Functional Safety

Relay Module KFD2-RSH-1.2D.FL2(-Y1), KFD2-RSH-1.2D.FL3(-Y1)

Original Instructions

ISO9001

CE SIL 3 PL e

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Worldwide

Pepperl+Fuchs Group

Lilienthalstr. 200

68307 Mannheim

Germany

Phone: +49 621 776 - 0

E-mail: info@de.pepperl-fuchs.com

North American Headquarters

Pepperl+Fuchs Inc.

1600 Enterprise Parkway

Twinsburg, Ohio 44087

USA

Phone: +1 330 425-3555

E-mail: sales@us.pepperl-fuchs.com

Asia Headquarters

Pepperl+Fuchs Pte. Ltd.

P+F Building

18 Ayer Rajah Crescent

Singapore 139942

Phone: +65 6779-9091

E-mail: sales@sg.pepperl-fuchs.com

https://www.pepperl-fuchs.com

1 Introduction

1.1 Content of this Document

This document contains safety-relevant information for usage of the device.
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

For full information on the product, refer to the 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 signal conditioner provides the galvanic isolation between field circuits and control circuits.

The de-energized to safe (DTS) function is permitted for SIL 3 and PL e applications.

An internal fault or a line fault is signalized by the impedance change of the relay contact input and an additional relay contact output.

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

The output must be protected against contact welding by an internal fuse or an external current limitation.

KFD2-RSH-1.2D.FL2(-Y1)

The device is a relay module that is suitable for safely switching applications of a load circuit. The device isolates load circuits up to 60 V DC and the 24 V DC control circuit.

KFD2-RSH-1.2D.FL3(-Y1)

The device is a relay module that is suitable for safely switching applications of a load circuit. The device isolates load circuits up to 230 V AC and the 24 V DC control circuit.

Y1 Version

This device is compatible to the following control: Emerson DeltaV CHARM. Compatibility check to other ESD/DCS systems on request.

2.2 Interfaces

The device has the following interfaces:

- Safety-relevant interfaces: input, output (DTS)
- Non-safety relevant interfaces: fault indication output

Note

For corresponding connections see datasheet.

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2.3 Marking

Pepperl+Fuchs Group Lilienthalstraße 200, 68307 Mannheim, Germany
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KFD2-RSH-1.2D.FL2, KFD2-RSH-1.2D.FL2-Y1, KFD2-RSH-1.2D.FL3, KFD2-RSH-1.2D.FL3-Y1	Up to SIL 3 and PL e

2.4 Standards and Directives for Functional Safe

Device-specific standards and directives

Functional safety	IEC/EN 61508, part 1 – 2, edition 2010: Functional safety of electrical/electronic/programmable electronic safety-related systems (manufacturer)

Machinery Directive 2006/42/EC	• EN/ISO 13849, part 1, edition 2015: Safety-related parts of control systems (manufacturer) • IEC 62061, edition 2005 + A1:2012 + A2:2015 EN 62061, edition 2005 + Cor. 2010 + A1:2013 + A2:2015: Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems

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**.
- 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 ºC may be assumed. For a higher average temperature of 60 ºC, 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 nominal voltage at the digital input is 24 V. Ensure that the nominal voltage does not exceed 26.4 V under all operating conditions.
- The DO card must be able to supply a signal current of at least 36 mA.
- Observe the useful lifetime limitations of the output relays.
- The relay contacts must be protected against overcurrent with a suitable current limitation. For this purpose, either the internal fuse or an external current limitation with the same limit values must be used.

SIL 3 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 3 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^{-3}, hence the maximum allowable PFD_{avg} value would then be 10^{-4}.
- For a SIL 3 application operating in high demand mode the total PFH value of the SIF should be smaller than 10^{-7} per hour, hence the maximum allowable PFH value would then be 10^{-8} per hour.
- Since the safety loop has a hardware fault tolerance of **0** and it is a type **A** device, the SFF must be > 90 % according to table 2 of IEC/EN 61508-2 for a SIL 3 (sub) system.

SILCL and PL application

- The device was qualified for use in safety functions acc. to IEC/EN 62061 and EN/ISO 13849-1. The device fulfills the requirements for a SILCL of SIL 3 acc. to IEC/EN 62061 and due to the equivalency between these standards PL e acc. to EN/ISO 13849-1.

3.3 Safety Function and Safe State

Safety Function

Whenever the input of the device is de-energized, the DTS output is not conducting.

Safe State

In the safe state of the safety function the DTS output is open (non-conducting).

Reaction Time

The reaction time is < 2 s.

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	
Safety function	Output is de-energized (DTS, de-energized to safe)	
	without diagnosis	with diagnosis
HFT	0	
SIL	3	
SILCL	3	
SC	3	
PL	e	
λ_s [1]	453 FIT	453 FIT
λ_{dd}	0 FIT	0.82 FIT
λ_{du} [2]	0.86 FIT	0.04 FIT
$\lambda_{total\ (safety\ function)}$ [1]	454 FIT	454 FIT
λ_{total}	1735 FIT	1735 FIT
SFF [1]	99.8 %	99.99 %
MTBF [3]	66 years	66 years
$MTTF_d$	1115 years (high)	1115 years (high)
DC_{avg} [4]	0 %	95.3 %
PTC	95.3 %	95.3 %
PFH	8.55×10^{-10} 1/h	4.00×10^{-11} 1/h
PFD_{avg} for T_1 = 1 year [5]	5.36×10^{-6}	2.50×10^{-7}
PFD_{avg} for T_1 = 2 years [5]	8.95×10^{-6}	4.18×10^{-7}
PFD_{avg} for T_1 = 3 years [5]	1.25×10^{-5}	5.86×10^{-7}
T_1 max. [6]	26.5 years	564 years
Reaction time [7]	< 2 s	

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. While the diagnostic function is signaling the dangerous failure of one relay, the other two redundant relays continue to provide the safety function. Exceptions are common cause failures that disrupt all three relays. While the diagnostic function is signaling the failure, the probability of a dangerous undetected failure for the remaining two relays is increasing to 2.0 FIT.
3. 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.
4. Enable the internal fault detection to achieve a diagnostic coverage of 95.3 %. See chapter 5.1.
5. 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}.
6. assuming 10 % of the PFD_{avg} budget in the safety loop, $T_1 = T_{service}$
7. Step response time, also valid under fault conditions (including fault detection and fault reaction)

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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, 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.

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 Mounting

Tighten the terminal screws with a torque of 0.5 ... 0.6 Nm.

4.2 Installation

To avoid contact welding we recommend using a serial fuse in the load circuit

The device is delivered with a replaceable fuse. Replace this fuse only with a fuse up to 5 AT. Optionally use an unfused terminal with an external current limitation.

4.3 Configuration

Note

The device configuration via DIP switches is not safety relevant.

Configuring the Device

The device is configured via DIP switches. The DIP switches are on the side of the device.

1. De-energize the device before configuring the device.
2. Remove the device.
3. Configure the device via the DIP switches.
4. Secure the DIP switches to prevent unintentional adjustments.
5. Mount the device.
6. Connect the device again.

Note

See corresponding datasheets for further information.

4.3.1 Output Configuration

Switch		Line fault detection	Internal fault detection
S1	S2		
Off	Off	disabled	disabled
On	Off	enabled	disabled
Off	On	not used	
On	On	enabled	enabled

Table 4.1

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.

Danger!
Danger to life from faulty or missing fuse protection of the relay contacts

Faulty or missing fuse protection of the relay contacts can compromise the safety function and the electrical safety of the device.

- Protect the relay contacts with a suitable current limitation against overcurrent.
- Use the internal fuse for protection.
- If you do not use the internal fuse, use an external current limitation with the same limit values.

Warning!
Risk of burns from hot surface

Touching the hot surface of the device can result in burns.

- Do not touch the hot surface of the device.
- Let the device surface cool down before touching the device.
- Do not cover the warning marking on the device. Do not remove the warning marking from 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 Internal Diagnosis

With enabled internal fault detection a diagnostic coverage of 95.3 % is achieved.
Monitor one of the 4 possible ways of fault detection:

- Input impedance change [1]
- Fault indication output
- Collective error message output
- LED indication

The device has three output relays. To ensure a complete diagnosis, three switching operations are necessary. You have 2 options to achieve the diagnostic coverage, see step 2 of the following section.

Internal Diagnosis Procedure

1. Enable the internal fault detection. See chapter 4.3.1.
2. You have 2 options to achieve the diagnostic coverage
   - Switch on the output manually three times.
     or
     Observe whether the output switches on three times during the normal operation.

     Note

     Maintain a distance of at least 2 s between the switching processes.

     or
   - Check the output function at periodic intervals. Switch on the output at least three times a year as described in the steps 1 and 2.

[1] In this case only use a safety PLC with digital output and line fault detection.

5.2 Proof Test Procedure

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.

Conditions

	KFD2-RSH-1.2D.FL2(-Y1)	KFD2-RSH-1.2D.FL3(-Y1)
Load power supply	> 5 V DC	> 35.5 V AC
Device power supply (LED PWR is on)	24 V DC	24 V DC
Output load	13.2 Ω < R < 7.3 kΩ	39.2 Ω < R < 45 kΩ
Current through load	14 mA < I < 1.9 A	13.5 mA AC < I < 4.9 A AC
Input current	≥ 36 mA	≥ 36 mA

Table 5.1

If the conditions are met, you can also check the device in the application.

Proof Test Procedure

1. Enable the internal fault detection and the line fault detection. See chapter 4.3.1.
2. Check the device as shown in the following tables.
3. After check reset the device to the necessary settings.
4. Check the correct behavior of the safety loop. Is the configuration correct?

Test No.	Input	Output
1	V = 0 V DC between terminals 7+ and 8-	
2	Wait at least 2 seconds.	• LED OUT is off. • LED FLT is off [1].
3	V = 24 V DC between terminals 7+ and 8-	
4	Wait at least 2 seconds.	• LED OUT is on. • LED FLT is off [1].
5	V = 0 V DC between terminals 7+ and 8-	
6	Wait at least 2 seconds.	• LED OUT is off. • LED FLT is off [1].
7	V = 24 V DC between terminals 7+ and 8-	
8	Wait at least 2 seconds.	• LED OUT is on. • LED FLT is off [1].
9	V = 0 V DC between terminals 7+ and 8-	
10	Wait at least 2 seconds.	• LED OUT is off. • LED FLT is off [1].
11	V = 24 V DC between terminals 7+ and 8-	
12	Wait at least 2 seconds.	• LED OUT is on. • LED FLT is off [1].

Table 5.2 Expected test results for the proof test

[1] When the FLT LED flashes, a line fault is present. Check whether the supply voltage and the connected load are in the OK area of the line fault detection.
When the FLT LED is lit continuously, an internal fault is present. Reset the internal fault by interrupting the power supply (terminals 14+/15-).

Only if all tests are successfully done, the proof test is successful.

5.3 Application Examples

5.3.1 Standard Application for Dual Pole Switching

For a switching application, the device has to be attached to the process control system and the load the following way.

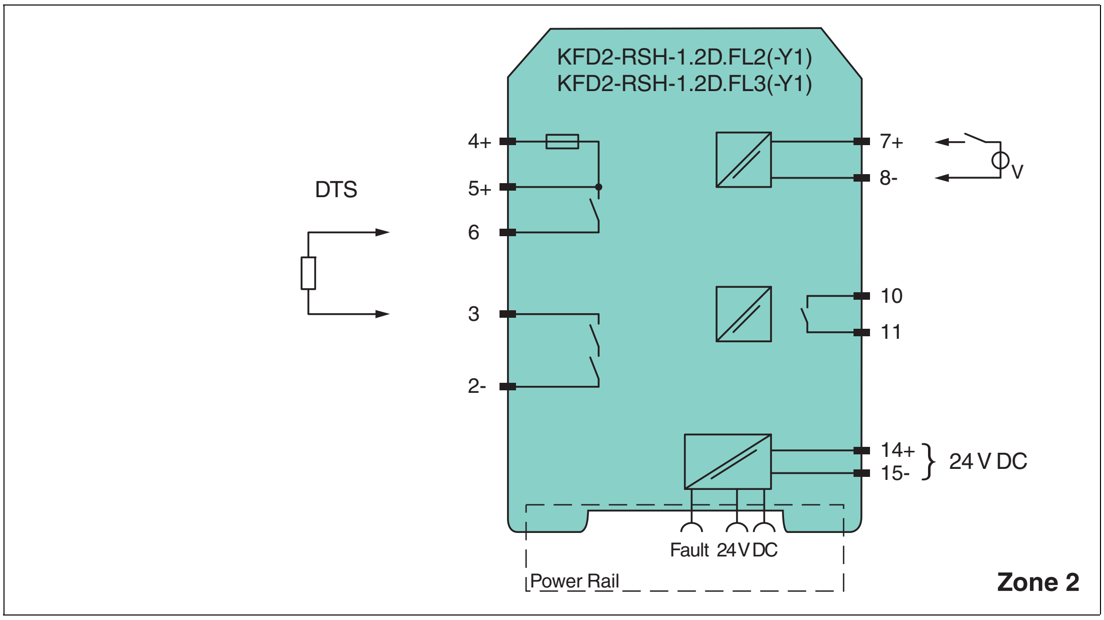

Figure 5.1 Standard application for dual pole switching

In the standard application, the process control system is connected to terminals 7+ and 8-. The line fault transparency (LFT) of the safety relay must be compatible with the line fault detection of the process control system output. Terminals 10 and 11 can be used as fault indication output to the process control system.

The characteristic safety values valid for the standard application can be found in Table 3.1.

5.3.2 Application with Fault Indication Output in the Signal Loop of the Dual Pole Switching

Some process control systems are not working with test pulses or with specific test pulses that do not recognize the impedance change of the device output signaling a line fault. Where the output of the process control system can detect an open circuit in the signal loop, the fault indication output of the device may be put in series to the input. See figure.

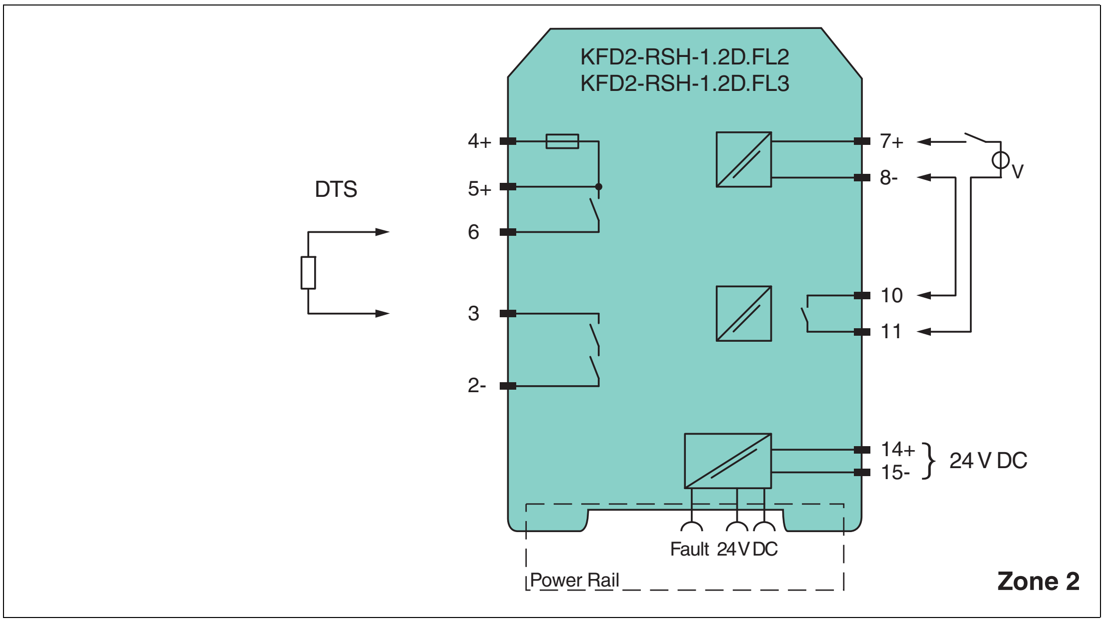

Figure 5.2 Application with fault indication output in the signal loop of the dual pole switching

If the fault indication output is open, the output relay contacts cannot be enabled. But as the fault is detected by the process control system a suitable reaction can be planned. The user must ensure that a suitable reaction on this detected fault is implemented.

For this application, the characteristic safety values are the same. The characteristic safety values can be found in Table 3.1.

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6 Maintenance and Repair

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.

Warning!

Risk of burns from hot surface

Touching the hot surface of the device can result in burns.

- Do not touch the hot surface of the device.
- Let the device surface cool down before touching the device.
- Do not cover the warning marking on the device. Do not remove the warning marking from 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

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
$\mathbf{PFD}_{avg}$	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
$\mathbf{T}_1$	Proof Test Interval
$\mathbf{T}_{service}$	Time from start of operation to putting the device out of service
DTS	**D**e-energized **T**o **S**afe
ETS	**E**nergized **T**o **S**afe
$\mathbf{B}_{10d}$	Number of switching cycles until 10 % of the components fail dangerously
DC	**D**iagnostic **C**overage of dangerous faults
$\mathbf{MTTF}_d$	**M**ean **T**ime **T**o dangerous **F**ailure
PL	**P**erformance **L**evel
SILCL	SIL **C**laim **L**imit (for a subsystem)

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