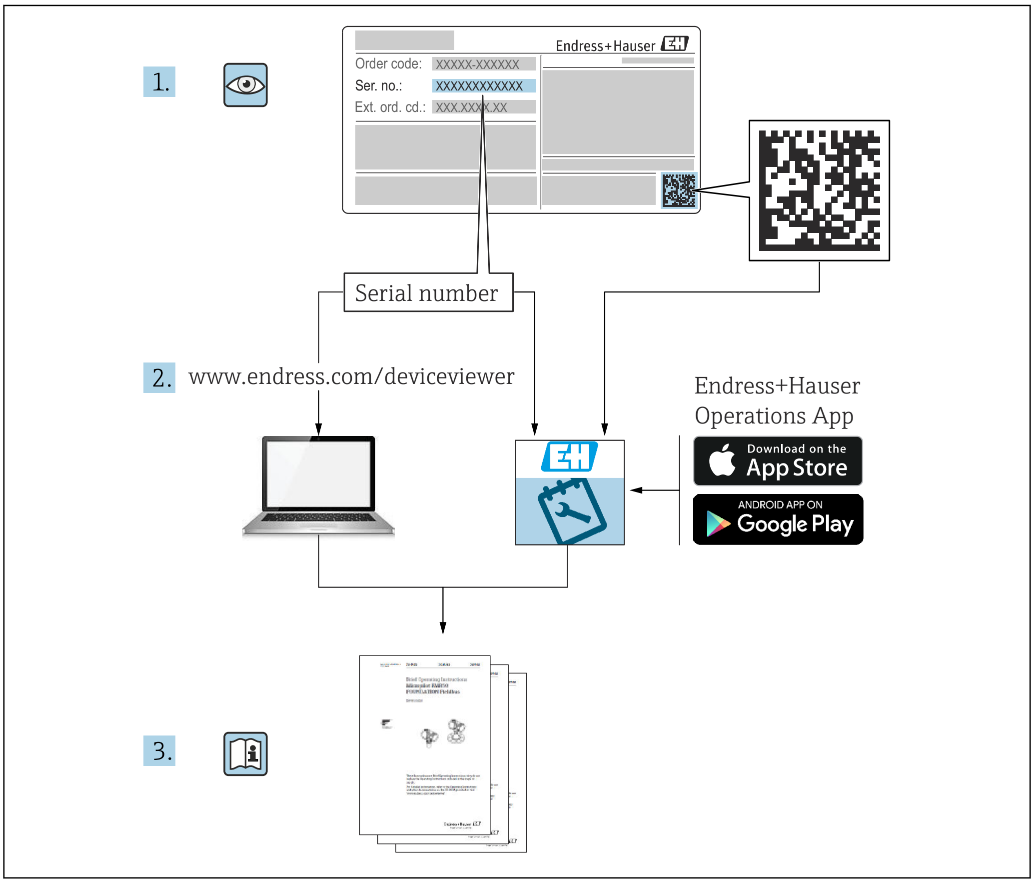
FY01106T/09/EN/01.24-00
71656176
2024-01-23



# Functional Safety Manual
# **iTEMP TMT162**

Endress+Hauser
People for Process Automation


1.
Endress+Hauser
Order code: XXXXX-XXXXXX
Ser. no.: XXXXXXXXXXXX
Ext. ord. cd.: XXX.XXXX.XX
Serial number
2. www.endress.com/deviceviewer
Endress+Hauser
Operations App
Download on the App Store
ANDROID APP ON Google Play
3.

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# 1 Declaration of Conformity

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**Herstellererklärung - Manufacturer Declaration**
**Funktionale Sicherheit - Functional Safety (IEC 61508:2010)**
Beiblatt 1 / NE130 Formblatt B1 – Supplement 1 / NE130 From B.1

**Endress+Hauser Wetzer GmbH+Co. KG Obere Wank 1, 87484 Nesselwang**

erklärt als Hersteller, dass der folgende Temperaturtransmitter
declares as manufacturer, that the following temperature transmitter

**iTEMP TMT162**

in sicherheitsrelevanten Anwendungen SIL2 (HFT=0) bzw. SIL3 (HFT=1) nach IEC61508:2010 eingesetzt werden kann.
is suitable for use in saftey relevant applications up to SIL2 (HFT=0) rep. SIL3 (HFT=1) according to IEC 61508:2010

Für einen Einsatz in sicherheitsrelevanten Anwendungen entsprechend IEC 61508 sind die Angaben des Handbuchs zur Funktionalen Sicherheit zu beachten.
In safety relevant applications according to IEC 61508, the instructions of the Safety Manual have to be followed.

Nesselwang, 24.01.2024
Endress+Hauser Wetzer GmbH+Co. KG

| | |
|---|---|
| ppa. Harald Müller<br>Director Technology | i.V. Thomas Jögel<br>Head of Department Tech. Transmitter |

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## 1.1 Safety-related characteristic values

SIL_00220_03.23

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| Allgemein | | | |
|---|---|---|---|
| Gerätebezeichnung und zulässige Ausführungen | TMT162 (Bestellmerkmal "Weitere Zulassungen": Option LA "SIL") | | |
| Sicherheitsbezogene Ausgangssignale | 4-20mA | | |
| Fehlerstrom | ≤ 3,6 mA oder ≥ 21,0 mA | | |
| Bewertete Messgröße / Funktion | Temperatur / Spannung / Widerstand | | |
| Sicherheitsfunktion(en) | sichere Messung | | |
| Gerätetyp gem. IEC 61508-2 | ☐ Typ A | ☑ Typ B | |
| Betriebsart | ☑ Low Demand Mode | ☑ High Demand | ☐ Continuous Mode |
| Gültige Hardware-Version | 04.01.00 oder höher | | |
| Gültige Firmware-Version | 04.01.00 oder höher | | |
| Sicherheitshandbuch | FY01106T/09 | | |
| Art der Bewertung (nur eine Variante wählbar) | ☑ | Vollständige entwicklungsbegleitende HW/SW Bewertung inkl. FMEDA und Änderungsprozess nach IEC 61508-2, 3 | |
| | ☐ | Bewertung über Nachweis der Betriebsbewährung HW/SW inkl. FMEDA und Änderungsprozess nach IEC 61508-2, 3 | |
| | ☐ | Auswertung von Felddaten HW/SW zum Nachweis "Frühere Verwendung" gem. IEC 61511 | |
| | ☐ | Bewertung durch FMEDA gem. IEC 61508-2 für Geräte ohne Software | |
| Bewertung durch / Zertifikatsnummer | TÜV SÜD Rail GmbH, Germany / Zertifikat Nr. Z10 012833 0004 Rev.2 | | |
| Prüfungsunterlagen | Entwicklungsdokumente, Testreports, Datenblätter | | |

| SIL - Integrität | | | |
|---|---|---|---|
| Systematische Sicherheitsintegrität | | ☐ SC 2 fähig | ☑ SC 3 fähig |
| Hardware Sicherheitsintegrität | Einkanaliger Einsatz (HFT = 0) | ☑ SIL 2 fähig | ☐ SIL 3 fähig |
| | Mehrkanaliger Einsatz (HFT ≥ 1) | ☐ SIL 2 fähig | ☑ SIL 3 fähig |

| FMEDA | Transmitter |
|---|---|
| Sicherheitsfunktion(en) | sichere Messung |
| $\lambda_{DU}$ [1),2)] | 29 FIT |
| $\lambda_{DD}$ [1),2)] | 269 FIT |
| $\lambda_S$ [1),2)] | 139 FIT |
| SFF - Safe Failure Fraction | 93% |
| $PFD_{avg}$ für T1 = 1 Jahr [2)] (einkanalige Architektur) | $1.3 \cdot 10^{-4}$ |
| $PFD_{avg}$ für T1 = 5 Jahre [2)] (einkanalige Architektur) | $6.4 \cdot 10^{-4}$ |
| PFH | $2.9 \cdot 10^{-8} \cdot 1/h$ |
| PTC [3)] | 96% |
| Fehlerreaktionszeit [4)] | < 16,2 s |
| Diagnose-Testintervall [5)] | 4,3 min |
| Prozesssicherheitszeit [6)] | 7,2 h |
| MTTF [7)] | 142 Jahre |

| Erklärung | |
|---|---|
| ☑ | Unser firmeninternes Qualitätsmanagement stellt die Information von zukünftig bekanntwerdenden sicherheitsrelevanten systematischen Fehlern sicher. |

1) FIT = Failure In Time, Anzahl der Ausfälle pro $10^9$ h
2) Gültig für gemittelte Umgebungstemperaturen bis zu +40 °C (+104 °F)
Bei einer durchschnittlichen Dauereinsatztemperatur nahe +60 °C (+140 °F) sollte ein Faktor von 2,1 berücksichtigt werden
3) PTC = Proof Test Coverage (Diagnoseaufdeckungsgrad von Gerätefehlern bei manueller Wiederholungsprüfung)
4) Maximale Zeit zwischen Fehlererkennung und Fehlerreaktion
5) In dieser Zeit werden alle online Diagnosefunktionen mindestens 1x ausgeführt (26,1 min inkl. Speichertest)
6) Die Prozesssicherheitszeit beträgt: Diagnose-Testintervall x 100 (Berechnung nach IEC 61508)
7) MTTF (Mean Time To Failure) Dieser Wert berücksichtigt alle Ausfallarten der Elektronikkomponenten gemäß Siemens SN29500

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| General | | | |
|---|---|---|---|
| Device designation and permissible types | TMT162 (Feature "additional approval": Option LA "SIL") | | |
| Safety-related output signal | 4-20 mA | | |
| Fault current | ≤ 3,6 mA or ≥ 21,0 mA | | |
| Process variable/function | Temperature, Voltage, Resistance | | |
| Safety function(s) | safe measurement | | |
| Device type acc. to IEC 61508-2 | ☐ Type A | ☑ Type B | |
| Operating mode | ☑ Low Demand Mode | ☑ High Demand | ☐ Continuous Mode |
| Valid Hardware-Version | 04.01.00 or higher | | |
| Valid Software-Version | 04.01.00 or higher | | |
| Safety manual | FY01106T/09 | | |
| Type of evaluation (check only one box) | ☑ | Complete HW/SW evaluation parallel to development incl. FMEDA and change request acc. to IEC 61508-2, 3 | |
| | ☐ | Evaluation of "Proven-in-use" performance for HW/SW incl. FMEDA and change request acc. to IEC 61508-2, 3 | |
| | ☐ | Evaluation of HW/SW field data to verify „prior use" acc. to IEC 61511 | |
| | ☐ | Evaluation by FMEDA acc. to IEC 61508-2 for devices w/o software | |
| Evaluation through / certificate no. | TÜV SÜD Rail GmbH, Germany / certificate no. Z10 012833 0004 Rev.2 | | |
| Test documents | development documents, test reports, data sheets | | |

| SIL - Integrity | | | |
|---|---|---|---|
| Systematic safety integrity | | ☐ SC 2 capable | ☑ SC 3 capable |
| Hardware safety integrity | Single channel use (HFT = 0) | ☑ SIL 2 capable | ☐ SIL 3 capable |
| | Multi-channel use (HFT ≥ 1) | ☐ SIL 2 capable | ☑ SIL 3 capable |

| FMEDA | Head transmitter |
|---|---|
| Safety function | safe measurement |
| $\lambda_{DU}$ 1) 2) | 29 FIT |
| $\lambda_{DD}$ 1) 2) | 269 FIT |
| $\lambda_{SU}$ 1) 2) | 139 FIT |
| SFF - Safe Failure Fraction | 93% |
| $PFD_{avg}$ T1 = 1 year 2) (single channel architecture) | $1.3 \cdot 10^{-4}$ |
| $PFD_{avg}$ T1 = 5 years 2) (single channel architecture) | $6.4 \cdot 10^{-4}$ |
| PFH | $2.9 \cdot 10^{-8} \cdot$ 1/h |
| PTC 3) | 96% |
| Fault reaction time 4) | < 16.2 s |
| Diagnostic test interval 5) | 4.3 min |
| Process safety time 6) | 7.2 h |
| MTTF 7) | 142 Jahre |

| Declaration | |
|---|---|
| ☑ | Our internal company quality management system ensures information on safety-related systematic faults which become evident in the future |

1) FIT = Failure In Time, Number of failures per $10^9$ h
2) Valid for average ambient temperature up to +40 °C (+104 °F)
For continuous operation at ambient temperature close to +60 °C (+140 °F), a factor of 2.1 should be applied
3 PTC = Proof Test Coverage
4) Maximum time between error recognition and error response
5) All online diagnostic functions are performed at least once within the Diagnostic test interval (26.1 min incl. memory test)
6) The Process safety time is: Diagnostic test interval x 100 (calculated acc. to IEC 61508)
7) MTTF (Mean Time To Failure) is the predicted elapsed time between inherent failures of a system during operation in accordance to Siemens SN29500

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## 1.2 Use as a safe measuring system

The temperature transmitter must be combined with a suitable sensor to implement a safe measuring system. The code numbers required for the system design for one year can be found in the following tables.

*Single channel operation*

| | $\lambda_{du}$ | $\lambda_{dd}$ | $\lambda_{su}$ | $\lambda_{sd}$ | SFF | $PFD_{avg}$ |
|---|---|---|---|---|---|---|
| Transmitter | 29 FIT | 269 FIT | 139 FIT | 0 FIT | 93% | $1.3 \cdot 10^{-4}$ |

| | | low stress | | high stress | | low stress | | high stress | |
|---|---|---|---|---|---|---|---|---|---|
| | | closed coupled | | | | extention wire | | | |
| | | Sensor | Sensor + TMT162 | Sensor | Sensor + TMT162 | Sensor | Sensor + TMT162 | Sensor | Sensor + TMT162 |
| Thermo-couple | $\lambda_{du}$ | 6 FIT | 35 FIT | 119 FIT | 148 FIT | 109 FIT | 138 FIT | 2180 FIT | 2209 FIT |
| | $\lambda_{dd}$ | 94 FIT | 363 FIT | 1881 FIT | 2150 FIT | 891 FIT | 1160 FIT | 17820 FIT | 18089 FIT |
| | $\lambda_{su}$ | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT |
| | $\lambda_{sd}$ | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT |
| | SFF | 94% | 94% / 93% | 94% | 94% / 93% | 89% | 89% / 93% | 89% | 89% / 93% |
| | $PFD_{avg}$ | | $1.5 \cdot 10^{-4}$ | | $6.5 \cdot 10^{-4}$ | | $6.1 \cdot 10^{-4}$ | | $9.7 \cdot 10^{-3}$ |
| RTD 2-/3-wire | $\lambda_{du}$ | 9 FIT | 38 FIT | 181 FIT | 210 FIT | 99 FIT | 128 FIT | 1976 FIT | 2005 FIT |
| | $\lambda_{dd}$ | 39 FIT | 308 FIT | 779 FIT | 1048 FIT | 376 FIT | 645 FIT | 7524 FIT | 7793 FIT |
| | $\lambda_{su}$ | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT |
| | $\lambda_{sd}$ | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT |
| | SFF | 81% | 81% / 93% | 81% | 81% / 93% | 79% | 79% / 93% | 79% | 79% / 93% |
| | $PFD_{avg}$ | | $1.7 \cdot 10^{-4}$ | | $9.2 \cdot 10^{-4}$ | | $5.6 \cdot 10^{-4}$ | | $8.8 \cdot 10^{-3}$ |
| RTD 4-wire | $\lambda_{du}$ | 6 FIT | 36 FIT | 129 FIT | 158 FIT | 74 FIT | 104 FIT | 1486 FIT | 1515 FIT |
| | $\lambda_{dd}$ | 44 FIT | 313 FIT | 871 FIT | 1140 FIT | 426 FIT | 695 FIT | 8514 FIT | 8783 FIT |
| | $\lambda_{su}$ | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT |
| | $\lambda_{sd}$ | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT |
| | SFF | 87% | 87% / 93% | 87% | 87% / 93% | 85% | 85% / 93% | 85% | 85% / 93% |
| | $PFD_{avg}$ | | $1.6 \cdot 10^{-4}$ | | $6.9 \cdot 10^{-4}$ | | $4.5 \cdot 10^{-4}$ | | $6.6 \cdot 10^{-3}$ |

| SFF | Typ | A | | | B | | |
|---|---|---|---|---|---|---|---|
| | HFT | 0 | 1 | 2 | 0 | 1 | 2 |
| < 60% | | SIL1 | SIL2 | SIL3 | --- | SIL1 | SIL2 |
| 60% - < 90% | | SIL2 | SIL3 | SIL4 | SIL1 | SIL2 | SIL3 |
| 90% - < 99% | | SIL3 | SIL4 | SIL4 | SIL2 | SIL3 | SIL4 |
| >99% | | SIL3 | SIL4 | SIL4 | SIL3 | SIL4 | SIL4 |

1 FIT = $1 \cdot 10^{-9}$ h

$PFD_{avg}$
- (green) $< 2.5 \cdot 10^{-3}$
- (yellow) $> 2.5 \cdot 10^{-3}$
- (red) $> 1 \cdot 10^{-2}$

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*Two channel operation*

| Transmitter | $\lambda_{du}$ | $\lambda_{dd}$ | $\lambda_{su}$ | $\lambda_{sd}$ | SFF | $PFD_{avg}$ |
|---|---|---|---|---|---|---|
| | 29 FIT | 269 FIT | 139 FIT | 0 FIT | 93% | $1.3 \cdot 10^{-4}$ |

| | | low stress | | high stress | | low stress | | high stress | |
|---|---|---|---|---|---|---|---|---|---|
| | | closed coupled | | | | extention wire | | | |
| | | 2 x Sensor | 2 x Sensor + TMT162 | 2 x Sensor | 2 x Sensor + TMT162 | 2 x Sensor | 2 x Sensor + TMT162 | 2 x Sensor | 2 x Sensor + TMT162 |
| Thermo-couple | $\lambda_{du}$ | 11 FIT | 40 FIT | 70 FIT | 99 FIT | 158 FIT | 187 FIT | 3160 FIT | 3189 FIT |
| | $\lambda_{dd}$ | 189 FIT | 458 FIT | 3786 FIT | 4055 FIT | 1842 FIT | 2111 FIT | 36840 FIT | 37109 FIT |
| | $\lambda_{su}$ | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT |
| | $\lambda_{sd}$ | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT |
| | SFF | 95% | 95% / 93% | 98% | 98% / 93% | 92% | 92% / 93% | 92% | 92% / 93% |
| | $PFD_{avg}$ | | $1.7 \cdot 10^{-4}$ | | $4.3 \cdot 10^{-4}$ | | $8.2 \cdot 10^{-4}$ | | $1.4 \cdot 10^{-2}$ |
| RTD 2-/3-wire | $\lambda_{du}$ | 8 FIT | 37 FIT | 154 FIT | 183 FIT | 84 FIT | 113 FIT | 1672 FIT | 1701 FIT |
| | $\lambda_{dd}$ | 88 FIT | 357 FIT | 1766 FIT | 2035 FIT | 866 FIT | 1135 FIT | 17328 FIT | 17597 FIT |
| | $\lambda_{su}$ | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT |
| | $\lambda_{sd}$ | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT |
| | SFF | 92% | 92% / 93% | 92% | 92% / 93% | 91% | 91% / 93% | 91% | 91% / 93% |
| | $PFD_{avg}$ | | $1.6 \cdot 10^{-4}$ | | $1.3 \cdot 10^{-4}$ | | $7.4 \cdot 10^{-4}$ | | $7.5 \cdot 10^{-3}$ |
| RTD 2-/3-wire + TC | $\lambda_{du}$ | 9 FIT | 38 FIT | 184 FIT | 213 FIT | 121 FIT | 150 FIT | 2416 FIT | 2445 FIT |
| | $\lambda_{dd}$ | 139 FIT | 408 FIT | 2776 FIT | 3045 FIT | 1354 FIT | 1623 FIT | 27084 FIT | 27353 FIT |
| | $\lambda_{su}$ | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT | 0 FIT | 139 FIT |
| | $\lambda_{sd}$ | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT | 0 FIT |
| | SFF | 94% | 94% / 93% | 94% | 94% / 93% | 92% | 92% / 93% | 92% | 92% / 93% |
| | $PFD_{avg}$ | | $1.7 \cdot 10^{-4}$ | | $9.3 \cdot 10^{-4}$ | | $6.6 \cdot 10^{-4}$ | | $1.1 \cdot 10^{-2}$ |

| SFF | Typ | A | | | B | | |
|---|---|---|---|---|---|---|---|
| | HFT | 0 | 1 | 2 | 0 | 1 | 2 |
| < 60% | | SIL1 | SIL2 | SIL3 | --- | SIL1 | SIL2 |
| 60% - < 90% | | SIL2 | SIL3 | SIL4 | SIL1 | SIL2 | SIL3 |
| 90% - < 99% | | SIL3 | SIL4 | SIL4 | SIL2 | SIL3 | SIL4 |
| >99% | | SIL3 | SIL4 | SIL4 | SIL3 | SIL4 | SIL4 |

1 FIT = $1 \cdot 10^{-9}$h

$PFD_{avg}$

- (green) $< 2.5 \cdot 10^{-3}$
- (yellow) $> 2.5 \cdot 10^{-3}$
- (red) $> 1 \cdot 10^{-2}$

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- Low stress: < ⅔ utilization of the maximum thermometer acceleration (vibration)
- High stress: > ⅔ utilization of the maximum thermometer acceleration (vibration)
- Closed coupled: < 30 cm
- Extension wire: > 30 cm
- Diagnosis for 2-channel operation: sensor drift

# 2 About this document

## 2.1 Document function

This Safety Manual applies in addition to the Operating Instructions, Technical Information and Ex-specific Safety Instructions. The supplementary device documentation must be observed during installation, commissioning and operation. The requirements specific to the protection function are described in this Safety Manual.

General information on functional safety (SIL) is available at: www.endress.com/SIL

## 2.2 Using this document

Information on the document structure

For the arrangement of the parameters according to the menu structure of the **Operation** menu, **Setup** menu, **Diagnostics** menu, along with short descriptions, see the Operating Instructions for the device

## 2.3 Symbols used

### 2.3.1 Safety symbols

**⚠ DANGER**
This symbol alerts you to a dangerous situation. Failure to avoid this situation will result in serious or fatal injury.

**⚠ WARNING**
This symbol alerts you to a dangerous situation. Failure to avoid this situation can result in serious or fatal injury.

**⚠ CAUTION**
This symbol alerts you to a dangerous situation. Failure to avoid this situation can result in minor or medium injury.

**NOTICE**
This symbol contains information on procedures and other facts which do not result in personal injury.

### 2.3.2 Symbols for certain types of information and graphics

**Tip**
Indicates additional information

Reference to documentation

Reference to graphic

▶
Notice or individual step to be observed

1., 2., 3.
Series of steps

↳
Result of a step

**1, 2, 3, ...**
Item numbers

**A, B, C, ...**
Views

## 2.4 Further applicable device documentation

For an overview of the scope of the associated Technical Documentation, refer to the following:
- *Device Viewer* (www.endress.com/deviceviewer): Enter the serial number from the nameplate
- *Endress+Hauser Operations app*: Enter serial number from nameplate or scan matrix code on nameplate.

The following document types are available in the download area of the Endress+Hauser website (www.endress.com/downloads):

### 2.4.1 Further applicable documents

- BA01801T
- KA00250R
- TI01344T
- SD01632T

- XA00031R
- XA00032R
- XA00033R
- XA00065R
- XA01688T
- XA01689T

#### Technical Information (TI)

**Planning aid**
The document contains all the technical data on the device and provides an overview of the accessories and other products that can be ordered for the device.

#### Brief Operating Instructions (KA)

**Guide that takes you quickly to the 1st measured value**
The Brief Operating Instructions contain all the essential information from incoming acceptance to initial commissioning.

#### Operating Instructions (BA)

**Your reference guide**
These Operating Instructions contain all the information that is required in various phases of the life cycle of the device: from product identification, incoming acceptance and storage, to mounting, connection, operation and commissioning through to troubleshooting, maintenance and disposal.

#### Safety Instructions (XA)

Depending on the approval, the following Safety Instructions (XA) are supplied with the device. They are an integral part of the Operating Instructions.

The nameplate indicates the Safety Instructions (XA) that are relevant to the device.

#### Functional Safety Manual (FY)

Depending on the SIL approval, the Functional Safety Manual (FY) is an integral part of the Operating Instructions and applies in addition to the Operating Instructions, Technical Information and ATEX Safety Instructions.

The different requirements that apply for the protective function are described in the Functional Safety Manual (FY).

# 3 Design

## 3.1 Permitted device types

The details pertaining to functional safety in this manual relate to the device versions listed below and are valid as of the specified firmware and hardware versions. Unless otherwise specified, all subsequent versions can also be used for safety functions.

*A modification process according to IEC 61508 is applied for any device modifications. Valid device versions for safety-related use:*

| Item | Designation | Version |
|---|---|---|
| 010 | Approval | All |
| ... | ... | ... |

| Item | Designation | Version |
|---|---|---|
| 590 | Additional approval | LA |
| ... | ... | ... |

*Order code:*

| | | |
|---|---|---|
| TMT162 - x x x x x x x x + x x x x LA x x x x x<br>↑<br>A0034088<br>The full order code is saved electronically in the device. It is shortened on the nameplate due to space limitations. | Valid firmware version | as of 04.01.00 |
| | Valid hardware version (electronics) | as of 04.01.00 |
| | Valid device drivers | DTM as of version 1.8.120.3991<br>DD as of revision 0x01 |

## 3.2 Identification marking

SIL-certified devices are marked with the SIL logo (SIL) on the nameplate.

## 3.3 Safety function

The device's safety function is:
Safe measurement → 11

### 3.3.1 Safety-related output signal

The device's safety-related signal is the analog output signal 4 to 20 mA as per NAMUR NE43. All safety measures refer to this signal exclusively. In addition, the device also communicates via HART® for information purposes and comprises all the HART® features with additional device information. HART® communication is **not** part of the safety function.

The safety-related output signal is fed to a downstream logic unit, e.g. a programmable logic controller or a limit signal transmitter, where it is monitored for the following:
- To ascertain if it exceeds or drops below a predefined limit value
- To establish the occurrence of a fault, e.g. failure current (≤ 3.6 mA, ≥ 21.0 mA, signal cable disconnection or short-circuit)

**NOTICE**

**In an alarm condition**
- ▶ Ensure that the equipment under control achieves or maintains a safe state.

### 3.3.2 Safe measurement

The transmitter's safety function is to indicate a voltage, resistance or temperature value proportional to the current at the output.

The safety function can be used in combination with all sensor configurations from the "Structure of the measuring system" section → 32. Please note that only the measured value of a sensor or the value of a function (mean/difference between two measured values) can ever be output at the current output.

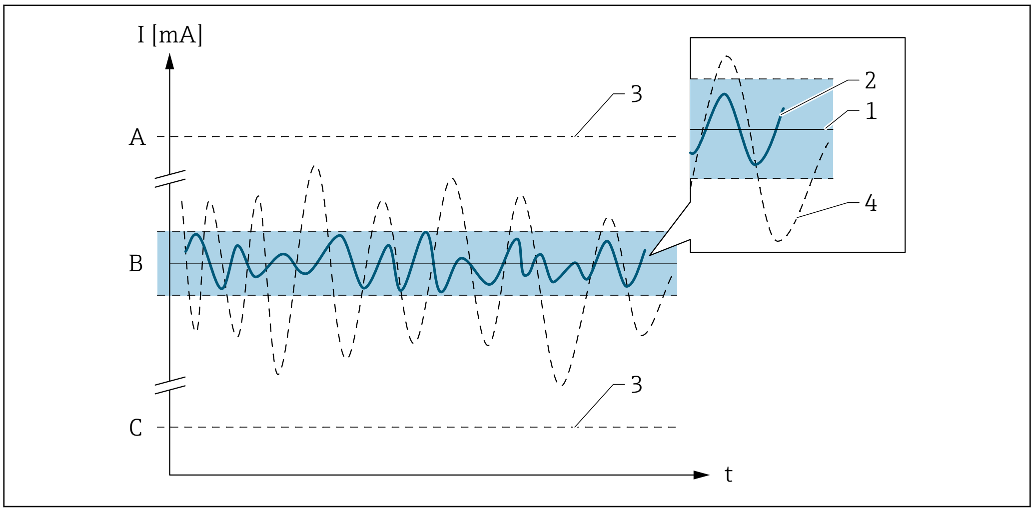
## 3.4 Basic conditions for use in safety-related applications

The measuring system must be used correctly for the specific application, taking into account the medium properties and ambient conditions. Carefully follow instructions pertaining to critical process situations and installation conditions from the Operating

Instructions. The application-specific limits must be observed. The specifications in the Operating Instructions and the Technical Information must not be exceeded.

- Information on the safety-related signal. → 📄 11
- Compliance with the specifications in the Operating Instructions is mandatory. → 📄 9
- The ambient temperature of the device is −40 to +75 °C (−40 to +167 °F)
- Compliance with the ambient conditions as per IEC 61326-3-2 Appendix B is mandatory.
- Use of the FXA291 and TXU10 communication interface is not possible in the expert mode (only via HART® communication).
- The device may only be powered by a power unit with an energy-limited circuit in accordance with UL/EN/IEC 61010-1, Section 9.4 and the requirements of Table 18.
- Configure the mains filter correctly (50 Hz/60 Hz).
- The fault response time must meet the safety requirements.
- Maximum permitted sensor cable resistance for voltage measurement: 1 000 Ω.
- The "Device temperature" measured value must not be output to the primary variable (PV) in safety-related mode.
- The "Sensor switching" and "Average with backup" functions both can **not** be used in safety-related mode.
- A shielded cable that is grounded on both sides must be used if the sensor cable is 30 m (98.4 ft) or longer. The use of shielded sensor cables is generally recommended.
- The following restriction also applies to safety-related use:
  Strong, pulse-like EMC interference on the power supply line can result in transient (< 1 s) deviations in the output signal (≥ ±1%). For this reason, filtering with a time constant of ≥ 1 s should be performed in the downstream logic unit.
  The specified error range (safety measurement error) is sensor-specific and is defined according to FMEDA (Failure Modes, Effects and Diagnostic Analysis) on delivery. It already includes all influencing factors described in the Technical Information TI (non-linearity, non-repeatability, hysteresis, zero error, temperature drift).
  According to IEC/EN 61508, the safety-related failures are classified into different categories, see the following table. The table shows the implications for the safety-related output signal and the measurement uncertainty.

### 3.4.1 Safety-related failures according to IEC/EN 61508

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*A High alarm ≥ 21 mA*
*B SIL error range ±2%*
*C Low alarm ≤3.6 mA*

**No device error**
- No error
- Implications for the safety-related output signal: none
- Impact on the measurement uncertainty:
  **1** – Within the specification, 📖 For detailed information, see TI/BA

**λS (Safe)**
- Safe failure
- No impact on the safety-related output signal:
  **2** – Moves within the specified SIL error range
- Output signal enters the safe state
- Impact on the measurement uncertainty:
  **2** – Moves within the specified SIL error range
  **3** – Has no effect

**$\lambda_{DD}$ (Dangerous detected)**
- Dangerous failure which can be detected
- Impact on the safety-related output signal: results in a failure mode at the output signal
- Impact on the measurement uncertainty:
  **3** – Has no effect

**$\lambda_{DU}$ (Dangerous undetected)**
- Dangerous failure which cannot be detected
- Implications for the safety-related output signal: can be outside the defined error range
- Impact on the measurement uncertainty:
  **4** – May be outside the specified error range

## 3.5 Safety measurement error

*Thermocouples*

| Standard | Description (index for unique identification) | Min. measuring span | Limited safety measuring range | Maximum measurement error | | Long-term drift in °C/ year [1] |
|---|---|---|---|---|---|---|
| | | | | Digital (+A/D), −40 to +70 °C (−40 to +158 °F) [2] | (D/A) [3] | |
| IEC 60584-1 | Type A (W5Re-W20Re) (30) | 50 K (90 °F) | 0 to +2 500 °C (+32 to +4 532 °F) | 12 K (21.6 °F) | 0.5% | 1.42 |
| | Type B (PtRh30-PtRh6) (31) | 50 K (90 °F) | +500 to +1 820 °C (+932 to +3 308 °F) | 5.1 K (9.2 °F) | | 2.01 |
| | Type E (NiCr-CuNi) (34) | 50 K (90 °F) | −150 to +1 000 °C (−238 to +1 832 °F) | 4.9 K (8.8 °F) | | 0.43 |
| | Type J (Fe-CuNi) (35) | 50 K (90 °F) | −150 to +1 200 °C (−238 to +2 192 °F) | 4.9 K (8.8 °F) | | 0.46 |
| | Type K (NiCr-Ni) (36) | 50 K (90 °F) | −150 to +1 200 °C (−238 to +2 192 °F) | 5.1 K (9.2 °F) | | 0.56 |
| | Type N (NiCrSi-NiSi) (37) | 50 K (90 °F) | −150 to +1 300 °C (−238 to +2 372 °F) | 5.5 K (9.9 °F) | | 0.73 |
| | Type R (PtRh13-Pt) (38) | 50 K (90 °F) | +50 to +1 768 °C (+122 to +3 214 °F) | 5.6 K (10.1 °F) | | 1.58 |
| | Type S (PtRh10-Pt) (39) | 50 K (90 °F) | +50 to +1 768 °C (+122 to +3 214 °F) | 5.6 K (10.1 °F) | | 1.59 |
| | Type T (Cu-CuNi) (40) | 50 K (90 °F) | −150 to +400 °C (−238 to +752 °F) | 5.2 K (9.4 °F) | | 0.52 |
| IEC 60584-1; ASTM E988-96 | Type C (W5Re-W26Re) (32) | 50 K (90 °F) | 0 to +2 000 °C (+32 to +3 632 °F) | 7.6 K (13.7 °F) | | 0.94 |
| ASTM E988-96 | Type D (W3Re-W25Re) (33) | 50 K (90 °F) | 0 to +2 000 °C (+32 to +3 632 °F) | 7.1 K (12.8 °F) | | 1.14 |
| DIN 43710 | Type L (Fe-CuNi) (41)<br>Type U (Cu-CuNi) (42) | 50 K (90 °F) | −150 to +900 °C (−238 to +1 652 °F)<br>−150 to +600 °C (−238 to +1 112 °F) | 4.3 K (7.7 °F)<br>5.0 K (9 °F) | | 0.42<br>0.52 |
| GOST R8.8585-2001 | Type L (NiCr-CuNi) (43) | 50 K (90 °F) | −200 to +800 °C (−328 to +1 472 °F) | 8.4 K (15.1 °F) | | 0.53 |
| Voltage transmitter (mV) | | 5 mV | −20 to 100 mV | 200 µV | | 27.39 µV/a |

1) Values valid for 25 °C. For other values, it is necessary to use the Arrhenius equation. This means a doubling of the drift per 10 °C temperature increase.
2) Measured value transmitted via HART®.
3) Percentages based on the configured span of the analog output signal.

*Resistance sensors*

| Standard | Designation | Min. measuring span | Limited safety measuring range | Maximum measurement error | | Long-term drift in °C/year [1] |
|---|---|---|---|---|---|---|
| | | | | Digital (+A/D), −40 to +70 °C (−40 to +158 °F) [2] | (D/A) [3] | |
| IEC 60751:2008 | Pt100 (1) | 10 K (18 °F) | −200 to +600 °C (−328 to +1 112 °F) | 1.1 K (2.0 °F) | 0.5% | 0.23 |
| | Pt200 (2) | 10 K (18 °F) | −200 to +600 °C (−328 to +1 112 °F) | 1.6 K (2.9 °F) | | 0.92 |
| | Pt500 (3) | 10 K (18 °F) | −200 to +500 °C (−328 to +932 °F) | 0.9 K (1.6 °F) | | 0.38 |

| Standard | Designation | Min. measuring span | Limited safety measuring range | Maximum measurement error | | Long-term drift in °C/year [1] |
|---|---|---|---|---|---|---|
| | | | | Digital (+A/D), −40 to +70 °C (−40 to +158 °F) [2] | (D/A) [3] | |
| | Pt1000 (4) | 10 K (18 °F) | −200 to +250 °C (−328 to +482 °F) | 0.6 K (1.1 °F) | | 0.19 |
| JIS C1604:1984 | Pt100 (5) | 10 K (18 °F) | −200 to +510 °C (−328 to +950 °F) | 1.0 K (1.8 °F) | | 0.32 |
| DIN 43760 IPTS-68 | Ni100 (6) | 10 K (18 °F) | −60 to +250 °C (−76 to +482 °F) | 0.4 K (0.7 °F) | | 0.22 |
| | Ni120 (7) | | −60 to +250 °C (−76 to +482 °F) | 0.3 K (0.54 °F) | | 0.18 |
| GOST 6651-94 | Pt50 (8) | 10 K (18 °F) | −180 to +600 °C (−292 to +1 112 °F) | 1.3 K (2.34 °F) | | 0.61 |
| | Pt100 (9) | 10 K (18 °F) | −200 to +600 °C (−328 to +1 112 °F) | 1.2 K (2.16 °F) | | 0.34 |
| OIML R84: 2003, GOST 6651-2009 | Cu50 (10) | 10 K (18 °F) | −180 to +200 °C (−292 to +392 °F) | 0.7 K (1.26 °F) | | 0.46 |
| | Cu100 (11) | 10 K (18 °F) | −180 to +200 °C (−292 to +392 °F) | 0.5 K (0.9 °F) | | 0.23 |
| | Ni100 (12) | 10 K (18 °F) | −60 to +180 °C (−76 to +356 °F) | 0.4 K (0.72 °F) | | 0.21 |
| | Ni120 (13) | 10 K (18 °F) | −60 to +180 °C (−76 to +356 °F) | 0.3 K (0.54 °F) | | 0.18 |
| OIML R84: 2003, GOST 6651-94 | Cu50 (14) | 10 K (18 °F) | −50 to +200 °C (−58 to +392 °F) | 0.7 K (1.26 °F) | | 0.45 |
| Resistance transmitter Ω | 400 Ω | 10 Ω | 10 to 400 Ω | 0.5 Ω | | 0.096 Ω/a |
| | 2 000 Ω | 100 Ω | 10 to 2 000 Ω | 2.1 Ω | | 0.51 Ω/a |

1) Values valid for 25 °C. For other values, it is necessary to use the Arrhenius equation. This means a doubling of the drift per 10 °C temperature increase.
2) Measured value transmitted via HART®.
3) Percentages based on the configured span of the analog output signal.

These values do not take into account deviations caused by EMC interference. In the event of non-negligible EMC interference, an additional deviation of 1% from the span must be added to the values above.

**⚠ CAUTION**

**When using a 2-wire resistance measurement:**
▶ Make the necessary adjustment to the cable resistance values.

*Sample calculation with Pt100 in 4-wire connection, measuring range 0 to +100 °C (+32 to +212 °F), ambient temperature +25 °C (+77 °F), supply voltage 24 V:*

| |
|---|
| Measurement error digital = 1.1 K (2.0 °F) |
| Measurement error D/A = 0.5 % x 100 °C (212 °F) = 0.5 K (0.9 °F) |
| **Measurement error: 1.6 K (2.9 °F)**; for safety measurement errors, the most unfavorable values must be anticipated. |

Validity of data for safety measurement error
- Total permitted temperature range of the transmitter in the SIL mode
- Defined range of the supply voltage
- Limited safety measuring range of sensor element

- Accuracy includes all linearization and rounding errors
- Observe the minimum span of each sensor.
- Values are 2σ values, i.e. 95.4 % of all measured values are within the specifications.

## 3.6 Dangerous undetected faults in this scenario

An incorrect output signal that deviates from the value specified in this manual but is still in the range of 4 to 20 mA is considered a "dangerous, undetected fault". → 📄 11

## 3.7 Useful lifetime of electrical components

The established failure rates of electrical components apply within the useful lifetime as per IEC 61508-2:2010 section 7.4.9.5 note 3.

In accordance with DIN EN 61508-2:2011 section 7.4.9.5, national footnote N3, appropriate measures taken by the manufacturer and operator can extend the useful lifetime.

This device does not contain any electronic components as per the "EMCRH Electrical & Mechanical Component Reliability Handbook" Third Edition (exida.com) that have a useful lifetime less than 50 years.

However, the useful lifetime can be significantly shorter if the device is operated at higher temperatures.

# 4 Commissioning (installation and configuration)

## 4.1 Requirements for personnel

The personnel for installation, commissioning, diagnostics and maintenance must fulfill the following requirements:
- ▶ Trained, qualified specialists must have a relevant qualification for this specific function and task.
- ▶ Personnel must be authorized by the plant owner/operator.
- ▶ Be familiar with federal/national regulations.
- ▶ Before starting work: personnel must read and understand the instructions in the manual and supplementary documentation as well as the certificates (depending on the application).
- ▶ Personnel must follow instructions and comply with general policies.

The operating personnel must fulfill the following requirements:
- ▶ Personnel are instructed and authorized according to the requirements of the task by the facility's owner-operator.
- ▶ Personnel follow the instructions in this manual.

## 4.2 Installation

The mounting and wiring of the device and the permitted orientations are described in the Operating Instructions pertaining to the device.

ℹ Correct installation is a prerequisite for safe operation of the device.

## 4.3 Commissioning

The commissioning of the device is described in the Operating Instructions pertaining to the device.

Prior to operating the device in a safety instrumented system, verification must be performed by carrying out a test sequence as described in **Section 6 Proof testing**.

## 4.4 Operation

The operation of the device is described in the Operating Instructions pertaining to the device.

## 4.5 Device configuration for safety-related applications

### 4.5.1 Adjustment of the measuring point

Measuring point adjustment is described in the Operating Instructions.

Check that the factory settings for the parameters are correct to suit the desired measuring range and correct if necessary.

#### Device protection

The devices can be protected against external influences as follows:
- Hardware write protection
- Software write protection

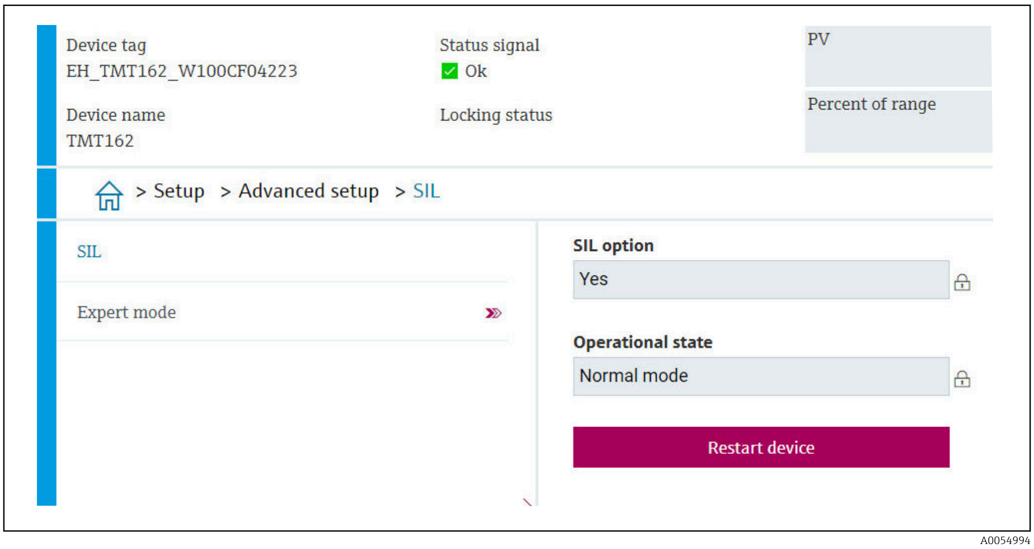
For detailed information regarding device write protection, see the Operating Instructions → 9

### 4.5.2 Configuration methods

When the devices are used in safety instrumented systems, the device configuration must meet two requirements:
- Confirmation concept:
  Proven, independent testing of safety-related parameters entered.
- Locking concept:
  Locking of the device following parameter configuration (as per IEC 61511-1 section 11.6.4).

To activate the SIL mode, the device must run through an operating sequence, during which it can be operated in the operating/configuration tool (e.g. FieldCare, DeviceCare, Pactware, AMS, PDM, Emerson TREX) for which device driver files (DD or DTM) are available.

**"Expert mode" (SIL mode activation = SiMA)**
Here, the current transmitter settings are adopted for the SIL mode (for restrictions, see "Parameters and default settings for the SIL mode" section → 22). This means that defined or preconfigured settings can be used for the appropriate application.




1 *Device parameter configuration method: Expert mode*

A detailed description is provided in the following sections. The expert mode can be implemented exclusively via HART only in the case of SIL devices (order code 590: "Additional approvals", option LA "SIL"). For this reason, only these devices can be used for protective systems.

**NOTICE**

**The configuration of the parameters for a SIL device must be documented!**
- ▶ Enter the configured parameters in the 'Set value' column. The date, time and the SIL checksum that is subsequently displayed must be documented.

All the safety-related parameters (SRP) and their settings can be saved locally and printed out using the "Save results as PDF" button.

The 'Commissioning or proof testing report' is suitable for this purpose → 36

The SIL checksum is unique and is based on the current safety-related parameter settings. This can be used to identify changes in the safety-related parameter settings or to verify multiple devices having identical settings.

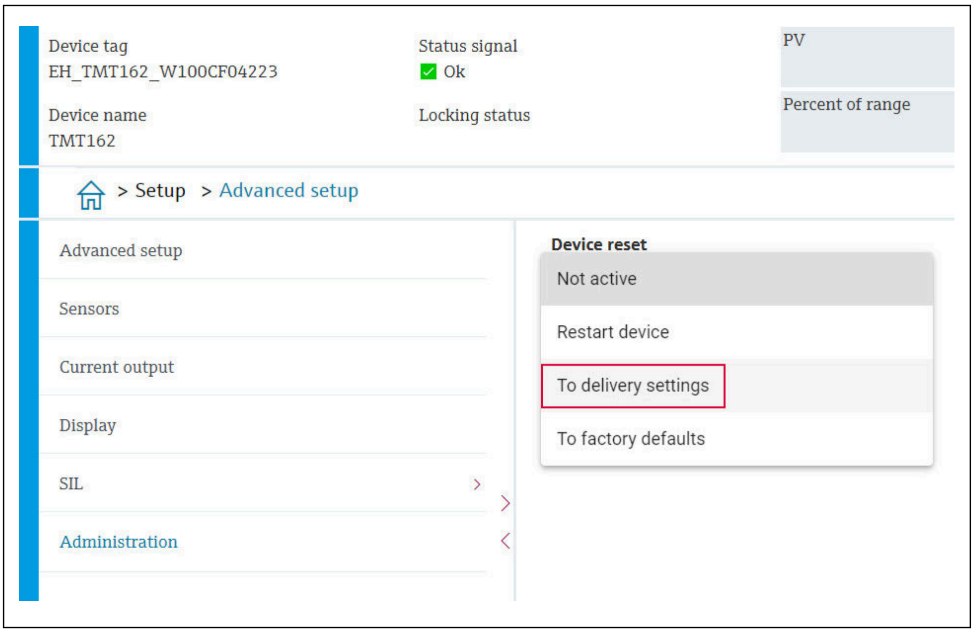
### 4.5.3 Locking in the expert mode, SIL mode activation = SiMA

The user interface can differ from the screens shown here depending on the operating tool used and the selected language.

**NOTICE**

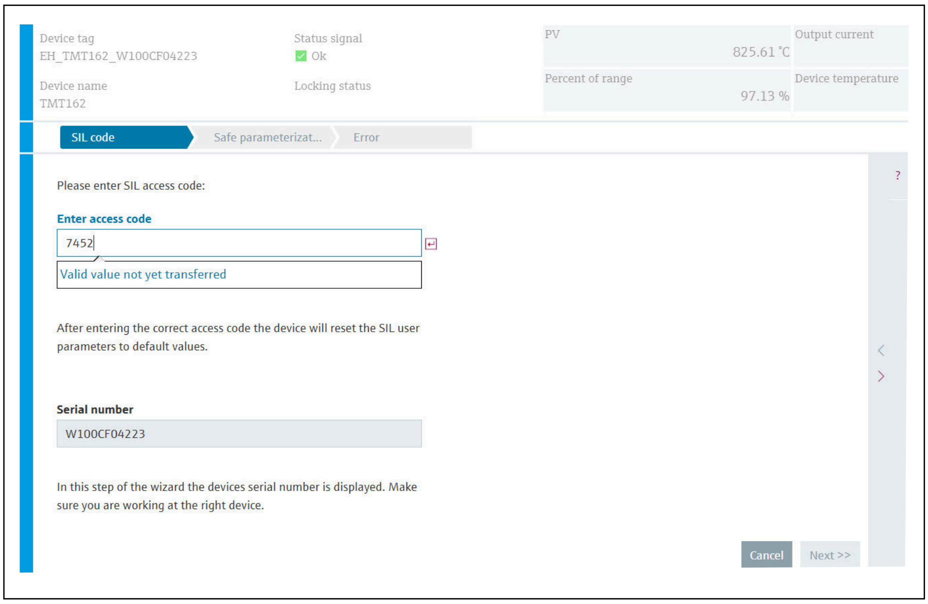
**Interruption to SIL mode activation**
- ▶ In the course of the SIL mode activation process in the expert mode, the transmitter outputs a failure current ≥ 21.5 mA (high alarm). If an error occurs during SIL mode activation in the expert mode or if the process is interrupted, SIL mode activation is not completed successfully and must be performed again.

SIL mode activation process

1. 

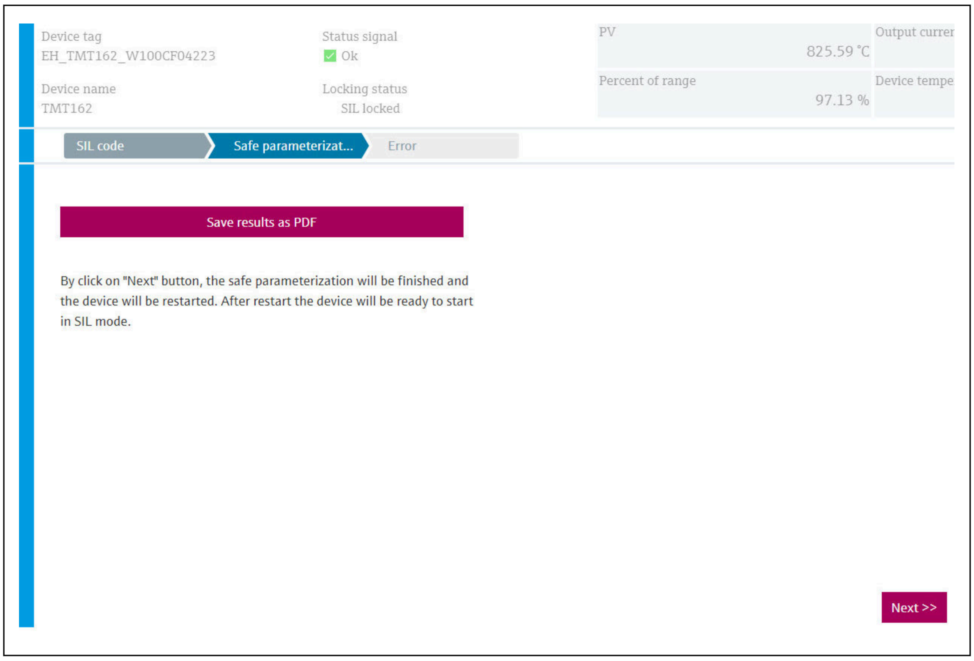

A0055001

   If the transmitter is not in the original as-delivered state, proceed as follows:
   In the menu Setup → Advanced setup → Administration, select 'To delivery settings' in the **Device reset** option.
2. Press ENTER to confirm.
3. Configure all parameters as required for use in the protective system.
4. SIL mode activation can be performed via HART® communication in the online mode only.
   In the submenu Setup → Advanced setup → SIL: start the **Expert mode** wizard.
   ↳ The **Expert mode** wizard opens.




A0055000

5. In the **Enter access code** input window, enter **7452** and press ENTER to confirm. Then press NEXT to continue.
   ↳ The parameters relevant to the safety of the device (SRP), which must not be changed in the SIL mode, are reset to the default setting. See the table of "Parameters and default settings for the SIL mode" (→ 🖹 22). All other safety-related parameters are adopted by the device and protected against tampering.

6. 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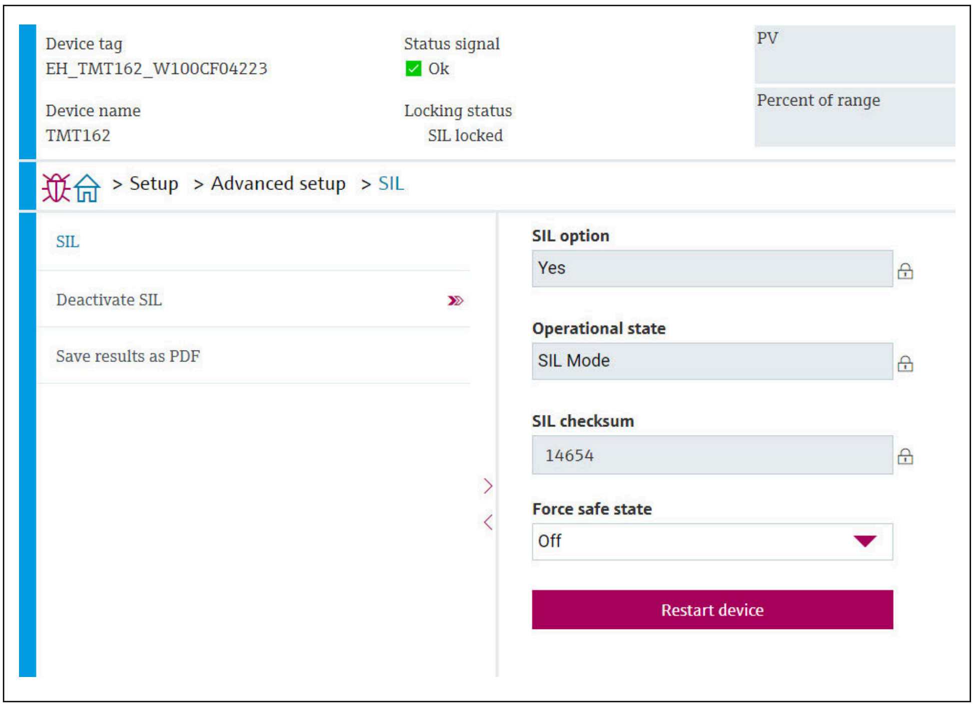
The device restarts itself automatically in the SIL mode once the **Next** button is activated.
   ↳ SIL mode activation in the expert mode is complete.

ℹ All the safety-related parameters (SRP) and their settings can be saved locally and printed out using the "Save results as PDF" button.

7. Take note of the **SIL checksum** in the commissioning report. This can be used to identify changes in the safety-related parameter settings or to verify multiple devices having identical settings.

Test operational state

8.




2 *Display of operational state*

Check the operational state of the transmitter (**SIL mode**) prior to use in protective systems.

9. A commissioning check must be performed prior to commissioning the transmitter in protective systems.

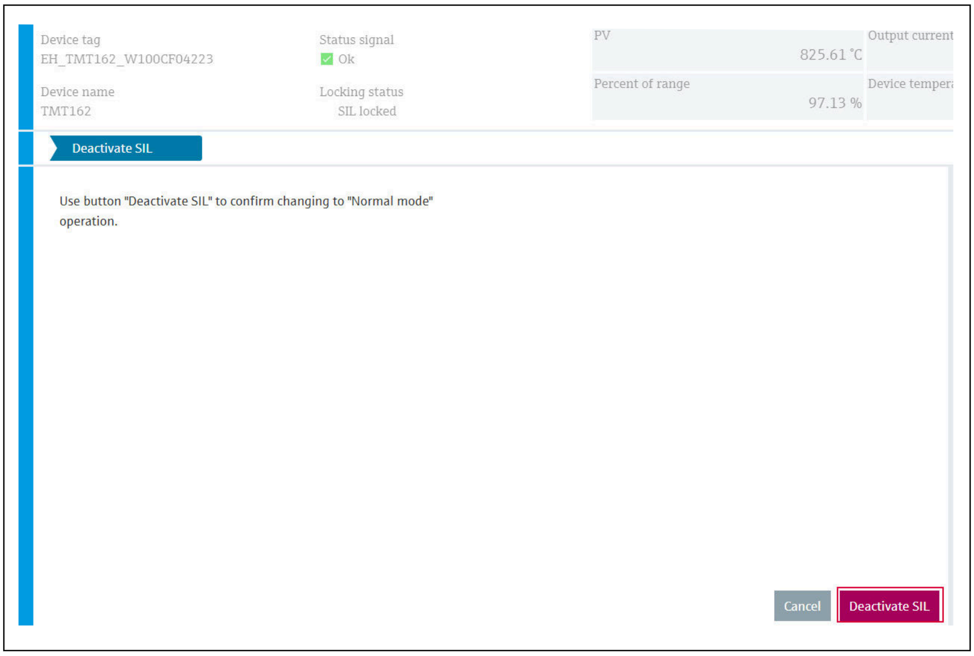
### 4.5.4 Deactivating the SIL mode

There is only one way to deactivate the SIL mode. First switch off the transmitter's write protection (if it is active).

The procedure for doing so is described in the associated Operating Instructions BA01801T.

1. Start the **Deactivate SIL** wizard in the submenu: **Setup → Advanced setup → SIL**.

2.




A0054997

Enable the **Deactivate SIL** button again. This confirms the switch to the "normal mode".

↳ After an automatic restart, the device is in the non-safe mode (normal mode).

**⚠ CAUTION**

**No safety function**

- When the SIL mode is ended, diagnostics are disabled and the device can no longer perform the safety function. Therefore, suitable measures must be taken to ensure that no danger can arise while the SIL mode is disabled.

### 4.5.5 Parameters and default settings for the SIL mode

The following parameters affect the safety function. **It is recommended** that configured or changed values be noted down.

| Parameters and default settings for the expert mode | |
|---|---|
| **Firmware version** | Displays the device firmware version that is installed. Display max. 6-digit character string in the format xx.yy.zz. The firmware version that is currently valid can be taken from the nameplate or the Operating Instructions associated with the device. |
| **Serial number** | Displays the serial number of the device. It can also be found on the nameplate. Max. 11-digit character string comprising letters and numbers. |
| **Enter access code** | Use this function to enable the service parameters via the operating tool.<br>Factory setting: **0** |
| **Device reset** | Use this function to reset the device configuration - either entirely or in part - to a defined state.<br>Factory setting: **Not active** (default setting for SIL mode, cannot be changed) |
| **Hardware revision** | Displays the hardware revision of the device. |
| **Current output simulation** | Use this function to switch simulation of the current output on and off. The display alternates between the measured value and a diagnostics message of the "function check" category (C) while simulation is in progress.<br>Factory setting: **Off** (default setting for SIL mode, cannot be changed) |

| Parameters and default settings for the expert mode | |
|---|---|
| **Current output simulation value** | Use this function to set a current value for the simulation. In this way, users can verify the correct adjustment of the current output and the correct function of downstream evaluation units.<br>Factory setting: **3.58 mA** (default setting for SIL mode, cannot be changed) |
| **20 mA current trimming** | Use this function to set the correction value for the current output at the end of the measuring range at 20 mA.<br>Factory setting: **20.000 mA** (default setting for SIL mode, cannot be changed) |
| **4 mA current trimming** | Use this function to set the correction value for the current output at the start of the measuring range at 4 mA.<br>Factory setting: **4.000 mA** (default setting for SIL mode, cannot be changed) |
| **Lower range value** | Use this function to assign a measured value to the current value 4 mA.<br>Factory setting: **0** |
| **Upper range value** | Use this function to assign a measured value to the current value 20 mA.<br>Factory setting: **100** |
| **Failure current** | Use this function to set the value the current output adopts in the event of a fault, with failure mode **high alarm** selected.<br>Factory setting: **22.5 mA** |
| **Failure mode** | Use this function to select the signal on alarm level of the current output in an event of an error.<br>Factory setting: **low alarm** |
| **HART® address** | Definition of the HART® address of the device.<br>Factory setting: **0** (default setting for SIL mode, cannot be changed) |
| **Device revision** | Use this function to view the device revision with which the device is registered with the HART® Communication Foundation. It is needed to assign the appropriate device description file (DD and DTM) to the device.<br>Factory setting: **5** (fixed value) |
| **Sensor type n** | Use this function to select the sensor type for the sensor input n in question:<br>▪ Sensor type 1: settings for sensor input 1<br>▪ Sensor type 2: settings for sensor input 2<br>Factory setting:<br>▪ **Sensor type 1: Pt100 IEC751**<br>▪ **Sensor type 2: no sensor** |
| **Sensor n upper limit** | Displays the maximum physical full scale value.<br>Factory setting:<br>▪ For sensor type 1 = Pt100 IEC751: **+850 °C (+1 562 °F)**<br>▪ Sensor type 2 = no sensor |
| **Sensor n lower limit** | Displays the minimum physical full scale value.<br>Factory setting:<br>▪ For sensor type 1 = Pt100 IEC751: **−200 °C (−328 °F)**<br>▪ Sensor type 2 = no sensor |
| **Sensor offset n** | Use this function to set the zero point correction (offset) of the sensor measured value. The specified value is added to the measured value.<br>Factory setting: **0.0** |
| **Connection type n** | Use this function to select the connection type for the sensor.<br>Factory setting:<br>▪ Sensor 1 (connection type 1): **4-wire**<br>▪ Sensor 2 (connection type 2): **2-wire** |
| **Reference junction n** | Use this function to select reference junction measurement for temperature compensation of thermocouples (TC).<br>Factory setting: **internal measurement** |
| **RJ preset value n** | Use this function to define the fixed preset value for temperature compensation. The **Preset value** parameter must be set if the **Reference junction n** (= fixed value) option is selected.<br>Factory setting: **0.00** |

| Parameters and default settings for the expert mode | |
|---|---|
| **Call.-V. Dusen coeff. A, B and C** | Use this function to set the coefficients for sensor linearization based on the Callendar-Van Dusen method.<br>Prerequisite: The RTD Platinum (Callendar-Van Dusen) option is enabled in the **Sensor type** parameter.<br>Factory setting:<br>▪ **Coefficient A: 3.910000e-003**<br>▪ **Coefficient B: -5.780000e-007**<br>▪ **Coefficient C: -4.180000e-012** |
| **Call.-V. Dusen coeff. R0** | Use this function to set the R0 value for linearization with the Callendar-Van Dusen polynomial.<br>Prerequisite: The RTD Platinum (Callendar-Van Dusen) option is enabled in the **Sensor type** parameter.<br>Factory setting: **100 Ω** |
| **Polynomial coeff. A, B** | Use this function to set the coefficients for sensor linearization of copper/nickel resistance thermometers.<br>Prerequisite: The RTD Polynomial Nickel or RTD Polynomial Copper option is enabled in the **Sensor type** parameter.<br>Factory setting:<br>▪ **Polynomial coeff. A = 5.49630e-003**<br>▪ **Polynomial coeff. B = 6.75560e-006** |
| **Polynomial coeff. R0** | Use this function to set the R0 value for linearization of nickel/copper sensors.<br>Prerequisite: The RTD Polynomial Nickel or RTD Polynomial Copper option is enabled in the **Sensor type** parameter.<br>Factory setting: **100 Ω** |
| **2-wire compensation** | Use this function to set the 2-wire compensation value.<br>Prerequisite: 2-wire must be selected in the **Connection type** parameter.<br>Factory setting: **0** (default setting for SIL mode, cannot be changed) |
| **Sensor trimming** | Use this function to select the linearization method to be used for the connected sensor.<br>Factory setting: **FactoryTrim** (default setting for SIL mode, cannot be changed) |
| **Alarm delay** | Use this function to set the time delay before an alarm is issued at the current output.<br>Factory setting: **0 s** (default setting for SIL mode, cannot be changed) |
| **Unit** | Use this function to select the engineering unit for all the measured values.<br>Factory setting: **°C** |
| **Mains filter** | Use this function to select the mains filter for A/D conversion.<br>Factory setting: **50 Hz** |
| **Drift/difference mode** | Use this function to choose whether the device reacts to the drift/difference set point being exceeded or undershot. Can only be selected for 2-channel operation.<br>Factory setting: **Off** |
| **Drift/difference set point** | Use this function to configure the maximum permissible measured value deviation between sensor 1 and sensor 2 which results in drift/difference detection.<br>Prerequisite: The **Drift/difference mode** parameter must be activated with the **Out band (drift)** or **In band** option.<br>Factory setting: **999.0** |
| **Drift/difference alarm delay** | Alarm delay for drift detection monitoring.<br>Prerequisite: The **Drift/difference mode** parameter must be activated with the **Out band (drift)** or **In band** option.<br>Factory setting: **5 s** (default setting for SIL mode, cannot be changed) |
| **Force safe state** | During the commissioning check or proof testing, this parameter can be used to test error detection and the safe state of the device.<br>Prerequisite: The **Operational state** parameter displays **SIL mode**.<br>Factory setting: **Off** |

| Parameters and default settings for the expert mode | |
|---|---|
| **Assign current output (PV)** | Use this function to assign a measured variable to the primary HART® value (PV)<br>Factory setting: **sensor 1** |
| **Assign SV** | Use this function to assign a measured variable to the secondary HART® value (SV)<br>Factory setting: **device temperature** |
| **Assign TV** | Use this function to assign a measured variable to the tertiary HART® value (TV)<br>Factory setting: **sensor 1** |
| **Assign QV** | Use this function to assign a measured variable to the quaternary HART® value (QV)<br>Factory setting: **sensor 1** |
| **Reset sensor backup** | Use this function to select the method by which the device is reset from the sensor backup function to normal measuring mode.<br>Factory setting: **Automatic** |
| **Damping** | Use this function to set the time constant for current output damping.<br>Factory setting: **0 s** (default setting for SIL mode, cannot be changed) |
| **Burst mode** | Activation of the HART® burst mode for burst message X. Message 1 has the highest priority, message 2 the second-highest priority, etc.<br>Factory setting: **Off** (default setting for SIL mode, cannot be changed) |

Those parameters which are not mentioned do not affect the safety function and can be configured to any meaningful values. Whether or not the above-mentioned parameters are visible in the operating menu depends in part on the user role, the firmware options ordered and on the configuration of other parameters.

# 5 Operation

## 5.1 Device behavior during operation

After SIL locking, additional diagnostics are active and critical parameters in the safety path are set to safe values. Therefore, the device behavior in the "SIL mode" may deviate from the "normal mode". If a test phase takes place before the system is finally put into production, it is recommended that this test phase be run in the "SIL mode" in order to obtain the most conclusive results possible.

## 5.2 Device behavior during power-up

After power-up, the device runs through a diagnostic phase. The current output is set to the failure current (low alarm, ≤ 3.6 mA) during this time.

During the diagnostic phase, no communication is possible via the service interface (CDI) or via HART®, and the screen of the display is not active.

## 5.3 Device behavior when safety function is requested

The device outputs a current value corresponding to the limit value to be monitored. This value must be monitored and processed further in a connected logic unit.

## 5.4 Safe states

The system assumes one of the three states depending on the error detected.

| Failure mode / Description | Safe state / Output current |
|---|---|
| Application errors are detected by the device, and the set failure current is output. The device can continue to communicate via HART® (device state: "Temporarily safe"). This state persists until all the application errors are resolved and the device can again supply a valid measured value at the current output. All parameters can be read.<br>Example: A cable open circuit is detected in the sensor. | I ≤ 3.6 mA (low alarm)<br>or<br>I ≥ 21.5 mA (high alarm) |
| The device can continue to communicate via HART® (device state: "Active safe"). However, the current output consistently outputs the set failure current. This state persists until the device is restarted. All parameters can be read.<br>Example: Undervoltage detected at device. | |
| The device ceases operation immediately and restarts after 0.5 s at the latest. The device does not display any error messages.<br>Example: An error is detected while the program is running. | |

## 5.5 Behavior of device in the event of an alarm and warnings

The output current in the event of an alarm can be set to a value of ≤ 3.6 mA or ≥ 21.5 mA. In some cases (e.g. failure of power supply, open circuit in power supply line and faults in the current output itself, where the failure current ≥ 21.5 mA cannot be output), output currents ≤ 3.6 mA occur irrespective of the failure current defined.

In some cases (e.g. short-circuit in the supply line), output currents ≥ 21.5 mA occur irrespective of the failure current defined.

NOTICE

**Alarm monitoring**

- ▶ The downstream logic unit must be able to detect high alarms (≥ 21.0 mA) and low alarms (≤ 3.6 mA) for alarm monitoring.

## 5.6 Alarm and warning messages

The behavior of the device in the event of an alarm and warnings is described in the relevant Operating Instructions.

Additional information is provided by the alarm and warning messages in the form of error codes and associated plain text messages.

NOTICE

**When SIL locking is active on the device, additional diagnostics are activated, e.g. the output current that is read back is compared against the set point value. If one of these diagnostics results in an error message (e.g. F261 electronics module), a failure current is output.**

- ▶ In this case, briefly disconnect the device from the power supply, e.g. by unplugging the terminals.
- ▶ When the device is subsequently restarted, a self-check is carried out. The error message is reset.
- ▶ The relevant sensor input for these diagnostic events can be identified with the **Actual diag. channel** parameter or on the display.

# 6 Proof testing

The safety-related functionality of the device in the SIL mode must be verified during commissioning, when changes are made to safety-related parameters, and also at appropriate time intervals. This enables this functionality to be verified within the entire safety instrumented system. The time intervals must be specified by the operator.

**CAUTION**

**The safety function is not guaranteed during a proof test**
Suitable measures must be taken to guarantee process safety during the test.
- ▶ The safety-related output signal 4 to 20 mA must not be used for the safety instrumented system during testing.
- ▶ A completed test must be documented; the reports provided in the Appendix can be used for this purpose (see Section 8.2).
- ▶ The operator specifies the test interval and this must be taken into account when determining the probability of failure $PFD_{avg}$ of the sensor system.

If no operator-specific proof testing requirements have been defined, the following is a possible alternative for testing the transmitter depending on the measured variable used for the safety function. The individual proof test coverages (PTC) that can be used for calculation are specified for the test sequences described below.

The device can be tested as follows:
- Test sequence A: complete test with HART operation
- Test sequence B: complete test without HART operation
- Test sequence C: simplified test with or without HART operation

**Note the following for the test sequences:**
- Test sequence C is **not** permitted for a commissioning test.
- The transmitter can be tested without a sensor using an appropriate sensor simulator (resistance decade, reference voltage source, etc.).
- The accuracy of the measuring instrument used must meet the transmitter specifications.
- If both transmitter input channels are used, the test for the second sensor must be repeated accordingly.
- A three-point calibration must be performed when customized linearization (e.g. with CvD coefficients) is used. In addition, the **Upper sensor limit** and **Lower sensor limit** must be checked.

**In the case of a commissioning check, please observe the following in addition to test sequences A and B:**
If both of the transmitter's input channels are used, the two-channel functions such as **Sensor drift** or **Backup** (channel assignment at current output) must also be tested.
If thermocouples are used, the setting for the **Reference junction** option and its preset value must be checked.
The function of the "Out of range category" must be tested to its limits, 3.8 mA or 20.5 mA.
The operational state of the transmitter must be checked (SIL mode).

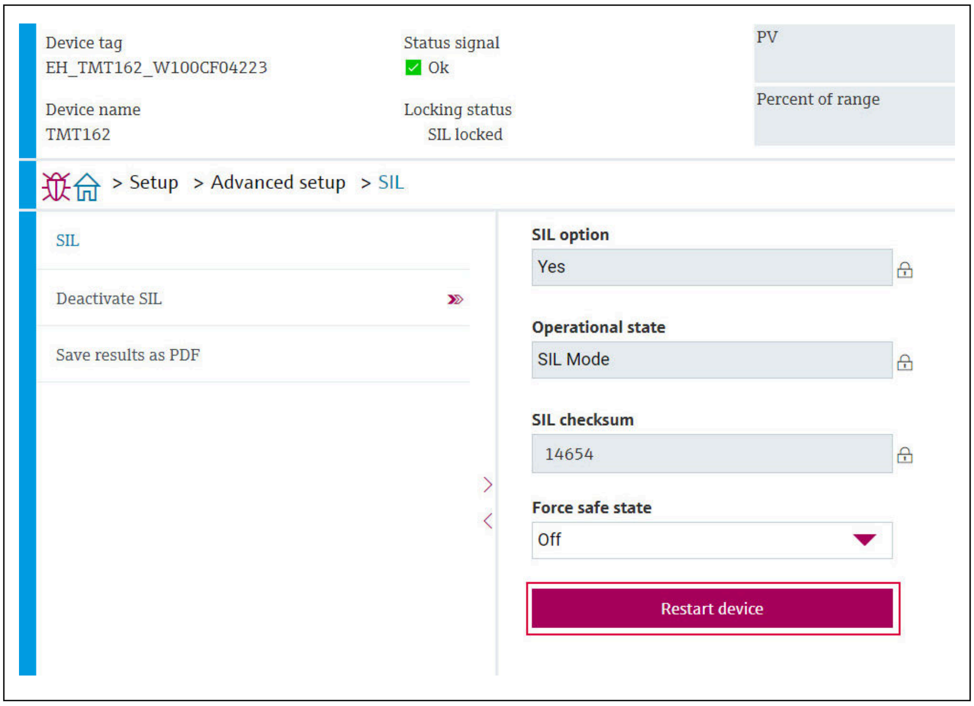
## 6.1 Test sequence A

1. Two-point calibration

   Test the current output by applying the reference temperature at the sensor or a corresponding reference signal (resistance, voltage) at 2 points. Select **4 to 6 mA** for the lower range value and **18 to 20 mA** for the upper range value.

   ↳ The measurement results must be within the specified safety measurement error. Otherwise the test has not been passed.

2.




A0054996

3 *Trigger a device restart using the appropriate function in the operating tool used or via HART command 42.*

Check the safe state (high and low alarm). If the transmitter's hardware or software write protection is enabled, switch it off first.

Check both alarm states (high and low) by restarting the device using the appropriate function in the operating tool used or via HART command 42.

↳ The alarm states, high alarm (≥ 21.0 mA) and low alarm (≤ 3.6 mA), are output consecutively for longer than 4 s in each case.
Both current values must be checked.

96% of dangerous, undetected failures are detected using this test (proof test coverage, PTC = 0.96). During the test sequence, the device's current output typically behaves as illustrated in → 28.

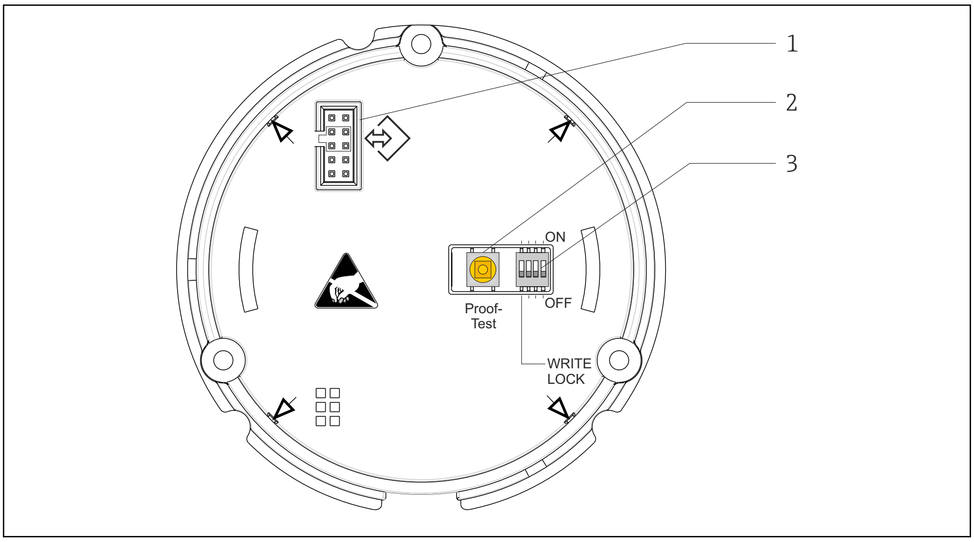
## 6.2 Test sequence B

1. Two-point calibration

Test the current output by applying the reference temperature at the sensor or a corresponding reference signal (resistance, voltage) at 2 points. Select **4 to 6 mA** for the lower range value and **18 to 20 mA** for the upper range value.

↳ The measurement results must be within the specified safety measurement error. Otherwise the test has not been passed.

2.



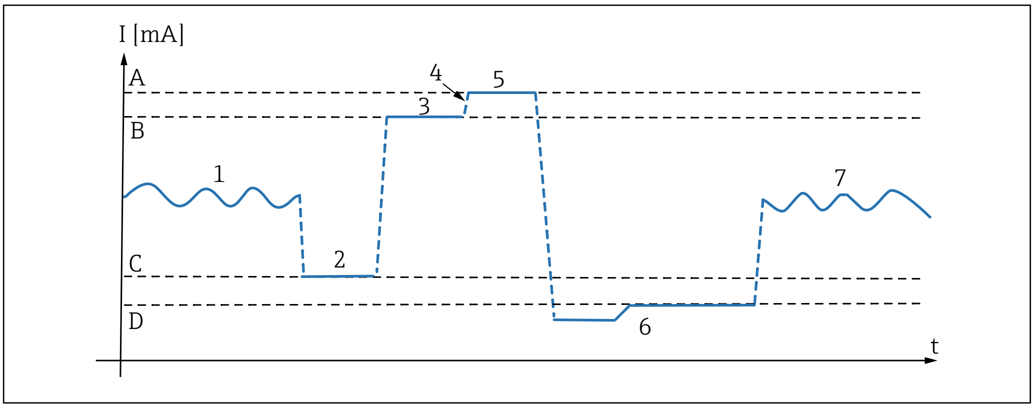

A0026573

1 *Electrical connection for the display module*
2 *Proof-test button for testing in SIL mode without HART operation*
3 *DIP switch for activating or deactivating device write protection*

Check both alarm states (high and low) by restarting the device using the proof-test button (see diagram above). To do this, press the proof-test button for at least 3 s.

↳ The alarm states, high alarm (≥ 21.0 mA) and low alarm (≤ 3.6 mA), are output consecutively for longer than 4 s in each case.
Both current values must be checked.

94% of dangerous, undetected failures are detected using this test (proof test coverage, PTC = 0.94). During the test sequence, the device's current output typically behaves as illustrated in → 28.




A0034407

4 *Current pattern during proof test A and B*

A *High alarm (≥ 21.0 mA)*
B *20 mA*
C *4 mA*
D *Low alarm (≤ 3.6 mA)*
1 *Measuring mode*
2 *Lower range value adjustment (two-point calibration)*
3 *Upper range value adjustment (two-point calibration)*
4 *Restart device (via HART or proof-test button)*
5 *High alarm (≥ 21.0 mA)*
6 *Low alarm (≤ 3.6 mA)*
7 *Measuring mode*

## 6.3 Test sequence C

**Test sequence C**

1. Check the plausibility of the current measuring signal. The measured value must be assessed on the basis of empirical values deriving from the operation of the device. This is the responsibility of the operator.

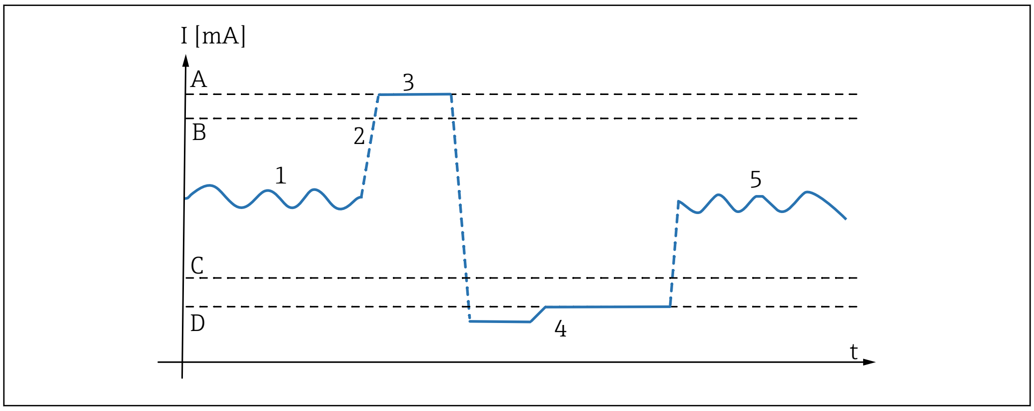
2. Check the safe state (high and low alarm)

   Check both alarm states (high and low) by restarting the device using the proof-test button → 📄 28. Alternatively, the restart can also be checked using the relevant function in the operating tool used or via HART command 42 (if necessary, remove device write protection for this). → 📄 27

   ↳ The alarm states, high alarm (≥ 21.0 mA) and low alarm (≤ 3.6 mA), are output consecutively for longer than 4 s in each case.
   Both current values must be checked.
   During the test sequence, the current output of the device typically behaves as illustrated in the graphic above. Points 2 and 3 are dispensed with. → 📄 28

ℹ The restart must not be initiated by means of a power cycle.

58% of dangerous, undetected failures are detected using this test (proof test coverage, PTC = 0.58). **Test sequence C is not permitted for a commissioning check.**




5 *Current pattern during proof test C*

*A High alarm (≥ 21.0 mA)*
*B 20 mA*
*C 4 mA*
*D Low alarm (≤ 3.6 mA)*
*1 Measuring mode*
*2 Restart device (via HART or proof-test button)*
*3 High alarm (≥ 21.0 mA)*
*4 Low alarm (≤ 3.6 mA)*
*5 Measuring mode*

**NOTICE**

▶ The purpose of proof-testing is to detect dangerous undetected device failures ($\lambda_{du}$).
The impact of systematic faults on the safety function is not covered by this test and must be assessed separately. Systematic faults can be caused, for example, by process material properties, operating conditions, build-up or corrosion.

## 6.4 Verification criterion

**If one of the test criteria from the test sequences described above is not fulfilled, the device may no longer be used as part of a safety instrumented system.**

- The purpose of proof-testing is to detect dangerous undetected device failures ($\lambda_{DU}$).
- This test does not cover the impact of systematic faults on the safety function, which must be assessed separately.
- Systematic faults can be caused, for example, by process material properties, operating conditions, build-up or corrosion.
- As part of the visual inspection, for example, ensure that all of the seals and cable entries provide adequate sealing and that the device is not visibly damaged.

# 7 Repair and error handling

## 7.1 Maintenance

Maintenance instructions and instructions regarding recalibration may be found in the Operating Instructions pertaining to the device.

Alternative monitoring measures must be taken to ensure process safety during configuration, proof-testing and maintenance work on the device.

## 7.2 Repair

NOTICE

**Repair means restoring functional integrity by replacing defective components. Components of the same type must be used for this purpose.**

▶ We recommend that you document the repair. This includes specifying the device serial number, the repair date, the type of repair and the individual who performed the repair.

*The following components may be replaced by the customer's technical staff if genuine spare parts are used and the appropriate installation instructions are followed:*

| Component | Checking the device after repair |
| --- | --- |
| Display | Visual inspection to establish if all parts are present and mounted correctly and to verify that the device is in the "Good" state. |
| Housing cover | |
| Seal kits for housing covers | |
| Securing clamps, housing | |
| Overvoltage protection module | |

For installation instructions for spare parts, see: download from www.endress.com

The replaced component or the defective device must be sent to the manufacturer for the purpose of fault analysis in cases where the device has been operated in a protective system and a device error cannot be ruled out. In this case, always enclose the "Declaration of Hazardous Material and Decontamination" with the note "Used as SIL device in safety instrumented system" when returning the defective device. For more information, please refer to the "Return" section in the Operating Instructions. → 9

## 7.3 Modification

Modifications are changes to SIL devices that are already delivered or installed:
- **Modifications to SIL devices by the user are not permitted because they can impair the functional safety of the device**
- Modifications to SIL devices may be performed onsite at the user's plant following approval by the Endress+Hauser manufacturing center
- Modifications to SIL devices must be performed by personnel authorized to do so by Endress+Hauser
- Only **original spare parts** from Endress+Hauser may be used for modifications
- All modifications must be documented in the Endress+Hauser Device Viewer (www.endress.com/deviceviewer)
- All modifications require a change nameplate or replacement of the original nameplate.

## 7.4 Decommissioning

When decommissioning, the requirements according to IEC 61508-1:2010 section 7.17 must be observed.

## 7.5 Disposal

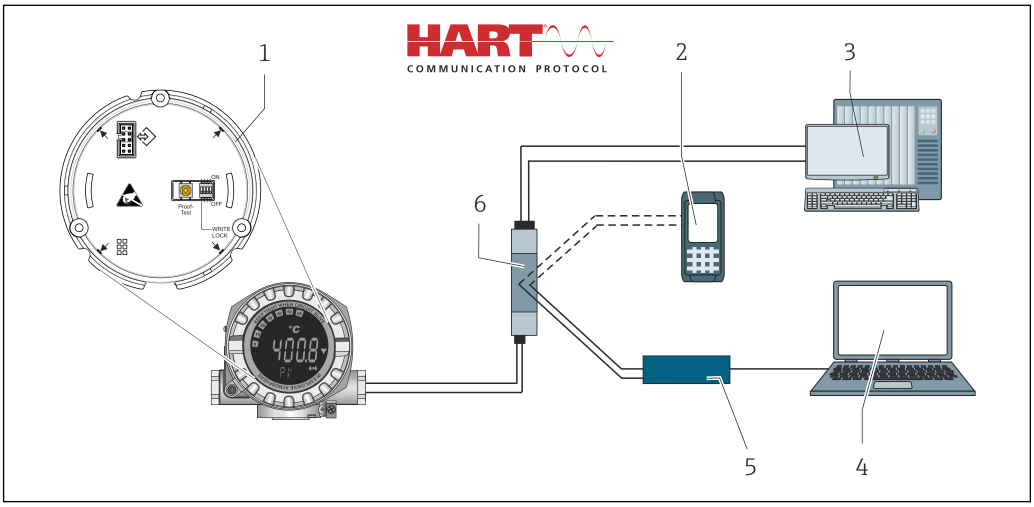
If required by the Directive 2012/19/EU on waste electrical and electronic equipment (WEEE), the product is marked with the depicted symbol in order to minimize the disposal of WEEE as unsorted municipal waste. Do not dispose of products bearing this marking as unsorted municipal waste. Instead, return them to the manufacturer for disposal under the applicable conditions.

# 8 Appendix

## 8.1 Structure of the measuring system

### 8.1.1 System components

An example of the devices in the measuring system is shown in the following graphic.

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6 *HART® connection with device of the RN series product family of Endress+Hauser, including integrated communication resistor*

1 *Temperature field transmitter*
2 *HART® handheld communicator*
3 *PLC/DCS*
4 *Configuration software, e.g. FieldCare*
5 *HART® modem*
6 *Configuration via Field Xpert SFX350/370*
7 *Device of the RN series*

An analog signal (4 to 20 mA) in proportion to the relevant sensor value is generated in the transmitter. This is sent to a downstream logic unit (e.g. PLC, limit signal transmitter) where it is monitored to determine whether it is above or below a specified limit value. For fault monitoring, the logic unit must be able to recognize and analyze both high alarms (≥ 21.0 mA) and low alarms (≤ 3.6 mA).

**NOTICE**

▶ The optional display is not part of the safety function. Neither the hardware nor the software of the display has a verifiable influence on the defined safety functions of the transmitter. The CDI interface is not safe and therefore may not be used in safety-related applications. The interface cannot be used for the expert mode.

Correct installation is a prerequisite for safe operation of the device.

### 8.1.2 Measurement function

**NOTICE**

**Galvanic isolation**

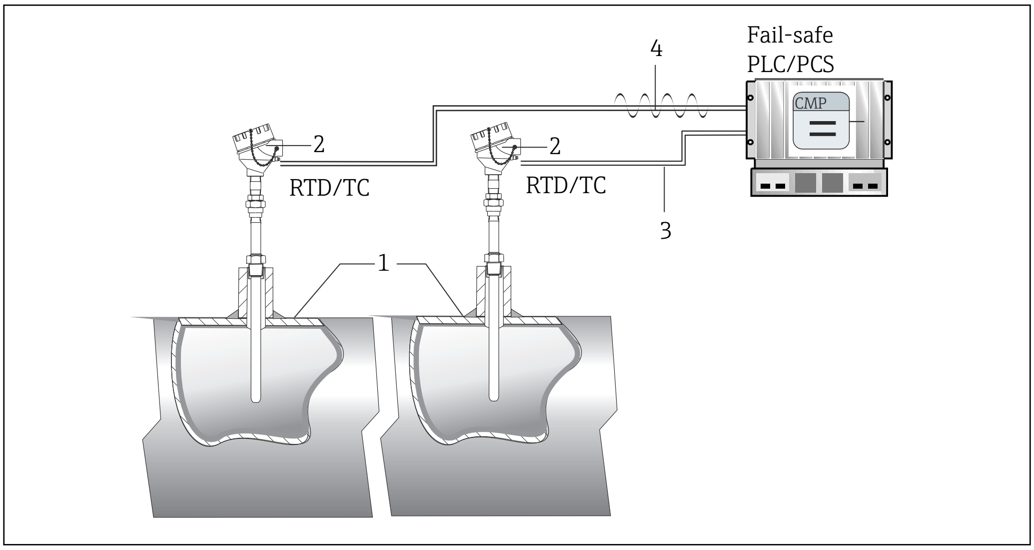
▶ When two sensors are connected to the transmitter, make sure the sensors are galvanically isolated from one another.

**Two-channel functions**
Two sensors can be connected to the transmitter and the transmitter can be operated in the following safe functions:

- **Averaging** function
  The measured values M1, M2 of the two sensors are output as an arithmetic mean (M1+M2)/2.
- **Difference** function
  The measured values M1, M2 of the two sensors are output as a difference (M1-M2).
- **Backup** function
  If one of the sensor fails, the transmitter automatically switches to the other measuring channel. For this the sensor types must be identical, e.g. two 3-wire RTD Pt100 sensors. The backup function is used to increase availability or improve the diagnostic capabilities.
  If the **backup** function is selected, the following sensor types are permitted in the SIL mode:
  - 2x thermocouple (TC)
  - 2x RTD, 3-wire
- **Sensor drift** function
  If redundant sensors are used, the long-term drift of a sensor can be detected, for instance. This is a diagnostic measure as the signal of the second sensor is only used for this diagnostic. If identical sensors are used, the **backup** function can also be used.

The configured drift/difference limit value should be at least twice the safety accuracy value.

**SIL 3 configuration: homogeneous redundancy**
Two temperature transmitters with one sensor per transmitter are required for a SIL 3 measuring point. The measured values of the two transmitters are evaluated in a logic unit using a safe voter.



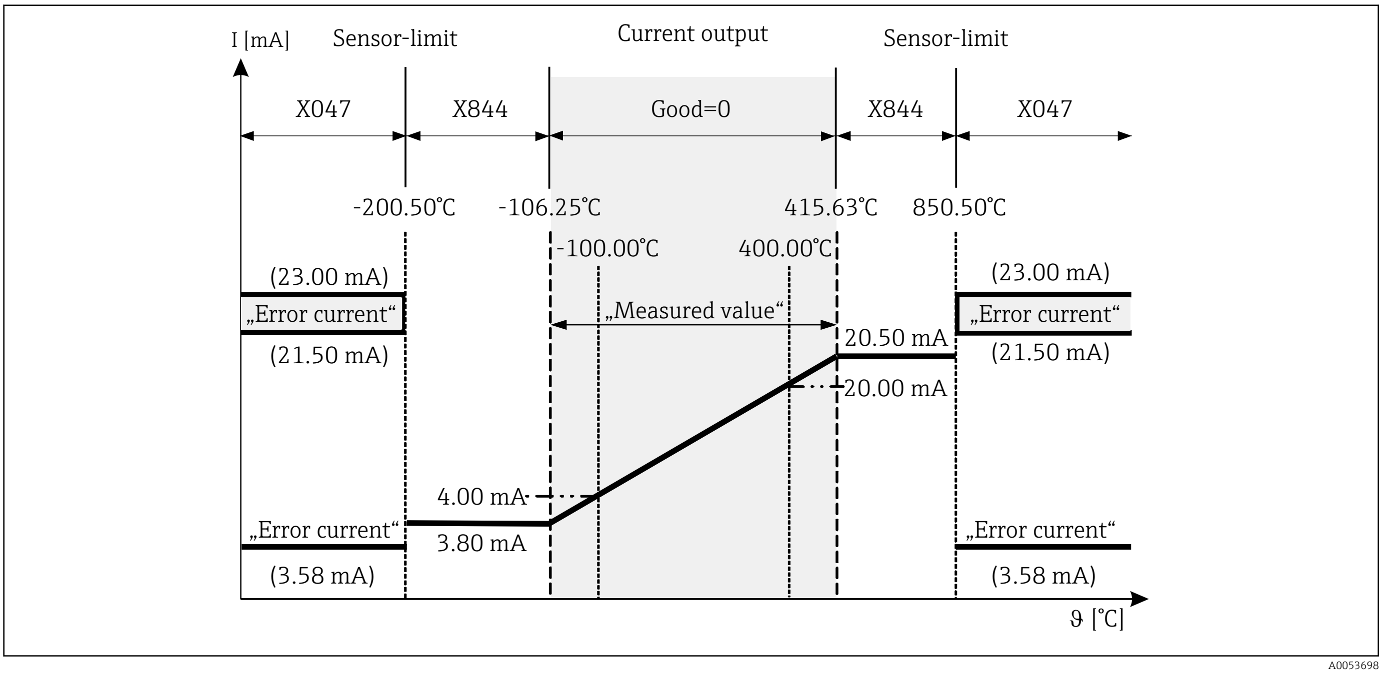

7 *Example with current output at the first transmitter and current output and HART® communication at the second transmitter. PLC/PCS voting of both sensor values: SIL 3*

1 *2 temperature sensors*
2 *2 temperature transmitters*
3 *4 to 20 mA current output*
4 *4 to 20 mA current output, optionally with HART® communication*

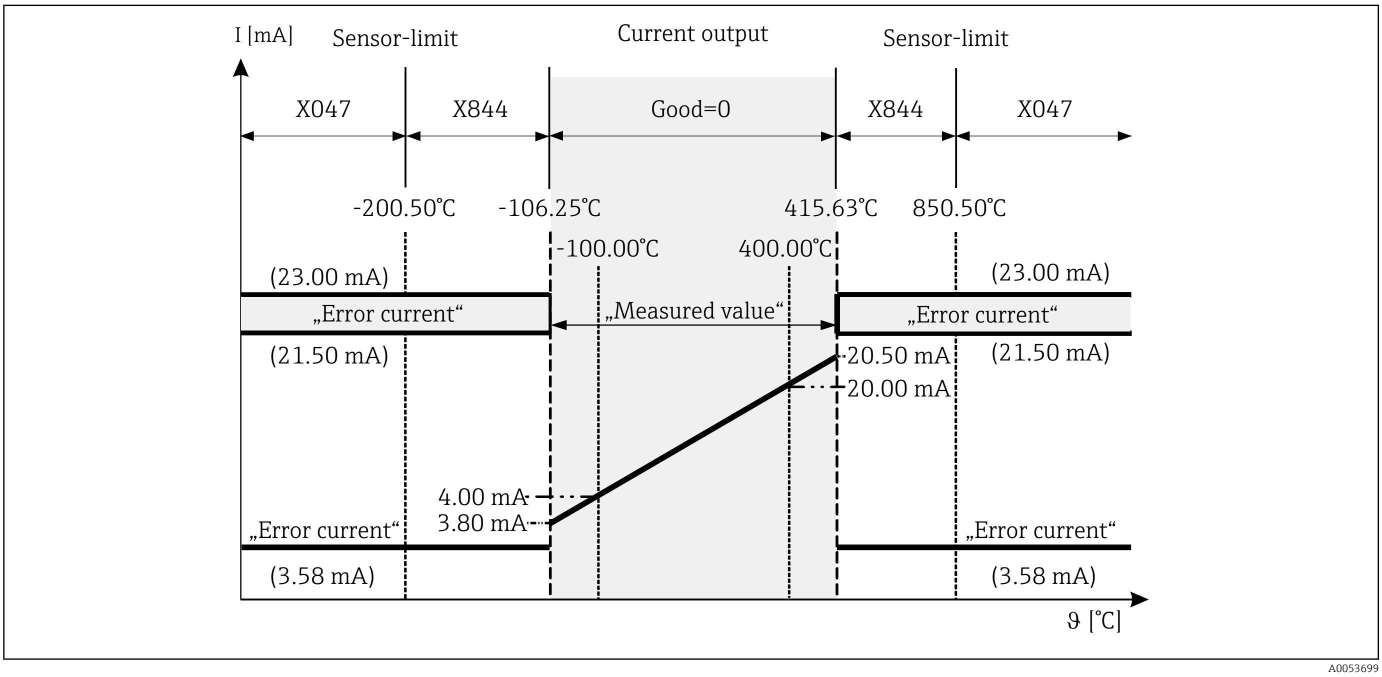
### 8.1.3 Device behavior in the event of out of range category (F, S, M)

The safety function is used to monitor the measured value. In the SIL mode, a failure current or saturation current is output in the event of a measurement outside a user-defined measuring range (4 to 20 mA), depending on the configuration of the "Out of range category" parameter (F, S, M).

Example in diagram: $I_{4\ mA}$ = -100 °C, $I_{20\ mA}$ = +400 °C, sensor type Pt100 IEC




8 *Output signals in the event of a warning*




9 *Output signals in the event of an alarm*

## 8.2 Commissioning or proof test report

| | |
|---|---|
| **Company / contact person** | **/** |
| **Tester** | |

| **Device information** | |
|---|---|
| System | Measuring point / TAG no.: |
| Device type / order code | |
| Serial number | Firmware version |
| Access code (if individual to each device) | SIL checksum |

| **Verification information** |
|---|
| Date / time |
| Performed by |

| **Verification result** | | |
|---|---|---|
| Overall result | ☐ Passed | ☐ Failed |

| **Comment:** |
|---|
| |

| Date | Signature of customer | Signature of tester |
|---|---|---|

| **Type of safety function** |
|---|
| ☐ Safe measurement |

| **Commissioning check** |
|---|
| ☐ Device parameter configuration via SIL mode activation (SiMA)<br>☐ Commissioning check, test sequence A<br>☐ Commissioning check, test sequence B |

| Proof testing |
|---|
| ☐ Test sequence A<br>☐ Test sequence B<br>☐ Test sequence C |

| Proof test report | | | |
|---|---|---|---|
| Test step | Target value | Actual value | Passed |
| 1. Lower range value adjustment, sensor 1 | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 2. Upper range value adjustment, sensor 1 | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 3. Lower range value adjustment, sensor 2 | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 4. Upper range value adjustment, sensor 2 | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 5. Current value alarm | | | ☐ Passed<br>☐ Failed |
| 6. Restart via HART | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 7. Restart via proof-test button | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |

| Protocol for commissioning check | | | |
|---|---|---|---|
| Test step | Target value | Actual value | Passed |
| 1. Lower range value adjustment, sensor 1 | | | ☐ Passed<br>☐ Failed |
| 2. Upper range value adjustment, sensor 1 | | | ☐ Passed<br>☐ Failed |
| 3. Lower range value adjustment, sensor 2 | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 4. Upper range value adjustment, sensor 2 | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 5. Two-channel function, sensor drift | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 6. Two-channel function, backup | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 7. Channel assignment, current output | | | ☐ Passed<br>☐ Failed |
| 8. Out of range category | | | ☐ Passed<br>☐ Failed |
| 9. Reference junction / Preset value | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 10. Current value alarm | | | ☐ Passed<br>☐ Failed |

| Protocol for commissioning check | | | |
|---|---|---|---|
| 11. Restart via HART | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |
| 12. Restart via proof-test button | | | ☐ Passed<br>☐ Failed<br>☐ Not applicable |

| **Comment:** |
|---|
| |

### 8.2.1 Parameter settings for the SIL mode

| Parameter name | Factory setting | Set value | Checked |
|---|---|---|---|
| Enter access code | 0 | | |
| Lower measuring range (4 mA) | 0 | | |
| Upper measuring range (20 mA) | 100 | | |
| Failure current | 22.5 mA | | |
| Failure mode | Low alarm | | |
| Sensor type 1 | Pt100 IEC60751 | | |
| Sensor type 2 | No sensor | | |
| Upper sensor limit 1 [1)] | +850 °C | | |
| Lower sensor limit 1 [1)] | −200 °C | | |
| Upper sensor limit 2 [1)] | - | | |
| Lower sensor limit 2 [1)] | - | | |
| Sensor offset 1 | 0 | | |
| Sensor offset 2 | 0 | | |
| Connection type 1 | 4-wire (RTD) | | |
| Connection type 2 | 2-wire (TC) | | |
| Reference junction 1,2 | Internal measurement (TC) | | |
| RJ preset value 1,2 | 0 (for **Preset value** setting) | | |
| Call.-V. Dusen coeff. A, B and C sensor 1 [1)] | A: 3.910000e-003<br>B: -5.780000e-007<br>C: -4.180000e-012 | | |
| Call.-V. Dusen coeff. A, B and C sensor 2 [1)] | A: 3.910000e-003<br>B: -5.780000e-007<br>C: -4.180000e-012 | | |
| Call.-V. Dusen coeff. R0 sensor 1 [1)] | 100 Ω | | |
| Call.-V. Dusen coeff. R0 sensor 2 [1)] | 100 Ω | | |
| Polynomial coeff. A, B sensor 1 [1)] | A = 5.49630e-003<br>B = 6.75560e-006 | | |
| Polynomial coeff. A, B sensor 2 [1)] | A = 5.49630e-003<br>B = 6.75560e-006 | | |
| Polynomial coeff. R0 sensor 1 [1)] | 100 Ω | | |
| Polynomial coeff. R0 sensor 2 [1)] | 100 Ω | | |
| Unit | °C | | |
| Mains filter | 50 Hz | | |
| Drift/difference mode | Off | | |
| Drift/difference alarm delay | 5 s | | |
| Drift/difference set point | 999 | | |
| Force safe state | Off | | |
| Assign current output (PV) | Sensor 1 | | |
| Reset sensor backup | Automatic | | |
| Assign SV | Device temperature | | |

| Parameter name | Factory setting | Set value | Checked |
|---|---|---|---|
| Assign TV | Sensor 1 | | |
| Assign QV | Sensor 1 | | |

1) Only for Call.-V. Dusen or polynomial Cu/Ni sensors

## 8.3 Version history

| Version of manual | Changes | Valid as of firmware version | Valid from hardware version | Reference to NE53 customer information |
|---|---|---|---|---|
| SD01632T/09/EN/01.17 | First version | 04.01.00 | 04.01.00 | |
| SD01632T/09/EN/02.23 | - | 04.01.11 | 04.01.00 | |
| FY01106T/09/EN/01.24 | Additional backup setting option | 04.02.00 | 04.01.00 | MI01524T/09/EN/01.24 |

This document must be archived for up to 10 years following delivery of the last device.