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MANUAL

Functional Safety

Transmitter Power Supply
KF**-CRG2-(Ex)1.D

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 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

General

The device supplies 2-wire and 3-wire transmitters, and can also be used with current sources.

Two relays and an active 0/4 mA to 20 mA current source are available as outputs.
The relay contacts and the current output can be integrated in security-relevant circuits.
The current output is easily scaled.

On the display the measured value can be indicated in various physical units.

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

The input has a line fault detection.

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

KFD2-CRG2-1.D

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

The device is supplied by a voltage of 20 V DC to 30 V DC via Power Rail or terminals.

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

KFD2-CRG2-Ex1.D

This isolated barrier is used for intrinsic safety applications.

The device is supplied by a voltage of 20 V DC to 30 V DC via Power Rail or terminals.

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

KFU8-CRG2-1.D

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

The device is supplied by a voltage of 20 V DC to 90 V DC or 48 V AC to 253 V AC via terminals.

A fault is signalized by LEDs.

KFU8-CRG2-Ex1.D

This isolated barrier is used for intrinsic safety applications.

The device is supplied by a voltage of 20 V DC to 90 V DC or 48 V AC to 253 V AC via terminals.

A fault is signalized by LEDs.

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2.2 Interfaces

The device has the following interfaces.

- Safety relevant interfaces: input and output
- Non-safety relevant interfaces: collective error message output (only KFD2-CRG2-(Ex)1.D)

Note!

For corresponding connections see datasheet.

2.3 Marking

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

KFD2-CRG2-1.D, KFD2-CRG2-Ex1.D, KFU8-CRG2-1.D, KFU8-CRG2-Ex1.D	Up to SIL 2

2.4 Standards and Directives for Functional Safety

Device-specific standards and directives

Functional safety	IEC/EN 61508, part 2, 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)

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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.
- Failure rates are constant, wear is not considered.
- 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).
- The safety-related device is considered to be of type **B** 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 °C may be assumed. For a higher average temperature of 60 °C, the failure rates must be multiplied by a factor of 2.5 based on experience. A similar factor must be used if frequent temperature fluctuations are expected.
- Since the outputs of the device use common components, these outputs must not be used in the same safety function.
- Features that extend the reaction time of the output are not considered within the specified reaction time. It is the user's responsibility to consider this time within the safety calculation.
- Observe the useful lifetime limitations of the output relays according to the datasheet.
- The device must be configured for the required safety function before the commissioning. During the operation any change of the configuration is not allowed. See chapter 4.1.1.
- The device configuration is protected by a password against changing.

Analog Output

- The application program in the programmable logic controller (PLC) is configured to detect underrange and overrange failures.

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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 (**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 control loop has a hardware fault tolerance of **0** and it is a type **B** device, the SFF must be > 60 % according to table 2 of IEC/EN 61508-2 for a SIL 2 (sub) system.
- The IEC/EN 61511-1 section 11.4.4 allows devices to be used in applications one SIL higher than given by table 3 of IEC/EN 61508-2, if the device is proven-in-use. The assessment and proven-in-use demonstration lead to the result that the device may be used in applications up to SIL 2. However, it is the responsibility of the end-user to decide on applying proven-in-use devices.

3.3 Safety Function and Safe State

Safe State

Relay contact output

The safe state is present when the output is de-energized.

Current output

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

Safety Function

Relay contact output

The safe state is initiated when the input current falls below a certain value (fault current Min) or exceeds a certain value (fault current Max).

Current output

The device transfers a current value with 5 % accuracy related to the full scale of the output.

Reaction Time

The reaction time for all safety functions is < 1 s.

Note!

See corresponding datasheets for further information.

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3.4 Characteristic Safety Values

Parameters	Characteristic values			
	Relay contact output		Current output	
	KFD2-CRG2-(Ex)1.D	KFU8-CRG2-(Ex)1.D	KFD2-CRG2-(Ex)1.D	KFU8-CRG2-(Ex)1.D
Assessment type	FMEDA report with proven-in-use assessment [1]			
Device type	B			
Mode of operation	Low demand mode or high demand mode			
HFT	0			
SIL	2			
SC	2			
Safety function	Digital output		Analog output	
λ_s [2]	165 FIT	213 FIT	137 FIT	177 FIT
λ_{dd} [2]	70 FIT	79 FIT	74 FIT	83 FIT
λ_{du} [2]	114 FIT	108 FIT	90 FIT	81 FIT
$\lambda_{no\ effect}$ [2]	164 FIT	194 FIT	151 FIT	178 FIT
$\lambda_{no\ part}$ [2]	35.8 FIT	34.4 FIT	35.0 FIT	34.8 FIT
$\lambda_{total\ (safety\ function)}$	348 FIT	399 FIT	300 FIT	341 FIT
$\lambda_{total\ (signal\ path)}$	548 FIT	628 FIT	486 FIT	554 FIT
SFF [3]	67 %	72 %	70 %	76 %
PTC	99 %	99 %	99 %	99 %
MTBF [4]	207 years	181 years	234 years	206 years
PFH [1]	1.13×10^{-7} 1/h [5]	1.08×10^{-7} 1/h [4]	9.00×10^{-8} 1/h	8.10×10^{-8} 1/h
PFD_{avg} for T_1 = 1 year	4.96×10^{-4} 1/h	4.75×10^{-4} 1/h	3.94×10^{-4} 1/h	3.56×10^{-4} 1/h
PFD_{avg} for T_1 = 2 years	9.92×10^{-4} 1/h	9.50×10^{-4} 1/h	7.88×10^{-4} 1/h	7.12×10^{-4} 1/h
PFD_{avg} for T_1 = 5 years	2.48×10^{-3} 1/h [4]	2.37×10^{-3} 1/h [4]	1.97×10^{-3} 1/h [3]	1.78×10^{-3} 1/h [3]
Reaction time [6]	< 1 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 The failure rates were adapted to most recent date base values. The edition 1 evaluation is still valid for existing installations.

3 For the calculation of the values acc. to IEC/EN 61508:2010, the "no effect" values are excluded from the SFF calculation.

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

5 For using this proof test interval for the safety application, the usage of more than 10 % of the failure rate for the safety loop is necessary.

6 Time between fault detection and fault reaction

Note!

The characteristic values apply to all modes of operation that can be set on 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).

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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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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.

Note!

See corresponding datasheets for further information.

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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. 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 via Keypad

The device is configured via keypad. The keypad for setting the safety functions is on the front of the device.

1. Open the cover.
2. Configure the device for the required safety function via the keypad, see chapter 4.1.1.
3. Activate the password protection in the device to prevent unauthorized or accidental changes to the configuration.
4. Leave the parameterization mode to prevent unintentional adjustments.
5. Close the cover.
6. Check the device to ensure that the expected safety function is guaranteed.
7. Document any changes to the device 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 to ensure that the expected safety function is guaranteed.
9. Document any changes to the device configuration.

Note!

For more information see the manual.

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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 keypad or the operating software.
2. Enable the short circuit (SC) detection and lead breakage (LB) detection.
3. Disable the HOLD function.
4. Set the characteristic of the current output to the 4 mA to 20 mA NE 43 mode.
5. Set the fault current of the current output to "Min" or "Max".
6. Activate the password protection in the device to prevent unauthorized or accidental changes to the configuration.

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.

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
- Load resistor i. e. 220 Ω, 150 mW
- Simulate the sensor state by a NAMUR sensor simulator for 4 mA to 20 mA signals. This simulator must also be capable to signal faults (i. e. with 0.3 mA or 22.5 mA).

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Proof Test Procedure for the Current Output

1. Connect a digital multimeter and the load defined by the application to terminals 7- and 8+.
2. Set the input current to 4 mA, 12 mA, and 20 mA, depending on the used configuration. Measure the output current and the relay function.

   ↳ The proof test for the current output is passed if the measured output values are:
   – for 4 mA application: 3.9 mA to 4.1 mA
   – for 12 mA application: 11.9 mA to 12.1 mA
   – for 20 mA application: 19.9 mA to 20.1 mA
3. Set the input current to 20 mA.
   Measure the input voltage on terminals 1+ and 3-.

   ↳ The proof test for the current output is passed if the measured input voltage is ≥ 15 V.
4. If the line fault detection is activated, remove the current source on terminals 1+ and 3-.

   ↳ The red LED flashes. The relay is in the high-impedance state.
5. Test the circuit diagnosis by simulating 2.0 mA on the input if a Max alarm is configured and 21.5 mA if a Min alarm is configured.

   ↳ The red LED is off. The relay is in the high-impedance state. The output current is again between 1.9 mA to 2.1 mA at Min alarm resp. 21.4 to 21.6 mA at Max alarm.

   Test the circuit diagnosis by simulating 0.3 mA on the input if a Max alarm is configured and 22.5 mA if a Min alarm is configured.

   ↳ The red LED flashes. The relay is in the high-impedance state. The output current is again between 1.9 mA to 2.1 mA at Min alarm resp. 21.4 to 21.6 mA at Max alarm.
6. Set back the device to the original settings for the current application after the test.

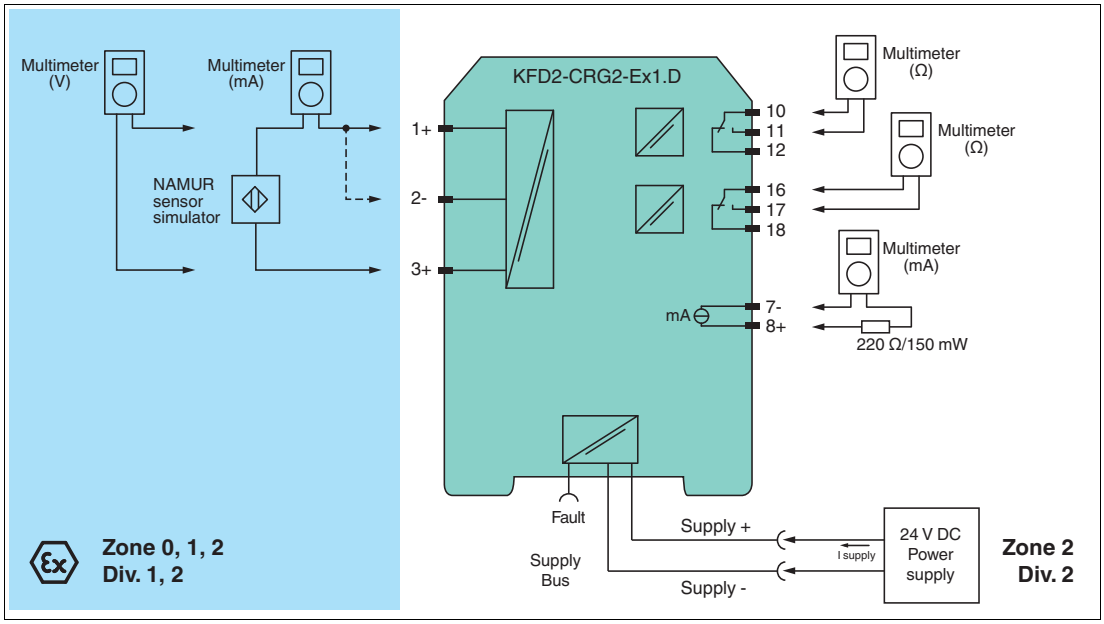

Figure 5.1 Proof test set-up for KF**-CRG2-(Ex)1.D

Usage in Zone 0, 1, 2/Div. 1, 2 only for KFD2-CRG2-Ex1.D or KFU8-CRG2-Ex1.D

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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
$\mathbf{PFD}_{avg}$	Average **P**robability of dangerous **F**ailure on **D**emand
PFH	Average frequency of dangerous failure
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

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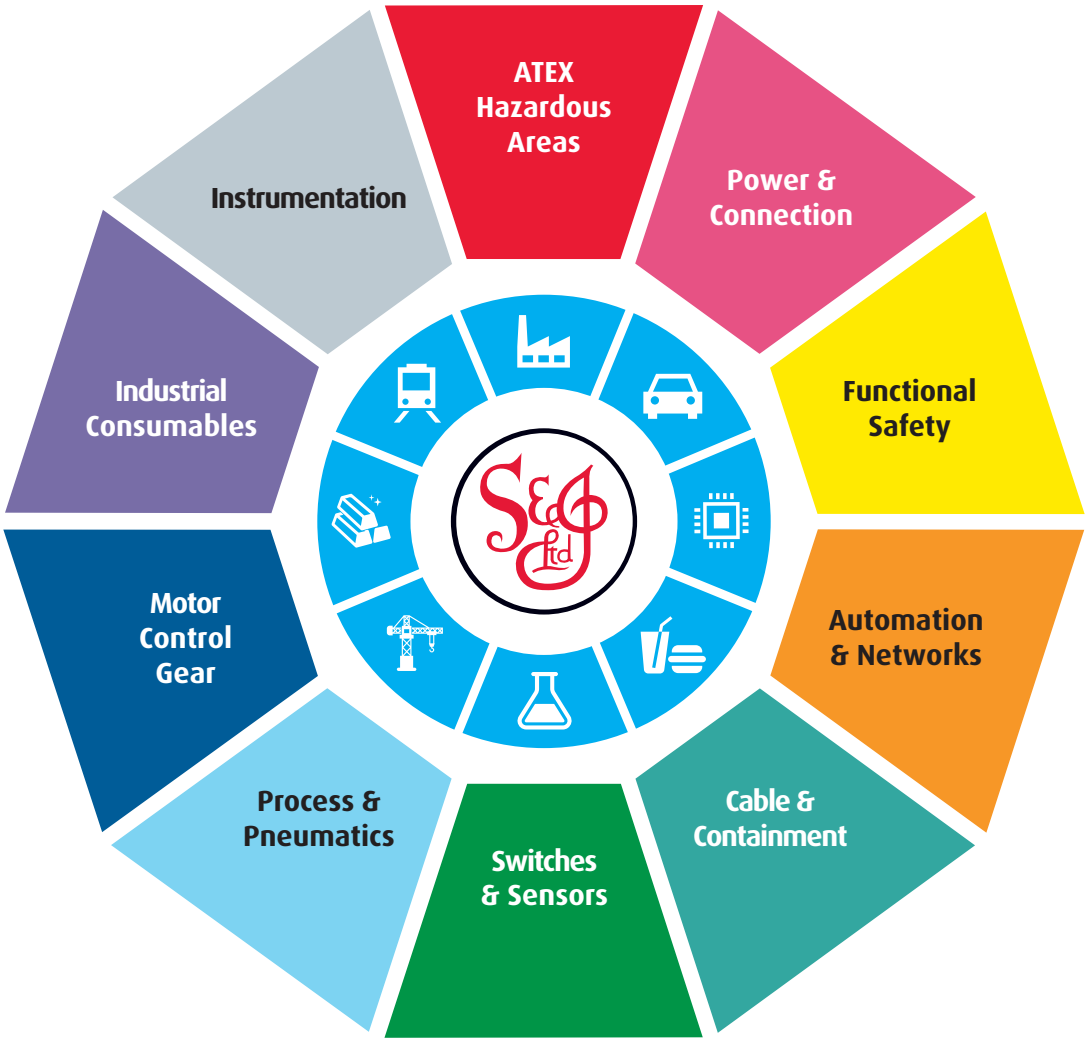

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