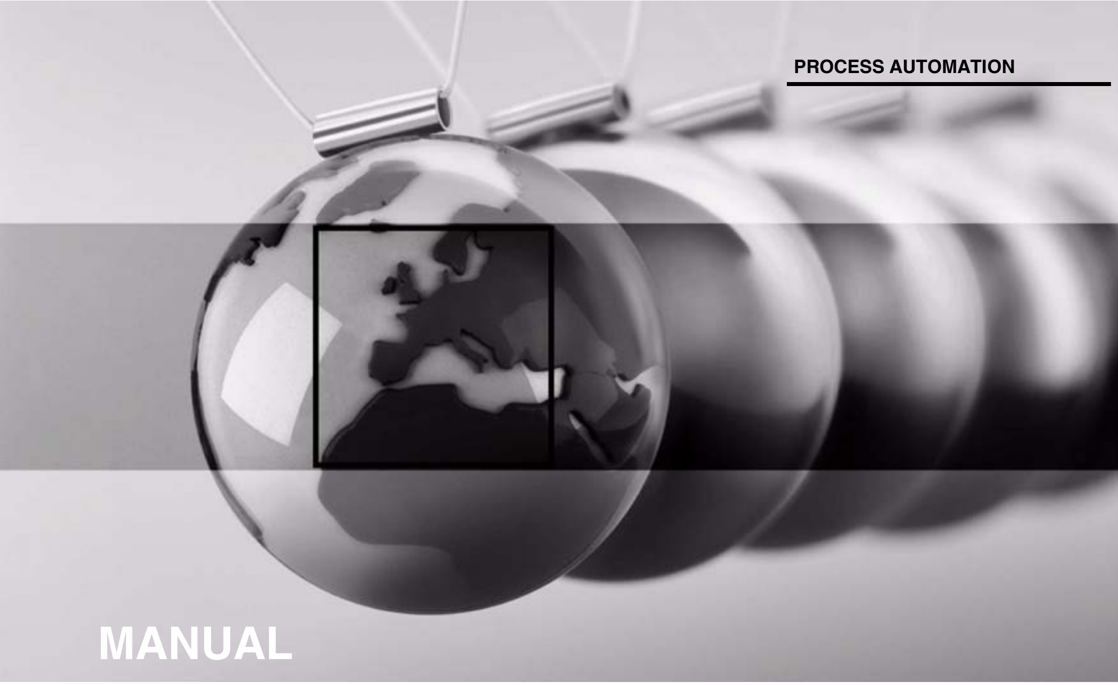
PROCESS AUTOMATION



MANUAL

Functional Safety

Switch Amplifier HiC283*

SIL

IEC 61508/61511

ISO9001

SIL 2

PEPPERL+FUCHS

PROTECTING YOUR PROCESS

1 Introduction

1.1 Contents

This document contains information for usage of the device in functional safety-related applications. You need this information to use your product throughout the applicable stages of the product life cycle. These can include the following:

- Product identification
- Delivery, transport, and storage
- Mounting and installation
- Commissioning and operation
- Maintenance and repair
- Troubleshooting
- Dismounting
- Disposal

Note!

This document does not substitute the instruction manual.

Note!

For full information on the product, refer to the instruction manual and further documentation on the Internet at www.pepperl-fuchs.com.

The documentation consists of the following parts:

- Present document
- Instruction manual
- Manual
- Datasheet

Additionally, the following parts may belong to the documentation, if applicable:

- EC-type of examination
- EU declaration of conformity
- Attestation of conformity
- Certificates
- Control drawings
- FMEDA report
- Assessment report
- Additional documents

For more information about functional safety products from Pepperl+Fuchs see www.pepperl-fuchs.com/sil.

1.2 Safety Information

Target Group, Personnel

Responsibility for planning, assembly, commissioning, operation, maintenance, and dismounting lies with the plant operator.

Only appropriately trained and qualified personnel may carry out mounting, installation, commissioning, operation, maintenance, and dismounting of the product. The personnel must have read and understood the instruction manual and the further documentation.

Intended Use

The device is only approved for appropriate and intended use. Ignoring these instructions will void any warranty and absolve the manufacturer from any liability.

The device is developed, manufactured and tested according to the relevant safety standards.

Use the device only

- for the application described
- with specified environmental conditions
- with devices that are suitable for this safety application

Improper Use

Protection of the personnel and the plant is not ensured if the device is not used according to its intended use.

1.3 Symbols Used

This document contains symbols for the identification of warning messages and of informative messages.

Warning Messages

You will find warning messages, whenever dangers may arise from your actions. It is mandatory that you observe these warning messages for your personal safety and in order to avoid property damage.

Depending on the risk level, the warning messages are displayed in descending order as follows:

STOP

Danger!

This symbol indicates an imminent danger.

Non-observance will result in personal injury or death.

⚠

Warning!

This symbol indicates a possible fault or danger.

Non-observance may cause personal injury or serious property damage.

△

Caution!

This symbol indicates a possible fault.

Non-observance could interrupt the device and any connected systems and plants, or result in their complete failure.

Informative Symbols

ℹ

Note!

This symbol brings important information to your attention.

➤

Action

This symbol indicates a paragraph with instructions. You are prompted to perform an action or a sequence of actions.

2 Product Description

2.1 Function

This isolated barrier is used for intrinsic safety applications.

The device transfers digital signals (NAMUR sensors or dry contacts) from a hazardous area to a safe area.

Via switches the mode of operation can be reversed and the line fault detection can be switched off.

This device mounts on a HiC Termination Board.

HiC2831 and HiC2832

The input controls two passive transistor outputs with a resistive output characteristic (acc. to EN60947-5-6).

The outputs have three defined states: 1-Signal = 1.8 kΩ, 0-Signal = 14 kΩ and fault > 100 kΩ.

This output characteristic offers line fault transparency on the signal lines.

HiC2831R1 and HiC2832R1

The input controls two passive transistor outputs with a resistive output characteristic.

The outputs have three defined states: 1-Signal = 6.5 V voltage drop, 0-Signal = 33 kΩ and 6.5 V voltage drop and fault > 100 kΩ.

This output characteristic offers line fault transparency on the signal lines.

HiC2831R2 and HiC2832R2

The input controls two passive transistor outputs with a resistive output characteristic.

The outputs have three defined states: 1-Signal = 5 kΩ, 0-Signal = 15 kΩ and fault > 100 kΩ.

This output characteristic offers line fault transparency on the signal lines.

HiC2831R3 and HiC2832R3

The input controls two passive transistor outputs with a resistive output characteristic.

The outputs have three defined states:
1-Signal = 100 Ω ... 600 Ω, 0-Signal = 19 kΩ and fault > 100 kΩ.

This output characteristic offers line fault transparency on the signal lines.

2.2 Interfaces

The device has the following interfaces:

- Safety relevant interfaces:
  - 1-channel devices: input I, output I, output II (optional)
  - 2-channel devices: input I, input II, output I, output II
- Non-safety relevant interfaces: output FAULT

ℹ ***Note!***

For corresponding connections see datasheet.

2.3 Marking

Pepperl+Fuchs GmbH Lilienthalstraße 200, 68307 Mannheim, Germany

HiC2831, HiC2832 HiC2831R1, HiC2832R1 HiC2831R2, HiC2832R2 HiC2831R3, HiC2832R3	Up to SIL 2

2.4 Standards and Directives for Functional Safety

Device-specific standards and directives

Functional safety	IEC/EN 61508, part 2, edition 2010: Functional safety of electrical/electronic/programmable electronic safety-related systems (manufacturer)

System-specific standards and directives

Functional safety	IEC/EN 61511, part 1 – 3, edition 2003: Functional safety – Safety instrumented systems for the process industry sector (user)

3 Planning

3.1 System Structure

3.1.1 Low Demand Mode of Operation

If there are two control loops, one for the standard operation and another one for the functional safety, then usually the demand rate for the safety loop is assumed to be less than once per year.

The relevant safety parameters to be verified are:

- the PFD_{avg} value (average **P**robability of dangerous **F**ailure on **D**emand) and the T_1 value (proof test interval that has a direct impact on the PFD_{avg} value)
- the SFF value (**S**afe **F**ailure **F**raction)
- the HFT architecture (**H**ardware **F**ault **T**olerance)

3.1.2 High Demand or Continuous Mode of Operation

If there is only one safety loop, which combines the standard operation and safety-related operation, then usually the demand rate for this safety loop is assumed to be higher than once per year.

The relevant safety parameters to be verified are:

- the PFH value (**P**robability of dangerous **F**ailure per **H**our)
- Fault reaction time of the safety system
- the SFF value (**S**afe **F**ailure **F**raction)
- the HFT architecture (**H**ardware **F**ault **T**olerance)

3.1.3 Safe Failure Fraction

The safe failure fraction describes the ratio of all safe failures and dangerous detected failures to the total failure rate.

$SFF = (\lambda_s + \lambda_{dd}) / (\lambda_s + \lambda_{dd} + \lambda_{du})$

A safe failure fraction as defined in IEC/EN 61508 is only relevant for elements or (sub)systems in a complete safety loop. The device under consideration is always part of a safety loop but is not regarded as a complete element or subsystem.

For calculating the SIL of a safety loop it is necessary to evaluate the safe failure fraction of elements, subsystems and the complete system, but not of a single device.

Nevertheless the SFF of the device is given in this document for reference.

3.2 Assumptions

The following assumptions have been made during the FMEDA:

- Failure rates are constant, wear is not considered.
- The device shall claim less than 10 % of the total failure budget for a SIL 2 safety loop.
- For a SIL 2 application operating in low demand mode the total PFD_{avg} value of the SIF (**S**afety **I**nstrumented **F**unction) should be smaller than 10^{-2}, hence the maximum allowable PFD_{avg} value would then be 10^{-3}.
- For a SIL 2 application operating in high demand mode the total PFH value of the SIF should be smaller than 10^{-6} per hour, hence the maximum allowable PFH value would then be 10^{-7} per hour.
- The stress levels are average for an industrial environment and the environment is similar to IEC/EN 60654-1 Class C (sheltered location) with temperature limits in the range of the manufacturer's specifications and an average temperature of 40 ºC over a long period. The humidity level is within manufacturer's rating.
- The listed failure rates are valid for operating stress conditions typical of an industrial field environment similar to IEC/EN 60654-1 Class C with an average temperature over a long period of time of 40 ºC. For a higher average temperature of 60 ºC, the failure rates must be multiplied by a factor of 2.5 based on experience. A similar factor must be used if frequent temperature fluctuations are expected.
- The safety-related device is considered to be of type **A** device with a hardware fault tolerance of **0**.
- Since the safety loop has a hardware fault tolerance of **0** and it is a type **A** device, the SFF must be > 60 % according to table 2 of IEC/EN 61508-2 for a SIL 2 (sub) system.
- Failure rate based on the Siemens standard SN29500.
- Since the two outputs of the device use common components, these outputs must not be used in the same safety function.

3.3 Safety Function and Safe State

Safe State

The safe state of output I and output II is the high impedant state or the fault state.

Safety Function

HiC2831*
for output I and output II:

S1 position II (normal mode of operation)	If a low current is present at input I, output I and output II are high impedant (safe state).
S1 position I (inverse mode of operation)	If a high current is present at input I, output I and output II are high impedant (safe state).

HiC2832*
for channel I:

S1 position II (normal mode of operation)	If a low current is present at input I, output I is high impedant (safe state).
S1 position I (inverse mode of operation)	If a high current is present at input I, output I is high impedant (safe state).

for channel II:

S3 position II (normal mode of operation)	If a low current is present at input II, output II is high impedant (safe state).
S3 position I (inverse mode of operation)	If a high current is present at input II, output II is high impedant (safe state).

Line Fault Diagnostics

The input circuit of all device versions is supervised, if the line fault detection is active (mandatory, see datasheet) If a line fault is detected, the outputs change in the fault state (safe state).

Reaction Time

1. The response time for the safety function between input and output is < 0.1 ms. Load conditions:
   - HiC283*: 8 V, 1 kΩ
   - HiC283*R1: 24 V, 2 kΩ
   - HiC283*R2: 24 V, 250 Ω
   - HiC283*R3: 24 V, 4.2 kΩ
2. The fault detect and fault reaction time is < 100 ms. A fault diagnostics at the input leads to fault state
3. The reaction time of the fault outputs is < 100 ms.

Note!

The fault indication output is not safety relevant.

Note!

For more information see the corresponding datasheets.

3.4 Characteristic Safety Values

Parameters acc. to IEC 61508	Characteristic values	
Assessment type and documentation	Full assessment	
Device type	A	
Mode of operation	Low Demand Mode or High Demand Mode	
HFT	0	
SIL (SC)	2	
MTBF [1] (HiC2831*)	154.8 years	
MTBF [1] (HiC2832*)	120.1 years	
PTC	99 %	
Safety function	Inverse mode of operation [2]	Normal mode of operation [2]
λ_{safe}	106 FIT	106 FIT
λ_{dd}	3.3 FIT	3.3 FIT
λ_{du}	26.8 FIT	22.8 FIT
$\lambda_{total\ (safety\ function)}$	136 FIT	132 FIT
SFF [3]	80.3 %	82.7 %
PFH	2.68×10^{-8} 1/h	2.28×10^{-8} 1/h
PFD_{avg} for T_1 = 1 year	1.28×10^{-4}	1.09×10^{-4}
PFD_{avg} for T_1 = 2 years	2.56×10^{-4}	2.18×10^{-4}
PFD_{avg} for T_1 = 5 years	6.40×10^{-4}	5.44×10^{-4}

Table 3.1

[1] acc. to SN29500. This value includes failures which are not part of the safety function/MTTR = 24 h.
[2] The device can be used in two modes of operation, inverse of mode operation and normal mode of operation.
[3] "Annunciation failures" and "No effect failures" are not influencing the safety function and are therefor not included in the calculation of the SFF.

The characteristic safety values like PFD, PFH, SFF, HFT and T_1 are taken from the FMEDA report. Observe that PFD and T_1 are related to each other.

The function of the devices has to be checked within the proof test interval (T_1).

3.5 Useful Life Time

Although a constant failure rate is assumed by the probabilistic estimation this only applies provided that the useful lifetime of components is not exceeded. Beyond this useful lifetime, the result of the probabilistic estimation is meaningless as the probability of failure significantly increases with time. The useful lifetime is highly dependent on the component itself and its operating conditions – temperature in particular. For example, the electrolytic capacitors can be very sensitive to the operating temperature.

This assumption of a constant failure rate is based on the bathtub curve, which shows the typical behavior for electronic components.

Therefore it is obvious that failure calculation is only valid for components that have this constant domain and that the validity of the calculation is limited to the useful lifetime of each component.

It is assumed that early failures are detected to a huge percentage during the installation and therefore the assumption of a constant failure rate during the useful lifetime is valid.

However, according to IEC/EN 61508-2, a useful lifetime, based on general experience, should be assumed. Experience has shown that the useful lifetime often lies within a range period of about 8 ... 12 years.

As noted in DIN EN 61508-2:2011 note N3, appropriate measures taken by the manufacturer and plant operator can extend the useful lifetime.

Our experience has shown that the useful lifetime of a Pepperl+Fuchs product can be higher

- if there are no components with reduced life time in the safety loop (for example electrolytic capacitors, relays, flash memories, optocoupler) which can produce dangerous undetected failures and
- if the ambient temperature is significantly below 60 °C.

Please note that the useful lifetime refers to the (constant) failure rate of the device. The effective life time can be higher.

4 Mounting and Installation

Installing the device

1. Observe the safety instructions in the instruction manual.
2. Observe the information in the manual.
3. Observe the requirements for the safety loop.
4. Connect the device only to devices that are suitable for this safety application.
5. Check the safety function to ensure the expected output behavior.

4.1 Configuration

Configuring the Device

The device is configured via DIP switches. The DIP switches for setting the safety functions are on the side of the device.

1. De-energize the device before configuring the device.
2. Remove the device.
3. Configure the device for the required safety function via the DIP switches, see chapter 3.3.
4. Secure the DIP switches to prevent unintentional adjustments.
5. Mount the device.
6. Connect the device again.

Note!

For more information see the corresponding datasheets.

5 Operation

Danger!

Danger to life from missing safety function

If the safety loop is put out of service, the safety function is no longer guaranteed.

- Do not deactivate the device.
- Do not bypass the safety function.
- Do not repair, modify, or manipulate the device.

Operating the device

1. Observe the safety instructions in the instruction manual.
2. Observe the information in the manual.
3. Use the device only with devices that are suitable for this safety application.
4. Correct any occurring safe failures within 24 hours. Take measures to maintain the safety function while the device is being repaired.

5.1 Proof Test Procedure

According to IEC/EN 61508-2 a recurring proof test shall be undertaken to reveal potential dangerous failures that are not detected otherwise.

Check the function of the subsystem at periodic intervals depending on the applied PFD_{avg} in accordance with the characteristic safety values.
See chapter 3.4.

It is under the responsibility of the plant operator to define the type of proof test and the interval time period.

Check the settings after the configuration by suitable tests.

Equipment required:

- Digital multimeter without special accuracy

  Use for the proof test of the intrinsic safety side of the device a special digital multimeter for intrinsically safe circuits.

  If intrinsically safe circuits are operated with non-intrinsically safe circuits, they must no longer be used as intrinsically safe circuits.
- Dual power supply, set to 24 V DC resp. 8 V DC (NAMUR voltage).

Proof Test Procedure

1. Prepare a test set-up, see figures below.
2. Test the devices in the mode of operation they are used in. If necessary, change the configuration of the device. Verify the input and output values as given in table below.
3. Test each input channel individually.
4. Simulate the sensor state by a potentiometer of 4.7 kΩ. The threshold must be between 1.4 mA and 1.9 mA. The hysteresis must be between 150 µA and 250 µA.

   ↳ For normal mode of operation the outputs must have a low impedance, if the input current is above the threshold. This state is indicated by yellow LED.

   ↳ For inverse mode of operation the outputs must have a low impedance, if the input current is below the threshold. This state is indicated by yellow LED.
5. Simulate the sensor state by a resistor R_{SC} (220 Ω, short circuit detection) or a resistor R_{LB} (150 kΩ, lead breakage detection).

   ↳ The device must detect an external fault. This state is indicated by red LED and the output of the corresponding channel must be in fault state.
6. Test the outputs with a certain current. Test that the outputs are definitely high impedant (see table, I_{off}), if the yellow LED is off.
7. Set back the device to the original settings after the test.
8. Secure the DIP switches to prevent unintentional adjustments.

Device	R	U	I_{on} (mA)	I_{off} (mA)	I_{fault} (mA)
HiC283*	1 kΩ	8 V	2.6 mA < I_{on} < 3.2 mA	0.5 mA < I_{off} < 0.6 mA	I_{fault} < 0.05 mA
HiC283*R1	2 kΩ	24 V	8.0 mA < I_{on} < 9.2 mA	0.46 mA < I_{off} < 0.62 mA	I_{fault} < 0.05 mA
HiC283*R2	250 Ω	24 V	4.2 mA < I_{on} < 4.6 mA	1.48 mA < I_{on} < 1.62 mA	I_{fault} < 0.05 mA
HiC283*R3	4.3 kΩ	24 V	4.9 mA < I_{on} < 5.2 mA	1.01 mA < I_{on} < 1.06 mA	I_{fault} < 0.05 mA

Table 5.1

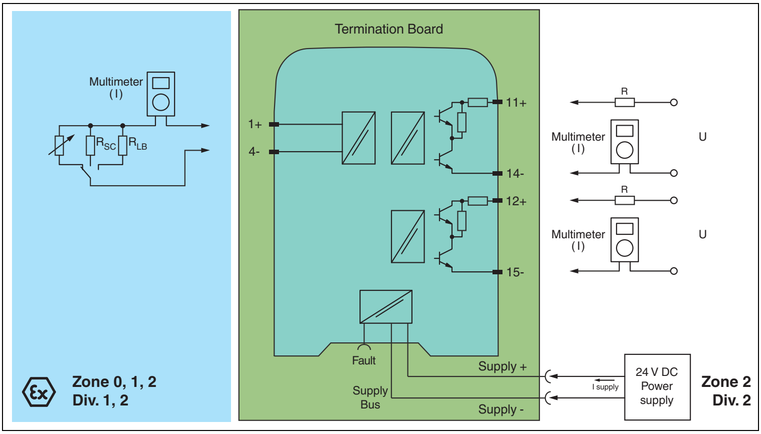


Figure 5.1 Proof test set-up for HiC2831, HiC2831R2, and HiC2831R3

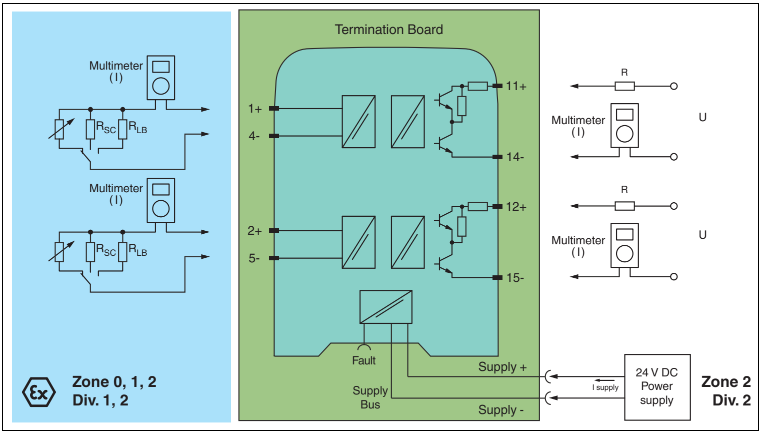


Figure 5.2 Proof test set-up for HiC2832, HiC2832R2, and HiC2832R3

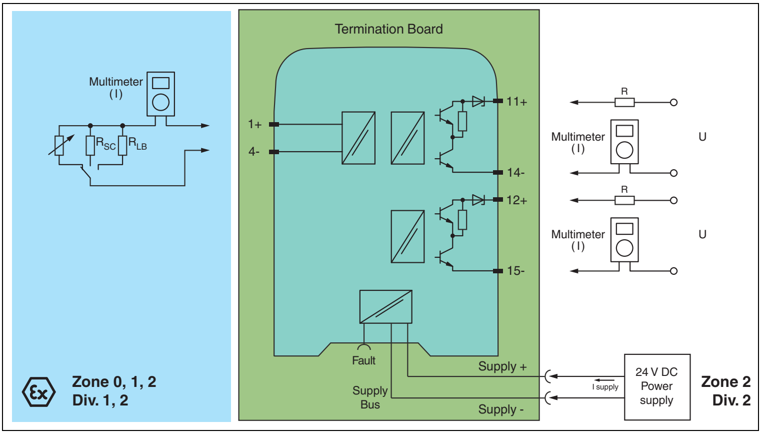


Figure 5.3 Proof test set-up for HiC2831R1

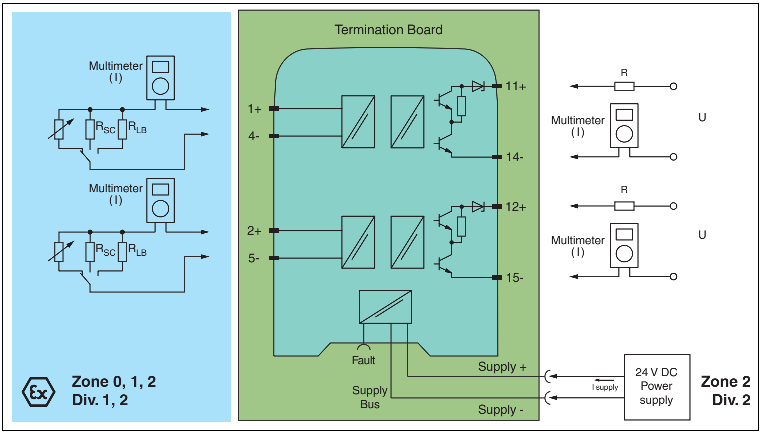


Figure 5.4 Proof test set-up for HiC2832R1

Tip

The easiest way to test HiC devices is by using a stand-alone HiCTB**-SCT-***-**-** termination board. In this test, it is not necessary to disconnect the wiring of the existing application. Faults in a subsequent wiring can be avoided.

6 Maintenance and Repair

Danger!

Danger to life from missing safety function

If the safety loop is put out of service, the safety function is no longer guaranteed.

- Do not deactivate the device.
- Do not bypass the safety function.
- Do not repair, modify, or manipulate the device.

Maintaining, Repairing or Replacing the Device

In case of maintenance, repair or replacement of the device, proceed as follows:

1. Implement appropriate maintenance procedures for regular maintenance of the safety loop.
2. Ensure the proper function of the safety loop, while the device is maintained, repaired or replaced.
   If the safety loop does not work without the device, shut down the application.
   Do not restart the application without taking proper precautions.
   Secure the application against accidental restart.
3. Do not repair a defective device. A defective device must only be repaired by the manufacturer.
4. Replace a defective device only by a device of the same type.

7 List of Abbreviations

ESD	**E**mergency **S**hut**d**own
FIT	**F**ailure **I**n **T**ime in 10^{-9} 1/h
FMEDA	**F**ailure **M**ode, **E**ffects, and **D**iagnostics **A**nalysis
λ_{s}	Probability of safe failure
λ_{dd}	Probability of dangerous detected failure
λ_{du}	Probability of dangerous undetected failure
$\lambda_{\text{no effect}}$	Probability of failures of components in the safety loop that have no effect on the safety function. The no effect failure is not used for calculation of SFF.
$\lambda_{\text{not part}}$	Probability of failure of components that are not in the safety loop
$\lambda_{\text{total (safety function)}}$	Safety function
HFT	**H**ardware **F**ault **T**olerance
MTBF	**M**ean **T**ime **B**etween **F**ailures
MTTR	**M**ean **T**ime **T**o **R**estoration
PCS	**P**rocess **C**ontrol **S**ystem
PFD$_{avg}$	Average **P**robability of dangerous **F**ailure on **D**emand
PFH	Average frequency of dangerous failure
PTC	**P**roof **T**est **C**overage
SFF	**S**afe **F**ailure **F**raction
SIF	**S**afety **I**nstrumented **F**unction
SIL	**S**afety **I**ntegrity **L**evel
SIL (SC)	**S**afety **I**ntegrity **L**evel (**S**ystematic **C**apability)
SIS	**S**afety **I**nstrumented **S**ystem
T$_{1}$	Proof Test Interval

FLT	Fault
LB	**L**ead **B**reakage
LFD	**L**ine **F**ault **D**etection
SC	**S**hort **C**ircuit

PROCESS AUTOMATION – PROTECTING YOUR PROCESS

Worldwide Headquarters
Pepperl+Fuchs GmbH
68307 Mannheim · Germany
Tel. +49 621 776-0
E-mail: info@de.pepperl-fuchs.com

For the Pepperl+Fuchs representative
closest to you check www.pepperl-fuchs.com/contact

www.pepperl-fuchs.com

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DOCT-2386D
09/2016