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MANUAL

Functional Safety

Temperature Converter
KFD2-UT2-(Ex)*(-1)

SIL
IEC 61508/61511

ISO9001

SIL 2

PEPPERL+FUCHS
PROTECTING YOUR PROCESS

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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.

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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.

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1.3 Symbols Used

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

Warning Messages

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

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

Danger!

This symbol indicates an imminent danger.

Non-observance will result in personal injury or death.

Warning!

This symbol indicates a possible fault or danger.

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

Caution!

This symbol indicates a possible fault.

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

Informative Symbols

Note

This symbol brings important information to your attention.

Action

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

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2 Product Description

2.1 Function

KFD2-UT2-*(-1)

This signal conditioner provides the galvanic isolation between field circuits and control circuits.

The device converts the signal of a resistance thermometer, thermocouple, or potentiometer to a proportional output current.

The device can also be configured as a signal splitter.

The removable terminal block K-CJC-** is available as an accessory for internal cold junction compensation of thermocouples.

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

The device is easily configured by the use of the PACTware configuration software.

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

KFD2-UT2-*-1

The device converts the signal of a resistance thermometer, thermocouple, or potentiometer to a proportional output voltage.

KFD2-UT2-Ex*(-1)

This isolated barrier is used for intrinsic safety applications.

The device converts the signal of a resistance thermometer, thermocouple, or potentiometer to a proportional output current.

The device can also be configured as a signal splitter.

The removable terminal block K-CJC-** is available as an accessory for internal cold junction compensation of thermocouples.

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

The device is easily configured by the use of the PACTware configuration software.

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

KFD2-UT2-Ex*-1

The device converts the signal of a resistance thermometer, thermocouple, or potentiometer to a proportional output voltage.

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2.2 Interfaces

The device has the following interfaces.

- Safety relevant interfaces:
  - Input I, input II (only 2-channel version)
  - Output I, output II (only 2-channel version)
- Non-safety relevant interfaces: programming socket, collective error message output

Note

For corresponding connections see datasheet.

2.3 Marking

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

KFD2-UT2-1, KFD2-UT2-1-1, KFD2-UT2-2, KFD2-UT2-2-1	Up to SIL 2
KFD2-UT2-Ex1, KFD2-UT2-Ex1-1,KFD2-UT2-Ex2, KFD2-UT2-Ex2-1	

2.4 Standards and Directives for Functional Safety

Device specific standards and directives

Functional safety	IEC/EN 61508, part 2 and 3, 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)

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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 rate based on the Siemens standard SN 29500.
- Failures during configuration are not considered.
- The collective error message output is not considered in the FMEDA and in the calculations.
- Propagation of failures is not relevant.
- External power supply failure rates are not included.
- The collective error message output is not safety relevant.
- The indication of a dangerous failure (via fault bus) is detected within 1 hour by the programmable logic controller (PLC).
- Only one input and one output are part of the safety function (only for 2-channel version).
- 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.
- The application program in the programmable logic controller (PLC) is configured to detect underrange and overrange failures. These failures have been classified as **dangerous detected** failures.

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 PFDavg/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}.
- According to IEC/EN 61511-1 section 11.4.5, a HFT = 0 can be considered sufficient for SIL 2 applications in low demand mode of operation. The evaluation is based on failure rates as described in section 11.9.

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3.3 Safety Function and Safe State

Safety Function

The safety function of the device is fulfilled, as long as the output repeats the **linearized** input signal with a tolerance of 2 %.

Safe State

The safe state is present when the output signal is < 4 mA or > 20 mA.

Reaction Time

- for temperature input: < 1.5 s
- for potentiometer input: < 3 s

Note

See corresponding datasheets for further information.

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3.4 Characteristic Safety Values

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

KFD2-UT2-(Ex)*

Parameters	Characteristic values
Assessment type	FMEDA report with proven-in-use assessment [1]
Device type	B
Mode of operation	Low demand mode
Safety function	Transfer of analog value
HFT	0 (acc. to IEC/EN 61511)
SIL	2
SC	2
λ_s	0 FIT
λ_{dd} [2]	333 FIT
λ_{du} [3]	79.2 FIT
$\lambda_{no\ effect}$ [4]	295 FIT
$\lambda_{total\ (safety\ function)}$	706 FIT
$\lambda_{no\ part}$	33.4 FIT
SFF	81 %
MTBF [5]	154 years
PFD_{avg} for T_1 = 1 year [6]	8.33×10^{-4}
PFD_{avg} for T_{proof} = 2 years [6]	1.14×10^{-3}
PFD_{avg} for T_{proof} = 5 years [6]	2.08×10^{-3}
PTC	90 %
Reaction time [7]	• for temperature input: < 1.5 s • for potentiometer input: < 3 s

Table 3.1

1 For the proven-in-use demonstration, sales figures, customer returns and questionnaires filled out by customers were used which show that no unknown systematic faults are expected. The device is based on a former device that was evaluated for a proven-in-use statement by exida.com GmbH.

2 "Fail high" and "Fail low" failures are considered as dangerous detected failures λ_{dd}.

3 "Annunciation failures" that only influence the diagnostic function were marginal and added to the λ_{du}.

4 "No effect failures" are not influencing the safety function and are therefore added to the λ_s.

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

6 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}.

7 Step response time

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, the electrolytic capacitors can be very sensitive to the operating temperature.

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

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

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

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

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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. Protect the device against manipulation. Mount the device in a lockable switch cabinet, for example.
5. Connect the device only to devices that are suitable for this safety application.
6. Check the safety function to ensure the expected output behavior.

4.1 Configuration

Configuring the Device via PACTware Operating Software

The device can also be configured via the PACTware operating software.
The interface for connecting a personal computer for configuring is on the front of the device.

1. Open the cover.
2. Connect a personal computer via the K-ADP-USB adapter to the device.
3. Configure the device for the required safety function via the PACTware operating software, see chapter 4.1.1.
4. Protect the device configuration by a password against changing.
5. Leave the parameterization mode to prevent unintentional adjustments.
6. Disconnect the personal computer from the device.
7. Close the cover.
8. Check the device configuration to ensure the expected output behavior.
9. Document any changes to the device configuration.

Note

For more information see the manual.

4.1.1 Configuration for Use in Safety Function

Configuring the Device for Use in Safety Function

1. Configure the device for the required safety function via the operating software.
2. Disable the simulation function.
3. Enable the short circuit (SC) detection and lead breakage (LB) detection.
4. Disable the fault indication function > Hold.
5. Set the characteristic of the current output to the 4 mA to 20 mA NE 43 mode.
6. Protect the device configuration by a password against changing.

Note

For more information see the manual.

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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.

The following sections describe the steps of the proof test. The proof test reveals almost all possible dangerous faults (diagnostic coverage > 90 %).

Check the settings after the configuration by suitable tests.

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5.2 Proof Test Procedure for KFD2-UT2-(Ex)*(-1)

Perform the proof test with the same configuration that you use in the application. Substitute the sensor with a sensor simulator or a calibrator.

Check the safety function at the input, which must be configured to set the output values to 4 mA, 12 mA, 20 mA.

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.
- TC simulator, RTD simulator, voltage source or resistor

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5.2.1 Thermocouple Input (TC)

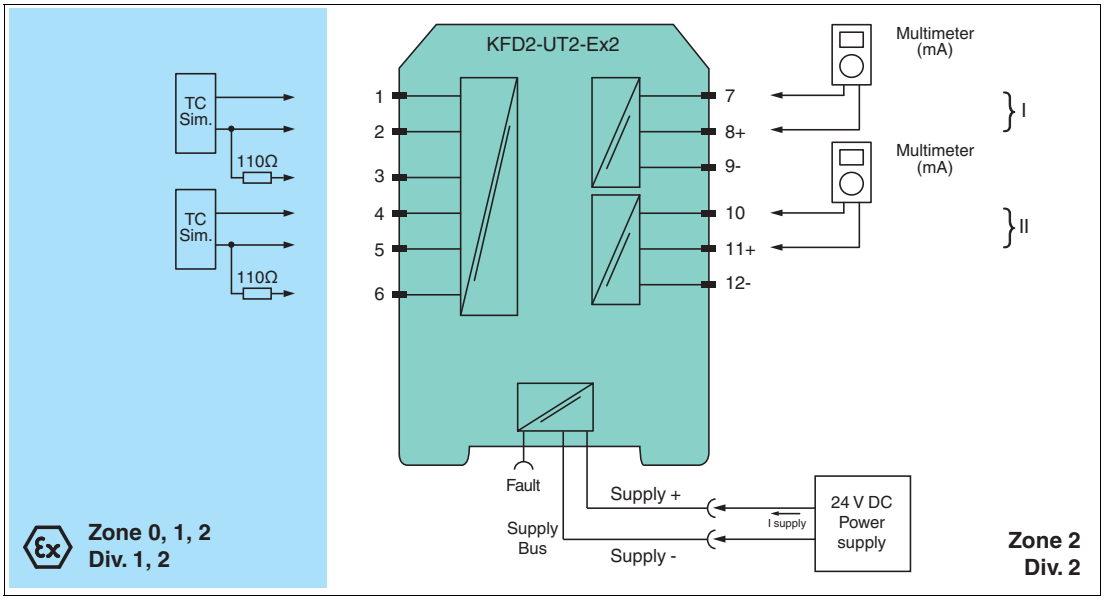

Figure 5.1 Proof test set-up for KFD2-UT2-(Ex)*(-1) with thermocouple input (TC)
Usage in Zone 0, 1, 2/Div. 1, 2 only for KFD2-UT2-Ex1(-1) and KFD2-UT2-Ex2(-1)
1-channel versions KFD2-UT2-1(-1) and KFD2-UT2-Ex1(-1) have only one channel.

Proof Test Procedure

Additional equipment: 110 Ω fixed resistor (accuracy of 0.1 %)

1. Connect the TC simulator to the terminals 1+ and 2- (channel I) and 4+ and 5- (channel II).
2. Connect the digital multimeter to the terminals 7 and 8 (channel I) and 10 and 11 (channel II).
3. Set the compensation/reference temperature on the TC simulator to 26 °C.
4. Connect the fixed resistor to terminals 2 and 3 (channel I) and 5 and 6 (channel II).
5. Set the TC simulator sequentially to the temperature values representing 4 mA, 12 mA, 20 mA at the output.
6. Measure the output current.

   ↳ The proof test is passed if the output values are within 2 % of the output span. [1]
   This means:
   – for the 4 mA application: 3.7 mA to 4.3 mA
   – for the 12 mA application: 11.7 mA to 12.3 mA
   – for the 20 mA application: 19.7 mA to 20.3 mA
7. Remove the TC simulator. Check if a lead breakage is detected.

   ↳ The red LED is flashing. The output behavior in the event of a fault depends on the device configuration.

[1] Additionally the loop diagnosis shall be tested to prove that the fault signaling via the current output is working correctly. The output current in the event of a failure depends on the device configuration. Please record this configuration and the resulting expected fault signaling current in the test report. Example: if downscale is configured, 2.0 mA ±1 % must be measured in the event of a failure. The red LED must be flashing.

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8. Remove the fixed resistor. Check if a lead breakage of the CJCs are detected.

   ↳ The red LED is flashing. The output behavior in the event of a fault depends on the device configuration.

9. Apply short circuit between terminals 2 and 3 (channel I) and between terminals 5 and 6 (channel II). Check if a short circuit of the cold junction compensation is detected.

   ↳ The red LED is flashing. The output behavior in the event of a fault depends on the device configuration.

10. Set the device back to the original settings after the test.

Proof Test for external Cold Junction Compensation

You can also use this proof test if you are using an external cold junction compensation. In this case set the preset compensation/reference temperature on the TC simulator, see step 3.

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5.2.2 Resistance Thermometer Input (RTD)

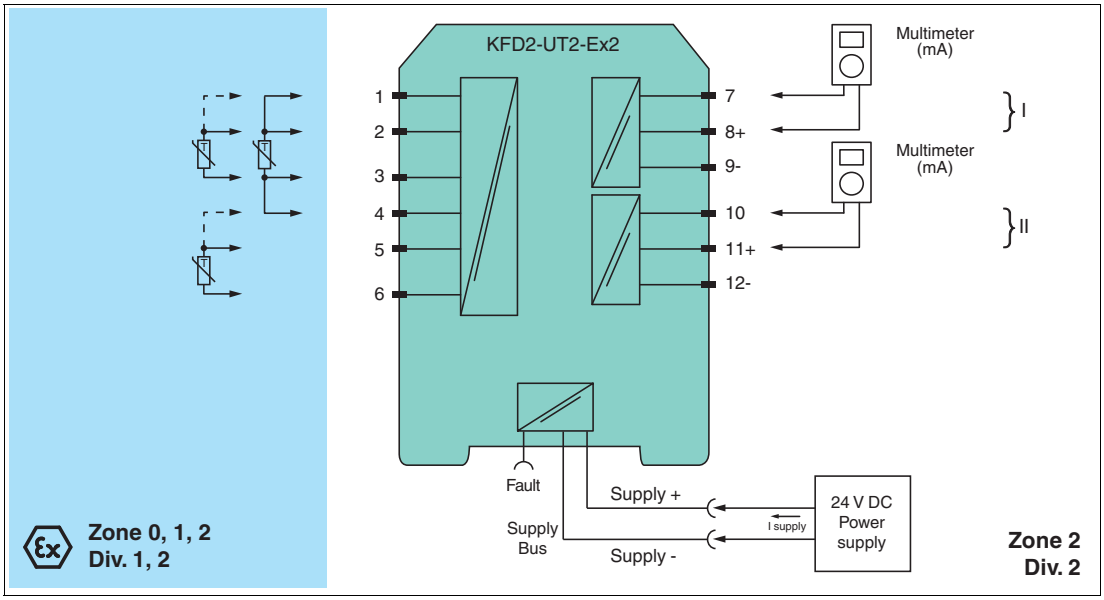

Figure 5.2 Proof test set-up for KFD2-UT2-(Ex)*(-1) with resistance thermometer input (RTD)
Usage in Zone 0, 1, 2/Div. 1, 2 only for KFD2-UT2-Ex1(-1) and KFD2-UT2-Ex2(-1)
1-channel versions KFD2-UT2-1(-1) and KFD2-UT2-Ex1(-1) have only one channel.

Proof Test Procedure

1. Connect a RTD simulator, depending on the application.
- for 4-wire connection: terminals 1, 2, 3, 4
- for 3-wire connection: terminals 1, 2, 3 (channel I) and 4, 5, 6 (channel II)
- for 2-wire connection: terminals 2, 3 (channel I) and 5, 6 (channel II)
2. Connect the digital multimeter terminals 7 and 8 (channel I) and 10 and 11 (channel II).
3. Set the RTD simulator sequentially to the temperature values representing 4 mA, 12 mA, 20 mA at the output.
4. Measure the output current.

   ↳ The proof test is passed if the output values are within 2 % of the output span. [1]
   This means:
   – for the 4 mA application: 3.7 mA to 4.3 mA
   – for the 12 mA application: 11.7 mA to 12.3 mA
   – for the 20 mA application: 19.7 mA to 20.3 mA
5. Apply short circuit between terminals 2 and 3 (channel I) and between terminals 5 and 6 (channel II). Do not remove the RTD simulator. Check if a short circuit of the cold junction compensation is detected.

   ↳ The red LED is flashing. The output behavior in the event of a fault depends on the device configuration.

[1] Additionally the loop diagnosis shall be tested to prove that the fault signaling via the current output is working correctly. The output current in the event of a failure depends on the device configuration. Please record this configuration and the resulting expected fault signaling current in the test report. Example: if downscale is configured, 2.0 mA ±1 % must be measured in the event of a failure. The red LED must be flashing.

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6. Remove the RTD simulator. Check if a lead breakage is detected.

   ↳ The red LED is flashing. The output behavior in the event of a fault depends on the device configuration.

7. Set the device back to the original settings after the test.

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5.2.3 Voltage Input (mV)

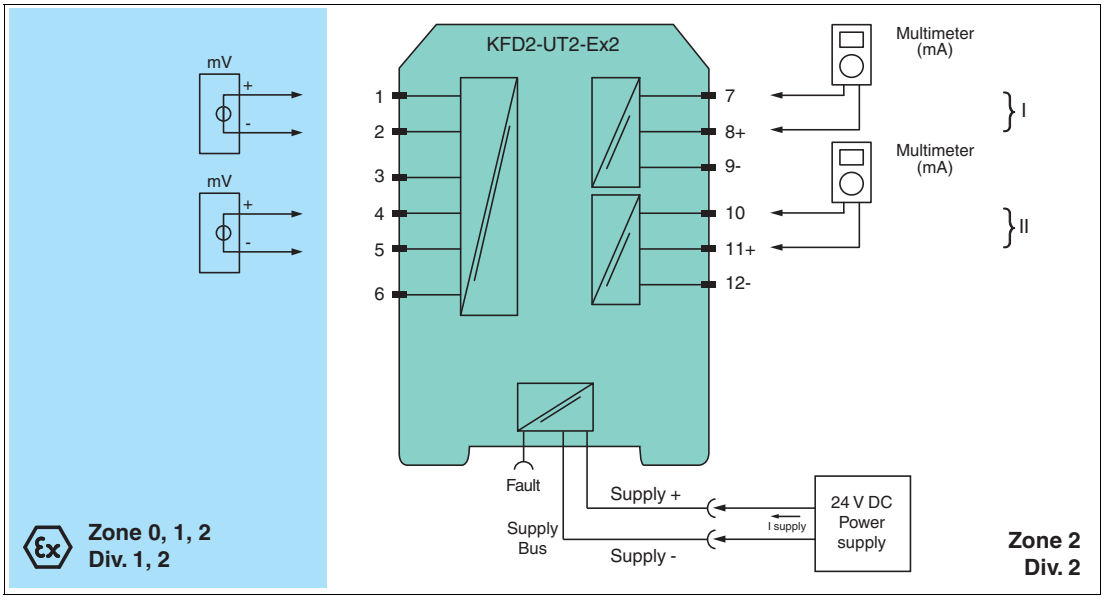

Figure 5.3 Proof test set-up for KFD2-UT2-(Ex)*(-1) with voltage input (mV)
Usage in Zone 0, 1, 2/Div. 1, 2 only for KFD2-UT2-Ex1(-1) and KFD2-UT2-Ex2(-1)
1-channel versions KFD2-UT2-1(-1) and KFD2-UT2-Ex1(-1) have only one channel.

Proof Test Procedure

1. Connect a voltage source to the terminals 1 and 2 (channel I) and 4 and 5 (channel II).
2. Connect the digital multimeter to the terminals 7 and 8 (channel I) and 10 and 11 (channel II).
3. Set the voltage source sequentially to the voltage values representing 4 mA, 12 mA, 20 mA at the output.
4. Measure the output current.

   ↳ The proof test is passed if the output values are within 2 % of the output span. [1]
   This means:
   – for the 4 mA application: 3.7 mA to 4.3 mA
   – for the 12 mA application: 11.7 mA to 12.3 mA
   – for the 20 mA application: 19.7 mA to 20.3 mA
5. Remove the voltage source. Check if a lead breakage is detected.

   ↳ The red LED is flashing. The output behavior in the event of a fault depends on the device configuration.
6. Set the device back to the original settings after the test.

[1] Additionally the loop diagnosis shall be tested to prove that the fault signaling via the current output is working correctly. The output current in the event of a failure depends on the device configuration. Please record this configuration and the resulting expected fault signaling current in the test report. Example: if downscale is configured, 2.0 mA ±1 % must be measured in the event of a failure. The red LED must be flashing.

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5.2.4 Potentiometer Input

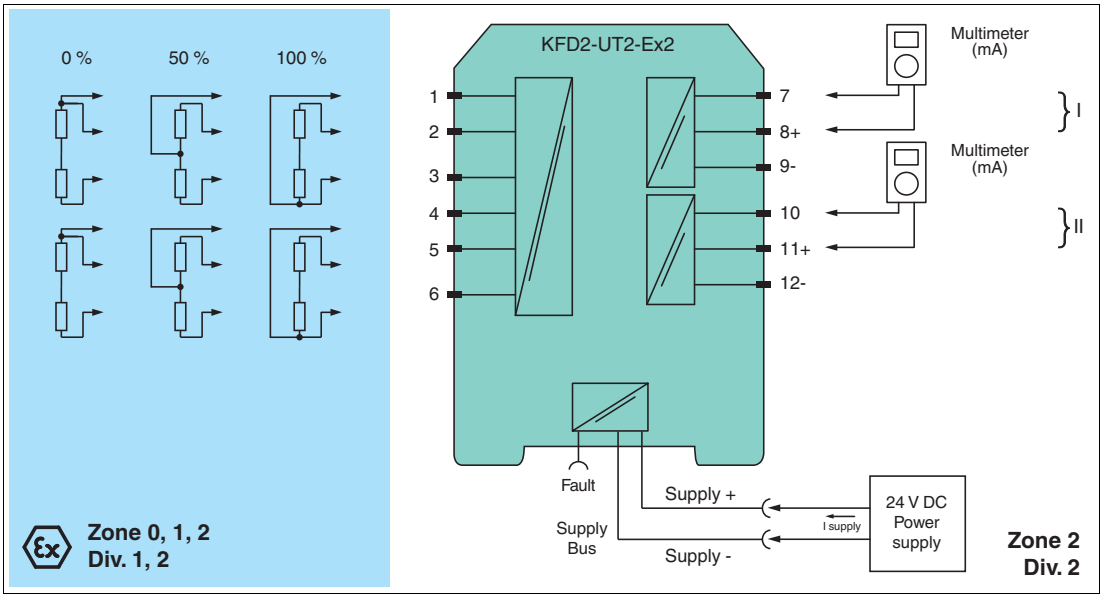

Figure 5.4 Proof test set-up for KFD2-UT2-(Ex)*(-1) with potentiometer input
Usage in Zone 0, 1, 2/Div. 1, 2 only for KFD2-UT2-Ex1(-1) and KFD2-UT2-Ex2(-1)
1-channel versions KFD2-UT2-1(-1) and KFD2-UT2-Ex1(-1) have only one channel.

Proof Test Procedure for Output as Current Source

The resistor values which are used to simulate the potentiometer shall be chosen so that they represent the full scale value of the potentiometer when connected in series. The individual resistors shall be of the same resistance value and have an accuracy of 1 %.

1. Connect the series resistors for 0 %, 50 % and 100 % of the potentiometer value to the terminals 2 and 3 (channel I) and 5 and 6 (channel II), see figure.
2. Connect the one-shot input to the terminals 1 (channel I) and 4 (channel II) to the junction of the two simulation resistors.
3. Connect the digital multimeter to the terminals 7 and 8 (channel I) and 10 and 11 (channel II).
4. Set the simulation resistor to 0 %, 50 % and 100 % of the potentiometer value.
5. Measure the output current.

   ↳ The proof test is passed if the output values are within 2 % of the output span. [1]
   This means:
   – for 0 % of the potentiometer value: 3.7 mA to 4.3 mA
   – for 50 % of the potentiometer value: 11.7 mA to 12.3 mA
   – for 100 % of the potentiometer value: 19.7 mA to 20.3 mA
6. Remove the series resistors.
7. Set the device back to the original settings after the test.

[1] Additionally the loop diagnosis shall be tested to prove that the fault signaling via the current output is working correctly. The output current in the event of a failure depends on the device configuration. Please record this configuration and the resulting expected fault signaling current in the test report. Example: if downscale is configured, 2.0 mA ±1 % must be measured in the event of a failure. The red LED must be flashing.

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Proof Test for Output as Current Sink

The criteria for a successful repeat test, which are specified for the output as a current source, are also valid for the output as current sink. In addition to the test setup described above, a voltage source must be connected to the output to simulate the original application.

Proof Test Procedure for Output as Voltage Source

The resistor values which are used to simulate the potentiometer shall be chosen so that they represent the full scale value of the potentiometer when connected in series. The individual resistors shall be of the same resistance value and have an accuracy of 1 %.

1. Connect the series resistors for 0 %, 50 % and 100 % of the potentiometer value to the terminals 2 and 3 (channel I) and 5 and 6 (channel II), see figure.
2. Connect the one-shot input to the terminals 1 (channel I) and 4 (channel II) to the junction of the two simulation resistors.
3. Connect the digital multimeter to the terminals 7 and 8 (channel I) and 10 and 11 (channel II).
4. Set the simulation resistor to 0 %, 50 % and 100 % of the potentiometer value.
5. Measure the output voltage

   ↳ The proof test is passed if the output values are within 2 % of the output span. This means:
   – for 0 % of the potentiometer value: 0.9 V to 1.1 V
   – for 50 % of the potentiometer value: 2.4 V to 2.6 V
   – for 100 % of the potentiometer value: 4.9 V to 5.1 V
6. Remove the series resistors.
7. Set the device back to the original settings after the test.

Proof Test Coverage

The Proof Test Coverage$_{device}$ is assumed to be min. 90 %.

With λ_{du} = 66 FIT (device), the proof test can reveal only 60 FIT.

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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.

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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. The no effect failure is not used for calculation of SFF.
$\lambda_{not\ part}$	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
$T_{service}$	Time from start of operation to putting the device out of service

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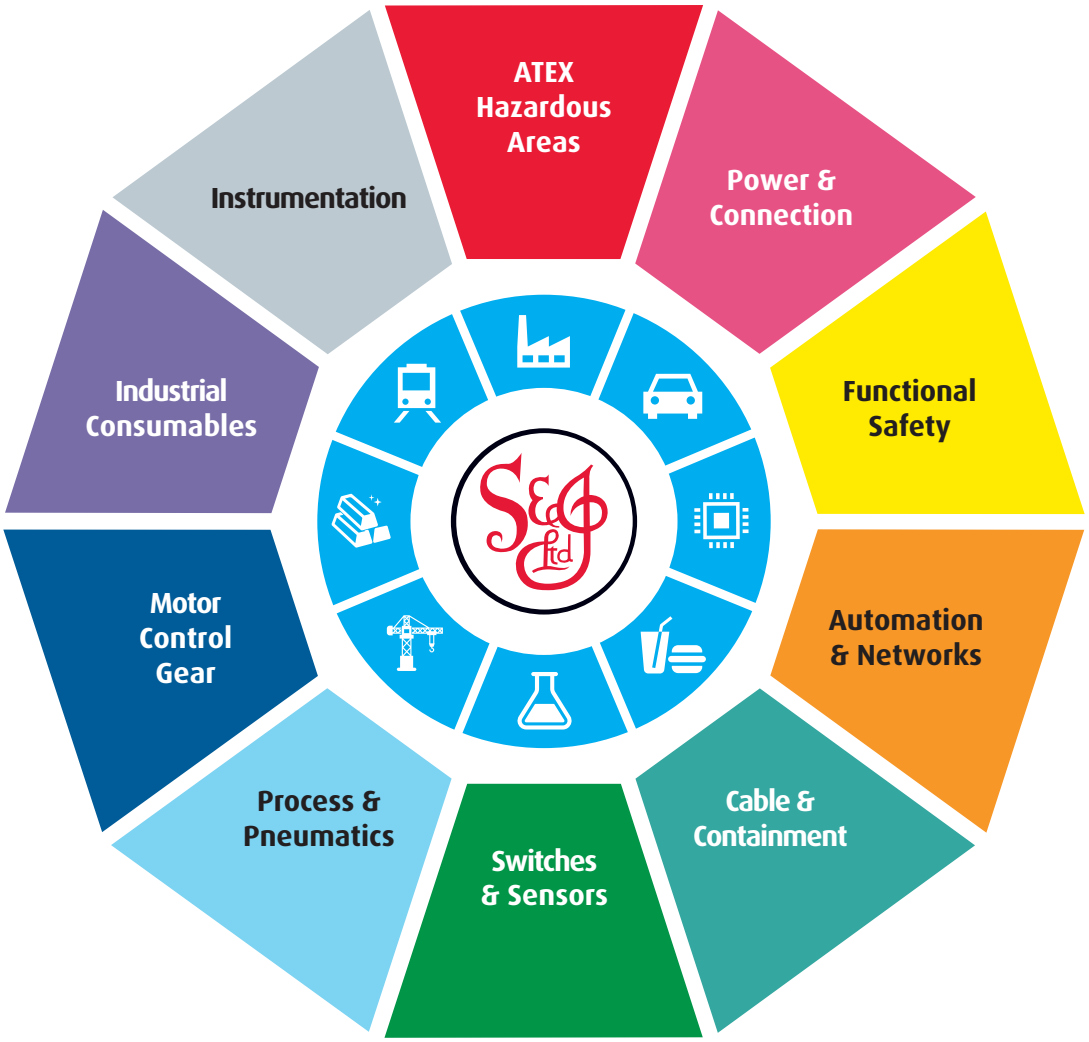

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