ifm electronic

Sensors, networking and control technology for automation

Training manual

Capacitive proximity switches
Level sensors
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1 Introduction

1.1 Proximity switches in industrial processes

Automated production processes require sensors for supplying information. These sensors provide signals about positions, limits, levels or serve as pulse pick-ups. Without sensors that work reliably even the best controller is not able to control processes.

In general, all these sensors consist of two parts: the first registers the change in the physical conditions (basic sensor), the second converts the signals of the basic sensor into electrical output signals (signal processing).

In general, a distinction is made between binary sensors which provide a definite high-low signal and analogue sensors which are preferably used for temperature, distance, pressure, force measurement, etc. The sensor supplies an analogue signal which is further analysed for measurement and control.

The figure shows the general diagram which basically applies to every sensor. Only some details are different, e.g. individual components are not used or cannot be separated. Sometimes the basic sensor is also just called sensor. In this case it must be seen from the context whether the whole unit or the basic sensor is meant. Some units consist of separate components, e.g. NAMUR sensors or often also temperature sensors. Here the transducer is connected to a separate evaluation unit or amplifier.

Figure 1: Configuration of a sensor
Capacitive proximity switches

Intelligent

A sensor which only supplies the binary information
  object detected (level reached) or
  object not detected (level not reached)
is in general not yet called intelligent. One also speaks of an intelligent sensor if it is able to supply additional information, e.g.
  object reliably detected or
  object not reliably detected.

An analogue sensor provides more information, of course.

Level

Binary sensors have been developed which are especially designed for monitoring levels. They are also called level switches. Below they are called binary level sensors. A new sensor family operates according to the analogue principle. To make the distinction easier and to avoid misunderstandings we will call them analogue level sensors (see 3.5).

This text will focus on binary sensors as position switches and level sensors as well as analogue level sensors as sensors generating a measured value. It will provide information about the operating principle, features and criteria for using capacitive sensor systems. Furthermore it will describe typical applications and suitable types thus making it easier for the user to select the unit suitable for his application. There are many different names for these sensors: proximity switches, initiators, non-contact position indicators, but also manufacturer-specific names such as efcator (registered trademark of ifm electronic gmbh) are used. This manual will use the term proximity switch for binary sensors.

In industrial applications mainly one system has been tried and tested: capacitive proximity switches. This sensor system is suitable for the non-contact detection of a wide range of different materials.

The new analogue level sensor also operates according to the capacitive principle. However, it has to be immersed in the medium, if necessary using a thermowell. There are differences as far as generation and evaluation of the measured signal are concerned which will be explained below.

Ifm has produced non-contact capacitive proximity switches for over 30 years. There must be a reason why these switches are used everywhere in industrial plants. Why are these units and in particular the efcators so successful?

A lot of experience made in the past few decades has led to more and more improvements. For more than 20 years ifm has granted a 5-year warranty for its standard units. Due to its high degree of reliability reached for the first time the capacitive proximity switch has been widely accepted in state-of-the-art technology. Moreover, new fields of applications open up where a high degree of automation was inconceivable before.

Next generation

When the electronic proximity switch was launched it was just seen as a replacement for the mechanical switch. Meanwhile the mechanical switches have been replaced in many applications. This means different types were developed, produced, sold to the user who contacted the manufacturer if the sensor needed additional features in his application. After years of experience with the units, another point of view can be
Capacitive proximity switches
Level sensors

taken. The first question is: What features does a sensor need to solve an application?

are there any examples? The correct sensitivity setting could be difficult in specific applications. This proved to be true for example for applications where the sensor had to detect the level through a wall (see 3.3.4). The first generation is set using a potentiometer. The level sensors are set automatically. The sensor selects the optimum setting to compensate for the wall concerned.
The increasing use of frequency converters generates an increased conducted high-frequency noise level to which the capacitive sensor reacts more sensitively than other sensors. Therefore the measuring principle was modified so that the capacitive sensor is virtually immune to such noise.

Details will be described in 3.2.2.

1.2 Layout

For a better understanding the layout will be explained to make reading the text and finding information easier.

keywords Keywords which refer to the topic to be dealt with in the following section are given in the left margin.

what does ‘FAQs’ mean? This stands for Frequently Asked Questions. This term is also used for modern electronic media. Almost everybody starting to deal with a new task faces the same questions. Sometimes FAQs introduce a section instead of keywords. To differentiate them from simple keywords, they are written in italics.

( 4) A figure in round brackets in the left margin refers to a formula used in the following text, e.g. see (4). Of course, these formulas do not need to be learnt by heart. They are meant to make understanding of the subject easier because a formula similar to an illustration describes a relation more briefly and clearly than many words.
1.3 On the contents

The purpose of this manual is to give basic information about capacitive proximity switches. Important terms and relations will be explained, state-of-the-art technology will be described and technical data of ifm’s units will be presented. This results in the following structure.

1. Introduction

This introduction is followed by the chapter:

2. Basics

Here the physical basics that are useful for a better understanding of the operating principle and the features will be briefly presented. A few basic terms and their context will be described.

3. Features of the capacitive proximity switches, binary and analogue level sensors

The binary as well as the analogue sensors will be discussed. Other systems in practical use will also be mentioned. Then a general overview of different sensing systems will follow. This is meant to facilitate the correct classification of sensors to the capacitive principle and to decide where they can and where they cannot be used. The knowledge of these features, the advantages and disadvantages is a prerequisite for successful use.

4. ifm units

Here the data of ifm sensors are listed and explained. The mechanical configuration, electrical features and use are described. Special units will be presented.

5. Applications

A few applications with illustrations will be briefly described.

Annex

This manual is also intended to help you study on your own. Therefore important terms will be briefly explained again in the glossary of technical terms. The points which are essential for the ifm sensor will be detailed in the chapters preceding the glossary. The index will help to look them up. The type key and the code for the production date will also be briefly presented.

much success!

Having this basic information everybody should be able to benefit from the chance this product offers and to use the efector 150 successfully.
2 Basics

**do I have to know this?**

Many operators use capacitive sensors successfully without knowing these basics. In the following chapters several notes on practical applications will be given. The basic knowledge helps to structure such information. This is more effective than learning a dozen rules by heart. Understanding the operating principle also makes the selection of the types and their application easier. Some basic knowledge is necessary to be a competent partner.

This chapter will also outline the physical basics. This description is not too long and theoretical. We have tried to focus on essential information. In this respect it is necessary to shorten and simplify facts and explanations.

In the following sections, we will recall a few basic terms which will be used without any further explanation in 3.2. Those who are familiar with these basic terms can skip this chapter or come back to it if necessary.

### 2.1 Capacitance

**what does it mean?**

Everybody is probably familiar with this term; it is used in many contexts. In connection with electric charge it has a special meaning.

**charge**

We only want to recall briefly that there are two kinds of electric charge which are characterised by + and -. These charges are tied to carriers, e.g. electrons and other elementary particles. Usually the charges in the objects surrounding us are balanced. These objects are electrically neutral. The fact that charges are always present is of special importance in the next chapter 2.2. If there is an excess of charge, positive or negative, the object is said to be charged.

**consumption capacity**

This is another term for capacitance. First of all we want to recall one characteristic of electric charges. They exert force on one another: equal ones repel one another, unequal ones attract one another. If you want to add more equal charges to an already charged object, these (or their carriers) have to move against the repelling force. This means work has to be performed. One unit for electrical work is the electrical voltage. Now you can characterise structures of conductors, capacitors by the amount of work that is needed to charge them. So it is obvious to define capacitance as:

\[
C = \frac{Q}{U}
\]

\( [C] = 1\ \text{F} = 1\ \text{farad, electrical capacitance} \)

\( [Q] = 1\ \text{C} = 1\ \text{coulomb, electric charge} \)

\( [U] = 1\ \text{V} = 1\ \text{volt, electrical voltage} \)

In words: the more charge flows onto an object at a certain voltage, the higher the capacitance.
**Capacitive proximity switches**

**Level sensors**

When it comes to a measuring unit it is useful to ask this question in order to get a feeling for this unit. 1 F is very much. It is quite difficult to generate such high capacitances. Capacitors are electrical components whose task is to store electric charges. 1 mF is already quite a lot, typical are rather µF. With capacitive sensors even changes in capacitance in the pF range are evaluated. This also applies to ifm’s pressure sensors, for example, which also operate to the capacitive principle.

**Reminder**

Meaning of the abbreviations:

- m milli \(10^{-3}\)
- µ micro \(10^{-6}\)
- n nano \(10^{-9}\)
- p pico \(10^{-12}\)

One problem should be clarified here in order to avoid misunderstandings. Charges are not simply generated, just as little as they can disappear. Charges are separated. This means that in order to apply charges to an object, they have to be taken away from another object. Bearing this in mind a simple example of a capacitor, the plate capacitor, becomes clearer (see Figure 2). Not only one plate is charged but both, with reversed signs, however. An electrical field is built up between the plates. This means that e.g. a negative charge between the plates is repelled by the negative plate and attracted by the positive plate. So far we have not mentioned, either, that the electrical voltage cannot be seen absolutely but that it only makes sense as the difference between two points. For the plate capacitor e.g. the voltage between the plates is meant.

**Plate capacitor**

Bearing this in mind the formula for the capacitance of a plate capacitor is easy to understand. If the distance between the plates is small, less work has to be performed to separate the charges. The capacitance is bigger. The larger the surface of the plates the better the charges can spread on it. Less work is required to apply additional charges. The capacitance is also bigger. The formula is:

\[
C = \varepsilon_0 \frac{A}{d}
\]

\[C = 1 \text{ F} = 1 \text{ farad}, \text{ electrical capacitance}\]
\[\varepsilon_0 = 8.8541 \times 10^{-12} \text{ F/m}, \text{ electric field constant}\]
\[A = 1 \text{ m}^2, \text{ surface of a plate}\]
\[d = 1 \text{ m}, \text{ distance between the plates}\]

![Figure 2: Plate capacitor](image-url)
The two basic terms, electrical field and electrical voltage are also important in connection with the EMC issue (see Training Manual CE Marking).

2.2 Dielectric constant

This term means a material property which is characteristic of the behaviour in the electrical field. This characteristic shows e.g. when material is placed between the plates of a capacitor (see 2.1). Non-conductive material is meant here, otherwise there would be a short circuit between the plates (see below). The following term will help clarify this background.

As mentioned above, matter consisting of elementary particles such as electrons is electrically neutral. The electric charges which are bound to the elementary particles are balanced. At this point we want to recall the structure of matter. The smallest parts are atoms (at this point we do not want to ask in detail what they consist of). It is only in inert gas that they are isolated, usually they combine to form molecules. Looking at this structure in more detail you will see that there are materials in whose molecules the charges are not arranged completely symmetrically. A well-known example is water. A water molecule is electrically neutral. However, it is easy to imagine that for example a “left-hand” side is slightly positive and the “right-hand” side is slightly negative. This is the cause of some properties of the water, e.g. the good solubility of salts. Usually this is hardly noticed because the water molecules are oriented completely irregularly. However, if you place them into an electrical field, e.g. between the plates of a capacitor, they orient themselves. The positive side will point to the negative plate and accordingly the negative side to the positive plate.

If you enter a material which is not polarised into an electric field, it can slightly stretch these charges. Even if before the charge distribution was symmetrical, there will be a polarisation in the electric field.

Is this of any significance for practical use?

Especially in connection with capacitors there is an important consequence. Whether the charges orient themselves or whether they stretch, the field is weakened in either case. For example, opposite the negative plate there will be positive charges which partly neutralise the negative charge of the plate. Thus less work is required to apply additional charges to the plates, i.e. the capacitance increases. Formula (2) has to be modified.

\[ C = \varepsilon_0 \varepsilon_r \frac{A}{d} \]

A comparison with (2) shows that \( \varepsilon_r \) is a dimensionless number. It is called relative dielectric constant. It represents the correction factor by which the capacitance is to be multiplied if there is matter between the plates. Its value depends on the material. Using the above term this value can be clearly explained. \( \varepsilon_r \) indicates how much the material can be polarised.
dielectric material

This term sounds very scientific and abstract but in fact a dielectric material is nothing special. Each non-conductive material is a dielectric material (we will discuss conductive material further below). This term only points out that in the current context polarisability is the essential property.

values

If there is no matter between the plates (vacuum), then \( r = 1 \). With air the difference is so small that \( r \) also virtually takes the value 1. With other materials this value can only be \( > 1 \). For many materials it is between 1 and 10. With water it is already unusually high, here \( r = 81 \). This means that the capacitance of a capacitor where there is water between the plates is 81 times higher than in air. \( r \) is considerably higher with only some “exotic” substances. For example they are used in the production of special capacitors with high capacitances.

half full?

A special case is of particular importance for the analogue level sensor. If you imagine that the water level between the capacitor plates can take any value between full and empty, e.g. half full, then what about capacitance? It depends on the level. It makes, of course, sense to take the empty capacitor to (2) as reference. Above we stated that the capacitance rises to about 81 times when it is filled with water, see (3). If it is only filled half, the capacitance will increase by only half the value. To be more precise we can say: the change in capacitance is proportional to the difference in height (for rectangular plates). This relation is used for the signal generation in the analogue level sensor (see 3.5.1).

, of metal?

In metals (by the way likewise in other electrical conductors such as graphite) charges (more precisely: charge carriers) move relatively freely. So what happens if the space between the capacitor plates is filled with metal? As already said this does not mean completely filled because otherwise the capacitor would be short-circuited. There must remain a small gap on both sides. If the capacitor is charged, an electrical field is generated between the plates. It acts on the electric charges which move freely in the metal. So the positive charges will accumulate opposite the
negative plate and vice versa. The movement of the charges will continue until the electrical field inside the metal has been compensated. Here the term polarisation is stripped of its meaning, however, cannot be indicated for conductors. You can easily understand the effect of the charge distribution if you imagine that this arrangement is replaced by two capacitors.

Figure 5: Metal inside the capacitor

will C become greater or smaller? We do not intend to explain more relations of electrical circuits. We just want to recall that with connection in series of two capacitors the overall capacitance is smaller than that of each individual capacitor. Now you have to be careful not to come to a wrong conclusion namely that the capacitance of the plate capacitor decreases when metal is placed between the plates. The two individual capacitors of the “replacement circuit” have a considerably higher capacitance than the capacitor without metal between the plates. The reason why is that d is much smaller, see (2). So the answer is: C becomes greater. Metal virtually acts as a good dielectric material. This special case will be discussed further below (see 3.3.3).
3 Properties of capacitive sensors

3.1 Comparison

3.1.1 Classification

universal

The capacitive proximity switch detects all materials. Thus it is more versatile than the inductive switch. It is, however, also more susceptible to interference, e.g. due to build-up of dirt.

The same capacitive principle is also used for ifm's pressure sensor, see Training Manual Pressure Sensors. Since this is a completely different unit of measurement it will not be discussed here.

The capacitive sensor has some common traits with the inductive sensor, however it cannot be compared as easily as the latter with a mechanical switch, see Training Manual Inductive Proximity Switches. Certain properties can hardly be compared, e.g. the ability to detect a medium through a wall, see 3.3.4, the sensitivity setting, see 4.4. or the evaluation of the analogue signal, see 3.5.1.

binary and analogue

First of all we want to describe in detail the binary type which has existed for quite a while and which is the most frequently used type. Below, 3.2 to 3.5, we will discuss the use as a binary position sensor. Here the analogue signal is not evaluated externally. For a better overview, the analogue level sensor will be discussed in a later chapter, see 4.5.

position sensor

The binary capacitive sensor belongs to the group of position sensors. The photoelectric or inductive sensors also belong to this group. Criteria to select the suitable position sensor will be discussed in the training manual Photoelectric Sensors, criteria to select a capacitive proximity switch will be discussed in the following chapters (see e.g. 3.3.6). Another group is formed by e.g. the fluid sensors. There is no clear distinction between these groups; there are fluent transitions. Capacitive sensors with binary output are, for example, often used for level monitoring of fluids. They can also be seen as part of the position sensors since in the end it is a position that is detected.

medium

The binary capacitive sensor cannot only be used for monitoring the level of liquids. It is also frequently used for bulk materials such as grains and plastic granulates.

Especially in this function as position sensor there are properties it shares with the inductive proximity switch. The statements made in the Training Manual Inductive Proximity Switches in comparison with mechanical limit switches also apply here.

alternatives

The criteria to select a position sensor for a certain application will be described, as mentioned, in 3.3.6. For measuring systems for lengths or distances the task is different. The capacitive sensor as limit monitor has a series of advantages. There is, of course, also interference. Important aspects shall once again be summarised here. The properties of other systems will be briefly discussed in 3.1.2.
Electronic output signal
It helps avoid problems such as contact bouncing, wear and tear, corrosion of the contacts, etc.
Contact with the medium not required
Non-contact detection even through walls or PTFE thermowells is of advantage here.

soiling, deposits
We will discuss this important aspect in more detail. Above we mentioned the susceptibility of the capacitive sensor to these influences. At first glance this seems to be a disadvantage. However, it has to be taken into consideration that many alternative systems can be affected to a higher degree. For the capacitive sensor these influences can be compensated for, within limits, however.
Remote setting
If the sensor is not in direct contact with the medium, this aspect refers to deposits, e.g. on the wall, through which the sensor detects the medium. By making another empty state adjustment, see 4.4, which can be effected as remote setting via the programming wire, see 4.3, this effect can easily be compensated for, if the layer is not too thick. For mechanical systems only cleaning will be a remedy for which they may have to be removed.
Dynamic evaluation
For the analogue level sensor even thick layers of deposit or encrustation can be compensated for by dynamic evaluation of the segments, see 3.5.1.

3.1.2 Systems for level monitoring

alternatives
Here we want to mention briefly some possible alternatives to capacitive sensors. These alternatives mainly concern level. In this context we will also discuss some analogue systems. For position monitoring of any (not only conductive) objects there are hardly any comparable and economical alternatives, apart from optical sensors, maybe. In this chapter we will therefore focus on alternatives to level monitoring.

floats
Since the inductive sensor is least susceptible to interference, among others to wetting due to water, (see Overview) people try to use it also for level monitoring. However, since it mainly reacts to metal materials a float made of metal is required. The latter is an indication of the level of the fluid. There are various systems with round and pear-shaped floats on the market. To ensure reliable detection they have to be mechanical. This fact makes the configuration quite complex. For example, if several levels are to be detected, several floats have to be used. Generation of analogue signals is possible but mechanically even more complex. As an alternative, reed switches are also used. Mechanical microswitches which are e.g. operated via a lever are partly used with the function of limit monitors. It is especially this solution most arguments favour which are described e.g. in the Training Manual Inductive Proximity Switches as an advantage of the electronic sensor.
Whichever way the signal is picked up, these devices are particularly susceptible to soiling. Mounting is complex and cost-intensive. A large variety of types makes the selection very difficult.

Buoyancy

This principle is also called displacement method. A specifically heavier cylinder is placed into the medium. Depending on the level the force at the suspension is reduced by the buoyancy. In principle analogue measurements are also possible, however they require some mechanical efforts. It is also due to the poor precision that they are rather used for simple monitoring tasks.

Pressure

As described in more detail in the Training Manual Pressure Sensors, pressure sensors can also be used for level measurement. To obtain a high degree of accuracy there have to be high demands on measurement accuracy and resolution. To measure level in a closed vessel in which the inside pressure may differ from the atmospheric pressure a differential pressure measurement becomes necessary.

These mechanical methods share the susceptibility to soiling, deposits or encrustation. In some cases the float and displacement systems have to be protected against movement of the medium, flow or eddies by means of complex modifications.
Capacitive proximity switches

**Level sensors**

This method is also called conductive level measurement. There are two electrodes in the medium which is required to have a certain minimum conductivity. In metal vessels the wall may also be used as the second electrode. The electrical resistance in between depends on the level. In order to avoid retroaction, e.g. electrolytic decomposition, alternating current is used. A condition is that a homogenous medium with constant conductivity is used. A variation of this system is based on the evaluation of changes in the potential curves. It is independent of the conductivity; only a minimum value is a condition here again. Conductive level measurement is rarely used.

**Radar**

This is a promising technology for the future. Radar sensors generate primarily analogue signals which can, of course, also be used for limit value detection. Direct determination of the pulse duration is too complex due to the relative short distances. Therefore interference procedures (see Training Manual Photoelectric Sensors) are used. There are also procedures evaluating the attenuation of the signal during penetration into the medium. This method is also called radiometry. The basic sensors, however, do not yet exist in large numbers so that the price is still relatively high. The EMC issue (see Training Manual CE Marking) entails that this method is only used in closed metal vessels. Similar to the capacitive principle the dielectric constant (see 2.2) must not be too small.

**Ultrasonics**

This technology is already being used. Ultrasonic sensors generate analogue signals.

![Figure 8: Radar or ultrasonics](image)

**Interference**

There are system-related problems also with the methods mentioned last. The waves are difficult to focus. Therefore the use in applications where baffles such as cross-struts or unevenly shaped vessels are present is problematic. The echoes from the vessel walls alone can cause interference. Furthermore the determination of level is uncertain with foaming liquids. Waves on the surface of the medium can also disturb measurement.

**Capacitive**

So far also various capacitive procedures have been used. They can partly be compared to the ifm systems. Other procedures where an electrode is directly introduced into the medium are susceptible to changes in the conductivity of the medium.

**Vibration**

Such units work to the principle of a tuning fork. It is generally known that the vibration frequency of a tuning fork is mainly restricted to one basic pitch due to the material and the shape. If you immerse a tuning
fork with the freely vibrating tines in a liquid, it will be off-tune. This detuning is electronically evaluated and enables the use as limit monitor. Here it is also called vibrating fork. We also talk of a vibration sensor. Since the tines are paddle-shaped they are also called paddle switches. They cannot generate an analogue signal. They have to be in direct contact with the medium which makes them susceptible to deposits, corrosion, etc. There are numerous types from which the unit best suitable for the application has to be selected. This unit, however, is less suitable for other applications. So you have to expect that several different types are necessary. It is in particular the types for the detection of liquids and bulk materials which are different.

Figure 9 shows the paddle-shaped vibrating fork as seen from the side. Hidden behind and symmetrically to it you will find the second arm. This is only a schematic representation and it should not be confused with figure 8 where a funnel-shaped transmitter and receiver are outlined.

Figure 9: Vibrating fork

This brief overview should be sufficient. There are more methods, e.g. optical ones, which will not be discussed here.
Problems with level determination

Finally we want to list briefly some conditions which make level detection especially difficult.

- movement of the medium
- movement of stirring devices
- mud or dust above the medium
- suspended matter, bubbles, deposits in the medium
- encrustation
- chemically aggressive media

We can see here again that electronic sensors are replacing mechanical solutions step by step. The above-listed types of interference especially affect a mechanical unit. The variety of methods also shows that level monitoring is an important task in process technology and that it presents a considerable potential. However, there will never be just one sensor which is suitable for all kinds of applications. The analogue level sensor from ifm is designed for certain applications (see 3.5.3).

### 3.2 Technology and operating principle

First of all we only want to discuss the binary sensor. The analogue level sensor will be explained in 3.5.

#### 3.2.1 Basic sensor capacitive

![Diagram of capacitive sensor](image)

1. Compensation electrode
2. Measuring electrode
3. Machine earth
4. Housing
5. Electrical field

Figure 10: Capacitive sensor

Below the sensor will be built up step by step: from plate capacitor to sensor.
Capacitive proximity switches

Level sensors

capacitor

In a plate capacitor the field is concentrated on the area between the plates. For the simple capacitor the small portion of the electromagnetic field extending beyond the circuit is rather neglected. Figure 11 corresponds to Figure 2 with the exception that here the field lines (see 2.1) are added.

![Diagram of plate capacitor field](image)

Figure 11: Field of the plate capacitor

object detection

It would mean a significant restraint on the function of a position sensor if the object to be detected had to fit in between the plates of a capacitor. On the contrary, in this case it is the emitted electromagnetic field that is used. To ensure optimum alignment of this field the plate capacitor is “deformed”. As a first step you can image that the surface of the one plate, here also called electrode, is enlarged. If you also image that this plate is bent to take the shape of a cup and the other plate is placed in front of the opening of this cup you already have the basic capacitive sensor. This structure also represents a capacitor. A further component is a ring-shaped compensating electrode which is designed to compensate for environmental influences.

The figures below show the arrangement of the plates (electrodes) where an electromagnetic field is formed between the active “hot” electrode and the ground electrode.
If material enters the electrical field emerging to the front, the capacitance of the capacitor changes. It is already sufficient if it is in front of the cup. The capacitive proximity switch thus has an active face similar to the inductive one (see Training Manual Inductive Proximity Switches).

The level of the change in capacitance depends on several factors:

- distance and position of the object in front of the proximity switch
- dimensions of the object and its shape
- its dielectric constant.

The values of the change are comparatively small. The smallest somehow reproducible values that can be evaluated are around 0.1 pF (see 2.1).
3.2.2 Signal generation

So the idea is to evaluate a change in capacitance. There are several possibilities to this end. First of all we will briefly describe the technologies which were used with earlier effectors.

You can imagine the capacitor to be a component of an oscillator circuit, similar to the coil of the inductive proximity switch. This oscillator circuit is excited close to the resonance frequency. As with the inductive principle the frequencies used to be between 100kHz and 1MHz. This means that it oscillates at a low amplitude. If the capacitance changes, according to (3) it can only increase, the resonance frequency is shifted, the amplitude increases. Nevertheless it is said: “the sensor is damped”. This description is somewhat simplified. It was not a simple LC oscillator circuit that used to be generated but a non-linear oscillator of the Wien-Robinson type. However, this principle is more susceptible to interference than the inductive one. High-frequency electromagnetic fields, e.g. from transmitters, can cause interference via electrodes acting as antennae. This problem could be solved by shifted frequencies. In addition there is high-frequency interference which is caused via the mains and which is mainly due to frequency converters. The consequence of this was that this principle is no longer used for today’s units.

Figure 14: Diagram of the former circuit
Capacitive proximity switches

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Figure 15: Block diagram of the former circuit

setting

In Figure 15 you can see that the sensitivity can usually be set which is
not the case with the inductive proximity switches. This feature remains,
nowadays, however, also advanced techniques without potentiometer
are used (see 4.4).

current situation

With today’s generation two things have changed:
operating principle of the circuit and
evaluation of the capacitance

Today evaluation is effected by a microprocessor. Therefore the
potentiometer was no longer needed which made the mechanical
configuration complex in order to obtain ingress resistance. The second
advantage is that setting to the optimum switch point is fully automated
by pressing a button or by a pulse on the programming wire (see 4.4).

capacitance of the capacitor

Similar to the inductive sensor, the relation between the distance of an
object and the change in the parameter affecting the oscillator circuit (in
this case the capacitance of the capacitor) is non-linear. That is why this
sensor type is hardly suited to distance measurements, its main
application is that of a binary switch.
fixed frequency

When high-frequency interference acts on the circuit you can say that it is a system of coupled oscillator circuits. You could see that the resulting frequency of the oscillator circuit has been shifted. An approach to avoid this effect was to force a fixed frequency by means of an oscillating quartz crystal. This principle which helped improve resistivity to such interference considerably in practical use was used for the next generation. However, it is no longer used today because an even better procedure has been developed.

charge balance

This principle, described in a simplified way, means that the actual measuring capacitor and a reference capacitor are charged alternately. This dynamic procedure ensures optimised compensation of noise. These units are designated ni (noise immune).

3.2.3 Evaluation

First, the information contained in the capacitance change must be converted into a switched signal. So only one of the two possible switching statuses “current flows” or “current does not flow” can be taken.

signal processing / output stage

The basic sensor is followed by further stages evaluating the signal. Figure 15 shows evaluation with the oscillator circuit procedure. A comparison with the Training Manual Inductive Proximity Switches clearly shows that the electronic configuration of inductive and capacitive sensors is basically the same. The following two points are different: type of basic sensor and setting possibility of capacitive units. Due to the further development of the capacitive principle the circuits can, however, not be directly compared any more. There are also differences now as far as setting of the switch point and/or sensitivity are concerned (see 4.4).

unambiguous

If the object is located precisely at this switch point or approaches it slowly, there is a risk that the output will constantly change between...
these two states, i.e. it would chatter. This is prevented by a clearly defined hysteresis which is generated electronically.

time characteristics

Also, it must be ensured by means of the circuitry that no false signal is provided at the moment the operating voltage is applied. There must be a power-on signal suppression. The time which elapses between applying the operating voltage and the sensor being ready for operation is called power-on delay time and is in the millisecond range. Occasionally, this leads to confusion. This time is not the same as the switching time (see 3.3.5). The latter is much shorter. Another parameter is the response time, i.e. the time which elapses between presence of the object and switching of the output. It depends on the switching frequency (see 3.3.5) and is also shorter.

switching function

With many units the normally open or normally closed switching functions can be selected. For the earlier units this was also called programming even if just a wire link had to be cut open.

output

For switching the output signal solid-state switches such as transistors and thyristors dominate the market. With respect to life, number of reliable switching operations, switching frequency, and bounce-free switching response they offer significant advantages.

The minor disadvantages, i.e. leakage current in the non-switched state, voltage drop in the switched state and greater sensitivity to overvoltage and current overloads (see e.g.4.3) can usually be tolerated or can be more or less avoided by taking the appropriate protective measures.
3.3 Practical use

3.3.1 Sensing range

what does it mean?

At first glance the answer seems quite easy. Taking a closer look reveals, however, that it is important to understand things right. Capacitive proximity switches operate without contact. It is sufficient for the object to be detected to come close to the sensor. But what is understood by close? This distance at which a proximity switch is capable of reliably detecting an object is called sensing range (in the IEC 60947-5-2 standard called “operating distance”). It depends on
- the type and design of the sensor
- the specific features of the individual switch
- external conditions
- shape, dimensions and material characteristics of the objects to be detected.

rated sensing range

A characteristic value is allocated to each type, the rated sensing range (also called nominal sensing range) which is also indicated on the type label. For capacitive systems it depends on the shape and the dimensions of the electrodes, i.e. the basic sensor. As a rule of thumb, the longer the sensing range the bigger the external dimensions of the sensor. The values are between 1 and 60mm.

is this a fixed value?

As compared to e.g. inductive proximity switches the sensing range or the sensitivity of the capacitive switches can be set. This is necessary for many typical applications (see 3.3.4). Since this setting is so important, the procedure has been further developed. The sensing range has been set by the factory so that an optimum excess gain is attained. This means that there is only minimum susceptibility to soiling, condensation or temperature fluctuations.

what does “rated” mean?

This means that this parameter cannot be seen as absolute but must be interpreted. How is the real sensing range related to the rated (nominal) sensing range? In other words: What does the sensing range depend on? There are a number of influences.

Different units of the same type cannot be completely identical. This means that variations have to be expected. Also, the sensor is exposed to changing environmental conditions, e.g. temperature variations, fluctuations of the operating voltage, etc. Objects close to the sensor but which are not detected, e.g. stationary equipment of a plant, can also affect the sensing range (cf. 3.3.3). Eventually, the characteristics of the objects must be taken into consideration. The effects of this will be explained below.

The indicated rated sensing range / nominal sensing range is determined for capacitive sensors by means of an earthed metal target plate.

meaning

When using capacitive proximity switches the following question is usually asked: How is the sensor adapted to the concrete application? The sensing range is not of the same importance as for the inductive type. Therefore we will discuss this term only briefly. For a more detailed
Capacitive proximity switches

Level sensors

explanation we refer you to the description of the inductive proximity switches, see Training Manual Inductive Proximity Switches. Most of what is said there also applies in general to the capacitive switch.

It goes without saying that for the design of the circuit and during the production of the capacitive sensor much care is taken that the permissible tolerances, ±10% variation and ±10% due to environmental influences, are not only kept but even improved. It is in particular the resistance to high-frequency noise that could be considerably enhanced, see 3.2.2.

operating distance

The minimum value of 0.81sₙ is important and interesting for the user. Each proximity switch should operate reliably at this distance, the assured sensing range.

The maximum value of i.e. 1.21 times the nominal sensing range is also of importance to avoid interference caused by remote objects.

rule of thumb

As a rule of thumb, the distance of the object (assumed to be an easily detectable material with sufficient surface area) should be about half the nominal sensing range.

repeatability

In practice, another term is frequently of importance, i.e. repeatability, also called reproducibility. Here the question is asked how the switch point scatters if the sensor is approached several times by one and the same object in the same way. The possible tolerances have no direct relation with this and should not be confused with it. The repeatability of the capacitive sensor is smaller than that of the inductive one, for example.

predamping

What are the effects if further detectable objects, e.g. the wall of a stationary housing or build-up of metal swarf, are close to the sensor? In this case we say that the efector is predamped. This means that the sensor is already influenced by these objects but has not yet switched. As a result, only a slight additional influence is necessary, e.g. a more distant or smaller object, so that the output switches. Thus the sensor has become more sensitive, the sensing range has enlarged. If possible, this case should be avoided because the risk of malfunction is increased.

compensation

However, in typical applications, see 5, the capacitive proximity switch is used so that it is influenced by objects, e.g. the wall of a vessel. Then it has to be set so that this influence is compensated for. This procedure is described in 4.4.

3.3.2 Hysteresis

is this intended?

The hysteresis is the difference between the distance at which the output switches when the object approaches and the distance at which the output switches back again when the object moves away. If an object is located precisely at the switch point, the switching output constantly changes between the two ON and OFF conditions. This is prevented by a clearly defined hysteresis which is electronically generated. The difference between the switch-on and switch-off points integrated into the circuit leads to a stroke of several millimetres which the object to be detected must move to ensure reliable switching on and off of the proximity switch.
The hysteresis is also of importance with other sensors, e.g. pressure and temperature sensors. Here it is of advantage if the hysteresis is freely adjustable because easy control functions can thus be implemented.

lateral approach

If the object does not approach the proximity switch axially but radially, i.e. from the side, the accurate switch-on and switch-off points depend on the shape of the electromagnetic field.

3.3.3 Correction factors

is there anything else you have to know? In practice the target is rarely an earthed metal surface (see 3.3.1). The objects may be bigger, smaller, irregularly shaped and consist of various materials. In such cases the nominal sensing range has to be multiplied by correction factors to determine the actual sensing range. This virtually means a change of scale. The tolerances of the standard, e.g. ± 10% for temperature fluctuations, are maintained. Also for the hysteresis graph the dimensions change accordingly. How these factors are determined will be described below.

side length

If a smaller or non-square-shaped plate is used, the sensing range should be corrected by a factor. As with the inductive sensor smaller sensing ranges will result for smaller objects and a virtually constant sensing range for longer sides.

rule of thumb

Another rule of thumb is that the sensing range corresponds to the nominal sensing range if the object is not smaller than the sensing face of the sensor (see 3.2.1). The limit where objects are no longer detected is with much smaller dimensions.

shape factor

For other shapes, e.g. when cylinders are to be detected, the factor can no longer be specified in general. For balls the sensing range will be slightly reduced. The value, however, depends on the radius of the ball. For objects which are shaped even more irregularly the sensing range can only be estimated based on experience and should be determined by practical tests. In contrast to the inductive sensor the sensing range hardly changes if instead of a compact object a slotted object, e.g. a comb, is detected.

material

If objects made of any kind of material are to be detected, the sensing range will also have to be corrected. For capacitive proximity switches the correction factor also depends on the capacitance change of the capacitor at the sensor tip (see (3) in 2.2). The bigger this change the sooner an object will be detected. So the correction factor depends directly on the relative specific dielectric constant of the material in question (see figure below).
The diagram shows that the capacitive sensor reacts especially to water. This is a desired effect, if e.g. the water level is monitored through a plastic or glass wall (see 3.3.4). On the other hand the sensor is more susceptible to interference caused by water splashes or condensation.

In principle the temperature dependence of $r$ must also be taken into account. However, in most media it is relatively weak so that it is of no practical significance. The situation is different if a temperature fluctuation is connected with a change in the physical condition, see the considerable difference between water and ice in Figure 17.

Electrically conductive materials such as all metals are not shown. Correction factor 1 applies to all of them, i.e. you will obtain the max. possible sensing range (see 2.2).

In contrast to the inductive type the sensing range increases with the material thickness. It only remains constant after a limit value. No definite statement can be made as to this limit value because it depends on the material and the type of the sensor.

**3.3.4 Compensation of the environment**

A frequent application already for binary sensors is level monitoring. The analogue level sensor will be described in 4.5. If the wall of a vessel or a tube is made from a suitable material (such as glass or PVC, but not metal) and if e.g. the level of water is to be detected, the sensor can be mounted outside the vessel or tube. By means of the sensitivity setting it can be achieved that the medium behind the wall and not the wall itself is detected. So the sensor can look through the wall. This is in particular possible whenever the dielectric constant of the material to be detected is much greater than that of the wall material.
Even if the dielectric constants of the medium and the wall are similar, the wall thickness is still of importance. If in doubt, a practical test is always useful.

methods

A part of the units is set by means of a potentiometer. Here it is tried to find an average position at which the sensor reacts to the medium but not to the wall. In individual cases a fine feeling on the part of the user is important; some experience is of advantage. If the sensor does not react at all or remains constantly switched, i.e. detects its environment, its own housing, the reason why is probably that you are far away from the switch point. Then you need to be patient enough to find the switch point again, maybe after some revolutions.

The new generation, i.e. units especially designed for the application level monitoring, features a microprocessor and membrane keys or a non-contact sensor. By activation of the corresponding keys or damping of the sensor the unit will automatically find the optimum setting. Usually empty adjustment is sufficient which determines a setting at which the wall is compensated for. In more critical cases full adjustment can be made. In 4.4. this procedure will be described in more detail. It is also called “teach in”.

It allows even the inexperienced user easy and reliable setting of the unit. If against all odds setting should be unsuccessful, the conditions are so unfavourable that you can assume that manual setting will not be successful, either.

accessories

Since this application is quite frequent there are also plastic windows as accessory which allow the sensor to be mounted by means of a mounting bracket. This window is either straight or elbowed and adapted to certain pipe diameters. There are also thermowells of PTFE which protect the unit against contact with aggressive media. You will find them in the catalogue or they will be sent to you on request at the address: info@ifm-electronic.com.

observe the distance!

In this application special care has to be taken that the sensor is very close in front of the wall. In individual cases it may even be useful to glue it to the wall. The greater the distance between the sensor and the wall the more difficult it is for the sensor to differentiate between the wall and the medium behind it.

remote setting

The units with microprocessor of type KN, see 4.3, have a programming wire. This wire allows empty adjustment from a distance. This is of special interest in the following cases:

- sites which are difficult to access or
- soiling of the wall

With level control of water it is possible that after the vessel is emptied there are still water drops on the wall. With level control in a flour silo it is possible that flour, e.g. due to electrostatic charging, sticks to the wall, even if the silo is empty. If empty adjustment was made on the clean wall, malfunction is possible. Another empty adjustment will eliminate this error.
3.3.5 Switching times and switching frequency

ms

The time which elapses between the moving of the object to be detected into the sensing field and the switching of the output signal of the proximity switch is in general around the few millisecond mark. The switching frequencies are between 50 and 5Hz. The lower value applies to the binary level sensors with microprocessor of type KN. Higher frequencies and thus shorter switching times are not useful for its typical applications.

We will not discuss this aspect in further detail. You will find examples of the optimum use of inductive sensors in time-critical processes in the Training Manual Inductive Proximity Switches. These examples can be transferred to the capacitive sensors should this application ever occur.

The switching time must not be confused with the power-on delay time which is much greater (see 3.2.3).

3.3.6 Notes on the practical use

In this chapter some aspects will be added and other aspects detailed above will be summed up.

First of all it must be emphasised that the capacitive proximity switch is a simple and uncomplicated unit. This is confirmed by the enormous number of pieces used without requiring trained specialists. Most explanations and notes in this text are often not followed in practice. But even with an uncomplicated unit it is possible to make mistakes. Moreover there are applications where you encounter certain limits. This manual is to help find solutions, especially with more difficult cases in which the sensor does not react as expected.

material of the object

A capacitive proximity switch can detect all objects which are good electrical conductors whether or not they are grounded. They are also capable of detecting materials which are no or poor electrical conductors, for example plastics, glass, ceramics as well as liquids such as water or oil. The sensitivity setting by means of an accurate potentiometer or automatically by pressing a button enables the switch to be adapted to detect certain materials.

movement of the object

As for the inductive sensor, this operating principle is independent of whether the target is moving or not. The surface characteristics of the object to be detected are not critical, either.

shape of the object

As for the inductive sensor, there should be sufficient material close to the basic sensor to enable detection. However, it is unimportant whether the objects are compact, flat and even or e.g. slotted like a comb. Individual objects which are small compared to the sensing face, e.g. chips from a machining process, marks or burrs on the surface of the workpiece, do not affect the function until they are present in a large number. In the case of irregularly shaped objects measurement is also integrating and hardly suitable for determining the distance.
Capacitive proximity switches

Level sensors

cleanliness

Cleanness is an important condition for reliable operation of capacitive sensors. An even minor dust or water layer caused by condensation can (only to a certain extent, of course) be compensated for. However, if for example saw dust collects on the sensor, malfunction is possible. If there are failures in automated processes which are caused by malfunction of the capacitive sensors, cleaning processes have to be carried out. For example, it has frequently become a routine in woodworking to clean the capacitive sensors from sawdust from time to time.

influence on the object

Since only a very small voltage is applied to the electrodes and only few microwatts of energy are needed to operate the electronics, the sensor is not electrically charged and does not take any static charge and causes no RF interference in its surroundings (no electrosmog). It works practically without any interaction.

through the wall

The capability of the sensor to “look” through the wall is used in the frequent application of level control. This is not possible through metal walls. Plastic windows with mounting brackets as accessories are available. Automatic compensation for the wall is simple and reliable. The sensor should be mounted close to the wall.

how do I find the suitable sensor?

In the past some often painful search in the catalogue was necessary. Here the electronic catalogue is of advantage. An automatic selector selects suitable units according to defined criteria.

3.4 Mounting instructions

3.4.1 Flush/Non-flush

This is an important criterion for the practical use of the units. This feature depends on the design of the unit and is therefore not only indicated in the data sheet but also on the type label.

f / nf

The international designation f (for flush mountable) and nf (for non flush mountable) is used.

The operating principle of the capacitive proximity switch makes it more difficult to develop units for flush mounting which also have a good noise immunity than for the inductive unit. This feature could be implemented in the newer generation of type KN in cylindrical housing. These units can be identified by a metal thread (M 30 x 1.5) up to the sensing face. It ends 15mm before it with the flush-mountable unit.
A: Sensing face

Figure 18: f and nf

The IEC 60947-5-2 standard stipulates the values indicated in the figure as minimum distances to the side and to the back referring to the mounting of frequently used cylindrical housings.

1: Free zone

Figure 19: Free zone nf

If there is no way to avoid that the sensor is influenced by an object in its vicinity, this is called predamping. This term is explained in 3.3.1.

3.4.2 Mutual interference

If several proximity switches of the same type which are mounted close together are to be operated on one machine, certain minimum distances between the units should also be observed. Here again the minimum distances indicated in the following figure have to be observed.
3.4.3 Mechanical stability

In an environment with high vibration the proximity switch must be carefully fixed. Although many threaded types look like bolts, the tightening torque for the nuts is limited. Only the fixing elements supplied or recommended by the manufacturer should be used. This is especially so for units with a smooth sleeve which should on no account be fixed using a grub screw.

If the tightening torque for the nuts specified by the manufacturer seems insufficient, metal threaded units can be used. For small types with plastic thread rubber washers are recommended to improve fixing. Proximity switches should be mounted in places where they are protected against mechanical damage as much as possible. In case of need, they can be covered: for example glass or ceramic plates are suitable for protecting the sensing face against sharp-edged or hot chips. Here it will have to be verified if their influence can be compensated for.

The standard connection cable of proximity switches is only suitable for slight mechanical stress. If the operating conditions require a stronger cable, a conduit is necessary for strengthening. As an alternative a switch with terminal chamber can be used. The cable should be laid so that no forces can be transferred to the housing. If the cable has to be moved constantly, using a conduit is also recommended (see the following figure).

The type of mounting shown at the top is not recommended as there is the risk of mechanical destruction. The switch should on no account be used as a "limit stop".

A: Sensing face  
D: Diameter

Figure 20: Free zone with mutual interference
Figure 21: Direction of movement
3.5 Analogue level sensors

In this context analogue means the extended operating principle. As will be described below there are also units with binary outputs as level switches.

3.5.1 Technology and operating principle

The basic sensor consists of a number of rectangular segments made of metal foils which are mounted on a flexible film. It is bent to take the shape of a cylinder and mounted on a rod. Each segment is separately connected to the evaluation unit.

![Figure 22: Segments of a level sensor](image)

Thus it is possible to determine the capacitance of each individual segment. Each segment represents an electrode of a capacitor. In contrast to the units described above the machine earth is not part of the sensor. This function is e.g. assumed by the metal wall of the vessel into which the sensor is immersed.

When placed into plastic vessels an earthed metal strip assuming the function of the second electrode of the capacitors should, for example, be mounted on the wall of the vessel.

The zone in which the segments are evaluated is called active zone. Mounting by using a bracket should always be effected in the inactive zone between the upper segment and the housing of the evaluation unit. As will be explained below it is also possible to mount the bracket within the upper 2/3 of the active zone. This reduces the zone which can be evaluated to the zone below the bracket. In this case the medium must not rise up to the bracket.
The use of microprocessors enables considerably more complex evaluations than with a binary sensor. The procedure is based on a comparison of the capacitances of the individual segments. Each segment is individually evaluated by means of multiplexing so that a number of capacitances can be evaluated. Several steps can be distinguished:

1. The determination of the capacitance of the lowest segment leads to a value for the dielectric constant of the medium. It can be seen as reference at which the sensor sets itself to the medium.
2. The first segment whose capacitance is lower than the reference is looked for. This enables a rough evaluation of the level.
3. In this segment we have the case of a partly filled capacitor, see 2.2. The evaluation of the difference in capacitance as compared to the reference value is the fine evaluation of the level. The resolution is 1mm.

For the moment evaluation is now completed. Installation in the vessel and even the bracket or flange fixing the sensor are ignored here; they cannot disturb the measurement. They do cause a change in capacitance, in another place than the level, however.

This is the background for hints about practical use and the installation instructions which will be summarised in 4.5.5.

The data of measuring ranges, error limits, etc. can be found in the overview in 4.5.4. Here only values are given which are important in connection with the operating principle.

The switching time or switching frequency is of no practical significance here. It is important how the sensor reacts when the level changes. If during evaluation it is found that the measuring signal changes quickly, a dynamic measurement is changed to. According to 2 above only that segment is followed where the level is at that moment. If the change is slower or comes to a standstill, fine adjustment is again changed to.
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100 - 300 mm/s
The maximum speed of the change of the level which can be detected in that way is 100 – 300 mm/s depending on the type.

dielectric constant > 2
The relative dielectric constant \( \varepsilon \) of the medium (see 2.2) should be at least 2.

3.5.2 Practical use

In 3.5.1 the operating principle was described. This helps to better understand the following notes, also the installation instructions, see 3.5.3. If time is pressing these notes can be simply used like a “cook book”. Brief reasons with respect to the notes are added in italics. They may be skipped.

link
Notes which refer specifically to the current units can be found in 4.5.5. Below you will find some notes resulting from the general operating principle.

change of the medium
For each measurement cycle the sensor adjusts itself automatically to the medium. Thus it is insensitive to changes in the characteristics of the medium. With an abrupt change of the medium we recommend, however, to disconnect the sensor briefly (reset) so that it can reinitialise.

why?
For example, if the sensor had adjusted to water with \( \varepsilon \approx 81 \) and is then immersed in a medium with \( \varepsilon \approx 2 \), e.g. oil, it may possibly not detect it.

set-up with overfilling
If the vessel is filled up to above the active zone of the sensor during set-up, adjustment is not always effected successfully. In this case we recommend to separate the sensor from the mains, to partly empty the vessel (up to below the upper limit of the active zone!) and then to set up the sensor again.

Data (lengths) to locate the active zone depend on the housing length and can be found in the data sheets (see also 4.5.4). To be noted: if the bracket fixing the sensor is mounted in that area, the measuring range is reduced. Only the part below the bracket can be evaluated.

why?
In the event of overfilling the sensor may not be able to distinguish between the medium and air. This means it cannot distinguish empty from full. If the bracket was mounted in the active zone and the level reaches up to the bracket, it will probably be detected as being the medium.

underfilling
This case is usually not critical. The sensor does indicate an error, however. However, if the medium rises above the lower limit of the active zone, it is automatically adjusted and the error message is reset. If the sensor is removed from the vessel during operation and then put back again, a reset is recommended for safety reasons (brief disconnection from the mains).

why?
The lowest segment is always taken as reference. If there is no medium present there (only air) the sensor does not find any segment with a lower capacitance. It is not possible to indicate the level. In the event of extreme changes of the environment the adjustment may fail. This also applies to the following case.
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Level sensors

contact
If the active zone has been touched during operation, e.g. with the hand or a grounded screwdriver, it is recommended to carry out a reset for safety reasons (brief disconnection from the mains).

medium
The sensor is very stable against soiling. Nevertheless there are limits for this measurement technique. Unsuitable media are:
- very conductive or extremely adhesive media (shampoo, toothpaste, glue, etc.)
- dry granulated material with low density
- media which are very inhomogeneous (several cm of water among several cm of oil), a thin oil film does not affect the function of the sensor

3.5.3 Installation instructions

water > 40°C
When used in water and hydrous media with temperatures > 40°C it is recommended to install the sensor into a climatic tube, see Accessories.

fixing
Fix the mounting elements within the inactive zone (I; mounting area M1). The active zone (A) should be completely in the vessel, see Figure 24.
For an optimum function we recommend: A part of the active zone should be above the upper edge of the vessel / above the overflow.
You can also fasten mounting elements in the upper half of the active zone (possible mounting area, M2). This reduces the active zone to the area between mounting element and probe end. In this case the mounting element should be above the upper edge of the vessel / above the overflow.

M1: Mounting zone 1
M2: Mounting zone 2

Figure 24: LK mounting

Mounting using the clamp is best in the inactive zone M1. The bracket can also be mounted in M2. Then a reduction of the measuring range has to be accepted; not the entire active zone is used then.
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special mounting conditions

In small plastic vessels mount the unit in the middle of the vessel, if possible.
With dirty media we recommend: Fasten the unit in a zone where there is much movement of the medium (e.g. at the supply inlet).
When installed in metal rising pipes (bypass) the sensor must be mounted in the middle of the pipe. The inside diameter of the pipe must be min. 120mm.
Metal objects within the vessel (e.g. metal pipes, components integrated into the vessel) should observe a minimum distance of 60mm to the active zone of the sensor. Otherwise, they are detected as mounting elements (this reduces the active zone to the area between the metal object and the probe end).
When installed in metal vessels the following distances should be observed:
- sensor – vessel wall: 40mm
- sensor – vessel bottom: 10mm

mounting accessories

For reliable and easy mounting use ifm's mounting accessories, see ifm on the Internet.

To comply with the EMC guidelines of the EU which allow the use of the CE marking the sensor housing has to be electrically connected to the ground. This is done either
- mechanically by a fixture which is electrically connected to ground or
- by means of the earthing ring supplied.

The sensor uses the ground / the vessel potential as reference. This means that a measuring current has to flow from the sensor probe back to the sensor through the medium to be detected. If the sensor housing is not grounded, the measured current can flow back to ground via electrical cables in an undefined way. This may influence other measuring components.

The level sensor conforms to the standard EN 50081-2 and is a class A product. The unit may cause radio interference in domestic areas. Therefore the user may have to take appropriate measures, if necessary.
3.6 Type LI

LI

This type will only be discussed in brief because its further development is in progress. As is often the case, the unit was developed with regard to a special application. Therefore the applications are at present limited to the detection of oil in closed vessels and lubricants. The application in all other media has to be checked in the application department beforehand.

Short description

The unit can simply be called an intermediate thing between the binary proximity switch and the analogue level sensor. This becomes clear in the following Figure 25.

![Figure 25: LI](image)

The LI detects the level like the LK. The measuring signal is not further evaluated, transformed, passed on to a display but compared with an adjustable threshold. Thus the output signal is binary.
4 Capacitive proximity switches from ifm

Here we will first of all discuss the capacitive proximity switches and level sensors whose features do not differ much. Since the difference to the analogue level sensors is bigger they will be described separately in 4.5. For the meaning of the designations see 1.1.

4.1 Mechanical configuration

A distinction can be made between main groups consisting of various individual components.

- Housing
- Basic sensor
- Circuit
- Connection

But they cannot be seen as independent of each other. Below they will not be discussed as separate elements but as related to each other.

The figure shows the schematic configuration of a capacitive proximity switch. Components used to be soldered onto a standard, rigid PCB. Today’s circuit is a flexible film with SMD components. For most types the basic sensor consists of cup-shaped electrodes (see 3.2.1) With type KNQ and the analogue level sensor they are located on a conductive layer on the film.

Figure 26: Configuration of a capacitive sensor

Another difference between the earlier and the new generation of the capacitive proximity switches is to be considered. In figure 26 a sensor with potentiometer is shown i.e. a unit of the earlier generation. Today a button is used for setting (cf. Figure 27 and Figure 31). The internal configuration is similar but there is no longer any potentiometer.
Capacitive proximity switches

Level sensors

trend integration

In order to reduce the number of components and perform additional functions, special integrated circuits are more and more often used. These ICs are made by semiconductor manufacturers according to ifm’s specifications. In particular they allow automatic setting of the optimum switch point, see 4.4, by means of a button instead of complex integration of a potentiometer. This minimises the risk of operating errors on the part of the user as well as damage to the unit. Price increases can be prevented.

potting

After the electronics has been incorporated into the housing, the remaining empty space is usually filled with a potting compound. The advantage of this is a better mechanical strength of the housing to protect the electronics against vibration and to prevent dust and moisture from entering. Thus the units conform to the requirements of the users for a robust switch which can be universally employed.

In the future a large number of unpotted units will probably be used. The subject of potting is discussed in more detail in the Training Manual Inductive Proximity Switches. Refraining from using potting compound has the following advantages: easier disposal of old units, better heat dissipation for the live components and further improvement of the ingress resistance by using materials better adapted to the process.

setting

For capacitive sensors the sensitivity can be set, see 3.3.1. With some types this is still effected using a potentiometer (see Figure 28).

potentiometer

For these types special care has to be taken to seal the potentiometer or the adjusting screw because an opening in the housing is required. There once was the approach not to set the sensitivity electrically by means of a potentiometer but mechanically by shifting an electrode. This approach has in the meantime been abandoned.

KN

These newer types do not have a potentiometer any longer. Here the sensor automatically adjusts to the optimum switch point. For example, for detecting a medium through a wall it is not this wall but the medium which is to be reliably detected. Adjustment of type KNM is effected using a membrane key, see Figure 27, and of type KNQ via an inductive sensor, see ifm on the Internet. With this unit the active face of the inductive sensor has to be touched e.g. by a screwdriver to effect adjustment.

Figure 27: Type KN

The internal configuration is similar to figure 26. A considerable difference is that the programming button whose position is marked by an arrow in figure 27, replaces the potentiometer. Figure 31 shows the setting process.

connection

As for the connection technology there are no major changes. Over the years there are only changes as to the preferred connection systems.

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Level sensors

connector units
There is a trend towards connector units because for the maintenance of automated installations, e.g. replacement of a failed unit, time is a major cost factor. The possible fault sources of a leaky connection are accepted. However, it can only become leaky, for example, by too loose or too tight a fastening (risk of mechanical damage) of the nut. Here the universal connector with M12 thread is the preferred choice.

food industry
To meet the special requirements of this application, units optimised for this industry can be supplied. For example, they feature gold-plated contact pins. The connector housing should be made of PVC because this material features the best resistance to water and cleaning agents.

tightening torque
In general it is not necessary to use a key with an adjustable maximum tightening torque for mounting. It should be evident that more care must be taken with plastic threads than with metal threads. For units with terminal chamber the screws must be tightened sufficiently to ensure the protection rating (see Training Manual Protection Ratings).

housing materials
In industrial processes capacitive proximity switches are subjected to environmental influence such as heat, cold, dust, vibration, moisture, aggressive liquids, vapours, etc. Therefore they have to be accommodated in housings which are resistant to such conditions.

As a rule, the material used for the housing is a glass-fibre reinforced plastic of good chemical resistance and insulating quality. Threaded units are often fitted with a metal sleeve which further improves the housing strength with regard to installation.

PBTP
The plastic ifm normally uses for the housing is cadmium-free polybutyleneterephthalate (PBTP) which is for example produced by Bayer under the trade name of Pocan. Information about experience with the chemical resistance to different media will be provided on request.

metal
ifm used to use nickel-plated brass for standard cylindrical units, today Optalloy is used for coating. This is an alloy of copper, tin and zinc which is also known as white bronze. With the flush-mount type (see 3.4.1) the metal sleeve goes up to the active face.
4.2 Designs

ifm’s standard product range covers rectangular and cylindrical designs commonly used in industry. They are also described in IEC60947-5-2.

rectangular

This design is mainly used for:
- units with a long sensing range
The long sensing range, at 50 or 60mm, is achieved by using big electrodes. They are mounted on the flat side, e.g. at 120 x 80mm² (see table below).

KNQ

This housing is a special case of the rectangular designs. Strictly speaking it is trapezoidal. The mounting holes for fixing are on the sloped sides. Alternatively it can also be fixed by a fixing strap, e.g. on a pipe. The electrode is mounted directly onto the film as a surface. This unit is specially designed for the detection of levels, i.e. it is a level sensor. It meets the user’s requirement for a particularly compact unit. Due to the low height the connector unit features an M8 connector.

The housing is made of plastic (Pocan).

cylindrical and smooth

The very first generation of effectors was of this design. It is still used today. They can be easily mounted and correctly positioned using a bracket. The bracket is usually supplied with the unit. When using the bracket care should be taken that the suitable original bracket is used to avoid mechanical damage (squeezing). The housing is usually made of plastic (Pocan).

It is in particular the KNM flush-mount unit which is of this design. The housing is made of metal.

cylindrical with thread

This design is also often used. The units can be fixed on an angle bracket (available as accessory) or by a mounting hole by means of a screw and a locknut.

The type key in the annex helps to get an overview of the designs.

connection

There are 3 variants:

<table>
<thead>
<tr>
<th>Design</th>
<th>Dimensions in mm</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>rectangular</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>120 x 80 x 30</td>
<td>plastic</td>
</tr>
<tr>
<td></td>
<td>105 x 80 x 40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>60 x 36 x 10</td>
<td></td>
</tr>
<tr>
<td>cylindrical</td>
<td>smooth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20 x 85</td>
<td>plastic</td>
</tr>
<tr>
<td></td>
<td>34 x 81</td>
<td></td>
</tr>
<tr>
<td></td>
<td>threaded</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M18 x 1</td>
<td>plastic</td>
</tr>
<tr>
<td></td>
<td>M30 x 1.5</td>
<td>or metal</td>
</tr>
<tr>
<td></td>
<td>M34 x 1.5</td>
<td></td>
</tr>
</tbody>
</table>

For the cylindrical housings the diameter and length or thread dimensions are indicated. The length refers to the housing, i.e. up to where the cable or the threaded block starts.

I want to know more!

More details, scale drawings, information about permitted tolerances of the dimensions, etc. are given in the catalogue or at www.ifm-electronic.com.

Training manual
Here the cable is firmly connected to the unit. Fault source: This reliably excludes a leaky connector due to incorrect mounting.

These units having the advantage of easy replaceability are used more and more often. Even during first mounting a fault by reversing the wires is excluded. Due to the increasing importance a brochure giving an overview of the connectors is now available. Moreover standard sockets or sockets with special features, which are for example especially suited for use in the food industry, are recommended for proximity switches with connector in the catalogues and brochures or on the Internet (see above).

Another variant are special units with terminal chamber where the user can mount the cable of his choice. Ingress resistance of the terminal chamber is achieved by a cable gland through which the cable enters. Here there are cylindrical designs with M8 for which the cable is either laid in direction of the longitudinal axis or, where space is at a premium, it can be laid at an angle by rotating the patented shroud by 90°.

A capacitive sensor used as a wear-free switch on traffic lights with pedestrian buttons to be pressed on request is another example of a design for a specific application.

### 4.3 Electrical data

There are a number of electrical characteristics which are the same for all electronic, binary position sensors, e.g. inductive and capacitive proximity switches, photoelectric sensors, etc. They are therefore separately presented in detail, see Training Manual Connection Technology. Only important points and particularities will be briefly pointed out in the following without explaining again in detail the technical terms used.

The data of the analogue level sensor are specific and will be discussed here in 4.5.

#### 4.3.1 Important parameters

The following parameters are of importance for practical use:

**Connection technology**

Binary sensors are offered in the so-called 2-wire and 3-wire technologies. For 3-wire switches the operating voltage is applied between +U\textsubscript{h} and 0V, the load is switched via a separate signal wire. For 2-wire switches the operating voltage is the voltage which is commonly available to the proximity switch and the load in series. The following points have to be taken into account for practical use:

- **Voltage drop and leakage current for 2-wire units**

  For older units the leakage current of a few mA could lead to uncertain switching statuses, e.g. when connected to electronic controllers. For more recent units, especially the quadronorm units, the leakage current could be reduced to typically 0.4 to 0.6mA. Due to the considerably easier wiring the current 2-wire units are a cost-effective alternative to the 3-wire units (if a system such as AS-Interface is not used anyway).

- **Connection in series and in parallel**

  For the current state of technology electronic position sensors are directly connected to plc inputs and then logically linked via the program. So this point is hardly important any more nowadays. But if this cannot be circumvented, some special points have to be taken into account, see Training Manual Connection Technology. They concern again the leakage
current and voltage drop for 2-wire units and for 3-wire units possible effects on the power-on delay time, e.g. for series connection.

voltage supply

It is the voltage range at which the units operate reliably and not the nominal voltage that is important for practical use. They are specified in the data sheets and on the type label. The standards the CE marking is based on define the degree of the conducted interference the unit has to withstand, see Training Manual CE Marking.

residual ripple

For DC voltage it has to be noted that the residual ripple does not exceed the limit values. It is not sufficient to check the root-mean-square value. If economies were made on the power supply so that no sufficiently smoothed voltage is provided, reliable function is no longer ensured.

If the residual ripple falls below the limit value of the operating voltage of the proximity switch, a smoothing capacitor will help. A rule of thumb: 1000µF per 1A current intensity.

protective circuitry

Depending on the design and type the units are fitted with different protective components. They protect against
- overload
- short-circuit
- reverse polarity

4.3.2 Overview

The following overview shows the “family” of the capacitive proximity switches in the shape of a “tree”. DC and AC are terms that should be known. UC stands for universal current or dual voltage. Such units can be connected to DC or AC within the specified range.

The figure is still in preparation.

The * refers to units with short-circuit protection.

It can be seen that the current rating for solid-state outputs is between approx. 100 and 400mA depending on the design.

In the meantime the nominal voltage of 24VDC has largely gained acceptance as control voltage. Other voltages are used in special applications or countries. Below an example of wiring diagrams for DC units is shown.

Figure 28: Wiring diagram 1
Type KNQ features a function check output which leads a signal with uncertain switching status. This is also indicated optically by the red LED, see 4.4.

quadronorm units (see 4.7.2) are particular units. They operate in both polarities.

### 4.4 Setting of the switch point (binary)

This chapter again refers to the binary capacitive proximity switches and level sensors.

A capacitive sensor which is only to detect objects and is not otherwise affected by objects or media (soiling, moisture) in its environment does not necessarily have to be set. However, setting is usually necessary in the frequent application of detection of a medium through a (non-metal!) wall, see 3.3.4.

In the earlier generation setting was made by means of the potentiometer:
- the sensitivity was changed until the sensor just responded to the wall
- the sensitivity was reduced until the wall, even with sticking medium, was no longer detected
- it had to be checked if the sensor then responded reliably to the medium

Whether setting was optimal or unreliable could not be found already because of the non-linearity of the signal, see Figure 16.
For binary level sensors setting is considerably more reliable and comfortable. Setting of KNQ can be simulated on the Internet. It is recommended to try it there. Empty adjustment of KN is described in Figure 31.

Figure 30: Empty adjustment

In most cases empty adjustment is sufficient. It can also be made via a controller, via a programming wire, see 4.3.2. In critical cases an additional full adjustment is possible which is also made via the button, see Operating Instructions.

Figure 31: Empty adjustment of KN

The red LED serves a similar function as the mounting aid for inductive sensors (see Training Manual Inductive Proximity Switches). The red LED indicates no malfunction of the unit, it indicates that the internal sensor signal is close to the switching threshold. 2 cases can be distinguished:

- Normal operation / reliable operation
  The red LED is lit temporarily during the change between "medium" and "no medium".
- Warning of possible malfunction
If the red LED is lit continuously, the operating conditions are no longer optimal. For example a change of the sensing range caused by deposits of dirt can be detected. You can take preventive measures to avoid malfunction. For example readjust or clean the unit.

**AS-i**

For photoelectric sensors some types have another switching output to indicate an unsafe switching condition. This is also called failure warning and can, for example, be used to remove soiling before problems occur. This option is also conceivable for capacitive proximity switches but has not yet been implemented. The extra work involved when two outputs per sensor must be connected to the controller is, for example, a reason not to do so. Therefore the uncertain switching status of these sensors is only indicated via the LED as mounting aid. However, this is different with the so-called intelligent sensors. They are direct participants of the AS-i system (see catalogue) and have up to 4 data bits. In addition to the uncertain switching status it is, for example, also possible to monitor readiness for operation. With the capacitive AS-i sensor remote setting of the sensitivity via parameters is in addition possible.

### 4.5 Analogue level sensors

#### 4.5.1 Design and mechanical characteristics

In principle there is only one design in at present three mechanical variants. They differ in the length of the probe.

![Figure 32: Design LK](image)

The unit consists of two components:
- evaluation unit with display and electrical connection
- probe as carrier of the capacitor elements (see 3.5.1)

The three probes of different lengths are distinguished by the number of capacitor elements. Owing to the measuring principle, see 3.5.1, the length cannot be significantly increased. With longer probes there would be more segments and thus more and more printed lines to the
Capacitive proximity switches

Level sensors

evaluation unit for which there would not be any more space on the probe.

Other differences can be found in the output circuit, see 4.5.4.

mechanics

Notes on mounting can be found in 3.5.3. Here a brief summary:
vertical mounting, evaluation unit on top
mounting clamp optimal in upper inactive zone, also possible in active zone, definitely not in the lower third

pressure rating

Maximum vessel pressure when mounted with ifm’s mounting accessories: 0.5 bar. For a short time (max. 1 minute) an overpressure of 3 bars is possible.

material

Housing material
- EPDM/X (Santoprene)
- FPM (Viton)
- Optalloy-plated brass
- NBR (Buna N)
- PA
- PBTP (Pocan)
- PC (Makrolon)
- PP (polypropylene)

Material (wetted parts)
- PP (polypropylene)

The use of other materials such as PTFE or glass (wetted parts), is possible, it does, however, require testing.

vibration resistance

Continuous vibrations of high amplitude affect the connection between probe and evaluation unit, especially when the probe is long. To ensure better withstandability to such extreme conditions the construction of this connection has been changed. The vibration and shock resistance to standard are indicated in the data sheet or the installation instructions.

4.5.2 Display

HMI

The unit features:
a three-digit LED display as well as additional LEDs to indicate the switching status and
two programming buttons.

transfer

Anybody who has already programmed other fluid sensors from ifm, e.g. pressure or temperature, see Training Manual Pressure Sensors or Training Manual Temperature Sensors, will notice that these units are always programmed according to the same pattern. There are, of course, differences as far as the measured quantity, the unit, the value range, etc, are concerned. Nevertheless it can almost be said: whoever knows one, knows all of them. Therefore programming does not have to be discussed here in detail.

where do I find more?

The detailed instructions are on the Internet in pdf-format (reminder: you will find our homepage at www.ifm-electronic.com), when you click the order number of the respective unit. First of all the data sheet will open.
By clicking “Additional Data” you will eventually find the operating instructions. The figures below are taken from these instructions.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LED display</strong></td>
<td><strong>display of the level, display of parameters and parameter values</strong></td>
</tr>
<tr>
<td><strong>LED red</strong></td>
<td>switching status; lights if the output has switched</td>
</tr>
<tr>
<td><strong>Mode / Enter button</strong></td>
<td>selection of the parameters and acknowledgement of the parameter values</td>
</tr>
<tr>
<td><strong>Set button</strong></td>
<td>setting of the parameter values (scrolling by holding pressed; incremental by pressing briefly)</td>
</tr>
</tbody>
</table>

**Figure 33: Display of the LK**

The numeric display shows:
- the initialisation phase during power-on delay time at power on
- the level during normal operation
- error messages in the event of failures
- parameters during programming

Here we will describe first of all examples of displays without activation of the buttons.

**Outputs**

There are currently two types (either one available in the three lengths of the probe) which differ in the circuitry of the outputs, see 4.5.4.

- four binary outputs 4 DO
- one binary and one analogue output 1 DO 1 AO

These abbreviations (DO for digital output and AO for analogue output) will be used below.

The display allows the different number of LEDs for indication of the switching status to be seen.

**Figure 33** shows a unit with 1 DO 1 AO.
4.5.3 Programming

The units with different output circuitry can, of course, also be easily distinguished by the programmable parameters.

You can try programming by yourself (in a simulation) on ifm’s website by clicking virtual product operation.

structure

The menu and programming structures are shown in the tables below.

Figure 34: Menu of LK
Press the Mode/Enter button several times until the respective parameter is displayed.

Press the Set button and keep it pressed. The current parameter value flashes for 5s.

Press the Mode/Enter button briefly (= acknowledgement). The parameter is displayed again, the set parameter value becomes effective.

Change more parameters: Start again with step 1.

Finish programming: Wait for 15s or press the Mode/Enter button until the current measured value is indicated again.

*Decrease the value: Let the display of the parameter value move to the maximum setting value. Then the cycle starts again at the minimum setting value.

Figure 35: Programming of LK

Most points are self-explanatory. The differences are, first of all, that with the unit with 1 DO only this one output can be parameterised and secondly the AO can be switched to current or voltage output. The following two parameters out of the common ones that are specific to the analogue level sensor are to be pointed out:

**OFS**

If the distance between the bottom of the vessel and the lower face of the probe is known, this value can be entered as offset. This value is added to the measured level. The display will then indicate the actual level.

**bin**

The unit with 4 DO can be operated as quasi analogue in binary mode. The level is then output in 4 bits, i.e. resolved in 16 steps.

The other parameters correspond largely to those of pressure and temperature, see Training Manual Pressure Sensors and Training Manual Temperature Sensors. There the terms “hysteresis” and “window” are described in more detail. Here they will be presented in brief.

**process**

The programming process is shown in Figure 35.

The Mode/Enter button is used to select the desired menu item. If you only want to check the parameter, it is sufficient to touch the set button briefly. Figure 34 and Figure 35 show how it is changed.

**internet**

An example for setting the switch point of the electronic (analogue) level sensor can be found on the Internet under “virtual product operation”.

Training manual
4.5.4 Electrical data and other features

The electrical data of the outputs are the usual ones. Only the essential values which can, of course, be found in the data sheet, will be listed here.

**DO (digital output)**

- **operating voltage [V]**
  - 18 ... 30 DC

- **current rating [mA]**
  - 200 for 1 DO 1 AO
  - 400 for 4 DO short-circuit protection, pulsed; reverse polarity and overload protection

- **voltage drop [V]**
  - < 2.5

- **current consumption [mA]**
  - < 80

- **analogue output**
  - 4 ... 20 mA (max. 500)
  - 0 ... 10 V (min. 2000)

The terms used are described in the Training Manual Connection Technology.

Below you will find some examples of connection diagrams, first of all the pin connection.

![Figure 36: Pin connection LK](image)

Core colours of ifm sockets:
- 1 = BN (brown),
- 2 = WH (white),
- 3 = BU (blue),
- 4 = BK (black).

![Figure 37: Wiring diagram LK3](image)
Core colours of ifm sockets:
1 = BN (brown), 2 = WH (white), 3 = BU (blue), 4 = BK (black).
Programmation of complementary outputs:
output 1: = Hno, output 2: = Hnc,
SP1 = SP2 / rP1 = rP2.

Figure 38: Wiring diagram LK7

LK8

The LK8 has four switching outputs. They can either be used as outputs in the same way as with the other types or as a kind of output of an AD converter with a 4-bit resolution. For further information we refer you to ifm on the Internet.

Figure 39: Pin connection LK8

Core colours of ifm sockets:
1 = BN (brown),
2 = WH (white),
3 = BU (blue),
4 = BK (black),
5 = GY (grey),
6 = PK (pink),
7 = VT (lilac),
n.c. = not connected

Figure 40: Connection diagram LK8
Strictly speaking, the following values are not exactly electrical data. However, since they influence the behaviour of the outputs they are mentioned here. (VMR stands for final value of measuring range)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch point accuracy [± % of VMR]</td>
<td>± 5</td>
</tr>
<tr>
<td>Repeatability [± % of VMR]</td>
<td>± 2</td>
</tr>
<tr>
<td>Max. speed of the level change [mm/s]</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>for LKX022</td>
</tr>
<tr>
<td>200</td>
<td>for LKX023</td>
</tr>
<tr>
<td>300</td>
<td>for LKX024</td>
</tr>
</tbody>
</table>

The X represents the various types, see 4.5.1

### 4.5.5 Notes on practical use

In 3.5.2 general notes were given which are directly related to the function principle. In this chapter you will find notes which refer to the current units and are specific to them.

Since Hanover Fair 1999 ifm electronic has marketed the level sensors of type LK. The unit was designed for applications in machine tools, mainly in the field of coolants and lubricants processing as well as monitoring of hydraulic oils. The sensor material was selected in accordance with this specification, a plastic which features high resistance to aggressive fluids. In applications with other fluids this high resistance cannot be guaranteed over a longer period of time. These are for example washing benches for degreasing machine-worked workpieces, aggressive media such as acids and alkalis as well as various other liquids.

In addition improvements have been made on the basis of experience made in special applications. These were, for example, failures due to vibration caused by significant movement of the fluid and uncertain level detection with metal build-up. We have looked at both problems from the development point of view and have made the respective optimisations.

Reliable use of all LK level sensors is ensured for monitoring coolants, e.g. in machine tools and for monitoring oils.

### what is the technical background?

In the Training Manual Inductive Proximity Switches one aspect is pointed out in connection with the new efector whose ingress resistance could also be further improved: there is no waterproof plastic! Plastics such as polypropylene (PP) used for the sensor probe have the characteristic to be permeable to water molecules. This process is called permeation. The higher the temperature, the faster the fluid penetrates into the sensor probe. In the probe the penetrated water molecules condense to water. This water causes the film to corrode. As a result the sensor will fail. As compared to water, oils consist of long molecular chains from the chemical point of view. Even at high temperatures these long molecular chains cannot permeate the plastic of the sensor probe. Therefore monitoring oils using the LK at temperatures of up to 80°C is possible without any restrictions.
The use in water and water with cleaning agents at temperatures exceeding 30°C causes the sensor to fail. Resulting from these findings the LK is considered to be reliable in the following applications:

**Coolants (oil / water emulsion) in a temperature window of 0...30°C**

**Oils in a temperature window of 0 ... 80°C**

All other applications require an assessment by our application team in Tettnang. Please contact the responsible branch office or ask for information here (via Internet, www.ifm-electronic.com).

**what are the next steps to cover other applications?**

Many of our sensors are used in plants for cleaning processed metal parts. The fluid to be monitored is water with cleaning agents. The temperature in these applications can be up to 70°C. To be able to offer you stable level monitoring over a long term we have designed a thermowell into which the LK can be inserted. There is a defined air gap between the sensor and the wall of the thermowell. Water penetrating through the thermowell due to the permeation described above escapes again without affecting the sensor. Matching thermowells and fixings are planned for all three lengths of the sensors. You should look for information about the exact operating principle, the relevant applications, article numbers, delivery dates and prices, see above. With the introduction of the thermowell the LK can also be used for applications with water and hydrous media in a temperature range of 0...70°C.

### 4.6 Approvals

An obvious application of the level sensors is overspill protection. However, this requires a special approval. The designation of such a unit is: limit switch with approval to the German overspill standard WHG section 19 (LI2). This approval is issued by the Deutsches Institut für Bautechnik (German Institute for Building and Civil Engineering Technology).

For the latest information about the approval procedure, whether it has been initiated, is in process or has been completed, we refer you to www.ifm-electronic.com.

This concludes the description of the types LI and LK.
4.7 4.4 Switches with special characteristics

In the following we will discuss binary capacitive proximity switches.

4.7.1 Use in hazardous areas

reference Since this subject is also common to many binary position sensors and in addition important for fluid sensors (such as CE marking, see Training Manual) it will likewise be discussed separately, see Training Manual ATEX. This manual details the terms, designations, in particular marking of the units, standards, etc.

important! The sensor manufacturer can have units tested and approved by notified bodies. However, he cannot make any statement about which unit may be used in a specific application. Each user is responsible for knowing the standards and regulations and for applying them correctly.

The use in hazardous areas, not only in the chemical industry but also e.g. in paint-spraying booths, mills or tank farms is the oldest of all applications for proximity switches. As only very low voltages can be applied in these areas there are often problems with mechanical switches. However, no sparks, light arcs or impermissibly high temperatures occur in proximity switches during normal operation so that many types can be used directly in certain Ex zones.

This briefly describes the requirements for the unit. On no account should a spark occur which can trigger an explosion, e.g. with mechanical destruction of a unit, by a short circuit through a component storing electrical energy, i.e. the coil or the capacitor. Such requirements are met by separating two units, for example. The sensor as such or the sensor element can be used in the hazardous area. The switching output is in a separate switching amplifier which is to be mounted outside this area.

KX Since capacitive proximity switches are also often used to check the level of bulk material, e.g. in flour silos, the risk of a dust explosion is an important subject. Flour dust, mixed in the right proportion with air, is a very explosive mix of high energy. ifm offers a sensor for this application, type KX. Below you will find an extract from the technical documentation for users who are used to deal with this subject. If you are not familiar with it, we refer you to the Training Manual ATEX where the terms are explained in more detail.

Use in hazardous areas according to the classification

| II 1D/G | (Group II, category 1D, apparatus for dust atmosphere) |
| II 1G | (Group II, category 1G, apparatus for gas atmosphere) |

The requirements of the standards EN50014, EN 50020, EN50281-1-1, EN50284, EN 60947-5-6 are complied with.

• EC type test certificate

| DMT 01 ATEX E020 |

• Marking

| II 1G EEx ia IIB T6 CE 0158 |
| II 1D IP65 T90°C |
4.7.2 Quadronorm units

leakage current

For the 2-wire units of the earlier generations the leakage current could be some mA. Thus reliable signal processing, e.g. by plc inputs, is no longer guaranteed.

polarity

For solid-state DC outputs polarity should be observed. In many countries and industries pnp switching sensors are commonly used. With imported controlgear from or export of a complete installation to countries where the other polarity is common, the different polarities are a potential fault source, in particular if a failed sensor must be replaced. For example, in Japan npn units are still frequently found.

normally open / normally closed

It frequently happens that two units which only differ in their switching functions and which are otherwise completely identical, are needed. This doubles storage of spare parts. Moreover, replacement of a failed unit is a possible source of failure. Especially for units with terminal chamber the switching function can be determined by selecting the terminals. But this is not possible with standard units.

The goal of the development of the quadronorm units was to improve the above-mentioned points. They have the following characteristics:

- leakage current usually 0.4 - 0.6mA
- automatic recognition and setting of polarity
- switching function is inverted by reversing the wires.

core colours

For the colour marking of the wires a new approach had to be pursued as the usual colours, e.g. BN for L+, could not be used (cf. Training Manual Inductive Proximity Switches).
4.7.3 Special designs

A special design is used as non-contact switch for pedestrian traffic lights. Mechanical switches encounter the usual problems such as corrosion of the contacts. In particular penetration of water due to damage to the seal or degrading of the seal due to exposure to sunlight require frequent and expensive maintenance. In this application special demands are, of course, also placed on capacitive proximity switches. Influences due to the environment, especially by water, have to be compensated for in a special way so that the traffic lights do not switch during each rainfall. Therefore it is better to touch the sensor with the palm of your hand, the fingertip may not be detected. Due to their reliability these switches are used in considerable quantities.
Criteria for practical use

**Overview**
Most of the following aspects have been discussed above in detail. To give you a better overview they are summarised and supplemented below.

As sensors in production processes are normally used at rather exposed points of the machine, they should directly withstand severe environmental conditions such as heat, cold, impact, vibration, dust, moisture, chemically aggressive liquids, etc. They should therefore be protected against malfunction due to such arduous conditions. The data sheets provide information about possible applications and operational conditions under which the units can be used without any problem.

**Operating temperature**
This indicates the temperature of the medium surrounding the proximity switch. The specified permissible temperature range is often between –25°C and +80°C. Within this range the switch can be operated as long as desired. Temperatures which are slightly above or below these limits for a short time are usually also tolerated by the switches. This means that the switch is not destroyed. However, the sensing range can differ from $S_a$ within this time. Special units are available for other temperature ranges.

**Shock and vibration resistance**
Proximity switches do not contain any moving parts. So they are extremely insensitive to shock and vibrational stress. The guide value for the maximum permissible shock is 30 times the gravitational acceleration (30g) and for the maximum vibrational stress a frequency of up to 55Hz at a 1mm amplitude.

**Foreign bodies and dust**
Capacitive proximity switches can be impaired by dust deposits of electrically non-conductive materials. Due to the measuring principle this cannot be avoided. The compensation electrode (see 3.2.1) of the binary sensor especially ensures compensation of these environmental influences. As described in 4.4 for automatic setting, this problem can be solved much more easily for the units of the newer generation, the binary level sensors. If another adjustment to compensate for the environment should not lead to the desired effect, cleaning of the sensor is the only measure to be taken that remains.

Due to the evaluation algorithm, see 3.5.1, the analogue level sensor is largely insensitive to wrong signals caused by deposits on the probe.

To identify ingress resistance (protection rating, see Training Manual Protection Ratings) of electrical apparatus an international standard combination of numbers is used by the proximity switch manufacturers to indicate ingress resistance of their units, e.g. IP67. IP stands for “international protection”. The first figure indicates the degree of protection against contact with and ingress of foreign bodies. Figure 6 means protection against the ingress of very fine dust and complete protection against contact. The second figure indicates up to what degree a proximity switch can be operated in a moist, wet environment.

**Moisture and water**
Proximity switches working on the capacitive principle can be affected in their function by water, moisture, mist or vapour. Preventive measures are described above under “Foreign bodies and dust”.
To be on the safe side, it is however important to know how well a proximity switch is protected against ingress of moisture. This is indicated by the second figure of the IP identification. 7, for example, means that a proximity switch is protected against the ingress of water to such a degree, that it can remain in 1m water depth for 30 minutes without water penetrating in harmful quantities.

As a rule, proximity switches are supplied with a rating of IP65 or IP67. Units with potted cable normally feature IP67. Units with terminal chamber or connector are specified with IP65. The latter can also be often used under conditions where IP67 is required. The protection rating is indicated because protection can be reduced by incorrect mounting, e.g. wrong placing of the gasket.

**chemical influences**

If the environment in which a proximity switch is used contains chemical substances in solid, liquid or gaseous form, great care should be taken to ensure that the housing and cable are sufficiently resistant. The nowadays common plastic housings of reinforced glass-fibre material or the units with metal sheath can, for the most part, also be used when exposed to chemicals. Special housings of corrosion-resistant stainless steel or PTFE are available for critical applications.

**electromagnetic interference**

In an industrial environment electromagnetic interference is very varied and can occur at high energy levels due to radio transmitters, switching processes in power lines, switching of inductive loads or lightning. Such electromagnetic interference can affect the sensor field of the proximity switch. Due to the small size of the sensor in relation to the wavelength of radio waves such periodic interference only carries a slight risk of influence. Transient interference of short duration can be filtered out by means of the circuit design so that noise immunity of the proximity switches is high.

Interference can also be picked up by the cable. If the cable is laid unfavourably, the cable to the proximity switch can act as a receiving antenna for radio waves or pick up transient interference from cables laid parallel to it. In particular the further development of frequency converters leads to increased requirements. In special cases the use of interference-suppression filters can help.

Limit values for resistance to this interference are defined in the EMC directive (see Training Manual CE Marking). The units must pass a number of tests to be allowed to carry the mandatory CE marking. Here resistance to defined interference is tested.

As mentioned above, see 3.2.2, capacitive sensors of the earlier generation react in a more sensitive way to such influences than e.g. inductive sensors. Recently developed measuring processes allowed this sensitivity to be considerably reduced. On the Internet in Overview or in the Selector they are characterised by “increased immunity”.

**other influences**

In contrast to other sensor types the function of capacitive proximity switches cannot be impaired by sound and light. The only influence to which proximity switches are not immune are intensive X-rays or radio activity.
5 Application examples

5.1 Overview

A major application for proximity switches is their use as position switches as an alternative to mechanical position switches. Mechanical switches are cheaper but they are subject to wear. If they fail, a whole production line, conveyor system, etc. can be brought to a standstill for hours. So for this reason it is worthwhile to use non-contact and wear-free electronic proximity switches in place of mechanical switches for all these applications.

For monitoring and counting tasks the product is detected directly. Using non-contact proximity switches it is possible to sense goods which are difficult to detect such as glass, food, paper, etc.

Capacitive proximity switches can be used in level measurement technology or in level monitoring in process technology and in the packaging industry. Levels in tanks and silos can be monitored but also jams in pipelines (e.g. in mills). Furthermore, capacitive proximity switches, if mounted and adjusted accordingly, can check the correct quantity through opaque packaging materials, e.g. detergents in cardboard boxes.

The use in hazardous areas in the chemical industry, mills or tank farms is the oldest of all applications for proximity switches. As only very low voltages can be used in these areas, proximity switches with additional safety are available for such applications. Proximity switches of type KX are approved for use in zone 10.

This can only be a short overview of the universal suitability of capacitive proximity switches. The user frequently comes across many tasks in areas which are not obvious at the moment of designing his plant. Thus one or other problem of one or other application can be resolved sooner or later by the knowledge alone of the function and characteristics of capacitive proximity switches.
5.2 Examples

Figure 41: Level monitoring 1

Two capacitive proximity switches which indicate the level in a silo. The minimum and maximum levels are monitored.

Figure 42: Sheets of glass

A capacitive proximity switch detects sheets of glass on a roller conveyor.
The two capacitive proximity switches detect the level of liquid in the vessel through the PVC wall. The signals are directly used to control a valve.

Capacitive effectors detect and monitor the minimum feed to rollers in a mill. The effectors are adjusted to react only to the product, not to the container wall.
Figure 45: Level using KX

When a sensor is used in a silo as shown in figure 45 it is within a hazardous area (see 4.7.1). Type KX has to be used if the conditions require it (see Training Manual ATEX).
Annex

Advantages

In general it can be assumed that effectors operate within the specified data on the safe side. Standards are complied with and even exceeded. IP 67 means that the unit operates correctly 1m under water for 30 min (see Training Manual Protection Ratings). There are applications where effectors are continuously immersed in deeper water and operate without any problems. In this case a capacitive sensor will, of course, change its switching status when it is no longer in the water. Values above or below the specified temperature range of e.g. –25°C to +80°C are possible within certain limits (cf. sensing range for inductive sensors). Only compliance with the values specified in the data sheets can, of course, be assured.

advantages

Other advantages of the ifm units are:

- Product availability
- Reliability (5-year warranty for standard units)
- Noise immunity
- Service (large sales force)
- Meeting special requests (special units)
- Use of SM technology
- Simplified operation (new generation)
## Capacitive proximity switches

### Level sensors

#### Type key and production code

<table>
<thead>
<tr>
<th>Pos.</th>
<th>Designation</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sensing principle</td>
<td>L = level sensor</td>
</tr>
<tr>
<td>2</td>
<td>Type</td>
<td>K = capacitive multiplexed probe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L = binary capacitive probe in 18 mm plastic tube (L shape)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A = analogue transmitter (multiplexed probe)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E = numerical display / EPDM seal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P = analogue pressure sensor (P) in level housing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R = analogue radar probe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T = combined sensor (level / temperature)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X = level sensors France (LX9000 – LX9089)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y = special units</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Z = special articles (cost for tools, development)</td>
</tr>
<tr>
<td>3-6</td>
<td>Probe length/</td>
<td>LK = probe length in mm</td>
</tr>
<tr>
<td></td>
<td>measuring range</td>
<td>LI = probe length in mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LA = probe length in mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LP = pressure range in mbar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LR = measuring range in cm</td>
</tr>
<tr>
<td>7</td>
<td>Display</td>
<td>- no display</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B = LED, 4 digits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A = LED, 3 digits</td>
</tr>
<tr>
<td>8</td>
<td>Additional designations</td>
<td>- = no additional designations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S = scalable analogue unit</td>
</tr>
<tr>
<td>9</td>
<td>Housing</td>
<td>A = cylindrical metal housing brass, Optelloy coated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B = cylindrical metal housing, stainless steel (V2A, 303522)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C = cylindrical metal housing brass, nickel-coated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E = cylindrical metal housing, stainless steel (V4A, 2205S1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K = plastic housing</td>
</tr>
<tr>
<td>10</td>
<td>Type of thread of</td>
<td>- = no thread, process connection via clamp connection</td>
</tr>
<tr>
<td></td>
<td>the process connection</td>
<td>A = pipe thread, cone for metal/metal sealing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B = pipe thread, slot for O-ring seal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C = pipe thread, surface for O-ring seal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M = metric thread</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N = NPT thread</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R = pipe thread</td>
</tr>
<tr>
<td>11-12</td>
<td>Size of thread and</td>
<td>00 = no thread, xx = diameter in mm for metric threads (pos. 10 = M)</td>
</tr>
<tr>
<td></td>
<td>diameter</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Material in contact</td>
<td>0 = non-contact sensor principle</td>
</tr>
<tr>
<td></td>
<td>with the medium</td>
<td>P = PVD (probe material among others for LK, LI and LA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T = PTFE (Teflon, probe among others for LK, LI and LA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A = stainless steel to DIN 17440</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D = Tantal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K = PP-H (polypropylene – homopolymer)</td>
</tr>
</tbody>
</table>
### Type key level sensors

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>14</strong></td>
<td><strong>Switching function</strong></td>
</tr>
<tr>
<td></td>
<td>A = analogue output 4-20mA</td>
</tr>
<tr>
<td></td>
<td>B = analogue output 0-10V</td>
</tr>
<tr>
<td></td>
<td>C = analogue output 0-20mA</td>
</tr>
<tr>
<td></td>
<td>D = analogue output 1-10V</td>
</tr>
<tr>
<td></td>
<td>E = EPS sensor</td>
</tr>
<tr>
<td></td>
<td>K = combined (analogue 4-20mA / binary)</td>
</tr>
<tr>
<td></td>
<td>L = combined (analogue / overflow protection)</td>
</tr>
<tr>
<td></td>
<td>M = combined (analogue 4-20mA, 0-10V selectable / binary)</td>
</tr>
<tr>
<td></td>
<td>N = 1 x binary</td>
</tr>
<tr>
<td></td>
<td>Q = 2 x binary</td>
</tr>
<tr>
<td></td>
<td>R = 3 x binary</td>
</tr>
<tr>
<td></td>
<td>S = 4 x binary</td>
</tr>
<tr>
<td></td>
<td>U = 1 x binary / 1 x overflow protection</td>
</tr>
<tr>
<td></td>
<td>V = 3 x binary / 1 x overflow protection</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>15</strong></th>
<th><strong>Output</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = semiconductor output negative switching</td>
</tr>
<tr>
<td></td>
<td>P = semiconductor output positive switching</td>
</tr>
<tr>
<td></td>
<td>T = two-wire (analogue)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>16</strong></th>
<th><strong>Short-circuit protection</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K = with short-circuit protection</td>
</tr>
<tr>
<td></td>
<td>O = without short-circuit protection</td>
</tr>
<tr>
<td></td>
<td>V = reverse polarity protection</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>17</strong></th>
<th><strong>Supply voltage</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A = dual voltage (AC/DC)</td>
</tr>
<tr>
<td></td>
<td>G = DC voltage</td>
</tr>
<tr>
<td></td>
<td>W = AC voltage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>19</strong></th>
<th><strong>Options</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>US = with US connector, 4 pins or 8 pins</td>
</tr>
</tbody>
</table>
### Capacitive proximity switches
### Level sensors

#### Type key level switch

<table>
<thead>
<tr>
<th>Pos.</th>
<th>Designation</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 1, 2 | System      | KN = Capacitive level switch  
|      |             | KT = dynamic capacitive touch control |
| 3 - 5 | Type       | M30 = Threaded type M30  
|      |            | Q01 = Rectangular type 1 (80 x 38 x 10)  
|      |            | Q02 = Rectangular type 1 (50 x 20 x 10)  
|      |            | R/A = pipe thread 1 1/4" |
| 6    | Application| --- = no information  
|      |            | B = flush mountable  
|      |            | N = non-flush mountable |
| 7    | Application| S = bulk material  
|      |            | F = liquids  
|      |            | P = dry plastic granulates  
|      |            | U = universal |
| 8    | Housing material| A = nickel-plated brass, PBT  
|      |            | B = V4A, PBT  
|      |            | P = PTFE  
|      |            | K = plastics |
| 9    | Switching function| A = normally open for two-wire units and for three-wire NPN units  
|      |            | B = normally closed for two-wire units and for three-wire NPN units  
|      |            | normally open for three-wire PNP units  
|      |            | C = complementary output  
|      |            | D = analog output  
|      |            | F = output function programmable  
|      |            | I = current output  
|      |            | V = voltage output  
|      |            | N = NAMUR sensors (positions 10-12 not used)  
|      |            | S = safety switch (positions 10-12 not used)  
|      |            | asi = asi sensors (position 12 not used) |
| 10   | Output system| B = semiconductor output for AC and AC / DC units  
|      |            | N = semiconductor output negative switching  
|      |            | P = semiconductor output positive switching  
|      |            | R = semiconductor output positive or negative switching |
| 11   | Short-circuit protection| K = with short-circuit protection  
|      |            | L = latching  
|      |            | O = without short-circuit protection |
| 12   | Supply voltage| A = choice of AC or DC voltage (AC / DC)  
|      |            | O = DC voltage  
|      |            | W = AC voltage |
| 13   | Stck       | 2LED5 = 2 LED's  
|      |            | SL = earth wire  
|      |            | V2A = 1/2A metal housing  
|      |            | V4A = 1/4A metal housing  
|      |            | M3 = metal conduit attachment  
|      |            | UP = non-polarised output  
|      |            | SC = safecoated  
|      |            | F = frequency offset |
| 14   | Options    | XM = cable x m long  
|      |            | SF = increased noise immunity  
|      |            | AC = with AC connector (only with ... / XM - JAPAN)  
|      |            | DC = with DC connector (only with ... / XM - JAPAN)  
|      |            | T2 = dual sensor T2  
|      |            | OF = without remote calibration  
|      |            | T = with timer module  
|      |            | PP = polypropylene |

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**Training manual**

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Explanation production code

The coding is indicated on the type and box labels of our products or on an alternative type of labelling, e.g. 'direct laser labelling' as it is used with the units in modular technology.

The coding covers information about

- production site
- production month
- special designation
  (meaning registered in the production site)
- production status

Legend 'production site'

- E: ifm ecomatic, Kressbronn
- K: ifm prover, Kressbronn (from 1/3/2000)
- P: (bought-in products)
- S: ifm syntron
- T: ifm Tettnang (parent plant)
- U: ifm USA (efector inc.)
- W: ifm Sweden
- F: ifm France

Current production code:

Standard coding
(conventional units)

- spec. des.
- prod. site (see legend)
- prod. month (hex.) 1..9
- prod. year (last pos.)
- prod. status AA...ZZ

Direct laser labelling
(modular units)

- prod. year (last two pos.)
- prod. month (dec.) 01...12
- prod. status AA...ZZ

Example:

SA8 made by ifm Syntron in October (A) 1998
- no special designation -

AA first production status (AA)

Example:

9903 made in 1999,
in March (03)

T AB in the parent plant ifm Tettnang;
second prod. status (AB)
- no special designation -

Old coding (until September 1995)

- spec. des.
- prod. month (dec.) 01..12
- prod. year (last pos.)
Glossary of technical terms

Active zone

The active zone is the area over the sensing face in which the proximity switch reacts to the approach of the damping material, e.g. changes its switching status.

Assured operating distance ($s_a$)

The assured operating distance is the distance from the sensing face where a proximity switch operates reliably under given temperature and voltage conditions (see operating distance). It is the minimum value of the usable operating distance.

Cable material

PVC

In order to avoid cable break PVC cables must not be moved if the temperature falls below -5°.

Correction factor

If the shape, material or thickness of the target is different from the standard target, operating distances other than the standard operating distance result. They can be calculated using correction factors which are specified in the technical data sheet. The following factors must also be taken into account:

Shape factor

If instead of the standard target, a smaller or non square target is used or if the target is not flat, the operating distance must be corrected with a shape factor.

Material factor

If instead of the target material defined in the standard, e.g. FE360 to ISO 630, another target material is used, the operating distance must be corrected with a material factor. For capacitive switches it depends on the dielectric constant of the material.

Material thickness factor

If a target is used with a thickness below the penetration depth of the sensing field, the operating distance must be corrected with a material thickness factor. For capacitive switches this factor is normally below 1.

Current rating/peak

Switch-on and switch-off capacity under usual/unusual conditions. The peak current rating is the maximum current which may flow for a short time at the moment of switch-on without destroying the proximity switch. Especially AC units are rated so that they can be operated with six times the nominal current for a short time due to the high inrush currents of many AC loads (pilot lamps, contactors...) (also see utilization categories).

Effective operating distance $s_r$

The effective operating distance of a proximity switch is the operating distance measured at rated voltage and room temperature ($23 \pm 5°C$). It must lie between 90 % and 110 % of the rated operating distance (see operating distance).

Flush mounting

The sensing face can be mounted flush with the surface of the damping material.

Housing materials

Metal housing

Aluminium
Stainless steel *
Steel sheet galvanised
Brass with Optalloy (nickel-free)*
PTFE coated brass (safe coating)*
*: Inductive units
Stainless steels (rust-free stainless steel and acid-resistant high-grade stainless steel):
Stainless steel: 303S22 (X10CrNiS 189) 304S15 (X2CrNiMo) 316S12 (X2CrNiMo 17132) 316S12 (X2CrNiMo 18143) 320S31 (X6CrNiMoTi 17122)

**Plastic housing**

**PBTP (polybutyleneterephtalate)**

The housing is largely resistant to aliphatic and aromatic hydrocarbons, oils, greases, hydraulic fluids, fuels; no stress cracking when exposed to air.

The housing is not resistant to hot water, hot steam, acetone, halocarbons, concentrated acids and alkalis.

**Modified PPO**

The housing is largely resistant to diluted mineral acids, weak alkalis, some alcohols, oils and greases depending on the additives.

**Chemically resistant fluoroplastics:** PTFE (polytetrafluoroethylene)

LCP, PEEK, PEI, PA, mod. PC

The resistance of plastics depends on the environmental and operating conditions. Therefore certain properties or the suitability for a certain application cannot be guaranteed.

For frequent or permanent exposure to chemicals it is recommended to test all housing materials prior to use.

The chemical resistance of the cast resin used for potting is comparable to that of the plastics for the efector housings. For unpotted efectorm units protection against contact with the medium other than the housing materials has been further improved due to the design..

**Hysteresis**

The hysteresis is the difference between switch-on and switch-off point of the proximity switch. It is indicated in percent referred to the switch-on point measured under the same conditions and serves to prevent uncontrolled switching of the proximity switch when the target is near the switch point ("output chattering").

**IP**

see protection rating

**Leakage current in 2-wire units**

The leakage current is the current which flows through 2-wire units when the output is blocked in order to supply the electronics with current. The leakage current also flows through the load.

**Measurement of the operating distance**

The operating distance is determined according to EN 60947-5-2.

**NAMUR**

NAMUR stands for Normenarbeitsgemeinschaft für Meß- und Regeltechnik (standardisation group for metrology) in the chemical industry. A NAMUR switch is a special version of a 2-wire DC unit to DN 19234 suitable for use in hazardous areas (today ATEX, see training manual).

**No-load current for 3-wire units**

The no-load current is the intrinsic current consumption of the proximity switch when it is not switched.

A very low leakage current of about 0.1 µA flows through the output transistor when the output is not switched (open collector).

**Nominal operating distance**

See rated operating distance.
### Capacitive proximity switches

### Level sensors

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normally closed</strong></td>
<td>Principle of normally closed operation. If an object is in the area of the active zone, the output is blocked (see output function).</td>
</tr>
<tr>
<td><strong>Normally open</strong></td>
<td>Principle of normally open operation. If an object is in the area of the active zone, the output is switched.</td>
</tr>
<tr>
<td><strong>Operating distance</strong></td>
<td>The operating distance of a proximity switch is the distance at which an object approaching the sensing face axially causes the output to change its state (see correction factors and measurement...). Also see rated operating distance, usable operating distance, effective operating distance and assured operating distance.</td>
</tr>
<tr>
<td><strong>Operating temperature range</strong></td>
<td>The temperature range specifies the temperatures at which proximity switches can be used. Common ranges for ifm efectors: Standard units -25...80°C Units with special features (e.g. increased operating distance) -25...70°C 0...100°C -40...85°C</td>
</tr>
<tr>
<td><strong>Operating voltage</strong></td>
<td>The voltage range (around the nominal voltage) in which the proximity switch operates reliably. For DC units the minimum and maximum values, including the residual ripple, must be adhered to.</td>
</tr>
<tr>
<td><strong>Output function</strong></td>
<td>Object within the active zone – output switched / high signal Object within the active zone – output blocked / low signal Normally closed or normally open selectable Normally open and normally closed output functions are available simultaneously.</td>
</tr>
<tr>
<td><strong>Overload protection</strong></td>
<td>The output of a proximity switch is protected against overload if any currents between nominal load current and short-circuit current can flow continuously without damage.</td>
</tr>
<tr>
<td><strong>Passing speed</strong></td>
<td>If the proximity switch is damped and undamped by one single target which moves through the active zone at high speed, there is a maximum passing speed at which a reliable switching signal is just provided.</td>
</tr>
<tr>
<td><strong>Programming</strong></td>
<td>For some efector types the output function can be programmed to be normally open or normally closed. Depending on the efector type the output function is programmed via a wire link, a jumper or pin connection.</td>
</tr>
<tr>
<td><strong>Protection rating</strong></td>
<td>See the training manual protection ratings. IP 65 Complete protection against contact with live parts. Protection against the ingress of dust. Protection against water jets. IP 67 Complete protection against contact with live parts. Protection against the ingress of dust. Protection against the ingress of water when submerged in 1 m depth for 30 minutes.</td>
</tr>
<tr>
<td><strong>Power-on delay time</strong></td>
<td>The time the proximity switch needs to be ready for operation after power on. It depends on the switch type and is in the ms range (5 ms to over 200 ms depending on the type). Within this time the internal voltage</td>
</tr>
<tr>
<td>Parameter</td>
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</tr>
<tr>
<td>-----------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Rated impulse withstand voltage $U_{imp}$</td>
<td>This is the voltage reference for clearance rating.</td>
</tr>
<tr>
<td>Rated insulation voltage $U_i$</td>
<td>This is the voltage reference for the dielectric voltage tests and creepage distances. For units with protection class II the voltage of the adjacent mains supply is considered to be $U_i$, 250 V AC.</td>
</tr>
<tr>
<td>Rated operating distance ($s_o$)</td>
<td>The rated operating distance is a value which does not take into account individual variations and changes due to external influence like temperature and voltage (also see operating distance).</td>
</tr>
<tr>
<td>Rated operating current</td>
<td>The rated operating current (continuous current rating) indicates the current at which a proximity switch can be continuously operated (also see current rating/peak).</td>
</tr>
<tr>
<td>Repeatability (reproducibility)</td>
<td>The difference between two operating distance measurements carried out for 8 hours under standardised conditions is called repeatability and specified in percent referred to the effective operating distance. The difference between two random measurements must not exceed 10% of the effective operating distance.</td>
</tr>
<tr>
<td>Reverse polarity protection</td>
<td>A switch is protected against reverse polarity if the wire connection to the terminals can be reversed without damage to the switch. As a rule 3-wire switches which are protected against reverse polarity must be short-circuit protected because otherwise reversing the output and ground connection (0 V) would destroy the unit.</td>
</tr>
<tr>
<td>Sensing face</td>
<td>The sensing face is the face on the proximity switch where the electric field is generated.</td>
</tr>
<tr>
<td>Short-circuit protection</td>
<td>The output of a proximity switch is short-circuit protected according to VDE 0160 if it withstands a short circuit of the load or a short to ground at the output permanently without damage and if it is ready for operation again without any switching after the short circuit has been removed.</td>
</tr>
<tr>
<td>In the event of a short circuit the output transistor is blocked immediately. After rectification of the short circuit the unit is ready again for operation immediately. Reversing the connection wires does not destroy the units. Short-circuit protected units are normally protected against overload and reverse polarity.</td>
<td></td>
</tr>
<tr>
<td>Smallest operating current in 2-wire units</td>
<td>This is the current which must at least flow in the switched state to ensure reliable operation of the proximity switch (sometimes also called minimum load current).</td>
</tr>
<tr>
<td>Switching delay</td>
<td>The switching delay is the time which elapses between moving the target into the active zone and switching of the output. The switching delays for damping and undamping can differ considerably. For ifm effectors these times (depending on the type) are normally 0.2 to 2 ms for damping and 0.3 to 3 ms for undamping. For units with F-IC a ratio of 1:1 for these two times can be achieved.</td>
</tr>
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</table>
| Switching frequency                           | The switching frequency is the limit frequency at which each periodic damping and undamping operation of the proximity switch is just reliably converted into a switching signal. Since the attainable switching  

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The supply must stabilise and the oscillator must start to oscillate. The output is not active.
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Frequency depends on several factors, a standard measurement arrangement is defined in EN 60947-5-2 to obtain values for comparison. The switching frequencies in real applications are often much higher. If the proximity switch is operated with a high inductive load (contactor, relay, solenoid valve) for a longer period and high switching frequency, additional protective measures must be taken to reduce the switching overvoltage (e.g. free-wheeling diodes).

Temperature / switch point drift

Switch point drift is the shifting of the switch point caused by a change of the operating temperature.

Types of mounting

When inductive proximity switches are mounted, a distinction is made between flush and non-flush mounting.

Flush mounting (f)
The sensing face can be mounted flush with the surface of the damping material.

Non-flush mounting (nf)
The sensing face must be surrounded by a clear space (see mounting instructions).

When proximity switches are mounted side by side or opposite each other defined minimum distances depending on the design must be adhered to.

Usable operating distance $s_u$
The usable operating distance is measured within the permissible operating voltage and operating temperature ranges according to EN 60947-5-2. It must lie between 90 % and 110 % of the effective operating distance (see operating distance).

Utilization category

The categories are listed and explained in the following table according to EN 60947-5-2.

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<td>AC-140</td>
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<td>Control of small electromagnetic loads with holding current &lt; 0.2 A; e.g. contactor relays</td>
</tr>
<tr>
<td>Direct current</td>
<td>DC-12</td>
<td>Control of resistive and solid-state loads</td>
</tr>
<tr>
<td>DC-13</td>
<td></td>
<td>Control of electromagnets</td>
</tr>
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</table>

Category AC-140 applies to AC/DC efectors, category DC-13 to 2 and 3-wire DC efectors and category DC-12 to NAMUR types.

Voltage drop (on-state voltage)

As the switching output of the proximity switch is equipped with a solid-state component (transistor, thyristor, triac), a (small) voltage drop occurs in series to the load in the switched state. In two-wire technology the voltage drop also serves to supply the electronics of the proximity switch with energy. The amount of the voltage drop depends on the type and lies between 2.5 V (DC) and 6.5 V (AC/DC).
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