Functional Safety

Switch Amplifier
KFD2-SR2-Ex*.W(.LB)

Manual

SIL

IEC 61508/61511

ISO9001

CE SIL 2

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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 Validity

This manual is only valid for devices with a part number **greater than #203350**.

Contact your Pepperl+Fuchs representative for information about older devices.

2.2 Function

KFD2-SR2-Ex1.W

This isolated barrier is used for intrinsic safety applications.

The device transfers digital signals from NAMUR sensors or dry contacts from the hazardous area to the non-hazardous area.

The proximity sensor or switch controls a change-over relay contact for the load in the non-explosion hazardous area. The output changes state when the input signal changes state. The normal output state can be reversed using switch S1. Switch S3 is used to enable or disable line fault detection of the field circuit.

During an error condition the outputs de-energize.

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

The device is mounted on a 35 mm DIN mounting rail according to EN 60715.

KFD2-SR2-Ex2.W

This isolated barrier is used for intrinsic safety applications.

The device transfers digital signals from NAMUR sensors or dry contacts from the hazardous area to the non-hazardous area.

The proximity sensor or switch controls a change-over relay contact for the load in the non-explosion hazardous area. The normal output state can be reversed using switches S1 and S2. Switch S3 is used to enable or disable line fault detection of the field circuit.

During an error condition the outputs de-energize.

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

The device is mounted on a 35 mm DIN mounting rail according to EN 60715.

KFD2-SR2-Ex1.W.LB

This isolated barrier is used for intrinsic safety applications.

The device transfers digital signals from NAMUR sensors or dry contacts from the hazardous area to the non-hazardous area.

The proximity sensor or switch controls a change-over relay contact for the load in the non-explosion hazardous area. The normal output state can be reversed using switch S1. Switch S2 allows output II to be switched between the signal output or the fault indication output. Switch S3 is used to enable or disable line fault detection of the field circuit.

During an error condition the outputs de-energize.

A fault is indicated by a LEDs and output via a fault indication output.

If the device is operated via Power Rail, additionally a collective error message is available.

The device is mounted on a 35 mm DIN mounting rail according to EN 60715.

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2.3 Interfaces

The device has the following interfaces:

- Safety-relevant interfaces:
  - KFD2-SR2-Ex1.W: input, output
  - KFD2-SR2-Ex2.W: input I, input II, output I, output II
  - KFD2-SR2-Ex1.W.LB: input, output I, output II
- Non-safety relevant interfaces: fault indication output and collective error message output

Note

For corresponding connections see datasheet.

2.4 Marking

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Internet: www.pepperl-fuchs.com

KFD2-SR2-Ex1.W, KFD2-SR2-Ex2.W, KFD2-SR2-Ex1.W.LB	Up to SIL 2

The *-marked letters of the type code are placeholders for versions of the device.

2.5 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 elements, subsystems and the complete system, but not of a single device.

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

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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.
- Only one input and one output are part of the safety function (only for 2-channel version).
- Short circuit (SC) detection and lead breakage (LB) detection are enabled.
- 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.

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.

SILCL and PL Application

- The device was qualified for use in safety functions up to SIL2 acc. to IEC/EN 61508. The risk reduction is equivalent to PL d acc. to EN/ISO 13849-1 or to SILCL2 acc. to IEC/EN 62061. See chapter 4 of EN/ISO 13849-1 for details on comparison between SIL and PL statements.

3.3 Safety Function and Safe State

Safe State

In the safe state of the safety function the output is de-energized.

Safety Function for 1-channel Devices

KFD2-SR2-Ex1.W

S1 position I (normal operation)	The safe state is reached if the NAMUR sensor input is in the off state.
S1 position II (inverse operation)	The safe state is reached if the NAMUR sensor input is in the on state.

KFD2-SR2-Ex1.W.LB

S1 position I (normal operation)	The safe state is reached if the NAMUR sensor input is in the off state.
S1 position II (inverse operation)	The safe state is reached if the NAMUR sensor input is in the on state.
S2 position I (output II as signal output)	Output II has the same switching state like output I.
S2 position II (output II as fault indication output)	LB/SC output – de-energized in case of fault. Not for safety relevant application of output II.

Safety Function for 2-channel Devices

KFD2-SR2-Ex2.W

S1 position I (normal operation input channel I)	The safe state of output I is reached if the NAMUR sensor input I is in the off state.
S1 position II (inverse operation input channel I)	The safe state of output I is reached if the NAMUR sensor input I is in the on state.
S2 position I (normal operation input channel II)	The safe state of output II is reached if the NAMUR sensor input II is in the off state.
S2 position II (inverse operation input channel II)	The safe state of output II is reached if the NAMUR sensor input II is in the on state.

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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 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 fault indication output and the collective error message output are not safety relevant.

Reaction Time

The fault reaction time is < 20 ms.

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	Output is de-energized	
λ_s [1]	113 FIT	
λ_{dd}	0 FIT	
λ_{du}	37.8 FIT	
$\lambda_{total\ (safety\ function)}$ [1]	151 FIT	
$\lambda_{no\ part}$	127 FIT	
SFF	75 %	
DC	0 %	
MTBF [2]	288 years	
$MTTF_D$	3023 years	
PFH	3.77×10^{-8} 1/h	
Test version	Manual proof test	In-loop proof test
PTC	100 %	90 %
PFD_{avg} for T_1 = 1 year [3]	1.65×10^{-4}	3.15×10^{-4}
PFD_{avg} for T_1 = 2 years [3]	3.31×10^{-4}	4.64×10^{-4}
PFD_{avg} for T_1 = 3 years [3]	4.96×10^{-4}	6.13×10^{-4}
Fault reaction time [4]	< 20 ms	

Table 3.1

1 "No effect failures" are not influencing the safety function and are therefore not included in SFF and in the failure rates of the safety function.

2 acc. to SN29500. This value includes failures which are not part of the safety function/MTTR = 8 h. The value is calculated for one safety function of the device.

3 Since the current PTC value is < 100 % and therefore the probability of failure will increase, calculate the PFD value according to the following formula:
$PFD_{avg} = (\lambda_{du} / 2) \times (PTC \times T_1 + (1 - PTC) \times T_{service})$
A service time $T_{service}$ of 10 years was assumed for the calculation of PFD_{avg}.

4 Step response time, also valid under fault conditions (including fault detection and fault reaction)

The characteristic safety values like PFD, SFF, HFT and T_1 are taken from the SIL report/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, the electrolytic capacitors can be very sensitive to the operating temperature.

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

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

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

The standard EN/ISO 13849-1:2015 proposes a useful lifetime T_M of 20 years for devices used within industrial environments. This device is designed for this lifetime.
Observe that the useful lifetime can be reduced if the device is exposed to the following conditions:

- highly stressful environmental conditions such as constantly high temperatures
- temperature cycles with high temperature differences
- permanent repeated mechanical stress (vibration)

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

Please note that the useful lifetime refers to the (constant) failure rate of the device. The effective lifetime 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.

Derating

For the safety application, reduce the number of switching cycles or the maximum current. A derating to 2/3 of the maximum value is adequate.

Maximum Switching Power of Output Contacts

The useful lifetime is limited by the maximum switching cycles of the relays under load conditions.

For requirements regarding the connected output load, refer to the documentation of the connected peripheral devices.

Devices with relay contact outputs are not intended for applications with continuous demand, as the relay contacts are subject to mechanical wear. To exclude higher failure rates, a maximum number of 10 switching cycles per hour is considered adequate. A higher number of switching cycles can lead to higher failure rates than given in the table.

Note

See corresponding datasheets for further information.

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.

5.1.1 Procedure for Manual Proof Test

Equipment required:

- Digital multimeter with an accuracy of 0.1 %
  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.
- Power supply set to nominal voltage of 24 V DC
- Simulate the sensor state by a potentiometer of 4.7 kΩ (threshold for normal operation), by a resistor of 220 Ω (short circuit detection) and by a resistor of 150 kΩ (lead breakage detection).

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. Simulate the sensor state by connecting a potentiometer, a resistor for short circuit detection or by a resistor for lead breakage detection.
   Test each input channel individually.
4. Connect a potentiometer of 4.7 kΩ (threshold for normal operation) to the input.

   ↳ The threshold must be between 1.4 mA and 1.9 mA, the hysteresis must be between 170 µA and 250 µA.
   - If the input current is above the threshold the relay must be activated for normal mode of operation. The yellow LED lights up.
   - If the input current is below the threshold the relay must be activated for inverted mode of operation. The yellow LED lights up.
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. This state is indicated by red LED and the relay of the corresponding output must be de-activated.
6. Test all relay outputs with a specific current, e. g. 100 mA. To avoid electric shock, use a test voltage of 24 V DC. Check that the relay contacts are open.

   ↳ The relays must be de-activated. The relay contacts must **definitely open**.
7. Set back the device to the original settings for the current application after the test.
8. Check the correct behavior of the safety loop. Is the configuration correct?
9. Secure the DIP switches to prevent unintentional adjustments.

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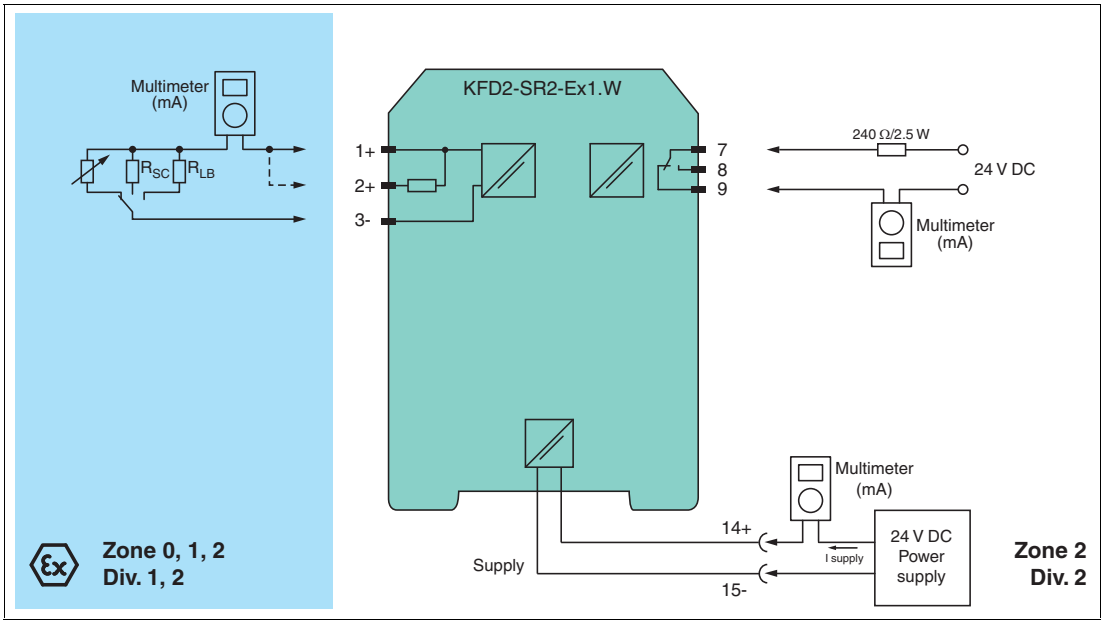

Figure 5.1 Proof test set-up for KFD2-SR2-Ex1.W

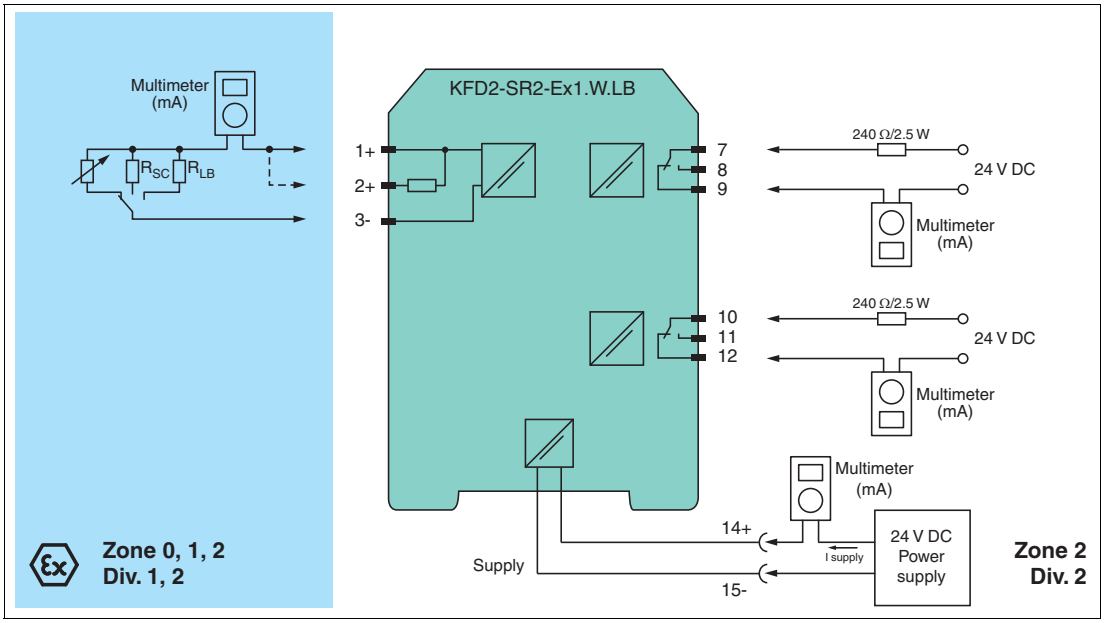

Figure 5.2 Proof test set-up for KFD2-SR2-Ex1.W.LB

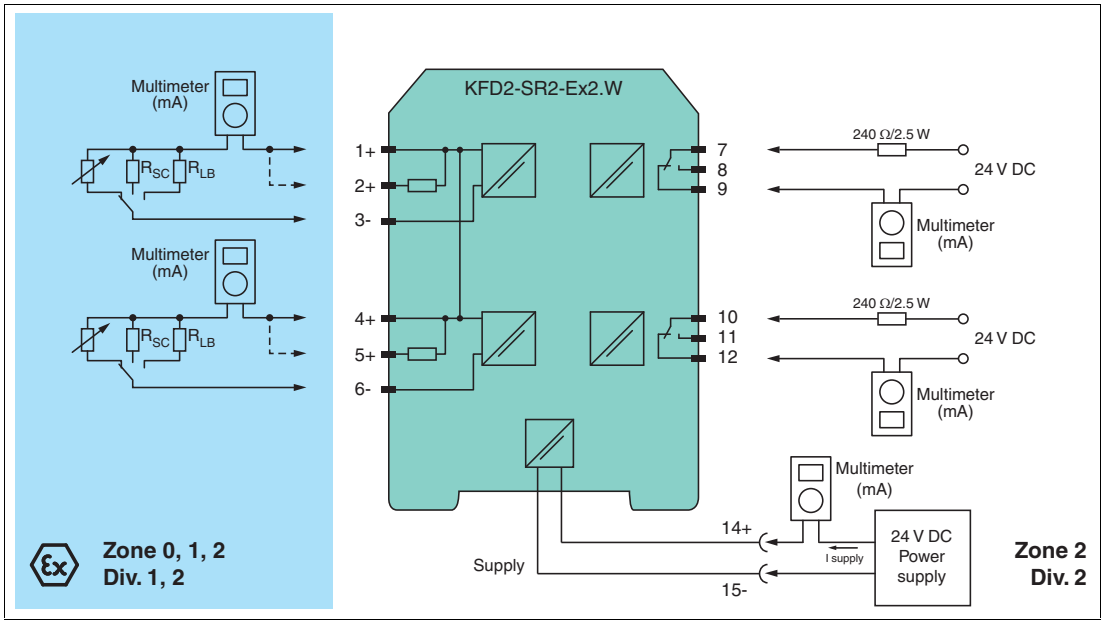

Figure 5.3 Proof test set-up for KFD2-SR2-Ex2.W

5.1.2 Procedure for In-Loop Proof Test

If you check the safety function within an application, 90 % of the dangerous undetected failures are revealed.

You can also use documented switching actions for verification within the framework of regular proof test intervals. The calculated values correspond to the values in the "Characteristic Safety Values" table, see chapter 3.4

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.

7 List of Abbreviations

DC	**D**iagnostic **C**overage of dangerous faults
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
$MTTF_D$	**M**ean **T**ime **T**o dangerous **F**ailure
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
PL	**P**erformance **L**evel
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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