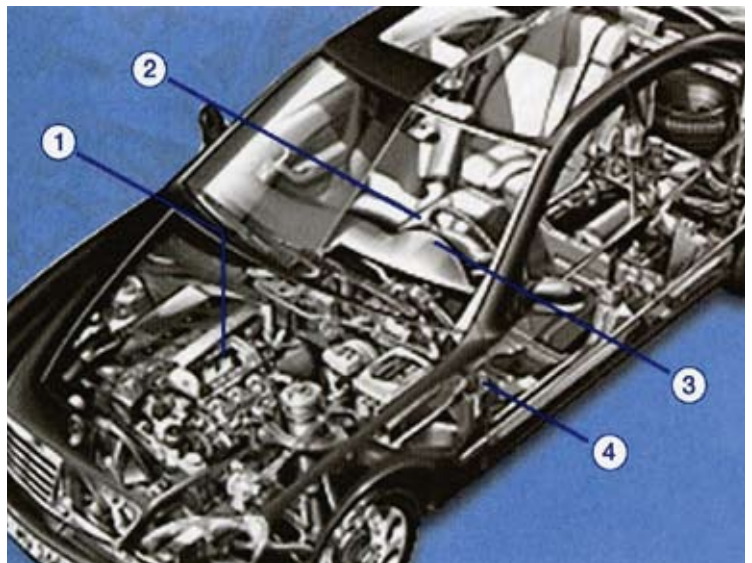
An unambiguous determination of the absolute angle over several turns is not possible without additional design features, as the resistance changes of the GMR sensor element cannot take on any clear values at the jump discontinuity, where you transition from one turn to another. This problem can be solved with the implementation of two multiturn elements offset by 90°. An even more elegant design includes a merging of these two structures, forming a diamond structure. With this structure a clear rotation value can be derived in any angular position with a corresponding evaluation algorithm.



Discontinuity between turns can be avoided when two sensor elements are combined with each other

Advancing New Technologies: Position and Angle Measuring Technology for the Automotive Industry

Today's automotive industry expects a high level of traffic safety, economy, driving convenience and an attractive design from modern cars. In the last 20 years modern electronics have made a major contribution to fulfilling these requirements. Some examples would be, electronic braking aids (ABS), stability control systems (DSC), which have achieved a permanent place in automotive technology. The trend, however, is moving away from these electromechanical solutions. Sensing systems of the future will be characterised without mechanical backup systems. Typical examples include steer-by-wire or e-gas systems. These systems are a major technical challenge for the future of the automotive industry, and therefore for the manufacturers of all components used in them. As a result, the most demanding requirements with regard to reliability, availability, ease of maintenance and safety must be met.



Sensor technology is becoming part of modern automotive technology. Typical examples are the detection of the throttle valve position (1), the gear selection sensor (2), the steering angle sensor (3) and the pedal-force sensor (4)

The traditional potentiometer comprised of conductive plastic material, has achieved a permanent place in automotive technology as position transducers and angle sensors. With its still unbeatable price-performance ratio, the potentiometer had been the ideal sensor solution. However, with the increased requirements of the automotive technology of the future, the principle-dependent wearing of the potentiometer technology is for the first time, showing some negative characteristics. As a result contactless

processes, which meet higher requirements for service life, are in demand.

To avoid the principle-dependent disadvantages of traditional potentiometers without having to go without their advantages, Novotechnik has developed a contactless sensor principle based on an inductive-resistive principle that makes it ideal for use in automotive technologies that have demanding dynamics requirements. The "INDRES" sensor signals produced are analogue and therefore require no computing

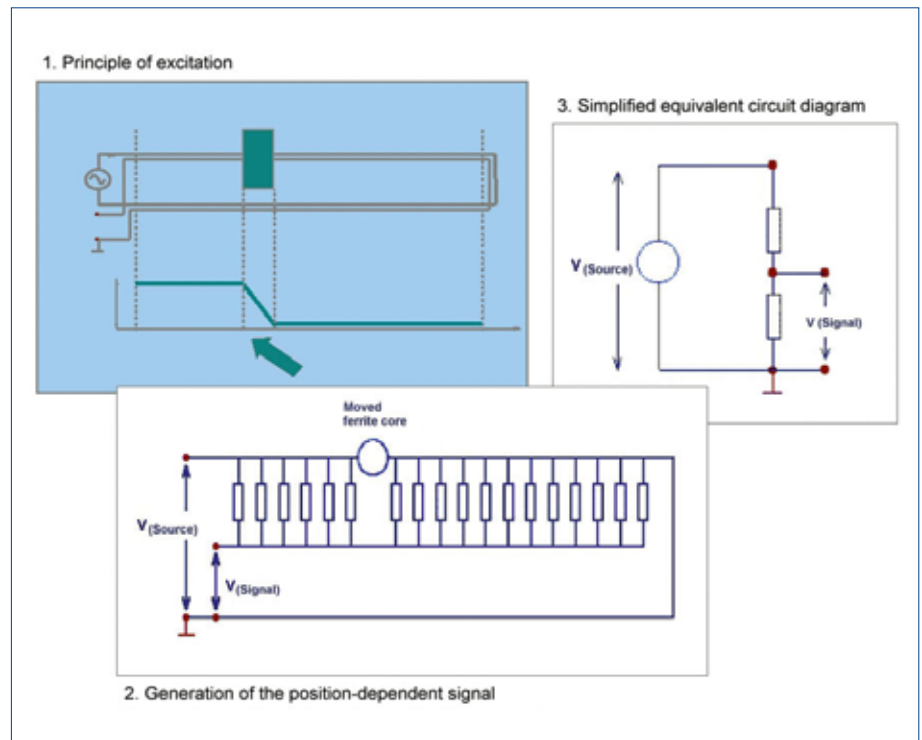
time which results in a position lag that is considerably smaller. Both rotary and linear sensors can be developed using this sensor principle.

INDRES: Position and angular measurement according to the inductive-resistive principle

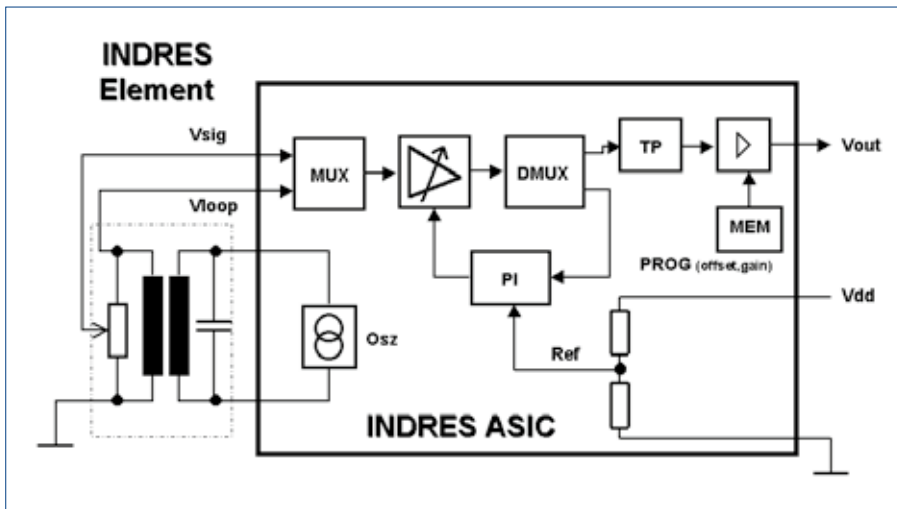
The fundamentals of the contactless, and virtually wear-free operation of the INDRES sensors, is simple: A primary and a

secondary coil are mounted on a carrier material and both are surrounded by a moving ferrite with a maintained air gap. Faraday's law states that a voltage is induced in the secondary winding if an alternating voltage is connected to the primary coil. As the field flow concentrates in the air gap of the ferrite yoke, this potential signal front follows the yoke of the ferrite during movement. A resistance layer in the secondary coil, in this case, the measuring element, now detects this change in location. As a result, the output voltage changes with the position of the ferrite core and evaluation electronics generates an analogue or digital signal from this.

The resolution is theoretically infinite, and typical values currently in the range of over 14 bits for linearity values of better than 0.1%. In contrast to potentiometers that are subject to wear, the linearity in this sensor principle is retained over the entire life of the sensor. The Figure above shows a schematic of the signal processing structure. This figure indicates that this is a ratiometric principle which compensates for fluctuations in the input voltage with signal processing.



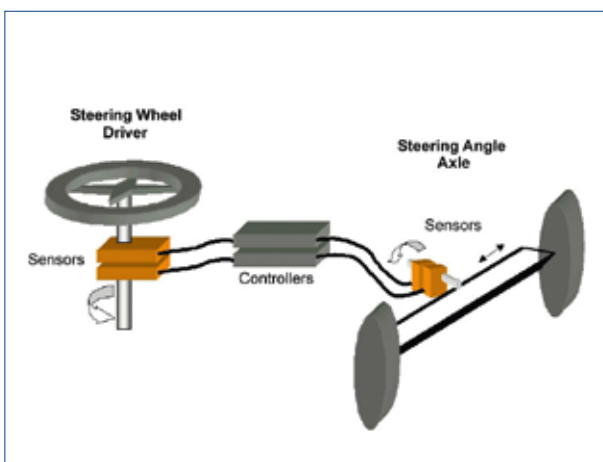
Mode of operation of inductive-resistive INDRES sensors



Schematic diagram of signal processing

Like a potentiometer, the Indres sensor operates as a voltage divider. As a result, with less than 30 ppm/K or 1 ppm/% relative humidity, the temperature and humidity coefficients are very small compared to other magnetic systems (e.g. magnetostrictive or Hall probes). This fact is especially interesting for automotive applications. There are hardly any restrictions with regard to the design or the geometric arrangement in these applications and the measuring element can be attached to the carrier material individually in any custom designs. The sensor geometry follows the application, and not vice versa. A typical application for the INDRES sensors is steer-by-wire systems.

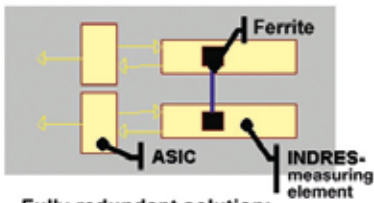
Steer-by-wire: Separation of steering wheel and wheel-angle adjustment unit



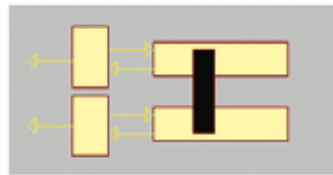
Steer-by-wire: The steering is no longer mechanically connected via an axis, but instead electrically with the tie rod or the wheel-angle adjustment unit

In this kind of "all-electronic" system, the steering is no longer mechanically connected via the steering column, but instead electrically with the tie rod or the wheel-angle adjustment unit. The driver's request is picked up with the steering angle sensor and passed on to the control unit. This specifies the signal for the actuator, which converts the request to a steering action in accordance with the respective driving condition. In practice, a wide range of advantages are seen compared to the traditional mechanical method, due to the elimination

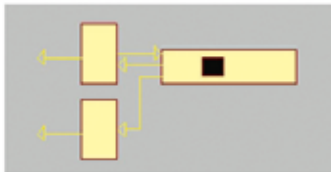
Possible redundancy levels

**Fully redundant solution:**

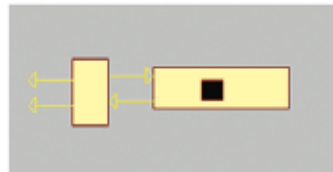
- two mechanically coupled ferrites
- two inductively decoupled primary circuits
- two separate secondary circuits

**Primarily redundant solution:**

- one ferrite
- two inductively coupled primary circuits
- two separate secondary circuits

**Secondarily redundant solution:**

- one ferrite
- one primary circuit
- supplies two secondary circuits

**Transmission redundancy:**

- one ferrite
- one primary circuit and one secondary circuit
- two different output signals of the ASICs

of the steering shaft. These advantages include a reduction in space and weight, more design freedom and, last but not least, also safety advantages, such as forced feedback to limit influences of the driver in extreme conditions.

Demanding requirements for sensor technology

At least two position and angular measuring systems are required for a steer-by-wire system, i.e. one sensor for detecting the steering angle and one that detects the actual value of the wheel position. For the steering angle sensor, a rotary system that operates over a full 360° is necessary. Depending on the actuator used, the wheel position can be detected with either a rotary or a linear position sensor. The sensors must operate with a resolution of 12 to 14 bits, and the required accuracy is in the range of 0.5°. These are values that the INDRES sensors can easily achieve.

Safety requires redundancy

To ensure the greatest possible fault tolerance, the systems used in this kind of steer-by-wire system must be redundant so as to not result in a steering failure. One way to achieve this goal is with the redundancy of the components, i.e. including the position and angle sensors. That is why two identical sensors are used for the steering angle detection and for the detection of the wheel

position. They are installed in the same installation space and have the same measuring task. This means both the steering angle and wheel positions are detected with one redundant measuring system each consisting of two sensors. If one of the sensors fails, the full reliability is retained by the other, and at the same time a fault message is generated.

In addition, each individual Indres sensor can also be designed with different levels

of redundancy depending on the requirements of the application: Fully redundant solutions with two mechanically coupled ferrites, two inductively decoupled primary and two separate secondary circuits are required, for example in brake systems. However, this kind of high and comparatively complex safety reserve is unnecessary for many other applications. Primarily redundant solutions without a double ferrite, but with a double primary circuit or secondarily redundant solutions in which only the secondary circuit has a double design then offer a better cost-benefit ratio. In addition to the analogue output signal, the sensor also supplies a pulse width modulated output signal so that transmission errors are reliably detected in systems with transmission redundancy.

Electronic throttle pedal and throttle valve control

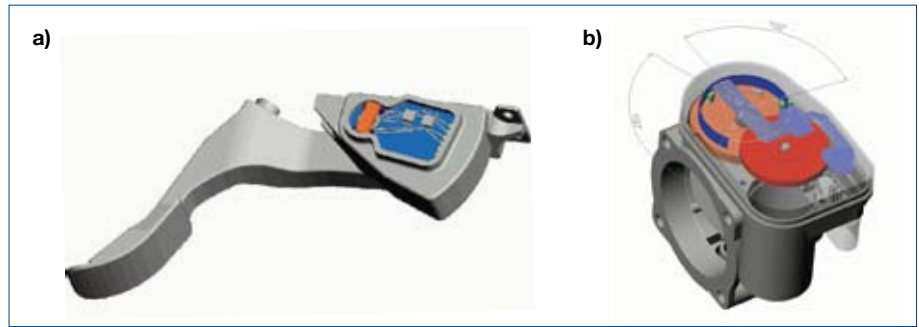
Another example of use for the Indres sensors is in electronic gas systems. Here again there is no need for mechanical links. The throttle pedal module determines the current throttle pedal position with its sensors and transmits a corresponding signal to the engine control unit, which converts the driver's request to an engine torque. It actuates the throttle valve drive to open the throttle valve wider or to close it more. With this kind of actuation, other engine torque requirements can also be taken into account, including torque limitation. The position of the throttle valve is determined



Steering angle sensor according to the INDRES principle

by a rotary sensor and reported back to the engine control unit.

Here again, the system requires two sensors: one for detecting the throttle pedal position and one sensor for the throttle valve position. For the same reasons as described in the steer-by-wire system, redundant sensors are also used here. Potentiometers are still frequently used today for this purpose. Here the quantities are manufactured in the millions. In the future, the contactless INDRES sensors will also replace potentiometer technology for this application



In future the contactless INDRES sensors will replace potentiometric solutions for the throttle pedal (a) and the throttle valve (b)

Individual and Simple:

Inexpensive Angle Sensors with a Broad Range of Uses

Development in angle measuring technology has been fast-paced over the past few years. In many areas, contactless processes based on greatly differing physical principles are beginning to supplement the proven but principle-dependent wear-prone conductive plastic potentiometers. However, interesting new measuring principles often remain nothing more than a theory, as it's still a long way from the idea to a functional and affordable product. As a result, technological competition alone is of little benefit to the user. Today manufacturers must primarily concentrate on "packaging" their innovative ideas in a practice-oriented manner and then offering them at interesting prices. The housing in turn plays an important role in every sensor. It protects the measuring system and enables it to be installed. It's the sum of a measuring principle's properties that decides whether it can be used successfully in practice.



No successful application without need-oriented "packaging". In order to prove itself in everyday industrial use, an angle sensor should therefore fulfil at least four important criteria - regardless of which operating principle it employs. It must be mechanically rugged, offer sufficient protection from environmental influences and be easy to connect both electrically and mechanically

In order to prove itself in everyday industrial use, an angle sensor should fulfil at least four important criteria - regardless of which operating principle it employs: It must be mechanically rugged, offer sufficient protection from environmental influences and be easy to connect both electrically and mechanically. With the SP 2800 (potentiometric) and RSC 2800 (contactless) sensor lines, Novotechnik has achieved a virtually exemplary solution in this sector.

The housing, with a diameter of 28 mm and a depth of approx. only 17 and 23 mm respectively, meets all requirements of industrial practice. At the same time, angle sensors with a broad range of operating principles are offered in the same design. This enables the advantages of the well thought-out housing and connection technology to be used in a wide variety of different applications. For example, both inexpensive con-

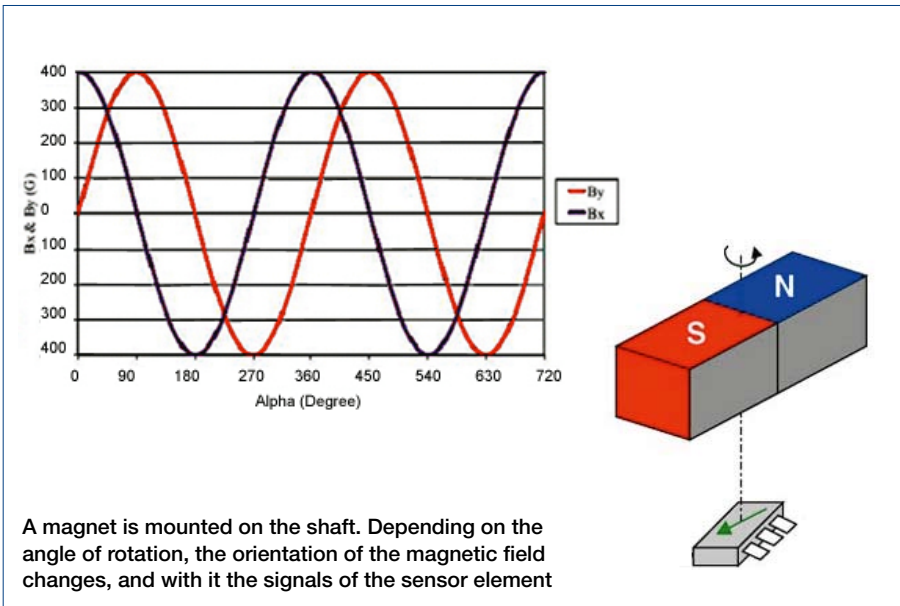
ductive plastic potentiometers and contactless angle sensors that operate based on the Hall principle are available.

User-friendly installation and connection technology are a must

Just how rugged the sensor's design is also becomes apparent during installation. For example, sturdy fastening lugs with oblong holes make mounting easy. The installer can fasten the angle sensor quite simply with two cheese head screws (M4) and the matching washers. The housing with fastening lugs consists of a durable, temperature-resistant plastic material with an elasticity that prevents the lugs from shearing off, avoiding damage to the sensor even when extreme forces are at work during installation. The mounting of the rotating shaft consists of a sturdy, maintenance-free

sintered bronze bushing. Durability is also a major factor in the mechanical connection between the sensor and the application.

When making the electrical connection, it also becomes apparent exactly how practice-oriented the sensor's design is. Every electrician knows what a thankless job it is to work with connection wires that are either too thin or too short - or both. That's why particular attention was paid to the corresponding details when developing the sensor described here. As a result, the individual, cast-in connection leads leave sufficient space for any installation technology suitable for industrial use. With a cross-section of approx. 1 mm² and a length of 300 mm, they are ideal both for soldering and for connection with screw terminals. In addition, the sensors are also offered with a shielded round cable and industrial-grade connectors that meet the requirements of the protection class IP65.



Protection against environmental influences is obligatory

Of course, the housing must protect the sensor against various environmental influences. Here the protection class IP65 provides sufficient protection against liquids and dust. The sensors are completely dust-tight and hose-proof in accordance with IEC 529. And of course, the temperature-resistance of the sensors is an important criterion for practical use. The conductive plastic potentiometers can withstand ambient temperatures between -40 and +150 °C, and contactless angle sensors are designed for ambient temperatures from -40 °C to +125 °C.

And the insensitivity to electromagnetic interference is just as important in the industrial environment. To ensure the greatest possible protection here, the RSC-2800 housing is electrically conductive, i.e. the sensor mechanism is provided with the best possible protection against electromagnetic interference.

One industrial-grade housing for different measuring principles

Depending on the application and requirements, the user can choose between different measuring principles with the same housing design. Conventional conductive plastic potentiometers are still viable in

many applications due to the attractive value for the money they offer.

The sensors with a conductive plastic resistance and collector track convert the angle of rotation into a proportional voltage. Here the independently spring-loaded, precious metal multi-finger wiper provides for reliable contact. The SP 2800 potentiometer offers unrestricted continuous rotation with a maximum electrical range of 340°. Even under the harshest operating conditions, the life expectancy is approximately 50 million rotations.

Contactless, magnetic process

However, with high-frequency or continuous unrestricted rotation, the user is usually better advised to use contactless measuring methods, as here the principle-dependent wearing of the potentiometer technology could have a negative effect. The RSC 2800 angle sensor in the single and the redundant form is positively predestined for angles of rotation between 30 and 360 degrees. The principle mode of operation is easy to understand:

A magnet is mounted on the shaft. Depending on the angle of rotation, the orientation of the magnetic field changes, and with it the signals of the sensor element mounted opposite. This signal change is then already converted into an analogue signal proportional to the angle of rotation within the sensor IC. The sensor has an internal resolution of 0.1° and an typical independent linearity of +/- 0.3 %.



Conventional conductive plastic potentiometers are viable in many applications due to the attractive value for the money they offer

From Signal Conditioning to Programmable On-Site Process Monitors: Signal Processing in many Variations

Sensor elements often supply a relatively low level signal. It is advisable to convert these signals or process them further directly on or at least near the sensor to be able to transmit them interference-free over longer distances. Potentiometric position transducers matched to signal processors are a typical example of this approach. With decentralized system structures, it is also advisable to display the measured value and to immediately process it further directly on site. Programmable display and measuring systems can relieve the strain on the higher-level controller and even sometimes eliminate the need for them in simpler applications.

Sensor technology applications are as diverse as the entire field of automation technology. Accordingly, the requirements for signal processing are also differentiated. Where it is a matter of selecting suitable components, environmental conditions and system structures, the required measuring accuracies or parameterization options are therefore important criteria. That's why Novotechnik, the specialist for sensor technology, offers both signal conditioners for conductive plastic potentiometers and "intelligent" on-site process monitors for sensors with various operating principles in a broad range of variants.

Signal conditioners for conductive plastic potentiometers

There are single or multi-channel signal conditioners designed especially for the industrial environment so that signals of potentiometric position transducers or angle sensors do not need to be transmitted over long distances. The devices pick up the wiper signal load-free with a high-resistance input stage and convert it into a standardised current or voltage signal (see textbox). The standardized signals can be fully utilized even if the maximum distance or angular range of the transducer is not

completely used with adjustable models. At the same time, the signal conditioners supply the sensors with a highly stable constant power supply voltage. Thanks to their broad operating voltage range of 18 to 30 V, potentiometers can also be powered by non-stabilised direct voltage sources. The devices operate with a linearity of typically 0.1 %. With 30 ppm/K, their temperature coefficient is excellent.

Different designs enable optimum adaptation to the respective application. For switch cabinet installation, for example, there are DIN-rail versions available, which can be simply snapped onto mounting rails in accordance with DIN EN 50022.

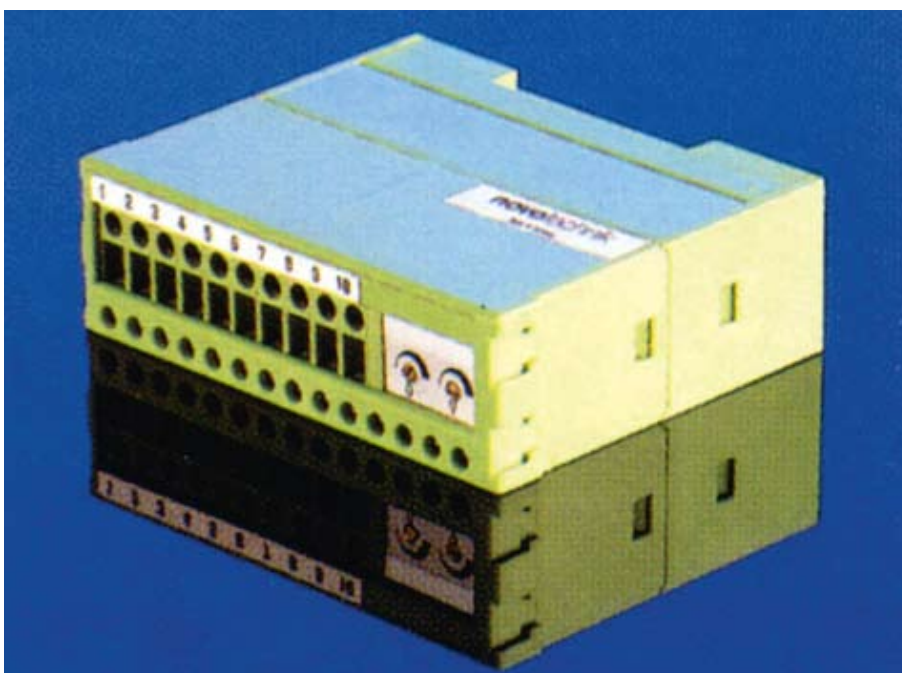
Signal processing for linear conductive plastic potentiometers is very simple. There is a signal conditioner design available for direct installation on the connector of the potentiometers. A design which meets the requirements of ingress protection class IP 67 is available for use under extreme environmental conditions. The signal conditioner is completely dust proof and submersible in water.

Intelligent process monitors for a broad range of different requirements

It is often advisable to display measured values on site and, if possible, to also process them further locally, in order to reduce the load on the higher-level controller. Intelligent process monitor devices, which can easily be programmed, are ideally suited for this purpose. Typical applications for the MAP 300/400 intelligent measuring system



Diese Messwertumformer-Bauform lässt sich direkt an der Steckverbindung linearer Potis montieren



Signal conditioner for mounting on DIN-rails

are quality and production control, testing equipment and custom machine design. The process monitor connects to all potentiometric position transducers and angle sensors, as well as to sensors with standardized output signals. The measured values are shown on a 4 ½ or 3 ¾-digit display and are processed in parallel with the integrated electronics.

Many options simplify adaptation to individual tasks. For example, the user can activate control functions via two or four logic inputs, allowing for setting of limit or tare functions, storage or blocking functions and



Intelligent on-site display. The measured value is not only displayed, it is also immediately processed further. Thanks to an accuracy of 0.01 %, the device is also suitable for demanding applications

printer start, darken display or a bias current function for wire breakage monitoring of the outputs. Remote interrogation via PLC or PC and the connection of a secondary display are possible. BCD or HEX format are further output options for the measured values. There is a 24 V auxiliary voltage output option available for the supply of active sensors. An analogue output is offered as another option. The measuring system operates with sample rates of up to 32 measurements per second and with an accuracy of up to 0.01 %, and makes these process monitors suitable for more demanding tasks.

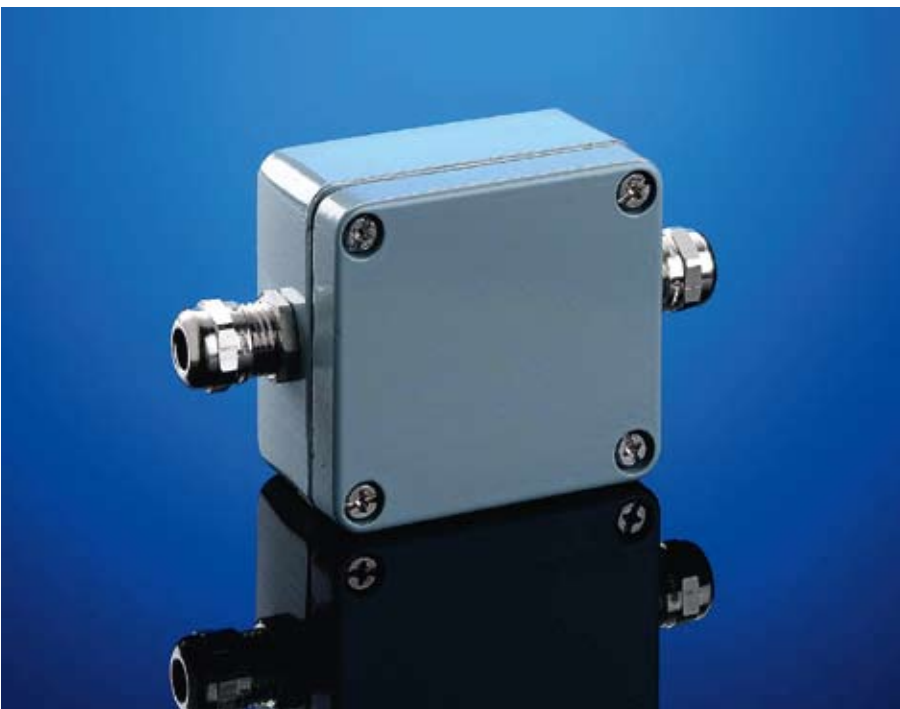
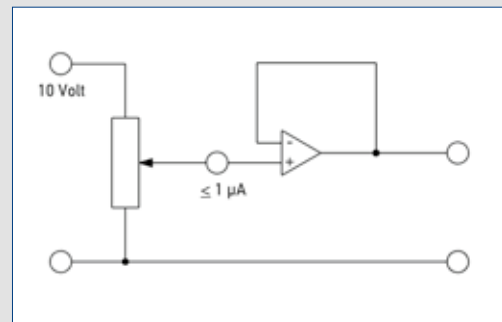


Cost-optimized, modern process monitor. A wide range of options enables individual adaptation to the respective application

Properly connecting conductive plastic potentiometers

Conductive plastic potentiometers are still the sensor solution with the best price-performance ratio in many applications today. They are rugged, reliable and precise. In order to perform to the specified values for linearity, resolution, service life, shock resistance or temperature coefficients, potentiometers cannot be used in variable resistor

mode. They have to be connected in voltage divider mode instead, which means that the wiper output voltage must be picked up load-free with an operation amplifier switched in isolation amplifier mode. In this mode, even temperature fluctuations and humidity changes have virtually no effect on the accuracy of the measurement. This is due to the fact, that in case of temperature fluctuations, the potentiometer resistance changes on both segments of the resistance track divided by the wiper itself. The picked-off voltage remains virtually unaffected by the resistance changes, as only the temperature coefficient of the voltage divider ratio is received. Whether more or less current is taken from the supply voltage source as a function of the temperature is generally irrelevant. The same applies for the effects of moisture.



Cost-optimized solution with many options

Such high accuracy is not always required, and there is hardly a user, who can afford to pay for technical overhead he does not really need. That is why the MAP 4000, a cost-optimized modern process monitor, was added to the Novotechnik product line. It operates with a somewhat lower accuracy of 0.1 %, but there are no other compromises. The sample rate, for example, is even higher with 40 measurements per second, and with -99.999 to +999.999 display counts, the measuring range is comparatively large.

This signal conditioner withstands the harshest environmental conditions with the ingress protection rating is IP67

Rugged, Reliable and, if necessary, also Redundant

Precision Rotary Transducers for the Heavy-Duty Segment

Automation technology is also used in harsh environmental conditions. Typical examples can be found in driven machines in road construction and in agriculture and forestry, on moving platforms, in container terminals and in harbour cranes. The sensors used here must meet special requirements. Sufficient accuracy alone is not enough. A high level of reliability must be ensured even with heavy vibrations, moisture and extreme temperature fluctuations. And the understandable desire for “affordable” technology also plays a role here. Conductive plastic potentiometers available today in surprisingly rugged designs are therefore usually unbeatable in applications of this kind.



Rugged, reliable and, if necessary, also redundant: Precision rotary transducers for the heavy-duty segment (photo: Novotechnik)

With the conductive plastic potentiometers of the IPX 7900 series (picture), Novotechnik has expanded its product line with rugged rotary transducers specially developed for use under extreme environmental conditions, e.g. for mobile applications. A typical application is, for example, actual value detection on the steered axle of electro-hydraulic steering systems. The heavy-duty potentiometers are available for detection ranges of 120°, 200° and 350° and offer unrestricted continuous rotation. All variants have either a single-channel or a two-channel, redundant design with two separate connections. As a result, the requirements as per SIL 3 are met in accordance with IEC 61508 (see text in box).

The angle sensors also meet the requirements of the protection type IP67 (plug variant M12) or IP69k (PG screwed cable gland with cable connection). They are impervious to dust, dirt or moisture. As potentiometers operate according to the

voltage divider principle, temperature fluctuations also have no effect on the measuring accuracy. Even with heavy vibrations, the expected service life of the rotary sensors is over 100 million movements. A rugged all-metal housing and a positive-locking cover protect the conductive plastic resistance tip and the extremely durable multi-finger

wiper. The solid yet compact design with dimensions of 79 x 35 mm² enables direct attachment to the axle without additional protective measures. The sturdy, one-piece shaft with dual ball-bearing mounting with a large bearing spacing and a 13 mm diameter enables direct steering via a strong lever or driver.

Redundant rotary transducer with SIL 3 approval

In accordance with IEC 61511 and IEC 61508, machines and risk-reducing measures are divided into four safety levels each: From SIL 1 for a low risk to SIL 4 for an extremely high risk. The abbreviation SIL stands for Safety Integrity Level; the SIL value describes the specified safety function if a fault occurs. The following applies here: The greater the risk, the more reliable the execution of the risk reduction measures and the components used must be. Of course, this also applies to conductive plastic potentiometers frequently used for actual value detection directly on the steered axles of mobile driven machines, e.g. harbour cranes, stone crushers, aircraft de-icing machines, vehicles for transporting heavy loads, etc. The two-channel, fully redundant model of the heavy-duty rotary sensor IPX 7900 meets the requirements according to SIL 3 with two separate connections.

Magnetic Rotary Sensor in Use: On the Road with London Taxis

Today the operating principles frequently used for contactless angle detection include magnetic methods. They supply absolute measured values, operate reliably even under harsh environmental conditions and, due to the low costs compared to other measuring methods, are suitable not only for countless measurements in mechanical and process plant engineering, but also for use in mobile applications. This is proven in the application examples from the motor vehicle engineering sector described in the following.

Taxis in London. Thanks to the retrofittable CleanCab System, the diesel engines can meet the requirements of the Euro 3 emission standard (Photo: Novotechnik)

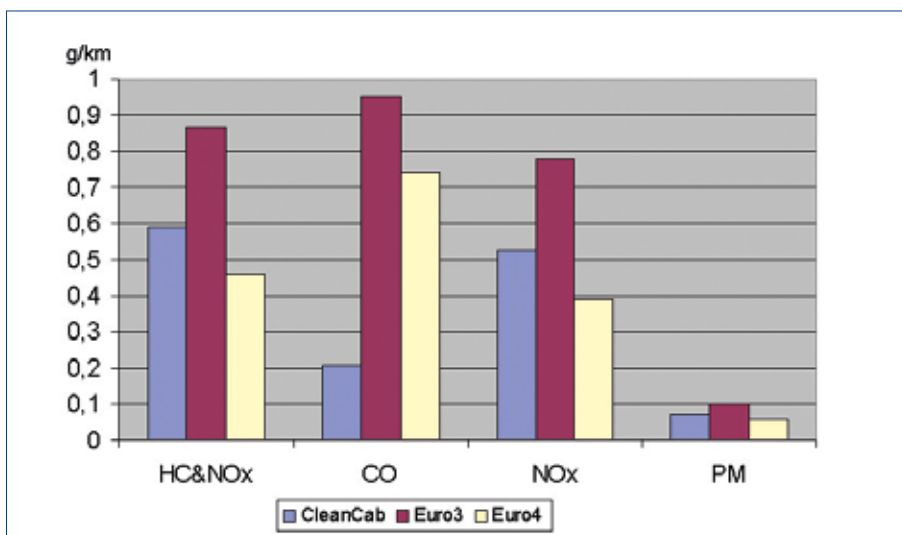


The Swedish company STT Emtec has developed a retrofittable exhaust-gas recirculation (EGR) system for the nostalgic-looking taxis in London with which the vehicles meet the requirements of the Euro 3 standard. The pollutant emissions are drastically reduced. The new CleanCab System has successfully passed all tests and was approved by both the EST (Energy Saving Trust) and the PCO (Public Carriage Office). It can easily be integrated in the taxis' diesel engines.

Install it and forget it is the motto for drivers and vehicle owners in this case. For nothing about the running characteristics changes due to the conversion, the exhaust system doesn't need to be modified and no fuel additive is required when refuelling. The rugged system requires no special maintenance measures, meaning that no additional operating costs are to be feared.

The system operates based on the principle of exhaust gas recirculation. That means

part of the exhaust gases is returned to the combustion process. The mixture which results in this way has a lower combustion value, and therefore no longer achieves the high temperature in the combustion chamber required for the formation of nitrogen oxide. This effect is intensified by the fact that the exhaust gases are also cooled prior to being returned. The CleanCab controller monitors the fresh and exhaust-gas feed and controls it in dependence on the engine



Emission values in comparison

The CleanCab™ system has successfully passed the Millbrook tests in accordance with the NEDC cycle described above, for all legislated emissions as HC, NOx, CO and PM. The tests were performed before and after a durability trial of 6 months, with close to Euro 4 emission levels, see graph

(Photo: STT Emtec)



A magnetic angle sensor in which the sensor and the position marker are designed as separate components (RFC 4800). The position-marker with incorporated magnet is simply mounted on the rotating shaft. With the CleanCab System as well, this simplifies the integration, as no shafts had to be centred (Photo: Novotechnik)

Great installation freedom and good integratability

Here there's no need to integrate the sensor and the magnet in a housing. They can also be designed as separate modules. The position-marking magnet is simply mounted on the rotating shaft. A marking shows the correct alignment relative to the sensor, which can be positioned at a distance of up to 1.5 mm from the position marker. And even greater distances up to approximately 4 mm are possible; a stronger magnet is available for this purpose. The CleanCab designers appreciated these advantages during installation. As neither a shaft nor a mount are necessary, and the measuring distance is variable, application-related installation tolerances are no problem at all. In addition, transmissive measurement is possible, i.e. through other (non-magnetic) materials, which opens up further design freedom.

load, speed and combustion chamber temperature. Here the valve position of the diesel injection pump provides information on the engine load. It is detected with a magnetic angle sensor from the standard product line of the sensor specialist Novotechnik.

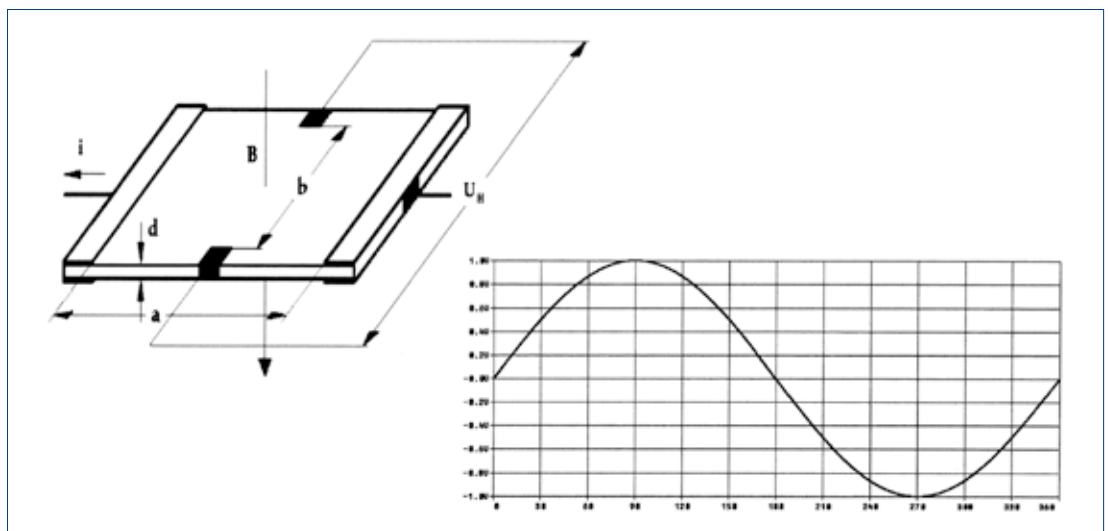
Rugged sensor with a broad range of possibilities

There were many reasons for this choice: The angle sensor supplies absolute measured values over the full 360°, and the electrical range is programmable in 10°-steps. The inevitably harsh environmental conditions in mobile use do not impair operation. The angle sensor operates at ambient temperatures between - 40 °C and + 125 °C and can withstand oscillations and vibrations of up to 2,000 Hz (in accordance with IEC 6672-6) and impacts of up to 100 g (11 s, in accordance with IEC 6672-27). In the standard version it

meets the requirements of the protection class IP67 , i.e. is completely dust-tight and protected against jet-water. On top of all that, the sensor is also very inexpensive and can be easily integrated in the application. As all components of the CleanCab System must be fitted into an engine concept that already exists, this was an important criterion when making the choice.

The simple integratability results from the magnetic operating principle: For contactless angle detection, a magnet is mounted on the rotating axis. Depending on the angle of rotation, the orientation of the magnetic field changes, and with it the signals of the sensor element. This signal change is then converted into an analogue signal proportional to the angle of rotation within the sensor IC, which is then available to the customer's controller. The sensor operates with a resolution of 12 bits and an independent linearity of +/- 0.3 % in the application.

An RSC 2800-600 magnetic angle sensor for detecting working angles up to a full 360° (Photo: Novotechnik)



For contactless angle detection, a magnet is mounted on the rotating shaft. Depending on the angle of rotation, the orientation of the magnetic field changes, and with it the signal voltage of the sensor element (Photo: Novotechnik)

Sensor Potentiometers ensure Safe Cornering: Segway Human Transporter – A Vehicle that's Fun to Drive

The Segway Human Transporter (HT) is a single-axle, self-stabilising scooter, which has gained in popularity over the past several years. The vehicle keeps itself and the drive in balance; braking, acceleration and steering are controlled by the operator shifting his weight or tilting his body.



Segway Human Transporter: a vehicle that's really fun to ride. The transporter keeps its balance all by itself; braking, acceleration and steering are carried out by tilting the body (Photo: Segway)

The Segway Human Transporter owes its handling to a dynamic stabilization system, which basically functions like a human being's sense of balance. The tasks of the inner ear, eyes, muscles and brain are replaced in the Human Transporter with gyroscopes (which are also used to display the artificial horizon in airplanes), pitch and angle sensors, high-speed processors and powerful, brushless servomotors as drives for the wheels. For stabilization, the rider's center of gravity is continually determined, the data collected is processed and operation is adjusted accordingly automatically. For

the drives this means that they are supplied with current reference values up to 1,000 times a second.

The vehicle therefore reacts to any change in body position of the rider. The rider shifting his weight to the front or rear controls driving forward and reverse. When standing vertically, the speed remains constant or the transporter stops. The latest model incorporates a new feature so that a slightly tilt the handlebars to the right or left results in a movement in either direction. This innovation results in an intuitive, natural kind of movement for the rider.

However, this does not apply to automatic control technology. The non-linear, instable system sets demanding requirements. A large number of sensor signals have to be processed and put in context to each other, for example, during cornering. For this purpose, the measured values of the tilt sensors that detect the position of the base platform must be compared with the angle signal, which provides information on the position of the handlebars. Only then can the control electronics distinguish whether cornering is intentional or whether the rider is moving over rough terrain.

Sensor potentiometer detects the position of the handlebar

On the latest model of the Segway Human Transporter the position of the handlebar is determined with a conductive plastic potentiometer mounted directly on the axis of the handlebar above the bearing block. The cost efficient angle sensor in a plastic housing from the Novotechnik product line is especially designed for use in industrial and automotive series production applications. For use in the Segway HT, the sensor was designed redundantly. Two complete systems with a measuring range of 0° to 140° each are integrated in the same installation space.

The SP28 sensor parameter supplies absolute, analogue output signals proportional to the angle of rotation that can be directly further processed by the Segway HT control electronics. The angle of rotation of the handlebar is constantly compared with the measuring signals of the tilt sensors. Cornering is initiated in case of a corresponding difference. In the process, the potentiometer operates with a resolution of <math><0.01^\circ</math> and a repeatability of 0.03°. The linearity is specified with $\pm 0.3\%$. However, the extremely compact angle sensor with a diameter of just 28 mm has a lot more to offer.

Rugged, long-lived and easy to install

The rather rough environmental conditions do not impair the operation of the potentiometer, and even in tough outdoor use it

The sensor potentiometer in the sturdy plastic housing was designed especially for use in industrial and automotive series production applications



easily achieves a service life of more than 50 million movements. The independently spring-loaded multi-finger wipers made of precious metal, which pick up the measured value on the resistance path, ensure reliable contact even when subjected to heavy vibration. The permissible temperature range is between -40° and $+100^\circ$. In the heat of summer, the angle sensor operates just as reliably as at arctic temperatures. Great importance was also placed on the stability of the housing: Just like the integrated mounting, it consists of high-quality, temperature-resistant plastic. The requirements for the dust and water protection class IP65 are also met in this design. This means the angle sensors are completely dust-tight and protected against jet water. The low current consumption (less than 1 mA) also complies

with the requirements of mobile applications. The angle sensor hardly places any load on the batteries of the Segway HT.

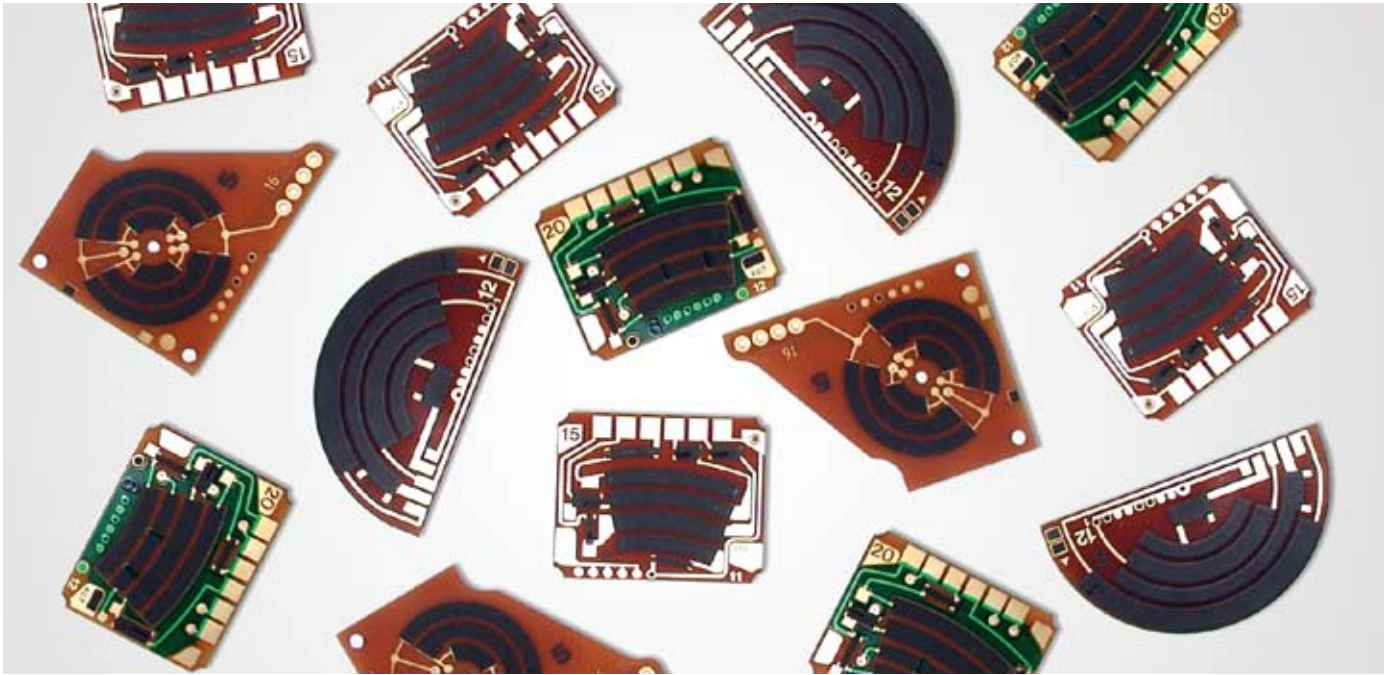
Both mechanically and electrically, the potentiometer can be integrated well in the application. Mounting tabs with oblong holes simplify attachment and enable easy mechanical adjustment. Thanks to the push-on coupling, installation is not only carried out quickly, it also guarantees a play-free connection. The electrical connection is possible via either flexible leads or a prefabricated connector. The large core cross-section also enables connection with screw terminals. With their use in the Segway HT, angle sensors on a potentiometer basis have once again proven that there are still applications in which they are virtually without serious competition.



The sensor potentiometer detects the angle of rotation at the lower end of the handlebars. For cornering, all that is required is a slight tilt the handlebars to the right or left (Photo: Segway)

Improved Engine Performance with Increased Environmental Protection: Potentiometers Accelerate

Modern vehicles depend on high-performance sensor technology to meet constantly increasing commercial and governmental requirements. For example, “throttle-by-wire” systems are an important component for the exact control of engine operation. Throttle-by-wire is used not only in modern automobiles and light trucks, but also increasingly in two and three-wheeled vehicles. Most often, conductive plastic potentiometers are used for position feedback for these systems.



Sensors used for throttle-by-wire systems must meet demanding requirements for precision and long-term durability while operating in difficult environments, and pricing is extremely competitive

The term “drive-by-wire” means the replacement of mechanical or hydraulic couplings with electronic coupling solutions. One of these drive-by-wire systems is the throttle-by-wire system, which replaces the classic mechanical connection between the throttle pedal and the butterfly valve in the throttle body with an electronic control system. In the throttle pedal module, the pedal position is determined with a rotary position sensor and is transmitted to the engine control unit as an electrical signal. The engine management system uses the pedal signal as the “driver request” part of a calculation that outputs an electrical drive signal to position the throttle valve using an electric motor. The position of the throttle valve is also detected by a rotary sensor and is reported to the engine management system, closing the control loop. Both the pedal sensor and the throttle valve sensor are typically “redundant” for safety reasons, meaning that there are actually two independent potentiometers for the pedal and

two more for the throttle valve. This type of control system goes beyond simply following the driver’s pedal position. With sophisticated software control, it allows for reduced fuel consumption and reduced tailpipe emissions. The system also reduces costs by replacing earlier independent systems for controlling engine idle, and for vehicle speed control.

Demanding requirements for mobile use

Sensors used for throttle-by-wire systems must meet demanding requirements for precision and long-term durability while operating in difficult environments, and pricing is extremely competitive. It’s not surprising then that conductive plastic potentiometers are strong leaders in the drive-by-wire market. They’re rugged and inexpensive, and their size and shape is easily customized to the needs of the application. Analog output signals from potentiometers

are available in real-time, without any delays due to limited sampling or update rates, as is common with semiconductor-based sensors. In addition, the excellent measuring speeds, linearity, resolution, repeatability, and temperature ranges of potentiometers are only achieved by other sensor technologies with great technical effort and expense.

Conductive plastic potentiometers withstand intense heat and biting cold, are insensitive to shocks and vibrations, and use very little electrical current. An operating durability of tens of millions of cycles is achieved by a skilled manufacturer. Potentiometers exhibit an extremely low coefficient of temperature because of the voltage divider principle, coupled with expertise in design and manufacturing. This is particularly important for under-hood applications which might range from -40° to +130 °C. Potentiometers are also fundamentally insensitive to Electromagnetic Interference (EMI). These characteristics make them well-suited for mobile applications.



Conductive plastic potentiometers for detecting throttle valve and throttle pedal positions and suitable for integration were first developed in the early 90's, and optimised versions are in series production today

Fully-housed sensors – with options

However, it is not always practical to integrate sensor components in some applications. Integration requires a level of application design and assembly complexity that can not always be justified. In addition, some applications may require sealing of the sensor components against dirt, liquids, and other environmental contaminants. These applications may require complete sensor assemblies with a rugged housing that protects the sensor components and provides a simple installation method. Customization of these “bolt-on” sensors is relatively easy. For example, any electrical range can be implemented, with pedal sensors in the range of 20 to 60 degrees, and throttle valve sensors typically in the range of 90 to 120 degrees. Changes can be made to sensor shaft length and shape, such as a special push-on coupling that minimizes free play between the sensor and the customer's shaft. In addition, contactless technology is available in the same housing, should there be a need to provide end customers with both potentiometric and contactless technologies.

Custom-tailored solutions

Conductive plastic potentiometers can be integrated into virtually any installation space, as they do not necessarily require a separate housing. The sensor specialist Novotechnik of Ostfildern, Germany, first developed integrated potentiometers for throttle valve and throttle pedal applications in the early 1990's, and optimised

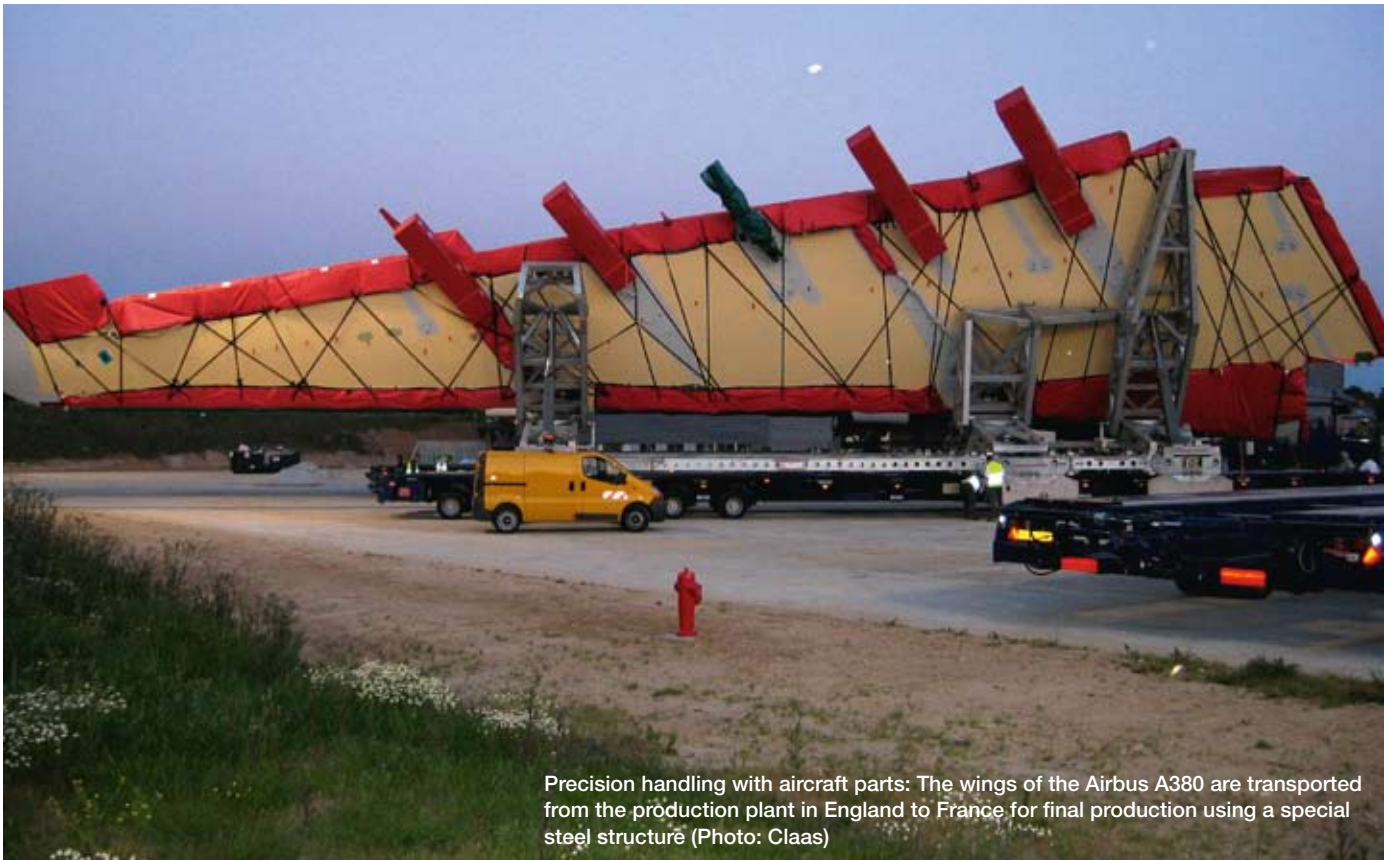
versions are in series production today. These systems integrate custom PCB resistive elements and wiper assemblies directly into the pedal and throttle body designs, eliminating the dedicated sensor housing, and providing the required redundancy without significantly increased costs. Novotechnik throttle-by-wire sensors have proven themselves in over 50 million vehicles to date.

A rugged housing, like that of the SP28 and SP50 series, protects the sensor components. However, many variants are available, including the choice between potentiometric and contactless sensing technology in the same housing



The Right Sensor for any Position Detection: Linear and Rotary Position Transducers in Transportation Technology

Transportation technology is an important topic in the construction of the Airbus A380 jumbo jet. Many different assemblies are transported from development and production plants in England, Spain, France and Germany to Hamburg, Germany or Toulouse, France for final production. Component parts are often extremely large, and transport of such components is very demanding. Airbus wing assemblies, for example, are produced at the English plant in Broughton. They are more than 45 m long and 11 m wide and more than 3 m thick at the mounting end. Despite their ultra-modern lightweight design, each wing weighs over 38 t. Transportation of such large and heavy components to Toulouse requires custom land and water-based transport machines that are well-designed and implemented.



Precision handling with aircraft parts: The wings of the Airbus A380 are transported from the production plant in England to France for final production using a special steel structure (Photo: Claas)

The transport specialists at Claas Manufacturing Technology in Beelen, Germany, developed a custom transport jig for transporting Airbus wings. The impressive steel structure is 20.5 m long, 6.7 m wide and has a height of just under 11 m when it's not loaded. Moving the jig requires a special 96-wheel vehicle that is pulled by an over-the-road tractor for long-distance travel, but can also run on its own power for short distances. At the destination the modular jig is dismantled, loaded onto trucks, and driven back to Broughton, where it is reassembled for the next transport.

To meet the height and width limitations imposed by transport by ship and on roads, the orientation of the wings must be

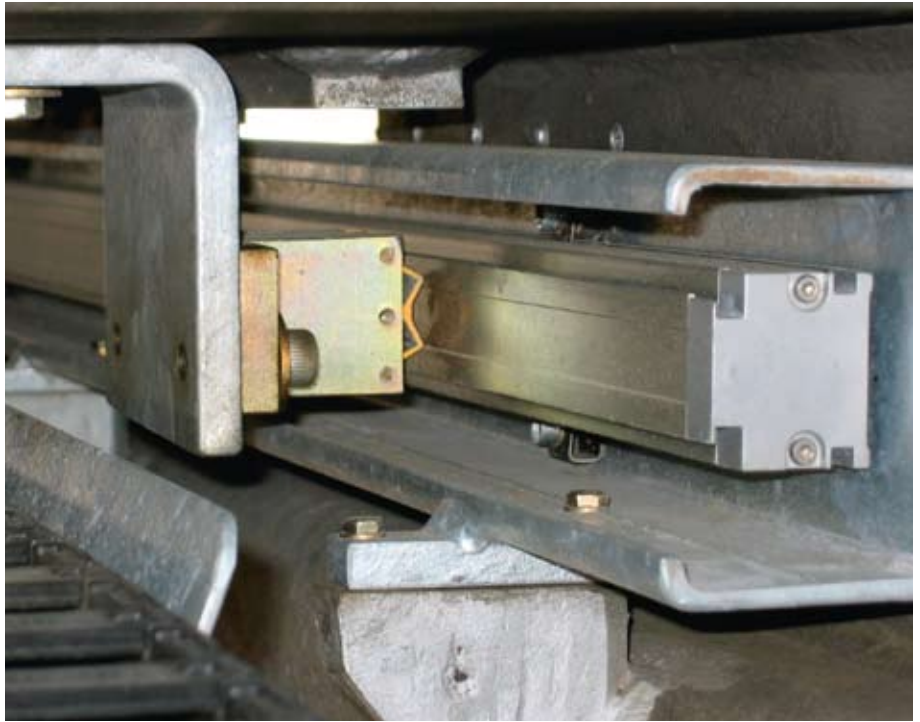
changed between the horizontal and vertical positions (when viewed end-on) during their journey of several days. To do this, the jig has been equipped with a special motorised suspension device. The wing is fastened on two moving swinging arms, are tilted via a spindle drive. The center of gravity of the wing and jig assembly is only allowed to shift vertically during this process, so the lower mounting point is moved laterally depending on the inclination process. The angular inclination and lateral offset of the assembly is critical to limit torsional stresses on the wing assembly. These motions must be measured precisely to synchronize movement of the two drive mechanisms (30 kW and 18.5 kW), and to switch them off

in their end positions. With millions of dollars of composite wing at stake, Novotechnik position transducers were selected for both of these critical measurements.

Magnetostrictive linear sensors: rugged, precise and easy to integrate

The lateral distance traversed is measured with magnetostrictive position transducers of the TLM series. The standard versions of the rugged TLM transducers are environmentally sealed to meet IP67 requirements under IEC 529. With excellent dynamic response and wear-free operation, they proved to be an excellent choice for the precision

measurements needed for transporting the aircraft wings, even under extreme ambient conditions. Series TLM provides the maximum data integrity during data transfer, and monitoring for potential failures is built-in. TLM transducers are linearized before leaving the factory, and their 5 μm resolution is independent of measuring length. For the A380 wings, TLM transducers with a measurement range of 3.5 m are easily integrated into jig assembly. The transducers are directly in the steel structure of the moving part of the lateral traversing device. Because of magnetic coupling, the allowable operating distance between the position marker and the transducer is quite flexible, allowing variability of ± 2 mm. This makes it easy to maintain the proper operating distance between position marker and transducer. TLM transducers are based on Novostriptive technology, combining conventional magnetostrictive sensing with proprietary Novotechnik evaluation technology. TLM transducers are available with measurement strokes as long as 4.5 m and as short as 50 mm. Details are provided in the technical article entitled "Magnetostrictive transducers – ideal for long distances" on Pg. 8.



It was possible to install the transducers with an effective length of 3.50 m directly in the moving part of the lateral traversing device in the steel structure of the jig. Because of magnetic coupling, the allowable operating distance between the position marker and the transducer allows variability of ± 2 mm. This makes it easy to maintain the proper operating distance between position marker and transducer (Photo: Claas)

Proven industrial potentiometers with an excellent price-performance ratio

To maintain proper orientation during motion of the jig, the angular motion of the device must also be controlled. For monitoring the angular position, Claas chose Novotechnik's IPE 6501 industrial potentiometer for its excellent performance and durability, and its excellent price-performance ratio. For optimum measurement resolution, Claas selected a 90 degree version of the IPE6501 to measure the maximum 70 degree angular motion of the jig. This results in an angular resolution of approximately 0.02 degrees from the sensor. The IPE 6501 provides a 4-20 mA current-type signal, guaranteeing a highly reliable signal transfer, even under difficult environmental conditions often found in mobile applications.

The IPE 6501 is environmentally sealed to IP 65 under IEC 529, and is exposed to moisture and variations in ambient temperature on the jig without additional protection, while providing angular repeatability of 0.007 degrees. Operating as a true potentiometer, temperature and humidity have virtually no effect on the measuring result, with a T_c of < 15 ppm/degree K. This is due to the fundamental principle of a voltage divider, and to careful design and manufacturing that minimizes the effects of

temperature on mechanical components. The permissible temperature range for the potentiometric sensor is between -25 and $+70$ $^{\circ}\text{C}$.

The sensor is housed in rugged aluminum housing. Electrical connection is by a standard industrial-type connector. Precision ball bearings allow for axial and radial loads of up to 45 N. Supply voltage may range between $+18$ to $+30$ VDC, making the sensor well-suited for $+24$ VDC battery power supply in mobile use.

With rugged housing, high performance ball bearings, and excellent sealing the

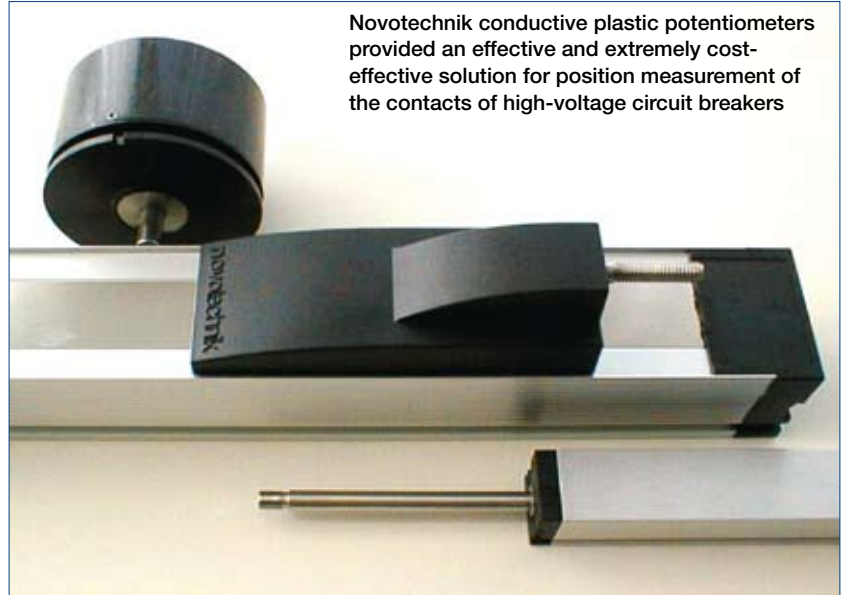
IPE 6501 achieves a service life of a hundred million rotations even, under unfavorable environmental conditions. That makes the IPE 6501 an excellent choice for analog output absolute position measurement for industrial applications, especially where the output must be transmitted over long distances. Other typical applications for the rugged, reliable potentiometric sensors transducers include position control circuits, plastic injection molding machines, machine tools, automatic handling devices, motor vehicle technology and custom test benches.

Claas chose Novotechnik's IPE 6501 industrial potentiometer for its excellent performance and durability, and its excellent price-performance ratio. The rugged device is designed for use under difficult environmental (Photo: Claas)



Potentiometers as Unmatched Problem-Solvers: Position Measurement under Extreme Conditions

Rotary position sensors and linear transducers are available with a number of different physical principles. There is a perception that contactless technologies are inherently superior to potentiometers, but this is not accurate. Although contactless technologies have clear advantages in some applications, potentiometers have advantages in measurement precision, speed, temperature range and response to thermal changes, power consumption, susceptibility to electromagnetic interference, and cost. The following example of a diagnostic system in high-voltage circuit breakers illustrates the capabilities of potentiometers.



Novotechnik conductive plastic potentiometers provided an effective and extremely cost-effective solution for position measurement of the contacts of high-voltage circuit breakers

Potentiometers owe their reliability primarily to a simple design. They consist mainly of three components; the resistance element of conductive plastic ink on circuit board material, the wiper, and the input shaft or push rod. The input shaft or push rod moves the wiper, which changes its position on the resistance element. The wiper picks off a voltage from the resistance element that is proportional to the linear or angular position. This analog voltage output signal is absolute. If there is an interruption in the supply voltage, the output voltage instantly

returns to the proper value as soon as the supply voltage is restored, without any need to re-reference to a known position. Tracking high speed motion is not a problem for properly designed potentiometers, and potentiometer output signals are available in real time, without any lag in reported position.

Potentiometers behave properly even under extreme environmental conditions. Because of the fundamental voltage divider technology, changes in temperature have little effect on precision. With proper

design, potentiometers are insensitive to physical shock, vibration, and high acceleration values. Consequently, potentiometers are often used for demanding applications

Exact analysis of erosion with high-voltage circuit breakers

In Bremen, Germany, the Weis Company needed a diagnostic solution for high-voltage circuit breakers. These breakers are used in power plants, transformer substations, blast furnaces, etc. Voltages are between



The Weis SA 100 is a rugged portable analysis system for high voltage circuit breakers, providing precise data on the condition of switch contacts without the need to open the circuit breaker housing (photo: Weis)



Fixed inner contact of a high-voltage circuit breaker. The erosion can clearly be observed (photo: Weis)

Weis found an ideal solution with Novotechnik conductive plastic potentiometers. Infrared sensors were considered, but would be many times more expensive, and provide no additional practical benefit. Novotechnik's potentiometers were not only extremely cost-effective, but they were easy to mount on circuit breakers of differing designs. Potentiometers of different types and lengths are used to adapt the SA 100 to a multitude of breaker designs.

For longer stroke requirements, Weis opted for the proven Novotechnik TLH series. These transducers are driven from the side, making for a much shorter transducer. The TLH is available in measuring lengths from 100 mm to 3.0 meters, and with repeatability of 0.01 mm. For short-stroke requirements, Weis selected the Novotechnik TS series. These are available with active stroke lengths of 25, 50, 75, 100 and 150 mm. A ball-style coupling for both types enables actuation free of play and lateral forces.

If the circuit breaker design does not permit use of a linear transducer, then a rotary angle sensor is required. For this need, Weis selected Novotechnik's IP 6000, with an excellent resolution of 0.007° and linearity up to +/- 0.025%. Lifetime durability for all three Novotechnik sensors mentioned above is 10 million rotations or strokes. "This has proven to be more than sufficient up until now for use in our test systems," explains Weis CEO, Detlev Weis, and if needed, "... it's easy to replace and doesn't cost all that much."

60 kV and 1000 kV. When these breakers switch, a massive arc of electricity initially flows between the contacts until they either physically closed or are sufficiently far apart. The arc causes erosion damage to the contacts, and this damage increases with every switching event. The amount of damage is limited by designing the circuit breakers to have very high opening and closing speeds, but the contacts still sustain damage.

This erosion damage requires replacement of the contacts when the damage becomes excessive. The previously existing practice was to physically inspect the contacts for wear. However, this was difficult and costly, as it required opening the circuit breaker housing. The housing of these breakers is filled with sulphur hexafluoride gas, which is inert to prevent fires, but is expensive. After physical inspection, the housing must be refilled.

To solve this problem, a method was needed to check the condition of the contact without opening the housing. Weis solved the problem with the help of Novotechnik potentiometers. The Weis SA 100 is a durable, portable system for analyzing high-voltage circuit breakers. It provides data on the operational state of the circuit breaker contacts without having to open the housing. The SA 100 measures virtually all critical characteristics of high voltage breakers in one test, with up to 32 analog and digital channels. This includes the operate time and opening/closing speeds, as well as the dynamic measurement of contact surface current and transitional resistances.

Linear or round potentiometers for position detection

The operational speed and acceleration of the breakers is quite high, with accelerations in the range of 30 to 40 g, and velocities of 20 meters/second. To monitor these criteria, Weis engineers needed position transducers that could keep up with the high dynamic requirements of the breakers, and were rugged, reliable, and cost effective.



The moving outer contact also shows considerable signs of wear (photo: Weis)

Contactless, Magnetostrictive Position Transducers with a Measuring Path of up to 2,500 mm: For Direct Integration in Pneumatic and Hydraulic Cylinders



Rugged, reliable and precise sensors are in demand for mobile applications. Contactless, magnetostrictive position transducers meanwhile play an important role in this field of application, as they guarantee maximum safety and dynamics when transmitting measured values. New designs can even be integrated directly in hydraulic or pneumatic cylinders.

Contactless, magnetostrictive position transducers with a measuring path of up to 2,500 mm: suitable for direct integration in the pressure area of pneumatic and hydraulic cylinders (photo: Novotechnik)

With the absolute-measuring position sensors of the TIM series, Novotechnik has now added magnetostrictive position transducers to its product line which are suitable for inexpensive position determination directly in the pressure area of hydraulic and pneumatic cylinders. The rod-shaped sensors offer a whole range of advantages compared to other measuring principles: Measuring lengths between 50 and 2,500 mm can be realised; stainless steel makes them extremely sturdy and impervious to virtually all media. In addition, the sensors operate extremely precisely and are reliable even under adverse ambient conditions. The linearity values are 0.04 %, and the repetition accuracy is 0.005 % regardless of the measuring length. The contactless, and therefore virtually wear-free sensors are pressure-resistant up to 350 bar (pressure peaks up to 530 bar).

The sensor consists of a pressure-resistant measuring rod which fits into the drilled piston rod. The ring-shaped position transducer is mounted on the piston base. The contactless connection simplifies assembly, as it permits comparatively large tolerances. The electronic signal processing unit is housed in a stainless-steel flange, which is welded to the measuring rod. The sensor therefore

forms a compact unit. As the sensors are not only available with the 48 mm push-on flange common in mobile hydraulics but, for example, also with an M18 screw flange and plug connection, they adapt well to the respective application. They are impact and vibration-resistant, withstand operating temperatures up to 105 °C and naturally meet all common requirements for EMC and vehicle electrical systems of the mobile sector. The measured value is available at the output for direct further processing as a common current or voltage signal.

Novotechnik – 60 years on: Precision you can trust... anywhere on earth.



Our sales, administration and development functions are based at our headquarters in Ostfildern-Ruit near Stuttgart, Southwest Germany

Wherever positions and angles need measuring with the utmost precision, sensors from Novotechnik are the first-choice solution. The expertise in measuring technology that we have amassed in the course of 60 years is just one of the secrets behind a success story that began back in 1947:

The other cornerstones of our success include a passion for technology and an obsession with precision and reliability. Then there is our delight in devising solutions, coupled with a fascination with new materials and production methods. And of course there is our constant awareness of the importance of providing sound advice and top-class service, as we strive day-by-day to optimise our measuring systems.

But the true secret of our success has always been our passionate pursuit of the best possible solution for each individual customer application. And to ensure that we remain the first-choice partner for our customers, in future we will be staying

focused on the strengths that made us the successful company that we are today.

Leading OEMs from a whole spectrum of industries put their trust in position transducers and rotary sensors made by Novotechnik: be it general engineering, hydraulics, pneumatics, measuring technology, medical technology or automotive engineering. And talking of the automobile industry, every day more than 30,000 of our sensor components are built into new cars.

Quality products

Just how high our quality requirements are is documented by the fact that we were one of the first companies in the world to have its operations certified to ISO/TS 16949.

And at Novotechnik the process that begins with stringent and demanding specifications ends with a 100% inspection of every single product. That way, we can be sure that every product we manufacture works perfectly.

A worldwide network

Today, Novotechnik is represented in all of the world's major markets – be it with our own offices or by approved dealers. Thanks to this tightly-knit network we can ensure that, wherever they happen to be, our customers can rely on first-class service and customer care.

Our partners

In order to guarantee maximum quality, we develop, design, manufacture and assemble the majority of our products ourselves at our sophisticated production facilities in Ostfildern near Stuttgart.

Whenever we are unable to make the required product ourselves, we can rely on the support of a selection of proven and renowned partner companies. As a result, we are in a position to fill almost every order of any size from anywhere in the world.

Novotechnik – 60 years on: Precision you can trust... anywhere on earth.



Our product portfolio comprises position transducers, rotary sensors, automotive products, signal conditioners and measuring devices

The products

We offer our products in many of sizes and versions to best meet the requirements of our customers. As a result, our position transducers are available in an extremely broad range of designs and in measuring lengths from 5 to 5,000 mm. Potentiometric or contactless models, with various signal outputs, as a complete sensor or as components. Our rotary sensors are also available in a wide variety of mechanical configurations from extremely small diameters with very low torque to sealed units in heavy cast housings. Our sensors are used extensively within the automotive industry to keep vehicles safely on track at their limits and generate signal feedback for optimum gearbox control. They also provide intelligent engine power control for environmentally conscious operation.

On land, at sea and in the air

There are countless applications for Novotechnik sensors. For example, our solutions ensure maximum efficiency of large solar and wind power plants. They enable innovative steering of the Human Transporters and assume control tasks in the high-speed ICE 3 train. Formula 1 teams put their trust in Novotechnik sensors in the chassis, gearboxes and engines, as do a large number of

mobile machine manufacturers in the agricultural and construction machine industry. Our sensor solutions have traditionally proven themselves in open and closed-loop control systems, automation and monitoring of processes in mechanical engineering and specifically in the field of plastic injection moulding technology. Novotechnik products can also be found in engine management of motor vehicles and in medical technology.

Our sensors are also at home on the seven seas and countless rivers. In the highly modern control systems of ferries, cruise liners and container ships they measure and control rudder blades and rudder propeller systems. They also ensure a consistently optimum position of the drive propellers of high-powered sports boats and perform valuable services on many oil drilling platforms worldwide. Novotechnik even provides sensors on large sailing ships, providing signal information for optimal alignment and lowering of the sails from the command bridge.

Salty sea air, high humidity and extreme temperature fluctuations place the most demanding requirements on the performance of sensors at sea. Here the linear position and rotary sensors from Novotechnik prove to be not only durable, but very precise as

well. In the course of our 60 years of experience, we have adapted our solutions in the best possible way to the special operating conditions that prevail both above and under water. Our knowledge and experience are also reflected at sea in the long life and high reliability of our products.

Precise control information is a vital requirement in the aerospace industry. Thanks to their high precision and reliability, our position and rotary sensors have also earned an outstanding reputation in this discipline. Whether in the joystick of an Airbus, during down-to-the-millimetre ground transport of a space shuttle or onboard the Cassini-Huygens Mission for investigating Saturn and its moons - measuring sensors from Novotechnik make a major contribution to keeping aircraft, space shuttles and satellites on course and bringing them safely to their destinations. Major air pressure fluctuations and large temperature differences including extreme cold are the greatest challenges for sensors in the aerospace sector. That's an environment in which our linear position and rotary sensors can provide impressive proof of all their strengths. In the field of flight safety, in which the reliability of the measuring systems is vitally important for survival aircraft builders and aerospace engineers put their trust in measuring sensors from Novotechnik.



C E R T I F I C A T E

DQS GmbH

Deutsche Gesellschaft zur Zertifizierung von Managementsystemen

hereby certifies that the company

novotechnik

Novotechnik Messwertaufnehmer OHG

Horbstraße 12
D-73760 Ostfildern

for the scope

Develop, manufacture and sale of sensors for linear and rotary position measurement

has implemented and maintains a

Quality Management System.

An audit, documented in a report, has verified that this quality management system fulfills the requirements of the following standard:

DIN EN ISO 9001 : 2000

December 2000 edition

This quality management system fulfills the requirements set out by the international and German Road Traffic Regulations including the approval objects as listed in the appendix.

This certificate is valid until 2009-09-03

Certificate Registration No. 003985 QM ST

Frankfurt am Main 2006-09-04

Ass. iur. M. Drechsel

Dipl.-Ing. S. Heinloth

MANAGING DIRECTORS

D-60433 Frankfurt am Main, August-Schanz-Straße 21



Representatives

Germany

Baden-Württemberg

Novotechnik
Messwertaufnehmer OHG
Dipl.-Ing. Hansjörg Rückert
73760 Ostfildern
Tel. (+49) 0711 4489-180
Fax (+49) 0711 4489-118
rueckert@novotechnik.de
www.novotechnik.de

Bayern

Hans Trinczek GmbH & Co.KG
Mess- und Regelungstechnik
86916 Kaufering
Tel. (+49) 08191 662 39
Fax (+49) 08191 652 93
hans.trinczek@trinczek.com
www.trinczek.com

Hessen, Rheinland-Pfalz, Saarland, Nordrhein-Westfalen (Süd)

Armin Bollmann Ingenieurbüro für
Mess- und Regeltechnik GmbH
63075 Offenbach
Tel. (+49) 069 865086
Fax (+49) 069 865517
Info@bollmann-messtechnik.de
www.bollmann-messtechnik.de

Sachsen, Thüringen, Sachsen- Anhalt, Berlin, Brandenburg, Mecklenburg-Vorpommern

TVS GmbH & Co.
08359 Breitenbrunn, OT Rittersgrün
Tel. (+49) 037757 7100
Fax (+49) 037757 7101
tvs@tvs-gmbh-co.de
www.tvs-gmbh-co.de

Bremen, Hamburg, Niedersachsen, Schlesw.-Hol., Nordrhein-Westfalen (Nord)

Leue Sensorics Ingenieurbüro für
Mess- und Regeltechnik
29358 Eicklingen-Sandlingen
Tel. (+49) 05149 92129
Fax (+49) 05149 92130
info@leue-sensorics.de
www.leue-sensorics.de

Europe

Austria, Brunn a.Gebirge
Reliste Steuerungstechnik
Tel. (+43) 2236 31525-0
Fax (+43) 2236 31525-60
office@reliste.at
www.reliste.at

Baltic States, Tallinn / Estonia
SKS-Tehnika OÜ
Tel. (+372) 6990 172
Fax (+372) 6990 170
peeter.kuus@sk.fi
www.sks.fi

BENELUX, NL-Dordrecht
AE Sensors B.V.
Tel. (+31) 78 6213152
Fax (+31) 78 6213146
aesensors@aesensors.nl
www.aesensors.nl

Denmark, Farum
Mikkelsen Electronics AS
Tel. (+45) 4434 0300
Fax (+45) 4434 0310
info@mikkelsen-electronics.dk
www.mikkelsen-electronics.dk

Finland, Vantaa
SKS-automaatio Oy
Tel. (+358) 20 76461
Fax (+358) 20 7646820
automaatio@sk.fi
www.sks.fi

France, Les Clayes Sous Bois
FGP Instrumentation
Tel. (+33) 1 30796540
Fax (+33) 1 30540143
scom@fgp.tm.fr
www.fgp-instrumentation.com

Great Britain, Towcester
Variohm Components
Tel. (+44) 1327 351004
Fax (+44) 1327 353564
sales@variohm.com
www.variohm.com

Italy, Pescantina - Verona
BTS Elettronica s.r.l.
Tel. (+39) 045 6700744
Fax (+39) 045 7156927
info@btsitalia.it
www.btsitalia.it

Norway

Mikkelsen Electronics AS, Stockholm
Tel. (+46) 850 150760
Fax (+46) 850 150765
info@mikkelsen-electronics.com
www.mikkelsen-electronics.com

Poland, Wroclaw

ELTRON
Tel. (+48) 71 3439755
Fax (+48) 71 3441141
eltron@eltron.pl
www.eltron.pl

Russia / Ukraina, Moscow
Inpromtex Engineering
Tel. (+7) 095 5445935
Fax (+7) 095 5445935
d.pavlenko@inpromtex.net.ru
www.inpromtex.ru

Sweden, Stockholm
Mikkelsen- Electronics AS
Tel. (+46) 850 150760
Fax (+46) 850 150765
info@mikkelsen-electronics.se
www.mikkelsen-electronics.se

Switzerland, Wallisellen
Dietrich + Blum AG
Tel. (+41) 848 300700
Fax (+41) 848 300701
dbnet@dietrichundblum.ch
www.dietrichundblum.ch

**Slovenia / Croatia / Bosnia-
Herzegovina / Montenegro /
Serbia**, Postojna
ADEPT PLUS d.o.o.
Tel. (+386) 57536136
Fax (+386) 57536138
info@ad-avtomatizacija.si
www.ad-avtomatizacija.si

Spain / Portugal, Barcelona
Mapro Ingenieria, S.A.
Tel. (+34) 902 328328
Fax (+34) 902 464363
info@maprosensor.es
www.maprosensor.es

Czech Republic / Slovakia, Praha
Orbit Merret s.r.o.
Tel. (+42) 02 81040200
Fax (+42) 02 81040299
orbit@merret.cz
www.orbit.merret.cz

Turkey, Maltepe-Istanbul
Alfa Elektronik Makine Ltd Sti
Cevizli Mah. Güven Sok. No. 11
Tel. (+90) 216 3994404
Fax (+90) 216 3994402
info@alfasanayi.com
www.alfasanayi.com

Hungary / Bulgaria / Romania, Pécs
Kontakt Elektro Kft Pécs
Tel. (+36) 72 516067
Fax (+36) 72 516069
kontakt@kontakt-elektro.hu
www.kontakt-elektro.hu

Africa

Southafrica, Bruma
Progressive Distributing
Enterprises cc/PDE
Tel. (+27) 11 6159786
Fax (+27) 11 6150786
pde@pde.co.za

Asia

China / Vietnam, Shanghai
Novotechnik Rep. Office
German Center
Tel. (+86) 1381 7054 506
Fax (+86) 21 28986211
gaowei@novotechnik.cn
www.novotechnik.cn

MIRLE Technology Co.,Ltd.
Shanghai
Tel. (+86) 21 50485800
Fax (+86) 21 50485216
nt_china@mirle.cn
www.mirle.com.cn

India, Thane
Accent Controls (P) Ltd.
Tel. (+91) 22 2582-2141/ 0162
Fax (+91) 22 2582-4746/ 2548
info@accentsensors.com
www.accentsensors.com

Japan, Saitama
B&PLUS K.K.
Tel. (+81) 493655771
Fax (+81) 493653171
b-plus-kk@b-plus-kk.jp
www.b-plus-kk.jp

Korea, Seoul
SUN-BEE Instruments, Inc.
Tel. (+82) 2 2065 5100
Fax (+82) 2 2065 8222
sunbees@unitel.co.kr
www.sunbees.co.kr

**Singapore / Indonesia / Cambodia /
Malaysia / Philippines / Thailand**
MOOG Singapore Pte.Ltd.
Tel. (+65) 67736238
Fax (+65) 67777627
sales.singapore@moog.com

Taiwan, Taipei
Daybreak International Corp.
Tel. (+886) 2 88661231
Fax (+886) 2 88661239
day111@ms23.hinet.net
www.daybreak.com.tw

Middle East

Iran, Tehran
Ricc Rashidian Industrial Automation
& Commercial Co. LTD.
Tel. (+98) 2188 9657 92
Fax (+98) 2188 9692 45
m.shahgolian@ricc.ir
www.ricc.ir

Israel, Bney Berak
Bruno International Corp.
Tel. (+972) 3 5705323
Fax (+972) 3 5705331
zeev@brunocorp.co.il

Australia

Moog Australia Pty. Ltd.
Tel. (+61) 3 95616044
Fax (+61) 3 95620246
sales.australia@moog.com

South America

Brazil, Sao Paulo
Signalworks Comercio
Importacao & Exportacao Ltda.
Tel. (+55) 11 5501-5310
Fax (+55) 11 5505-5682
info@signalworks.com.br
www.signalworks.com.br

USA, Canada, Mexico

Novotechnik U.S., Inc.
Southborough, Massachusetts
01772 USA Tel. (+1) 508
4852244
Fax (+1) 508 4852430
info@novotechnik.com
www.novotechnik.com

