Functional Safety

Surge Protection Barriers K-LB-*.*, F*-LB-I, P-LB-*.*.*

Manual

SIL

IEC 61508/61511

ISO9001

SIL 3

Your automation, our passion.

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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.

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.

2 Product Description

2.1 Function

General

The surge protection barriers are used as modules positioned upstream in the circuit from the corresponding electrical equipment. The surge protection barriers make it possible to protect against overvoltages originating from various causes (lightning strikes, switching processes, etc.). This is achieved by diverting the transient current and limiting the voltage throughout the duration of the overvoltage surge. Various modules are available for protecting 2 or 4 conductors.

DIN Mounting Rail Modules

K-LB-*.*

This surge protection barrier provides low line-to-line clamping voltage and 500 V line-to-ground clamping voltage for a protected device. The device can be used to protect devices **that have more than 500 V** isolation-to-ground, such as intrinsic safety isolated barriers, signal conditioners and most field devices.

K-LB-*.*G

This surge protection barrier provides a low line-to-line clamping voltage and line-to-ground clamping voltage for the protected device. The device can be used to protect instruments **that have less than 500 V** isolation-to-ground, such as zener barriers, standard I/O cards, and some field devices.

Plug-In Modules

P-LB-*.*.*

This surge protection barrier is designed for use with the isolators of the K-System. By simply snapping the device into a standard isolator, the isolator are safely protected. The end digits of the model designation correspond to the protected terminals of the respective isolator.

Field Mount Modules

F*-LB-I

This surge protection barrier provides 85 V line-to-line and 500 V line-to-ground clamping voltage for the protected field device. The device also protects field devices that have less than 500 V isolation-to-ground. The device is installed in an available conduit or cable gland opening like those found on most process transmitters.

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

K-LB-*.**, F*-LB-I, P-LB-*.*.*	Up to SIL 3

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

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:

- 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.
- Failure rate based on the Siemens standard SN 29500.
- 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.

Application Information

The surge protection 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, see Figure 5.1:

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

As an overview for SIL 2/SIL 3 safety loop this means:

	SIL 2		SIL 3	
	PFH	PFD_{avg}	PFH	PFD_{avg}
Total	10^{-6}	10^{-2}	10^{-7}	10^{-3}
Actuator (40 %)	4×10^{-7}	4×10^{-3}	4×10^{-8}	4×10^{-4}
Transmitter (25 %)	2.5×10^{-7}	2.5×10^{-3}	2.5×10^{-8}	2.5×10^{-4}
Isolator (10 %)	10^{-7}	10^{-3}	10^{-8}	10^{-4}

Table 3.1 Overview PFD_{avg}/PFH budget

3.3 Safety Function and Safe State

The surge protection barrier has to be considered in conjunction with the connected field device. The safety function of the surge protection 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 ± 1 % 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

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

DIN Mounting Rail Modules

K-LB-1.30, K-LB-2.30, K-LB-1.6, K-LB-2.6 (1oo1 structure)

Parameters	Characteristics			
Assessment type and documentation	FMEDA report			
Device type	A			
Mode of operation	Low demand mode or high demand mode			
Safety function [1]	Pass through the signal			
HFT	0			
SIL [2]	2 or 3			
Signal type [1]	AI	AO	DI	DO
Safe state [1]	I_{in} < 3.6 mA Signal line interrupted	I_{out} < 3.6 mA Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted
Safety loop fault detection [3]	< 3.6 mA and > 21 mA can be detected	No fault detection since < 3.6 mA is safe state of the safety loop	SC and LB detection of the safety loop	No fault detection
$\lambda_{sd} + \lambda_{su}$	0 FIT	16.1 FIT	8.1 FIT	16.1 FIT
λ_{dd}	16.1 FIT	0 FIT	8.0 FIT	0 FIT
λ_{du}	0 FIT	0 FIT	0 FIT	0 FIT
$\lambda_{no\ effect}$	41.1 FIT	41.1 FIT	41.1 FIT	41.1 FIT
$\lambda_{not\ part}$	0 FIT	0 FIT	0 FIT	0 FIT
$\lambda_{total\ (safety\ function)}$	16.1 FIT	16.1 FIT	16.1 FIT	16.1 FIT
MTBF [4]	2002 years (1-channel device), 1001 years (2-channel device)			
PFH	0 1/h	0 1/h	0 1/h	0 1/h
PFD_{avg} for T_1 = 1 year	0	0	0	0

Table 3.2

1 The safe state of the surge protection barrier depend on the application.

2 The maximum safety integrity level of the safety loop in which the device might be used depends on the characteristics of the whole saftey loop and the connected field devices in the application.

3 This fault detection has to be provided by the safety loop architecture (e. g. NAMUR signal – lead breakage and short circuit detection, current loop > 20 mA).

4 acc. to SN29500. This characteristic includes failures which are not part of the safety function/MTTR = 8 h.

K-LB-1.30G, K-LB-2.30G, K-LB-1.6G, K-LB-2.6G (1oo1 structure)

Parameters	Characteristics			
Assessment type and documentation	FMEDA report			
Device type	A			
Mode of operation	Low demand mode or high demand mode			
Safety function [1]	Pass through the signal			
HFT	0			
SIL [2]	2 or 3			
Signal type [1]	AI	AO	DI	DO
Safe state [1]	I_{in} < 3.6 mA Signal line interrupted	I_{out} < 3.6 mA Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted
Safety loop fault detection [3]	< 3.6 mA and > 21 mA can be detected	No fault detection since < 3.6 mA is safe state of the safety loop	SC and LB detection of the safety loop	No fault detection
$\lambda_{sd} + \lambda_{su}$	0 FIT	15.1 FIT	8.1 FIT	15.1 FIT
λ_{dd}	15.1 FIT	0 FIT	7.0 FIT	0 FIT
λ_{du}	0 FIT	0 FIT	0 FIT	0 FIT
$\lambda_{no\ effect}$	22.1 FIT	22.1 FIT	22.1 FIT	22.1 FIT
$\lambda_{not\ part}$	14.0 FIT	14.0 FIT	14.0 FIT	14.0 FIT
$\lambda_{total\ (safety\ function)}$	26.9 FIT	26.9 FIT	26.9 FIT	26.9 FIT
MTBF [4]	2238 years (1-channel device), 1119 years (2-channel device)			
PFH	0 1/h	0 1/h	0 1/h	0 1/h
PFD_{avg} for T_1 = 1 year	0	0	0	0

Table 3.3

1 The safe state of the surge protection barrier depend on the application.

2 The maximum safety integrity level of the safety loop in which the device might be used depends on the characteristics of the whole saftey loop and the connected field devices in the application.

3 This fault detection has to be provided by the safety loop architecture (e. g. NAMUR signal – lead breakage and short circuit detection, current loop > 20 mA).

4 acc. to SN29500. This characteristic includes failures which are not part of the safety function/MTTR = 8 h.

Field Mount Modules

FN-LB-I, FS-LB-I, FP-LB-I (1oo1 structure)

Parameters	Characteristics			
Assessment type and documentation	FMEDA report			
Device type	A			
Mode of operation	Low demand mode or high demand mode			
Safety function [1]	Pass through the signal			
HFT	0			
SIL [2]	2 or 3			
Signal type [1]	AI	AO	DI	DO
Safe state [1]	I_{in} < 3.6 mA Signal line interrupted	I_{out} < 3.6 mA Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted
Safety loop fault detection [3]	< 3.6 mA and > 21 mA can be detected	No fault detection since < 3.6 mA is safe state of the safety loop	SC and LB detection of the safety loop	No fault detection
$\lambda_{sd} + \lambda_{su}$	0 FIT	6.95 FIT	0 FIT	6.95 FIT
λ_{dd}	6.95 FIT	0 FIT	6.95 FIT	0 FIT
λ_{du}	0 FIT	0 FIT	0 FIT	0 FIT
$\lambda_{no\ effect}$	20.1 FIT	20.1 FIT	20.1 FIT	20.1 FIT
$\lambda_{not\ part}$	10.1 FIT	10.1 FIT	10.1 FIT	10.1 FIT
$\lambda_{total\ (safety\ function)}$	6.95 FIT	6.95 FIT	6.95 FIT	6.95 FIT
MTBF [4]	3085 years (all components of the device)			
PFH	0.5×10^{-8} 1/h	0.5×10^{-8} 1/h	0.5×10^{-8} 1/h	0.25×10^{-8} 1/h
PFD_{avg} for T_1 = 1 year	2.19×10^{-5}	2.19×10^{-5}	2.19×10^{-5}	1.09×10^{-5}

Table 3.4

1 The safe state of the surge protection barrier depend on the application.

2 The maximum safety integrity level of the safety loop in which the device might be used depends on the characteristics of the whole saftey loop and the connected field devices in the application.

3 This fault detection has to be provided by the safety loop architecture (e. g. NAMUR signal – lead breakage and short circuit detection, current loop > 20 mA).

4 acc. to SN29500. This characteristic includes failures which are not part of the safety function/MTTR = 8 h.

Plug-In Modules

P-LB-1.D.*, P-LB-1.F.* (1oo1 structure)

Parameters	Characteristics					
Assessment type and documentation	FMEDA report					
Device type	A					
Mode of operation	Low demand mode or high demand mode					
Safety function [1]	Pass through the signal					
HFT	0					
SIL [2]	2 or 3					
Signal type [1]	4-wire resistance thermometer (RTD)	3-wire resistance thermometer (RTD)	Voltage source	2-wire resistance thermometer (RTD)	Potentiometer	Thermocouple (TC)
Safe state [1]	Threshold	Threshold	Threshold	Threshold	Threshold	Threshold
Safety loop fault detection [3]	< 3.6 mA and > 21 mA can be detected	< 3.6 mA and > 21 mA can be detected	< 3.6 mA and > 21 mA can be detected	< 3.6 mA and > 21 mA can be detected	< 3.6 mA and > 21 mA can be detected	< 3.6 mA and > 21 mA can be detected
$\lambda_{sd} + \lambda_{su}$	0 FIT	0 FIT	0 FIT	0 FIT	0 FIT	0 FIT
λ_{dd}	43 FIT	23.1 FIT	27 FIT	16 FIT	12.1 FIT	8.1 FIT
λ_{du}	16 FIT	12 FIT	8.1 FIT	0.02 FIT	22.9 FIT	8 FIT
$\lambda_{no\ effect}$	143 FIT	101 FIT	101 FIT	41.1 FIT	101 FIT	41.1 FIT
$\lambda_{not\ part}$	0 FIT	66 FIT	66.1 FIT	145 FIT	66.1 FIT	145 FIT
$\lambda_{total\ (safety\ function)}$	59 FIT	35.1 FIT	35.1 FIT	16.02 FIT	34 FIT	16.1 FIT
MTBF [4]	564 years (all components of the device)					
PFH	1.79×10^{-8} 1/h	1.79×10^{-8} 1/h	1.79×10^{-8} 1/h	1.79×10^{-8} 1/h	1.79×10^{-8} 1/h	1.79×10^{-8} 1/h
PFD_{avg} for T_1 = 1 year	7.84×10^{-5}	7.84×10^{-5}	7.84×10^{-5}	7.84×10^{-5}	7.84×10^{-5}	7.84×10^{-5}

Table 3.5

1 The safe state of the surge protection barrier depend on the application.

2 The maximum safety integrity level of the safety loop in which the device might be used depends on the characteristics of the whole saftey loop and the connected field devices in the application.

3 This fault detection has to be provided by the safety loop architecture (e. g. NAMUR signal – lead breakage and short circuit detection, current loop > 20 mA).

4 acc. to SN29500. This characteristic includes failures which are not part of the safety function/MTTR = 8 h.

P-LB-1.A.*, P-LB-2.A.* (1oo1 structure)

Parameters	Characteristics			
Assessment type and documentation	FMEDA report			
Device type	A			
Mode of operation	Low demand mode or high demand mode			
Safety function [1]	Pass through the signal			
HFT	0			
SIL [2]	2 or 3			
Signal type [1]	AI	AO	DI	DO
Safe state [1]	I_{in} < 3.6 mA Signal line interrupted	I_{out} < 3.6 mA Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted
Safety loop fault detection [3]	< 3.6 mA and > 21 mA can be detected	No fault detection since < 3.6 mA is safe state of the safety loop	SC and LB detection of the safety loop	No fault detection
$\lambda_{sd} + \lambda_{su}$	0 FIT	16.1 FIT	8.1 FIT	16.1 FIT
λ_{dd}	16.1 FIT	0 FIT	8.0 FIT	0 FIT
λ_{du}	0 FIT	0 FIT	0 FIT	0 FIT
$\lambda_{no\ effect}$	41.1 FIT	41.1 FIT	41.1 FIT	41.1 FIT
$\lambda_{not\ part}$	0 FIT	0 FIT	0 FIT	0 FIT
$\lambda_{total\ (safety\ function)}$	16.1 FIT	16.1 FIT	16.1 FIT	16.1 FIT
MTBF [4]	2002 years (1-channel device), 1001 years (2-channel device)			
PFH	0 1/h	0 1/h	0 1/h	0 1/h
PFD_{avg} for T_1 = 1 year	0	0	0	0

Table 3.6

1 The safe state of the surge protection barrier depend on the application.

2 The maximum safety integrity level of the safety loop in which the device might be used depends on the characteristics of the whole saftey loop and the connected field devices in the application.

3 This fault detection has to be provided by the safety loop architecture (e. g. NAMUR signal – lead breakage and short circuit detection, current loop > 20 mA).

4 acc. to SN29500. This characteristic includes failures which are not part of the safety function/MTTR = 8 h.

P-LB-1.B.*, P-LB-2.B.*, P-LB-1.C.*, P-LB-2.C.*, P-LB-2.D.*, P-LB-1.E.* (1oo1 structure)

Parameters	Characteristics			
Assessment type and documentation	FMEDA report			
Device type	A			
Mode of operation	Low demand mode or high demand mode			
Safety function [1]	Pass through the signal			
HFT	0			
SIL [2]	2 or 3			
Signal type [1]	AI	AO	DI	DO
Safe state [1]	I_{in} < 3.6 mA Signal line interrupted	I_{out} < 3.6 mA Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted	I_{out} = 0 mA U_{out} = 0 V Signal line interrupted
Safety loop fault detection [3]	< 3.6 mA and > 21 mA can be detected	No fault detection since < 3.6 mA is safe state of the safety loop	SC and LB detection of the safety loop	No fault detection
$\lambda_{sd} + \lambda_{su}$	0 FIT	16.1 FIT	8.1 FIT	16.1 FIT
λ_{dd}	16.1 FIT	0 FIT	8.0 FIT	0 FIT
λ_{du}	5.95 FIT	5.95 FIT	5.95 FIT	5.95 FIT
$\lambda_{no\ effect}$	42.1 FIT	42.1 FIT	42.1 FIT	42.1 FIT
$\lambda_{not\ part}$	52 FIT	52 FIT	52 FIT	52 FIT
$\lambda_{total\ (safety\ function)}$	22.05 FIT	22.05 FIT	22.05 FIT	22.05 FIT
MTBF [4]	984 years (1-channel device), 492 years (2-channel device)			
PFH	0.59×10^{-8} 1/h	0.59×10^{-8} 1/h	0.59×10^{-8} 1/h	0.59×10^{-8} 1/h
PFD_{avg} for T_1 = 1 year	2.60×10^{-5}	2.60×10^{-5}	2.60×10^{-5}	2.60×10^{-5}

Table 3.7

1 The safe state of the surge protection barrier depend on the application.

2 The maximum safety integrity level of the safety loop in which the device might be used depends on the characteristics of the whole saftey loop and the connected field devices in the application.

3 This fault detection has to be provided by the safety loop architecture (e. g. NAMUR signal – lead breakage and short circuit detection, current loop > 20 mA).

4 acc. to SN29500. This characteristic includes failures which are not part of the safety function/MTTR = 8 h.

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).

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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 60 °C.

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 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 8 hours. Take measures to maintain the safety function while the device is being repaired.

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 voltage of 0 V DC to 50 V DC and current limitation.

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, see figures below.
3. Test all channels of the device. Verify the current and resistance values as given in table below.
   ↳ Only if all tests are successfully done, the proof test is successful.
4. After the test, reset the device to the original settings.

DIN Mounting Rail Modules

The following figures show the proof test set-up for K-LB-2.30 and K-LB-2.30G.
Prepare the proof test set-up of the other devices of this device family accordingly.

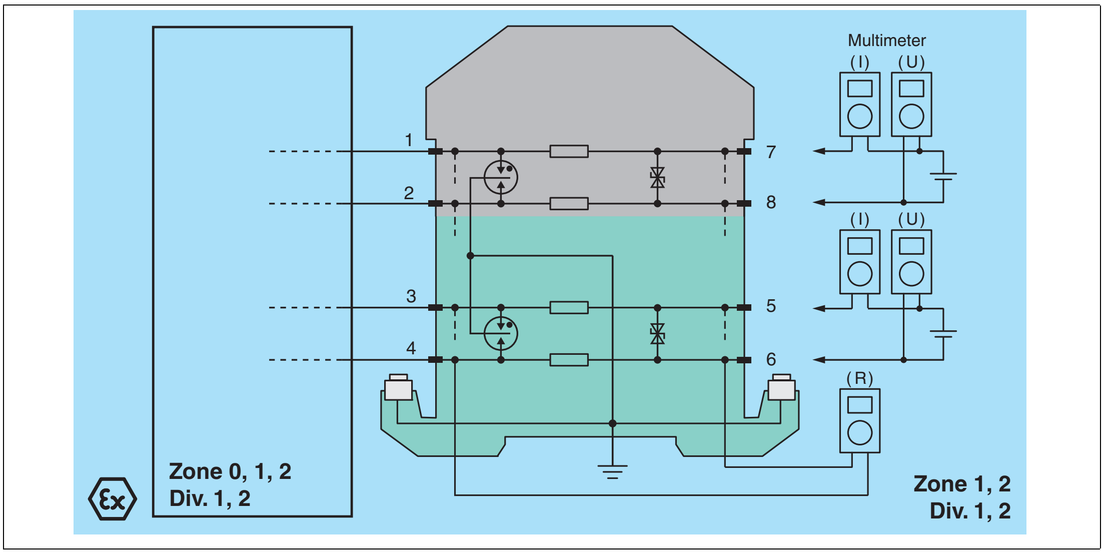

Figure 5.1 Proof test set-up for K-LB-*.* (example surge protection barrier K-LB-2.30)

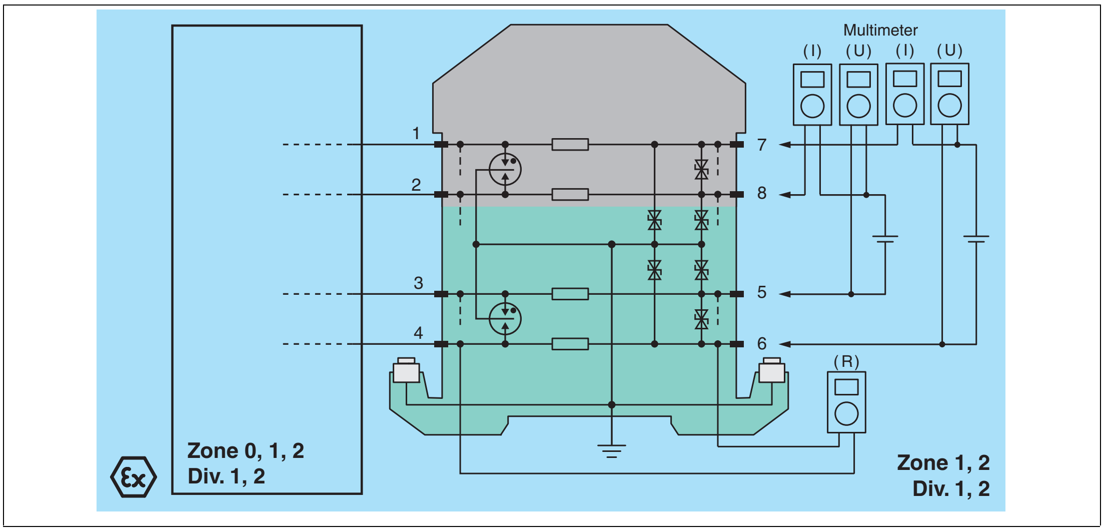

Figure 5.2 Proof test set-up for K-LB-*.*G (example surge protection barrier K-LB-2.30G)

Current and Voltage Measurement

Device	Step no.	Rated voltage	Leakage current	Comment
K-LB-1.30 K-LB-1.30G	1	30 V between Pins 7, 8	< 50 µA	Test passed if leakage current is below 200 µA.
K-LB-2.30	1 2	30 V between Pins 7, 8 30 V between Pins 5, 6	< 50 µA	Test passed if leakage current is below 200 µA.
K-LB-2.30G	1 2 3 4	30 V between Pins 7, 8 30 V between Pins 5, 6 30 V between Pins 5, 7 30 V between Pins 5, 8	< 50 µA	Test passed if leakage current is below 200 µA.

Table 5.1

Device	Step no.	Rated voltage	Leakage current	Comment
K-LB-1.6 K-LB-1.6G	1	6 V between Pins 7, 8	< 50 µA	Test passed if leakage current is below 200 µA.
K-LB-2.6	1 2	6 V between Pins 7, 8 6 V between Pins 5, 6	< 50 µA	Test passed if leakage current is below 200 µA.
K-LB-2.6G	1 2 3 4	6 V between Pins 7, 8 6 V between Pins 5, 6 6 V between Pins 5, 7 6 V between Pins 5, 8	< 50 µA	Test passed if leakage current is below 200 µA.

Table 5.2

Resistance Measurement

Device	Step no.	Measurement	Comment
K-LB-1.6 K-LB-1.30 K-LB-1.6G K-LB-1.30G	1 2	Resistance between Pins 1, 7 Resistance between Pins 2, 8	Test passed if resistance is below 2 Ω.
K-LB-2.6 K-LB-2.30 K-LB-2.6G K-LB-2.30G	1 2 3 4	Resistance between Pins 1, 7 Resistance between Pins 2, 8 Resistance between Pins 3, 5 Resistance between Pins 4, 6	Test passed if resistance is below 2 Ω.

Table 5.3

Field Mount Modules

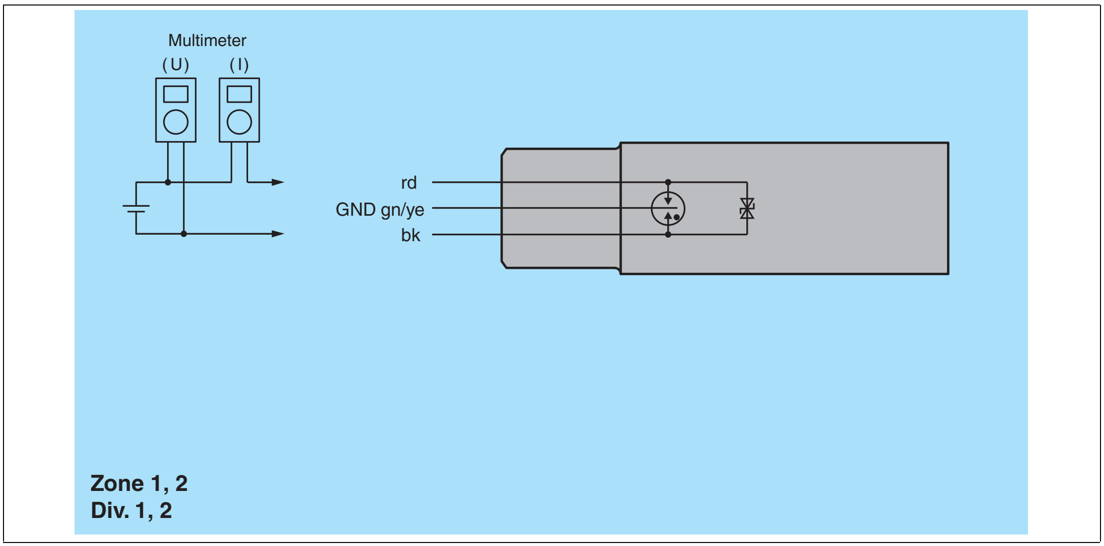

Figure 5.3 Proof test set-up for F*-LB-I

Device	Step no.	Rated voltage	Leakage current	Comment
F*-LB-I	1	45 V between red (rd) and black (bk) cable	< 50 µA	Test passed if leakage current is below 200 µA.

Table 5.4

Plug-In Modules

The following figures show the proof test set-up for P-LB-1.C.123. Prepare the proof test set-up of the other devices of this device family accordingly.

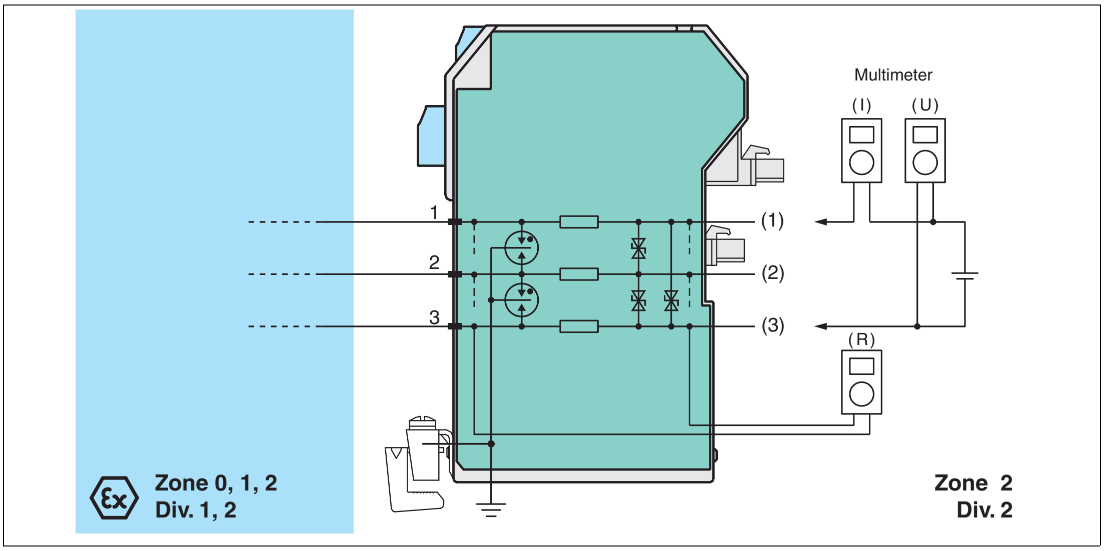

Figure 5.4 Proof test set-up for P-LB-*.*.* (example surge protection barrier P-LB-1.C.123)

2021-09

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Current and Voltage Measurement

Device	Step no.	Rated voltage	Leakage current	Comment
P-LB-1.A.13	1	30 V between Pins 1, 3	< 50 µA	Test passed if leakage current is below 200 µA.
P-LB-2.A.1346	1 2	30 V between Pins 1, 3 30 V between Pins 4, 6	< 50 µA	Test passed if leakage current is below 200 µA.
P-LB-1.B.12	1	30 V between Pins 1, 2	< 50 µA	Test passed if leakage current is below 200 µA.
P-LB-2.B.1245	1 2	30 V between Pins 1, 2 30 V between Pins 4, 5	< 50 µA	Test passed if leakage current is below 200 µA.
P-LB-1.C.123	1 2 3	30 V between Pins 1, 2 30 V between Pins 2, 3 30 V between Pins 1, 3	< 50 µA	Test passed if leakage current is below 200 µA.
P-LB-2.D.123456	1 2 3 4 5 6	30 V between Pins 1, 2 30 V between Pins 2, 3 30 V between Pins 1, 3 30 V between Pins 4, 5 30 V between Pins 5, 6 30 V between Pins 4, 6	< 50 µA	Test passed if leakage current is below 200 µA.
P-LB-1.E.23	1	30 V between Pins 2, 3	< 50 µA	Test passed if leakage current is below 200 µA.
P-LB-2.C.2356	1 2	30 V between Pins 2, 3 30 V between Pins 5, 6	< 50 µA	Test passed if leakage current is below 200 µA.
P-LB-1.D.1234	1 2 3 4 5 6	30 V between Pins 1, 2 30 V between Pins 1, 3 30 V between Pins 1, 4 30 V between Pins 2, 3 30 V between Pins 2, 4 30 V between Pins 3, 4	< 50 µA	Test passed if leakage current is below 200 µA.
P-LB-1.F.1236	1 2 3 4 5 6	30 V between Pins 1, 2 30 V between Pins 1, 3 30 V between Pins 1, 6 30 V between Pins 2, 3 30 V between Pins 2, 6 30 V between Pins 3, 6	< 50 µA	Test passed if leakage current is below 200 µA.

Table 5.5

Resistance Measurement

Device	Step no.	Rated voltage	Comment
P-LB-1.A.13	1 2	Resistance between Pins 1, (1) Resistance between Pins 3, (3)	Test passed if resistance is below 2 Ω.
P-LB-2.A.1346	1 2 3 4	Resistance between Pins 1, (1) Resistance between Pins 3, (3) Resistance between Pins 4, (4) Resistance between Pins 6, (6)	Test passed if resistance is below 2 Ω.
P-LB-1.B.12	1 2	Resistance between Pins 1, (1) Resistance between Pins 2, (2)	Test passed if resistance is below 2 Ω.
P-LB-2.B.1245	1 2 3 4	Resistance between Pins 1, (1) Resistance between Pins 2, (2) Resistance between Pins 4, (4) Resistance between Pins 5, (5)	Test passed if resistance is below 2 Ω.
P-LB-1.C.123	1 2 3	Resistance between Pins 1, (1) Resistance between Pins 2, (2) Resistance between Pins 3, (3)	Test passed if resistance is below 2 Ω.
P-LB-2.D.123456	1 2 3 4 5 6	Resistance between Pins 1, (1) Resistance between Pins 2, (2) Resistance between Pins 3, (3) Resistance between Pins 4, (4) Resistance between Pins 5, (5) Resistance between Pins 6, (6)	Test passed if resistance is below 2 Ω.
P-LB-1.E.23	1 2	Resistance between Pins 2, (2) Resistance between Pins 3, (3)	Test passed if resistance is below 2 Ω.
P-LB-2.C.2356	1 2 3 4	Resistance between Pins 2, (2) Resistance between Pins 3, (3) Resistance between Pins 5, (5) Resistance between Pins 5, (5)	Test passed if resistance is below 2 Ω.
P-LB-1.D.1234	1 2 3 4	Resistance between Pins 1, (1) Resistance between Pins 2, (2) Resistance between Pins 3, (3) Resistance between Pins 4, (4)	Test passed if resistance is below 2 Ω.
P-LB-1.F.1236	1 2 3 4	Resistance between Pins 1, (1) Resistance between Pins 2, (2) Resistance between Pins 3, (3) Resistance between Pins 6, (6)	Test passed if resistance is below 2 Ω.

Table 5.6

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, 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. While the device is maintained, repaired or replaced, the safety function does not work.
   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. A defective device must only be repaired by the manufacturer.
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.

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.

In these cases, contact your local sales partner or the Pepperl+Fuchs technical sales support (service line).

It is not necessary to report failures in the safety function that are due to external influences or damage.

7 Application Examples

All characteristics used in the following chapter were actual when this safety manual was released but may vary. The main purpose of this section is to show how to include a surge protected device into a safety loop.

Integration of a Surge Protection Barrier into a Safety Loop

The general considerations given above lead to the conclusion that it is mandatory before starting any safety loop calculation to have a clear understanding of:

1. the signal type of the safety loop (analog, digital),
2. the signal direction of the safety loop as seen from the perspective of the safety DCS (input or output),
3. the safe state of the field device allocated to the surge protection barrier,
4. the desired SIL level of the safety loop.

After the safety loop under consideration is defined, a surge protection barrier can be integrated into this safety loop by allocating it to a field device. It should be possible to get a principled overview as shown below.

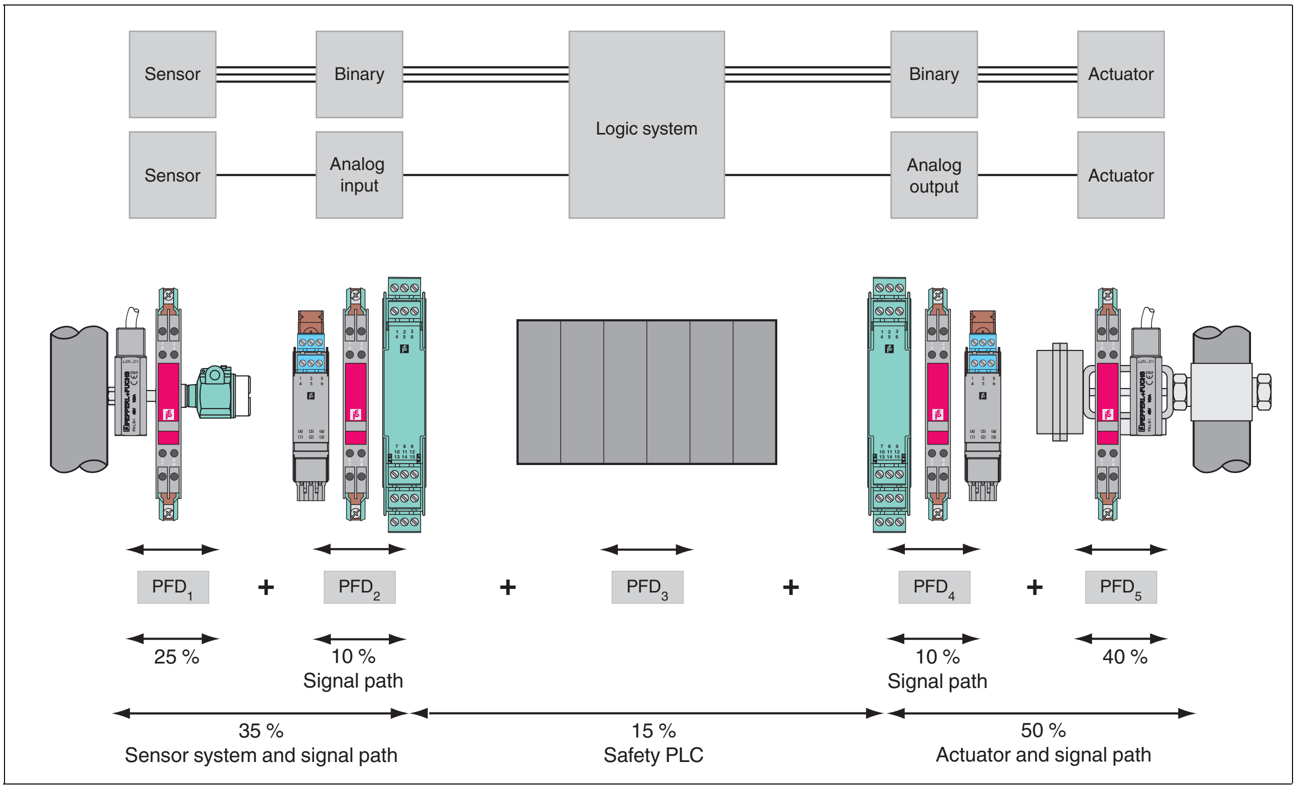

Figure 7.1 Example of a complete safety loop with allocated surge protection barriers

In principle the IEC/EN 61508 characteristics of the surge protection barrier have to be added to the IEC/EN 61508 characteristics of the field device. By doing so it is assumed that the surge protection barrier becomes an integral part of this device.
After that the **Probability of Failure on Demand** (PFD_{avg}) and the **Safe Failure Fraction** (SFF) have to be recalculated. With these new characteristics it can be verified if the desired SIL level can be reached.

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Basically the calculations are always very similar. Nevertheless it is important to understand the application completely and to interpret the figure above correctly. The calculation has to show that the subpart of the safety loop under consideration allows the overall safety loop to get into the range given in the following table:

SIL level	PFD_{avg}	SFF
SIL 2	$\geq 10^{-2}$ to $< 10^{-1}$	$\geq$ 60 %
SIL 3	$\geq 10^{-3}$ to $< 10^{-2}$	$\geq$ 90 %

Table 7.1 IEC/EN 61508 characteristics for type A subcomponents

SIL level	PFD_{avg}	SFF
SIL 2	$\geq 10^{-3}$ to $< 10^{-2}$	$\geq$ 90 %
SIL 3	$\geq 10^{-4}$ to $< 10^{-3}$	$\geq$ 99 %

Table 7.2 IEC/EN 61508 characteristics for type B subcomponents

Examples of various combinations are given in the following text.

Example 1 – Digital Input - NAMUR NE 22 Signals

When using a switch amplifier from Pepperl+Fuchs it is possible to implement safety loops up to SIL 2 with a standard NAMUR NE 22 digital input signal. A sample configuration of a surge protected device would be KCD2-SR-Ex1.LB and K-LB-*.**.

The basic requirements are:

1. Signal type of the safety loop = digital
2. Signal direction of the safety loop as seen from the perspective of the safety DCS = input
3. Safe state of the field device allocated to the surge protection barrier = de-energized
4. Desired SIL level of the safety loop = SIL 2

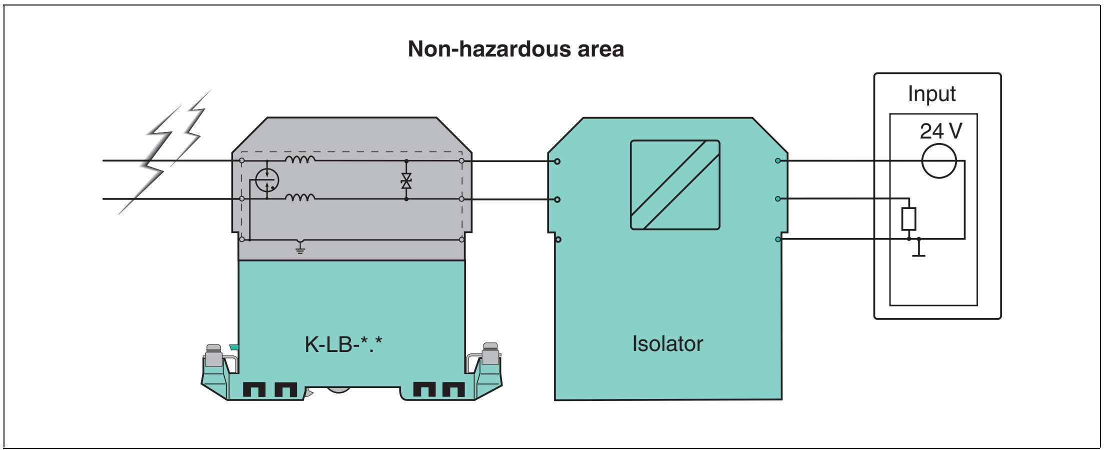

Figure 7.2 Combination of K-LB-1.30 and an isolator, e. g. KCD2-SR-Ex1.LB

Has the Safety Loop SIL 2 after the Surge Protection Barrier is inserted?

- SFF of the safety loop is as demanded for type A components > 60 %
- As an optimum the combination of surge protection barrier and field barrier claims 10 % of the overall PFD_{avg} maximum 1×10^{-2} and therefore has a $PFD_{avg} < 1 \times 10^{-3}$.

2021-09

The IEC/EN 61508 characteristics of the KCD2-SR-Ex1.LB are:

Total failure rate	254 FIT
PFD_{avg} for T_1 = 1 year	2.05 x 10^{-4}
SFF	81.5 %

Table 7.3 Characteristics of isolator KCD2-SR-Ex1.LB

For further calculation λ_{du} of the KCD2-SR-Ex1.LB has to be calculated by using the PFD_{avg} formula given in IEC/EN 61508:

- $PFD_{avg} = 1/2 \times \lambda_{du} \times T_1$ (1)
- $\lambda_{du} = 2 \times PFD_{avg} / T_1 = 2 \times 2.05 \times 10^{-4} / 8760$ [h] = 47 FIT

For the surge protection barrier K-LB-1.30 the following characteristics are given:

Total failure rate	16.1 FIT
Dangerous undetected failure rate	0 FIT

Table 7.4 Failure rates of surge protection barrier K-LB-1.30

The next step is to allocate the surge protection barrier to the device by adding the total failure rates of both components.

- $\sum \lambda_{total} = \lambda_{Isolator} + ... + \lambda_{Surge\ protection\ barrier}$ (2)
- $\sum \lambda_{total}$ = 254 FIT + 16 FIT = 270 FIT (rounded)

The same has to be done for the dangerous undetected failure rates of both devices.

- $\sum \lambda_{du} = \lambda_{du/Isolator} + ... + \lambda_{du/Surge\ protection\ barrier}$ (3)
- $\sum \lambda_{du}$ = 47 FIT + 0 FIT = 47 FIT

These characteristics allow calculating the SFF and PFD_{avg} for the combination of both devices.

- SFF = 1 – ($\lambda_{du} / \lambda_{total}$) (4)
- SFF = 1 – (47 FIT / 270 FIT) = 82 %
- $PFD_{avg\_1y} = 1/2 \times \lambda_{du} \times 8760$ [h] (5)
- PFD_{avg_1y} = 1/2 x 47 FIT x 8760 [h] = 2.05 x 10^{-4}

The following table summarizes the results of the calculations:

Total failure rate	270 FIT
Dangerous undetected failure rate	47 FIT
PFD_{avg} for T_1 = 1 year	2.05 x 10^{-4}
SFF	82 %

Table 7.5 Sum of failure rates of isolator KCD2-SR-Ex1.LB and surge protection barrier K-LB-1.30

This means that for this specific combination the requirements for a SIL 2 safety loop are still fulfilled.

Example 2 – Digital Output – Solenoid Drivers

The Pepperl+Fuchs digital output modules can be categorized into two groups – loop powered devices and bus powered devices.

Bus powered Solenoid Drivers

If a bus powered Solenoid Driver from Pepperl+Fuchs is considered it is possible to use virtually the same calculation method as used for NAMUR NE 22 inputs described above.

The basic requirements are:

1. Signal type of the safety loop = digital
2. Signal direction of the safety loop as seen from the perspective of the safety DCS = output
3. Safe state of the field device allocated to the surge protection barrier = de-energized
4. Desired SIL level of the safety loop = SIL 2

A standard KFD2-SL2-Ex1.LK device has the following characteristics:

Total failure rate	714 FIT
Dangerous undetected failure rate	10.3 FIT
PFD_{avg} for T_1 = 1 year	4.51 x 10^{-5}
SFF	85 %

Table 7.6 Characteristics of isolator KFD2-SL2-Ex1.LK

For the surge protection barrier P-LB-1.A the following characteristics are given:

Total failure rate	16.1 FIT
Dangerous undetected failures	0 FIT

Table 7.7 Failure rates of surge protection barrier P-LB-1.A

The combination of both devices is done by simply adding the characteristics again as before. The SFF and PFD_{avg} values can be calculated by using the equations given above.

Total failure rate	730 FIT (rounded)
Dangerous undetected failure rate	10.3 FIT
PFD_{avg} for T_1 = 1 year	4.51 x 10^{-5}
SFF	85 % (rounded)

Table 7.8 Sum of failure rates of isolator KFD2-SL2-Ex1.LK and surge protection barrier P-LB-1.A

This means that for this specific combination the requirements for a SIL 2 safety loop are still fulfilled.

Example 3 – Analog Inputs – 4 mA to 20 mA Signals

The basic requirements are:

1. Signal type of the safety loop = analog
2. Signal direction of the safety loop as seen from the perspective of the safety DCS = input
3. Safe state of the field device allocated to the surge protection barrier = output signal < 4 mA or respectively > 20 mA
4. Desired SIL level of the safety loop = SIL 3

A standard KCD2-STC-Ex1 device has the following characteristics:

Total failure rate	348 FIT
Dangerous undetected failure rate	67 FIT
PFD_{avg} for T_1 = 1 year	2.93 x 10^{-4}
SFF	80 %

Table 7.9 Characteristics of isolator KCD2-STC-Ex1

For the corresponding surge protection barrier P-LB-1.A the following characteristics are given:

Total failure rate	16 FIT
Dangerous undetected failures	0 FIT

Table 7.10 Failure rates of surge protection barrier P-LB-1.A

The combination of both devices is done by simply adding the characteristics again as before. The SFF and PFD_{avg} values can be calculated by using the equations given above.

Total failure rate	364 FIT (rounded)
Dangerous undetected failure rate	67 FIT
PFD_{avg} for T_1 = 1 year	2.93 x 10^{-4}
SFF	81 %

Table 7.11 Sum of failure rates of isolator KCD2-STC-Ex1 and surge protection barrier P-LB-1.A

This means that if compared with table 1 for this specific combination the requirements for a SIL 2 safety loop are still easily fulfilled.

Example 4 – Surge Protection Barriers and Field Devices

The same method can be applied when the DIN mounting rail variant K-LB-*.**
or the field mount module F*-LB-I has to be combined with any other field device.

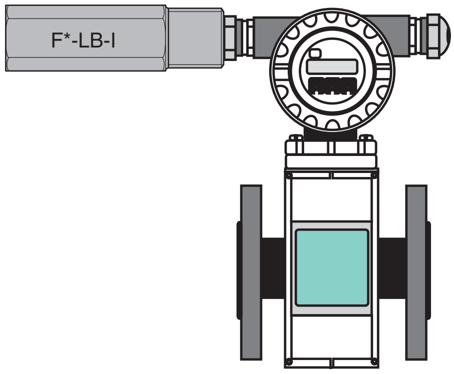

Figure 7.3 Combination of F*-LB-I and a transmitter

The basic requirements are:

1. Signal type of the safety loop = analog
2. Signal direction of the safety loop as seen from the perspective of the safety DCS = input
3. Safe state of the field device allocated to the surge protection barrier = output signal < 4 mA or respectively > 20 mA

Since the availability of SIL 3 field devices is very limited, it is most likely that the end user wants to know wether he can integrate a surge protection barrier into his SIL 2 application.

The following example deals with a differential pressure transmitter Rosemount 3051S_C getting combined with a surge protection barrier F*-LB-I.

Total failure rate	536 FIT
MTBF	213 years
Safe undetected failure rate	143 FIT
Safe detected failure rate	0 FIT
Dangerous undetected failure rate	37 FIT
Dangerous detected failure rate	356 FIT
SFF	93 %

Table 7.12 Characteristics of isolator KCD2-SCD-Ex1

Combined with the characteristics for the surge protection barrier F*-LB-I the result is:

Total failure rate	536 FIT + 7 FIT = 543 FIT (rounded)
MTBF	210 years
Safe failure rate	143 FIT
Dangerous undetected failure rate	57 FIT
Dangerous detected failure rate	356 FIT + 7 FIT = 363 FIT (rounded)
SFF	89 %

Table 7.13 Sum of failure rates of Rosemount 3051S_C and surge protection barrier F*-LB-I

Derived from this results using equation 4:

T_1	1 year	2 years	5 years
PFD_{avg}	2.50×10^{-4}	5.00×10^{-4}	1.25×10^{-4}

Table 7.14 PFD_{avg} values of the combination of Rosemount 3051S_C and surge protection barrier F*-LB-I

The proof that the transmitter is still feasible for IEC/EN 61508 SIL 2 safety loops is done, since SFF and PFD_{avg} values are still sufficient.

8 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

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- Surge Protection
- Wireless Solutions
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- Proximity Sensors
- Photoelectric Sensors
- Industrial Vision
- Ultrasonic Sensors
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- Positioning Systems
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