

MANUAL

Functional Safety Switch Amplifier KFD2-SR3-(Ex)2.2S



SIL 2



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1 Introduction

1.1 Contents

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:

- EC-type of examination
- EU declaration of conformity
- Attestation of conformity
- Certificates
- Control drawings
- FMEDA report
- Assessment report
- Additional documents

For more information about functional safety products from Pepperl+Fuchs see www.pepperl-fuchs.com/sil.

1.2 Safety Information

Target Group, Personnel

Responsibility for planning, assembly, commissioning, operation, maintenance, and dismantling lies with the plant operator.

Only appropriately trained and qualified personnel may carry out mounting, installation, commissioning, operation, maintenance, and dismantling 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

Each input controls a relay contact output.

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

A fault is signaled by LEDs acc. to NAMUR NE44 and a separate collective error message 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.

KFD2-SR3-2.2S

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

The device transfers digital signals (NAMUR sensors or dry contacts) from the field to the control system.

KFD2-SR3-Ex2.2S

This isolated barrier is used for intrinsic safety applications.

The device transfers digital signals (NAMUR sensors or dry contacts) from a hazardous area to a safe area.

2.2 Interfaces

The device has the following interfaces:

- Safety relevant interfaces: 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

| |
|---|
| Pepperl+Fuchs GmbH Lilienthalstraße 200, 68307 Mannheim, Germany |
|---|

| | |
|--------------------------------|-------------|
| KFD2-SR3-2.2S, KFD2-SR3-Ex2.2S | 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/EN 61511, part 1 – 3, edition 2003: 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 T₁ 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.

$$\text{SFF} = (\lambda_s + \lambda_{dd}) / (\lambda_s + \lambda_{dd} + \lambda_{du})$$

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.

3.2 Assumptions

The following assumptions have been made during the FMEDA:

- Failure rate based on the Siemens standard SN29500.
- Failure rates are constant, wear is not considered.
- External power supply failure rates are not included.
- The device will be used under average industrial ambient conditions, which are comparable with the classification "stationary mounted" in MIL-HDBK-217F. Alternatively, the following ambient conditions are assumed:
 - IEC/EN 60654-1 Class C (sheltered location) with temperature limits in the range of the manufacturer's specifications and an average temperature of 40 °C over a long period. The humidity level is within manufacturer's rating. 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 fault indication output which signals if the field circuits are broken or shorted is not considered in the FMEDA and the calculations.
- The indication of a dangerous failure (via fault bus) is detected within 1 hour by the programmable logic controller (PLC).

SIL 2 Application

- The device shall claim less than 10 % of the total failure budget for a SIL 2 safety loop.
- For a SIL 2 application operating in low demand mode the total PFD_{avg} value of the SIF (Safety Instrumented Function) 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.
- The safety-related device is considered to be of type **A** device with a hardware fault tolerance of **0**.
- 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 de-energized state.

Safety Function

The safety function has two modes of operation:

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

Observe that only one input and one output are part of the same safety function in the 2-channel version.

DIP Switch Settings

| Function | Mode | KFD2-SR3-2.2S, KFD2-SR3-Ex2.2S |
|----------------------|------------------|-----------------------------------|
| Mode channel I | normal mode | S1 position I |
| | inverted mode | S1 position II |
| Mode channel II | normal mode | S2 position I |
| | inverted mode | S2 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.

Line Fault Detection

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

The input loop of all versions is supervised. The related safety function is that the outputs go to fault state (safe state) if a line fault is detected.

Reaction Time

The reaction time for the safety function is < 20 ms.



Note!

The collective error message output is not safety relevant.

3.4 Characteristic Safety Values

| Parameters acc. to IEC 61508 | Characteristic values |
|---|-------------------------------------|
| Assessment type and documentation | Full assessment |
| Device type | A |
| Mode of operation | Low demand mode or high demand mode |
| HFT | 0 |
| SIL (SC) | 2 |
| Safety function | Normal/inverted operation |
| λ_s^1 | 145 FIT |
| λ_{dd} | 4.1 FIT |
| λ_{du} | 73 FIT |
| $\lambda_{total} \text{ (safety function)}^1$ | 222 FIT |
| $\lambda_{not\ part}$ | 77 FIT |
| SFF ¹ | 67 % |
| MTBF ² | 270 years |
| PFH | 7.26×10^{-8} 1/h |
| PFD _{avg} for $T_1 = 1$ year | 3.18×10^{-4} |
| PFD _{avg} for $T_1 = 2$ years | 6.36×10^{-4} |
| PFD _{avg} for $T_1 = 5$ years | 1.59×10^{-3} |
| PTC | 100 % |

Table 3.2

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

² acc. to SN29500. This value includes failures which are not part of the safety function/MTTR = 24 h. The value is calculated for one safety function of the device.

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.

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 ... 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 there are no components with reduced life time in the safety loop (for example electrolytic capacitors, relays, flash memories, optocoupler) which can produce dangerous undetected failures and
- 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.

Maximum Switching Power of Output Contacts

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



Note!

For more information see the corresponding datasheets.

4 Mounting and Installation



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!

For more information see the corresponding datasheets.

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 instruction 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 24 hours. Take measures to maintain the safety function while the device is being repaired.

5.1 Proof Test

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.

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
- Load resistor i. e. 240 Ω , 2.5 W
- Simulate the sensor state by a potentiometer of 4.7 k Ω (threshold for normal operation), by a resistor of 220 Ω (short circuit detection) and by a resistor of 150 k Ω (lead breakage detection).

Check the settings after the configuration by suitable tests.

Proof Test Procedure

1. Test each input channel individually. The threshold must be between 1.4 mA and 1.9 mA. The hysteresis must be between 170 μ A and 250 μ A.

↳ For normal mode of operation the relay of the corresponding output must have switched, if the input current is above the threshold. This state is indicated by yellow LED.

For inverse mode of operation the relay of the corresponding output must have switched, if the input current is below the threshold. This state is indicated by yellow LED.

2. Connect a resistor R_{SC} (220 Ω) or a resistor R_{LB} (150 k Ω) 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.
3. Test the outputs with a certain current, i. e. 100 mA and a voltage set to 24 V DC. Test that the contacts of the relays are definitely open, if the relay is de-activated.
4. Set back the device to the original settings for the current application after the test.
5. Secure the DIP switches to prevent unintentional adjustments.

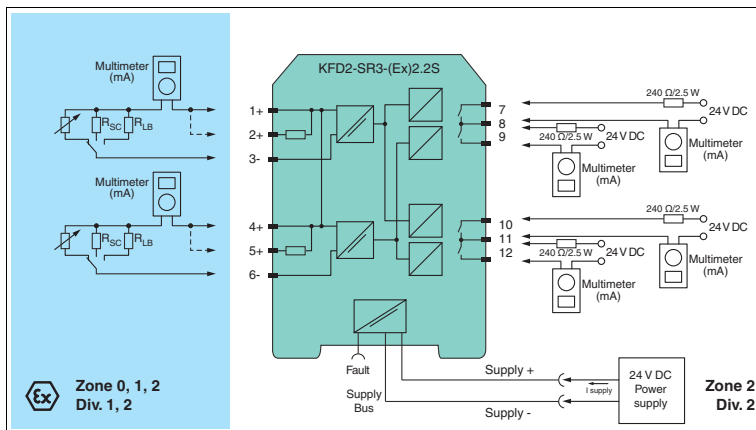


Figure 5.1 Proof test set-up for KFD2-SR3-(Ex)2.2S

Usage in Zone 0, 1, 2/Div. 1, 2 only for KFD2-SR3-Ex2.2S.

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.



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. Ensure the proper function of the safety loop, while the device is maintained, repaired or replaced.
If the safety loop does not work without the device, shut down the application.
Do not restart the application without taking proper precautions.
Secure the application against accidental restart.
3. Do not repair a defective device. A defective device must only be repaired by the manufacturer.
4. Replace a defective device only by a device of the same type.

7 List of Abbreviations

| | |
|---------------------------------------|--|
| ESD | Emergency Shutdown |
| FIT | Failure In Time in 10^{-9} 1/h |
| FMEDA | Failure Mode, Effects, and Diagnostics Analysis |
| 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 |
| $\lambda_{total\ (safety\ function)}$ | Safety function |
| HFT | Hardware Fault Tolerance |
| MTBF | Mean Time Between Failures |
| MTTR | Mean Time To Restoration |
| PCS | Process Control System |
| PFD_{avg} | Average Probability of dangerous Failure on Demand |
| PFH | Average frequency of dangerous failure |
| PTC | Proof Test Coverage |
| SFF | Safe Failure Fraction |
| SIF | Safety Instrumented Function |
| SIL | Safety Integrity Level |
| SIL (SC) | Safety Integrity Level (Systematic Capability) |
| SIS | Safety Instrumented System |
| T₁ | Proof Test Interval |
| FLT | Fault |
| LB | Lead Breakage |
| LFD | Line Fault Detection |
| SC | Short Circuit |



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