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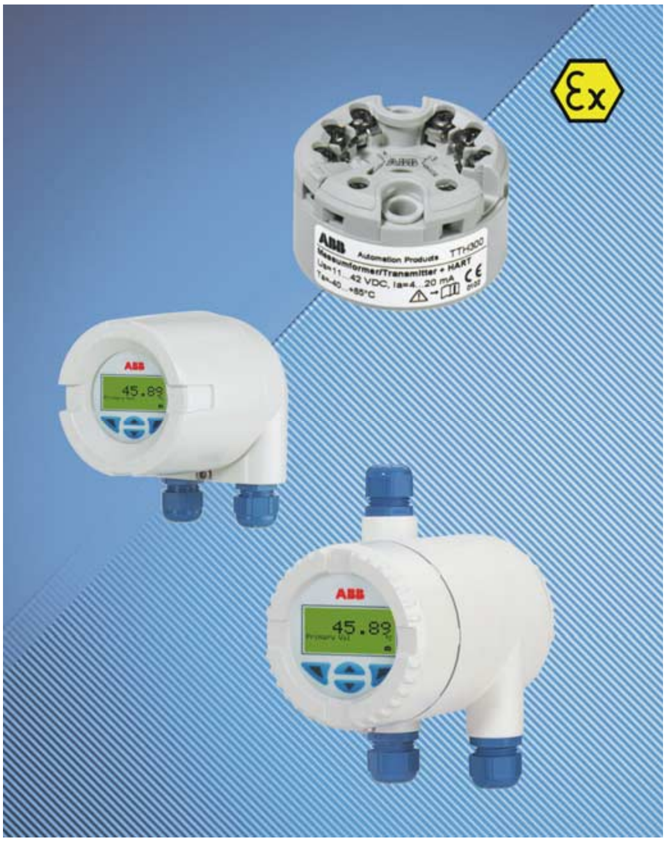
SIL-Safety Instructions

SM/TTX3X0/SIL-EN

Temperature Transmitter
TTH300, TTF300, TTF350

Information regarding functional safety



SIL2
Safety Integrity Level
IEC 61508

ABB

Temperature Transmitter
TTH300, TTF300, TTF350

SIL-Safety Instructions

SM/TTX3X0/SIL-EN

05.2007

Manufacturer:

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1 Field of Application

Temperature monitoring of solids, fluids and gases of all types in containers and pipes according to the special safety engineering requirements of IEC 61508.

The operating limits are defined in the data sheets and operating instructions for the separate models. In case of questions, please contact your ABB partner.

2 Acronyms and abbreviations

Acronym / Abbreviation	Designation	Description
HFT	Hardware Fault Tolerance	The hardware fault tolerance of the device. This is the capability of a functional unit to continue the execution of the demanded function in case of faults or deviations.
MTBF	Mean Time Between Failures	This is the mean time period between two failures.
MTTR	Mean Time To Repair	This is the mean time period between the occurrence of a failure in a device or system and its repair.
PFD	Probability of Failure on Demand	This is the likelihood of dangerous safety function failures occurring on demand.
PFD_{AVG}	Average Probability of Failure on Demand	This is the average likelihood of dangerous safety function failures occurring on demand.
SIL	Safety Integrity Level	The international standard IEC 61508 specifies four discrete safety integrity levels (SIL 1 to SIL 4). Each level corresponds to a specific probability range regarding the failure of a safety function. The higher the safety integrity level of the safety-related systems, the lower likelihood of non-execution of the demanded safety functions.
SFF	Safe Failure Fraction	The fraction of non-hazardous failures, i.e. the fraction of failures without the potential to set the safety-related system to a dangerous or impermissible state.
Low demand mode	Low demand mode of operation	Measuring mode with low demand rate. Measuring mode, in which the demand rate for the safety-related system is not more than once a year and is not greater than double the frequency of the periodic test.
DCS	Distributed Control System	Control systems that are used in industrial engineering applications to monitor and control distributed equipment.

Acronym / Abbreviation	Designation	Description
HMI	Human Machine Interface	Here, the HMI is the combined module consisting of LCD and local keypad.
DTM	Device Type Manager	The DTM is a software module that provides functions for accessing device parameters, configuring and operating the devices and diagnosing problems. By itself, a DTM is not executable software. It only 'comes to life' in an so called FDT 'container' program.
LRV	Device Configuration	Lower Range Value of the measurement range
URV	Device Configuration	Upper Range Value of the measurement range
Multidrop	Multidrop mode	In multidrop mode, up to 15 field devices are connected in parallel to a single wire pair. The analog current signal serves just to energize the two-wire devices providing a fixed current of 4mA.

3 Relevant standards

Standard	Designation
IEC 61508, Part 1 to 7	Functional safety of electrical/electronic/programmable electronic safety-related systems

4 Other applicable documents and papers

Observe the following documents in addition to the SIL-safety information:

Product name	Document name	Designation and application
TTH300	DS/TTH300	Data Sheet TTH300
TTH300	OI/TTH300	Operating Instructions TTH300
TTH300	CI/TTH300	Commissioning Instructions TTH300
TTF300	DS/TTF300	Data Sheet TTH300
TTF300	OI/TTF300	Operating Instructions TTF300
TTF300	CI/TTF300	Commissioning Instructions TTF300
TTF350	DS/TTF350	Data Sheet TTF350
TTF350	OI/TTF350	Operating Instructions TTF350
TTF350	CI/TTF350	Commissioning Instructions TTF350

Documents are available in the respective languages: -DE German, -EN English, -FR French, etc.

These are available on the ABB internet at www.abb.com/temperature.

In addition, the user of this device is responsible for ensuring compliance with the respective legal regulations and standards.

5 Terms and definitions

Terms	Definitions
Dangerous failure	A failure that has the potential to place the safety-related system in a dangerous state or render the system inoperative.
Safety-related system	A safety-related system carries out the safety functions that are required to achieve or maintain a safe state, e.g., for a system. Example: A pressure meter, a logics unit (e.g., limit transmitter) and a valve constitute a safety-related system.
Safety-related functions	A specified function that is carried out by a safety-related system with the goal, under consideration of a defined dangerous incident, of achieving or maintaining a safe state for the system. Example: limit temperature monitoring.

6 Safety function

TTH300, TTF300 and TTF350 transmitters generate a linear temperature signal proportional to the connected temperature sensor (4 … 20 mA). All safety functions refer strictly to the analog output signal.

The entire valid range for the output signal must be configured between min. 3.8 mA and max. 20.5 mA (factory setting).

Warning!
In safety mode, HART communication occurs only when write protection is activated. The HART master must comply with the safety requirements of the customer application.

Alarm behavior and current output

When a critical error is detected, the configured alarm current is generated and fed to a downstream logics unit, e.g., a DCS, which checks for overshoots of a defined maximum value. There are two selectable modes for the alarm current:

- HIGH ALARM (high alarm, max. alarm current); this is the factory setting
- LOW ALARM (low alarm, min. alarm current)

The low alarm current can be configured in a range from 3.5 to 4.0 mA. The factory setting is 3.6 mA.

The high alarm current can be configured in a range from 20.0 to 23.6 mA. The factory setting is 22 mA.

In the following cases, a detected error is displayed independently of the configured alarm current within the low alarm range:

- Runtime errors
- Memory error (non-volatile data, RAM, ROM)

After switching on or restarting the transmitter electronic unit, the minimum low alarm time (LOW - alarm, startup time) is 10 to 15 seconds.

Warning!

To ensure accurate error monitoring, the following conditions must be fulfilled:

- The low alarm must be configured to a value of ≤ 3.6 mA.
- The high alarm must be configured to a value of ≥ 21 mA.
- The DCS must identify the configured high and low alarms as malfunctions, and the alarm must be configured according to the desired setup.

Warning!

To ensure the current output is functioning properly, the terminal on the standard device must be between +11 V … +42 V DC (Ex version: +11 V … +30 V DC).

The DCS loop must be capable of providing the required voltage level when the current output is running with the configured high alarm.

The device does not meet safety requirements under the following conditions:

- During configuration
- When write protection is deactivated
- With activated HART-multidrop-mode
- During a simulation
- During an inspection of the safety function

Warning!
The safety function of the device includes the basic model TTH 300, TTF300 or TTF350 with connected sensor, as well as housing and the temperature process connections used. Information in the corresponding documentation must be taken into consideration.

The percentage of failures that do not place the device in a hazardous functional state is provided by the SFF value.

Total safety accuracy

The value defined for the overall accuracy of the safety function for this device is ± 2% of the measuring range.

The basic accuracy depends on the sensor model and can be found in the appropriate data sheets.

Switch-on time and safety operating mode

After switching on the device, all safety-relevant errors are detected after 2 minutes in low demand mode.

7 Periodic checks

Safety inspections

The safety function for the entire safety loop must be checked regularly in accordance with IEC 61508. The inspection intervals are defined when calculating the individual safety loops for a system.

Users are responsible for selecting the type of inspection and the intervals within the specified period. The PFD_{AV} value depends on the selected inspection interval. For the PFD_{AV} values in the SIL declaration of conformity, the inspection interval T[Proof] for checking the safety function is 1 year. For additional inspection intervals with corresponding PFD_{AV} values, refer to the chapter “Management Summary FMEDA”.

Inspections must be conducted in a manner that enables users to verify proper function of the safety equipment in combination with all components.

One possible procedure for recurring tests to detect hazardous and unidentified device errors is described in the following section. Some 99% of the “Du” errors in the transmitter electronic unit are detected by this test.

Checking the safety function

To check the safety function of the device, proceed as follows:

1. Bridge the safety DCS or take other appropriate measures to ensure the alarm is not triggered unintentionally.
2. Deactivate write protection (refer to the relevant operating instructions).
3. Set the current output of the transmitter to a high alarm value by using the DTM simulation command (Diagnosis/Simulation/Current Output).
4. Check whether the current output signal reaches this value.
5. Set the current output of the transmitter to a low alarm value by using the DTM simulation command.
6. Check whether the current output signal reaches this value.
7. Activate write protection (refer to the relevant operating instructions) and wait at least 20 seconds.
8. Restart by switching off the device.
9. Check the current output with reference temperature; set the LRV value (4 mA) and URV (20 mA) via 2-point calibration.
10. Remove the bridge from the safety DCS or use another method to restore the standard operating mode.
11. After performing the test, the events must be documented and archived properly.

A suitable sensor simulator (PT100 - simulator, Ref. voltage source) can be used to check the transmitter electronic unit without sensor. Test the sensor according to SIL requirements for customer applications. SensyTemp TSP temperature sensors from ABB can be checked via a quick check function, according to the relevant operating instructions OI/TSP-….

Repairs

Defective devices must be sent to ABB Service. The type of error and possible reason must also be provided.

Use the original packaging or a suitably secure packaging for returning the device for repair or for recalibration. Include the properly filled out return form (see attachment) with the device.

According to EC guidelines for hazardous materials, the owner of hazardous waste is responsible for its disposal or must observe the following regulations for its shipping:

All delivered devices to ABB Automation Products GmbH must be free from any hazardous materials (acids, alkali, solvents, etc.).

When ordering spare parts always provide the serial number of the device. This information is located on the model plate of the original device.

Address:

ABB Automation GmbH

Service Department

Borsigstr. 2

D-63755 Alzenau

GERMANY

8 Configuration

The device was configured and tested according to customer order.

The device can be additionally configured with the local HMI or DTM using the HART interface. Other configuration tools such as mobile handheld terminals are not described in these instructions.

During setup, proper operation of the device is not ensured.

Warning!

Inspections:

Before commissioning the device, check as part of the safety function whether the device setup supports the safety function for the system.

Make sure that the proper device was installed at the correct measuring point.

Each time the device is updated as part of the safety function, e.g., changing the mounting position for the device or modifying the setup, the safety function of the device must be checked again.

After checking the safety function, the device must be write-protected to prevent unintended changes to the setup, since every change to the measurement system or parameters could affect the safety function.

To ensure safe operation, the device must be write-protected.

To do so, follow these steps:

Activate/deactivate write protection

1. Write protection using local HMI (human-machine interface).

   Go to “Device Setup", “Write Protection” and then enter the password “0110” to activate write protection and password "0110" to disable write protection. (see operating instructions)

2. Write protection via DTM

   Go to “Device Setup” and select “Write Protection” to activate the function.

   If the device is locked (write-protected), it cannot be configured. Write protection is applied for the entire device. Enter the password “0110” to disable write protection.

Warning!

Inspections:

Write protection must be checked as follows:

1. Lock via HMI (human-machine interface):
   - Check whether the lock icon is displayed on the LCD display.
   - Select the menu item “Fault Signaling” and make sure the edit icon is not displayed on the LCD display.
   - Press the Edit button to make sure that there is no response on the LCD display.
2. Lock via DTM:
   - HMI available: Check whether described under item 1.
   - No HMI available (check the write protection):

     Go to <Device>,<Parametrize> Current Output / Damping and update the damping value. Select “Save Device Data in Device” and check whether the message "Device is write-protected" is displayed.

Warning!

The software write protection does not lock again automatically. It remains unlocked until it is reset.

Diagnostic Setup

The diagnostic setup of the device meets safety requirements and includes the following error detections:

- Sensorboard communication error
- Sensorboard error
- Sensorboard A/D converter error
- Measuring error device temperature
- Sensor limit value alarm upper and lower
- Sensor error Ch. 1 and Ch. 2
  - Sensor configuration RTD,R with 2, 3, 4-wire breakage and short circuit
  - Sensor configuration TC, mV with wire break
  - Redundancy-Mode Ch1 and Ch2 with enabled drift, drift monitoring

Configuration parameters with effect on the safety function

All configuration parameters that are changed via HMI, DTM EDD or HART communication for disabled write protection have an effect on the safety function of the device. The parameters are described in the operating instructions. The safety function is checked according to the SIL safety manual.

For redundancy mode with drift monitoring, the following parameters must be set in DTM, EDD:

- Sensor type-Freestyle characteristics and Callendar van Dusen

  When using these two configurations, it is necessary to check at least 3 reference points to verify the configured characteristic. For complex curves, check several sampling points according to complexity.

- Redundancy mode
  - Pulse output enabled
  - Pulse time 60 s, continuous pulse
  - Drift value Configured acc. to customer application
  - Drift duration max. 120 s.

9 Characteristics for functional safety

For the safety-relevant technical parameters, refer to the following SIL declaration of conformity.

49/TTX300_EN
Rev. 1.00

SIL DECLARATION OF CONFORMITY

Manufacturer: ABB Automation Products GmbH
Address: Borsigstraße 2 – D-63755 Alzenau
Product name: Temperature Transmitter TTH300, TTF300 und TTF350

Functional safety according to IEC 61508

We as the manufacturer declare that the a.m. products are suitable for the use in a safety related application up to SIL 2 according to IEC 61508 Edition2000, provided that the attached safety instructions are observed. The assessment of the safety critical and dangerous random errors results, in case of an annual function test, in the following parameters:

Software revision: 01.01.03 **Hardware revision:** 1.05 und 1.06

HFT (Hardware failure tolerance): 0

SIL (Safety integrity level): 2 (see Table) **Type:** B

Transmitter Type	Measuring Range	SIL-Level	SFF	PFDav	λ_{dd} / λ_{du}	λ_{sd} / λ_{su}
TTH300, TTF300, TTF350 Electronic	acc. IEC751, acc. IEC584, mV – Input, Ohm – Input	2	91 %	$1{,}79 * 10^{-4}$	327 FIT / 41 FIT	0 FIT / 110 FIT
TTH300, TTF300, TTF350 Redundanz Mode, Drift with Thermocouple, mV-Input high stress extension wire	acc. IEC584, -125 mV… +1100 mV	2	99 %	$1{,}04 * 10^{-3}$	40133 FIT / 238 FIT	0 FIT / 110 FIT
TTH300, TTF300, TTF350 Redundanz Mode, Drift with 2/3-wire RTD, Ohm-Input high stress extension wire	acc. IEC751 0 … 5000 Ohm	2	98 %	$9{,}98 * 10^{-4}$	19143 FIT / 228 FIT	0 FIT / 113 FIT

Ref.: TÜV Nord Certificate and FMEDA Report exida.com Page 1 of 2

Transmitter Type	Measuring Range	SIL-Level	SFF	PFDav	λ_{dd} λ_{du}	λ_{sd} λ_{su}
TTH300, TTF300, TTF350 Redundanz Mode, Drift with Thermocouple and 2/3-wire RTD high stress extension wire	**acc. IEC751 acc. IEC584**	**2**	**99 %**	**$1{,}02 * 10^{-3}$**	**29638 FIT 233 FIT**	**0 FIT 113 FIT**
TTH300, TTF300, TTF350 with Thermocouple, mV Input high stress close coupled	**acc. IEC584, -125 mV… +1100 mV**	**2**	**94 %**	**$6{,}17 * 10^{-4}$**	**2227 FIT 141 FIT**	**0 FIT 110 FIT**
TTH300, TTF300, TTF350 with 4-wire RTD, Ohm high stress extension wire	**acc. IEC751 0 … 5000 Ohm**	**2**	**98 %**	**$6{,}17 * 10^{-4}$**	**10227 FIT 141 FIT**	**0 FIT 110 FIT**
TTH300, TTF300, TTF350 with 2/3-wire RTD, Ohm high stress close coupled	**acc. IEC751 0 … 5000 Ohm**	**2**	**97 %**	**$2{,}42 * 10^{-4}$**	**2236 FIT 55 FIT**	**0 FIT 113 FIT**

*) Remark 1 FIT = 1 * 10^{-9}, TTH300, TTF300 and TTF350 ordering code CS

30.03.2007
Date

i.V. [signature]
i.V. Reiner Laurinat
Head of Quality Management

i.A. [signature]
i.A. Harald Müller
Head of Hardware Development

Ref.: TÜV Nord Certificate and FMEDA Report exida.com

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10 Appendix

Statement about the contamination of devices and components

The repair and/or maintenance of devices and components will only be performed when a completely filled out explanation is present.

Otherwise, the shipment can be rejected. This explanation may only be filled out and signed by authorized specialist personnel of the operator.

Customer details:

Company:	
Address:	
Contact person:	Telephone:
Fax:	E-Mail:

Device details:

Type:	Serial no.:
Reason for the return/description of the defect:	

Was this device used for working with substances which pose a threat or health risk?

☐ Yes ☐ No

If yes, which type of contamination (please place an X next to the applicable items)

biological	☐	corrosive/irritating	☐	combustible (highly/extremely combustible)	☐
toxic	☐	explosive	☐	other toxic substances	☐
radioactive	☐				

Which substances have had contact with the device?

1.

2.

3.

We hereby certify that the devices/parts shipped were cleaned and are free from any dangerous or poisonous materials.

City, Date Signature and company stamp

11 Management Summary FMEDA

Management summary for TT*3*0, 4..20 mA output

This report summarizes the results of the hardware assessment according to IEC 61508 carried out on the temperature transmitters TT*3*0 with 4..20 mA output in hardware version 1.05 and 1.06 and software version 1.01.03. Table 1 gives an overview of the different types that belong to the considered temperature transmitters.

The hardware assessment consists of a Failure Modes, Effects and Diagnostics Analysis (FMEDA). A FMEDA is one of the steps taken to achieve functional safety assessment of a device per IEC 61508. From the FMEDA, failure rates are determined and consequently the Safe Failure Fraction (SFF) is calculated for the device. For full assessment purposes all requirements of IEC 61508 must be considered.

Table 1: Version overview

TTF300	Field mounted temperature transmitter[1]
TTF350	Field mounted temperature transmitter[2]
TTH300	Head mounted temperature transmitter

For safety applications only the 4..20 mA output was considered. All other possible output variants or electronics are not covered by this report.

The failure rates of the electronic components used in this analysis are the basic failure rates from the Siemens standard SN 29500.

According to table 2 of IEC 61508-1 the average PFD for systems operating in low demand mode has to be ≥ 1,00E-03 to < 1,00E-02 for SIL 2 safety functions. A generally accepted distribution of PFD_{AVG} values of a SIF over the sensor part, logic solver part, and final element part assumes that 35% of the total SIF PFD_{AVG} value is caused by the sensor part.

For a SIL 2 application operating in low demand mode the total PFD_{AVG} value of the SIF should be smaller than 1,00E-02, hence the maximum allowable PFD_{AVG} value for the sensor part would then be 3,50E-03.

The temperature transmitters TT*3*0 with 4..20 mA output are considered to be Type B[3] components with a hardware fault tolerance of 0. For Type B components with a SFF of 90% to < 99% a hardware fault tolerance of 0 is sufficient according to table 3 of IEC 61508-2 for SIL 2 (sub-) systems.

The failure rates do not include failures resulting from incorrect use of the temperature transmitters TT*3*0 with 4..20 mA output, in particular humidity entering through incompletely closed housings or inadequate cable feeding through the inlets.

The listed failure rates are valid for operating stress conditions typical of an industrial field environment similar to IEC 60654-1 class C (sheltered location) with an average temperature over a long period of time of 40ºC. For a higher average temperature of 60°C, the failure rates should be multiplied with an experience based factor of 2,5. A similar multiplier should be used if frequent temperature fluctuation must be assumed.

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[1] With single compartment

[2] With dual compartment

[3] Type B component: "Complex" component (using micro controllers or programmable logic); for details see 7.4.3.1.3 of IEC 61508-2.

It is assumed that the connected logic solver is configured per the NAMUR NE43 signal ranges, i.e. the temperature transmitters TT*3*0 with 4..20 mA output communicate detected faults by an alarm output current ≤ 3,6mA or ≥ 21mA. Assuming that the application program in the safety logic solver does not automatically trip on these failures, these failures have been classified as dangerous detected failures. The following tables show how the above stated requirements are fulfilled.

Table 2: Failure rates [4]

Failure category	**Failure rates (in FIT)**
Fail Dangerous Detected	**327**
Fail dangerous detected (internal diagnostics or indirectly[5])	227
Fail high (detected by the logic solver)	23
Fail low (detected by the logic solver)	77
Annunciation detected	0
Fail Dangerous Undetected	**41**
Fail dangerous undetected	39
Annunciation undetected	2
No Effect	**110**
Not part	**91**

Table 3: IEC 61508 failure rates

λ_{SD}	λ_{SU} [6]	λ_{DD}	λ_{DU}	**SFF** [7]	**DC_S** [8]	**DC_D** [8]
0 FIT	110 FIT	327 FIT	41 FIT	91%	0%	88%

Table 4: PFD_{AVG} values

T[Proof] = 1 year	**T[Proof] = 5 years**	**T[Proof] = 10 years**
PFD_{AVG} = 1,79E-04	PFD_{AVG} = 8,95E-04	PFD_{AVG} = 1,79E-03

A complete temperature sensor assembly consisting of the temperature transmitters TT*3*0 and a thermocouple or RTD can be modeled by considering a series subsystem where a failure occurs if there is a failure in either component. For such a system, failure rates are added.

Appendix 3 gives typical failure rates and failure distributions for thermocouples and RTDs which were the basis for the following tables.

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[4] It is assumed that practical fault insertion tests can demonstrate the correctness of the failure effects assumed during the FMEDAs.

[5] "indirectly" means that these failure are not necessarily detected by diagnostics but lead to either fail low or fail high failures depending on the transmitter setting and are therefore detectable.

[6] Note that the SU category includes failures that do not cause a spurious trip

[7] Note: SFF should be calculated for the sensor subsystem. This SFF is only for reference.

[8] DC means the diagnostic coverage (safe or dangerous) for the temperature transmitters by the safety logic solver.

Assuming that the temperature transmitter TT*3*0 will go to the pre-defined alarm state on detected failures of the thermocouple or RTD, the failure rate contribution or the PFD_{AVG} value (T[Proof] = 1 year) for the thermocouple or RTD in a **low stress environment** is as follows:

Table 5: TT*3*0 with thermocouple (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	422 FIT	46 FIT	92%	2,01E-04

Table 6: TT*3*0 with two thermocouples (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	533 FIT	38 FIT	94%	1,68E-04

Table 7: TT*3*0 with 2/3-wire RTD (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	366 FIT	50 FIT	90%	2,17E-04

Table 8: TT*3*0 with two 2/3-wire RTDs (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	428 FIT	39 FIT	93%	1,70E-04

Table 9: TT*3*0 with thermocouple and 2/3-wire RTD (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	481 FIT	43 FIT	93%	1,90E-04

Table 10: TT*3*0 with 4-wire RTD (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	375 FIT	44 FIT	91%	1,90E-04

Table 11: TT*3*0 with thermocouple (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	1227 FIT	141 FIT	90%	6,17E-04

Table 12: TT*3*0 with two thermocouples (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	2323FIT	48 FIT	98%	2,10E-04

Table 13: TT*3*0 with 2/3-wire RTD (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	707 FIT	136 FIT	85%	5,95E-04

Table 14: TT*3*0 with two 2/3-wire RTDs (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	1274 FIT	47 FIT	96%	2,08E-04

Table 15: TT*3*0 with thermocouple and 2/3-wire RTD (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	1799 FIT	48 FIT	97%	2,09E-04

Table 16: TT*3*0 with 4-wire RTD (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	822 FIT	46 FIT	95%	2,01E-04

Assuming that the temperature transmitters TT*3*0 will go to the pre-defined alarm state on detected failures of the thermocouple or RTD, the failure rate contribution or the PFD_{AVG} value (T[Proof] = 1 year) for the thermocouple or RTD in a **high stress environment** is as follows:

Table 17: TT*3*0 with thermocouple (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	2227 FIT	141 FIT	94%	6,17E-04

Table 18: TT*3*0 with two thermocouples (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	4323 FIT	48 FIT	98%	2,10E-04

Table 19: TT*3*0 with 2/3-wire RTD (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	1114 FIT	214 FIT	85%	9,36E-04

Table 20: TT*3*0 with two 2/3-wire RTDs (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	2236 FIT	55 FIT	97%	2,42E-04

Table 21: TT*3*0 with thermocouple and 2/3-wire RTD (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	3280 FIT	146 FIT	95%	6,38E-04

Table 22: TT*3*0 with 4-wire RTD (close coupled)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	1277 FIT	91 FIT	93%	3,98E-04

Table 23: TT*3*0 with thermocouple (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	18327 FIT	2041 FIT	90%	8,94E-03

Table 24: TT*3*0 with two thermocouples (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	40133 FIT	238 FIT	99%	1,04E-03

Table 25: TT*3*0 with 2/3-wire RTD (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	7927FIT	1941 FIT	80%	8,50E-03

Table 26: TT*3*0 with two 2/3-wire RTDs (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	19143 FIT	228 FIT	98%	9,98E-04

Table 27: TT*3*0 with thermocouple and 2/3-wire RTD (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	113 FIT	29638 FIT	233 FIT	99%	1,02E-03

Table 28: TT*3*0 with 4-wire RTD (with extension wire)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	PFD_{AVG}
0 FIT	110 FIT	10227 FIT	141 FIT	98%	6,17E-04

The boxes marked in yellow (☐) mean that the calculated PFD_{AVG} values are within the allowed range for SIL 2 according to table 2 of IEC 61508-1 but do not fulfill the requirement to not claim more than 35% of this range, i.e. to be better than or equal to 3,50E-03. The boxes marked in green (☐) mean that the calculated PFD_{AVG} values are within the allowed range for SIL 2 according to table 2 of IEC 61508-1 and do fulfill the requirement to not claim more than 35% of this range, i.e. to be better than or equal to 3,50E-03.

A user of the temperature transmitters TT*3*0 with 4..20 mA output can utilize these failure rates in a probabilistic model of a safety instrumented function (SIF) to determine suitability in part for safety instrumented system (SIS) usage in a particular safety integrity level (SIL). A full table of failure rates is presented in section 5.1 along with all assumptions.

It is important to realize that the "no effect" failures are included in the "safe undetected" failure category according to IEC 61508, Edition 2000. Note that these failures on its own will not affect system reliability or safety, and should not be included in spurious trip calculations.

The failure rates are valid for the useful life of the temperature transmitters TT*3*0 with 4..20 mA output (see Appendix 2).

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