Functional Safety

Switch Amplifier HiC2853R1, HiC2853R4, HiC2853R6

Manual

SIL

IEC 61508/61511

ISO9001

SIL 3

Your automation, our passion.

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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.

Note

For specific device information such as the year of construction, scan the QR code on the device. As an alternative, enter the serial number in the serial number search 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.

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 isolated barrier is used for intrinsic safety applications.

The device transfers digital signals from SN/S1N safety sensors or approved dry contacts from the explosion-hazardous area to the non-explosion-hazardous area.

Lead breakage (LB) and short circuit (SC) conditions of the control circuit are continuously monitored.

If using a dry contact, a 1.5 kΩ resistor must be connected in series and a 10 kΩ resistor in parallel with the dry contact.

During a fault state, both outputs switch to their fault state and LEDs indicate the fault according to NAMUR NE 44. A separate fault bus is available. This fault bus can be monitored if the termination board supports a module fault detection.

This device mounts on a HiC termination board.

HiC2853R1

The input controls one active voltage output and one passive transistor output with a resistive output characteristic.

The passive transistor output has three defined states: 1-signal = 6.5 V voltage drop, 0-signal = 39 kΩ and fault > 100 kΩ.

This output characteristic offers line fault transparency on the signal lines.

HiC2853R4

The input controls one active voltage output and one passive transistor output with a resistive output characteristic.

The passive transistor output has three defined states: 1-signal = 472 Ω, 0-signal = 1385 Ω and fault > 100 kΩ.

This output characteristic offers line fault transparency on the signal lines.

HiC2853R6

The input controls one active voltage output and one passive transistor output with a resistive output characteristic (voltage divider).

The passive transistor output has three defined states: 1-signal ≈ 64 % x U_r, 0-signal ≈ 28 % x U_r and fault < 200 mV.

This output characteristic offers line fault transparency on the signal lines.

2.2 Interfaces

The device has the following interfaces:

- Safety relevant interfaces: input, output I, output II
- Non-safety relevant interfaces: power supply, fault output

Note

For corresponding connections see datasheet.

2.3 Marking

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

HiC2853R1, HiC2853R4, HiC2853R6	Up to SIL 3

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 61511-1:2016+COR1:2016+A1:2017 EN 61511-1:2017+A1:2017 Functional safety – Safety instrumented systems for the process industry sector (user)

3 Planning

3.1 System Structure

3.1.1 Low Demand Mode of Operation

If there are two control loops, one for the standard operation and another one for the functional safety, then usually the demand rate for the safety loop is assumed to be less than once per year.

The relevant safety parameters to be verified are:

- the PFD_{avg} value (average **P**robability of dangerous **F**ailure on **D**emand) and the T_1 value (proof test interval that has a direct impact on the PFD_{avg} value)
- the SFF value (**S**afe **F**ailure **F**raction)
- the HFT architecture (**H**ardware **F**ault **T**olerance)

3.1.2 High Demand or Continuous Mode of Operation

If there is only one safety loop, which combines the standard operation and safety-related operation, then usually the demand rate for this safety loop is assumed to be higher than once per year.

The relevant safety parameters to be verified are:

- the PFH value (**P**robability of dangerous **F**ailure per **H**our)
- Fault reaction time of the safety system
- the SFF value (**S**afe **F**ailure **F**raction)
- the HFT architecture (**H**ardware **F**ault **T**olerance)

3.1.3 Safe Failure Fraction

The safe failure fraction describes the ratio of all safe failures and dangerous detected failures to the total failure rate.

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

A safe failure fraction as defined in IEC/EN 61508 is only relevant for elements or (sub)systems in a complete safety loop. The device under consideration is always part of a safety loop but 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.

For calculations according to IEC 61508:2010, **no effect** failures are neither counted to the SFF nor to the failure rate of the safety function as these failures have no direct influence on the safety function of the devices.

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3.2 Assumptions

The following assumptions have been made during the FMEDA:

- The collective error message output is not considered in the FMEDA and in the calculations.
- Failure rate based on the Siemens standard SN 29500.
- External power supply failure rates are not included.
- 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 indication of a dangerous failure (via fault bus) is detected within 1 hour by the programmable logic controller (PLC).
- Since the outputs of the device use common components, these outputs must not be used in the same safety function.

Applications according to IEC/EN 61508

- 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.

3.3 Safety Function and Safe State

Safe State

The safe state is reached when the input goes to the low current state (I < 2.1 mA) or the fault state (I > 5.9 mA).

Safety Function

HiC2853R1, HiC2853R4

The safe state for the resistive transistor output (output I) is the high impedant state. The safe state for the electronic output (output II) is de-energized. The safe state will also be achieved if the device is not powered.

HiC2853R6

The safe state for the resistive transistor output (output I) is an output level < 7.5 V. The safe state for the electronic output (output II) is de-energized. The safe state will also be achieved if the device is not powered.

General

The output II safe state initiated by an input low condition will be reached within 20 ms at 4.7 kΩ load impedance. This mode of operation cannot be changed.
This is part of the safety concept of the device.

Fault Reaction Time

The reaction time for all safety functions is < 20 ms.

Note

See corresponding datasheets for further information.

3.4 Characteristic Safety Values

Parameters	Characteristic values	
Assessment type and documentation	Full assessment	
Device type	A	
Demand mode	Low demand mode or high demand mode	
HFT	0	
SIL	3	
SC	3	
Safety function	Signal transfer via electronic output	Signal transfer via resistive transistor output
λ_s	135 FIT	151 FIT
λ_{dd}	0 FIT	0 FIT
λ_{du}	3.31 FIT	5.1 FIT
$\lambda_{total\ (safety\ function)}$	138 FIT	156 FIT
λ_{total}	510 FIT	511 FIT
$\lambda_{no\ part}$	147 FIT	105 FIT
SFF	98 %	97 %
MTBF [1]	223,7 years	223,4 years
PFH	3.31×10^{-9} 1/h	5.09×10^{-9} 1/h
PFD_{avg} for T_1 = 1 year	1.45×10^{-5}	2.23×10^{-5}
PFD_{avg} for T_1 = 2 years	2.90×10^{-5}	4.46×10^{-5}
PFD_{avg} for T_1 = 5 years	7.25×10^{-5}	1.11×10^{-4}
PTC	100 %	
Fault reaction time [2]	≤ 20 ms	
Reaction time [3]	< 1 s	

Table 3.1

1 acc. to SN29500. This value includes failures which are not part of the safety function/MTTR = 8 h.
2 Time between fault detection and fault reaction
3 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).

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, 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 the maximum ambient temperature.

Please note that the useful lifetime refers to the (constant) failure rate of the device. The effective life time can deviate from this.

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. 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

A configuration of the device is not necessary and not possible.

5 Operation

Danger!

Danger to life from missing safety function

If the safety loop is put out of service, the safety function is no longer guaranteed.

- Do not deactivate the device.
- Do not bypass the safety function.
- Do not repair, modify, or manipulate the device.

Operating the device

1. Observe the safety instructions in the instruction manual.
2. Observe the information in the manual.
3. Use the device only with devices that are suitable for this safety application.
4. Correct any occurring safe failures within 8 hours. Take measures to maintain the safety function while the device is being repaired.

5.1 Proof Test

This section describes a possible proof test procedure. The user is not obliged to use this proposal. The user may consider different concepts with an individual determination of the respective effectiveness, e. g. concepts according to NA106:2018.

According to IEC/EN 61508-2 a recurring proof test shall be undertaken to reveal potential dangerous failures that are not detected otherwise.

Check the function of the subsystem at periodic intervals depending on the applied PFD_{avg} in accordance with the characteristic safety values. See chapter 3.4.

It is under the responsibility of the plant operator to define the type of proof test and the interval time period.

Check the settings after the configuration by suitable tests.

As the device does not have any switches or settings, no special actions have to be taken in terms of different configurations. The mode of operation is only interchangeable by the use of a different sensor (S1N type instead of SN type).

Tip

The easiest way to test HiC devices is by using a stand-alone HiCTB**-SCT-***-**-** termination board. In this test, it is not necessary to disconnect the wiring of the existing application. Faults in a subsequent wiring can be avoided.

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5.1.1 HiC2853R1

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.
  Intrinsically safe circuits that were operated with non-intrinsically safe circuits may not be used as intrinsically safe circuits afterwards.
- Power supply set at nominal voltage of 24 V DC
- Potentiometer 4.7 kΩ
- Resistor 220 Ω/150 kΩ
- Load resistances 2 kΩ, 0.5 W and 1.3 kΩ, 0.5 W

Proof Test Procedure

1. Prepare a test set-up, see figures below.
2. Verify the output values as given in table below.
3. Simulate the sensor state by a potentiometer of 4.7 kΩ. The threshold must be between 2.1 mA and 2.8 mA. The hysteresis must be between 170 µA and 350 µA.
   ↳ If the input current is above the threshold, the resistive transistor output must have a low impedance and the voltage output must be enabled (voltage level higher than 20 V DC). This state is indicated by the yellow LED.
4. Simulate the sensor state by a resistor R_{SC} (220 Ω, short circuit detection) or a resistor R_{LB} (150 kΩ, lead breakage detection).
   ↳ The device must detect an external fault. This state is indicated by red LED and the outputs must be in fault state. The resistive transistor output is high impedant (> 100 kΩ) and the voltage output is off.
5. Check the output with a certain voltage. Check that the resistive transistor output is definitely high impedant (see table, I_{off} or respectively U_{off})and the voltage output is off, if the yellow LED is off (voltage level 0 V).

Device	R	U	I_{on}	I_{off}	I_{fault}
HiC2853R1	2 kΩ	24 V	8.0 mA < I_{on} < 9.2 mA	0.46 mA < I_{off} < 0.62 mA	I_{fault} < 0.05 mA

Table 5.1 Output values for HiC2853R1

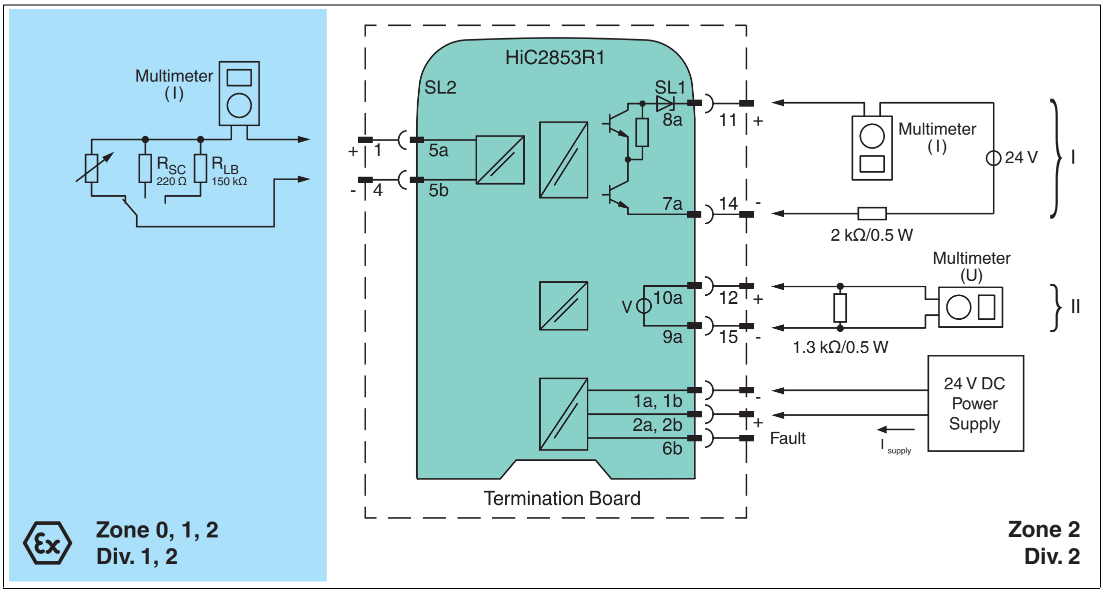

Figure 5.1 Proof test set-up for HiC2853R1

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5.1.2 HiC2853R4

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.

  Intrinsically safe circuits that were operated with non-intrinsically safe circuits may not be used as intrinsically safe circuits afterwards.

- Power supply set at nominal voltage of 24 V DC
- Current source 10.0 mA ±1 %
- Potentiometer 4.7 kΩ
- Resistor 220 Ω/150 kΩ
- Load resistance 1.3 kΩ, 0.5 W

Proof Test Procedure

1. Prepare a test set-up, see figures below.
2. Verify the output values as given in table below.
3. Simulate the sensor state by a potentiometer of 4.7 kΩ. The threshold must be between 2.1 mA and 2.8 mA. The hysteresis must be between 170 µA and 350 µA.

   ↳ If the input current is above the threshold, the resistive transistor output must have a low impedance and the voltage output must be enabled (voltage level higher than 20 V DC). This state is indicated by the yellow LED.
4. Simulate the sensor state by a resistor R_{SC} (220 Ω, short circuit detection) or a resistor R_{LB} (150 kΩ, lead breakage detection).

   ↳ The device must detect an external fault. This state is indicated by red LED and the outputs must be in fault state. The resistive transistor output is high impedant (> 100 kΩ) and the voltage output is off.
5. Check the output with a certain current. Check that the resistive transistor output is definitely high impedant (see table, I_{off} or respectively U_{off})and the voltage output is off, if the yellow LED is off (voltage level 0 V).

Device	I	U_{on}	U_{off}	I_{fault}
HiC2853R4	10.0 mA	$4.58 V < U_{on} < 4.85 V$	$13.3 V < U_{off} < 14.35 V$	$I_{fault} < 0.05 mA$

Table 5.2 Output values for HiC2853R4

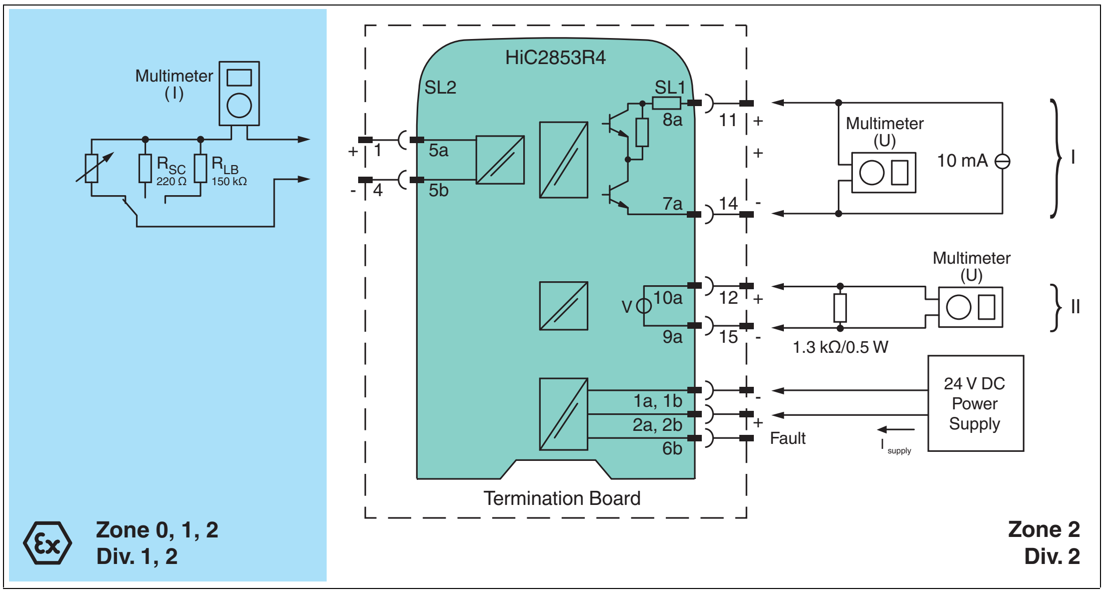

Figure 5.2 Proof test set-up for HiC2853R4

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5.1.3 HiC2853R6

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.

  Intrinsically safe circuits that were operated with non-intrinsically safe circuits may not be used as intrinsically safe circuits afterwards.
- 2nd power supply
- Power supply set at nominal voltage of 24 V DC
- Potentiometer 4.7 kΩ
- Resistor 220 Ω/150 kΩ
- Load resistance 1.3 kΩ, 0.5 W

Proof Test Procedure

1. Prepare a test set-up, see figures below.
2. Verify the output values as given in table below.
3. Simulate the sensor state by a potentiometer of 4.7 kΩ. The threshold must be between 2.1 mA and 2.8 mA. The hysteresis must be between 170 µA and 350 µA.

   ↳ If the input current is above the threshold, a voltage of approx. 64 % of the supply voltage must be present at the resistive transistor output and the voltage output must be enabled (voltage level higher than 20 V DC). This state is indicated by the yellow LED.
4. Simulate the sensor state by a resistor R_{SC} (220 Ω, short circuit detection) or a resistor R_{LB} (150 kΩ, lead breakage detection).

   ↳ The device must detect an external fault. This state is indicated by red LED and the outputs must be in fault state. The resistive transistor output is de-energized (< 0.2 V) and the voltage output is off.
5. Check that the resistive transistor output provides a voltage of approx. 28 % of the supply voltage (see table, U_{off}) and the voltage output is off (voltage level 0 V), if the yellow LED is off.

U at terminal 11	U_{on}	U_{off}	U_{fault}
23.4 V	14.7 V < U_{on} < 15.6 V	6.2 V < U_{off} < 6.8 V	U_{fault} < 0.2 V

Table 5.3 Measured values for HiC2853R6

Note

As an alternative to a 2nd power supply, the operating voltage of the termination board can also be bridged to terminal 11. In this case, the supply voltage of the termination board must be reduced to 23.4 V. This has no effect on other values.

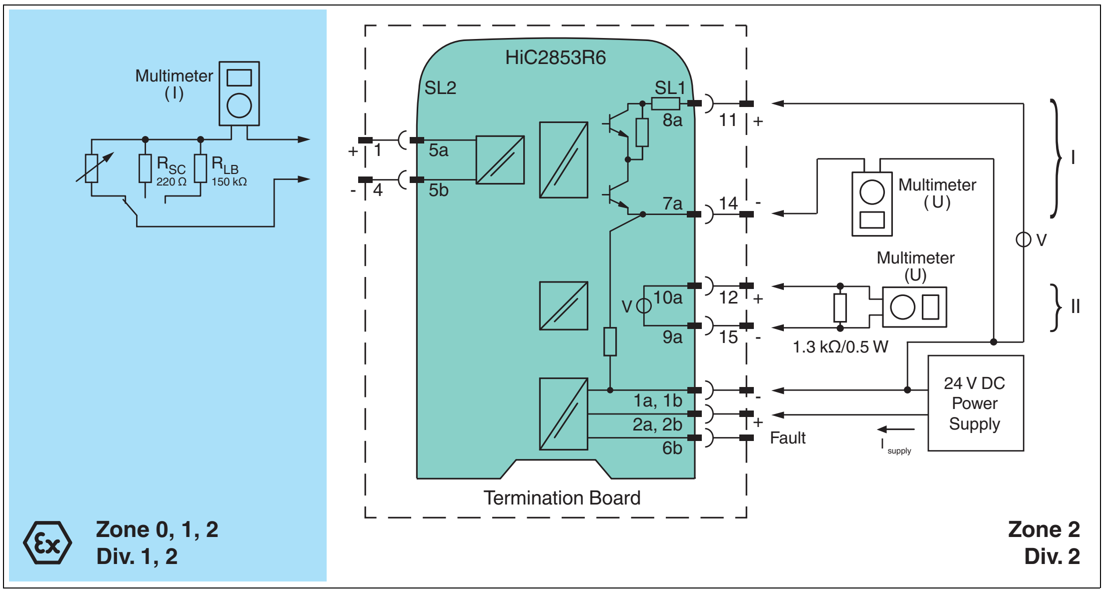

Figure 5.3 Proof test set-up for HiC2853R6

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.

Reporting Device Failure

If you use the device in a safety loop according to IEC/EN 61508, it is required to inform the device manufacturer about possible systematic failures.

Report all failures in the safety function that are due to functional limitations or a loss of device function – especially in the case of possible dangerous failures.

In these cases, contact your local sales partner or the Pepperl+Fuchs technical sales support (service line).

It is not necessary to report failures in the safety function that are due to external influences or damage.

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
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
FLT	Fault
LB	**L**ead **B**reakage
LFD	**L**ine **F**ault **D**etection
SC	**S**hort **C**ircuit
$T_{service}$	Time from start of operation to putting the device out of service

Your automation, our passion.

Explosion Protection

- Intrinsic Safety Barriers
- Signal Conditioners
- FieldConnex® Fieldbus
- Remote I/O Systems
- Electrical Ex Equipment
- Purge and Pressurization
- Industrial HMI
- Mobile Computing and Communications
- HART Interface Solutions
- Surge Protection
- Wireless Solutions
- Level Measurement

Industrial Sensors

- Proximity Sensors
- Photoelectric Sensors
- Industrial Vision
- Ultrasonic Sensors
- Rotary Encoders
- Positioning Systems
- Inclination and Acceleration Sensors
- Fieldbus Modules
- AS-Interface
- Identification Systems
- Displays and Signal Processing
- Connectivity

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