Functional Safety Manual

This manual is valid for pressure and screw-in transmitters as well as submersible transmitters of the series

DMK, DMP, LMK and LMP with SIL 2-conformity

Important notes:

- ☞ Please read this manual carefully before installing and starting up the device in a safety-relevant application.
- ☞ This manual must be kept at an easy accessible location for further use.
- ⚠ The device may only be installed, used and serviced by persons who are familiar with this manual as well as with the current regulations of occupational safety and accident prevention.
- ⚠ This manual is only valid in combination with the product-specific as possibly the additional manual for installation in intrinsic safe areas.

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Applications with Functional Safety

1. General

1.1 Information on the intended use

This manual constitutes a supplement to the product-specific operating manual. It is therefore only valid in conjunction with it. Generally, this manual only applies to devices with SIL 2-conformity.

1.2 Target group

This operating manual is intended for qualified technical personnel.

1.3 Symbols used

⚠ : Caution! ☞ : Note

1.4 Safety notes

The following notes must be observed to avoid hazards for the operator and his environment:

⚠ For the installation, maintenance and cleaning of the device you must absolutely observe the relevant regulations and stipulations governing Functional Safety (IEC 61508, IEC 61511, etc.) as well as the occupational safety provisions.

⚠ Have the installation, maintenance and cleaning of the devices performed exclusively by persons specifically trained and authorized for this purpose as far as they are familiar with the devices!

⚠ Modifications on devices and connections void Functional Safety and the warranty!

⚠ It is the responsibility of the user to verify whether the chosen version of the device is suitable for the intended application and the existing environmental conditions. BD SENSORS does not assume any liability for an incorrect selection and its consequences!

⚠ Please take the specific technical data for the Functional Safety from the enclosed Functional Safety Data Sheet®.

2. Product identification

Make sure that your device has been ordered with SIL-conformity and has been delivered conformably. You can check this easily by reading the type plate. If the third or with devices of series LMP the fifth segment block of the ordering code consists of "1S" or "ES", your device is SIL 2-conform.

3. Premises

- The device generates an analogue output signal of 4 ... 20 mA that is proportional to the current pressure. This has to be control by a downstream logical unit (e.g. PLC). For the malfunction detection, the logical unit has to distinguish between 4 ... 20 mA-signals and the fault current < 3.6 mA or > 21 mA.
- Observe with the conception of the system, that the technical data of the product-specific as well as Functional Safety Data Sheet® may not be exceeded. Especially the permissible operating condition (permissible temperatures, etc.) have to be ensured.
- Make sure that the entire interconnection of different components fulfils the requirements of the application. The operator is responsible for correct construction of the overall system.
- When starting up the device, it is recommended to check the whole safety function.
- The operability of the measuring device should be checked via proof test in regularly intervals. For defining the scope and interval of tests the operator is responsible.

4. Determination of the obtainable Safety Integrity Level

An E/E/PE safety-related system normally considers of input, logical and output subsystems. In following figure a possible fraction of the average probability of failure on demand is shown.

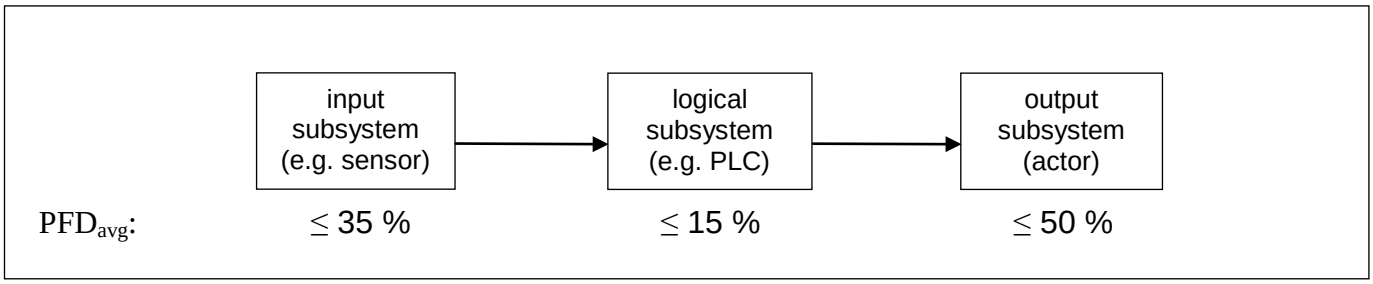

Fig. 2 usual fraction of PFD_{avg} to the subsystems

As a result of the maximal average probability of failure on demand of the constructed safety function, the Safety Integrity Level of the subsystem could be defined via table 1. Where the frequency of demands for operation made on a safety-related system is no greater than one per year and no greater than twice the proof test frequency.

Safety Integrity Level	**average probability of failure on demand for the constructed function (PFD_a)** for operation in low demand mode
SIL 4	$\geq 10^{-5}$ up to $<10^{-4}$
SIL 3	$\geq 10^{-4}$ up to $<10^{-3}$
SIL 2	$\geq 10^{-3}$ up to $<10^{-2}$
SIL 1	$\geq 10^{-2}$ up to $<10^{-1}$

Tab. 1 Safety Integrity Levels relating to PFD_a

To define the Safety Integrity Level of a device, two further parameters are necessary. Once is SFF (Safe Failure Fraction), which gives the fraction of safe failures in reference to all possible failures and the other is HFT (Hardware Failure Tolerance). Subjected to these parameters the Safety Integrity Level could be defined according to table 2.

Safe Failure Fraction (SFF)	**Hardware Failure Tolerance (HFT)** for operation in low demand mode		
	0	**1**	**2**
< 60 %	SIL 1	SIL 2	SIL 3
60 % ... < 90 %	SIL 2	SIL 3	SIL 4
90 % ... < 99 %	SIL 3	SIL 4	SIL 4
≥ 99 %	SIL 3	SIL 4	SIL 4

Tab. 2 Safety Integrity Levels relating to HFF

All pressure measuring devices from BD SENSORS, which have SIL-conformity, are suitable for safety-relevant applications for operation in low demand mode up to SIL 2. Permissible Safety Integrity Levels have a grey background in the table for clear identification.

5. Technical report

5.1 Explanation / definitions according technical report

Following the most important terms are explained. (excerpt of standard EN 61508-4:2001)

Term	**Explanation**
functional safety	part of the overall safety, relating to the EUC and the EUC control system which depends on the correct functioning of the E/E/PE safety-related systems, other technology safety-related systems and external risk reduction facilities
safe function	function to be implemented by a safety-related system for risk reduction, with the aim to achieve or maintain a safe state for the system, in respect of a specific hazardous event
safe integrity	probability, that a safety-related system achieving its safety functions under all stated conditions within a stated period of time
SIL (safety integrity level)	one, out of a possible four, discrete levels for specifying the safety integrity requirements of the safety functions to be allocated to the E/E/PE safety-related systems, where Safety Integrity Level 4 has the highest level of safety integrity and Safety Integrity Level 1 has the lowest
mode of operation	way in which a safety-related system is intended to be used, with respect to the frequency of demands made upon it, which may be either - low demand mode, where the frequency of demands for operation made on a safety-related system is no greater than one per year and no greater than twice the proof test frequency - high demand or continuous mode, where the frequency of demands for operation made on a safety-related system is greater than one per year or greater than twice the proof test frequency
fault tolerance	ability of a functional unit to continue to perform a required function in the presence of faults or errors
dangerous failure	failure which has the potential to put the safety-related system in a hazardous or fail-to-function state
safe failure	failure which does not have the potential to put the safety-related system in a hazardous or fail-to-function state

Following further abbreviations and explanations are given, which are used in the Functional Safety Data Sheet®:

Term	Explanation
type	corresponds to the mode of operation according to EN 61508-4:2001
hardware fault tolerance (HFT)	hardware fault tolerance indicates the number of failures the product or subsystem can withstand without losing the safety function
safe failure fraction (SFF)	fraction of the failure without the potential to put the safety-related system in a hazardous or fail-to-function state
mean time to failure, dangerous (MTTFd)	mean (average) time to the first failure, which has the potential to put the safety-related system in a hazardous or fail-to-function state
mean time to failure, safe (MTTFs)	mean (average) time to the first failure, which does not have the potential to put the safety-related system in a hazardous or fail-to-function state
probability of failure on demand (PFD)	probability that the safety function has failed upon demand
average probability of failure on demand (PFD_{avg})	average probability that the safety function has failed upon demand
PFS	probability that the safety function causes a spurious trip of the process
AV	probability that function of the product (or process) is available
OK	probability that the product is running without any internal failures
FMEA	failure mode and effects analysis

Summary

BD Sensors has requested Risknowlogy to support a reliability study on pressure transmitters. Risknowlogy has carried out an FMEA and a Markov study to determine the most important reliability properties of the product. These studies have been carried out following the rules of IEC 61508 and IEC 61511.

To fully understand the calculation results it is necessary to read the complete report. Table 1 gives and overview of the different product names and groups them for further analysis. Table 2 summarizes the functional safety results per group. Table 3 summarize the results for sample calculations that have been carried out on the following reliability properties:

- PFD: The probability that the safety function has failed upon demand
- PFDavg: The average probability that the function has failed upon demand
- PFS: The probability that the safety function causes a spurious trip of the process
- AV: The probability that the function of the product is available
- OK: The probability that the product is running without any internal failures

Table 1 – Product overview per group

Group	Product Names
Group 1	DMP 331, DMP 457, DMP 331P, LMP 331, LMP 307, LMP 308, LMP 808, DMP333
Group 2	DMK 331, DMK 457, DMK 331P, LMK 331, LMK 307, LMK 807
Group 3	DMP 331 Ex, DMP 457 Ex, DMP 331P Ex, LMP 331 Ex, LMP 307 Ex, LMP 308 Ex, DMP 333 Ex
Group 4	DMK 331 Ex, DMK 457 Ex, DMK 331P Ex, LMK 331 Ex, LMK 307 Ex

Table 2 – Functional safety summary results per group – 55 °C

Properties	Group 1	Group 2	Group 3	Group 4
Type	A	A	A	A
Hardware fault tolerance	0	0	0	0
Safe failure fraction	61,0%	61,0%	61,1%	61,5%
Safe detected failure rate [1/h]	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Safe undetected failure rate [1/h]	6,13E-08	6,13E-08	6,13E-08	5,95E-08
Dangerous detected failure rate [1/h]	3,66E-08	3,66E-08	3,74E-08	3,79E-08
Dangerous undetected failure rate [1/h]	6,28E-08	6,28E-08	6,28E-08	6,10E-08
Dangerous diagnostic coverage	37%	37%	37%	38%
MTTFd [y]	1138	1138	1139	1154
MTTFs [y]	1863	1863	1863	1920
Fit for use in Safety Integrity Level	2	2	2	2
Fit for use in Spurious Trip Level™	5	5	5	5

Table 3 – Sample probability calculations per group – 55 °C

Property	Group 1	Group 2	Group 3	Group 4
Mission time	10 years	10 years	10 years	10 years
Periodic testing	None	None	None	None
PFD	5.49E-03	5.49E-03	5,49E-03	5.33E-03
PFDavg	2,75E-03	2,75E-03	2,75E-03	2,67E-03
PFS	1,46E-06	1,46E-06	1,46E-06	1,42E-06
AV	9,95E-01	9,95E-01	9,95E-01	9,95E-01
OK	9,95E-01	9,95E-01	9,95E-01	9,95E-01

5.2 Excerpt of technical report

The different devices are allocated to the groups 1 up to 4, which are shown in table 1 of the technical report.

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