Vibrating Level Switch

Two-wire (8/16 mA)

With SIL qualification
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## 1 Document language

<table>
<thead>
<tr>
<th>Language</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN</td>
<td>The current Safety Manual for Functional Safety is available in German, English, French and Russian language.</td>
</tr>
<tr>
<td>RU</td>
<td>Данное руководство по функциональной безопасности Safety Manual имеется на немецком, английском, французском и русском языках.</td>
</tr>
</tbody>
</table>
2 Scope

2.1 Instrument version
This safety manual applies to point level sensors
OPTISWITCH 5300C - Two-wire (8/16 mA) with SIL qualification
Electronics module:
• SG60HT-L
Valid versions:
• from HW Ver 1.0.0
• from SW Ver 1.1.0
The version “remote housing” is excluded!
Permissible version of SU 501:
• from HW Ver 1.0.1

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:
• Two-wire current output 8/16 mA

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

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 determined status is signalled at the output with "\( \text{Current} = 8 \text{ mA} \)" or "\( \text{Current} = 16 \text{ mA} \)".

3.2 Safe state

The safe state of the output signal is independent of the mode adjusted on the sensor.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Overflow protection (mode max.)</th>
<th>Dry run protection (mode min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>vibrating element</td>
<td>covered</td>
<td>uncovered</td>
</tr>
<tr>
<td>output current</td>
<td>( 16 \text{ mA} \pm 1.5 \text{ mA} )</td>
<td>( 16 \text{ mA} \pm 1.5 \text{ mA} )</td>
</tr>
</tbody>
</table>

When the sensor is being operated with an SU 501 signal conditioning instrument, the mode "max." must be set on the sensor. Mode selection is carried out on the signal conditioning instrument.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Overflow protection (mode max.)</th>
<th>Dry run protection (mode min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>vibrating element</td>
<td>covered</td>
<td>uncovered</td>
</tr>
<tr>
<td>output current</td>
<td>( 16 \text{ mA} \pm 1.5 \text{ mA} )</td>
<td>( 8 \text{ mA} \pm 1.5 \text{ mA} )</td>
</tr>
</tbody>
</table>

The safe state of the output signal is independent of the mode evaluated by an SPLC.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Overflow protection</th>
<th>Dry run protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>vibrating element</td>
<td>covered</td>
<td>uncovered</td>
</tr>
<tr>
<td>output current when mode on the sensor is set to &quot;max.&quot;</td>
<td>( 16 \text{ mA} \pm 1.5 \text{ mA} )</td>
<td>( 8 \text{ mA} \pm 1.5 \text{ mA} )</td>
</tr>
<tr>
<td>output current when mode on the sensor is set to &quot;min.&quot;</td>
<td>( 8 \text{ mA} \pm 1.5 \text{ mA} )</td>
<td>( 16 \text{ mA} \pm 1.5 \text{ mA} )</td>
</tr>
</tbody>
</table>

Possible fault currents:
- \( \leq 3.6 \text{ mA} \) ("fail low")
- \( > 21 \text{ mA} \) ("fail high")

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Integrity Level</td>
<td>SIL2 in single-channel architecture</td>
</tr>
<tr>
<td></td>
<td>SIL3 in multiple channel architecture 2)</td>
</tr>
<tr>
<td>Hardware error tolerance</td>
<td>HFT = 0</td>
</tr>
<tr>
<td>Instrument type</td>
<td>Type B</td>
</tr>
<tr>
<td>Mode</td>
<td>Low demand mode, High demand mode</td>
</tr>
<tr>
<td>SFF</td>
<td>&gt; 90 %</td>
</tr>
<tr>
<td>MTTR</td>
<td>8 h</td>
</tr>
<tr>
<td>MTBF = MTTF + MTTR 3)</td>
<td>1.25 x 10^6 h (143 years)</td>
</tr>
<tr>
<td>Diagnostic test interval 4)</td>
<td>&lt; 120 s</td>
</tr>
<tr>
<td>Fault reaction time 5)</td>
<td>&lt; 2 s</td>
</tr>
</tbody>
</table>

Failure rates

<table>
<thead>
<tr>
<th>$\lambda_s$</th>
<th>$\lambda_{DD}$</th>
<th>$\lambda_{DU}$</th>
<th>$\lambda_H$</th>
<th>$\lambda_L$</th>
<th>$\lambda_{AD}$</th>
<th>$\lambda_{AU}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 FIT</td>
<td>307 FIT</td>
<td>29 FIT</td>
<td>3 FIT</td>
<td>81 FIT</td>
<td>11 FIT</td>
<td>8 FIT</td>
</tr>
</tbody>
</table>

PFD$_{AVG}$ 0.025 x 10^{-2} (T1 = 1 year)
PFD$_{AVG}$ 0.036 x 10^{-2} (T1 = 2 years)
PFD$_{AVG}$ 0.071 x 10^{-2} (T1 = 5 years)
PFH 0.029 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)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTTFd</td>
<td>265 years</td>
</tr>
<tr>
<td>DC</td>
<td>93 %</td>
</tr>
<tr>
<td>Performance Level</td>
<td>2.95 x 10^{8} 1/h (corresponds to <em>e</em>)</td>
</tr>
</tbody>
</table>

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.

---

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" reetermined!

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.

Operation with a signal conditioning instrument  When the sensor is being operated with an SU 501 signal conditioning instrument, the mode "max." must be set on the sensor. Mode selection is carried out on the signal conditioning instrument.

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

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

SIL  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

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 \( \text{PFD}_{\text{AVG}} \) (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 dismounting the sensor

Conditions

- Instrument in installed condition
- Output signal corresponds to the level (covered or uncovered vibrating element)

Procedure

1. Carry out a restart (push test key on the sensor or on the signal conditioning instrument)
2. Push the min./max. switch

Expected result

to 1: Output of a defined starting current in three steps:
Fault message - Empty signal - Full signal (see operating instructions). Afterwards, the output signal corresponds to the level.
to 2: Output signal changes status

Proof Test Coverage

Remaining dangerous, undetected failures: 12 FIT (PTC = 61 %)
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).

Procedure

1. Carry out a restart (push test key on the sensor or on the signal conditioning instrument)
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 of a defined starting current in three steps: Fault message - Empty signal - Full signal (see operating instructions). Afterwards, the 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

<table>
<thead>
<tr>
<th>Company/Tester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant/Instrument TAG</td>
</tr>
<tr>
<td>Meas. loop TAG</td>
</tr>
<tr>
<td>Instrument type/Order code</td>
</tr>
<tr>
<td>Instrument serial number</td>
</tr>
<tr>
<td>Date, setup</td>
</tr>
<tr>
<td>Date, last function test</td>
</tr>
</tbody>
</table>

### 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

<table>
<thead>
<tr>
<th>Value</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 0.7 g/cm³</td>
<td>(0.025 lbs/in³)</td>
</tr>
<tr>
<td>≥ 0.5 g/cm³</td>
<td>(0.018 lbs/in³)</td>
</tr>
</tbody>
</table>

### Test result (if necessary)

<table>
<thead>
<tr>
<th>Test step</th>
<th>Level</th>
<th>Expected measured value</th>
<th>Real value</th>
<th>Test result</th>
</tr>
</thead>
</table>

### Confirmation

<table>
<thead>
<tr>
<th>Date</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Appendix B - Term definitions

### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIL</td>
<td>Safety Integrity Level (SIL1, SIL2, SIL3, SIL4)</td>
</tr>
<tr>
<td>SC</td>
<td>Systematic Capability (SC1, SC2, SC3, SC4)</td>
</tr>
<tr>
<td>HFT</td>
<td>Hardware Fault Tolerance</td>
</tr>
<tr>
<td>SFF</td>
<td>Safe Failure Fraction</td>
</tr>
<tr>
<td>PFD&lt;sub&gt;Avg&lt;/sub&gt;</td>
<td>Average Probability of dangerous Failure on Demand</td>
</tr>
<tr>
<td>PFH</td>
<td>Average frequency of a dangerous failure per hour (Ed.2)</td>
</tr>
<tr>
<td>FMEDA</td>
<td>Failure Mode, Effects and Diagnostics Analysis</td>
</tr>
<tr>
<td>FIT</td>
<td>Failure In Time (1 FIT = 1 failure/10&lt;sup&gt;9&lt;/sup&gt; h)</td>
</tr>
<tr>
<td>λ&lt;sub&gt;SD&lt;/sub&gt;</td>
<td>Rate for safe detected failure</td>
</tr>
<tr>
<td>λ&lt;sub&gt;SU&lt;/sub&gt;</td>
<td>Rate for safe undetected failure</td>
</tr>
<tr>
<td>λ&lt;sub&gt;S&lt;/sub&gt;</td>
<td>λ&lt;sub&gt;S&lt;/sub&gt; = λ&lt;sub&gt;SD&lt;/sub&gt; + λ&lt;sub&gt;SU&lt;/sub&gt;</td>
</tr>
<tr>
<td>λ&lt;sub&gt;DD&lt;/sub&gt;</td>
<td>Rate for dangerous detected failure</td>
</tr>
<tr>
<td>λ&lt;sub&gt;DU&lt;/sub&gt;</td>
<td>Rate for dangerous undetected failure</td>
</tr>
<tr>
<td>λ&lt;sub&gt;H&lt;/sub&gt;</td>
<td>Rate for failure, who causes a high output current (&gt; 21 mA)</td>
</tr>
<tr>
<td>λ&lt;sub&gt;L&lt;/sub&gt;</td>
<td>Rate for failure, who causes a low output current (≤ 3.6 mA)</td>
</tr>
<tr>
<td>λ&lt;sub&gt;AD&lt;/sub&gt;</td>
<td>Rate for diagnostic failure (detected)</td>
</tr>
<tr>
<td>λ&lt;sub&gt;AU&lt;/sub&gt;</td>
<td>Rate for diagnostic failure (undetected)</td>
</tr>
<tr>
<td>DC</td>
<td>Diagnostic Coverage</td>
</tr>
<tr>
<td>PTC</td>
<td>Proof Test Coverage</td>
</tr>
<tr>
<td>T1</td>
<td>Proof Test Interval</td>
</tr>
<tr>
<td>LT</td>
<td>Useful Life Time</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failure</td>
</tr>
<tr>
<td>MTTF</td>
<td>Mean Time To Failure</td>
</tr>
<tr>
<td>MTTR</td>
<td>Mean Time To Restoration (Ed.2)</td>
</tr>
<tr>
<td>MTTF&lt;sub&gt;d&lt;/sub&gt;</td>
<td>Mean Time To dangerous Failure (ISO 13849-1)</td>
</tr>
<tr>
<td>PL</td>
<td>Performance Level (ISO 13849-1)</td>
</tr>
</tbody>
</table>
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

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