EN

WHITEPAPER

FILLING LEVEL SENSORS: PROCESSES AND TECHNICAL SOLUTIONS FOR LEVEL SENSING AND CONTROL

Author: Dipl.-Ing. Christian Fiebach
Chief Exective Officer ipf electronic gmbh

IPF ELECTRONIC

CONTENT

1 INTRODUCTION

Filling level sensors are used for level control of liquid media or bulk solids in both open and closed vessels. In many industrial sectors, a whole range of very different tasks arise for such devices. However, it is not always easy to meet the corresponding requirements for a reliable technical solution.

It is good to know that a wide range of processes with equally diverse and in some cases highly specialized sensor technology is available in this context. With regard to the product range of sensor solutions for level detection, ipf electronic is probably one of the most versatile suppliers. The rich product range is complemented by many years of experience in this field, flanked by a large number of successfully realized projects in customer-specific applications.

This white paper gives an overview of the different measuring principles for level control and presents specific sensor solutions. Depending on the application, task and medium to be monitored, the following information is primarily intended as a possible aid or orientation in the search for a suitable device or system. The sensor experts at ipf electronic will be happy to answer any further questions.

At the end of the white paper, a few selected examples illustrate the potential that can be realized in practice in the face of very different tasks and challenges.

2 MEASURING PRINCIPLES FOR LEVEL SENSING

There is a wide range of sensor solutions for the detection of filling levels or media levels. The selection of a suitable device depends primarily on the medium or material to be detected and the ambient conditions prevailing at the place of use. Various solutions are available for this purpose, which operate according to different measuring principles and are presented below.

2.1 CAPACITIVE FILLING LEVEL CONTROL

Capacitive sensors for level control function according to the principle of a plate capacitor. The active surface of the sensors consists of two concentrically arranged electrodes or field plates (opened plate capacitor), between which an electric field is built up. The capacitance of a capacitor is influenced, among other things, by the permittivity of the material between the field plates. Consequently, the capacitance of the electrode arrangement of a capacitive sensor also depends on the material that is in its electric field. If an object (e.g. a liquid medium) approaches the active surface of the sensor, the electric field in front of the electrode surfaces changes and thus the capacitance. This change in capacitance is converted into a switching signal via an evaluation unit.

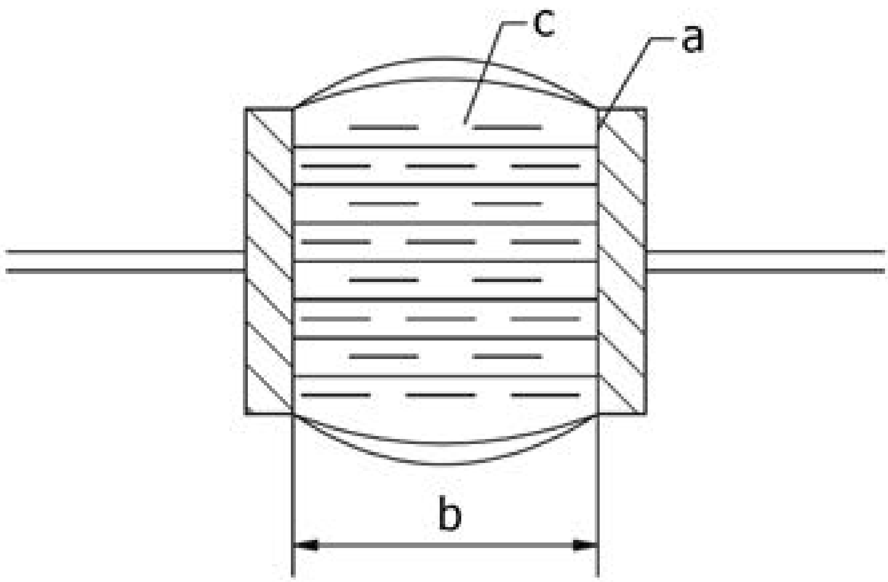

Fig. 1: Calculation of the capacitance of a plate capacitor: a: plate size (A), b: plate spacing (d), permittivity of vacuum ε0 and c: Permittivity of material εr. The formula is: capacitance = ε0 x εr x A / d

2.1.1 FOR MEDIA TEMPERATURES UP TO +100°C

In a way, the devices of the FK92E series belong to the „classics“ among the capacitive level sensors from ipf electronic. The sensors with M12 connector for electrical connection have measuring probes in different lengths (235mm to 1185mm) and are suitable for media temperatures from-25°C to +100°C. Various switching points can be flexibly set via the integrated digital output (2 x 100mA). The analog output (4 to 20mA), on the other hand, provides a continuous signal for permanent interrogation of a level. These sensors, which have proven themselves many times over, are particularly suitable for classic level sensing in storage tanks, e.g. for cooling emulsions of machines.

Fig. 2: A „classic“ for capacitive level measurement: A sensor of the FK92E series, via whose digital output flexible different switching points can be set.

2.1.2 CONTINUOUS LEVEL SENSING

The capacitive level sensors **FK300100** and **FK900400** are characterized by a large sensor area and thus high sensitivity. The sensors are used in practice for sensing fill levels at the point of installation. The sensitivity of the FK30 can be set manually, whereas the sensitivity of the **FK90** is preset. For this reason, these sensors are more frequently used, for example, for dry-running protection of pumps or overfill protection in containers.

Fig. 3: The **FK300100** (top) and **FK900400** are characterized by high sensitivity.

2.1.3 VERY GOOD COMPENSATION OF MATERIAL BUILDUP

The capacitive level sensors of the **FK92** series offer excellent dripping behavior even with viscous media thanks to their striking piston-shaped Teflon housing, which is also anti-electrostatic and resistant to acids and alkalis. The special electrode in the device makes it possible to compensate very well for any buildup on the sensor, e.g. residues of viscous or pasty media, during level sensing.

The size of the active area of a capacitive sensor can be calculated according to the following formula: A = r2 x 3.14, where r is the radius of the active area. Therefore, the size of the active area of an M30 size device for non-flush mounting is 490.6mm2. Due to the piston-shaped design of the **FK92**, the active area located in the shaft of the sensor can be designed differently. Therefore, for its size calculation, the formula for hemispherical surfaces applies: A = 2r2 x 3.14. With a diameter of only 26mm, the **FK920420** therefore has an active area of 904mm2 and is thus almost twice as large as the active area of a conventional sensor in size M30 (non-flush).

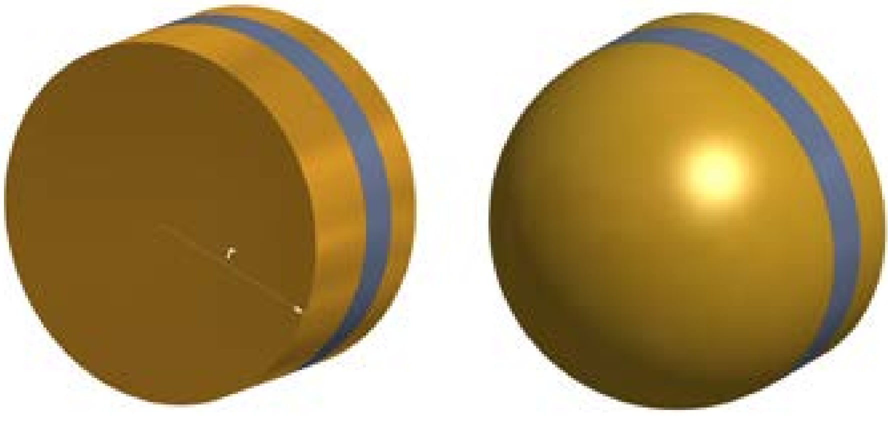

Fig. 4: Differences in size of a classical electrode (left) compared to a hemispherical electrode whose area is almost twice as large.

Since the size of the active area has a direct effect on the capacity of the sensor, critical materials can also be detected with this type of sensor. The sensors of the **FK92** series are therefore virtually predestined for monitoring the fill level in containers, e.g. with coolants or lubricants for tools of machines, or the fill level in containers with acids, oils, alkalis or cleaning agents, for example.

Fig. 5: The capacitive level sensors of the **FK92** series have a very conspicuous piston-shaped Teflon housing.

Fig. 6: **FK92** series sensors in a reservoir for permanent lubrication of punching tools.

2.1.4 KEY ADVANTAGES AT A GLANCE

The main advantages of the capacitive level sensors from ipf electronic can be summarized as follows. The devices are suitable for a wide range of media, have a high sensitivity due to a large sensor area and allow extremely flexible use due to the optional setting of fixed switching points or a continuous level signal. Even difficult media can be reliably interrogated with the sensors, whereby their response sensitivity can be precisely adjusted over a wide setting range. Due to their very high capacity, among other things due to an active sensor area that is twice as large (e.g. compared to sensors in size M30), they are also ideal for viscous media. In addition, the solutions (optionally as plug-in or cable devices) are easy to mount and intuitively adjustable.

2.2 CONDUCTIVE FILLING LEVEL CONTROL

ZOne of the simplest methods for level control of electrically conductive media, mainly water-based, is conductive level measurement, which functions according to the basic principle of an open or closed circuit. Therefore, the measurements require several probes or electrodes between which the resistance of the medium to be controlled is measured. For this purpose, the level relay is connected via signal lines to a reference electrode or to a metallic vessel or pipe wall (as reference electrode) and to a measuring electrode or several measuring electrodes. The AC voltage generated by the integrated electronics in the probe relay is applied either between the individual or the measuring electrodes and the reference electrode. The use of an AC voltage prevents corrosion at the measuring electrodes and electrolytic decomposition of the medium. As soon as the electrically conductive filling medium closes the circuit between the single or the measuring electrodes and the reference electrode, an alternating current flows and the relay output switches. Accordingly, the length of the single or the measuring electrodes in the vessel determines the level at which a switching signal is triggered.

ipf electronic's solutions for conductive level measurement can generally be divided into robust solutions for higher ambient and media temperatures and very versatile field devices.

2.2.1 FOR HIGHER AMBIENT AND MEDIA TEMPERATURES

The former category includes the level electrodes of the **FS90** series with one probe (probe lengths from 500mm to 1000mm) and the measuring electrodes of the **FS92** series, optionally with two or three probes, also in lengths from 500mm to 1000mm. Both instrument series are designed for ambient temperatures from -40°C to +150°C as well as media temperatures from -20°C to +100°C. All solutions are, without exception, pressure-resistant up to 10bar and have an electrode rod made of stainless steel 1.4571. Potential applications of the conductive level relays in combination with the **FS90** and **FS92** probe series include level sensing of electrically conductive media, even in plastic containers.

Fig. 7: The conductive level probes of the **FS90** and **FS92** series are very robust and suitable for higher ambient and media temperatures

2.2.2 FLEXIBLE DETECTION OF FILLING LEVEL OR LIMIT LEVEL

In conjunction with the probes, the level relays detect the level or limit level of conductive media, whereby the solutions can be used for pump control or as overfill protection or dry-running protection by means of a two-point control. The wear-free and maintenance-free field devices feature adjustable switching delays (to suppress wave movements of the medium) and integrated function monitoring.

In addition to level or limit detection of electrically conductive media, even in plastic containers, the **FV56** probe relays can be used for overfill protection of containers with non-flammable, water-polluting liquids. As already mentioned, the solutions are also recommended for dry-running protection of pumps and for two-point control of systems.

Fig. 8: In addition to level or limit detection of electrically conductive media, also in plastic containers, the FV56 field devices can be used in conjunction with the probes for overfill protection of containers with non-flammable, water-polluting liquids.

2.2.3 KEY ADVANTAGES AT A GLANCE

The decisive advantages of the conductive level probes from ipf electronic consist of both robust and flexible device versions with up to three electrodes (simple switching point function via specific probe lengths) for media temperatures up to +100°C and ambient temperatures up to +150°C, as well as field devices that offer a wide range of potential applications through the detection of level or limit level. Further plus points include: high-quality corrosion-resistant electrode probes, wear- and maintenance-free level sensing, and the ability to detect pasty media with the devices.

Fig. 9: A field device of the **FV56** series for controlling a container filling.

2.3 LEVEL MONITORING WITH GUIDED MICROWAVE

This method is based on the guided microwave principle. For this purpose, the microwaves are „guided“ in a measuring rod. When the medium comes into contact, the waves are reflected. The level is calculated from the transit time from the sensor through the measuring rod to the media surface and back. The lower end of the measuring rod marks the zero point for the level measurement.

2.3.1 HIGHEST PRECISION DUE TO PARALLEL ROD

Due to their parallel rod (probe lengths from 200mm to 800mm), level sensors of the **FM9103** series with integrated LED display and membrane keypad enable highly precise level measurements without prior media adjustment. The devices are designed for media temperatures from -20°C to +80°C and feature a switching output. Solutions such as the **FM910023**, **FM910024** or **FM910025** additionally integrate an analog output. The response sensitivity of these very easy-to-install solutions can be adjusted via pushbuttons. The potential tasks of the FM91 sensor series include level detection in containers with oils, alkalis, cleaning agents or release agents, to name just a few examples of the extremely wide range of applications.

Fig. 10: Due to their parallel rod, level sensors of the **FM91** series enable high-precision level measurements without prior media adjustment.

2.3.2 SPECIAL SOLUTION ALSO FOR POWDER AND GRANULES

A special design of the sensors operating according to the guided microwave principle is the **FM9101** series of devices with a measuring rod (probe lengths from 120mm to 400mm), which respond to media contact at the measuring tip. The response sensitivity of the sensors with M12 connection and integrated LED display can be adjusted via the membrane keypad. In containers, it is possible to distinguish between different liquids such as water and oil. For example, an oil film floating on the surface of water can be suppressed during level control, so that the sensor only responds to the level of the water. In addition, the instruments are suitable for level measurement of powdery media and granulates. No media adjustment is required for commissioning. The sensor probe of the sensors is made of stainless steel 1.4571, the sensor tip of PTFE. The devices are also insensitive to media buildup. Therefore, these solutions can be used for monitoring the levels in plastic or metal containers, for example, with hydraulic oils, emulsions, powders, granulates, etc.

Fig. 11: Special design of the **FM9101** series, which reacts to the media contact at the measuring tip.

2.3.3 KEY ADVANTAGES AT A GLANCE

The easy-to-install level sensors of the **FM9103/FM9100** and **FM9101** series are suitable for applications in a wide range of media temperatures. They are pressure resistant up to 10bar and available with probe lengths up to 800mm. The instruments with G3/4“ process connection have analog outputs and configurable or programmable switching outputs. The integrated membrane keypad, e.g. for setting the response sensitivity, allows particularly easy operation. The current level can be read on the display in „cm“ or „%“. The solutions of the **FM9103/FM9100** series impress with particularly precise level measurements due to their parallel rod as measuring probe. In addition to liquid and viscous media, these sensors can also be used to measure levels in containers with solids such as powders and granulates.

Fig. 12: Level sensing at a reservoir for hydraulic oil with a sensor of the **FM9103** series.

2.4 HYDROSTATIC LEVEL CONTROL

Sensors that operate according to this principle determine the level based on the hydrostatic pressure that acts on the measuring diaphragm in the device due to the height of a liquid column in a vessel. The determination of the level also depends on the specific density of a medium and the so-called gravitational constant (9.81m/s2). Due to gravity, the hydrostatic pressure increases as the height of a liquid column in a vessel increases. The corresponding formula for this is: h = p / ρ x g (h = level height, p = pressure, ρ = density of the medium, g = gravitational constant).

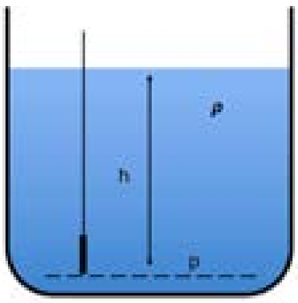

Fig. 13: Calculation of the level height via the hydrostatic pressure: h = p / ρ x g
(h = level height, p = pressure, ρ = density of the medium, g = gravitational constant (9.81m/s2))

2.4.1 MAINTENANCE-FREE „ONE-FOR-ALL“ SOLUTIONS FOR SIMPLE QUERIES

The FY98 sensors for hydrostatic level sensing from ipf electronic are, in a sense, „one-for-all“ solutions because they are suitable for a very wide range of applications and are also extremely easy to install. Thus, users only need a single sensor plus evaluation unit for their high-precision specific level inquiries. The maintenance-free hydrostatic pressure sensors are designed for a water column of 1.5m or for a pressure range of 0 to 0.4bar and can be easily installed by „hanging“ mounting without any further adjustments. As already described in the introduction to hydrostatic level monitoring, the sensors integrate a pressure measuring cell with downstream electronics, which converts the static pressure of a liquid column into an analog measuring signal. Since the static pressure is determined metrologically here, gel-like or pasty media can also be interrogated. These sensors are mostly used for level monitoring of liquid media such as water, wastewater, solvents, oil sludge, greases, etc.

Fig. 14: So-called rope probes of the **FY98** series can be installed extremely easily as „one-for-all“ solutions and are very versatile.

2.4.2 FILLING LEVEL MONITORING WITH PRESSURE SENSORS

When talking about hydrostatic level monitoring, pressure sensors such as the **DW363111** from ipf electronic must also be mentioned. The functional principle of the device is similar to that of rope probes and is based on a diaphragm design widely used in electronic pressure measurement technology. In piezoresistive thin and thick film sensors, resistors are applied to a diaphragm for this purpose, the values of which change under a pressure-induced mechanical stress. Each pressure measurement is a differential pressure measurement between the two surfaces of the diaphragm, whereby a distinction is made between absolute and relative pressure. In most cases, the relative pressure of a liquid or gaseous medium is measured in practice- in relation to atmospheric air pressure.

The **DW363111** pressure sensor is designed for a measuring range of 0 to 1bar and can be installed for level monitoring with a corresponding connection on the side in the lower area of a container filled with a liquid medium. A special feature of the pressure sensor is its scalable display, which can show not only the pressure in millibars, but alternatively also the correlating filling level in a vessel in millimeters. This is particularly advantageous if, for example, a container is filled with oil instead of water. Since oil is lighter than water, the conversion from pressure to the corresponding fill level is cumbersome. However, this procedure is not necessary with the **DW363111** pressure sensor.

Fig. 15: The **DW363111** pressure sensor has a scalable display that shows not only the pressure in millibars, but alternatively also the correlating filling level in millimeters.

2.4.3 KEY ADVANTAGES AT A GLANCE

Sensors or so-called rope probes for hydrostatic level monitoring consist of very easy-to-use device solutions with a media-resistant housing made of stainless steel (protection class IP68), which are suitable for many liquid and pasty media, whereby only one sensor is required for continuous level sensing. The solutions with G1/2 inch or 1 inch process connection are available with different line lengths depending on the respective vessel height and provide highly accurate measurement results.

As an alternative to such devices, however, pressure sensors such as the **DW363111** can also be used for level monitoring, provided there is an appropriate connection on a vessel. Since the display of the pressure sensor is capable of indicating the fill level in millimeters, there is no need for a cumbersome conversion from millibars to millimeters.

Fig. 16: Hydrostatic determination of the level of a caustic tank.

2.5 LEVEL CONTROL WITH ULTRASOUND

Ultrasonic sensors or ultrasonic diffuse-reflection sensors for level monitoring operate according to the so-called echo transit time method. Here, the transducer of the device, which also serves as a receiver, cyclically emits a high-frequency sound pulse that is reflected by a media surface. The time taken for the sound pulse to travel from the sensor to the surface and back to the device can be used to determine the level in a container.

Ultrasonic sensors achieve high ranges and operate contactlessly, ergo wear-free. Moreover, they are suitable for level measurements from greater distances. In this context, the sensors can be used with all media that are capable of reflecting the sound in sufficient quantity. It is irrelevant whether the material is transparent or opaque. Thus, ultrasonic sensors are used especially where, for example, highly transparent liquids have to be scanned.

2.5.1 FLEXIBLE SOLUTIONS WITH A BROAD RANGE

Ultrasonic sensors for level control of the **UT12**, **UT18**, **UT30**, **UT36** and **UT80** series from ipf electronic achieve high ranges (up to 6m, e.g. in silos) depending on the device version and operate without contact. Thus, the wear-free sensors can also be used for level sensing in containers with extremely aggressive media. Temperature-compensated level measurement is generally possible in the ambient temperature range from-20°C to +70°C. However, the use in warm air convection currents must be evaluated separately, since turbulent currents strongly influence the echo propagation time. Sometimes there are limits to the use of the devices here. The adjustment of the sensors is very simple and is done by means of teach-in. Depending on the device variant, the sound can be emitted either axially or laterally.

Fig. 17: Various ultrasonic sensors from ipf electronic for non-contact level monitoring.

In addition to the „standard solutions“ for level monitoring, ipf electronic's portfolio also offers devices for very specific areas of application. In this context, solutions such as the **UT12** series, whose transducer has an aperture angle of only 6°, are particularly worth mentioning. In addition, these sensors can be equipped with a sound nozzle or a sound reducer that additionally focuses the sound pulse of the device. These devices have been designed especially for level control of containers with particularly small openings (e.g. test tubes). Also worth mentioning are particularly robust and extremely tight instrument versions with full metal housings such as the **UT30E278**, in which the transducer is also completely metal-closed.

In view of such diverse technical properties, the ultrasonic sensors are designed for use in all conceivable industrial sectors, e.g. for level detection in silos, in containers with aggressive media or containers with extremely small openings, such as those used in medical, pharmaceutical or laboratory technology.

2.5.2 MORE FREEDOM THANKS TO IO-LINK INTERFACE

From the wide range of ultrasonic sensors from ipf electronic, the IO-Link devices with analog output can also be highlighted. These solutions can be parameterized very flexibly via the IO-Link interface and thus offer maximum freedom for very individual tasks. In the standard setting, the analog output provides a distance-proportional measurement signal in the range of 4-20mA. Thanks to IO-Link, however, the signal can also be switched to 0-20mA or 0-10V. The user is thus completely free to choose the measurement signals suitable for an application. In addition to the analog output, the IO-Link ultrasonic sensors integrate a versatile teach input, which can be assigned several functions at once via the IO-Link interface, e.g. switching output, synchronization output or multiplex input.

If the teach input becomes a switching output via IO-Link, all functions and setting options that are also offered by the sensors with switching output can be used. In addition, however, the analog output is also available for measurement signals.

Fig. 18: A **UT800320** ultrasonic sensor for sensing the water level in a cistern.

If several sensors have to be operated next to each other, e.g. for level control at a filling station, the teach input can be used as a synchronization input. As already described above, the transducer of ultrasonic sensors serves as a transmitter and receiver. It is therefore not able to transmit a sound pulse and receive its echo at the same time. If several sensors are used next to each other, the sound pulse of one sensor can therefore interfere with the transducer of the neighboring sensor. However, with the teach input as a synchronization input, all sensors generate a sound pulse at the same time and then switch to receive. The devices thus work in perfect harmony and thus interference-free with each other.

Fig. 19: Filling level control with several IO-Link ultrasonic sensors at a filling station.

In multiplex mode, however, only one sensor ever generates a sound pulse and then switches to receive to evaluate the echo before the next sensor becomes active. In this case, when several devices are used simultaneously, only one sensor is in operation at a time, which reliably prevents mutual interference.

2.5.3 KEY ADVANTAGES AT A GLANCE

Ultrasonic sensors for level detection are wear-free and therefore completely maintenance-free. Due to their adjustable working distances of 2mm to 6m, they can be used very flexibly, from level monitoring in a silo to a test tube. As the devices operate without contact, they are ideally suited for particularly demanding level detection, e.g. of aggressive media or liquids. Other advantages of the ultrasonic sensors include high resolutions of 0.25mm to 1.5mm and short response times of 100ms to 400ms. Ultrasonic sensors with IO-Link interface and analog output also offer a high degree of application flexibility, since they can be parameterized completely freely via IO-Link, even with regard to very individual tasks, and also provide a measurement signal (4-20mA, 0-20mA or 0-10V) as desired.

2.6 OPTICAL FILLING LEVEL CONTROL

Diffuse-reflection sensors with background suppression, proximity switches, and throughbeam light barriers are suitable for optical level monitoring. Optical diffuse-reflection sensors operate without contact and offer high switching accuracy. The sensors have a precisely defined sensing range within which they detect objects almost independently of their surface and color. Outside this sharply defined sensing range, however, i.e. in the background, all objects are ignored by the device regardless of their nature or surface. Diffuse-reflection sensors integrate transmitter and receiver in one device. The transmitted light is reflected by the medium or material to be scanned and detected by the receiver, whereupon the switching output of the sensor changes its state in the defined detection range.

Laser diffuse-reflection sensors also integrate transmitters as well as receivers in one device and are suitable for particularly precise level sensing due to the focused laser light. Against this background, specific solutions from ipf electronic have some special features, which are described in more detail below.

However, if optical scanners do not achieve the desired goal in certain applications for a variety of reasons, Hhgh-performance light barriers may be an option. As disposable systems, high-performance light barriers consist of a separate transmitter and receiver as well as an additional amplifier. This combination of devices opens up interesting potential for level monitoring, especially in applications with particularly high dust and dirt loads, as will become clear.

2.6.1 OPTICAL DIFFUSE-REFLECTION SENSOR WITH BACKGROUND SUPPRESSION

The use of optical diffuse-reflection sensors with background suppression always pursues the goal of obtaining a clear switching signal from a certain filling level (minimum or maximum level) of a container. The choice of a suitable diffuse-reflection sensor therefore depends, among other things, on the type of medium or material to be queried and the range of the sensor required for a specific application. Which solution ultimately proves to be ideal for an application can therefore only be assessed by taking a closer look at the specific task in hand, taking into account all the influencing factors in practice. In general, however, devices with comparatively higher ranges are particularly recommended in connection with optical level monitoring, such as the **OT430423** with background suppression from ipf electronic, which operates with visible red light and has a maximum switching distance of 500mm.

Fig. 20: Optical sensors with background suppression such as the OT430423 have a maximum range of up to 500mm.

However, if longer ranges are required, the optical diffuse-reflection sensors of the **OT59** series with switching distances of up to 2500mm can be an alternative. Due to the relatively large light spot alone, these devices are very well suited for level sensing where, for example, materials with rather irregular surface structures must be reliably detected. As the sensors of the **OT59** series are also available with integrated time functions, a predefined switch-on delay can be set, for example, to avoid false signals from the sensor when refilling a container with material.

For continuous optical level control via an analog signal (4...20mA), the **OT450021** with a measuring range of 550mm is recommended, for example. The optical diffuse-reflection sensors works according to the triangulation method. Here, the distance to an object is measured indirectly via the angle of incidence of the light signal reflected by the object and converted into a measurement signal by the internal electronics. This operating principle enables distance measurement that is almost independent of color and surface.

Fig. 21: The OT595905 has a maximum switching distance of 2500mm and is particularly suitable for materials with rather irregular surface structures.

2.6.2 LONG-RANGE LASER PROBE FOR PRECISE LEVEL SENSING

Diffuse-reflection laser sensors with background suppression are also recommended for reliable, non-contact level sensing from greater distances. From the portfolio of solutions, the **PT370520** (laser class 1) with a maximum range of 400mm, the **PT490375** (laser class 2) with a maximum range of 550mm, the **PT440304** (laser class 2) with a range of up to 600mm and the **PT630525** (laser class 1) with a maximum switching distance of 1750mm should be mentioned here.

For continuous level sensing, ipf electronic also has a range of solutions with analog outputs (0...10V/4...20mA) in its portfolio, e.g. the **PT64** series, which operates according to the triangulation method. In this series, the **PT640026** (laser class 2) with a point-shaped light beam and the **PT643026** (laser class 2) with a linear laser beam have high ranges of up to 1000mm.

The **PT900021** diffuse-reflection laser sensor from ipf electronic, on the other hand, is something of an exception. Not only does it have an enormous range of up to 35,000mm, but it is also particularly suitable for media with high surface temperatures and thus high heat radiation. A good example of this is provided by companies that process liquid aluminum, such as manufacturers of fittings or vehicle rims. The raw material, usually in the form of aluminum ingots, is usually melted in a central furnace and then filled into transport containers for further processing. The **PT900021** monitors the fill level of the containers from a safe distance and is not affected in its operation by the high infrared radiation of the surface of the liquid aluminum.

Fig. 22: Ideal for media with high surface temperatures and thus high infrared radiation, the PT900021 diffuse-reflection laser sensor.

2.6.3 HIGH-PERFORMANCE LIGHT BARRIERS

High-performance light barriers are basically used in applications where other optical systems for level monitoring fail, showing their strengths especially in applications with high dust and dirt loads. As described above, these light barriers are three-part systems consisting of a transmitter, receiver and an amplifier as the central component. Depending on the combination of the individual components, high-performance light barriers from ipf electronic achieve ranges of up to 70 meters. However, these ranges are mostly not exhausted, but the systems are used instead with similar ranges known from classic light barriers. The power reserves of high-performance light barriers available due to the high transmitting power are primarily used for highly efficient contamination compensation at shorter distances.

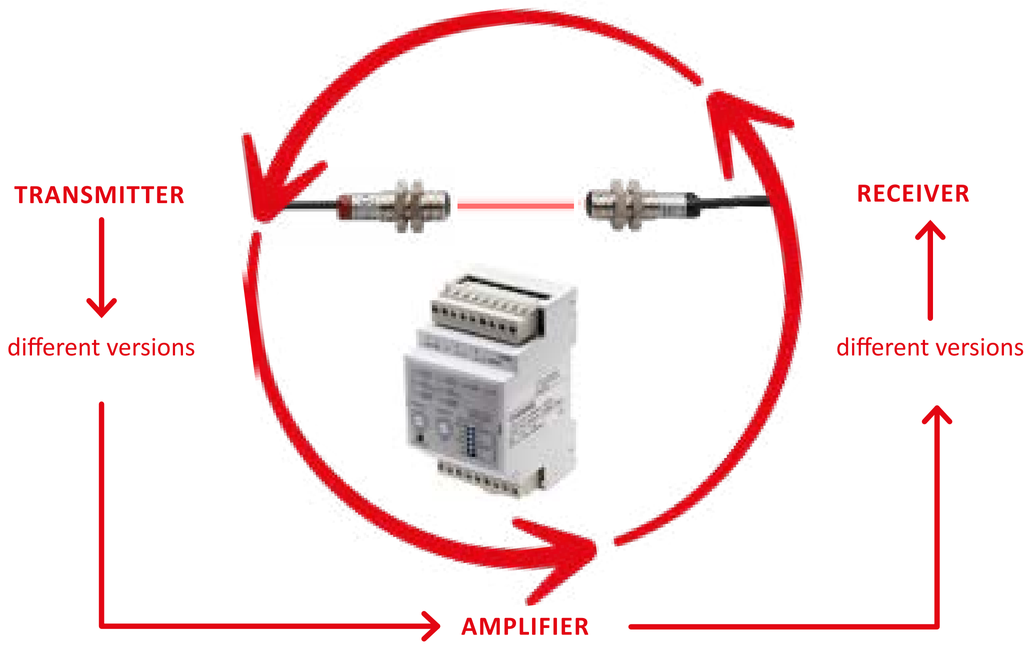

Fig. 23: As three-part systems, high-performance light barriers consist of a transmitter, receiver and amplifier. ipf electronic's portfolio enables more than 5,400 different device combinations.

The range of high-performance light barriers from ipf electronic is extremely wide and includes more than 50 products, which enable more than 5,400 different device combinations. The light barriers work with non-visible infrared light as a transmission signal with a wavelength of 880nm, which has excellent penetration properties.

Which system consisting of transmitter, receiver and amplifier is ultimately suitable for a specific application depends, as with diffuse-reflection sensors, primarily on the respective application and the prevailing ambient conditions. Against this background, we will refrain here from presenting specific products or system solutions from the portfolio of ipf electronic portfolio.

However, in connection with a wide variety of level sensing applications, especially in environments with a high level of contamination, it is important that the single-channel and multiplex amplifiers for connecting one light barrier or several light barriers (multiplex operation) enable, among other things, manual or automatic power control of the system solutions. For level control, single-channel amplifiers with manual power control are generally used. For the sake of completeness, however, the automatic operating mode will also be briefly described here. In this operating mode, the amplifier automatically readjusts an initially predefined transmit power depending on the prevailing ambient conditions, keeping the light barriers at a minimum but continuously monitored transmit power for this purpose. If the specified signal strength on the receiver side decreases, e.g. due to increasing contamination of the sensor optics, the amplifier automatically adjusts the transmit power until the received signal returns to the previous output value. The signal drift is thus compensated for by a corresponding increase in the transmitted signal.

In the manual operating mode, which is preferably used for fill level inquiries, the transmitter of the light barrier is given a fixed and thus constant power for the application. This operating mode is therefore particularly suitable for interrogations in which residual media adhesion to the sensors is to be reliably suppressed or compensated, or in order to avoid triggering a switching function during refilling by a material flow. Examples of this can be found, for example, in the overfill protection of containers or in the level control in silos, as the following figures illustrate.

Fig. 24: Light barrier with single-channel amplifier (manual operating mode) for overfill protection on a rock crusher. The material flow does not trigger a switching function during refilling.

Fig. 25: Light barriers with single-channel amplifier (manual mode) for level control in a silo.

2.6.4 KEY ADVANTAGES AT A GLANCE

Diffuse-reflection sensors with background suppression are usually the first choice for optical level monitoring, since the devices can be easily integrated into an application as a stand-alone solution. Due to the visible red light or laser light (laser class 1 or 2), the diffuse-reflection sensors can be easily adjusted during installation and are immediately ready for operation after teach-in. Optical diffuse-reflection sensors from ipf electronic with background suppression allow ranges of up to 500mm (visible red light) or up to a maximum of 1750mm (laser sensors). If even larger switching distances have to be realized, the optical diffuse-reflection sensors of the **OT59** series with ranges up to a maximum of 2500mm are recommended. These diffuse-reflection sensors are particularly suitable for sensing materials with rather irregular surface structures and, depending on the device version, are also available with time functions. The **PT900021** laser probe from ipf electronic has a certain unique selling point in optical level monitoring. A high range of up to 35,000mm and the possibility to use the sensor also for media with high surface temperatures predestine this probe for very special applications.

Level control with High-performance light barriers is particularly recommended for applications in which optical scanners reach their limits. The power reserves provided by the high-performance light barriers due to their high transmitting power enable highly effective compensation of dirt or other disturbing conditions that can affect transmitter and receiver optics during operation. In the manual operating mode, the overall system can be optimally adjusted to the respective application in any case by presetting a constant power.

2.7 INDUCTIVE FILLING LEVEL MEASUREMENT

Inductive level sensors are ideally suited for level monitoring in so-called vibratory bowls or vibratory conveyors. To a certain extent, these are highly specialized solutions. Inductive proximity switches detect all conductive metals at short range and are not influenced by other materials. And it is precisely this property that the **FI52** series of inductive level sensors from ipf electronic takes advantage of. They consist of a holder with an integrated inductive proximity switch and a movable pendulum containing a metal part for sensing. In its initial position, the pendulum follows gravity and therefore hangs vertically downwards. The metal part embedded in the pendulum makes contact with the active surface of the inductive sensor, which then outputs a switching signal.

The system is mounted over a vibratory conveyor so that the pendulum extends into the container. When the conveyor is switched on, the vibrations cause the material inside to move in a certain direction, with the pendulum being carried along by the material. The metal part integrated in the pendulum therefore moves away from the sensor, which does not output a switching signal. If there is little or no material left in the vibratory feeder, the pendulum moves back to its vertical starting position. The sensor then switches, signaling that the conveyor must be refilled with new material.

With the **FI52**, ipf electronic offers a whole range of inductive level sensors, which essentially differ in the materials used for the pendulum and the joint on the holder.

Fig. 26: Level sensor **FI520172** for a vibratory feeder. The pendulum is made of stainless steel. The thickening in the upper area can also be seen, which is used for interrogation with the inductive proximity switch integrated in the holder.

2.8 CALORIMETRIC FILLING LEVEL CONTROL

A lesser known method is level control with flow sensors, which operate according to the calorimetric principle, which will be briefly explained here in connection with the actual operation of the devices. Flow sensors or so-called thermodynamic flow sensors have a measuring sensor or sensor element which is heated from the inside by a few degrees Celsius relative to the medium into which the sensor element projects. The heat generated in the sensor element is dissipated by the medium. This heat dissipation or cooling effect is stronger the faster the medium flows past the sensor element. The temperature generated in the sensor element is measured and compared with the temperature of the medium, which is also detected. The resulting temperature difference can now be used to derive the flow state for each medium.
In level control, however, such a sensor does not measure the flow in the actual sense. Nevertheless, the special operating principle, in which the heated sensor element emits the heat generated to a medium to be controlled, makes it possible to monitor the level in a container. The prerequisite for this is that the medium is able to absorb sufficient heat

from the sensor element. In this case, the sensor element is cooled when in contact with a medium, whereas this effect is absent when there is no contact or medium level. The sensor therefore „interprets“ a pending medium level as a flow, so to speak, and supplies a switching signal. If, on the other hand, the level drops below the sensor element, the latter is surrounded by the air in a container, for example. Air has very good insulating properties. Therefore, less heat is dissipated via the sensor element, which in principle is equivalent to a „missing flow“. The sensor therefore does not provide a switching signal.

2.8.1 COMPACT UNIT OR TWO-PART SOLUTION?

For level control with flow sensors, compact devices of the **SS40**, **SS41** and **SS42** series with a measuring sensor as well as two-piece systems of the **SS89** series and **SS90** from ipf electronic are possible. Which solution is used in a specific application depends on the one hand on the medium to be controlled and on the other hand on the installation situation at the sensor installation site.

Fig. 27: Flow sensors: compact unit (top) and a sensor element of a two-part system, which also includes a separate evaluation unit.

While the compact devices already integrate the evaluation unit and therefore the adjustment of the sensor can be carried out directly on site, the two-part systems consist of a sensor element, which protrudes into a container with a medium to be monitored, as well as an evaluation unit separate from it for adjustments and for signal evaluation. The two-part systems with separate evaluation electronics are particularly suitable for level control of media with higher temperatures. In addition, they are always useful if there is not enough space at the installation site for a compact device or if the sensor cannot be reached for parameterization after installation.

2.8.2 KEY ADVANTAGES AT A GLANCE

Flow sensors for calorimetric level monitoring are rather seldom used, since the technology for this field of application is in many cases still too little known. Nevertheless, the solutions for level control, which are available as compact devices or two-part systems, offer some decisive advantages. The compact devices are easy to install because they integrate all the necessary functions for precise level monitoring in a single solution. The two-part systems consisting of sensor and separate connection amplifier, on the other hand, can be used for level sensing of media with higher temperatures. In addition, if the sensor is no longer accessible or only accessible with difficulty for parameterization after installation, they offer the option of continuing to adjust it easily via the connection amplifier. Flow sensors have sensing elements made of stainless steel V4A and are therefore suitable for use in a wide range of media that can be rather problematic for other sensors, e.g. alkalis, oils, light acids, etc. In addition, flow sensors withstand pressures of up to 100bar and are therefore also predestined for level control in vessels that are under pressure.

3 APPLICATION EXAMPLES

In the following application examples, various solutions for level control in different applications are presented. It becomes clear that the wide-ranging experience of a sensor supplier in this field can be of particular advantage when designing a suitable system for level monitoring.

3.1 ULTRASONIC SENSOR IN COMBINATION WITH AN ANALOG CONVERTER

For the level monitoring of large containers, sensors with analog evaluation are particularly necessary. An ultrasonic diffuse-reflection sensors of the **UT30** series in combination with the versatile **BA050100** analog converter from ipf electronic proved to be an ideal solution for this task.

Fig. 28: Clever combination: Simple and effective level monitoring with the **UT309023** ultrasonic diffuse-reflection sensors (right) with a maximum range of 6,000mm and the BA050100 transmitter.

For this purpose, the ultrasonic diffuse-reflection sensors **UT309023** (measuring range from 600mm to 6,000mm) is mounted in the lid area of a silo container in such a way that the transducer of the sensor and thus the sound lobe is directed downwards towards the material to be detected. The diffuse-reflection sensors works according to the echo propagation time method already described in chapter 2.5, whereby the device calculates the exact distance from the time required for the ultrasonic waves to travel from the sensor to the material surface in the container and back to the device, and outputs this value via a distance-proportional analog signal. It is easy to switch between current and voltage signal via the teach mode or the integrated IO-Link interface of the **UT309023**. For the evaluation of the filling level, a PLC is not necessarily required, as this can also be done directly via the **BA050100** transmitter.

Fig. 29: The ultrasonic diffuse-reflection sensors were mounted in the lid area of a silo container (right). The transmitter (left)

is located in a control cabinet, close to the silo (center).

With the two 16-bit analog inputs and the four digital outputs of the **BA050100**, this application could be realized with little effort. The transmitter, which can be set to both a current and voltage signal, is parameterized via the front touch screen. In addition, the four digital outputs can be freely assigned to the analog inputs and an event can be set for each output individually. In this specific case, the digital outputs control different colored segments of a signal light as well as an acoustic signal, which are switched for a short time via the pulse output setting at 90 percent of tank filling. By means of an additional setting, the switching processes of the signal lamps can also be reproduced in parallel on the display of the **BA050100** by means of color change.

Fig. 30: The display of the BA050100 shows the switching operations of the signal lamps in parallel by corresponding color changes.

3.2 PRECISE CONTROL EVEN THROUGH THE SMALLEST OPENINGS

A chemical company fills products into small glass bottles at an automatic dosing station. For this purpose, the bottles with openings the size of a test tube are transported by a transport unit to a dosing unit, where they are filled with an exact quantity of a clear, transparent liquid. The amount of product filled into each bottle must be absolutely identical. Therefore, each container has to be checked for the correct fill level before it is sealed. For this task, the company first tested a cover-proportional light barrier (transmitter/receiver system) with a linear light beam to detect the fill level laterally through the glass wall of the bottles. However, the transparent liquid inside did not allow sufficient attenuation and therefore did not provide a clear signal. Light refraction also made reliable level control difficult. Due to the various challenges, the chemical company next decided on an ultrasonic sensor. The advantage: ultrasound can be used, among other things, to detect levels in containers almost completely independently of the specific media properties. For level control, it is necessary to position the sensor above the bottle opening, which in this case has a diameter of only 10mm.

But even this solution did not deliver success. The reason: As already described in more detail in chapter 2.5, the transducer of the device simultaneously assumes the function of transmitter and receiver. After generating the sound pulse, the transducer therefore acts as a receiver for a short period of time. Since the propagation velocity of sound in air is known, the distance of an object surface to the sensor and thus the filling level in a container can be determined by measuring the transit time of the pulse from transmission to reception. The first echo signal, i.e. the signal from the reflection surface closest to the sensor, is always evaluated, regardless of whether other reflection signals are received from more distant surfaces.

In this context, the area of the transducer and the opening angle of the emerging sound lobe are decisive. Since standard ultrasonic diffuse-reflection sensors have transducers with a comparatively large area depending on their size, the resulting sound lobe of the sensor used also detected the edge of the narrow bottle openings due to its large aperture angle. The echo signal generated by the bottle edge was thus the first received signal and was used to determine the distance. However, the ultrasonic sensor only detected the distance from the sensor to the edge of the bottle.

Even if the attempts with the standard device failed, the choice of technology nevertheless pointed the right way. In the end, an ultrasonic sensor from the **UT12** series was used, which has a diameter of just 12mm. In the filling plant of the chemical company, the **UT129021** from ipf electronic was mounted directly behind the dosing unit to detect the fill level.

Fig. 31: The sonic nozzle on the sensor head of the **UT129021** focuses the ultrasound so that levels in containers with very small openings can be scanned.

The special feature of this device is the sound nozzle attached to the sensor head, which focuses the ultrasound and thus generates an almost linear sound lobe. This reduces the exit or opening angle of the sound again compared to a device without sound nozzle. In this way, it is possible to detect levels in containers with very small openings. The resulting level-proportional analog signal from the sensor is evaluated by the higher-level control system. The advantage of this is that the reference value and the permissible tolerances for the fill level can be set flexibly in the control system, so that different batches with different fill levels can be produced. Bottles with a fill level that is too high or too low are rejected from production by the system controller. A **UT129520** with digital switching output for presence checking is also installed on the dosing unit itself to ensure that a bottle is also in the desired position before the filling process.

Fig. 32: The **UT12** series ultrasonic sensors in the automated dosing unit: A sensor with switching output is used to check presence. The device behind the dosing unit checks the fill levels from above through the small bottle openings.

3.3 ALWAYS RELIABLE EVEN IN HARSH ENVIRONMENTS

A company specializing in steel products treats, among other things, stainless steel wire in its in-house pickling plant. The wastewater from the pickling process is neutralized in a special system and must have a high pH value. This is achieved by adding milk of lime, which the company produces itself by mixing the lime supplied in powder form with water in a tank. Since the milk of lime is prepared fully automatically, the tank must have a level control system that is connected to the plant control system (PLC). However, the float switches initially used for this task could not withstand the harsh operating conditions in the long term. For example, heavy lime deposits repeatedly formed on the float switches, causing the devices to jam. As a result, the tank for the lime milk treatment had to be opened regularly in order to clean the switches. Sometimes it was even necessary to pump the tank empty for the necessary work, which interrupted production. In addition, the cables of the float switches to the PLC were also attacked and decomposed.

With the **FK92E117** filliing level sensor, ipf electronic finally had a solution that withstood the aggressive ambient conditions and, in combination with the **BA960900** digital transmitter for signal conditioning, could be easily integrated into the automated lime milk preparation system.

The housing of the capacitive sensor with M12-connection is made of stainless steel, the active zone (probe) of PTFE. The **FK92E117** with integrated evaluation electronics is extremely resistant to chemicals, whereby the actual probe (in this application with a length of 1100mm) can be used in an ambient temperature range from-25°C to +100°C. The device provides an analog current output 4...20mA as well as two programmable switch points.

Fig. 33: Housing and connection of the capacitive level sensor are made of stainless steel. The limescale deposits are also clearly visible on the container of the preparation unit.

Fig. 34: View into the lime milk tank. To the left of the mixer, the rod probe can be seen, on which only little lime deposits even after longer operation.

The **BA960900** digital transmitter processes the current signals of the level sensor preset for the maximum and minimum levels and, when these values are reached, sends the corresponding signals to the lime milk preparation PLC via its relay outputs. Up to four freely programmable relay switching points can be assigned to the input signal of the level sensor at the transmitter. If, for example, the lime milk treatment tank has reached its minimum level, the automatic mixing of new lime milk is initiated via a switching signal to the PLC. The sensor also monitors the addition of the correct amount of water. In addition, the sensor controls the maximum filling level of the milk of lime as overflow protection and functions as dry-running protection for the pumps located in the milk of lime preparation tank..

Fig. 35: The **BA960900** digital transmitter processes the level sensor current signals preset for the maximum and minimum levels.

4 SUMMARY AND CONCLUSION

The preceding application examples demonstrate once again how wide-ranging and thus versatile the potential fields of application for level monitoring can be. The selection of a truly optimal solution essentially depends on the medium to be monitored, the place of use and thus, among other things, the prevailing environmental conditions. Whatever the conditions may be, the sensor technologies from ipf electronic provide a whole range of different processes and thus also concrete solutions for all conceivable applications, which will be summarized once again here.

The classic solutions in the field of level control include capacitive sensors, which optionally allow the setting of fixed switching points or a continuous level signal. The devices are suitable for a wide range of media with different consistencies and are particularly convincing due to their high response sensitivity and thus high precision. Solutions with special electrodes are also able to compensate for media buildup on the sensor.

One of the simplest methods is conductive level control for detecting electrically conductive media, for which both extremely robust electrodes for media temperatures up to +100°C and versatile field devices are available. In addition to level and limit detection, these solutions are also suitable for overfill protection of containers with non-flammable, water-polluting liquids as well as for pump controls or dry-running protection.

High-precision level measurements without prior media adjustment are made possible by sensors of the **FM9103** and **FM9100** series from ipf electronic, which operate according to the guided microwave principle. Devices with G3/4“ process connection have configurable or programmable switching outputs and, if necessary, an additional analog output for continuous level queries. The integrated membrane keypad, e.g. for setting the response sensitivity, allows particularly easy operation. As a special design, the sensor specialist has a device in its portfolio here that reacts to media contact at the measuring tip and can distinguish between different liquids. All solutions are also insensitive to media adhesion. In addition to liquid and viscous media such as hydraulic oils or emulsions, these sensors can also be used to measure levels in plastic and metal containers with solids such as powders and granulates.

As one-for-all solutions and thus for a very wide range of applications, the extremely easy-to-install rope probes are again suitable for determining the level on the basis of hydrostatic pressure. They are therefore more frequently found in applications for level detection of liquid media such as water, wastewater, solvents, oil sludge, grease, etc. The easy-to-use devices with a media-resistant stainless steel housing are thus designed for many liquid and also pasty media, with only a single sensor being required for continuous level sensing. The **DW363111** pressure sensor, which is also presented in this context, allows reliable level monitoring with a corresponding connection at the side in the lower area of a container filled with a liquid medium. The sensor has a scalable display that can be used to show not only the pressure in millibars but also, alternatively, the correlating fill level in a container in millimeters.

If an application requires non-contact level sensing and additionally a high range of the solution used for this, then this can be a task for ultrasonic sensors. They operate absolutely wear-free and enable ranges from 2mm to 6m. The sensors are adjusted by means of teach-in and are therefore extremely simple. ipf electronic also has extremely compact devices for this technology in its product range, which can check levels even in containers with very small openings by means of a sound reducer. Ultrasonic sensors are therefore suitable for applications in all conceivable industrial sectors, e.g. for level detection in silos, in containers with aggressive media or, as already emphasized, in containers with extremely small openings, such as those used in medical, pharmaceutical or laboratory technology. From the wide range of ultrasonic sensors from ipf electronic, the very flexibly parameterizable IO-Link devices with analog output should also be highlighted, which allow maximum freedom for very individual tasks.

Optical sensors are also non-contact and therefore wear-free. For level monitoring, diffuse-reflection sensors with visible red light and laser sensors, each with background suppression, as well as through-beam sensors (high-performance light barriers) are available. For optical level monitoring, diffuse-reflection sensors with background suppression are usually the first choice because they are particularly easy to integrate into an application as a single solution. The visible red light or laser light (laser class 1 or 2) enables simple adjustment of the devices during assembly, which are immediately ready for operation after teach-in. The optical diffuse-reflection sensors allow switching distances from 400mm to 1750mm. If longer switching distances are required, the devices of the **OT59** series with ranges up to a maximum of 2500mm are recommended. They have a relatively large light spot and are therefore suitable for level sensing where, for example, materials with rather irregular surface structures must be reliably detected..

For continuous optical level control via an analog signal (4...20mA), the **OT450021** with a measuring range of 550mm is recommended, for example. The optical diffuse-reflection sensors operates according to the triangulation method, in which the distance to an object is measured indirectly via the angle of incidence of the light signal reflected by the object and converted into a measurement signal. This operating principle enables distance measurement that is virtually independent of color and surface.

For continuous level detection with laser scanners, ipf electronic also has a range of solutions with analog outputs (0...10V/4...20mA) in its portfolio, e.g. the **PT64** series, which also operates according to the triangulation method. Especially the devices **PT640026** (laser class 2) with a point-shaped light beam and the **PT643026** (laser class 2) with a line-shaped laser beam have high ranges of up to 1000mm..

The **PT900021 diffuse-reflection** laser sensor with a maximum switching distance of 35,000mm is also outstanding. This sensor can also be used with media with high surface temperatures and is therefore recommended for very special areas of application. High-performance light barriers are also optical systems with very special properties. The power reserves that these through-beam sensors provide due to the high transmitting power enable highly effective compensation of dirt, moisture or other disturbing conditions that can affect the transmitter and receiver optics during operation.

With the calorimetric operating principle, this white paper also presented a rather lesser known method for level monitoring with flow sensors. Since the functionality of these sensors has already been adequately described in chapter 2.8, the main advantages of the compact devices and two-part system solutions should be mentioned again at this point. Flow sensors from ipf electronic have a sensor made of stainless steel V4A and are therefore suitable for use in a wide range of aggressive media that can be rather problematic for other sensors, including alkalis, light acids, but also certain oils. The sensors can also withstand very high pressures of up to 100bar, which means that they can also be used in vessels that are under high pressure. These comparatively unique properties of flow sensors make the solutions particularly interesting for applications in which other sensors and thus methods for level control are likely to reach their limits very quickly.

Considering the rich offer of devices based on very different technologies, ipf electronic can react very flexibly to the diverse requirements for sensors for level control. Last but not least, the very multi-layered challenges that ipf electronic has mastered together with customers in this context over the course of decades make the company a specialist in the field of level monitoring.

ipf electronic gmbh
info@ipf-electronic.com • **www.ipf-electronic.com**

Subject to alteration! Version: May 2023