EN

WHITEPAPER

FLUID TECHNOLOGY

WIDE RANGE OF SOLUTIONS

FOR A VARIETY OF TASKS

Author: Dipl.-Ing. Christian Fiebach
Chief Executive ipf electronic

IPF ELECTRONIC

CONTENT

1 INTRODUCTION

There is probably hardly any other field in which the possible tasks and thus potential sensor solutions are as broad as in fluid technology. Basically, this is not surprising, since fluid technology is a generic term for all processes in which energy is transferred through the flow of gases and liquids. In addition to the technical application focus on hydraulics and pneumatics, this term can also be used in the field of sensor technology to include all processes used to detect the condition of gases and liquids. These include, for example, pressure, temperature, filling level and flow. But how do these processes work in detail? And what solutions are available? Questions to which this white paper provides answers.

On the following pages, the individual processes for pressure, temperature, flow and filling level measurement are described in more detail, the corresponding sensor solutions are presented and finally some practical fields of application are introduced.

2 METHODS FOR PRESSURE MEASUREMENT

A pressure gauge is used to measure and display the physical pressure of a medium (liquid, gas). Before the method of pressure measurement is introduced in more detail, here are first of all some general explanations on the subject of pressure.
The earth is surrounded by air, whose weight creates an ambient pressure of about 1bar (1000mbar) at sea level. The air pressure is specified in mbar (millibar) or Pa (Pascal), where 100Pa = 1mbar.
Pascal, named after the mathematician Blaise Pascal, is a derived SI-unit of pressure and mechanical tension.
Water is 1000 times heavier than air. A water column with the area of 1cm^2 and a height of 10m results in a weight of 1kg. If you dive into water, the pressure increases by 1bar per 10m depth. The absolute pressure at 100 meters water depth is 11bar. This value is composed of 1bar air pressure on the water surface plus 10bar water pressure.

Membrane constructions are mostly used in electronic pressure measurement technology. In the piezoresistive thin and thick film sensors, resistors are applied to the membrane, which change their value under a pressure-related mechanical tension. Each pressure measurement is a differential pressure measurement between the two surfaces of the membrane, whereby a distinction is made between absolute pressure and relative pressure (Fig. 1).

Fig. 1: Absolute pressure (left): The measurement is performed against a closed room, usually a vacuum).
Relative pressure (right): The measurement is performed against an ambient pressure.

In most cases the relative pressure of a liquid or gaseous medium – in relation to the atmospheric air pressure – is measured.

ipf electronic gmbh | Rosmarter Allee 14 • 58762 Altena • Germany | Tel +49 2351 9365-0 • info@ipf-electronic.com • www.ipf-electronic.com

2.1 PRESSURE SENSORS: FROM THE "ALL-ROUNDER" TO THE "SPECIALIST"

Pressure sensors from ipf electronic are suitable for a wide range of pressure measurements of gases and liquids and enable, for example, the monitoring of the system pressure of hydraulic units or the pressure at vacuum lifting devices. Furthermore, such solutions are used for controlling compressors or monitoring compressed air, to name just a few fields of application.

The sensors with front-flush membrane or installation thread cover pressure ranges from -1bar to +600bar or -1bar to +1bar, have optionally 2 or 3 output functions and can be used in temperature ranges from-20°C to +80°C. The „all-rounders“ are supplemented by parameterization software (Fig. 2).

Fig. 2: Pressure sensors of the series **DW34**, **DW 35** and **DW36** are suitable for various pressure measurements of gases and liquids. Here is a pressure sensor of the **DW35** series for monitoring a transport pipe filled with compressed air for dust, which is produced in nodular cast iron and is discharged into a silo.

The vacuum and pressure sensors of the **DW16** series are the "specialists" of ipf electronic for compressed air measurements (Fig. 3). They are designed for pressure ranges from -1bar to 10bar, have a short response time (<2.5ms) as well as a high switching frequency (200Hz) and withstand pressure peaks up to 5bar or 16bar. The sensors with IO-Link interface are suitable for filtered, dried or oiled air as well as neutral gases and can also be used to monitor a "pressure window". Possible applications of these devices are e.g. pressure monitoring and vacuum control or the control of compressors.

ipf electronic gmbh | Rosmarter Allee 14 • 58762 Altena • Germany | Tel +49 2351 9365-0 • info@ipf-electronic.com • www.ipf-electronic.com

Fig. 3: The compact, lightweight vacuum and pressure sensors of the **DW16** series are immediately ready for use and have 2 independently adjustable switching outputs.

3 METHODS OF TEMPERATURE MEASUREMENT

When measuring temperature using temperature sensors, a general distinction is made between contact and contactless methods. For this reason, both media-contacting devices with a probe and contactless sensors with infrared technology are available.

The temperature-dependent change of the electrical resistance in conductors and semi-conductors is used for temperature measurement in contact with the medium.
Alternatively, the temperature of a surface can be determined without contact by measuring the thermal radiation, provided that the emissivity is known with sufficient accuracy. The measured object must have a uniform temperature distribution and completely fill the detection range of the sensor. Such measurements are made with so-called pyrometers.

3.1 TEMPERATURE SENSORS: FROM "ALL IN ONE" TO "TWO-PIECE"

The temperature sensors from ipf electronic generally differ in compact one-piece and two-piece solutions, both for the optical infrared sensors and for devices for PT100.

As compact devices, the one-piece optical infrared sensors integrate the electronics and detect radiant heat in a temperature range from +300°C to +2000°C. The switching thresholds can be adjusted in a range between +300°C and +750°C.
The two-part optical infrared sensors with separate evaluation unit from ipf electronic, on the other hand, are designed for a much more flexible range of applications in a wide measurement and adjustment range from -50°C to +1800°C. There are different sensor heads available, with which the size of the measuring spot and the measuring distance can be influenced or optimized for specific applications (fig. 4).
The areas of application for both the one-piece and two-piece optical infrared sensors include forges, rolling mills and generally metalworking industries.

ipf electronic gmbh | Rosmarter Allee 14 • 58762 Altena • Germany | Tel +49 2351 9365-0 • info@ipf-electronic.com • **www.ipf-electronic.com**

Fig. 4: The optical infrared sensors are available as compact one-piece version (top) or available as a two-part solution with separate amplifier.

Applications for both one-piece and two-piece infrared optical sensors include forging, rolling mills and general metalworking industries.

A PT100 is a temperature sensor with a platinum resistance, which has a defined nominal resistance of 100 Ohm at a temperature of 0°C according to IEC 751 (EN 60751).
Particularly pressure-resistant (up to 100 bar) are the one-piece temperature sensors for PT100 with measuring sensor made of stainless steel 1.4571, which are suitable for media temperatures from-20°C to +120°C and therefore for applications e.g. in cooling circuits, exhaust systems or exhaust and ventilation systems.
The two-part device solutions for PT100 ensure a fast evaluation of the measurement result within only 2ms. As all common PT100s in 2-, 3- or 4-wire technology can be connected to the display via an M12 socket, these sen-sors allow for a very variable use, e.g. in cooling circuits, storage tanks, exhaust systems and ventilation systems etc. (Fig. 5).

Fig. 5: One-piece and two-piece temperature sensor for **PT100** (from left). The two-part version with separate evaluation electronics has wear-free transistor switching outputs (1A per channel).

4 METHODS FOR MEASURING FLOWS

Flow sensors, more precisely thermodynamic flow sensors, monitor flows or measure the flow velocity of media in closed systems (e.g. pipelines).

The function of flow sensors is based on the calorimetric principle. Here, the sensor element is heated from the inside by a few degrees Celsius compared to the medium into which the sensor element is immersed. The heat generated in the sensor element is dissipated by the medium, whereby 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 measured medium temperature. From the resulting temperature difference, the flow condition of each medium can now be derived.
Since air has a lower cooling effect than liquids, the individual sensor elements of flow sensors for air measurements are larger and therefore more sensitive.

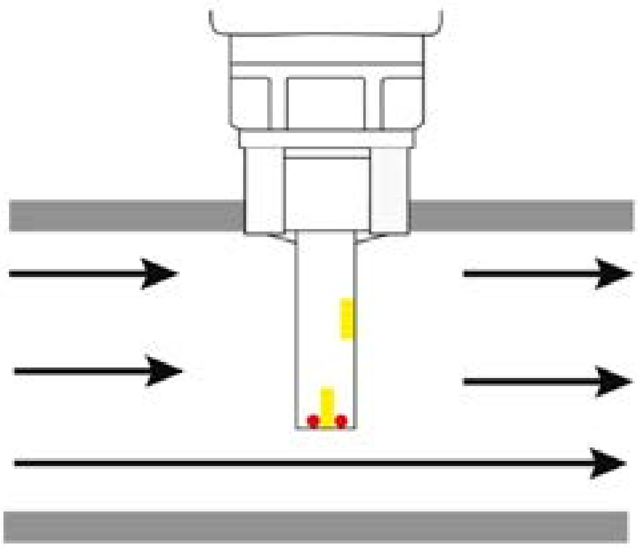

Fig. 6: Functionality of flow sensors. The figure shows a compact device.
The sensor integrates two temperature sensors (yellow elements). The temperature sensor in the tip of the sensor is heated from inside by heating elements (red). The second sensor in the sensor tip measures the temperature of the medium flowing past.

Since air has a lower cooling effect than liquids, the individual sensor elements of flow sensors for air measurements are larger and therefore more sensitive compared to the sensor elements in devices for measuring liquid media.

Flow sensors can also be divided into one-piece compact units and two-piece units. Compact devices are designed as solutions with measuring sensor (screw-in devices for pipe sockets) and as inline sensors, which can detect even the smallest flows.
Two-piece devices consist of a sensor element that projects into a medium and a separate evaluation unit for settings and signal evaluation. Such solutions are recommended, for example, for measuring media with higher temperatures or if the sensor cannot be reached even after mounting for parameterization.

4.1 FLOW SENSORS FOR LIQUIDS AND AIR

Analogous to the explanations in chapter 4, ipf electronic offers a wide range of flow sensors both in one-piece design with integrated measuring probe and two-piece device solutions with separate evaluation unit. The flow sensors in IP67 are pressure-resistant up to 100bar and designed for media temperatures from -20°C to +160°C. Possible applications for such devices are cooling circuits, hydraulic and pneumatic applications (e.g. dry-running protection of pumps), air conditioning and ventilation systems as well as applications with flow measurements.

4.2 AIRFLOW SENSORS FOR CONSUMPTION MEASUREMENTS

Airflow sensors or flow meters are used for consumption measurements in various supply networks. Neither the pressure nor the temperature of the medium has any influence on the measuring results with the underlying calorimetric measuring principle of the sensors. Therefore, the flowmeters or consumption meters can be used at different pressures and temperatures without further compensation. The flowmeters of ipf electronic measure the actual flow rate e.g. in m^3/h or l/min as well as the consumption in m^3 or l.

Leaks in consumption networks occur more frequently than is generally known.
Therefore, the installation of air flow sensors for continuous compressed air consumption measurements is generally recommended in order to identify deviating high consumption levels at an early stage and, in addition, to be able to generally better recognize where there is potential for savings when using compressed air.
Depending on the area of application and also the installation situation on site, various solutions are available for the continuous consumption measurement of compressed air: Puncture sensors, devices with integrated assembly line and compact solutions with rectifier (Fig. 7). In the following, these solutions are only briefly described, since a separate White Paper from ipf electronic is dedicated in detail to the important topic of Compressed Air Consumption Measurement.

Fig. 7: Possible applications of different airflow sensors e.g. on machines or in the immediate vicinity of a compressor.

So-called insertion sensors (Fig. 8) offer themselves in a certain way as an entry solution for continuous compressed air consumption measurement due to their easy installation and handling. The programmable devices with TFT display can be installed under pressure, i.e. with the compressor running, via a ball valve and record the measured variables flow rate, consumption and speed.

Fig. 8: Airflow sensor **SL870020**.
The blue arrows on the sensor housing mark the flow direction for mounting the device.

Flow sensors with integrated assembly section were designed for easy integration into existing pipelines (Fig. 9). Various solutions for pipe sizes from R 1/4“ to R 2“ are available.

Fig. 9: Programmable airflow sensor **SL900020** with integrated assembly section for the R 1/2“ pipe connection.

Flow sensors with rectifier have been developed for applications (e.g. inside machines, in the immediate vicinity of a plant or behind a maintenance unit), in which the integration of the devices described so far under 4.2 is difficult or even impossible, since e.g. the mounting space is not sufficient for such solutions due to the limited space available. Moreover, in such cases, the required installation space for the inlet and outlet sections is often also missing, which means that the minimum lengths required for the sections cannot be maintained (for more information, please refer to the White Paper Compressed Air Consumption Measurement. For such applications the units with flow straightener are suitable (Fig. 10).
The devices with connection thread G 1/2“ to 2“ do not require an inlet and outlet section to calm the media flow, since the rectifier (measuring block made of aluminum) always ensures an optimal flow to the integrated sensor elements, completely independent of the respective installation situation. Except for the flow sensor of the series with measuring block for the 1/4“ connection, which has no rectifier.

Fig. 10: Airflow sensor **SL920021** with integrated rectifier for space-saving installation e.g. on machines or behind maintenance units.

Flow sensors are a sensible investment in any case, since continuous consumption measurement in combination with suitable measures can usually lead to lower compressed air consumption and thus noticeable energy cost savings. If, however, conspicuously deviating high consumption levels are measured in a compressed air network, it is recommended that leaks are specifically identified as a possible cause and thus quickly eliminated.

The **UY000001** leak detector was developed primarily for this purpose (Fig. 11), which can also be used on gas and steam lines and vacuum systems (this solution for targeted leak detection is also described in more detail in the White Paper Compressed Air Consumption Measurement.

Fig. 11: The leakage detector integrates, among other things, a microphone and a camera with color display. There are also headphones, a bell and a shotgun.

ipf electronic gmbh | Rosmarter Allee 14 • 58762 Altena • Germany | Tel +49 2351 9365-0 • info@ipf-electronic.com • **www.ipf-electronic.com**

5 METHODS FOR FILLING LEVEL CONTROL

There is a whole range of different methods for filling level control:

- capacitive
- conductive
- mikrowave
- static pressure
- ultrasonic

Capacitive sensors for filling level measurement work according to the principle of a plate capacitor. The active sensor surface consists of two concentrically arranged metallic electrodes (opened plate capacitor). If a metallic or non-metallic object approaches the active surface, it changes the electric field in front of the electrode surfaces and thus the capacitance. The change in capacitance is converted into a switching or analog signal via an evaluation circuit.

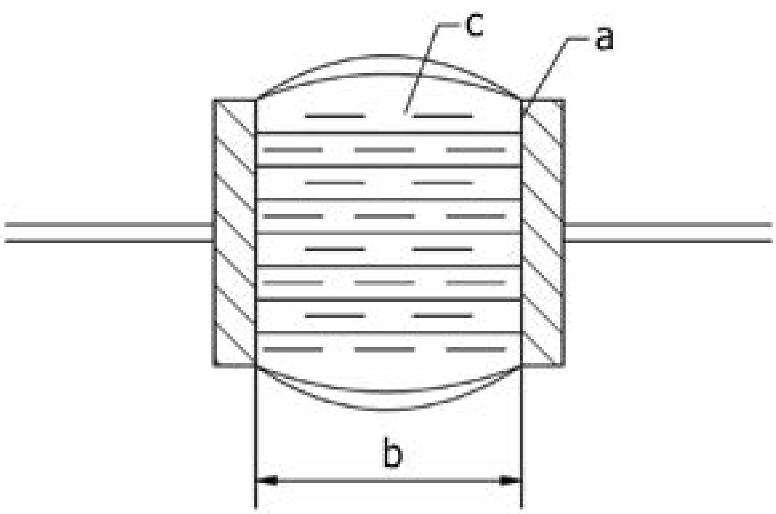

Fig. 12: The capacity of a level sensor is mainly determined by the mechanical design of the device, since it depends on the size of the field plates and the distance of the plates to each other. Analogous to the plate capacitor (figure) the capacitance is calculated as follows: $\varepsilon 0 \times \varepsilon r \times A / d$.
ε0: Dielectric constant for vacuum, εr: Dielectric constant for the dielectric
(a: plate size (A), b: plate distance (d) and c: dielectric)

This is the simplest method for filling level control of conductive media, mainly water-based. As it works on the principle of an open or closed circuit, several probes or electrodes, between which the resistance of the medium to be controlled is measured, are necessary for the measurement. The signal line of a filling level relay is connected to a reference electrode or to a metallic container or pipe wall (as reference electrode) and to one or more measuring electrodes. The alternating voltage generated by the integrated electronics is applied either between the measuring electrodes or between an electrode probe and the reference electrode. As soon as the electrically conductive medium closes the circuit between the measuring electrodes or between an electrode and a reference electrode, an alternating current flows and the relay output switches.

The "microwave" method is based on the guided microwave principle. Here, the running time of a microwave is detected by the sensor through a measuring rod to the medium surface and back. From this, the filling level is calculated. The lower end of the measuring rod is the zero point for the filling level measurement.

The "static pressure" method is based on the determination of the so-called hydrostatic pressure, which is the pressure exerted by the height of a liquid column in a container on a measuring membrane in a sensor. The level to be determined also depends on the specific density of a medium and the so-called gravitational constant (9.81m/s^2). Due to gravity, the hydrostatic pressure increases with increasing height of the liquid column in a vessel. The formula for this is: h = p / ρ x g (h = level, p = pressure, ρ = density of the medium, g = gravitational constant) (Fig. 13).

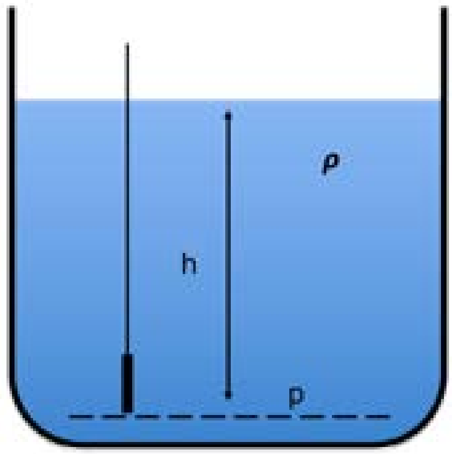

Fig. 13: h: height of filling level, p: pressure, ρ: density of the medium, gravitational constant g = 9.81 m/s^2

Regarding the ultrasonic method, the echo runtime method measures the time required for a sound pulse from the sensor to a medium surface and back and from this the level in a container is determined.

5.1 CAPACITIVE FILLING LEVEL SENSORS

In addition to solutions for classical filling level monitoring, ipf electronic offers devices with continuous level signal and sensors with a particularly large active area and thus very high capacity.
The "classics" among the capacitive filling level sensors are suitable for media temperatures from -25°C to +100°C and have a digital as well as an analog output to set switching points or to generate a continuous signal for monitoring the filling level. The devices are suitable, for example, for level monitoring in storage tanks, for example for cooling emulsions of machines.
The capacitive sensors with continuous level signal are characterized by a high sensitivity due to their large sensor surface and allow a very good basic adjustment, independent of the medium to be scanned. Such solutions are ideal, for example, for dry-running protection of pumps in containers.

A special feature are the sensors with piston-shaped Teflon housing, which offer excellent dripping behavior and are also anti-electrostatic as well as acid and alkali resistant. The devices have a very high capacity due to their particularly large active area and also have excellent compensation of moisture by a special electrode.
The capacitive sensors, designed for media temperatures from -25°C to +75°C, enable monitoring of the filling level in containers with viscous media such as coolants and lubricants for machine tools. Furthermore, they are ideal for monitoring the filling level of containers with e.g. acids, caustic solutions, oils or cleaning agents (Fig. 14).

Fig. 14: Capacitive sensor **FK920420** for monitoring the level in a container, which contains graphite paste for permanent lubrication of a tool.

5.2 CONDUCTIVE FILLING LEVEL SENSORS

The portfolio of conductive filling level systems consists of various, flexibly applicable evaluation devices and different probes with up to three electrodes. The versions with one or two electrodes are suitable for media temperatures from -20°C to +100°C, are pressure-resistant up to 10bar and have electrode lengths from 500mm to 1000mm. Special designs are also available with either two or three electrodes. Potential applications for these solutions are the level monitoring of electrically conductive media, which can also be found in plastic containers (Fig. 14).
Further application areas of the systems would be for example the overfill protection of containers with non-flammable, water-polluting liquids, as dry run protection for pumps or for the two-point control of systems. Furthermore, the solutions can be used in agitators or other vessels where the medium causes wave movements during filling or emptying.

5.3 FILLING LEVEL SENSORS (GUIDED MICROWAVE)

Thanks to their parallel rod, the level sensors, which operate according to the guided microwave principle, enable high-precision measurements, whereby no media adjustment is required beforehand. The devices are designed for media temperatures from -20°C to +80°C and integrate an analog and switching output with programmable/configurable switching function. The sensors are available with probe lengths from 200mm to 800mm and are very easy to install and are suitable for level monitoring of containers with oils, alkalis, cleaning agents, separating agents, etc. (fig. 15).

Fig. 15: A wide variety of sensors are available for level monitoring of electrically conductive media.
solutions with up to 3 electrodes are available, which are connected to an evaluation unit.

The special design with a measuring rod reacts to media contact at the measuring tip and is also suitable for the detection of media such as powder or granulates. The devices, which are insensitive to media build-up, are available with probe lengths of 120mm to 400mm and also enable the monitoring of filling levels in plastic as well as metal containers with e.g. hydraulic oils, emulsions, etc.

5.4 HYDROSTATIC PRESSURE SENSORS FOR FILLING LEVEL CONTROL

Hydrostatic pressure sensors from ipf electronic enable a simple and highly precise level monitoring of liquid media with only one sensor (Fig. 16). The devices work maintenance-free and are adjusted to a water column of 1.5m or for pressure ranges from 0 to 0.4bar. The sensors can be installed very easily by "hanging mounting", whereby no further adjustments are necessary for the measurements. Alternatively to the "hanging installation" the devices can also be installed laterally in tank walls. The solutions integrate a pressure measuring cell with downstream electronics, which converts the static pressure of the liquid column into an analog measuring signal. Since the static pressure is determined by measurement, gel-like or pasty media can also be monitored in addition to liquids.
The fields of application of hydrostatic pressure sensors can be found in the level monitoring of liquid media such as water, waste water, solvents, oil sludge, greases, etc.

Fig. 16: High-precision measurements without prior media adjustment.
The figure shows a level sensor **FM910321** (above) and the special design **FM910122**.

ipf electronic gmbh | Rosmarter Allee 14 • 58762 Altena • Germany | Tel +49 2351 9365-0 • info@ipf-electronic.com • **www.ipf-electronic.com**

5.5 ULTRASONIC SENSORS

The ultrasonic sensors from ipf electronic are designed for a wide range spectrum and thus for simple level monitoring even from a great distance. For example, ranges of up to 6 meters can be achieved for use in silos. The measurement is contactless, so that the devices are ideal for level monitoring e.g. of containers with aggressive media in all imaginable industrial areas. There is a wide range of solutions with cylindrical or cuboid housing designs as well as housing materials in brass or plastic available. The adjustment of the ultrasonic sensors is done by teach-in.

A special feature in the portfolio of ultrasonic sensors are the very compact devices of the **UT12** series, whose transducer has an aperture angle of only 6°. These solutions with a measuring range of 20mm to 200mm therefore enable level control in containers with extremely small openings, such as those found in medical or laboratory technology (e.g. test tubes or sample containers) (Fig. 17).

Fig. 17: ipf's hydrostatic pressure sensors (here a "hanging installation" in a container) have degree of protection IP68 and are suitable for media temperatures from -20°C to +70°C.

Fig. 18: Ultrasonic sensors of the **UT12** series in an automated dosing system of a chemical company. The sensor behind the dosing unit (left) controls the filling levels from above by the small bottle openings. A further sensor with switching output is used for presence monitoring.

ipf electronic gmbh | Rosmarter Allee 14 • 58762 Altena • Germany | Tel +49 2351 9365-0 • info@ipf-electronic.com • **www.ipf-electronic.com**

6 APPLICATION EXAMPLES

Below are some practical examples of the use of sensors in fluid power applications. From the abundance of very different applications, it is clear how versatile this area is and thus also the potential uses of the solutions.

PRESSURE SENSORS

Pressure sensors are used, for example, in the field of air compressor control to monitor the system pressure on a unit.

Vacuum lifting devices are used to lift a wide variety of products (cartons, glass sheets, plates, etc.) using negative pressure. A pressure sensor ensures that the required minimum negative pressure is reached to lift the corresponding product.

TEMPERATURE SENSORS

High temperatures are necessary for forming forged parts. Pyrometers monitor the minimum temperature of the forged part with infrared technology for a safer forming process.

In cooling circuits at the machine infeed, e.g. PT100 sensors monitor the correct cooling water temperature for the subsequent production processes, e.g. in metal cutting.

ipf electronic gmbh | Rosmarter Allee 14 • 58762 Altena • Germany | Tel +49 2351 9365-0 • info@ipf-electronic.com • **www.ipf-electronic.com**

FLOW SENSORS

Flow sensors or flow monitors monitor the flow of the coolant in cooling circuits, e.g. of sintering furnaces in the manufacture of indexable inserts. This ensures that there is always sufficient coolant circulating in the circuit and that the furnaces do not overheat.

FILLING LEVEL SENSORS

Conductive filling level sensors can be used, for example, to monitor filling level limits in containers. In this case, the inlet of a storage tank can be controlled via a valve. If a predefined minimum filling level is reached, the valve opens until the container has reached its maximum filling level again.

Capacitive sensors can be used, for example, to monitor the minimum filling level in a lubricant reservoir, e.g. for the permanent lubrication of machine tools.

Sensors working according to the guided microwave method can, for example, monitor the level in a container with hydraulic oil. For this purpose the sensors are mounted in the container lid.

Ultrasonic sensors are suitable e.g. for level control in clarifiers or, as here, in a cistern or fresh water well. With the echo runtime procedure the time is measured, which needs a sound impulse from the sensor to a medium surface and back and from this the filling level is determined.

Hydrostatic pressure sensors measure, as the name suggests, the hydrostatic pressure that acts on a measuring membrane in the sensor due to the height of a column of liquid. Such devices are often used for level control in containers. The solutions of ipf electronic enable a simple and high-precision level monitoring of liquid media with only one sensor, whereby the devices work maintenance-free.

ipf electronic gmbh | Rosmarter Allee 14 • 58762 Altena • Germany | Tel +49 2351 9365-0 • info@ipf-electronic.com • **www.ipf-electronic.com**

ipf electronic gmbh • info@ipf-electronic.com • **www.ipf-electronic.com**
Subject to alteration! Version March 2020