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2024-01-22

Functional Safety Manual
iTEMP TMT82

Endress+Hauser
People for Process Automation

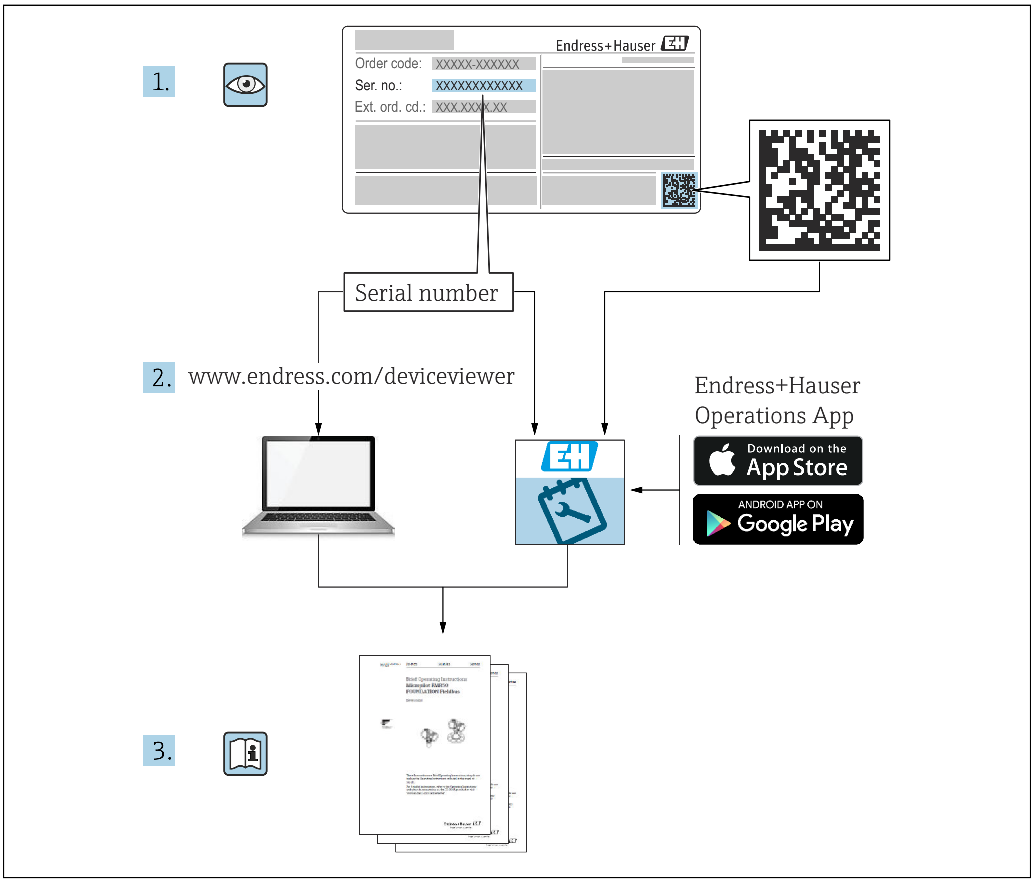
1.
Endress+Hauser
Order code: XXXXX-XXXXXX
Ser. no.: XXXXXXXXXXXX
Ext. ord. cd.: XXX.XXXX.XX
Serial number
2. www.endress.com/deviceviewer
Endress+Hauser
Operations App
Download on the App Store
ANDROID APP ON Google Play
3.

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Table of contents

1 **Declaration of Conformity** 4
1.1 Safety-related characteristic values 5
1.2 Use as a safe measuring system 7

2 **About this document** 8
2.1 Document function 8
2.2 Using this document 8
2.3 Symbols 9
2.3.1 Safety symbols 9
2.3.2 Symbols for certain types of information and graphics 9
2.4 Supplementary device documentation 9
2.4.1 Further applicable documents 9

3 **Design** 11
3.1 Permitted device types 11
3.2 Identification marking 11
3.3 Safety function 11
3.3.1 Safety-related output signal 11
3.3.2 Safe measurement 12
3.4 Basic conditions for use in safety-related applications 12
3.4.1 Random failures in accordance with IEC/EN 61508 13
3.4.2 Safety measured error 13
3.5 Dangerous undetected faults in this scenario . 16
3.6 Useful lifetime of electrical components 16

4 **Commissioning (Installation and configuration)** 16
4.1 Requirements for personnel 16
4.2 Installation 17
4.3 Commissioning 17
4.4 Operation 17
4.5 Device configuration for safety-related applications 17
4.5.1 Adjustment of the measuring point . . 17
4.5.2 Configuration methods 17
4.5.3 Locking in the expert mode, SIL mode activation = SiMA 18
4.5.4 Deactivating the SIL mode 21
4.5.5 Parameters and default settings for the SIL mode 22

5 **Operation** 25
5.1 Device behavior during operation 25
5.2 Device behavior during power-up 25
5.3 Device behavior when safety function is requested 25
5.4 Safe states 26
5.5 Behavior of device in the event of an alarm and warnings 26
5.6 Alarm and warning messages 26

6 **Proof testing** 27
6.1 Test sequence A 27
6.2 Test sequence B 28
6.3 Test sequence C 30
6.4 Verification criterion 31

7 **Appendix** 31
7.1 Structure of the measuring system 31
7.1.1 Structure of the measuring system . . . 31
7.2 Commissioning or proof test report 35
7.2.1 Parameter settings for the SIL mode . . 38
7.3 Version history 39

1 Declaration of Conformity

SIL_00023_05.23

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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 TM82

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, 10.10.2024
Endress+Hauser Wetzer GmbH+Co. KG

ppa. Harald Müller
Director Technology

i.V. Eva Rizzo
Head of Department Technology Safety

1/3

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1.1 Safety-related characteristic values

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Allgemein			
Gerätebezeichnung und zulässige Ausführungen	TMT82 (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	Kopftransmitter: 01.00.07 oder höher Hutschienentransmitter: 01.00.04 oder höher		
Gültige Firmware-Version	01.02.11 oder höher (Dev.Rev.: 3)		
Sicherheitshandbuch	FY01105T		
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 0005		
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	**Kopftransmitter**	**Hutschienentransmitter**
Sicherheitsfunktion(en)	sichere Messung	sichere Messung
λ_{DU} 1),2)	40 FIT	41 FIT
λ_{DD} 1),2)	258 FIT	258 FIT
λ_{S} 1),2)	130 FIT	126 FIT
SFF - Safe Failure Fraction	91%	90%
PFD_{avg} für T1 = 1 Jahr 2) (einkanalige Architektur)	$1.75 \cdot 10^{-4}$	$1.80 \cdot 10^{-4}$
PFD_{avg} für T1 = 5 Jahre 2) (einkanalige Architektur)	$8.76 \cdot 10^{-4}$	$8.98 \cdot 10^{-4}$
PFH	$4.0 \cdot 10^{-8} \cdot 1/h$	$4.1 \cdot 10^{-8} \cdot 1/h$
PTC 3)	96%	96%
Fehlerreaktionszeit 4)	< 16,2 s	< 16,2 s
Diagnose-Testintervall 5)	4,3 min	4,3 min
Prozesssicherheitszeit 6)	7,2 h	7,2 h
MTTF 7)	156 Jahre	156 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 (32 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

2/3

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General

Device designation and permissible types	TMT82 (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	Head transmitter: 01.00.07 or higher DIN Rail transmitter: 01.00.04 or higher		
Valid Software-Version	01.02.11 or higher (Dev.Rev.: 3)		
Safety manual	FY01105T		
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 0005		
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	DIN Rail transmitter
Safety function	safe measurement	safe measurement
λ_{DU} 1) 2)	40 FIT	41 FIT
λ_{DD} 1) 2)	258 FIT	258 FIT
λ_{SU} 1) 2)	130 FIT	126 FIT
SFF - Safe Failure Fraction	91%	90%
PFD_{avg} T1 = 1 year 2) (single channel architecture)	$1.75 \cdot 10^{-4}$	$1.80 \cdot 10^{-4}$
PFD_{avg} T1 = 5 years 2) (single channel architecture)	$8.76 \cdot 10^{-4}$	$8.98 \cdot 10^{-4}$
PFH	$4.0 \cdot 10^{-8} \cdot 1/h$	$4.1 \cdot 10^{-8} \cdot 1/h$
PTC 3)	96%	96%
Fault reaction time 4)	< 16.2 s	< 16.2 s
Diagnostic test interval 5)	4.3 min	4.3 min
Process safety time 6)	7.2 h	7.2 h
MTTF 7)	156 years	156 years

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 (32 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

3/3

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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. Here, based on the example of the head transmitter:

Single channel operation

	λ_{du}	λ_{dd}	λ_{su}	λ_{sd}	SFF	PFD_{avg}
Headtransmitter	40 FIT	258 FIT	127 FIT	3 FIT	91%	$1.75 \cdot 10^{-4}$

		low stress		high stress		low stress		high stress	
		closed coupled				extension wire			
		Sensor	Sensor + TMT82	Sensor	Sensor + TMT82	Sensor	Sensor + TMT82	Sensor	Sensor + TMT82
Thermo-couple	λ_{du}	6 FIT	46 FIT	119 FIT	159 FIT	109 FIT	149 FIT	2180 FIT	2220 FIT
	λ_{dd}	94,1 FIT	352,1 FIT	1881,0 FIT	2139 FIT	891 FIT	1149 FIT	17820 FIT	18078 FIT
	λ_{su}	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT
	λ_{sd}	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT
	SFF	94%	94% / 91%	94%	94% / 91%	89%	89% / 91%	89%	89% / 91%
	PFD_{avg}		$2.0 \cdot 10^{-4}$		$7.0 \cdot 10^{-4}$		$6.5 \cdot 10^{-4}$		$9.7 \cdot 10^{-3}$
RTD 2-/3-wire	λ_{du}	9 FIT	49 FIT	180,7 FIT	220,7 FIT	98,8 FIT	138,8 FIT	1976 FIT	2016 FIT
	λ_{dd}	38,9 FIT	296,9 FIT	779,3 FIT	1037,3 FIT	376,2 FIT	634,2 FIT	7524 FIT	7782 FIT
	λ_{su}	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT
	λ_{sd}	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT
	SFF	81%	81% / 91%	81%	81% / 91%	79%	79% / 91%	79%	79% / 91%
	PFD_{avg}		$2.1 \cdot 10^{-4}$		$9.7 \cdot 10^{-4}$		$6.1 \cdot 10^{-4}$		$8.8 \cdot 10^{-3}$
RTD 4-wire	λ_{du}	6,4 FIT	46,4 FIT	128,8 FIT	168,8 FIT	74,3 FIT	114,3 FIT	1486 FIT	1526 FIT
	λ_{dd}	43,6 FIT	301,6 FIT	871,2 FIT	1129,2 FIT	425,7 FIT	683,7 FIT	8514 FIT	8772 FIT
	λ_{su}	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT
	λ_{sd}	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT
	SFF	87%	87% / 91%	87%	87% / 91%	85%	85% / 91%	85%	85% / 91%
	PFD_{avg}		$2.0 \cdot 10^{-4}$		$7.4 \cdot 10^{-4}$		$5.0 \cdot 10^{-4}$		$6.7 \cdot 10^{-3}$

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

Headtransmitter	λ_{du}	λ_{dd}	λ_{su}	λ_{sd}	SFF	PFD_{avg}
	40 FIT	258 FIT	127 FIT	3 FIT	91%	$1.75 \cdot 10^{-4}$

		low stress		high stress		low stress		high stress	
		closed coupled				extension wire			
		2x Sensor	2x Sensor + TMT82	2x Sensor	2x Sensor + TMT82	2x Sensor	2x Sensor + TMT82	2x Sensor	2x Sensor + TMT82
Thermo-couple	λ_{du}	10,7 FIT	50,7 FIT	70 FIT	110 FIT	158 FIT	198 FIT	3160 FIT	3200 FIT
	λ_{dd}	189,3 FIT	447,3 FIT	3786 FIT	4044 FIT	1842 FIT	2100 FIT	36840 FIT	37098 FIT
	λ_{su}	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT
	λ_{sd}	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT
	SFF	95%	95% / 91%	98%	98% / 91%	92%	92% / 91%	92%	92% / 91%
	PFD_{avg}		$2.2 \cdot 10^{-4}$		$4.8 \cdot 10^{-4}$		$8.7 \cdot 10^{-4}$		$1.4 \cdot 10^{-2}$
RTD 2-/3-wire	λ_{du}	7,7 FIT	47,7 FIT	154 FIT	194 FIT	83,6 FIT	123,6 FIT	1672 FIT	1712 FIT
	λ_{dd}	88,1 FIT	346,1 FIT	1766 FIT	2024 FIT	866,4 FIT	1124,4 FIT	17328 FIT	17586 FIT
	λ_{su}	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT
	λ_{sd}	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT
	SFF	92%	92% / 91%	92%	92% / 91%	91%	91% / 91%	91%	91% / 91%
	PFD_{avg}		$2.1 \cdot 10^{-4}$		$8.5 \cdot 10^{-4}$		$5.4 \cdot 10^{-4}$		$7.5 \cdot 10^{-3}$
RTD 2-/3-wire + TC	λ_{du}	9,2 FIT	49,2 FIT	184 FIT	224 FIT	120,8 FIT	160,8 FIT	2416 FIT	2456 FIT
	λ_{dd}	138,7 FIT	396,7 FIT	2776 FIT	3034 FIT	1354,2 FIT	1612,2 FIT	27084 FIT	27342 FIT
	λ_{su}	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT	0 FIT	127 FIT
	λ_{sd}	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT	0 FIT	3 FIT
	SFF	94%	94% / 91%	94%	94% / 91%	92%	92% / 91%	92%	92% / 91%
	PFD_{avg}		$2.2 \cdot 10^{-4}$		$9.8 \cdot 10^{-4}$		$7.0 \cdot 10^{-4}$		$1.1 \cdot 10^{-2}$

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

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 potentially dangerous situation. Failure to avoid this situation can result in serious or fatal injury.

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

NOTICE
This symbol alerts you to a potentially harmful situation. Failure to avoid this situation can result in damage to the product or something in its vicinity.

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 Supplementary 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

- Operating Instructions iTHERM ModuLine: BA01915T
- Operating Instructions iTHERM SurfaceLine: BA02366T
- Operating Instructions iTEMP TMT82: BA01028T
- Operating Instructions iTEMP TMT162: BA01801T

- Technical Information iTHERM ModuLine TM111: TI01445T
- Technical Information iTHERM ModuLine TM131: TI01373T
- Technical Information iTHERM ModuLine TM151: TI01707T
- Technical Information iTHERM SurfaceLine TM611: TI01801T
- Safety Instructions iTHERM ModuLine TM1x1: XA00044R
- Safety Instructions iTHERM ModuLine TM1x1: XA01799T
- Safety Instructions iTHERM ModuLine TM1x1: XA01817T
- Safety Instructions iTHERM SurfaceLine TM1611: XA03256T
- Safety Instructions iTHERM SurfaceLine TM1611: XA03258T
- Functional Safety Manual iTEMP TMT82: SD01172T/FY01105T
- Functional Safety Manual iTEMP TMT162: SD01632T/FY01106T

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.

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.

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.

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.

Certificate

The associated certificate is available in the Endress+Hauser Device Viewer (Section 2.3) or can be found in the Declaration of Conformity (Section 1) of the applicable Functional Safety Manual. This certificate must be valid at the time of delivery of the device.

3 Design

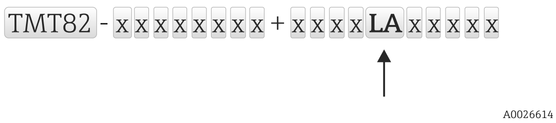
3.1 Permitted device types

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
...	...	...
590	Additional approval	LA
...	...	...

Order code:

 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 01.02.00
	Valid hardware version (electronics)	as of 01.00.00 (head transmitter) as of 01.00.00 (DIN rail device)
	Valid device drivers	DTM as of version 1.11.479.5304 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 → 📄 12

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. The device additionally communicates for information only via HART and contains all HART features with additional device information. The 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 level switch where it is monitored for the following:
- Overshooting and/or undershooting of a specified limit value
- The occurrence of a fault: e.g. failure current (≤ 3.6 mA, ≥ 21.0 mA, signal cable open circuit or short-circuit)

ℹ In the SIL mode, the transmitter cannot be configured for inverse value display at the current output.

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 comprises a transmitted current output signal proportional to the voltage, resistance or temperature value.

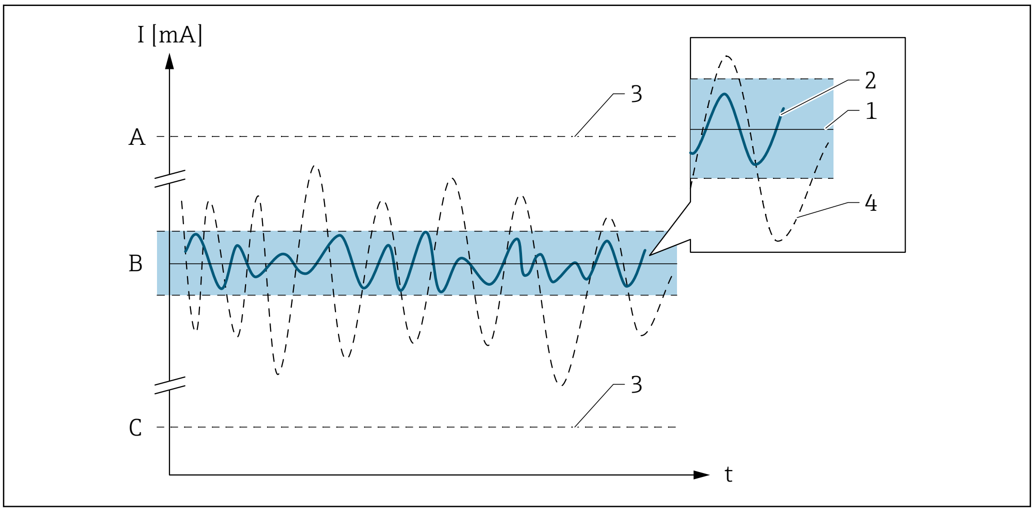
The safety function can be used with all sensor configurations from the "Structure of the measuring system" section→ 🗎 31. Note here that only the measured value of one sensor or the output of a function (e.g. the averaging or differential function) can ever be displayed via the current output.

3.4 Basic conditions for use in safety-related applications

The device 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 +70 °C (–40 to +158 °F)
- Compliance with the ambient conditions as per IEC 61326-3-2 Appendix B is mandatory.
- The head transmitter must not be operated as a DIN rail substitute in a cabinet by using the DIN rail clip with remote sensors.
- 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.
- The network frequency filter must be configured 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.
- Wire resistance compensation for two-wire measurement is not possible.
- With the version in the housing for field mounting with separate terminal compartment, the second channel is used for measuring the reference temperature during the thermocouple measurement. (See also Operating Instructions BA01028T.)
- 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 contains all the influence factors described in the Technical Information (TI).
  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 Random failures in accordance with IEC/EN 61508



A HI alarm ≥ 21 mA
B SIL error range ±2%
C LO alarm ≤ 3.6 mA

No device error
- No failure
- No impact on the safety-related output signal
- Impact on measurement uncertainty:
  1 – within the specification (TI, BA etc.)

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

λ_{DD} (Dangerous detected)
- Dangerous, detected failure
- 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

λ_{DU} (Dangerous undetected)
- Dangerous and undetected failure
- Impact on the safety-related output signal: can be outside the defined error range B
- Impact on the measurement uncertainty:
  4 – May be outside the specified error range

3.4.2 Safety measured 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

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]	
	Type E (NiCr-CuNi) (34)	50 K (90 °F)	−150 to +1000 °C (−238 to +1832 °F)	4.9 K (8.8 °F)		0.43
	Type J (Fe-CuNi) (35)	50 K (90 °F)	−150 to +1200 °C (−238 to +2192 °F)	4.9 K (8.8 °F)		0.46
	Type K (NiCr-Ni) (36)	50 K (90 °F)	−150 to +1200 °C (−238 to +2192 °F)	5.1 K (9.2 °F)		0.56
	Type N (NiCrSi-NiSi) (37)	50 K (90 °F)	−150 to +1300 °C (−238 to +2372 °F)	5.5 K (9.9 °F)		0.73
	Type R (PtRh13-Pt) (38)	50 K (90 °F)	+200 to +1768 °C (+392 to +3214 °F)	5.6 K (10.1 °F)		1.58
	Type S (PtRh10-Pt) (39)	50 K (90 °F)	+200 to +1768 °C (+392 to +3214 °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 +2000 °C (+32 to +3632 °F)	7.6 K (13.7 °F)		0.94
ASTM E988-96	Type D (W3Re-W25Re) (33)	50 K (90 °F)	0 to +2000 °C (+32 to +3632 °F)	7.1 K (12.8 °F)		1.14
DIN 43710	Type L (Fe-CuNi) (41) Type U (Cu-CuNi) (42)	50 K (90 °F)	−150 to +900 °C (−238 to +1652 °F) −150 to +600 °C (−238 to +1112 °F)	4.3 K (7.7 °F) 5.0 K (9 °F)		0.42 0.52
GOST R8.8585-2001	Type L (NiCr-CuNi) (43)	50 K (90 °F)	−200 to +800 °C (−328 to +1472 °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	Name	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 +1112 °F)	1.1 K (2.0 °F)		0.23
	Pt200 (2)	10 K (18 °F)	−200 to +600 °C (−328 to +1112 °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
	Pt1000 (4)	10 K (18 °F)	−200 to +250 °C (−328 to +482 °F)	0.6 K (1.1 °F)	0.5%	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

Standard	Name	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]	
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. In the event of non-negligible EMC interference, an additional deviation of 1% from the span must be added to the values above.

NOTICE

When using a 2-wire resistance measurement - valid from hardware version 01.00.07 (head transmitter) and 01.00.05 (DIN rail device):

- ▶ Make the necessary adjustment to the cable resistance values by performing an offset correction.
- ▶ An additional error of 5 °C (9 °F) must be added to the values of the safety measured errors.

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.

NOTICE

For the version in the housing for field mounting with separate terminal compartment:

- ▶ With a thermocouple measurement, pay attention to the settings of the reference measuring point. The setting internal measurement **must not** be selected. (See also Operating Instructions BA01028T.)

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
- Minimum span of each sensor observed
- Housing types: DIN rail transmitter and head transmitter
- Values are 2σ values, i.e. 95.4 % of all measured values are within the specifications.

3.5 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". → 🗎 12

3.6 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.

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 carried out by means of a test sequence as described in **the section "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 (optionally via plug-in display)
- Software write protection

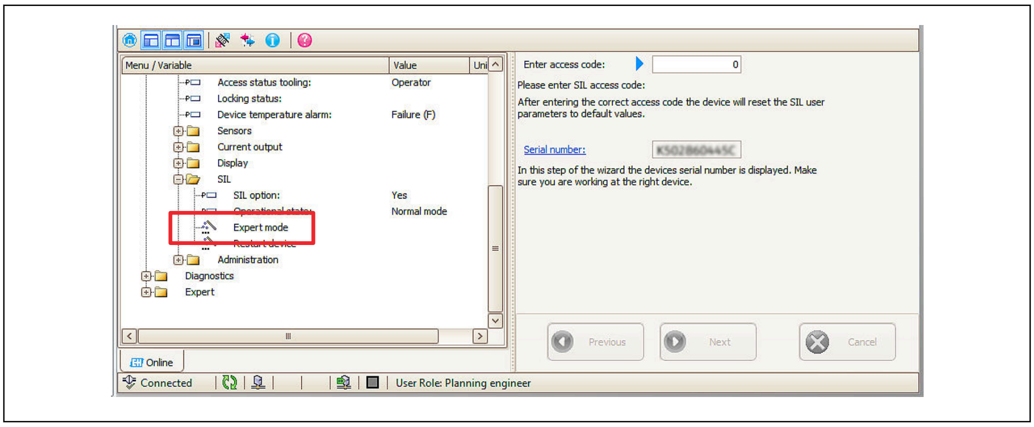
For detailed information on device write protection, see the Operating Instructions: → 9

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.



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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. The 'Commissioning or proof testing report" is suitable for this purpose. → 35

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

The SIL checksum can be used to verify the configured parameters of several devices.

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

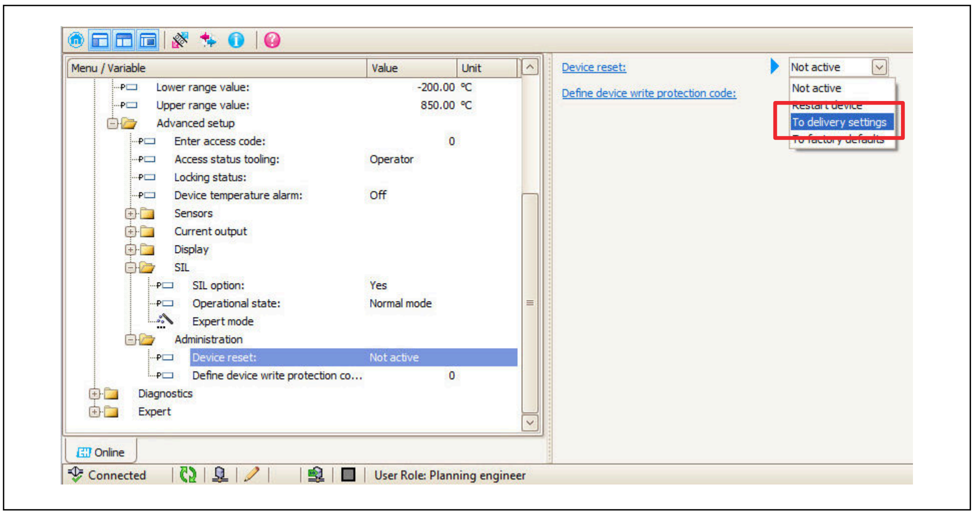
The user interface can differ from the screens shown here depending on the operating tool used and the selected language.

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. 

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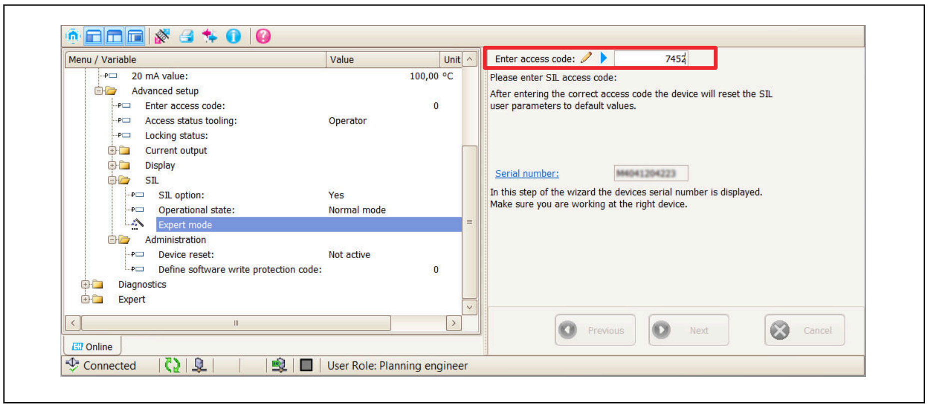
If the transmitter is not in the original as-delivered state, proceed as follows:
In the menu Setup → Extended setup → Administration, select 'To delivery settings' in the **Device reset** option.

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 → Extended setup → SIL: start the **Expert mode** wizard.
↳ The **Expert mode** wizard opens.



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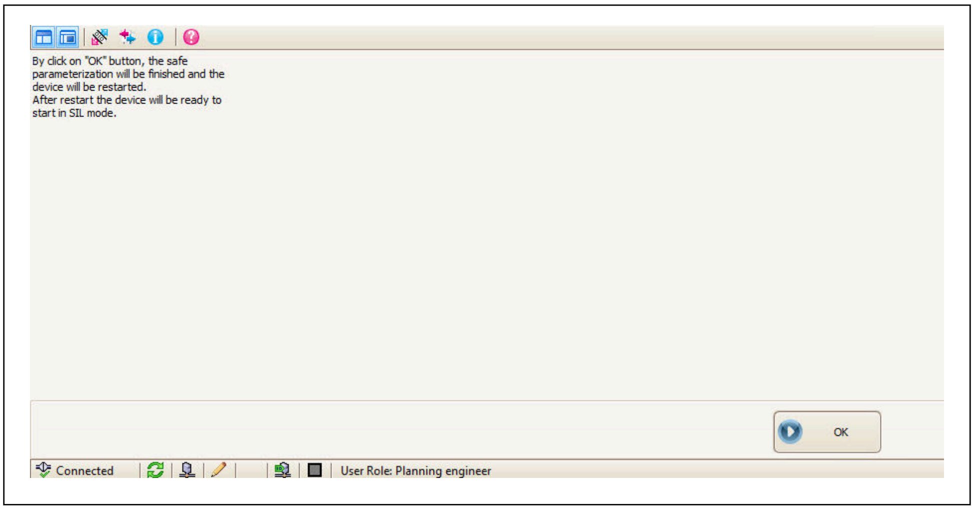
5. In the **Enter access code** input window, enter **7452** and press ENTER to confirm. Then press NEXT to continue.
↳ The parameters relevant to the safety of the device (SRP), which must not be changed in the SIL mode, are reset to the default setting. See the table of "Parameters and default settings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

6. 

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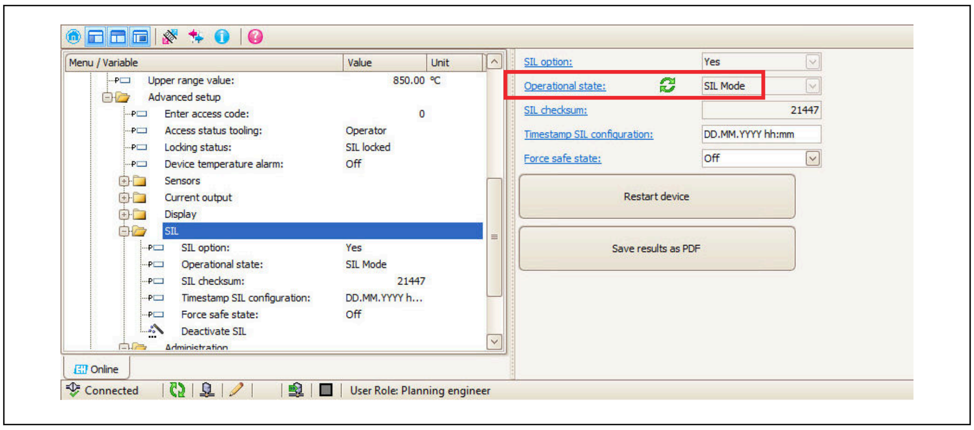
The device restarts automatically in the SIL mode once the OK button is pressed.
↳ SIL mode activation in the expert mode is complete.

7. Take note of the **SIL checksum** in the commissioning report. This can be used to verify the configuration of several devices.

Test operational state

8. 

A0053704

2 *Display operational state*

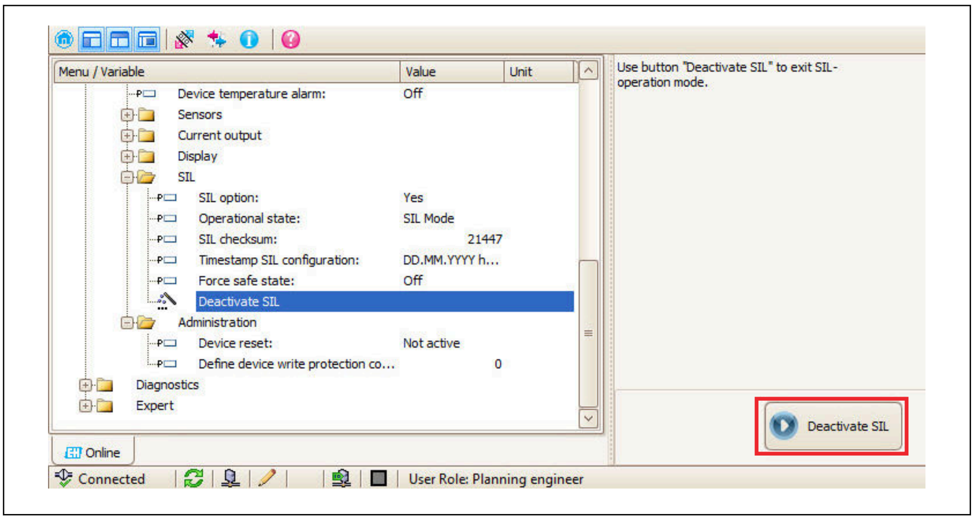
Check the operational state of the transmitter (**SIL mode**) prior to use in protective systems.

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 BA01028T.

1. 

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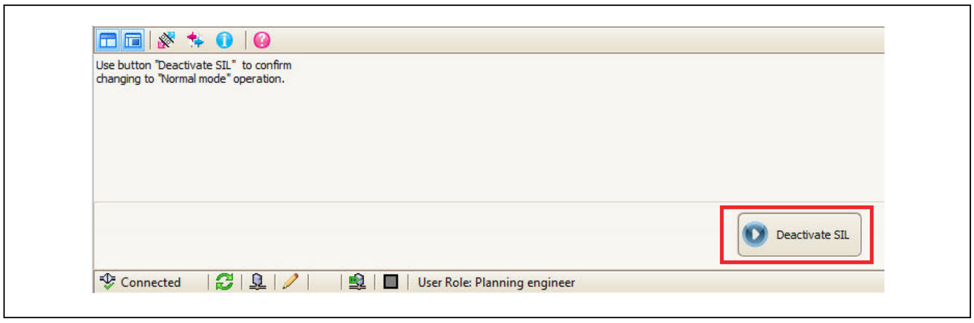
In the submenu **Setup → Extended setup → SIL**, start the **Deactivate SIL** wizard.

2. 

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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. Factory setting: **0**
Device reset	Use this function to reset the device configuration - either entirely or in part - to a defined state. 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 diagnostic message of the "function check" category (C) while simulation is in progress. Factory setting: **Off** (default setting for SIL mode, cannot be changed)
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. 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. 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. 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. Factory setting: **0**
Upper-range value	Use this function to assign a measured value to the current value 20 mA. Factory setting: **100**
Out of range category	Use this function to select the category (status signal) as to how the device reacts when the value is outside the set measuring range. Factory setting: **maintenance required (M)**
Failure current	Use this function to set the current value issued by the current output in the event of a fault, with failure mode **high alarm** selected. Factory setting: **22.5 mA**
Failure mode	Use this function to select the failure signal level issued by the current output in the event of a fault. Factory setting: **High alarm**
HART address	Use this function to define the HART address of the device. Factory setting: **0** (default setting for SIL mode, cannot be changed)
Device revision	Displays the device revision with which the device is registered with the HART FieldComm Group. It is needed to assign the appropriate device description file (DD and DTM) to the device. Factory setting: **3** (fixed value)

Parameters and default settings for the expert mode	
Measuring mode	Possibility of inverting the output signal. Options: standard (4 to 20 mA) or inverse (20 to 4 mA). Factory setting: **Standard** (default setting for SIL mode, cannot be changed)
Sensor type n	Use this function to select the sensor type for the sensor input n in question: ▪ Sensor type 1: settings for sensor input 1 ▪ Sensor type 2: settings for sensor input 2 Factory setting: ▪ **Sensor type 1: Pt100 IEC751** ▪ **Sensor type 2: no sensor**
Sensor n upper limit	Displays the maximum physical full scale value. Factory setting: ▪ For sensor type 1 = Pt100 IEC 60751: **+850 °C (+1 562 °F)** ▪ Sensor type 2 = no sensor
Sensor n lower limit	Displays the minimum physical full scale value. Factory setting: ▪ For sensor type 1 = Pt100 IEC 60751: **−200 °C (−328 °F)** ▪ 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. Factory setting: **0.0**
Connection type n	Use this function to select the connection type for the sensor. Factory setting: ▪ Sensor 1 (connection type 1): **4-wire** ▪ Sensor 2 (connection type 2): **2-wire**
Reference junction n	Use this function to select reference junction measurement for temperature compensation of thermocouples (TC). 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. Factory setting: **0.00**
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. Prerequisite: The RTD Platinum (Callendar-Van Dusen) option is enabled in the **Sensor type** parameter. Factory setting: ▪ **Coefficient A: 3.910000e-003** ▪ **Coefficient B: -5.780000e-007** ▪ **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. Prerequisite: The RTD Platinum (Callendar-Van Dusen) option is enabled in the **Sensor type** parameter. Factory setting: **100 Ω**
Polynomial coeff. A, B	Use this function to set the coefficients for sensor linearization of copper/nickel resistance thermometers. Prerequisite: The RTD Polynomial Nickel or RTD Polynomial Copper option is enabled in the **Sensor type** parameter. Factory setting: ▪ **Polynomial coeff. A = 5.49630e-003** ▪ **Polynomial coeff. B = 6.75560e-006**
Polynomial coeff. R0	Use this function to set the R0 value for linearization of nickel/copper sensors. Prerequisite: The RTD Polynomial Nickel or RTD Polynomial Copper option is enabled in the **Sensor type** parameter. Factory setting: **100 Ω**

Parameters and default settings for the expert mode	
2-wire compensation	Use this function to set the 2-wire compensation value. Prerequisite: 2-wire must be selected in the **Connection type** parameter. 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. 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. 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. Factory setting: **°C**
Mains filter	Use this function to select the mains filter for A/D conversion. 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. Factory setting: **Off**
Drift/difference alarm category	Use this function to select the category (status signal) as to how the device reacts when a drift/difference is detected between sensor 1 and sensor 2. Prerequisite: The **Drift/difference mode** parameter must be activated with the **Out band (drift)** or **In band** option. Factory setting: **maintenance required (M)**
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. Prerequisite: The **Drift/difference mode** parameter must be activated with the **Out band (drift)** or **In band** option. Factory setting: **999.0**
Drift/difference alarm delay	Alarm delay for drift detection monitoring. Prerequisite: The **Drift/difference mode** parameter must be activated with the **Out band (drift)** or **In band** option. Factory setting:**0 s** (default setting for SIL mode, cannot be changed)
Device temperature alarm	Use this function to select the category (status signal) as to how the device reacts when the electronics temperature of the transmitter is exceeded or undershot, < −40 °C (−40 °F) or > +82 °C (+180 °F). Factory setting: **out of specification (S)**
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. Prerequisite: The **Operational state** parameter displays **SIL mode**. Factory setting: **Off**
Assign current output (PV)	Use this function to assign a measured variable to the primary HART value (PV). Factory setting: **sensor 1**
Assign SV	Use this function to assign a measured variable to the secondary HART value (SV). Factory setting: **device temperature**
Assign TV	Use this function to assign a measured variable to the tertiary HART value (TV). Factory setting: **sensor 1**
Assign QV	Use this function to assign a measured variable to the quaternary (fourth) HART value (QV). 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. Factory setting: **Automatic**

Parameters and default settings for the expert mode	
Damping	Use this function to set the time constant for current output damping. 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. 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 optional plug-in 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 communicating 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. Example: A cable open circuit is detected in the sensor.	I ≤ 3.6 mA (low alarm) or 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. 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. Example: An error is detected while the program is running.	

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

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

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. cabling short circuit), output currents ≥ 21.5 mA occur irrespective of the configured failure current.

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

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 optional plug-in 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 the section on Commissioning or proof testing report).
- ▶ The operator specifies the test interval. 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 (with plug-in display)
- 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).

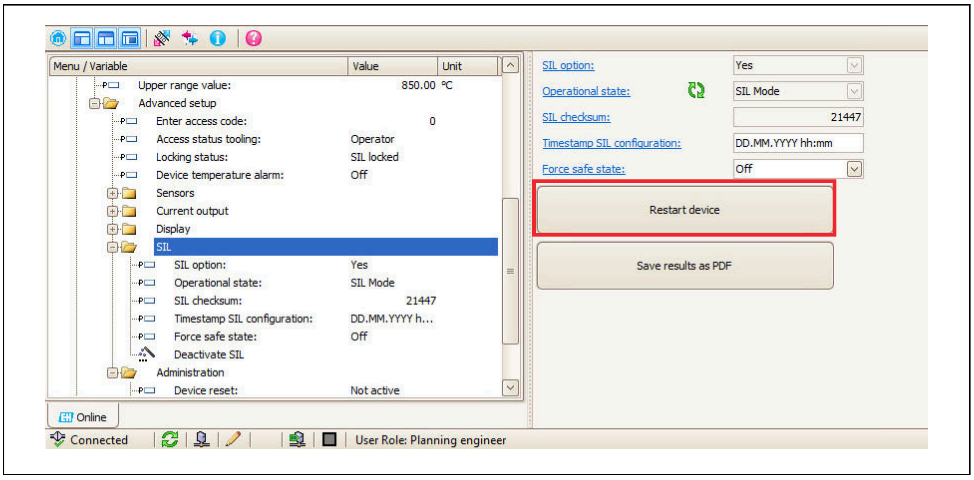
6.1 Test sequence A

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.



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 → 6, 30.

6.2 Test sequence B

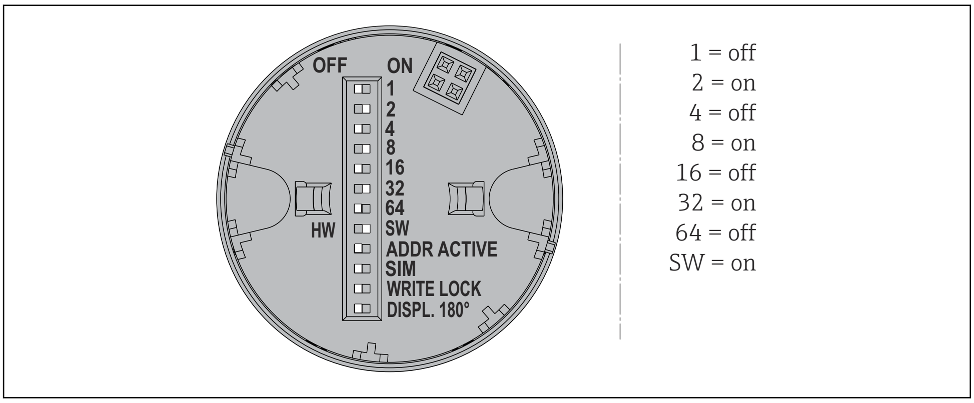
1. Two-point calibration

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. NOTICE

▶ If the display remains attached to the head transmitter for the rest of the application, the setting of the DIP switches must be changed again after the test sequence.

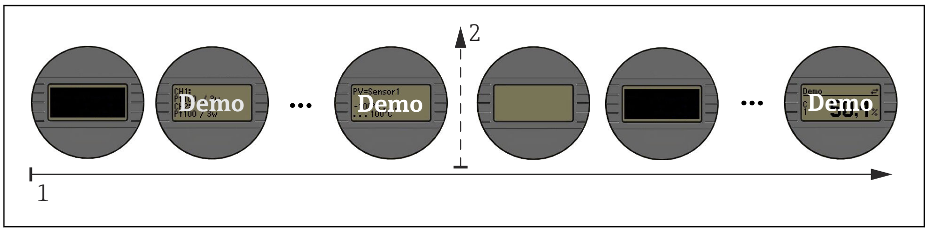


A0026451

4 *Setting for the DIP switches on the plug-in display*

Check both alarm states (high and low alarm) by restarting the device by plugging in a display unit and setting the DIP switches on the back to the appropriate position.

↳ When the device is restarted the following start-up sequence appears on the plug-in display:



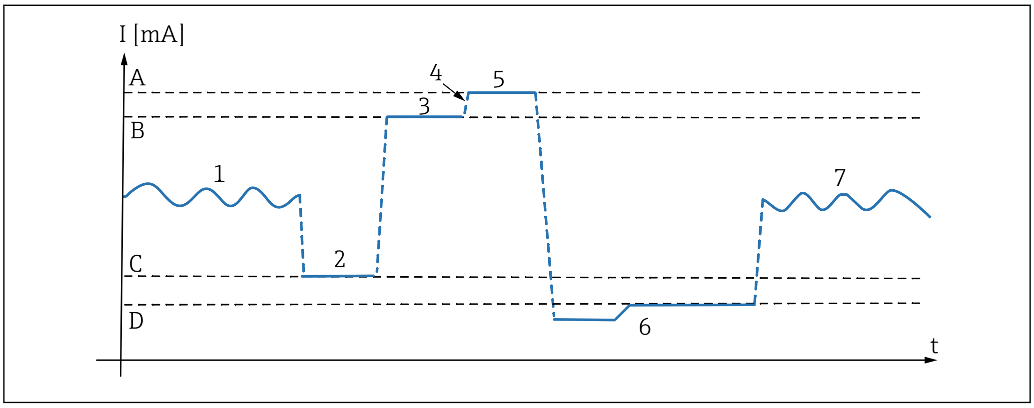
A0026471

5 *Device start-up sequence on the display*

1 *Start of sequence*
2 *Device restart*

The start-up sequence on the display indicates whether the restart is being performed.
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.

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 below.



A0034407

6 *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 plug-in display)
5 High alarm (≥ 21.0 mA)
6 Low alarm (≤ 3.6 mA)
7 Measuring mode

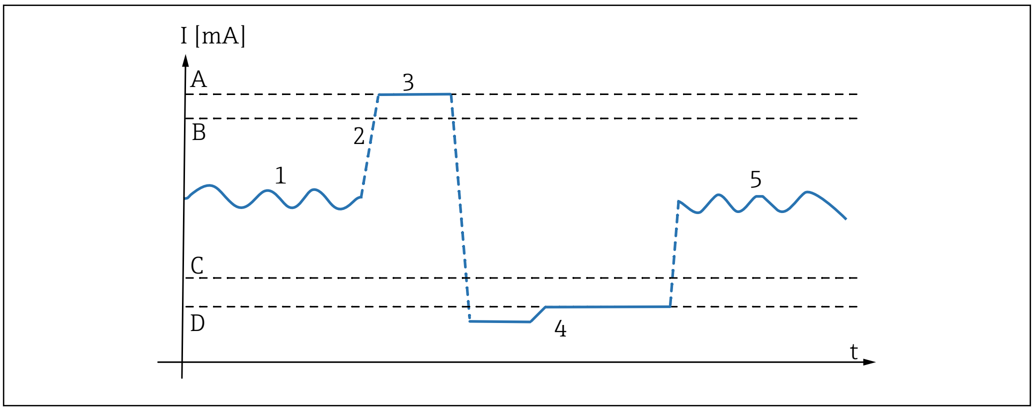
6.3 Test sequence C

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 plug-in display . Alternatively, you can also check the restart using the corresponding function in the operating tool used or via HART command 42 (disabling any 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 device's current output typically behaves as illustrated in the graphic below.

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.**



7 *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 plug-in display)
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 (λ_{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.

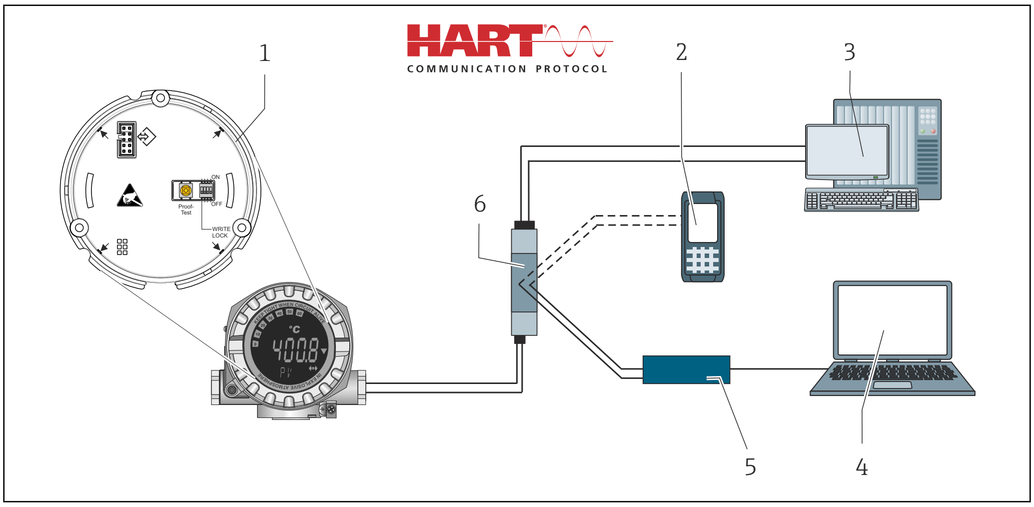
- The purpose of proof-testing is to detect dangerous undetected device failures (λ_{DU}).
- This test does not cover the impact of systematic faults on the safety function, which must be assessed separately.
- Systematic faults can be caused, for example, by process material properties, operating conditions, 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 Appendix

7.1 Structure of the measuring system

7.1.1 Structure of the measuring system

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



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

1 *Temperature transmitter*
2 *HART handheld communicator*
3 *PLC/process control system*
4 *Configuration software, e.g. FieldCare*
5 *Configuration via FXA195 (HART modem)*
6 *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 signal is sent to a downstream logic unit (e.g. PLC, level switch) 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 plug-in display is not part of the safety function. Neither the hardware nor the software of the display have 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.

Measurement function

NOTICE

Galvanic isolation

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

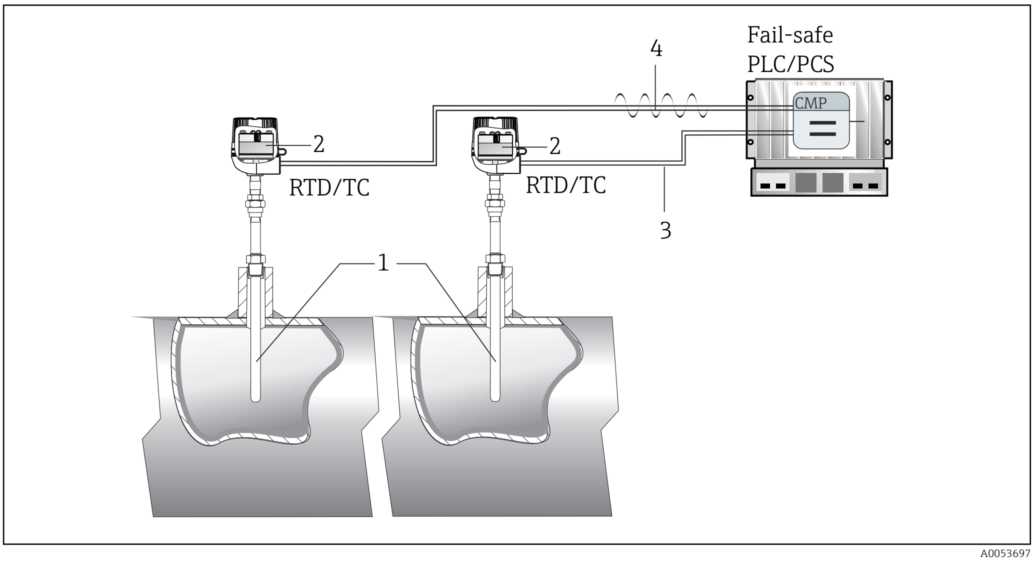
Two-channel functions

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 a 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. Therefore the following types of sensor are permitted in the SIL mode:
  - 2x thermocouple (TC)
  - 2x RTD, 2/3-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. Recommendation: set the "Drift/difference alarm delay" parameter to 5 seconds.

The configured drift/difference set point 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. → 9, 33



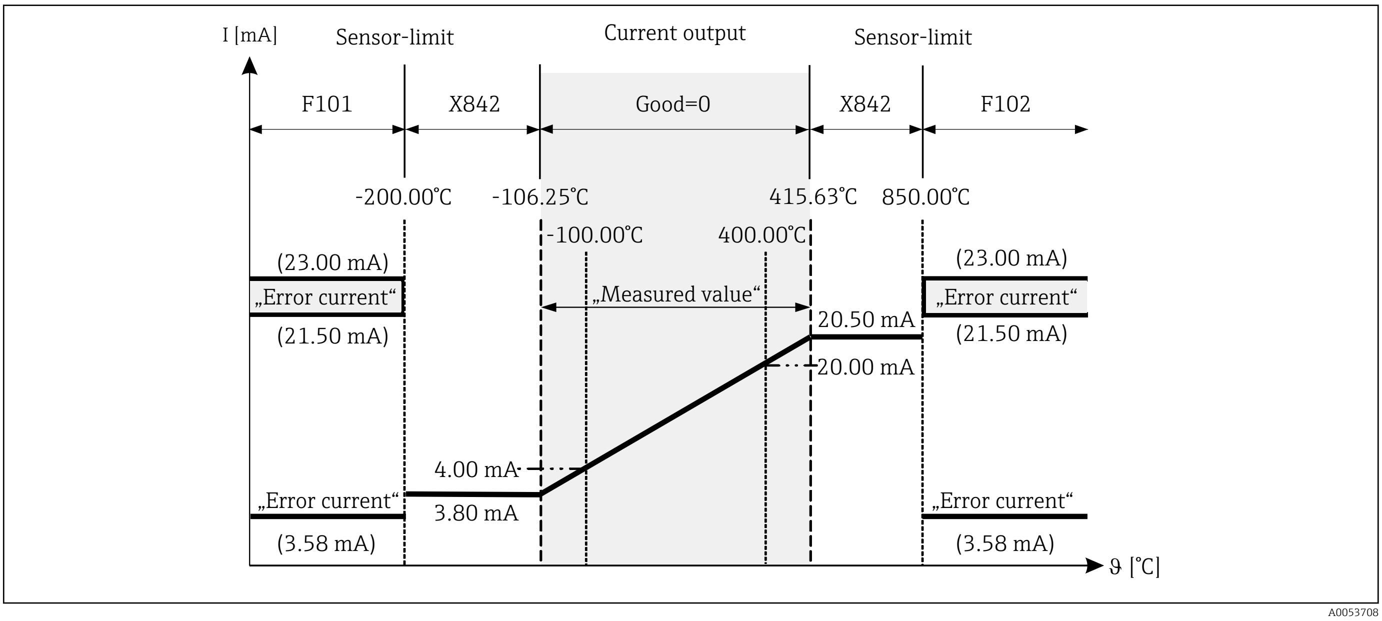
9 *Example with current output at the first transmitter, as well as the current output and HART communication at the second transmitter. PLC/PCS voting of both sensor values: SIL 3*

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*

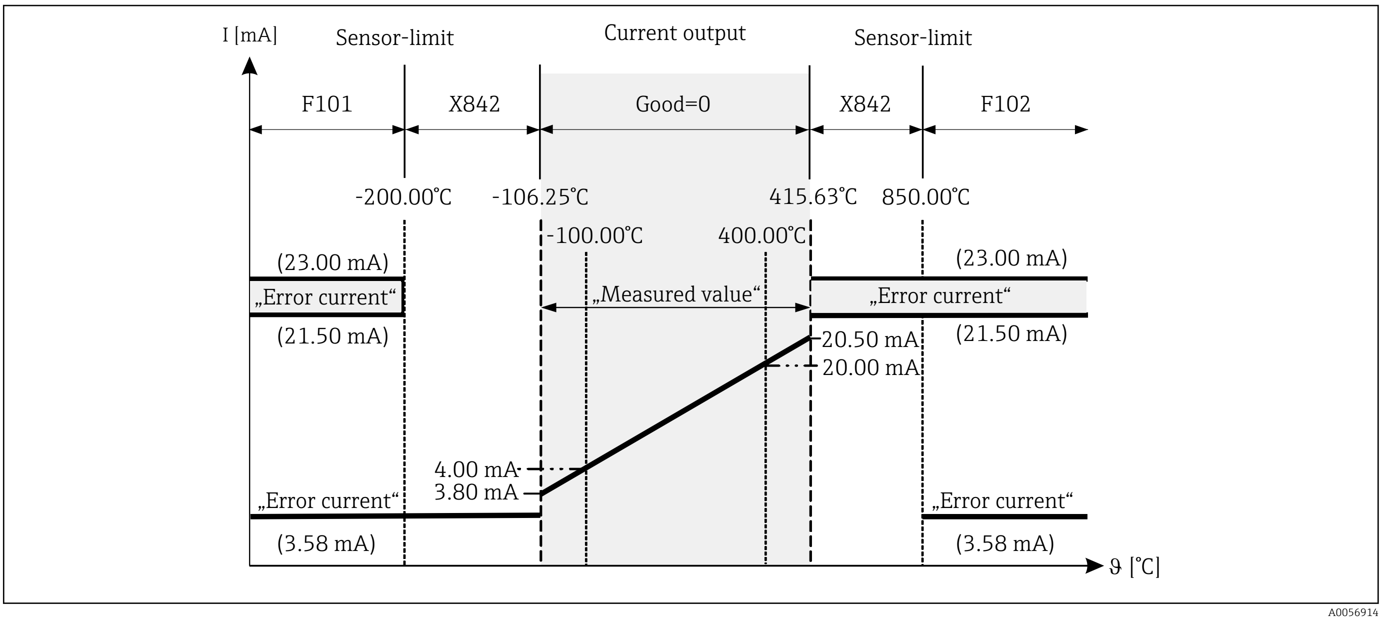
Device behavior in the event of out of range category (F, S, M)

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



10 *Range violation category = out of specification (X=S) or maintenance required (X=M)*



11 *Range violation category = failure (F)*

7.2 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) ☐ Commissioning check, test sequence A ☐ Commissioning check, test sequence B

Proof testing
☐ Test sequence A ☐ Test sequence B ☐ Test sequence C

Proof test report			
Test step	Target value	Actual value	Passed
1. Lower-range value adjustment, sensor 1			☐ Passed ☐ Failed ☐ Not applicable
2. Upper-range value adjustment, sensor 1			☐ Passed ☐ Failed ☐ Not applicable
3. Lower-range value adjustment, sensor 2			☐ Passed ☐ Failed ☐ Not applicable
4. Upper-range value adjustment, sensor 2			☐ Passed ☐ Failed ☐ Not applicable
5. Current value alarm			☐ Passed ☐ Failed
6. Restart via HART			☐ Passed ☐ Failed ☐ Not applicable
7. Restart via plug-in display			☐ Passed ☐ Failed ☐ Not applicable

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

Protocol for commissioning check			
11. Restart via HART			☐ Passed ☐ Failed ☐ Not applicable
12. Restart via plug-in display			☐ Passed ☐ Failed ☐ Not applicable

Comment:

7.2.1 Parameter settings for the SIL mode

Parameter name	Factory setting	Set value	Tested
Enter access code	0		
Lower measuring range (4 mA)	0		
Upper measuring range (20 mA)	100		
Fault current	22.5 mA		
Failure mode	High alarm		
Out of range category	Factory setting: Maintenance required (M)		
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 B: -5.780000e-007 C: -4.180000e-012		
Call./v. Dusen coeff. A, B and C sensor 2 [1)]	A: 3.910000e-003 B: -5.780000e-007 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 B = 6.75560e-006		
Polynomial coeff. A, B sensor 2 [1)]	A = 5.49630e-003 B = 6.75560e-006		
Polynomial coeff. R0 sensor 1 [1)]	100 Ω		
Polynomial coeff. R0 sensor 2 [1)]	100 Ω		
Unit	°C		
Mains frequency filter	50 Hz		
Drift/difference mode	Off		
Drift/difference alarm category	Maintenance required (M)		
Drift/difference alarm delay	0 s		
Drift/difference set point	999		
Device temperature alarm	Out of specification (S)		

Parameter name	Factory setting	Set value	Tested
Force safe state	Off		
Assign current output (PV)	Sensor 1		
Reset sensor backup	Automatic		
Assign SV	Device temperature		
Assign TV	Sensor 1		
Assign QV	Sensor 1		

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

7.3 Version history

Version	Changes	Valid as of firmware version	Valid from hardware version	Reference to NE 53 customer information
SD01172T/09/EN/ 02.14	Initial version	01.01.00	01.00.00	-
SD01172T/09/EN/ 03.15	Revised version	01.01.08	01.00.00	-
SD01172T/09/EN/ 04.17	New method of device parameter configuration: SIL mode activation = SiMA	01.01.10	01.00.00	-
SD01172T/09/EN/ 05.19	Device revision 3	01.02.00	01.00.00	MI01444T/09/EN/ 01.19
SD01172T/09/EN/ 06.21	New field mount housing available	01.02.00	01.00.00	-
SD01172T/09/EN/ 07.23	-	01.02.12	01.00.00	-
FY01105T/09/EN/ 01.24	Additional setting option: backup	01.02.13	01.00.00	-

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

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