144LD / 244LD Intelligent Buoyancy Transmitter for Level, Interface and Density

Functional Safety

Safety **I**ntegrity **L**evel

SIL 2 certified

acc. to IEC 61508 / IEC 61511

The intelligent transmitter 144LD / 244LD measures the level, interface and density of liquids continuously in processes of all industrial applications which meet the particular demands on safety equipment required according to IEC 61508 / IEC 61511-1.

FEATURES

- Functional safety in compliance with IEC 61508 / IEC 61511-1
- Suitable for use up to SIL 2, independently assessed by *exida.com*
- Explosion protection (depending on the version)
- Electromagnetic compatibility to EN 61326 and NAMUR recommendation NE21

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1 RANGE OF APPLICATION

1.1 General

The range of application encompasses the intelligent transmitters for level, interface and density of type 144LD and 244LD (HART and 4-20mA without communications) for continuous measurement.

The measurement is based on the Archimedes buoyancy principle. The devices can be conveniently and reliably accessed and adjusted remotely using a PC or hand terminal, but can also be adjusted by conventional means with pushbuttons. The transmitters are suitable for use in explosion hazard zones.

Other features:
- Continuous self-diagnosis
- Configurable safety level
- Software locking for pushbuttons and reconfiguration
- Simple commissioning
- Measurements are virtually independent of the product properties

1.2 Requirements

The following requirements must be taken into account for applications under the specific demands on safety equipment according to IEC 61508 / IEC 61511-1:

- It must be observed during project planning that the technical data specified in [Ref. 5], particularly with regard to the application and ambient conditions, are fulfilled by the transmitters.
- The average operating temperature over longer periods is not higher than 40°C.
- After project planning with the transmitters, a function test must be conducted. The necessary tests must be specified in the safety manual of the system. The following tests should be conducted:
- Zero point verification
- Measured value verification
- Simulation of various measured values
- Verification of the preset safety values
- The above function tests should also be conducted for remote adjustment of the parameters relevant to measurements.
- Before the safe process is put into operation, the HART communications and local operation must be locked (activate write protection).
- Regular function tests (see recurring tests) musty be conducted
- The intelligent transmitters for level, interface and density 144LD / 244LD can be employed in applications with low and also high requirement rates.

2 GENERAL

2.1 Relevant standards

- DIN EN 61508 Parts 1 to 7: Functional safety-related electric/electronic/programmable electronic systems
- DIN IEC 61511 Parts 1 to 3: Functional safety – Safety instrumented systems for industrial processes

2.2 Definitions

The terms listed below are defined according to [Ref. 1], part 4 and [Ref. 2], part 1.

Name	Description
Actuator	Part of the safety system that performs interactions with the process to achieve a safe condition.
Failure	Completion of the ability of a functional unit to perform a demanded function.
Diagnostic coverage factor	Relationship of the failure rate of the errors recognized by diagnostic tests to the failure rate of the component or subsystem. The degree of diagnostic does not contain errors determined at repeated inspections.
Fault	Abnormal condition, which can cause a reduction or a loss of the ability of a functional unit to perform a demanded function.
Functional safety	Part of the total safety, which refers to the process and the BPCS and the intended function of the SIS and other safety levels.
Functional unit	Unit from hardware or software or both, which are suitable for the execution of a fixed task.
Dangerous Failure	Loss with the potential to shift the safety-relevant system into a dangerous condition or a non functioning state.
Safety	Liberty of untenable risks
Safety function	Function, which is executed by a SIS, safety-related systems based on other technologies or from external installations and mechanisms for risk-reduction, with the goal of achieving or keeping up, under consideration of a fixed dangerous incident, a safe condition for the process.
Safety Integrity	Average probability that a safety-relevant system executes the demanded safety-relevant functions, in accordance with the required conditions within a fixed period of time.
Safety Integrity Level (SIL)	One out of four discrete levels to specify the requirements for the safety integrity of the safety functions, which are assigned to the safety-related system, whereby the safety integrity level 4 represents the highest degree of the safety integrity, the safety integrity level 1 the lowest.
Safety Instrumented System (SIS)	Safety-related system for the execution of one or several safety-related functions. A SIS consists of sensor(s), logic system and actuator(s).
Safe failure	Failure without the potential to set the safety-related system into a dangerous or a nonfunctioning condition.

2.3 Abbreviations

Abbreviation	Description
BPCS	Basic process control system
DC	Diagnostic coverage
HFT	Hardware fault tolerance
PFD	Probability of failure on demand
PFD_{avg}	Average probability of failure on demand
SFF	Safe failure fraction
SIL	Safety integrity level
SIS	Safety instrumented system

2.4 Design tables

The tables below are used to determine the safety integrity level (SIL).

2.4.1 Average probability of a failure on demand (PFD_{avg})

This table reflects the achievable safety integrity level (SIL) in dependency on the average probability of a failure on demand. The specified failure tolerances in this case apply to a safety function operated in the **mode with low requirement rate** (see [Ref. 1] Part 1, Chapter 7.6.2.9).

Safety integrity level (SIL)	**PFD_{avg} with low requirement rate**
4	$\geq 10^{-5}$ to $< 10^{-4}$
3	$\geq 10^{-4}$ to $< 10^{-3}$
2	$\geq 10^{-3}$ to $< 10^{-2}$
1	$\geq 10^{-2}$ to $< 10^{-1}$

2.4.2 Probability of a dangerous failure per hour (PFH)

If the requirement rate is more than once per year or greater than twice the frequency of recurring tests, the measurement system must be employed in the **mode with high requirement rate** (see [Ref. 1] Part 1, Chapter 3.5.12).

Safety integrity level (SIL)	**PFH with high requirement rate** Probability of a dangerous failure per hour
4	$\geq 10^{-9}$ to $< 10^{-8}$
3	$\geq 10^{-8}$ to $< 10^{-7}$
2	$\geq 10^{-7}$ to $< 10^{-6}$
1	$\geq 10^{-6}$ to $< 10^{-5}$

2.4.3 Safety integrity of the hardware

The following table indicate the attainable safety integrity level (SIL) as a function of the fraction of the safe failures (SFF) and the fault tolerance of the hardware (HFT) for safety-related subsystems of type type B (see [Ref. 1] Part 2, Chapter 7.4.3.1.4).

Proportion of non-dangerous failures (SFF)	**Fault tolerance of the hardware (HFT) for Type B**		
	0	**1 (0)[1]**	**2**
< 60%	Not permitted	SIL 1	SIL 2
60% - < 90%	SIL 1	SIL 2	SIL 3
90% - < 99%	SIL 2	SIL 3	SIL 4
≥ 99%	SIL 3	SIL 4	SIL 4

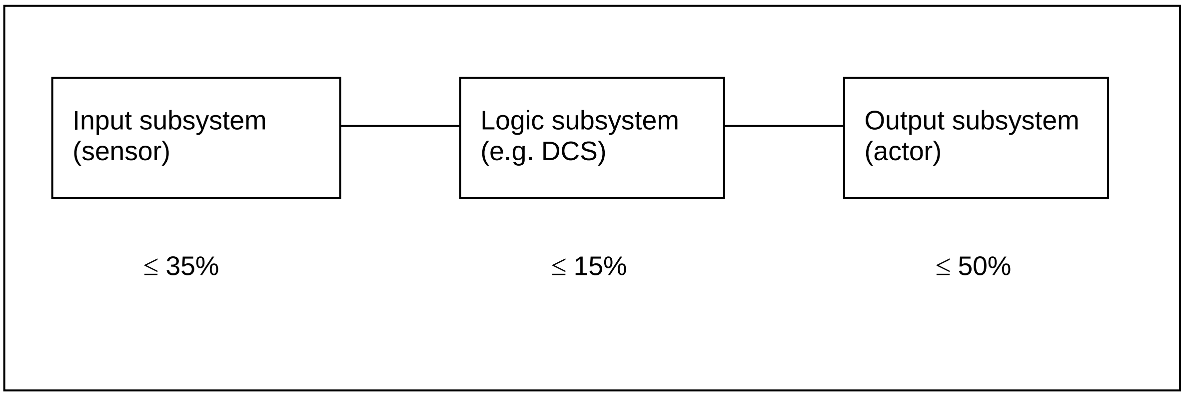
1) Based on [Ref. 2] part 1, chapters 11.4.4 it is possible for subsystems e.g. sensors and actuators to reduce the value for the hardware failure tolerance (HFT) by one (values in parentheses), if the used equipment fulfills all following conditions:

- The device is proven in operation
- The device only allows to change process-relevant parameters
- Changes of the process-relevant parameters is protected (e.g. password, Jumper, etc..)
- The function/application has a demanded safety integrity level of less than SIL 4.

These listed conditions apply to the intelligent transmitters for level, interface and density 144LD / 244LD.

2.4.4 Safety-related system

Safety-related systems usually consist of three subsystems, the input subsystem (sensor), logic subsystem (SPS or control system) and output system (control valve consisting of positioner, actuator and valve). The average probability of a failure on demand is usually divided as follows:



3 BEHAVIOUR IN OPERATION AND FAULT STATE

The behaviour during operation and fault state is described in the commissioning and maintenance instructions MI EML0610 A-(de) and MI EML0710 A-(de) [Ref. 4].

4 RECURRING EXAMINATIONS OF THE TRANSMITTER FOR LEVEL, INTERFACE AND DENSITY

4.1 Security Examination

In accordance with IEC 61508/61511 the safety function of the entire safety circuit is to be examined regularly. The therefore necessary test intervals are determined for the respective safety circuit.

4.2 Function Examination

The orderly function of the transmitter for level, interface and density must be tested regularly every 5 years. The test may be conducted by the manufacturer or an authorised workshop. The following work must be conducted:

- Dismantle the sensor (MI EML0610 A-de, Chapter 10.6 ff, MI EML0710 A-de, Chapter 10.7 ff).
- Examine the torsion tube to detect corrosion and leaks (replace if necessary)
- Examine the sandwich housing support (195-197) for dirt, Chapter. 10.12 ff (clean or replace if necessary)
- Examine the ball bearing in baseplate (163) for easy action
- Replace the sealing rings in the sensor (use Cu-based grease)
- Examine the sealing rings in the amplifier and replace as necessary (apply grease)
- Observe the tightening torques for the screws specified in the MI when assembling
- Adjust the transmitter as described in MI EML0610 A-de / MI EML0710 A-de, Chapter 8
- Adjust the safety range
- Verify all adjustments by setting to the zero point, the end value, a medium value (e.g. 50% value) and the safety settings
- Lock the settings (hardware write protection, MI EML0610 A-de / MI EML0710 A-de, Chapter 8.2)

The transmitter for level, interface and density of types 144LD and 244LD is subject to the pressure equipment directive (DGRL 97/23/EC). The intervals for recurring tests specified in the safety operating instructions Ex EML0010 A-(de) must therefore be observed (according to German BertrSichV dated 27.09.2002). [Rev.6]

4.3 Repairs

Defective devices should be returned to the service & repair department of Foxboro Eckardt, under indication and description of the possible failure reason.

5 SAFETY RELEVANT CHARACTERISTICS

Information not included in this summary is contained in Chapter 8.

5.1 Assumptions

The specified characteristics are applicable under the following assumptions:

- ❖ The conditions stated in Chapter 1.2 are fulfilled.
- ❖ The repair time (MTTR) after a device has failed is 8 hours.
- ❖ Test interval: ≤ 5 years.
- ❖ Diagnostic time: < 5 min

5.2 Characteristics

Unit type	❖ HFT	❖ SFF	❖ PFD_{avg}	❖ λ_{du}	❖ λ_{dd}	❖ λ_{su}	❖ λ_{sd}
❖ B	❖ 0	❖ 82%	3.3E-03	150 FIT	421 FIT	217 FIT	60 FIT

6 BIBLIOGRAPHY

[Ref. 1] DIN EN 61508 Teil 1-7
Beuth-Verlag, Berlin

[Ref. 2] DIN IEC 61511 Teil 1-3
Beuth-Verlag, Berlin

[Ref. 3] Functional safety and IEC 61508 – A basic guide, November 2002
IEC

[Ref. 4] 144LD / 244LD Intelligent Buoyancy Transmitter for Level, Interface and Density
Master Instruction
Foxboro Eckardt GmbH, MI EML0610 A / MI EML0710 A

[Ref. 5] 144LD / 244LD Intelligent Buoyancy Transmitter for Level, Interface and Density
Product Specification Sheet
Foxboro Eckardt GmbH, PSS EML0610 A-(en), PSS EML0710 A-(en)

[Ref. 6] Safety Operating Instructions for 140 Series Devices
Foxboro Eckardt GmbH, EX EML0010 A

[Ref. 7] Failure Modes, Effects and Diagnostic Analysis for Intelligent Buoyancy Transmitter 144LD / 244LD
exida, Report No. Foxboro 04/08-16 R002 V0R4.

7 DECLARATION OF CONFORMITY

SIL Konformitätserklärung
SIL Declaration of Conformity

FOXBORO ECKARDT

Foxboro Eckardt GmbH Pragstrasse 82 D-70376 Stuttgart

Stuttgart, 20.1.2005

Funktionale Sicherheit nach IEC 61508 / IEC61511
Functional Safety according to IEC 61508 / IEC61511

Wir erklären, dass die Geräte
We declare, that the devices

144LD , 244LD

für den Einsatz in einer sicherheitsgerichteten Anwendung entsprechend der IEC 61511-1 geeignet sind, wenn die Sicherheitshinweise und die nachfolgenden Parameter beachtet werden:
are suitable for use in safety related application according IEC 61511-1, if the savety instructions and the following parameters are observed:

Produkt / Product	144LD / 244LD
SIL	2
Prüfintervall / Proof test interval	≤ 5 Jahre / Years
Gerätetyp / Device Type	B
HFT	0 [1] (einkanalige Verwendung / single channel using)
SFF	82%
PFD_{avg}	$3,3 \times 10^{-3}$
PFH [2]	$< 0,15 \times 10^{-6}$
λ_{du}	150 FIT
λ_{dd}	421 FIT
λ_{su}	217 FIT
λ_{sd}	60 FIT
MTTF [3]	135 Jahre / Years
DC_S	22%
DC_D	74%

1) gemäss Kapitel / according to chapter 11.4.4. of IEC 61511-1
2) Diagnosezeit / Error response time < 5min
3) für / for MTTR = 8h

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8 MANAGEMENT SUMMARY

Failure Modes, Effects and Diagnostics Analysis

Project:

Intelligent Buoyancy Transmitter 144LD / 244LD

Customer:

Foxboro Eckardt GmbH
Stuttgart
Germany

Contract No.: Foxboro 04/08-16
Report No.: Foxboro Eckardt 04/08-16 R002
Version V0, Revision R4, December 2004
Audun Opem, Rainer Faller

Management summary

This report summarizes the results of the hardware assessment according to IEC 61508 carried out on the Intelligent Buoyancy Transmitter 144LD / 244LD. For safety applications only the current output 4..20 mA was considered.

The hardware assessment consists of a Failure Modes, Effects and Diagnostics Analysis (FMEDA). A FMEDA is one of the steps taken to achieve functional safety assessment of a device per IEC 61508. From the FMEDA, failure rates are determined and consequently the Safe Failure Fraction (SFF) is calculated for the device. For full assessment purposes all requirements of IEC 61508 must be considered.

Failure rates used in this analysis are basic failure rates from the Siemens standard SN 29500. For mechanical components experience-based *exida* data and field failure evaluations from Foxboro Eckardt GmbH were used.

Foxboro Eckardt GmbH and *exida* did a qualitative analysis (see [R2]) of the (electro-)mechanical components of the Intelligent Buoyancy Transmitter 144LD / 244LD. This analysis was used to calculate the failure rates of the (electro-)mechanical components of the Intelligent Buoyancy Transmitter 144LD / 244LD using experience-based *exida* data and field failure evaluations from Foxboro Eckardt GmbH.

It is assumed that the connected logic solver is configured as per the NAMUR NE43 signal ranges, i.e., the transmitter communicates detected faults by an output current ≤ 3,6mA or ≥ 21mA. For this configuration the following tables show how the above stated requirements are fulfilled.

Under the assumptions described in section 4 the following table shows the failure rates according to IEC 61508:

Table 1 Summary for the Intelligent Buoyancy Transmitter 144LD / 244LD – IEC 61508 Failure rates

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF	DC_S[1]	DC_D
60 FIT	217 FIT	421 FIT	150 FIT	82%	22%	74%

These failure rates do not include failures resulting from incorrect use of the intelligent transmitter, in particular humidity entering through incompletely closed housings or inadequate cable feeding through the PG inlets.

A user of the Intelligent Buoyancy Transmitter 144LD / 244LD can utilize these failure rates in a probabilistic model of a safety instrumented function (SIF) to determine suitability in part for safety instrumented system (SIS) usage in a particular safety integrity level (SIL). A full table of failure rates is presented in section 5.2 along with all assumptions.

The failure rates are valid for the useful life of the instrument. According to section 7.4.7.4 note 3 of IEC 61508-2, experience has shown that the useful lifetime often lies within a range of 8 to 12 years.

[1] DC means the diagnostic coverage (safe or dangerous).

The PFD_{AVG} was calculated for three different proof test intervals.

Table 2 Summary for the Intelligent Buoyancy Transmitter 144LD / 244LD - PFD_{AVG} values

T[Proof] = 1 year	T[Proof] = 5 years	T[Proof] = 10 years
PFD_{AVG} = 6,6E-04	PFD_{AVG} = 3,3E-03	PFD_{AVG} = 6,6E-03

The boxes marked in yellow ( ) mean that the calculated PFD_{AVG} values are within the allowed range for SIL 2 according to table 2 of IEC 61508-1 but do not fulfill the requirement to not claim more than 35% of this range, i.e. to be better than or equal to 3,5E-03. The boxes marked in green ( ) mean that the calculated PFD_{AVG} values are within the allowed range for SIL 2 according to table 2 of IEC 61508-1 and table 3.1 of ANSI/ISA–84.01–1996 and do fulfill the requirement to not claim more than 35% of this range, i.e. to be better than or equal to 3,5E-03.

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