Functional Safety

Z-System Zener Barriers

Manual

SIL

IEC 61508/61511

ISO9001

SIL 2

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PEPPERL+FUCHS

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Worldwide

Pepperl+Fuchs Group
Lilienthalstr. 200
68307 Mannheim
Germany
Phone: +49 621 776 - 0
E-mail: info@de.pepperl-fuchs.com

North American Headquarters

Pepperl+Fuchs Inc.
1600 Enterprise Parkway
Twinsburg, Ohio 44087
USA
Phone: +1 330 425-3555
E-mail: sales@us.pepperl-fuchs.com

Asia Headquarters

Pepperl+Fuchs Pte. Ltd.
P+F Building
18 Ayer Rajah Crescent
Singapore 139942
Phone: +65 6779-9091
E-mail: sales@sg.pepperl-fuchs.com
https://www.pepperl-fuchs.com

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1 Introduction

1.1 Content of this Document

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.

Note

For specific device information such as the year of construction, scan the QR code on the device. As an alternative, enter the serial number in the serial number search 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:

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

For more information about Pepperl+Fuchs products with functional safety, 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:

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

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.

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2 Product Description

2.1 Function

General

The zener barrier prevents the transfer of unacceptably high energy from the non-explosion-hazardous area into the explosion-hazardous area.

The zener diodes in the device are connected in the reverse direction. The breakdown voltage of the diodes is not exceeded in normal operation. If this voltage is exceeded, due to a fault in the non-explosion-hazardous area, the diodes start to conduct, causing the fuse to blow.

In terms of function, 3 device versions are distinguished, which differ in their safety characteristics. For more information see chapter 3.4.

Z7** Zener Barrier, DC Version, Positive Polarity

The device has a positive polarity, i. e. the anodes of the zener diodes are grounded.

Z8** Zener Barrier, DC Version, Negative Polarity

The device has a negative polarity, i. e. the cathodes of the zener diodes are grounded.

Z9** Zener barrier, AC Version

The device has alternating polarities, i. e. interconnected zener diodes are employed and one side is grounded. The device can be used for both alternating voltage signals and direct voltage signals.

Z***.F Zener Barrier

This device is equipped with a replaceable fuse.

Z***.1K Zener Barrier

The device has an increased nominal resistance of 1 kΩ.

Z***.CL Zener Barrier

The connection to the field circuit is equipped with a current limitation.

Z***.H Zener Barrier

This high power version has a smaller serial resistance and therefore provides higher voltage to the field device.

Z***.R Zener Barrier

Asymmetrical devices are for optimization of applications which have different voltage levels regarding to ground potential.

Depending on the application, increased or decreased intrinsic safety parameters apply for serial or parallel connection. For the detailed parameters refer to the zener barrier certificate. Application examples can be found in the system description of the zener barriers.

2.2 Interfaces

The device has the following interfaces:

- Safety relevant interfaces: input and output

Note

For corresponding connections see datasheet.

2.3 Marking

Pepperl+Fuchs Group Lilienthalstraße 200, 68307 Mannheim, Germany
Internet: www.pepperl-fuchs.com

Z7**(.1K)(.CL)(.F)(.H)(.R), Z8**(.1K)(.CL)(.F)(.H)(.R), Z9**(.1K)(.F)(.H)(.R)	Up to SIL 2

The stars replace a combination of characters, depending on the product.

2.4 Standards and Directives for Functional Safety

Device specific standards and directives

Functional safety	IEC/EN 61508, part 1 – 7, edition 2010: Functional safety of electrical/electronic/programmable electronic safety-related systems (manufacturer)

System-specific standards and directives

Functional safety	IEC 61511-1:2016+COR1:2016+A1:2017 EN 61511-1:2017+A1:2017 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)

3.2 Assumptions

The following assumptions have been made during the FMEDA:

- Failure rate based on the Siemens standard SN 29500.
- Failure rates are constant, wear is not considered.
- If you use 2 channels of one device for one safety function, double the values given in the assessment.
- 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 °C 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 °C. For a higher average temperature of 60 °C, 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 control loop has a hardware fault tolerance of **0** and it is a type **A** device. A SFF value for this device is not given, since this value has to be calculated in conjunction with the connected field device, as described in the following section.
- It was considered how the device transmits input signals and output signals.
  Since the differences between the different transfer types are not signficant, only the results of the worst tranfer type are given, since they represent the worst use case.

Application Information

The zener barrier and the connected device (field device, isolator or actuator) have to be considered together. The PFD_{avg}/PFH budget of the device categories in the entire safety loop is:

- Actuator (valve) 40 %
- Transmitter (sensor) 25 %
- Isolator 10 %

As an overview for SIL 2 safety loop this means:

	SIL 2	
	PFH	PFD_{avg}
Total	10^{-6}	10^{-2}
Actuator (40 %)	4×10^{-7}	4×10^{-3}
Transmitter (25 %)	2.5×10^{-7}	2.5×10^{-3}
Isolator (10 %)	10^{-7}	10^{-3}

Table 3.1 Overview PFD_{avg}/PFH budget

3.3 Safety Function and Safe State

The zener barrier has to be considered in conjunction with the connected field device. The safety function of the zener barrier is defined by the signals and settings of the connected device (e. g. isolator, DCS input, output, field device).

Safety Function

The safety function of the device is to behave like a piece of copper wire, passing through the process signal without being altered. In case of a 0/4 mA to 20 mA signal the maximum additional loop current fault of the device is maximum 2 % full scale.

Safe State

The safe state is defined as the device interrupting the input signal.

Reaction Time

The reaction time is < 20 ms.

3.4 Characteristic Safety Values

In terms of function, 3 device versions are distinguished, which differ in their safety characteristics. In the following tables, the worst case values for the type of barriers are given for each device version.

The following tables contain no SFF characteristics, since this characteristics has to be calculated with consideration of the connected field device.

Simple Zener Barriers, 1oo1 Structure

Z705, Z710, Z715(.1K)(.F), Z755, Z757, Z764, Z765(.F), channel 2 of Z788(.H)(.R)
Z810, Z815(.1K)(.F), Z857, Z864, Z865(.F), channel 2 of Z888(.H)(.R)

Table 3.2

Parameters	Characteristics
Assessment type and documentation	FMEDA report and proven-in-use
Device type	A
Mode of operation	Low demand mode or high demand mode
Safety function	Signal transfer to the field device
HFT	0
SIL	2
SC	3
λ_{s}	10 FIT
λ_{dd}	0 FIT
λ_{du}	3 FIT
$\lambda_{no\ effect}$	46 FIT
$\lambda_{not\ part}$	0 FIT
$\lambda_{total\ (safety\ function)}$	13 FIT
PTC	100 %
MTBF [1]	1968 years
PFH	2.45×10^{-9} 1/h
PFD_{avg} for T_1 = 1 year	1.07×10^{-5}
PFD_{avg} for T_1 = 2 years	2.14×10^{-5}
PFD_{avg} for T_1 = 5 years	5.35×10^{-5}

Table 3.3

1 acc. to SN29500. This value includes failures which are not part of the safety function/MTTR = 24 h. The value is calculated for one safety function of the device.

Complex Zener Barriers, 1oo1 Structure

Z713, Z722, Z728(.F)(.H), Z772, Z778, Z779(.F)(.H), Z786, Z787(.F)(.H), channel 1 of Z788(.H)(.R), Z796
Z813, Z822, Z828(.F)(.H), Z872, Z878, Z886, channel 1 of Z888(.H)(.R), Z896
Z905, Z910, Z915(.1K), Z928, Z954, Z955, Z960(.F), Z961(.F)(.H), Z964, Z965, Z966(.F)(.H), Z967, Z972, Z978

Table 3.4

Parameters	Characteristics
Assessment type and documentation	FMEDA report and proven-in-use
Device type	A
Mode of operation	Low demand mode or high demand mode
Safety function	Signal transfer to the field device
HFT	0
SIL	2
SC	3
λ_s	5,62 FIT
λ_{dd}	0 FIT
λ_{du}	6,28 FIT
$\lambda_{no\ effect}$	24,3 FIT
$\lambda_{not\ part}$	0 FIT
$\lambda_{total\ (safety\ function)}$	11,9 FIT
PTC	100 %
MTBF [1]	3153 years
PFH	6.28×10^{-9} 1/h
PFD_{avg} for T_1 = 1 year	2.75×10^{-5}
PFD_{avg} for T_1 = 2 years	5.50×10^{-5}
PFD_{avg} for T_1 = 5 years	1.38×10^{-4}

1 acc. to SN29500. This value includes failures which are not part of the safety function/MTTR = 24 h.
The value is calculated for one safety function of the device.

Zener Barriers with Current Limitation, 1oo1 Structure

Z728.CL, Z728.CL

Table 3.5

Parameters	Characteristics
Assessment type and documentation	FMEDA report and proven-in-use
Device type	A
Mode of operation	Low demand mode or high demand mode
Safety function	Signal transfer to the field device
HFT	0
SIL	2
SC	3
λ_s	6 FIT
λ_{dd}	0 FIT
λ_{du}	12 FIT
$\lambda_{no\ effect}$	24 FIT
$\lambda_{not\ part}$	0 FIT
$\lambda_{total\ (safety\ function)}$	18 FIT
PTC	100 %
MTBF [1]	2691 years
PFH	1.19×10^{-8} 1/h
PFD_{avg} for T_1 = 1 year	5.21×10^{-5}
PFD_{avg} for T_1 = 2 years	1.04×10^{-4}
PFD_{avg} for T_1 = 5 years	2.61×10^{-4}

1 acc. to SN29500. This value includes failures which are not part of the safety function/MTTR = 24 h. The value is calculated for one safety function of the device.

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 Lifetime

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, 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 to 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 the ambient conditions support a long life time, for example if the ambient temperature is significantly below the maximum ambient temperature.

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

The estimated useful lifetime is greater than the warranty period prescribed by law or the manufacturer's guarantee period. However, this does not result in an extension of the warranty or guarantee services. Failure to reach the estimated useful lifetime is not a material defect.

4 Mounting and Installation

Mounting and 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

A configuration of the device is not necessary and not possible.

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 instruction 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 replaced.

5.1 Proof Test

This section describes a possible proof test procedure. The user is not obliged to use this proposal. The user may consider different concepts with an individual determination of the respective effectiveness, e. g. concepts according to NA106:2018.

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 provided. 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.

Equipment required:

- 2 digital multimeters providing the possibility to measure current voltage and resistance with an accuracy of ±1 %
- Power supply with a selectable AC or DC voltage up to the maximum voltage, see datasheet

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Proof Test Procedure

1. Put out of service the entire safety loop. Protect the application by means of other measures.
2. Prepare a test set-up.
3. Measure the series resistance specified in the datasheet between input and output (e. g. terminals 1 and 8) with a multimeter.
   ↳ The measured value should correspond approximately to the specification in the datasheet.
4. Limit the supply current for the device to the maximum current specified in the datasheet.
5. Set the voltage limit of the supply for the device to the supply loop working voltage specified in the datasheet.
6. Supply the device at the input (e. g. terminals 7 and 8) with the supply loop working voltage specified in the datasheet.
7. Check the value at the output (e. g. terminals 1 and 2) with a multimeter.
   ↳ The measured value should be approximately equal to the voltage applied to the input.
8. Supply the device at the input (e. g. terminals 7 and 8) with the measurement loop working voltage specified in the datasheet. [1]
9. Set the current in the measurement loop to the maximum value of the application. [1]
10. Check that the difference between the input current and output current is less than 10 µA. [1]
11. After the test, reset the device to the original settings.

Checking the Current Limitation

For devices with current limitation (Z***.CL), the current can be set at the supply at the device input up to the maximum current specified in the datasheet.
Make sure that the current rating of the fuse specified in the datasheet of the device is not exceeded.

Test the current limitation by connecting a suitable resistor as a load to the output.

↳ The resistance value results from the current and voltage specified in the datasheet (R = U / I). For the power rating of the resistor, P_o from the datasheet or P = U x I can be used.

[1] Perform steps 8 to 10 for applications where current accuracy measurement is important.

6 Maintenance and Repair

Danger!

Danger to life from missing safety function

Changes to the device or a defect of the device can lead to device malfunction.
The function of the device and the safety function is no longer guaranteed.

Do not repair, modify, or manipulate the device.

Maintaining or Replacing the Device

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

1. Implement appropriate maintenance procedures for regular maintenance of the safety loop.
2. While the device is maintained or replaced, the safety function does not work.
   Exception: The safety function is still guaranteed if the device is operated in redundancy.
   Take appropriate measures to protect personnel and equipment while the safety function is not available.
   Secure the application against accidental restart.
3. Do not repair a defective device.
4. If there is a defect, always replace the device with an original device.

Reporting Device Failure

If you use the device in a safety loop according to IEC/EN 61508, it is required to inform the device manufacturer about possible systematic failures.

1. Report all failures in the safety function that are due to functional limitations or a loss of device function – especially in the case of possible dangerous failures.
1. In these cases, contact your local sales partner or the Pepperl+Fuchs technical sales support (service line).
1. It is not necessary to report failures in the safety function that are due to external influences or damage.

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
$\lambda_{no\ effect}$	Probability of failures of components in the safety loop that have no effect on the safety function.
$\lambda_{not\ part}$	Probability of failure of components that are not in the safety loop
$\lambda_{total\ (safety\ function)}$	Probability of failure of components that are in the safety loop
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 per hour
PLC	**P**rogrammable **L**ogic **C**ontroller
PTC	**P**roof **T**est **C**overage
SC	**S**ystematic **C**apability
SFF	**S**afe **F**ailure **F**raction
SIF	**S**afety **I**nstrumented **F**unction
SIL	**S**afety **I**ntegrity **L**evel
SIS	**S**afety **I**nstrumented **S**ystem
T_1	Proof Test Interval

Your automation, our passion.

Explosion Protection

- Intrinsic Safety Barriers
- Signal Conditioners
- FieldConnex® Fieldbus
- Remote I/O Systems
- Electrical Ex Equipment
- Purge and Pressurization
- Industrial HMI
- Mobile Computing and Communications
- HART Interface Solutions
- Surge Protection
- Wireless Solutions
- Level Measurement

Industrial Sensors

- Proximity Sensors
- Photoelectric Sensors
- Industrial Vision
- Ultrasonic Sensors
- Rotary Encoders
- Positioning Systems
- Inclination and Acceleration Sensors
- Fieldbus Modules
- AS-Interface
- Identification Systems
- Displays and Signal Processing
- Connectivity

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