Instruction

MI 023-157 (en)

SIL LRx4-x5 R02
06/2022

LR54, LR64, LR65, LR74 and LR75
Free Space Radar
24 GHz and 80GHz Radar (FMCW) Level Transmitters

Supplementary Instructions

Safety manual

Schneider Electric

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1 INTRODUCTION

1.1 Scope of the document

This document supplies functional safety data for the devices that follow:

- LRx4 Free Space Radar: LR54, LR64 and LR74
  - 24 GHz FMCW radar level transmitters
- LRx5 Free Space Radar: LR65 and LR75
  - 80 GHz FMCW radar level transmitters

This data agrees with the IEC 61508 standard (document [N2]) if the device operates in SIL mode.

	***NOTICE!*** *The data in this supplement only contains the data applicable to the SIL approval. The technical data for the standard version in the master instruction (document [N1]) shall be valid, provided that it is not rendered invalid or replaced by this supplement. If necessary, parts of document [N1] are referenced herein.*

	***NOTICE!*** *Installation, commissioning and maintenance can only be done by qualified personnel. The system integrator is responsible for correct operation and parameterization of the device. The system integrator is responsible for the definition and application of measures against manipulation (e.g. lightning protection system, position of valves etc.).*

1.2 Revision history

Release date	Electronic revision	Changes and compatibility	Documentation
2021-10-01	ER ≥2.1.1	First issue	MI 023-157 - SIL LRx4-x5 R01
2022-06-28	ER ≥2.1.1	The maximum fault response time changed from 50 s to 90 s. It is necessary to do a proof test immediately after temporary failures.	MI 023-157 - SIL LRx4-x5 R02

Table 1-1: Revision history

Do a check at regular intervals to make sure that the firmware (electronic revision) and the safety manual for the device is up to date. You can download the latest edition of the safety manual from the website (Download Center). If the electronic revision is different, speak to your supplier about the procedure to change the electronic revision of the device.

1.3 Type code for devices that can operate in SIL mode

The model name for the level transmitter and its options are identified by the LRxx type code on the device nameplate. The type code is a series of alphanumeric characters (0...9 and A...Z).

Do a check of the device nameplate to make sure that device has the correct options for functional safety.

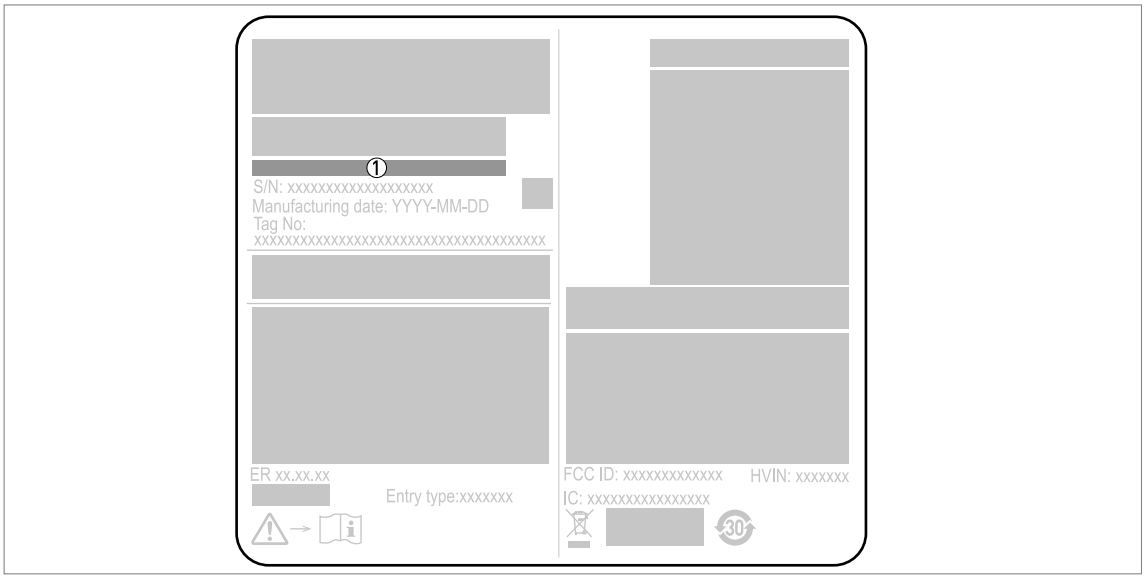


Figure 1-1: Location of the type code on the device nameplate

① Type code

Refer to the table that follows to find which positions in the type code are related to functional safety. The position is shown with the letter "x".

Type code	LRxx	cdef	g	h	i	j	k	l	m	n	opqrstuvw
Options related to functional safety	x		x		x	x		x		x	

Table 1-2: Type code - Options related to functional safety

The table that follows shows which alphanumeric codes in each position are related to function safety. If a dash ("—") is shown, all options in this type code position are applicable to functional safety.

Code	Description	Applicable options for SIL devices
LRxx	Device prefix and model	LR54; LR64; LR65; LR74; LR75
cdef	Standard, Version, Regional Directives, Ex Approvals	—
g	**Industry / Safety**	1, 3, 5, 7, D, E, F, M, N, P

Code	Description	Applicable options for SIL devices
h	Construction	—
i	Converter version	2, 3
j	**Output**	1
k	Cable entry / cable gland	—
l	**Display**	4
m	Display - documentation language	—
n	Enhanced functions	0
opqrstuvw	All other device descriptors	—

Table 1-3: Applicable options for SIL devices

1.4 Device description

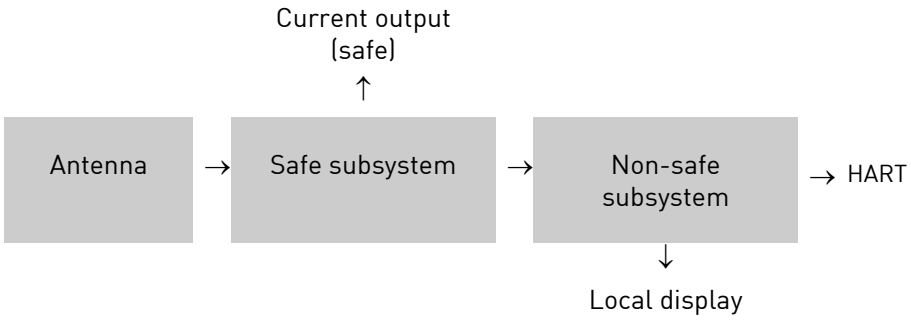
A device that operates in SIL mode is a functionally safe level transmitter. It can be used in safety-critical systems where the safety function is necessary (for more data, refer to *Definition of the safety function* on page 9).

Measurement data is supplied as a current output signal. This output can be used as a safe output. When the device detects an internal device error or a measurement error, it supplies a failure current.

The conditions that follow are applicable for measurement in SIL mode:

- The current output can supply a failure current. The current output is the only safe output.
- The local display screen and the HART® interface are not related to the safety function.
- The local display screen and the HART® interface are read-only in SIL mode.
- You can only change parameters in non-SIL mode.

For more data about the failure current, refer to *Error conditions* on page 19.



1.5 Related documentation

[N1] The applicable master instruction for the LR54, LR64 LR65, LR74 or LR75. .

[N2] IEC 61508-1 to 7:2010 Functional safety of electrical / electronic / programmable electronic safety-related systems

[N3] NAMUR Recommendation NE 043 Standardization of the Signal Level for the Failure Information of Digital Transmitters

1.6 Terms and definitions

DC	Diagnostic Coverage of dangerous failures
EUC	Equipment Under Control
Firmware	Software embedded in the device.
FIT	Failure In Time (1×10^{-9} failures per hour)
FMEDA	Failure Modes, Effects and Diagnostics Analysis
FRT	Fault Response Time (diagnostic test interval + Fault Reaction Time). This is the maximum time that is necessary for the current output to change to the error value when the safety function has an error condition.
HFT	Hardware Fault Tolerance
High demand or continuous mode	Where the frequency of demands for operation made on a safety-related system is greater than one time per year
I/O	Input / output
λ_{DD}	Rate for dangerous detected failure
λ_{DU}	Rate for dangerous undetected failure
λ_{SD}	Rate for safe detected failure
λ_{SU}	Rate for safe undetected failure
Low demand mode	Where the frequency of demands for operation made on a safety-related system is no greater than one time per year
MTBF	Mean Time Between Failures
MTTF	Mean Time To Failure
MTTR	Mean Time To Recovery
MTR	Mean Time To Restoration
PFD_{AVG}	Average Probability of Failure on Demand
PFH	Probability of a dangerous Failure per Hour
PLC	Programmable logic controller
PTC	Proof Test Coverage
Process safety time	Time starting when something fails and ending when the 'undesired event' can no longer be prevented
SAC	Safety Application Conditions. Conditions that must be obeyed when you use a safety-related system or a safety-related sub-system.
SFF	Safe Failure Fraction
SIL	Safety Integrity Level

SIS	Safety Instrumented System
Systematic Capability	Measure (given as a scale of SC 1 to SC 3) of the confidence that the systematic safety integrity of an element agrees with the conditions of the specified SIL (related to the safety function of an element), when the element is applied in accordance with the instructions.
Type A system	"Non-complex" system (all failure modes are well defined). For more data, refer to subsection 7.4.4.1.2 of IEC 61508-2.
Type B system	"Complex" system (all failure modes are not well defined). For more data, refer to subsection 7.4.4.1.3 of IEC 61508-2.
T[Proof]	Proof Test Interval
T[Repair]	Time to Repair
T[Test]	Internal Diagnostics Test Interval
1oo1	1 out of 1 channel architecture (single architecture performs the safety function)
1oo1D	1 out of 1 channel architecture with diagnostics
1oo2	1 out of 2 channel architecture (architecture with homogeneous or heterogeneous redundancy performs the safety function) ①

Table 1-4: Terms and definitions

① A system with homogeneous redundancy has two devices that operate with the same parameters. A system with heterogeneous redundancy has two devices that operate with different parameters.

2.1 Preconditions

The device must be operated in the process and ambient conditions given in the master instruction (document [N1]) of the device.

Other conditions must be obeyed for safety applications. For more data refer to *Safety application conditions (SAC)* on page 12.

2.2 Definition of the safety function

2.2.1 General notes

The device contains a safety function that agrees with International Standard IEC 61508 (document [N2]). It can be used in safety-critical systems where the safety function is necessary.

The device can be used in standard configuration with a safety integrity level of "2" and in a homogeneously redundant configuration at safety integrity level of "3". For more data about homogeneous redundancy, refer to *Homogeneous redundancy* on page 23.

For safe operation, the operator / SIS engineer must obey Safety Application Conditions (SAC). For more data about Safety Application Conditions, refer to *Safety application conditions (SAC)* on page 12.

When the device detects a failure, it sends a failure current signal at one of two values: ≤ 3.6 mA or ≥ 21 mA. For more data, refer to *Error conditions* on page 19. Although the device can be set to send a high failure current signal (≥ 21 mA), some hardware failures that have an effect on the current output (for example, an open circuit or a power supply failure) will always cause the device to send a low failure current signal (≤ 3.6 mA). Also, if the device is set to send a low failure current signal, then a short circuit failure can cause the device to send a high failure current signal. Thus, a logic controller must be able to identify the two failure current signals (high and low) at all times.

It is possible that the device will identify radar signal interference (parasitic signals) as a temporary failure. For example, obstacles in the tank can cause unwanted reflections.

Do a check (proof test) for the correct operation of the device after a temporary failure. For the proof test procedure, refer to *Operation modes and proof tests* on page 26.

2.2.2 Current output

The device sends a current output signal that agrees with the correct measured value. This output has these properties:

- A current that is related to the correct measured value in an interval that is equal to or less than the Fault Response Time.
- The maximum permitted measurement error is ±4% of the nominal current output range
- The primary measured value is 'distance'. The secondary (calculated) values include "level", "volume", "mass" or "linearized measurement". You can set these secondary (calculated) values as parameters for device operation in SIL mode. These values can then be sent as safety-related output signals.
- The "volume", "mass", "flow" and the "linearized measurement" values use a strapping table. This strapping table does a linear interpolation between points for the measured distance and the secondary (calculated) value (e.g. volume).

CAUTION!
If the device measures volume, mass or flow, or uses a linearized scale, then do a check to make sure that the values used in the strapping table are accurate. For an example of the procedure you must use, refer to How to check measurement accuracy before operation in SIL mode on page 25.

The value for **Current Output, Full Scale** (0...100% range) must be in the maximum measuring range. If the measurement is the same as or less than the minimum limit of the normal range, then the device will continue to show the minimum value (output "saturated" at 4 mA (standard output range) or 3.8 mA (extended output range)). If the measurement is the same as or more than the maximum limit of the normal range, then the device will continue to show the maximum value (output "saturated" at 3.8 mA (standard output range) or 20.5 mA (extended output range)). In these two conditions, the current output value is identified as a "non-safe" measurement. The safe range of the current output is between:

- 0.2 mA more than the minimum (saturated) current output for the measuring range, and
- 0.5 mA less than the maximum (saturated) current output for the measuring range.

CAUTION!
Make sure that the measured value is not less than the minimum limit or more than the maximum limit of the measuring range. Do not let the current output become "saturated".

If the device has an internal failure, then this failure causes the device to send a permanent failure current signal. To restart measurement after a permanent failure, you must reset the device. For more data, refer to *How to reset the fail-safe flags* on page 29.

Process conditions that have an effect on the devices status can cause temporary failures. The device will try to restart operation.

2.2.3 Fault response time

If the device detects a failure, then it changes the current output to the low or high failure current value in an interval equal to or less than the fault response time. The maximum fault response time is 90 seconds.

	***CAUTION!*** *Do regular checks for high and low failure currents. If the device cannot automatically restart operation after a temporary failure, then you must reset the device. For more data, refer to How to reset the fail-safe flags on page 29.*

	***CAUTION!*** *Make sure that the device operates correctly in the safety loop after a manual restart and that the failure condition does not continue to be applicable.*

	***CAUTION!*** *Make sure that you use other safety precautions to prevent safety-critical failures that can have an effect on all of the system. For more data, refer to Operation modes and proof tests on page 26.*

2.3 Safety application conditions (SAC)

	***WARNING!*** *The device must have the applicable options and settings for the application. The ambient and process conditions must agree with the technical data given in the master instruction (document [N1]) and this document (safety manual). Obey the installation instructions given in the master instruction (document [N1]).*

	***CAUTION!*** *We recommend that the 4 mA and 20 mA limits of the measuring range are not in the top or bottom dead zones and the non-linearity zones.*

The handbook (document [N1]) gives instructions to correctly install the device and connect it to an electrical circuit. These instructions are mandatory if you use the device in a safety-related system.

2.3.1 General

- Unless they are specified in this safety manual, changes to the device configuration are not permitted. Make sure that the device is in the approved configuration after you do maintenance on the device. Also make sure that all Safety Application Conditions are obeyed. For more data, refer to *Parameter types* on page 20.

2.3.2 Installation

- The maximum permitted measuring distance is 18 m / 59 ft.
- Do the Quick Setup procedures in Program Mode (A Quick Setup menu) before the device starts to operate in SIL mode. Make sure that the device configuration is correct (parameters and values).
- If there is build-up on the antenna, make sure that you clean it at regular intervals.
- If it is necessary to set up a system with homogeneous redundancy, then it is permitted to install more than one device on the same tank or silo. For more data, refer to *Homogeneous redundancy* on page 23.
- It is not permitted to install more than one independent operating radar on one tank. If there is more than one, they have to be set up in a redundant configuration, where their output signals are voted against each other.
- Only qualified personnel are permitted to remove or attach mechanical parts. Do a check of the device configuration and electronic parts before you operate the device in SIL mode.
- Attach the weather protection accessory if you install the device more than 2000 m / 6560 ft above sea level.

2.3.3 Electrical connection

- Only connect the device to PELV circuits that agree with International Standard IEC 61140.
- Wait for 120 seconds after you de-energize the device before you connect the electrical cables again.

2.3.4 Functionally safe configuration

- If you use the device in a continuous mode or high demand mode of operation, the process safety time must be more than 90 seconds. This minimum time agrees with International Standard IEC 61508 Part 2 (document [N2]), section 7.4.4.1.4).
- If you use the device in a high demand mode of operation, the maximum frequency of demands is 1 demand every 83 minutes. This frequency agrees with International Standard IEC 61508 Part 2 (document [N2]), section 7.4.4.1.4.
- Make sure that the device measures correctly before you operate the device in SIL mode. For more data about the procedure, refer to *How to check measurement accuracy before operation in SIL mode* on page 25.
- The SIS engineer must make sure that changes to the device configuration do not have an effect on the performance of the safety-related system. Use safety precautions for system protection, if it necessary.

2.4 Operation modes

2.4.1 SIL mode

The device operates with a safety function. If the safety function detects a failure, it will send a failure current signal that gives a warning that the safety function cannot continue to operate correctly. The device continues to be functionally safe and the safety-related data (e.g. hazard rate, FRT etc.) continues to be applicable.

Devices in SIL mode have these operational conditions:

- **Program Mode** is not available. Thus, you cannot use the device display screen or a HART® controller to change the device configuration.
- **HART® multidrop** mode is not available.
- The device cannot simulate measurement values at the output terminals.

2.4.2 Non-SIL mode

The device operates as a standard device. Device operation and error detection agrees with all the values set in Program Mode by the user. SIL mode constraints are not applicable.

2.4.3 Maintenance mode

You can use "Maintenance" mode to start a device and do tests in normal conditions in the system.

Enter the "Expert" password to enter "Maintenance" mode. During the tests, you are responsible for device operation and the possible effects it can have on the system. Make sure that you change the device configuration back to SIL mode when you complete the tests.

	***WARNING!*** *Make sure that you change from "Maintenance" mode to "SIL" mode after you complete the tests. If you do not change from "Maintenance" mode to "SIL" mode, then the device will not operate correctly in a safety-related system. Make sure that the safety-related system has protection from the effects of device operation in "Maintenance" mode.*

3.1 Operation in SIL mode

3.1.1 General notes

The device must have the SIL option to operate in SIL mode and use the safety function. If you sent an order for a device with a SIL option, then SIL mode activation is unlocked and the safety function is available. A SIL symbol is shown on the top right side of the display screen when the device operates in SIL mode.

⚠	***WARNING!*** *Only qualified personnel can change the device configuration. Record changes to the device configuration. This report must include the date, the menu item, the old value and the new value.*

The configuration is protected with a password. For more data on password protection and device configuration, refer to the "Operation" chapter in the master instruction (document [N1]).

For more data about the procedure, refer to *Device configuration for operation in SIL mode* on page 15.

3.1.2 Device configuration for operation in SIL mode

Equipment needed

- Device with the integrated display option
- Ammeter (not supplied)
- Display extractor

Part 1: Set the parameters

- The device is on a measurement screen in Normal mode. Push [▲] again and again to go to the SIL setup screen.
- Push [>] to enter Program mode. Push [>] again to enter the Quick Setup menu.
- Push [▼] two times to go to A3 Login and enter the 4-digit password for the "Expert" access level (default password: 0058) and push [↵].
- Go to **A4 Application Assistant** or **C Full Setup menus** to change values.

➲ It is not permitted to change menu items that have parameters that are important for the safety function. The device shows a padlock symbol next to important parameters that are automatically set and locked for SIL mode.

- Push [↵] again and again to go back to the top menu.
- Save the new device configuration. Select "Yes".

➲ The display screen shows the text: Switch to SIL mode?

- Select "Yes" to change from **non-SIL** mode to **SIL** mode.
- Enter the 4-digit password for the "Expert" access level (default password: 0058) and push [↵] to accept the change to SIL mode.

➲ The device starts again after 60 seconds. The display screen shows the text "Press key for verification".

Part 2: Current output check

- Connect an ammeter to the circuit.
- Push a button on the keypad.

➲ The device will do a check of the current output.

- Look at the current values on the ammeter display screen. The current output automatically changes in this sequence at intervals of 1 second: 3.5 mA, 4 mA, 6 mA, 8 mA, 10 mA, 12 mA, 14 mA, 16 mA, 18 mA, 20 mA and 21.5 mA.

➲ The display screen shows the text "Set SIL jumper or press key to cancel" during this test. This sequence repeats continuously until you lock the device configuration in SIL Mode (refer to Part 3) or you push a button on the keypad to cancel this procedure.

Part 3: Lock the device configuration in SIL mode

- Find the two clips that hold the display module in the housing.
- Use the display extractor to remove the display module from the housing. Put the display extractor in the slots on the module for these clips.
- Carefully remove the display module from housing and then remove the display extractor from the display module.
- Remove the jumper from the non-SIL mode position.
- Put the jumper in the SIL mode position.

➲ Make sure that the jumper is correctly connected to the pins on the circuit board. Refer to the illustration that follows.

- Put the display module back on the electronics block.

➲ If the clips make a click sound, then the display module is correctly attached to the electronics block. The device display screen shows the text "LEVEL SENSOR starting up..." and then measurements in normal mode.

- Make sure that the SIL symbol is shown in the top right corner of the display screen.

➲ The device configuration is "locked" and parameters cannot be changed in SIL mode.

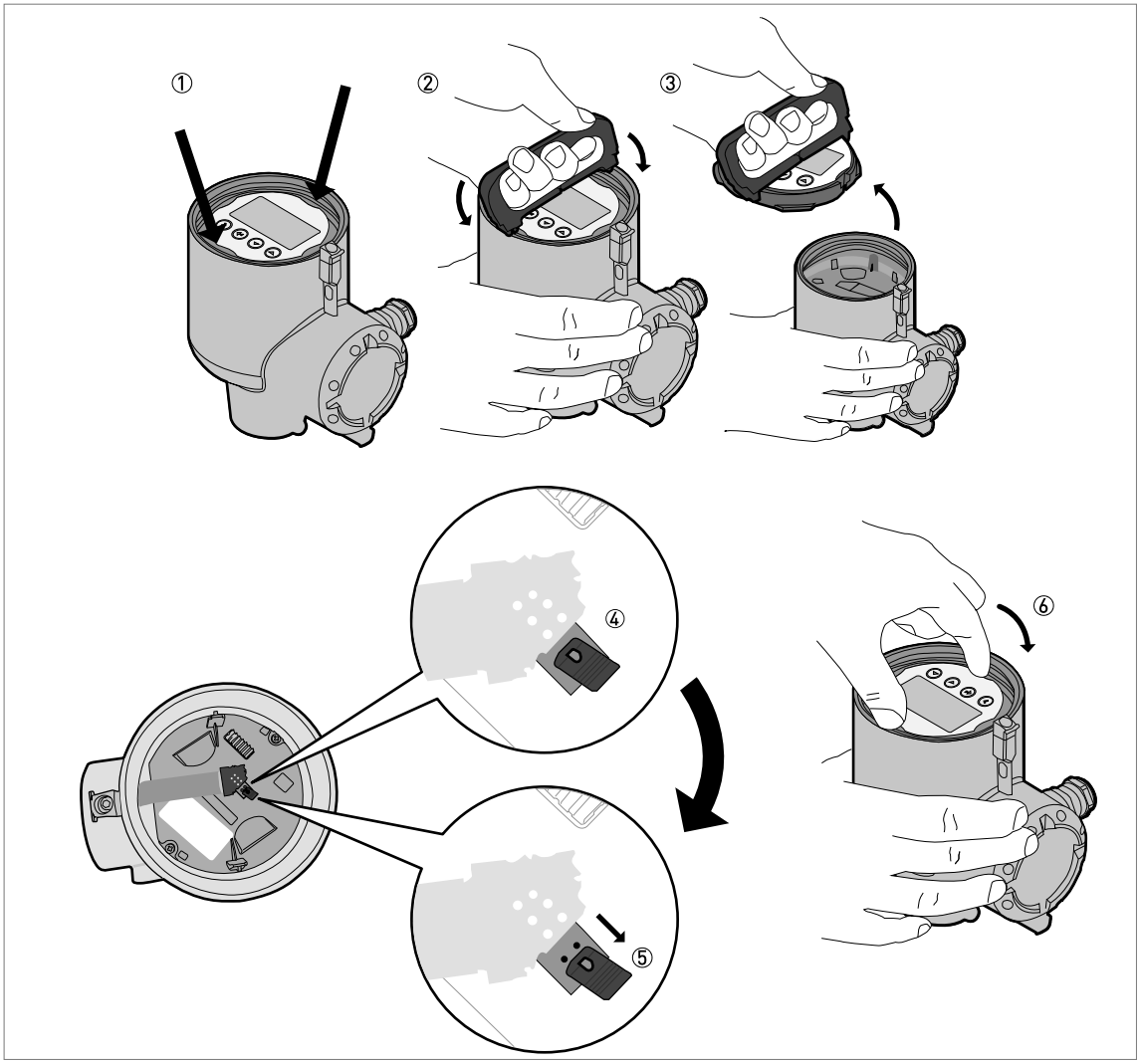


Figure 3-1: How to lock the device configuration in SIL mode

You will see the screens that follow after you connect the display module to the electronics block:

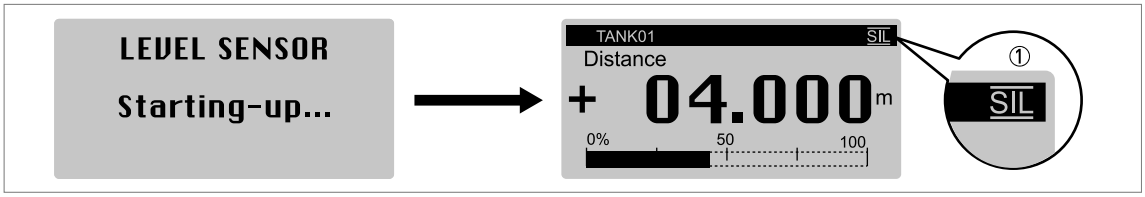


Figure 3-2: Device operation in SIL mode

① SIL mode symbol (this symbol is only shown in SIL mode)

3.2 How to change the configuration of a device operated in SIL mode

3.2.1 General notes

It is not permitted to change the configuration of a device in SIL mode. If it is necessary for the device to use a new parameter in SIL mode, you must put the device in non-SIL mode to change the configuration.

3.2.2 How to change device operation from SIL mode to non-SIL mode

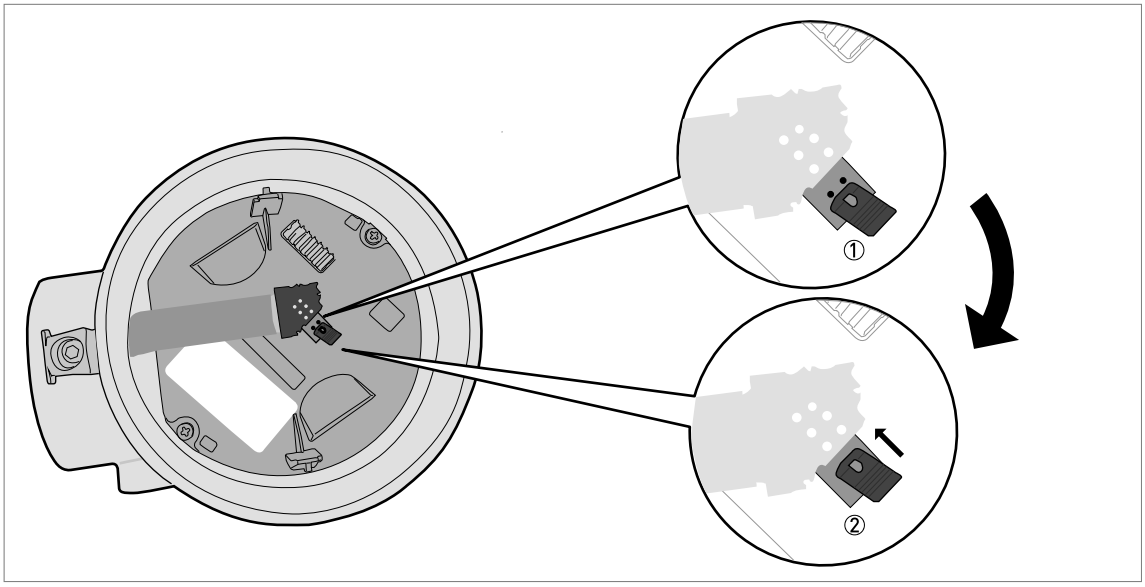


Figure 3-3: How to change from SIL mode to non-SIL mode

① "SIL mode" position
② "non-SIL mode" position

Equipment needed

- Display extractor

- Find the two clips that hold the display module in the housing.
- Use the display extractor to remove the display module from the housing. Put the display extractor in the slots on the module for these clips.
- Carefully remove the display module from housing and then remove the display extractor from the display module.
- Remove the jumper from the **SIL** mode position.
- Put the jumper in the **non-SIL** mode position.

➲ Make sure that the jumper is correctly connected to the pins on the circuit board.

- Put the display module back on the electronics block.

➲ If the clips make a click sound, then the display module is correctly attached to the electronics block. The device display screen shows the text "LEVEL SENSOR starting up..." and then the text "Press key for verification".

- Push a button on the keypad.

➲ The device will do a check of the current output.

- Look at the current values on the ammeter display screen. The current output automatically changes in this sequence at intervals of 1 second: 3.5 mA, 4 mA, 6 mA, 8 mA, 10 mA, 12 mA, 14 mA, 16 mA, 18 mA, 20 mA and 21.5 mA.

➲ This sequence repeats continuously until you push a button to stop the sequence. The display screen shows the text "Set SIL jumper or press key to cancel" during this test.

- Push a button on the keypad and enter the password (0058) and push [↵].

➲ First, the device display screen shows the text "Wait for reboot" and then measurements in normal mode. The device is in non-SIL mode. The SIL mode symbol is not shown on the top right corner of the display screen.

NOTICE!
For more data about the procedure to remove the display module, refer to "Turning the display" section in the handbook (document [N1]).

3.3 Error conditions

The device can detect error conditions. When the device detects an error, it supplies a failure current value to show that this a temporary (transient) or permanent (persistent) failure.

Error conditions are the same for non-SIL mode and SIL mode, but special conditions are applicable to SIL mode. These special conditions are:

- The device will supply a failure current if there is a safety-critical failure.
- The failure current is the only signal that is related to the safety function. Ignore data from other outputs and display options (e.g. HART® handheld controller etc.).
- Make sure that you monitor the low failure current value (≤ 3.6 mA) and the high failure current value (≥ 21 mA).
- The tables that follows shows the types of error that is related to safety (SIL). Errors in this group will only occur if you operate the device in SIL mode.

CAUTION!
Although the device can be set to send a high failure current signal (≥ 21 mA), some hardware failures will always cause the device to send a low failure current signal (≤ 3.6 mA).

For more data about error conditions, refer to the tables that follows:

Error conditions related to the device hardware

Status type	Error message	Description	Corrective actions
F	Electronics		
	All error messages	This type of error causes the device to automatically stop operation.	Restart the device. For more data about the procedure to restart the device, refer to *How to reset the fail-safe flags* on page 29.

Table 3-1: Error conditions that can cause a permanent failure current

3.4 Parameter types

3.4.1 Safety-critical parameters

You cannot change safety-critical parameters. The menu items for these parameters are automatically set, locked and show a padlock symbol adjacent to the related parameters in the device menu.

CAUTION!
Safety-critical parameters for SIL mode do not always have the same values as the values set in non-SIL mode. A safety-critical parameter has a SIL-specific value in SIL mode. Make sure that your device is in the correct configuration with the correct values in a given mode.

Menu No.	Menu item	Safety-critical values	Description
C1.6	Time Constant	3.000 s	This is the approved time to change measurement values on the device display screen and current output. This value cannot be changed.
C2.4	Measuring Mode	Direct	"TBF Auto", "TBF Full" and "Direct Plus" measurement modes are not permitted.
C2.5	Overfill Detection	Disabled	"Enabled" is not permitted.
C2.11	Error Delay	10 Sec	This is the approved time before the device records an error. This value cannot be changed for operation in SIL mode.
C4.1.9.2	4mA Trimming	0	Do not adjust the current output of the device.
C4.1.9.5	20mA Trimming	0	Do not adjust the current output of the device.
C5.1.1	Current Loop Mode	On	Operation in HART® multidrop mode ("Off") is not permitted.
D3.3.1	Manual Correction Offset	0.0 m	Service menu parameters. The Service menu is only available to personnel approved by the manufacturer. These values cannot be changed for operation in SIL mode.
D3.3.2	Manual Correction Factor	1.0	

Table 3-2: Safety-critical parameters

3.4.2 Safety-relevant parameters

You can change safety-relevant parameters, but the range of values can be different from those that are used in non-SIL mode. These values can have an effect on the current output.

Refer to the table that follows. This table only shows parameters that have lists or ranges of values that are different from those that used in non-SIL mode. Other safety-relevant parameters, where the lists or ranges of values are the same as those available in non-SIL mode, are not shown.

You can change the parameters given in the table that follows and then use this new configuration in SIL mode. The device does a check of the new configuration to make sure that it is compatible with SIL mode. For more data, refer to *Operation in SIL mode* on page 15.

CAUTION!
The device configuration must agree with the Safety Application Conditions. For more data, refer to Safety application conditions (SAC) on page 12.

Menu No.	Menu item	Safety-relevant values	Description
C1.2	Tank Height	min-max: 0.0...18.0 m / 0.0...59.0 ft	Tank height cannot be more than 18 m / 59 ft.
C2.3	Epsilon R Product	min-max: 1.5...20.0	-
C4.1.1	Current Output 1 Variable	Level, Distance, Sensor Value, Linearized Level, Linearized Distance, Volume, Volume flow, Mass, Ullage Volume, Ullage Mass	"Reflection" is not available in SIL mode.
C4.1.5	Error Function	Low, High	"Off" and "Hold" are not available in SIL mode.

Table 3-3: Safety-relevant parameters

3.4.3 Non-SIL parameters

Non-SIL parameters do not have an effect on the safety function and can be changed with same procedures used for devices that are not for safety-related systems. For more data about these parameters, refer to the Operation chapter in the master instruction (document [N1]).

CAUTION!
The device configuration must agree with the Safety Application Conditions. For more data, refer to Safety application conditions (SAC) on page 12.

3.4.4 Limits for parameters related to tank configuration

§	***LEGAL NOTICE!*** *The manufacturer declines all responsibility for the incorrect operation of the safety function.*

⚠	***WARNING!*** *If the device was delivered without a process connection and antenna (LR74 only), then do a check to make sure that the safety function operates correctly. For more data, refer to How to check measurement accuracy before operation in SIL mode on page 25.*

⚠	***CAUTION!*** *If you change the values of one or more safety-critical or safety-relevant parameters, this can have an unwanted effect on the safety function. Do a check of the safety function after you change a parameter.*

Make sure that the device measures correctly. For more data, refer to *How to check measurement accuracy before operation in SIL mode* on page 25.

3.5 Homogeneous redundancy

3.5.1 Description of a homogeneously redundant system

If two devices with the same parameters are used to measure a level (or a distance), then they can be used as a SIL 3 safety function. The two devices take the same measurements.

The safety function data from each device are sent to one or more logic solvers. If the logic solver uses the current output of each device as the safety function to make sure that the system is homogeneously redundant, then the logic solver compares the continuous measurement data from the current output of each device.

The logic solver compares the data from the two devices to select a device status for each device. If the difference between the data from each device is more than a user-specified percentage of the current output, then the logic solver uses the safety function to send a failure current signal.

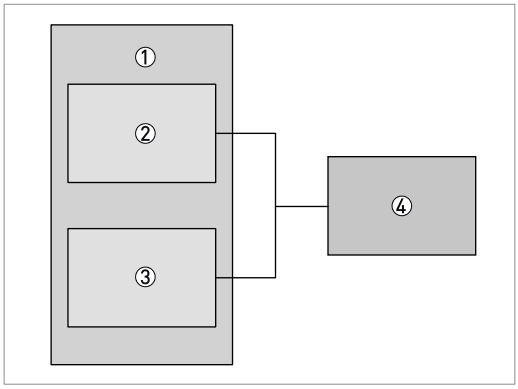


Figure 3-4: Homogeneous redundancy

① Sensor subsystem
② Measurement device A
③ Measurement device A' (second device with the same configuration as device A)
④ Logic subsystem

3.5.2 How to estimate the effect of common cause failures

An estimate of the effect of common cause failures (random hardware failures and systematic failures) must agree with the methods given in Annex D of International Standard IEC 61508-6 (reference document [N2]).

The installation method and maintenance strategy, and how you use the device will have an effect on how you calculate the estimate. In normal conditions, the common cause failure can be calculated to a β-factor of 2%.

To make an estimate, the analysis includes these conditions:

- Different persons do the commissioning procedure and the proof tests,
- the device has a failure detection system,
- maintenance procedures are available in a document,
- approved maintenance personnel must identify and repair common cause failures, and
- only approved personnel can get access to the devices

4.1 Maintenance

Obey the maintenance instructions given in the master instruction (document [N1]).

4.2 Availability of services

The manufacturer offers a range of services to support the customer. These services include repair, maintenance, technical support and training.

	***NOTICE!*** *For more data, speak or write to your local sales office.*

4.3 How to check measurement accuracy before operation in SIL mode

4.3.1 General notes

If the antenna is not in the same customer order as the signal converter, it is necessary to check the measurement accuracy of the device.

Equipment needed

- A device with the integrated display option.
- An ammeter.
- Reference device: an approved level measurement device

Requirements

- The ammeter must be correctly calibrated and connected directly to device.
- You must have 2 reference points (levels) in the tank given by a different measurement solution. These points are identified as "ref_pt1" and "ref_pt2".

	***CAUTION!*** *Do not connect the ammeter across the safety system PLC because this configuration can open the circuit breaker.* *Make sure that the 2 reference points are not in the top or bottom dead zones.*

4.3.2 Measurement accuracy check (in process conditions)

The complete device (the signal converter, the process connection and the antenna) is installed on the tank in process conditions. We recommend that you use this procedure to do a measurement accuracy check.

Procedure

- Change the level of the tank contents until you have level reference point 1 (**ref_pt1**). Use the test device to make sure that you have level reference point 1. We recommend that the location of this point is 33% of the measuring range (from the bottom of the tank).

- Measure the level at reference point 1 with the reference device (refer to "Equipment needed"). Record the value (**meas_pt1**).
- Change the level of the tank contents until you have level reference point 2 (**ref_pt2**). Use the test device to make sure that you have level reference point 2.
- Measure the level at reference point 2 with the reference device (refer to "Equipment needed" on page 25). Record the value (**meas_pt2**).
- End of the procedure.

The tolerance is ±2 mm / 0.08¨ in reference conditions. If the difference between **ref_pt1** and **meas_pt1** and between **ref_pt2** and **meas_pt2** agrees with the safety loop tolerance, then the results of the test are satisfactory. If the 2 values do not agree with the tolerance, then the results of the test are unsatisfactory. To change the device settings to get satisfactory results, speak to the supplier.

For more data about reference conditions, refer to the "technical data" chapter in the master instruction.

4.4 Operation modes and proof tests

Continuous and high demand mode

If the device operates in a continuous or high-demand mode in the specified environmental limits, it is not necessary to do a proof test during the lifetime of the device (for more data, refer to *Characteristics for the device safety function* on page 30).

Low demand mode

The device has a full set of online diagnostic tests which are done quickly and frequently. The device is not in operation (downtime) is very short. In normal conditions only a short time is necessary to repair the device. If you immediately install the device again after repairs, then the device performance agrees with the SIL2-compatible PFD values.

Proof tests

Do proof tests in maintenance mode. For more data about this mode, refer to *Maintenance mode* on page 14. Proof tests are necessary in these conditions:

- Operation in conditions that are less than the minimum design limits or more than the maximum design limits. The failure rate can increase in these environmental conditions. Increase the frequency of proof tests to decrease the probability of undetected failures. For more data, refer to *Characteristics for the device safety function* on page 30. The values must not be more than the operational limits (as given in safety application conditions).
- If the PFD_{AVG} value is near the specified limits.

Make sure that the safety functions are applicable to the full measuring range. We recommend that you do a proof test:

- immediately after you install and start the device,
- immediately after you change the parameters of the device in configuration mode, and

- immediately after temporary failures.

	***WARNING!*** *SIS engineers must use the PFD_{AVG} target value to calculate the interval of time between proof tests. This interval must that agree with the specified PFD_{AVG}.*

Prepare the device for the proof tests. Do a check of the device parameters.

	***CAUTION!*** • *Proof tests done by the customer must be equivalent or more difficult than the tests given in this section.* • *Keep a report of each proof test. These reports must include the date, the tests results (performance of the safety function or faults found), a list of approved personnel who did the test and the report revision number. These reports must be put into storage and made easily available.* • *The location of the device and how it is installed on the tank can have an effect on the performance. Obey the installation instructions given in the master instruction.*

Equipment needed:

- Device with the integrated display option
- Ammeter
- Reference device: an approved level measurement device

PART 1: How to make sure that the device parameters are correct

Do a check of the tank height

- Measure the height of the tank or the silo (or the depth of the pit).
- Make sure that the value shown agrees with the tank height.
- If necessary, go to menu item **C1.2 Tank Height**, change the value and record the new value in the proof test report.

Do a check of the Current Output 1 Variable

- Make sure that the output function is set to the correct parameter.
- If necessary, go to menu item **C.4.1.1 Current Out. 1 Var.**, change the parameter and record the new parameter in the proof test report.

Do a check of the 4 mA and the 20 mA values for current output 1

- Find the data for the 4 mA and the 20 mA values in the SIS specification.
- If the Scale 4mA value does not agree with the SIS specification, make sure that this data is correct. If necessary, go to menu item **C.4.1.2 0% Range**, change the value and record the new value in the proof test report.
- If the Scale 20mA value does not agree with the SIS specification, make sure that this data is correct. If necessary, go to menu item **C.4.1.3 100% Range**, change the value and record the new value in the proof test report.

Do a check of the output range for current output 1

- Make sure that the current output range is set to "4-20", "4-20; reversed", "3.8-20.5 / NAMUR" or "3.8-20.5 / reversed".
- If necessary, go to menu item **C.4.1.4 Current Out. Range**, change the parameter and record the new parameter in the proof test report.

Make sure that the polling address is correct

- Do a check of the value in menu item **C5.1.2.1 Polling Address**.

➲ If the Polling Address value is not set to "000", then the safety function will not operate correctly.

- If necessary, push [>] to change the value to "000". Push [↵] to confirm.

PART 2: How to check the measurements (example procedure given)

- Find the data for the 4 mA and the 20 mA settings in the SIS specification.
- Push [↵] to start.
- Fill the tank to the maximum level (without overfill). Measure the level of the product in the tank with an approved level measurement device (reference device).
- If the menu item menu item **Current Out. 1 Var.** (C4.1.1) is set to "LEVEL", make sure the output current value is 20 mA. If the menu item **Current Out. 1 Var.** (C4.1.1) is set to "DISTANCE", make sure the output current value is 4 mA.
- Remove the product from the tank until it is 50% full. Measure the level of the product in the tank with an approved level measurement device (reference device).
- Make sure the output current value is 12 mA.
- Remove the product from the tank to the minimum level. Measure the level of the product in the tank with an approved level measurement device (reference device).
- If the menu item **Current Out. 1 Var.** (C4.1.1) is set to "LEVEL", make sure the output current value is 4 mA. If the menu item **Current Out. 1 Var.** (C4.1.1) is set to "DISTANCE", make sure the output current value is 20 mA.

➲ If the current output values are correct, then the current output agrees with the measured level of the product.

You can adapt this procedure to special conditions. For example, if you use the safety function to prevent an overfill, it is not necessary to remove the product from the tank to the minimum level. It is only necessary to measure the level and current output of the product in the tank when it is full (without overfill) and 50% full.

Proof test coverage

Measurement signal	Device	Version	Proof Test Coverage (PTC)
Current output 1	LRx4 Free Space Radar	non-Ex / Ex i	76%
		Ex d	77%
	LRx5 Free Space Radar	non-Ex / Ex i	81%
		Ex d	82%

Table 4-1: Proof test coverage

4.5 How to reset the fail-safe flags

If a permanent failure is detected, then you must restart the device manually. The device display screen displays the text that follows:

SIL locked!
Press key to start test

Push a button to go to the procedure to restart the device.

Text shown on the display screen	Step	Keypad buttons
SIL locked! Press key to start test	• Start the **Maintenance** mode. Make sure that the device does not stay in **Maintenance** mode after you have completed the test.	Push a button.
Password?	• Enter the 4-digit password for the "Expert" access level.	**** , then [↵] ①
	• Test the device. • Enter the menu item and exit it after you complete the tests.	1 × [>], 1 × [↵]
Clear fail safe flag?	• Select "YES" if you found a solution for the safety-critical failure. Are you sure that the device will operate correctly in SIL mode? • Select "NO" if the device does not operate correctly and it is necessary to speak to the supplier.	YES / NO, then [↵]
Password?	• Enter the 4-digit password for the "Expert" access level.	**** , then [↵] ①
Wait for Reboot	• Wait for the device to restart.	-

Table 4-2: How to reset the fail-safe flags

① The default password is "0058"

CAUTION!
The device is in SIL mode, but the header bar of the display screen will not show the SIL mode symbol until the device restarts without a safety-critical failure. Make sure that you use other safety precautions to prevent safety-critical failures that can have an effect on all of the system.

If you cannot restart the device without a safety-critical failure, then speak to your supplier.

4.6 Troubleshooting

NOTICE!
- *The user must not make modifications to devices that operate in SIL mode.*
- *Only approved personnel from the manufacturer are permitted to repair the device.*

If the device has a critical failure that is related to functional safety, send a report to the technical support department of the manufacturer. If you find a problem, please tell your local representative. If you must return the device to the manufacturer, refer to "Returning the device to the manufacturer" in the master instruction (document [N1]).

5.1 Characteristics for the device safety function

Version	LRx4		LRx5	
	non-Ex / Ex i	Ex d	non-Ex / Ex i	Ex d
Electronic revision	2.1.1			
Device type	Type B system			
Systematic capability	3			
Safety integrity level				
Single channel (HFT = 0)	SIL2			
Homogeneously redundant (HFT = 1)	SIL3			
Architecture	1oo1D			
HFT	0			
PFH (in FIT)	60.51	60.51	75.17	75.17
SFF	94.21%	94.50%	93.85%	94.11%
λ_{SD} (in FIT)	-	-	-	-
λ_{SU} (in FIT)	460.93	515.65	460.73	515.45
λ_{DD} (in FIT)	523.84	523.84	686.69	686.69
λ_{DU} (in FIT)	60.51	60.51	75.17	75.17
PFD_{AVG} (T[Proof] = 1 year)	2.7×10^{-4}	2.7×10^{-4}	3.3×10^{-4}	3.3×10^{-4}
PFD_{AVG} (T[Proof] = 3 years)	8.0×10^{-4}	8.0×10^{-4}	9.9×10^{-4}	9.9×10^{-4}
PFD_{AVG} (T[Proof] = 5 years)	1.3×10^{-3}	1.3×10^{-3}	1.6×10^{-3}	1.6×10^{-3}
PFD_{AVG} (T[Proof] = 10 years)	2.6×10^{-3}	2.6×10^{-3}	3.2×10^{-3}	3.2×10^{-3}
Diagnostic test interval	90 s			
Fault reaction time	< 1 s			
MTBF ①	109	103	93	89

Table 5-1: Characteristics for the device safety functions

① This calculation includes data for hardware that is necessary for safe operation

5.2 Useful lifetime of electronic components

The established failure rates of electronic components apply within the useful lifetime according to IEC 61508-2, section 7.4.9.5 note 3. The useful lifetime can only be extended under responsibility of the plant operator regarding special operation conditions and the employment of suitable intervals for testing and maintenance.

5.3 Assumptions

FMEDA is applicable for the conditions that follow:

- Use of the device agrees with its design and performance characteristics. This includes ambient and process conditions.
- Installation of the device must agree with the instructions and the requirements of the application.
- We can ignore wear of mechanical parts. Failure rates are constant.
- Failures that follow one after the other are put in the same group as the failure that is the source of the problem.
- The HART® protocol is only used for set-up, calibration and diagnostic purposes. It is not used during safety operation mode.
- All components that are not part of the safety function and cannot influence the safety function (feedback immune) are not included.
- Only the analog output (4...20 mA or 3.8...20.5 mA) is used for safety applications.
- The Mean Time to Recovery after safe failure is 72 hours (MTTR = 72 h).
- External power failure rates are not included.

NOTICE!
The FMEDA of the device was calculated with the exida tool FMEDA v7.1.17, with the configuration that follows:

- *Database SN 29500*
- *Ambient temperature is 40°C*
- *T[Proof] is from 1 to 10 years (87600 hours)*
- *T[Repair] is 72 hours*
- *T[Test] is 90 seconds (all internal test functions are done a minimum of one time during this period)*

5.4 Measuring accuracy

The device measures with the same accuracy in both operation modes of operation (non-SIL mode and SIL mode), if the device is undamaged.

For these values to be correctly monitored by the device diagnostics, there must be a sufficient interval of time between normal measurements and failure signals. Safety engineers must include measurement errors that are possibly higher in their calculations for the complete system.

The graph that follows shows the worst-case conditions for the accuracy limits. These accuracy limits are defined from a combination of the digitally processed measurement signal and the analog current output.

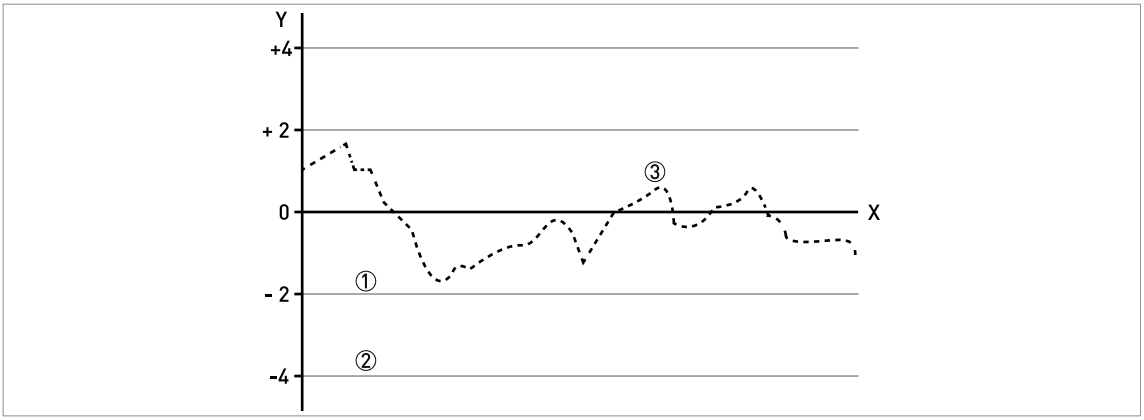


Figure 5-1: Measuring accuracy in relation to level

X: level / [mm] or [inches]
Y: measuring accuracy / [%]
① Limits for a non-SIL device (undamaged device, tested)
② SIL limits (monitored limits)
③ Typical level measurements in process conditions with parasitic signals etc.

The calculation also includes the possible effects of:

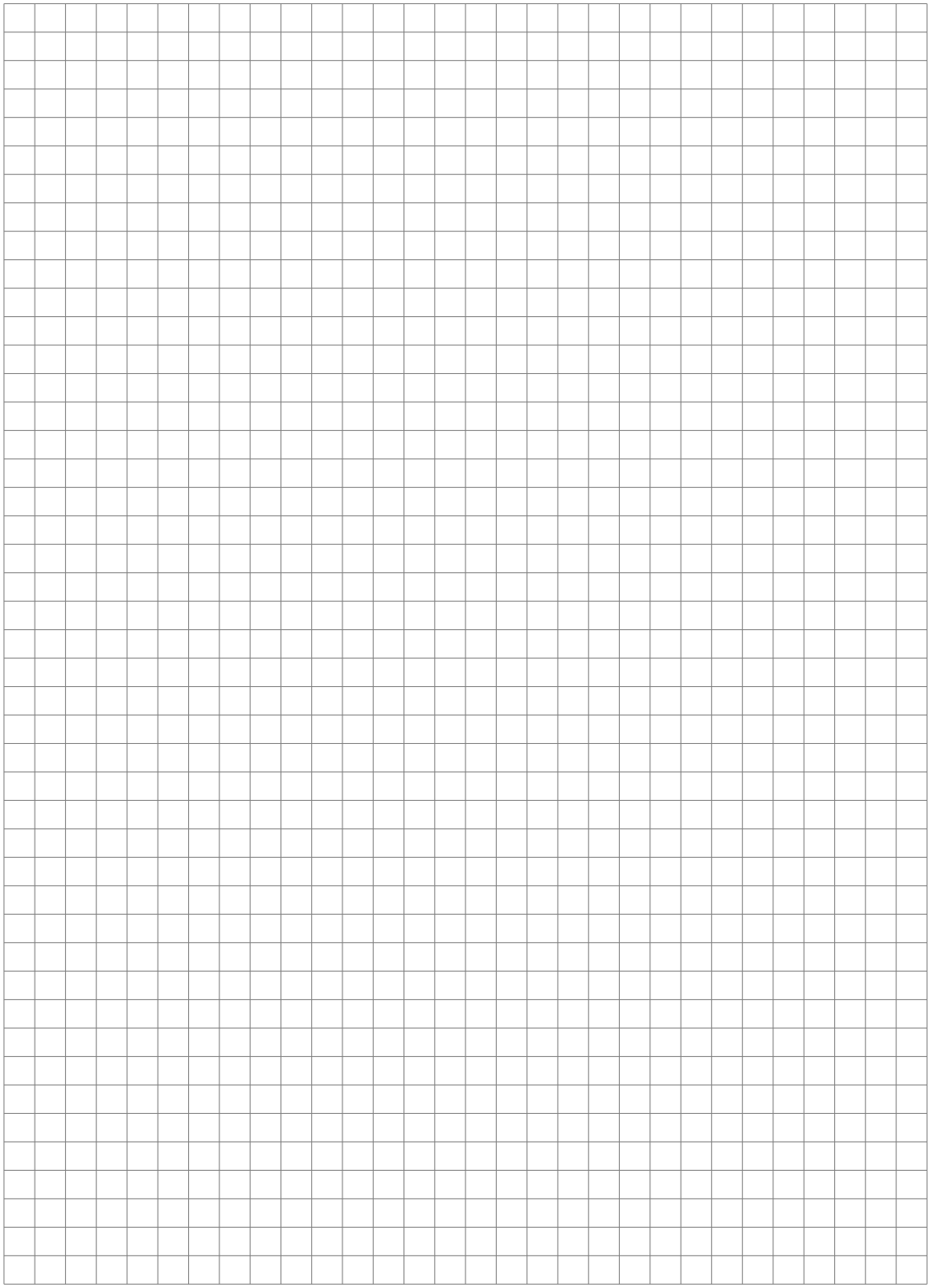
- reference conditions (temperature, pressure, type of radar target etc.) that agree with EN 61298-1,
- safety-related failures, and
- the limits of the diagnostic functions of the device.

CAUTION!
Measurement of solids: Because the surface of a solid is usually not flat, it is possible that the measuring accuracy will be worse than the accuracy data given for reference conditions. For the best performance, we recommend that you use the default values for the configuration of the device. For more data about default values, refer to the "Function description" section in the master instructions for the LR64 and LR65 level transmitters (document [N1]).

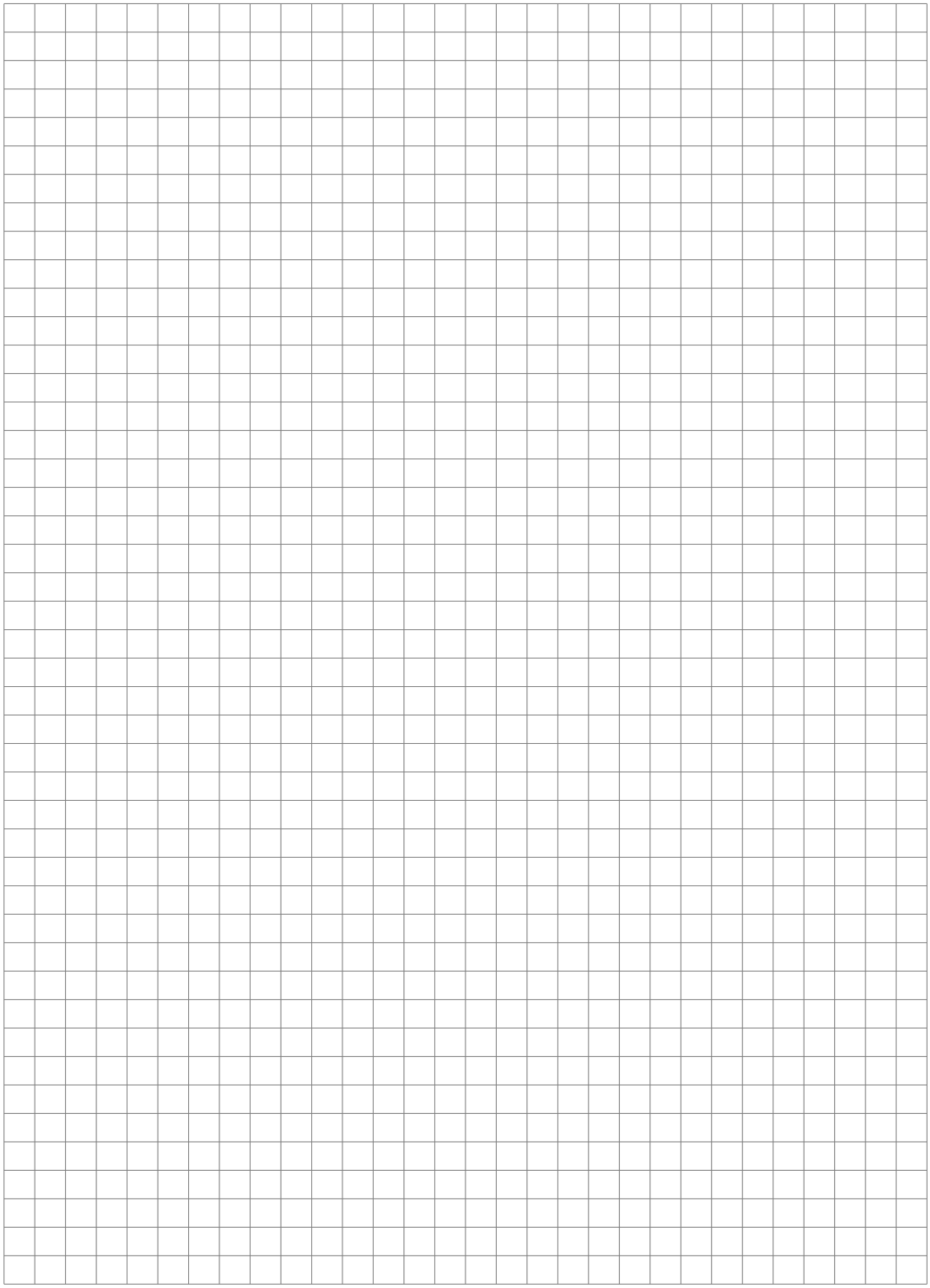
NOTICE!
If there is a voltage surge in the electrical circuit, it is possible that the current output of an Ex d-approved device will temporarily deviate by some milliamperes for less than 1 second. Thus, this condition can have a temporary effect on the measuring accuracy of the device.

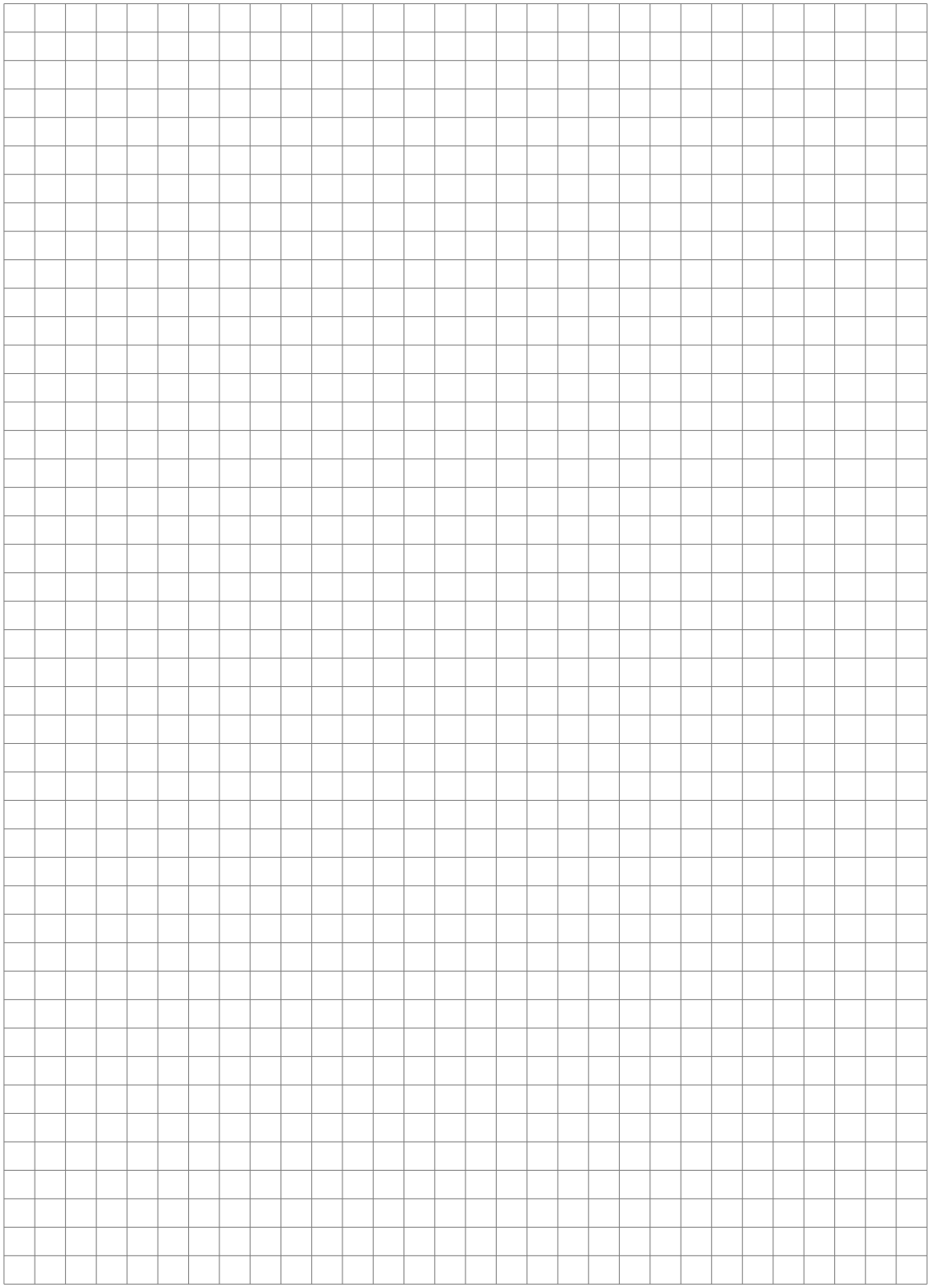
5.5 Support for SIL-approved devices

If the manufacturer makes a modification that has an effect on the safety function of the device, the manufacturer will tell you about the modification immediately.



6 NOTES





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