Sensor Technology

Components of Automation Technology

4th Edition

SystemTechnik
Competence in Training

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Preface

In recent years sensors have become essential components in automation technology. The structures of industrial manufacturing have changed to such a degree that direct operation and supervision of processes by personnel is on the decline and is being taken over increasingly by central process controls. The increasing automation and control of ever more complex manufacturing processes demand components which enable the data and information belonging to the manufacturing process to be acquired automatically. The human senses must be simulated by sensors, which are able to detect the environment. Whereas previously, a wide range of different terms such as measuring probe, initiator, proximity switch, light scanner, transmitter, pick-up, momentary action switch, switch and transducer was used, the term „sensor“ has since established itself in international technical jargon. This term refers to all components, which serve to pick up measured values in the widest sense.

Sensors are signal elements, which usually operate as non-contact probes, detecting elements and transmitters and measure physical values such as temperature, force, speed etc. The sensor converts the physical value usually into an electrical output signal. The analog or digital output signals are processed by microprocessors and EDP systems or can operate control positioning elements or actuators directly through amplifiers.

The SENSORICS BOARD (type 3840) of hps SystemTechnik, in conjunction with the manual „Sensor Technology – Components of Automation Technology“, is aimed at making the user familiar with the most important sensor types and their functions.

The individual chapters in this manual each deal with one type of sensor. They are composed of a general section, which explains the set-up, function and the basic terminology used, an experiments section with detailed descriptions of the experiments and a solutions section.

The data sheets of the description (type V 3840) specify the exact technical data of each sensor type for a more in-depth study.

Special terms such as series and parallel circuit, installation examples (flush, non-flush, pre-attenuation), two and three-wire systems etc. are described additionally in detail in the overhead foils.

Tolerances in a range from 10 ... 20 % are possible in all the measuring series. The reference positions on the guide rail (p_0, p_1, p_2, etc.) need not necessarily always correspond with the values in the solution tables because these positions are dependent on the respective adjustment of the sensor in its holder. Positions on the guide rail are always read on the right of the carriage unless specified otherwise.

The SENSORICS BOARD can be equipped with the following options:

- Ultrasonic Sensor (type 3840.21)
- Fibre Optic Sensor (type 3840.22)
- NAMUR Sensors with Post-Switchgear (inductive, capacitive and magnetic) (type 3840.23)
- Inductive Analog Sensor (type 3840.24)

Contents

1 Operation of the SENSORICS BOARD

1.1 General

The SENSORICS BOARD (type 3840) of hps SystemTechnik enables a number of experiments in the field of sensorics and can also be used in combination with a PLC or another control system (PC) as a training unit in the field of automation technology.

It composes the following components:

- **Segment disk** with an electrical drive and an angle scale to examine the dynamic switching behaviour of various sensors with jacks for mounting the material sample holder.
- Electric or manual **carriage** drive with holes for mounting the different pluggable sensors. Segment disk and carriage in each case have an automatic current disconnection.
- **Guide rail** with a millimetre scale to determine the exact position of the sensor and to establish the switching distance.
- Various **stroke markings** to examine the scanning properties of optical sensors
- Switchable electronic **counter/frequency meter**.
- **Supply and indication field** for the voltage supply or for the switching outputs of the various sensors as well as two LEDs for indicating the switching states.
- Slot for mounting a **top-hat rail** as a holder for various sensors and post-switchgears.
- **Control field** for the driving motors of the segment disk and the carriage.
- **Adapter fields** for adapting 2-mm to 4-mm connections.

1.2 Segment Disk

1.2.1 Motor Control

The motor of the segment disk is controlled by the control field of the SENSORICS BOARD. For this, the switch must point to the symbol of the segment disk. The driving motor is switched on with the RIGHT or LEFT pushbutton and switched off with the STOP pushbutton.

These functions can also be controlled remotely by applying an high signal (< 30 V, e.g. from a sensor) at the appropriate jacks in the control field AUTO.

The speed of the disk can be set with the SPEED CONTROL knob in the range from 0 ... approx. 3000 rpm. This function cannot be controlled remotely.

NOTE: The segment disk requires a certain time to run up to the desired speed because of its inertia.

1.2.2 Mounting the Material Sample Holder

For most of the experiments, the material sample should be perpendicular to the sensor axis and have a defined distance. This is achieved by turning the segment disk until the two marking arrows face each other. The material sample holder can then be plugged into the outer jacks of the segment disk so that the clamping rail of the material sample holder is pointing towards the left hand end of the guide rail.

To realize other angles than 90° between the sensor axis and the material sample, the marking arrow on the segment disk must point to the appropriate angle marking of the SENSORICS BOARD. The material sample holder is then plugged into the inner two jacks of the segment disk.

WARNING! Do not push the material sample holder too far into the jacks otherwise the segment disk may be bent!

1.3 Carriage

1.3.1 Manual Drive

An even more accurate setting of the distance between the sensor and the material sample can be achieved by moving the carriage very finely by turning the pulley.

1.3.2 Electrical Drive

The motor of the spindle drive for the carriage is controlled by the control field of the SENSORICS BOARD. For this, the switch must point to the symbol for the carriage. The driving motor is switched on with the pushbuttons RIGHT and LEFT and switched off with the STOP pushbutton. Touch mod is also possible when the STOP pushbutton is held down and the pushbuttons RIGHT or LEFT are touched.

The three functions RIGHT, LEFT and STOP can also be remotely controlled by applying an high signal (< 30 V, e.g. from a sensor) to the appropriate jacks in the control field.

The speed of the carriage can be set with the SPEED CONTROL knob. This function cannot be controlled remotely.

NOTE: At very low speeds, the carriage may jam because of friction with the guide rail.

1.3.3 Sensor Control

To detect the distance at which an object can be recognized, the sensor must be driven to the right until the object is no longer detected (LED off).If the switching output of the sensor (SENSOR OUT) on the AUTO connector panel is then connected to the STOP jack, the carriage can be started with the LEFT pushbutton. The carriage then moves towards the object until the sensor switches (LED on).The converse is also possible. For this, the slide must be brought close to the object until the sensor recognizes it (LED on). If the STOP jack is then connected to +24 V DC of the connector panel and the sensor switching output to the RIGHT jack, the carriage moves away from the object until the sensor switches (LED off).

1.3.4 Mounting the Sensors

The sensors can be mounted on the carriage in four different positions. To examine switching distances and material dependences, the sensor must be plugged, for example so, that its top is facing to the left towards the material sample holder on the segment disk (see figure 1.3.4.1). To examine the dynamic switching behaviour, the sensor must be plugged in on the left-hand side of the slide so that its top is facing towards the segment disk (figure 1.3.4.2). For this, the carriage must be driven to the left until the sensor axis is in the centre of the appropriate segment.

NOTE: If necessary the sensors can be adjusted in their holders by turning the nuts for better reading of the distances.

WARNING! **The carriage should not be driven to the stop on the guide rail. If it is, the carriage may only be released manually!**

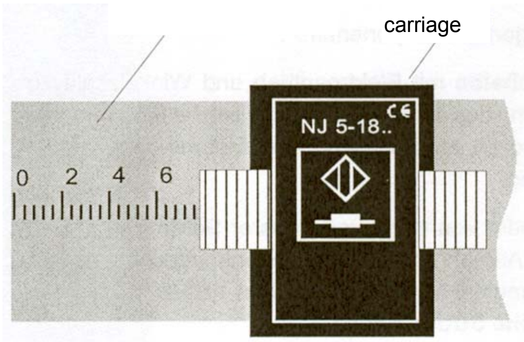

Figure 1.3.4.1

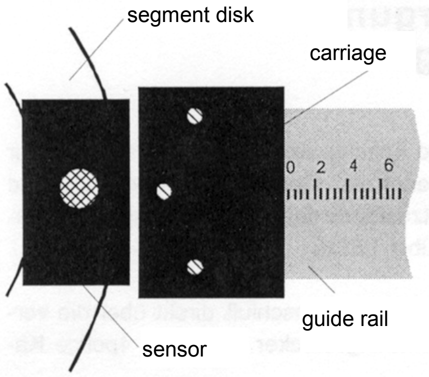

Figure 1.3.4.2

In order to scan the stroke markings, the optical sensor can also be plugged to the side of the carriage (see figure. 1.3.4.3 and figure 1.3.4.4 on the next page). Only the front centre pin should be plugged in this case, too.

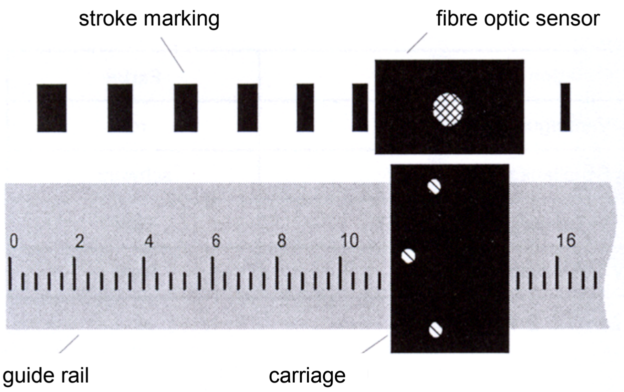

Figure 1.3.4.3

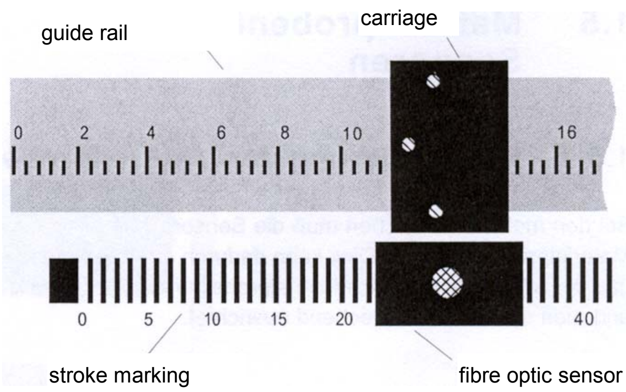

Figure 1.3.4.4

1.4 Electronic Counter / Frequency Meter

For pulse counting or frequency metering, the appropriate sensor output must be connected to the signal input „+" of the counter. With the switch in the COUNT position the counter counts all the positive edges of the input signal up to the overflow. Then it starts again at zero. The counter reading can be reset to zero at any time by pressing the RESET pushbutton. If, the switch is turned to FREQUENCY, the frequency of the input signal is displayed in Hertz (Hz) (gate time = 1 s).

1.5 Material Sample Holder and Sensors

1.5.1 Positioning of the Material Sample

For most of the experiments, the sensor axis must run centrally to the material sample. This can be achieved by driving the sensor close up to the material sample and then adjusting it accordingly.

1.5.2 Positioning of the Sensor

Since the material samples cannot be held free of play in their clamping rail and have different thicknesses, the distance between the material sample and the sensor cannot be read directly from the scale of the guide rail as a rule. It is therefore advisable, when positioning the material sample, to drive the sensor manually towards the material sample and to record the position read on the scale of the guide rail as the reference position p_0 (zero).

The axial distances s can then be calculated with $s = p_n - p_0$ from the read values p_n and the reference position p_0. Another possibility is to shift the sensors in their holders by turning the nuts so that zero of the carriage scale corresponds to the distance s = 0. This is only recommendable, however, if the material sample was not shifted or exchanged because otherwise it will be necessary to readjust the sensor every time.

NOTE: When not stated otherwise, positions must be read to the right of the carriage on the guide rail.

1.6 Supply and Indication Field

The supply and indication field serves to supply the sensors with a standard voltage of 24 V DC and to display the switching status of the sensor (output jacks SENSOR OUT) through LEDs.

Depending on its type, the sensor is connected directly with the available 2-mm connecting plugs or with the 4-pole cable socket. The cable socket has a groove which together with the tongue of the sensor connector ensures that the connections are correct. The designations according to table 1.6.2.1 are used.

Function	supply voltage (+)	switching output 1	supply voltage (-)	switching output 2
Colour	red	black	blue	white

Table 1.6.2.1

2 Inductive Sensors

2.1 Fundamentals

Inductive sensors, also known as inductive proximity switches or initiators, are widely used in automation and process technology. They are designed for self-protection against environmental influences; they are highly reliable and operate without contact and without feedback.

2.1.1 Structure and Function

The active element of an inductive sensor consists of a coil and a ferrite core (figure 2.1.1.1). If, the LC resonance circuit is excited by an oscillator, the coil generates a magnetic field which can only emerge on one side of the ferrite core (figure 2.1.1.3). This is referred to as the active surface of the inductive sensor (figure 2.1.1.2).

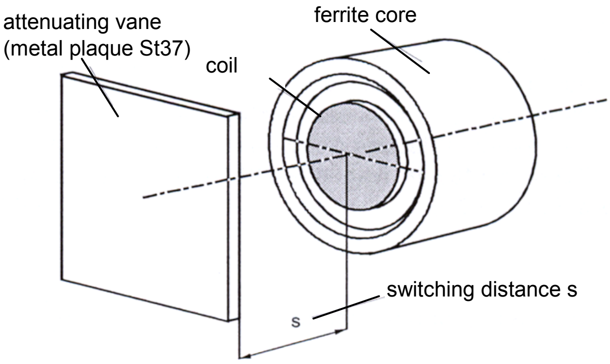

Figure 2.1.1.1

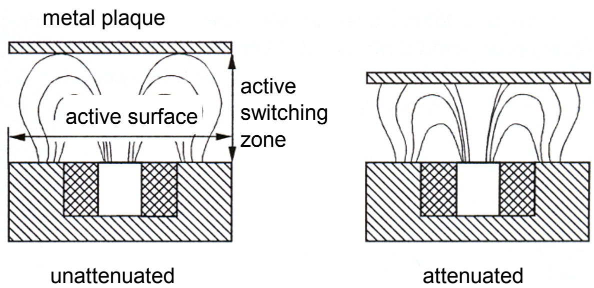

Figure 2.1.1.2 Attenuation

The emergent magnetic field is only active over a spatially restricted area (active switching zone). If, a metal plaque (e.g. attenuating vane made of St37) enters this zone, the magnetic field will be deformed or attenuated (figure 2.1.1.2).

The impedance of the coil is changed by an alteration in the magnetic field. If, the attenuation is so high that the resonance amplitude drops below a certain value, a comparator responds and outputs an output signal through the final stage.

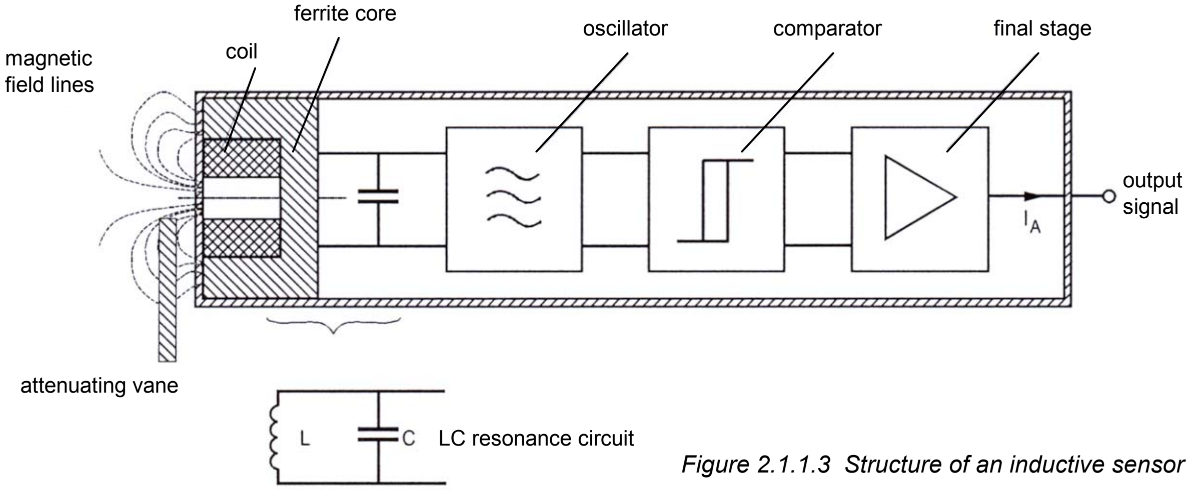

Figure 2.1.1.3 Structure of an inductive sensor

2.1.2 Rated Switching Distance

The **rated switching distance s_n** describes the maximum distance which a standard measuring plaque may be away from the sensor in order to be able to trigger a switching process. This is a pure parameter which ignores production tolerances and temperature or voltage fluctuations.

For the inductive sensor used here, the standard measuring plaque must have an area of 18 x 18 mm and a thickness of 1 mm (see figure 2.1.2.1).

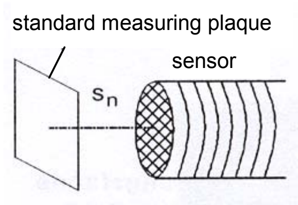

Figure 2.1.2.1

2.1.3 Reduction Factor

The **reduction factor R** allows the estimation of the switching distance s, if another material than St37 is to be detected (figure 2.1.3.1). Since magnetic reversal and eddy current losses occur in the case of ferromagnetic metals, the attenuation effect is greater than in non-ferromagnetic metals in which only eddy current losses occur. This results in different switching distances.

$$R = \frac{s}{s_n} \quad \text{etc.}$$

$$R\% = R \cdot 100\%$$

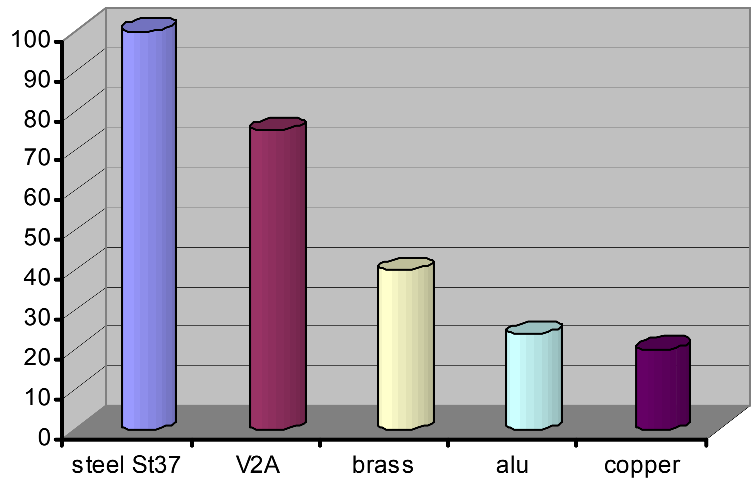

Figure 2.1.3.1 Reduction factors of different metals

2.1.4 Switching Hysteresis

The **switching hysteresis H** is the difference in displacement between the turn-on point when approaching and the turn-off point when removing the sensor from the material sample. It is given as a percentage of the rated switching distance.

$$w = p_a - p_e$$

$$H = \frac{w}{s_n} \cdot 100\%$$

w = displacement difference
p_e = turn-off position on the guide rail
p_a = turn-on position on the guide rail

2.1.5 Switching Frequency

The **switching frequency f_s** indicates how many switching processes per second are possible.

2.1.6 Speed

The **speed n** indicates the number of revolutions per minute (rpm) of the segment disk.

$$n = \frac{f_S}{N} \cdot 60$$

N = number of segments

2.1.7 Response Curve

The response curve of an inductive or capacitive sensor is the boundary line at which the output of the sensor switches when the measuring plaque crosses it (figure 2.1.7.1). The measuring plaque can be driven lateral or axial.

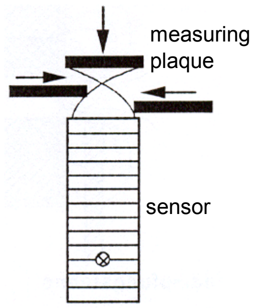

Figure 2.1.7.1

2.2 Experiments

2.2.1 Response Curve

Task:
Record the response curve (dependence of the switching distance s on the lateral shift x of the measuring plaque) of the inductive sensor with the material samples St37 and brass.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field (see figure 2.2.1.1, next page).
- Plug the sensor into the carriage of the SENSORICS BOARD with the top facing left.
- Clamp the holder with the material sample St37 into the material sample holder so that the material sample is pointing towards the sensor.
- Drive the sensor slowly towards the material sample with the carriage until it touches (distance s = 0 mm).
- Move the material sample so that it covers the sensor completely. Make sure that it is perpendicular.

  NOTE:
  - Positions on the guide rail are always read right of the carriage.
  - The carriage should be flush with a scale stroke marking to make it easier to read the positions driven to (readjust the sensor in its holder if necessary).
- Move the material sample upwards transversely to the sensor axis in the material sample holder until the sensor switches (LED off) and note the positions x_1 and $p_1 = p_0$ (n = 1).
- Move back the material sample about 2 mm transversely to the sensor axis in the material sample holder and note the position x_2 (n = 2) in table 2.2.1.1.

material sample	steel St37			brass		
n	p_n/mm	x_n/mm	s/mm	p_n/mm	x_n/mm	s/mm
1						
2						
3						
4						
5						
6						
7						
8						
9						

Table 2.2.1.1

- Now drive the sensor slowly by hand away from the material sample until the sensor switches (LED off) and note the position p_2 (n = 2).
- Repeat this step until the material sample St37 is back in its initial position x_0. Note all positions x_n in table 2.2.1.1. Repeat this with the material sample brass.

- Calculate all switching distances $s = p_n - p_0$ from the read values and enter them in table 2.2.1.1.
- Transfer the switching distance s via lateral shift x to the diagram (figure 2.2.2.2).

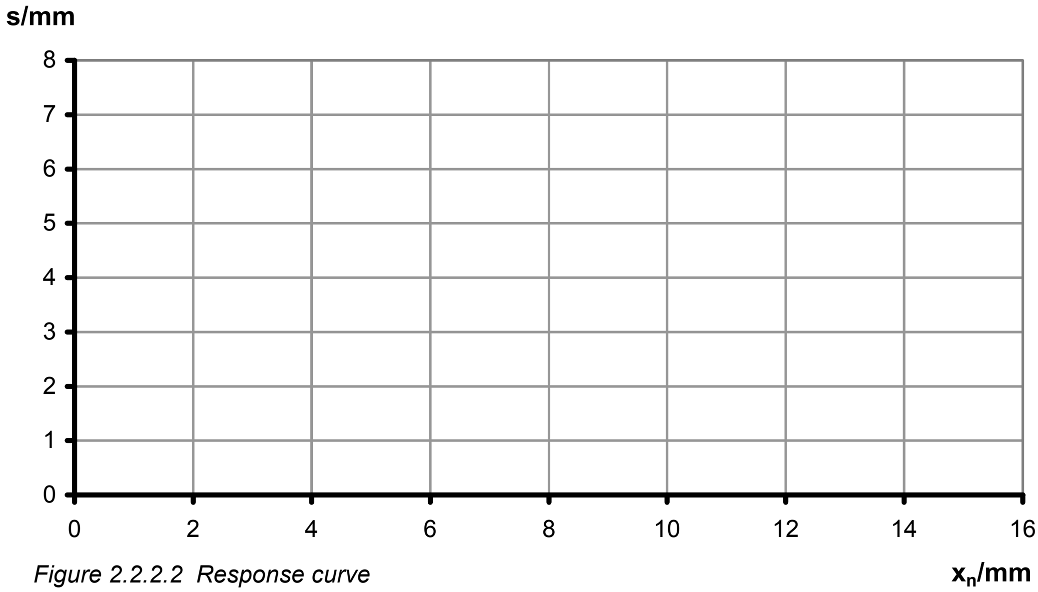

Figure 2.2.2.2 Response curve

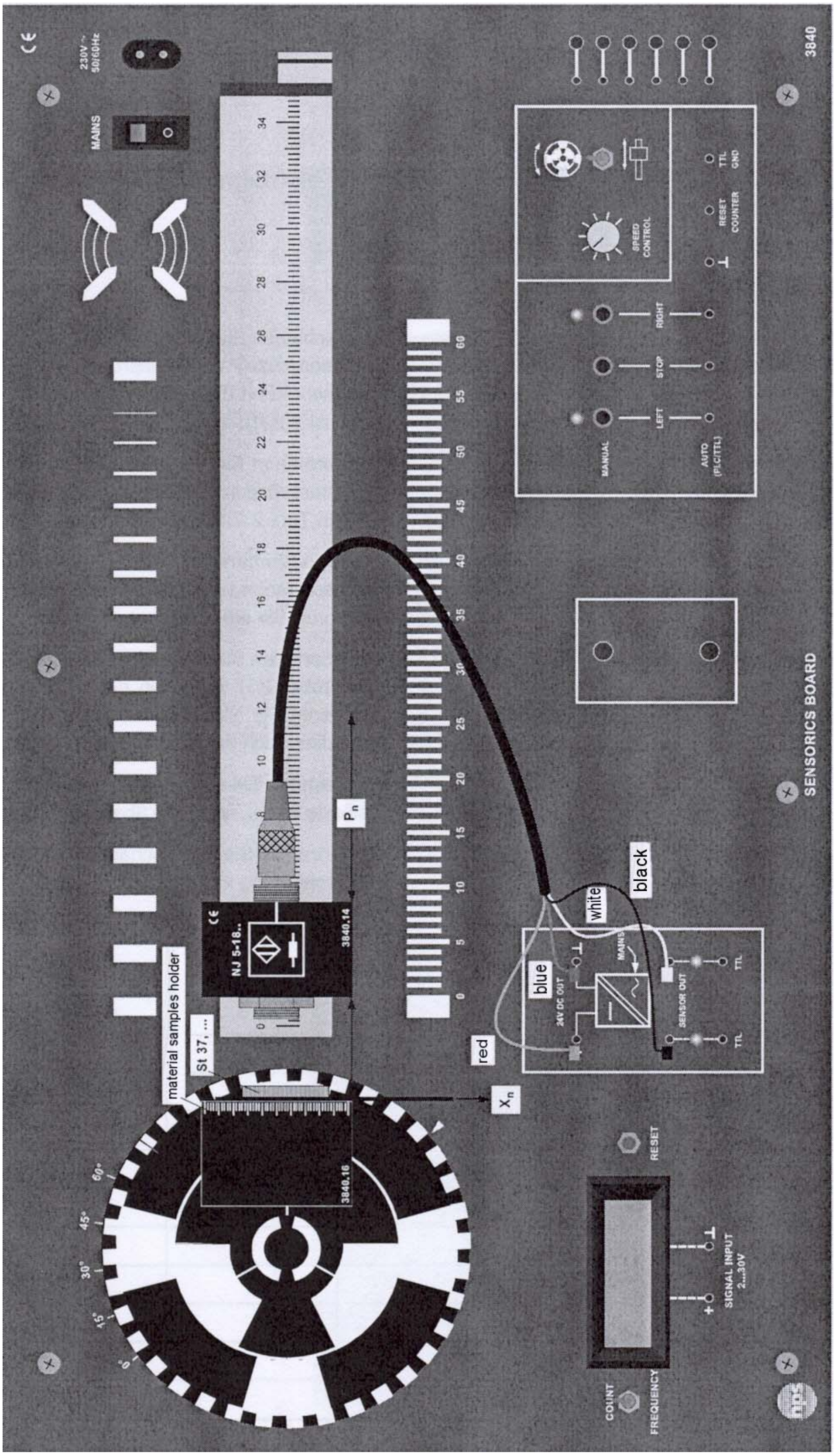

Figure 2.2.1.1 Experiment set-up: Response curve

2.2.2 Switching Hysteresis

Task:
Record the displacement distance between the turn-on and turn-off point (switching hysteresis) of the inductive sensor with the material samples St37, brass and aluminium.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with the top facing left.
- Clamp the holder with the material sample St37 into the material sample holder so that the material sample is pointing towards the sensor.
- Drive the sensor slowly towards the material sample with the carriage until it touches and move the material sample so that it covers the sensor completely.
- Drive the sensor away from the material sample slowly until it switches (LED off) and note the turn-off position pa of the carriage in table 2.2.2.1.
- Drive the sensor slowly towards the material sample until it switches (LED on) and note the turn-on position p_e of the carriage in table 2.2.2.1 (take a few readings and average them if necessary).
- Calculate the displacement difference $w = p_a - p_e$ and enter the result in table 2.2.2.1.
- Repeat this procedure with the other material samples specified in table 2.2.2.1.
- Calculate the switching hysteresis H in percent from the displacement distance w and the rated switching distance s_n = 5 mm.

material sample	p_a/mm	p_e/mm	w/mm	s_n/mm	H/%
steel St37					
brass					
aluminium					

Table 2.2.2.1

2.2.3 Switching Behaviour – Material Dependence

Task:
Examine the switching behaviour of the inductive sensor with different materials.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with the top facing left.
- Clamp the holder with the material sample St37 into the material sample holder so that the material sample is pointing towards the sensor.
- Adjust the material sample centrally to the sensor and drive the sensor to a starting position about 10 mm away from the material sample.
- Then drive the sensor slowly towards the material sample with the carriage until the sensor switches (LED on) or touches the material sample.
- Repeat this procedure with the other material samples specified in table 2.2.3.1.

material sample	steel St37	brass	aluminium	copper*	synthetic material	permanent magnet (large)
LED on						
LED off						

Table 2.2.3.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil".

Question:	With which materials does the sensor switch, with which not? Give reasons for your answer.
Answer:	

2.2.4 Reduction Factor

Task:
Determine the reduction of the switching distance of the inductive sensor in relation to that with St37 for different materials. The reduction factor can be calculated from this.

Experiment procedure:
- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with the top facing left and clamp the holder with the material sample St37 into the material sample holder so that the material sample is pointing towards the sensor.
- Drive the sensor slowly towards the material sample with the carriage until the sensor touches the material sample (distance s = 0 mm).
- Move the material sample so that it covers the sensor completely. Make sure that it is perpendicular (move the sensor if necessary).
- Read the reference position (zero) p_0 of the carriage from the scale of the guide rail and enter it in table 2.2.4.1 (see chapter 1.5.2).
- Now drive the sensor slowly away from the material sample with the carriage until the sensor switches (LED off) and note the turn-off position p_a.
- Repeat this procedure with the other material samples specified in table 2.2.4.1 and determine the switching distance $s = p_a - p_0$ for each sample.
- Calculate the reduction factor R with s_n = 5 mm for all material samples as a decimal number and a percentage.

material sample	p_0/mm	p_a/mm	s/mm	R	R/%
steel St37					
copper*					
brass					
aluminium					

Table 2.2.4.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil“.

Question:	Compare the reduction factor of copper with that in figure 2.1.3.1. Give reasons for any differences.
Answer:	

2.2.5 Releasing a Switching Process through a Casing Wall

Task:
Examine the possibility of releasing switching processes through a casing wall with the inductive sensor.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with the top facing left (see figure 2.2.5.1).
- Clamp the holder with the material sample St37 in the material sample holder so that it is pointing towards the sensor (see figure 2.2.5.1).
- Then hold the material sample thick/thin directly in front of the material sample St37 so that the thin casing wall touches the material sample (see figure 2.2.5.1).

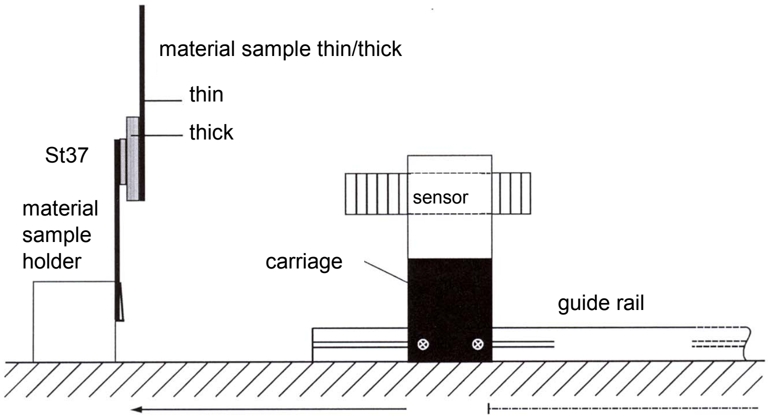

Figure 2.2.5.1 Experiment set-up

- Drive the sensor slowly towards the casing wall until it switches and note the turn-on position p_e in table 2.2.5.1.
- Repeat the procedure with the other metallic material samples specified in table 2.2.5.1.
- Repeat this procedure with the thicker casing wall.

casing wall	p_e/mm for St37	p_e/mm for brass	p_e/mm for aluminium
board thin			
board thick			

Table 2.2.5.1

Question 1:	Does the casing wall affect the switching distance?
Answer:	

Question 2:	How does the inductive sensor react to a metallic casing wall?
Answer:	

2.2.6 Frequency Counting – Speed Measuring

Task:
Examine the detection of rotary movements with the inductive sensor and determine the frequency f_s and the speed n.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field. Connect the switching output of the sensor to the signal input of the counter (switching position COUNT), (see figure 2.2.6.1 on the next page).
- Drive the carriage of the SENSORICS BOARD to the left end of the guide rail.
- Plug the sensor into the carriage so that its top facing is pointing to the segment disk and shift the carriage in such a way that the sensor detects the four outer segments of the disk.

  WARNING! Sensor may not touch the segment disk!
- Then check, by turning the segment disk, whether the sensor recognizes all segments reliably and the counter indicates the recognized segments (adjust the sensor if necessary).
- Switch the counter to frequency metering (switching position FREQUENCY) and set the speed of the segment disk so that a switching frequency f_s = 80 Hz is indicated.
- Then shift the carriage with the segment disk still running so that the sensor detects the inner segments of the disk and enter the switching frequency in table 2.2.6.1.
- Adjust the SPEED CONTROL knob so that max. switching frequency is indicated and enter the values in table 2.2.6.1.
- Then shift the carriage with the segment disk still running so that the sensor detects the outer segments of the disk again and enter the switching frequency in table 2.2.6.1.
- Calculate the speeds n of the segment disk for the switching frequencies f_s to be determined with the number of segments N.

segment ring	N	f_S/Hz	$n = f_S/N \cdot 60$ (rpm)
outer	4	80	
inner	3		
outer	3		
inner	4		

Table 2.2.6.1

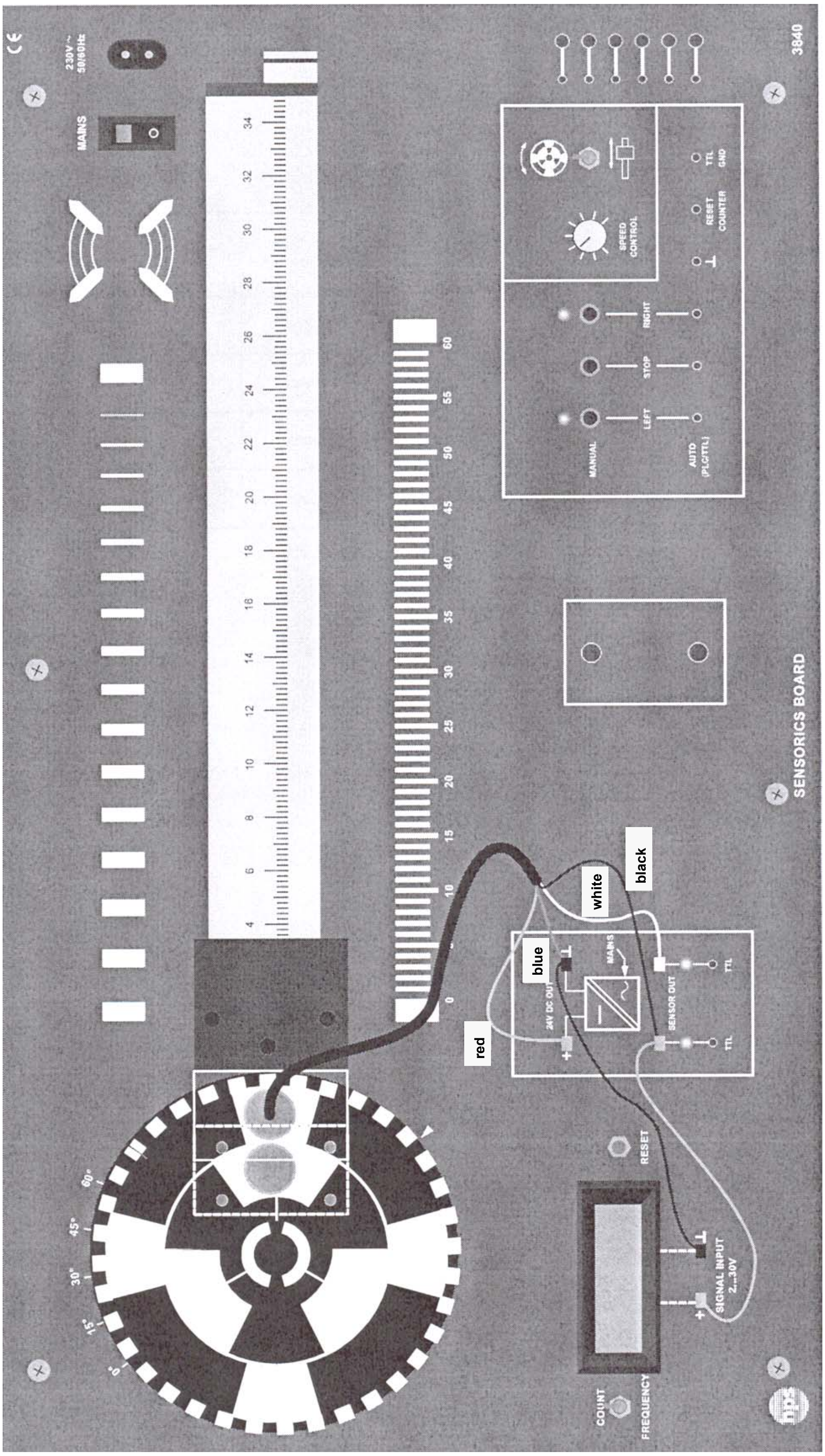

Figure 2.2.6.1 Experiment set-up: Frequency counting – speed measuring

2.2.7 Oscillator Frequency

Task:
Measure the oscillator frequency of the inductive sensor (LC resonance circuit) with the aid of an additional material sample „coil“ and an oscilloscope.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field (see figure 2.2.7.1, next page).
- Plug the sensor into the carriage of the SENSORICS BOARD with the top facing left.
- Clamp the holder with the material sample „coil“ into the material sample holder so that the material sample is pointing towards the sensor.
- Adjust the material sample centrally to the face of the sensor.
- Connect an oscilloscope to the material sample „coil“ jacks with a screened line.
- Set the oscilloscope to a voltage range of 10 mV DC and a time of 0.5 μs.
- Drive the sensor manually towards the material sample until the amplitude on the oscilloscope has reached its maximum voltage value.
- Read the time of one period T from the oscilloscope, calculate the frequency f and enter the signal in the given grid (figure 2.2.7.2).

$T = \ldots\ldots\ldots\ldots\ldots$

$f = \ldots\ldots\ldots\ldots\ldots$

Settings on the oscilloscope:

U = 10 mV / div.

t = 0.5 μs / div.

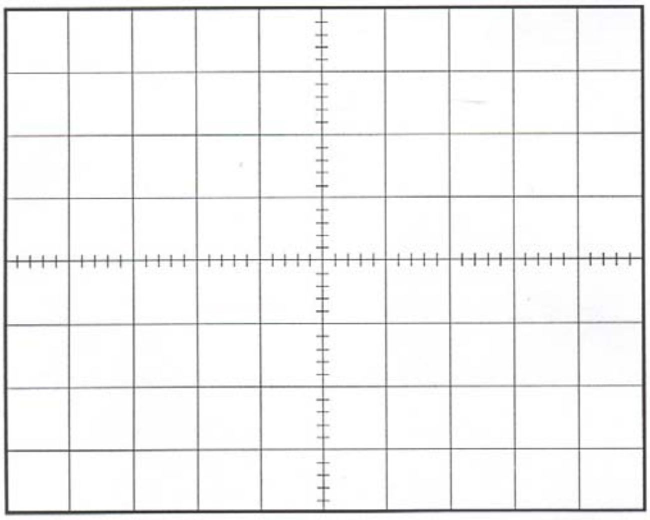

Figure 2.2.7.2

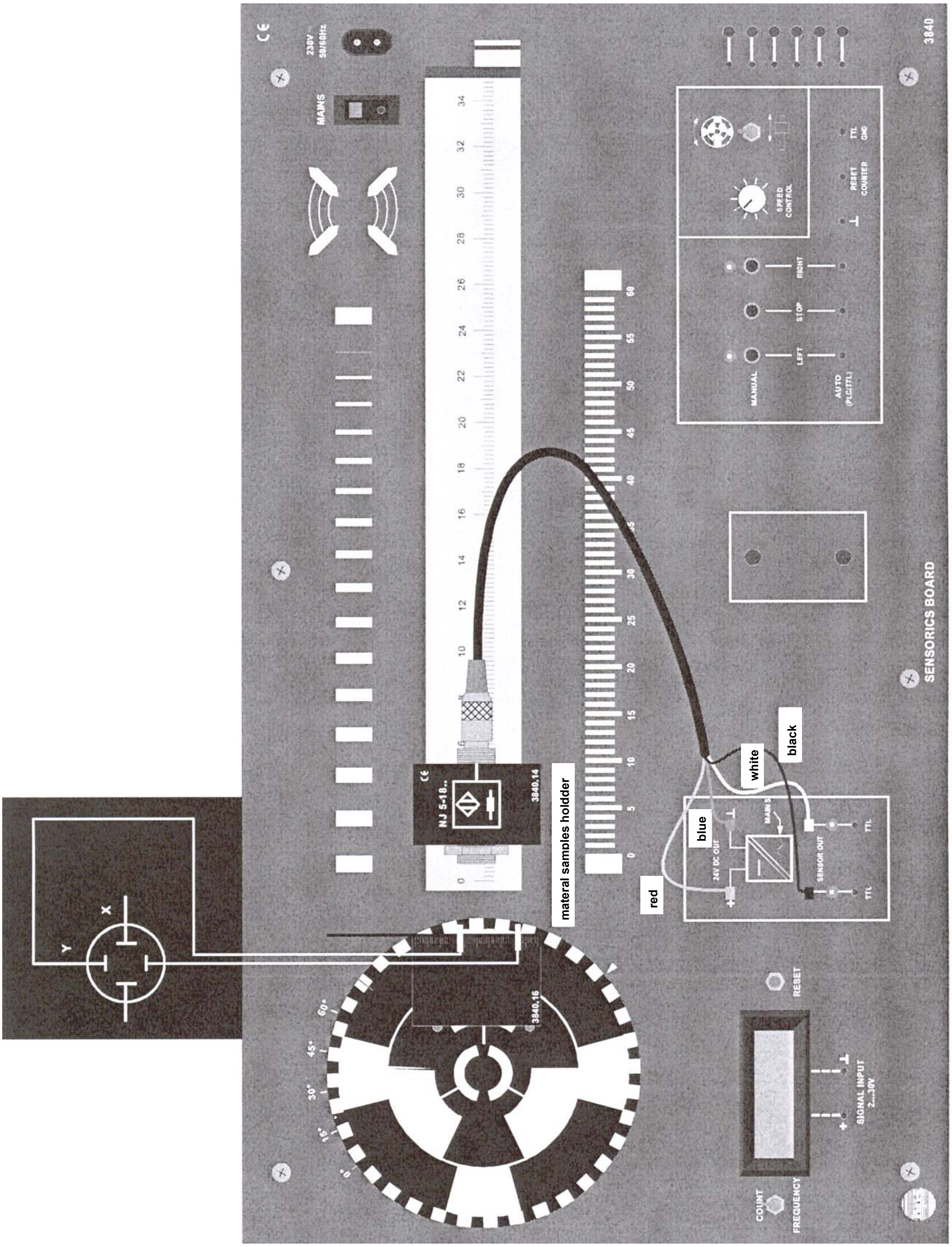

Figure 2.2.7.1 Experiment set-up: Oscillator frequency

3 Capacitive Sensors

3.1 Fundamentals

Capacitive sensors, also known as capacitive proximity switches, are used to detect non-conductive materials such as plastic, wood, glass, etc. Like the inductive sensors, they operate without contact and without feedback.

3.1.1 Structure and Function

The active element of a capacitive sensor consists of a sensor electrode and a screen (figure 3.1.1.1). These two electrodes together form a capacitor.

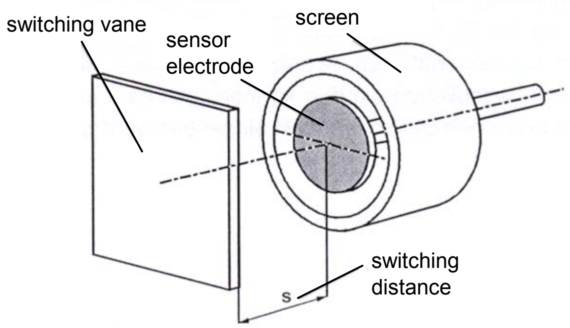

Figure 3.1.1.1

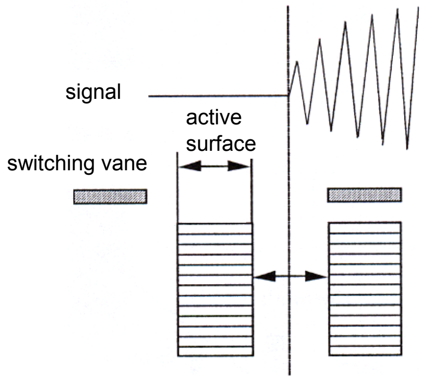

Figure 3.1.1.2

If, a switching vane (metallic or non-metallic object) approaches the sensor, there is a change in capacitance in the electrical field of this capacitor, i.e. the capacitor of the RC resonance circuit is arranged (figure 3.1.1.3) so that its capacitance increases when an object approaches (change in capacitance ΔC).

The oscillator is tuned in such a way that it is capable of oscillating until this increase in capacitance takes place. The start of oscillation caused by an approaching object (figure 3.1.1.2) is detected by a comparator and output through the final stage.

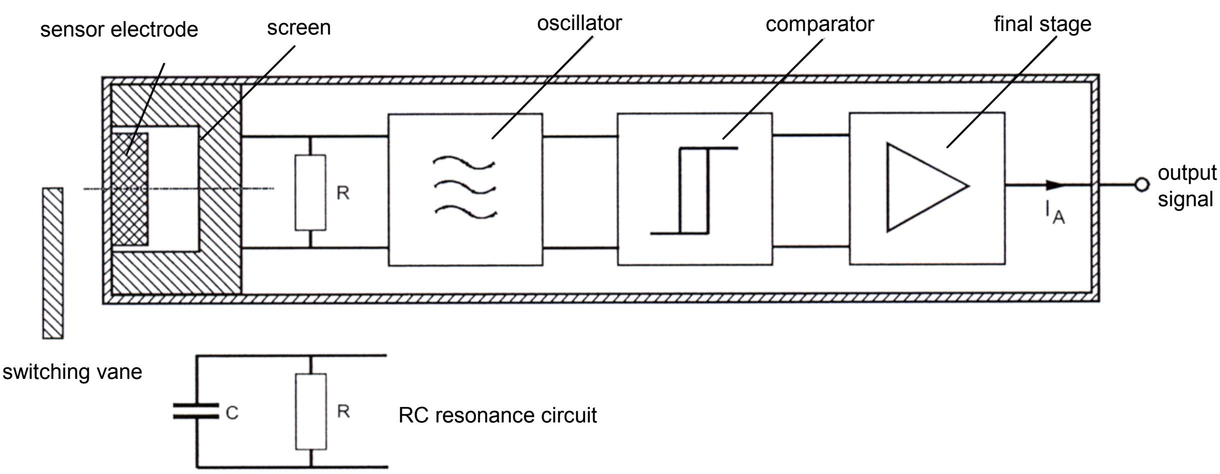

Figure 3.1.1.3 Structure of a capacitive sensor

3.1.2 Reduction Factor

Like in the inductive sensors the **reduction factor R** is material-dependent. It describes by what factor the switching distance s is reduced for a certain material, in relation to the rated switching distance s_n, which results from using an earthed metal plaque (switching vane).

A deviation of the switching distance is to be expected in the case of a temperature-dependent permittivity factor ε_r. Capacitive sensors with an adjustable switching point are available in order to be able to compensate different switching distances of different materials.

WARNING! The switching distance may not be set too high because the oscillator would otherwise become instable!

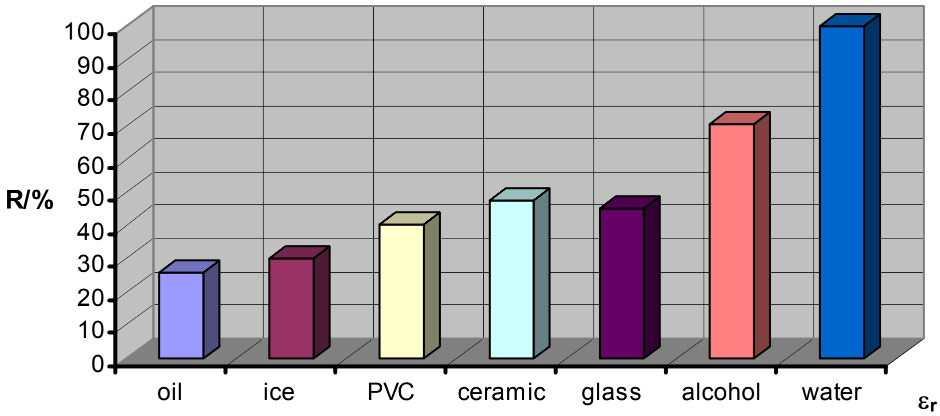

Figure 3.1.2.1 Permittivity factors of different materials

3.1.3 Sensitivity

The sensitivity is determined by the change in capacitance ΔC_s at which a change in the switching signal takes place at the sensor output. For reasons of simplification the system „material sample/sensor“ is considered as a plate capacitor with circular plates (diameter d = 18 mm).

$$\Delta C_S = C_e - C_a \qquad C_e = \frac{\varepsilon_0 \cdot A}{p_e} \qquad C_a = \frac{\varepsilon_0 \cdot A}{p_a} \qquad A = \pi \cdot d^2$$

C_e = capacitance in the turn-on piont
C_a = capacitance in the turn-off point

A = plate area
d = diameter of the plates

3.1.4 Permittivity Factor

The **permittivity factor ε_r** (permittere (lat.) = penetrate) of an insulator indicates how much greater the electrical flow density becomes when the appropriate insulator is used as a dielectric instead of vacuum (air).

$$\varepsilon_r = \frac{D}{D_0} \qquad D = \varepsilon_0 \cdot \varepsilon_r \cdot E \qquad \varepsilon_0 = 8.85 \cdot 10^{-12} \, (As \cdot m^{-1})$$

D = electrical flow density in the dielectric
D_0 = electrical flow density in the vacuum
E = electrical field strength
ε_0 = electrical field constant

3.2 Experiments

3.2.1 Response Curve

Task:
Record the response curve of the capacitive sensor with steel St37 and synthetic material.

Experiment procedure:

- Connect the sensor into the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor to the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the holder with the material sample St37 into the material sample holder so that the material sample is pointing towards the sensor.
- Then drive the sensor slowly towards the material sample with the carriage until it touches it (distance s = 0 mm).

  NOTE:
  - Make sure that the material sample is perpendicular and completely covers the sensor.
  - The carriage should be flush with the scale stroke of the guide rail for easier reading of the positions (readjust the sensor in the holder if necessary).
- Drive the sensor back so that the distance s from the material sample is equal to the rated switching distance s_n= 8 mm and increase the sensitivity by turning the potentiometer until the material sample is recognized (LED on).
- Then reduce the sensitivity so that the sensor does not quite switch.
- Drive the sensor back to position p_0.
- Then shift the material sample upwards transversely to the sensor axis in the material sample holder until the sensor switches (LED off) and note the positions x_1 and $p_1 = p_0$ (n = 1).
- Move the material sample back about 2 mm transversely to the sensor axis and note the position x_2 (n = 2).

material sample	steel St37			synthetic material		
n	p_n/mm	x_n/mm	s/mm	p_n/mm	x_n/mm	s/mm
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Table 3.2.1.1

- Then drive the sensor slowly away from the material sample until the sensor switches (LED off) and note position p_2 (n = 2). Repeat this procedure until the material sample is back in its initial position x_0 (n = 3 ... 10). Repeat this method with the material sample synthetic material (do not alter the sensitivity).
- Calculate all switching distances $s = p_n - p_0$ from the read values and enter them in table 3.2.1.1. Transfer the switching distance s via the lateral shift x to figure 3.2.1.1.

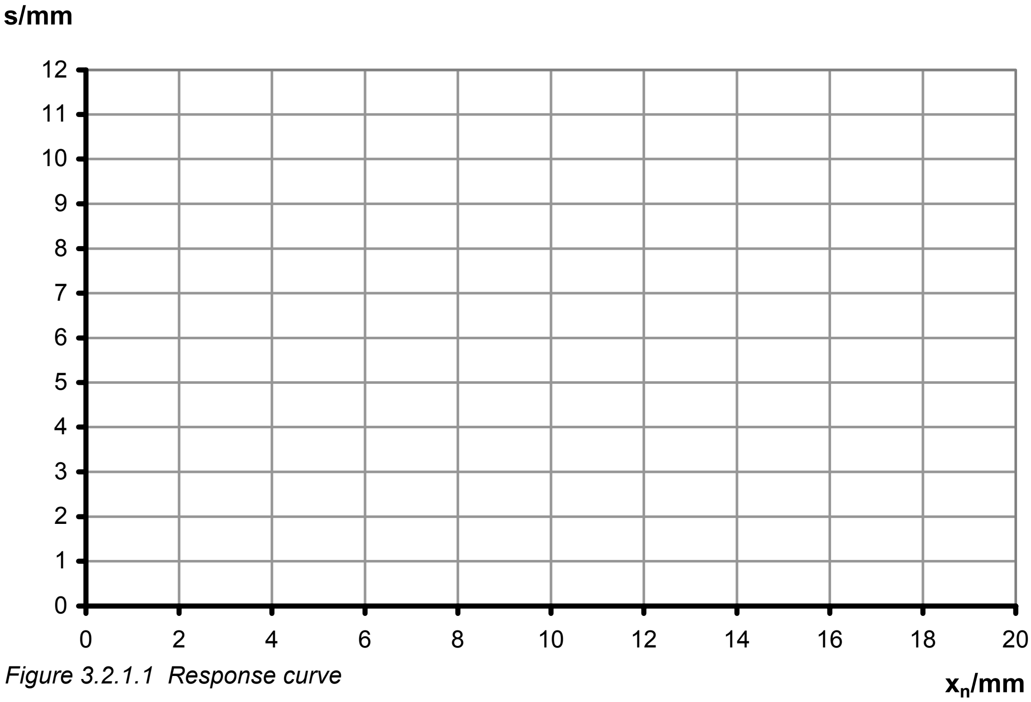

Figure 3.2.1.1 Response curve

3.2.2 Types of Actuation

Task:
Examine the types of actuation of the capacitive sensor for:

- material sample non-conductive (synthetic material
- material sample conductive insulated (copper)
- material sample conductive earthed (copper)

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the holder with the material sample synthetic material into the material sample holder so that the material sample is pointing towards the sensor (type of actuation 1).
- Then drive the sensor slowly towards the material sample until it touches it (s = 0 mm) and record position p_0. Enter the value in table 3.2.2.1.

  NOTE: Make sure that the material sample is perpendicular and completely covers the sensor. Fahren Sie den Sensor so weit nach rechts, bis die LED erlischt.
- Drive the sensor to the right until the LED goes out.
- Drive the sensor towards the material sample until it switches (LED on).
- Record the position p_e. Enter the value in table 3.2.2.1.
- Calculate the switching distance $s = p_e - p_0$.
- Clamp the material sample copper into the material sample holder (type of actuation 2).
- Repeat the same procedure as above and enter the positions in table 3.2.2.1.
- Then connect the material sample copper to the ground of the supply and indication field through a jack and repeat the procedure above (type of actuation 3).
- Compare the results of the three different types of actuation in a summary (table 3.2.2.2).

type of actuation	p_0/mm	p_e/mm	s/mm
1			
2			
3			

Table 3.2.2.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil“.

1. material sample non-conductive	2. material sample conductive insulated	3. material sample conductive earthed

Table 3.2.2.2 Summary

3.2.3 Switching Behaviour – Material Dependence

Task:
Examine the switching behaviour of the capacitive sensor in dependence of different materials.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the holder with the material sample St37 into the material sample holder so that the material sample is pointing towards the sensor.
- Drive the sensor to its starting position about 4 mm away from the material sample.
- Then set the sensitivity of the sensor so that it switches reliably (LED on).
- Then drive the sensor slowly away from the material sample with the carriage and check whether the sensor switches (LED off). This guarantees that the sensor does not overload (LED lights steady).
- Now change the material sample according table 3.2.3.1. Examine whether the material sample is detected by the sensor and the sensor is overloaded.
- Summarize the results in a generally valid statement.

material sample	steel St37	brass	aluminium	copper*	synthetic material	permanent magnet, (large)
LED on						
LED off						

Table 3.2.3.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil“.

summary:

3.2.4 Reduction Factor

Task:
Determine the reduction of the switching distance of the capacitive sensor in relation to that with St37 for different materials. The reduction factor can be calculated from this.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with the top facing left.
- Clamp the holder with the material sample St37 into the material sample holder so that the material sample is pointing towards the sensor.
- Drive the sensor slowly towards the material sample with the carriage until the sensor touches it (distance s = 0 mm).
- Transfer the reference position (zero) p_0 of the carriage to the measuring scale in table 3.2.4.1 (see chapter 1.5.2).
- Now drive the sensor to the position $p_a = p_0 + s_n$ (s_n = 8 mm) and set the sensitivity of the sensor so that the material sample is just recognized (LED is still alight).
- Check whether the sensor switches (LED off) when the sensor is driven away from the material sample. Then determine the positions p_0 (s = 0) and p_a (LED off) for the material samples specified in table 3.2.4.1 (do not change the sensitivity).
- Note all the results in table 3.2.4.1 and determine the switching distance $s = p_a - p_0$ for each.
- Calculate the reduction factor R for all material samples as a decimal number and a percentage. Select s_n so that R = 1 (100%) for St37.

material sample	p_0/mm	p_a/mm	s/mm	R	R/%
steel St37					
copper*					
board thin					
board thick					

Table 3.2.4.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil“.

3.2.5 Releasing a Switching Process through a Casing Wall and Detecting of Wall Thicknesses

Task:
Examine the possibility of releasing switching processes through a casing wall or detect wall thicknesses with the capacitive sensor.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with the top facing left.
- Clamp the holder with the material sample board thick/thin in the material sample holder.
- Then drive the sensor slowly towards the material sample with the carriage until it touches the material sample (s = 0 mm).
- Set the sensitivity so that the material sample is not quite recognized.
- Then hold the material sample synthetic material against the back of the simulated casing wall. Note the switching state of the LED in table 3.2.5.1.
- Repeat this procedure for the material sample St37.
- Then drive the sensor about 6 mm away from the material sample and check the switching states of the two material samples.
- Set the same sensitivity as above.
- Repeat the experiment with the thicker casing wall for both material samples.

casing wall	board thin				board thick			
switching distance	s_0 = 0 mm		s_1 = 6 mm		s_0 = 0 mm		s_1 = 6 mm	
LED	on	off	on	off	on	off	on	off
synthetic material								
steel St37								

Table 3.2.5.1

3.2.6 Filling Level Detection

Task:
Watch the fill level of a vessel with the capacitive sensor.

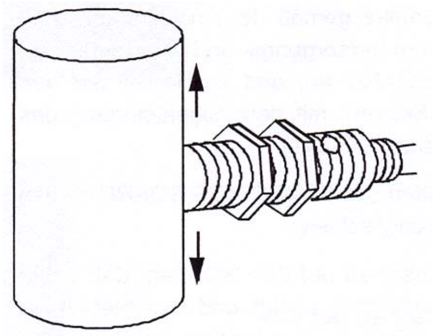

Figure 3.2.6.1

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Place the sensor on a table with its pins facing upwards.
- Place a glass (beaker) in front of the sensor so that its face touches the casing wall (figure 3.2.6.1).

  NOTE: The glass should have a smooth wall and a thin bottom if possible. You can also use a plastic or paper cup.
- Set the sensitivity so that the vessel is just not recognized (LED off).
- Now fill the vessel with water or another liquid and observe the switching behaviour of the sensor.
- Repeat the procedure with different filling levels and sensitivity settings.
- Summarize the results in a general statement.

summary:

3.2.7 Frequency Counting – Speed Measuring

Task:
Examine the detection of rotational movements with the capacitive sensor and determine the frequency f_s and the speed n.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field. Connect the switching output of the sensor to the signal input of the counter (switching position COUNT).
- Drive the carriage of the SENSORICS BOARD to the left end of the guide rail.
- Plug the sensor into the carriage so that its top is pointing towards the segment disk and shift the carriage so that the sensor detects the inner three segments of the disk.

  WARNING! The sensor may not touch the segment disk!
- Now check, by turning the segment disk, whether the sensor recognizes all segments reliably and the counter indicates the number of detected segments (readjust the sensor sensitivity if necessary).
- Switch-over the counter to frequency metering (switch position FREQUENCY) and set the speed of the segment disk so that a switching frequency f_s = 60 Hz is indicated.
- Then, whilst the segment disk is in motion, move the carriage so that the sensor detects the outer segments of the disk and enter the switching frequency in table 3.2.7.1
- Turn the SPEED CONTROL knob to its end stop and set the sensitivity so that the maximum switching frequency is indicated. Enter the value in table 3.2.7.1.
- Then, whilst the segment disk is in motion, shift the carriage so that the sensor detects the inner segments again and enter the switching frequency in table 3.2.7.1
- Calculate the speeds n of the segment disk.

segment ring	N	f_S/Hz	$n = f_S/N \cdot 60$ (rpm)
inner	3	60	
outer	4		
outer	4		
inner	3		

Table 3.2.7.1

4 Magnetic Field Sensors

4.1 Fundamentals

Magnetic field sensors react to magnetic fields of permanent magnets or electromagnets. Different principles are implemented in the construction of these sensors, e.g. Hall sensors, magnetoresistive sensors and saturation core probes.

In Hall sensors and magnetoresistive sensors, the lateral deflection of an electron flow through a magnetic field (Hall effect) is evaluated. Because of the implemented semiconductor materials (effect of temperature), these two methods are less suitable for use as proximity switches.

Saturation core probes on the other hand have a more stable operating behaviour on account of their low eddy-current and hysteresis losses.

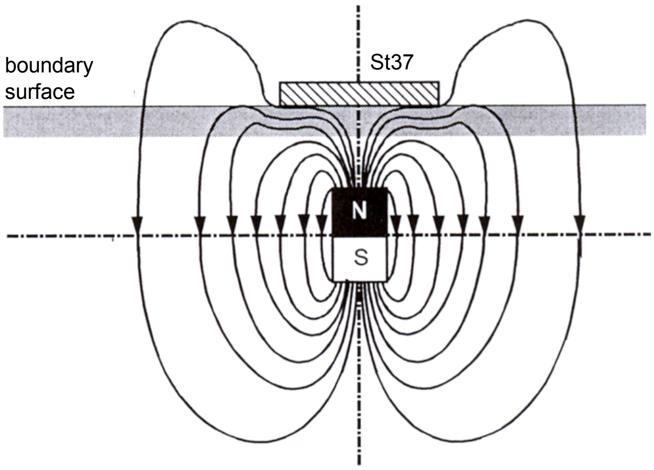

Figure 4.1.1 Magnetic field of a permanent magnet

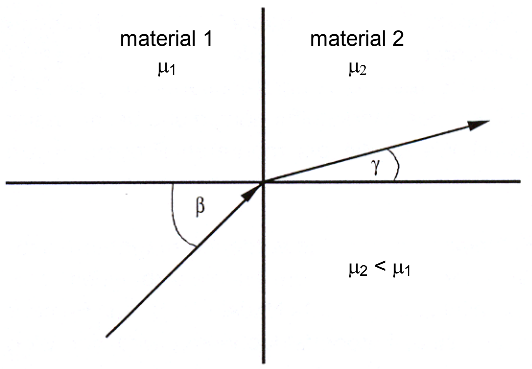

Figure 4.1.2 Refraction of magnetic field lines at a boundary surface

Figure 4.1.1 shows that the field lines outside a permanent magnet run from the north to the south pole. The field lines are broken at the boundary between two contacting materials if they are not vertical. The two materials must exhibit different permeability. This effect (figure 4.1.2) can be exploited by deflecting and guiding the field lines through ferromagnetic materials (e.g. St37).

$$\frac{\tan\beta}{\tan\gamma} = \frac{\mu_1}{\mu_2} \quad mit\ \mu_2 < \mu_1 \qquad \mu = permeability$$

The magnetic field (figure 4.1.1) is deformed by a plaque made of St37. This deformation can be measured with a suitable magnetic field sensor.

4.1.1 Magnetoresistive Sensors

Magnetorsistive sensors are based on the change in electrical resistance of soft magnetic alloys under the influence of a longitudinal or transversal magnetic field. This relative change in resistance may reach values of several percent in such sensors (material-dependent and at normal room temperature). The magnetoresistive sensors which became well-known as field plates are semiconductor elements in which fine needles

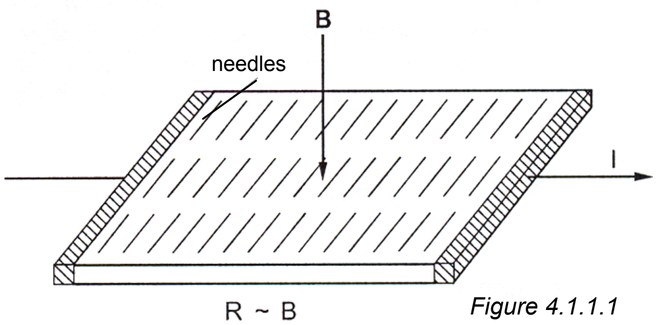

Figure 4.1.1.1

(e.g. Fe or NiSb) are embedded in parallel (figure 4.1.1.1). The path through the sensor element is prolonged dependent on the magnetic field which causes an increase in the resistance. Magnetoresistive sensors are used increasingly for measuring DC and AC magnetic fields. They are more sensitive than Hall sensors and can be used over a greater temperature range.

4.1.2 Hall Sensors

In Hall sensors, the lateral deflection of the electron flow through the magnetic field is evaluated as **Hall voltage U_H**. The Lorentz force is responsible for the fact that the electrons are deflected by the magnetic field. One side is then lacking in electrons whilst the other side is enriched with electrodes. This produces the Hall voltage.

$$U_H = R_H \cdot \frac{B \cdot I}{s}$$

R_H = *Hall coefficient* | B = *magnetic flow density*
I = *current strength* | s = *conductor thickness*

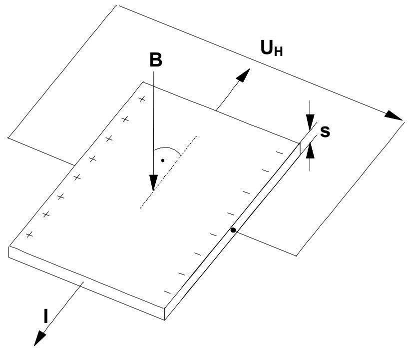

Figure 4.1.2.1 Hall effect

4.1.3 Saturation Core Probes

Saturation core probes are used mainly to determine small field strengths. They exploit the non-linearity of magnetization curves of high-permeable, soft magnetic materials. The probe consists of one or two highly permeable core rods or a toroidal core (figure 4.1.3.1).The core material is controlled periodically into saturation by an alternating current in the magnetization winding. This induces a voltage in the probe winding. An alternative method for saturation core probes is the method with a ferrite core and yoke (figure 4.1.3.2). In this type of probe a resonance circuit is used as in the inductive sensor. The strong preattenuation from the yoke, however, causes the saturation core probe to behave similarly to the capacitive sensor and exactly opposite to the inductive sensor. Without an external magnetic field the oscillator does not oscillate on account of the preattenuation. If a magnetic field is moved towards the sensor the yoke quickly goes into saturation and the magnetic resistance increases. The oscillator can then oscillate and the sensor current I increases (figure 4.1.3.3).

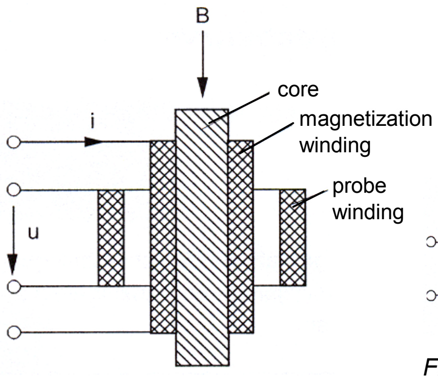

Figure 4.1.3.1 Saturation core probe with one core

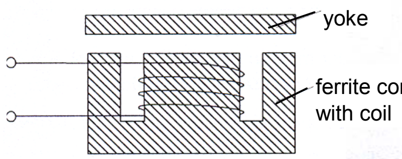

Figure 4.1.3.2 Saturation core probe with ferrite core and yoke

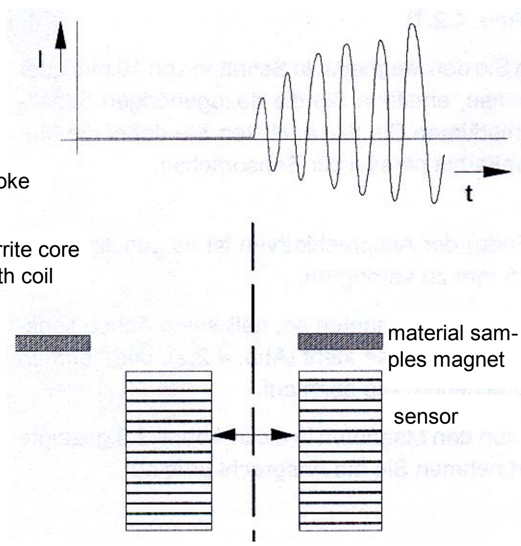

Figure 4.1.3.3 Current consumption of a saturation core probe with yoke

4.2 Experiments

4.2.1 Response Curve

Task:
Record the response curve of the magnetic field sensor at different positions of the pole axis of a permanent magnet.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.

  WARNING! The active surface of the sensor must be flush with the installation nut!
- Place the sensor with its pins facing upwards on the worksheet provided (figure 4.2.1.4, next page).
- Mark the position of the sensor and its axis.
- Remove the large permanent magnet from the board.
- Move the large permanent magnet axially towards the sensor and mark the switching point. Make sure that the magnet axis runs parallel to the sensor axis (figure 4.2.1.1)
- Move the magnet in steps of 10 mm transversely to the sensor axis, determine the corresponding switching points and mark them. Keep the magnet axis held parallel to the sensor axis.

  NOTE: At the edge (end) of the response curves, it is advisable to reduce the steps to 5 mm.
- Then turn the magnet so that its axis is perpendicular to the sensor axis (figure 4.2.1.2) and record the response curve as above.
- Then move the magnet to the position shown in figure 4.2.1.3 and record the response curve.

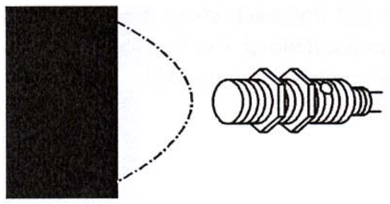

Figure 4.2.1.1

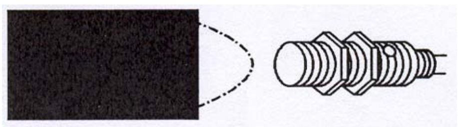

Figure 4.2.1.2

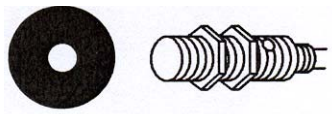

Figure 4.2.1.3

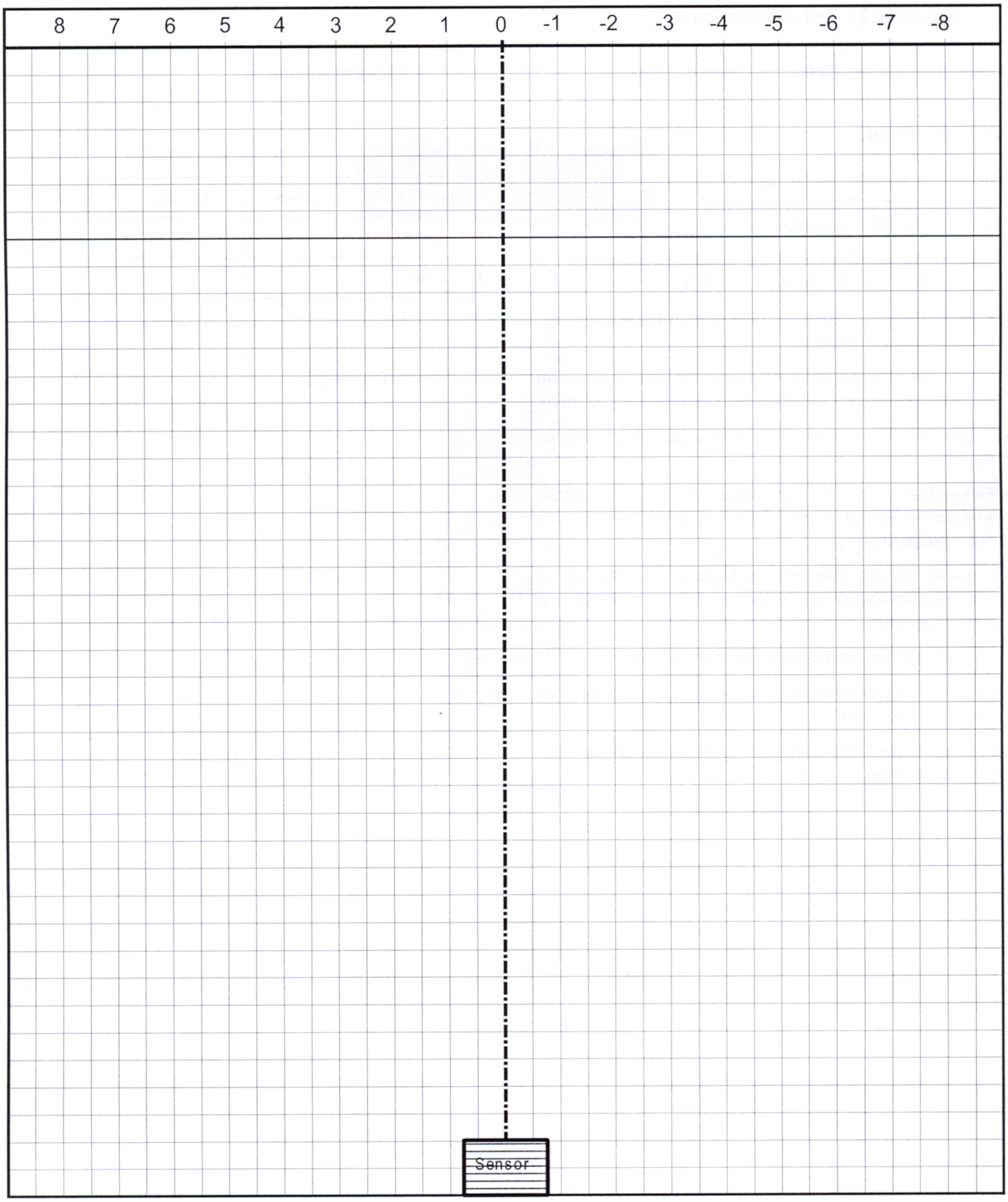

Figure 4.2.1.4 Worksheet: Response curve of the magnetic field sensor

4.2.2 Switching Distance

Task:
Determine the influence of permanent magnets on the switching distance of the magnetic field sensor.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the board with the large permanent magnet into the material sample holder.
- Then drive the sensor slowly towards the magnet with the carriage until it touches (distance s = 0 mm).
- Enter the reference position (zero) p_0 of the carriage on the (measuring scale) in table 4.2.2.1.
- Then drive the sensor slowly away from the permanent magnet until the sensor switches (LED off) and note the turn-off position p_a.
- Clamp the holder with the material sample St37 into the material sample holder and fix the small permanent magnet to it.
- Repeat the procedure as above.
- Calculate the switching distance $s = p_a - p_0$ and enter it in table 4.2.2.1.
- Summarize the results in a general statement.

permanent magnet	p_0/mm	p_a/mm	s/mm
large			
small			

Table 4.2.2.1

summary

4.2.3 Switching Hysteresis

Task:
Record the displacement difference between the turn-on and turn-off point (switching hysteresis) of the magnetic field sensor with two different permanent magnets.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the board with the large permanent magnet into the material sample holder so that the magnet is pointing towards the sensor.
- Then drive the sensor slowly towards the magnet with the carriage until it switches (LED on) and note the turn-on position p_e.
- Then drive the sensor slowly away from the magnet until it switches (LED off) and note the turn-off position p_a (take several readings and average them if necessary).
- Calculate the displacement difference $w = p_a - p_e$ and enter the result in table 4.2.3.1.
- Repeat the procedure with the small permanent magnet.
- Calculate the switching hysteresis H in percent from the values for the displacement difference and the rated switching distance (s_n = 60 mm).
- Summarize the results in a general statement.

  NOTE: Strong magnetic fields in the surrounding of the experiment arrangement may influence the switching hysteresis of a magnetic field sensor.

permanent magnet	p_a/mm	p_e/mm	w/mm	s_n/mm	H/%
large					
small					

Table 4.2.3.1

summary

4.2.4 Switching Behaviour – Material Dependence

Task:
Examine the switching behaviour of the magnetic field sensor for different materials.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the holder with the material sample St37 into the material sample holder so that the material sample is pointing towards the sensor.
- Drive the sensor to its start position about 70 mm away from the material sample.
- Then drive the sensor slowly towards the material sample with the carriage until the sensor switches (LED on) or touches the material sample.
- Then drive the sensor back to its start position with the carriage.
- Repeat this procedure with the other material samples specified in table 4.2.4.1
- Enter all the results in the table and summarize them in a general statement on the switching behaviour of the magnetic field sensor.

material sample	steel St37	brass	aluminium	copper*	synthetic material	permanent magnet (large)
LED on						
LED off						

Table 4.2.4.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil".

summary

4.2.5 Releasing a Switching Process through a Casing Wall

Task:
Examine the possibility of releasing switching processes through a casing wall with the magnetic field sensor.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the holder with the large permanent magnet into the material sample holder so that the magnet is pointing towards the sensor.
- Then drive the sensor slowly towards the material sample with the carriage until it just switches (LED on).
- Then hold one of the material samples specified in table 4.2.5.1 between the sensor and the permanent magnet and note the behaviour of the switching output (LED).
- Repeat this procedure with the other material samples specified in table 4.2.5.1.
- Summarize the results in a general statement.

material sample	synthetic material	paper, carton	steel St37	brass	aluminium	copper*
LED on						
LED off						

Table 4.2.5.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil“.

summary

5 Optical Sensors

5.1 Fundamentals

The light can be considered as an electromagnetic wave (figure 5.1.1). It propagates linearly and in all directions in space. With the aid of mirrors or lenses, the light can be deflected or concentrated in a beam. Unlike ultrasonic waves it also propagates in a vacuum since it is not bound to a carrier medium.

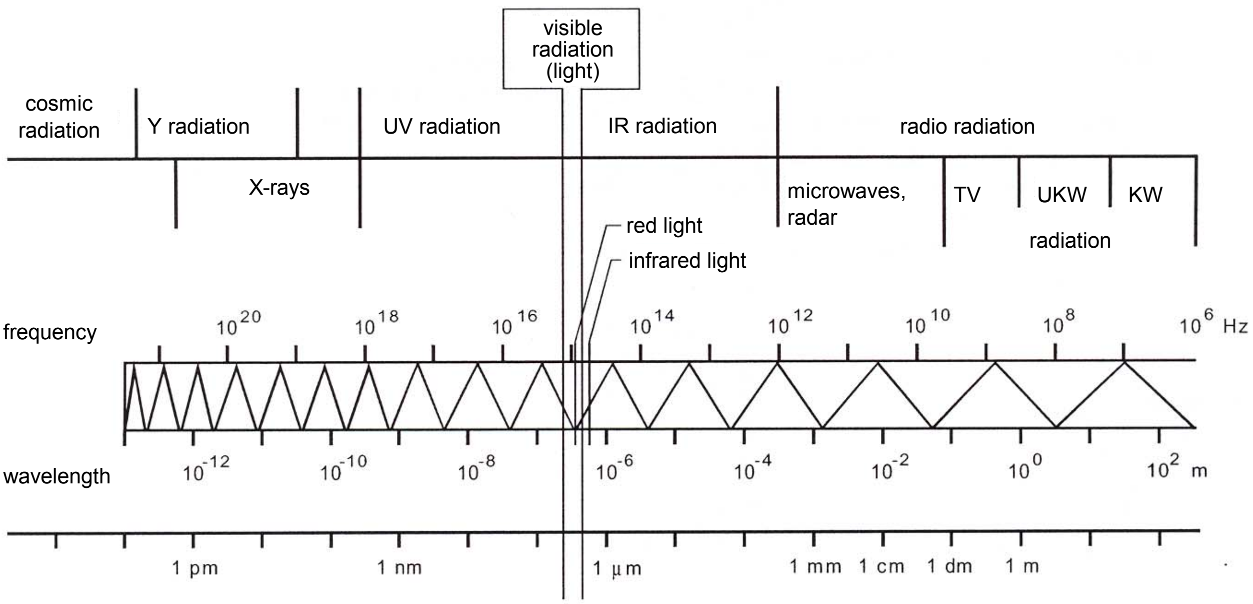

Figure 5.1.1 Frequencies and wavelengths from electromagnetic waves

5.1.1 Structure and Function

Optical sensors basically consist of a light transmitter (LED), a light receiver (photodiode or phototransistor), an electronic evaluation unit and an output stage. The transmitter radiates light flashes and the evaluation unit evaluates the intensity of the received light signal (figure 5.1.1.1). The optical properties (colour, surface) of the objects to be detected therefore determine the switching behaviour of the optical sensors to a great extent.

Optical sensors operate mainly with infrared and red light because the LEDs, photodiodes and phototransistors used are at their most efficiency in this frequency range.

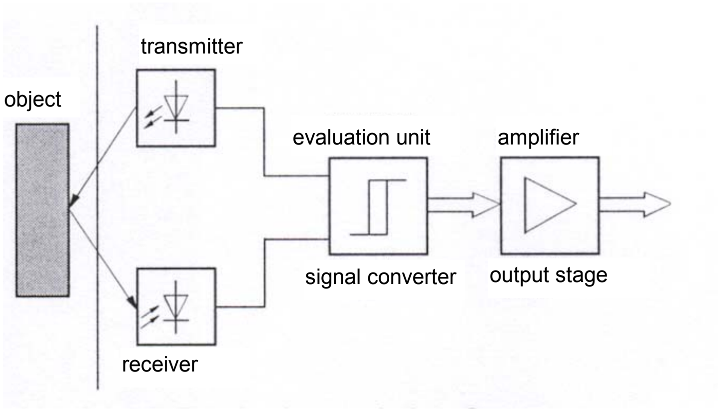

Figure 5.1.1.1 Principle of a optical sensor

As we have already mentioned above, the light is radiated in the form of light flashes. This allows a momentary increase in the transmitter power and guarantees high anti-interference (figure 5.1.1.2).

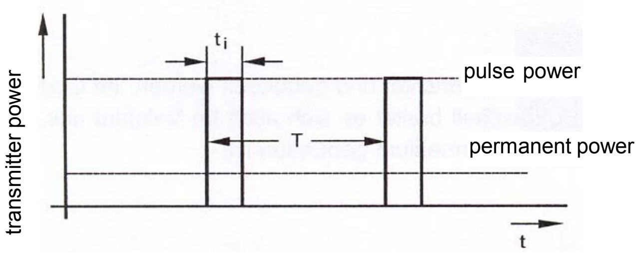

Figure 5.1.1.2 Transmitter power in permanent mode and pulse mode

In optical sensors, the transmitter and receiver are accommodated in one casing (figure. 5.1.1.1). The transmitter radiates light which is reflected diffusely from the object back to the receiver. A signal is passed through the evaluation unit to the output stage when a certain light intensity is received.

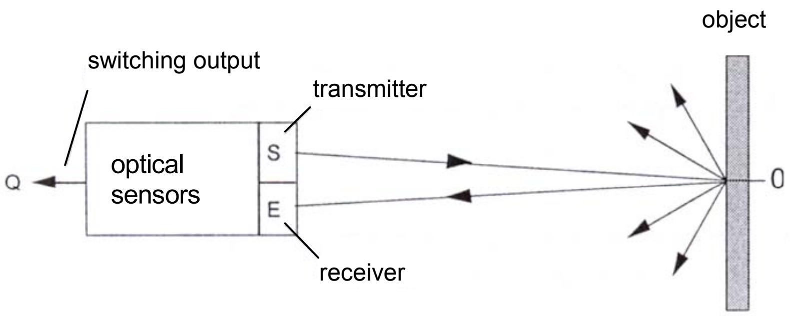

Figure 5.1.1.3 Function of a optical sensor

5.1.2 Scanning Width

The **scanning width l_{TW}** indicates at what distance an object can be reliably detected. It is related to a standard white test card with a reflectance of 90 %. The intensity of the received light is decisive for the scanning distance to be achieved.

The **photometric distance law** applies:

$$E = \frac{I_V}{r^2}$$

E = density of light
I_V = luminous intensity in candela (cd)
r = distance in metre (m)

5.2 Experiments

5.2.1 Frequency Counting – Speed Measuring

Task:
Examine the detection of rotational movements with the optical sensor and determine the frequency f_s and the speed n.

Experiment procedure:

- Connect the optical sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field. Connect the switching output of the optical sensor to the signal input of the counter (switching position COUNT).
- Drive the carriage of the SENSORICS BOARD to the left end of the guide rail.
- Plug the optical sensor into the carriage so that its top is pointing towards the segment disk (centre pin in the top hole, the other two are touching the carriage).
- Move the carriage so that the optical sensor detects the three inner segments of the disk.

  NOTE: The optical sensor may not detect the holes of the segment disk!
- Check by turning the segment disk, whether the optical sensor recognizes all segments reliably and the counter indicates the number of detected segments.

  WARNING! The optical sensor is adjusted from works so that this experiment functions faultlessly. The optical sensor which is used here is an industry sensor. Industry sensors are adjusted usually only „once“, i.e. the potentiometer should not used unnecessary because of potential damaging!
- Switch the counter over to frequency metering (FREQUENCY) and set the speed of the segment disk so that a switching frequency f_s = 60 Hz is indicated.
- Now, whilst the segment disk is in motion, move the carriage so that the sensor detects the outer segments of the disk and enter the switching frequency in table 5.2.1.1.
- Gradually increase the speed of the segment disk until the sensor no longer counts perfectly (instable indication or maximum) and note the maximum switching frequency in table 5.2.1.1.
- Then, whilst the segment disk is in motion, move the carriage so that the sensor detects the inner three segments of the disk again and enter the switching frequency in table 5.2.1.1.
- Calculate the speeds n of the segment disk with the number of segments N and the switching frequencies to be determined.

segment ring	N	f_S/Hz	$n = f_S/N \cdot 60$ (rpm)
inner	3	60	
outer	4		
outer	4		
inner	3		

Table 5.2.1.1

5.2.2 Switching Behaviour

Task:
Examine the switching behaviour of the optical sensor.

Experiment procedure:

- Connect the optical sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Drive the sensor to the right end of the guide rail.
- Turn the segment disk so that the arrow is pointing to 0°. Insert the material sample holder into the two inner holes in such a way that the clamping rail is pointing towards the sensor (see chapter 1.2.2).
- Now insert the material samples specified in table 5.2.2.1 in the material sample holder, drive the sensor towards the material sample until it switches (LED on) or touches the material sample and note the turn-on position p_e in table 5.2.2.1.
- Remove the material sample holder, turn the segment disk to 15°, 30°, 45° and 60°, reinsert the material sample holder and record the switching behaviour as above.
- Summarize the results in a general statement of the switching behaviour.

angle	0°	15°	30°	45°	60°
material sample	turn-on position p_e/mm				
black gloss					
standard white					
mirror					

Table 5.2.2.1

summery

5.2.3 Scanning Width – Spacing Hysteresis

Task:
Examine the influence of the object surface on the scanning width of the optical sensor and calculate the spacing hysteresis H_a.

Experiment procedure:

- Connect the optical sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the standard white material sample into the material sample holder.
- Drive the sensor slowly towards the material sample with the carriage until it switches (LED on).
- Enter the reference position p_0 (zero) of the carriage on the measuring scale in table 5.2.3.1 (see chapter 1.5.2).
- Then drive the sensor with the carriage away from the material sample until it switches (LED off) and note the turn-off position p_a (control the carriage with the optical sensor if necessary, see chapter 1.3.3).
- Repeat this procedure with the other material samples specified in table 5.2.3.1.
- Note all the results in Table 5.2.3 and determine the scanning width $l_{TW} = p_a - p_0$ for each.
- Calculate the scanning width and the percentage. Enter the values in table 5.2.3.1.

  NOTE: The value of the maximal scanning width (nominal scanning width) l_{TWn} is token over from experiment 2, each (standard white at 0°). It achieves here only approx. 50 mm. This is dependent on the adjustment from works!

material sample	p_0/mm	p_a/mm	l_{TW}/mm	l_{TWn}/mm	H_a/%
black gloss					
standard white					
mirror					

Table 5.2.3.1

6 Inductive Analog Sensors

6.1 Fundamentals

Inductive analog sensors, also known as inductive analog transmitters, can convert the distance of a metallic object into a proportional output signal, whereby no more switching behaviour takes place. They are therefore especially suitable for use in measuring and control technology.

6.1.1 Structure and Function

Unlike inductive sensors which can only detect a metallic object from a certain rated switching distance onwards, inductive analog sensors can detect the position of a metallic object in their entire working range (figure 6.1.1.1). The measured value is output approximately proportional to the distance in the form of a current signal.

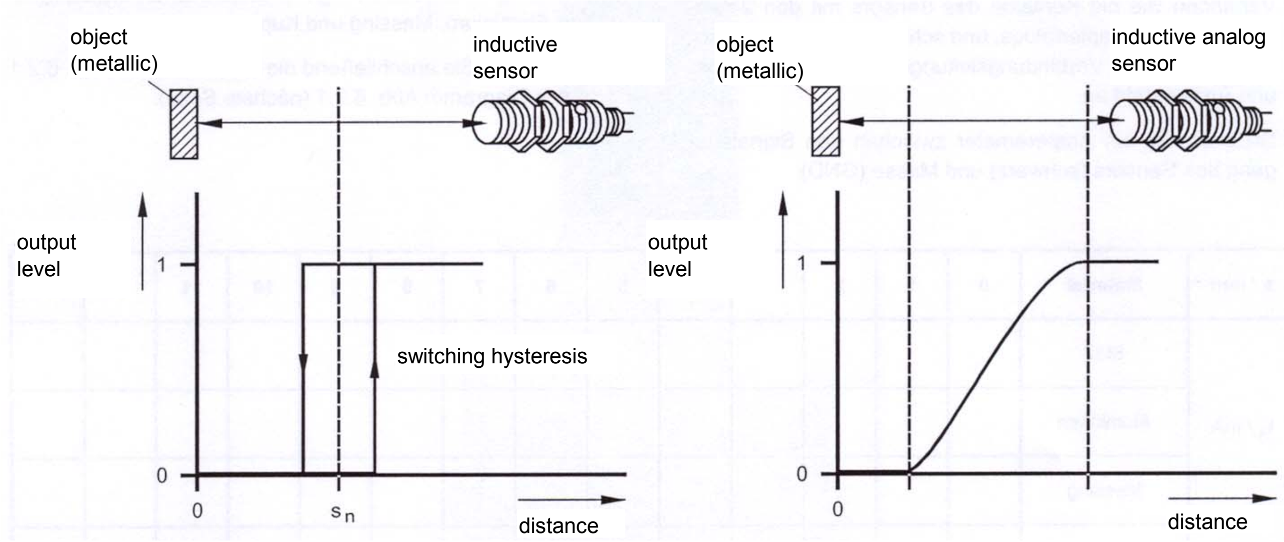

Figure 6.1.1.1 Comparison of an inductive sensor / inductive analog sensor

Alternating magnetic fields are also emitted through the active surface in the inductive analog sensor. Eddy currents are induced in this field when a metallic object approaches, i.e. the nearer the object gets to the sensor, the stronger the attenuation. A specially adapted oscillator converts the variable attenuation into a linear measuring signal which is available after amplification and correction as a current source (figure 6.1.1.2).

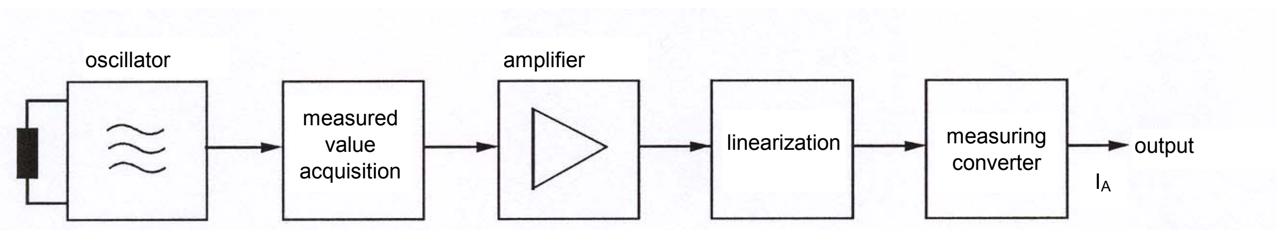

Figure 6.1.1.2 Principle of an inductive analog sensor

6.2 Experiments

6.2.1 Material Dependence

Task:
Demonstrate with the inductive analog sensor that materials can be differentiated (by the current flows) at a constant distance.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Insert the material sample holder in the segment disk so that the arrows are pointing towards each other.
- Clamp the material sample St37 into the material sample holder so that the material sample is pointing towards the sensor.
- Plug the sensor to the carriage with its top facing left.
- Connect the sensor contacts to the 2-mm jacks of the adapter field and connect additional leads to the sensor from the supply and indication field of the SENSORICS BOARD.
- Connect an ampere meter between the signal output of the sensor (black) and ground (GND).
- Set a measuring range > 20 mA DC on the ampere meter.
- Then drive the sensor slowly towards the material sample until it touches the material sample (s = 0 mm), and adjust it centrally to the sensor surface.
- Increase the distance between the sensor and the material sample (millimetre by millimetre) until no more alteration of current is detected and enter the measured values in table 6.2.1.1.
- Repeat this procedure for the other material samples aluminium, brass and copper.
- Enter the measured values from table 6.2.1.1 in the diagram in figure 6.2.1.1.

material	s/mm	0	1	2	3	4	5	6	7	8	9	10	11	12	13
St37	I_A/mA														
alu															
brass															
copper*															

Table 6.2.1.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil“.

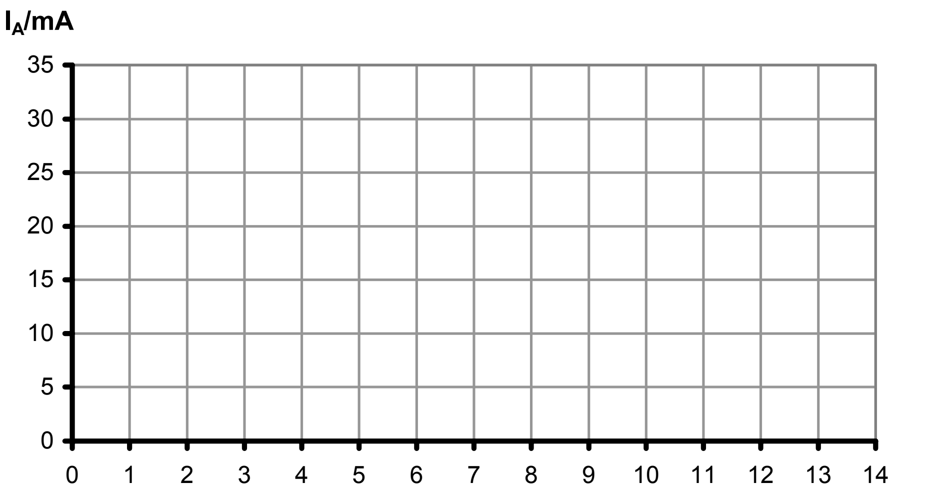

Figure 6.2.1.1 Dependence of the current on the switching distance

6.2.2 Oscillator Frequency

Task:
Measure the oscillator frequency of the inductive analog sensor with the aid of an additional material sample „coil“ and an oscilloscope (experiment set-up see figure 2.2.7.1).

Experiment procedure:
- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the holder with the material sample „coil“ into the material sample holder so that the material sample is pointing towards the sensor.
- Adjust the material sample centrally to the sensor surface.
- Connect an oscilloscope directly to the material sample „coil“ jacks with a screened line.
- Set the oscilloscope to a voltage range of 20 mV DC and a time of 1 μs.
- Move the sensor towards the material sample manually until the amplitude on the oscilloscope has reached its maximum voltage value.
- Read the time of one period T from the oscilloscope and calculate the frequency f. Draw the signal in the grid provided (figure 6.2.2.1).

$T =$ ……………

$f =$ ……………

Settings on the oscilloscope:

U = 20 mV / div.

t = 1 μs / div.

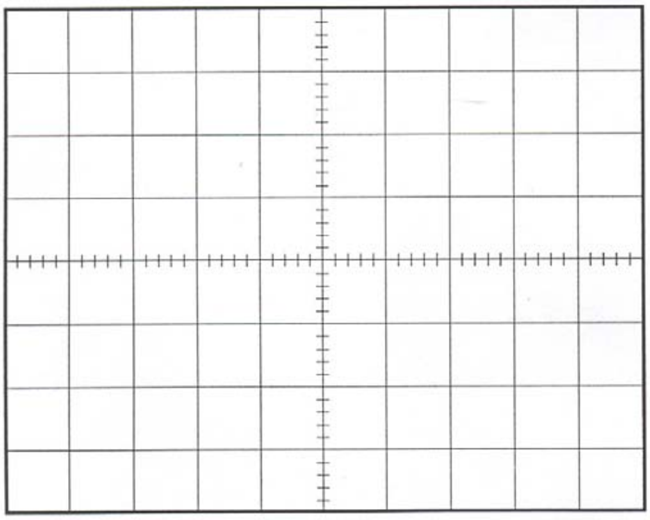

Figure 6.2.2.1

7 Ultrasonic Sensors

7.1 Fundamentals

Acoustic waves with a frequency > 20 kHz are designated to as ultrasound (figure 7.1.1). Unlike electromagnetic waves, sound waves can only propagate in matter. In order for sound to propagate in media, these must be elastic.

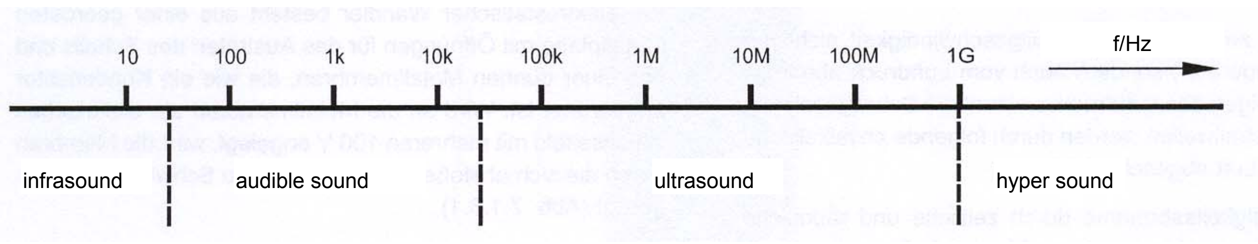

Figure 7.1.1 Sound types – frequency ranges

7.1.1 Transmission and Reflection at Boundary Areas

If, a longitudinal sound wave hits a boundary area between two media, the wave splits into a longitudinal part and a transmitted part. If both media are solid bodies, shear waves also occur (figure 7.1.1.1).

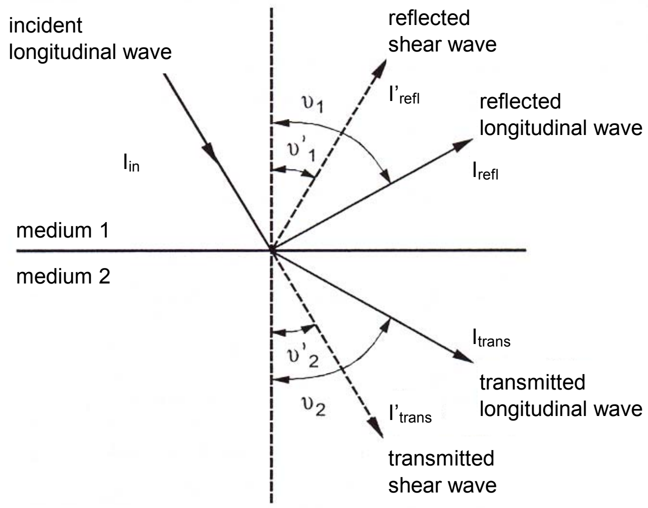

Figure 7.1.1.1

7.1.2 Sound Waves in Air

$$c = c_0 \cdot \sqrt{1 + \frac{T}{273}} \qquad \text{with} \qquad c_0 = 331.6\ m/s$$

c = sound velocity
c_0 = sound velocity at 0 °C
T = temperature in °C

Figure 7.1.2.1 shows that the sound velocity is not only dependent on temperature but also on atmospheric pressure.

The sound velocity increases with the atmospheric pressure. Sound waves are weakened in air by the following physical causes:

- reduction in velocity due to fluctuations in time and space between adjacent air layers
- energy loss by conduction of heat in the propagation medium
- rotations and vibrations of the molecules in the medium

Like the sound velocity, the wavelength is also greatly dependent on the medium in which the ultrasonic wave propagates. The sound propagates in water or metal for example faster than in air because in air, as in all other gases, the sound velocity essentially depends on the atmospheric pressure and temperature.

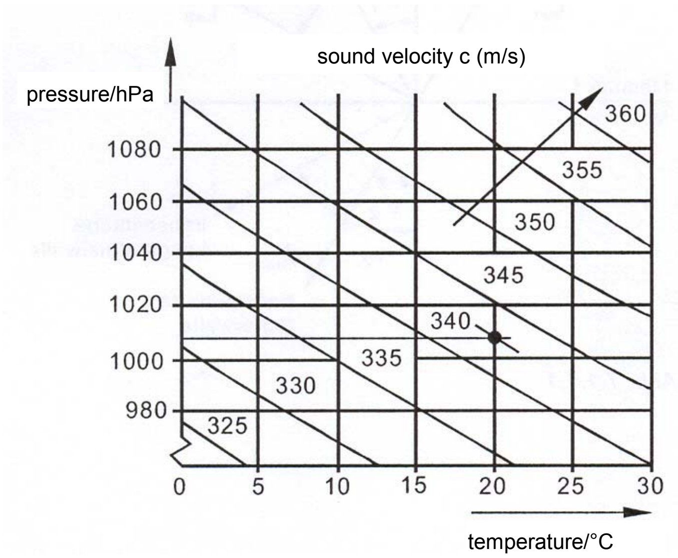

Figure7.1.2.1 Sound velocity depending on the atmospheric pressure and temperature

7.1.3 Generation of Ultrasound in Air

Two main techniques are used to generate ultrasound in air, whereby the second has a wider range of application:

- electrostatic converter
- piezoelectric converter

Electrostatic converter
An electrostatic converter consists of an earthed metal plaque with openings for emitting sound waves and a thin metal diaphragm which is arranged as a capacitor. If an alternating electrical field of several 100 V is applied to the metal diaphragm, the diaphragm is excited to oscillate due to the repelled charges (figure 7.1.3.1).

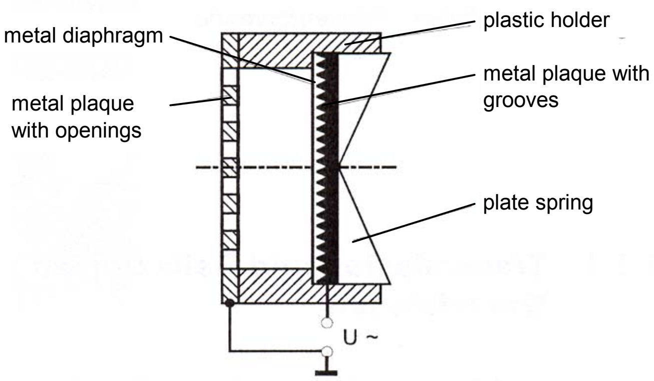

Figure 7.1.3.1 Electrostatic converter principle

Properties:

- wide banded
- very short decay and rise time
- good directional characteristic
- relatively low acoustic pressure
- open design

Piezoelectric converter
Piezoelectric crystals have the property of changing their dimensions when an external voltage is applied, i.e. they are capable of converting electrical into mechanical energy. Conversely, application of an external force produces a surface charge, which can be measured as an electrical voltage.

Lead titanates ($PbTiO_3$) and lead zirconates ($PbZrO_3$) are used for example as materials. In order to generate ultrasound in air, the sound generator must be able to emit great surface amplitudes on account of the material transformation of piezoceramic in air, i.e. an adapting mechanism is required which transforms the large forces but small amplitudes in the piezoceramic into a movement with large amplitudes but smaller forces.

There are three different adapter mechanisms:

Flexural resonator
A metal plaque, e.g. aluminium, is stuck to a piezoceramic disk. When a voltage is applied, the piezoceramic disk changes its diameter, i.e. shear forces are produced and the whole system bends (figure 7.1.3.2). This produces large amplitudes.

Properties:

- wide radiation characteristic
- relatively low frequency
- low sound level
- narrow banded
- very long decay time
- encapsulated design

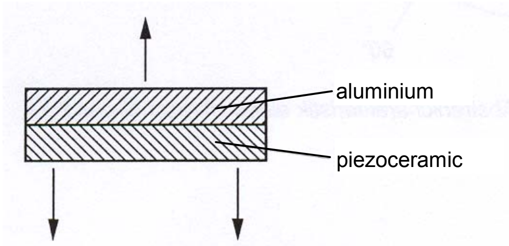

Figure 7.1.3.2 Principle of a flexural resonator

Diaphragm resonator
An elastic diaphragm (resonating lamellas), e.g. of metal, is excited to self-oscillation by a piezoceramic (figure 7.1.3.3).

Properties:

- wide radiation characteristic
- relatively low frequency
- low sound level
- narrow banded
- very long decay time
- open design

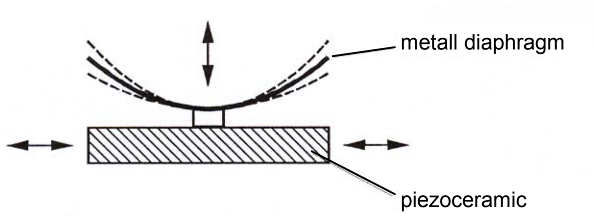

Figure 7.1.3.3 Principle of a diaphragm resonator

λ/4 resonator
A piezoceramic is deformed when a voltage is applied. The deformations are so slight, however, that no useful sound amplitude is produced, i.e. acoustic impedance conversion must be carried out with the aid of the decoupling layer (figure 7.1.3.4).

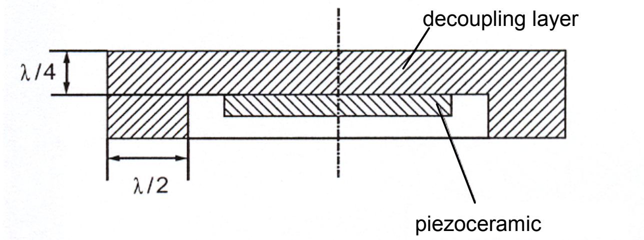

Figure 7.1.3.4 Principle of a λ/4 resonator

The directional characteristic of an ultrasonic converter depends on the geometrical shape of the radiating surface, its diameter and the transmission frequency. The technique also solves the problems that a large radiating surface is necessary to obtain a good directional characteristic (figure 7.1.3.6) and the characteristic frequency of the ceramic may not become too great.

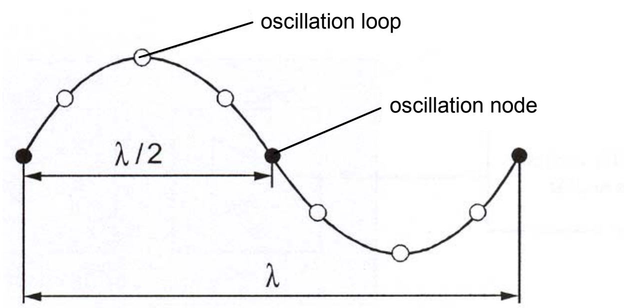

Figure 7.1.3.5 Oscillation loops and oscillation nodes

With the λ/4 resonator, the transition piezoceramic/de-coupling layer corresponds to one nodal surface of the oscillation (figure 7.1.3.5), i.e. the λ/4 layer is enlarged outwards.

Properties:

- high acoustic pressure
- good directional effect
- medium decay time
- narrow banded
- high frequencies
- no live parts at the surface

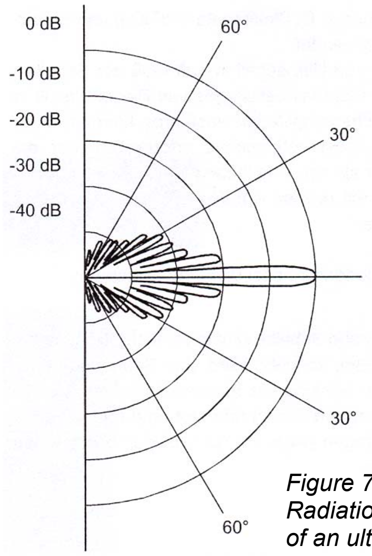

Figure 7.1.3.6 Radiation characteristic of an ultrasonic converter

7.1.4 Ultrasonic Transmitter

The oscillator is always only switched on for a short time by an electronic switch to which a clock pulse is fed, i.e. single pulse packets are generated. The oscillator is tuned to the resonance frequency of the ultrasonic converter. The oscillator signal is adapted to the ultrasonic converter with the aid of an amplifier.

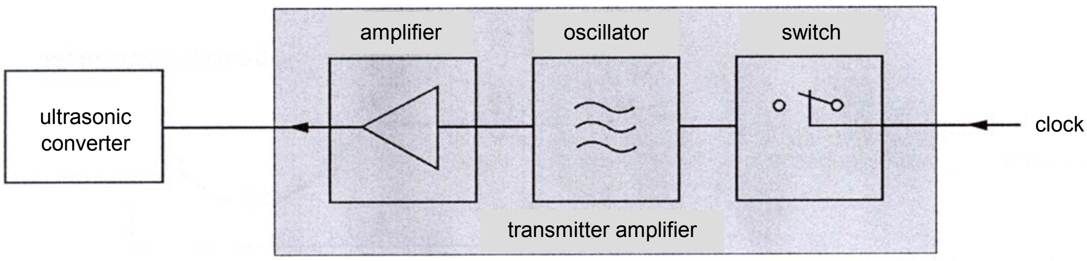

Figure 7.1.4.1 Principle of an ultrasonic transmitter

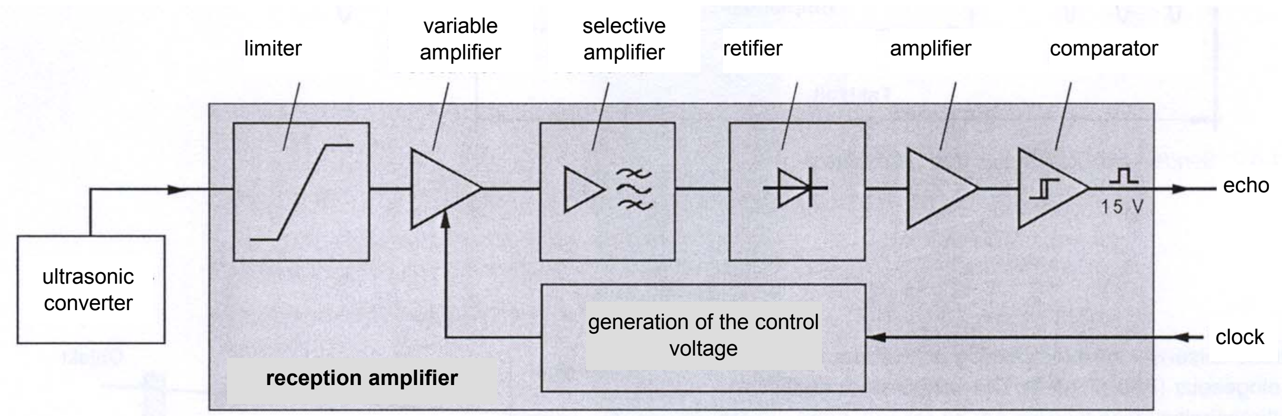

Figure 7.1.5.1 Principle of an ultrasonic receiver

7.1.5 Ultrasonic Receiver

The ultrasonic signal to be received usually fluctuates in a voltage range from a few µV ... V. It is limited to ±0.7 V by a limiter. This avoids overloading of the reception amplifier. The distance-dependent incoming signal amplitude can be kept smaller in the „near“ detection range than in the „distant“ detection range by an variable amplifier. The selective amplifier filters out the external sound with the help of other frequencies, i.e. only the information signal is passed on. This information signal is rectified and amplified again. A comparator converts the information signal into a square wave signal (figure 7.1.5.1). An ultrasonic converter operates in receive mode in exactly the opposite way to in transmit mode.

7.1.6 Operation as a Proximity Switch

The ultrasonic sensor is used simultaneously as transmitter and receiver (figure 7.1.6.1). The ultrasonic pulses transmitted by the sensor are reflected from the object to be detected.

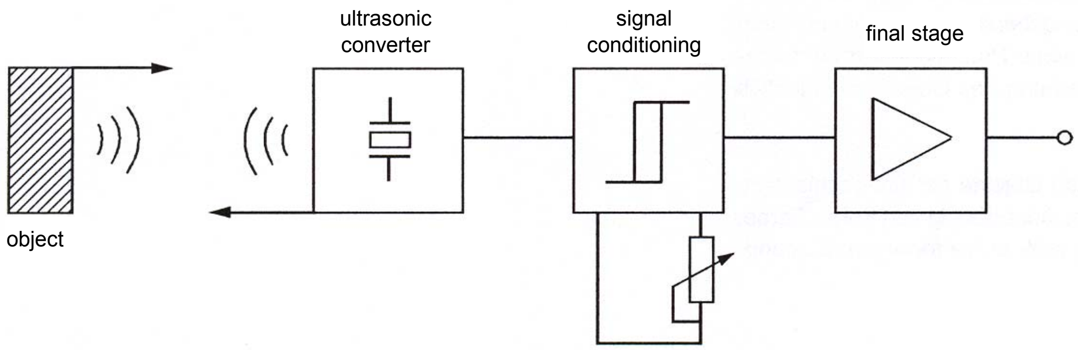

Figure 7.1.6.1 Ultrasonic sensor as a proximity switch

The echo returns to the converter where it is converted into an electrically evaluatable signal (figure 7.1.6.2). An ultrasonic sensor measures the propagation time of the sound from the time it is transmitted to its reception. The propagation time is directly proportional to the distance of the object from the sensor and can be set to the object distance.

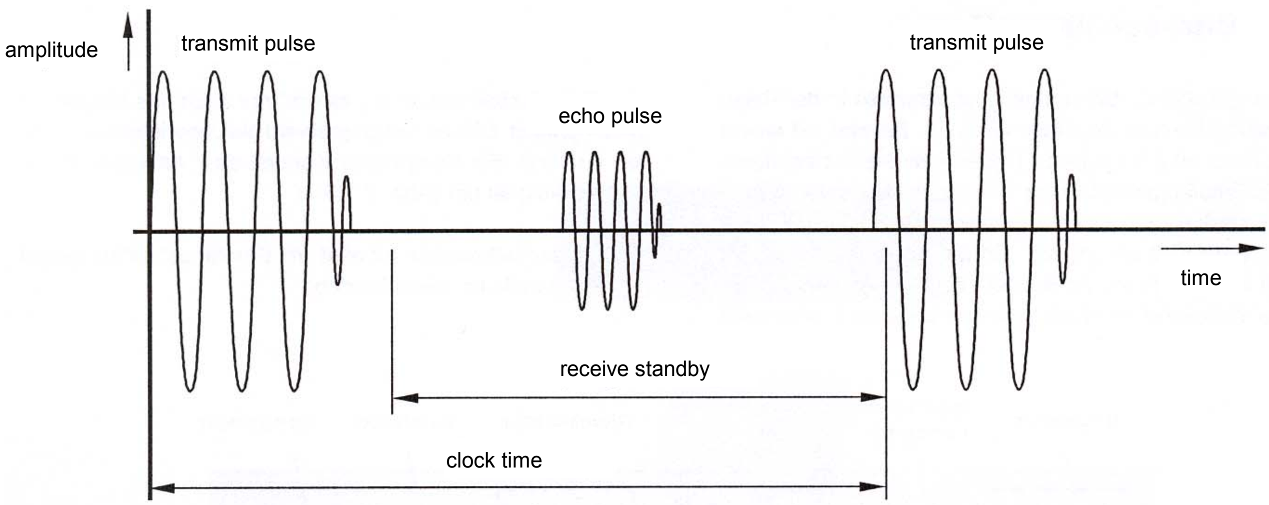

Figure 7.1.6.2 Transmit and echo pulse of the ultrasonic wave

The transmit and receive procedures must take place in chronological sequence. This is taken into account by the near range (figure 7.1.6.3). No objects may be placed in the near range because there is no defined switching state. Therefore the object may be in the acquisition range in which the switching state can be set according to the actual distance of the object with the aid of a potentiometer.

Objects made of many different materials can be detected with ultrasonic sensors independently of their shape, colour, material and in solid, liquid or powder form.

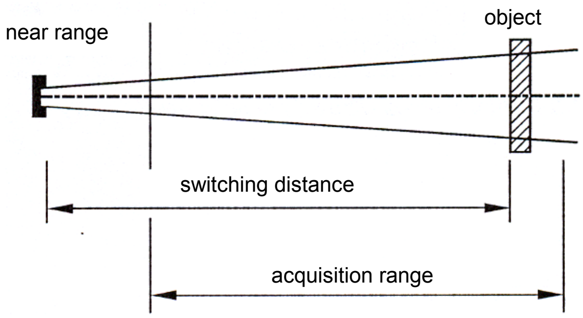

Figure 7.1.6.3 Near range – acquisition range

7.1.7 Axial Approach

All data for the switching points of ultrasonic sensors are valid for the axial approach of objects.

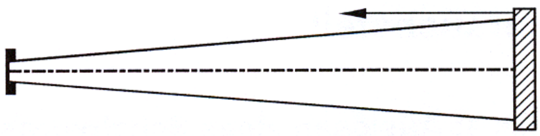

Figure 7.1.7.1

7.1.8 Radial Approach

If an object is inserted in the sound lobe radially (vertically or at any angle), the switching point must be determined by experimentation.

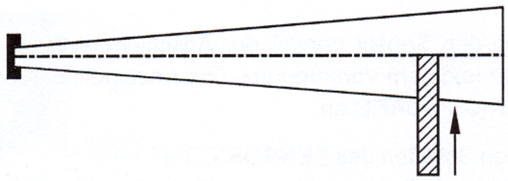

Figure 7.1.8.1

7.1.9 Switching Hysteresis

The switching hysteresis H is the difference in displacement between the turn-on and turn-off point in axial direction (figure 7.1.9.1).

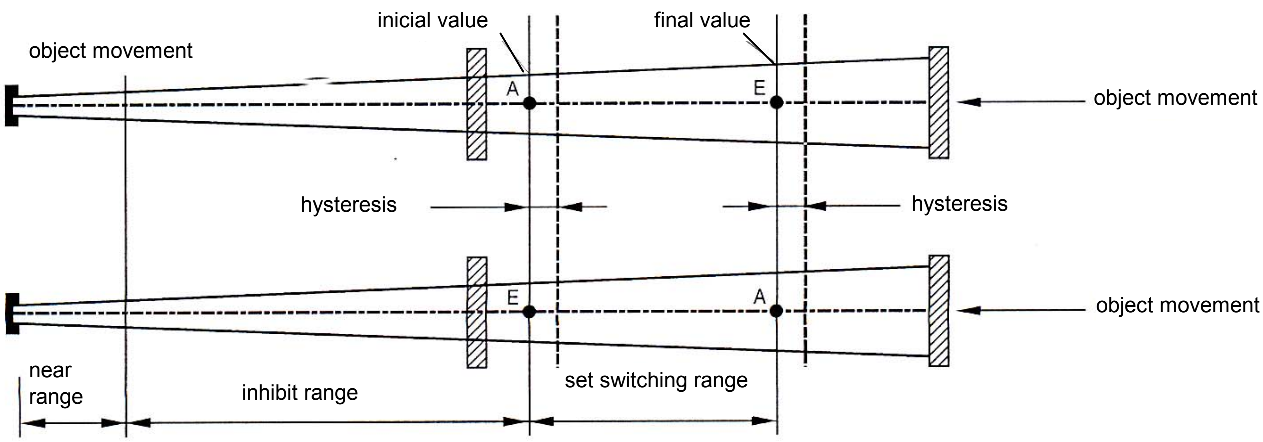

Figure 7.1.9.1 Switching hysteresis

7.2 Experiments

7.2.1 Releasing a Switching Process through an Object in the Acquisition Range

Task:
Examine the possibility of setting a monitor window with the ultrasonic sensor.

NOTE: Read the measured values on the left of the carriage.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Drive the carriage of the SENSORICS BOARD to the right hand side of the guide rail and plug the sensor into the carriage with its top facing left.
- Plug the material sample holder into the segment disk so that the arrow is pointing to 0° and clamp in the material sample matt black.
- Drive the carriage to the left so that its left hand end is at the 200 mm mark.
- Program with the help of teach insert the switching point S1.
  Consider in addition the programming description in the data sheet.
- For programming the switching point S2 drive the carriage to the position 100 mm.
- Program the switching point S2.
- Drive the carriage back to the right end of the guide rail and check switching points S1 and S2. Enter the values in table 7.2.1.1.
- Drive over S2 and check the switching prints form left to right. Enter the read values in table 7.2.1.1.
- Calculate the switching hysteresis H in each case.

switching point	S1	S2
distance right to left / mm		
distance left to right / mm		
H/mm		

Table 7.2.1.1

7.2.2 Propagation Time Measuring

Task:
Show that ultrasonic sensors have no reduction factor (propagation time measuring).

NOTE: Read the measured values on the left of the carriage.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Drive the carriage of the SENSORICS BOARD to the right end of the guide rail and plug the sensor into the carriage with its top facing left.
- Plug the material sample holder into the segment disk so that the arrow is pointing to 0°. First clamp in the material sample matt black.
- Set the monitor window to 100 ... 200 mm.
- Check the switching points S1 and S2 for both directions and note the values in table 7.2.2.1.
- Repeat this procedure for the attenuation materials cork and foam.
- Summarize the results in a general statement. Give an example.

material sample	S1/mm	S2/mm
matt black		
cork		
foam		

Table 7.2.2.1

summary

7.2.3 Response Curve

Task:
Examine the response curve or sound lobe of the ultrasonic sensor.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Plug the material sample holder to the segment disk in such a way that the two arrows are pointing towards each other.
- Clamp the material sample black gloss in the material sample holder.
- Set the switching point S1 to 300 mm and S2 to 60 mm.
- Pull the material sample out of the sound lobe so that it is held in the material sample holder by its lower part and the attenuation part (higher part) is outside the sound lobe (LED off). The dividing edge must be at the beginning of the material sample holder scale (see figure 7.2.3.1).
- Push the material sample into the sound lobe until the sensor switches „reliably" (no flickering of the LED).
  WARNING! The sensor may not detect your hand!
- Enter distance y (distance of material sample on the material sample holder) in table 7.2.3.1.

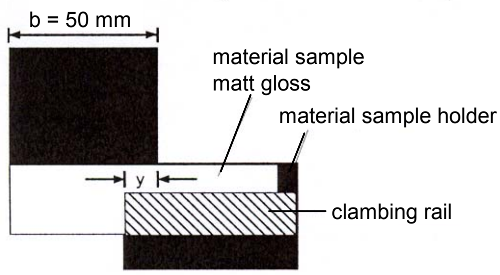

Figure 7.2.3.1

- Reduce the distance between the sensor and the guide rail to the distances specified in the table and record the new switching point as described above, each.
  NOTE: This procedure can only be carried out until there is no more switching behaviour because a near range has to be observed for ultrasonic sensors in which there is no longer any defined switching state.
- The point of response s is given by the width b of the attenuating plate of the material sample minus the measured distance y divided by 2.

$$s = \frac{b - y}{2} \qquad with \qquad b = 50\ mm$$

- Calculate the point of response s in and enter it in table 7.2.3.1, each.
- Transfer the distance y depending on the point of response s in the diagram (figure 7.2.3.2, next page) and reflect the sound lobe for the negative side on the p axis.

p/mm	300	280	260	240	220	200	180	160	140	120	100	80	60	40	20	10
y/mm																
s/mm																

Table 7.2.3.1

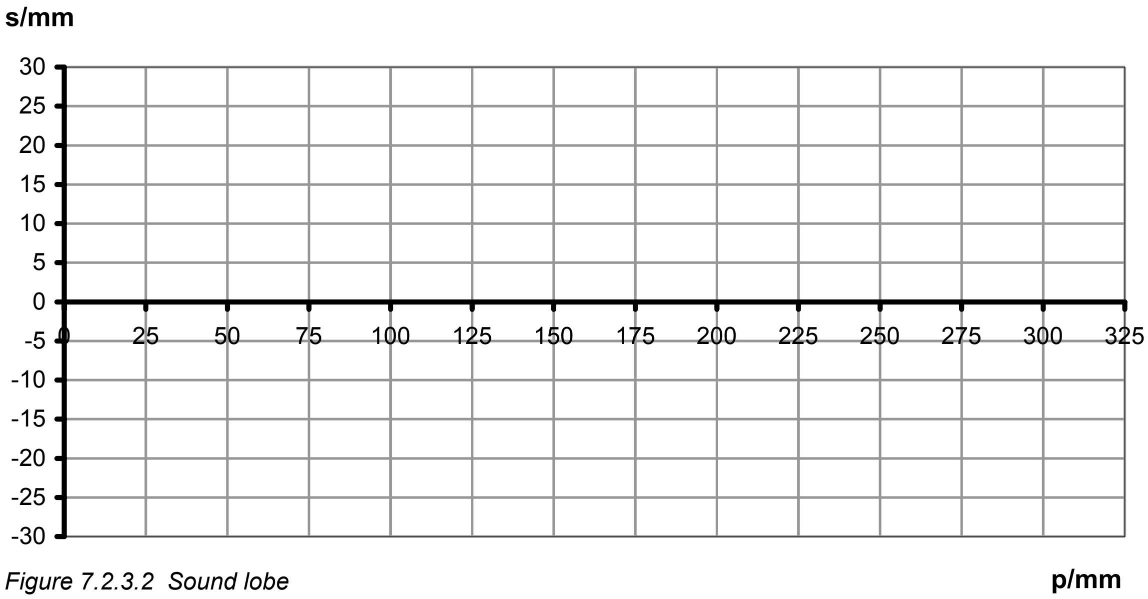

Figure 7.2.3.2 Sound lobe

7.2.4 Determining of the Maximum Permissible Speed

Task:
Determine the maximum permissible speed of an object within the acquisition range of an ultrasonic sensor.

Experiment procedure:

- Connect the sensor to the SENSORICS BOARD according to the pin assignment of the cable socket and the supply and indication field.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Plug the material sample holder to the segment disk in such a way that the two arrows are pointing towards each other.
- Set switching point S1 to 200 mm and S2 to 100 m.
- Drive the carriage to the position where the sound lobe has the largest width (see measuring results diagram 7.2.3.2, 130 mm).
- Determine the points of response (y_1/y_2) for this position by slipping the material sample in the material sample holder. Use the material sample black gloss.

  NOTE: First the front edge and then the rear edge of the material sample is detected. This gives the distance which the object may cover within the maximum detection time.
- Determine the maximum permissible speed of the object from the two points of response.

  NOTES:
  - The distance to be covered is given by the width of the acquisition range and the object.
  - The maximum time which the sensor may take to detect an object reliably is always specified in the respective data sheet.

point of response no. 1
y_1 =
$s_1 = (b-y_1)/2$ =

point of response no. 2
y_2 =
$s_2 = (b-y_2)/2$ =

width of the sound lobe
$b_S = s_1 + s_2$ =

response time (in data sheet)
t =

max. permissible speed
$v = s/t = (b_S + b)/t$ =

8 NAMUR Sensors

8.1 Fundamentals

NAMUR sensors are simple DC voltage switches in two-wire technology and consist basically of an oscillator circuit (see figure 8.1.1).

NAMUR is the acronym for Normen-Arbeits-gemeinschaft Mess- und Regelungstechnik (automatic control engineering standards body) in the chemical industry.

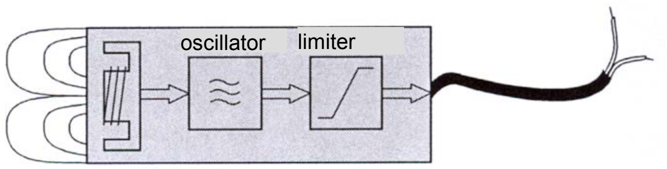

Figure 8.1.1 Principle of NAMUR sensors

Since this type of circuit requires only a few components, it guarantees maximum operational reliability for all types of capacitive and inductive sensors as well as all magnetic field sensors.

NAMUR sensors are also insensitive to inductive or cross talks and have self-protection against destruction.

The electrical characteristics are defined in DIN 19 234. It defines the technical data of the interface between a NAMUR sensor and an electronic amplifier. Connection is made by a two-wire line. This is also used to supply power to the sensor. The amplifier itself is controlled by external influences which alter the current consumption.

To guarantee reliable interaction of the sensor and the amplifier, the following values are specified in DIN 19 234 for the amplifier:

- Power supply for the control current circuit:
  - no-load voltage: U_0 = 7 ... 9 V (preferred: 8 V)
  - short-circuit current: I_K = 7 ... 16 mA (preferred: 8.2 mA)
- Current-dependent switching and monitoring points:

  Switching point: The switching point of the amplifier must be in the range of a current consumption of the sensor of 1.2 ... 2.1 mA (figure 8.1.2).

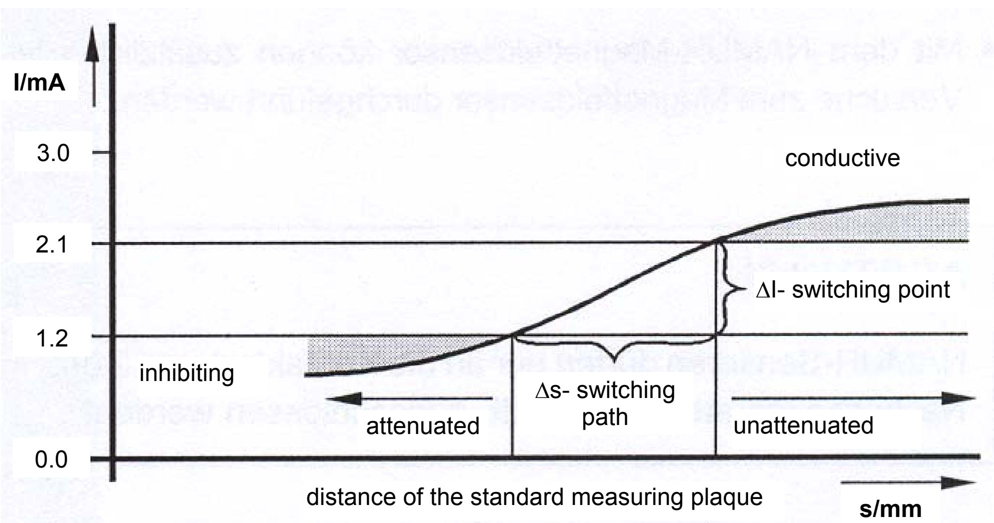

Figure 8.1.2 Current-path characteristic of a NAMUR sensor according to DIN 19 234

- Line break monitoring:

  If the current of the sensor drops below a certain value; t is assumed that there is a break in the line or an similar error in the sensor. The line break monitor must respond in the range from 0.05 ... 0.15 mA.

- Line short-circuit monitoring:

  If the current of the sensor exceeds a certain value, it is assumed that there is a short-circuit or an similar error in the sensor. The short-circuit monitor must respond in a current range which corresponds to a compensating resistance of the sensor of 100 ... 360 Ω. At a priority power supply according to point 1, this would correspond to a current range of 6 ... 7.45 mA.

These values specified in DIN 19 234 show that the current in the interface between the sensor and the amplifier is decisive for releasing switching or monitoring procedures. A current evaluation must therefore be made for the set-up and design of an amplifier for sensors according to DIN 19 234.

NOTES on the measuring series:

- All experiments on the inductive sensor can be conducted additionally with the inductive NAMUR sensor.
- All experiments on the capacitive sensor can be conducted additionally with the capacitive NAMUR sensor.
- All experiments on the magnetic field sensor can be conducted additionally with the NAMUR magnetic field sensor.

WARNING! **NAMUR sensors may only be connected to contacts 1 and 2 of the post-switchgear KCD2-E2L!**

8.2 Experiments

8.2.1 Current-path Characteristic of the Inductive NAMUR Sensor

Task:
Record the current-path characteristic of the inductive NAMUR sensor. In addition it is to be demonstrated that this is a constant characteristic without hysteresis.

Experiment procedure:

- Plug the sensor to the carriage with the top facing left.
- Plug the material sample holder into the segment disk in such a way that the two arrows are pointing towards each other.
- Clamp the material sample steel St37 into the material sample holder in such a way that it is pointing towards the sensor.
- Connect the sensor and the post-switchgear as shown in figure 8.2.1.1.
- Connect an ampere meter between sensor and post-switchgear and set a measuring range of 20 mA DC (figure 8.2.1.1).
- Drive the carriage to the left until the sensor touches the material sample and read the indicated current value. Enter the value in table 8.2.1.1.
- Increase the distance between sensor and material sample (millimetre by millimetre), record the respective current values and enter them in the table.
- Repeat this experiment for the material samples aluminium, brass and copper.
- Transfer the measured values from table 8.2.1.1 to diagram (figure 8.2.1.2).

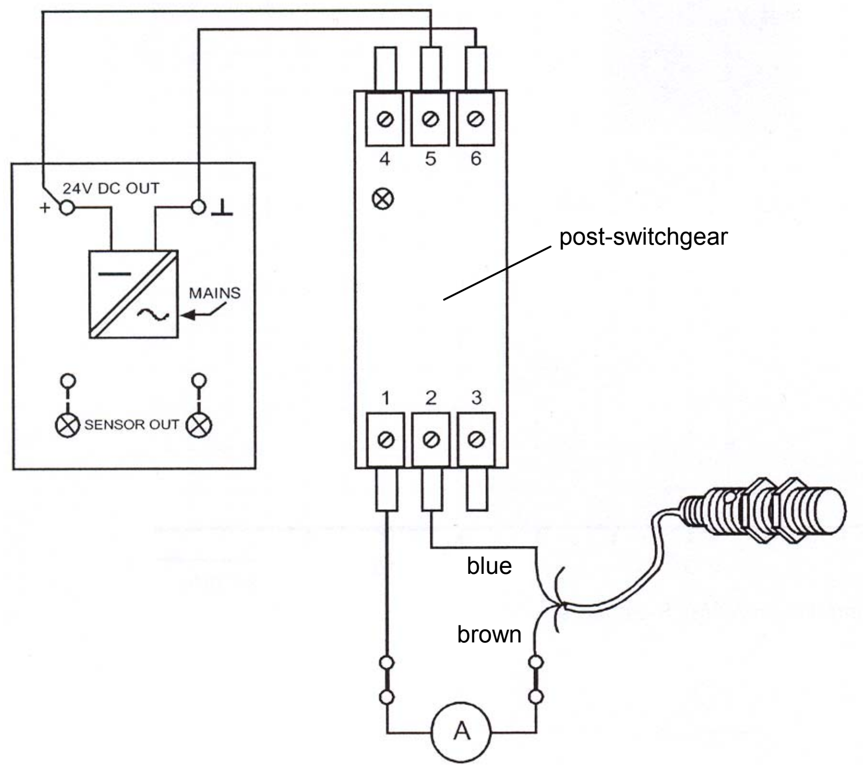

Figure 8.2.1.1 Experiment set-up: Current-path characteristic of the inductive NAMUR sensor

material	s/mm	0	1	2	3	4	5	6	7	8	9
steel St37	I_A/mA										
alu											
brass											
copper*											

Table 8.2.1.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil“.

Figure 8.2.1.2 Dependence of the current on the switching distance

8.2.2 Checking the Switching Points of an Inductive NAMUR Sensor

Task:
Check whether the switching points for the material samples St37, aluminium, brass and copper are below or above a current consumption of 1.2 ... 2.1 mA.

Experiment procedure:

- Plug the sensor into the carriage with its top facing left.
- Plug the material sample holder into the segment disk so that the two arrows are pointing towards each other.
- Clamp the material sample steel St37 into the material sample holder in such a way that it is pointing towards the sensor.
- Connect the sensor and the post-switchgear as shown in figure 8.2.1.1.
- Connect an ampere meter between sensor and post-switchgear and set a measuring range of 20 mA DC (figure 8.2.1.1).
- Record the current value between the sensor and the post-switchgear for the switching point p_2 when you drive the sensor towards the material sample (LED on post-switchgear is shining). Note the value in table 8.2.2.1.
- Then record the current value between the sensor and the post-switchgear for the switching point p_1 when you drive the sensor away from the material sample (LED on the post-switchgear is not shining). Note the value in table 8.2.2.1.
- Repeat the experiment for the material samples aluminium, brass and copper.
- Check whether the switching points of the amplifier are within the current range 1.2 ... 2.1 mA. Note this in table 8.2.2.1.

material sample	I_A/mA for p_1	I_A/mA for p_2	in the range? yes/no
steel St37			
aluminium			
brass			
copper*			

Table 8.2.2.1 *The copper surface (18 x 18 mm) is on the back side of the material sample „coil“.

8.2.3 Line Break and Short-circuit Monitoring with the Inductive NAMUR Sensor

Task:
Examine the behaviour of the control circuit in the event of a short-circuit or break with the inductive NAMUR sensor.

Experiment procedure:

- Plug the material sample holder into the segment disk so that the two arrows are pointing towards each other.
- Plug the sensor to the carriage with its top facing left.
- Clamp the material sample St37 into the material sample holder in such a way that it is pointing towards the sensor.
- Connect the sensor and the post-switchgear as shown in figure 8.2.3.1.
- Drive the carriage to the left until the material sample and the sensor are about 2 mm away from each other.
- Short-circuit the control circuit and observe the behaviour of the LEDs of the post-switchgear (measurement 1). Note the output switching state in table 8.2.3.1.
- Increase the distance between sensor and material sample to 10 mm and observe the behaviour in the event of line break (measurement 2). Note the output switching state in table 8.2.3.1.
- Drive the carriage back to 2 mm away from the material sample and connect contacts 1 and 3 of the post-switchgear.
- Repeat measurement 1(measurement 3).
- Repeat measurement 2 (measurement 4).
- Summarize the results in a general statement.

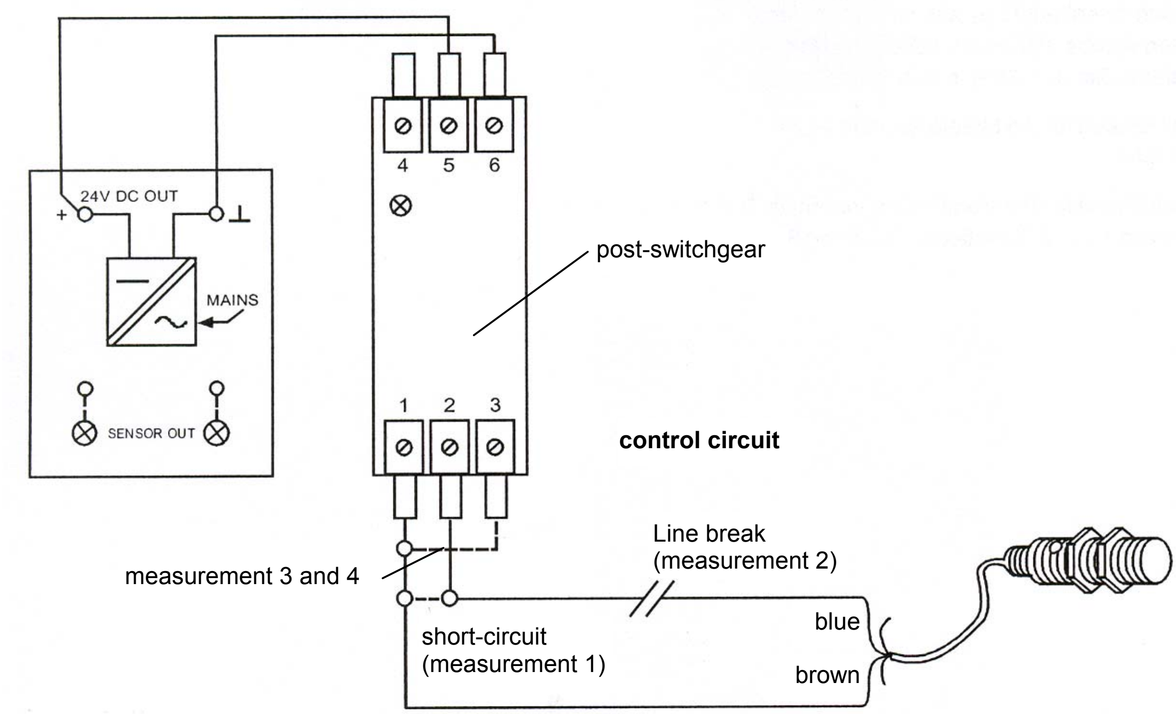

Figure 8.2.3.1 Experiment set-up: Short-circuit monitoring with the inductive NAMUR sensor

measurement	error	LED on	LED off
1	no error		
	short-circuit		
	line break		
2	no error		
	short-circuit		
	line break		
3	no error		
	short-circuit		
	line break		
4	no error		
	short-circuit		
	line break		

Table 8.2.3.1

summary

8.2.4 Oscillator Frequency of the Inductive NAMUR Sensor

Task:
Measure the oscillator frequency of the inductive NAMUR sensor with the aid of an additional material sample „coil“ and an oscilloscope.

Experiment procedure:

- Set up the experiment according figure 2.2.7.1 and connect the sensor and the post-switchgear as shown in figure 8.2.1.1.
- Plug the sensor into the carriage of the SENSORICS BOARD with its top facing left.
- Clamp the holder with the material sample „coil“ into the material sample holder in such a way that the material sample is pointing towards the sensor.
- Adjust the material sample centrally to the sensor surface.
- Connect an oscilloscope to the material sample „coil“ jacks with a screened line.
- Set the oscilloscope to a voltage range of 50 mV DC and a time of 0.5 μs.
- Move the sensor manually towards the material sample until the amplitude at the oscilloscope has reached its maximum voltage.
- Read the time of a period T from the oscilloscope, calculate the frequency f and draw the signal in the grid provided (figure 8.2.4.1).

$T = \ldots\ldots\ldots\ldots\ldots$

$f = \ldots\ldots\ldots\ldots\ldots$

Settings on the oscilloscope:

U = 50 mV / div.

t = 0.5 μs / div.

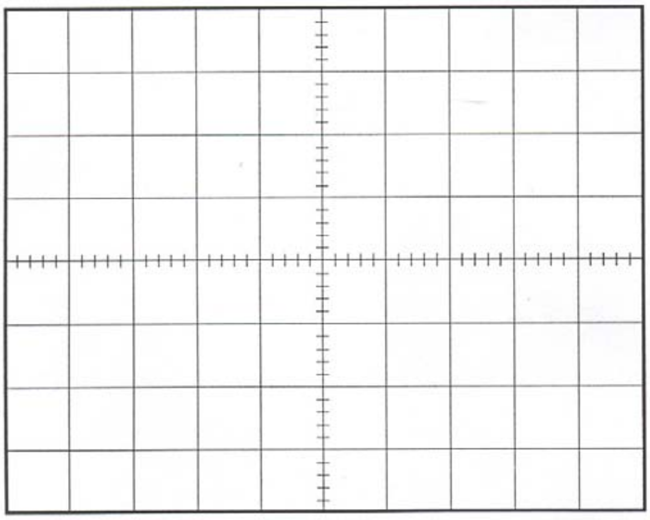

Figure 8.2.4.1

8.2.6 Current-path Characteristic of the NAMUR Magnetic Field Sensor

Task:
Show with this experiment that the current-path characteristic is dependent on the strength of a permanent magnet.

Experiment procedure:

- Plug the material sample holder into the segment disk in such a way that the two arrows are pointing towards each other.
- Clamp the material sample St37 into the material sample holder.
- Fix the large permanent magnet to the material sample so that it is pointing towards the sensor.
- Plug the sensor into the carriage with its top facing left and drive the carriage to the left until the sensor touches the permanent magnet.
- Adjust the material sample centrally to the sensor surface.
- Connect the sensor and the post-switchgear as shown in figure 8.2.6.1
- Connect an ampere meter between sensor and post-switchgear and set a measuring range of 20 mA DC (see figure 8.2.6.1).
- Drive the carriage to the right and record the current values of the control current circuit for the distances between the sensor and the material sample specified in table 8.2.6.1. Note the measured values in the table.
- Record the current value for the switching point and enter it in the table.
- Then drive the carriage to the left and record the current value for the switching point.
- Now replace the large permanent magnet with the small one. This can be fixed on the material sample St37.
- Repeat the experiment for the small permanent magnet.
- Transfer the characteristics for the two permanent magnets to diagram (figure 8.2.6.2).
- Mark the switching points for moving the sensor away and towards the material sample in diagram.

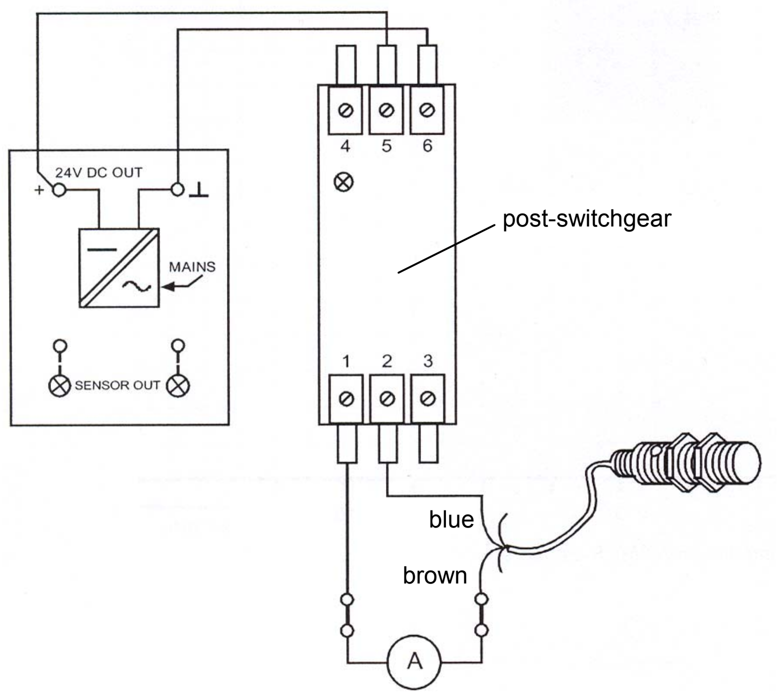

Figure 8.2.6.1 Experiment set-up: Current-path characteristic of the NAMUR magnetic field sensor

s/mm	0	1	2	3	4	5	6	7
I_A/mA								

Table 8.2.5.1

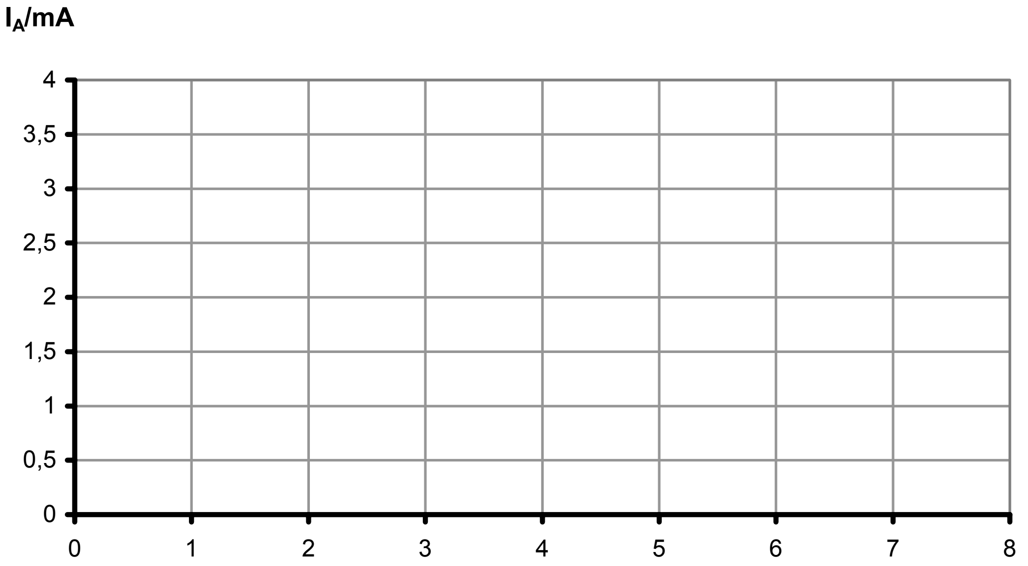

Figure 8.2.5.2 Dependence of the current on the switching distance

8.2.6 Current-path Characteristic of the NAMUR Magnetic Field Sensor

Task:
Show with this experiment that the current-path characteristic is dependent on the strength of a permanent magnet.

Experiment procedure:

- Plug the material sample holder into the segment disk in such a way that the two arrows are pointing towards each other.
- Clamp the material sample St37 into the material sample holder.
- Fix the large permanent magnet to the material sample so that it is pointing towards the sensor.
- Plug the sensor into the carriage with its top facing left and drive the carriage to the left until the sensor touches the permanent magnet.
- Adjust the material sample centrally to the sensor surface.
- Connect the sensor and the post-switchgear as shown in figure 8.2.6.1
- Connect an ampere meter between sensor and post-switchgear and set a measuring range of 20 mA DC (see figure 8.2.6.1).
- Drive the carriage to the right and record the current values of the control current circuit for the distances between the sensor and the material sample specified in table 8.2.6.1. Note the measured values in the table.
- Record the current value for the switching point and enter it in the table.
- Then drive the carriage to the left and record the current value for the switching point.
- Now replace the large permanent magnet with the small one. This can be fixed on the material sample St37.
- Repeat the experiment for the small permanent magnet.
- Transfer the characteristics for the two permanent magnets to diagram (figure 8.2.6.2).
- Mark the switching points for moving the sensor away and towards the material sample in diagram.

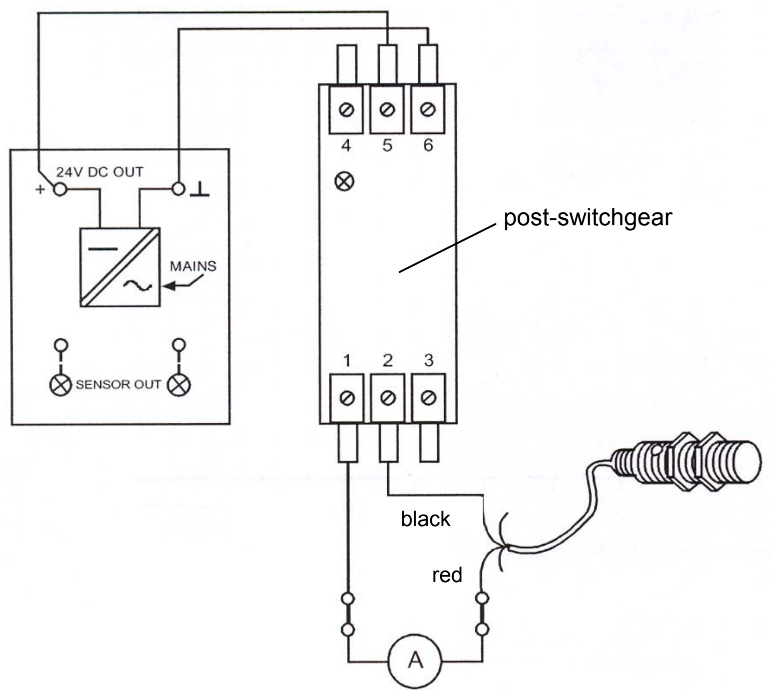

Figure 8.2.6.1 Experiment set-up: Current-path characteristic of the NAMUR magnetic field sensor

s/mm	0	5	10	20	30	50	53	55	56	58	63	(1)*	(2)*
I_A/mA (magnet large)													
I_A/mA (magnet small)													

Table 8.2.6.1

(1)* switching point for approaching
(2)* switching point for moving away

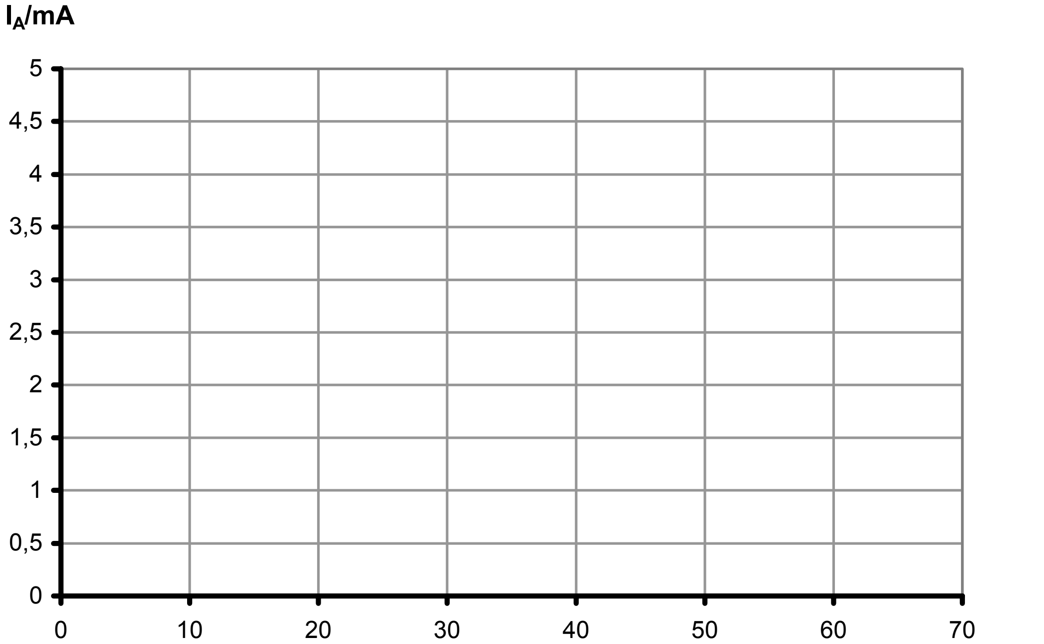

Figure 8.2.6.2 Dependence of the current on the switching distance

8.2.7 Response Curves of the NAMUR Magnetic Field Sensor with a Moving Permanent Magnet

Task:
Demonstrate that the horizontal acquisition range of the NAMUR magnetic field sensor may be restricted if the wrong distance between the „sensor/magnet“ is selected.

Experiment procedure:

- Plug the material sample holder into the segment disk in such a way that the two arrows are pointing towards each other.
- Clamp the material sample St37 into the material sample holder.
- Fix the large permanent magnet to the material sample so that it is pointing towards the sensor.
- Plug the sensor into the carriage with its top facing left and drive the carriage to the left until the sensor touches the permanent magnet.
- Adjust the material sample centrally to the sensor surface.
- Connect the sensor and the post-switchgear as shown in figure 8.2.6.1. Connect an ampere meter between sensor and post-switchgear.
- Drive the carriage to the right until the current in the control current circuit is approx. 1.6 mA.
- Then pull the material sample with the permanent magnet about 30 mm out of the material sample holder (sensor axis) and note the current value in table 8.2.7.1.
- Push the permanent magnet about 5 mm towards the sensor axis and record the current value. Note the value in the table.
- Measure the current values for the distances x specified in the table and enter the values (measurement 1).
- Now reduce the distance between the sensor and the permanent magnet so that the control current is 2 mA (measurement 2) and 2.5 mA (measurement 3).
- Transfer the three characteristics to diagram (figure 8.2.7.1).

measurement	x/mm	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30
1	I_A/mA													
2														
3														

Table 8.2.7.1

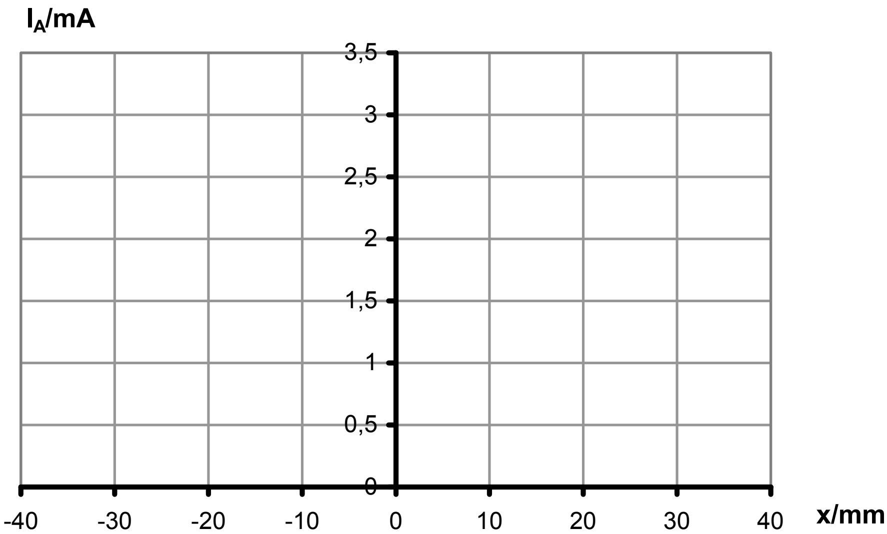

Figure 8.2.7.1 Response curve

9 Fibre Optic Sensors

9.1 Fundamentals

See chapter 5 (Optical Sensors) for introduction part (electromagnetic waves, frequencies and wavelengths).

9.1.1 Structure and Function

Fibre optic sensors transmit light from a punctiform light source P_0 (transmitter) to another place. The light propagates radially and in all directions equally (figure 9.1.1.1):

$$P = \frac{P_0}{r^2}$$

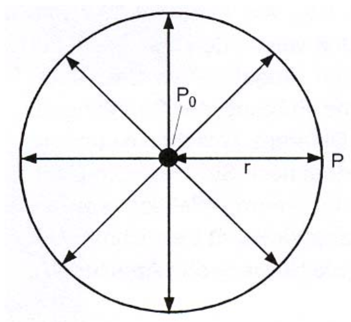

Figure 9.1.1.1 Radial propagation of light

If this radiation is bundled, a parallel beam is produced. This remains constant in power when it does not meet with any obstacle (figure 9.1.1.2).

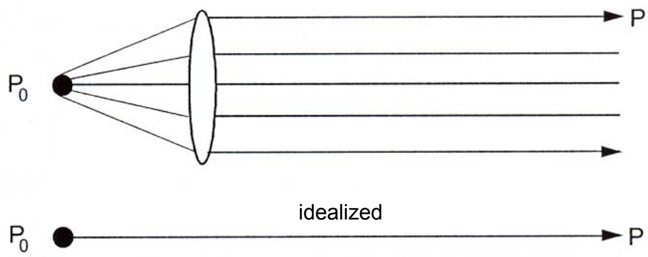

Figure 9.1.1.2 Parallel beam

All media except for a vacuum are contaminated or at least irregular. The radiation is absored or diffused here. This is designated as **attenuation**. Even the purest glass has flaws.

The propagation of light can be represented in simplified form by individual finely bundled beams. If such a beam hits the transition between two media n_1 and n_2, a small part of it will be reflected (angle of incidence = angle of reflection), the rest penetrates in the second medium and is refracted slightly (figure 9.1.1.3). The angles (sines) behave here as the refraction coefficients of the media.

$$\frac{\sin\alpha}{\sin\beta} = \frac{n_1}{n_2}$$

If the angle of incidence in relation to the vertical is increased continuously, a point is reached at which the unreflected part of the beam is first parallel to the boundary line (limit of beam) and finally reflected totally beyond the limit angle. This is referred to as **total reflection**.

Total reflection can only be achieved at the boundary between an optically denser and thinner medium (small refraction coefficient), (see figure 9.1.1.4, next page).

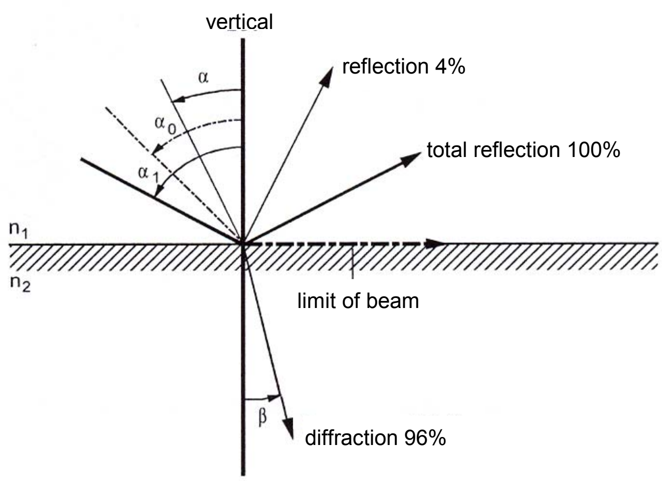

Figure 9.1.1.3 Diffraction, reflection and total reflection

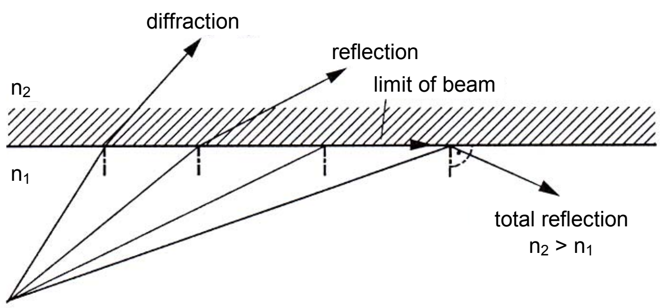

Figure 9.1.1.4 Course of beam in a fibre optic sensor

In a cylindrical fibre optic sensor the light is constantly reflected to and fro by total reflection. In this way the light can also follow the bends in a curved fibre optic sensor (figure 9.1.1.5). Glass or synthetic material is used as a light conductor. The total reflection of the glass fibre core n_2 to the surrounding glass fibre sheath n_1 ($n_1 > n_2$) guides the light radiation through the fibre optic sensor. The greater the difference between n_1 and n_2, the greater the angle at which beams are accepted by the fibre optic sensor and reflected back inside. This angle is known as the angle of **acceptance** Θ. The sine of the angle of acceptance is the **numeric aperture NA**.

$$NA = sin\Theta = \sqrt{n_1^2 - n_2^2}$$

The greater the numeric aperture, the more radiation the fibre optic sensor accepts and the wider the radiated cone at the other end.

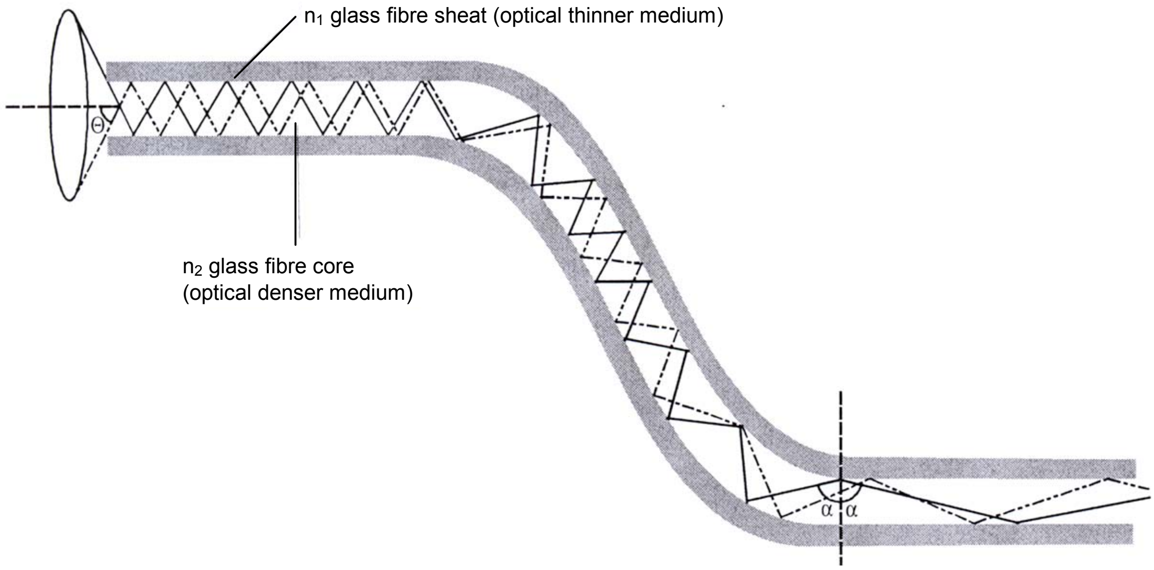

Figure 9.1.1.5 Total reflection in the curved fibre optic sensor

9.2 Experiments

9.2.1 Scanning Width – Acquisition Range

Task:
Examine the acquisition range of the fibre optic sensor for different material samples. Calculate the scanning widths.

Experiment procedure:

- Plug the fibre optic sensor into the carriage so that its top is facing left and clamp it into the holder in such a way that it is protruding about 10 mm on the left.
- Clamp the fibre optic sensor to the top-hat rail.
- Plug both light conductors into the two jacks provided on the top of the fibre optic sensor and fix them with the screw.
- Connect the fibre optic sensor to the supply and indication field of the SENSORICS BOARD as shown in figure 9.2.1.1.
- Plug the material sample holder into the segment disk in such a way that the two arrows are pointing towards each other.

  WARNING!
  - **Only shorten the light conductors with the special cutting tool provided (make sure that the cut is vertical)!**
  - **The light conductors must be exchanged at the post-switchgear in the event of functional problems with the fibre optic sensor!**
  - **The light conductors must snap into the jacks (end stop)!**
  - **Screw must be fixed firmly!**

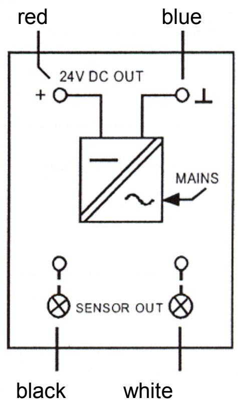

Figure 9.2.1.1

- Clamp the material sample standard white into the material sample holder.
- Drive the fibre optic sensor towards the material sample until the sensor touches it (s = 0 mm). Adjust the material sample centrally to the fibre optic sensor. Note the basic position p_0 in table 9.2.1.1.
- Adjust the optical sensor to the maximum acquisition range (+/-scanning width pushbutton).
- Then drive the fibre optic sensor away from the material sample until the yellow LED on the sensor or the left green LED on the supply and indication field goes out.
- Drive the fibre optic sensor towards the material sample until it switches and note the position p_e.
- Repeat the procedure with the material samples specified in table 9.2.1.1.
- Summarize the results in a general statement.

material sample	standard white	matt black	black gloss	mirror
p_0/mm				
p_e/mm				

Table 9.2.1.1

summary

9.2.2 Frequency Counting – Speed Measuring

Task:
Examine the detection of rotary movements with the fibre optic sensor and determine the frequency f_s and the speed n.

Experiment procedure:

- Connect the fibre optic sensor to the supply and indication field of the SENSORICS BOARD as shown in figure 9.2.1.1 and connect the switching output to the signal input of the counter (switching position COUNT).
- Drive the carriage to the left end of the guide rail.
- Plug the fibre optic sensor into the carriage so that its top is pointing towards the segment disk (centre pin in top hole, the other two are touching the carriage).
  WARNING! The fibre optic sensors may not touch the segment disk!
- Move the carriage so that the fibre optic sensor detects the inner three segments of the disk.
- Now check, by turning the segment disk, whether the sensor recognizes all segments reliably and the counter indicates the number of detected segments (if necessary readjust the fibre optic sensor in the holder or set with potentiometer).
- Switch the counter to pulse counting (switching position FREQUENCY) and set the speed of the segment disk so that a switching frequency of f_s = 60 Hz is indicated. Note the values in table 9.2.2.1.
- Then shift the carriage with the segment disk still running so that the fibre optic sensor detects the four segments in the middle and then the outer 36 segments of the disk. Note the values in the table.
- Then gradually increase the speed of the segment disk until the fibre optic sensor no longer counts perfectly (instable indication or maximum) and note the maximum switching frequency in the table.
- Calculate the speeds n of the segment disk for the determined switching frequencies with the number of segments N.

number of segments N	f_S/Hz	$n = f_S/N \cdot 60$ (rpm)
3	60	
4		
36		
36		
4		
3		

Table 9.2.2.1

9.2.3 Acquisition of Stroke Markings

Task:
Examine the acquisition of stroke markings with the fibre optic sensor.

Experiment procedure:

- Connect the fibre optic sensor to the supply and indication field of the SENSORICS BOARD as shown in figure 9.2.1.1.
- Drive the carriage to the left end of the guide rail.
- Plug the fibre optic sensors into the carriage so that it detects the stroke markings above the carriage (centre pin in side hole, the other two are touching the carriage).
- Shift the carriage in such a way that the fibre optic sensor detects the first marking from the left.
- Check by driving the carriage, whether the fibre optic sensor recognizes the first marking reliably and the counter indicates the number of detected markings (if necessary readjust the fibre optic sensor in the holder or use +/-scanning width pushbutton for adjustment.

  NOTE: The last wide marking on the right should not be counted.
- Then drive the carriage to a position in front of the first marking on the left and set the counter to zero with the RESET pushbutton.
- Drive the carriage to the right until the fibre optic sensor detects the last recognizable marking and enter the counter reading in table 9.2.3.1.
- Determine the position P_R of the narrowest still recognizable marking from the counter readings Z and the total number of markings N and calculate the stroke width b of this marking.

direction	Z	P_R	b
right			
$b = P_R/2$ P_R (position counted from right): $P_R = N – Z + 1$			

Table 9.2.3.1

9.2.4 Acquisition of Relative Positions

Task:
Examine the acquisition of relative positions with the fibre optic sensor.

Experiment procedure:

- Connect the fibre optic sensor to the supply and indication field of the SENSORICS BOARD as shown in figure 9.2.1.1.
- Drive the carriage to the left end of the guide rail.
- Plug the fibre optic sensor into the carriage so that it detects the stroke markings below the carriage (centre pin in side hole, the other two are then touching the carriage).
- Check, by driving the carriage, whether the fibre optic sensor recognizes the markings reliably and the counter displays the number of detected markings (if necessary readjust the fibre optic sensor in the holder or set with potentiometer).
- Then drive the fibre optic sensor over the marking $P_0 = 0$ and set the counter to $Z_0 = 0$ with the RESET pushbutton.
- Drive the carriage to the right until the counter indicates the value Z = 40 and note the position P of the marking which the fibre optic sensor is standing above, in table 9.2.4.1.
- Drive the fibre optic sensor back to marking P = 0 and note the start position P0 (the counter reading Z0 at the start and the counter reading Z at the end) in the table.
- Then drive the fibre optic sensor over marking $P_0 = 10$ and set the counter to zero ($Z_0 = 0$).
- Drive the fibre optic sensor to marking P = 40 and note the counter reading Z.
- Switch the SENSORICS BOARD first off and then on, and drive the fibre optic sensor back over the marking P = 0.

direction	Z_0	P_0	Z	P
right	0	0	40	
left	40			0
right	0	10		40
left		40		0

Table 9.2.4.1

Question:	With which lines from table 9.2.4.1 can the absolute position P be determined from the counter reading and the start values!
Answer:	

9.2.5 Diameter

Task:
Determine the diameter of a coin with the fibre optic sensor.

Experiment procedure:

- Connect the fibre optic sensor to the supply and indication field of the SENSORICS BOARD as shown in figure 9.2.1.1.
- Place a small coin in the positioning field and position it centrally.

  NOTE: The holder of the fibre optic sensor must be pulled out of the carriage so that the sensor is positioned centrally above the coin.
- Adjust the sensor in its holder so that it almost touches the surface of the coin and set it so that it just detects the coin (LED on).
- Connect the output of the sensor to the STOP jack in the control field.
- Drive with the fibre optic sensors over the coin once from the left and once from the right. Note the turn-on positions ($p_{e\ le}$, $p_{e\ ri}$).
- Calculate the diameter of the coin from the two turn-on positions.

$p_{e\ le}$ =
$p_{e\ ri}$ =
diameter d =

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Contents

2 Inductive Sensors

2.2 Experiments

2.2.1 Response Curve

material sample	steel St37			brass		
n	p_n/mm	x_n/mm	s/mm	p_n/mm	x_n/mm	s/mm
1	50.0	15	0.0	50	14	0.0
2	52.0	13	2.0	51	12	1.0
3	53.5	11	3.5	51.8	10	1.8
4	54.5	9	4.5	52.3	8	2.3
5	55.0	7	5.0	52.5	6	2.5
6	55.3	5	5.3	52.5	4	2.5
7	55.5	3	5.5	52.5	2	2.5
8	55.5	1	5.5	52.5	0	2.5
9	55.5	0	5.5			

Table 2.2.1.1

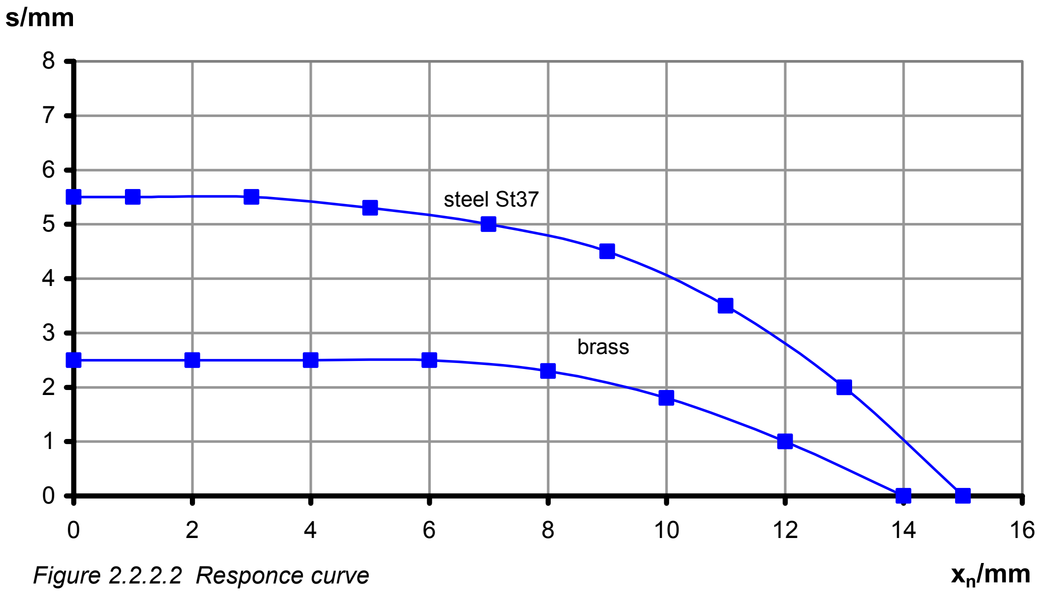


Figure 2.2.2.2 Responce curve

2.2.2 Switching Hysteresis

material sample	p_a/mm	p_e/mm	w/mm	s_n/mm	H/%
steel St37	55.2	55.0	0.2	5	4
brass	52.0	51.9	0.2	5	2
aluminium	52.0	51.9	0.1	5	2

Table 2.2.2.1

2.2.3 Switching Behaviour – Material Dependence

material sample	steel St37	brass	aluminium	copper	synthetic material	permanent magnet (large)
LED on	✔	✔	✔	✔		✔
LED off					✔	

Table 2.2.3.1

Question:	With which materials does the sensor switch, with which not? Give reasons for your answer.
Answer:	Inductive sensors only react to conductive materials because only conductive materials can attenuate the magnetic field of the LC resonance circuit in the inductive sensor.

2.2.4 Reduction Factor

material sample	p_0/mm	p_a/mm	s/mm	R	R/%
steel St37	50.0	55.0	5.0	1.00	100
copper	49.5	52.2	2.7	0.54	54
brass	50.0	52.0	2.0	0.40	40
aluminium	50.0	51.5	1.5	0.30	30

Table 2.2.4.1

Question:	Compare the reduction factor of copper with that in figure 2.1.3.1. Give reasons for any differences.
Answer:	Because the standard measuring plaque used for copper does not have the prescribed thickness of 1 mm, the result deviates from the one in figure 2.1.3.1.

2.2.5 Releasing a Switching Process through a Casing Wall

casing wall	p_e/mm for St37	p_e/mm for brass	p_e/mm for aluminium
board thin	48	46	45
board thick	48	----	----

Table 2.2.5.1

Question 1:	Does the casing wall affect the switching distance?
Answer:	The casing wall has no effect on the switching distance because it is not able to attenuate the magnetic field of the sensor. From the measurements with a thicker casing wall (brass and aluminium) it can be seen that the casing wall may not be thicker than the length of the switching distance.

Question 2:	How does the inductive sensor react to a metallic casing wall?
Answer:	The materials in Table 2.2.5 cannot be detected through a metallic casing wall because the inductive sensor already reacts to the metallic casing wall.

2.2.6 Frequency Counting – Speed Measuring

segment ring	N	f_S/Hz	$n = f_S/N \cdot 60$ (rpm)
outer	4	80	1200
inner	3	60	1200
inner	3	180	3600
outer	4	240	3600

Table 2.2.6.1

2.2.7 Oscillator Frequency

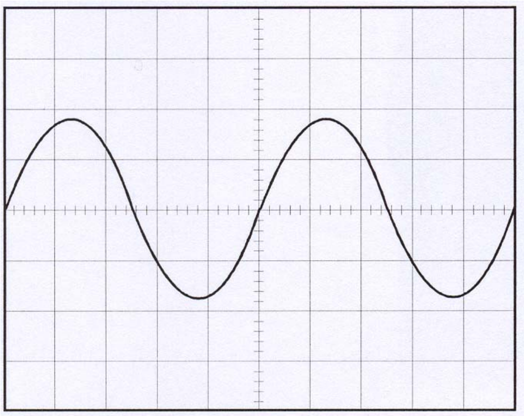


Figure 2.2.7.2

Settings on the oscilloscope:

U = 10 mV / div.

t = 0.5 µs / div.

$$T = 5\ div. \cdot 0.5\ \mu s = 2.5\ \mu s$$

$$f = \frac{1}{T} = \frac{1}{2.5\ \mu s} = 400\ kHz$$

3 Capacitive Sensors

3.2 Experiments

3.2.1 Response Curve

material sample	steel St37			synthetic material		
n	p_n/mm	x_n/mm	s/mm	p_n/mm	x_n/mm	s/mm
1	50.0	18	0.0	50.0	17	0.0
2	58.0	16	8.0	55.0	15	5.0
3	59.5	14	9.5	56.8	13	6.8
4	60.2	12	10.2	57.7	11	7.7
5	60.7	10	10.7	58.2	9	8.2
6	60.8	8	10.8	58.5	7	8.5
7	60.9	6	10.9	58.7	5	8.7
8	60.9	4	10.9	58.8	3	8.8
9	60.9	2	10.9	58.9	1	8.9
10	60.9	0	10.9	58.9	0	8.9

Table 3.2.1.1

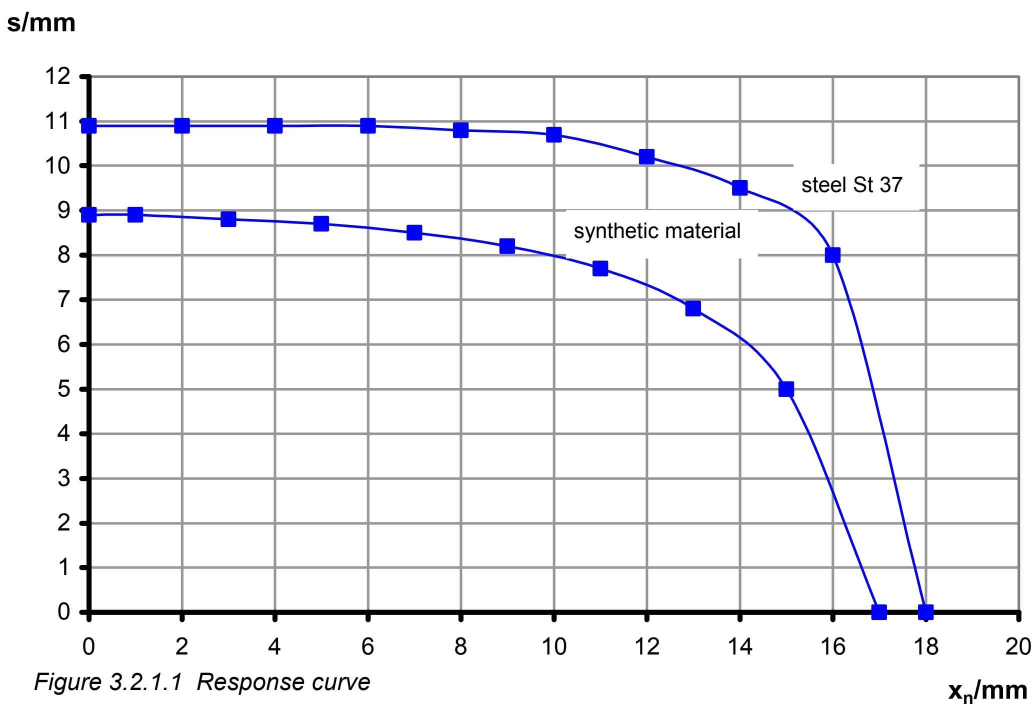


Figure 3.2.1.1 Response curve

3.2.2 Types of Actuation

type of actuation	p_0/mm	p_e/mm	s/mm
1	50.0	57	7.0
2	49.5	61	11.5
3	49.5	65	15.5

Table 3.2.2.1

1. material sample non-conductive	2. material sample conductive insulated	3. material sample conductive earthed
The capacitance is only increased by a change in the dielectric in the area of the capacitor's field (figure 3.2.2.1). The increase in the capacitance is very slight and depends on the permittivity factor ε_r of the material sample.	Two additional series-connected capacitor circuits are produced here between the sensor electrode and the material sample parallel the basic capacitance (figure 3.2.2.2). The increase in the capacitance is therefore greater than with the non-conductive material sample.	The capacitance between the sensor electrode and the material sample is directly parallel to the basic capacitance of the sensor (figure 3.2.2.3). The increase in the capacitance is at its greatest in this case.

Table 3.2.2.2 Summary

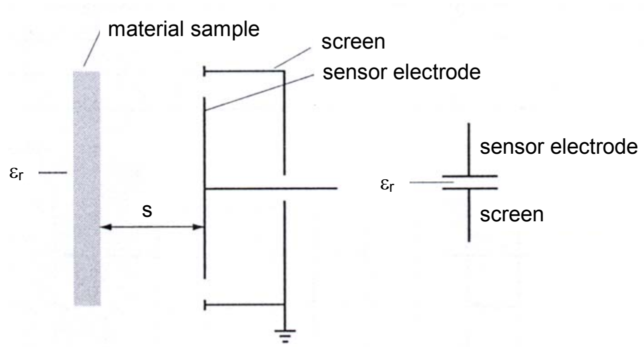


Figure 3.2.2.1 Material sample non-conductive

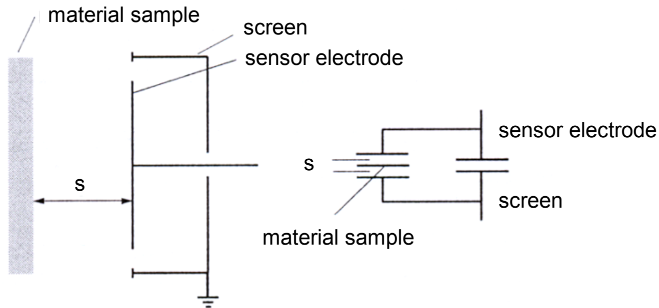


Figure 3.2.2.2 Material sample conductive insulated

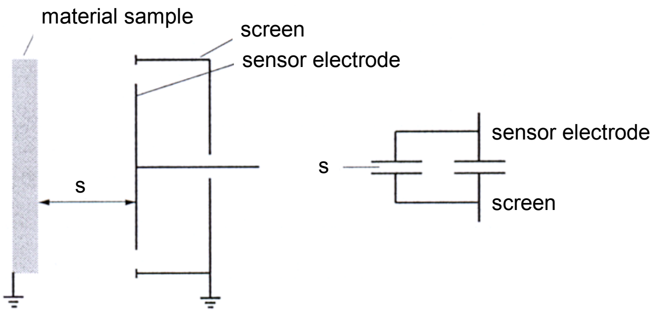


Figure 3.2.2.3 Material sample conductive earthed

3.2.3 Switching Behaviour – Material Dependence

material sample	steel St37	brass	aluminium	copper	synthetic material	permanent magnet, (large)
LED on	✔	✔	✔	✔	✔	✔
LED off						

Table 3.2.3.1

summary
All the materials in table 3.2.2.1 can be detected with the capacitive sensor without overloading. Capacitive sensors react to almost all materials.

3.2.4 Reduction Factor

material sample	p_0/mm	p_a/mm	s/mm	R	R/%
steel St37	50	59.5	9.5	1.00	100
copper	50	59.2	9.2	0.97	97
board thin	49	57.0	8.0	0.84	84
board thick	51	60.2	9.2	0.97	97

Table 3.2.4.1

3.2.5 Releasing a Switching Process through a Casing Wall and Detecting of Wall Thicknesses

casing wall	board thin				board thick			
switching distance	s_0 = 0 mm		s_1 = 6 mm		s_0 = 0 mm		s_1 = 6 mm	
LED	on	off	on	off	on	off	on	off
synthetic material	✔		✔		✔			✔
steel St37	✔		✔		✔		✔	

Table 3.2.5.1

3.2.6 Filling Level Detection

summary
Liquids can be detected by a capacitive sensor through glass, porcelain and synthetic material walls.

3.2.7 Frequency Counting – Speed Measuring

Segment ring	N	f_S/Hz	$n = f_S/N \cdot 60$ (rpm)
inner	3	60	1200
outer	4	80	1200
outer	4	240	3600
inner	3	180	3600

Table 3.2.7.1

NOTE: The value for maximum switching frequency must be not always alike.

4 Magnetic Field Sensors

4.2 Experiments

4.2.1 Response Curve

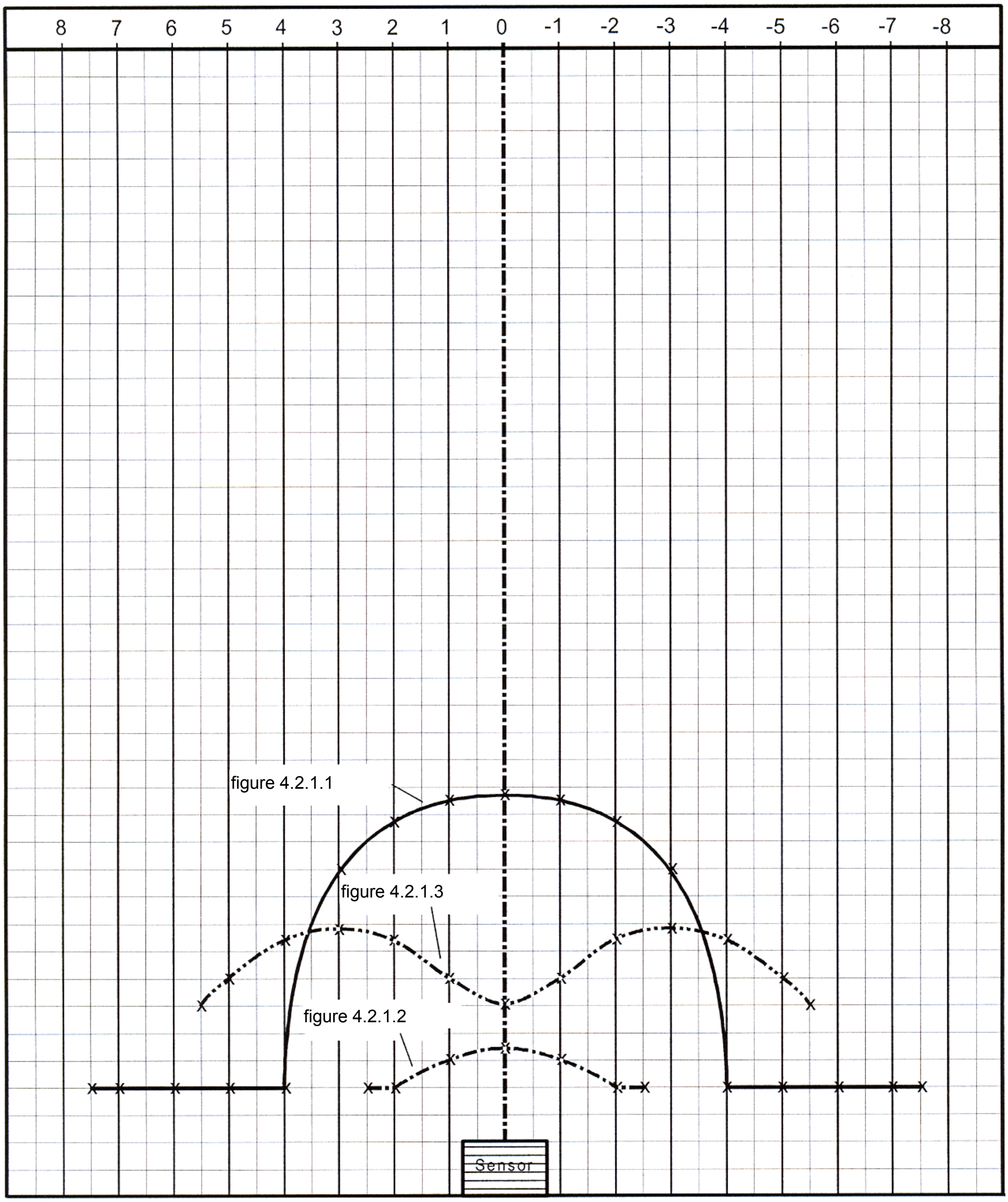


Figure 4.2.1.4 Worksheet: Response curve of the magnetic field sensor

4.2.2 Switching Distance

permanent magnet	p_0/mm	p_a/mm	s/mm
large	55	113	58
small	48	77	29

Table 4.2.2.1

summary
The switching distance s of a magnetic field sensor depends on the strength of the magnetic field of the object to be detected (e.g. permanent magnet).

4.2.3 Switching Hysteresis

permanent magnet	p_a/mm	p_e/mm	w/mm	s_n/mm	H/%
large	114.5	111.5	3.0	60	5,0
small	78.5	77.0	1.5	60	2.5

Table 4.2.3.1

summary
The switching hysteresis should be about the same size for different permanent magnets with the same magnetic field sensor. The switching hysteresis of the magnetic field sensor may, however, be negatively influenced by strong external magnetic fields and a switching hysteresis as of approx. 1 % as specified in the data sheet is no longer guaranteed.

4.2.4 Switching Behaviour – Material Dependence

material sample	steel St37	brass	aluminium	copper	synthetic material	permanent magnet (large)
LED on						✔
LED off	✔	✔	✔	✔	✔	

Table 4.2.4.1

summary
Magnetic field sensors only react to materials which are magnetic and radiate magnetic fields.

4.2.5 Releasing a Switching Process through a Casing Wall

material sample	synthetic material	paper, carton	steel St37	brass	aluminium	copper
LED on	✔	✔	✔	✔	✔	✔
LED off						

Table 4.2.5.1

summary
Switching processes can be released with the magnetic field sensor through all casing walls listed in table 4.2.5.1. The magnetic field can be screened with a large steel spoon or similar so that the magnetic field sensor can no longer detect the object.

5 Optical Sensors

5.2 Experiments

5.2.1 Frequency Counting – Speed Measuring

segment ring	N	f_S/Hz	$n = f_S/N \cdot 60$ (rpm)
inner	3	60	1200
outer	4	80	1200
outer	4	200	3000
inner	3	150	3000

Table 5.2.1.1

5.2.2 Switching Behaviour

angle	0°	15°	30°	45°	60°
material sample	turn-on position p_e/mm				
black gloss	(24)	----	----	----	----
standard white	47	42	37	33	27
mirror	198	(29)	----	----	----

Table 5.2.2.1

summery
The more light the material sample absorbs, the smaller the acquisition angle between sensor and object.

5.2.3 Scanning Width – Spacing Hysteresis

material sample	p_0/mm	p_a/mm	l_{TW}/mm	l_{TWn}/mm	H_a/%
black gloss	55	59	4	48	8,3
standard white	104	111	7	48	12,5
mirror	236	252	16	48	30,0

Table 5.2.3.1

NOTE: The spacing hysteresis of the material sample ,,mirror“ lies outside of the permitted range (> 15 mm, see data sheets).

6 Inductive Analog Sensors

6.2 Experiments

6.2.1 Material Dependence

material	s/mm	0	1	2	3	4	5	6	7	8	9	10	11	12	13
St37	I_A/mA	0	0	0	2	5	10	15	20	23	27	29	30	30	30
alu		3	6	12	18	23	28	30	30	30	30	30	30	30	30
brass		2	5	11	16	22	27	30	30	30	30	30	30	30	30
copper		0	0	1	4	9	14	19	23	27	29	30	30	30	30

Table 6.2.1.1

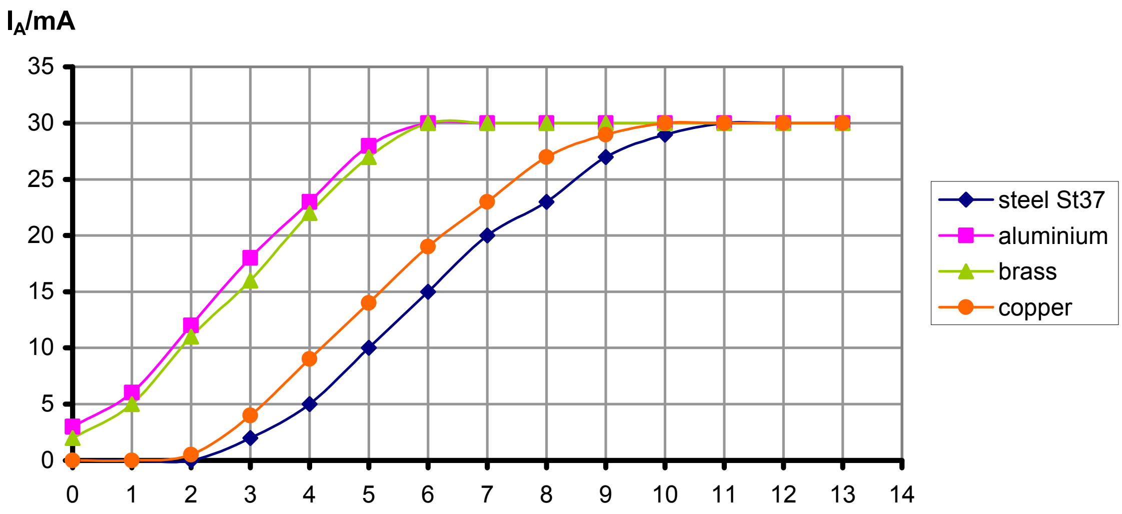


Figure 6.2.1.1 Dependence of the current on the switching distance

6.2.2 Oscillator Frequency

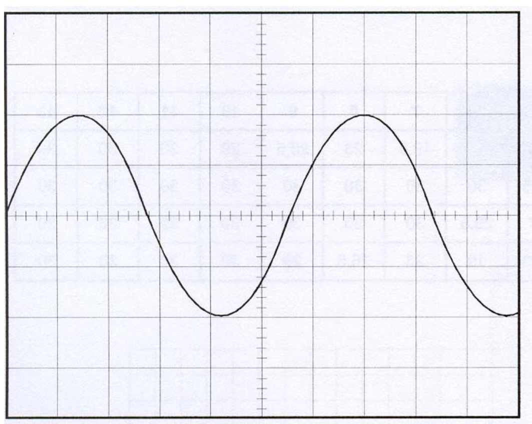


Figure 6.2.2

Settings on the oscilloscope:

U = 20 mV / div.

t = 1 µs / div.

$$T = 5.6\ div. \cdot 1\ \mu s = 5.6\ \mu s$$

$$f = \frac{1}{T} = \frac{1}{5.6\ \mu s} = 178.6\ kHz$$

7 Ultrasonic Sensors

7.2 Experiments

7.2.1 Releasing a Switching Process through an Object in the Acquisition Range

switching point	S1	S2
distance right to left / mm	200	100
distance left to right / mm	208	105
H/mm	8	5

Table 7.2.1.1

7.2.2 Propagation Time Measuring

material sample	S1/mm	S2/mm
matt black	200.0	100
	208.0	105
cork	202.5	103
	210.5	108
foam	207.0	107
	212.5	110

Table 7.2.2.1

summary
The ultrasonic sensor exhibits none or a negligibly reduction factor for all three attenuating materials if the materials have the same thickness (compare e.g. cork / matt black): S1 (cork) - S1 (matt black) = 202.5 - 199.5 = 3 mm. The spacing 3 mm is equivalent to the thickness of the material sample cork.

7.2.3 Response Curve

p/mm	300	280	260	240	220	200	180	160	140	120	100	80	60	40	20	10
y/mm	25	20	20	18	17	16	15	13	0	0	2	6	10	18	20	25
s/mm	13	15	15	16	17	17	18	19	25	25	24	22	20	16	15	13

Table 7.2.3.1

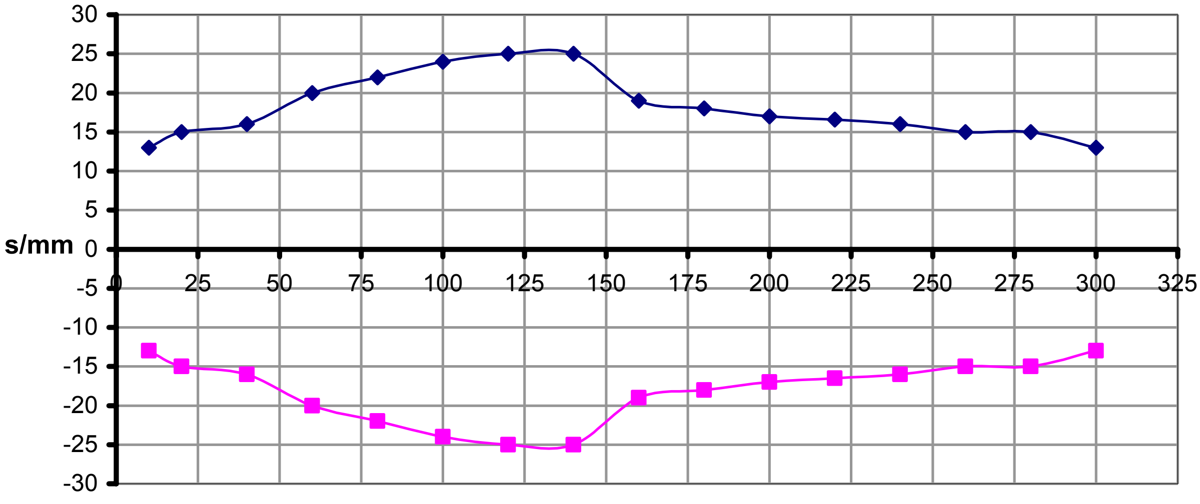


Figure 7.2.3.2 Sound lobe

p/mm

7.2.4 Determining of the Maximum Permissible Speed

point of response no. 1
y_1 = 0 mm
$s_1 = (b-y_1)/2$ = (50 mm – 0 mm)/2 = 25 mm

point of response no. 2
y_2 = 5 mm
$s_2 = (b-y_2)/2$ = (50 mm – 5 mm)/2 = 22.5 mm

width of the sound lobe
$b_S = s_1 + s_2$ = 25 mm + 22.5 mm = 47.5 mm

response time (in data sheet)
t = 35 s (vgl. Datenblatt)

max. permissible speed
$v = s/t = (b_S + b)/t$ = (47.5 mm + 50 mm)/35 ms = 2.78 m/s

8 NAMUR Sensors

8.2 Experiments

8.2.1 Current-path Characteristic of the Inductive NAMUR Sensor

material	s/mm	0	1	2	3	4	5	6	7	8	9
St37	I_A/mA	0.5	0.5	0.5	0.5	0.6	0.9	4.5	4.7	4.8	4.8
alu		0.5	0.7	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
brass		0.5	0.6	4.2	4.8	4.8	4.8	4.8	4.8	4.8	4.8
copper		0.5	0.5	0.5	1.2	4.7	4.8	4.8	4.8	4.8	4.8

Table 8.2.1.1

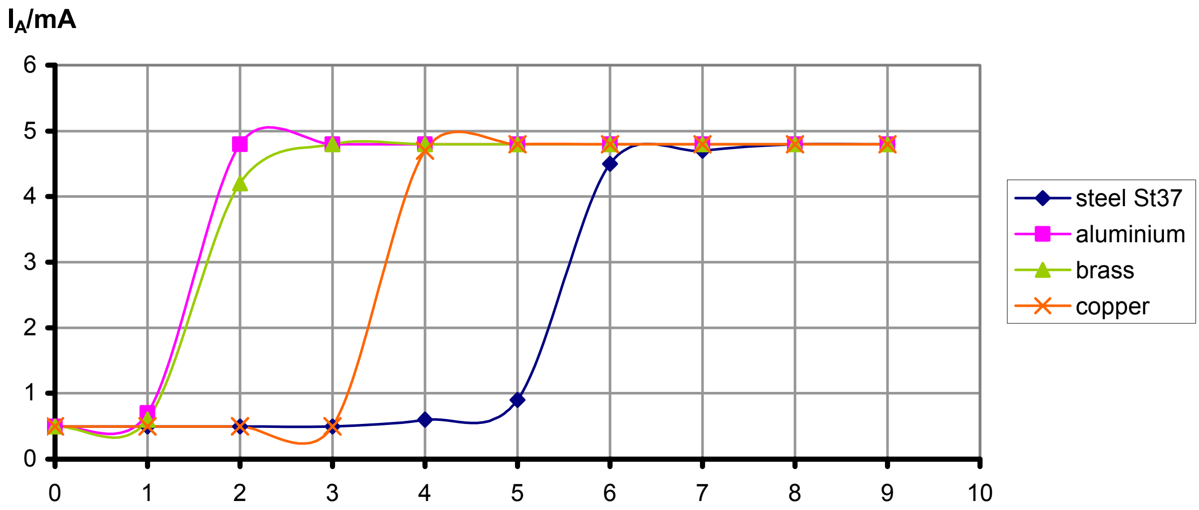


Figure 8.2.1.2 Dependence of the current on the switching distance

8.2.2 Checking the Switching Points of an Inductive NAMUR Sensor

material sample	I_A/mA for p_1	I_A/mA for p_2	in the range? yes/no
steel St37	1.9	1.5	yes
aluminium	1.7	1.5	yes
brass	1.8	1.4	yes
copper	1.7	1.4	yes

Table 8.2.2.1

8.2.3 Line Break and Short-circuit Monitoring with the Inductive NAMUR Sensor

measurement	error	LED on	LED off
1	no error	✔	
	short-circuit		✔
	line break		✔
2	no error		✔
	short-circuit		✔
	line break		✔
3	no error	✔	
	short-circuit		✔
	line break	✔	
4	no error		✔
	short-circuit		✔
	line break	✔	

Table 8.2.3.1

summary
In measurements 1 and 2 the post-switchgear has a defined state (LED off or „material absent") in the event of a malfunction (short-circuit, line break). In measurements 3 and 4 the „material present" state is simulated for a line break and the state „material absent" for a short-circuit. Therefore there is no line break monitoring. No defined state can be adopted in the event of an error.

8.2.4 Oscillator Frequency of the Inductive NAMUR Sensor

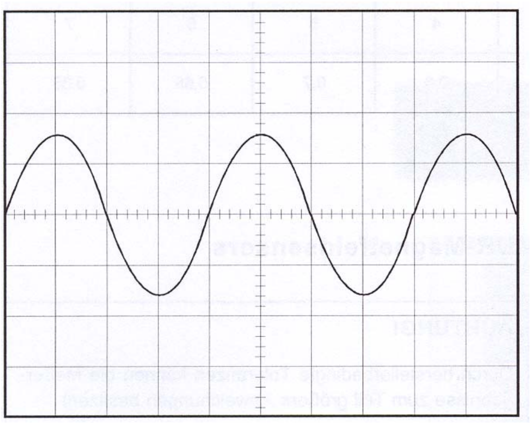


Figure 8.2.4.1

Settings on the oscilloscope::

U = 50 mV / div.

t = 0.5 µs / div.

$$T = 4\ div. \cdot 0.5\ \mu s$$

$$f = \frac{1}{T} = \frac{1}{2\ \mu s} = 500\ kHz$$

8.2.5 Current-path Characteristic of the Capacitive NAMUR Sensor

s/mm	0	1	2	3	4	5	6	7
I_A/mA	3.7	3.0	2.4	1.6	0.8	0.7	0.65	0.65

Table 8.2.5.1

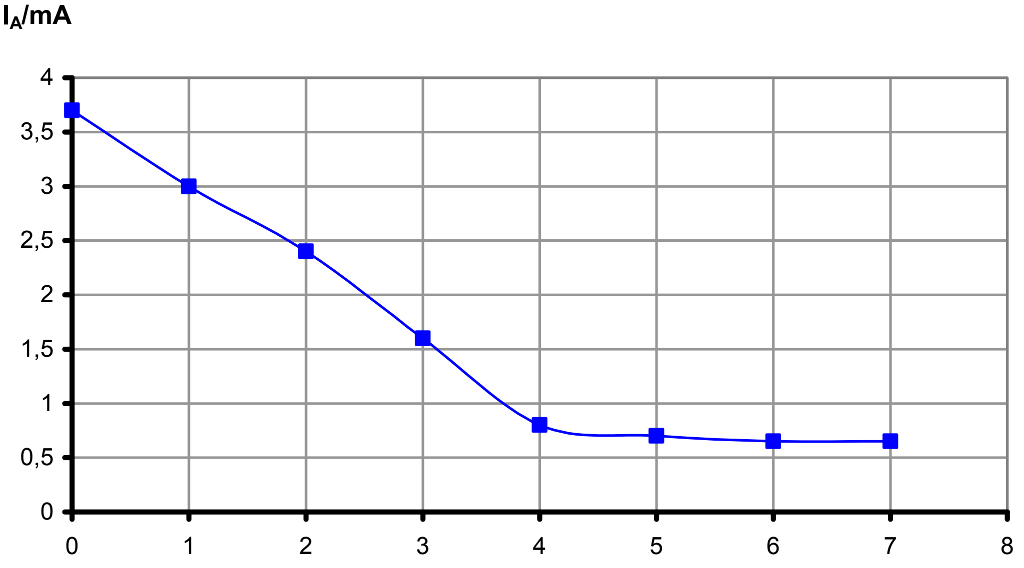


Figure 8.2.5.2 Dependence of the current on the switching distance

WARNING! The measured values for the current I_{out} may be different depending on the setting of the sensitivity potentiometer of the capacitive NAMUR sensor!

8.2.6 Current-path Characteristic of the NAMUR Magnetic Field Sensor

s/mm	0	5	10	20	30	50	53	55	56	58	63	(1)*	(2)*
I_A/mA (magnet large)	3.65	3.70	3.75	3.75	3.75	3.70	3.50	1.40	1.00	0.70	0.50	1.70	1.60
I_A/mA (magnet small)	3.75	3.75	3.75	3.70	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.70	1.60

Table 8.2.6.1 (1) switching point for approaching, 2)* switching point for moving away*

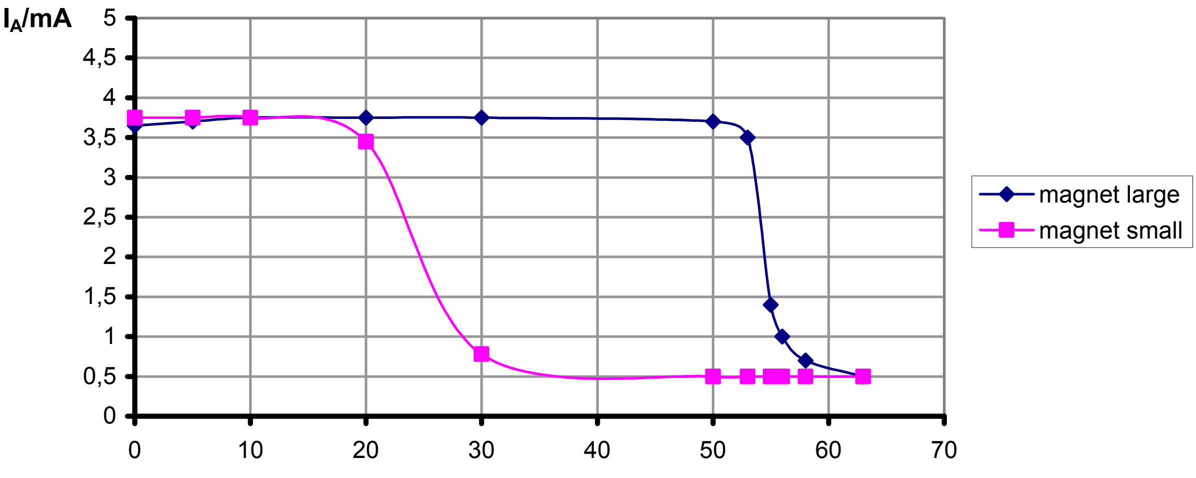


Figure 8.2.6.2 Dependence of the current on the switching distance

WARNING! **Because of tolerances produced by the manufacturer the measuring results may have wider deviations from the values!**

8.2.7 Response Curves of the NAMUR Magnetic Field Sensor with a Moving Permanent Magnet

measurement	x/mm	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30
1	I_A/mA	0.47	0.47	0.51	0.63	0.87	1.21	1.58	1.52	1.08	0.73	0.49	0.47	0.47
2		0.47	0.47	0.54	0.69	1.03	1.66	2.21	2.15	1.45	0.88	0.64	0.47	0.47
3		0.47	0.49	0.55	0.76	1.25	2.32	3.15	3.00	2.00	1.10	0.72	0.47	0.47

Table 8.2.7.1

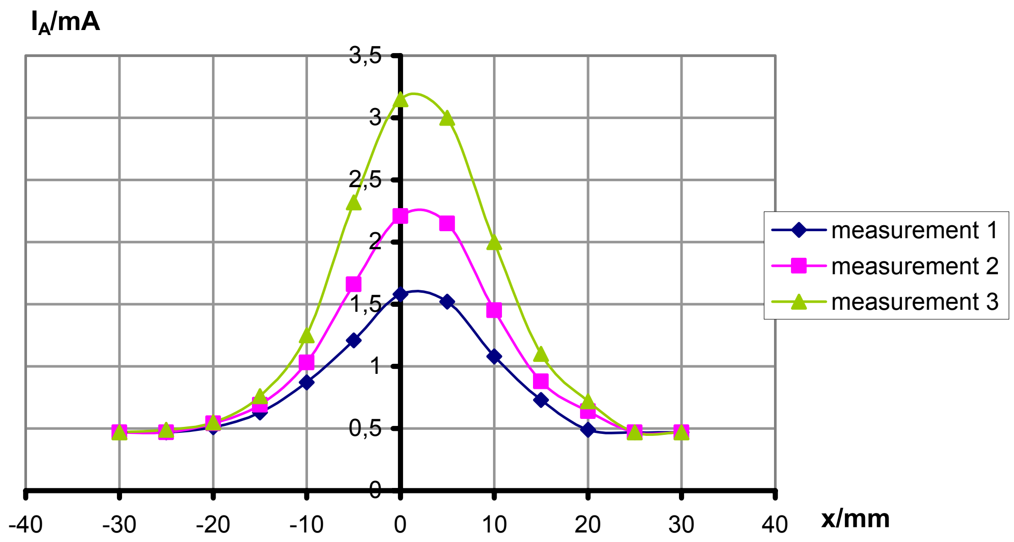


Figure 8.2.7.1 Response curve

9 Fibre Optic Sensors

9.2 Experiments

9.2.1 Scanning Width – Acquisition Range

material sample	standard white	matt black	black gloss	mirror I
p_0/mm	50.0	50.0	50.0	50.0
p_e/mm	93.5	61.9	62.2	110.3

Table 9.2.1.1

WARNING! The values in Table 9.2.1 are subject to strict tolerances!

summary
The more light the material sample absorbs, the greater the acquisition range Δl_{TW}.

9.2.2 Frequency Counting – Speed Measuring

number of segments N	f_S/Hz	$n = f_S/N \cdot 60$ (rpm)
3	60	1200
4	80	1200
36	720	1200
36	756	1260
4	244	3660
3	183	3660

Table 9.2.2.1

9.2.3 Acquisition of Stroke Markings

direction	Z	P_R	b
right	16	1	0.5
$b = P_R/2$ P_R (position counted from right): $P_R = N – Z + 1$			

Table 9.2.3.1

9.2.4 Acquisition of Relative Positions

direction	Z_0	P_0	Z	P
right	0	0	40	**40**
left	40	**40**	**80**	0
right	0	10	**30**	40
left	**0**	40	**40**	0

Table 9.2.4.1

Question:	With which lines from table 9.2.4.1 can the absolute position P be determined from the counter reading and the start values!		
Answer:	**right**	line 1 and 3	$P = Z + Z_0 + P_0$
	left	line 2 and 4	$P = Z - Z_0 - P_0$

9.2.5 Diameter

$p_{e\ le}$ = 306.5 mm
$p_{e\ ri}$ = 328 mm
diameter $d = p_{e\ ri} - p_{e\ le}$ = 328 mm – 306.5 mm = 21.5 mm

Notes

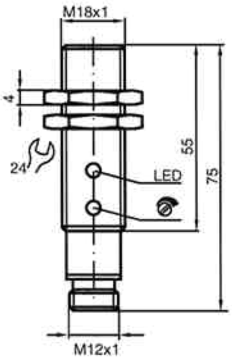
Capacitive proximity switches

CJ8-18GM-E2-V1

Comfort series

8 mm embeddable

The switching distance can be set over a wide range with the potentiometer

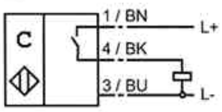


CE

Switching element function	PNP	Make function
Rated operating distance s_n	8 mm	
Installation	embeddable	
Assured operating distance s_a	0 ... 5,76 mm	
Operating voltage U_B	10 ... 35 V	
Switching frequency f	0 ... 100 Hz	
Reverse polarity protection	Protected against reverse polarity	
Short circuit protection	pulsing	
Voltage drop U_d	≤ 3 V	
Operating current I_L	0 ... 300 mA	
No-load supply current I_0	≤ 10 mA	
Indication of the switching state	LED, yellow	
EMC in accordance with	EN 60947-5-2	
Ambient temperature	-30 ... 70 °C (243 ... 343 K)	
Connection type	V1-connector	
Housing material	brass	
Sensing face	PBT	
Protection degree	IP67	

Connection_type:

E2



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2003-07-16

www.pepperl-fuchs.com

PEPPERL+FUCHS GmbH

Reflection light scanner

OBT200-18GM60-E5-V1

with 4-pin, M12 connector

CE

- **Dual colour indication LED**
- **High switching frequency**
- **Light/dark ON, programmable**
- **Strong metallic housing in cylindrical shape M18 x 1**
- **Protection degree IP67**

Date of edition 06/04/04

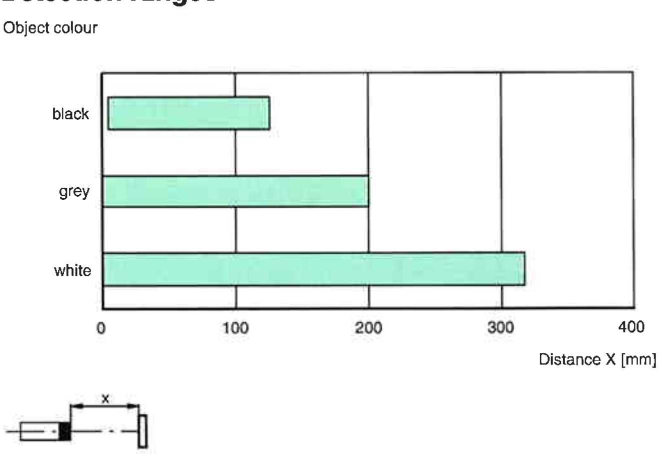
Pepperl+Fuchs Group • Tel.: Germany +49 621 776-0 • USA +1 330 4253555 • Singapore +65 67799091 • Internet http://www.pepperl-fuchs.com

General specifications	
Detection range	0 ... 200 mm
Light source	IRED , 880 nm
Approvals	CE
Reference target	standard white 200 mm x 200 mm
Light type	Infrared
Diameter of the light spot	approx. 40 mm at 200 mm
Ambient light limit	10000 Lux
Indicators/operating means	
Operating display	LED green
Function display	dual colour-LED, yellow/green yellow: switching state grün: power on flashing: stability control
Operating elements	sensing range adjuster
Electrical specifications	
Operating voltage	10 ... 30 V DC
Ripple	10 %
No-load supply current I_0	≤ 25 mA
Time delay before availability t_v	≤ 25 ms
Output	
Switching type	Light/dark on selectable electrically switchable
Signal output	1 PNP output, short-circuit proof, protected from reverse polarity, open collector
Switching voltage	max. 30 V DC
Switching current	max. 100 mA
Voltage drop U_d	≤ 2,5 V
Switching frequency f	≤ 500 Hz
Response time	≤ 1 ms
Standard conformity	
Standards	EN 60947-5-2
Ambient conditions	
Ambient temperature	-25 ... 55 °C (248 ... 328 K)
Storage temperature	-40 ... 70 °C (233 ... 343 K)
Mechanical specifications	
Protection degree	IP67
Connection	connector M12 x 1, 4-pin
Material	
Housing	brass, nickel-plated
Optical face	PC
Mass	45 g

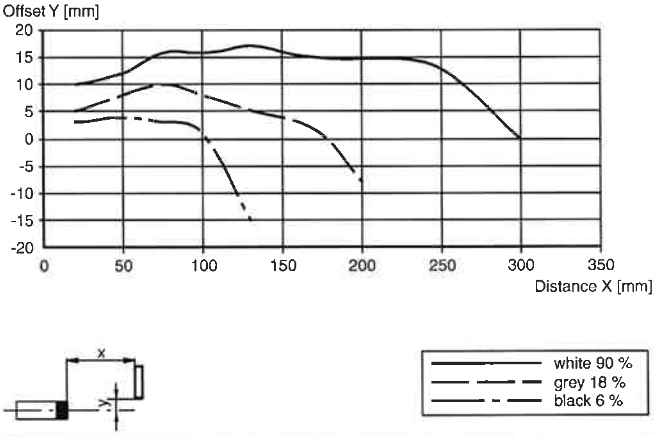
Date of edition 06/04/04

Curves/Diagrams

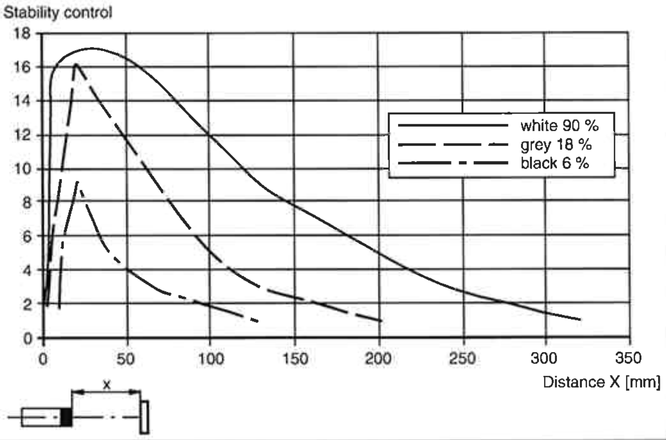
Detection ranges



Characteristic response curve

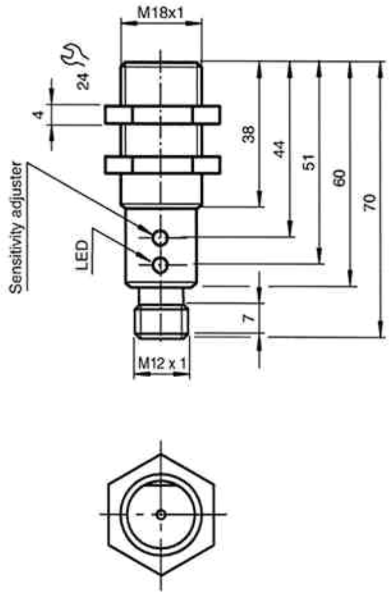


Relative received light strength

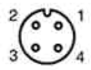


Date of edition 06/04/04

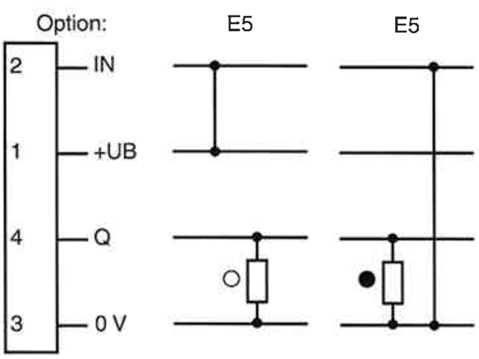
Dimensions



Unit connector



Electrical connection



Caution:

Series 18GM60 devices are not wiring compatible to series 18GM70 devices!

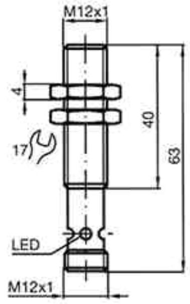
❍ = light on, ● = dark on

Date of edition 06/04/04

Magnetic proximity switches

MB60-12GM50-E2-V1

Comfort series
60 mm embeddable
Basic series
60 mm embeddable

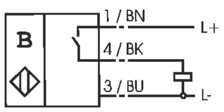


CE

Switching element function	PNP Make function
Rated operating distance s_n	60 mm
Installation	embeddable, in non-magn. metal
Assured operating distance s_a	10 ... 48,6 mm
Operating voltage U_B	10 ... 30 V
Switching frequency f	0 ... 5000 Hz
Reverse polarity protection	Protected against reverse polarity
Short circuit protection	pulsing
Voltage drop U_d	≤ 1,5 V
Operating current I_L	0 ... 300 mA
No-load supply current I_0	≤ 10 mA
Indication of the switching state	ring LED, yellow
Standards	EN 60947-5-2
Ambient temperature	-25 ... 75 °C (248 ... 348 K)
Connection type	V1-connector
Housing material	brass, nickel-plated
Sensing face	PA
Protection degree	IP67

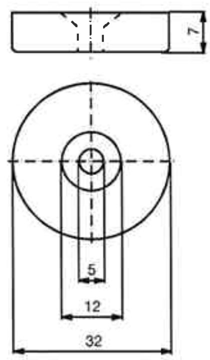
Connection_type:

E2



Magnet DM 60-31-15

Magnet DM 25-32-07



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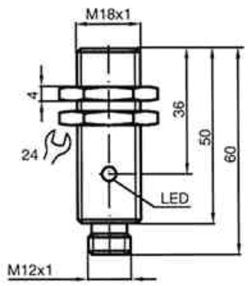
Inductive proximity switches

NJ5-18GM50-E2-V1

Comfort series

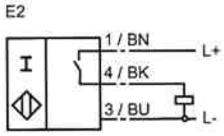
5 mm embeddable



CE

Switching element function	PNP Make function
Rated operating distance s_n	5 mm
Installation	embeddable
Assured operating distance s_a	0 ... 4,05 mm
Reduction factor r_{Al}	0,2
Reduction factor r_{Cu}	0,15
Reduction factor r_{V2A}	0,62
Mounting conditions	
A	0 mm
B	0 mm
C	15 mm
Operating voltage U_B	10 ... 60 V
Switching frequency f	0 ... 1500 Hz
Hysteresis H	1 ... 15 typ. 6 %
Reverse polarity protection	yes
Short circuit protection	pulsing
Voltage drop U_d	≤ 3 V
Operating current I_L	0 ... 200 mA
Off-state current I_r	0 ... 0,5 mA typ. 0,01 mA
No-load supply current I_0	≤ 9 mA
Indication of the switching state	LED, yellow
Standards	EN 60947-5-2
Ambient temperature	-25 ... 70 °C (248 ... 343 K)
Storage temperature	-40 ... 85 °C (233 ... 358 K)
Connection type	V1-connector
Core cross-section	-
Housing material	high grade steel
Sensing face	PBT
Protection degree	IP67

Connection_type:



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2003-03-25

www.pepperl-fuchs.com

PEPPERL+FUCHS GmbH

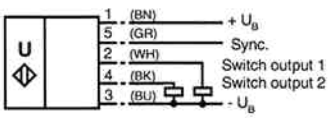
Ultrasonic sensor
UC500-30GM-E6R2-V15

Features

- Parameterisation interface for the application-specific adjustment of the sensor setting via the service program ULTRA 2001
- 2 switch outputs freely adjustable
- Hysteresis mode selectable
- Window function can be selected
- Synchronisation options
- Adjustable acoustic power and sensitivity
- Temperature compensation

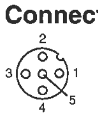
Electrical connection

Standard symbol/Connection:
(version E6, pnp)

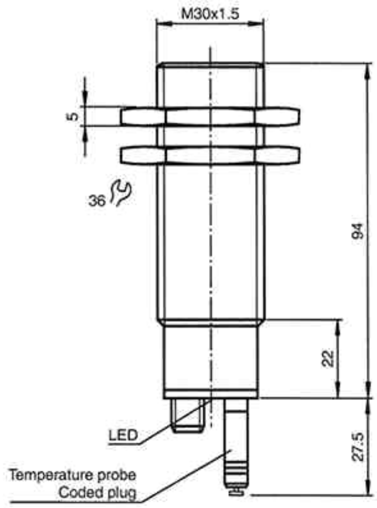


Core colours in accordance with EN 60947-5-2.

Connector V15



Dimensions



CE

Technical data

General specifications	
Sensing range	30 ... 500 mm
Adjustment range	50 ... 500 mm
Unusable area	0 ... 30 mm
Standard target plate	100 mm x 100 mm
Transducer frequency	approx. 380 kHz
Response delay	21 ms minimum 63 ms factory setting
Indicators/operating means	
LED green	permanent: Power-on flashing: Standby mode or TEACH-IN function object detected
LED yellow 1	permanent: switching state switch output 1 flashing: TEACH-IN function
LED yellow 2	permanent: switching state switch output 2 flashing: TEACH-IN function
LED red	permanent: temperature/TEACH-IN plug not connected flashing: fault or TEACH-IN function object not detected
Temperature/TEACH-IN connector	temperature compensation , TEACH-IN of the switch points , output function setting
Electrical specifications	
Operating voltage	10 ... 30 V DC , ripple 10 $\%_{SS}$
No-load supply current I_0	≤ 50 mA
Interface	
Interface type	RS 232, 9600 Bit/s , no parity, 8 data bits, 1 stop bit
Input/Output	
Synchronisation	bi-directional 0 level $-U_B$...+1 V 1 level: +4 V...$+U_B$ input impedance: > 12 KOhm synchronisation pulse: ≥ 100 µs, synchronisation interpulse period: ≥ 2 ms
Synchronisation frequency	
Common mode operation	≤ 95 Hz
Multiplex operation	≤ 95/n Hz, n = number of sensors
Output	
Output type	2 switch outputs pnp, NO/NC, parameterisable
Repeat accuracy	≤ 0,1 % of full-scale value
Rated operational current I_e	200 mA , short-circuit/overload protected
Voltage drop U_d	≤ 2,5 V
Switching frequency f	≤ 7 Hz
Range hysteresis H	1 % of the adjusted operating range (default settings), programmable
Temperature influence	≤ 2 % from full-scale value (with temperature compensation) ≤ 0,2 %/K (without temperature compensation)
Standard conformity	
Standards	EN 60947-5-2
Ambient conditions	
Ambient temperature	-25 ... 70 °C (248 ... 343 K)
Storage temperature	-40 ... 85 °C (233 ... 358 K)
Mechanical specifications	
Protection degree	IP65
Connection	connector V15 (M12 x 1), 5 pin
Material	
Housing	stainless steel 1.4303 plastic parts PBT
Transducer	epoxy resin/hollow glass sphere mixture; polyurethane foam
Mass	140 g

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Notes

Description of the sensor functions

This ultrasonic sensor features a four-pole temperature/TEACH-IN plug, that can be connected in four different positions. These have the following significance.

Plug position	Meaning
A1	TEACH-IN switching point A1
A2	TEACH-IN switching point A2
E2/E3	Switching: 2 independent switching points/window mode/hysteresis mode
T	Temperature compensation

Description of the TEACH-IN procedure

TEACH-IN of switching points 1 or 2

- Cut supply voltage
- Remove TEACH-IN plug
- Restore supply voltage (Reset)
- Set object to desired switching point
- Plug and remove the TEACH-IN plug in pos. A1 or A2. Switching point A1 or A2 is taught.
  Caution: Removing the temperature/TEACH-IN plug, the values of the object position will be adopted.
- The TEACH-IN procedure is controlled with the LED. The green LED flashes, when object is detected, the red LED flashes when no object is detected.
- Connect TEACH-IN plug in pos. T. The TEACH-IN procedure is completed, the sensor is working in normal mode.

TEACH-IN of switching function

- Cut supply voltage
- Remove TEACH-IN plug
- Restore supply voltage (Reset)
- Connect TEACH-IN plug in pos. E2/E3. By multiple plugging, three different modes of operation can be set in cyclical sequence:
  - switching point mode, LED A1 is flashing,
  - window mode, LED A2 is flashing
  - hysteresis mode, LED A1 and A2 are flashing
- Connect TEACH-IN plug in pos. T. The TEACH-IN procedure is completed, the sensor is working in normal mode.

Note: If the temperature/TEACH-IN plug has not been plugged in within 5 minutes in position T, the sensor will return to normal mode (with the latest permanent stored values) without temperature compensation.

Synchronisation

The sensor features a synchronisation input for the suppression of mutual interference. If this input is not used, the sensor will operate using an internally generated clock rate. It can be synchronised by applying a square wave voltage. A falling edge leads to the transmission of a single ultrasonic pulse. A low level ≥ 1 s or an open synchronisation input will result in the normal operation of the sensor.

A high level > 1 s will result in the standby mode of the sensor (indicator green LED). The outputs pause in the latest status.

Synchronisation cannot be performed during TEACH-IN and vice versa.

Multiple operating modes are possible

1. Two to five sensors can be synchronised by interconnecting their synchronisation inputs. In this case, the sensors alternately transmit ultrasonic pulses.
2. Multiple sensors can be controlled by the same synchronisation signal. The sensors are synchronised.
3. The synchronisation pulses are sent cyclically to individual sensors. The sensors operate in multiplex mode.
4. A high level at the synchronisation input disables the sensor.

The response time increases when the sensor is synchronised, because the synchronisation increases the measurement cycle time.

Note:

If the option for synchronization is not used, the synchronization input has to be connected to ground (0V) or the sensor has to be operated via a V1 cable connector (4-pin).

Default setting

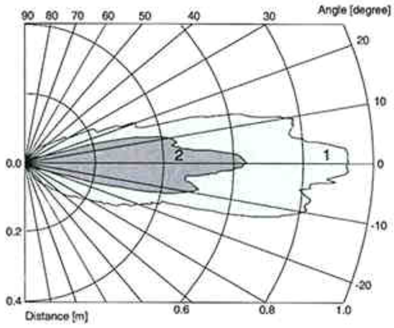
A1: unusable area
A2: nominal sensing range

Model number

UC500-30GM-E6R2-V15

Characteristic curves/additional information

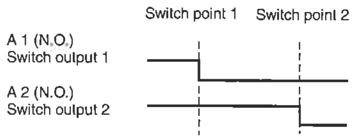
Characteristic response curve



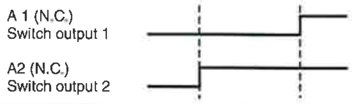
Curve 1: flat surface 100 mm x 100 mm
Curve 2: round bar, Ø 25 mm

Possible operating modes

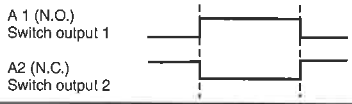
1. Switch point mode
When A1 < A2, both switch outputs are activated as N.O. contacts.



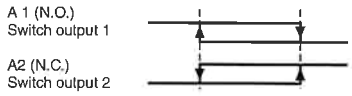
When A1 > A2, both switch outputs are activated as N.C. contacts.



2. Window mode
To exchange the switching distances is of no effect.



3. Hysteresis mode
To exchange the switching distances is of no effect.

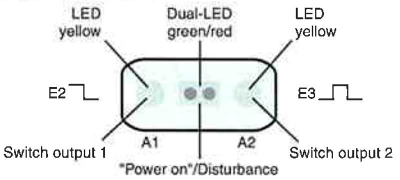


LED Displays

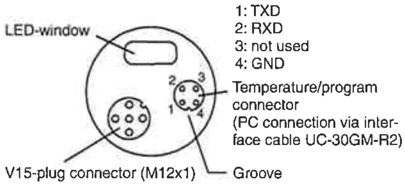
Displays in dependence on operating mode	Dual LED green	LED red	LED yellow A1	LED yellow A2
TEACH-IN of switching point A1 object detected no object detected	 flashing off	 off flashing	 flashing flashing	 off off
TEACH-IN switching point A2 object detected no object detected	 flashing off	 off flashing	 off off	 flashing flashing
TEACH-IN mode of operation (E2/E3) two independent switching points window mode Hysteresis mode	 on on on	 off off off	 flashing off flashing	 off flashing flashing
Normal mode temperature compensated plug pulled or shorted	 on off	 off on	 switching state A1 switching state A1	 switching state A2 switching state A2
Interference (e.g. compressed air)	off	flashing	last or defined condition	last or defined condition
Standby	flashes	off	previous state	previous state

LED ON indicates closed switch output.

LED-Window



RS 232-connection



Note on communication with the UC-30GM-R2 interface cable

The UC-30GM-R2 interface cable allows for communication with the ultrasonic sensor using the ULTRA 2001 service program. The cable creates a connection between the PC-internal RS 232 interface and the plug-in connection for the temperature/program plug on the sensor. When setting up the connection on the sensor, make certain the plug is lined up correctly; otherwise no communication will be possible. The protrusion of the round plug must be inserted into the groove of the plug connection on the sensor side and **not** into the arrow symbol on the sensor.

Adjustable parameter with service program ULTRA 2001

- Switching point 1 and 2
- NO/NC function
- Mode of operation
- Sonic speed
- Temperature offset (The inherent temperature-rise of the sensor can be considered in the temperature compensation)
- Expansion of the unusable area (for suppression of unusable area echoes)
- Reduction of the detection range (for suppression of remote range echoes)
- Time of measuring cycle
- Acoustic power (interference of the burst duration)
- Sensitivity
- Behaviour of the sensor in case of echo loss
- Behaviour of the sensor in case of a fault
- Average formation via an allowed number of measuring cycles
- On/off-delay
- Switching hysteresis
- Selection of the parameter set, RS 232 or manually.

Accessories

Mounting aids

BF30
BF30F
BF5-30
M-105

Sound deflectors

UVW90-M30
UVW90-K30

External temperature probe

UC-30GM-TEMP

Extension cable

UC-30GM-PROG

Programming tools

Service program ULTRA 2001
Interface cable UC-30GM-R2

Cable sockets *)

V15-G-2M-PVC
V15-W-2M-PUR

*) For additional cable sockets see section „Accessories“.

Fibre optic device for plastic fibre optics

SU15-K/32/82f/115

with 2 m fixed cable

CE

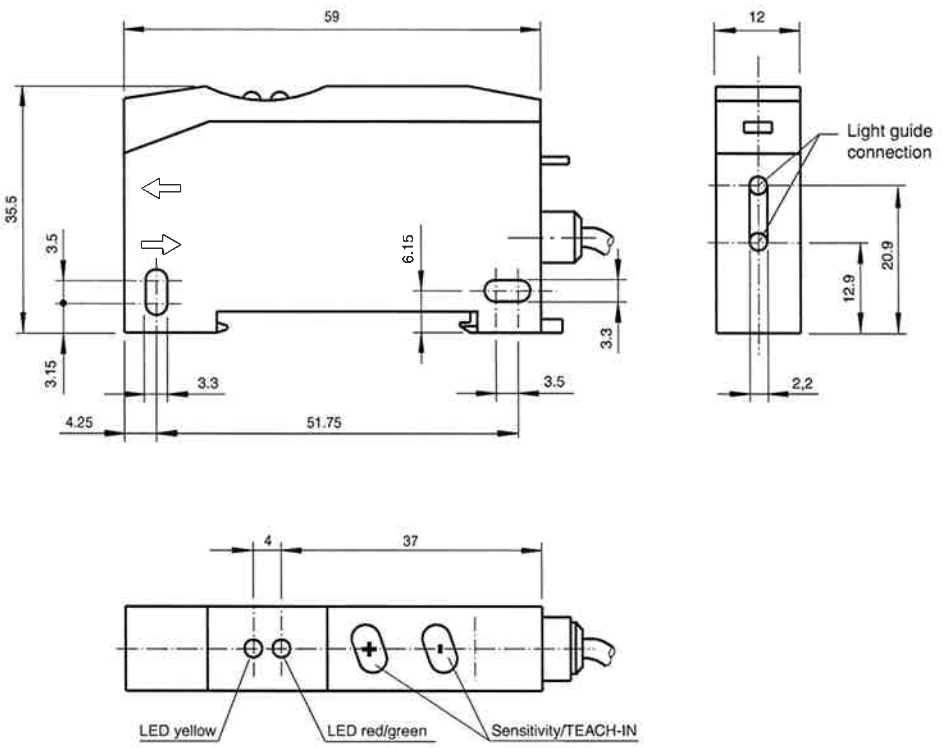
- Parameterisation via optical communication link (e.g. optional time increments)
- Pre-fault indication and output (dynamic and static)
- Visible red light
- Protected against mutual interference
- DIN rail mounting
- Extensive fibre optic product selection as accessories

Date of edition 06/15/04

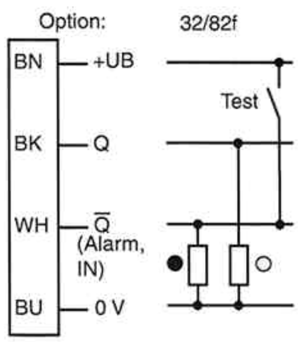
General specifications	
Effective detection range	depends on the fibre optics being used see selection table for fibre optics
Light source	LED , 660 nm
Approvals	CE
Reference target	standard white, 50 mm x 50 mm (in direct detection)
Light type	red, alternating light
Ambient light limit	10000 Lux
Indicators/operating means	
Operating display	LED green
Function display	TEACH-IN: LED green flashing switching state: LED yellow pre-fault indicator: LED red flashing
Operating elements	membrane keys for setting sensitivity and TEACH IN
Electrical specifications	
Operating voltage	10 ... 30 V DC
Ripple	10 %
No-load supply current I_0	≤ 26 mA
Input	
Control input	parameterisable
Output	
Output of the pre-fault indication	pnp, dynamic/static configurable
Switching type	light/dark ON, switchable
Signal output	1 switch output, pnp, NC or NO 1 multi-function input/complementary switch output/pre-fault output (pnp), paramete-risable
Switching voltage	max. 30 V DC
Switching current	max. 200 mA
Voltage drop U_d	≤ 2 V DC
Switching frequency f	≤ 1,5 kHz
Response time	≤ 0,33 ms
Timer function	parameterisable
Standard conformity	
Standards	EN 60947-5-2
Ambient conditions	
Ambient temperature	-25 ... 70 °C (248 ... 343 K)
Storage temperature	-40 ... 80 °C (233 ... 353 K)
Mechanical specifications	
Protection degree	IP65
Connection	2 m cable, 4 x 0,14 mm², PVC
Material	
Housing	PBT
Mass	30 g

Date of edition 06/15/04

Dimensions



Electrical connection



Date of edition 06/15/04

○ = light on, ● = dark on

Selection table for fibre

	Model number	Range in mm	Detection range in mm	Fig.
Plastic fibre optics, single path	KLE 00-2,2-2,0-K53	150		1
	KLE 00-2,2-2,0-K55	150		2
	KLE 00-1,0-2,0-K56	50		3
	KLE 00-2,2-2,0-K52	150		4
	KLE 00-1,0-2,0-K54	50		5
	KLE 00-2,2-2,0-K51	50		6
Plastic fibre optics, reflex	KLR 00-2,2-2,0-K57		60	7
	KLR 00-2,2-2,0-K59		70	8
	KLR 00-1,0-2,0-K58		25	9
	KLR 00-2,2-2,0-K60		60	10
	KLR 00-1,0-2,0-K61		20	11
	KLR 00-2,2-2,0-K40		70	12

Other lengths and end pieces available on request

Date of edition 06/15/04

Fig.1

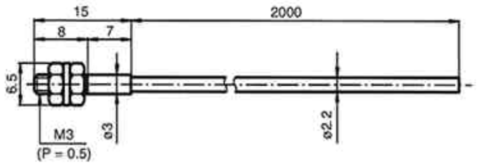


Fig.2

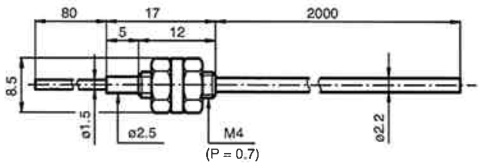


Fig.3

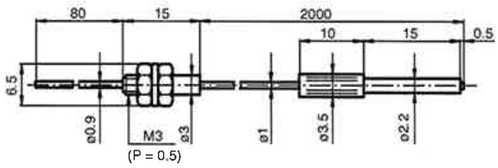


Fig.4

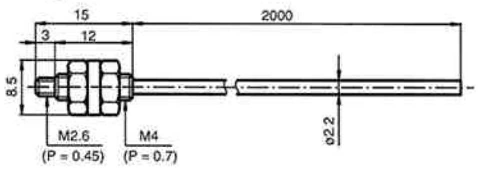


Fig.5

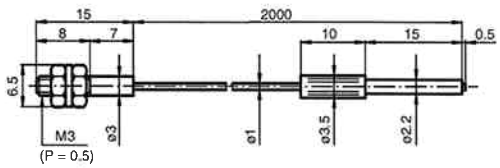


Fig.6

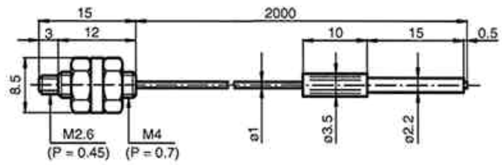


Fig.7

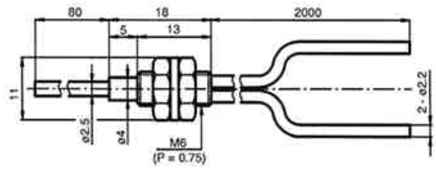


Fig.8

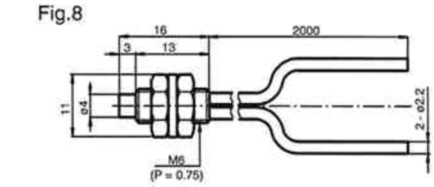


Fig.9

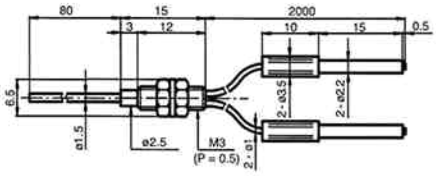


Fig.10

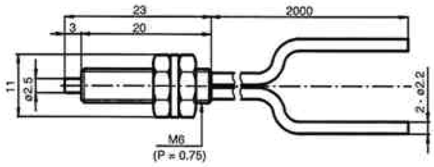


Fig.11

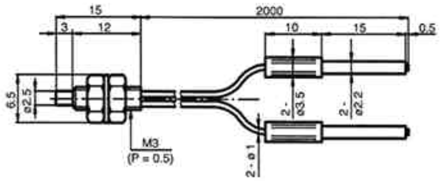
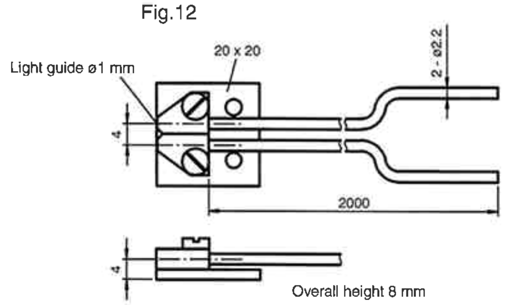
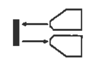
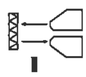


Fig.12





Direct detection
If both light guide heads are fixed **parallel** to the base plate, then the direct detection or reflex operation is possible.

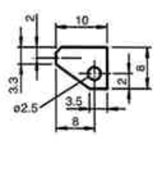


Retro-reflective operation
A blind zone exists in front of the heads. This is larger in reflex operation than in direct detection (diffuse reflection). The actual size of the zone depends on the application.

Through-beam operation
Through-beam operation is achieved by removing the base plate and mounting the heads so that they are mutually opposed on a **common** reference axis.

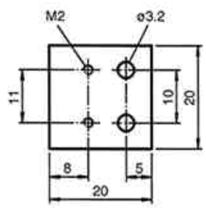
Triangulation
By loosening and changing the positions of the heads on the base plate, the heads can be inclined at an arbitrary angle to each other. The reference axes of the light guides then form a **triangle**. Objects are detected which are located at the point of intersection of the axes.

Head



4 mm thick

Base plate

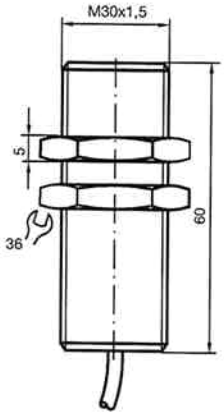


Aluminium 2 mm thick

Date of edition 06/15/04

Inductive proximity switches

Inductive analog transmitter
Output 0 ... 20 mA
Embeddable mountable

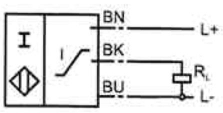


CE

Switching element function	Analogue current output
Installation	embeddable
Measurement range	3 ... 8 mm
Operating voltage U_B	15 ... 30 V
Output signal	0 ... 20 mA
Temperature drift	±1 $^{0}/_{00}$/K v.E.
Repeat accuracy	15 ... 15 µm
Operating voltage	≤ 0.5 %
Rate of current rise	
0 ... 20 mA	≤ 3,5 A/s
20 ... 0 mA	≤ 3,3 A/s
Output ripple	± 30 µA
Recovery time acc. EN 50319	1 ... 10 ms typ. 5 ms
No-load supply current I_0	≤ 8 mA
Load resistor	0 ... 500 Ohm
Adjustment tolerance zero point	± 5 % v.E.
EMC in accordance with	EN 50319
Ambient temperature	-10 ... 70 °C (263 ... 343 K)
Connection type	2 m, PVC cable
Core cross-section	0.5 mm²
Housing material	brass, nickel-plated
Sensing face	PBT
Protection degree	IP67

Connection_type:

I3



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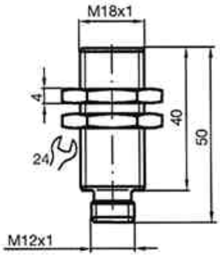
Inductive proximity switches

NJ5-18GM-N-V1

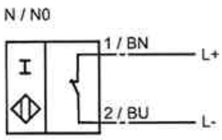
Comfort series
5 mm embeddable



CE 0102

Switching element function	NAMUR NC
Rated operating distance s_n	5 mm
Installation	embeddable
Assured operating distance s_a	0 ... 4,05 mm
Reduction factor r_{Al}	0,21
Reduction factor r_{Cu}	0,18
Reduction factor r_{V2A}	0,63
Nominal voltage U_o	8 V
Operating voltage U_B	5 ... 25 V
Switching frequency f	0 ... 500 Hz
Hysteresis H	3 %
Current consumption	
Measuring plate not detected	≥ 3 mA
Measuring plate detected	≤ 1 mA
EMC in accordance with	EN 60947-5-2
Standards	DIN EN 60947-5-6 (NAMUR)
Ambient temperature	-25 ... 100 °C (248 ... 373 K)
Connection type	V1-connector
Housing material	high grade steel
Sensing face	PBT
Protection degree	IP67
Use in the hazardous area	see instruction manuals
Category	1G; 2G

Connection_type:



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PEPPERL+FUCHS GmbH

Instruction	Manual electrical apparatus for hazardous areas
Device category 1G	BR for use in hazardous areas with gas, vapour and mist
Directive conformity	94/9/EG
Standard conformity	EN 50014:1997; EN 50020:1994; EN 50284:1999 Ignition protection "Intrinsic safety" Use is restricted to the following stated conditions
CE symbol	CE 0102
Ex-identification	Ⓔx II 1G EEx ia IIC T6
EC-Type Examination Certificate	PTB 00 ATEX 2048 X
Assigned type	NJ 5-18GM-N...
Effective internal capacitance C_i	≤ 70 nF ; a cable length of 10 m is considered.
Effective internal inductance L_i	≤ 50 μH ; a cable length of 10 m is considered.
General	The apparatus has to be operated according to the appropriate data in the data sheet and in this instruction manual. The EU prototype test certificate must be observed. The special conditions must be adhered to!
Highest permissible ambient temperature	The temperature ranges, according to temperature class, are given in the EU prototype test certificate. Note: Use the temperature table for category 1 !!! The 20 % reduction in accordance with EN 1127-1:1997 has already been accounted for in the temperature table for category 1.
Installation, Comissioning	Laws and/or regulations and standards governing the use or intended usage goal must be observed. The intrinsic safety is only assured in connection with an appropriate related apparatus and according to the proof of intrinsic safety. The associated apparatus must satisfy the requirements of category "ia" and have galvanic isolation between the power supply and signal circuits. The sensor must be protected from strong electromagnetic fields.
Maintenance	No changes can be made to apparatus, which are operated in hazardous areas. Repairs to these apparatus are not possible.
Special conditions	
Protection from mechanical danger	The sensor must be protected from mechanical damage.
Electrostatic charging	Electrostatic charges must be avoided on the mechanical housing components. Dangerous electrostatic charges on the mechanical housing components can be avoided by incorporating these in the equipotential bonding.

Instruction	Manual electrical apparatus for hazardous areas
Device category 2G	for use in hazardous areas with gas, vapour and mist
Directive conformity	94/9/EG
Standard conformity	EN 50014:1997, EN 50020:1994 Ignition protection "Intrinsic safety" Use is restricted to the following stated conditions
CE symbol	CE 0102
Ex-identification	Ex II 1G EEx ia IIC T6
EC-Type Examination Certificate	PTB 00 ATEX 2048 X
Assigned type	NJ 5-18GM-N...
Effective internal capacitance C_i	≤ 70 nF ; a cable length of 10 m is considered.
Effective internal inductance L_i	≤ 50 µH ; a cable length of 10 m is considered.
General	The apparatus has to be operated according to the appropriate data in the data sheet and in this instruction manual. The EU prototype test certificate must be observed. The special conditions must be adhered to!
Highest permissible ambient temperature	The temperature ranges, according to temperature class, are given in the EU prototype test certificate.
Installation, Comissioning	Laws and/or regulations and standards governing the use or intended usage goal must be observed. The intrinsic safety is only assured in connection with an appropriate related apparatus and according to the proof of intrinsic safety. The sensor must be protected from strong electromagnetic fields.
Maintenance	No changes can be made to apparatus, which are operated in hazardous areas. Repairs to these apparatus are not possible.
Special conditions	
Protection from mechanical danger	The sensor must be protected from mechanical damage.
Electrostatic charging	Electrostatic charges must be avoided on the mechanical housing components. Dangerous electrostatic charges on the mechanical housing components can be avoided by incorporating these in the equipotential bonding.

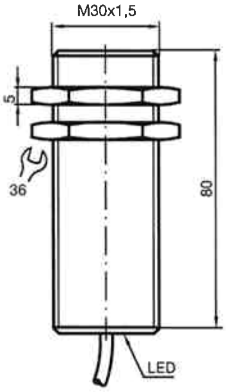
Capacitive proximity switches

CCB10-30GM80-N1

Comfort series

10 mm embeddable

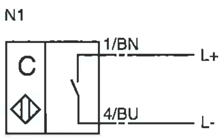
The switching distance can be set over a wide range with the potentiometer



CE

Switching element function	NAMUR NO
Rated operating distance s_n	10 mm
Installation	embeddable
Assured operating distance s_a	0 ... 8,1 mm
Nominal voltage U_o	8 V
Operating voltage U_B	5,9 ... 22,7 V
Switching frequency f	0 ... 10 Hz
Reverse polarity protection	Protected against reverse polarity
Current consumption	
Measuring plate not detected	≤ 1 mA
Measuring plate detected	≥ 3 mA
Indication of the switching state	LED, yellow
EMC in accordance with	EN 60947-5-2
Standards	DIN EN 60947-5-6 (NAMUR)
Ambient temperature	-20 ... 70 °C (253 ... 343 K)
Connection type	2 m, PVC cable
Core cross-section	0.75 mm²
Housing material	high grade steel
Sensing face	PBT
Protection degree	IP67
Use in the hazardous area	see instruction manuals
Category	1D; 2G

Connection_type:



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2003-07-17

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PEPPERL+FUCHS GmbH

Instruction	**Manual electrical apparatus for hazardous areas**
Device category 2G	for use in hazardous areas with gas, vapour and mist
Directive conformity	94/9/EG
Standard conformity	EN 50014:1997, EN 50020:1994 Ignition protection "Intrinsic safety" Use is restricted to the following stated conditions
CE symbol	CE 0102
Ex-identification	Ex II 2G EEx ia IIC T6
EC-Type Examination Certificate	TÜV 03 ATEX 2003 X
Assigned type	CCB10-30GM..-N...
Effective internal capacitance C_i	≤ 155 nF ; a cable length of 10 m is considered.
Effective internal inductance L_i	negligibly small
General	The apparatus has to be operated according to the appropriate data in the data sheet and in this instruction manual. The EU prototype test certificate must be observed. The special conditions must be adhered to!
Highest permissible ambient temperature	The temperature ranges, according to temperature class, are given in the EU prototype test certificate.
Installation, Comissioning	Laws and/or regulations and standards governing the use or intended usage goal must be observed. The intrinsic safety is only assured in connection with an appropriate related apparatus and according to the proof of intrinsic safety.
Maintenance	No changes can be made to apparatus, which are operated in hazardous areas. Repairs to these apparatus are not possible.
Special conditions	
Protection from mechanical danger	The sensor must not be mechanically damaged.
Electrostatic charging	Electrostatic charges must be avoided on the mechanical housing components. Dangerous electrostatic charges on the mechanical housing components can be avoided by incorporating these in the equipotential bonding.

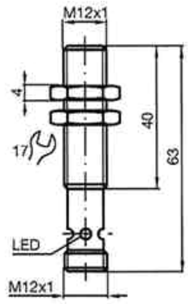
Instruction	**Manual electrical apparatus for hazardous areas**
Device category 1D	zur Verwendung in explosionsgefährdeten Bereichen mit brennbarem Staub
Directive conformity	94/9/EG
Standard conformity	IEC 61241-11:2002: draft; prEN61241-0:2002 Zünschutzart Eigensicherheit "iD" Use is restricted to the following stated conditions
CE symbol	CE 0102
Ex-identification	Ex II 1D Ex iaD 20 T 85 °C
EC-Type Examination Certificate	ZELM 03 ATEX 0128 X
Assigned type	CCB10-30GM..-N...
Effective internal capacitance C_i	≤ 155 nF ; a cable length of 10 m is considered.
Effective internal inductance L_i	negligibly small
General	The apparatus has to be operated according to the appropriate data in the data sheet and in this instruction manual. The EU prototype test certificate must be observed. The special conditions must be adhered to!
Maximum housing surface temperature	Die maximale Gehäuseoberflächentemperatur ist der EG-Baumusterprüfbescheinigung zu entnehmen.
Installation, Comissioning	Laws and/or regulations and standards governing the use or intended usage goal must be observed. The intrinsic safety is only assured in connection with an appropriate related apparatus and according to the proof of intrinsic safety. The associated apparatus must satisfy at least the requirements of category ia IIB or iaD. Because of the possibility of the danger of ignition, which can arise due to faults and/or transient currents in the equipotential bonding system, galvanic isolation in the power supply and signal circuits is preferable. Associated apparatus without galvanic isolation must only be used if the appropriate requirements of IEC 60079-14 are met. Der eigensichere Stromkreis muss gegen Blitzbeeinflussung geschützt sein. When used in the isolating wall between Zone 20 and Zone 21 or Zone 21 und Zone 22 the sensor must not be exposed to any mechanical danger and must be sealed in such a way, that the protective function of the isolating wall is not impaired. The applicable directives and standards must be observed.
Maintenance	No changes can be made to apparatus, which are operated in hazardous areas. Repairs to these apparatus are not possible.
Special conditions	
Electrostatic charging	The connection cables are to be laid in accordance with EN 50281-1-2 and must not normally be subjected to chaffing during use. Electrostatic charges must be avoided on the mechanical housing components. Dangerous electrostatic charges on the mechanical housing components can be avoided by incorporating these in the equipotential bonding.

Magnetic proximity switches

MC60-12GM50-1N-V1

Comfort series

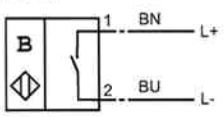
60 mm embedded with
permanent magnet
DM 60-31-15



CE 0102

Switching element function	NAMUR NO
Rated operating distance s_n	60 mm
Installation	embeddable, in non-magn. metal
Assured operating distance s_a	10 ... 60 mm
Nominal voltage U_o	8 V
Switching frequency f	0 ... 5000 Hz
Current consumption	
Magnet detected	≥ 2,5 mA
Magnet not detected	≤ 1 mA
Indication of the switching state	LED, yellow
EMC in accordance with	EN 60947-5-2
Standards	DIN EN 60947-5-6 (NAMUR)
Ambient temperature	-25 ... 70 °C (248 ... 343 K)
Connection type	V1-connector
Housing material	brass, nickel-plated
Sensing face	PA
Protection degree	IP67
Use in the hazardous area	see instruction manuals
Category	2G

Connection_type:



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2003-07-14

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Instruction	**Manual electrical apparatus for hazardous areas**
Device category 2G	for use in hazardous areas with gas, vapour and mist
Directive conformity	94/9/EG
Standard conformity	EN 50014:1997, EN 50020:1994 Ignition protection "Intrinsic safety" Use is restricted to the following stated conditions
CE symbol	CE 0102
Ex-identification	Ex II 2G EEx ib IIC T6
EC-Type Examination Certificate	TÜV 01 ATEX 1718
Assigned type	MC60-12GM50-1N-V1
Effective internal capacitance C_i	≤ 15 nF ; a cable length of 10 m is considered.
Effective internal inductance L_i	≤ 25 μH ; a cable length of 10 m is considered.
General	The apparatus has to be operated according to the appropriate data in the data sheet and in this instruction manual. The EU prototype test certificate must be observed. The special conditions must be adhered to!
Installation, Comissioning	Laws and/or regulations and standards governing the use or intended usage goal must be observed. The intrinsic safety is only assured in connection with an appropriate related apparatus and according to the proof of intrinsic safety.
Maintenance	No changes can be made to apparatus, which are operated in hazardous areas. Repairs to these apparatus are not possible.
Special conditions	
Protection from mechanical danger	The sensor must not be mechanically damaged.
Electrostatic charging	Electrostatic charges must be avoided on the mechanical housing components. Dangerous electrostatic charges on the mechanical housing components can be avoided by incorporating these in the equipotential bonding.

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Model number

KCD2-E2L

CE

Features

- 1-channel terminal amplifier
- Input for NAMUR sensors
- DC 24 V supply voltage
- Standard interface for prevention of signal transmission errors
- Switching status indicator, yellow LED
- Lead breakage monitoring: The lead breakage monitoring can be disconnected by bridging terminals 1 and 3 (When using a mechanical contact a 10 kOhm resistor is required in parallel circuit)
- Short-circuit proof electronic output
- Low noise sensitivity
- Compact terminal housing
- Mounting by clipping onto standard 35 mm rail to DIN EN 50022
- Protection degree IP20

Technical data

Indicators/operating means	
LED yellow	switch output
Electrical specifications	
Operating voltage	10 ... 30 V DC
Operating current	approx. 22 mA
Ripple	≤ 10 %
Input	
Connection	terminals 1+, 2-
Connectable sensor types	NAMUR
Pulse length/pulse interval	≥ 0,5 ms / ≥ 0,5 ms
Short-circuit current	approx. 8 mA
Sensor supply	8 V DC
Switching point	1,2 ... 2,1 mA hysteresis approx. 0.2 mA
Cutoff frequency	1 kHz
Output	
Connection	terminal 4+
Current	200 mA short-circuit proof
Transistor	PNP
Signal level	U_B - 1.1V
Transfer characteristics	
Mode of operation	NO
Switching frequency	1 kHz
Ambient conditions	
Ambient temperature	-25 ... 70 °C (248 ... 343 K)
Storage temperature	-25 ... 85 °C (248 ... 358 K)
Mechanical specifications	
Connection	self-opening apparatus connection terminals, max. core cross-section 0.34 ... 2.5 mm^2
Mass	60 g
Dimensions	20x60x40 (in mm)

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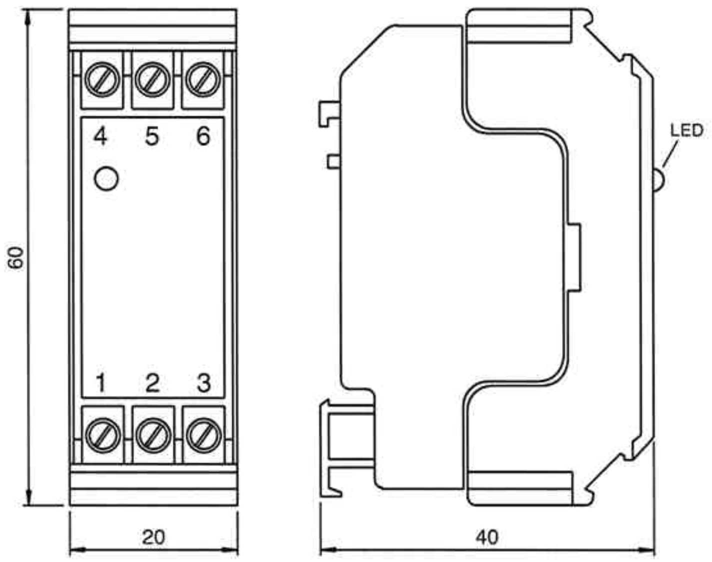
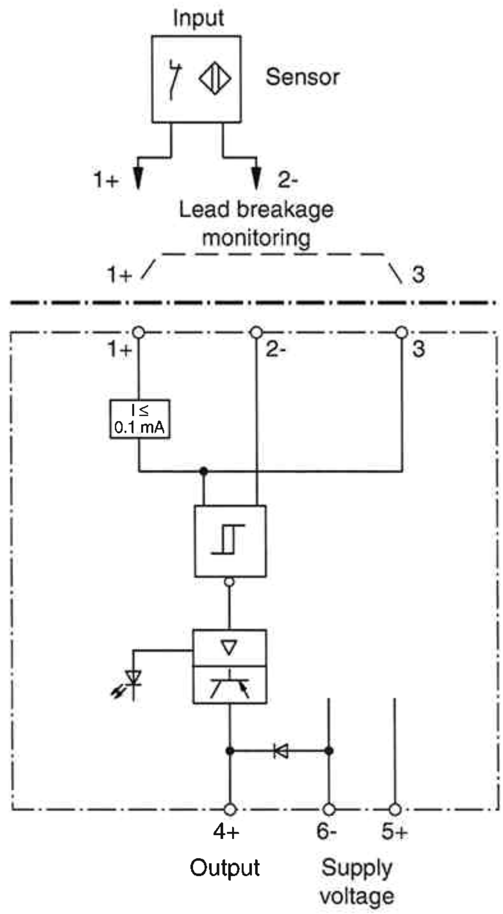
Dimensions



Electrical connection



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What are Sensors

Sensors are to be understood as transducers (feelers, ...), which measure physical elements, temperature, force, pressure a.s.o., in the environment.

Sensors simulate the human senses technically.

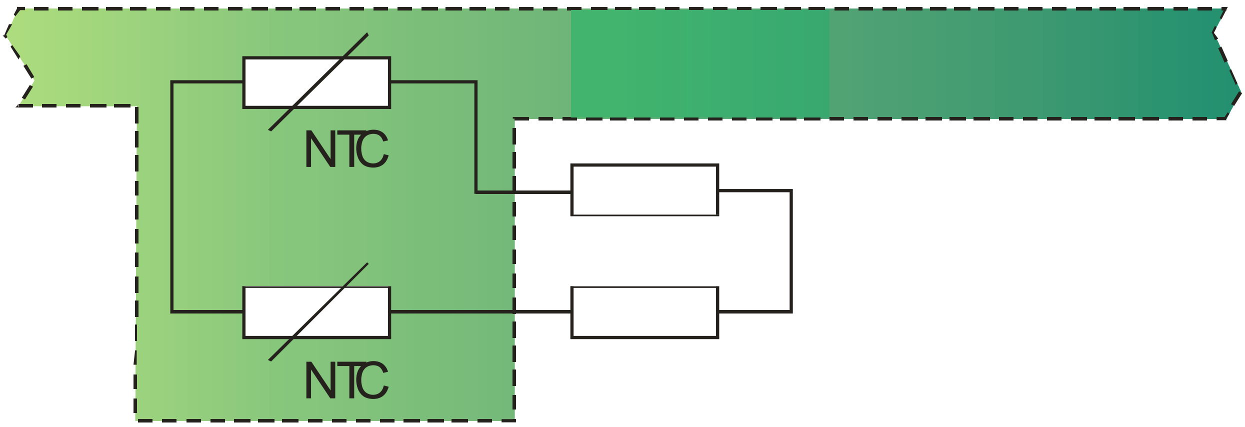
Sense	Organ	Sensor	Detected quantity
hearing	ears	microphone	sound
seeing	eyes	photocell, photo-resistor	light, contours
feeling	skin, muscles	thermometer, wire strain gauge	heat, force
smelling	nose	gas sensors	gas

Sensors as Control Elements

Sensors	Control	Actuators
Input	**Processing (program)**	**Output**
Task: provision of the processing signals necessary for the process run; conversion of physical values into a usable form	**Task:** logical linking of the input signals in the sense of the process	**Task:** control of the switching states of the loads, conversion into a processable form for the output level
Examples: pushbuttons, reflex nozzles, inductive sensors, capacitive sensors, light barriers	**Examples:** manual controls, cam controls, program switching device, clock stages, PLC	**Examples:** pulse valves, relays-contactors, magnetic valves, electro-cylinders, motors, monitors

Function of Sensors

Example: **flow sensor**



The **flow speed** is measured → The flow speed changes the **temperature** → The change in temperature is measured as a change in electrical **resistance R**

Example: **inductive sensor**

body → oscillating coil → oscillator → demodulator → trigger → amplifier

The approached body is measured way s → The body attenuates the oscillating coil frequency f → The change in oscillator results in a change in voltage U

Sensor Construction Types

Base Sensor

detecting detecting physical values with suitable physical principles	converting converting the non-electrical values into an electrical value(measuring bridges)	further signal processing

Analog Sensor

detecting	converting	signal matching linearization, amplification	analog signal

Digital Sensor

detecting	converting signal	signal matching Linearisieren, Verstärken	AD converter	digital signal

Intelligent Sensor

detecting	converting signal	IC section matching, amplification, calculation, coding, linking, compensation, error display

Physical Principles

sensors

active sensors

Active sensors are voltage generators. They convert following energy into electrical energy.

- mechanical energy
- chemical energy
- light energy
- heat energy

The following effects are used here:

- thermal effect
- photo effect
- Hall effect
- Piezo effect
- Wiegand effect
- electrodynamic principle

passive sensors

Passive sensors require an auxiliary energy. They react to a change in a non-electrical value with a change in the electrical value (e.g. temperature/resistance change). Therefore the bridge circuits of resistors, capacitors or coils are often used.

- change in resistance:
  piezo-resistive (rsg)
  magnetoresistive (field plates)
  thermoresistive (NTC, PTC)
- change in inductance
- change in capacitance
- inductive coupling

Sensor Applications

production

- shear force
- tension force
- torque
- spindle excursion
- cutting temperature
- power consumption
- workpiece type
- tool wear
- tool fracture
- surface quality
- workpiece position
- workpiece dimension
- workpiece shape
- distance measurement

transport – storage

- filling level
- dimensions
- shape
- hardness
- material analysis
- surface quality

maintenance – operatingdata acquisition

- leakage indication
- filling levels
- bearing vibration
- operating time
- non-productive time
- selapsed hours

work preparation

- manning hours
- set-up times
- utilization
- working hours
- material flow
- job progress
- machine operation

vehicle technology

- speeds for engine motor
- filling levels
- temperature
- ignition time
- mixture
- exhaust
- knock
- compression
- torque
- steering lock

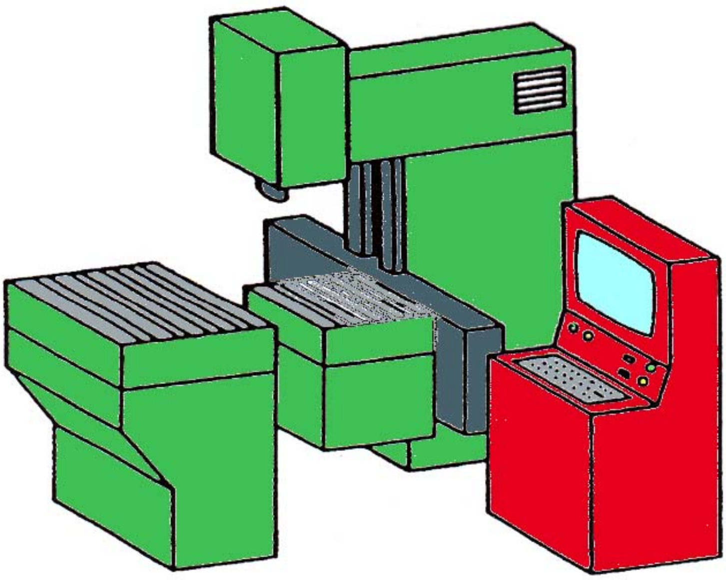
heating – airconditioning – ventilation

- humidity
- air circulation
- flame monitoring
- chemical constituency
- temperature
- air pressure
- polluant content
- mixture
- control
- mass flow
- exhaust

safety technology

- final positions
- locks
- smoke
- flames
- gases
- ice

Use of Sensors in Production Machines



main spindle

- bearing force
- vibrations
- torque
- deformation

tool

- cutting force
- wear
- fracture
- temperature

workpiece

- position
- form
- tension force
- presence

motor

- speed
- power
- voltage
- temperature

oil and cooling system

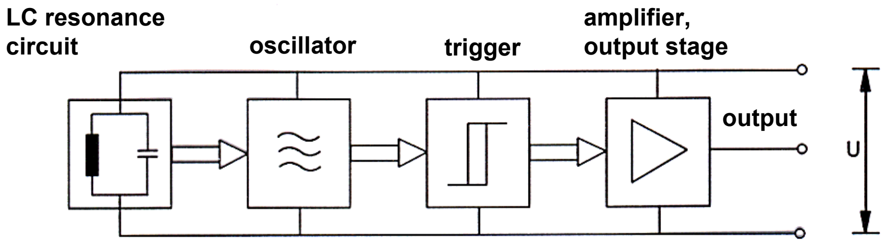
- filling level
- pressure
- temperature
- flow

feed

- measuring system
- limit switch
- speed
- force
- position

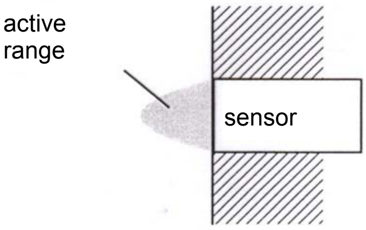
Inductive Sensors

Block diagram

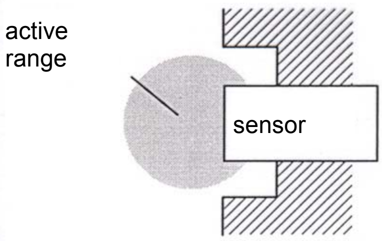


Active zone and installation type

flush installation in metal



non-flush installation
(larger switching distance at same sensor diameter)



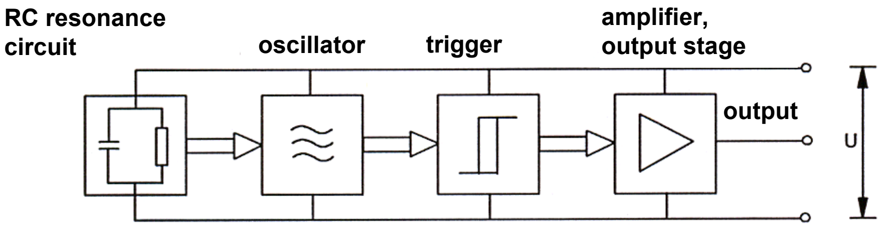
switching distance depends on

- type of metal
- diameter of coil
- surface of the approaching object
- type of installation (flush/non-flush)

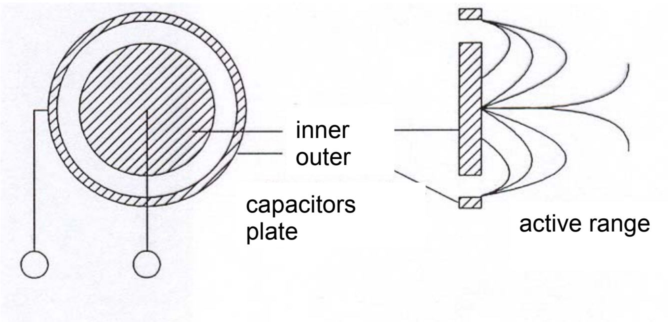
Inductive sensors only react to metals!

Capacitive Sensors

Block diagram



Active zone



The capacitors plates are installed on the top side (large plate on in-side; small ring on outside).

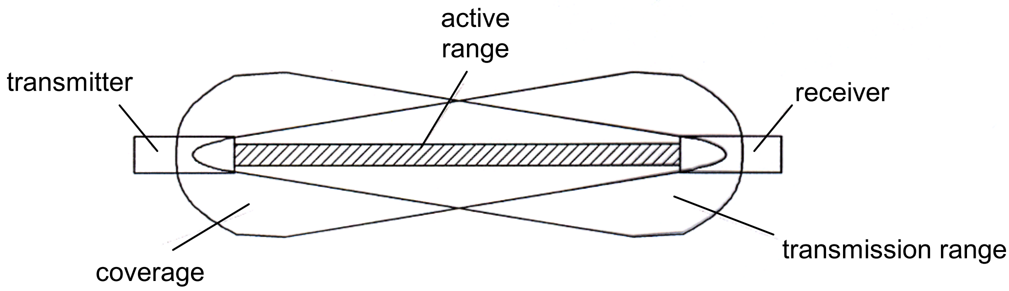
switching distance depends on

- sensor diameter
- material of the approaching object
- mass of the approaching object
- installation type (flush/non-flush)

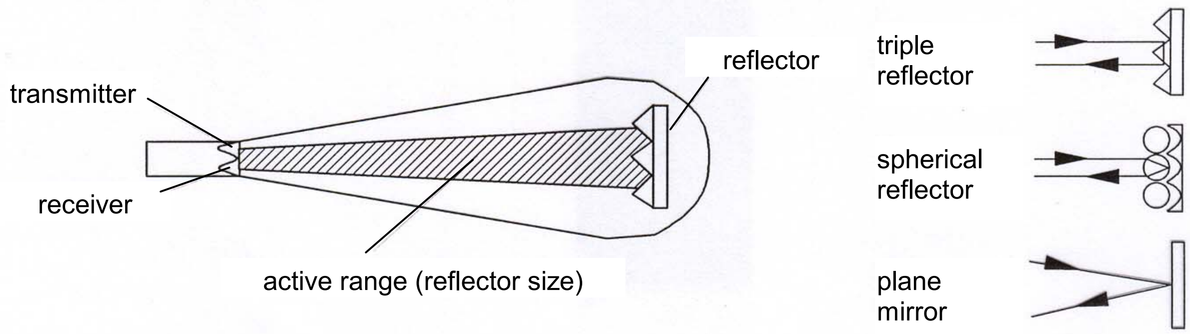
Capacitive sensors react to metals and non-metals!

Optical Sensors

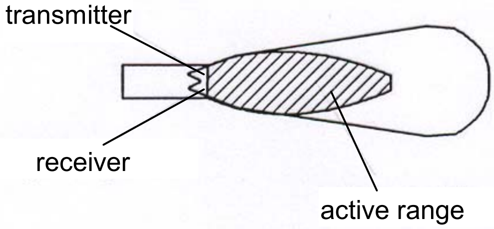
One-way light barrier



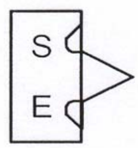
Reflection light barrier



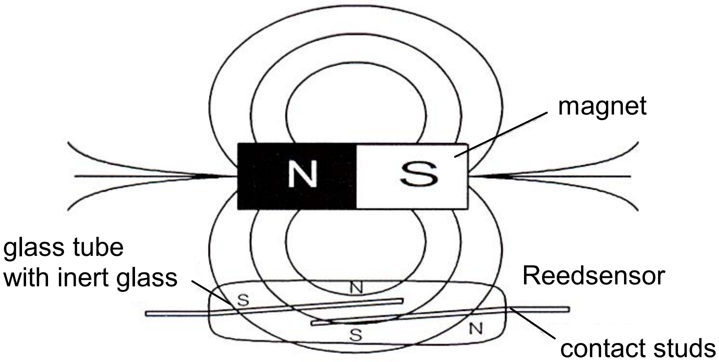
Light scanner



angle light scanner
(exact switching distance)

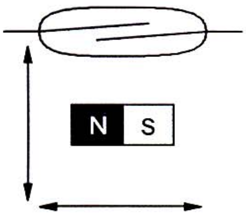


Magnetic Sensors



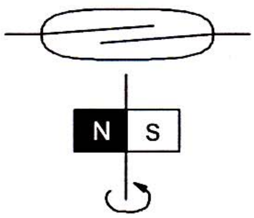
When a magnet approaches, the contact studs reverse their polarity and close abruptly.

Switching behaviour



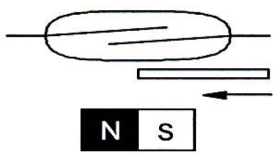
longitudinal monitor

Switching procedures:
vertical once and horizontal twice



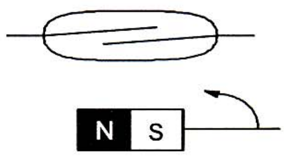
rotational monitor

Switching procedures:
once per rotation



shielding

Switching procedures:
once per movement to-and-fro

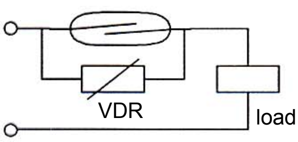


swivel motion

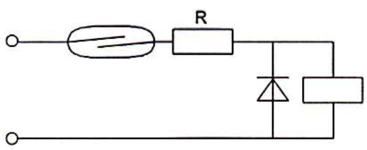
Switching procedures:
once, but with undetermined switching points

Spark extinction

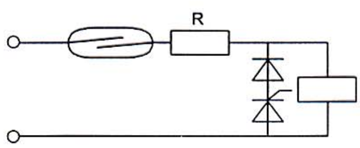
by VDR resistor



by diodes

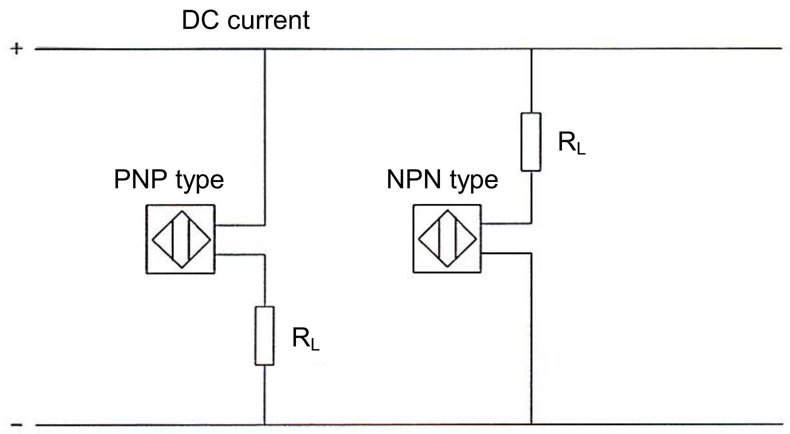


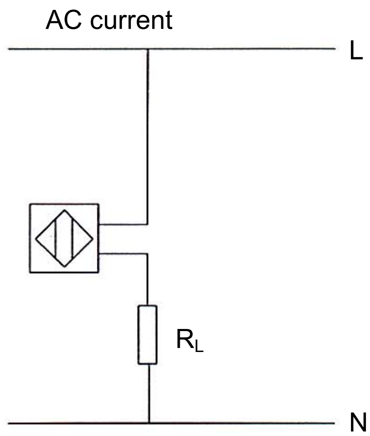
by Zener diodes



Electrical Connection of Sensors

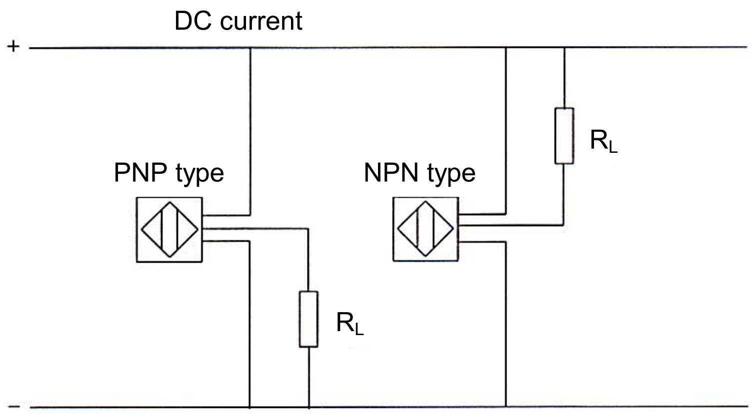
Two-wire systems

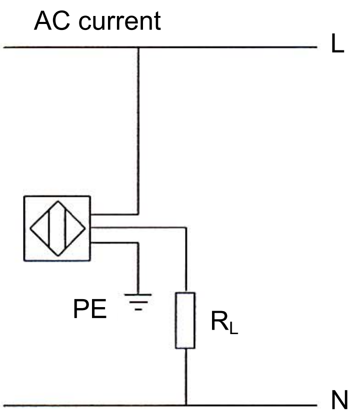




for AC and all-current sensors

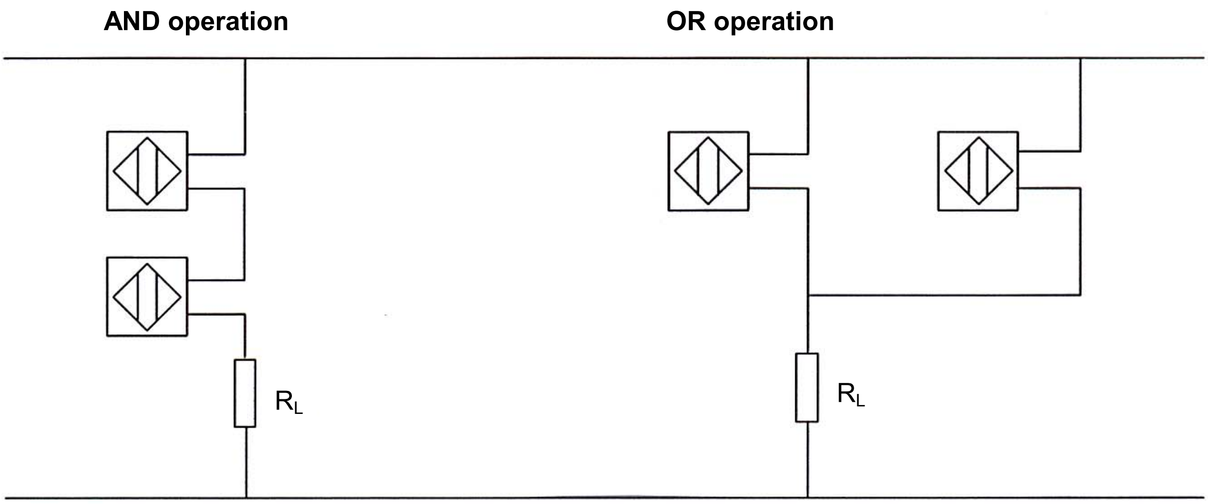
Three-wire systems



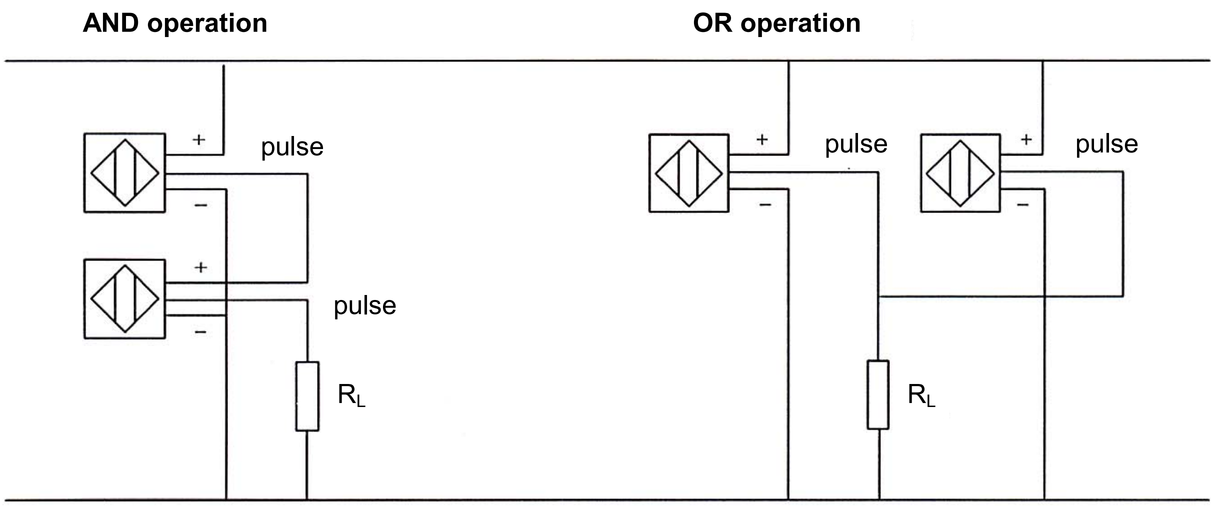


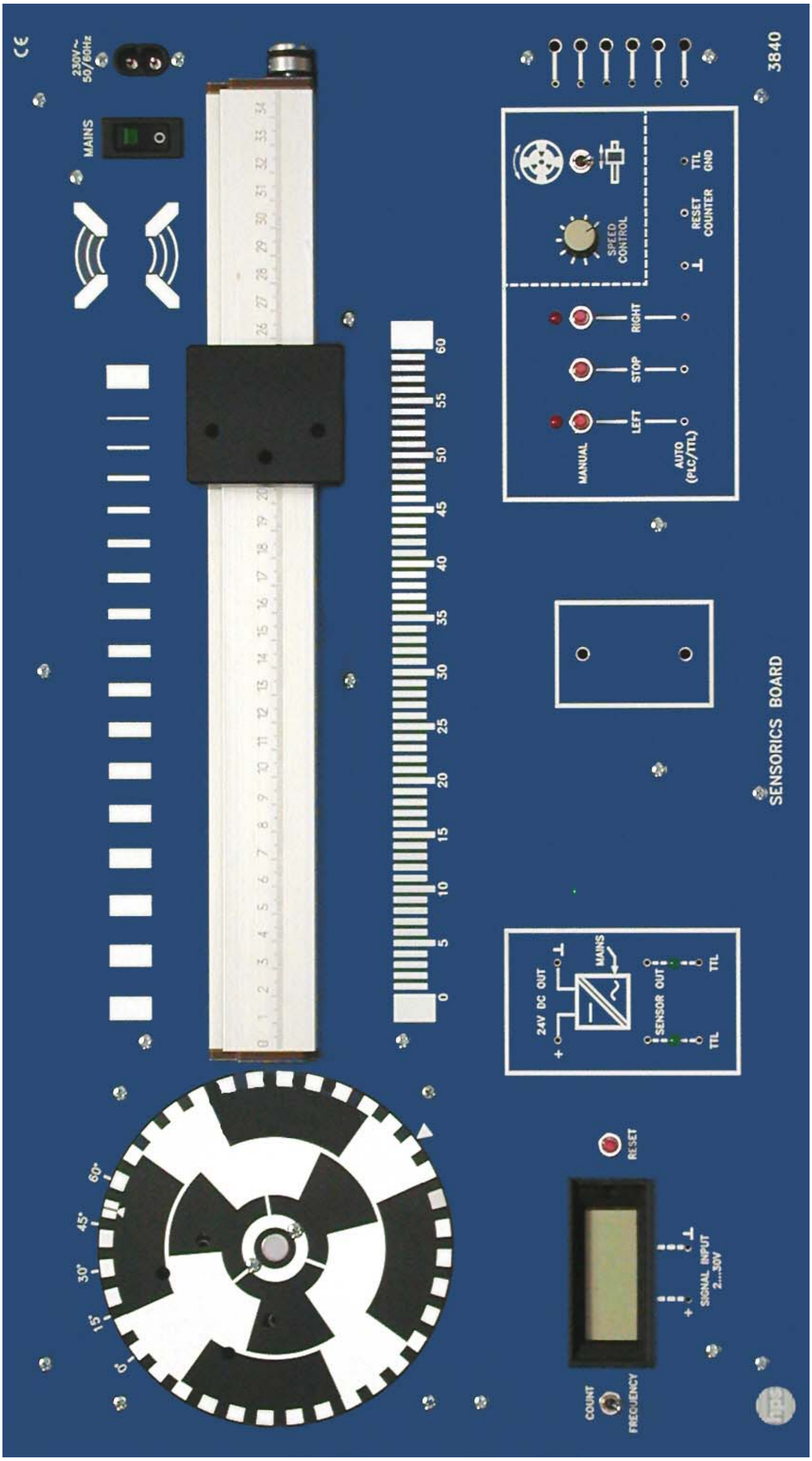
Series and Parallel Circuiting of Sensors

Two-wire systems



Three-wire systems




230V~ 50/60Hz
MAINS
3840
SPEED CONTROL
RESET COUNTER
TTL GND
MANUAL
LEFT
STOP
RIGHT
AUTO (PLC/TTL)
SENSORICS BOARD
24V DC OUT
MAINS
SENSOR OUT
TTL
TTL
RESET
SIGNAL INPUT 2...30V
COUNT
FREQUENCY