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WHITEPAPER

DISTANCE AND ANGLE MEASUREMENT

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IPF ELECTRONIC

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1 INTRODUCTION

Distance and angle measurements are found in almost every industrial sector, as they play a central role in the precise recording of lengths, positions, fill levels, and rotational movements, to name just a few examples. Whether in manufacturing, robotics, automation, or quality assurance, accurate measurements are essential for efficient processes, high product quality, and safe machine control. With the help of various measuring principles, both linear and rotary movements can be recorded, with the exception of distance-measuring fill level controls, which ultimately makes displacement and angle measurement systems an indispensable link between mechanical processes and digital control technology.

Against this backdrop, determining distances and angles is by no means a trivial matter. Anyone who considers the wealth of potential applications for such solutions will usually recognize the full complexity associated with a wide variety of tasks.
Here are just a few examples of distance measurements: monitoring and controlling travel distances in automation and logistics, positioning tools on machines and systems, checking the diameter of coils, monitoring press-fit and joining processes, checking fill levels and distances in tanks or containers, and so on.
The areas of application for angle measurement are equally diverse: position detection and control in automated processes, monitoring of bending process equipment, control of tilting devices in metalworking, positioning and leveling of mobile construction, work, and agricultural machinery, adjustment of tools and machine axes, etc.

Right now, the question basically arises as to how, given the wealth of possible applications, the right and therefore optimal technology for path and/or angle measurement can always be selected. In addition, many applications also require the corresponding solutions to have very specific properties, e.g., insensitivity to dirt, moisture, temperature, and vibrations, high precision and ranges, high dynamics and travel speeds, measurements independent of material properties, high flexibility, easy integration, easy installation, easy operation, and so on.

This white paper presents a wide variety of methods and devices for distance and/or angle measurement from ipf electronic and can therefore provide initial guidance for selecting a suitable technology for a specific application. In this context, it also becomes clear that there are sometimes lesser-known approaches to distance and angle measurement, which are also shown here.

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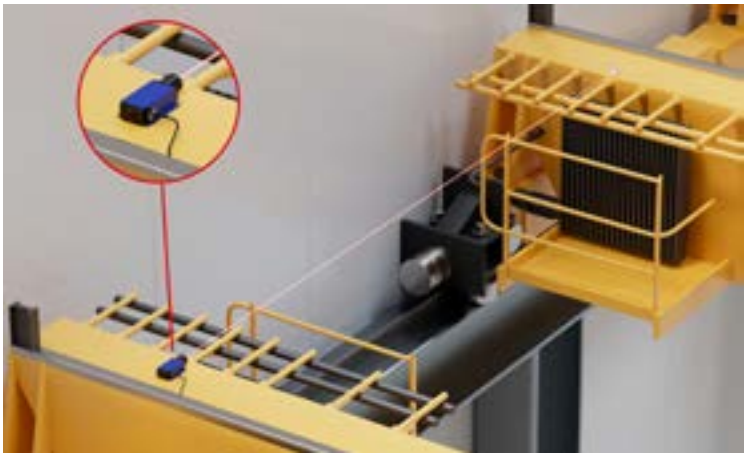
2 METHODS AND TECHNOLOGIES FOR DISTANCE MEASUREMENTS

For distance measurements, ipf electronic offers a wide range of different device technologies, e.g., laser sensors, ultrasonic sensors, inductive sensors, light grids, line scan cameras, draw-wire encoders, or incremental optical sensors, to give you a small impression. The individual solutions are presented below and their functionality is described with regard to possible fields of application.

2.1 DISTANCE-MEASURING LASER SENSORS

Laser sensors are highly accurate, which is generally well known. The devices from ipf electronic also enable long ranges and are very robust. The sensors operate either according to the phase comparison principle or the triangulation method.

In phase comparison measurement, sensors such as the **PT23**, **PT73**, **PT90**, or **PT98E294** emit a light beam modulated at a specific frequency, which generates a periodic waveform. The light beam reflected by an object hits the receiver of the laser scanner with a phase shift. The phase shift (difference between the transmitted and received light waves) depends directly on the distance traveled by the light and is converted into an analog signal (4...20mA, 0...10V) for distance measurement.



Collision monitoring of a crane runway on a bridge crane with a PT90 (range up to 35,000 mm).
(All images: ipf electronic gmbh)

Sensors such as the **PT34**, **PT44**, and **PT64** operate according to the highly accurate triangulation method. This method measures the distance to an object indirectly via the angle of incidence of the light reflected from the object's surface. To determine the angle of incidence, the sensor's receiver has a CCD line detector with a large number of individual receiving elements that together form a receiver line. The position within this line at which the light reflected from a material surface hits one or more receiving elements depends on the angle of incidence of the light beam. The angle of incidence is then evaluated and output as an analog signal proportional to the distance.

The laser sensors presented here are ideal when distance measurements with very fine resolutions are required. The measurements can be taken almost independently of the shape, color, structure, and surface of the material to be detected. The devices from ipf electronic also differ from the widely used conventional sensors in this area due to their special features. These include ranges of up to 150m (**PT90** with reflector) and absolutely reliable operation even under particularly difficult operating conditions, such as those prevailing in heavy industry. For example, the **PT98E294** integrates a dust trap for the optics.

Distance-measuring laser sensors: the **PT98E294**, **PT64**, **PT23**, and **PT44** (from left).

Potential applications for these high-precision sensors include collision monitoring of crane runways on overhead cranes, component positioning in automated production lines, positioning of robots in automated applications, measurements on difficult surfaces, e.g., red-hot metal parts, molten aluminum, etc., high-precision measurements of material thicknesses, widths, and diameters, and ovality control of pipes.

2.2 DISTANCE-MEASURING ULTRASONIC SENSORS

Ultrasonic sensors from ipf electronic, such as the **UT189023**, **UT129021**, or **UT309023**, are particularly suitable for contactless, wear-free distance measurements when long distances need to be covered or materials with rather difficult surfaces need to be detected.

Ultrasonic sensors operate on the basis of the echo time-of-flight method. The devices integrate a sound transducer that cyclically emits sound waves. The sensor then switches to receive mode to detect the waves or sound echoes reflected by a material. The transit time of the sound between the transmitter and receiver is proportional to the distance between the sensor and a material surface and results in the output of an analog signal.

Precise distance measurements on a transparent film in confined spaces using an ultrasonic sensor and deflector plate.

Ultrasonic sensors from ipf electronic impress with their long ranges of up to 6,000mm and detect even transparent and thin objects such as foils with extreme reliability.

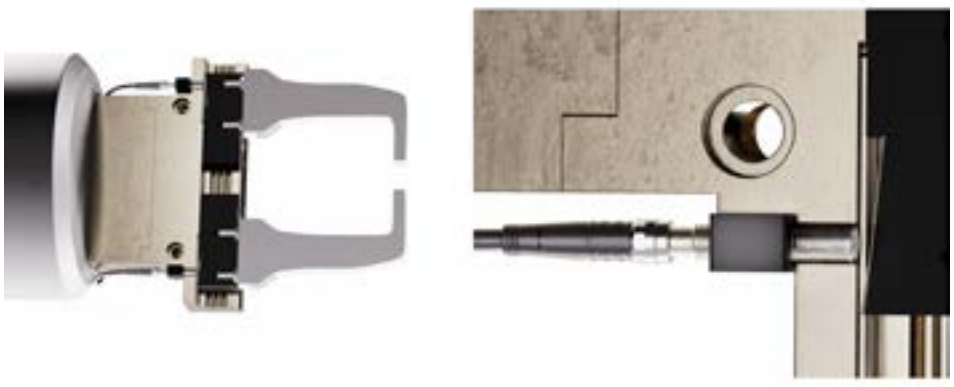
Measurements through even the smallest openings, such as test tubes, are also possible thanks to the use of a sound reduction attachment that further focuses the ultrasound (see application example at the end of the white paper). The devices can usually be used without any problems in environments with high levels of dirt or smoke, and the measuring range can be easily set using teach-in. Devices with an IO-Link interface can also be configured flexibly.

Given these characteristics, the fields of application are particularly diverse: e.g., reliable measurements on transparent glass or thin transparent films, level control in silos or cisterns, loop control on reels, control of belt tension and height scanning in production facilities, or collision control and navigation of driverless transport systems (AGVs).

Ultrasonic sensors from ipf electronic, including a device with a sound reduction attachment (below) for focusing the sound beam for measurements through the smallest openings.

2.3 INDUCTIVE DISTANCE MEASUREMENT OVER SHORT DISTANCES

Inductive sensors (e.g., **IB120026**, **IB180026**, **IB300026**, and **IB98C798**) from ipf electronic detect all metallic objects at short distances, regardless of whether they are moving or not. The outstanding feature of these extremely robust and durable inductive sensors is their enormous endurance, even in environments with high levels of contamination, such as dust, oils, lubricants, etc.

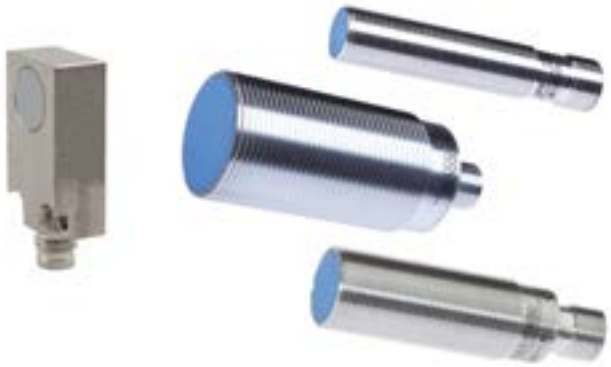


Precise detection of the opening width of a gripper using an inductive sensor.

These long service lives are made possible by, among other things, the special mode of operation of inductive sensors. Put simply, inductive sensors consist of a coil directly behind the sensor head, which is part of an oscillating circuit, followed by the evaluation

electronics and an output stage or amplifier. The resonant circuit coil behind the active surface of the sensor generates an alternating electromagnetic field. When a metallic object approaches the active sensor surface, eddy currents are induced in the object, which draw energy from the resonant circuit. This influence on the resonant circuit allows the distance between the sensor and an object to be determined and output as an analog signal (4...20mA, 0...10V) proportional to the distance.

Inductive sensors from ipf electronic are ideal for reliable, wear-free distance measurement on all moving and stationary metallic objects under the harshest operating conditions with high levels of dirt or strong vibrations. Larger measuring ranges from 4mm to 20mm can also be covered.



Various designs of inductive sensors, including a rectangular device.

Experience has shown that ipf electronic solutions are very often used for querying the opening width of grippers, for press-fit control of components, for measuring travel and querying the direction of rotation, e.g., of coding discs, or for positioning, e.g., of workpieces or components.

2.4 LINE SCAN CAMERAS/LASER LINE SENSORS: DISTANCE MEASUREMENT OVER LARGE OBJECT AREAS

Laser line sensors as through-beam sensors with transmitter (**PS75**) and receiver (**PE75**) are easy to install due to the visible red light and provide high resolutions (0.008mm) for high-precision distance measurements. The **PYSI0317** line scan camera has a C-mount lens connection. By selecting a suitable lens in combination with an LED line light, distance measurements over large object measurement ranges with greater distances are possible.

Line sensors from ipf electronic generate a type of light curtain with a very homogeneous linear light beam as transmitter-receiver systems. If, for example, a material web is located in the detection range of the transmitter and receiver, its shadow image is projected onto the receiver‘s line detector. The degree of coverage or the size of the shadow cast provides information about the respective position of the detected object. The size of the shadow cast is therefore directly dependent on the movement of the object into the light beam. The change in the shadow cast is used for high-precision distance measurements to output an analog signal. The transmitter-receiver systems achieve ranges of up to 2,000mm.

The line cameras from ipf electronic work in a similar way. However, a linear light source is used as the counter element (transmitter) for the camera with the CCD receiver line. Line scan cameras therefore work in the same way as line sensors, with coverage proportional to the image. The change in the shadow cast on the camera‘s line detector can therefore also be output as corresponding analog signals for highly accurate distance measurements.

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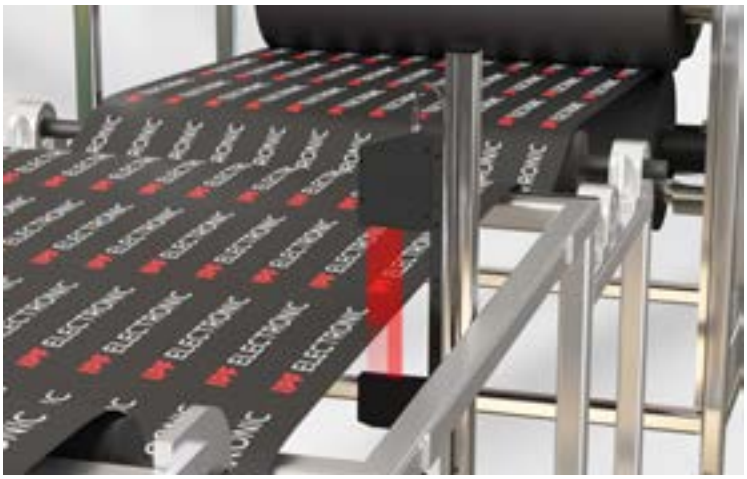

Safe track edge control from a greater distance with a transmitter/receiver system (PS75/PE75).

Laser line sensors or line scan cameras are recommended for high-precision monitoring of larger web edge areas. Transmitter/receiver systems are used for web edge control of thin material webs, among other things, due to their high precision. Another advantage of such systems in this context is that accurate measurement results are achieved even with height fluctuations of web edges, for example due to low material tension in the manufacturing process.

Line scan camera (left) and PE75 (receiver) and PS75 (transmitter) laser line sensors.

Potential areas of application for such devices include wear-free distance measurements even on thin material webs such as fabrics, films, paper, etc., or highly accurate web edge control and diameter determination of coils, to name just a few examples.

2.5 LIGHT GRIDS: DETECTION OF LARGE OBJECTS FROM LONG DISTANCES

Due to their dimensions, it is difficult or even impossible to measure many objects using conventional sensor solutions. Examples of this include diameter control of coils or height measurement (stack heights) in wood processing companies such as sawmills.

The **OY41002x**-series of light grids from ipf electronic are ideal for these and a whole range of similar tasks. With their flexible field heights (measuring range) and resolutions (depending on the number of light beams), these light grids are ideal for the reliable detection of particularly large objects over long distances.

Safe height control of pallets with OSB boards using a light grid from the OY41002x series.

As transmitter-receiver systems, light grids transmit individual light beams instead of a homogeneous linear light beam like the laser line sensors described in section 2.4. The coverage or interruption of the light beam results in path information that can be represented by an analog signal.

Light grids in the **OY41002x**series enable measuring ranges from 75mm to 2010mm, with the resolutions of the systems (from 1 mm to 25mm) depending on the respective number of light beams. The light grids also impress with their very long ranges, which can be up to 8m depending on the model.

The light grids of the **OY41002x**-series are available for various measuring ranges with different resolutions.

Areas of application for light grids, such as checking coil diameters in metal processing or height measurements in the wood industry, were already mentioned at the beginning of this chapter. However, determining permissible vehicle heights in car washes, at entrances, or on loading ramps, monitoring the speed of conveyor belts and transport belts, and measuring the distance between objects in automated processes are further good examples of the versatility of light grids from ipf electronic.

2.6 INCREMENTAL OPTICAL DISTANCE MEASUREMENT

The **VO33** incremental optical sensor from ipf electronic has a relatively new mode of operation, which proves extremely useful for objects with very different material surfaces, among other things. In addition, the **VO33** can be parameterized using free software, allowing the device to follow the trend toward multifunctional sensor technology.

A transmitter (laser class 1) integrated into the sensor and operating with infrared light periodically emits light pulses that are reflected by an object surface. A photosensor in the device receives the reflection signals and detects the pixel changes that occur from one image to the next due to the object surface moving under the sensor. These pixel changes can be used, among other things, to detect the distance traveled by an object without contact and thus without slippage.

If the incremental optical sensor is connected to a PC during operation, the free software can also be used to determine the travel speed of an object. In addition, the **VO33** has a rotary encoder output that provides two 90-degree phase-shifted square wave signals A/B. These outputs can be used, for example, to control the travel path. Another switching output also offers the option of parameterizing a zero point for a predefined distance (e.g., every 50mm) in order to reset a counter or process the signal, for example, to control automated cutting of strip materials in a PLC. With a view to high process reliability, the second output can also be parameterized as an alarm output.

Non-contact, slip-free, and surface-independent distance measurement with the **VO33**.

Due to its special mode of operation, the **VO33** detects all objects within a sensing range of 15 to 60mm, regardless of material and color. Thanks to its high scanning rate of 0.9ms, the sensor can even detect materials in fast-moving processes. Flexible parameterization using the free software also gives the device additional practical application options.

2.7 CABLE PULL SENSOR: PARTICULARLY SIMPLE DISTANCE MEASUREMENT

The functionality of the **VS98** cable pull sensor from ipf electronic is immediately apparent to the observer. The device is one of a number of solutions that enable distance measurements to be carried out in an extremely straightforward manner.

The sensor housing (cable pull body) contains a cable with spring return. The eyelet at the start of the cable is simply attached to an object. When the object moves, the cable is pulled out of the housing. The distance traveled by the object is then determined based on the length of cable unwound and output as a measured value (4...20mA) at the analog output via a potentiometer. This also works “indirectly,” e.g., by guiding the cable over a

deflection roller.

The **VS98** cable pull sensor is a prime example of a very simple, reliable absolute displacement measurement system that can also be used indirectly, with measurements possible over a distance of up to 1,500mm. Other key features of the **VS98** in its robust zinc die-cast housing include an absolute accuracy of 0.15mm and a high travel speed of up to 1m/s.

It couldn't be easier: position measurement on a lift table using a cable pull encoder.

Potential areas of application for this simple yet highly reliable solution include monitoring the fork lift height of forklifts, measuring the lift height on many means of transport with lifting devices, measuring the lift on telescopic and hydraulic cylinders, measuring the position on cranes, pallet trucks, scissor lifts, or lifting platforms, and the general monitoring of all conceivable movement processes.

2.8 MECHANICAL SENSOR: BECAUSE TACTILE IS SOMETIMES BETTER

With the exception of the cable pull sensor, only contactless sensors for distance measurement have been presented so far. However, there are a number of applications in which only mechanical systems with tactile detection of an object can achieve the desired results in distance measurement. The **YM12** mechanical sensor from ipf electronic has a particularly sophisticated mode of operation and therefore offers a very robust and precise solution for a range of such tasks.

The **YM12** works on the principle of a differential transformer (a special type of transformer). A spring-mounted measuring rod serves as the movable core of the excitation coil, which is arranged symmetrically between two secondary coils. As soon as the rod is no longer in its middle position (0mm position), a voltage is induced in one of the two adjacent secondary coils, which enables distance measurement via the output of an analog signal (0...10V).

Cross-section of the YM12: The spring-mounted measuring rod (core) with the excitation coil and secondary coils (red).

The **YM12** (measuring range ±5mm) is therefore a robust and highly precise solution for all types of mechanical distance measurements with an accuracy of <0.1mm. The stainless steel housing integrates a plunger with a hardened tip and shock resistance up to 200g (g= gravitational acceleration of 9.81m/s2). Thanks to its particularly high-quality industrial design, the sensor can also be used in very harsh environmental conditions (e.g., moisture, aggressive chemicals, elevated temperatures, etc.).

Tactile assembly inspection of transmission components with the **YM12**.

The **YM12** can be used wherever tactile distance measurements with very high accuracy are required, e.g., for positioning glass plates, checking the presence of seals on housing covers, or detecting and positioning small components.

3 METHODS AND TECHNOLOGIES FOR ANGLE MEASUREMENTS

For pure angle measurements, ipf electronic currently offers both inclination sensors and magnetic angle measurement systems.

3.1 INCLINATION SENSORS – PARTICULARLY EASY TO INSTALL

Inclination sensors should be as easy to install as possible and therefore quickly ready for use. However, installing the devices while taking alignment (axis, zero point) into account often requires a great deal of skill in practice, if not additional aids such as spirit levels, laser alignment aids, or electronic levelers, especially for particularly precise applications. This effort is eliminated with the **YN58**-series of inclination sensors from ipf electronic for measuring the angle of inclination in the X and Y directions.

The reasons for this can be found in the “inner values” of the sensors, because during installation, an integrated LED display visualizes the angle of inclination of the device. In addition, crosshair LEDs arranged around this display indicate the direction (X or Y) in which the sensor is currently tilted. The **YN58**-series inclination sensors are therefore ready for immediate use with minimal effort.

Easy installation and alignment: The YN58 series inclination sensors feature an LED display and crosshair LED for this purpose.

The sensors use Earth‘s gravity to measure the angle of inclination. To do this, they integrate a high-precision acceleration measuring cell (MEMS: microelectromechanical system) and output the angles according to the respective measuring axis or measuring axes.
If an angle to Earth‘s gravity changes, this is detected by the measuring cell. The correspondingly processed signal is linearized and output via the two analog outputs (4...20mA) as a value for the X and Y axes as angle information.

The resolution of the output signal is 0.02°. The repeat accuracy is typically 0.03° or 0.1%. The sensors are available with different tilt angle measuring ranges for a wide variety of applications: from-10° to +10°, from-45° to +45°, and from-85° to +85°.

YN58-series inclination sensors ensure precise alignment of the angle of attack of a crane boom and the alignment of the crane vehicle on the ground.

Against this background, the **YN58**-series has a wide range of applications, e.g., for continuous inclination control on mobile machines such as excavators, cranes, lifting platforms, tractors, or various construction machines, for monitoring the angle of attack of crane jibs, for safe alignment or leveling of vehicles and machines in the field, for monitoring and aligning PV systems and wind turbines, for optimizing agricultural machinery, e.g., for precise plowing and sowing, for monitoring the movement and alignment of industrial robots, and much more.

3.2 MAGNETIC ANGLE SENSORS – HIGHLY VERSATILE IN TERMS OF INSTALLATION

The **MD42002x**-series of absolute angle sensors are very compact devices that cover the entire 360° angle range. The sensors can be used even under the most adverse environmental conditions. Another advantage is that the separate mounting of the encoder and sensor opens up many variable mounting options, making the devices ideal for easy integration into existing machine assemblies.

As mentioned above, the devices consist of two main components: a movable encoder (magnet) and a stationary sensor. In relation to the sensor, the direction of the field lines in space changes depending on the rotational movement of the encoder. The fixed sensor detects the changes in direction in the field lines, allowing the exact position of the encoder relative to the sensor to be determined. The corresponding angular position in the range from 0° to 360° is output as an analog current or voltage signal (4...20mA, 1...10V).

The angle sensors in the **MD42002x**-series consist of a movable encoder (left) and a stationary sensor (right) with an M12 connector.

Magnetic angle measurement systems such as the **MD42002x**-series are highly resistant to many environmental influences such as dirt, dust, moisture, or oils, and enable particularly simple, variable installation and commissioning. As absolute encoders, the devices do not need to be calibrated or referenced before commissioning, covering the entire angle range from 0° to 360°.

Integration into existing industrial applications is therefore straightforward, e.g., for position control of turning stations for heavy wire coils, for controlling tilting devices in metalworking, or for a wide range of other industrial control and regulation tasks.

If, for example, the angle of attack of a coil tilting station needs to be monitored, a space-saving angle sensor from the **MD42002x**-series is ideal for this purpose.

4 METHODS AND TECHNOLOGIES FOR DISTANCE AND ANGLE MEASUREMENTS

Of course, ipf electronic's portfolio also includes devices that can do both, i.e., distance and angle measurement. The range extends from a wide variety of magnetic systems to parameterizable rotary encoders.

4.1 MAGNETIC MEASURING SYSTEMS: HIGHLY DYNAMIC, PRECISE, FAST, AND ROBUST

If any product group deserves to be called "particularly versatile" in terms of displacement and angle measurement, it is magnetic measuring systems such as the **MW10**, **MW11**, **MW20**, and **MW09** from ipf electronic.
These particularly durable systems are valued above all for their high dynamics and travel speeds, while solutions such as the **MW09** can also be used anywhere thanks to their mobile display.

High-precision position measurement on a linear unit with a magnetic measuring system from ipf electronic.

Magnetic measuring systems from ipf electronic are a combination of magnetic tape or magnetized measuring wheel and probe (sensor). On the magnetic tapes or the circumference of the measuring wheels, north and south poles alternate in exact pole width.
The sensor detects the magnetic fields (field lines) of the north and south poles without contact and generates a high-resolution signal similar to that of a rotary encoder, either for precise distance measurements or, via the angle of rotation, for exact angle measurements. Incremental systems such as devices in the **MW10**, **MW11**, and **MW09**-series must be referenced for position indication. This is not necessary for absolute encoders with a unique sequence of north and south poles, such as the **MW20**.

The **MW09** mobile incremental encoder, e.g., for precise measurements of length stops and miter angles.

The magnetic systems from ipf electronic offer everything you need for wear-free and slip-free position and angle measurements, with solutions that prove themselves even in harsh industrial environments, e.g., with dirt and moisture. The systems, which are available as either absolute encoders or incremental encoders, impress in practical use above all with their high travel speeds of 25m/s and high resolutions of up to 0.01mm. A special feature in the ipf electronic portfolio is certainly the **MW09** incremental encoder, which can be used in mobile applications.

Whether in plants and systems in the wood and metal industry, as a component of various stop systems, for position measurements on linear axes, for setting and adjusting tools on machines, or for determining rotation angles on rotationally symmetrical or curved shafts, ipf electronic‘s magnetic position measurement systems leave nothing to be desired in terms of precision and versatility.

4.2 CONFIGURABLE ROTARY ENCODERS: FAST RESPONSES AT HIGH SPEEDS

Rotary encoders are known to be particularly suitable for measuring distance and angle. The devices from ipf electronic can also be parameterized via a PC and can therefore be set directly on site to the required number of pulses per revolution (between 1 and 65,536 revolutions). This opens up immense flexibility when using the **VD58982x** rotary encoders from ipf electronic.

The incremental encoders operate on the principle of optical scanning. They integrate a pulse disc with a repeating (incremental) scale. This is scanned by an optical system and converted into encoder-specific output signals (A, B, 90°) by integrated electronics.

Precise length measurement of a labeled film using a configurable rotary encoder and a suitable measuring wheel.

For length or distance measurements, the encoder shaft is connected directly to a deflection pulley or mounted on a measuring wheel. The encoders, which are available with hollow or solid shafts, are ideal for applications with fast-running processes and high speeds of up to 6,000rpm. In addition, the encoders are extremely robust due to their high shock and vibration resistance.

The **VD58982x**-series rotary encoders are available in various designs with solid shafts (6 mm, 10 mm) (left) and hollow shafts (8mm, 10mm, 12mm).

Due to their demand-specific parameterization and wide range of variants with hollow or solid shafts, the VD58982x series encoders are particularly suitable for industrial sectors with a high demand for encoders for different applications.
There are virtually no limits to the potential fields of application: high-precision monitoring and control of travel paths in automation and logistics, precise positioning of tools on machines and systems, highly accurate length measurement on conveyor systems, high-precision angle measurement on bending machines, monitoring of die presses during bending processes, or speed measurements on winding systems, to name just a few examples.

5 OVERVIEW OF TECHNOLOGIES FOR DISTANCE AND ANGLE MEASUREMENT

The following table summarizes the key features and special characteristics of ipf electronic‘s solutions for displacement and angle measurement. Note: The columns “Measuring range” and “Resolutions” are not related to each other, but can also describe separate devices. For example, in the case of laser sensors, the measuring range of up to 150m is not related to the resolution of up to 6µm.

TECHNOLOGY	DIS-TANCE	ANGLE	MEASURING RANGE	SOLUTION	SPECIAL FEATURES	ENVIRON-MENT
Laser sensors	✓	✗	to 150m	to 6µm	Measurements independent of shape, color, structure, and surface	Particularly difficult environmental conditions
Ultrasonic sensors	✓	✗	to 6,000mm	1mm	Detection even of thin, transparent materials	Dirt, smoke
Inductive sensors	✓	✗	4mm to 20mm	0mm to 1µm	Extremely long service life	extremely high levels of dirt and moisture
Line camera/ Line sensor	✓	✗	Depending on the lens (line camera) up to 2,000 mm (line sensors),	<0.5mm 0.008mm	Ideal for web edge control, e.g., on thin materials	also for harsh environments
Light curtains	✓	✗	75mm to 2010mm	1mm to 25mm	Capture of particularly large objects	
Inkrementaler Optosensor	✓	✗	15mm to 60mm		High sampling rate: 0.9 ms Display of travel distance and travel speed	
Seilzugsensor	✓	✗	bis 1.500mm	0.15mm	very simple and reliable	
Mechanical sensor	✓	✗	±5mm	<0.1mm	tactile distance measurement	Moisture, aggressive chemicals, elevated temperatures
Inclination sensor	✗	✓	-10° to +10° -45° to +45° -85° to +85°	0.02° (Output signal)	Easy alignment via LED display and crosshair LED	For indoor and outdoor applications with typical environmental conditions
Magnetische Winkelsensoren	✗	✓	0° to 360°		Ideal for easy retrofitting	Most adverse environmental conditions
Magnetic measuring systems	✓	✓	Depending on magnetic tape length: up to 75 m (incremental), up to 5.12 m (absolute)	to 0.01mm	MW09 incremental encoder with mobile display	Harsh industrial environment, e.g., dirt, moisture
Configurable rotary encoders	✓	✓	1 to 65,536 increments/ revolution		Can be parameterized on site based on pulse count	High shock and vibration resistance

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6 SUMMARY AND CONCLUSION

There are a wide variety of very different industrial tasks for displacement and angle measurements. With its technologies, ipf electronic covers the entire range of applications, whether specifically for displacement or angle measurement, or for both disciplines together.

Distance-measuring laser sensors from ipf electronic, which operate either according to the phase comparison principle or the triangulation method, stand for high-precision distance measurements. The systems achieve long ranges of up to 150m (with reflector) and prove to be extremely robust in operation.

With ranges of up to 6,000mm, ultrasonic sensors also offer a great deal of freedom in distance measurement, regardless of the shape, color, or transparency of the objects. The sensors are therefore ideal for detecting transparent thin films or for level measurements in large containers such as silos. Level detection through the smallest openings, such as test tubes, is also possible with ultrasonic sensors from ipf electronic.

If the operating environment is particularly harsh, then distance measurement is a task for inductive sensors, which are known for their high tolerance qualities. The sensors not only withstand extreme dirt (dust, oils, lubricants, etc.), but are also insensitive to strong vibrations. Inductive sensors from ipf electronic also cover larger measuring ranges from 4mm to 20mm.

If large object areas need to be monitored, e.g., to control the web edge of thin materials, then the properties of line scan cameras or laser line sensors from ipf electronic are particularly in demand. The systems impress with their long ranges of up to 2,000 mm and high resolutions of 0.008mm (line sensors). Even with height fluctuations of web edges due to insufficient material tension in the manufacturing process, the devices deliver accurate measurement results.

Light grids are suitable for detecting particularly large objects over long distances, such as diameter control of coils or measuring the stack height of chipboard in wood processing. Thanks to their selectable field heights with measuring ranges from 75mm to 2010mm and their different resolutions from 1mm to 25mm, the light grids with ranges of up to 8m are extremely flexible in use.

If distances on objects need to be determined regardless of their material and color, then incremental optical distance measurement with the **VO33** offers an interesting range of features. The sensor can also perform additional tasks, such as determining a travel speed or detecting a zero point that has been previously parameterized for a specific distance. In addition, the sensor is able to provide a travel distance for a control system via a rotary encoder output.

Cable pull sensors have proven time and again to be a particularly simple and effective solution for absolute distance measurement. The devices from ipf electronic enable measurements over distances of up to 1,500mm and impress with a high travel speed of up to 1m/s, among other things.

However, there are often applications in which contactless displacement measurement, as with the systems described above (with the exception of the cable pull encoder), is not an option. This is where high-precision tactile methods based on mechanical sensors come into their own. These devices are not only particularly robust, but also perform all mechanical displacement measurements with a high accuracy of <0.1mm.

For angle measurements, ipf electronic currently offers inclination sensors and magnetic angle sensors.

The inclination sensors for measuring the angle of inclination in the X and Y directions are very easy to install and align using a display integrated in the device (angle of inclination display) and four crosshair LEDs (inclination direction display), and are therefore quickly ready for use.
The magnetic angle sensors (**MS42002x**) are ideal for retrofitting existing machine or plant assemblies, for example, as they allow for highly variable mounting and cover the entire angle range from 0° to 360° after commissioning. Another advantage: The measuring system, consisting of a stationary sensor and a movable encoder, is highly resistant to environmental influences such as dirt, dust, moisture, and oils.

If both distance and angle measurements are required, the extremely versatile magnetic measuring systems from ipf electronic are often a good choice. The highly durable devices are particularly valued for their high dynamics and travel speeds, with the MW09 incremental encoder standing out from the range as a mobile device with a transportable display.

The encoders from ipf electronic offer extremely fast response times even at very high speeds and, in addition, a high degree of flexibility. The solutions with solid or hollow shafts can be parameterized at any time and can therefore be set to the required number of pulses directly on site. For length or distance measurements, the rotary encoders are either connected directly to a deflection roller or mounted on a measuring wheel. ipf electronic offers a range of accessories for this purpose, which are tailored to different tasks.

7 APPLICATION EXAMPLES

Below are two practical application examples that demonstrate how ipf electronic's technologies for distance and angle measurement also meet specific customer requirements.

7.1 LEVEL CONTROL THROUGH TINY OPENINGS

Chapter 2.2 presented several distance-measuring ultrasonic sensors from ipf electronic for distance-proportional distance measurement, including a device with a sound nozzle that is used at a chemical company.

The company fills small glass bottles with very small openings at an automatic dosing station. The bottles transported to a dosing unit receive an exact amount of a clear, transparent liquid. The requirements: Because the amount of product per bottle must be exactly the same, each container must be checked for the correct fill level. In addition, the presence of a glass bottle must be monitored at the dosing station before filling.

To meet these requirements, a cover-proportional light barrier (transmitter/receiver system) with a linear light beam was tested to detect the fill level laterally through the glass wall of the bottle. However, due to its high transparency, the liquid contained in the bottles did not allow sufficient attenuation of the sensor system, which was therefore unable to provide a clear signal. In addition, light refraction at the glass bottle made reliable level control difficult.

In the next attempt, a distance-measuring ultrasonic sensor was positioned above the bottle opening, which has a diameter of only 10mm. This attempt also failed because standard ultrasonic sensors have a comparatively large surface area sound transducer in relation to their size. Due to its large opening angle, the sensor's sound beam detected not only the liquid in the glass bottle, but also the upper edge of the bottle, and used this as the first evaluable signal for distance and thus level measurement.

The ultrasonic sensors of the **UT12**-series from ipf electronic, on the other hand, have a diameter of only 12mm and, like the **UT129021**, are suitable for precise level measurements thanks to their analog output.
A sound nozzle was mounted on the sensor for the dosing station, which additionally focuses the ultrasound in order to query liquids in containers with very narrow openings, for example. The **UT129520** with digital switching output for presence monitoring was also installed on the dosing unit to ensure that a bottle is present in the desired position before the filling process begins.

Level control and presence control with two ultrasonic sensors at a dosing station.

7.2 COMBINING DIFFERENT SIGNALS INTO ONE RESULT

Flexibly rolled sheet metal blanks for hot forming or press hardening usually have different material thicknesses in different segments. If the material thicknesses specified for a blank are outside the permissible tolerances and this is first noticed in the forming process, then non-conforming parts are produced and, in the worst case, costly tool breakage occurs. A well-known automotive supplier therefore uses a special solution to check the entire sheet metal blanks as soon as they arrive.

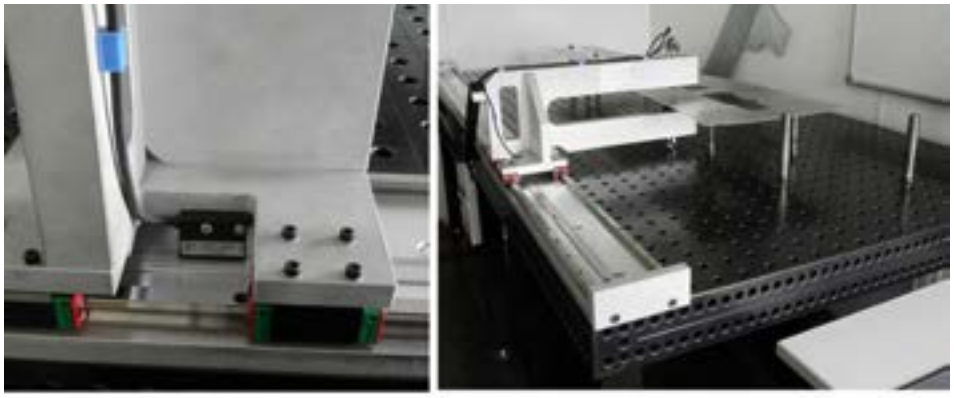
However, this was not always the case. In the past, individual sheet metal blanks from different delivery batches were checked using hand-held measuring devices. However, such random samples only allowed individual measured values from different sheet metal segments to be determined. The company was therefore looking for a way to check individual sheet metal blanks thoroughly at the goods receiving stage on the basis of a combined thickness and distance measurement.

A special machine manufacturer then developed a testing device consisting of a base table for holding the sheet metal blanks and various support points, some of which also serve as stops. The measuring system is mounted on the base table and can be moved manually along the entire length of the table. The thickness measurement is performed depending on the distance traveled by the measuring system, which is measured using the **MW100405** from ipf electronic. For non-contact distance measurement, the **MW100405** sensor is moved at a distance of 0.1 to 2mm above a magnetic tape, whereby the system achieves a high repeat accuracy of ±0.1mm.

The thickness of the sheets, on the other hand, is measured using a master-slave system (high-precision laser sensors **PTSI0292** and **PTSI0274**) from ipf electronic. The master is connected to a host computer running QA software for analyzing the combined thickness and distance measurements. The software converts the analog signals from the master-slave system as well as the incremental TTL signals from the distance measurement system (**MW100405**) and synchronizes them to produce uniform output results.

Deviations from the permissible tolerances for sheet metal blanks are now immediately

apparent thanks to the meaningful results provided by the system. This means that immediate action can always be taken to prevent faulty sheet metal deliveries from entering production.



A magnetic position measuring system (left) and laser sensors from ipf electronic enable continuous inspection of sheet metal blanks directly at goods receipt.

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Subject to alterations! Version: January 2026