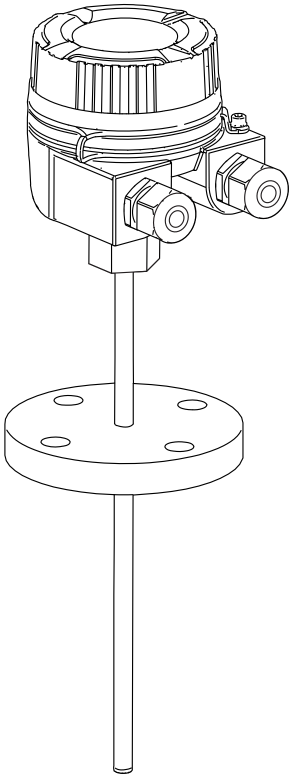
SD02427T/09/EN/01.19
71443295
2019-07-30

Special Documentation
iTHERM ModuLine TM131

Functional Safety Manual



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1 Declaration of Conformity

SIL_00327_01.19

Endress+Hauser
People for Process Automation

Declaration of Conformity

Functional Safety according to IEC 61508:2010
Supplement 1 / NE130 Form B.1

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

declares as manufacturer, that the following thermometer

iTHERM TM131

in combination with the transmitters
iTEMP TMT82 or
iTEMP TMT162

is suitable for use in safety-instrumented systems up to SIL2 (HFT=0) or SIL3 (HFT=1) according to IEC61508:2010.

In safety instrumented systems according IEC 61508 and IEC 61511, the instructions of the Safety Manual have to be followed.

Nesselwang, 11.07.2019
Endress+Hauser Wetzer GmbH+Co. KG

Harald Hertweck Managing Director	i.V. Alfred Umkehrer Head of Division R&D-Temperature

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1.1 Safety-related characteristic values

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Endress+Hauser
People for Process Automation

General			
Device designation and permissible types	TM131 (Order code for "Additional approval": Option LA "SIL")		
Safety-related output signal	4...20mA		
Fault current	≤ 3,6 mA oder ≥ 21,0 mA		
Process variable/function	Temperature, Voltage, Resistance		
Safety function(s)	min., max., range		
Device type acc. to IEC 61508-2	☐ Type A	☑ Type B	
Operating mode	☑ Low Demand Mode	☑ High Demand	☐ Continuous Mode
Safety manual	SD02427T/09, SD01172T/09, SD01632T/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 IEC61508-2 for devices w/o software	
Evaluation through / certificate no.	TM131: internal assessment TMT82: Z10 16 03 128333 003 TMT162: Z10 18 02 128333 004		
Test documents	development documents, test reports, data sheets		

SIL - Integrity			
Systematic safety integrity		☐ SIL 2 capable	☑ SIL 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

key figures	Thermometer and Transmitter
TM131 with TMT82	see Chapter 1.2.1 (SD02427T/09)
TM131 with TMT162	see Chapter 1.2.2 (SD02427T/09)

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

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1.2 Use as a safe measuring system

The temperature transmitter must be combined with a suitable sensor (iTHERM StrongSens, Wirewound, TC type K, J, N) to implement a safe measuring system. The code numbers required for the system design for one year can be found in the following tables.

1.2.1 Code numbers for TM131 with TMT82

Single channel operation

	λ_{du}	λ_{dd}	λ_{su}	λ_{sd}	SFF	PFD_{avg}
Transmitter	40 FIT	258 FIT	129 FIT	4 FIT	91%	$1.8 \cdot 10^{-4}$

		closed coupled				extention wire			
		low stress		high stress		low stress		high stress	
		Sensor	Sensor + Transmitter	Sensor	Sensor + Transmitter	Sensor	Sensor + Transmitter	Sensor	Sensor + Transmitter
Thermo-couple	λ_{du}	6 FIT	46 FIT	119 FIT	148 FIT	109 FIT	138 FIT	2180 FIT	2209 FIT
	λ_{dd}	94 FIT	352 FIT	1881 FIT	2150 FIT	891 FIT	1160 FIT	17820 FIT	18089 FIT
	λ_{su}	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT
	λ_{sd}	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 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 4-wire	λ_{du}	6 FIT	46 FIT	129 FIT	168 FIT	74 FIT	114 FIT	1486 FIT	1526 FIT
	λ_{dd}	44 FIT	302 FIT	871 FIT	1129 FIT	426 FIT	684 FIT	8514 FIT	8772 FIT
	λ_{su}	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT
	λ_{sd}	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 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

	λ_{du}	λ_{dd}	λ_{su}	λ_{sd}	SFF	PFD_{avg}
Transmitter	**40 FIT**	**258 FIT**	**129 FIT**	**4 FIT**	**91%**	**$1.8 \cdot 10^{-4}$**

		closed coupled				extention wire			
		low stress		high stress		low stress		high stress	
		Sensor	Sensor + Transmitter	Sensor	Sensor + Transmitter	Sensor	Sensor + Transmitter	Sensor	Sensor + Transmitter
2 x Thermo-couple	λ_{du}	11 FIT	51 FIT	70 FIT	110 FIT	158 FIT	198 FIT	3160 FIT	3200 FIT
	λ_{dd}	189 FIT	447 FIT	3786 FIT	4044 FIT	1842 FIT	2100 FIT	36840 FIT	37098 FIT
	λ_{su}	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT
	λ_{sd}	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 FIT
	SFF	**95%**	**95% / 91%**	**98%**	**98% / 91%**	**92%**	**92% / 91%**	**92%**	**92% / 91%**
	PFD_{avg}		**$2.2 \cdot 10^{-4}$**		**$4.8 \cdot 10^{-4}$**		**$8.7 \cdot 10^{-4}$**		**$1.4 \cdot 10^{-2}$**
2 x RTD 2/3-wire	λ_{du}	8 FIT	48 FIT	154 FIT	194 FIT	84 FIT	124 FIT	1672 FIT	1712 FIT
	λ_{dd}	88 FIT	346 FIT	1662 FIT	2024 FIT	866 FIT	1124 FIT	17328 FIT	17586 FIT
	λ_{su}	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT
	λ_{sd}	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 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 FIT	49 FIT	184 FIT	224 FIT	121 FIT	161 FIT	2416 FIT	2456 FIT
	λ_{dd}	139 FIT	397 FIT	2776 FIT	3034 FIT	1354 FIT	1612 FIT	27084 FIT	27342 FIT
	λ_{su}	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT	0 FIT	129 FIT
	λ_{sd}	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 FIT	0 FIT	4 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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1.2.2 Code numbers for TM131 with TMT162

Single channel operation

	λ_{du}	λ_{dd}	λ_{su}	λ_{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 + Field Transmitter	Sensor	Sensor + Field Transmitter	Sensor	Sensor + Field Transmitter	Sensor	Sensor + Field Transmitter
Thermo-couple	λ_{du}	6 FIT	35 FIT	119 FIT	148 FIT	109 FIT	138 FIT	2180 FIT	2209 FIT
	λ_{dd}	94 FIT	363 FIT	1881 FIT	2150 FIT	891 FIT	1160 FIT	17820 FIT	18089 FIT
	λ_{su}	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT
	λ_{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	λ_{du}	9 FIT	38 FIT	181 FIT	210 FIT	99 FIT	128 FIT	1976 FIT	2005 FIT
	λ_{dd}	39 FIT	308 FIT	779 FIT	1048 FIT	376 FIT	645 FIT	7524 FIT	7793 FIT
	λ_{su}	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT
	λ_{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	λ_{du}	6 FIT	36 FIT	129 FIT	158 FIT	74 FIT	104 FIT	1486 FIT	1515 FIT
	λ_{dd}	44 FIT	313 FIT	871 FIT	1140 FIT	426 FIT	695 FIT	8514 FIT	8783 FIT
	λ_{su}	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT
	λ_{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

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

		closed coupled				extention wire			
		low stress		high stress		low stress		high stress	
		Sensor	Sensor + Field Transmitter	Sensor	Sensor + Field Transmitter	Sensor	Sensor + Field Transmitter	Sensor	Sensor + Field Transmitter
2 x Thermo-couple	λ_{du}	11 FIT	40 FIT	70 FIT	99 FIT	158 FIT	187 FIT	3160 FIT	3189 FIT
	λ_{dd}	189 FIT	458 FIT	3786 FIT	4055 FIT	1842 FIT	2111 FIT	36840 FIT	37109 FIT
	λ_{su}	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT
	λ_{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}		$1.7 \cdot 10^{-4}$		$4.3 \cdot 10^{-4}$		$8.2 \cdot 10^{-4}$		$1.4 \cdot 10^{-2}$
2 x RTD 2/3-wire	λ_{du}	8 FIT	37 FIT	154 FIT	183 FIT	84 FIT	113 FIT	1672 FIT	1701 FIT
	λ_{dd}	88 FIT	357 FIT	1766 FIT	2035 FIT	866 FIT	1135 FIT	17328 FIT	17597 FIT
	λ_{su}	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT
	λ_{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	λ_{du}	9 FIT	38 FIT	184 FIT	213 FIT	121 FIT	150 FIT	2416 FIT	2445 FIT
	λ_{dd}	139 FIT	408 FIT	2776 FIT	3045 FIT	1354 FIT	1623 FIT	27084 FIT	27353 FIT
	λ_{su}	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT	0 FIT	139 FIT
	λ_{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}
- $< 2.5 \cdot 10^{-3}$
- $> 2.5 \cdot 10^{-3}$
- $> 1 \cdot 10^{-2}$

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2 About this document

2.1 Document function

This supplementary Safety Manual applies in addition to the Operating Instructions, Technical Information and ATEX 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
- CP01008Z, Brochure "Functional Safety – SIL, Safety Instrumented Systems in the Process Industry"

2.2 Symbols used

2.2.1 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.

2.2.2 Symbols for certain types of information

Symbol	Meaning
	**Permitted** Procedures, processes or actions that are permitted.
	**Preferred** Procedures, processes or actions that are preferred.
	**Forbidden** Procedures, processes or actions that are forbidden.
	**Tip** Indicates additional information.
	Reference to documentation.
	Reference to page.
	Reference to graphic.
	Notice or individual step to be observed.
1., 2., 3.…	Series of steps.
	Result of a step.
	Help in the event of a problem.
	Visual inspection.

2.3 Supplementary device documentation

For an overview of the scope of the associated Technical Documentation, refer to the following:
- *W@M Device Viewer* (www.endress.com/deviceviewer): Enter the serial number from nameplate
- *Endress+Hauser Operations App*: Enter the serial number from the nameplate or scan the 2D matrix code (QR code) on the nameplate

The following documentation types are available in the Downloads section of the Endress+Hauser website (www.endress.com/downloads):

2.3.1 Further applicable documents

- TI01373T, TM131
- BA01915T, Modular thermometers
- XA01799T, TM131
- XA01817T, TM111 + TM131
- SD01172T/09, TMT82
- SD01632T/09, TMT162

2.3.2 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.

2.3.3 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.

2.3.4 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.

2.3.5 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.

2.3.6 Special Documentation (SD)

The document is part of the Operating Instructions and serves as a reference for application specific parameters and notes.

- General information about functional safety: SIL
- General information about SIL is available in the Download Area of the Endress +Hauser Internet site: www.de.endress.com/SIL

3 Design

3.1 Permitted devices 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 device changes.

Valid device versions for safety-related use:

3.1.1 Order codes

Product root: TM131 -

Feature: 010 "Approval"
Version: all

Feature: 020 "Thermowell"
Version: all

Feature: 030 "Thermometer structure"
Version: all except Y

Feature: 050 "Process connection; material"
Version: all except YY

Feature: 060 "Thermowell diameter; material"
Version: all except YY

Feature: 070 "Shape of tip"
Version: all except Y

Feature: 080 "Immersion length U"
Version: all except YY

Feature: 090 "Removable extension neck, length E"
Version: all except Y

Feature: 100 "Thermowell lagging, length T"
Version: all except Y

Feature: 110 "Sensor type; measuring range; material"
Version: all except A, E, Y

Feature: 130 "Sensor standard; classification"
Version: all except Y

Feature: 140 "Electrical connection"
Version: only 2E, 2G, 3D

Feature: 150 "Terminal head; material; degree of protection"
Version: all except B1, B2, P1, YY

Feature: 170 "Cable entry terminal head"
Version: all Y

Feature: 560 "Second transmitter (mounted)"
Version: none

Feature: 570 "Service"
Version: all except I9

Feature: 580 "Test, certificate, declaration"
Version: all except K9

Feature: 590 "Additional approval"
Version: mandatory LA, except L9

Feature: 600 "Additional option"
Version: all except M9

Feature: 610 "Accessory mounted"
Version: all except O9

Feature: 630 "Thermometer calibration"
Version: all except S9

Feature: 640 "Calibration points >= 0 oC"
Version: all except T9

Feature: 650 "Calibration points <= 0 oC"
Version: all except U9

Feature: 850 "Firmware version"
Version: none

Feature: 895 "Marking"
Version: all except Z9

Valid firmware version:

- TMT162 from 04.01.00 or higher
- TMT82 from 01.02.00 or higher

Valid hardware version (electronics):

- TMT162 from 04.01.00 or higher
- TMT82 head transmitter from 01.00.07 or higher
- TMT82 DIN rail transmitter from 01.00.04 or higher

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 functions are:

- Limit value monitoring
- Safe measurement

The safety functions comprise the measurement of the temperature of a medium.

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 mA), signal cable disconnection or short-circuit

In the event of a fault, it must be ensured that the equipment under control achieves or maintains a safe state.

3.3.2 Limit value monitoring

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 (Xmin to Xmax). This current depends on the configuration of the "Diagnostic behavior" parameter (alarm, warning).

Detailed information:

- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

3.3.3 Safe measurement

The transmitter's safety function comprises a transmitted current output signal that is proportional to the temperature value.

All safety functions can be used in combination with all sensor configurations from the "Structure of the measuring system" section → 26. Please 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 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.

Basic conditions and limitations for the TM131 thermometer:

Sensors, wiring scheme and temperature ranges

- StrongSens resistance sensor
  - Temperature range –50 to +400 °C, 4-wire connection
  - Range of validity of accuracy classes:
    Class B: –50 to +400 °C
    Class A: –30 to +300 °C
    Class AA: 0 to +150 °C
- Wire wound (WW) resistance sensor
  - Temperature range –200 to +400 °C,
    Single sensor element, 4-wire connection,
    Double sensor element, 2x3-wire connection,
  - Range of validity of accuracy classes:
    Class B: –200 to +400 °C
    Class A: –100 to +400 °C
    Class AA: –50 to +250 °C
- Thermocouple type J
  Single or double elements 0 to +600 °C
- Thermocouple type K or N
  Single or double elements 0 to +800 °C
- Acceleration from vibrations at the measuring element, maximum 2g

The following restriction also applies to safety-related use:

- Strong, pulse-like EMC interference on the power supply line can cause transient (<1 s) deviations in the output signal (≥±1 %). For this reason, filtering with a time constant ≥1 s should be performed in the downstream logic unit.
- The specified error range (safety measured error, → 17) 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 drift, temperature drift). The safety-related failures are classified into different categories according to IEC/EN 61508 (see the following table). The table shows the implications for the safety-related output signal and the measuring uncertainty.

Response times:

- The information regarding typical response times is based on a measurement according to DIN EN 60751 in water with a flow velocity of 0.4 m/s.
- The response time t90 is indicated. This is the time the temperature sensor needs to indicate 90 % of the temperature increase.
- The total response time comprises the response time of the temperature sensor including the thermowell and the response time of the temperature transmitter, and is indicated in the Operating Instructions (Supplementary Documentation → 11) of the transmitters and thermometers ("Technical data" section).

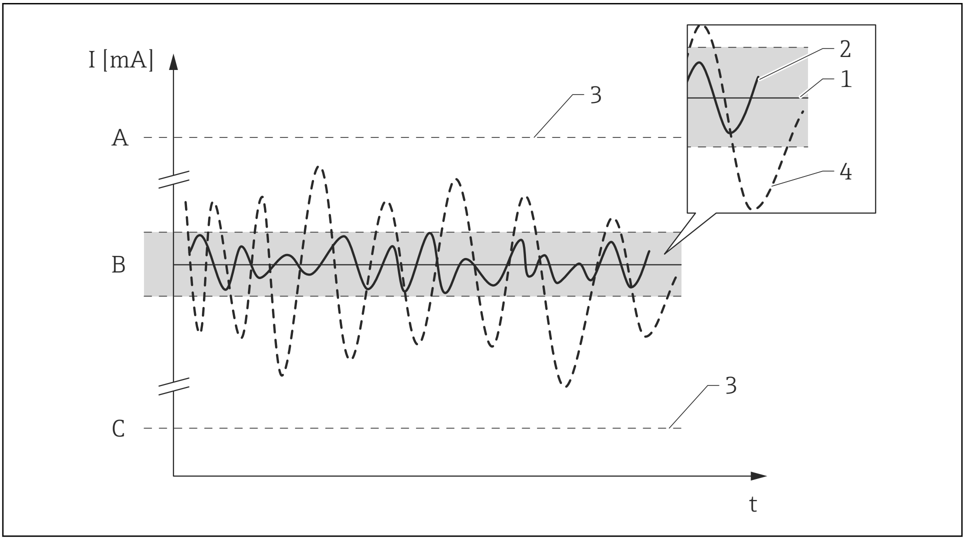
Comments:

These are typical values for standard designs (such as designs according to DIN 43772) and should be used as general reference values.

Prior to using the thermometer, the user must check whether the entire response time for the particular application guarantees the safe shutdown of the entire system.

The safety-related failures are classified into different categories according to IEC/EN 61508 (see the following table). The table shows the implications for the safety-related output signal and the measuring uncertainty.

Safety-related error	Explanation	Implications for the measuring uncertainty (Position, see figure→ 📄 17)
No device error	Safe: No error	1 Is within the specification (see TI, BA, ...)
λ_{SD}	Safe detected: Safe failure which can be detected	3 No implications
λ_{SU}	Safe undetected: Safe failure which cannot be detected	2 May be beyond the specification
λ_{DD}	Dangerous detected: Dangerous failure which can be detected (Diagnostic within the device)	3 No implications
λ_{DU}	Dangerous undetected: Dangerous failure which cannot be detected	4 May be outside the defined error range



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A HI-Alarm ≥21 mA
B Error range ±2 %
C LO-Alarm ≤3.6 mA

3.5 Dangerous undetected failures 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 failure".

3.6 Safety measured error

Permitted temperature ranges for resistance sensors in conjunction with SIL:

Temperature ranges

Sensor type	Class B	Class A	Class AA
Pt100 (TF) iTHERM® StrongSens	−50 to +400 °C (−58 to +752 °F)	−30 to +300 °C (−22 to +572 °F)	0 to 150 °C (−58 to +302 °F)
Wire wound sensor (WW)	−200 to 400 °C (−328 to 752 °F)	−100 to 400 °C (−328 to 742 °F)	−50 to 250 °C (−58 to 482 °F)

Permitted temperature ranges for thermocouples in conjunction with SIL:

Sensor type according to IEC 60584 / ASTM E230 / ANSI MC96.1	Class 1 and 2 / special and standard
J (Fe-CuNi)	0 to 600 °C (32 to 1 112 °F)
K (NiCr-NiAl) N (NiCrSi-NiSi)	0 to 800 °C (32 to 1 472 °F)

Detailed information: Technical Information TM131: TI01373T

Detailed information:
- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

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.

Validity of data for safety measured 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

3.7 Useful lifetime of electric 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.

According to DIN EN 61508-2:2011 section 7.4.9.5 (national footnote N3) appropriate measures taken by the operator can extend the useful lifetime.

The useful lifetime can be significantly shorter, however, if the device is operated at higher temperatures or outside specifications.

Detailed information:
- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

As the maximum application temperature influences the drift behavior of the sensors, a recalibration should be performed or the inserts should be replaced at defined intervals for reliable and accurate temperature measurement. Typical intervals are listed in the following table:

Max. application temperature	Resistance temperature detector	Thermocouple
200 °C (392 °F)	5 years	5 years
400 °C (752 °F)	2 years	2 years

Max. application temperature	Resistance temperature detector	Thermocouple
600 °C (1 112 °F)	-	2 years
800 °C (1 472 °F)	-	1 year

The testing intervals indicated here are suggestions. Special conditions at the place of use may require the user to significantly shorten the application duration.

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.

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.

Detailed information:

- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

4.5 Device configuration for safety-related applications

4.5.1 Calibration of the measuring point

The calibration of the measuring point 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.

Detailed information:

- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

Device protection

The devices can be protected against external influences as follows:

- Hardware write protection
- Software write protection

The use of these methods is described in the following documents.

Detailed information:

- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

4.5.2 Locking in Expert mode

The procedure for activating SIL locking on a device is described in the following documents.

Detailed information:

- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

4.5.3 Unlocking a SIL device

When SIL locking is active on a device, the device is protected against unauthorized operation by means of a locking code and, as an additional option, by means of a hardware write protection switch. The device must be unlocked to change parameter configuration.

CAUTION

▶ Unlocking the device deactivates diagnostic functions, and the device may not be able to carry out its safety function when unlocked. Therefore, independent measures must be taken to ensure that there is no risk of danger while the device is unlocked.

The procedure for unlocking the device is described in the following documents.

Detailed information:

- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

5 Operation

5.1 Device behavior when switched on

The behavior of the device when switched on is described in the relevant Operating Instructions.

Detailed information:
- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

5.2 Device behavior in safety function demand mode

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.

Detailed information:
- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

5.3 Safe states

The system adopts the safe state depending on the error detected. The behavior of the device is described in the corresponding Safety Manuals:

Detailed information:
- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

Safe state / output current:
- I ≤ 3.6 mA (low alarm)
  or
- I ≥ 21.5 mA (high alarm)

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

The output current on alarm can be set to a value of ≤ 3.6 mA or ≥ 21 mA. In some cases (e.g. failure of power supply, a cable open circuit and faults in the current output itself, where the failure current ≥ 21 mA cannot be set), output currents ≤ 3.6 mA can occur irrespective of the configured failure current.

In some other cases (e.g. short circuit of cabling), output currents ≥ 21 mA occur irrespective of the configured failure current.

For alarm monitoring, the downstream logic unit must therefore be able to detect HI alarms (≥ 21 mA) and LO alarms (≤ 3.6 mA).

5.5 Alarm and warning messages

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

Detailed information:

- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

Additional information is provided by the alarm and warning messages in the form of error codes and associated clear text messages. Please refer to the following table for the correlation between the error code and the output current.

Detailed information:

- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

6 Proof testing

The functional integrity of the device in the SIL mode must be verified during commissioning, when changes are made to safety-related parameters, as well as at appropriate time intervals. The operator must determine the time intervals.

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 may not be used for the protective system during the test.
- Any test performed must be documented. The template in the Appendix can be used for this purpose → 29.

The operator specifies the testing interval and this must be taken into account when determining the probability of failure PFDavg 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.

Please refer to the transmitter safety documents for information on the test procedures for the transmitters.

Detailed information:

- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

The following inspections are recommended at regular intervals for the iTHERM TM131 thermometer:

Component: terminal head
Visual inspection of the head and seals for damage and wear

Component: insert
The insulation resistance of the measuring circuit in relation to the protection fitting must be measured every 12 months (only for non-grounded sensors in the case of thermocouples; in the case of several sensors the insulation check must also be performed between the individual circuits). The minimum insulation resistance at room temperature should be 100 MΩ at 100 V.

Component: thermometer thermowell
- Visual inspection of the thermowell and extension neck for damage, leaks, corrosion and wear.
- Visual inspection of sealing points for leaks.

Component: transmitter
Please refer to the transmitter safety documents for information on the proof test for the transmitter.

Detailed information:
- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

6.1 Test sequence A

Proof test procedure

The procedure for performing the proof test is described in the following documents.

Detailed information:
- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

6.2 Test sequence B

Proof test procedure

The procedure for performing the proof test is described in the following documents.

Detailed information:
- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

6.3 Test sequence C

Proof test procedure

The procedure for performing the proof test is described in the following documents.

Detailed information:
- Functional Safety Manual TMT82: SD01172T
- Functional Safety Manual TMT162: SD01632T

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 (λdu).
- 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.
- As part of the visual inspection, for example, ensure that all of the seals and cable entries provide adequate sealing.

7 Repair and error handling

7.1 Maintenance

Maintenance instructions and instructions regarding calibration 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

Repair means restoring functional integrity by replacing defective components.

Components may be repaired/replaced by the customer's technical staff if **genuine spare parts** from Endress+Hauser are used (they can be ordered by the end user) and the appropriate installation instructions are followed.

A proof test must always be performed after every repair

Spare parts are grouped into logical kits with the associated replacement instructions.

Document the repair with the following information:
- Serial number of the device
- Date of the repair
- Type of repair
- Person who performed the repair

Sensor with or without process connection
Device check following repair: proof test, test sequence A or B

Seal sets for the sensor
Device inspection following repair: proof test, test sequence A or B

Display
Device inspection following repair: visual inspection to establish if all parts are present and mounted correctly and to verify that the device is in the "OK" state.

Electronic insert
Device inspection following repair: proof test, test sequence A or B

Housing cover
Device inspection following repair: visual inspection to establish if all parts are present and mounted correctly and to verify that the device is in the "OK" state.

Cable gland
Device inspection following repair: proof test, test sequence A or B

Seal kits for housing covers
Device inspection following repair: visual inspection to establish if all parts are present and mounted correctly and to verify that the device is in the "OK" state.

Safety clamps, housing
Device inspection following repair: visual inspection to establish if all parts are present and mounted correctly and to verify that the device is in the "OK" state.

Installation Instructions are supplied with the orginal spare part and can also be accessed in the Download Area at www.endress.com

Return the replaced component to Endress+Hauser for fault analysis.

When returning the defective component, always enclose the "Declaration of Hazardous Material and Decontamination" with the note "Used as SIL device in a safety instrumented system.

For information on device returns, please see:
http://www.endress.com/support/return-material

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.

7.4 Decommissioning

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

7.5 Disposal

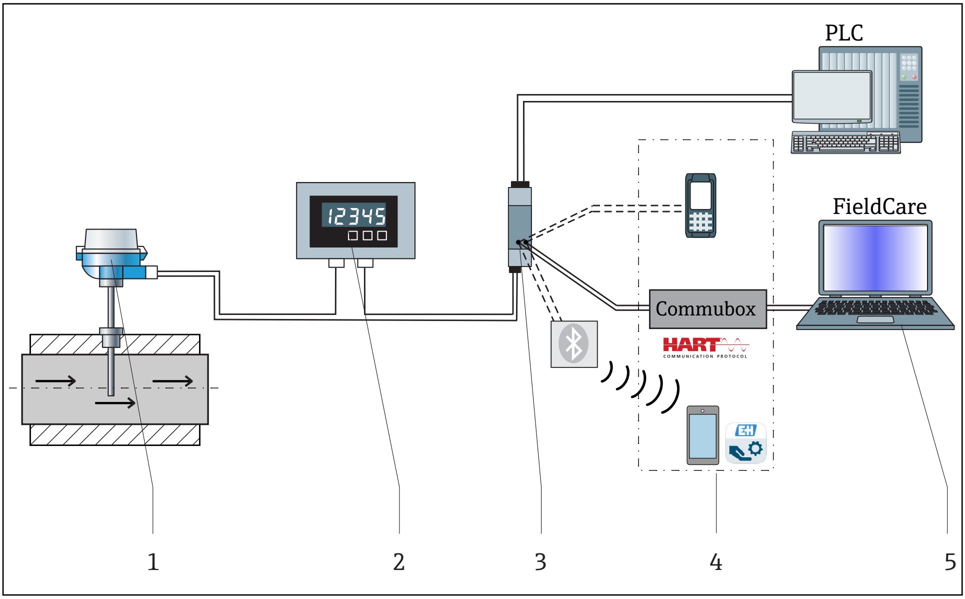
In accordance with the European Directive 2012/19/EC on Waste Electrical and Electronic Equipment (WEEE), our products may not be disposed of as unsorted municipal waste and can be returned to Endress+Hauser for disposal under our General Terms and Conditions or individually agreed conditions.

8 Appendix

8.1 Structure of the measuring system

8.1.1 System components

The measuring system's devices are shown in the following diagram (example).



1 Example of application, measuring point layout with additional Endress+Hauser components

1 *Installed iTHERM thermometer with HART® communication protocol*
2 *RIA15 2-wire process indicator - The process indicator is incorporated into the current loop and displays the measuring signal or the HART® process variables in digital form. The process indicator does not require an external power supply. It is powered directly via the current loop. More detailed information on this is provided in the device documentation.*
3 *Active barrier RN221N - The RN221N active barrier (24 V DC, 30 mA) has a galvanically isolated output for powering 2-wire transmitters. The universal power supply works with an input supply voltage of 20 to 250 V DC/AC, 50/60 Hz, which means that it can be used in all international power grids. More detailed information on this is provided in the device documentation.*
4 *Communication examples: HART® Communicator (handheld terminal), FieldXpert, Commubox FXA195 for intrinsically safe HART® communication with FieldCare via the USB interface, Bluetooth® technology with SmartBlue App.*
5 *FieldCare is an FDT-based plant asset management tool from Endress+Hauser.*

An analog signal (4 to 20 mA) in proportion to the relevant sensor value is generated in the thermometer with a 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 recognize both HI alarms (≥ 21 mA) and LO alarms (≤ 3.6 mA).

NOTICE

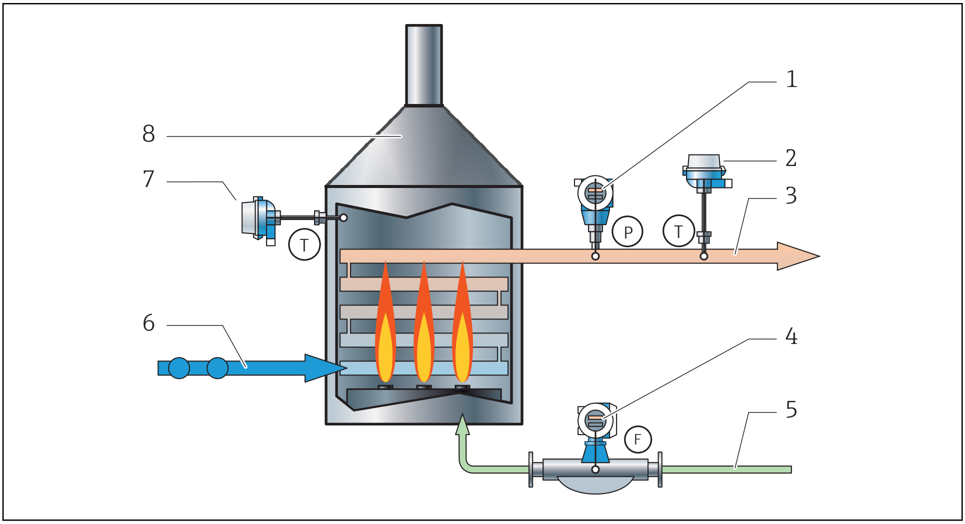
- The optional display is not part of the safety function. Neither the hardware nor the software of the display has a verifiable influence on the defined safety functions of the transmitter.

8.1.2 Description of application as a safety instrumented system

The TM131 thermometer applies the **resistance sensor RTD** and **thermocouple TC** measuring principles. These resistance thermometers use a Pt100 temperature sensor according to IEC 60751. The temperature sensor is a temperature-sensitive platinum resistor with a resistance of 100 Ω at 0 °C (32 °F) and a temperature coefficient $\alpha = 0.003851\ ^\circ C^{-1}$.

Thermocouples are comparatively simple, robust temperature sensors which use the Seebeck effect for temperature measurement: if two electrical conductors made of different materials are connected at a point, a weak electrical voltage can be measured between the two open conductor ends if the conductors are subjected to a thermal gradient. This voltage is called thermoelectric voltage or electromotive force (emf.). Its magnitude depends on the type of conducting materials and the temperature difference between the "measuring point" (the junction of the two conductors) and the "cold junction" (the open conductor ends).

Accordingly, thermocouples primarily only measure differences in temperature. The absolute temperature at the measuring point can be determined from these if the associated temperature at the cold junction is known or is measured separately and compensated for. The material combinations and associated thermoelectric voltage/temperature characteristics of the most common types of thermocouple are standardized in the IEC 60584 and ASTM E230/ANSI MC96.1 standards. The device's safety-related signal is the analog 4 to 20 mA output signal in accordance with 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.



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2 *Example of the measuring arrangement*

1 *Pressure sensor*
2 *Thermometer TM131*
3 *Finished product*
4 *Flow sensor*
5 *Fuel*
6 *Starting material*
7 *Thermometer TM131*
8 *Furnace*

The TM131 thermometer can be used in this arrangement in safety instrumented systems for MAX temperature and range monitoring.

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

8.1.3 Measurement function

Galvanic isolation
When two sensors are connected to the transmitter, make sure the sensors are galvanically isolated from one another; this does not apply to grounded thermocouples, however.

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 average (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.
  The following sensor types are therefore 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.

8.2 Commissioning or proof test report

The following device-specific test report acts as a print/master template and can be replaced or supplemented any time by the customer's own SIL reporting and testing system.

8.2.1 Test Report - Page 1 -

Company/contact person
Tester

Device information
System
Measuring points/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 Signature of tester

8.2.2 Test Report - Page 2 -

Type of safety function
☐ Limit value monitoring MIN
☐ Limit value monitoring MAX
☐ Safe measurement

Commissioning check
☐ Device parameter configuration via SIL Modbus 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 stage	**Set point**	**Actual value**	**Result**
1 Terminal head			☐ Passed ☐ Failed ☐ Not applicable
2 Insert			☐ Passed ☐ Failed ☐ Not applicable
3 Thermometer thermowell			☐ Passed ☐ Failed ☐ Not applicable
4 Lower range value adjustment, sensor 1			☐ Passed ☐ Failed
5 Upper range value adjustment, sensor 1			☐ Passed ☐ Failed
6 Lower range value adjustment, sensor 2			☐ Passed ☐ Failed ☐ Not applicable
7 Upper range value adjustment, sensor 2			☐ Passed ☐ Failed ☐ Not applicable
8 Current value alarm			☐ Passed ☐ Failed

Proof test report			
Test stage	**Set point**	**Actual value**	**Result**
9 Restart via HART			☐ Passed ☐ Failed ☐ Not applicable
10 Restart via plug-in display			☐ Passed ☐ Failed ☐ Not applicable

8.2.3 Test Report - Page 3 -

Protocol for commissioning check			
Test stage	**Set point**	**Actual value**	**Result**
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 ☐ Not applicable
8 Out of range category			☐ Passed ☐ Failed ☐ Not applicable
9 RJ / preset value			☐ Passed ☐ Failed ☐ Not applicable
10 Current value alarm			☐ Passed ☐ Failed
11 Restart via HART			☐ Passed ☐ Failed ☐ Not applicable
12 Restart via plug-in display			☐ Passed ☐ Failed ☐ Not applicable

8.2.4 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		
Failure current	22.5 mA		
Failsafe mode	Low alarm		
Sensor type 1	Pt100 IEC60751		
Sensor type 2	No sensor		
Upper sensor limit 1	+850 °C		
Lower sensor limit 1	−200 °C		
Upper sensor limit 2	-		
Lower sensor limit 2	-		
Sensor offset 1	0		
Sensor offset 2	0		
Connection type 1	4-wire (RTD)		
Connection type 2	2-wire (TC)		

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