



OPTISWITCH 5300C

Safety Manual

Vibrating Level Switch

Transistor (NPN/PNP)

With SIL qualification

KROHNE

Contents

1 Document language	
2 Scope	
2.1 Instrument version	4
2.2 Area of application	4
2.3 SIL conformity	4
3 Planning	
3.1 Safety function	5
3.2 Safe state	5
3.3 Prerequisites for operation	5
4 Safety-related characteristics	
4.1 Parameter according to IEC 61508.....	6
4.2 Figures according to ISO 13849-1.....	6
4.3 Supplementary information	6
5 Setup	
5.1 General information.....	8
5.2 Instrument parameter adjustment.....	8
6 Diagnostics and servicing	
6.1 Behaviour in case of failure	9
6.2 Repair	9
7 Proof test	
7.1 General information.....	10
7.2 Test 1 - without filling or dismantling the sensor	10
7.3 Test 2 - with filling or dismantling of the sensor	11
8 Appendix A - Test report	
9 Appendix B - Term definitions	

1 Document language

DE	Das vorliegende <i>Safety Manual</i> für Funktionale Sicherheit ist verfügbar in den Sprachen Deutsch, Englisch, Französisch und Russisch.
EN	The current <i>Safety Manual</i> for Functional Safety is available in German, English, French and Russian language.
FR	Le présent <i>Safety Manual</i> de sécurité fonctionnelle est disponible dans les langues suivantes: allemand, anglais, français et russe.
RU	Данное руководство по функциональной безопасности <i>Safety Manual</i> имеется на немецком, английском, французском и русском языках.

2 Scope

2.1 Instrument version

This safety manual applies to point level sensors

OPTISWITCH 5300C - Transistor (NPN/PNP) with SIL qualification

Electronics module:

- SG60HT-I

Valid versions:

- from HW Ver 1.0.0
- from SW Ver 1.1.0



The versions "Plastic housing" and "external housing" are excluded!

2.2 Area of application

The instrument can be used for level detection of liquids in a safety-related system according to IEC 61508 in the modes *low demand mode* or *high demand mode*:

- Up to SIL2 in single-channel architecture
- Up to SIL3 in a multiple-channel architecture (systematic suitability SC3)

The following interface can be used to output the measured value:

- Transistor (NPN/PNP)



Both transistor outputs must be evaluated!

Screened cable must be used for connection!

2.3 SIL conformity

The SIL conformity was independently judged and certified by the *TÜV Rheinland* according to IEC 61508:2010 (Ed.2).¹⁾



The certificate is valid for the entire service life of all instruments that were sold before the certificate expired!

¹⁾ Verification documents see appendix.

3 Planning

Safety function

3.1 Safety function

To monitor a limit level, the sensor detects via the conditions "*Vibrating element uncovered*" or "*Vibrating element covered*" a limiting value defined by the mounting location.

The detected status is signalled on the output with "*Transistor non-conductive*" or "*Transistor conductive*".

Safe state

3.2 Safe state

The safe state of the transistor outputs is independent of the mode adjusted on the sensor.

SIL

For the safety function, both transistor outputs must be used!

Examples:

- When controlling an output load, it is connected to terminals 2 and 3
- With connected SPLC, the outputs NPN and PNP are evaluated by two separate channels

Mode	Overflow protection Mode max.	Dry run protection Mode min.
Vibrating element	covered	uncovered
Transistors	Non-conductive (currentless)	Non-conductive (currentless)

Output signals in case of malfunction

Transistor outputs:

- Non-conductive

Instructions and restrictions

3.3 Prerequisites for operation

- The measuring system should be used appropriately taking pressure, temperature, density and chemical properties of the medium into account. The application-specific limits must be observed.
- The specifications according to the operating instructions manual, particularly the current load on the output circuits, must be kept within the specified limits
- The instructions in chapter "*Safety-related characteristics*", paragraph "*Supplementary information*" must be noted
- All parts of the measuring chain must correspond to the planned "*Safety Integrity Level (SIL)*"

4 Safety-related characteristics

4.1 Parameter according to IEC 61508

Parameter	Value
Safety Integrity Level	SIL2 in single-channel architecture SIL3 in multiple channel architecture ²⁾
Hardware error tolerance	HFT = 0
Instrument type	Type B
Mode	Low demand mode, High demand mode
SFF	> 90 %
MTTR	8 h
MTBF = MTTF + MTTR ³⁾	1.17 x 10 ⁶ h (134 years)
Diagnostic test interval ⁴⁾	< 120 s
Fault reaction time ⁵⁾	< 2 s

Failure rates

λ_s	λ_{DD}	λ_{DU}	λ_H	λ_L	λ_{AD}	λ_{AU}
211 FIT	167 FIT	31 FIT	0 FIT	0 FIT	11 FIT	43 FIT

PFD _{AVG}	0.026 x 10 ⁻²	(T1 = 1 year)
PFD _{AVG}	0.038 x 10 ⁻²	(T1 = 2 years)
PFD _{AVG}	0.075 x 10 ⁻²	(T1 = 5 years)
PFH	0.031 x 10 ⁻⁶ 1/h	

4.2 Figures according to ISO 13849-1

Derived from the safety-related characteristics, the following figures result according to ISO 13849-1 (machine safety):⁶⁾

Parameter	Value
MTTFd	544 years
DC	85 %
Performance Level	3.12 x 10 ⁻⁸ 1/h (corresponds to "e")

4.3 Supplementary information

The failure rates of the instrument were determined by an FMEDA according to IEC 61508. Basis for the calculations are the component failure rates according to **SN 29500**.

Determination of the failure rates

²⁾ Homogeneous redundancy possible.

³⁾ Including errors outside the safety function.

⁴⁾ Time during which all internal diagnoses are carried out at least once.

⁵⁾ Time between the occurrence of the event and the output of a fault signal.

⁶⁾ ISO 13849-1 was not part of the certification of the instrument.

All figures refer to an average ambient temperature of 40 °C (104 °F) during the operating time. For higher temperatures, the values should be corrected:

- Continuous application temperature > 50 °C (122 °F) by factor 1.3
- Continuous application temperature > 60 °C (140 °F) by factor 2.5

Similar factors apply if frequent temperature fluctuations are expected.

Assumptions of the FMEDA

- The failure rates are constant. Take note of the useful service life of the components according to IEC 61508-2.
- Multiple failures are not taken into account
- Wear on mechanical parts is not taken into account
- Failure rates of external power supplies are not taken into account
- The environmental conditions correspond to an average industrial environment

Calculation of PFD_{AVG}

The values for PFD_{AVG} specified above were calculated as follows for a 1oo1 architecture:

$$PFD_{AVG} = \frac{PTC \times \lambda_{DU} \times T1}{2} + \lambda_{DD} \times MTTR + \frac{(1 - PTC) \times \lambda_{DU} \times LT}{2}$$

- T1 = Proof Test Interval
- PTC = 90 %
- LT = 10 years
- MTTR = 8 h

Boundary conditions relating to the configuration of the processing unit

A connected control and processing unit must have the following properties:

- The output circuit of the transmitter is judged according to the idle current principle
- "fail low" and "fail high" signals are interpreted as a failure, which triggers a fault message

If this is not the case, the respective percentages of the failure rates must be assigned to the dangerous failures and the values stated in chapter *Safety-related characteristics* redetermined!

Multiple channel architecture

Due to the systematic suitability SC3, this instrument can also be used in multiple channel systems up to SIL3, also with a homogeneously redundant configuration.

The safety-related characteristics must be calculated especially for the selected structure of the measuring chain using the stated failure rates. In doing this, a suitable Common Cause Factor (CCF) must be considered (see IEC 61508-6, appendix D).

5 Setup

5.1 General information

Mounting and installation Take note of the mounting and installation instructions in the operating instructions manual.

Setup must be carried out under process conditions.

5.2 Instrument parameter adjustment

Adjustment elements The following adjustment elements are used to parameterize the safety function:

- Slide switch for changeover of the mode (min./max.)
- Slide switch for changeover of the sensitivity

The function of the adjustment elements is described in the operating instructions manual.

Instructions



During parameter adjustment, the safety function must be considered as unreliable!

If necessary, you must take other measures to maintain the safety function.



The sensor must be protected against inadvertent or unauthorized modification!

6 Diagnostics and servicing

6.1 Behaviour in case of failure

Internal diagnosis

If a malfunction is detected, the respective output signals change to safe condition (see section "*Safe state*").

This condition is maintained for at least 1 second. If an error is no longer detected, the safety function is performed correctly again.

The diagnosis interval is specified in chapter "*Safety-related characteristics*".

6.2 Repair

Reaction when malfunction occurs

If faults are detected, the entire measuring system must be shut down and the process held in a safe state by other measures.

The manufacturer must be informed of the occurrence of a dangerous, undetected error (incl. fault description).

Electronics exchange

The procedure is described in the operating instructions manual. Note the instructions for parameter adjustment and setup.

7 Proof test

7.1 General information

Objective

To identify possible dangerous undetected failures, the safety function must be checked by a proof test at adequate intervals. It is the user's responsibility to choose the type of testing. The time intervals are determined by the selected PFD_{AVG} (see chapter "Safety-related characteristics").

For documentation of these tests, the test protocol in the appendix can be used.

If one of the tests proves negative, the entire measuring system must be switched out of service and the process held in a safe state by means of other measures.

In a multiple channel architecture this applies separately to each channel.

Preparation

- Determine safety function (mode, switching points)
- If necessary, remove the instruments from the safety chain and maintain the safety function by other means

Unsafe device status



Warning:

During the function test, the safety function must be treated as unreliable. Take into account that the function test influences downstream connected devices.

If necessary, you must take other measures to maintain the safety function.

After the function test, the status specified for the safety function must be restored.

7.2 Test 1 - without filling or dismantling the sensor

Conditions

- Instrument in installed condition
- Output signal corresponds to the level (covered or uncovered vibrating element)
- **The two transistor outputs NPN and PNP must be tested separately!**

Procedure

1. Carry out a restart (switch the instrument off and then on again)
2. Push the min./max. switch

Expected result

to 1: Output signal corresponds to the level
to 2: Output signal changes status

Proof Test Coverage

Remaining dangerous, undetected failures: 11 FIT (PTC = 64 %)

7.3 Test 2 - with filling or dismounting of the sensor

Conditions

- **Alternative 1:** the instrument remains mounted; the condition "*Vibrating element uncovered*" / "*Vibrating element covered*" can be changed by filling or emptying to the switching point.
- **Alternative 2:** the instrument is dismounted; the condition "*Vibrating element uncovered*" / "*Vibrating element covered*" can be changed by dipping the instrument into the original medium
- Output signal corresponds to the level (covered or uncovered vibrating element)
- **The two transistor outputs NPN and PNP must be tested separately!**

Procedure

1. Carry out a restart (switch the instrument off and then on again)
2. Push the min./max. switch
3. Filling or emptying up to the switching point or immersion into the original medium

Expected result

to 1: Output signal corresponds to the level

to 2: Output signal changes status

to 3: Output signal corresponds to the modified level

Proof Test Coverage

Remaining dangerous, undetected failures: 2 FIT (PTC = 95 %)

8 Appendix A - Test report

Identification	
Company/Tester	
Plant/Instrument TAG	
Meas. loop TAG	
Instrument type/Order code	
Instrument serial number	
Date, setup	
Date, last function test	

Test reason/Test scope	
	Setup without "filling or dismounting the sensor"
	Setup with "filling or dismounting the sensor"
	Proof test without "filling or dismounting the sensor"
	Proof test with "filling or dismounting the sensor"

Mode	
	Overflow protection
	Dry run protection

Sensitivity	
	≥ 0.7 g/cm³ (0.025 lbs/in³)
	≥ 0.5 g/cm³ (0.018 lbs/in³)

Test result (if necessary)				
Test step	Level	Expected measured value	Real value	Test result

Confirmation	
Date:	Signature:

9 Appendix B - Term definitions

Abbreviations

SIL	Safety Integrity Level (SIL1, SIL2, SIL3, SIL4)
SC	Systematic Capability (SC1, SC2, SC3, SC4)
HFT	Hardware Fault Tolerance
SFF	Safe Failure Fraction
PFD _{AVG}	Average Probability of dangerous Failure on Demand
PFH	Average frequency of a dangerous failure per hour (Ed.2)
FMEDA	Failure Mode, Effects and Diagnostics Analysis
FIT	Failure In Time (1 FIT = 1 failure/10 ⁹ h)
λ_{SD}	Rate for safe detected failure
λ_{SU}	Rate for safe undetected failure
λ_S	$\lambda_S = \lambda_{SD} + \lambda_{SU}$
λ_{DD}	Rate for dangerous detected failure
λ_{DU}	Rate for dangerous undetected failure
λ_H	Rate for failure, who causes a high output current (> 21 mA)
λ_L	Rate for failure, who causes a low output current (≤ 3.6 mA)
λ_{AD}	Rate for diagnostic failure (detected)
λ_{AU}	Rate for diagnostic failure (undetected)
DC	Diagnostic Coverage
PTC	Proof Test Coverage
T1	Proof Test Interval
LT	Useful Life Time
MTBF	Mean Time Between Failure
MTTF	Mean Time To Failure
MTTR	Mean Time To Restoration (Ed.2)
MTTF _d	Mean Time To dangerous Failure (ISO 13849-1)
PL	Performance Level (ISO 13849-1)





KROHNE product overview

- Electromagnetic flowmeters
- Variable area flowmeters
- Ultrasonic flowmeters
- Mass flowmeters
- Vortex flowmeters
- Flow controllers
- Level meters
- Temperature assemblies
- Pressure transmitters
- Analysis products
- Products and systems for the oil and gas industry

KROHNE Messtechnik GmbH & Co. KG
Ludwig-Krohne-Straße 5
D-47058 Duisburg
Tel.: +49 (0) 203 301 0
Tel.: +49 (0) 203 301 10389
info@krohne.de

The current list of all KROHNE contacts and addresses can be found at:
www.krohne.com

KROHNE