Failure Modes, Effects and Diagnostic Analysis

Project:

Universal dual-input 2-wire transmitters TT 51 C * and TT 51 R *

Customer:

Krohne Messtechnik GmbH
Duisburg
Germany

Contract No.: KROHNE 09/12-72

Report No.: KROHNE 09/12-72 R011

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Management summary

This report summarizes the results of the hardware assessment carried out on the universal dual-input 2-wire transmitters TT 51 C * and TT 51 R * in hardware version 9 and software versions OPM-SW 01.01.04 and IPM-SW 01.01.03. Table 1 gives an overview of the different configurations that belong to the considered universal dual-input 2-wire transmitters TT 51 C * and TT 51 R *.

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: Configuration overview

TT 51 C SIL	Head mounted, dual input 2-wire temperature transmitter, SIL suitable
TT 51 C Ex SIL	Head mounted, dual input 2-wire temperature transmitter, SIL suitable and intrinsically safe
TT 51 R SIL	Rail mounted, dual input 2-wire temperature transmitter, SIL suitable
TT 51 R Ex SIL	Rail mounted, dual input 2-wire temperature transmitter, SIL suitable and intrinsically safe

For safety applications only the described versions were considered. All other possible output variants or electronics are not covered by this report.

The failure rates used in this analysis are from the *exida* Electrical & Mechanical Component Reliability Handbook (see [N2]) for Profile 2.

The failure rates for the universal dual-input 2-wire transmitters TT 51 C * and TT 51 R * do not include failures resulting from incorrect use of the universal dual-input 2-wire transmitters TT 51 C * and TT 51 R *, in particular humidity entering through incompletely closed housings or inadequate cable feeding through the inlets.

The universal dual-input 2-wire transmitters TT 51 C * and TT 51 R * are considered to be Type B[1] elements with a hardware fault tolerance of 0. For Type B elements with a hardware fault tolerance of 0 the SFF has to be ≥ 90% for SIL 2 elements according to table 2 of IEC 61508-2.

It is assumed that the connected safety logic solver is configured as per the NAMUR NE43 signal ranges, i.e. the universal dual-input 2-wire transmitters TT 51 C * and TT 51 R * 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 table shows how the above stated requirements are fulfilled for the worst case configuration of the universal dual-input 2-wire transmitters TT 51 C * and TT 51 R *.

[1] Type B element: "Complex" element (using micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2.

Table 2: Summary – IEC 61508:2010 failure rates

	exida **Profile 2** [2]
Failure category	**Failure rates (in FIT)**
Fail Safe Detected (λ_{SD})	**0**
Fail Safe Undetected (λ_{SU})	**0**
Fail Dangerous Detected (λ_{DD})	**399**
Fail detected (detected by internal diagnostics)	303
Fail high (detected by safety logic solver)	66
Fail low (detected by safety logic solver)	30
Annunciation detected (λ_{AD})	0
Fail Dangerous Undetected (λ_{DU})	**40** [3]
Annunciation undetected (λ_{AU})	1
No effect	153
No part	47
Total failure rate (safety function)	**439 FIT**
SFF	**90%**
DC_D	**90%**
MTBF	**178 years**
SIL AC [4]	**SIL2**

The failure rates are valid for the useful life of the universal dual-input 2-wire transmitters TT 51 C * and TT 51 R * (see Appendix 2).

[2] For details see Appendix 3.

[3] This value corresponds to a PFH of 4.04E-08 1/h. A fault reaction time of 5 minutes requires also that a connected device can detect the output state within a time that allows reacting within the process safety time.

[4] SIL AC (architectural constraints) means that the calculated values are within the range for hardware architectural constraints for the corresponding SIL but does not imply all related IEC 61508 requirements are fulfilled.

Single RTD 2/3w sensor

	Failure category				SFF	PFD_{avg} at T_{proof} =				PFH	SIL AC
	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}							
	[FIT]				[%]	1 year	2 years	5 years	10 years		
Close coupled low stress	0	0	438	49	89.9	2.44E-04	4.57E-04	1.09E-03	2.16E-03	4.90E-08	(SIL 2)
Close coupled high stress	0	0	1186	213	84.8	1.05E-03	1.97E-03	4.74E-03	9.36E-03	2.13E-07	(SIL 2)
Extension wires low stress	0	0	779	135	85.2	6.63E-04	1.25E-03	3.00E-03	5.93E-03	1.35E-07	(SIL 2)
Extension wires high stress	0	0	7999	1940	80.5	9.45E-03	1.79E-02	4.31E-02	8.52E-02	1.94E-06	(SIL 1)

The boxes marked in light grey in the following tables mean that the calculated PFD_{avg} and/or PFH values are within the allowed range for SIL 2 according to table 2 / 3 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 respectively 3.50E-07 1/h.

The boxes marked in medium grey mean that the calculated PFD_{avg} and PFH values are within the allowed range for SIL 2 according to table 2 / 3 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 respectively 3.50E-07 1/h.

The boxes marked in dark grey indicate that the PFD_{avg} respectively the PFH values do not fulfill the requirements for SIL 2 of table 2 / 3 of IEC 61508-1.

Dual RTD 3w sensor with activated sensor drift monitoring

	Failure category				SFF	PFD_{avg} at T_{proof} =				PFH	SIL AC
	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}							
	[FIT]				[%]	1 year	2 years	5 years	10 years		
Close coupled low stress	0	0	494	41	92.3	2.07E-04	3.85E-04	9.18E-04	1.81E-03	4.10E-08	SIL 2
Close coupled high stress	0	0	2302	57	97.6	3.27E-04	5.74E-04	1.35E-03	2.55E-03	5.70E-08	SIL 2
Extension wires low stress	0	0	1340	50	96.4	2.71E-04	4.87E-04	1.14E-03	2.22E-03	5.00E-08	SIL 2
Extension wires high stress	0	0	19209	230	98.8	1.56E-03	2.56E-03	5.55E-03	1.05E-02	2.30E-07	(SIL 1)

Single RTD 4w sensor

	Failure category				SFF	PFD_{avg} at T_{proof} =				PFH	SIL AC
	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}							
	[FIT]				[%]	1 year	2 years	5 years	10 years		
Close coupled low stress	0	0	447	43	91.2	2.16E-04	4.02E-04	9.62E-04	1.89E-03	4.30E-08	SIL 2
Close coupled high stress	0	0	1379	90	93.7	4.62E-04	8.52E-04	2.02E-03	3.97E-03	9.00E-08	(SIL 2)
Extension wires low stress	0	0	894	45	95.2	2.36E-04	4.31E-04	1.024E-03	1.99E-03	4.50E-08	SIL 2
Extension wires high stress	0	0	10299	140	98.7	9.16E-04	1.52E-03	3.34E-03	6.38E-03	1.40E-07	(SIL 2)

The boxes marked in light grey in the following tables mean that the calculated PFD_{avg} and/or PFH values are within the allowed range for SIL 2 according to table 2 / 3 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 respectively 3.50E-07 1/h.

The boxes marked in medium grey mean that the calculated PFD_{avg} and PFH values are within the allowed range for SIL 2 according to table 2 / 3 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 respectively 3.50E-07 1/h.

The boxes marked in dark grey indicate that the PFD_{avg} respectively the PFH values do not fulfill the requirements for SIL 2 of table 2 / 3 of IEC 61508-1.

Dual RTD 4w sensor with activated sensor drift monitoring (only for TT 51 R SIL versions); in preparation

	Failure category				SFF	PFD_{avg} at T_{proof} =				PFH	SIL AC
	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}							
	[FIT]				[%]	1 year	2 years	5 years	10 years		
Close coupled low stress	0	0	499	40	92.6	2.03 E-04	3.76 E-04	8.97 E-04	1.76 E-03	4.00 E-08	SIL 2
Close coupled high stress	0	0	2394	45	98.2	2.72 E-04	4.67 E-04	1.05 E-03	2.03 E-03	4.50 E-08	SIL 2
Extension wires low stress	0	0	1399	41	97.2	2.29 E-04	4.07 E-04	9.40 E-04	1.83 E-03	4.10 E-08	SIL 2
Extension wires high stress	0	0	2038 9	50	99.8	7.28 E-04	9.45 E-04	1.60 E-03	2.68 E-03	5.00 E-08	SIL 2

Single TC sensor

	Failure category				SFF	PFD_{avg} at T_{proof} =				PFH	SIL AC
	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}							
	[FIT]				[%]	1 year	2 years	5 years	10 years		
Close coupled low stress	0	0	494	45	91.7	2.27E-04	4.22E-04	1.01E-03	1.98E-03	4.50E-08	SIL 2
Close coupled high stress	0	0	2299	140	94.3	7.24E-04	1.33E-03	3.15E-03	6.19E-03	1.40E-07	(SIL 2)
Extension wires low stress	0	0	1299	140	90.3	7.00E-04	1.31E-03	3.13E-03	6.16E-03	1.40E-07	(SIL 2)
Extension wires high stress	0	0	18399	2040	90.0	1.02E-02	1.90E-02	4.56E-02	8.98E-02	2.04E-06	(SIL 1)

The boxes marked in light grey in the following tables mean that the calculated PFD_{avg} and/or PFH values are within the allowed range for SIL 2 according to table 2 / 3 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 respectively 3.50E-07 1/h.

The boxes marked in medium grey mean that the calculated PFD_{avg} and PFH values are within the allowed range for SIL 2 according to table 2 / 3 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 respectively 3.50E-07 1/h.

The boxes marked in dark grey indicate that the PFD_{avg} respectively the PFH values do not fulfill the requirements for SIL 2 of table 2 / 3 of IEC 61508-1.

Dual TC sensor

	Failure category				SFF	PFD_{avg} at T_{proof} =				PFH	SIL AC
	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}							
	[FIT]				[%]	1 year	2 years	5 years	10 years		
Close coupled low stress	0	0	599	41	93.6	2.10E-04	3.88E-04	9.21E-04	1.81E-03	4.10E-08	SIL 2
Close coupled high stress	0	0	4389	50	98.9	3.44E-04	5.61E-04	1.21E-03	2.30E-03	5.00E-08	SIL 2
Extension wires low stress	0	0	2389	50	97.9	2.96E-04	5.13E-04	1.16E-03	2.25E-03	5.00E-08	(SIL 2)
Extension wires high stress	0	0	40199	240	99.4	2.11E-03	3.15E-03	6.27E-03	1.15E-02	2.40E-07	(SIL 1)

Single TC + Single RTD 2/3w

	Failure category				SFF	PFD_{avg} at T_{proof} =				PFH	SIL AC
	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}							
	[FIT]				[%]	1 year	2 years	5 years	10 years		
Close coupled low stress	0	0	546	41	93.0	2.09E-04	3.87E-04	9.20E-04	1.81E-03	4.10E-08	SIL 2
Close coupled high stress	0	0	3345	54	98.4	3.38E-04	5.72E-04	1.27E-03	2.45E-03	5.40E-08	SIL 2
Extension wires low stress	0	0	1864	50	97.4	2.83E-04	5.00E-04	1.15E-04	2.23E-03	5.00E-08	SIL 2
Extension wires high stress	0	0	29704	235	99.2	1.83E-03	2.85E-03	5.91E-03	1.10E-02	2.35E-07	(SIL 1)

The boxes marked in light grey in the following tables mean that the calculated PFD_{avg} and/or PFH values are within the allowed range for SIL 2 according to table 2 / 3 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 respectively 3.50E-07 1/h.

The boxes marked in medium grey mean that the calculated PFD_{avg} and PFH values are within the allowed range for SIL 2 according to table 2 / 3 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 respectively 3.50E-07 1/h.

The boxes marked in dark grey indicate that the PFD_{avg} respectively the PFH values do not fulfill the requirements for SIL 2 of table 2 / 3 of IEC 61508-1.

Single TC + Single RTD 4w

	Failure category				SFF	PFD_{avg} at T_{proof} =				PFH	SIL AC
	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}							
	[FIT]				[%]	1 year	2 years	5 years	10 years		
Close coupled low stress	0	0	549	40	93.2	2.04E-04	3.78E-04	8.98E-04	1.77E-03	4.00E-08	SIL 2
Close coupled high stress	0	0	3392	48	98.6	3.11E-04	5.19E-04	1.14E-03	2.18E-03	4.80E-08	SIL 2
Extension wires low stress	0	0	1894	45	97.7	2.60E-04	4.55E-04	1.04E-03	2.02E-03	4.50E-08	SIL 2
Extension wires high stress	0	0	30294	145	99.5	1.42E-03	2.05E-03	3.93E-03	7.08E-03	1.45E-07	(SIL 2)

KROHNE
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SIL2

DECLARATION OF CONFORMITY

KONFORMITÄTSERKLÄRUNG DECLARATION DE CONFORMITE

KROHNE INOR, Travbanegatan 10, SE-213 77 Malmö, SWEDEN

We declare herewith under sole responsibility that:
Wir erklären hiermit unter alleiniger Verantwortung:
Nous déclarons sous notre seule responsabilité:

OPTITEMP TT 51 C / R

temperature transmitters are suitable for the use in a safety-related application up to SIL2 according IEC 61508:2010 provided that the safety instructions are observed (see safety manual). The assessment of the safety critical and dangerous random errors lead to the following parameters:

Die oben genannten Temperatur Transmitter sind unter Beachtung der Sicherheitshinweise im Sicherheitshandbuch für den Einsatz in sicherheitsgerichteten Applikationen bis SIL2 nach IEC 61508:2010 geeignet. Die Untersuchung der sicherheitsrelevanten und gefährlichen, zufälligen Fehler führt zu folgenden Kenndaten:

Les transmetteurs de la Température peuvent être utilisés pour des applications de sécurité fonctionnelle jusqu'á SIL2 selon IEC 61508:2010 en respectant les consignes de sécurité spécifiées dans le Safety Manual. L'évaluation des défaillances aléatoires et dangereuses pour la sécurité donne les valeurs suivantes :

Type B device | Hardware Fault Tolerance HFT=0

TT 51 C / R with 4..20 mA output signal

	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	SIL Level
Exida profile 2	**0 FIT**	**0 FIT**	**399 FIT**	**40 FIT**	**90,0%**	**SIL2**

Low demand mode

T[Proof]	1 year	5 years	10 years
$PFD_{AVG(Profile2)}$	**2,03E-04**	**9,04E-04**	**1,78E-03**

High demand mode

$PFH_{(Profile2)}$	**4,04E-08 1/h**

Reference: *exida* FMEDA report "KROHNE 09/12-72 R011, V3R1"

SP full assessment report "Functional safety assessment of OPTITEMP TT51C* /OPTITEMP TT51R* according to IEC 61508:2010".

For complete data of combinations of TT51 and sensors, see safety manual.

Alle Kombinationsmöglichkeiten des TT51 mit geeigneten Sensoren finden Sie im Sicherheitshandbuch.

Pour toutes les combinaisons possible de sondes avec le TT51, se reporter au manuel de sécurité (safety manual).

Malmö 2013-04-16

Benny Björkander
MD Krohne INOR

CERTIFIKAT

Type Examination Certificate
No. SC0267-13

OPTITEMP TT51C*/TT51R* temperature transmitter

Holder / Issued for / Manufacturer

Krohne Messtechnik GmbH, Ludwig-Krohne-Strasse 5, DE-470 58 Duisburg, Germany
Reg.number: DE119560126

Product name

OPTITEMP TT51C*/TT51R*

Product description

The OPTITEMP TT51C*/TT51R* are programmable transmitters designed primarily for temperature measurements in the process industry. They are two-wire, 4-20 mA current loop transmitters with power supply via the current loop.
OPTITEMP TT51C*/TT51R* have dual sensor input channels to make elaborate supervision and diagnostics possible.

OPTITEMP TT51C*/TT51R* temperature transmitter	Description
OPTITEMP TT51C SIL	SIL
OPTITEMP TT51C Ex SIL	SIL and ATEX
OPTITEMP TT51R SIL	SIL
OPTITEMP TT51R Ex SIL	SIL and ATEX

Certification

The product described above fulfils the requirements for SIL 2 of the standard IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems, part 1-3 for the following element safety function:

- Provide measurement values of the measured unit (typically temperature) with a maximum deviation from specified accuracy on 2%

The certification is based on a functional safety assessment according to IEC 61508 described in SP report PX25144:B dated 11th February 2013 together with functional tests and fault injections performed by SP on OPTITEMP TT51C*/TT51R* temperature transmitter described in SP report PX25144:D dated 11th January 2013 and safety manual for OPTITEMP TT51C*/TT51R* in the currently valid revision.

Note: The SIL (Safety Integrity Level) reached for the complete safety function must be determined by the end user.

SP Technical Research Institute of Sweden

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CERTIFIKAT

Type Examination Certificate
No. SC0267-13

Marking

Each sample that conforms in all respects with the original item certified may display the text "Type-examined by SP". When this marking is applied the marking shall also contain reference to the standard IEC 61508:2010, the reached SIL (Safety Integrity Level) of the item, the number of this certificate and the serial number or equivalent of the item.

Validity

This certificate is valid until not later than 18th February 2018.

Miscellaneous

Other terms and conditions are set out in SP's certification rules for type-examination, SPCR 123. This is the first edition of this certificate.

Borås, 18th February 2013

SP Technical Research Institute of Sweden
Certification

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