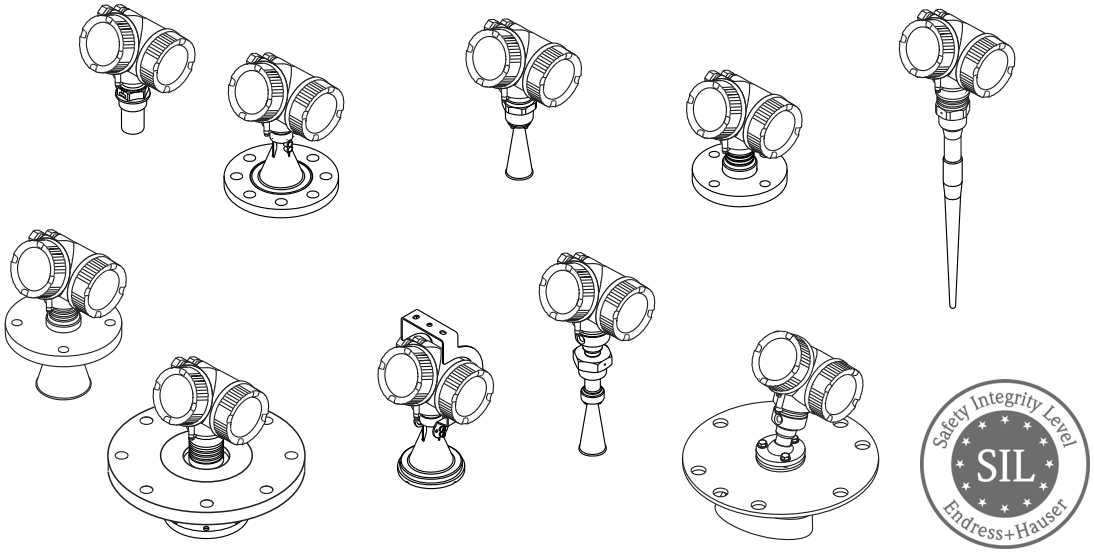
Level | Pressure | Flow | Temperature | Liquid Analysis | Registration | Systems Components | Services | Solutions

Functional Safety Manual

Micropilot FMR50/51/52/53/54/56/57

Level-Radar for Liquids and Bulk Solids with 4 to 20 mA Output Signal



Application

Operating minimum (e.g. dry run protection), maximum (e.g. overfill protection) and range monitoring of liquids and bulk solids of all types in systems to satisfy particular safety systems requirements as per IEC 61508 Edition 2.0.

The measuring device fulfils the requirements concerning

- Functional safety as per IEC 61508 Edition 2.0
- Explosion protection (depending on the version)
- Electromagnetic compatibility as per EN 61326 and NAMUR recommendation NE 21
- Electrical safety as per IEC/EN 61010-1

Your benefits

- Used for level monitoring (MIN, MAX, range) up to SIL 2 (single-channel architecture) or SIL 3 (multi-channel architecture, also with homogeneous redundancy)
  - Independently assessed and certified by TÜV Rheinland as per IEC 61508 Edition 2.0
- Permanent self-monitoring
- Continuous measurement
- Non-contact measurement is virtually independent of product properties
- Easy commissioning
- Proof-test possible without demounting of the device and without variation of the level

SD01087F/00/EN/01.12
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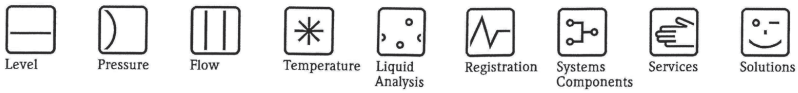
SIL Declaration of Conformity



SIL-12132a/00/A2

SIL-Konformitätserklärung

Funktionale Sicherheit nach IEC 61508

SIL Declaration of Conformity

Functional safety according to IEC 61508

Endress+Hauser GmbH+Co. KG, Hauptstraße 1, 79689 Maulburg
erklärt als Hersteller, dass das Gerät
declares as manufacturer, that the device

Micropilot FMR50/51/52/53/54/56/57

für den Einsatz in Schutzeinrichtungen entsprechend der IEC 61508 Edition 2.0 geeignet ist, wenn das Handbuch zur Funktionalen Sicherheit und die Kenngrößen in der folgenden Tabelle beachtet werden:
is suitable for the use in safety-instrumented systems according to IEC 61508 Edition 2.0, if the functional safety manual and the characteristics specified in the following table are observed:

Gerät/Device	Micropilot FMR50/51/52/53/54/56/57
Handbuch zur Funktionalen Sicherheit/ Functional safety manual	SD001087F/00
Sicherheitsfunktion/Safety function	MIN, MAX, Bereich/Range
SIL	2, 3 *3
HFT	0
Gerätetyp/Device type	B
Betriebsart/Mode of operation	Low demand mode, High demand mode
SFF	92 %
PFD_{avg} *1 T_1 = 1 Jahr/year (einkanalig/single channel)	1.09×10^{-3}
PFD_{avg} *1 T_1 = 2 Jahre/years (einkanalig/single channel)	2.17×10^{-3}
PFH	2.45×10^{-7} 1/h
λ_{sd} *2	15 FIT
λ_{su} *2	520 FIT
λ_{dd} *2	2438 FIT
λ_{du} *2	245 FIT
λ_{tot} *2	3218 FIT
MTBF *4	50 Jahre/years

*1 Die Werte entsprechen SIL 2 nach ISA S84.01. PFD_{avg}-Werte für andere T_1-Werte siehe Handbuch zur Funktionalen Sicherheit./ The values comply with SIL 2 according to ISA S84.01. PFD_{avg} values for other T_1-values see Functional Safety Manual.
*2 Gemäß Siemens SN29500./ According to Siemens SN29500.
*3 SIL 3 bei (homogen) redundantem Einsatz. Die Gerätesoftware erfüllt die Anforderungen an SIL 3./ SIL 3 for (homogeneous) redundant application. The device software meets SIL 3 requirements.
*4 Gemäß Siemens SN29500, unter Berücksichtigung funktionsrelevanter Fehler in der Elektronik./ According to Siemens SN29500, with consideration of failures of the electronics with functional relevance.

Das Gerät wurde in einem vollständigen Functional Safety Assessment unabhängig bewertet.
The device was assessed independently in a complete Functional Safety Assessment.

Maulburg, 14.12.2012

i.V. (Dr. Arno Götz)
Leitung Zertifizierung / Manager Certification

i.V. Udo Grittke
(Udo Grittke)
Leitung Projekt / Project Manager

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SIL-11001b

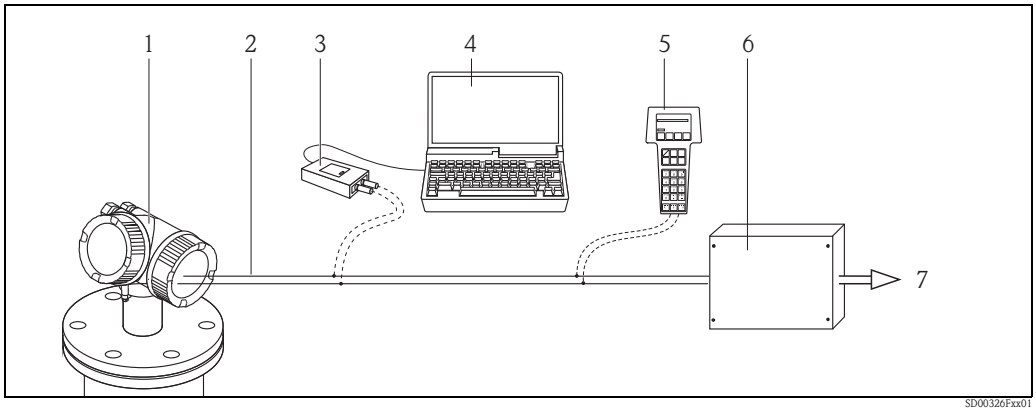
Introduction

Note!
General information on functional safety (SIL) is available at:
www.de.endress.com/SIL (German) or www.endress.com/SIL (English) and in Competence Brochure CP002Z "Functional Safety in the Process Industry – Risk Reduction with Safety Instrumented Systems".

Structure of the measuring system

System components

The measuring system's devices are displayed in the following diagram (example).



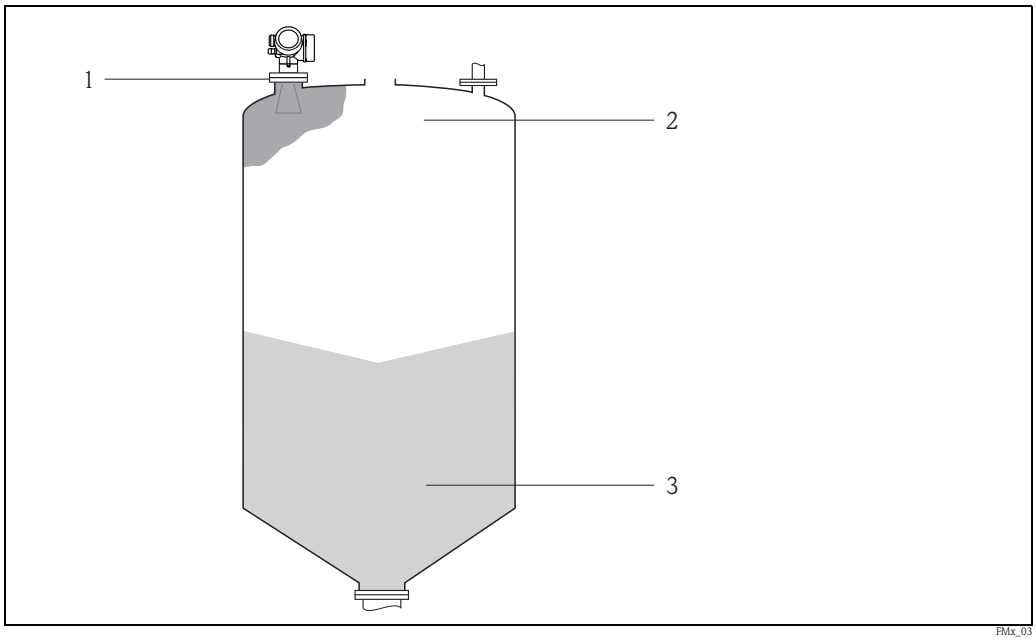
1 Micropilot (optional with display module SD02/SD03)
2 4...20 mA line
3 Commubox FXA191/195
4 Computer with operating tool, e.g. FieldCare
5 Field Communicator 375/475
6 Logic Unit, e.g. PLC, limit signal generator, ...
7 Actuator

An analog signal (4 to 20 mA) in proportion to the level is generated in the transmitter. This is sent to a downstream logic unit (e.g. PLC, limit signal transmitter, etc.) where it is monitored to determine whether it is below or above a specified limit value.
For fault monitoring, the logic unit must recognize both HI-alarms (≥ 21.0 mA) and LO-alarms (≤ 3.6 mA).

Description of use as a protective system

The Micropilot is a "downward-looking" measuring system that functions according to the ToF method (ToF = Time of Flight). The distance from the reference point (process connection of the measuring device) to the product surface is measured. High-frequency pulses are emitted by an antenna.
The pulses are reflected by the product surface, received by the electronic evaluation unit and converted into level information. This method is also known as level radar.

Typical measuring arrangement:



1 Flange: reference point of measurement
2 20 mA, 100 %
3 4 mA, 0 %

The Micropilot can be used in this arrangement in safety instrumented systems for MIN safety, MAX safety and range monitoring.

Note!
Correct installation is a prerequisite for safe operation of the device.

Permitted device types

The details pertaining to functional safety in this manual relate to the device versions listed below and are valid as of the specified software and hardware version.
Unless otherwise specified, all subsequent versions can also be used for safety instrumented systems.
A modification process according to IEC 61508 is applied for device changes.

Valid device versions for safety-related use:

Feature	Designation	Version
010	Approval	all
020	Power Supply; Output	A, B*[1], C*[2], K
030	Display; Operation	all
040	Housing	all
050	Electrical Connection	all
070	Antenna	all
090	Seal (only FMR51/54/57)	all
100	Process Connection	all
110	Air Purge Connection (only FMR57)	all
500	Additional Operation Language	all
540	Application Package	all
550	Calibration	all
570	Service	all
580	Test; Certificate (only FMR51/52/53/54/57)	all
590	Additional Approval	LA An additional selection of any further versions is possible.
610	Accessory Mounted	all
620	Accessory Enclosed	all
850	Firmware Version	If no version is selected here, the latest SIL-enabled SW is supplied. Alternatively, the following SW version may be selected: 78 (01.00.zz, HART, DevRev01)

*1 For this version with current output and switch output, only the current output (terminals 1 and 2) is approved for safety functions. The switch output can, if necessary, be wired for non-safety-oriented purposes.

*2 For this version with 2 current outputs, only the first output (terminals 1 and 2) is approved for safety functions. The second output can, if necessary, be wired for non-safety-oriented purposes.

Valid firmware version: as of 01.00.zz (→ nameplate of the device)
Valid hardware version (electronics): as of date of production 17.12.2012 (→ nameplate of the device)

Note!
SIL certified devices are marked with the following symbol on the nameplate: (SIL)

Supplementary device documentation

Documentation	Contents	Comment
Technical Information TI01039F/00 (FMR50) TI01040F/00 (FMR51/52) TI01041F/00 (FMR53/54) TI01042F/00 (FMR56/57)	– Technical data – Instructions on accessories	– The documentation is supplied with the device in pdf format on a CD. – The documentation is also available on the Internet. → www.endress.com.
Operating Instructions (HART) BA01045F/00 (FMR50) BA01049F/00 (FMR51/52) BA01050F/00 (FMR53/54) BA01048F/00 (FMR56/57)	– Basic safety instructions – Product description – Incoming acceptance and product identification – Storage, Transport – Mounting – Electrical connection – Operating options – Device integration via the HARTprotocol – Commissioning – Trouble shooting – Repairs – Maintenance – Accessories – Return – Disposal – Overview of the operating menu – Description of device parameters	– The documentation is supplied with the device in pdf format on a CD. – The documentation is also available on the Internet. → www.endress.com.
Brief Operating Instructions (HART) KA01099F/00 (FMR50) KA01100F/00 (FMR51/52) KA01101F/00 (FMR53/54) KA01102F/00 (FMR56/57)	– Basic safety instructions – Product description – Incoming acceptance and product identification – Storage, Transport – Mounting – Electrical connection – Commissioning	– The documentation is supplied with the device in pdf format on a CD. – The documentation is also available on the Internet. → www.endress.com.
Description of Device Parameters GP01014F/00	– Operating options – Overview of the operating menu – The "Expert" menu	– The documentation is supplied with the device in pdf format on a CD. – The documentation is also available on the Internet. → www.endress.com.
Safety instructions depending on the selected version "Approval"	– Safety, installation and operating instructions for devices, which are suitable for use in potentially explosive atmospheres or as overfill protection (WHG, German Water Resources Act).	Additional safety instructions (XA, ZE) are supplied with certified device versions. Please refer to the nameplate for the relevant safety instructions.

Description of the safety requirements and restrictions

Safety function

The measuring system's safety functions are:

– Maximum level limit monitoring (overfill protection)
– Minimum level limit monitoring (dry run protection)
– Level range monitoring

The safety functions include level measurement of a liquid or bulk solid.

Safety-related signal:

The Micropilot's safety-related signal is the 4 to 20 mA analog output signal.
All safety measures refer to this signal exclusively.

For devices with current output and switch output (feature 020, version "B" in the product structure), only the current output (terminals 1 and 2) is approved for safety functions. The switch output (terminals 3 and 4) can, if necessary, be wired for non-safety-oriented purposes.

For devices with two current outputs (feature 020, version "C" in the product structure), only the first current output (terminals 1 and 2) is approved for safety functions. The second output (terminals 3 and 4) can, if necessary, be wired for non-safety-oriented purposes.

The Micropilot additionally communicates for information only via HART and contains all HART features with additional device information.

The safety-related output signal is fed to a downstream logic unit, e.g. a programmable logic controller or a limit signal transmitter where it is monitored for the following:

– Exceeding and/or deceeding a specified level limit.
– The occurrence of a fault, e.g. error current (≤ 3.6 mA, ≥ 21.0 mA, interruption or short-circuit of the signal line).

Note!
In case of fault it must be ensured that the equipment under control achieves or maintains a safe state.

Restrictions for use in safety-related applications

The measuring system must be used correctly for the specific application, taking into account the medium properties and ambient conditions. Carefully follow instructions pertaining to critical process situations and installation conditions from the Operating Instructions.

The application-specific limits must be observed.

Information on the safety-related signal, → 🖹 8, "Safety function".
The specifications from the Operating Instructions (→ 🖹 7, "Supplementary device documentation") must not be exceeded.

The following restriction also applies to safety-related use:

– The accuracy of the 4 to 20 mA safety-related output signal is ±2 %.
– Strong, pulse-like electromagnetic interferences at the supply line may result in short-term (< 1 s) deviations ≥ ±2 % of the output signal.
  Therefore, a filter with a time constant ≥ 1 s should be applied in the downstream logic unit.

Functional safety parameters

The table shows the specific functional safety parameters:

Characteristic as per IEC 61508	Value
Safety function	MIN, MAX, Range
SIL	SIL 2 (single-channel architecture 1oo1), SIL 3 (multi-channel architecture, also with homogeneous redundancy, e.g. 1oo2, 2oo3)
HFT	0
Device type	B
Mode of operation	Low demand mode, High demand mode
SFF	92 %
MTTR	8 h
Recommended time interval for proof-testing T_1	2 years
λ_{sd}	15 FIT
λ_{su}	520 FIT
λ_{dd}	2438 FIT
λ_{du}	245 FIT
λ_{tot} *1	3218 FIT
PFD_{avg} for T_1 = 1 year *2	1.09×10^{-3}
PFD_{avg} for T_1 = 2 years *2	2.17×10^{-3}
PFH	2.45×10^{-7} 1/h
MTBF *1	50 years
Diagnostic test interval *3	30 min
Fault reaction time *4	30 s
System reaction time *5	– In "Increased safety mode": – for "Medium type = Liquid": dependent on the "Tank type" parameter: "Workbench test" (not recommended during operation): < 1 s "Bypass/pipe": < 5 s "Storage vessel": < 40 s all others: < 20 s – for "Medium type = Solid": dependent on the parameters "Max. filling speed solid" and "Max. draining speed solid" for filling or draining, respectively: "No filter/test" (not recommended during operation): < 1 s "Very fast > 8 m (26 ft)/h": < 10 s "Fast < 8 m (26 ft)/h": < 70 s "Medium < 4 m (13 ft)/h": < 170 s "Standard < 2 m (6.5 ft)/h": < 340 s "Slow < 1 m (3.3 ft)/h": < 600 s "Very slow < 0.5 m (1.6 ft)/h": < 910 s – In "Expert mode": freely configurable, shortest response time: – for level measurement: 1 s

*1 According to Siemens SN29500. This value takes into account failure types relevant to the function of the electronic components without soft errors.

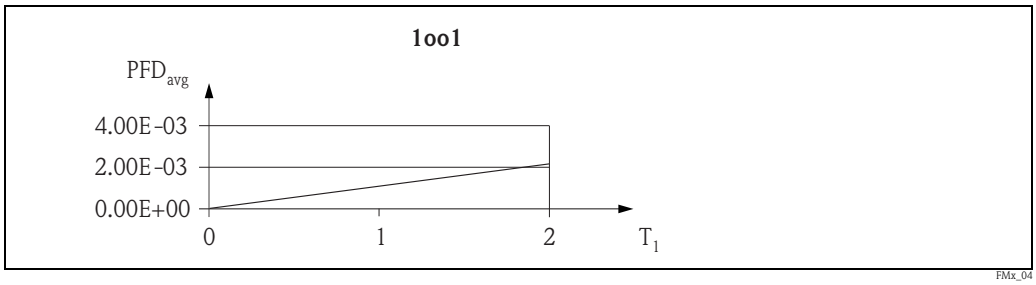
*2 Valid for ambient temperatures up to 40°C. Where the average temperature when in continuous use is in the region of 50°C, a factor of 1.3 should be taken into account.

*3 During this time, all diagnostic functions are executed at least once.

*4 Time between error detection and error response.

*5 Step response time as per DIN EN 61298-2. For steps greater than 175 mm/6.89 in (FMR50/51/52/53/54) or 400 mm/15.7 in (FMR56/57) the step response time may exceed these values.

PFD_{avg} as a function of the proof-testing interval, in the case that the proof-test detects all dangerous undetected failures:



T_1 Proof-test interval

Dangerous undetected failures in this scenario:

An incorrect output signal that deviates from the real value by more than 2 %, but is still in the range of 4 to 20 mA, is considered a dangerous, undetected failure.

Useful lifetime of electrical components:

The established failure rates of electrical components apply within the useful lifetime as per IEC 61508-2, section 7.4.9.5 note 3.

Note!
In accordance with DIN EN 61508-2, Note NA4, appropriate measures taken by the manufacturer and operator can extend the useful lifetime.

Behavior of device during operation and in case of error

Device behavior when switched on

When switched on, the device runs through a diagnostic phase lasting approx. 30 seconds. During this time, the current output is at error current. For approx. 5 seconds during the diagnostic phase, this current is ≤ 3.6 mA.

After that, depending on the setting of the "Start-up mode" parameter, the current is:
– at the MIN value: ≤ 3.6 mA
– at the MAX value: ≥ 21 mA.

During the diagnostic phase, no communication is possible via the service interface (CDI) or via HART.

Behavior of device on demand

The device outputs a current value corresponding to the limit value to be monitored. This value must be monitored and processed further in an attached logic unit.

Device response in the event of alarms or warnings

Fault current

In the event of an alarm, the output current is set to the configured value of ≤ 3.6 mA or ≥ 21 mA.

In some cases (e.g. failure of power supply, a cable open circuit and faults in the current output itself, where the error current ≥ 21 mA cannot be set), output currents ≤ 3.6 mA irrespective of the configured fault current can occur.
In some other cases (e.g. short circuit of cabling), output currents ≥ 21 mA can occur irrespective of the configured fault current.

For alarm monitoring, the logic unit must therefore be able to recognize both HI-alarms (≥ 21 mA) and LO-alarms (≤ 3.6 mA).

Alarm and warning messages

Additional information is provided by the alarm and warning messages in the form of error codes and associated clear text messages.
The following table shows the correlation between the error code and the current output.

Error code*[1]	**Current output (message type)**	**Note**
Fxxx	≥ 21 mA or ≤ 3.6 mA	xxx = three-digit number
Mxxx	corresponding to measuring mode	xxx = three-digit number
Cxxx	corresponding to measuring mode	xxx = three-digit number
Sxxx	corresponding to measuring mode	xxx = three-digit number

Exceptions:

Error code*[1]	**Current output (message type)**	**Note**
M272	≥ 21 mA or ≤ 3.6 mA	Main electronic failure
C484	≥ 21 mA or ≤ 3.6 mA	Simulation failure mode
S942	≥ 21 mA or ≤ 3.6 mA	In safety distance

*[1] The error codes are listed in the Operating Instructions.

Note!
When SIL locking is active on the device, additional diagnostics are activated (e.g. a comparison between the readback-current with the nominal value). If one of these diagnostics results in an error message (e.g. F803 loop current) and the SIL locking is then deactivated, the error message remains while the error persists, even if the diagnostics is no longer active in the unlocked state.
In this case, the device must be disconnected briefly from the power supply (e.g. by unplugging the terminals). When the device is then restarted, a self-check is carried out, and the error message is reset where applicable.

Installation

Mounting and wiring

The mounting and wiring of the device is described in the accompanying Operating Instructions (→ 🖹 7, "Supplementary device documentation").

Mounting orientation

The permitted mounting orientations of the device are described in the Operating Instructions.

Commissioning

Commissioning of the device is described in the accompanying Operating Instructions (→ 🖹 7, "Supplementary device documentation").

Operation

Calibration of the measuring point

Calibration of the measuring point is described in the Operating Instructions.

Check the initial factory setting of the E (zero point) and F (range) parameters in accordance with the desired measuring range and correct if necessary.

Methods of device configuration

When using the devices in process control safety systems, the device configuration must comply with two requirements:

1. Confirmation concept:
   Proven, independent testing of safety-related parameters entered.
2. Locking concept:
   Locking of the device once configuration is complete (as required by IEC 61511-1 §11.6.4 and NE 79 §3).

To activate SIL mode, the Micropilot must run through an operating sequence, during which the device can be operated by means of the device display or any Asset Management Tool (FieldCare, Pactware, AMS, PDM, Field Communicator 375, …), for which integration is available.

Two methods of configuring the device are provided, which differ mainly with regard to the confirmation concept:

1. "Increased safety mode"
   While running through the commissioning sequence here, critical parameters which control functions in the safety path are either set automatically by the device to safe values or transferred to the display/ operating tool via an alternative data format, to enable checking of the setting.
   This mode can be used for standard applications.
   As there are only a few safety-related parameters which can be freely configured, the risk of operating errors is greatly reduced, and the level in the tank does not need to be changed during commissioning in order to check the settings.
2. "Expert mode"
   A larger number of safety-related parameters can be freely configured here. This means that the device difficult applications can be adapted to. However, the settings must be checked by directly approaching the level in the tank.

A detailed description of both modes is provided in the following sections.

Note!
It is only in the case of SIL devices (feature 590 "Additional Approval", version "LA", "SIL declaration of conformity") that the SIL commissioning sequence is visible on the display and in external operating tools. For this reason, SIL locking can only be activated on these devices.

Locking in increased safety mode

To commission the device, carry out and document the following steps in the order shown (template → 📄 24).

1. Reset device.
   To do this, select "Diagnostics > Device reset > To factory defaults" or "Diagnostics > Device reset > To delivery settings". This resets all parameters to defined values.
2. Carry out configuration.
   The configuration procedure and the meaning of the individual parameters are described in the Operating Instructions.
   The following restrictions must be taken into account:

Description	Parameter displayed		
These parameters affect the safety function. However, they may be freely configured in accordance with the application. In increased safety mode, it is necessary to confirm the configured values during the remainder of the commissioning process. Confirmation is not required in expert mode. Recommendation: Note configured values!	Setup	> Level	> Tank type *[1] > Tube diameter *[1], *[2] > Bin type *[3] > Max. filling speed *[3] > Max. draining speed *[3] > Empty calibration > Full calibration
		> Advanced setup	> Level > Advanced process conditions > Tank/silo height
These parameters affect the safety function and are not freely configurable in increased safety mode. Instead, they are automatically set by the device at the start of the SIL/WHG confirmation to the safety-oriented values mentioned. If these parameters are to be set to other values, expert mode must be selected.	Setup	> Advanced setup	> Level > Linearization > Curr.output 1 > Display
			> Level correction = 0 > Linearization type = None > Assign current output = Level > Damping = 0 > Backlight = Disable
	Expert	> Sensor	> Level > Safety sett.
			> Distance offset = 0 > L max. drain speed = 0 > L max. fill speed = 0 > Level limit mode = Off > Output mode = Level > Jump delay echo lost = Off > Delay time echo lost = 3 s
		> Output	> Curr.output 1
			> Turn down = Off > Measuring mode = Standard
		> Communication	> Configuration
			> HART address = 0

Description	Parameter displayed			
These parameters affect the safety function and are automatically set by the device when configuring higher-ranking parameters (known as application parameters). This indirect setting is permitted in increased safety mode. However, it is not permitted to change the parameters directly. If these parameters were changed directly, only expert mode is available for selection in the SIL/WHG confirmation.	Setup	> Advanced setup	> Level	> Max. draining speed > Max. filling speed
	Env. curve	> Envelope curve statistic > Envelope statistics down > Envelope statistics up > Envelope smoothing mode > Asymmetric envelope smoothing near down > Asymmetric envelope smoothing near up > Asymmetric envelope smoothing far down > Asymmetric envelope smoothing far up > Envelope smoothing		
	Expert	> Sensor	> Sensor prop.	> HF module mode
			> Distance	> Dead time > Integration time > Max. integration time > Delta at integration time
			> Safety sett.	> Echo lost window right > Echo lost window left > Draining filter > Filling filter
			> Weighting curves	> Weighting curve selection > FAC window size > FAC offset > FMC window size > FMC offset > IEC offset
			> Mapping	> Map offset > Mapping window size
			> First echo fact.	> First echo mode > First echo factor
			> Echo adjust.fine	> Fine adjustment mode > Parabolic fit window size > Merge echo distance > Merging echo window > Merging ratio
			> Tank bottom eval	> Tank bottom range > Min. amplitude TBD > Lower level area
			> Echo tracking	> Evaluation mode > Window size tracking > Maximal track counter
These parameters affect the safety function and cannot be freely configured neither in increased safety mode nor in expert mode. Instead they are automatically set at the start of the SIL/WHG confirmation to the safety-oriented values mentioned.	Setup	> Advanced setup	> Safety sett.	> Output echo lost = Alarm
	Diagnostics	> Simulation	> Assign measurement variable = Off > Simulation current output 1 = Off > Simulation device alarm = Off > Simulation diagnostic event = 65533	
	Expert	> Sensor	> Distance	> Hysteresis = 0 > Velocity filter = Off

Description	Parameter displayed			
These parameters affect the safety function. If the settings differ from the as-delivered state of the device, only expert mode is available for selection in the SIL/WHG confirmation.	Setup	> Advanced setup	> Level	> Medium type > Blocking distance
			> Curr.output 1	> Current span
	Env. curve	> Asymmetric envelope smoothing near dist.		
	Expert	> Sensor	> Sensor prop.	> Sensor type > Antenna ext.len. > Antenna ext. diameter > Microfactor > Antenna zero distance > Cable zero distance > Inactive length
			> Distance	> Blocking dist. evaluation mode
			> Gas phase comp.	> GPC mode > Gas phase compensation factor > Reference distance > Reference echo window > Reference echo threshold > Const. GPC factor
			> Weighting curves	> Max Value EWC
			> Mapping	> Map gap
			> First echo fact.	> First echo factor > Fix factor EWC > First echo factor threshold
			> Echo adjust.fine	> Edge correction
These parameters affect the safety function. If the settings differ from the permitted values mentioned, the SIL/WHG confirmation is canceled automatically, and the device cannot be locked neither in increased safety mode nor in expert mode.	Setup	> Advanced setup	> Curr.output 1	> Failure mode = "Min" or "Max"
	Expert	> Output	> Curr.output 1	> Start-up mode = "Min" or "Max"

*1 Only for liquid measurement
*2 Only for stilling well or bypass
*3 Only for bulk solid measurement

Those parameters which are not mentioned do not affect the safety function and can be configured to any meaningful values. The visibility of the parameters mentioned in the operating menu depends in part on the user role, the SW options ordered and on the configuration of other parameters.

Note!
In SIL mode, the device must not be operated in HART multidrop mode, as otherwise the current output will have a fixed value. For this reason, only the setting "Expert > Communication > HART address = 0" is permitted in SIL mode and in the combined SIL/WHG mode when in increased safety mode. In pure WHG mode, HART multidrop is permitted in expert mode as long as the HART signal is evaluated in an external switching unit (e.g. Tank Side Monitor NRF590) which complies with the approval principles as per WHG.

3. Carry out "Device check"
   Activate the "Diagnostics > Device check > Start device check" parameter (more information available in the Operating Instructions → 🖹 7, "Supplementary device documentation"). The signal quality is tested and possible installation errors are detected.

4. Start SIL/WHG confirmation sequence.
   To do so, enter the appropriate locking code in the "Setup > Advanced setup > SIL/WHG confirmation > Set write prot." parameter:
   – WHG: 7450
   – SIL: 7452
   – SIL and WHG: 7454

   ✎ Note!
   In this way, forbidden parameter changes (e.g. via external operating tools if the confirmation sequence is performed at the device display) are prevented already during the SIL/WHG confirmation sequence.

5. For "Commissioning" select the "Increased safety mode" entry from the list.
   The device checks the parameter settings in accordance with the table (→ 🖹 13) and carries out a forced switching of parameters if necessary. Once testing is complete, "SIL/WHG preparation: Finished" is displayed, and the commissioning sequence can continue.

   ✎ Note!
   If configuration was not performed in accordance with the specifications in point 2, only "Expert mode" can be selected at this point.

6. Simulate distance values via the "Value sim. dist." parameter, and verify that the response of the current output is correct. For MIN monitoring and MAX monitoring, in each case simulate a distance directly above and below the switch point. For range monitoring, 5 distance values should be simulated which cover the entire measuring range.

   ☝ Caution!
   During distance simulation, the loop current does not correspond to the measured value. It must be ensured that there is no risk of danger arising from this.

7. Confirm that the distance simulation is correct. To do so, select the "Yes" value for the "Sim. correct" parameter.

8. Compare the character string which is now output ("0123456789+–,.") with the reference string printed here, and confirm if the output is correct.

9. The parameters previously configured and which require confirmation are transferred via an independent data format to the display/operating tool.
   Check the parameters one after the other and confirm if correct.

10. Enter locking code again under "Set write prot.":
    – WHG: 7450
    – SIL: 7452
    – SIL and WHG: 7454
    The "End of sequence" message indicates that the device was successfully locked.

11. Optional, hardware locking may also be activated (via the DIP switch marked "WP" on main electronics).

Locking in expert mode

To commission the device, carry out and document the following steps in the order shown (template → 24).

1. Reset device.
   To do this, select "Diagnostics > Device reset > To factory defaults" or "Diagnostics > Device reset > To delivery settings". This resets all parameters to defined values.
2. Carry out configuration.
   The configuration procedure and the meaning of the individual parameters are described in the Operating Instructions.
   The basic conditions under point 2 in "Increased safety mode" must be taken into account.
3. Carry out "Device check".
   Activate the "Diagnostics > Device check > Start device check" parameter (more information available in the Operating Instructions → 7, "Supplementary device documentation"). The signal quality is tested here and possible installation errors are detected.
4. Start SIL/WHG confirmation sequence.
   To do so, enter the appropriate locking code in the "Setup > Advanced setup > SIL/WHG confirmation > Set write prot." parameter:
   – WHG: 7450
   – SIL: 7452
   – SIL and WHG: 7454
5. For "Commissioning" select the "Expert mode" entry from the list.
   The device checks the parameter settings in accordance with the table (→ 13) and forces the switching of parameters if necessary. Once testing is complete, "SIL/WHG preparation: Finished" is displayed, and the commissioning sequence can continue.
6. Carry out function test.
   For MIN monitoring and MAX monitoring, in each case approach a level directly above and below the switch point. For range monitoring, 5 distance values should be approached which cover the entire measuring range.
7. Confirm that the function test has been successful. To do so, select the "Yes" entry for "Conf. funct. test".
8. Enter locking code again under "Set write prot.":
   – WHG: 7450
   – SIL: 7452
   – SIL and WHG: 7454
   The "End of sequence" message indicates that the device was successfully locked.
9. Optional, hardware locking may also be activated (via the dip switch marked "WP" on main electronics).

Unlocking a SIL device

When SIL locking is active on a device, the device is protected against unauthorized operation by means of a locking code and, as an additional option, by means of a hardware write protection switch. The device must be unlocked in order to change the configuration for proof-tests as per test sequence B (→ 20) or test sequence C (→ 21), as well as to reset self-holding diagnostic messages.

Caution!
Unlocking the device deactivates diagnostic functions, and the device may not be able to carry out its safety function when unlocked. Therefore, independent measures must be taken to ensure that there is no risk of danger while the device is unlocked.

To unlock, proceed as follows:

1. Check the position of the hardware write protection switch (dip switch marked "WP" on main electronics), and set this switch to "Off".
2. Select the "Setup > Advanced setup > Deactivate SIL/WHG" sequence, and enter the appropriate unlocking code for the "Res. write prot." parameter:
   – WHG: 7450
   – SIL: 7452
   – SIL and WHG: 7454
   The "End of sequence" message indicates that the device was successfully unlocked.

Maintenance

Please refer to the relevant Operating Instructions (→ 7, "Supplementary device documentation") for instructions on maintenance and recalibration.
Alternative monitoring measures must be taken to ensure process safety during configuration, proof-testing and maintenance work on the device.

Proof-test

Proof-test

Check the operativeness and safety of safety functions at appropriate intervals!
The operator must determine the time intervals.
You can refer to the diagram "Proof-test interval", → 10, for this purpose.

Note!
In a single-channel architecture, the PFD_{avg} value to be used depends on the diagnostic rate of coverage for the proof-test (PTC = Proof Test Coverage) and the intended lifetime (LT = Lifetime), as specified in the following formula:

$$PFD_{avg} = \frac{1}{2} \bullet PTC \bullet \lambda_{DU} \bullet T_I + \lambda_{DD} \bullet MTTR + \frac{1}{2} \bullet (1 - PTC) \bullet \lambda_{DU} \bullet LT$$

For the proof-tests described as follows, the respective proof test coverages are specified, which may be used for calculation.

Proof-testing of the device can be performed as follows:

- Approaching the level in the original tank (→ test sequence A).
- Removing of the device and measurement of the surface of a medium with comparable properties (→ test sequence B).
- Device self-test and level simulation (→ test sequence C).
  No change of level in the tank is necessary for this sequence.

You must also check that all cover seals and cable entries are sealing correctly.

Caution!
During the proof-test, alternative monitoring measures must be taken to ensure process safety.

Note!
If one of the test criteria from the following test sequences is not fulfilled, the device may no longer be used as part of a safety instrumented system.
The purpose of proof-testing is to detect random device failures (λ_{du}). The impact of systematic faults on the safety function is not covered by this test and must be assessed separately.
Systematic faults can be caused, for example, by process material properties, operating conditions, build-up or corrosion.

Process for proof-testing

Test sequence A

Preparation

1. Connect suitable measuring device (recommended accuracy better ±0.1 mA) to the current output.
2. Determine the safety setting (level limit or range monitoring).

Procedure for level limit monitoring

1. Approach a level directly below (MAX monitoring) or directly above (MIN monitoring) the level limit to be monitored.
2. Read the output current, record it and assess for accuracy.
3. Approach a level directly above (MAX monitoring) or directly below (MIN monitoring) the level limit to be monitored.
4. Read the output current, record it and assess for accuracy.
5. The test is deemed successful if the current in step 2 does not result in activation of the safety function but the current in step 4 does.

Procedure for range monitoring

1. Approach five levels within the range to be monitored.
2. Read the output current at each level value, record it and assess for accuracy.
3. The test is deemed successful if the current values in step 2 are within the required level of accuracy.

Note!
The proof-test is deemed to have failed if the expected current value deviates for a specific level by > ±2 %.
For troubleshooting, → Operating Instructions (→ 7, "Supplementary device documentation").
98 % of dangerous, undetected failures are detected using this test (Proof test coverage, PTC = 0.98).

Test sequence B

Preparation

1. Prepare a test tank with test medium (dielectric constant comparable to that of the medium to be measured). The tank may be open or closed.
   For installation instructions, → Operating Instructions (→ 7, "Supplementary device documentation").
2. Deactivate SIL mode. To do so, enter the appropriate unlocking code in the "Setup > Advanced setup > Deactivate SIL/WHG" operating menu:
   – WHG: 7450
   – SIL: 7452
   – SIL and WHG: 7454
3. Remove the device and mount it in the closed or above the open test tank, respectively.
4. Connect suitable measuring device (recommended accuracy better than ±0.1 mA) to the current output.
5. Perform interference echo mapping if the shape and size of the test tank is different.
6. Determine the safety setting (level limit or range monitoring).

Procedure for level limit monitoring
→ Test sequence A

Procedure for range monitoring
→ Test sequence A.

Note!
The proof-test is deemed to have failed if the expected current value deviates for a specific level by > ±2 %.
For troubleshooting, → Operating Instructions (→ 7, "Supplementary device documentation").
98 % of dangerous, undetected failures are detected using this test (Proof test coverage, PTC = 0.98).

Caution!
After re-installation in the original tank, SIL mode must be reactivated, → 12.
If an interference echo mapping was performed in the test tank, it is necessary following installation in the original tank to carry out another interference echo mapping that is valid for that tank.

Test sequence C

Preparation

1. Deactivate SIL mode. To do so, enter the appropriate unlocking code in the "Setup > Advanced setup > Deactivate SIL/WHG" operating menu:
   – WHG: 7450
   – SIL: 7452
   – SIL and WHG: 7454
2. Connect suitable measuring device (recommended accuracy better than ±0.1 mA) to the current output.
3. Determine the safety setting (level limit or range monitoring).

Procedure for level limit monitoring

1. Perform device self-check. To do so, select the value "Yes" in the menu[1)] in the "Expert > Sensor > Sensor diag. > Start self check" list. After performing the test, read the result in the "Expert > Sensor > Sensor diag. > Result self check" parameter.
   This part of the test has been passed only when "OK" is displayed here.
2. Simulate a level directly below (MAX monitoring) or directly above (MIN monitoring) the level limit to be monitored. To do so, select the value "Level" in the operating menu in the "Diagnostics > Simulation > Assign measurement var." list and enter the value in the "Diagnostics > Simulation > Value proc. var." parameter.
3. Read the output current, record it and assess for accuracy.
4. Simulate a level directly above (MAX monitoring) or directly below (MIN monitoring) the level limit to be monitored.
5. Read the output current, record it and assess for accuracy.
6. The test is deemed successful if the current in step 2 does not result in the activation of the safety function but the current in step 4 does.

Procedure for range monitoring

1. Perform device self-check. To do so, select the value "Yes" in the menu[1)] in the "Expert > Sensor > Sensor diag. > Start self check" list. After performing the test, read the result in the "Expert > Sensor > Sensor diag. > Result self check" parameter.
   This part of the test has been passed only when "OK" is displayed here.
2. Simulate five levels within the range to be monitored. Procedure → Limit value monitoring, point 2.
3. Read the output current at each level value, record it and assess for accuracy.
4. The test is deemed successful if the current values in step 2 are within the required level of accuracy.

Note!
The proof-test is deemed to have failed if the expected current value deviates for a specific level by > ±2 %.
For troubleshooting, → Operating Instructions (→ 🖹 7, "Supplementary device documentation").
55 % of dangerous, undetected failures are detected using this test (Proof test coverage, PTC = 0.55).
A number of faults of the sensor (antenna) and the sensor electronics are not detected.

1) When selecting the "Expert" menu group, a prompt for the access code appears on the display. If an access code was defined under "Setup > Advanced setup > Def. access code", this must be entered here. If no access code was defined, the prompt can be acknowledged by pressing the "E" key.

Repairs

Repairs

Repairs on the devices must always be carried out by Endress+Hauser.
Safety functions cannot be guaranteed if repairs are carried out by anybody else.

Exceptions:
The customer may replace the following components on condition that original replacement parts are used, the member of staff responsible has previously been trained by Endress+Hauser to carry out this task and the relevant repair instructions are observed:

- Display
- Antennas
- Overvoltage protection
- Main electronics
- I/O modules
- Terminals for I/O modules
- Housing covers
- Seal kits for housing covers
- Housing filters (vent plugs)
- Safety clamps, housing

The replaced components must be sent to Endress+Hauser for the purpose of fault analysis.
Once the components have been replaced, a proof-test must be carried out as per test sequence A (→ 19) or test sequence B (→ 20).

In the event of failure of a SIL-labeled Endress+Hauser device, which has been operated in a protection function, the "Declaration of Contamination and Cleaning" with the corresponding note "Used as SIL device in protection system" must be enclosed when the defective device is returned.
Please refer to the Section "Return" in the Operating Instructions (→ 7, "Supplementary device documentation").

Appendix

Notes on the redundant use of multiple sensors

This section provides additional information regarding the use of homogeneously redundant sensors e.g. 1oo2 or 2oo3 architectures.

The common cause factors ß and $ß_D$ indicated in the table below are minimum values for the Micropilot. These must be used when designing the sensor subsystem.

Minimum value ß with homogeneous redundant use	2 %
Minimum value $ß_D$ with homogeneous redundant use	1 %

The device meets the requirements for SIL 3 in homogeneously redundant applications.

The following must be taken into account in proof-testing:

– If an error is detected in one of the redundantly operated devices, the other devices must be checked to see if there is the same error.

Commissioning or proof test protocol

System-specific data		
Company		
Measuring point / TAG no.		
System / Plant		
Device type / Order code		
Serial number of device		
Name		
Date		
Access code (if individual to each device)		
Locking code used	WHG: SIL: SIL and WHG:	7450 7452 7454
Signature		
Device-specific commissioning parameters (only in "Increased safety mode")		
Tank type *[1]		
Tube diameter *[1], *[2]		
Bin type *[3]		
Max. filling speed *[3]		
Max. draining speed *[3]		
Empty calibration		
Full calibration		
Advanced process conditions		
Tank/silo height		

	Set point	Actual value
Proof-test protocol		
Test step		
1. Current value 1		
2. Current value 2		
3. Current value 3 (if necessary)		
4. Current value 4 (if necessary)		
5. Current value 5 (if necessary)		

Protokoll_01-EN

*[1] *Only for liquid measurement*
*[2] *Only for stilling well or bypass*
*[3] *Only for bulk solid measurement*

Certificate

TÜVRheinland®

ZERTIFIKAT
CERTIFICATE

Nr./No.: 968/EL 882.00/12

Prüfgegenstand **Product tested**	Sichere Überwachung eines Füllstandes Safe detection of a level	**Zertifikats-inhaber** **Certificate holder**	Endress + Hauser GmbH + Co. KG Hauptstraße 1 79689 Maulburg Germany
Typbezeichnung **Type designation**	Micropilot FMR5x [x = 0..4 & 6..7]	**Hersteller** **Manufacturer**	wie Zertifikatsinhaber see certificate holder
Prüfgrundlagen **Codes and standards forming the basis of testing**	IEC 61508 Parts 1-7:2010		
Bestimmungsgemäße Verwendung **Intended application**	Das Gerät erfüllt die Anforderungen der Prüfgrundlagen (Hardware Sicherheitsintegrität SIL 2 nach IEC 61508 und systematische Eignung SIL 3 nach IEC 61508) und kann in Anwendungen bis SIL 2 (HFT=0) bzw. SIL 3 (HFT=1) nach IEC 61508 für die Sicherheitsfunktionen MIN, MAX oder Bereichsüberwachung eingesetzt werden. The device complies with the requirements of the relevant standards (Hardware safety integrity SIL 2 acc. to IEC 61508 and systematic capability SIL 3 acc. to IEC 61508) and can be used in applications up to SIL 2 (HFT=0) resp. SIL 3 (HFT=1) acc. to IEC 61508 for the safety functions MIN, MAX or monitoring of a range.		
Besondere Bedingungen **Specific requirements**	Die Hinweise in der zugehörigen Betriebsanleitung und dem Sicherheitshandbuch sind zu beachten. The instructions of the associated Operating Manual and Safety Manual shall be considered.		

Dieses Zertifikat ist gültig bis 11.12.2017.
This certificate is valid until 2017-12-11.

Der Prüfbericht-Nr.: 968/EL 882.00/12 vom 11.12.2012 ist Bestandteil dieses Zertifikates.

Dieses Zertifikat ist nur gültig für Erzeugnisse, die mit dem Prüfgegenstand übereinstimmen. Es wird ungültig bei jeglicher Änderung der Prüfgrundlagen für den angegebenen Verwendungszweck.

The test report-no.: 968/EL 882.00/12 dated 2012-12-11 is an integral part of this certificate.

This certificate is valid only for products which are identical with the product tested. It becomes invalid at any change of the codes and standards forming the basis of testing for the intended application.

TÜV Rheinland Industrie Service GmbH
Bereich Automation
Funktionale Sicherheit
Am Grauen Stein, 51105 Köln

Köln, 2012-12-11

Certification Body for FS-Products

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