Functional Safety

Switch Amplifier KCD2-SON-Ex*(.R*)(.SP)

Manual

SIL

IEC 61508/61511

ISO9001

SIL 2

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

This devices are used for intrinsic safety applications.

The devices transfer digital signals (NAMUR sensors or dry contacts) from the hazardous area to the non-hazardous area.

The devices offer line fault transparency on the signal lines.

A fault is signalized by LEDs and a separate collective error message output.

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

The devices are available with screw terminals or spring terminals.
The type code of the versions of the devices with spring terminals has the extension ".SP".

The devices are mounted on a 35 mm DIN mounting rail according to EN 60715.

KCD2-SON-Ex1(.SP)

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.

KCD2-SON-Ex1.R1

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.

KCD2-SON-Ex1.R2

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.

KCD2-SON-Ex1.R3

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.

KCD2-SON-Ex2(.SP)

Each input controls a passive transistor output 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.

KCD2-SON-Ex2.R1

Each input controls a passive transistor output 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.

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KCD2-SON-Ex2.R2

Each input controls a passive transistor output with a resistive output characteristic.

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

KCD2-SON-Ex2.R3

Each input controls a passive transistor output 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.

2.2 Interfaces

The device has the following interfaces.

- Safety-relevant interfaces:
  - KCD2-SON-Ex1(.R*)(.SP): input I, output I, output II (optional)
  - KCD2-SON-Ex2(.R*)(.SP): input I, input II, output I, output II
- Non-safety-relevant interfaces: collective error message output

Note

For corresponding connections see datasheet.

2.3 Marking

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Internet: www.pepperl-fuchs.com

KCD2-SON-Ex1, KCD2-SON-Ex1.SP, KCD2-SON-Ex1.R1, KCD2-SON-Ex1.R2, KCD2-SON-Ex1.R3, KCD2-SON-Ex2, KCD2-SON-Ex2.SP, KCD2-SON-Ex2.R1, KCD2-SON-Ex2.R2, KCD2-SON-Ex2.R3	Up to SIL 2

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)

3.1.3 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 the elements and subsystems, but not of a single device.

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

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3.2 Assumptions

The following assumptions have been made during the FMEDA:

- Failure rates are constant, wear is not considered.
- Failure rate based on the Siemens standard SN 29500.
- The safety-related device is considered to be of type **A** device with a hardware fault tolerance of **0**.
- External power supply failure rates are not included.
- The device will be used under average industrial ambient conditions comparable to the classification "stationary mounted" according to MIL-HDBK-217F.

  Alternatively, 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 may be assumed. 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.
- Since the outputs of the device use common components, these outputs must not be used in the same safety function.
- The indication of a dangerous failure is detected within 1 hour by the programmable logic controller (PLC).
- The the collective error message output is not considered in the FMEDA and in the calculations.

SIL 2 application

- To build a SIL safety loop for the defined SIL, it is assumed as an example that this device uses 10 % of the available budget for PFD_{avg}/PFH.
- 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.
- 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.

3.3 Safety Function and Safe State

Safe State

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

The fault state is the open circuit. The high impedance state is defined as 0-signal in the respective datasheet.

Safety Function

The safety function has 2 modes of operation:

- normal operation (output follows input)
- inverted operation (output inverts input)

The 1-channel devices have 2 outputs where output II may be used in safety-relevant applications if it is configured to follow output I.

Here are the DIP switch settings for all channels used in safety-relevant applications:

DIP Switch Settings 1-channel Devices

Function	Mode	KCD2-SON-Ex1(.R*)(.SP)
Output mode	Normal operation	S1 position I
	Inverted operation	S1 position II
Line fault detection	ON	S3 position I
	OFF [1]	S3 position II

Table 3.1

1 This switch setting may not be used if the device is used for safety-relevant applications.

DIP Switch Settings 2-channel Devices

Function	Mode	KCD2-SON-Ex2(.R*)(.SP)
Mode channel I	Normal operation	S1 position I
	Inverted operation	S1 position II
Mode channel II	Normal operation	S2 position I
	Inverted operation	S2 position II
Line fault detection channel I	ON	S3 position I
	OFF[1]	S3 position II
Line fault detection channel II	ON	S4 position I
	OFF [1]	S4 position II

Table 3.2

1 This switch setting may not be used if the device is used for safety-relevant applications.

LB/SC Diagnosis

For use in a safety function enable the line fault detection.

If the line fault detection is active (mandatory, see datasheet), the input loops of all device versions are supervised. The line fault detection is activated if switch S3 and switch 4 (2-channel devices) is in position I.

The related safety function is defined as the outputs are de-energized (safe state), if there is a line fault detected.

Note

The collective error message output are not safety relevant.

Note

See corresponding datasheets for further information.

3.4 Characteristic Safety Values

Parameters	Characteristic values	
Assessment type and documentation	Full assessment	
Device type	A	
Mode of operation	Low demand mode or high demand mode	
HFT	0	
SIL	2	
SC	3	
Safety function	Inverted operation [1]	Normal operation [1]
λ_{safe} [2]	108 FIT	109 FIT
λ_{dd}	3.3 FIT	3.3 FIT
λ_{du} [3]	26.0 FIT	24.2 FIT
$\lambda_{total\ (safety\ function)}$	137 FIT	136 FIT
SFF	81 %	82 %
MTBF [3]	328 years	328 years
PFH	2.60×10^{-8} 1/h	2.42×10^{-8} 1/h
PTC	100 %	100 %
PFD_{avg} for T_1 = 1 year	1.14×10^{-4}	1.12×10^{-4}
PFD_{avg} for T_1 = 2 years	2.28×10^{-4}	2.24×10^{-4}
PFD_{avg} for T_1 = 5 years	5.69×10^{-4}	5.59×10^{-4}
Reaction time [4]	< 20 ms	

Table 3.3

1 The device can be used in 2 modes of operation, inverted operation and normal operation.

2 "Annunciation failures" do not directly influence the safety function and are therefore not considered.

3 acc. to SN29500. This value includes failures which are not part of the safety function/MTTR = 8 h.
The value is valid for one channel only.

4 Time between fault detection and fault reaction

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 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

Configuring the Device

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

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

Note

See corresponding datasheets for further information.

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. 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 respective 8 V DC (NAMUR voltage).
- Load resistor R. See table, value R.
- Sensor simulator:
  - Potentiometer of 4.7 kΩ (threshold for normal operation)
  - Resistor of 220 Ω (short circuit detection)
  - Resistor of 150 kΩ (lead breakage detection)

Proof Test Procedure

1. Test in the proof test with the same configuration which is used in the application.
2. Attach a load and supply defined by the application's current and voltage.
3. Substitute the sensors by sensor simulators
4. Test the respective input channel. The threshold must be between 1.4 mA and 1.9 mA. The hysteresis must be between 170 µA and 250 µA.
   ↳ For normal operation the corresponding yellow LED must have lit, if the input current is above the threshold. See table, value I_{on}.
   ↳ For inverted operation the corresponding yellow LED must have lit, if the input current is below the threshold. See table, value I_{on}.
5. Connect a resistor R_{SC} (220 Ω) or a resistor R_{LB} (150 kΩ) to the input.
   ↳ The device must detect an external fault for the respective channel. This state is indicated by red LED and the output of the corresponding channel shall be in fault state.
6. Test, that the outputs are definitely high impedant if the yellow LED is off. See table, values I_{off}.
7. Set the device back to the original settings after the test.
8. Check the settings after the configuration by suitable tests.

Device	R	U	I_{on}	I_{off}	I_{fault}
KCD2-SON-Ex*(.SP)	1 kΩ	8 V	2.6 mA < I_{on} < 3.2 mA	0.5 mA < I_{off} < 0.6 mA	< 0.05 mA
KCD2-SON-Ex*.R1	2 kΩ	24 V	8.0 mA < I_{on} < 9.2 mA	0.46 mA < I_{off} < 0.62 mA	< 0.05 mA
KCD2-SON-Ex*.R2	250 Ω	24 V	4.2 mA < I_{on} < 4.6 mA	1.48 mA < I_{off} < 1.62 mA	< 0.05 mA
KCD2-SON-Ex*.R3	4.3 kΩ	24 V	4.9 mA < I_{on} < 5.2 mA	1.01 mA < I_{off} < 1.06 mA	< 0.05 mA

Table 5.1

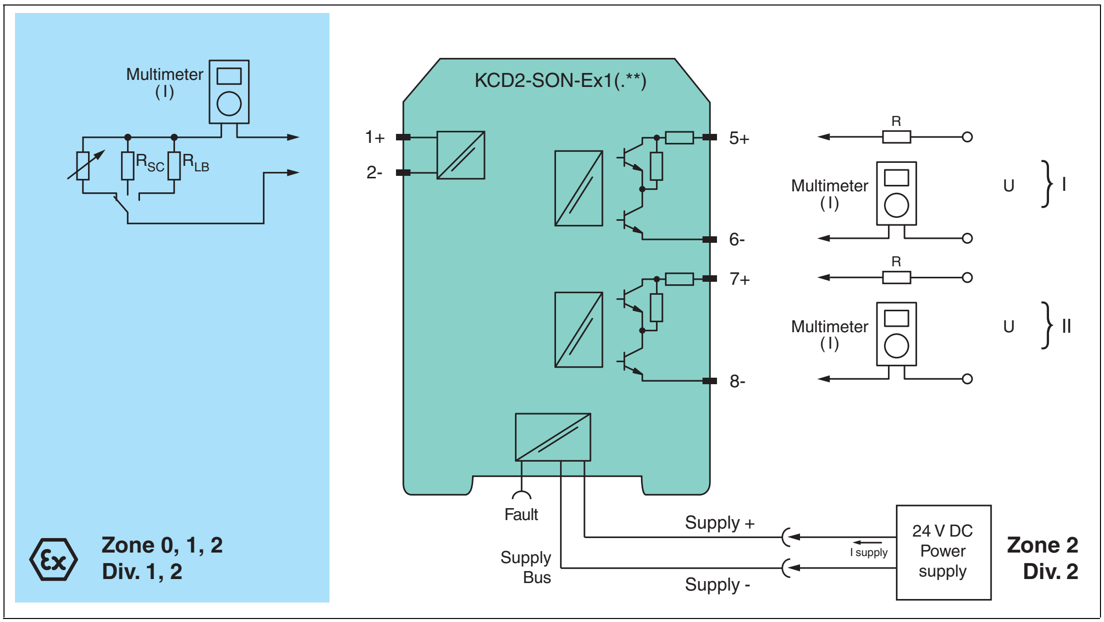

Figure 5.1 Proof test set-up for KCD2-SON-Ex1(.SP), KCD2-SON-Ex1.R2, KCD2-SON-Ex1.R3

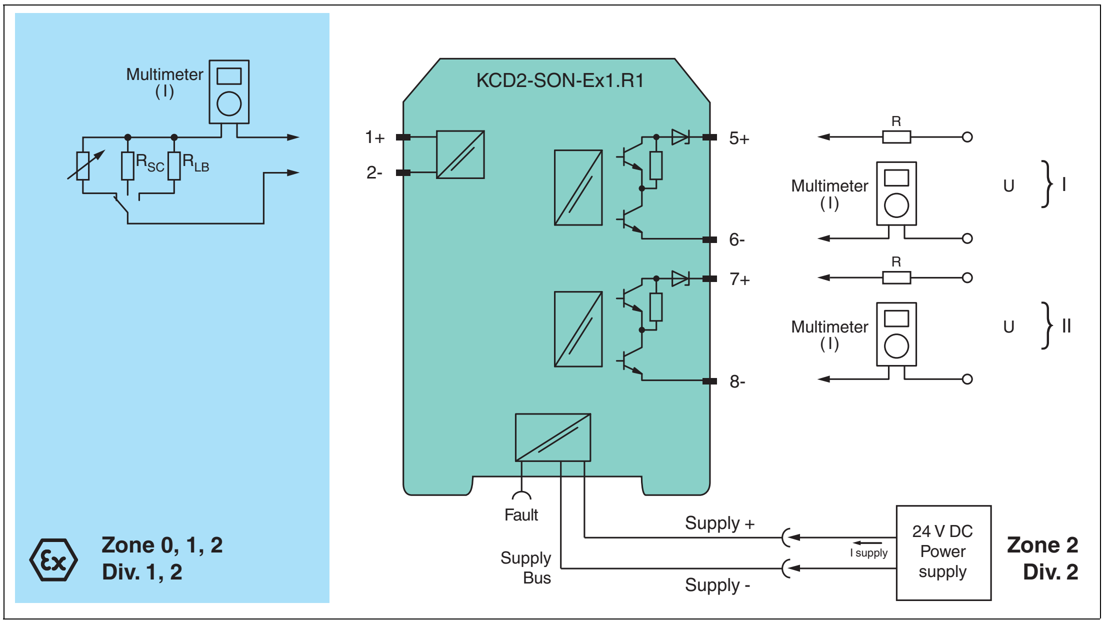

Figure 5.2 Proof test set-up for KCD2-SON-Ex1.R1

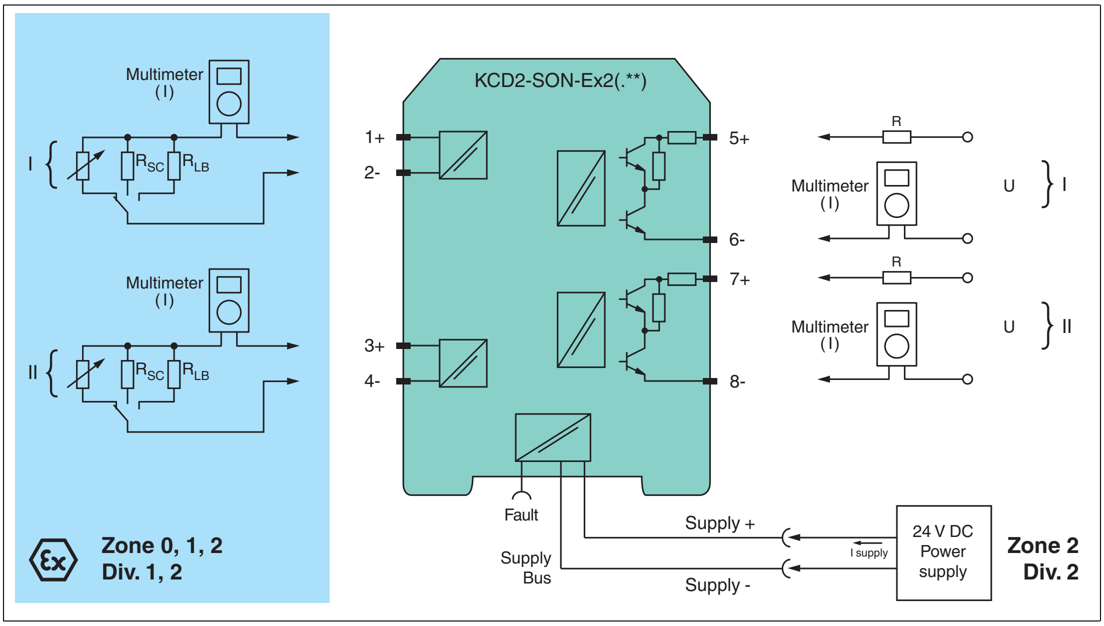

Figure 5.3 Proof test set-up for KCD2-SON-Ex2(.SP), KCD2-SON-Ex2.R2, KCD2-SON-Ex2.R3

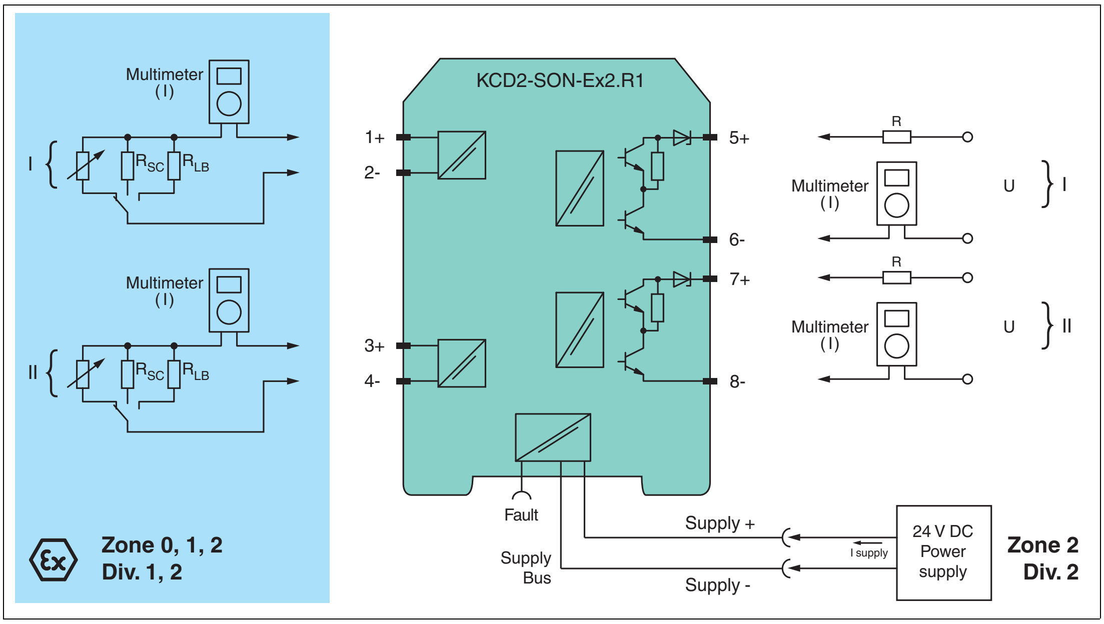

Figure 5.4 Proof test set-up for KCD2-SON-Ex2.R1

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 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
FLT	Fault
LB	**L**ead **B**reakage
LFD	**L**ine **F**ault **D**etection
SC	**S**hort **C**ircuit
$T_{service}$	Time from start of operation to putting the device out of service

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