Endress+Hauser
People for Process Automation

Functional Safety Manual
KSG2-SIL sensor head as part of Memosens pH glass sensors

Application

Used to connect to a measuring system which satisfies the particular requirements for safety related systems as per IEC 61508.

The measuring device meets the following requirements:

- Functional safety in accordance with IEC 61508
- Explosion protection
- Electromagnetic compatibility in accordance with EN 61326 and NAMUR-recommendation NE 21
- Electrical Safety in accordance with IEC/EN 61010-1
- Ingress Protection IP68 in accordance with DIN EN 60529

Your benefits

- For all Memosens compatible systems up to SIL 2
- Independently assessed (Functional Safety Assessment) by TÜV Süd in accordance with IEC 61508
- Permanent self-monitoring
- Permanent connection monitoring

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Manufacturer's Declaration

Endress+Hauser
People for Process Automation

Safety Integrity Level
SIL
Endress+Hauser

Company **Endress+Hauser Conducta GmbH+Co. KG**
Dieselstrasse 24, 70839 Gerlingen, Germany

declares as manufacturer of analytical products that the

Product KSG2-SIL electronics for pH glass sensor head

Regulations has been evaluated under requirements of functional safety according to IEC 61508 Edition 2.
IEC 61508-1:2010
IEC 61508-2:2010
IEC 61508-3:2010
IEC 61508-4:2010
IEC 61010-1:2010
EN 60529:2010

The initial certification process has been done by TÜV SÜD according to IEC 61508 Edition 1 and is documented in test report EG83499T and certified on April 29th, 2011.

Parameters

Safety function	Measuring, amplifying, digitizing and communicating of pH voltage value and temperature value using Memosens protocol V1.x to a higher system (e. g. a transmitter).
Systematic SIL	2
Software SIL	3
HFT	0
Device type	B
Mode of operation	Low demand mode
Safe failure fraction SFF	91.3 %
MTTR	8 h
Proof test interval T1	1 year, strongly dependent on application!
λ_{SD} / λ_{SU}	0 FIT / 647 FIT
λ_{DD} / λ_{DU}	1670 FIT / 191 FIT
PFD_{avg} T1 = 1 years	8.39×10^{-4}
MTBF	46 years (reciprocal of λ_{total}, assuming constant failure rate)
$MTBF_{DU}$	597 years (reciprocal of λ_{DU}, assuming constant failure rate)

The device was assessed independently in a complete Functional Safety Assessment. All values shown above have been calculated at an electronics temperature of 100 °C.
In the event of device modifications, a modification process compliant with IEC 61508 is applied.

Gerlingen, 03.12.2018

i.V. U. Rößiger (signature)
i. V. Uwe Rößiger
Manager Certifications and Approvals

i.A. F. Fetz (signature)
i. A. Florian Fetz
Manager Functional Safety

HE_01056_01.18

SIL Konformitätserklärung / SIL Declaration of Conformity

Funktionale Sicherheit nach IEC 61508 / Functional Safety according to IEC 61508
Endress+Hauser Conducta GmbH+Co. KG, Dieselstr. 24, 70839 Gerlingen
erklärt als Hersteller die Richtigkeit der folgenden Angaben / declares as manufacturer the correctness of the following data:

Gerät/Product	**KSG2-SIL pH glass sensor head**
Schutzfunktion / Safety function	Measuring, amplifying, digitizing and communicating the pH-voltage value and the temperature value using the Memosens protocol V1 to a higher system (e.g. a transmitter).
Systematischer SIL / Systematic SIL :: Software SIL / Software SIL	2 :: 3
HFT	0
Gerätetyp / Device type	B
Betriebsart / Mode of operation	Low demand mode
SFF	91.3 %
MTTR	8 h
Prüfintervall T_1 / Proof test interval T_1	1 Jahr / year, strongly dependent on application!
λ_{SD} / λ_{SU}	0 FIT / 647 FIT
λ_{DD} / λ_{DU}	1670 FIT / 191 FIT
PFD_{avg} T_1 = 1 Jahre/years	8.39×10^{-4}
MTBF :: $MTBF_{DU}$ (reciprocal of λ_{total} / λ_{DU}, assuming constant failure rate)	46 Jahre / years :: 597 Jahre / years

The device was assessed independently in a complete Functional Safety Assessment.In the event of device modifications, a modification process compliant with IEC 61508 will be applied.

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Note!

Installation and operation is only allowed to be done by personnel trained for safety related systems acc. to IEC 61508.

Note!

General information about functional safety (SIL) is available at www.endress.com/SIL and in the competence brochure CP002Z "Functional safety in the Process Industry - risk reduction with Safety Instrumented Systems".

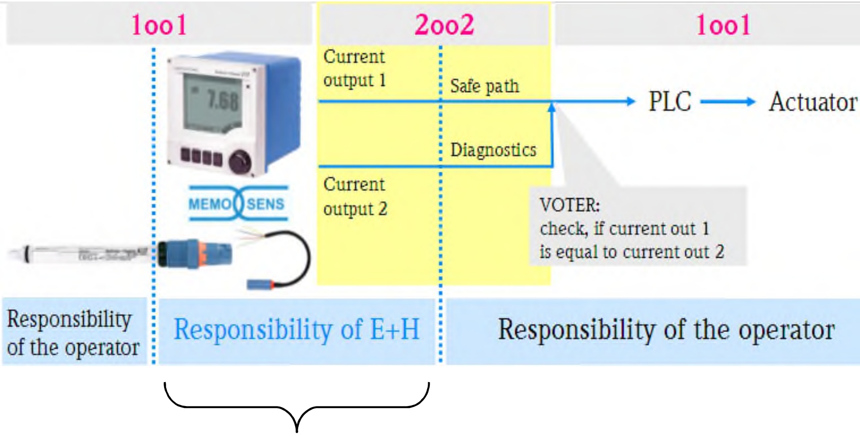
Note!

For general and technical information read the documentation of the sensor Orbisint CPS11D.

1 Structure of a measuring system using a Memosens pH SIL sensor

1.1 System Components

A system using a pH sensor looks for example like the following:



This part, especially the sensor, is covered by this document.

1. **Memosens pH glass sensor**
2. Memosens cable CYK10 SIL
3. Memosens transmitter Liquiline M CM42 SIL

The sensor determines the voltages of the pH and the temperature value by processing the analog values with an analog to digital converter (A/D). Furthermore, it uses the aforementioned digital values together with the stored calibration data in order to calculate a pH-Value. Once all necessary values have been calculated the sensor transmits the raw voltages (of pH and temperature) and the computed pH value to a transmitter, using the Memosens protocol. In order to connect the sensor to the transmitter a Memosens CYK10-SIL cable must be used.

The sensor is only a small part of the complete safety function. The sensor head of the Memosens pH glass sensor is a compliant item with IEC 61508.

1.2 Description of the application as a safety related system

To use the sensor in a safety related system, you need a safe Memosens transmitter and a safe Memosens cable, e.g. from the Endress+Hauser Conducta GmbH+Co. KG.

Note!

All information contained in this document is **only valid for the sensor head electronics of a memosens pH glass SIL sensor, NOT the glass sensor element itself!** The sensor element is a pure mechanical element with no electronics and is in chemical contact with the process medium. This has to be handled separately by the operator of the safety function, where the sensor is applied.

1.3 Valid device types

The information regarding functional safety in this manual applies to the device versions listed below and is valid from the stated software and hardware versions.

Unless otherwise indicated, all subsequent versions can also be used for safety functions.

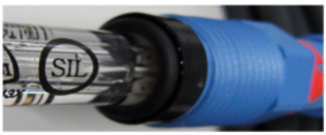
Device versions valid for use in safety-related applications:	CPS11D-8BA2/4/5G
Valid Hardware-Versions (sensor head electronics):	≥ V0.00.08
Valid Firmware-/Software-Versions:	≥ V1.02.02

The versions can be checked by using a transmitter displaying the relevant information about versions (e.g. the transmitter Liquiline M CM42). Please consult the manual of the used transmitter on how to do that.

The SIL sensor is distinguishable from Non-SIL versions by the nameplate with the Endress+Hauser SIL logo and can be identified using the order code.

Order code: e.g. Orbisint CPS11D-**8**BA2/4/5G

"8" refers to SIL with ATEX approval only



In the event of device modifications, a modification process compliant with IEC 61508 is in place at Endress+Hauser.

1.4 Applicable device documentation

Additional documentation is delivered with the device. Please see the TI and the Operating Manual of the sensor.

Documentation	Contents
Technical Information TI	- Technical data - Details to accessories
Operating Manual BA	- Identification - Installation - Cabling - Usage - Commissioning - etc.

2 Description of safety requirements and boundary conditions

2.1 Safety Function – Safe measuring mode

Measuring, amplifying, digitizing and communicating the pH-voltage value and the temperature value using the Memosens protocol to a higher system (e.g. a transmitter).

The following table shows the precision of the measurements (only for sensor head):

(It takes into account all errors related to temperature effects, electronic component variation and EMC)

Measurement	Temperature range	Precision	Precision in measure-ment range in %	Precision in pH temperature compensated
pH (not tempe-rature com-pensated)	-20 to 0°C/-4 to 32 °F	± 8.7 mV	± 0.60 %	± 0.30 pH
	0 to 60°C/32 to 140 °F	± 7.9 mV	± 0.55 %	± 0.20 pH
	60 to 90°C/140 to 194 °F	± 14.8 mV	± 1.00 %	± 0.30 pH
	90 to 110°C/194 to 230 °F	± 21.1 mV	± 1.40 %	± 0.40 pH
	110 to 125°C/230 to 257 °F	± 27.5 mV	± 1.85 %	± 0.45 pH
Temperature	-20 to 0°C/-4 to 32 °F	± 2 K	---	---
	0 to 85°C/32 to 185 °F	± 1 K	---	---
	85 to 125°C/185 to 257 °F	± 2 K	---	---

This table does not take into account any physically or chemically related errors caused by the medium in contact with the senor element, nor does it regard any errors related to the sensor element itself.

2.2 Safety-related signal and safe state

The safety-related signal is the communication of the measured values using the Memosens protocol. There are no other safe outputs of the device.

The safe state is defined as either:

- **Passive safe state**:
  Stopping the communication completely (no telegrams are answered anymore) for more than 5 seconds (the boot time of the sensor is at least 7 seconds) or

- **Active safe state**:
  Answering all telegram requests with the "Fatal Error Bit" set (see Memosens protocol specification). The sensor indicates the type of error using the status byte of the header of the Memosens protocol.

Both safe states will be kept until you restart the sensor.

The (safe) signals have to be processed by a connected component (e.g. transmitter).

2.3 Restrictions for the use in safety-related applications

The given environmental conditions have to be obeyed at all times. All remarks in the device Operating Manual and Installation Instructions (see chapter 1.4) have to be obeyed.

Additional mandatory restrictions for the use in safety related applications:

- Usage of the sensor head (not the sensor element) at a maximum average environment temperature of 100 °C / 212 °F (the) calculations of the failure rates have been based on this assumption).
  The minimum allowed operation temperature is -20 °C /32°F and the maximum allowed operation temperature for the sensor is 125 °C / 257 °F.
  The sensor head checks for temperatures below -20°C /32 °F and above 150°C / 302 °F and enters safe state if these values are reached.
- The sensor head (with the electronics) must be kept dry and must not be in contact with the medium.
- At installation time it has to be checked, that a SIL capable cable is used (e.g. CYK10 SIL - look for the nameplate with the SIL- and TÜV logo). This can not be checked by the sensor in operational mode.
- The environmental conditions from IEC 61326-3-2 have to be obeyed.
- The connection of the Memosens cable to the sensor has to be carefully checked, see installation instructions.
- Minimum distance between two or more SIL Sensors: 3 cm / 0.1 ft
- It is not allowed to use the system in a radioactive environment.
- The environmental pressure has to be checked against the values given in the BA. Never operate the system outside the allowed range.
- The used sensor must not be older than 3 years, starting from the day of production. This is checked by the Endress+Hauser Liquiline M CM42 transmitter.
- The sensor does not check, if the temperature is within the "allowed range" of application.
- The sensor is not checking, if the pH-value or the voltage pH-value is in an "allowed range of the application".
- The power supply voltage is supervised by the sensor. If no voltage is available, the sensor does not work at all and therefore is in passive safe state. All other voltage errors are detected internally the sensor enters the active safe state.
- Installation of the sensor has to be done carefully: Use the correct torque to install the sensor with the cable (see installation instructions of sensor).
- The storage temperature of the sensor must be 0°C…125°C / 32…257 °F.

2.4 Mandatory diagnostics for the transmitter

Please note that the Liquiline M CM42 transmitter from Endress+Hauser is fulfilling all stated requirements in the list below.

If you are using the Endress+Hauser transmitter Liquiline M CM42, you do not have to read the rest of this chapter.

Diagnostics to be done by the transmitter:

- [Optional diagnostics]:
  The pH-value is calculated by the sensor with the following formulae:

  $$pH = \frac{U_x}{S_{Tx}} + NP \text{ , where}$$

  $$S_{Tx} = S_{T25°C} \cdot \frac{273.15 + T_x(°C)}{298.15} \text{ and}$$

  U_x *measured voltage*

  NP *offset / zero value (stored in Index* 0x10)

  $S_{T25°C}$ *slope at* 25°C *(stored in Index* 0x10)

  T_x *temperature at time of voltage measurement*

- The pH-value of the sensor can be compared with the pH value computed by the transmitter using the raw voltage value.
- Checking of the measurement counter has to be done by the connected transmitter.
  The transmitter receiving the measurement counter has to take care of checking this counter, so that it does not increase by more than 12 in 2 seconds.
  The transmitter also has to check, that the counter is at least increased by 1 every 2 seconds.
  If one or both of the two above mentioned checks fail, there is a serious problem in the sensor and the transmitter has to enter the safe state.
  The measurement counter is incremented, if:
  - o pH- and T-measurement have been finished successfully and
  - o the computed values are within reasonable ranges.
- The transmitter has always to check the communication to the sensor. If the communication is disturbed for more than 5 seconds (no telegrams in this time), the transmitter has to enter the safe state.

- The sensor is checking for a broken glass of the sensor element by using the so called SCS method (sensor check system), which is basically checking the resistance of the glass. This diagnostics has a diagnostic coverage (DC) of 90% and can be used for the FMEDA according to IEC 61508 of the sensor element.
- The calibration (and adjustment) of the sensor can be done as a "safe calibration" or an "unsafe calibration". This depends on the capability of the transmitter. Please consult the manuals of the transmitter for this point, e.g. the E+H Liquiline M CM42 transmitter safety manual.
- All diagnostics described in the Memosens protocol documentation/ specification have to be used. Consult the Memosens specification for details.
- The interface to the sensor is described by the "sensors index list". Please consult it for details about the data to be transferred from and to the sensor.

2.5 Functional safety parameters

The table shows the specific functional safety parameters for single-channel device operation:

Parameters according to IEC 61508	**Memosens pH glass sensor**
Safety function	Measuring and communicating the pH-voltage and temperature value to a higher system (e.g. a transmitter).
SIL	Hardware: 2, Software: 3 in homogenous redundancy: 3
HFT	0
Device type	B
Mode of operation	Low demand mode
SFF	92.3 %
MTTR (used for PFDavg calculation)	8 h
T_1 (Proof test interval)	Recommended: 1 year
λ_{SD}	0 FIT
λ_{SU}	630 FIT
λ_{DD}	1660 FIT
λ_{DU}	190 FIT
λ_{Total} *1	2476 FIT
PFD_{avg} (for T_1 = 1 year) *4	0.83×10^{-3}
PFH	1.90×10^{-8}
MTBF / $MTBF_{DU}$ *1	46 years / 600 years
Diagnostic test interval *2	< 60 min
Error reaction time *3	< 1 second - only sensor reaction time, no communication reaction time - communication reaction time depends on communication properties used by transmitter and the link quality
DC_D (Diagnostic coverage dangerous)	90 %

*1 According to Siemens SN29500 at 100 degrees Celsius. MTBF calculated as reciprocal of PFH/ λ_{Total}, assuming constant failure rate.

*2 During this time all diagnostic functions are completed at least once.

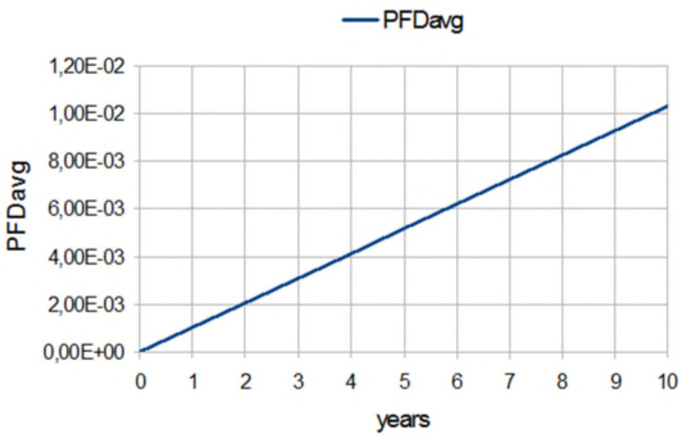
*3 Time between failure detection and failure reaction.

*4 Of course you can choose different (e.g. longer) proof test intervals. Choose the one suited for your application by using the chart given below.

Note!

For the calculation of the PFD_{avg} a Markov model for a 1oo1D system was used. External power supply failure rates are not included.

Proof test interval depending on PFDavg for the 1oo1D structure.



Dangerous undetected failures in this scenario:

A dangerous undetected failure is defined as a failure preventing the sensor to communicate the value to the connected component or a measurement error higher than the precision given in chapter 2.1.

Useful lifetime of electronic components:

The underlying failure rates apply within the useful lifetime according to IEC 61508-2 Clause 7.4.7.4 Note 3 [IEC61508:2000] or Clause 7.4.9.5 Note 3 [IEC61508:2010].

Other values can be used from experience of the previous use in a similar environment.

It is assumed that early failures are detected to a huge percentage during the production testing and installation period and therefore the assumption of a constant failure rate during the useful lifetime is valid.

For this special sensor type the **useful lifetime is 3 years**.

Note!

The safe operation of the device requires a correct installation according to chapter 2.3.

2.6 Behavior of the device during operation and in case of failure

2.6.1 Behavior of device when switched on

After the device has been switched on, it runs its self diagnostics. This takes less than 10 seconds. During that time no measurement is done and no Memosens communication can take place.

2.6.2 Behavior of device on demand

If an internal error is detected, the device enters the safe state within the error reaction time (see chapter 2.2).

2.6.3 Behavior of the device in the event of alarms and warnings

Depending on the detected error, the device enters one of the two safe states. In passive safe state, the sensor no longer communicates, in active safe state the sensor is still communicating and sending the detected error to the connected component (e.g. transmitter).

3 Installation

Wiring and commissioning

The Wiring and commissioning of the device is described in the Operating Instructions of the device (see chapter 1.4).

All remarks in chapter 2.3 have to be obeyed.

Orientation

There are no other restrictions to the orientation of the device, except the restrictions in chapter 2.3 and the ones stated in the documentation (see chapter 1.4).

4 Operation

4.1 Calibrating the measuring point

Calibration/Adjustment of the sensor is always necessary to use it in a safety function. The process of calibration/adjustment is described in the documentation of the connected transmitter. Please consult it for more information.

4.2 Method of device parameterization

The only parameterization is the calibration of the sensor. See chapter 4.1.

5 Maintenance, recalibration

The recalibration cycle, a cleaning cycle or other "cleaning" procedures are the responsibility of the operator of the measurement chain and is not discussed in this safety manual.

Note!

These cycles are essential for the safety of the whole measuring chain and must be analyzed before using this device in a safety chain.

6 Proof test

6.1 Proof test

Safety functions must be tested at appropriate intervals to ensure that they are working correctly and are safe.

The time interval must be defined by the operator (refer to chapter 2.5).

Recommendation: It is recommended to replace the device completely after the proof test period has elapsed.

Proof testing must be carried out in accordance with the following procedure.

If several devices are used in MooN ("M out of N") votings, the proof test described here must be performed separately for each device.

In addition, checks must be carried out to ensure that all restrictions for the operation are still obeyed (see chapter 2.3).

6.2 Testing to ensure safe functioning

Note!

You need a Memosens cable and a transmitter capable of doing this test, e.g. a Liquiline M CM42 SIL.

You also need two buffer solutions, one with pH 7.00 and the other with pH 4.00.

1. To force the sensor head to enter the safe state, you need a special "calibration procedure" supported by the used transmitter. Refer to the safety manual of the transmitter.
   After running this procedure, you can be sure that the sensor head is still executing its safety function and entering it safe state correctly.
2. Safe calibration:
   You MUST do a safe calibration afterwards.
   Use buffer pH 4.00 and pH 7.00 to do this safe calibration.
3. Use a pH 4.00 buffer and measure, if the measured value is deviating not more than ±0.2 pH from the expected value given by the pH 4.00 buffer temperature table, given by the manufacturer of the buffer.
   Temperature table for E+H buffers:

°C	0	5	10	15	20	25	30	35	40	45
pH	2,01	2,01	2,01	2,00	2,00	2,00	2,00	2,00	2,00	2,00
	4,05	4,04	4,02	4,01	4,00	4,01	4,01	4,01	4,01	4,01
	7,13	7,07	7,05	7,02	7,00	6,98	6,98	6,96	6,95	6,95
	9,46	9,40	9,33	9,28	9,22	9,18	9,14	9,10	9,07	9,04
	11,45	11,32	11,20	11,10	11,00	10,90	10,81	10,72	10,64	10,56

°C	50	55	60	65	70	75	80	85	90	95
pH	2,00	2,00	2,00	2,00	2,01	2,01	2,01	2,01	2,01	2,01
	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00
	6,95	6,95	6,96	6,96	6,96	6,96	6,97	6,98	7,00	7,02
	9,01	8,99	8,96	8,95	8,93	8,91	8,89	8,87	8,85	8,83
	10,48	10,35	10,23	10,21	10,19	10,12	10,06	10,00	9,93	9,86

4. Repeat step 3 using a buffer of pH 7.00.
5. Do a safe temperature calibration. Use a calibration time (for the stability criteria) of at least 60 seconds.
6. Measure the temperature and check if the deviation of the measured temperature does not deviate for more than 1.0 Kelvin.

The proof test has to be documented with date, tester and the result (see example in chapter 9).

This test detects approx. 99 % (proof test coverage) of all possible dangerous undetected device failures.

Note!

Please see also the section "Maintenance, recalibration" in chapter 5.

Note!

If one of the above described proof criteria is not satisfied, you are not allowed to use the device as a part of a safety related system anymore.

The proof test is used to detect random failures. The influence of systematic errors on the safety function is not covered by this test and has to be considered separately. Systematic errors can for example be forced by medium properties, environmental conditions, corrosion, etc.

7 Repair

The device must not be repaired. In case your device does not work reliably (NOT caused by normal aging,) please fill in the form "Declaration of de-contamination" on www.endress.com/service - support - returned material or copy the last but one side of this manual and send it together with the clean device back to your local service address.

Our R&D will check the device then. If the reason for error is safety relevant we will replace your device.

8 Notes on the redundant use of the device for SIL 3

Right now, this is not possible in homogenous redundancy. But you can use inhomogeneous redundancy to reach SIL3 using this device.

Redundant use of the E+H SIL2 measuring chain (Liquiline M CM42 SIL, CYK10 SIL, Memosens SIL sensor) and one of another manufacturer is an option to reach a SIL3 pH measuring chain.

9 Proof test protocol example

You can use the following table for the documentation of the proof test.

Application Specific Data	
Company	
Measuring point	
Facility	
Device type:	
Serial number	
Checked restrictions for use	O yes O no
Sensor calibration data measured slope [pH/mV] offset [pH]	
pH 4: Temperature [°C or °F] expected pH value [pH] measured value [pH]	
pH 7: Temperature [°C or °F] expected pH value [pH] measured value [pH]	
Sensor temperature calibration result [K]	
Measured temperature: expected [°C or °F] measured [°C or °F]	
PFD_{avg} value before proof test	
PFD_{avg} value after proof test	
Date of last proof test	
Date of next proof test	
Next proof test (estimated)	
Name of tester	
Date	
Signature	

10 PFD_{avg} computation examples

In this chapter we provide some examples to compute the PFD_{avg} values of a measuring chain and the PFD_{avg} value after doing proof tests.

Remark: $PFD_{avg}(T) = 1/T \int_0^T (\lambda_{DU}\, t)\, dt = ½\, \lambda_{DU}\, t$ (for a1oo1D system, assuming constant and small failure rate λ_{DU}). Usually PFD_{avg} is given without a parameter T, which means this is the value of PFD_{avg} at time T of the mandatory proof test.

10.1 Example to calculate PFD_{avg} after a proof test

The aim of a proof test is to show, that the system does not have any dangerous undetected failures. The proof test coverage denotes the effectiveness of the proof test.

So after the proof test has been successfully finished, the systems PFD_{avg} value has been "improved" and you can determine when the next proof test has to be carried out.

Here we use the Memosens cable CYK10 SIL in a 1oo1D setting for the example.

Assumptions for this example:

Proof test is done after two years of operation, because the system is not allowed to have a higher PFD_{avg} than 1.80×10^{-4} at all times.

Initial PFD_{avg} of new cable: PFD_{avg} (0) = 0

PFD_{avg} of a two year old cable: PFD_{avg} (2 years) = 1.80×10^{-4}

assuming $\lambda_{DU} = 2.05 \times 10^{-8}$ 1/h (= 20.5 FIT) and

where $PFD_{avg}(t) = 1/2 \times t \times \lambda_{DU}$, t in hrs.

Then you do the proof test (follow the CM42 menu guidance) successfully.

Proof test coverage is (see Memosens cable safety manual): 90%.

New values **after the proof test** has been successfully finished:

New PFD_{avg} value after two years and after a successful proof test

PFD_{avg} (2 years; proof test successful) = $1.80 \times 10^{-4} \times (1.00 – 0.90) = 0.18 \times 10^{-4}$

PFD_{avg} value after two additional years (no additional proof test done yet):

PFD_{avg} (4 years) = $0.18 \times 10^{-4} + 1.80 \times 10^{-4} = 1.98 \times 10^{-4}$

Further questions:

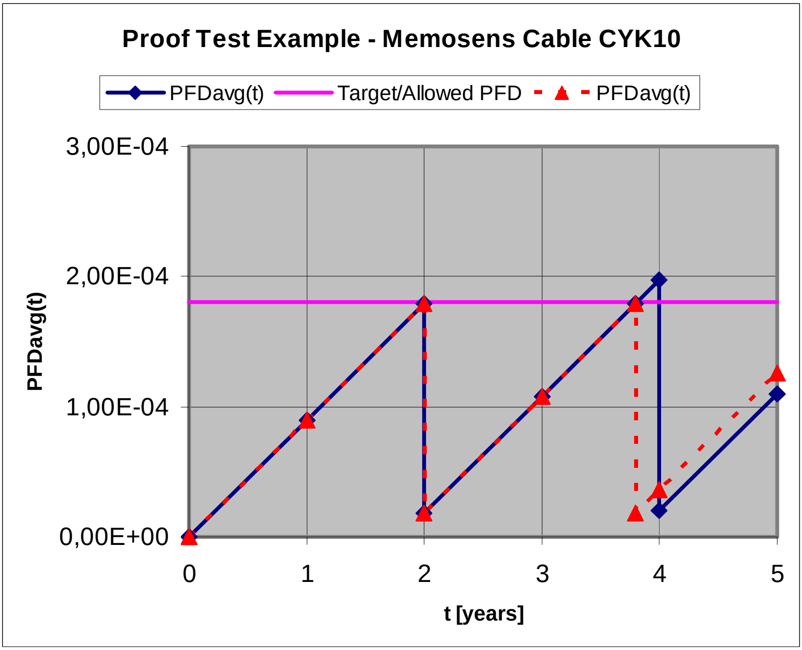
What is the time period T, after which the $PFD_{avg}(t)$ value of this once "proof tested system" reaches again 1.80×10^{-4}?

Find T, where $PFD_{avg}(T) = 1.80 \times 10^{-4}$

$\Rightarrow 1.80 \times 10^{-4} = 0.18 \times 10^{-4} + 0.50 \times \lambda_{DU} \times T$

=> T in years: $T = 0.9 \times 2.0$ years = 1.8 years = 21.6 months

And therefore the proof test interval T after the first "incomplete" proof test with a proof test coverage of 90%, will be smaller than two years.



The dotted line is the $PFD_{avg}(t)$ value, if the proof test is done after 2 years and 21.6 months. The solid line, if the proof test is done after 2 years and 4 years. And the straight horizontal line denotes the limit of the PFD_{avg} value given by the customer.

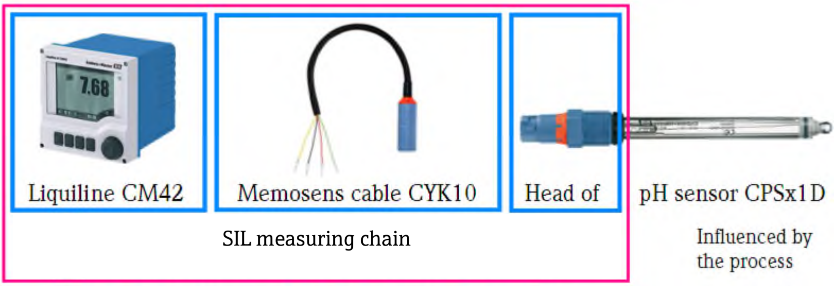
10.2 PFD_{avg} computation example for a pH measuring point

Note!

The following example can be used as the result for the safety parameters of the complete Endress+Hauser pH SIL measuring chain (see table at end of chapter).

Assume we have a measuring point consisting of the following components from Endress+Hauser:

1. Memosens pH glass sensor , SIL
2. Memosens cable CYK10, SIL
3. Memosens transmitter Liquiline M CM42, SIL



The measuring chain is connected to a PCS (e.g. a PLC), which is itself connected to some kind of actor to activate the safe state.

You can calculate the PFD value of the complete chain (PFD_{avg} mc; mc means measuring chain) by summing up the individual PFD values of all components in the chain, including the communication protocol (here the Memosens protocol):

PFD_{avg} mc = PFD_{avg} sensor
+ PFD_{avg} cable
+ PFD_{avg} transmitter
+ PFD_{avg} Memosens protocol)

Then for a complete safety instrumented system (SIS) you get:

PFD_{avg} sis = PFD_{avg} mc
+ PFD_{avg} PCS
+ PFD_{avg} actor

As an example, the value of the complete (non-redundant) Endress+Hauser pH measuring chain, described at the beginning of this section, we get
(The Memosens protocol has been taken into account with 1% of the PFD SIL2 value = 1.0 E-4):

$$\mathbf{PFD_{avg}\ mc} = 8.4 \cdot 10^{-4} + 0.9 \cdot 10^{-4} + 10.3 \cdot 10^{-4} + 1.0 \cdot 10^{-4} = \mathbf{20.6 \cdot 10^{-4}}$$

(Proof test intervals are chosen to be 1 year for all devices)

According to IEC 61508 you need a maximum PFD_{avg} of 10^{-2} to realize a SIL2 SIS. So the just calculated value accords to about 21% of the SIL2 PFD_{avg} value. That means the PCS and actors can use the remaining 79% of the SIL2 PFD_{avg} value.

Of course, you also have to calculate and use the SFF given in the IEC 61508 to fulfil all requirements of the standard.

For the SFF of this specific chain you get:

SFF mc = **93.8 %** with

SFF_{sensor} = 91.3 %,

SFF_{cable} = 90.4 % and

$SFF_{transmitter}$ = 94.8 %.

The table shows the specific functional safety parameters for the operation of a single-channel chain:

Parameters according to IEC 61508	**E+H Memosens pH SIL measuring chain**
Safety Function	1: pH limit monitoring 2: pH value measurement 3+4: safe calibration and adjustment
SIL	Hardware: 2, Software: 3 in homogenous redundancy: 3
HFT	0
Device Type	B
Mode of Operation	Low demand mode
SFF	93.6 %
MTTR (used for PFD calculation)	8 h
T_1 (Proof test interval)	Recommended: 1 / 1 / 1 year, (sensor / cable / transmitter)
λ_{SD}	688 FIT
λ_{SU}	1641 FIT
λ_{DD}	4484 FIT
λ_{DU}	447 FIT
λ_{Total} *1	7260 FIT
PFD_{avg} (for T_1 = 1 / 1 / 1 year) *4	19.6×10^{-4}
MTBF *1	15 years
Diagnostic-Test-Interval *2	< 60 min
Error Reaction Time *3	< 10 seconds
DC_D (Diagnostic Coverage Danger-ous)	91 %

*1 According to Siemens SN29500 at 60°/100° Celsius. MTBF calculated as reciprocal of PFH/ λ_{Total}

*2 During this time all diagnostic functions are completed at least once.

*3 Time between failure detection and failure reaction.

*4 Of course, you can choose different (e.g. longer) proof test intervals. Choose the one suited for your application.

Note!

These values do NOT include the PFD/SFF values of the used voter and the sensor element in contact with the medium, nor does it take into account any medium interactions with the sensor element.

Version history

Version	Changed by	Date of change	Change
2.0	Nentwich	21.02.2011	- Text in chapter 7 - New: Declaration of De-Contamination
2.1	Nentwich	01.06.2011	- New: Buffer tables in chapter 6.2 - Exchange of „Orbisint CPS11D“ to „Memosens pH glass sensor“
2.2	Nentwich	01.02.2012	- SIL 3 for software - Valid software version updated
2.3	Felcmann	04.02.2014	- Exclusion of non ATEX versions added
2.4	Felcmann	02.01.2019	- updated manufacturer declaration, minor updates

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Declaration of Decontamination
Dekontaminationserklärung

Endress+Hauser
People for Process Automation

ID:

In order to comply with legal regulations and for the safety of our employees and operating equipment, we need this 'Declaration of decontamination' with your signature, before your order can be handled. Please reference the Case ID, obtained from Endress+Hauser, on all paperwork and mark the ID clearly on the outside of the box. If this procedure is not followed, it may result in the refusal of the package at our facility.

Aufgrund der gesetzlichen Vorschriften und zum Schutz unserer Mitarbeiter und Betriebseinrichtungen benötigen wir diese unterschriebene 'Dekontaminationserklärung', bevor ihr Auftrag bearbeitet werden kann. Bitte geben Sie die von Endress+Hauser mitgeteilte Fall Nr. (ID) auf allen Lieferpapieren an und vermerken Sie die ID auch außen auf der Verpackung. Nichtbeachtung dieser Anweisung kann zur Ablehnung ihrer Lieferung führen.

Type of instrument / sensor
Geräte- / Sensortyp ____________________

Serial number
Seriennummer ____________________

☐ **Used as SIL device in a Safety Instrumented System** / *Einsatz als SIL Gerät in Schutzeinrichtungen*

Process data / *Prozessdaten*

Temperature / *Temperatur* __________ [°C / °F]
Pressure / *Druck* __________ [hPa]
Conductivity / *Leitfähigkeit* __________ [μs/cm]
pH value / *pH-Wert* __________ [-]

Medium and warnings /
Warnhinweise zum Medium

	Medium / conc. *Medium / Konz.*	**CAS No.** *CAS Nr.*	**flammable** *entzündlich*	**toxic** *giftig*	**corrosive** *ätzend*	**harmful/ irritant** *gesundheits-schädlich*	**other*** *sonstiges**	**harmless** *unbedenk-lich*
Process medium / *Prozess-medium*			☐	☐	☐	☐		☐
Medium for process cleaning / *Medium zur Prozessreinigung*			☐	☐	☐	☐		☐
Returned part cleaned with / *Medium zur Reinigung des Gerätes*			☐	☐	☐	☐		☐

*** explosive, oxidizing, dangerous for the environment, biological hazard, radioactive** **(please specify)**
** explosiv, brandfördernd, umweltgefährlich, biogefährlich, radioaktiv* *(bitte angeben)*

Please check mark any applicable. If available, include safety data sheets and special handling instructions.
Zutreffendes bitte ankreuzen. Wenn verfügbar, legen Sie Sicherheitsdatenblätter und spezielle Handhabungsvorschriften bei.

Description of error, notes /
Fehlerbeschreibung, Bemerkungen ____________________

Company data / *Angaben zum Absender*

Company, contact person and adress / *Firma, Ansprech-partner und Adresse* ____________________

Phone / *Telefon* ____________________
Fax / *Fax* ____________________
Order number / *Auftragsnummer* ____________________

Email / *Email* ____________________

We certify that the returned parts have been carefully cleaned. To the best of our knowledge they are free of any residues in dangerous quantities.
Wir bestätigen, dass die zurückgesandten Teile sorgfältig gereinigt wurden und nach unserem besten Wissen frei von Rückständen in gefahrbringender Menge sind.

Date / *Datum* ____________________
Name / *Name* ____________________
Signature / *Unterschrift* ____________________

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