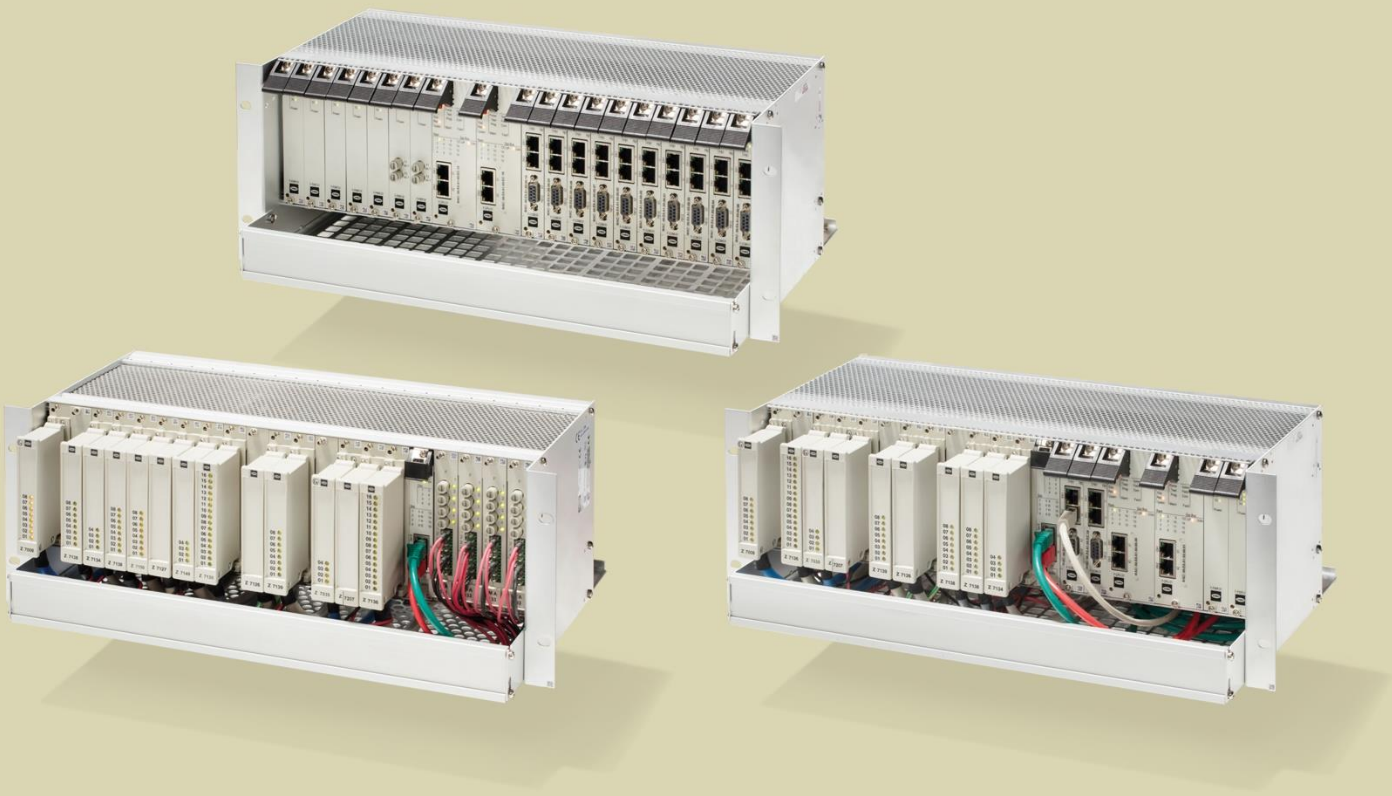
Manual

HIQuad®X

Functional Safety Data



All the current manuals can be obtained upon request by sending an e-mail to: documentation@hima.com.

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Table of Contents

1 HIQuad Functional Safety Data in Accordance with IEC 61508

The following chapter lists the values for MTTF, PFH and PFD in accordance with IEC 61508.

General	
Safety manual	HI 803 209 E, in the latest edition
Test standards	IEC 61508, Part 1 - 7:2010 IEC 61511-1:2016 + Corr.1:2016 + AMD1:2017
Certificate	EC Type Test Certificate 01/205/5666.00/18
Certified by	TÜV Rheinland Industrie Service GmbH

Table 1: General Information (IEC 61508)

1.1 Functional Safety Data for the HIQuad X Modules

The values specified in the following tables were calculated in accordance with the IEC 61508 requirements.

Calculating the Functional Safety Data

No conclusions on the internal functional units and architectures can be drawn from the failure rates listed below (λ_S, λ_{DD}, λ_{DU}). The failure rates for a module are obtained by adding the failure rates of all module components, taking the internal structures into account. For this reason, the specified failure rates (in particular λ_{DU}) cannot be directly applied to the values for PFD and PFH indicated by HIMA using the simplified formulas of the IEC 61508-6.

The PFD and PFH values specified by HIMA take into account the internal architecture of the HIQuad X modules. For this reason, the PFD and PFH values provided in this document are lower. The calculation of the PFD and PFH values based on the failure rates returns a conservative higher result.

The PFD and PFH values indicated in this document are examined and approved by an independent body (TÜV Rheinland) as part of the certification of the modules.

For this reason, HIMA recommends using the specified PFD and PFH values.

Calculating the Safety Function

The calculation of the safety function performed by a user must be based on the following assumptions:

Parameter	Value / Description
Type	B element
HFT	0 (internal redundant architectures)
MTTR = MRT	8 h
β factor	2 %
β_D factor	1 %
Mode of operation	Low demand / high demand
Safe state	In accordance with the de-energize to trip principle, see Chapter 1.1.1 In accordance with the energize to trip principle, see Chapter 1.1.2

Table 2: Calculation Assumptions (IEC 61508)

i All modules must meet the operating requirements specified in the module-specific manuals as well as in the safety manual.

1.1.1 De-Energize to Trip Principle

Table 3 includes the failure rates as well as the PFD and PFH values for the proof test interval of T_1 = 1 year:

Module	MTTF in years	λ_S / h^{-1}	λ_{DD} / h^{-1}	λ_{DU} / h^{-1}	PFD	PFH / h^{-1}	SFF	SIL
F-CPU 01	64.24	6.94E-07	6.50E-07	3.35E-09	5.46E-05	1.27E-09	99.75 %	3
F-IOP 01	48.98	8.29E-07	7.44E-07	4.00E-09	2.10E-05	1.54E-09	99.75 %	3
F 3236	448.02	1.56E-07	9.82E-08	9.92E-10	5.14E-06	9.92E-10	99.61 %	3
F 3237	330.69	2.43E-07	1.01E-07	1.02E-09	5.28E-06	1.02E-09	99.71 %	3
F 3238	184.87	4.55E-07	1.61E-07	1.63E-09	8.43E-06	1.63E-09	99.74 %	3
F 3240	220.29	3.93E-07	1.24E-07	1.25E-09	6.50E-06	1.25E-09	99.76 %	3
F 3248	220.29	3.93E-07	1.24E-07	1.25E-09	6.50E-06	1.25E-09	99.76 %	3
F 3330	235.03	1.66E-07	1.23E-07	1.25E-09	3.98E-06	7.68E-10	99.57 %	3
F 3331	232.83	1.69E-07	1.26E-07	1.27E-09	4.10E-06	7.91E-10	99.57 %	3
F 3333	278.50	1.49E-07	1.05E-07	1.07E-09	3.55E-06	6.86E-10	99.58 %	3
F 3334	260.21	1.63E-07	1.20E-07	1.21E-09	4.30E-06	8.30E-10	99.57 %	3
F 3335	101.53	5.43E-07	2.09E-07	2.11E-09	6.22E-06	1.20E-09	99.72 %	3
F 3349	116.93	4.32E-07	2.83E-07	2.86E-09	8.25E-06	1.59E-09	99.60 %	3
F 3430	112.69	2.87E-07	1.37E-07	2.73E-08	6.51E-06	1.37E-09	≥ 99 %	3
F 5220	45.12	8.76E-07	7.32E-07	5.59E-09	1.30E-05	2.25E-09	99.65 %	3
F 6217	154.20	3.58E-07	2.33E-07	1.75E-09	7.77E-06	1.41E-09	99.71 %	3
F 6220	56.34	8.42E-07	5.76E-07	3.83E-09	9.28E-06	1.49E-09	99.73 %	3
F 6221	58.12	7.72E-07	5.68E-07	3.74E-09	8.62E-06	1.36E-09	99.72 %	3
F 6705	180.37	3.28E-07	2.29E-07	2.32E-09	1.01E-05	1.96E-09	99.59 %	3

Table 3: Proof Test with T_1 = 1 Year (De-Energized to Trip Principle)

Table 4 includes the PFD and PFH values for additional proof test intervals:

Module	T_1 = 2 years		T_1 = 3 years		T_1 = 5 years		T_1 = 10 years	
	PFD	PFH / h^{-1}	PFD	PFH / h^{-1}	PFD	PFH / h^{-1}	PFD	PFH / h^{-1}
F-CPU 01	6.01E-05	1.27E-09	6.57E-05	1.27E-09	7.68E-05	1.27E-09	1.05E-04	1.27E-09
F-IOP 01	2.76E-05	1.54E-09	3.42E-05	1.54E-09	4.75E-05	1.54E-09	8.05E-05	1.54E-09
F 3236	9.48E-06	9.92E-10	1.38E-05	9.92E-10	2.25E-05	9.92E-10	4.42E-05	9.92E-10
F 3237	9.74E-06	1.02E-09	1.42E-05	1.02E-09	2.31E-05	1.02E-09	4.54E-05	1.02E-09
F 3238	1.56E-05	1.63E-09	2.27E-05	1.63E-09	3.69E-05	1.63E-09	7.26E-05	1.63E-09
F 3240	1.20E-05	1.25E-09	1.75E-05	1.25E-09	2.85E-05	1.25E-09	5.59E-05	1.25E-09
F 3248	1.20E-05	1.25E-09	1.75E-05	1.25E-09	2.85E-05	1.25E-09	5.59E-05	1.25E-09
F 3330	7.34E-06	7.68E-10	1.07E-05	7.68E-10	1.74E-05	7.68E-10	3.43E-05	7.68E-10
F 3331	7.56E-06	7.91E-10	1.10E-05	7.91E-10	1.80E-05	7.91E-10	3.53E-05	7.91E-10
F 3333	6.55E-06	6.86E-10	9.56E-06	6.86E-10	1.56E-05	6.86E-10	3.06E-05	6.86E-10
F 3334	7.93E-06	8.30E-10	1.16E-05	8.30E-10	1.88E-05	8.30E-10	3.70E-05	8.30E-10
F 3335	1.15E-05	1.20E-09	1.68E-05	1.20E-09	2.73E-05	1.20E-09	5.36E-05	1.20E-09
F 3349	1.52E-05	1.59E-09	2.22E-05	1.59E-09	3.62E-05	1.59E-09	7.11E-05	1.59E-09
F 3430	1.25E-05	1.37E-09	1.85E-05	1.37E-09	3.05E-05	1.37E-09	---	---
F 5220	2.29E-05	2.25E-09	3.27E-05	2.25E-09	5.24E-05	2.25E-09	1.02E-04	2.25E-09
F 6217	1.39E-05	1.41E-09	2.01E-05	1.41E-09	3.24E-05	1.41E-09	6.33E-05	1.41E-09
F 6220	1.58E-05	1.49E-09	2.23E-05	1.49E-09	3.54E-05	1.49E-09	6.80E-05	1.49E-09
F 6221	1.46E-05	1.36E-09	2.06E-05	1.36E-09	3.25E-05	1.36E-09	6.23E-05	1.36E-09
F 6705	1.87E-05	1.96E-09	2.73E-05	1.96E-09	4.45E-05	1.96E-09	8.74E-05	1.96E-09

Table 4: PFD and PFH Values Applying to Different Proof Test Intervals (De-Energized to Trip Principle)

1.1.2 Energize to Trip Principle

Table 5 includes the failure rates as well as the PFD and PFH values for the proof test interval of T_1 = 1 year:

Module	MTTF in years	λ_S / h^{-1}	λ_{DD} / h^{-1}	λ_{DU} / h^{-1}	PFD	PFH / h^{-1}	SFF	SIL
F-CPU 01	51.27	9.02E-07	8.91E-07	3.74E-09	5.82E-05	1.66E-09	99.79 %	3
F-IOP 01	40.11	1.07E-06	1.01E-06	6.73E-09	3.52E-05	4.26E-09	99.68 %	3
F-PWR 01	125.20	4.56E-07	4.51E-07	4.56E-09	2.36E-05	4.56E-09	99.50 %	3
F-PWR 01 (1oo2)	8.58E06	4.56E-07	4.51E-07	4.56E-09	4.37E-07	9.14E-11	99.50 %	3
F-PWR 01 (2oo3)	1.17E07	4.56E-07	4.51E-07	4.56E-09	4.39E-07	9.18E-11	99.50 %	3
F 3236	448.02	1.29E-07	1.24E-07	1.26E-09	6.51E-06	1.26E-09	99.51%	3
F 3237	330.69	1.74E-07	1.70E-07	1.71E-09	8.88E-06	1.71E-09	99.50%	3
F 3238	184.87	3.10E-07	3.04E-07	3.08E-09	1.59E-05	3.08E-09	99.50%	3
F 3240	220.29	2.64E-07	2.51E-07	2.54E-09	1.32E-05	2.54E-09	99.51%	3
F 3248	220.29	2.64E-07	2.51E-07	2.54E-09	1.32E-05	2.54E-09	99.51%	3
F 3330	235.03	1.53E-07	1.52E-07	1.53E-09	1.05E-05	2.02E-09	99.50%	3
F 3331	232.83	1.67E-07	1.65E-07	1.67E-09	1.12E-05	2.16E-09	99.50%	3
F 3333	278.50	1.34E-07	1.32E-07	1.34E-09	8.93E-06	1.72E-09	99.50%	3
F 3334	260.21	1.48E-07	1.47E-07	1.48E-09	9.68E-06	1.87E-09	99.50%	3
F 3335	101.53	5.28E-07	2.38E-07	2.41E-09	1.73E-05	3.33E-09	99.69%	3
F 3349	116.93	3.59E-07	3.55E-07	3.59E-09	2.10E-05	4.06E-09	99.50%	3
F 5220	45.12	8.07E-07	8.00E-07	6.28E-09	2.33E-05	4.22E-09	99.61%	3
F 6217	154.20	2.97E-07	2.94E-07	2.37E-09	1.10E-05	2.02E-09	99.60%	3
F 6220	56.34	7.11E-07	7.06E-07	5.13E-09	1.61E-05	2.80E-09	99.64%	3
F 6221	58.12	6.72E-07	6.67E-07	4.74E-09	1.38E-05	2.36E-09	99.65%	3
F 6705	180.37	2.80E-07	2.77E-07	2.80E-09	1.64E-05	3.16E-09	99.50%	3

Table 5: Proof Test with T_1 = 1 Year (Energized to Trip Principle)

Table 6 includes the PFD and PFH values for additional proof test intervals:

Module	T_1 = 2 years		T_1 = 3 years		T_1 = 5 years		T_1 = 10 years	
	PFD	PFH / h^{-1}	PFD	PFH / h^{-1}	PFD	PFH / h^{-1}	PFD	PFH / h^{-1}
F-CPU 01	6.55E-05	1.66E-09	7.27E-05	1.66E-09	8.73E-05	1.66E-09	1.24E-04	1.66E-09
F-IOP 01	5.37E-05	4.26E-09	7.23E-05	4.26E-09	1.09E-04	4.26E-09	2.02E-04	4.26E-09
F-PWR 01	4.36E-05	4.56E-09	6.36E-05	4.56E-09	1.03E-04	4.56E-09	2.03E-04	4.56E-09
F-PWR 01 (1oo2)	8.38E-07	9.16E-11	1.24E-06	9.17E-11	2.05E-06	9.21E-11	4.09E-06	9.30E-11
F-PWR 01 (2oo3)	8.43E-07	9.23E-11	1.25E-06	9.29E-11	2.08E-06	9.39E-11	4.19E-06	9.66E-11
F 3236	1.20E-05	1.26E-09	1.75E-05	1.26E-09	2.85E-05	1.26E-09	5.60E-05	1.26E-09
F 3237	1.64E-05	1.71E-09	2.39E-05	1.71E-09	3.89E-05	1.71E-09	7.64E-05	1.71E-09
F 3238	2.94E-05	3.08E-09	4.29E-05	3.08E-09	6.98E-05	3.08E-09	1.37E-04	3.08E-09
F 3240	2.43E-05	2.54E-09	3.54E-05	2.54E-09	5.76E-05	2.54E-09	1.13E-04	2.54E-09
F 3248	2.43E-05	2.54E-09	3.54E-05	2.54E-09	5.76E-05	2.54E-09	1.13E-04	2.54E-09
F 3330	1.93E-05	2.02E-09	2.81E-05	2.02E-09	4.58E-05	2.02E-09	9.00E-05	2.02E-09
F 3331	2.06E-05	2.16E-09	3.01E-05	2.16E-09	4.90E-05	2.16E-09	9.62E-05	2.16E-09
F 3333	1.65E-05	1.72E-09	2.40E-05	1.72E-09	3.91E-05	1.72E-09	7.69E-05	1.72E-09
F 3334	1.79E-05	1.87E-09	2.60E-05	1.87E-09	4.24E-05	1.87E-09	8.33E-05	1.87E-09
F 3335	3.19E-05	3.33E-09	4.65E-05	3.33E-09	7.57E-05	3.33E-09	1.49E-04	3.33E-09
F 3349	3.88E-05	4.06E-09	5.66E-05	4.06E-09	9.22E-05	4.06E-09	1.81E-04	4.06E-09
F 5220	4.18E-05	4.22E-09	6.03E-05	4.22E-09	9.73E-05	4.22E-09	1.90E-04	4.22E-09
F 6217	1.98E-05	2.02E-09	2.87E-05	2.02E-09	4.64E-05	2.02E-09	9.07E-05	2.02E-09
F 6220	2.83E-05	2.80E-09	4.06E-05	2.80E-09	6.51E-05	2.80E-09	1.26E-04	2.80E-09
F 6221	2.41E-05	2.36E-09	3.45E-05	2.36E-09	5.52E-05	2.36E-09	1.07E-04	2.36E-09
F 6705	3.03E-05	3.16E-09	4.41E-05	3.16E-09	7.18E-05	3.16E-09	1.41E-04	3.16E-09

Table 6: PFD and PFH Values Applying to Different Proof Test Intervals (Energized to Trip Principle)

2 HIQuad Functional Safety Data in Accordance with EN ISO 13849

The following chapter lists the values in accordance with EN ISO 13849.

General	
Safety manual	HI 803 209 E, in the latest edition
Test standards	EN ISO 13849-1:2015
Certificates	EC Type Test Certificate 01/205/5666.00/18
Certified by	TÜV Rheinland Industrie Service GmbH

Table 7: General Information (EN ISO 13849)

2.1 Functional Safety Data for the HIQuad X Modules

The values specified in the following table were calculated in accordance with the EN ISO 13849-1 and IEC 61508 requirements.

Calculating the Safety Function

The calculation of the safety function performed by a user must be based on the following assumptions:

Parameter	Value / Description
Type	B element
HFT	0 (internal redundant architectures)
MTTR = MRT	8 h
β factor	2 %
β_D factor	1 %
Mode of operation	Low demand / high demand
Safe state	In accordance with the de-energize to trip principle

Table 8: Calculation Assumptions (EN ISO 13849)

i All modules must meet the operating requirements specified in the module-specific manuals as well as in the safety manual.

With a proof test of 20 years (T_1 = 20 years),the following values are obtained:

Modules	$PFH_{IEC\ 61508}$ / h^{-1}	PL
F-CPU 01	1.27E-09	e
F-IOP 01	1.54E-09	e
F 3236	9.92E-10	e
F 3237	1.02E-09	e
F 3238	1.63E-09	e
F 3240	1.25E-09	e
F 3248	1.25E-09	e
F 3330	7.68E-10	e
F 3331	7.91E-10	e
F 3333	6.86E-10	e
F 3334	8.30E-10	e
F 3335	1.20E-09	e
F 3349	1.59E-09	e
F 5220	2.17E-09	e
F 6217	1.41E-09	e
F 6220	1.49E-09	e
F 6221	1.36E-09	e
F 6705	1.96E-09	e

Table 9: Functional Safety Data for the HIQuad X Modules (EN ISO 13849)

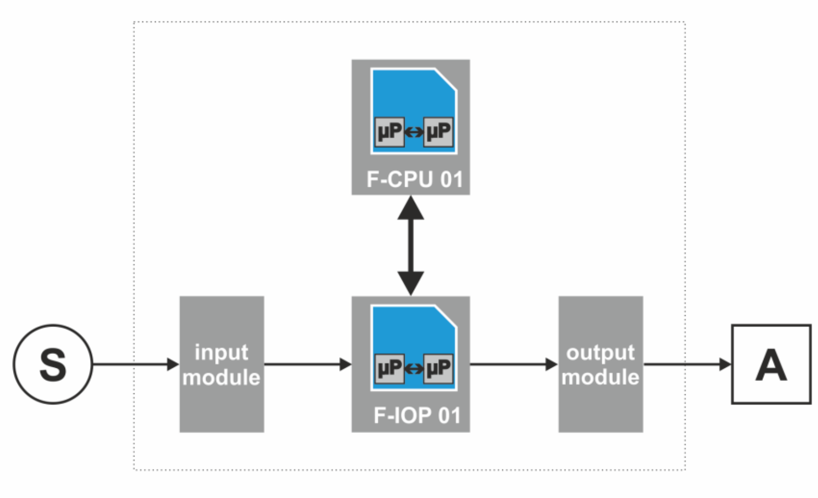
3 Calculation Examples

The following chapter shows examples for calculating the safety loop for different system configurations. For all configurations, the application is assumed to be in accordance with the de-energized to trip principle and have a proof test interval of 10 years (T1 = 10 years).

The calculations are in accordance with IEC 61508, Part 6, Annex B.

3.1 Mono System

The following figure shows the structure of a mono system:



The input module used for the calculation is the F 3236 and the output module is the F 3330:

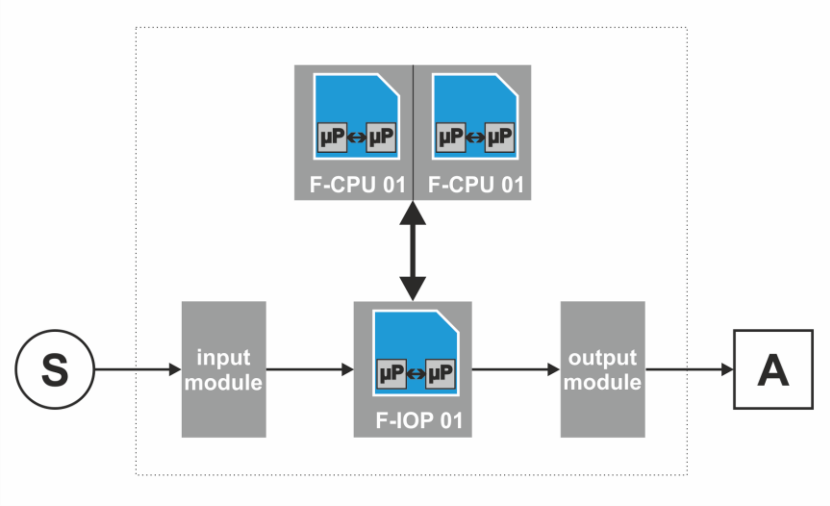
The λ values specified in Table 3 apply to the modules. Refer to Table 4 for the PFD and PFH values of 1oo1 architectures.

The PFD and PFH values for the safety loop are determined by adding the individual values.

Module	F 3236	F-IOP 01	F-CPU 01	F 3330	**Loop**
Architecture	1oo1	1oo1	1oo1	1oo1	---
λ_S / h^{-1}	1.56E-07	8.29E-07	6.94E-07	1.66E-07	---
λ_D / h^{-1}	9.92E-08	7.48E-07	6.53E-07	1.25E-07	---
λ_{DD} / h^{-1}	9.82E-08	7.44E-07	6.50E-07	1.23E-07	---
λ_{DU} / h^{-1}	9.92E-10	4.00E-09	3.35E-09	1.25E-09	---
SFF	99.61%	99.75%	99.75%	99.57%	---
PFD	4.42E-05	8.05E-05	1.05E-04	3.43E-05	2.64E-04
PFH / h^{-1}	9.92E-10	1.54E-09	1.27E-09	7.68E-10	4.57E-09

3.2 Redundancy System

The following figure shows the structure of a redundancy system:



The input module used for the calculation is the F 3236 and the output module is the F 3330:

The λ values specified in Table 3 apply to the modules. Refer to Table 4 for the PFD and PFH values of 1oo1 architectures.

The PFD and PFH values for the F-CPU 01 modules with 1oo2 architecture is calculated as follows:

$$PFD = 2 \cdot \left((1 - \beta_D) \cdot \lambda_{DD} + (1 - \beta) \cdot \lambda_{DU}\right)^2 \cdot t_{CE} \cdot t_{GE} + \beta_D \cdot \lambda_{DD} \cdot MTTR + \beta \cdot \lambda_{DU} \cdot \left(\frac{T_1}{2} + MRT\right)$$

$$PFH = 2 \cdot \left((1 - \beta_D) \cdot \lambda_{DD} + (1 - \beta) \cdot \lambda_{DU}\right) \cdot (1 - \beta) \cdot \lambda_{DU} \cdot t_{CE} + \beta \cdot \lambda_{DU}$$

where

$$t_{CE} = \frac{\lambda_{DU}}{\lambda_D} \cdot \left(\frac{T_1}{2} + MRT\right) + \frac{\lambda_{DD}}{\lambda_D} \cdot MTTR$$

$$t_{GE} = \frac{\lambda_{DU}}{\lambda_D} \cdot \left(\frac{T_1}{3} + MRT\right) + \frac{\lambda_{DD}}{\lambda_D} \cdot MTTR$$

The following also applies:

- $\beta = 2\ \%$
- $\beta_D = 1\ \%$
- MTTR = MRT = 8 h
- T_1 = 10 years = 87 600 h

For t_{CE} and t_{GE}, this results in:

$$t_{CE} = \frac{3.35 \cdot 10^{-9}}{6.53 \cdot 10^{-7}} \cdot \left(\frac{87600}{2} + 8\right) + \frac{6.5 \cdot 10^{-7}}{6.53 \cdot 10^{-7}} \cdot 8$$

$\underline{t_{CE} = 232.71\ h}$

$$t_{GE} = \frac{3.35 \cdot 10^{-9}}{6.53 \cdot 10^{-7}} \cdot \left(\frac{87600}{3} + 8\right) + \frac{6.5 \cdot 10^{-7}}{6.53 \cdot 10^{-7}} \cdot 8$$

$\underline{t_{GE} = 157.81\ h}$

For PFD and PFH, this results in:

$$PFD = 2 \cdot \left((1 - 0.01) \cdot 6.5 \cdot 10^{-7} + (1 - 0.02) \cdot 3.35 \cdot 10^{-9}\right)^2 \cdot 232.71 \cdot 157.81 + 0.01 \cdot 6.5 \cdot 10^{-7} \cdot 8$$

$$+ 0.02 \cdot 3.35 \cdot 10^{-9} \cdot \left(\frac{87600}{2} + 8\right)$$

$\underline{PFD = 3.02 \cdot 10^{-6}}$

$$PFH = 2 \cdot \left((1 - 0.01) \cdot 6.5 \cdot 10^{-7} + (1 - 0.02) \cdot 3.35 \cdot 10^{-9}\right) \cdot (1 - 0.02) \cdot 3.35 \cdot 10^{-9} \cdot 232.71$$

$$+ 0.02 \cdot 3.35 \cdot 10^{-9}$$

$\underline{PFH = 6.80 \cdot 10^{-11}}$

The PFD and PFH values for the safety loop are determined by adding the individual values.

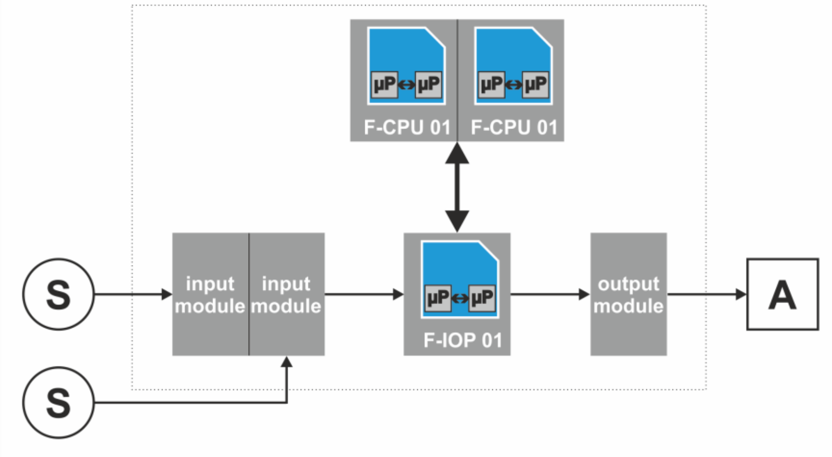
Module	F 3236	F-IOP 01	F-CPU 01	F 3330	Loop
Architecture	1oo1	1oo1	1oo2	1oo1	---
λ_S / h^{-1}	1.56E-07	8.29E-07	6.94E-07	1.66E-07	---
λ_D / h^{-1}	9.92E-08	7.48E-07	6.53E-07	1.25E-07	---
λ_{DD} / h^{-1}	9.82E-08	7.44E-07	6.50E-07	1.23E-07	---
λ_{DU} / h^{-1}	9.92E-10	4.00E-09	3.35E-09	1.25E-09	---
SFF	99.61%	99.75%	99.75%	99.57%	---
PFD	4.42E-05	8.05E-05	3.02E-06	3.43E-05	1.62E-04
PFH / h^{-1}	9.92E-10	1.54E-09	6.80E-11	7.68E-10	3.37E-09

3.3 Redundancy Systems with Redundant Inputs

The following examples show the calculation for redundancy systems with redundant input modules.

3.3.1 Redundant Input Modules in One Rack

The following figure shows the structure of a redundancy system with redundant input modules:



The input module used for the calculation is the F 3236 and the output module is the F 3330:

The λ values specified in Table 3 apply to the modules. Refer to Table 4 for the PFD and PFH values of 1oo1 architectures.

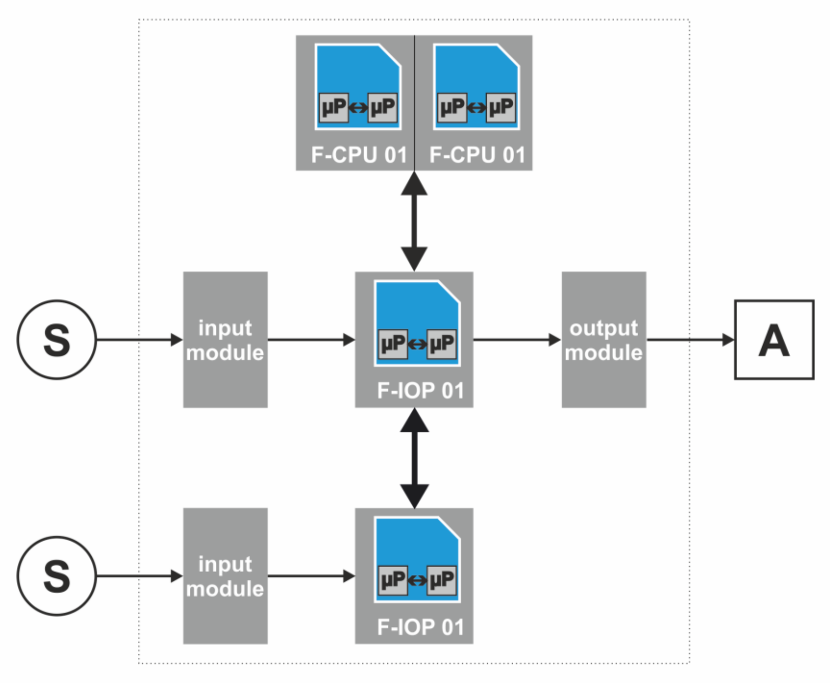
Chapter 3.2 provides an example of how to calculate the PFD and PFH values for modules with 1oo2 architecture.

The PFD and PFH values for the safety loop are determined by adding the individual values.

Module	F 3236	F-IOP 01	F-CPU 01	F 3330	Loop
Architecture	1oo2	1oo1	1oo2	1oo1	---
λ_S / h^{-1}	1.56E-07	8.29E-07	6.94E-07	1.66E-07	---
λ_D / h^{-1}	9.92E-08	7.48E-07	6.53E-07	1.25E-07	---
λ_{DD} / h^{-1}	9.82E-08	7.44E-07	6.50E-07	1.23E-07	---
λ_{DU} / h^{-1}	9.92E-10	4.00E-09	3.35E-09	1.25E-09	---
SFF	99.61%	99.75%	99.75%	99.57%	---
PFD	8.80E-07	8.05E-05	3.02E-06	3.43E-05	1.19E-04
PFH / h^{-1}	1.99E-11	1.54E-09	6.80E-11	7.68E-10	2.40E-09

3.3.2 Input Modules in Redundant Racks

The following figure shows a redundancy system with redundant input modules in different racks:



The input module used for the calculation is the F 3236 and the output module is the F 3330:

The λ values specified in Table 3 apply to the modules. Refer to Table 4 for the PFD and PFH values of 1oo1 architectures.

Chapter 3.2 provides an example of how to calculate the PFD and PFH values for modules with 1oo2 architecture.

The PFD and PFH values for the safety loop are determined by adding the individual values.

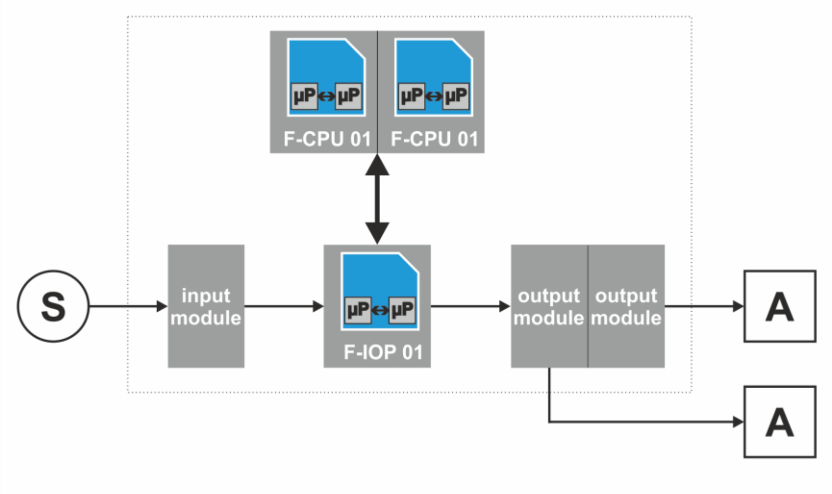
Module	F 3236	F-IOP 01	F-CPU 01	F 3330	Loop
Architecture	1oo2	1oo2	1oo2	1oo1	---
λ_S / h^{-1}	1.56E-07	8.29E-07	6.94E-07	1.66E-07	---
λ_D / h^{-1}	9.92E-08	7.48E-07	6.53E-07	1.25E-07	---
λ_{DD} / h^{-1}	9.82E-08	7.44E-07	6.50E-07	1.23E-07	---
λ_{DU} / h^{-1}	9.92E-10	4.00E-09	3.35E-09	1.25E-09	---
SFF	99.61%	99.75%	99.75%	99.57%	---
PFD	8.80E-07	3.61E-06	3.02E-06	3.43E-05	4.18E-04
PFH / h^{-1}	1.99E-11	8.13E-11	6.80E-11	7.68E-10	9.37E-09

3.4 Redundancy Systems with Redundant Outputs

The following examples show the calculation for redundant systems with redundant output modules.

3.4.1 Redundant Output Modules in One Rack

The following figure shows the structure of a redundancy system with redundant output modules:



The input module used for the calculation is the F 3236 and the output module is the F 3330:

The λ values specified in Table 3 apply to the modules. Refer to Table 4 for the PFD and PFH values of 1oo1 architectures.

Chapter 3.2 provides an example of how to calculate the PFD and PFH values for modules with 1oo2 architecture.

The PFD and PFH values for the F 3330 modules with 2oo2 architecture is calculated as follows:

$PFD_{2oo2} = 2 \cdot PFD_{1oo1}$

$PFH_{2oo2} = 2 \cdot PFH_{1oo1}$

Using the values from Table 4, we obtain:

$PFD = 2 \cdot 3.43 \cdot 10^{-5}$

$\underline{PFD = 6.86 \cdot 10^{-5}}$

$PFH = 2 \cdot 7.68 \cdot 10^{-10}$

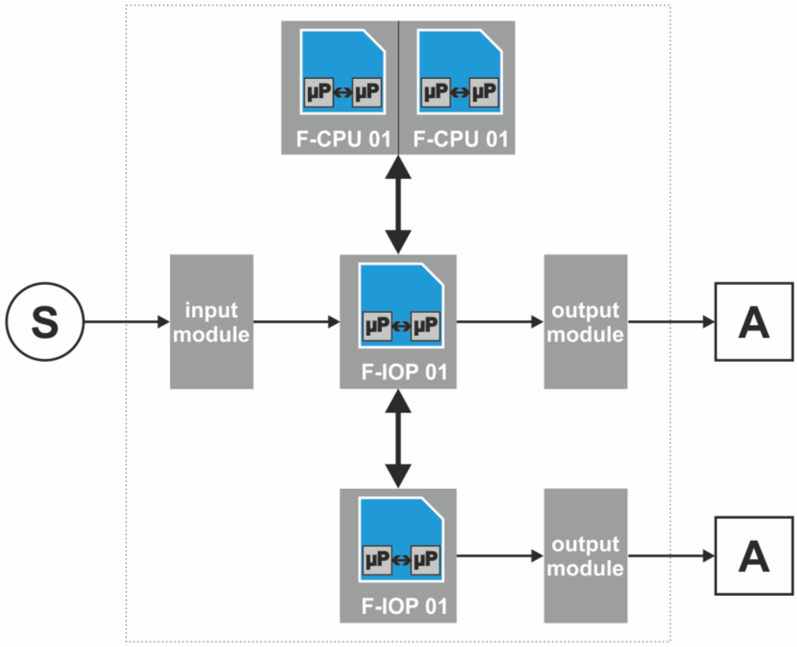
$\underline{PFH = 1.54 \cdot 10^{-9}}$

The PFD and PFH values for the safety loop are determined by adding the individual values.

Module	F 3236	F-IOP 01	F-CPU 01	F 3330	Loop
Architecture	1oo1	1oo1	1oo2	2oo2	---
λ_S / h^{-1}	1.56E-07	8.29E-07	6.94E-07	1.66E-07	---
λ_D / h^{-1}	9.92E-08	7.48E-07	6.53E-07	1.25E-07	---
λ_{DD} / h^{-1}	9.82E-08	7.44E-07	6.50E-07	1.23E-07	---
λ_{DU} / h^{-1}	9.92E-10	4.00E-09	3.35E-09	1.25E-09	---
SFF	99.61%	99.75%	99.75%	99.57%	---
PFD	4.42E-05	8.05E-05	3.02E-06	6.86E-05	1.96E-04
PFH / h^{-1}	9.92E-10	1.54E-09	6.80E-11	1.54E-09	4.14E-09

3.4.2 Output Modules in Redundant Racks

The following figure shows a redundancy system with redundant output modules in different racks:



The input module used for the calculation is the F 3236 and the output module is the F 3330:

The λ values specified in Table 3 apply to the modules. Refer to Table 4 for the PFD and PFH values of 1oo1 architectures.

Chapter 3.2 provides an example of how to calculate the PFD and PFH values for modules with 1oo2 architecture.

Chapter 3.4.1 provides an example of how to calculate the PFD and PFH values for modules with 2oo2 architecture.

The PFD and PFH values for the safety loop are determined by adding the individual values.

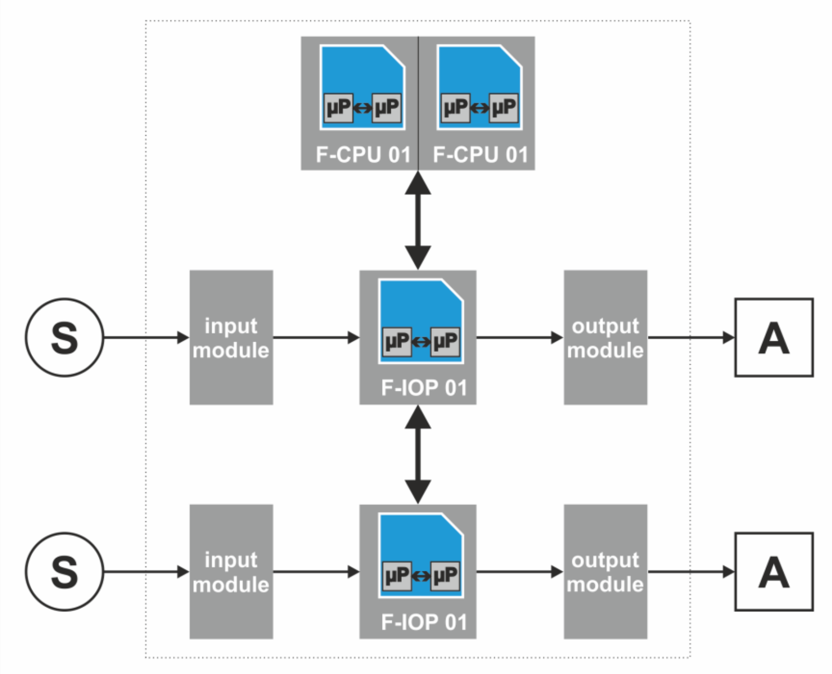
Module	F 3236	F-IOP 01	F-CPU 01	F 3330	Loop
Architecture	1oo1	1oo2	1oo2	2oo2	---
λ_S / h^{-1}	1.56E-07	8.29E-07	6.94E-07	1.66E-07	---
λ_D / h^{-1}	9.92E-08	7.48E-07	6.53E-07	1.25E-07	---
λ_{DD} / h^{-1}	9.82E-08	7.44E-07	6.50E-07	1.23E-07	---
λ_{DU} / h^{-1}	9.92E-10	4.00E-09	3.35E-09	1.25E-09	---
SFF	99.61%	99.75%	99.75%	99.57%	---
PFD	4.42E-05	3.61E-06	3.02E-06	6.86E-05	1.19E-04
PFH / h^{-1}	9.92E-10	8.13E-11	6.80E-11	1.54E-09	2.68E-09

3.5 Redundancy Systems with Redundant Inputs and Outputs

The following examples show the calculation for redundant systems with redundant inputs modules and redundant output modules.

3.5.1 1oo2 Wiring

The following figure shows a 1oo2 wiring structured for high safety:



The input module used for the calculation is the F 6217 and the output module is the F 3330:

The λ values specified in Table 3 apply to the modules.

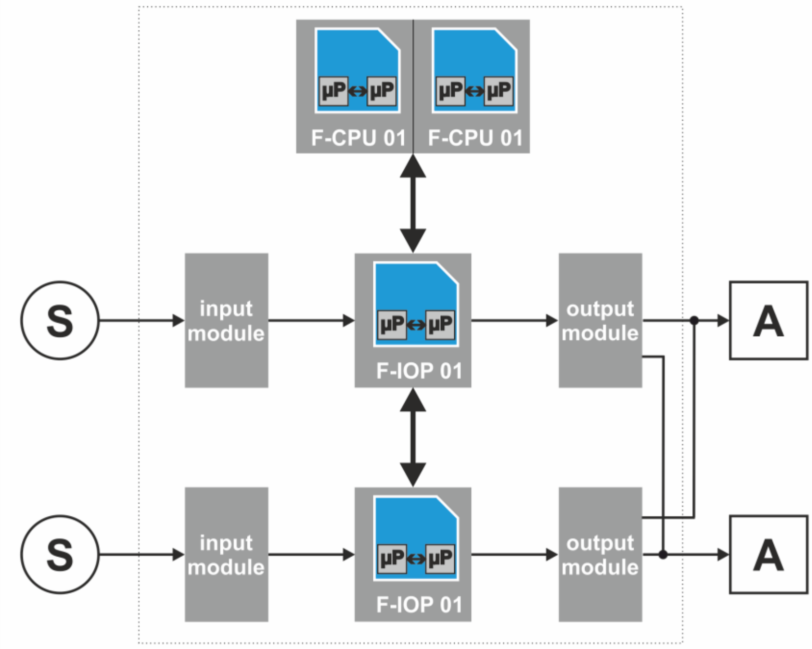
Chapter 3.2 provides an example of how to calculate the PFD and PFH values for modules with 1oo2 architecture.

The PFD and PFH values for the safety loop are determined by adding the individual values.

Module	F 6217	F-IOP 01	F-CPU 01	F 3330	Loop
Architecture	1oo2	1oo2	1oo2	1oo2	---
λ_S / h^{-1}	3.58E-07	8.29E-07	6.94E-07	1.66E-07	---
λ_D / h^{-1}	2.35E-07	7.48E-07	6.53E-07	1.25E-07	---
λ_{DD} / h^{-1}	2.33E-07	7.44E-07	6.50E-07	1.23E-07	---
λ_{DU} / h^{-1}	1.75E-09	4.00E-09	3.35E-09	1.25E-09	---
SFF	99.71%	99.75%	99.75%	99.57%	---
PFD	1.56E-06	3.61E-06	3.02E-06	1.11E-06	9.29E-06
PFH / h^{-1}	3.53E-11	8.13E-11	6.80E-11	2.51E-11	2.10E-10

3.5.2 2oo2 Wiring

The following figure shows a 2oo2 wiring structured for high availability:



The input module used for the calculation is the F 6217 and the output module is the F 3330:

The λ values specified in Table 3 apply to the modules.

Chapter 3.2 provides an example of how to calculate the PFD and PFH values for modules with 1oo2 architecture.

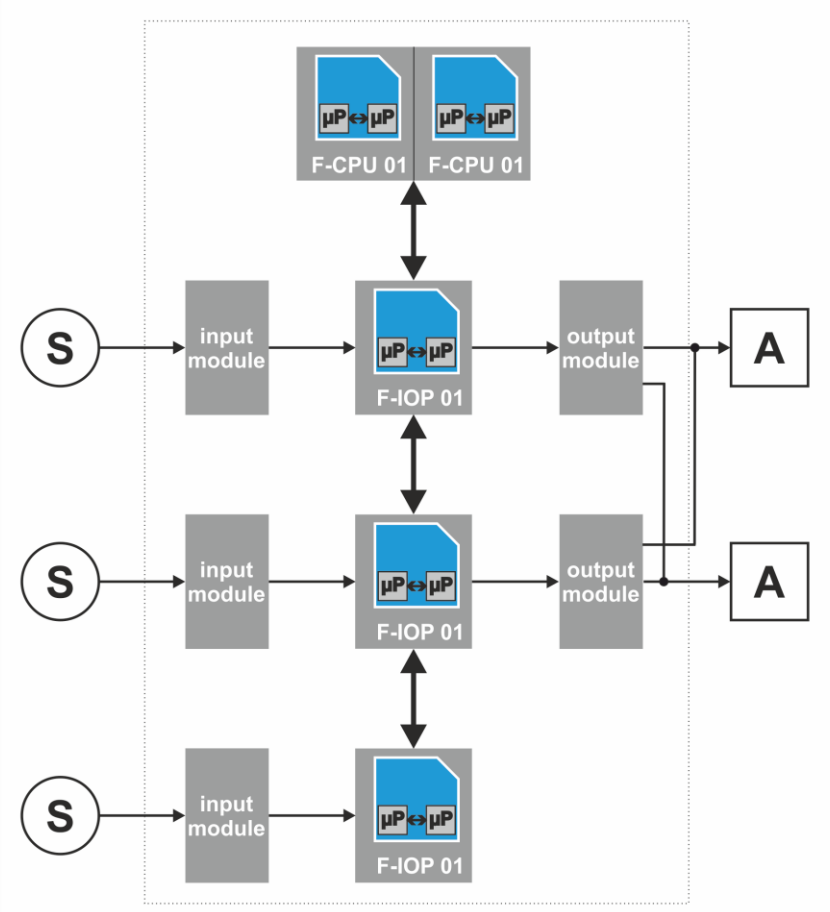
Chapter 3.4.1 provides an example of how to calculate the PFD and PFH values for modules with 2oo2 architecture.

The PFD and PFH values for the safety loop are determined by adding the individual values.

Module	F 6217	F-IOP 01	F-CPU 01	F 3330	Loop
Architecture	1oo2	1oo2	1oo2	2oo2	---
λ_S / h^{-1}	3.58E-07	8.29E-07	6.94E-07	1.66E-07	---
λ_D / h^{-1}	2.35E-07	7.48E-07	6.53E-07	1.25E-07	---
λ_{DD} / h^{-1}	2.33E-07	7.44E-07	6.50E-07	1.23E-07	---
λ_{DU} / h^{-1}	1.75E-09	4.00E-09	3.35E-09	1.25E-09	---
SFF	99.71%	99.75%	99.75%	99.57%	---
PFD	1.56E-06	3.61E-06	3.02E-06	6.86E-05	7.67E-05
PFH / h^{-1}	3.53E-11	8.13E-11	6.80E-11	1.54E-09	1.72E-09

3.5.3 2oo3 Architecture of the Inputs and 2oo2 Architecture of the Outputs

The following figure shows a configuration structured for high availability and high safety:



The input module used for the calculation is the F 6217 and the output module is the F 3330:

The λ values specified in Table 3 apply to the modules.

Chapter 3.2 provides an example of how to calculate the PFD and PFH values for modules with 1oo2 architecture.

Chapter 3.4.1 provides an example of how to calculate the PFD and PFH values for modules with 2oo2 architecture.

The PFD and PFH values for the F 6217 modules with 2oo3 architecture is calculated as follows:

$$PFD = 6 \cdot \left((1-\beta_D) \cdot \lambda_{DD} + (1-\beta) \cdot \lambda_{DU}\right)^2 \cdot t_{CE} \cdot t_{GE} + \beta_D \cdot \lambda_{DD} \cdot MTTR + \beta \cdot \lambda_{DU} \cdot \left(\frac{T_1}{2} + MRT\right)$$

$$PFH = 6 \cdot \left((1-\beta_D) \cdot \lambda_{DD} + (1-\beta) \cdot \lambda_{DU}\right) \cdot (1-\beta) \cdot \lambda_{DU} \cdot t_{CE} + \beta \cdot \lambda_{DU}$$

where

$$t_{CE} = \frac{\lambda_{DU}}{\lambda_D} \cdot \left(\frac{T_1}{2} + MRT\right) + \frac{\lambda_{DD}}{\lambda_D} \cdot MTTR$$

$$t_{GE} = \frac{\lambda_{DU}}{\lambda_D} \cdot \left(\frac{T_1}{3} + MRT\right) + \frac{\lambda_{DD}}{\lambda_D} \cdot MTTR$$

The following also applies:

- β = 2 %
- β_D = 1 %
- MTTR = MRT = 8 h
- T_1 = 10 years = 87 600 h

For t_{CE} and t_{GE}, this results in:

$$t_{CE} = \frac{1.75\cdot10^{-9}}{2.35\cdot10^{-7}} \cdot \left(\frac{87600}{2} + 8\right) + \frac{2.33\cdot10^{-7}}{2.35\cdot10^{-7}} \cdot 8$$

$\underline{t_{CE} = 334.16\text{ h}}$

$$t_{GE} = \frac{1.75\cdot10^{-9}}{2.35\cdot10^{-7}} \cdot \left(\frac{87600}{3} + 8\right) + \frac{2.33\cdot10^{-7}}{2.35\cdot10^{-7}} \cdot 8$$

$\underline{t_{GE} = 225.44\text{ h}}$

For PFD and PFH, this results in:

$$PFD = 6 \cdot \left((1 - 0.01) \cdot 2.33\cdot10^{-7} + (1 - 0.02) \cdot 1.75\cdot10^{-9}\right)^2 \cdot 334.16 \cdot 225.44$$

$$+ 0.01 \cdot 2.33\cdot10^{-7} \cdot 8 + 0.02 \cdot 1.75\cdot10^{-09} \cdot \left(\frac{87600}{2} + 8\right)$$

$\underline{PFD = 1.58\cdot10^{-6}}$

$$PFH = 6 \cdot \left((1 - 0.01) \cdot 2.33\cdot10^{-7} + (1 - 0.02) \cdot 1.75\cdot10^{-9}\right) \cdot (1 - 0.02) \cdot 1.75\cdot10^{-9} \cdot 334.16$$

$$+ 0.02 \cdot 1.75\cdot10^{-9}$$

$\underline{PFH = 3.58\cdot10^{-11}}$

The PFD and PFH values for the safety loop are determined by adding the individual values.

Module	F 6217	F-IOP 01	F-CPU 01	F 3330	Loop
Architecture	2oo3	2oo3	1oo2	2oo2	---
λ_S / h^{-1}	3.58E-07	8.29E-07	6.94E-07	1.66E-07	---
λ_D / h^{-1}	2.35E-07	7.48E-07	6.53E-07	1.25E-07	---
λ_{DD} / h^{-1}	2.33E-07	7.44E-07	6.50E-07	1.23E-07	---
λ_{DU} / h^{-1}	1.75E-09	4.00E-09	3.35E-09	1.25E-09	---
SFF	99.71%	99.75%	99.75%	99.57%	---
PFD	1.58E-06	3.69E-06	3.02E-06	6.86E-05	7.68E-05
PFH / h^{-1}	3.58E-11	8.42E-11	6.80E-11	1.54E-09	1.72E-09

Appendix

Index of Tables

MANUAL

Functional Safety Data

HI 803 233 E

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