



INSTRUCTION MANUAL

SIL 3 Repeater Power Supply
Hart, DIN-Rail and Termination Board,
Models D5011S, D5011D



Characteristics

General Description: The single and dual channel Repeater Power Supply, D5011S and D5011D module is a high integrity analog input interface suitable for applications requiring SIL 3 level (according to IEC 61508) in safety related systems for high risk industries. Provides a fully floating dc supply for energizing conventional 2 wires 4-20 mA transmitters located in Hazardous Area, and repeats the current in floating circuit to drive a Safe Area load. The circuit allows bi-directional communication signals, for Hart transmitters.

Mounting on standard DIN-Rail, with or without Power Bus, or on customized Termination Boards, in Safe Area or in Zone 2.

Technical Data

Supply: 24 Vdc nom (18 to 30 Vdc) reverse polarity protected, ripple within voltage limits ≤ 5 Vpp, 2 A time lag fuse internally protected.

Current consumption @ 24 V: 85 mA for 2 channels D5011D, 42.5 mA for 1 channel D5011S with 20 mA output typical.

Power dissipation: 1.25 W for 2 channels D5011D, 0.62 W for 1 channel D5011S with 24 V supply voltage and 20 mA output typical.

Isolation (Test Voltage): I.S. In/Out 2.5 KV; I.S. In/Supply 2.5 KV; I.S. In/I.S. In 500 V; Out/Supply 500 V; Out/Out 500 V.

Input: 4 to 20 mA (2 wires Tx current limited at ≈ 25 mA), reading range 0 to 24 mA.

Transmitter line voltage: 15.0 V typical at 20 mA with max. 20 mVrms ripple on 0.5 to 2.5 KHz frequency band, 14.5 V minimum.

Output: 4 to 20 mA, on max. 550 Ω load in source mode (typical 12 V compliance).

Response time: 5 ms (0 to 100 % step change).

Output ripple: ≤ 20 mVrms on 250 Ω communication load on 0.5 to 2.5 KHz band.

Frequency response: 0.5 to 2.5 KHz bidirectional within 3 dB (Hart protocol).

Performance: Ref. Conditions 24 V supply, 250 Ω load, 23 ± 1 °C ambient temperature.

Calibration accuracy: $\leq \pm 0.1$ % of full scale.

Linearity error: $\leq \pm 0.05$ % of full scale.

Supply voltage influence: $\leq \pm 0.02$ % of full scale for a min to max supply change.

Load influence: $\leq \pm 0.02$ % of full scale for a 0 to 100 % load resistance change.

Temperature influence: $\leq \pm 0.01$ % of full scale on zero and span for a 1 °C change.

Compatibility:



CE mark compliant, conforms to 94/9/EC Atex Directive and to 2004/108/CE EMC Directive.

Environmental conditions:

Operating: temperature limits - 40 to + 70 °C, relative humidity 95 %, up to 55 °C.

Storage: temperature limits - 45 to + 80 °C.

Safety Description:



ATEX: II 3(1) G Ex nA [ja Ga] IIC T4 Gc, II (1) D [Ex ia Da] IIIC, I (M1) [Ex ia Ma] I

IECEx: Ex nA [ja Ga] IIC T4 Gc, [Ex ia Da] IIIC, [Ex ia Ma] I, associated apparatus and non-sparking electrical equipment.

Uo/Voc = 25.9 V, Io/Isc = 92 mA, Po/Po = 594 mW at terminals 7-8, 9-10.

Um = 250 Vrms, -40 °C \leq Ta \leq 70 °C.

Approvals: BVS 10 ATEX E 113 X conforms to EN60079-0, EN60079-11, EN60079-15, EN60079-26, EN61241-11, EN50303,

IECEx BVS 10.0072 X conforms to IEC60079-0, IEC60079-11, IEC60079-15, IEC60079-26, IEC1241-11.

Russia according to GOST 12.2.007.0-75, R 51330.0-99, R 51330.10-99, R 51330.14-99 2ExnA[ja]IIC T4 X.

Ukraine according to GOST 12.2.007.0, 22782.0, 22782.3, 22782.5 2Exs[ja]IIC T4 X.

TUV Certificate No. C-IS-204194-01, SIL 2 / SIL 3 conforms to IEC61508.

Mounting: T35 DIN-Rail according to EN50022, with or without Power Bus or on customized Termination Board.

Weight: about 130 g D5011D, 110 g D5011S.

Connection: by polarized plug-in disconnect screw terminal blocks to accommodate terminations up to 2.5 mm².

Location: Safe Area/Non Hazardous Locations or Zone 2, Group IIC T4 installation.

Protection class: IP 20.

Dimensions: Width 12.5 mm, Depth 123 mm, Height 120 mm.

Ordering Information

Model:	D5011	
1 channel		S
2 channels		D

Power Bus and DIN-Rail accessories:

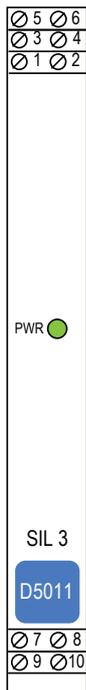
Connector JDFT049

Terminal block male MOR017

Cover and fix MCHP196

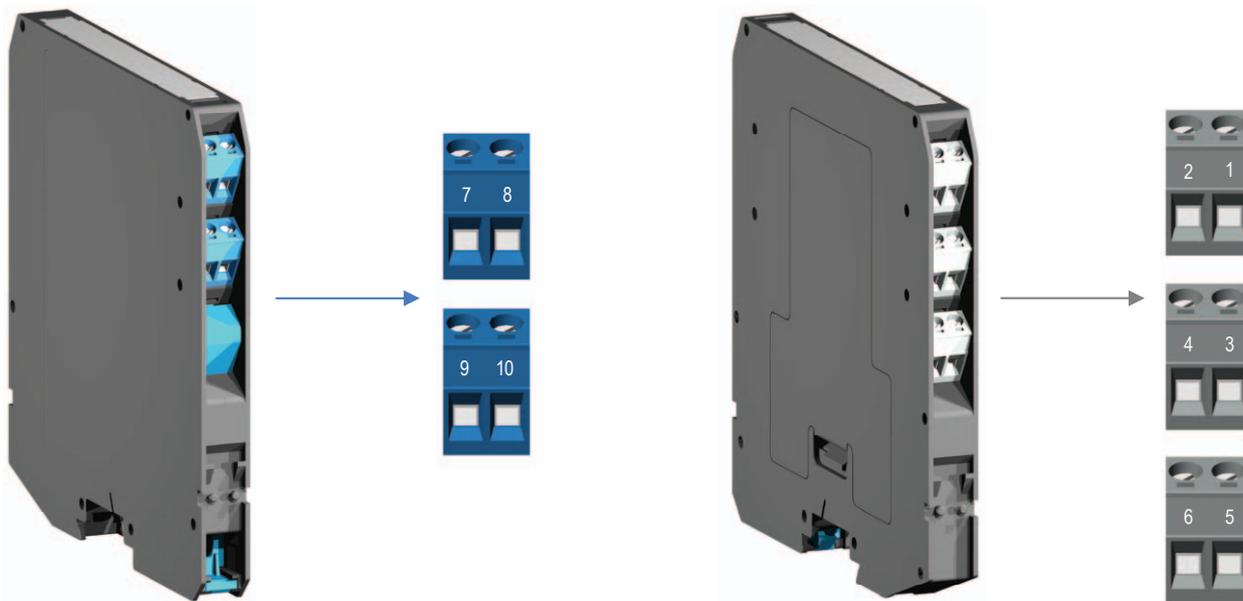
Terminal block female MOR022

Front Panel and Features



- SIL 3 according to IEC 61508 for Tproof = 1 / 2 yrs (10 / 20 % of total SIF).
- SIL 2 according to IEC 61508 for Tproof = 10 / 20 yrs (10 / 20 % of total SIF).
- PFDavg (1 year) 8.73 E-05, SFF 93.96 %.
- Input from Zone 0 (Zone 20), installation in Zone 2.
- 4-20 mA Input / Output Signal, Source mode.
- Hart compatible.
- Input and Output short circuit proof.
- High Accuracy.
- Three port isolation, Input/Output/Supply.
- EMC Compatibility to EN61000-6-2, EN61000-6-4, EN61326-1, EN61326-3-1 for safety system.
- ATEX, IECEx, Russian and Ukrainian Certifications.
- High Density, two channels per unit.
- Simplified installation using standard DIN-Rail and plug-in terminal blocks, with or without Power Bus, or customized Termination Boards.
- 250 Vrms (Um) max. voltage allowed to the instruments associated with the barrier.

Terminal block connections



HAZARDOUS AREA

7	+ Input Ch 1 for 2 wires Transmitters
8	- Input Ch 1 for 2 wires Transmitters
9	+ Input Ch 2 for 2 wires Transmitters
10	- Input Ch 2 for 2 wires Transmitters

SAFE AREA

1	+ Output Ch 1
2	- Output Ch 1
3	+ Output Ch 2
4	- Output Ch 2
5	+ Power Supply 24 Vdc
6	- Power Supply 24 Vdc

Parameters Table

In the system safety analysis, always check the Hazardous Area/Hazardous Locations devices to conform with the related system documentation, if the device is Intrinsically Safe check its suitability for the Hazardous Area/Hazardous Locations and group encountered and that its maximum allowable voltage, current, power (U_i/V_{max} , I_i/I_{max} , P_i/P_i) are not exceeded by the safety parameters (U_o/V_{oc} , I_o/I_{sc} , P_o/P_o) of the D5011 series Associated Apparatus connected to it. Also consider the maximum operating temperature of the field device, check that added connecting cable and field device capacitance and inductance do not exceed the limits (C_o/C_a , L_o/L_a , L_o/R_o) given in the Associated Apparatus parameters for the effective group. See parameters indicated in the table below:

D5011 Terminals		D5011 Associated Apparatus Parameters		Must be	Hazardous Area/ Hazardous Locations Device Parameters
Ch1	7 - 8	$U_o / V_{oc} = 25.9 \text{ V}$		\leq	U_i / V_{max}
Ch2	9 - 10				
Ch1	7 - 8	$I_o / I_{sc} = 92 \text{ mA}$		\leq	I_i / I_{max}
Ch2	9 - 10				
Ch1	7 - 8	$P_o / P_o = 594 \text{ mW}$		\leq	P_i / P_i
Ch2	9 - 10				
D5011 Terminals		D5011 Associated Apparatus Parameters Cenelec (US)		Must be	Hazardous Area/ Hazardous Locations Device + Cable Parameters
Ch1	7 - 8	$C_o / C_a = 100 \text{ nF}$	IIC (A, B)	\geq	$C_i / C_i \text{ device} + C \text{ cable}$
Ch2	9 - 10	$C_o / C_a = 770 \text{ nF}$	IIB (C)		
		$C_o / C_a = 2.63 \mu\text{F}$	IIA (D)		
		$C_o / C_a = 4.02 \mu\text{F}$	I		
		$C_o / C_a = 770 \text{ nF}$	iaD (E, F, G)		
Ch1	7 - 8	$L_o / L_a = 4.2 \text{ mH}$	IIC (A, B)	\geq	$L_i / L_i \text{ device} + L \text{ cable}$
Ch2	9 - 10	$L_o / L_a = 16.8 \text{ mH}$	IIB (C)		
		$L_o / L_a = 33.7 \text{ mH}$	IIA (D)		
		$L_o / L_a = 55.2 \text{ mH}$	I		
		$L_o / L_a = 16.8 \text{ mH}$	iaD (E, F, G)		
Ch1	7 - 8	$L_o / R_o = 59.9 \mu\text{H}/\Omega$	IIC (A, B)	\geq	$L_i / R_i \text{ device and}$ $L \text{ cable} / R \text{ cable}$
Ch2	9 - 10	$L_o / R_o = 239.7 \mu\text{H}/\Omega$	IIB (C)		
		$L_o / R_o = 479.4 \mu\text{H}/\Omega$	IIA (D)		
		$L_o / R_o = 786.6 \mu\text{H}/\Omega$	I		
		$L_o / R_o = 239.7 \mu\text{H}/\Omega$	iaD (E, F, G)		

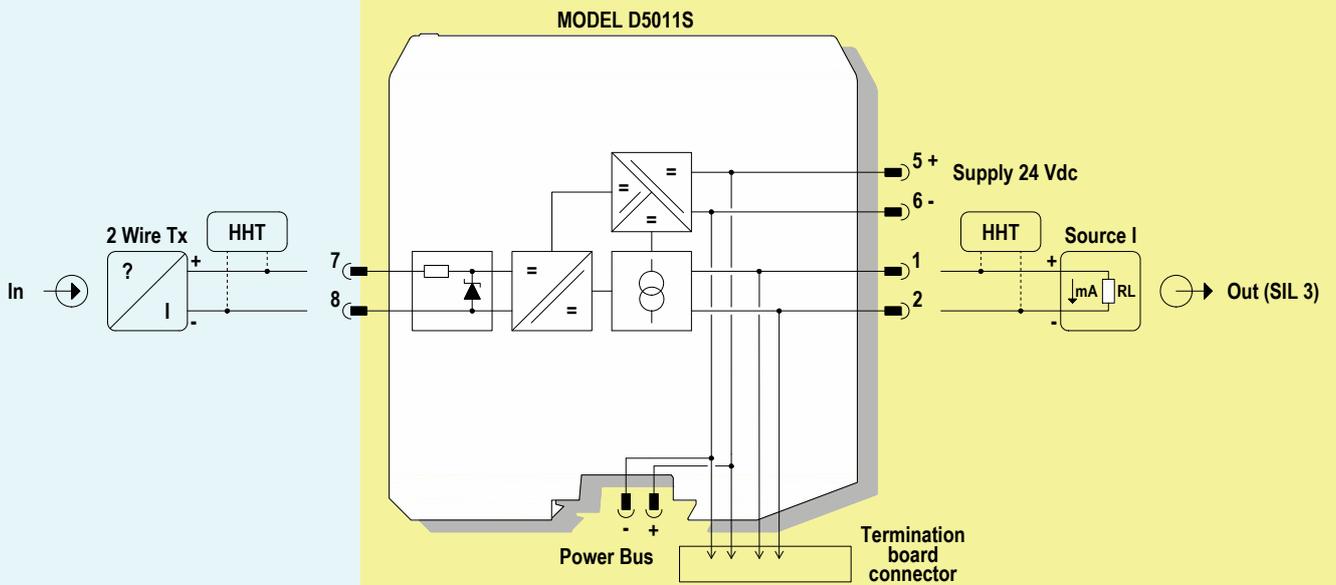
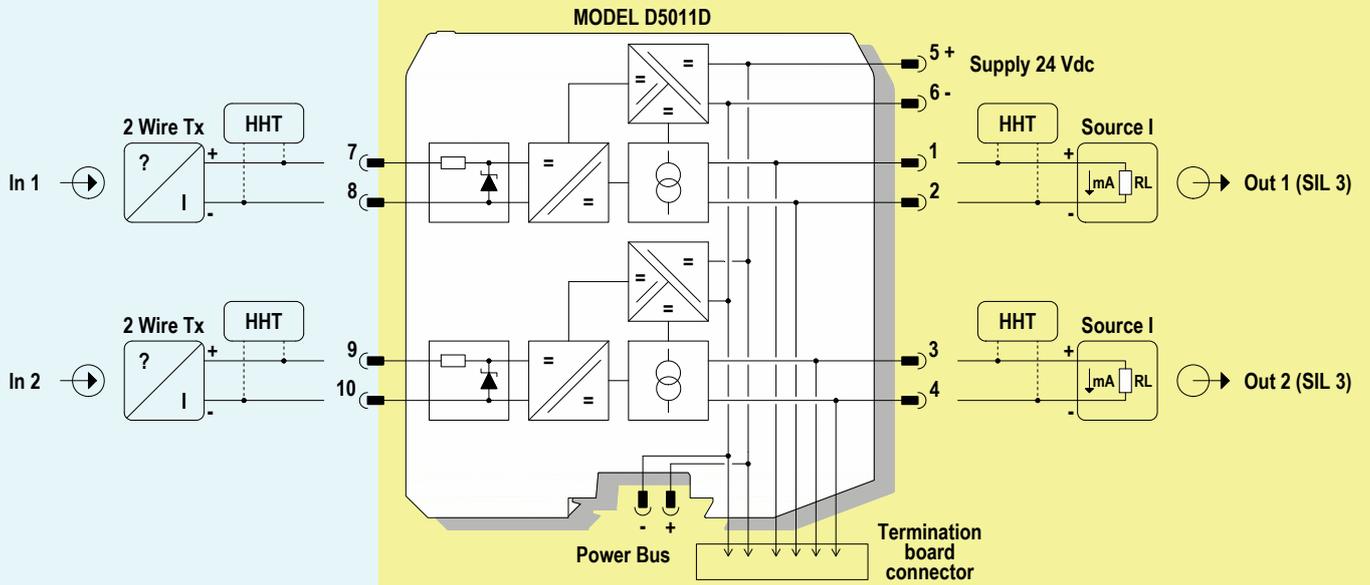
For installations in which both the C_i and L_i of the Intrinsically Safe apparatus exceed 1 % of the C_o and L_o parameters of the Associated Apparatus (excluding the cable), then 50 % of C_o and L_o parameters are applicable and shall not be exceeded (50 % of the C_o and L_o become the limits which must include the cable such that $C_i \text{ device} + C \text{ cable} \leq 50 \% \text{ of } C_o$ and $L_i \text{ device} + L \text{ cable} \leq 50 \% \text{ of } L_o$).

If the cable parameters are unknown, the following value may be used: Capacitance 180pF per meter (60pF per foot), Inductance 0.60μH per meter (0.20μH per foot).

Function Diagram

HAZARDOUS AREA ZONE 0 (ZONE 20) GROUP IIC

SAFE AREA, ZONE 2 GROUP IIC T4



Warning

D5011 series are isolated Intrinsically Safe Associated Apparatus installed into standard EN50022 T35 DIN-Rail located in Safe Area or Zone 2, Group IIC, Temperature T4, Hazardous Area (according to EN/IEC60079-15) within the specified operating temperature limits Tamb -40 to +70 °C, and connected to equipment with a maximum limit for AC power supply Um of 250 Vrms.

Not to be connected to control equipment that uses or generates more than 250 Vrms or Vdc with respect to earth ground.

D5011 series must be installed, operated and maintained only by qualified personnel, in accordance to the relevant national/international installation standards (e.g. IEC/EN60079-14 Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)), following the established installation rules, particular care shall be given to segregation and clear identification of I.S. conductors from non I.S. ones.

De-energize power source (turn off power supply voltage) before plug or unplug the terminal blocks when installed in Hazardous Area or unless area is known to be nonhazardous.

Warning: substitution of components may impair Intrinsic Safety and suitability for Zone 2.

Explosion Hazard: to prevent ignition of flammable or combustible atmospheres, disconnect power before servicing or unless area is known to be nonhazardous.

Failure to properly installation or use of the equipment may risk to damage the unit or severe personal injury.

The unit cannot be repaired by the end user and must be returned to the manufacturer or his authorized representative.

Any unauthorized modification must be avoided.

Operation

D5011 provides fully floating DC supply for energizing 2 wires 4-20 mA transmitters located in Hazardous Area and repeats the current to a 4-20 mA floating output signal to drive a Safe Area load.

The circuit allows bi-directional communication signal for smart transmitters, a "POWER ON" green led lits when input power is present.

Installation

D5011 series are repeater power supply hart compatible housed in a plastic enclosure suitable for installation on T35 DIN-Rail according to EN50022, with or without Power Bus or on customized Termination Board.

D5011 unit can be mounted with any orientation over the entire ambient temperature range.

Electrical connection of conductors up to 2.5 mm² are accommodated by polarized plug-in removable screw terminal blocks which can be plugged in/out into a powered unit without suffering or causing any damage (**for Zone 2 installations check the area to be nonhazardous before servicing**).

The wiring cables have to be proportionate in base to the current and the length of the cable.

On the section "Function Diagram" and enclosure side a block diagram identifies all connections.

Identify the number of channels of the specific card (e.g. D5011S is a single channel model and D5011D is a dual channel model), the function and location of each connection terminal using the wiring diagram on the corresponding section, as an example:

Connect 24 Vdc power supply positive at terminal "5" and negative at terminal "6".

For Model D5011S connect positive output of channel 1 at terminal "1" and negative output at "2".

For Model D5011D in addition to channel 1 connections above, connect positive output of channel 2 at terminal "3" and negative output at "4".

For Model D5011S for 2 wires Transmitter, connect the wires at terminal "7" for positive and "8" for negative.

For Model D5011D in addition to channel 1 connections above, connect terminal "9" for positive and "10" for negative on channel 2.

Intrinsically Safe conductors must be identified and segregated from non I.S. and wired in accordance to the relevant national/international installation standards (e.g. EN/IEC60079-14 Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)), make sure that conductors are well isolated from each other and do not produce any unintentional connection.

The enclosure provides, according to EN60529, an IP20 minimum degree of mechanical protection (or similar to NEMA Standard 250 type 1) for indoor installation, outdoor installation requires an additional enclosure with higher degree of protection (i.e. IP54 to IP65 or NEMA type 12-13) consistent with the effective operating environment of the specific installation.

Units must be protected against dirt, dust, extreme mechanical (e.g. vibration, impact and shock) and thermal stress, and casual contacts.

If enclosure needs to be cleaned use only a cloth lightly moistened by a mixture of detergent in water.

Electrostatic Hazard: to avoid electrostatic hazard, the enclosure of D5011 must be cleaned only with a damp or antistatic cloth.

Any penetration of cleaning liquid must be avoided to prevent damage to the unit. Any unauthorized card modification must be avoided.

According to EN61010, D5011 series must be connected to SELV or SELV-E supplies.

Start-up

Before powering the unit check that all wires are properly connected, particularly supply conductors and their polarity, input and output wires, also check that Intrinsically Safe conductors and cable trays are segregated (no direct contacts with other non I.S. conductors) and identified either by color coding, preferably blue, or by marking. Check conductors for exposed wires that could touch each other causing dangerous unwanted shorts. Turn on power, the "power on" green led must be lit, for 2 wires transmitter connection the supply voltage on each channel must be ≥ 14.5 V, output signal should be corresponding to the input from the transmitter. If possible change the transmitter output and check the corresponding Safe Area output.

Testing procedure at T-proof

The proof test shall be performed to reveal dangerous faults which are undetected by diagnostic. This means that it is necessary to specify how dangerous undetected fault, which have been noted during the FMEDA, can be detected during proof test. **The Proof test 1** consists of the following steps:

Steps	Action
1	Bypass the safety-related PLC or take other appropriate action to avoid a false trip.
2	By HART command or other technique, set the transmitter connected to the input of the repeater in order to go to high alarm current and verify that the output current of the repeater reaches that value. This tests for compliance voltage problems such as a low loop power supply voltage or increased wiring resistance.
3	By HART command or other technique, set the transmitter connected to the input of the repeater in order to go to low alarm current and verify that the output current of the repeater reaches that value. This tests for possible quiescent current related failures.
4	Restore the loop to full operation.
5	Remove the bypass from the safety-related PLC or restore normal operation.

This test will detect approximately 30 % of possible Dangerous Undetected failures in the repeater.

The **Proof test 2** consists of the following steps:

Steps	Action
1	Bypass the safety-related PLC or take other appropriate action to avoid a false trip.
2	Perform step 2 and 3 of the Proof Test 1 .
3	Perform a two-point calibration (i.e. down scale as 4 mA and full scale as 20 mA) of the transmitter connected to the input of the repeater. Then set the transmitter to impose some input current values of 4-20 mA range and verify that the correspondent output current values of repeater are within the specified accuracy. This proof requires that the transmitter has already been tested without the repeater and it works correctly according to its performance.
4	Restore the loop to full operation.
5	Remove the bypass from the safety-related PLC or restore normal operation.

This test will detect approximately 99 % of possible Dangerous Undetected failures in the repeater.

SIL Applications

D5011S and D5011D Repeater Power Supplies

- Safety function**

The failure behaviour when output current range is 4 to 20 mA is described from the following definitions:

- fail-Safe State: is defined as the output going to fail low or high;
- fail Safe: failure mode that causes the module to go to the defined fail-safe state without a demand from the process;
- fail Dangerous: failure mode that does not respond to a demand from the process (i.e. being unable to go to the defined fail-safe state) or deviates the output current by more than 5 % (0.8 mA) of full span;
- fail High: failure mode that causes the output signal to go above the maximum output current (> 20 mA);
- fail Low: failure mode that causes the output signal to go below the minimum output current (< 4 mA);
- fail "No Effect": failure mode of a component that is part of the safety function but that has no effect on the safety function or deviates the output current by not more than 5 % (0.8 mA) of full span. For the calculation of the SFF it is considered a safe undetected failure;
- fail "Not part": failure mode of a component which is not part of the safety function but part of the circuit diagram and is listed for completeness.
When calculating the SFF this failure mode is not taken into account. It is also not considered for the total failure rate (safety function) evaluation;
- fail "Not considered": failure mode not associated to the previous categories and divided in the 50 % safe failures and 50 % dangerous undetected failures;

Assuming that the application program in the safety logic solver is configured to detected under-range (Low) and over-range (High) failures and does not automatically trip on these failures, these failures have been classified as dangerous detected (DD) failures. The following PFDavg values have been calculated for different T[Proof] test intervals using the Markov model for 1oo1D architecture system, considering that the safety logic solver can convert the fail dangerous detected to the selected fail-safe state.

D5011S Repeater Power Supply

- Failure rates table:

Failure category	Failure rates (FIT)
$\lambda_{dd} = \text{Total Dangerous Detected failures} = \lambda_{dd \text{ int.}} + \lambda_{high} + \lambda_{low}$	137.10
↳ $\lambda_{dd \text{ int.}}$ = Dangerous Detected failures (detected by diagnostics)	20.17
↳ λ_{high} = High failures (detected by the logic solver)	26.94
↳ λ_{low} = Low failures (detected by the logic solver)	89.99
$\lambda_{du} = \text{Total Dangerous Undetected failures} = \lambda_{du \text{ int.}} + 50\% * \lambda_{not \text{ considered}}$	19.94
↳ $\lambda_{du \text{ int.}}$ = Dangerous Undetected failures	19.86
↳ $50\% * \lambda_{not \text{ considered}}$ = "Not considered" or "undefined" failures	0.08
$\lambda_{sd} = \text{Total Safe Detected failures}$	0.00
$\lambda_{su} = \text{Total Safe Undetected failures} = \lambda_{no \text{ effect}} + 50\% * \lambda_{not \text{ considered}}$	172.97
↳ $\lambda_{no \text{ effect}}$ = "No Effect" failures	172.89
↳ $50\% * \lambda_{not \text{ considered}}$ = "Not considered" or "undefined" failures	0.08
$\lambda_{tot \text{ safe}} = \text{Total Failure Rate (Safety Function)} = \lambda_{dd} + \lambda_{du} + \lambda_{sd} + \lambda_{su}$	330.01
$\lambda_{not \text{ part}} = \text{"Not Part" failures}$	5.20
$\lambda_{tot \text{ device}} = \text{Total Failure Rate (Device)} = \lambda_{tot \text{ safe}} + \lambda_{not \text{ part}}$	335.21
MTBF (single channel) = $(1 / \lambda_{tot \text{ device}}) + \text{MTTR (8 hours)}$	340 years
$\text{MTTF}_S \text{ (Total Safe)} = 1 / (\lambda_{sd} + \lambda_{su})$	660 years
$\text{MTTF}_D \text{ (Dangerous)} = 1 / \lambda_{du}$	5725 years

- Failure rates table according to IEC 61508:

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF	DC _s	DC _d
0.0 FIT	172.97 FIT	137.10 FIT	19.94 FIT	93.96%	0%	87.30%

- PFDavg vs T[Proof] table, with determination of SIL supposing module contributes 10% of entire safety function:

T[Proof] = 1 year	T[Proof] = 10 years
PFDavg = 8.73 E-05 Valid for SIL 3	PFDavg = 8.73 E-04 Valid for SIL 2

- PFDavg vs T[Proof] table, with determination of SIL supposing module contributes 20% of entire safety function:

T[Proof] = 2 years	T[Proof] = 20 years
PFDavg = 1.75 E-04 Valid for SIL 3	PFDavg = 1.75 E-03 Valid for SIL 2

D5011D Repeater Power Supplies

- The 2 channels of D5011D module should not be used to increase the hardware fault tolerance, needed for a Safety Function requiring higher SIL, as they are not completely independent from each other.

- Failure rates table:

Failure category	Failure rates (FIT)
$\lambda_{dd} = \text{Total Dangerous Detected failures} = \lambda_{dd \text{ int.}} + \lambda_{high} + \lambda_{low}$	161.10
↳ $\lambda_{dd \text{ int.}} = \text{Dangerous Detected failures (detected by diagnostics)}$	20.17
↳ $\lambda_{high} = \text{High failures (detected by the logic solver)}$	26.94
↳ $\lambda_{low} = \text{Low failures (detected by the logic solver)}$	113.99
$\lambda_{du} = \text{Total Dangerous Undetected failures} = \lambda_{du \text{ int.}} + 50\% * \lambda_{not \text{ considered}}$	19.94
↳ $\lambda_{du \text{ int.}} = \text{Dangerous Undetected failures}$	19.86
↳ $50\% * \lambda_{not \text{ considered}} = \text{"Not considered" or "undefined" failures}$	0.08
$\lambda_{sd} = \text{Total Safe Detected failures}$	0.00
$\lambda_{su} = \text{Total Safe Undetected failures} = \lambda_{no \text{ effect}} + 50\% * \lambda_{not \text{ considered}}$	205.97
↳ $\lambda_{no \text{ effect}} = \text{"No Effect" failures}$	205.89
↳ $50\% * \lambda_{not \text{ considered}} = \text{"Not considered" or "undefined" failures}$	0.08
$\lambda_{tot \text{ safe}} = \text{Total Failure Rate (Safety Function)} = \lambda_{dd} + \lambda_{du} + \lambda_{sd} + \lambda_{su}$	387.01
$\lambda_{not \text{ part}} = \text{"Not Part" failures}$	184.20
$\lambda_{tot \text{ device}} = \text{Total Failure Rate (Device)} = \lambda_{tot \text{ safe}} + \lambda_{not \text{ part}}$	571.21
MTBF (single channel) = $(1 / \lambda_{tot \text{ device}}) + \text{MTTR (8 hours)}$	199 years
$\text{MTTF}_S \text{ (Total Safe)} = 1 / (\lambda_{sd} + \lambda_{su})$	554 years
$\text{MTTF}_D \text{ (Dangerous)} = 1 / \lambda_{du}$	5725 years

- Failure rates table according to IEC 61508:

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF	DC _s	DC _d
0.0 FIT	205.97 FIT	161.10 FIT	19.94 FIT	94.85%	0%	88.98%

- PFDavg vs T[Proof] table, with determination of SIL supposing module contributes 10% of entire safety function:

T[Proof] = 1 year	T[Proof] = 10 years
PFDavg = 8.73 E-05 Valid for SIL 3	PFDavg = 8.73 E-04 Valid for SIL 2

- PFDavg vs T[Proof] table, with determination of SIL supposing module contributes 20% of entire safety function:

T[Proof] = 2 years	T[Proof] = 20 years
PFDavg = 1.75 E-04 Valid for SIL 3	PFDavg = 1.75 E-03 Valid for SIL 2