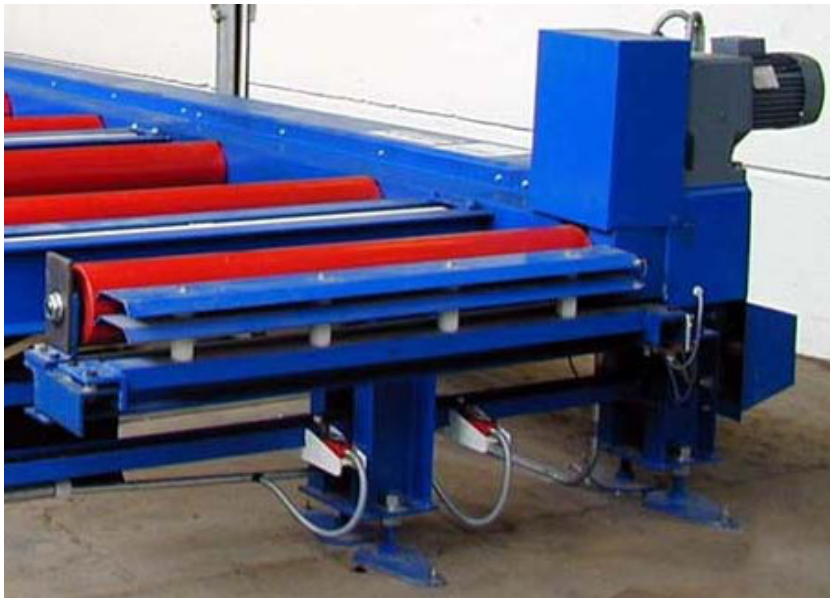
Notes on the

Construction of a Sensor for S-SW



Contents

1 Principle of the S-SW Sensor

The evaluation units (electronic sensor devices) S-SW-[3; 4; 8; 10; 3/8; 3/10] require a special capacitive sensor to be able to detect the presence of conductive objects without contact using a differential evaluation method.

The sensor consists of two equal size metal electrodes arranged in parallel proximity. The measuring electrode is located at the top position while the counter one is arranged at a defined distance below. Both together must be fixed over an earthed metal carrier plate. There must be no electrical connection between the tree parts. The spacers between the electrodes and the carrier plate must be made of insulating material.

The measuring and the counter electrodes plus the carrier plate are electrically connected to the S-SW evaluation unit. A common coaxial cable must be used for the measuring and the counter electrodes (see figure 1 and 2).

The function of the carrier plate is to provide the S-SW evaluation unit with the electrical potential from the area around of the two electrodes as a reference potential. For the system to function properly, it is important that the carrier plate is connected to the earth potential independently of the evaluation unit and that a separate cable connects the already earthed carrier plate to the corresponding connection on the S-SW evaluation unit (see "3 Connecting the Sensor to the S-SW Evaluation Unit").

The dimensions of the S-SW sensor must be proportional to the dimensions of the objects to be detected. The length, width and distance of the electrodes determine the detection range where objects have an effect on the sensor signal. In terms of sensibility, the larger objects are, the easier to detect, while detecting smaller objects requires greater efforts.

The sensor electrodes are not included in the scope of delivery of the S-SW evaluation unit. Their design depends on the user's specific application and must be designed by the user in accordance with the technical requirements.

The following instructions are intended to help with the design of the sensor.

2 Construction

The shape, size and arrangement of the electrodes determine the detection range and influence the sensitivity of the sensor. The electrodes are usually elongated and straight. In principle, however, other shapes are also possible, e.g. curved.

The design rules listed below should help to make the sensor as suitable as possible for the application. However, the effect of the sensor is influenced by many conditions, e.g. by the sensor's surroundings, by the sensor itself and also by the object to be detected. Unfortunately, no direct mathematical correlations can be given for the design of the electrodes, only indications of the effect of design measures. It may be necessary to try out different variations in order to find the best solution.

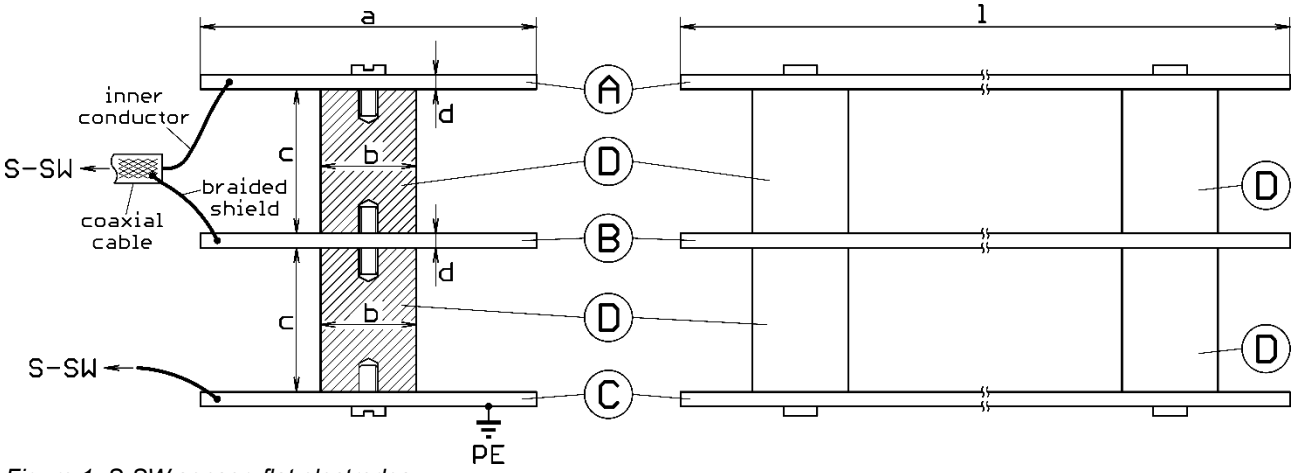


Figure 1: S-SW sensor, flat electrodes

A: measuring electrode B: counter electrode C: carrier plate D: spacer

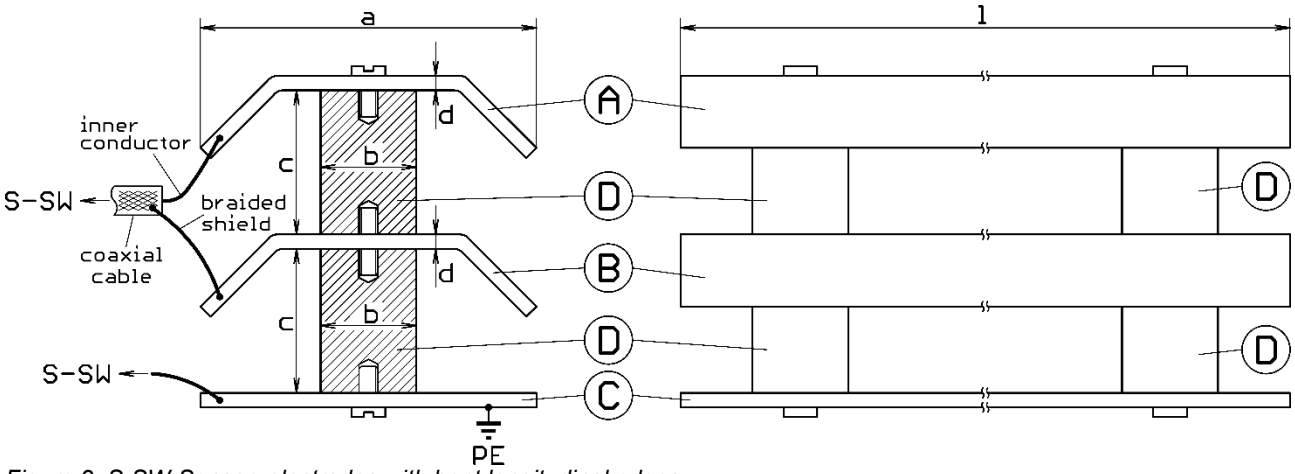


Figure 2: S-SW-Sensor, electrodes with bent longitudinal edges

		min.	max.	Info
Electrode width	a	10 mm	200 mm	See "2.2.2 Electrode Width 'a'"
Spacer, Ø	b	n.s.	n.s.	Electrically insulating material (plastic, ceramic, ...) The selected cross-section should ensure sufficient mechanical stability.
Electrode spacing	c	5 mm	80 mm	See "2.3 Distances between the Electrodes and to the Carrier Plate".
Electrode thickness	d	n.s.	n.s.	The electrode thickness is not critical. It should be selected so that the electrodes have sufficient mechanical stability.
Length of the electrodes	l	100 mm	4000 mm	The length of the electrodes is based on the widest object to be detected. See "2.2.1 Lenght 'l' of the Electrodes".

Spacers are also available as accessories from UNICONTROL (UC insulator M4, M6, M8, M10 and M12).

2.1 Properties of the Electrodes

The measuring and counter electrodes must be made of electrically conductive material (sheet steel, aluminum, copper, etc.). They can have any geometric shape. It is only important that the two electrodes have approximately the same surface area, are arranged parallel to each other and are fixed in parallel over a metal, earthed support.

The thickness of the electrode plates is not critical. It should be selected so that the electrodes have sufficient mechanical stability.

Flat metal sheets are sufficient for the basic function. In many applications, electrodes with longitudinal edges that are bent downwards are used. This gives the electrodes greater stability and has the further advantage that less impurities such as slag, metal dust and abrasive can accumulate on the electrodes.

The measuring and counter electrodes must not be fixed to the carrier plate with through bolts. This could result in short circuits preventing them from functioning properly and making them unusable for the application.

2.2 Size of the Electrodes

The size of the electrodes depends on the size of the object to be detected. The minimum object surface is decisive for the effect on the sensor signal. It will not be possible to detect the presence of an object with an area of a few mm^2 using a 4 m long sensor. On the other hand, the presence

of a large object above a smaller sensor is easy to detect, but the sensor signal level may overload the sensor electronics. In this case, however, the object is still considered to be present.[1]

When dimensioning the sensor, the following rule applies: the larger the base area of the object to be detected, the larger the dimensions of the sensor should be and vice versa.

Only surface areas of the object that extend beyond the measuring electrode contribute to the effect on the sensor signal. The sensor is “blind” for objects directly above the measuring electrode that do not extend beyond it in width and length.

The following applies within the detection range of the sensor: Of two objects with the same surface area, the long and narrow one - in the direction of movement - causes a larger sensor signal than the wide and short one. This is more evident the smaller the object is in relation to the sensor electrodes.

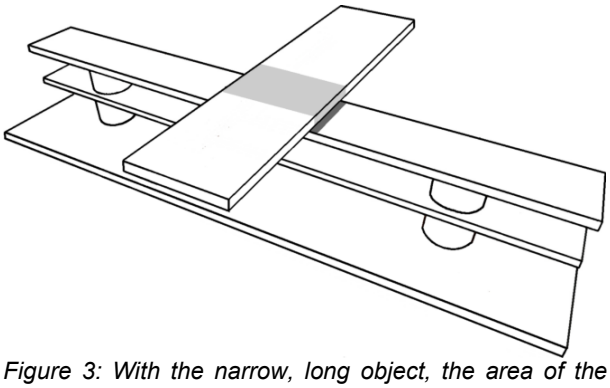


Figure 3: With the narrow, long object, the area of the object extending beyond the measuring electrode is relatively large compared to the area above the electrode.

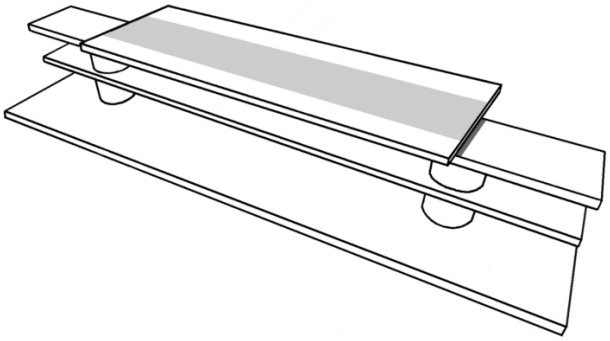


Figure 4: With a wide, short object, the area of the object extending beyond the measuring electrode is relatively small compared to the area above the electrode.

In terms of overall function, small sensor electrodes for detecting correspondingly small objects pose a greater challenge for the S-SW evaluation unit than vice versa. The more the electrode size approaches or even falls below the specified minimum dimensions, the more challenging it becomes for the S-SW evaluation unit to find an operating point during calibration.

2.2.1 Lenght 'l' of the Electrodes

The length 'l' of the electrodes is based on the width of the widest detection object. As a guideline, the length 'l' of the electrodes should at least correspond to the width of the object. If the electrodes are extended further than the width of the object, the sensor signal will be reduced. This can be avoided by moving the object closer to the measuring electrode. In practice, the length of the sensor is often adapted to the width of the roller conveyor used to transport the objects, e.g. because the point at which the objects cross the sensor is not specified (see cover image).

If the electrodes are shortened so that their length becomes smaller than the object width, this initially has an increasing effect on the sensor signal, as the proportion of the object's surface that extends beyond the measuring electrode increases in relation to the electrode surface. As the electrodes are shortened, their detection area is also reduced. If the detection range is then restricted accordingly, there is no further increase in the sensor signal.

Under some conditions, the evaluation electronics may be overloaded by the high sensor signal. This should be avoided, e.g. by distancing the object from the sensor.

In extreme cases, the electrodes should not be shorter than 100 mm and not longer than 4000 mm.

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[1] During clipping, the S-SW-8 and S-SW-10 evaluation unit cannot guarantee automatic tracking of the reference value required for object detection, as there is no signal effect defined to match the object. If the object is in this position for too long, slow changes in the ambient conditions (e.g. temperature fluctuations) can shift the operating point. This may then lead to malfunctions after the object leaves the sensor if automatic correction functions can no longer compensate for the shifting.

2.2.2 Electrode Width 'a'

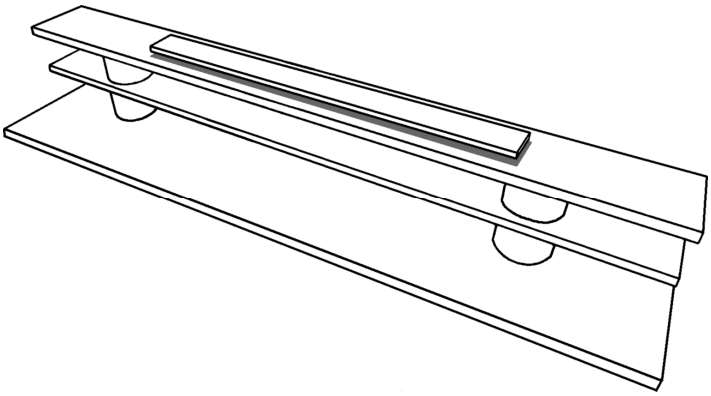


Figure 5: A short and wide object - in the direction of movement - above the sensor. This object is not detected as it does not extend beyond the measuring electrode.

As only the parts of the object base area that extend beyond the measuring electrode contribute to the sensor signal, the electrodes must be narrower than the length of the detection object. For proper functionality, it is even necessary that the object length be at least twice the electrode width. If the object were shorter than the electrode width, the object would only generate an occupied signal for a brief moment when approaching and leaving the electrode, but not while is directly above the measuring electrode. This applies regardless of the width of the object or the length of the electrode, as long as the object does not extend far enough beyond the end faces of the electrode (see "Figure 5").

The same effect can occur if a narrow object crossing the electrode in its central position shows too little surface area that still overhangs the electrode.

The width of the electrodes has an influence on the “switching hysteresis”. This refers to the distance between the positions where the detection object is recognized as present and absent when moving towards and backwards to the detection area (the red LED5 lights ON and OFF). The wider the electrodes are, the greater this distance is.

2.3 Distances between the Electrodes and to the Carrier Plate

The distances between the two electrodes and between the lower electrode (counter electrode) and the carrier plate should be approximately the same and should only be varied together. In principle, however, the system is also functional if the distances differ.

Changing these distances has the following effects:

- Reducing the distances
  - increases the signal strengths generated by the objects and
  - causes a reduction in the detection range or effective range around the electrodes. This means that the distance between the object and the measuring electrode required for a sufficient signal effect becomes smaller. Objects that are rather small in relation to the electrodes must be guided correspondingly close above the measuring electrode.
- Increasing the distances
  - reduces the signal strengths generated by the objects and
  - enlarges the detection area around the electrodes.

The spacers between the electrodes and the carrier plate must be made of electrically insulating material (plastic, ceramic, ...). Their cross-section should ensure sufficient mechanical stability. Also, for reasons of stability, an appropriate number of spacers should be distributed over the length of the electrodes.

For electrodes from lengths of several 10 cm, as they occur in many standard applications, plastic insulators with threaded holes M4, M6, M8, M10 or M12 (depending on the size/width and spacing of the electrodes) are used as spacers. Such spacers are also available directly from UNICONTROL (see data sheet on our website).

2.4 Distance between Object and Measuring Electrode

The distance between the object and the measuring electrode has a strong influence on the size of the sensor signal. If an object approaches the measuring electrode, the sensor signal increases in a quadratic relationship with the distance to the electrode. In other words, the closer the object is to the measuring electrode, the larger the sensor signal and the smaller the objects that can still be detected as being present by the sensor. The intensity of the sensor signal can be roughly as-

sessed based on the activity of the green LED1 on the evaluation unit (see S-SW-8/10 instructions).

As long as objects do not touch the measuring electrode when crossing it, there are no specifications for the minimum distance. However, the distance between the measuring electrode and the object must be at least large enough to prevent the object from touching the electrode under all possible operating conditions and mechanical adversities. In compliance with this requirement, the distance between objects and the measuring electrode should be determined as follows:

- If it is also necessary to detect the presence of objects with a weaker signal, the distance at which objects move above the measuring electrode should only be reduced to such an extent that the green LED1 does not light up permanently when the object with the strongest signal is present, i.e. it flashes quickly at most (4/s). The required minimum distance to ensure fault-free operation must not be ignored (see above).
  If the green LED1 lights up permanently or if the red LED3 also lights up (measuring range exceeded), the distance must be increased.
- If it is not necessary to detect objects with a weaker signal, the distance between the measuring electrode and the object should be selected so that the green LED1 flashes slowly, i.e. it does not flash faster than 1/s. However, if a high sensitivity setting is required to detect the object, the distance between the object and the measuring electrode should be reduced slightly to ensure reliable detection.

2.5 Carrier Plate

The design of the carrier plate depends on the conditions at the installation location. It must be made of metal.

The carrier plate should have the same or larger dimensions than the electrodes. If space is available, the effect of the sensor could be increased somewhat by making the carrier plate larger. The larger the surface area of the carrier plate and the object base area, the greater the signal effect of the sensor. However, the effect of enlarging the carrier plate is lower for small objects than for larger ones.

Increasing the size of the carrier plate has a rather moderate overall effect on the sensitivity of the sensor. In addition, the sensitivity does not increase linearly with the enlargement of the carrier plate, but even decreases sharply beyond defined size. Therefore, it should be sufficient enlarging the carrier plate by a maximum of three to five electrode widths in the direction of movement of the object in front of and, if necessary, behind the sensor.

It is neither necessary nor disadvantageous to enlarge the carrier plate beyond the end faces of the electrodes.

There is no limit to the maximum size of the carrier plate.

2.6 Effect of Machine Parts in the Vicinity of the Electrodes

2.6.1 Stationary Machine Parts

Electrically conductive, stationary machine parts in the immediate vicinity of the electrodes do not change the basic function of the overall system. However, just like the approaching objects, the machine parts have an effect on the sensor signal. They practically represent a basic assignment of the sensor. The closer the machine part is to the electrodes, the stronger the effect.

The S-SW evaluation unit must be able to distinguish between the fixed machine parts and the objects that are actually to be detected. Fixed machine parts are part of the static ambient conditions of the sensor. At least during the very first commissioning or after modifications to the system, the S-SW evaluation unit must therefore be calibrated (see S-SW instructions). Calibration means that the system adapts to the conditions at the installation location and sets its operating point accordingly. The stationary machine parts around the sensor are added to the static operating conditions.

The range for setting the operating point is relatively large but still limited. Under certain circumstances, the S-SW evaluation unit may not be able to find a suitable operating point. The following

conditions make it difficult to find an operating point, especially if the conditions are present at the same time:

- There are many machine parts in the vicinity of the electrodes.
- The machine parts are very close to the electrodes.
- The machine parts are electrically connected to the earthed carrier plate or independently earthed themselves.

Machine parts that are close to the electrodes can have a local influence on the detection range of the sensor. The detection range is reduced. At the same time, the sensitivity of the sensor may increase slightly. This effect offers the possibility of increasing the sensitivity of a sensor with the appropriate arrangement of metal sheets electrically connected to the carrier plate. However, its detection range is also greatly reduced. In particular, this type of sensitivity increase is especially interesting for detecting small objects with correspondingly small sensors (see "4.3 Small Sensor with Shielding").

2.6.2 Moving Machine Parts

Moving, more or less electrically conductive machine parts located in the detection range of the sensor electrodes distort the sensor signal. Possible consequences are

– incorrect object recognition,
– a shift in the operating point, which the S-SW evaluation unit may no longer be able to correct with its automatic correction functions.

Care should therefore be taken to ensure that moving machine parts are outside the detection range of the sensor. The detection range of a sensor depends on its size and the distance between the electrodes. The effective range around the sensor electrodes can range from a few mm for small sensors with a small distance between the electrodes to several cm for large sensors with a correspondingly larger distance between the electrodes. If it is not possible to maintain the necessary distance, you can try to shield moving machine parts from the sensor with metal sheets connected to earth potential.

Rotating machine parts with a symmetrical design are rather uncritical.

3 Connecting the Sensor to the S-SW Evaluation Unit

See Figure 6 on page 8.

The measuring electrode, the counter electrode and the earthed carrier plate are electrically connected to the S-SW evaluation unit.

It is essential to use a common coaxial cable for the measuring electrode and counter electrode. Otherwise the system would be very susceptible to interference and could easily malfunction.

The inner conductor of the coaxial cable must be connected to the measuring electrode (upper electrode). On the S-SW evaluation unit, the inner conductor is connected to X3/1.

The braided shield must be connected to the electrode below it, the counter electrode. On the evaluation unit, the braided shield is connected to X3/2.

The coaxial cable should be limited to a maximum length of 100 cm.

The task of the carrier plate is to provide the evaluation unit S-SW with the electrical potential from the surroundings of the two electrodes as a reference potential. For the system to function, it is important that the carrier plate is connected to the earth potential independently of the evaluation unit and that a separate cable is routed from the already earthed carrier plate to the corresponding connection X1/3 on the S-SW evaluation unit. No special requirements are placed on the cable to be used for this. A simple cable is sufficient.

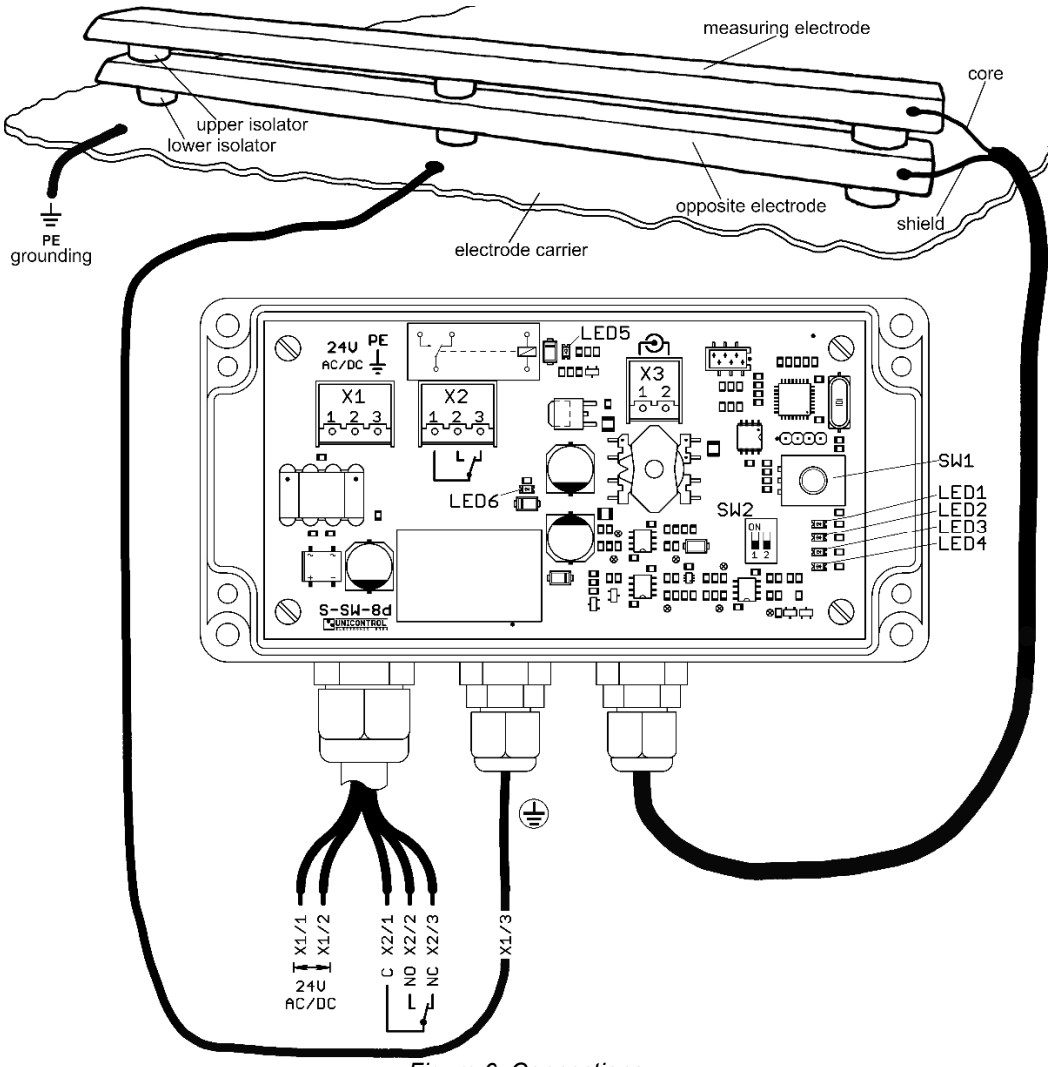
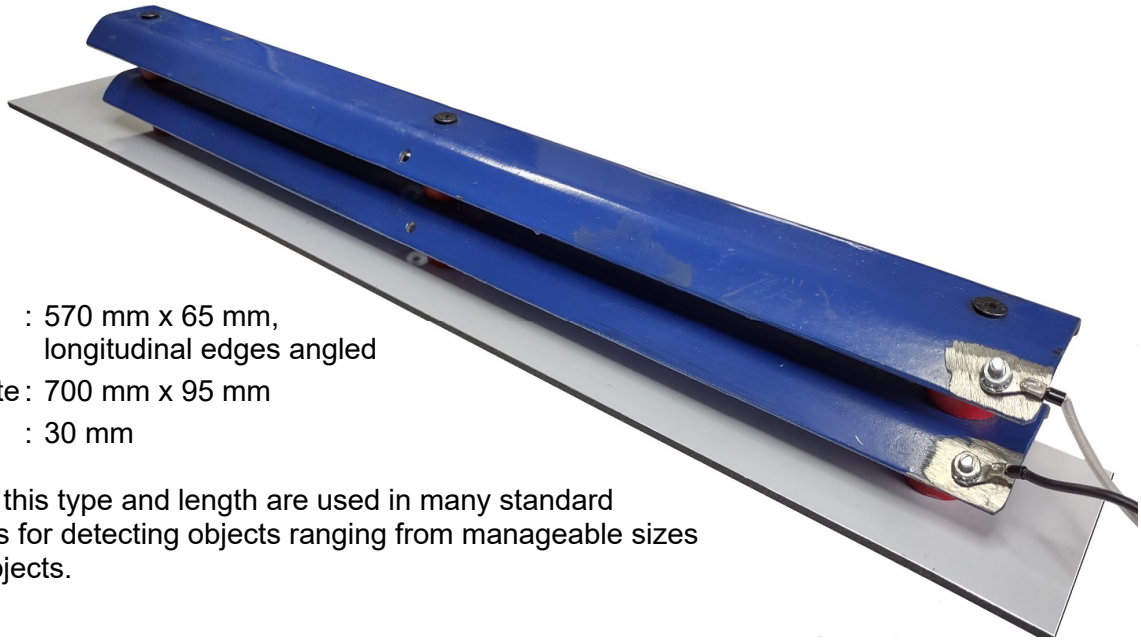


Figure 6: Connections

4 Examples of Sensors

The sensor variants shown below are used at UNICONTROL for development and test purposes.

4.1 Standard Sensor



Electrodes : 570 mm x 65 mm,
longitudinal edges angled
Carrier Plate : 700 mm x 95 mm
Distances : 30 mm

Sensors of this type and length are used in many standard applications for detecting objects ranging from manageable sizes to larger objects.

4.2 Small Sensor

According to the technical specification, this sensor corresponds to the smallest version.

Electrodes : 100 mm x 10 mm
Carrier plate : 100 mm x 30 mm
Distances : 5 mm
Sensor hight : 14.8 mm (without feet)

1.6 mm thick FR4 PCB base material with a 35 µm thick copper coating on one side was used for production.

The electrodes were attached to the carrier plate using plastic spacers and an adhesive.

4.3 Small Sensor with Shielding

The sensor shown corresponds practically to the sensor from chapter 4.2. To increase the sensitivity, the sensor electrodes were surrounded by a shield. The shielding is 10 mm away from the electrodes. In height, it extends to about 2 mm below the surface of the measuring electrode.

Electrodes : 100 mm x 10 mm
Carrier plate : 120 mm x 30 mm
Distances : 5 mm
Sensor hight : 14.8 mm
Shielding hight : 13 mm

The same circuit board base material was used to manufacture the sensor electrodes, the carrier plate and the shielding as for the sensor in chapter 4.2.

Plastic spacers and adhesive were used to mount the electrodes. The shielding plates are soldered to the carrier plate and thus mechanically and electrically connected to it. An additional shield plate was added to the left end face for mechanical stabilization. A shielding plate was omitted on the right-hand side so that the connection leads can be routed away from the sensor without kinking.