Operating Instructions
RIA15

Loop-powered 4 to 20 mA process display unit
with HART® communication
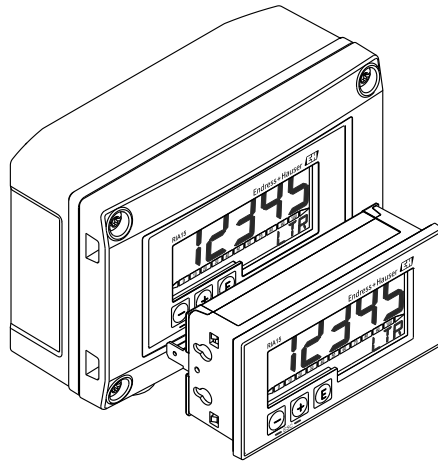
HART
COMMUNICATION PROTOCOL

Endress+Hauser
People for Process Automation

Table of contents

1   Document information

1.1   Document function

These Operating Instructions contain all the information that is required in various phases of the life cycle of the device: from product identification, incoming acceptance and storage, to mounting, connection, operation and commissioning through to troubleshooting, maintenance and disposal.

1.2   Document conventions

1.2.1   Safety symbols

Symbol	Meaning
⚠ DANGER	**DANGER!** This symbol alerts you to a dangerous situation. Failure to avoid this situation will result in serious or fatal injury.
⚠ WARNING	**WARNING!** This symbol alerts you to a dangerous situation. Failure to avoid this situation can result in serious or fatal injury.
⚠ CAUTION	**CAUTION!** This symbol alerts you to a dangerous situation. Failure to avoid this situation can result in minor or medium injury.
NOTICE	**NOTE!** This symbol contains information on procedures and other facts which do not result in personal injury.

1.2.2   Electrical symbols

Symbol	Meaning
⎓ A0011197	**Direct current** A terminal to which DC voltage is applied or through which direct current flows.
∼ A0011198	**Alternating current** A terminal to which alternating voltage is applied or through which alternating current flows.
∼ A0017381	**Direct current and alternating current** • A terminal to which alternating voltage or DC voltage is applied. • A terminal through which alternating current or direct current flows.
⏚ A0011200	**Ground connection** A grounded terminal which, as far as the operator is concerned, is grounded via a grounding system.
⏚ A0011199	**Protective ground connection** A terminal which must be connected to ground prior to establishing any other connections.
▽ A0011201	**Equipotential connection** A connection that has to be connected to the plant grounding system: This may be a potential equalization line or a star grounding system depending on national or company codes of practice.
▲ A0012751	**ESD - Electrostatic discharge** Protect the terminals against electrostatic discharge. Failure to comply with this instruction can result in the destruction of parts or malfunction of the electronics.
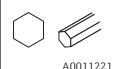
1.2.3   Symbols for certain types of information

Symbol	Meaning
✓	**Permitted** Indicates procedures, processes or actions that are permitted.
✓✓	**Preferred** Indicates procedures, processes or actions that are preferred.
✗	**Forbidden** Indicates procedures, processes or actions that are forbidden.
🛈	**Tip** Indicates additional information.
📖	**Reference to documentation** Refers to the corresponding device documentation.
📄	**Reference to page** Refers to the corresponding page number.
🖼	**Reference to graphic** Refers to the corresponding graphic number and page number.
1., 2., 3. ...	**Series of steps**
↳	**Result of a sequence of actions**
❓	**Help in the event of a problem**
👁	**Visual inspection**

1.2.4   Symbols in graphics

Symbol	Meaning
1, 2, 3,...	Item numbers
1., 2., 3. ...	Series of steps
A, B, C, ...	Views
A-A, B-B, C-C, ...	Sections
≈➡ A0013441	Flow direction
⚠EX A0011187	**Hazardous area** Indicates a hazardous area.
⚠ A0011188	**Safe area (non-hazardous area)** Indicates a non-hazardous area.

1.2.5   Tool symbols

Symbol	Meaning
🖉 A0011220	Flat blade screwdriver
🖉 A0011221	Allen key
🖉 A0011222	Open-ended wrench
🖉 A0013442	Torx screwdriver

1.3   Registered trademarks

HART®
Registered trademark of the HART® Communication Foundation

2 Safety instructions

2.1 Requirements for the personnel

The personnel for installation, commissioning, diagnostics and maintenance must fulfill the following requirements:
- ▶ Trained, qualified specialists must have a relevant qualification for this specific function and task
- ▶ Are authorized by the plant owner/operator
- ▶ Are familiar with federal/national regulations
- ▶ Before beginning work, the specialist staff must have read and understood the instructions in the Operating Instructions and supplementary documentation as well as in the certificates (depending on the application)
- ▶ Following instructions and basic conditions

The operating personnel must fulfill the following requirements:
- ▶ Being instructed and authorized according to the requirements of the task by the facility's owner-operator
- ▶ Following the instructions in these Operating Instructions

2.2 Designated use

The process display unit displays analog process variables or HART $^{®}$ process variables on its screen.

The device is powered via the 4 to 20 mA current loop and does not require an additional power supply.

- The manufacturer accepts no liability for damages resulting from incorrect use or use other than that designated. It is not permitted to convert or modify the device in any way.
- Panel-mounted device
  The device is designed for installation in a panel and must only be operated in an installed state.
- Field device:
  The device is designed for installation in the field.
- The device may only be operated under the permitted ambient conditions (→ 🖺 43).

2.3 Workplace safety

For work on and with the device:
- ▶ Wear the required personal protective equipment according to federal/national regulations.

2.4 Operational safety

Risk of injury.
- ▶ Operate the device in proper technical condition and fail-safe condition only.
- ▶ The operator is responsible for interference-free operation of the device.

Conversions to the device

Unauthorized modifications to the device are not permitted and can lead to unforeseeable dangers.
- ▶ If, despite this, modifications are required, consult with Endress+Hauser.

Repair

To ensure continued operational safety and reliability,
▸ Carry out repairs on the device only if they are expressly permitted.
▸ Observe federal/national regulations pertaining to repair of an electrical device.
▸ Use original spare parts and accessories from Endress+Hauser only.

Environmental requirements

If a plastic transmitter housing is permanently exposed to certain steam and air mixtures, this can damage the housing.
▸ If you are unsure, please contact your Endress+Hauser Sales Center for clarification.
▸ If used in an approval-related area, observe the information on the nameplate.

2.5   Product safety

This measuring device is designed in accordance with good engineering practice to meet state-of-the-art safety requirements, has been tested, and left the factory in a condition in which it is safe to operate.

It meets general safety standards and legal requirements. It also complies with the EC directives listed in the device-specific EC Declaration of Conformity. Endress+Hauser confirms this by affixing the CE mark to the device.

3   Product description

3.1   Function

Process display unit RIA15 is integrated in the 4 to 20 mA/HART® loop and transmits the measuring signal in digital form. The process display unit does not require an external power supply. It is powered directly from the current loop.

The device meets the requirements of the HART® Communication Protocol Specifications and can be used with devices with HART® Revision ≥ 5.0.

3.2   Operating modes

The process display unit can be used in two different operating modes:

4 to 20 mA mode:

In this operating mode, the process display unit is incorporated into the 4 to 20 mA current loop and measures the transmitted current. The variable calculated based on the current value and range limits is displayed in digital form on the 5-digit LCD. In addition, the associated unit and a bar graph can be displayed.

HART mode:

The device functions as a display unit even when operating with a HART® sensor/actor. In this case, the display is also powered from the current loop.

The process display unit can choose to function as a primary master or secondary master (default) in the HART® loop. When it functions as a master, the device can read process values from the measuring device and display them. HART® communication operates on the principle of master/slave. As a general rule, the sensor/actor is a slave and only transmits information if a request has been made by the master.

A HART® loop can have a maximum of two HART® masters at any one time. A distinction is made between primary (e.g. the control system) and secondary master (e.g. handheld terminal for on-site operation of the measuring devices) for these HART® masters. The two masters in the loop/in the network cannot be masters of the same type, e.g. they cannot be two "secondary masters".

If a third HART® master is added to the network, one of the other masters must be disabled; otherwise a collision occurs in the network.

If the process display unit is operating as "secondary master" and another "secondary master", e.g. a handheld device, is added to the network, the device interrupts HART® communication as soon as it detects that there is another "secondary master". The display alternates between error message C970 "Multi master collision" and "- - -". A measured value is not displayed in this case. The device leaves the HART® loop for 30 seconds and tries to re-establish HART® communication once again. Once the additional "secondary master" is removed from the network, the device continues communication and displays the measured values of the sensor/actor once more.

ℹ️ Please note that if two process display units are to be used in a multidrop connection, one device must be configured as "primary master" and the other as "secondary master" to prevent a master collision.

In HART mode, the process display unit can show up to four device variables of a multivariable measuring device. These variables are referred to as the Primary Variable (PV), Secondary Variable (SV), Tertiary Variable (TV) and Quaternary Variable (QV). These variables are placeholders for measured values that can be called up using HART® communication.

For a flowmeter, such as the Promass, these four values can be as follows:
- Primary process variable (PV) →Mass flow
- Secondary process variable (SV) → Totalizer 1
- Third process variable (TV) → Density
- Fourth process variable (QV) → Temperature

The HART® section at the end of these Operating Instructions provides examples of these four device variables for multivariable measuring devices (→ 🖹 54).

ℹ️ Please refer to the Operating Instructions for each device for details on the variables that are set as default on the sensor/actor and how they can be changed.

The process display unit can show each of these values. The individual values must be activated in the SETUP – HART1 to HART4 menu for this purpose. The individual parameters are assigned to fixed process variables in the device in this case:

HART1 = PV

HART2 = SV

HART3 = TV

HART4 = QV

For example, if the PV and TV are to be displayed on the process display unit, HART1 and HART3 must be activated.

The values can either be shown alternately on the process display unit or one value is displayed continuously and the other values are only shown by pressing '+' or '−'. The switching time can be configured in the "EXPRT" – "SYSTM" – "TOGTM" menu.

3.3   Input channels

The process display unit has one analog 4 to 20 mA input. In "HART" operating mode, this channel can be used for measuring and displaying HART® values for a connected sensor/actor. In this case, a HART® device can be directly connected to the process display unit in a point-to-point connection or the process display unit can be incorporated in a HART® multidrop network.

4   Identification

4.1   Nameplate

The nameplate is located on the right-hand side of the housing in the case of the field device, and on the rear of the housing in the case of the panel-mounted device.
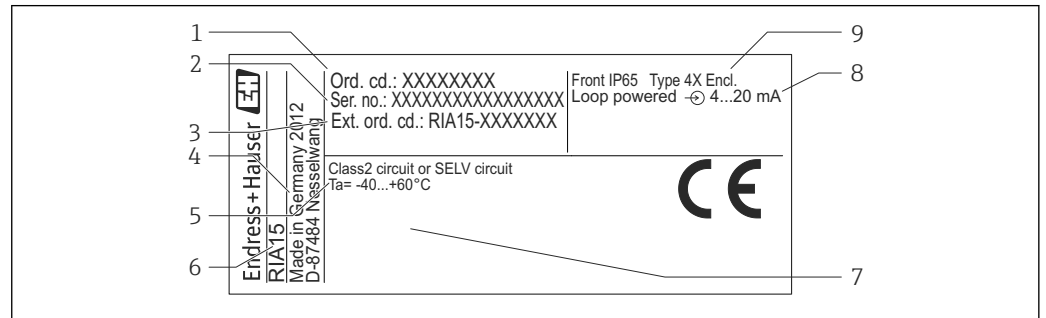
⊞ 1   Nameplate of the process display unit (example)

1	*Order code of the device*	*6*	*Device designation*
2	*Serial number of the device*	*7*	*Approvals (optional)*
3	*Extended order code of the device*	*8*	*Input signal*
4	*Manufacturer's address*	*9*	*Housing degree of protection*
5	*Ambient temperature range*		

4.2   Scope of delivery

The scope of delivery of the device comprises:
- Panel-mounted device
  - Process display unit
  - Brief Operating Instructions
  - Ex Safety Instructions (optional)
  - Fastening fixtures
  - HART® communication resistance module (optional)
- Field device
  - Process display unit
  - Brief Operating Instructions
  - Ex Safety Instructions (optional)
  - Fastening fixtures for wall/pipe mounting (optional)
  - HART® communication resistance module (optional)
  - Weather protection cover (optional)

4.3   Certificates and approvals

An overview of all available approvals is provided in the "Technical data" section. (→ 🕮 42).

CE mark, Declaration of Conformity

The device is designed to meet state-of-the-art safety requirements, has been tested, and left the factory in a condition in which it is safe to operate. The device complies with the applicable standards and regulations in accordance with EN 61010-1 "Safety requirements for electrical equipment for measurement, control and laboratory use".

The device described in these Operating Instructions therefore complies with the statutory requirements of the EU Directives. The manufacturer confirms that the device has been successfully tested by applying the CE mark.

4.4   HART® protocol certification

The RIA15 is registered by the HART® Communication Foundation. The device fulfills the requirements of HCF Specification, Revision 7.1. This version is downwards compatible with all sensors/actuators with HART® versions ≥ 5.0.

5   Installation

5.1   Incoming acceptance, transport, storage

Compliance with the permitted environmental and storage conditions is mandatory.
Precise specifications for this are provided in the "Technical data" (→ 🕮 42).

5.1.1   Incoming acceptance

On receipt of the goods, check the following points:
• Is the packaging or the content damaged?
• Is the delivery complete? Compare the scope of delivery against the information on your
  order form.

5.1.2   Transport and storage

Please note the following:
• Pack the device so that is protected against impact for storage and transport. The
  original packaging provides optimum protection.
• The permitted storage temperature is −40 to +85 ℃ (−40 to +185 ℉); it is possible to
  store the device at borderline temperatures for a limited period (48 hours maximum).

5.2   Installation conditions

ℹ️ At temperatures below −25 ℃ (−13 ℉) the readability of the display can no longer be
   guaranteed.

5.2.1   Display unit in the panel-mount housing

Permitted ambient temperature range −40 to 60 ℃ (−40 to 140 ℉), horizontal orientation.
IP65 protection at front, IP20 at rear

See "Technical data" section (→ 🕮 42).

5.2.2   Display unit in the field housing

Permitted ambient temperature range −40 to 60 ℃ (−40 to 140 ℉). IP66 protection,
NEMA 4x (aluminum housing).

See "Technical data" section (→ 🕮 42).

5.3   Installation instructions

For the dimensions of the device, see "Technical data" (→ 🕮 44).

5.3.1   Panel housing
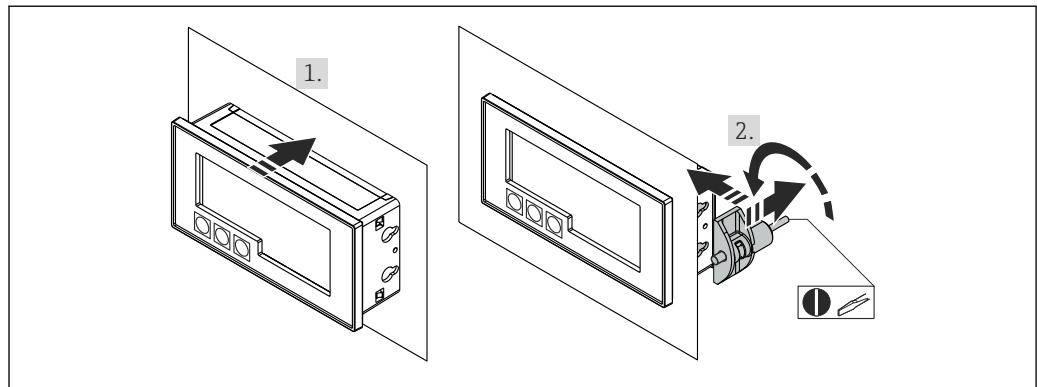
🖼 *2   Installation instructions for the panel housing*

Installation in a panel with a panel cutout 92x45 mm (3.62x1.77 in), max. panel thickness 13 mm (0.51 in).

1. Slot the device into the panel cutout from the front.

2. Fit the mounting clips on the side of the housing and tighten the threaded rods.

5.3.2   Field housing

Pipe mounting (with optional mounting kit)

The device can be mounted on a pipe with a diameter of up to 50.8 mm (2 in) with the mounting kit (optionally available).
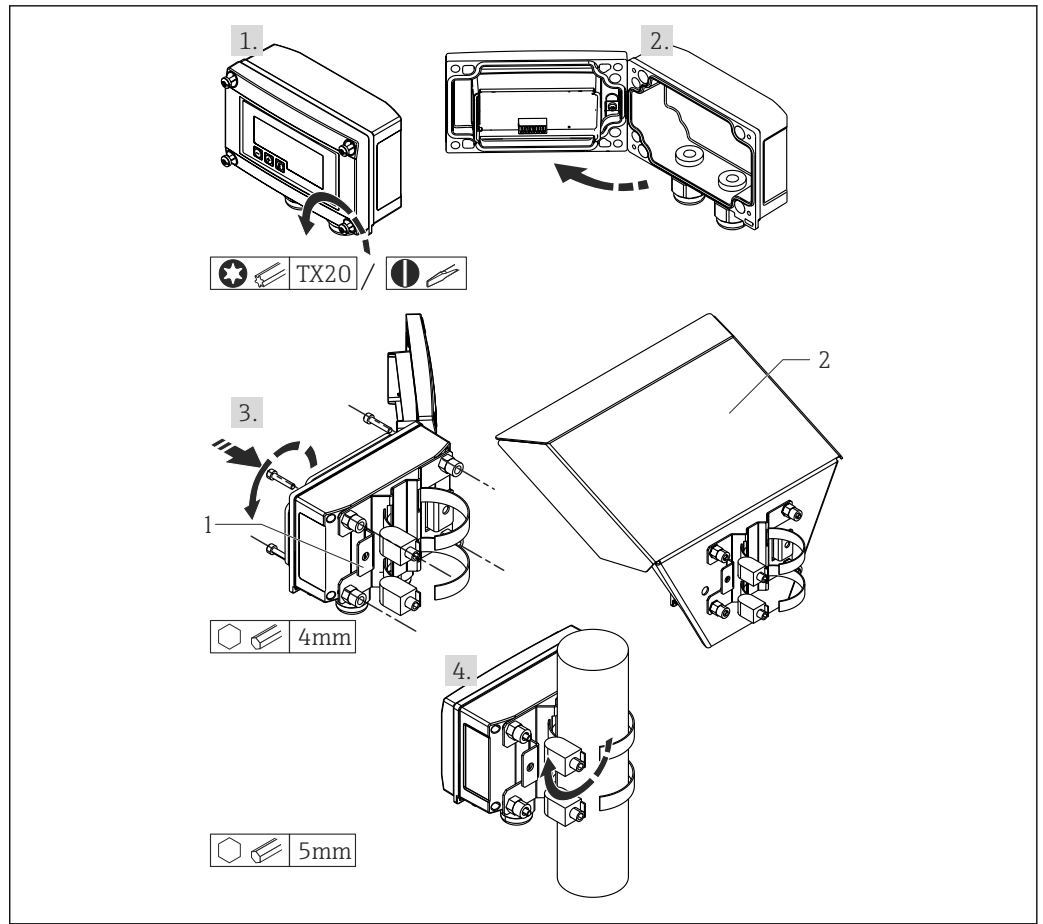
🖻 3   Mounting the process display unit on a pipe

1   Mounting plate for pipe/wall mounting
2   Weather protection cover (optional)

1. Release the 4 housing screws

2. Open the housing

3. Secure the mounting plate to the rear of the device with 4 screws supplied. The optional weather protection cover can be secured between the device and the mounting plate.

4. Guide the two gripper clamps through the mounting plate, fit them around the pipe and tighten.

Wall mounting

With optionally available mounting kit.
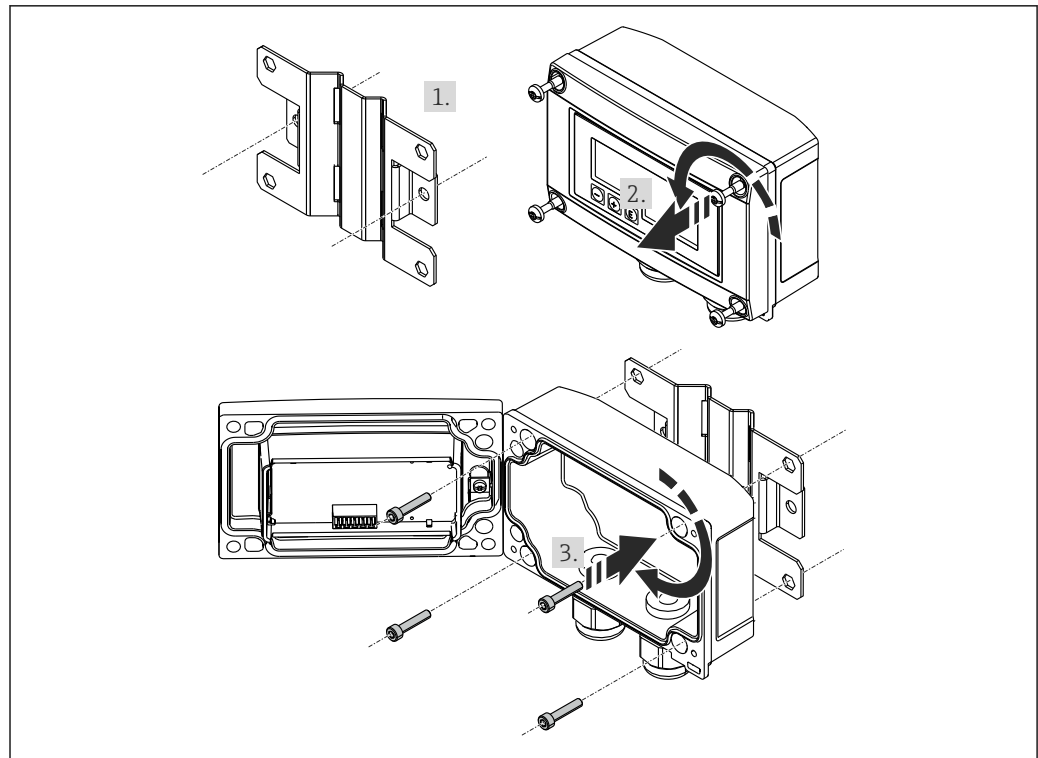
4   *Mounting the process display unit on a wall*

1. Use the mounting plate as a stencil for 2 6 mm (0.24 in) bore holes, 82 mm (3.23 in) apart, and secure the plate on the wall with 2 screws (not supplied).

2. Open the housing.

3. Secure the display unit on the mounting plate with the 4 screws supplied.

4. Close the cover and tighten the screws.

Without a mounting kit.

1. Open the housing.

2. Use the device as a stencil for 4 6 mm (0.24 in) bore holes, 99 mm (3.9 in) apart on the horizontal plane, 66 mm (2.6 in) apart on the vertical plane.

3. Secure the display unit on the wall with 4 screws.

4. Close the cover and tighten the housing screws.

5.3.3   Mounting the optional HART® communication resistance module

Panel housing

The HART® communication resistance module is available as an accessory, see section Accessories (→ 🖺 46).
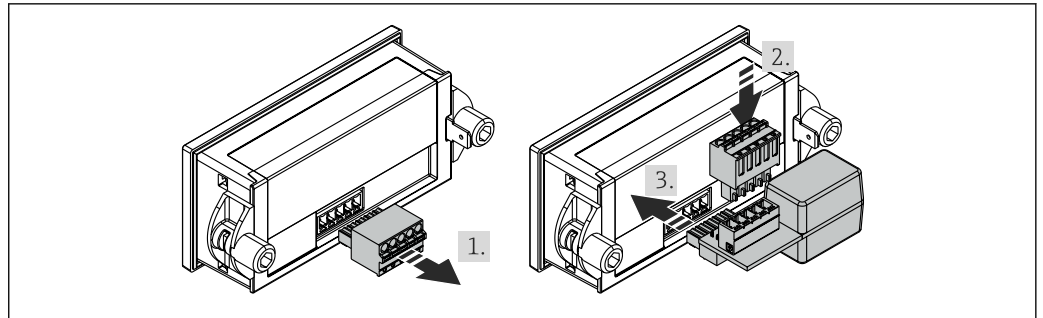
⊡ *5   Mounting the optional HART® communication resistance module*

1. Unplug the pluggable terminal block.

2. Plug terminal block into the suitable plug-in position on the HART® communication resistance module.

3. Plug the HART® communication resistance module into the plug-in position on the housing.

Field housing

The HART® communication resistance module is available as an accessory, see section Accessories (→ 🕮 46).
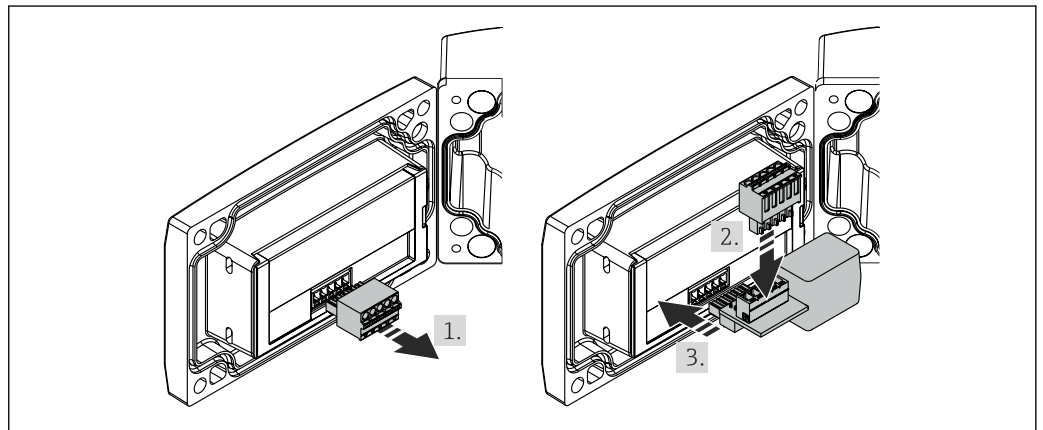
⊡ *6   Mounting the optional HART® communication resistance module*

1. Unplug the pluggable terminal block.

2. Plug terminal block into the suitable plug-in position on the HART® communication resistance module.

3. Plug the HART® communication resistance module into the plug-in position in the housing.

5.4   Post-installation check

5.4.1   Display unit in the panel-mount housing

- Is the seal undamaged?
- Are the mounting clips securely fastened on the housing of the device?
- Are the threaded rods properly tightened?
- Is the device located in the center of the panel cutout?

5.4.2   Display unit in the field housing

- Is the seal undamaged?
- Is the housing firmly screwed to the mounting plate?
- Is the mounting bracket firmly secured on the wall/pipe?
- Are the housing screws firmly tightened?

6   Wiring

⚠ WARNING

Danger! Electric voltage!

▸ The entire connection of the device must take place while the device is de-energized.

Only certified devices (optionally available) may be connected in the hazardous area

▸ Observe corresponding notes and wiring diagrams in the Ex-specific supplement to these Operating Instructions. If you have any questions, please do not hesitate to contact your E+H representative.

NOTICE

SELV / Class 2 device

▸ The device may only be powered by a power unit with an energy-limited circuit in accordance with IEC 61010-1: 'SELV or Class 2 circuit'.

Device destroyed if current too high

▸ Do not operate the device at a voltage source without a current limiter. Instead, operate the device only in the current loop with a transmitter.

- **Panel housing:**
  The terminals are located on the rear of the housing.
- **Field housing:**
  The terminals are located inside the housing. The device has two M16 cable entries. The housing must be opened for wiring purposes.

Operation of the spring terminals
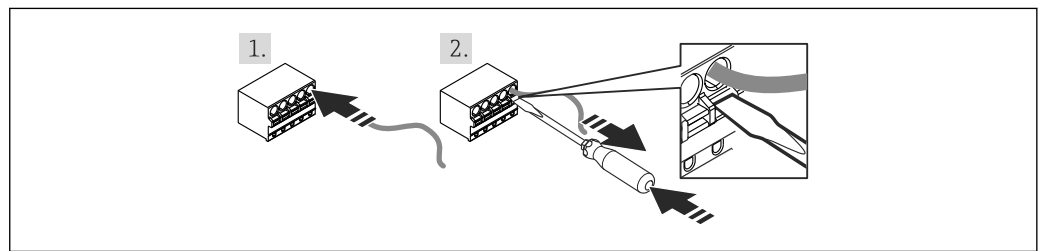
🖻 7   Operation of the spring terminals

A0020848

1. When using rigid cable with ferrule, just plug the cable into the terminal. No tools required. With flexible wire the spring mechanism of the terminal must be operated as shown in step 2.

2. In order to loosen the cable, push the spring mechanism in completely using a screwdriver or other suitable tool and pull out the cable.

6.1   Quick wiring guide

Terminal	Description
+	Positive connection, current measurement
-	Negative connection, current measurement (without backlighting)
LED	Negative connection, current measurement (with backlighting)

Terminal	Description
⊓	Auxiliary terminals (electrically connected internally)
⏚	Functional grounding: • Panel-mounted device: Terminal on the rear of the housing • Field device: Terminal in the housing

6.2   Connection in 4 to 20 mA mode

The following diagrams show how the process display unit is connected in 4 to 20 mA mode.

	Connection without backlighting	Connection with backlighting
Connection with transmitter power supply and transmitter	 A0017704 *1 Transmitter power supply*	 A0017705 *1 Transmitter power supply*
Connection with transmitter power supply and transmitter using the auxiliary terminal	 A0017706 *1 Transmitter power supply*	 A0017707 *1 Transmitter power supply*
Connection with PLC and transmitter	 A0019720 *1 PLC*	 A0019721 *1 PLC*
Connection without transmitter power supply directly in the 4 to 20 mA circuit	 A0017708 *2 4 to 20 mA power source*	 A0017709 *2 4 to 20 mA power source*

6.3   Connection in HART mode

The following diagrams show how the process display unit is connected in HART mode.
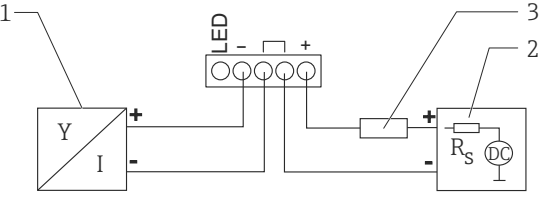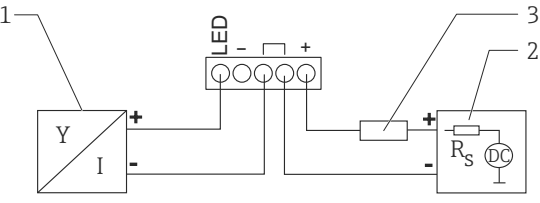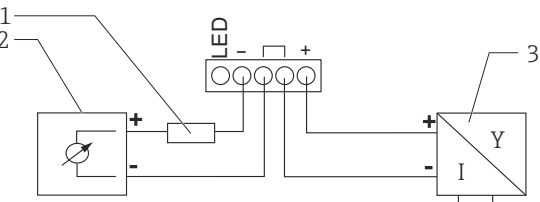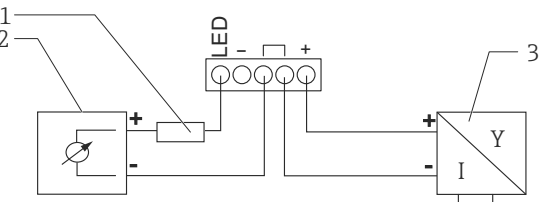
6.3.1 HART® connection
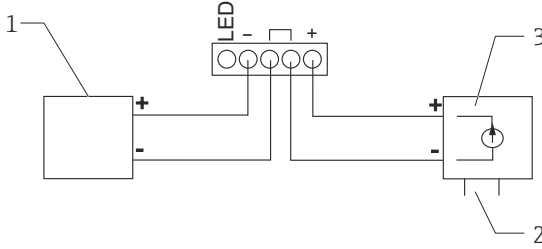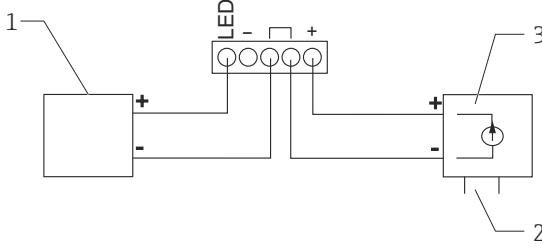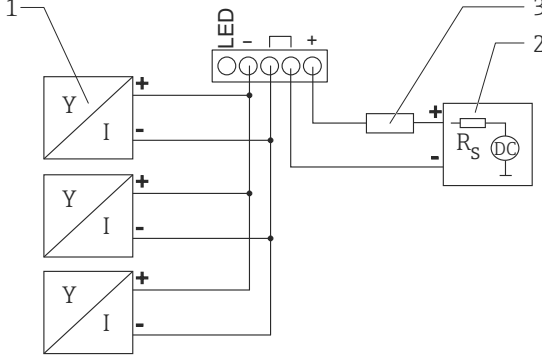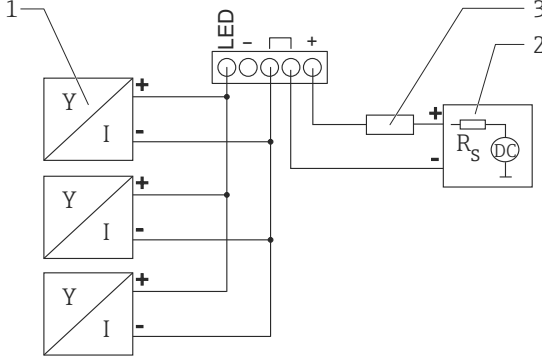
NOTICE

Undefined behavior due to incorrect wiring of an actuator

▶ When installing the process display unit together with an actuator, the Operating Instructions for the actuator must be followed!

ℹ The HART® communication resistance of 230 Ω in the signal line is always necessary in the case of a low-impedance power supply. It must be installed between the power supply and the display unit.

	Circuit diagram / Description
2-wire sensor with process display unit and loop power supply, without backlighting	 *1 Sensor* *2 Power supply* *3 HART® resistance*
2-wire sensor with process display unit and loop power supply, with backlighting	 *1 Sensor* *2 Power supply* *3 HART® resistance*
4-wire sensor with process display unit and loop power supply, without backlighting	 *1 HART® resistance* *2 Current meter (optional)* *3 Sensor* *4 Power supply 4-wire device*
4-wire sensor with process display unit and loop power supply, with backlighting	 *1 HART® resistance* *2 Current meter (optional)* *3 Sensor* *4 Power supply 4-wire device*

Circuit diagram / Description
Current output with process display unit and actuator (e.g. actuator valve), without backlighting   A0019573   *1   Actuator*   *2   Power supply 4-wire device*   *3   Current output*
Current output with process display unit and actuator (e.g. actuator valve), with backlighting   A0019574   *1   Actuator*   *2   Power supply 4-wire device*   *3   Current output*
Multi-drop 2-wire sensors with process display unit and loop power supply   A0019575   *1   Sensors*   *2   Power supply*   *3   HART® resistance*
Multi-drop 2-wire sensors with process display unit and loop power supply, with backlighting   A0019722   *1   Sensors*   *2   Power supply*   *3   HART® resistance*

	Circuit diagram / Description
2-wire sensor with process display unit and active barrier RN221N as loop power supply	*1 Sensor* *2 HART® primary master* *3 HART® resistance*
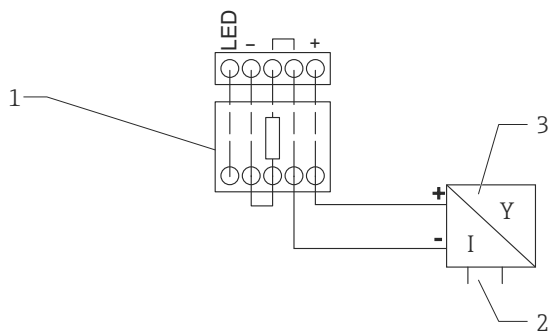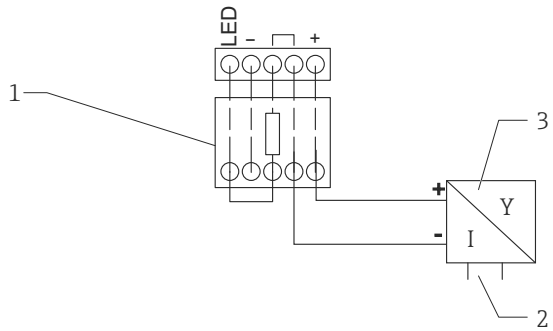
Optional HART® communication resistance module

A HART® communication resistance module is available as an accessory, see section Accessories (→ 🖺 46).

Mounting of the HART® communication resistance module see section Installation instructions (→ 🖺 16)

Wiring

	Circuit diagram / Description
2-wire sensor with process display unit and loop power supply, without backlighting	*1 HART® communication resistance module* *2 Sensor* *3 Power supply*
2-wire sensor with process display unit and loop power supply, with backlighting	*1 HART® communication resistance module* *2 Sensor* *3 Power supply*

	Circuit diagram / Description
4-wire sensor with process display unit and loop power supply, without backlighting	 *1 HART® communication resistance module* *2 Power supply of 4-wire device* *3 Sensor*
4-wire sensor with process display unit and loop power supply, with backlighting	 *1 HART® communication resistance module* *2 Power supply of 4-wire device* *3 Sensor*

Configuration of HART® devices

The process display unit cannot be used to configure connected HART® devices. Configuration is done using the Field Xpert SFX100 device configurator, for example.
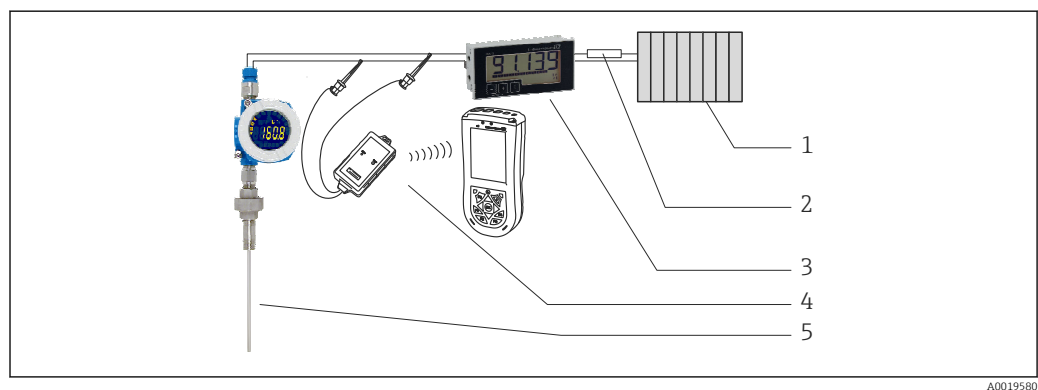
⊞ *8   Configuration of HART® devices; example TMT162*

1   HART® primary master (e.g. PLC)
2   HART® resistance
3   RIA15 process display unit
4   HART® handheld, e.g. Field Xpert SFX100
5   Sensor with HART® transmitter, e.g. TMT162

6.4   Inserting the cable, field housing
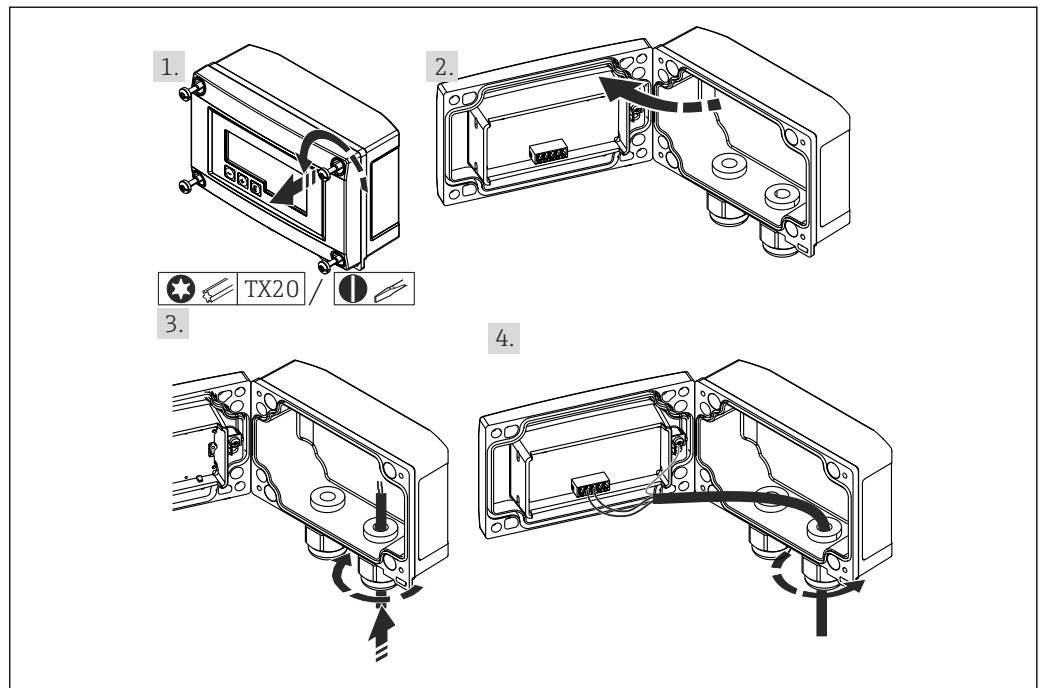
⊞ 9   *Inserting the cable, field housing*

Inserting the cable, field housing, connection without transmitter power supply (example)

1. Release the housing screws

2. Open the housing

3. Open the cable gland (M16) and insert the cable.

4. Connect the cable incl. functional grounding and close the cable gland

6.5   Shielding and grounding

Optimum electromagnetic compatibility (EMC) can only be guaranteed if the system components and, in particular, the lines are shielded and the shield forms as complete a cover as possible. A shield coverage of 90% is ideal.

- To ensure an optimum EMC protective effect when communicating with HART®, connect the shield as often as possible to the reference ground.
- For reasons of explosion protection, you should refrain from grounding however.

To comply with both requirements, three different types of shielding are possible when communicating with HART®:
- Shielding at both ends
- Shielding at one end on the feed side with capacitance termination at the field device
- Shielding at one end on the feed side

Experience shows that the best results with regard to EMC are achieved in most cases in installations with one-sided shielding on the feed side (without capacitance termination at the field device). Appropriate measures with regard to input wiring must be taken to allow unrestricted operation when EMC interference is present. These measures have been taken into account for this device. Operation in the event of disturbance variables as per NAMUR NE21 is thus guaranteed. Where applicable, national installation regulations and guidelines must be observed during the installation! Where there are large differences in potential between the individual grounding points, only one point of the shielding is connected directly with the reference ground. In systems without potential equalization,

therefore, cable shielding of fieldbus systems should only be grounded on one side, for example at the supply unit or at safety barriers.

> **NOTICE**
>
> **If the shielding of the cable is grounded at more than one point in systems without potential matching, power supply frequency equalizing currents can occur that damage the signal cable or have a serious effect on signal transmission.**
> ▸ In such cases the shielding of the signal cable is to be grounded on only one side, i.e. it must not be connected to the ground terminal of the housing. The shield that is not connected should be insulated!

6.6   Connecting to functional grounding

6.6.1   Panel-mounted device

For EMC reasons the functional grounding should always be connected. When the device is used in explosion hazardous environment (with optional Ex approval) the connection is obligatory.
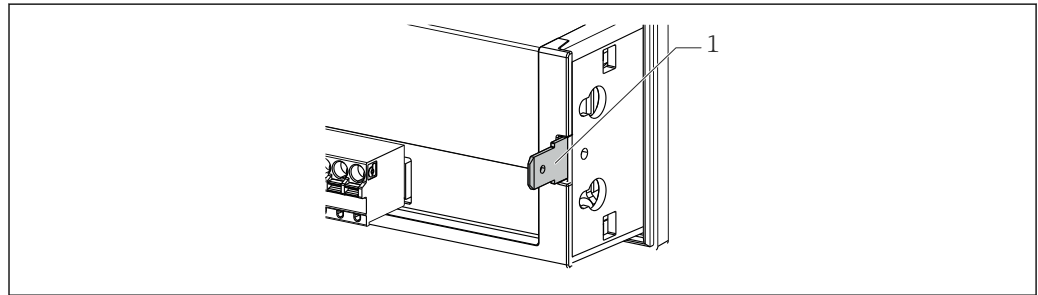
🖻 *10   Functional grounding terminal on panel-mounted device*

6.6.2   Field device

For EMC reasons the functional grounding should always be connected. When the device is used in explosion hazardous environment (with optional Ex approval) the connection is obligatory and the field housing must additionally be grounded via a grounding screw fitted on the outside of the housing.
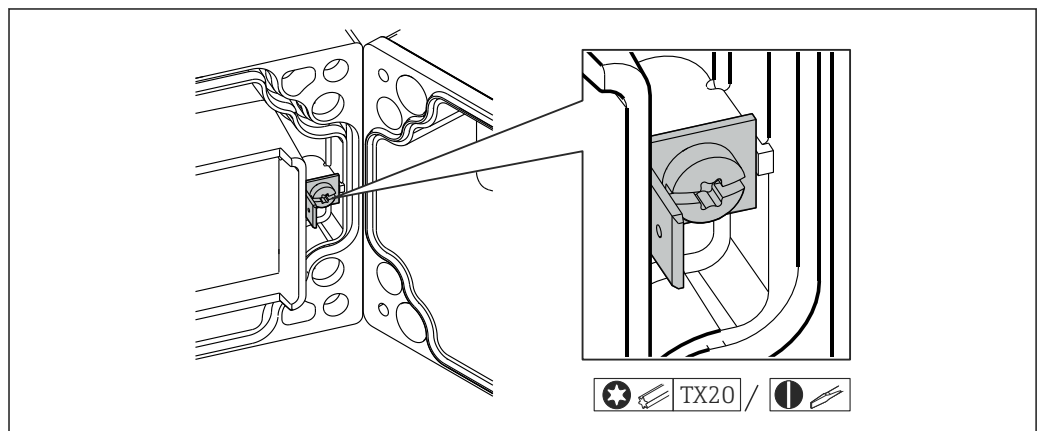
🖻 *11   Functional grounding terminal in field housing*
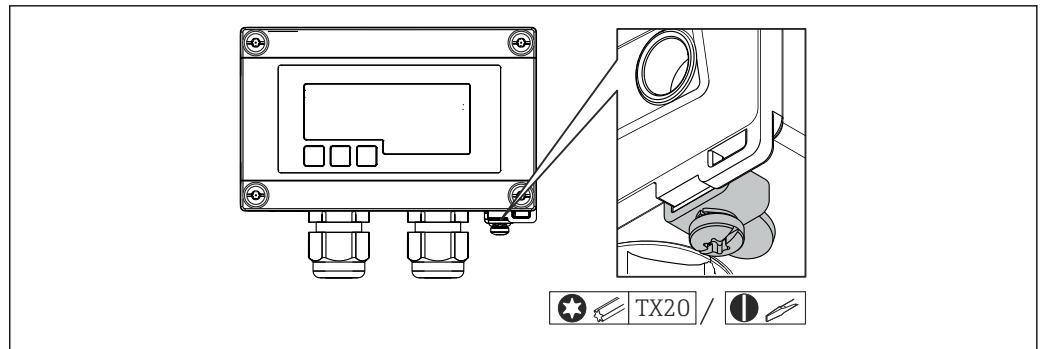
⊠ *12 Ground terminal on field housing*

6.7 Degree of protection

6.7.1 Field housing

The devices meet all the requirements of IP66. It is absolutely essential to comply with the following points to ensure this protection is guaranteed after mounting or servicing the device:

- The housing seal must be clean and undamaged when inserted into the groove. The seal must be cleaned, dried or replaced if necessary.
- The cables used for connection must be of the specified outside diameter (e.g. M16 x 1.5, cable diameter 5 to 10 mm (0.2 to 0.39 in)).
- Mount the measuring device in such a way that the cable entries point downwards.
- Replace unused cable entries with dummy plugs.
- The housing cover and the cable entries must be firmly tightened.

6.7.2 Panel housing

The front of the device meets the requirements of IP65. It is absolutely essential to comply with the following points to ensure this protection is guaranteed after mounting or servicing the device:

- The seal between the front of the housing and the panel must be clean and undamaged. The seal must be cleaned, dried or replaced if necessary.
- The threaded rods of the panel mounting clips must be firmly tightened.

6.8 Post-connection check

Device condition and specifications	Notes
Are cables or the device damaged?	Visual inspection
Electrical connection	**Notes**
Does the supply current match the specifications on the nameplate?	-
Are the mounted cables, incl. functional grounding, connected correctly and strain-relieved?	-
Field housing: Are the cable glands securely closed?	-

7 Operation
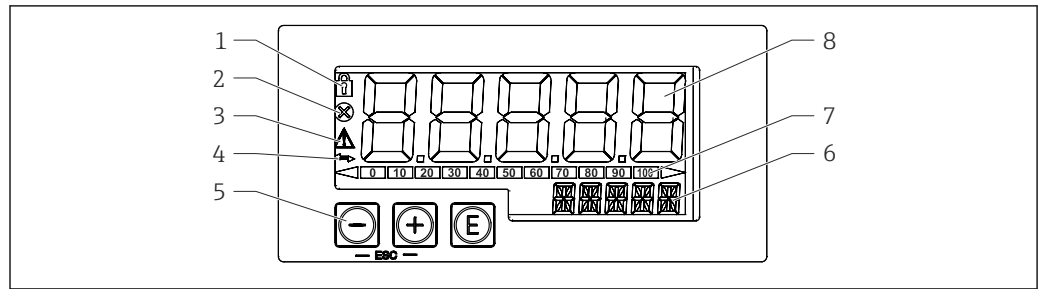
A0017719

13   Display and operating elements of the process display unit

1   Symbol: operating menu disabled
2   Symbol: error
3   Symbol: warning
4   Symbol: HART® communication active
5   Operating keys "-", "+", "E"
6   14-segment display for unit/TAG
7   Bar graph with indicators for under range and over range
8   5-digit 7-segment display for measured value, digit height 17 mm (0.67 in)

The device is operated using three operating keys on the front of the housing. The device setup can be disabled with a 4-digit user code. If the setup is disabled, a padlock symbol appears on the display when an operating parameter is selected.

 A0017716	Enter key; calling up the operating menu, confirming the option/setting parameters in the operating menu
 A0017714	Selecting and setting/changing values in the operating menu; pressing the '-' and '+' keys simultaneously takes the user back up a menu level. The configured value is not saved.
 A0017715	

7.1 Operating functions

The operating functions of the process display unit are divided into the following menus. The individual parameters and settings are described in the "Commissioning" section.

If the operating menu is disabled by means of a user code, the individual menus and parameters can be displayed but not changed. To change a parameter, the user code must be entered. As the display unit can only display digits in the 7-segment display and not alphanumeric characters, the procedure for number parameters is different to that for text parameters.

If the operating position contains only numbers as parameters, the operating position is displayed in the 14-segment display and the configured parameter is displayed in the 7-segment display. To edit, press the 'E'-button followed by the user code.

If the operating position contains text parameters, only the operating position is initially displayed in the 14-segment display. If the 'E' button is pressed again, the configured parameter is displayed in the 14-segment display. To edit, press the '+' button followed by the user code.

Setup (SETUP)	Basic device settings (→ 🗎 30)
Diagnostics (DIAG)	Device information, display of error messages (→ 🗎 32)
Expert (EXPRT)	Expert settings for the device setup (→ 🗎 32) The Expert menu is protected from editing by an access code (default 0000).

8 Commissioning

8.1 Post-installation check and switching on the device

Perform the final checks before commissioning the device.
- Checklist for "post-installation check" (→ 🕮 17).
- Checklist for "post-connection check" (→ 🕮 27).

The device starts after being connected to the 4 to 20 mA/HART® circuit. The firmware version appears on the display during the start-up phase.

When the device is being commissioned for the first time, program the setup in accordance with the descriptions in the Operating Instructions.

If you are commissioning a device that is already configured or preset, the device immediately starts measuring the current or making a HART® request as defined in the settings. The values of the currently activated process variables appear in the display.

🛈 Remove the protective film from the display as this would otherwise affect the readability of the display.

8.2 Operating matrix

Setup menu (SETUP)			
Parameter	**Values**	**visible at**	**Description**
MODE	**4-20** HART		Select the operating mode for the display unit 4-20: The circuit's 4 to 20 mA signal is displayed HART: Up to four HART® variables (PV, SV, TV, QV) of a sensor/actor in the loop can be displayed.
DECIM	0 DEC **1 DEC** 2 DEC 3 DEC 4 DEC	MODE = 4-20	Number of decimal places for display
SC__4	Numerical value −19 999 to 99 999 Default: **0.0**	MODE = 4-20	5-digit value (number of decimal places as configured under DECIM) for scaling the measured value at 4 mA Example: SC__4 = 0.0 ⇒ 0.0 displayed at 4 mA measuring current The unit selected under UNIT is used to display the value.
SC_20	Numerical value −19 999 to 99 999 Default: **100.0**	MODE = 4-20	5-digit value (number of decimal places as configured under DECIM) for scaling the measured value at 20 mA Example: SC_20 = 100.0 ⇒ 100.0 displayed at 20 mA measuring current The unit selected under UNIT is used to display the value.
UNIT	% °C °F K USER	MODE = 4-20	Use this function to select the unit for displaying the value. If "USER" is selected, a user-defined unit can be entered in the TEXT parameter.
TEXT	Customized text, 5-digit	MODE = 4-20	User-defined unit, only visible if the "USER" option has been selected under UNIT.

Setup menu (SETUP)			
Parameter	**Values**	**visible at**	**Description**
SCAN	**NO** YES	MODE = HART	Select "YES" to start scanning. All addresses are then automatically scanned once in a HART® application until a sensor/actor is found. Scanning runs from 0 to 63. Only addresses up to 15 are permitted for HART 5. Once the address of the sensor/actor whose values are to be displayed is found, the address must be confirmed by pressing the 'E' key. This address is adopted and is used even after a device restart. By pressing the '+' or '−' key, it is possible to search for other addresses. Pressing '+'- and '-' simultaneously will cancel scanning. If "NO" is selected, scanning is not active. The address of the sensor/actor, whose values are to be displayed on the process display unit, must be configured manually using the operating keys.
ADDR	Numerical value 0 to 63 Default: **0**	MODE = HART	Use this function to enter manually the address of the HART® sensor/actor whose values are to be displayed. ⓘ If the address of the HART® slave is changed, it must also be changed on the process display unit. To do this, either enter the address manually or search using SCAN mode.
MTYPE	PRIM **SEC**	MODE = HART	Use this function to select the HART® master type: PRIM = Primary master SEC = Secondary master
HART1-HART4		MODE = HART	Use this function to select which HART® value of a sensor/actor (PV, SV, TV, QV) should be activated and configured: HART1 = PV HART2 = SV HART3 = TV HART4 = QV Press the E key to open the configuration submenu.
	DISP1 –DISP4	OFF MAN **AUTO**	MODE = HART	Use this function to select how or whether the value should be displayed. OFF: Value is not displayed MAN: You can manually scroll through activated HART® values by pressing '+' or '−'. Otherwise the values are not displayed. If all four HART® values (HART1 to HART4) are set to "MAN", HART1 (PV) is displayed if you do not scroll manually through the values. AUTO: Activated HART® values are shown alternately (switching time can be configured in the EXPRT menu under "TOGTM"). If one value is set to AUTO, this value is displayed continuously on the device.
	DEC1 – DEC4	0 DEC **1 DEC** 2 DEC 3 DEC 4 DEC	MODE = HART	Number of decimal places
	BGLO1-BGLO4	Numerical value −19 999 to 99 999 Default: **0.0**	MODE = HART	5-digit value (number of decimal places as configured under DEC1-DEC4) for scaling the lower range of the bar graph for HART1 - HART4. The bar graph is disabled if BGLOx and BGHIx are set to "0.0".
	BGHI1-BGHI4	Numerical value −19 999 to 99 999 Default: **0.0**	MODE = HART	5-digit value (number of decimal places as configured under DEC1-DEC4) for scaling the upper range of the bar graph for HART1 - HART4. The bar graph is disabled if BGLOx and BGHIx are set to "0.0".

Setup menu (SETUP)

Parameter		Values	visible at	Description
	UNIT1-UNIT4	**HART** % °C °F K USER	MODE = HART	Use this function to select the unit for displaying the HART® value. If "HART" is selected, the unit configured on the sensor/actor is automatically adopted for the relevant HART® value. Only units with a maximum of 5 characters can be shown. Longer units are displayed as unit code "UCxxx". The table in the HART® communication section at the end of these Operating Instructions provides an overview of the units that can be displayed. If "USER" is selected, a user-defined unit can be entered in the TEXT1-TEXT4 parameter.
	TEXT1-TEXT4	Customized text, 5-digit	MODE = HART	User-defined unit. Only visible if the "USER" option has been selected under UNIT

Diagnostics menu (DIAG)

Parameter	Values	Description
AERR	Read only	The current diagnostic message appears on the display. If two or more messages occur simultaneously, the message with the highest priority is shown on the display.
LERR	Read only	The last diagnostic message with the highest priority appears on the display.
FWVER	Read only	The firmware version appears on the display.

Expert menu (EXPRT); a code must be entered

In addition to all the parameters in the Setup menu, the Expert menu also contains the parameters described in this table. If you call up the Expert menu, you will be asked to enter the user code (UCODE, default: 0000).

Parameter		Values	visible at	Description
SYSTM				
	UCODE	Numerical value 0000 to 9999 Default: **0000**		4-digit user code With the user code it is possible to protect the device setup from unauthorized modifications. If the setup is disabled, a padlock symbol appears on the display when an operating parameter is selected. The user code is not active with the default setting "0000". This means that setup parameters can be changed without entering the code. The code must always be entered for the Expert menu, even for the default setting.
	FRSET	**NO** YES		Resets the device setup. The values are reset to the preset values for preconfigured devices, and to the default values for all other devices. Select "YES" and press "E" by way of confirmation to reset the device.
	TOGTM	**5** 10 15 20	MODE = HART	Use this function to select the switching time in seconds between HART® values if "AUTO" was selected in the DISP1-DISP4 menu.
INPUT				The following parameters are available in addition to the parameters from the Setup menu.

Expert menu (EXPRT); a code must be entered			
In addition to all the parameters in the Setup menu, the Expert menu also contains the parameters described in this table. If you call up the Expert menu, you will be asked to enter the user code (UCODE, default: 0000).			
Parameter		**Values**	**visible at**	**Description**
	CURV	**LINAR** SQRT		**Use this to select the calculation function for the process value (for MODE = 4-20)** **LINAR** (scaling with SC__4 and SC_20): Process value = (mA value - 4)/16 * (SC_20 - SC__4) + SC__4 + OFFST **SQRT** (square root extraction and scaling): Process value = Square root((mA value - 4)/16) * (SC_20 - SC__4) + SC__4 + OFFST Negative values when calculating the square root are set to 0. **Use this to select the calculation function for the HART1 value (PV) (for MODE = HART)** **LINAR**: HART1 value (PV) = "exported PV value" * FACT1 + OFFS1 **SQRT** (square root extraction and scaling with BGLO1 and BGHI1): HART1 value (PV) = (square root("exported percentage PV value" / 100) * (BGHI1 - BGLO1) + BGLO1) * FACT1 + OFFS1 Negative values when calculating the square root are set to 0. **Example for SQRT:** • exported percentage PV value = 50 • BGLO1 = 100.0 • BGHI1 = 200.0 • FACT1 = 1 • OFFS1 = 0.0 HART1 value (PV) = (square root(50/100) * (200 - 100) + 100) * 1 + 0 = 170.7
	NAMUR	NO **YES**	MODE = 4-20	Use this function to define the error limits in accordance with standard NAMUR NE 43 (→ 🗏 35)
	RNGLO	Numerical value	NAMUR = NO	Lower range limit. An error message is displayed if the measured current falls below this limit.
	RNGHI	Numerical value	NAMUR = NO	Upper range limit. An error message is displayed if the measured current exceeds this limit.
	OFFST	Numerical value −19 999 to 99 999	MODE = 4-20	Use this function to enter an offset value to display the measured value.
	FACT1-FACT4	1E-6 1E-5 1E-4 1E-3 1E-2 1E-1 **1** 1E1 1E2 1E3 1E4 1E5 1E6	MODE = HART	As the display is limited to 5 characters, the measured value must be multiplied by a factor if necessary. For example: conductivity 0.00003 S multiplied by factor 1E6 ⇒30.000 μS. ℹ If a factor is used, it is recommended to set the unit under UNIT1-4 to "UNIT" and to enter user-defined text because the unit automatically delivered via HART® no longer matches the displayed value.
	OFFS1-OFFS4	Numerical value −19 999 to 99 999	MODE = HART	Use this function to enter an offset value to display the HART1-HART4 measured value. If a factor is used, the offset is added to the multiplied value (displayed value = measured value*factor + offset)

Expert menu (EXPRT); a code must be entered			
In addition to all the parameters in the Setup menu, the Expert menu also contains the parameters described in this table. If you call up the Expert menu, you will be asked to enter the user code (UCODE, default: 0000).			
Parameter	Values	visible at	Description
EXP1-EXP4	**YES** NO	MODE = HART	Measured value display for measured values larger than 99999. • YES: Measured value is represented in exponential form in the event of a display overflow. • NO: Digits higher than 5-place are not displayed in the event of a display overview. The value is represented with leading zeros. **Example:** Measured value: 130002.4 YES => 1.30E5 NO => 0002.4
DIAG			
CNTHI	Read only	MODE = HART	Counter for the number of values transmitted via HART® , 5 top positions. The counter goes back to 0 after a device restart or scan.
CNTLO	Read only	MODE = HART	Counter for the number of values transmitted via HART® , 5 bottom positions. The counter goes back to 0 after a device restart or scan.
RETRY	Read only	MODE = HART	Counter for the number of retries to establish HART® communication. The counter goes back to 0 after a device restart or scan.
FAIL	Read only	MODE = HART	Counter for the number of failed attempts to establish HART® communication. The counter goes back to 0 after a device restart or scan.
HLEVL			
Tx mV	Read only	MODE = HART	Value of the peak-to-peak level of the transmission signal in mV
Rx mV	Read only	MODE = HART	Value of the peak-to-peak level of the received signal in mV
NOISE	Read only	MODE = HART	Displays the level of the interference signal LO = low interference signal MED = medium interference signal HI = high interference signal
Rc Ω	Read only	MODE = HART	Value of the total resistance in the HART® loop in Ohm

9 Troubleshooting

9.1 Error limits as per NAMUR NE 43

In Mode=4-20, the device can be configured for error limits as per NAMUR NE 43 (→ 🖹 32).

The device displays an error message if a value is outside these limits.

Current value	Error	Diagnostic code
≤3.6 mA	Under range	F100
3.6 mA < x ≤3.8 mA	Unpermitted measured value	S901
20.5 mA≤ x < 21.0 mA	Unpermitted measured value	S902
> 21.0 mA	Over range	F100

9.2 Diagnostic messages

ℹ️ If several errors are present at the same time the device always displays the error with the highest priority.

1 = highest priority

Diagnostic number	Short text	Corrective measure	Status signal	Diagnostic behavior	Priority
		Diagnostics for the sensor			
F100	Sensor error	• Check electrical wiring • Check sensor • Check sensor settings	F	Alarm	6
S901	Input signal too small	• Check transmitter output for defect and conformity error • Check transmitter for incorrect configuration	S	Warning	4
S902	Input signal too large		S	Warning	5
		Diagnostics for the electronics			
F261	Electronics module	Replace electronics	F	Alarm	1
F283	Memory content	• Restart device • Reset device • Replace electronics	F	Alarm	2
F431	Factory calibration	Replace electronics	F	Alarm	3
		Diagnostics for the configuration			
M561	Display overshoot	Check scaling	M	Warning	7

9.2.1 HART® diagnostic messages

ℹ️ If several errors are present at the same time the device always displays the error with the highest priority.

1 = highest priority

Diagnostic number	Short text	Corrective measure	Status signal	Diagnostic behavior	Priority
F960	HART® communication (slave not responding)	• Verify HART slave address • Check electrical wiring (HART®) • Check HART® function sensor/actor	F	Alarm	8
C970	Multi-master collision	• Check additional master in HART network (e.g. handheld) • Check master setting (secondary/primary)	C	Check	9
F911	HART® slave device error (HART® Field Device Status)	Check sensor/actor configuration or check for defects	F	Alarm	10
S913	HART® slave current output saturated (HART Field Device Status)	• Commissioning: Check sensor/actor for incorrect configuration, check sensor/actor configuration • Operation: Process parameter outside valid range	S	Warning	11
S915	HART® slave variable outside limits of range (HART® Field Device Status)		S	Warning	12

9.2.2 Other diagnostics in the HART® mode

The process display unit has an integrated HART® diagnostics function. This function can be used to estimate the HART® signal level, the applicable communication resistance, and the noise of the network.

The display unit can measure and display the following values:

Parameter	Description	Display	
Tx mV	Process display unit signal level	mV	Peak-to-peak level of the transmission signal
Rx mV	Slave signal level	mV	Peak-to-peak level of the received signal
NOISE	Weighting of the interference signal	LO / MED / HI	Categorization of the interference into low, medium or high
Rc Ω	Effective communication resistance	Ω	Resistance in Ohm

The values can be called up in the EXPRT – DIAG – HLEVL menu.

Measuring the transmission signal level "Tx":

The Tx measurement can be used to assess the signal level of the transmission signal.

Ideally this should be between 200 mV and 800 mV . The following values are displayed:

Tx	< 120 mV	120 to 200 mV	200 to 800 mV	800 to 850 mV	> 850 mV
Display	LO	Level in mV			HI
Bargraph	<	<	0 to 100 %	>	>

Measuring the received signal level "Rx":

The Rx measurement can be used to assess the signal level of the received signal. Ideally this should be between 200 mV and 800 mV .

The Rx signal value that is displayed is a filtered signal level as assessed by the process display unit. In this way, the value measured externally and the displayed value can differ from one another, for example in the case of a trapezoidal received signal.

The following values are displayed:

Rx	< 120 mV	120 to 200 mV	200 to 800 mV	800 to 850 mV	> 850 mV
Display	LO		Level value in mV		HI
Bargraph	<	<	0 to 100 %	>	>

Measuring the "NOISE" interference signal:

When the interference signal level is measured, the interference signal determined is divided into three categories:

LO = low

MED = medium

HIGH = high

The noise measurement is also a filtered signal level as assessed by the process display unit. The value measured externally and the displayed value can therefore differ from one another, depending on the frequency and the form of the signal.

ℹ️ With low wanted signal levels (Rx, Tx), transmission errors can occur even if the interference signal level is low ("LO" displayed).

Measuring the communication resistance "Rc":

The "Rc" measurement can be used to determine the network resistance of the HART® network. Ideally this should be between 230 Ω and 600 Ω .

ℹ️ The network resistance is the sum of the HART® communication resistance, the device's input resistance, the transmission line resistance and line capacitance.

The following values are displayed:

Rc	< 100 Ω	100 to 230 Ω	230 to 600 Ω	600 to 1 000 Ω	> 1 000 Ω
Display	LO		Resistance in Ω		HI
Bargraph	<	<	0 to 100 %	>	>

9.3   Spare parts
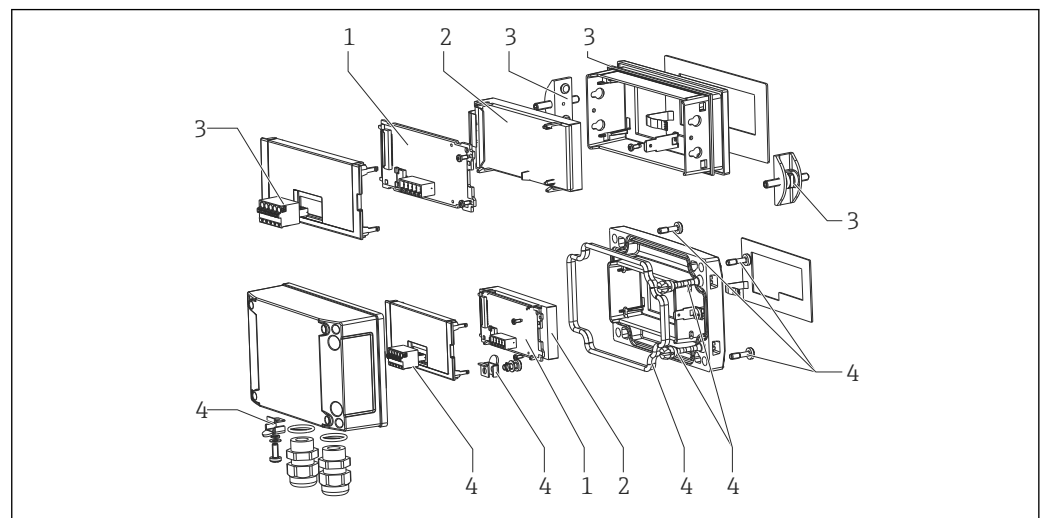
🖼 *14   Spare parts of the process display unit*

Item No.	Designation	Order number
1	Mainboard HART®	XPR0005-ABA
2	LCD module	XPR0006-A1
3	Small parts set for panel-mount housing (5-pin plug-in terminal, seal on front frame, 2x fastening clip)	XPR0006-A2
4	Small parts set for field housing (5-pin plug-in terminal, seal on cover, 2x cover hinge, grounding connection on bottom, cover screws, grounding lug)	XPR0006-A3

9.4 Software history and overview of compatibility

Release

The firmware version on the nameplate and in the Operating Instructions indicates the device release: XX.YY.ZZ (example 1.02.01).

XX Change to main version.
     No longer compatible. The device and Operating Instructions change.

YY Change to functions and operation.
     Compatible. The Operating Instructions change.

ZZ Fixes and internal changes.
     No changes to the Operating Instructions.

Date	Firmware Version	Software changes	Documentation
11/2012	1.00.01	Original software	Analog: BA01073K/09/EN/02.13
03/2013	1.01.00	HART option	Analog: BA01073K/09/EN/03.13 HART: BA01170K/09/EN/02.13
07/2013	1.02.00	HART level measurement	Analog: BA01073K/09/EN/04.13 HART: BA01170K/09/EN/03.13
11/2014	1.03.00	New parameter EXP1-EXP4 for HART option	Analog: BA01073K/09/EN/05.14 HART: BA01170K/09/EN/04.14

10   Maintenance

No special maintenance work is required on the device.

11   Return

The measuring device must be returned if repairs or a factory calibration are required, or if the wrong measuring device has been ordered or delivered. According to legal regulations, Endress+Hauser, as an ISO-certified company, is required to follow certain procedures when handling returned products that are in contact with medium.

To ensure swift, safe and professional device returns, please read the return procedures and conditions on the Endress+Hauser website at
www.services.endress.com/return-material

12   Disposal

The device contains electronic components and must therefore be disposed of as electronic waste. Comply with local disposal regulations.

13   Technical data

13.1   Input

Voltage drop	
Standard device with 4 to 20 mA communication	≤ 1.0 V
Device with HART® communication	≤ 1.9 V
Display lighting	additionally 2.9 V

HART® input impedance
Rx = 40 kΩ
Cx = 2.3 nF

Measured variable	The input variable is either the 4 to 20 mA current signal or the HART® signal. HART® signals are not affected.
Measuring range	4 to 20 mA (scalable, reverse polarity protection) Max. input current 200 mA

13.2   Power supply

Supply voltage	The display unit is loop-powered and does not require any external power supply. The voltage drop is ≤1 V in the standard version with 4 to 20 mA communication, ≤1.9 V with HART® communication and an additional 2.9 V if display lighting is used.

13.3   Performance characteristics

Reference operating conditions	Reference temperature 25 ℃±5 ℃ (77 ℉±9 ℉) Humidity 20 to 60 % relative humidity

Maximum measured error	Input	Range	Measured error of measuring range
	Current	4 to 20 mA Over range up to 22 mA	±0.1 %

Resolution	Signal resolution > 13 bit
Influence of ambient temperature	< 0.02 %/K (0.01 %/℉) of measuring range
Warm-up period	10 minutes

13.4   Installation

Mounting location	**Panel housing**

Panel housing

The device is designed for use in a panel.

Required panel cutout 45x92 mm (1.77x3.62 in)

Field housing

The field housing version is designed for use in the field. The unit is mounted directly on a wall, or on a pipe with a diameter of up to 2 " with the aid of an optional mounting bracket. An optional weather protection cover protects the device from the effects of weather conditions.

Orientation   **Panel housing**

The orientation is horizontal.

Field housing

The device must be mounted in such a way that the cable entries point downwards.

13.5   Environment

Ambient temperature range   –40 to 60 °C (–40 to 140 °F)

> At temperatures below –25 °C (–13 °F) the readability of the display can no longer be guaranteed.

Storage temperature   –40 to 85 °C (–40 to 185 °F)

Climate class   IEC 60654-1, Class B2

Altitude   Up to 5 000 m (16 400 ft) above MSL in accordance with IEC61010-1

Degree of protection   **Panel housing**

IP65 at front, IP20 at rear

Field housing

IP66, NEMA4x (aluminum housing)

Electromagnetic compatibility
- Interference immunity:
  As per IEC61326 (Industrial Environments) / NAMUR NE 21
  Maximum measured error < 1 % of MR
- Interference emission:
  As per IEC61326, Class B

Electrical safety   Class III, overvoltage protection category II, pollution degree 2

13.6   Mechanical construction

Design, dimensions   **Panel-mount housing**
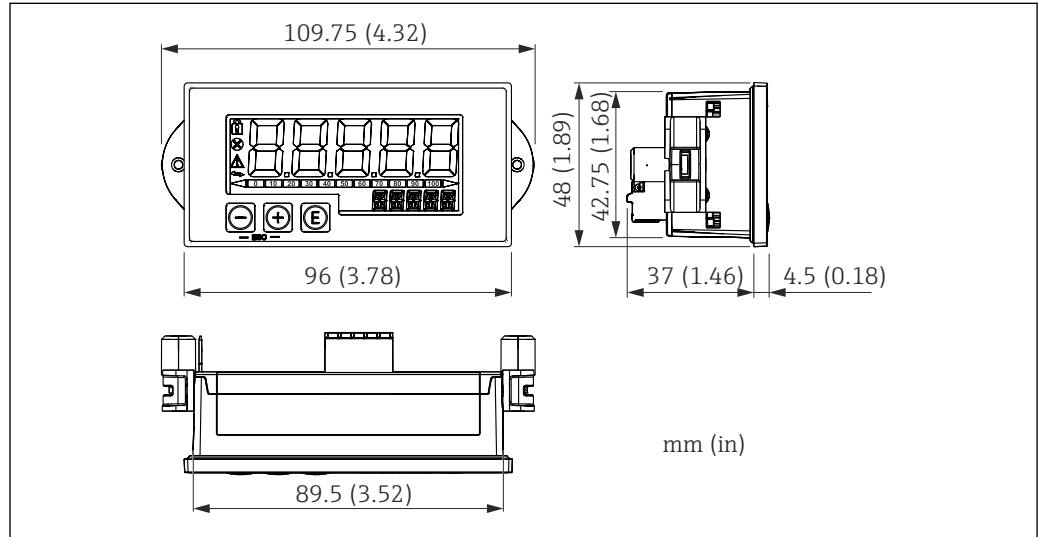
15   Dimensions of the panel housing

Required panel cutout 45x92 mm (1.77x3.62 in), max. panel thickness 13 mm (0.51 in).

Field housing
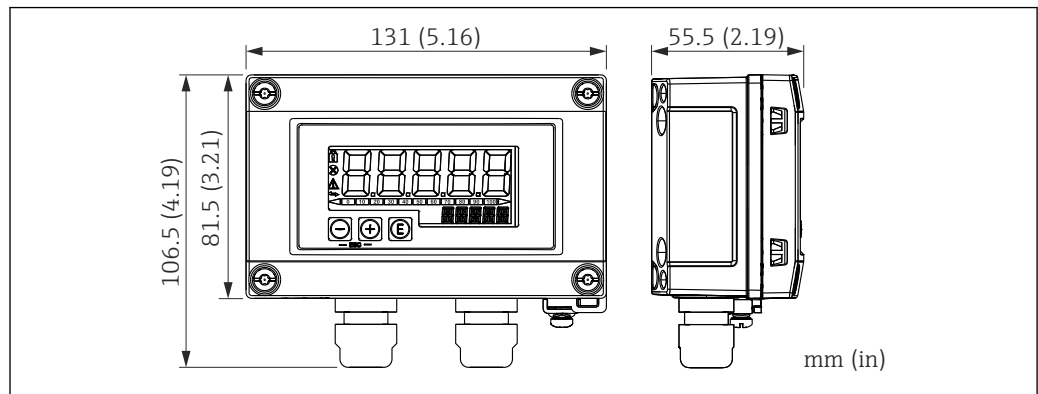
16   Dimensions of the field housing incl. cable glands (M16)

Weight   **Panel-mount housing**

115 g (0.25 lb.)

Field housing
- Aluminum: 520 g (1.15 lb)
- Plastic: 300 g (0.66 lb)

Materials   **Panel-mount housing**

Front: aluminum

Rear panel: polycarbonate PC

Field housing

Aluminum or plastic (PBT with steel fibers, antistatic)

13.7   Operability

| Local operation | The device is operated with the 3 operating keys on the front of the housing. The device setup can be disabled with a 4-digit user code. If the setup is disabled, a padlock symbol appears on the display when an operating parameter is selected. |

ⒺE A0017716	Enter key; calling up the operating menu, confirming the option/setting parameters in the operating menu
⊖ A0017714	Selecting and setting values in the operating menu; pressing the - and + keys simultaneously takes the user back up a menu level. The configured value is not saved (ESC)
⊕ A0017715	

13.8   Certificates and approvals

CE mark	The measuring system meets the legal requirements of the EU Directives. Endress+Hauser confirms that the device has been successfully tested by applying the CE mark.

Ex approval	Information about currently available Ex versions (ATEX, FM, CSA, etc.) can be supplied by your E+H Sales Center on request. All explosion protection data are given in a separate documentation which is available upon request.

Functional safety	SIL interference freeness according to EN61508 (optional)

Marine approval	GL marine approval (optional)
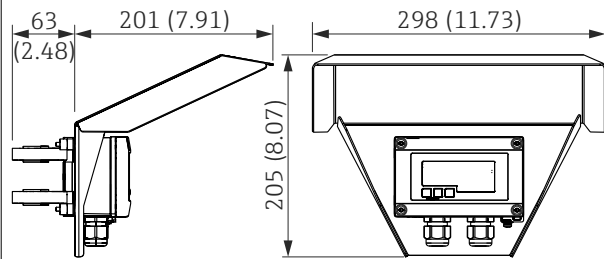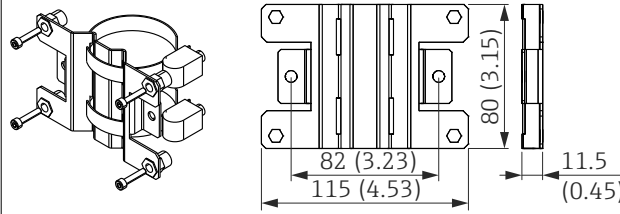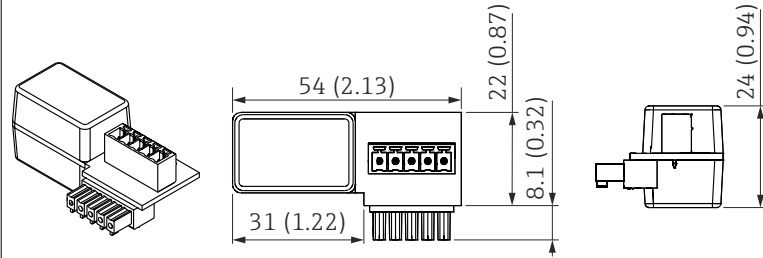
HART® communication	The display unit is registered by the HART® Communication Foundation. The device meets the requirements of the HART® Communication Protocol Specifications, May 2008, Revision 7.1. This version is downwards compatible with all sensors/actuators with HART® versions ≥ 5.0.

Other standards and guidelines	• IEC 60529: Degrees of protection provided by enclosures (IP code) • IEC 61010-1: 2010 cor 2011 Safety requirements for electrical equipment for measurement, control and laboratory use • IEC 61326 series: Electromagnetic compatibility (EMC requirements) • NAMUR NE21, NE43 Association for Standards for Control and Regulation in the Chemical Industry

13.9 Accessories

Various accessories, which can be ordered with the device or subsequently from Endress +Hauser, are available for the device. Detailed information on the order code in question is available from your local Endress+Hauser sales center or on the product page of the Endress+Hauser website: www.endress.com.

Device-specific accessories	Protective cover	
		17 Dimensions of the protective cover, dimension unit mm (in)
	Mounting kit for wall/ pipe mounting	
		18 Dimensions of the mounting bracket, dimension unit mm (in)
	HART® communication resistance module	
		19 Dimensions of the communication resistance module, dimension unit mm (in)

14   HART® communication

HART® (Highway Addressable Remote Transducer) is a well-established industry standard worldwide that has been tried and tested in the field and has an installed base of over 14 million devices.

HART® is a "smart" technology which enables 4 to 20 mA analog transmission and digital communication simultaneously on the same two wires. The HART® protocol is based on the Bell 202 Frequency Shift Keying standard (FSK). A high-frequency wave (±0.5 mA) is superimposed on the low-frequency analog signal (4 to 20 mA). Maximum transmission distances depend on the network structure and ambient conditions.

In many applications, the HART® signal is only used for configuration. However, using the appropriate tools, HART® can be used for device monitoring, device diagnostics and recording multivariable process information.

The HART® communication protocol operates on the principle of master/slave. This means that each communication activity is initiated by the master during normal operation. Unlike other master/slave communication types, HART® allows two masters in one loop/network: a primary master, e.g. the control system, and a secondary master, e.g. a handheld terminal. However, two masters of the same type are not permitted simultaneously. Secondary master devices can be used without affecting communication to and from the primary master. The field devices are generally the HART® slaves and respond to HART® commands from the master sent directly to them or to other devices.

The HART® specification defines that master devices send voltage signals, while the sensors/actors (slaves) convey their messages using load-independent currents. The current signals are converted to voltage signals at the internal resistance of the receiver (at its load).

To ensure reliable signal reception, the HART® protocol specifies the total load of the current loop - including the cable resistance - to be between minimum 230 Ω and maximum 600 Ω. If the resistance is less than 230 Ω, the digital signal is extremely damped or short-circuited. HART® communication resistance is thus always required in the 4 to 20 mA cable for a low-impedance supply.

14.1   HART® protocol command classes

Each command is assigned to one of the following three classes:
- Universal commands
  supported by all devices using the HART® protocol (e.g. device designation, firmware no. etc.)
- Standard commands (common practice commands)
  Offer functions which are supported by many but not by all HART® instruments (e.g. read out value, parameter configuration etc.)
- Device specific commands
  Provide access to device data which are not HART® standard but rather unique to a particular device type (e.g. linearization, extended diagnostic functions)

The HART® protocol is an open communication protocol which interfaces the master device with the field device and can be implemented by any manufacturer and freely employed by the user. The required technical support is provided by the HART® Communication Foundation (HCF).

14.2   HART® commands used

The process display unit uses the following HART® universal commands:

Universal command number	Response data used
0 Device unique identifier	The device identifier provides information on the device and manufacturer; it cannot be changed. The response comprises a 12-byte device identifier. The following bytes are used by the process display unit: • Byte 0: Fixed value 254 • Byte 2: Device type ID, for slave addressing with long address form • Byte 3: Number of preambles • Byte 9-11: Device identification, for slave addressing with long address form
2 Read the primary process variable as current in mA and percentage of current range	The response comprises 8 bytes: • Byte 0-3: Current in mA • Byte 4-7: Percentage value
3 Read the primary process variable as current in mA and four dynamic process variables	The response comprises 24 bytes: The following bytes are used by the process display unit: • Byte 4: HART® unit code of the primary process variable • Byte 5-8: Primary process variable • Byte 9: HART® unit code of the secondary process variable • Byte 10-13: Secondary process variable • Byte 14: HART® unit code of the third process variable • Byte 15-18: Third process variable • Byte 19: HART® unit code of the fourth process variable • Byte 20-23: Fourth process variable

The universal commands used by the process display unit must be supported by the slaves to ensure proper communication.

14.3   Field device status

The field device status is contained in the second data byte of a slave/actor response.

The following bits are analyzed by the process indicator and displayed as a diagnostic message:

Bit mask	Definition	Used in the process display unit
0x80	Device error function – The device has detected a serious error or an error function which affects the operation of the device.	Diagnostic F911
0x40	Configuration changed – A function was executed which has changed the device configuration.	No
0x20	Cold start – The supply voltage has failed or the device has been reset.	No
0x10	Additional status available – Additional status information is available via command #48.	No
0x08	Loop current is fixed – The loop current is maintained at a fixed value and does not react to changes in the process.	No
0x04	Loop current saturated – The loop current has reached its upper (or lower) limit point and cannot increase (decrease) further.	Diagnostic S913
0x02	HART slave variable out of range.	Diagnostic S915

14.4   Supported units

The process display unit can be configured in such a way that the unit code which is sent from the slave in response to the universal command no. 3, is displayed as text, as listed in the following table (HCF-SPEC 183).

However, since the field available for the unit is limited in the process indicator to a 5-digit, 14-segment display, it is not possible to display all units completely. Therefore, some units are displayed as unit codes in the form of UCxxx, where xxx is the unit code number.

In addition, the operating parameter TEXT can be used to create and display an individual unit text.

Unit code	Description	Display text
1	Inches of water at 68 ℉	inH2O
2	Inches of mercury at 0 ℃	inHG
3	Feet of water at 68 ℉	FTH2O
4	Millimeters of water at 68 ℉	mmH2O
5	Millmeters of mercury at 0 ℃	mmHG
6	Pounds per square inch	PSI
7	Bar	BAR
8	Millibars	mBAR
9	Grams per square centimeter	g/cm2
10	Kilograms per square centimeter	UC010
11	Pascals	Pa
12	Kilopascals	kPa
13	Torr	TORR
14	Atmospheres	ATM
15	Cubic feet per minute	UC015
16	Gallons per minute	UC016
17	Liters per minute	l/min
18	Imperial gallons per minute	UC018
19	Cubic meters per hour	m3/h
20	Feet per second	FT/S
21	Meters per second	m/S
22	Gallons per second	gal/S
23	Million gallons per day	MGD
24	Liters per second	l/S
25	Million liters per day	MLD
26	Cubic feet per second	FT3/S
27	Cubic feet per day	FT3/d
28	Cubic meters per second	m3/S
29	Cubic meters per day	m3/d
30	Imperial gallons per hour	UC030
31	Imperial gallons per day	UC031
32	Degrees Celsius	℃
33	Degrees Fahrenheit	℉
34	Degrees Rankine	℟

Unit code	Description	Display text
35	Kelvin	K
36	Millivolts	mV
37	Ohm	Ohm
38	Hertz	HZ
39	Milliamperes	mA
40	Gallons	gal
41	LITER	LITER
42	Imperial gallons	Igal
43	Cubic meters	m3
44	Feet	FEET
45	Meters	METER
46	Barrels	bbl
47	Inches	inch
48	Centimeters	cm
49	Millimeters	mm
50	minutes	min
51	Seconds	SEC
52	Hours	HOUR
53	Days	DAY
54	Centistokes	cST
55	Centipoises	cP
56	Microsiemens	uS
57	Percent	%
58	Volts	VOLT
59	pH	PH
60	Grams	g
61	Kilograms	Kg
62	Metric tons	T
63	Pounds	lb
64	American tons	TN SH
65	British tons	TN L
66	Millisiemens per centimeter	mS/cm
67	Microsiemens per centimeter	uS/cm
68	Newton	N
69	Newton meters	Nm
70	Grams per second	g/S
71	Grams per minute	g/min
72	Grams per hour	g/h
73	Kilograms per second	Kg/S
74	Kilograms per minute	Kg/mi
75	Kilograms per hour	Kg/h
76	Kilograms per day	Kg/d
77	Metric tons per minute	T/min

Unit code	Description	Display text
78	Metric tons per hour	T/h
79	Metric tons per day	T/d
80	Pounds per second	lb/S
81	Pounds per minute	lb/mi
82	Pounds per hour	lb/h
83	Pounds per day	lb/d
84	American tons per minute	TnS/m
85	American tons per hour	TnS/h
86	American tons per day	TnS/d
87	British tons per hour	Tnl/h
88	British tons per day	Tnl/d
89	Deka therm	dTh
90	Specific gravity units	UC090
91	Grams per cubic centimeter	g/cm3
92	Kilograms per cubic meter	Kg/m3
93	Pounds per gallon	lb/ga
94	Pounds per cubic feet	lb/F3
95	Grams per milliliter	g/ml
96	Kilograms per liter	Kg/l
97	Grams per liter	g/l
98	Pounds per cubic inch	lb/ci
99	American tons per cubic yard	UC099
100	Degrees Twaddell	°Tw
101	Degrees Brix	°BX
102	Degrees Baumé heavy	UC102
103	Degrees Baumé light	UC103
104	Degrees API	°API
105	Percent solids per weight	%wT
106	Percent solids per volume	%VOL
107	Degrees Balling	°bal
108	Proof per volume	P/VOL
109	Proof per mass	P/maS
110	Bushels	bSh
111	Cubic yards	YARD3
112	Cubic feet	FEET3
113	Cubic inches	inch3
114	Inches per second	in/S
115	Inches per minute	in/mi
116	Feet per minute	F/min
117	Degrees per second	DEG/S
118	Revolutions per second	RPS
119	Revolutions per minute	RPM
120	Meters per hour	m/h

Unit code	Description	Display text
121	Normal cubic meters per hour	Nm3/h
122	Normal liters per hour	Nl/h
123	Normal cubic feet per minute	F3/mi
124	Barrel liquid (1 barrel = 31.5 U.S. gallons)	UC124
125	Ounces	ouncE
126	Foot Pound Force	FTLBF
127	Kilowatts	kW
128	Kilowatt hours	kWh
129	Horse power	HP
130	Cubic feet per hour	FT3/h
131	Cubic meters per minute	m3/mi
132	Barrels per second	bbl/S
133	Barrels per minute	bbl/m
134	Barrels per hour	bbl/h
135	Barrels per day	bbl/d
136	Gallons per hour	gal/h
137	Imperial gallons per second	UC137
138	Liters per hour	l/h
139	Parts per million	PPm
140	Mega calories per hour	UC140
141	Mega joules per hour	mJ/h
142	British Thermal Units per hour	Btu/h
143	Degrees	DEG
144	Radian	rad
145	Millimeters of water at 60 ℉	inH2O
146	Micrograms per liter	ug/l
147	Micrograms per cubic meter	ug/m3
148	Percent consistency	%con
149	Volume percent	VOL%
150	Percent steam quality	%SQ
151	Feet inch sixteenths	UC151
152	Cubic feet per pound	F3/lb
153	Picofarads	PF
154	Milliliters per liter	ml/l
155	Microliters per liter	ul/l
156-159	Unit Code Expansion Tables	UC156 - UC159
160	Percent Plato	%P
161	Percent lower explosion level	%LEL
162	Mega calories	Mcal
163	Kilo ohms	KOHM
164	Mega joules	MJ
165	British Thermal Unit	BTU

Unit code	Description	Display text
166	Normal cubic meters per hour	Nm3/h
167	Normal liters	Nl
168	Normal cubic feet	SCF
169	Parts per billion	PPb
170 - 219	Unit Code Expansion Tables	UC170 - UC219
220 - 234	not defined	UC220 - UC234
235	Gallons per day	gal/d
236	Hectoliters	hl
237	Megapascals	MPa
238	Inches of water at 4 ℃	inH2O
239	Millimeters of water 4 ℃	mmH2O
240 - 249	Manufacturer-specific	UC240 - UC249
250	Not used	-----
251	None	
252	Unknown	UC252
253	Special	UC253

14.5   HART® protocol connection types

The HART protocol can be used for point-to-point or multidrop connections:

Point-to-point (TYPICAL)

In point-to-point mode, the HART® master is connected with exactly one HART® slave.

A point-to-point connection should always be the preferred option where possible.

Multidrop (measurement not by current, slower)

In multidrop mode, several HART® devices are incorporated in a single current loop. Analog signal transmission is disabled in this case and data and measured values are exchanged exclusively via the HART® protocol. The current output of each connected device is set to a fixed value of 4 mA and is only used to supply current to two-wire devices.

Several sensors/actors can be connected in parallel to one wire pair in multidrop mode. The master then differentiates between devices based on the configured addresses. Each device must have a different address. If more than 7 sensors/actors are connected in parallel an increased voltage drop occurs.

The loop must not include a mixture of devices with an active current output (e.g. four-wire devices) and devices with a passive current output (e.g. two-wire devices).

The HART® protocol is immune to interference. This means that, during operation, communication devices can be connected or removed without putting components of the other devices at risk or interrupting their communication.

14.6   Device variables for multivariable devices

Multivariable measuring devices can transmit up to four device variables via HART®: the Primary Variable (PV), Secondary Variable (SV), Tertiary Variable (TV) and Quaternary Variable (QV).

Below you will find some examples of what default values can be set for these variables for various sensors/actors:

Flowmeter, e.g. Promass:

- Primary process variable (PV) -> Mass flow
- Secondary process variable (SV) -> Totalizer 1
- Third process variable (TV) -> Density
- Fourth process variable (QV) -> Temperature

Temperature transmitter, e.g. TMT82:

- Primary process variable (PV) -> Sensor 1
- Secondary process variable (SV) -> Device temperature
- Third process variable (TV) -> Sensor 1
- Fourth process variable (QV) -> Sensor 1

For a level measuring device such as the Levelflex FMP5x, these four values can be as follows:

Level measurement:
- Primary process variable (PV) → Level linearized
- Secondary process variable (SV) → Distance
- Third process variable (TV) → Absolute echo amplitude
- Fourth process variable (QV) → Relative echo amplitude

Interface measurement:
- Primary process variable (PV) → Interface
- Secondary process variable (SV) → Level linearized
- Third process variable (TV) → Upper interface thickness
- Fourth process variable (QV) → Relative interface amplitude

HART® actor, e.g. positioner:

- Primary process variable (PV) -> Actuating value
- Secondary process variable (SV) -> Valve set point
- Third process variable (TV) -> Target position
- Fourth process variable (QV) -> Valve position

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