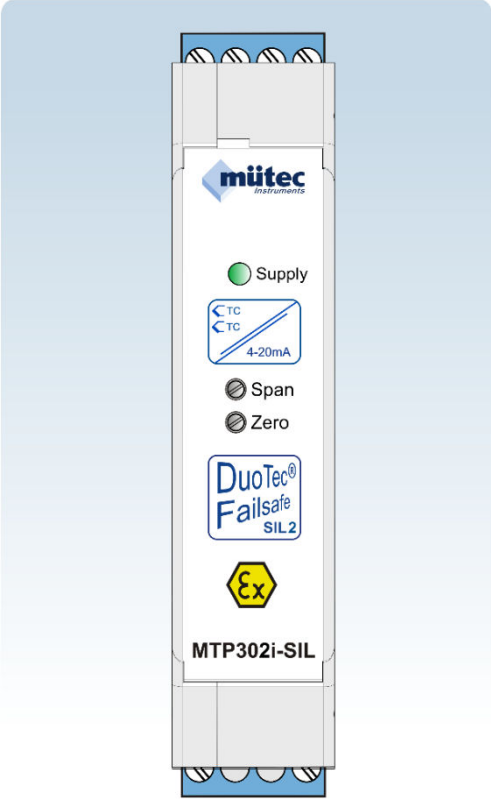
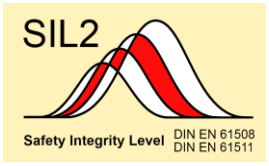
MTP302i-SIL-K

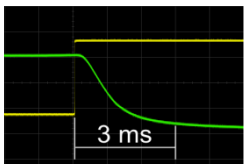
Loop-powered transmitter for thermocouple type K (NiCr-Ni) with 2nd output for extended measuring range.



Properties

- 2-wire temperature transmitter for DIN rails
- Two temperature ranges
- Galvanically isolated TC-inputs with cold-junction compensation
- Signal pass-through time:
  without Butterworth filter ≤ 3 ms
  with Butterworth filter ≤ 38 ms
- Installation in zone 1 or 2 permissible
- Intrinsic safety according to IEC/EN 60079-11
- SIL 2 according to IEC/EN 61508:2011
  but not for the 2nd output
- Error indication according to NAMUR NE 43
- LED status indication





Description

The temperature transmitter **MTP302i-SIL-K** has been designed for the operation of intrinsically safe thermocouple circuit installed in the Ex area.
The TC input is equipped with a Pt100 sensor for the cold-junction compensation (CJC).
The thermocouple signal is electrically isolated.
The TC transmitter must be intrinsically safe supplied by a two-channel repeater power supply.
The two power supply circuits must be electrically separeted.
The device can be installed in zone 1 with the “i” (IEC/EN 60079-11) protection type.

WARNING: Explosion hazard
The device is an intrinsically safe electrical equipment for intrinsically safe circuits. It is designed for use in zone 1, if specific conditions are observed.
When installing and operating the device, the applicable safety directives (including national safety directives), accident prevention regulations, as well as general technical regulations, must be observed.
Observe the safety regulations and installation notes on page 6.

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Table of Contents

1 Technical Data

Certificate

Ex certificate	**BVS 08 ATEX E 082 X – 5. Supplement** II 2(1)G Ex ib [ia Ga] IIC T4 Gb
Functional Safety (SIL)	SIL 2 according to IEC 61508

Safety data according to IECEx for intrinsically safe circuits

1st Power supply - Ex ib IIC (terminals 1 and 4)
2nd Power supply - Ex ib IIC (terminals 13 and 16)

Voltage	Ui	28 Vdc
Current	Ii	95 mA
Power	Pi	655 mW
Effective inner capacity	Ci	26 nF
Effective inner inductivity	Li	negligible

Thermocouple inputs - Ex ia IIC and Ex ib IIC (terminals 5 and 8, 9 and 12)

Voltage	Uo	1 Vdc
Current	Io	1.8 mA
Power	Po	0.5 mW
Permissible outer capacity	Co	10 µF
Permissible outer inductivity	Lo	100 mH

Input signals (terminals 5 + 8 and 9 + 12)

Thermocouple type NiCr-Ni	K	0 … 1200°C
Measuring range (can't be changed)	see nameplate	
Cold-junction compensation with Pt100 sensor (see Fig. 3)		-10 … +70°C

mA output_1 signal (terminals 1 + 4)

Current proportional to temperature	Io	4 … 20 mA
Temperature range	R	0 … 400°C
Maximum current	Imax	< 24 mA
Behavior by failure (according to NE 43)	Ifail	≤ 3.6 mA

mA output_2 (terminals 13 and 16) without linearization

Current proportional to the value of the TC	Io	4 … 20 mA
Temperature range	TR	0 … 1200°C
Maximum current	Io	< 24 mA

Status indicator for 1st power supply respectively mA signal_1

Green LED	luminosity corresponds to 4 … 20 mA
Behavior by failure	off

General data

Signal pass-through time for Output_1

Input to output without Butterworth filter (OFF, Fig. 2)	≤ 3 ms
Input to output with Butterworth filter (ON, Fig. 2)	≤ 38 ms (default)

Signal pass-through time for Output_2

Input to output without Butterworth filter (OFF, Fig. 2)	≤ 6 ms
Input to output with Butterworth filter (ON, Fig. 2)	≤ 41ms (default)

Transmission error

Typical	< 0.05 % (of final value)

Temperature coefficient

Typical		< 0.05 %/10 K

Pt100 sensor error

DIN IEC 751, Class B by 0°C		< 0.3°C

Cold-junction compensation error

Temperature range 0°C to +50°C		< 0.5°C
Temperature range -10°C to +70°C		< 0.8°C

Linearization error

Typical		< 0.1°C

Measured value deviation

Typical		< 0.6°C at 20°C

Electric isolation

Tested according norms & rules EN 60079-11		

Electromagnetic compatibility

Tested according norms & rules EN 61326-3-2		

Current loop supply

Voltage range (R_{Load} = 70 Ω … 800 Ω)		12.5 … 28 V
Current range		> 3.5 …< 24 mA

Power dissipation

Minimum (12.5 V x 4 mA)		50 mW
Maximum (28 V x 20 mA)		560 mW

Ambient temperature

Operation		-10°C to +70°C
Storage/transport		-20°C to +80°C

Humidity

Permissible operation humidity (no condensing)	10 % … 95 %	

Housing

Material		Polyamide
Color		light grey
Degree of protection		IP20
Width x length x height (with connection terminal blocks)		22.5 x 115 x 108 mm
Inflammability class according to UL 94		V0
Housing type for mounting		35 mm DIN rails
Weight with terminal blocks		approx. 200 g

Connection data

Solid (minimum/maximum)	0.2 mm²/2.5 mm²
Stranded wire (minimum/maximum)	0.2 mm²/2.5 mm²
AWG/kcmil (minimum/maximum)	24/14
Stripping length	7 mm
Connection method	plugable screw connection
Tightening torque	0.5 … 0.6 Nm

Installation

Safe area:	Install the device in a clean and dry environment.
Ex area (zone 1):	Install the device in a suitable housing with a minimum of IP54 degree of protection.

Cold-junction compensation (CJC) error

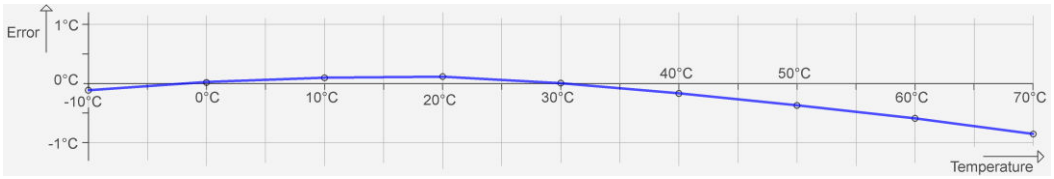


Fig. 1

Dimensions

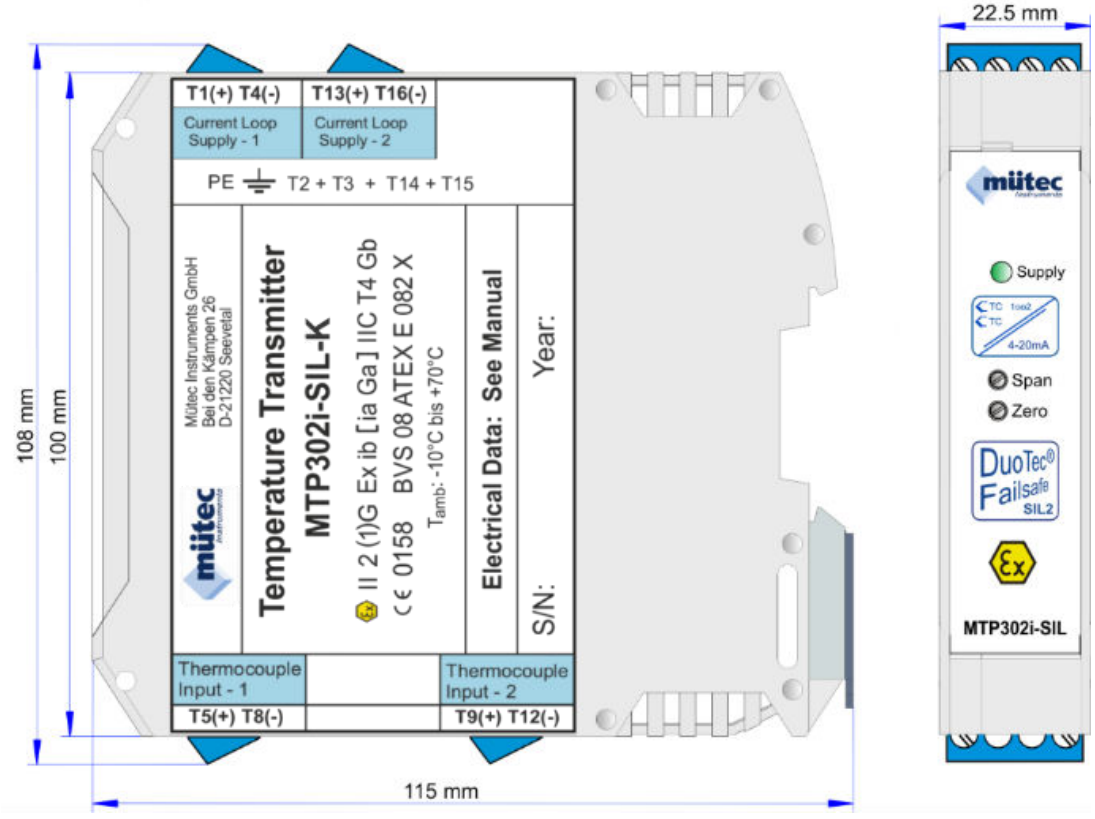


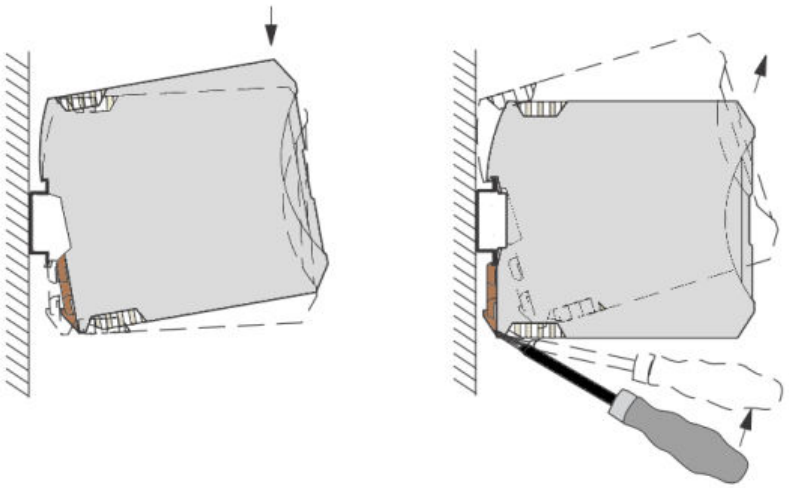
Fig. 2

Fine adjustment with trimmer ZERO and SPAN

Fig. 3

Mounting and removal:

Mount the module on a 35 mm DIN rail according to EN 60715
Install the module in a suitable housing to meet the requirements for the protection class
Mounting: Snap-on foot below (left part of drawing)
Removal: With a screwdriver (right part of drawing)



Before start up, check the correct wiring and labelling of the intrinsically safe circuits.

Fig. 4

Connecting the cables: Permissible cable cross-section are 0.2 mm^2 to 2.5 mm^2.
Stranded wires provided with ferrules.

Screw connection: Insert the wire into the corresponding connection terminal block and use a screwdriver to tighten the screw in the opening above the connection terminal block.

2 Safety Regulations and Installation Notes

Follow the installation instructions:

NOTE: Installation, operation, and maintenance may only be carried out by qualified specialist personnel.

When installing and operating the device, the applicable safety directives (including national safety directives), accident prevention regulations, as well as general technical regulations, must be observed.

NOTE: The circuits inside the device must not be accessed.

Do not repair the device yourself, but replace it with an equivalent device. Repairs may only be carried out by the manufacturer.

NOTE: The device is suitable for IP20 degree of protection if:

- It is installed outside potentially explosive areas
- The environment is clean and dry

Install the device in a suitable housing with a suitable degree of protection in accordance with IEC 60529 in order to protect it from mechanical and electrical damage.
For the safety data, please refer to the operating instructions and certificates (EC examination certificate, other approvals, if necessary).

Safety regulations for installation in potentially explosive areas and regulations for intrinsically safe circuits:

WARNING: Explosion hazard
When carrying out measurements on the intrinsically safe side, be sure to observe the relevant regulations regarding the connection of intrinsically safe equipment.
Only use devices approved for use in intrinsically safe circuits.

WARNING: Explosion hazard
If the device has been used in non-intrinsically safe circuits, it must not be used again in intrinsically safe circuits.
Clearly label the module as being non-intrinsically safe.

Installation in zone 1:

WARNING: Explosion hazard
The device is an intrinsically safe equipment of the “Ex-i” protection type and suitable for installation in zone 1.

Observe the specified conditions for use in potentially explosive areas.

WARNING: Explosion hazard
Install the device in a suitable housing with a minimum of IP54 degree of protection and in accordance with DIN EN 60529.

Installation in areas with a danger of dust explosions:

WARNING: Explosion hazard
The device is not designed for installation in areas with a danger of dust explosions.

Connection to the intrinsically safe circuit in areas with a danger of dust explosions (zones 20, 21, and 22) is only permitted if the equipment connected to this circuit is approved for this zone (e.g., category 1D, 2D or 3D).

3 Installation

NOTE: Electrostatic discharge
The device contains components that can be damaged or destroyed by electrostatic discharge. When handling the device, observe the necessary safety precautions against electrostatic discharge (ESD) according to EN 61340-5-1 and EN 61340-5-2.

Circuit diagram of the MTP300i-SIL-K:

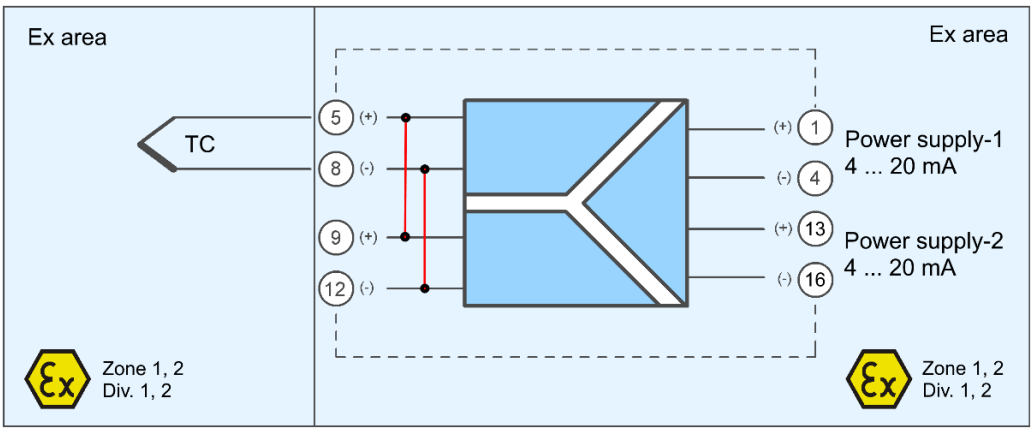


Fig. 5

Measuring input (intrinsically safe):

Thermocouple with connection to terminal 5/+ and 8/- or 9/+ and 12/-
Attention: The terminals 5+8 and 9+12 are already connected internally!

Power supplies/output signals (intrinsically safe):

Repeater power supply-1 with connection to terminal 1/+ and 4/-
Repeater power supply-2 with connection to terminal 13/+ and 16/-

4 Comparison of Safety Data

WARNING: Explosion hazard
Compare the safety data before connecting a device located in the Ex-i area to the MTP302i-SIL-K.

Safety data for	**MTP302i-SIL-K**:	**U_i, I_i, P_i, L_i, C_i**
	Power supply:	**U_o, I_o, P_o, L_o, C_o**

For the values for **U_o, I_o, P_o, L_o** and **C_o** please refer to “Safety data according to Ex for intrinsically safe circuits” on page 2.

Ex-i requirements (simple circuits)

$U_i \geq U_o$	
$I_i \geq I_o$	
$P_i \geq P_o$	
$L_i + L_c \leq L_o$	(L_c is depend on the cables/lines used)
$C_i + C_c \leq C_o$	(C_c is depend on the cables/lines used)

5 Principle of Function:

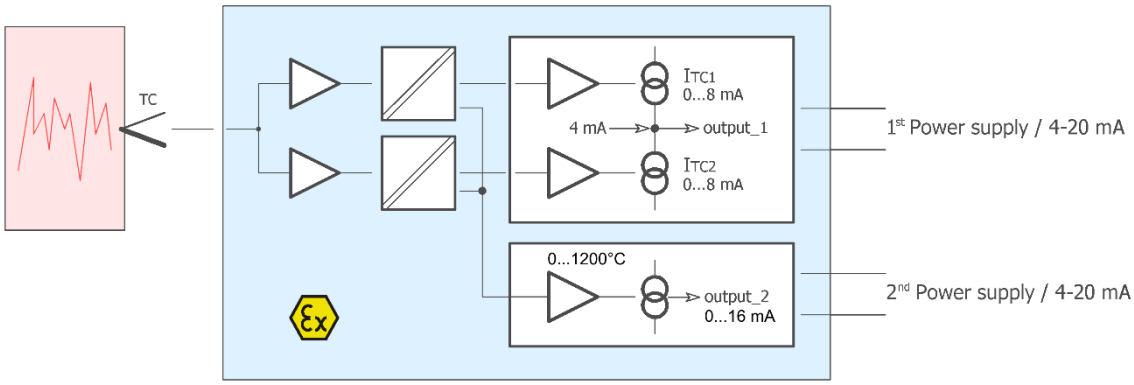


Fig. 6

The **MTP302i-SIL-K** has two input channels that are internally connected to each other.
The two-channel structure of the transmitter guarantees a high degree of Functional Safety (λ_{du} = 4,7 FIT).
The functions of the internal circuits as well as the measuring circuits in the input for the thermocouples with the CJC are subject of a continuous self-diagnosis. In the event of an error, the output signal is reduced to < 3.6 mA according to NE43 (NAMUR recommendation).
The two constant current sources are galvanically isolated from the measuring inputs and each control a partial current of 0 to 8 mA for the 4-20 mA signal in the supply circuit.
A 3rd constant current source drives the current from 0 to 16 mA in the second supply circuit according to the measuring temperature from 0 to 1200°C. This circuit part is not subject of the SIL requirements and does not meet the NAMUR criteria. Nevertheless, the correct function can be monitored by an mA comparison with the 1st supply circuit in the range of 0 to 400°C.

6 Safety Function:

Activation of the Safety Function: **$I_a \leq 3.6$ mA**

A deviation > 5 % between the two galvanic isolated temperature channels or an internal failure leads to a value reduction of the mA output (< 3.6 mA). The output signal (see Fig. 7) returns after a break of about 7 to 9 seconds and the self monitoring checks again, whether the failure still is present and thus the shutdown must be repeated.
Only an external failure (Thermocouple or wire break) leads to a permanent reduction of the mA-value in the supply circuit (< 3.6 mA).

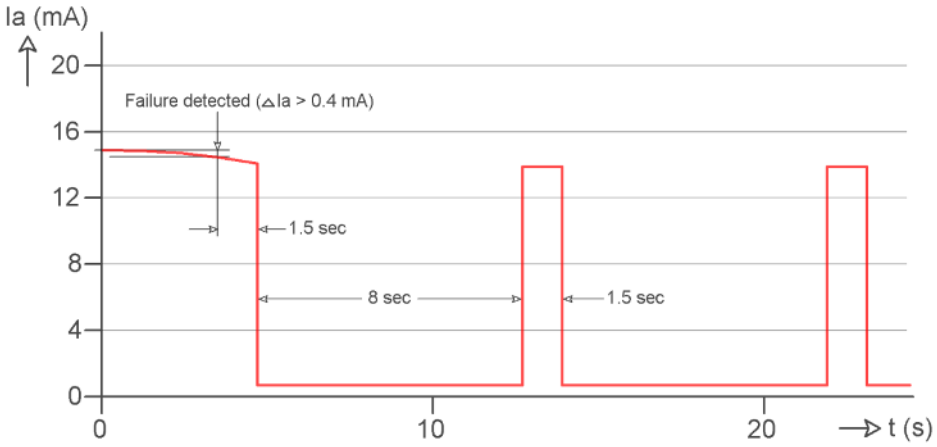


Fig. 7

Behavior of the output signal for internal errors:

- Monitoring of the two measurement channels

  If the deviation exceeds the value of 5 %, the mA value of the output circuit jumps periodically to < 3.6 mA.

- Monitoring of the internal supply voltage

  If the deviation exceeds the value of 5 %, the mA value of the output circuit jumps periodically to < 3.6 mA.

- Monitoring of the internal supply current

  If the deviation exceeds the value of 5 %, the mA value of the output circuit jumps periodically to < 3.6 mA.

- Monitoring of the clock frequency

  If the deviation of the clock frequency exceeds the value of 10 %, the mA value of the output circuit jumps periodically to < 3.6 mA.

Behavior of the output signal-1 for external errors of the MTP302-SIL-K:

- Sensor or cable break

  The transmitter output signal is permanently limited < 3.6 mA.

- Short circuit in the measuring circuit

  The mA value of the output circuit corresponds to the cold-junction temperature value of the Pt100 sensor.

Behavior of the output signal for external errors of the MTP302-SIL-2K:

- Sensor or cable break (transmitter with only 1 thermocouple)

  The transmitter output signal is permanently limited < 3.6 mA.

- Short circuit in the measuring circuit (transmitter with only 1 thermocouple)

  The transmitter output signal corresponds to the cold-junction temperature value of the Pt100 sensor.

- Sensor or cable break (transmitter with 2 thermocouples)

  The transmitter output signal corresponds to the temperature value averaged Between the two mV signals of the measuring inputs. Exceeds the difference between both channels the value of 5 %, the transmitter output signal jumps periodically to the value of < 3.6 mA.

- Short circuit in the measuring circuit (transmitter with 2 thermocouples)

  The mA output signal corresponds to the cold-junction temperature value of the Pt100 sensor of the faulty channel plus the temperature value of the temperature value of the undisturbed second channel.
  Exceeds the difference between both channels the value of 5 %, the transmitter output signal jumps periodically to the value of < 3.6 mA.

7 Safety Applications for SIL 2

Safety integrity requirements (see also technical report **4.139.18 / Risknowlogy**)

Failure rates of temperature measurement channels:
Type B device (according to IEC/EN 61508-2), Safety Integrity Level (SIL 2)

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF
0 FIT	78.5 FIT	61.3 FIT	4.7 FIT	96.8 %

λ_{su} includes failure that not cause a spurious trip
SFF = Safe Failure Fraction
FIT = Failure In Time (1 FIT = 1 failure / 10^9 h)

PFD_{AVG} values of MTP300i-SIL… without TC-sensor(s):
The beta factor is 2 % and was derived from IEC/EN 61508-6, Annex D

T [PROOF]	**1 Year**	**2 Years**	**5 Years**	**10 Years**	**20 Years**
PFD_{AVG}	5.63E-05	1.11E-04	2.77E-04	5.54E-04	1.11E-03
% SIL 2	0.56 %	1.11 %	2.77 %	5.54 %	11.07 %

PFD_{AVG} = Average value of the Probability of Failure on Demand
T [PROOF] = Proof test interval

The calculated PFD_{AVG} values are within the allowed range for SIL 2 according to table 2 of IEC/EN 61508-1, and do fulfill the requirement to not cover more than 15 % of this range after 20 years.

PFS_{AVG} for 1 Year: **2.63E-05**

PFS_{AVG} = Average value of the Probability of Fail Safe

Failure limit:
The operating mode is based on low demand mode.
The proportion of MTP300i-SIL on the PFD_{AVG} of safety chain shall be not more 15 %.

Sensors (2TC)	MTP300i-SIL	Repeater power supply	Processing
35 %	**15 %**	**35 %**	**15 %**

Conditions:

- The failure rates of the components used remain constant throughout the period of use.
- Propagation of errors by the device in the system is not taken into consideration.
- The repair time (= replacement) should be 72 hours.
- The average temperature at which the device is to be used is +40°C. This is based on standard industrial conditions.
- The failure rates given refer to an ambient temperature of +40°C. For an ambient temperature of +60°C, you will need to multiply the failure rates by a factor of 2.5. The factor is based on empirical values gathered.

Proof test

Carry out the appropriate steps to prevent incorrect use.
An example for TC type K:
An input signal of 0…16.395 mV corresponds to a temperature range from 0 to 400°C.
The output must be set to 4.00…20.00 mA.
Setting ≤ 3.6 mA or > 22 mA verifies that the subsequent processing can provide signals outside the range.
In the event of an error, the device must be replaced by an equivalent device.
Restore the safety circuit to full functionality.
Return to normal operation.

8 PFD Calculations

Typical TC sensor has the following failure rates:

	TC sensor without extension wire				TC sensor with extension wire			
	s [FIT]	d [FIT]	DC	SFF	s [FIT]	d [FIT]	DC	SFF
Low Stress	40	9	95 %	81.63 %	381	95	95 %	80.04 %
High Stress	787	173	95 %	81.98 %	7600	1900	95 %	80.00 %

Typical extension wire has the following failure rates:

	Extension wire			
	s [FIT]	d [FIT]	DC	SFF
Low Stress	341	86	95 %	79.86 %
High Stress	6813	1727	95 %	79.96 %

Variants (A, B, C) for the TC connection:

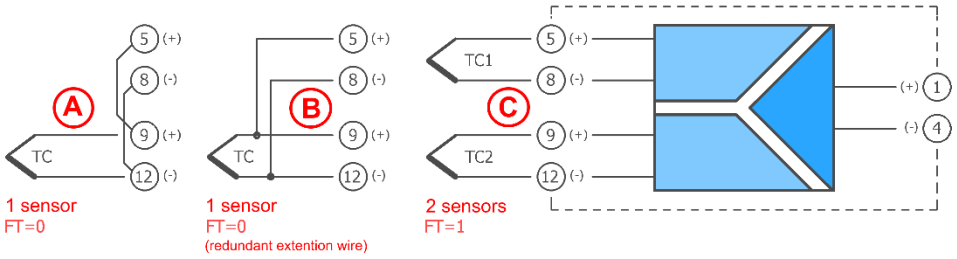


Fig. 8

A: Failure rate for 1 TC sensor with extension wire (high stress):

MTP302i-SIL-K (terminals 5+8 und 9+12 are connected internally)
MTP302i-SIL-2K (terminals 5+8 und 9+12 are to be connected externally)

T [PROOF]	**1 Year**	**2 Years**	**5 Years**	**10 Years**	**20 Years**
tce	291	510	1167	2262	4452
PFD_{AVG} sensor + wire	5.53E-04	9.69E-04	2.22E-03	4.30E-03	8.46E-03
PFD_{AVG} MTP302i-SIL	5.63E-05	1.11E-04	2.77E-04	5.54E-04	1.11E-03
PFD_{AVG} total	6.09E-04	1.08E-03	2.49E-03	4.85E-03	9.57E-03
% SIL 2	6.1 %	10.8 %	24.9 %	48.5 %	95.7 %

B: Failure rate for 1 TC sensor with redundant extension wire (high stress):

MTP302i-SIL-2K (extension wire from terminals 5+8 and 9+12 first contacted at the TC)

T [PROOF]	**1 Year**	**2 Years**	**5 Years**	**10 Years**	**20 Years**
tce	291	510	1167	2262	4452
PFD_{AVG} sensor	5.03E-05	8.82E-05	2.02E-04	3.91E-04	7.70E-04
tge 2 extention wire	218	364	802	1532	2992

T [PROOF]	**1 Year**	**2 Years**	**5 Years**	**10 Years**	**20 Years**
PFD_{AVG} redundant wire	2.55E-05	4.50E-05	1.06E-04	2.14E-04	4.56E-04
PFD_{AVG} MTP302i-SIL	5.63E-05	1.11E-04	2.77E-04	5.54E-04	1.11E-03
PFD_{AVG} total	1.32E-04	2.45E-04	5.85E-04	1.16E-03	2.33E-03
% SIL 2	1.3 %	2.5 %	5.9 %	11.6 %	23.3 %

C: Failure rate for 2 TC sensors with extension wire (high stress):

MTP300i-SIL-2* (extension wire for TC1 on terminal 5 and 8,
extension wire for TC2 on terminal 9 and 12)

T [PROOF]	**1 Year**	**2 Years**	**5 Years**	**10 Years**	**20 Years**
tce	218	364	802	1532	2992
PFD_{AVG} Sensor + wire	2.81E-05	4.97E-05	1.17E-04	2.37E-04	5.10E-04
PFD_{AVG} MTP302i-SIL	5.63E-05	1.11E-04	2.77E-04	5.54E-04	1.11E-03
PFD_{AVG} total	8.44E-05	1.61E-04	3.94E-04	7.91E-04	1.62E-03
% SIL 2	0.8 %	1.6 %	3.9 %	7.9 %	16.2 %

PFD formula for single TC sensor:

$$PFD_{AVG}\ \text{Sensor} \approx 0.5 \times \lambda_{du} \times T_1 \qquad \lambda_{du} = (1 - DC) \times \lambda_d$$

PFD formula for dual TC sensors:

$$PFD_{AVG}\ \text{Sensor} \approx 0.5 \times \beta \times \lambda_{du} \times T_1 \qquad \beta = 5\ \%\ \text{(for sensors)}$$

PFD formula for transmitter with the measuring circuit(s):

$$PFD_{AVG}\ \text{total} = PFD_{AVG}\ \text{MTP300i} + PFD_{AVG}\ \text{Sensor + Wire}$$

9 Conversion of the mA value into the measured temperature

$$U_{TC} = (I_{OUT} - 4.0mA) \times 3.0524\Omega$$

I_{OUT} is the current value of the power supply-2!

ITS-90 Table for type K thermocouple in mV

°C	0	1	2	3	4	5	6	7	8	9	10
0	0.000	0.039	0.079	0.119	0.158	0.198	0.238	0.277	0.317	0.357	0.397
10	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.718	0.758	0.798
20	0.798	0.838	0.879	0.919	0.960	1.000	1.041	1.081	1.122	1.163	1.203
30	1.203	1.244	1.285	1.326	1.366	1.407	1.448	1.489	1.530	1.571	1.612
40	1.612	1.653	1.694	1.735	1.776	1.817	1.858	1.899	1.941	1.982	2.023
50	2.023	2.064	2.106	2.147	2.188	2.230	2.271	2.312	2.354	2.395	2.436
60	2.436	2.478	2.519	2.561	2.602	2.644	2.685	2.727	2.768	2.810	2.851
70	2.851	2.893	2.934	2.976	3.017	3.059	3.100	3.142	3.184	3.225	3.267
80	3.267	3.308	3.350	3.391	3.433	3.474	3.516	3.557	3.599	3.640	3.682
90	3.682	3.723	3.765	3.806	3.848	3.889	3.931	3.972	4.013	4.055	4.096
100	4.096	4.138	4.179	4.220	4.262	4.303	4.344	4.385	4.427	4.468	4.509
110	4.509	4.550	4.591	4.633	4.674	4.715	4.756	4.797	4.838	4.879	4.920
120	4.920	4.961	5.002	5.043	5.084	5.124	5.165	5.206	5.247	5.288	5.328
130	5.328	5.369	5.410	5.450	5.491	5.532	5.572	5.613	5.653	5.694	5.735
140	5.735	5.775	5.815	5.856	5.896	5.937	5.977	6.017	6.058	6.098	6.138
150	6.138	6.179	6.219	6.259	6.299	6.339	6.380	6.420	6.460	6.500	6.540
160	6.540	6.580	6.620	6.660	6.701	6.741	6.781	6.821	6.861	6.901	6.941
170	6.941	6.981	7.021	7.060	7.100	7.140	7.180	7.220	7.260	7.300	7.340
180	7.340	7.380	7.420	7.460	7.500	7.540	7.579	7.619	7.659	7.699	7.739
190	7.739	7.779	7.819	7.859	7.899	7.939	7.979	8.019	8.059	8.099	8.138
200	8.138	8.178	8.218	8.258	8.298	8.338	8.378	8.418	8.458	8.499	8.539
210	8.539	8.579	8.619	8.659	8.699	8.739	8.779	8.819	8.860	8.900	8.940
220	8.940	8.980	9.020	9.061	9.101	9.141	9.181	9.222	9.262	9.302	9.343
230	9.343	9.383	9.423	9.464	9.504	9.545	9.585	9.626	9.666	9.707	9.747
240	9.747	9.788	9.828	9.869	9.909	9.950	9.991	10.031	10.072	10.113	10.153
250	10.153	10.194	10.235	10.276	10.316	10.357	10.398	10.439	10.480	10.520	10.561
260	10.561	10.602	10.643	10.684	10.725	10.766	10.807	10.848	10.889	10.930	10.971
270	10.971	11.012	11.053	11.094	11.135	11.176	11.217	11.259	11.300	11.341	11.382
280	11.382	11.423	11.465	11.506	11.547	11.588	11.630	11.671	11.712	11.753	11.795
290	11.795	11.836	11.877	11.919	11.960	12.001	12.043	12.084	12.126	12.167	12.209
300	12.209	12.250	12.291	12.333	12.374	12.416	12.457	12.499	12.540	12.582	12.624
310	12.624	12.665	12.707	12.748	12.790	12.831	12.873	12.915	12.956	12.998	13.040
320	13.040	13.081	13.123	13.165	13.206	13.248	13.290	13.331	13.373	13.415	13.457
330	13.457	13.498	13.540	13.582	13.624	13.665	13.707	13.749	13.791	13.833	13.874
340	13.874	13.916	13.958	14.000	14.042	14.084	14.126	14.167	14.209	14.251	14.293
350	14.293	14.335	14.377	14.419	14.461	14.503	14.545	14.587	14.629	14.671	14.713
360	14.713	14.755	14.797	14.839	14.881	14.923	14.965	15.007	15.049	15.091	15.133
370	15.133	15.175	15.217	15.259	15.301	15.343	15.385	15.427	15.469	15.511	15.554
380	15.554	15.596	15.638	15.680	15.722	15.764	15.806	15.849	15.891	15.933	15.975
390	15.975	16.017	16.059	16.102	16.144	16.186	16.228	16.270	16.313	16.355	16.397
400	16.397	16.439	16.482	16.524	16.566	16.608	16.651	16.693	16.735	16.778	16.820
410	16.820	16.862	16.904	16.947	16.989	17.031	17.074	17.116	17.158	17.201	17.243
420	17.243	17.285	17.328	17.370	17.413	17.455	17.497	17.540	17.582	17.624	17.667
430	17.667	17.709	17.752	17.794	17.837	17.879	17.921	17.964	18.006	18.049	18.091
440	18.091	18.134	18.176	18.218	18.261	18.303	18.346	18.388	18.431	18.473	18.516
450	18.516	18.558	18.601	18.643	18.686	18.728	18.771	18.813	18.856	18.898	18.941
460	18.941	18.983	19.026	19.068	19.111	19.154	19.196	19.239	19.281	19.324	19.366
470	19.366	19.409	19.451	19.494	19.537	19.579	19.622	19.664	19.707	19.750	19.792
480	19.792	19.835	19.877	19.920	19.962	20.005	20.048	20.090	20.133	20.175	20.218
490	20.218	20.261	20.303	20.346	20.389	20.431	20.474	20.516	20.559	20.602	20.644

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500	20.644	20.687	20.730	20.772	20.815	20.857	20.900	20.943	20.985	21.028	21.071
510	21.071	21.113	21.156	21.199	21.241	21.284	21.326	21.369	21.412	21.454	21.497
520	21.497	21.540	21.582	21.625	21.668	21.710	21.753	21.796	21.838	21.881	21.924
530	21.924	21.966	22.009	22.052	22.094	22.137	22.179	22.222	22.265	22.307	22.350
540	22.350	22.393	22.435	22.478	22.521	22.563	22.606	22.649	22.691	22.734	22.776
550	22.776	22.819	22.862	22.904	22.947	22.990	23.032	23.075	23.117	23.160	23.203
560	23.203	23.245	23.288	23.331	23.373	23.416	23.458	23.501	23.544	23.586	23.629
570	23.629	23.671	23.714	23.757	23.799	23.842	23.884	23.927	23.970	24.012	24.055
580	24.055	24.097	24.140	24.182	24.225	24.267	24.310	24.353	24.395	24.438	24.480
590	24.480	24.523	24.565	24.608	24.650	24.693	24.735	24.778	24.820	24.863	24.905
600	24.905	24.948	24.990	25.033	25.075	25.118	25.160	25.203	25.245	25.288	25.330
610	25.330	25.373	25.415	25.458	25.500	25.543	25.585	25.627	25.670	25.712	25.755
620	25.755	25.797	25.840	25.882	25.924	25.967	26.009	26.052	26.094	26.136	26.179
630	26.179	26.221	26.263	26.306	26.348	26.390	26.433	26.475	26.517	26.560	26.602
640	26.602	26.644	26.687	26.729	26.771	26.814	26.856	26.898	26.940	26.983	27.025
650	27.025	27.067	27.109	27.152	27.194	27.236	27.278	27.320	27.363	27.405	27.447
660	27.447	27.489	27.531	27.574	27.616	27.658	27.700	27.742	27.784	27.826	27.869
670	27.869	27.911	27.953	27.995	28.037	28.079	28.121	28.163	28.205	28.247	28.289
680	28.289	28.332	28.374	28.416	28.458	28.500	28.542	28.584	28.626	28.668	28.710
690	28.710	28.752	28.794	28.835	28.877	28.919	28.961	29.003	29.045	29.087	29.129
700	29.129	29.171	29.213	29.255	29.297	29.338	29.380	29.422	29.464	29.506	29.548
710	29.548	29.589	29.631	29.673	29.715	29.757	29.798	29.840	29.882	29.924	29.965
720	29.965	30.007	30.049	30.090	30.132	30.174	30.216	30.257	30.299	30.341	30.382
730	30.382	30.424	30.466	30.507	30.549	30.590	30.632	30.674	30.715	30.757	30.798
740	30.798	30.840	30.881	30.923	30.964	31.006	31.047	31.089	31.130	31.172	31.213
750	31.213	31.255	31.296	31.338	31.379	31.421	31.462	31.504	31.545	31.586	31.628
760	31.628	31.669	31.710	31.752	31.793	31.834	31.876	31.917	31.958	32.000	32.041
770	32.041	32.082	32.124	32.165	32.206	32.247	32.289	32.330	32.371	32.412	32.453
780	32.453	32.495	32.536	32.577	32.618	32.659	32.700	32.742	32.783	32.824	32.865
790	32.865	32.906	32.947	32.988	33.029	33.070	33.111	33.152	33.193	33.234	33.275
800	33.275	33.316	33.357	33.398	33.439	33.480	33.521	33.562	33.603	33.644	33.685
810	33.685	33.726	33.767	33.808	33.848	33.889	33.930	33.971	34.012	34.053	34.093
820	34.093	34.134	34.175	34.216	34.257	34.297	34.338	34.379	34.420	34.460	34.501
830	34.501	34.542	34.582	34.623	34.664	34.704	34.745	34.786	34.826	34.867	34.908
840	34.908	34.948	34.989	35.029	35.070	35.110	35.151	35.192	35.232	35.273	35.313
850	35.313	35.354	35.394	35.435	35.475	35.516	35.556	35.596	35.637	35.677	35.718
860	35.718	35.758	35.798	35.839	35.879	35.920	35.960	36.000	36.041	36.081	36.121
870	36.121	36.162	36.202	36.242	36.282	36.323	36.363	36.403	36.443	36.484	36.524
880	36.524	36.564	36.604	36.644	36.685	36.725	36.765	36.805	36.845	36.885	36.925
890	36.925	36.965	37.006	37.046	37.086	37.126	37.166	37.206	37.246	37.286	37.326
900	37.326	37.366	37.406	37.446	37.486	37.526	37.566	37.606	37.646	37.686	37.725
910	37.725	37.765	37.805	37.845	37.885	37.925	37.965	38.005	38.044	38.084	38.124
920	38.124	38.164	38.204	38.243	38.283	38.323	38.363	38.402	38.442	38.482	38.522
930	38.522	38.561	38.601	38.641	38.680	38.720	38.760	38.799	38.839	38.878	38.918
940	38.918	38.958	38.997	39.037	39.076	39.116	39.155	39.195	39.235	39.274	39.314
950	39.314	39.353	39.393	39.432	39.471	39.511	39.550	39.590	39.629	39.669	39.708
960	39.708	39.747	39.787	39.826	39.866	39.905	39.944	39.984	40.023	40.062	40.101
970	40.101	40.141	40.180	40.219	40.259	40.298	40.337	40.376	40.415	40.455	40.494
980	40.494	40.533	40.572	40.611	40.651	40.690	40.729	40.768	40.807	40.846	40.885
990	40.885	40.924	40.963	41.002	41.042	41.081	41.120	41.159	41.198	41.237	41.276
1000	41.276	41.315	41.354	41.393	41.431	41.470	41.509	41.548	41.587	41.626	41.665
1010	41.665	41.704	41.743	41.781	41.820	41.859	41.898	41.937	41.976	42.014	42.053
1020	42.053	42.092	42.131	42.169	42.208	42.247	42.286	42.324	42.363	42.402	42.440
1030	42.440	42.479	42.518	42.556	42.595	42.633	42.672	42.711	42.749	42.788	42.826
1040	42.826	42.865	42.903	42.942	42.980	43.019	43.057	43.096	43.134	43.173	43.211
1050	43.211	43.250	43.288	43.327	43.365	43.403	43.442	43.480	43.518	43.557	43.595
1060	43.595	43.633	43.672	43.710	43.748	43.787	43.825	43.863	43.901	43.940	43.978
1070	43.978	44.016	44.054	44.092	44.130	44.169	44.207	44.245	44.283	44.321	44.359
1080	44.359	44.397	44.435	44.473	44.512	44.550	44.588	44.626	44.664	44.702	44.740
1090	44.740	44.778	44.816	44.853	44.891	44.929	44.967	45.005	45.043	45.081	45.119

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1100	45.119	45.157	45.194	45.232	45.270	45.308	45.346	45.383	45.421	45.459	45.497
1110	45.497	45.534	45.572	45.610	45.647	45.685	45.723	45.760	45.798	45.836	45.873
1120	45.873	45.911	45.948	45.986	46.024	46.061	46.099	46.136	46.174	46.211	46.249
1130	46.249	46.286	46.324	46.361	46.398	46.436	46.473	46.511	46.548	46.585	46.623
1140	46.623	46.660	46.697	46.735	46.772	46.809	46.847	46.884	46.921	46.958	46.995
1150	46.995	47.033	47.070	47.107	47.144	47.181	47.218	47.256	47.293	47.330	47.367
1160	47.367	47.404	47.441	47.478	47.515	47.552	47.589	47.626	47.663	47.700	47.737
1170	47.737	47.774	47.811	47.848	47.884	47.921	47.958	47.995	48.032	48.069	48.105
1180	48.105	48.142	48.179	48.216	48.252	48.289	48.326	48.363	48.399	48.436	48.473
1190	48.473	48.509	48.546	48.582	48.619	48.656	48.692	48.729	48.765	48.802	48.838
1200	48.838	48.875	48.911	48.948	48.984	49.021	49.057	49.093	49.130	49.166	49.202
1210	49.202	49.239	49.275	49.311	49.348	49.384	49.420	49.456	49.493	49.529	49.565
1220	49.565	49.601	49.637	49.674	49.710	49.746	49.782	49.818	49.854	49.890	49.926
1230	49.926	49.962	49.998	50.034	50.070	50.106	50.142	50.178	50.214	50.250	50.286
1240	50.286	50.322	50.358	50.393	50.429	50.465	50.501	50.537	50.572	50.608	50.644
1250	50.644	50.680	50.715	50.751	50.787	50.822	50.858	50.894	50.929	50.965	51.000
1260	51.000	51.036	51.071	51.107	51.142	51.178	51.213	51.249	51.284	51.320	51.355
1270	51.355	51.391	51.426	51.461	51.497	51.532	51.567	51.603	51.638	51.673	51.708
1280	51.708	51.744	51.779	51.814	51.849	51.885	51.920	51.955	51.990	52.025	52.060
1290	52.060	52.095	52.130	52.165	52.200	52.235	52.270	52.305	52.340	52.375	52.410