SIL Manufacturer's Declaration

Functional safety of inductive slot proximity sensors acc. to IEC 61508:2000; PF21CERT6455

1 Safety Evaluation

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declares as manufacturer that for the inductive proximity sensors, types mentioned below, the calculated PFD_{avg} values for low demand mode of operation are within the allowed range for SIL 2 according to IEC 61508-1:2000 table 2 and do fulfil the requirement to not claim more than 25% of this range, i.e. to be better than or equal to $2.5 \cdot 10^{-3}$.

For high demand mode of operation, the PFH is within the allowed range for SIL 2 according to IEC 61508-1:2000 table 3. It fulfils the requirement to not claim more than 25% of this range, i.e. to be better than or equal to $2.5 \cdot 10^{-7}$ 1/h.

The sensors are considered to be Type A components. Therefore, the SFF has to be 60 % to 90 % according to EN/IEC 61508-2 table 2 for SIL 2 (sub-) systems with a hardware fault tolerance of 0.

2 Products

Inductive slot proximity sensors with NAMUR interface in accordance with IEC 60947-5-6:1999 or EN 60947-5-6:2000, see product list.

The nominal switching immersion depth s_n and therefore the assured operating immersion depth S_{ao} depend on the dimensions and the material of the target. The immersion depth is the distance that the leading edge of the target enters the slot, measured from the leading edge of the sensor. The target is centered in the slot width.

Product List, Nominal Switching Immersion Depth (s_n), Assured Operating Immersion Depth (S_{ao}) and Targets

Part No.	Product Name	Function[1)]	s_n	S_{ao}	Reference Target
70132972	SJ2-N	NC	4.5 mm	7.0 mm	8.0 x 8.0 x 0.5 mm³, Al
70133002	SJ5-N	NC	6.0 mm	8.0 mm	10 x 8.0 x 0.3 mm³, Al
70132970	SJ10-N	NC	15 mm	22 mm	22 x 22 x 0.5 mm³, Al

[1)] NC = normally closed (break)

3 Safety Function

The safe state is reached when the target is immersed into the slot laterally. The target (actuator element, damping material) must be immersed at least up to the assured operating depth S_{ao}. In this case the sensor is in the high impedance state ('off state', I < 1.2 mA).

The nominal switching immersion depth s_n and therefore the assured operating depth S_{ao} depends on the dimensions and the material of the target.

If customized targets are used it must be ensured that the immersion depth is more than 1.3 times the individual measured real switching immersion depth and the target is long enough that it is immersed less or equal to the middle of the slot length.

This evaluation is only valid for using amplifiers/safety functions that rely on the 'OFF state' as safe state.

Sensor respective amplifier output	Sensor condition
ON state (low impedance)	active faces uncovered (target not present) and sensor functioning
OFF state (high impedance, safe state)	active faces covered (target present) or sensor defective

4 Safety Characteristic Values

Parameter	Symbol	Condition	Value	Unit
Type			A	
Hardware Fault Tolerance	*HFT*		0	
Safe Failure Rate	λ_{safe}		17.7	FIT
No Effect Failure Rate	$\lambda_{no\ effect}$		4.42	FIT
Dangerous Failure Rate	$\lambda_{dangerous}$		6.91	FIT
Total Failure Rate	λ_{total}		29.0	FIT
Total Safe Failure Rate	λ_S		22.1	FIT
Total Dangerous Failure Rate	λ_D		6.91	FIT
Safe Failure Fraction	*SFF*		76	%
Mean Time to Failure	*MTTF*		3.45E+07	h
Average Probability of Failure on Demand	PFD_{avg} [1)]	T_1 = 1 year	3.02E-05	
Average Probability of Failure on Demand	PFD_{avg} [1)]	T_1 = 2 years	6.05E-05	
Average Probability of Failure on Demand	PFD_{avg} [1)]	T_1 = 5 years	1.51E-04	
Probability of Dangerous Failure per Hour	*PFH* [1)]		6.91E-09	1/h
Safety Integrity Level	*SIL*		2	
Diagnostic Coverage	*DC*		0	%

[1)] 1oo1 structure

5 Conditions and Assumptions

The following assumptions have been made during the Failure Mode Effect and Diagnostic Analysis:

- Failure rates are based on the Siemens standard SN 29500.
- Failure rates are constant, wear is not included.
- Propagation of failures is not relevant.
- All component failure modes are known (Type A).
- PFD and PFH values are calculated for use in a 1oo1 structure.
- The repair time after a safe failure is 8 hours.
- The average temperature over a long period of time is 40 °C.
- The stress levels are average for an industrial environment and can be compared to the Ground Fixed classification of MIL-HDBK-217F. Alternatively, the assumed environment is similar to IEC 60645-1, Class C (sheltered location) with an average temperature over a long period of time of 40 ºC.
- For the high impedance state the object is immersed deeper than the assured operating immersion depth ($s > S_{ao}$).
- The 2-wire connection cable between the sensor and the switching amplifier must meet the qualities as follows: Line resistance $R_{series} < 50\ \Omega$ (both leads in series); Insulation resistance $R_{insulation} > 1\ M\Omega$, as stated in IEC 60947-5-6:1999 and EN 60947-5-6:2000 (NAMUR). The wires must be isolated from any other circuit.
- The sensor is operated within the limits given in its datasheet.
- The sensor is connected to a NAMUR interface in accordance with EN 60947-5-6:2000 or IEC 60947-5-6:1999 that relies on the high impedance state (“OFF state”) of the sensor as safe state and is qualified for SIL 2 applications.
- As noted in EN/IEC 61508-2, a useful lifetime of 8-12 years can be assumed. However, this value strongly depends on the application and can even be higher if e.g., ambient conditions support a long lifetime (moderate usage temperatures and temperature cycles, low mechanical stress).

6 Definitions

The following definitions for the failure of the product were considered.

Application according to EN 60947-5-6:2000 or IEC 60947-5-6:1999 (DC interface for proximity sensors and switching amplifiers (NAMUR)):

Safe State	The safe state is defined as the output being below 1.2 mA (high impedance).
Safe Failure	Failure that causes the sensor current consumption to go to the defined safe state without a demand from the process.
Dangerous Failure	Failure leading to an output current above 1.2 mA when the target is within the assured operating immersion depth (i.e., being unable to go to the defined safe state).
“no effect” Failure	Failure of a component that is part of the safety function but has no effect on the safety function. For the calculation of the *SFF* it is treated like a safe undetected failure.

For the calculation of the Safe Failure Fraction (*SFF*) the following has to be noted:

$\lambda_{total} = \lambda_{safe} + \lambda_{dangerous} + \lambda_{no\ effect}$

$SFF = 1 - \lambda_{dangerous} / \lambda_{total}$

The failure categories listed above expand on the categories listed in IEC 61508:2000 which are only safe and dangerous. It is important to realize that the „no effect“-failures are included in the safe failure category according to IEC 61508:2000.

Note that these failures on their own will not affect system reliability or safety, and should not be included in spurious trip calculations.

Although the safety characteristic values of the sensor are within the allowed range for SIL 2 according to IEC 61508:2000 it depends on the failure rates of the other devices in the safety loop whether a SIL 2 safety function can be implemented.

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