SIEMENS

SIMATIC

ET 200SP HA
AQ 8xI HART HA

Equipment Manual

6DL1135-6TF00-0PH1
6DL1135-6TF00-0EH1

10/2021
A5E39401849-AD

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

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⚠ WARNING

indicates that death or severe personal injury **may** result if proper precautions are not taken.

⚠ CAUTION

indicates that minor personal injury can result if proper precautions are not taken.

NOTICE

indicates that property damage can result if proper precautions are not taken.

If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

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The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

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We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

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Security information

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Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

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Preface

Validity of the documentation

This equipment manual describes the following I/O modules:

System family	I/O module	Article No.
SIMATIC Distributed I/O System ET 200SP HA	AQ 8xI HART HA	6DL1135-6TF00-0PH1
SIMATIC Distributed I/O System ET 200SP HA	AQ 8xI HART HA	6DL1135-6TF00-0EH1

It supplements the system manual ET 200SP HA distributed I/O system.

Functions that generally relate to the system are described in this manual.

The information provided in this manual and in the system/function manuals supports you in commissioning the ET 200SP HA.

Conventions

Please also observe notes marked as follows:

Note

A note contains important information on the product described in the documentation, on the handling of the product and on the section of the documentation to which particular attention should be paid.

2D Matrix code (QR code / EAN code)

3

The 2D matrix code on the product is a coded representation of the product-specific article number.

Access to product-related information

For reading the 2D matrix code, SIEMENS offers an app for mobile use.
Information about the app and the download can be found on the Internet: "Mobile use via app (https://support.industry.siemens.com/cs/ww/en/sc/2067)".

The app provides direct access to the technical forum and product-related posts, such as:

- FAQs
- Application examples
- Manuals
- Certificates
- Product notices

Product overview

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4.1 I/O module

Definition

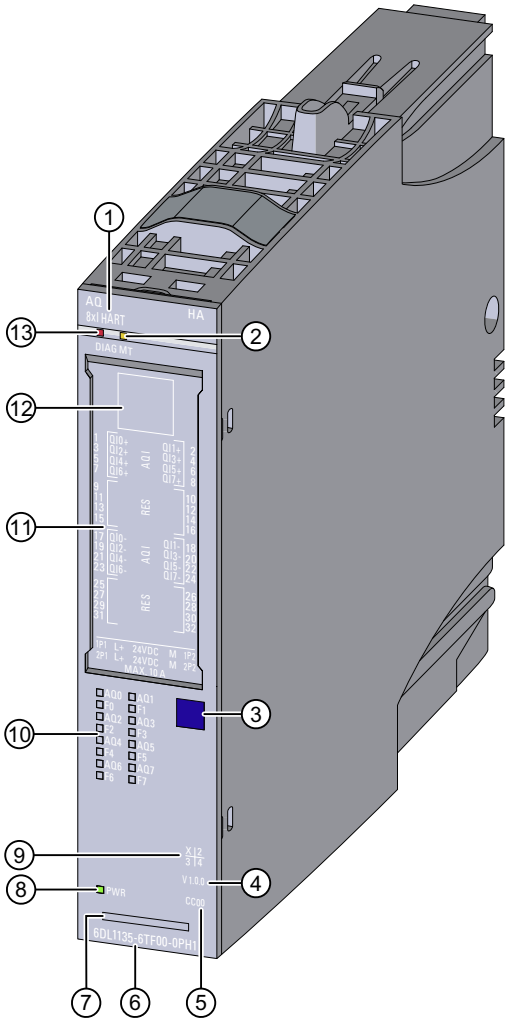
The AQ 8xI HART HA I/O module is an analog output module with 8 current outputs for process control.

In addition to the technical specifications, this module has the following properties:

- HART communication (Rev. 5 to Rev. 7)
- Up to 8 HART variables directly in the input range
- A multiHART range in the input/output range

Description

The I/O module consists of the following components:



① Module type and designation
② LED for maintenance
③ Module type color coding
④ Function status and firmware version
⑤ Color code for selection of the color-coded labels
⑥ Article No.
⑦ Serial number
⑧ LED for supply voltage
⑨ Product version
⑩ LEDs for channel status/channel fault
⑪ Wiring diagram
⑫ 2D matrix code
⑬ LED for diagnostics

4.2 Accessories

Definition

Accessories for the I/O module must be ordered separately.

Description

The following accessories are available:

- Labeling strips
- Color-coded labels
- Reference identification label
- Shield connector
- Terminal blocks

4.3 Terminal blocks

Definition

The terminal blocks provide the process terminals (push-in terminals) for components such as devices to be connected.

Description

The following terminal blocks are available for the I/O module:

Article number	Color	Description
6DL1193-6TP00-0DH1	Lit	
6DL1193-6TP00-0BH1	Dark	
6DL1193-6TP00-0DM1	Lit	For redundant configuration
6DL1193-6TP00-0BM1	Dark	For redundant configuration
6DL1193-6TP00-0DN0	Lit	With additional potential distributors for ground connection of the actuators
6DL1193-6TP00-0BN0	Dark	With additional potential distributors for ground connection of the actuators

Note

Terminal blocks are not included in the scope of delivery of the I/O module and must be ordered separately.

You can find additional information on the configuration in the system manual.

Terminal

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5.1 Terminal assignment

Definition

The pin assignment provides information about the arrangement and marking of the connections when wiring the terminal block.

Description

The pin assignment is structured as follows:

Terminal	Assignment	Terminal	Assignment
1	QI_0+	**2**	QI_1+
3	QI_2+	**4**	QI_3+
5	QI_4+	**6**	QI_5+
7	QI_6+	**8**	QI_7+
9	-	**10**	-
11	-	**12**	-
13	-	**14**	-
15	-	**16**	-
17	QI_0-	**18**	QI_1-
19	QI_2-	**20**	QI_3-
21	QI_4-	**22**	QI_5-
23	QI_6-	**24**	QI_7-
25	-	**26**	-
27	-	**28**	-
29	-	**30**	-
31	-	**32**	-
1P1	L+	**1P2**	M
2P1[1]	L+	**2P2**	M

Terminal 1 to 8:

QI_n+: Output signal "+", channel n

Terminal 17 to 24:

QI_n-: Output signal "-", channel n

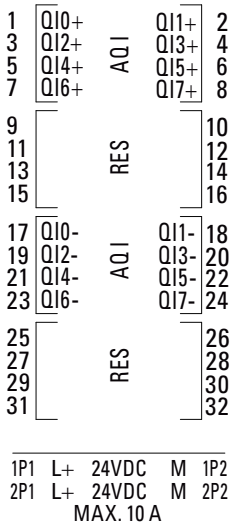
Terminal 25 to 32:
not assigned

1P1: Supply voltage L+ of the voltage bus 1P

2P1: Supply voltage L+ of the voltage bus 2P

1P2: Ground reference of the voltage bus 1P

2P2: Ground reference of the voltage bus 2P



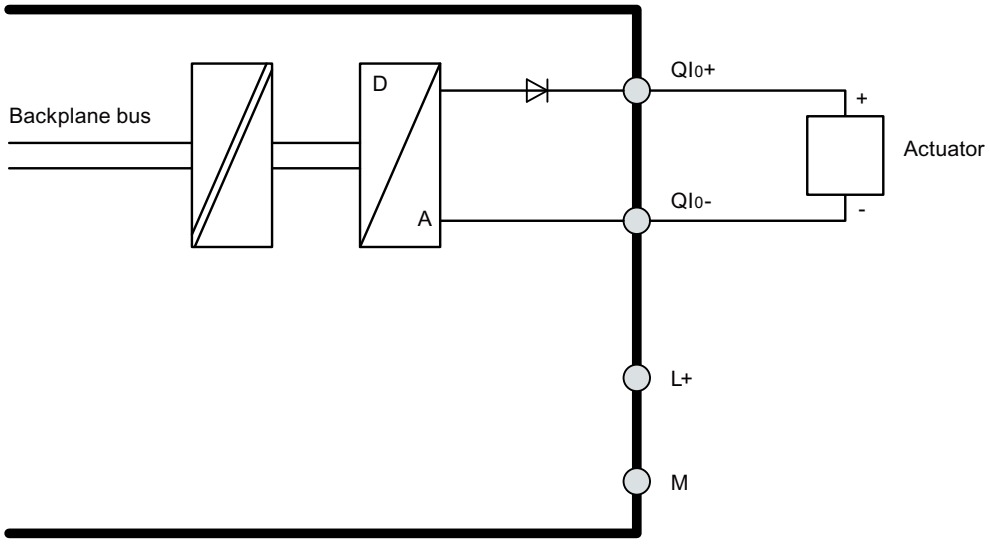
[1] If the module is plugged into a TB45R-P32 terminal block suitable for IO redundancy, the potential at this terminal is 1P3.

5.2 Wiring diagram for actuators

Example

The wiring diagram shows an example actuator connection.

The following view shows an example of an actuator connection to channel 0.

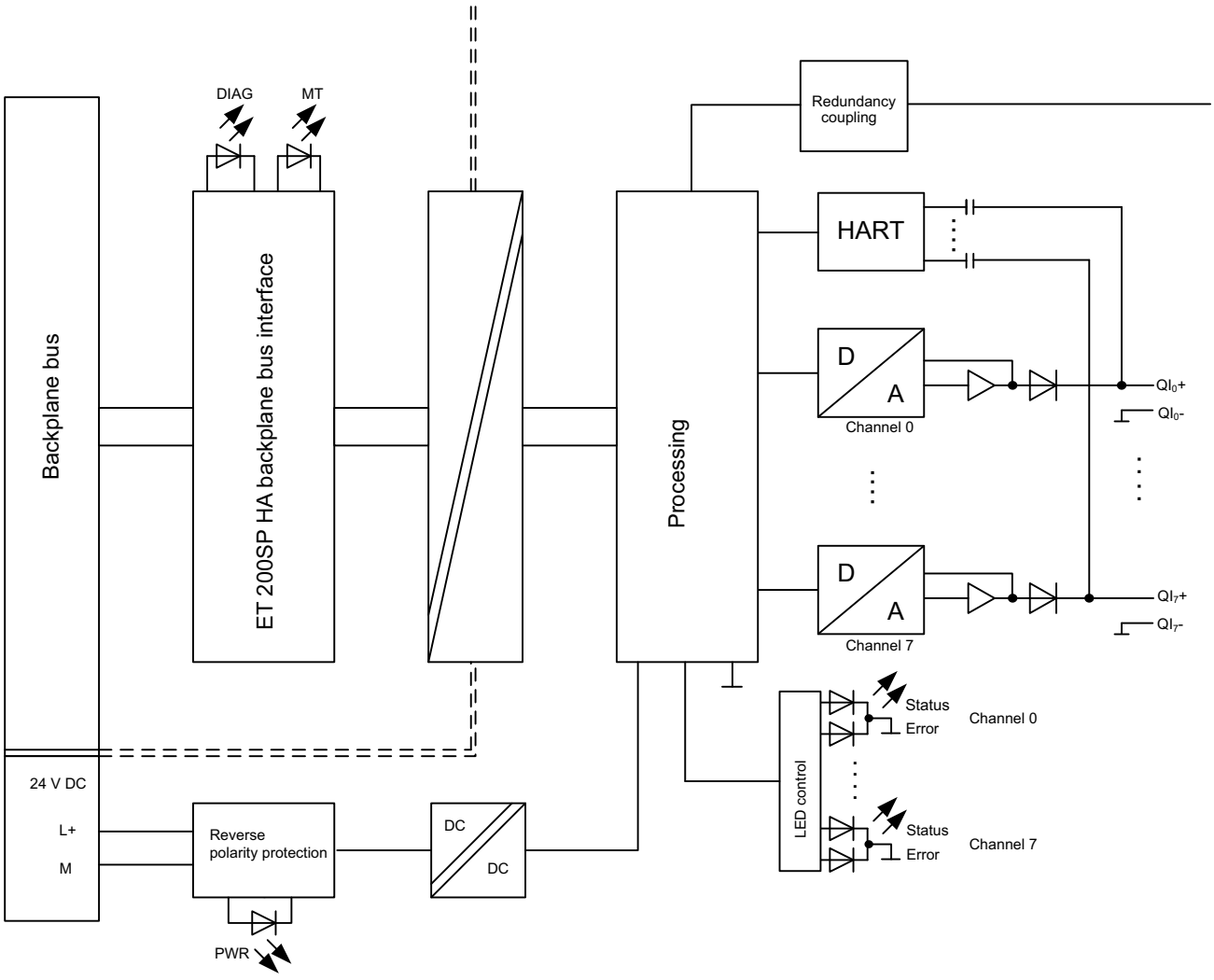


5.3 Schematic circuit diagram

Definition

A block diagram contains the schematic representation of individual function blocks.

Description



Supply voltage L+/M

Connect the supply voltage L+ to the connections L+ and M. An internal protective circuit protects the module against polarity reversal. The I/O module monitors whether the supply voltage is connected and present.

Firmware update

The supply voltage L+ must be applied to the I/O module at the start of a firmware update and during the firmware update.

Parameters

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6.1 Configuration options

Definition

The selected configuration determines the scope of the input and output address areas that are used in the I/O system.

Description

The following configurations are possible, with value status in each case:

- without HART variables in the input address area
- with 8 HART variables in the input address area
- with one multiHART range in the input/output address area

Note

Direct re-assignment of parameters of the I/O module to another of the listed configurations is not possible in the RUN of the CPU. For this, in a first step you have to remove the I/O module in the RUN of the CPU and in a further step add the I/O module with new configuration in the RUN of the CPU. Please note that this might change the I/O address area.

6.2 Parameter types

Definition

You define operation of the I/O module and thereby influence the functions supported by the module via the parameter types.

Description

The parameters are divided into three types:

- Module/channel parameters (data record 128)
- Parameters which determine the display of HART variables in the address space of the module; HART mapping parameters (data record 130)
- System parameters (potential group, IO redundancy)

Note

With the exception of parameter assignment of the potential group, all parameters can be changed when the CPU is in RUN.

6.3 Module/channel parameters

Definition

Module/channel parameters are specific parameters whose configuration can affect the entire module or channels.

Description

The following module/channel parameters are available:

Parameters	Value range	Default	Parameter re-assignment in RUN	Efficiency range
Output type/range (Page 23)	• Disabled • Current 0 to 10 mA • Current 0 to 20 mA • Current 4 to 20 mA • Current 4 to 20 mA HART	Current 4 to 20 mA HART	Yes	Channel
Diagnostics, Missing supply voltage L+ (Page 25)	• Enabled • Disabled	Enabled	Yes	Module
Diagnostics overflow (Page 25)	• Enabled • Disabled	Enabled	Yes	Channel
Diagnostics underflow (Page 26)	• Enabled • Disabled	Enabled	Yes	Channel
Diagnostics short-circuit (Page 25)	• Enabled • Disabled	Enabled	Yes	Channel
Diagnostics, Wire break (Page 25)	• Enabled • Disabled	Enabled	Yes	Channel
Diagnostics HART (Page 26)	• Enabled • Disabled	Enabled	Yes	Channel
Number of HART repetitions (Page 26)	0...10	5	Yes	Channel
Reaction to CPU STOP (Page 26)	• Switch off • Keep last value • Output substitute value	Switch off	Yes	Channel

Parameters	Value range	Default	Parameter re-assignment in RUN	Efficiency range
Substitute value (Page 26)	The value range depends on the set output range. The substitute value must be in the nominal range or in the overrange/underrange.	0	Yes	Channel
IO redundancy (Page 27)	• None • 2 modules	None	Yes	Module
Potential group (Page 27)	• Potential group of the left module (dark gray terminal block) • New potential group (light gray terminal block) • No potential group (black terminal block)	Use potential group of the left module	No	Module

6.4 Explanation of the module/channel parameters

6.4.1 Output type/range

Definition

The output type is used to disable a channel or enable it as a current output.

You can choose between different output areas with an active channel.

Note

Unused channels

Disable unused channels in the configuration to improve the cycle time of the module.

A deactivated channel always returns the output value 0 mA.

An overview of the output range, overflow and overrange etc. can be found in the analog value representation.

Representation of analog values in the current output ranges (Page 83)

Configuration

The I/O module has the following output ranges:

Type of output	Output range	Resolution
Disabled	-	-
Current	0 to 10 mA	15 bits
Current	0 to 20 mA	15 bits

Current	4 to 20 mA	15 bits
Current	4 to 20 mA HART	15 bits

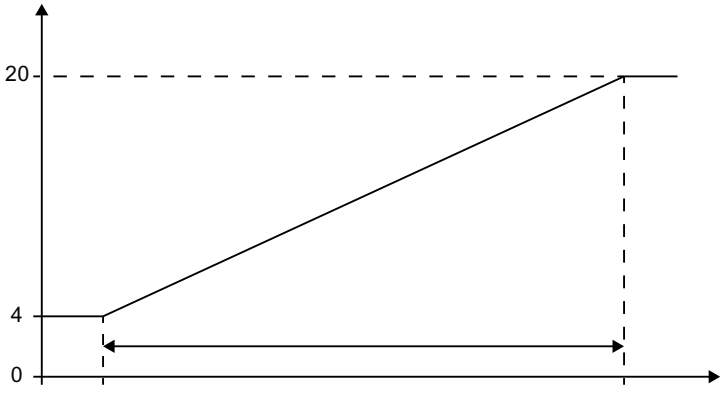
Settling time

The settling time depends on whether HART communication is activated for the output area.

You can find the settling time without HART communication (x ms) in the technical specifications.

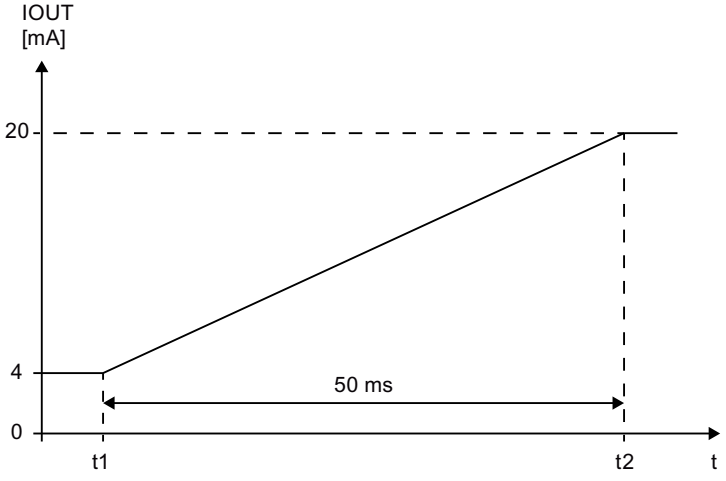
Technical specifications (Page 49)

The settling time without HART communication is represented as follows:



If HART communication is activated for the output area, the settling time of the output value is set to 50 ms.

The settling time with HART communication is represented as follows:



6.4.2 Diagnostics, Missing supply voltage L+

Definition

Enabling of the diagnostics for missing or insufficient supply voltage L+.

6.4.3 Diagnostics, Wire break

Definition

Enabling the wire break diagnostics. A wire break diagnostic message occurs if it is detected that the current flow is too low.

Monitoring is effective from an output current of ≥ 240 µA.

If the output current drops below 240 µA when the "Wire break" diagnostics message is pending, the diagnostic message cannot be canceled until the output current is set above 240 µA again and the error has been eliminated.

6.4.4 Diagnostics short-circuit

Definition

Enabling the short-circuit diagnostics. Short-circuit detection is possible for all current output areas (short-circuit of output QI_n+ to QI_n-).

Monitoring is effective from an output current of at least 1 mA.

The diagnostics short-circuit applies from a connected load of < 20 Ω. From a load of > 30 Ω the short-circuit is reported as outgoing again.

6.4.5 Diagnostics overflow

Definition

Enabling of the diagnostics for overrange.

The current output is also limited to the end of the overrange if the overrange is exceeded.

6.4.6 Diagnostics underflow

Definition

Enable diagnostics for underrange.

6.4.7 Reaction to CPU STOP

Definition

Specifies how the I/O module responds to CPU STOP or to the failure of communication between the interface module and CPU.

6.4.8 Substitute value

Definition

The substitute value is output by the module at CPU STOP if you set the "Reaction to CPU STOP" parameter to "Substitute value".
The substitute value must not exceed the overrange and must not fall below the underrange.

6.4.9 Diagnostics HART

Definition

Enabling the diagnostics of the HART frame-specific monitoring and the status information supplied by the connected field device in the HART frame (HART device status).

The HART diagnostics are reported as maintenance events.

Maintenance events (Page 63)

6.4.10 Number of HART repetitions

Definition

Specifies the number of HART frame repetitions. If the I/O module receives no response or a response with errors to a HART frame sent to the field device, the frame is repeated, i.e. sent to the field device again.

Because HART communication of the individual channels uses multiplex operation, faulty HART frames affect the other channels when the number of HART repetitions is high. In other words, the other channels are processed less frequently.

6.4.11 IO redundancy

Definition

You can configure two identical modules redundantly. To do so, plug both modules into a redundant terminal block side by side. You can find additional information on mounting modules in an IO redundancy configuration in the ET 200SP HA System Manual, section "Installing", "Installing terminal block".

In IO redundancy mode, the left module is the master and the right module is the slave. The HART communication takes place exclusively via one of the two redundant channels.

Description

In error-free redundant operation, the channels of the master and slave each output half of the specified current.
In the event of a channel-specific error, the full current is output via the remaining channel of the partner module. As soon as the error has been corrected, each of the two redundant channels outputs half of the current again.

When IO redundancy operates without error, HART communication takes place exclusively via one of the two redundant channels. The HART interface of all channels is associated with the master by default. If a module fails or a channel failure is detected, the HART interface of the affected channels changes to the partner module. Once an error has been corrected, there is no changeover of the HART interface of the current-carrying channels involved.

6.4.12 Potential group

Definition

A potential group consists of a group of directly adjacent I/O modules within an ET 200SP HA station that are supplied via a common supply voltage.

Description

A potential group is built up from left to right by using terminal blocks.

A new potential group starts on the left side with a light gray terminal block, via which the supply voltage for the potential group is fed in.

The potential group is continued to the right with dark gray terminal blocks and ends when a new potential group is built up next to it.

The potential group also ends if there is a black terminal block next to it. Black terminal blocks are fed individually and cannot be included in potential groups.

You can find additional information on the configuration of the potential group in the system manual *SIMATIC; Distributed I/O System; ET 200SP HA*.

6.5 HART mapping parameters

Definition

The HART mapping parameters allow a maximum of 8 HART variables to be configured (mapped) in the input address space of the I/O module.

If you want to use the maximum of 8 HART variables directly in the input range of the I/O module, assign these parameters in the properties dialog of the I/O module.

Description

You have the following setting options:

Parameters		Value range	Default	Parameter reassignment in RUN
Variable 0	Channel	0...7	0	Yes
	Type	• Non / CiR • Primary • Secondary • Tertiary • Quaternary	Non / CiR	Yes
:				
:				
Variable 7	Channel	0...7	0	Yes
	Type	• Non / CiR • Primary • Secondary • Tertiary • Quaternary	Non / CiR	Yes

Displays and interrupts

7

7.1 Status and error displays

Definition

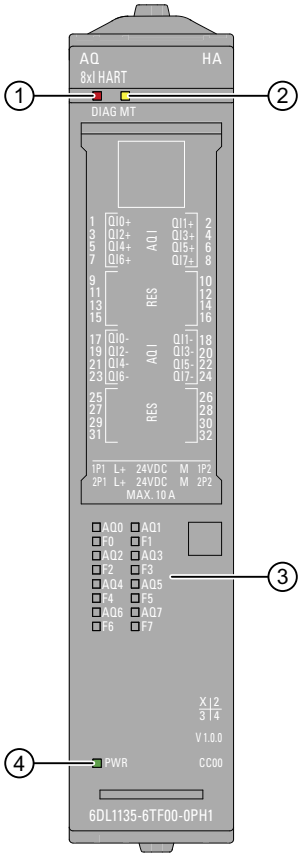
The LED displays are status and error indicators.

Diagnostics messages and maintenance events, as well as their possible causes or solutions, are described in the diagnostics messages and maintenance events.

Diagnostics alarms (Page 62)

Description

The following figure explains the LED displays of the I/O module.



① DIAG LED (Page 30) (green / red)
② MT LED (Page 31) (yellow)
③ Channel status / fault LEDs (Page 31) Channel status (green) / channel fault (red)
④ PWR LED (Page 32) (green)

7.2 LEDs

7.2.1 DIAG LED

Definition

The DIAG LED provides you diagnostic information.

Description

The diagnostic display of the DIAG LED is as follows:

DIAG LED	Meaning
Off	The power supply of the ET 200SP HA is disrupted or switched off.
flashes	Module is not configured.
On	Module parameters are assigned. No diagnostic message is pending.
flashes	Module parameters are assigned. At least one diagnostic message is pending.

7.2.2 MT LED

Definition

The MT LED provides maintenance information.

Description

The MT LED indicates the following maintenance status:

MT LED	Meaning
Off	No maintenance is required.
On	Maintenance is required. At least one maintenance event has occurred.

7.2.3 Channel status / fault LEDs

Definition

The channel status and channel fault LEDs provide you information about the status and faults of the channels.

Description

The channel status and channel fault LEDs indicate the following:

Channel status LED	Channel fault LED	Meaning
□ Off	□ Off	Channel deactivated or module switched off
■ On	□ Off	Channel enabled and no channel/module diagnostics pending.
□ Off	■ On	Channel enabled and channel diagnostics/module diagnostics pending.

7.2.4 PWR LED

Definition

The PWR LED provides you status information about supply voltage L+.

Description

The PWR LED indicates the following status:

PWR LED	Meaning
□ Off	Supply voltage L+ missing.
■ On	Supply voltage L+ present.

7.3 Interrupts

Definition

A diagnostics interrupt is an alarm that reports activated events of a device status to the system operator with the appropriate operating authorization (maintenance and service).

Description

The I/O module generates a diagnostic interrupt at the following events:

- Channel/component temporarily unavailable
- Wire break
- Short-circuit

- Overtemperature
- Measuring range / low limit value undershot
- Measuring range / upper limit value exceeded
- Parameter assignment error
- Module is faulty
- Supply voltage missing
- HART communication error or error of HART field device
- Retentive memory in carrier module defective
- Retentive memory in the terminal block defective
- Redundancy partner has different hardware/firmware
- IO redundancy warning
- Redundancy parameter assignment inconsistent

Note

Pending diagnostic "Module is disrupted" or "Overtemperature" is not deleted again by the module without a restart.

HART function

8

8.1 Use

8.1.1 Useful information on use

Reference is made to the functions and use of HART in the following.

Use of HART

The use of HART modules enables you to exchange additional data with the connected HART field devices. You can commission and re-configure the HART field devices.

HART (Page 36)

Advantages of HART

Using the I/O module with HART offers the following advantages:

- Connection compatibility with standard analog modules: Current loop 4 - 20 mA
- Numerous field devices with HART functions are in use
- Application of HART devices on an IO device based on the ET 200SP HA
- Additional digital communication using the HART protocol
  HART protocol (Page 37)

HART applications

The following applications are typical:

- Commissioning of field devices (centralized parameter assignment)
- Online modification of field device parameters
- Information, maintenance and diagnostic displays for the field devices
- Integration of configuration tools for field devices via the HART interface

Commissioning a HART field device

Only HART devices that are set to short frame address 0 can be operated. If a HART field device with a different short frame address is connected or a connected field device is reconfigured to a short frame address other than 0 during operation, the module starts a scan of all possible short frame addresses at the next re-establishment of HART communication (command 0 with short frame addresses 1...63). As soon as the connected field device responds, it is converted to the short frame address 0 (HART command 6) by the module. During the scan, the module reports a HART communication error.

8.1.2 Notes on use

Reference is made to the functions and use of HART in the following.

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The use of HART modules enables you to exchange additional data with the connected HART field devices. You can commission and re-configure the HART field devices.

AUTOHOTSPOT

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  AUTOHOTSPOT

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8.1.3 HART

Definition

"HART" stands for "Highway Addressable Remote Transducer" = via communications addressable remote field devices (sensor or measuring transducer or final controlling element).

The HART functionality also enables you to use the I/O module to exchange data with the connected field devices. The HART protocol is generally accepted as a standard protocol for communication with intelligent field devices: HART is a registered trademark of the HART Communication Foundation (HCF), which owns all the rights to the HART protocol. You can find detailed information about HART in the HART specification.

8.1.4 HART protocol

Definition

The HART protocol describes the physical form of the transfer: transfer procedures, message structure, data formats and commands.

Description

Each HART telegram (request frame) sent from the module to the connected field device and each HART telegram (response frame) received by the field device has the following basic structure:

PREAMBLE	STRT	ADDR	COM	BCNT	STATUS	DATA	CHK

PREAMBLE: Bytes (0xFF) for synchronizing.
5 to 20 bytes depending on parameter assignment

STRT: Start character (start delimiter)

ADDR: Address of the field device (1 byte; short address or 5 bytes; long address)

COM: HART command number

BCNT: Byte count, number of bytes to follow without checksum

STATUS: HART device status (1st and 2nd status byte). Only present for a response frame.
HART device status (Page 40)

DATA: Transferred user data / parameters, quantity depending on command (0...230 bytes)

CHK: Checksum

With the exception of the preamble bytes, this structure is contained in the communication data of the HART command interface.

HART job and response data records (Page 72)

HART responses always contain data. Status information (HART device status; 1st and 2nd status bytes) is always sent together with a HART response. status bytes) is always sent together with a HART response. You should evaluate these to make sure the response is correct.

8.2 System connection

8.2.1 Useful information about system connection

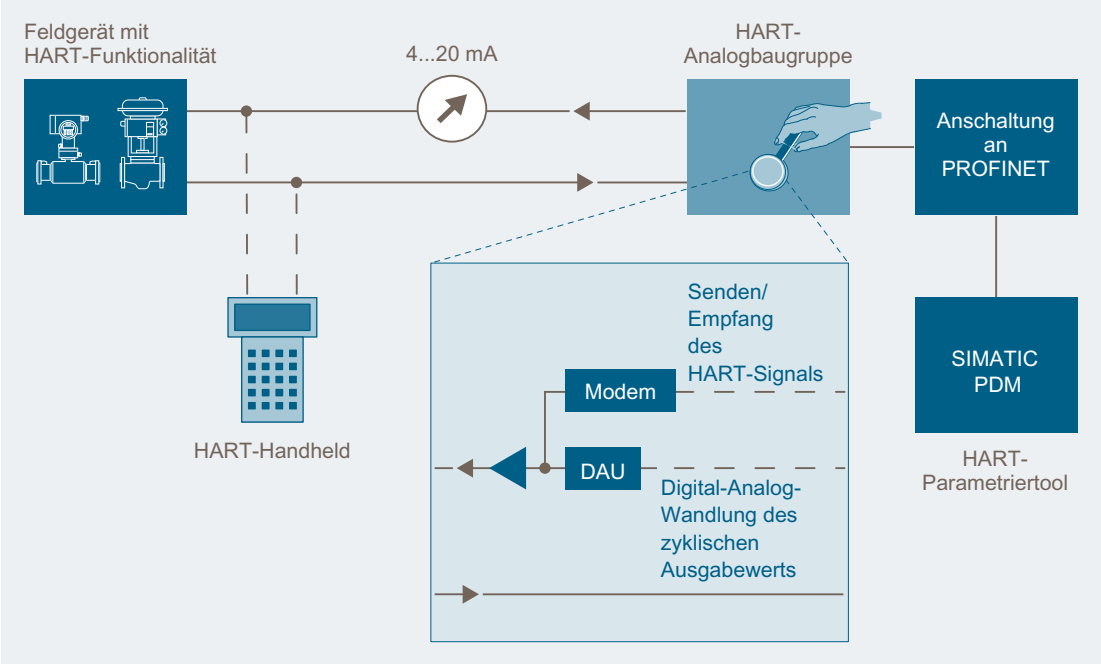
The following describes the system connection and configuration of the field devices.

System environment

To use an intelligent field device with HART functionality, you require the following system environment:

- 4 to 20 mA current loop
- Connecting field devices to the I/O module

The system connection is shown as follows:



The I/O module is used in an IO device based on ET 200SP HA. You can connect a HART field device to each channel (monodrop operation). The I/O module operates as a HART master and the field devices as HART slaves.

The I/O module receives the commands, e.g. from the HART configuration tool, forwards them to the intelligent field device and returns the responses. The interface of the I/O module is made up of data records that are transferred internally between the IM and I/O module via the ET 200SP HA IO device. The data records must be created and interpreted by the client.

- HART signal (Page 39)
- HART configuration tool (Page 39)
- HART device status (Page 40)

Configuration

You configure the I/O module in the SIMATIC system with HW Config. You configure the individual channels with respect to the actual analog value output and the use of the HART variables in the input address space of the module.
You can configure one field device per channel. The configuration/parameter assignment of the connected field device is then carried out from this configured field device using PDM or the EDD for the ET 200SP HA.

Parameter reassignment of the field devices

The I/O module generally accepts triggered reconfigurations for field devices. Access rights can only be allocated in the parameter assignment tool.

You trigger reconfiguration of a field device that is connected to an I/O module with a HART command entered using the SIMATIC PDM configuration tool. The corresponding bit is set in the HART device status of the connected field device (in the 2nd status byte) after parameter reassignment of a HART field device is completed.

The parameter reassignment of the field device causes the analog module to issue a maintenance message "Configuration changed", if this is enabled. This maintenance message should be regarded as a notice and not an error. It is automatically deleted again by the I/O module after approximately 1 minute.

Maintenance events (Page 63)

If enabled, a maintenance message can also be triggered by a new parameter assignment with the handheld device.

8.2.2 HART configuration tool

Definition

The HART parameters can be set either using an external hand-held device (HART Handheld) or a HART configuration tool (PDM). Both assume the function of a "client":

The parameter assignment tool affects the entire I/O module; the HART handheld is connected in parallel to the field device.

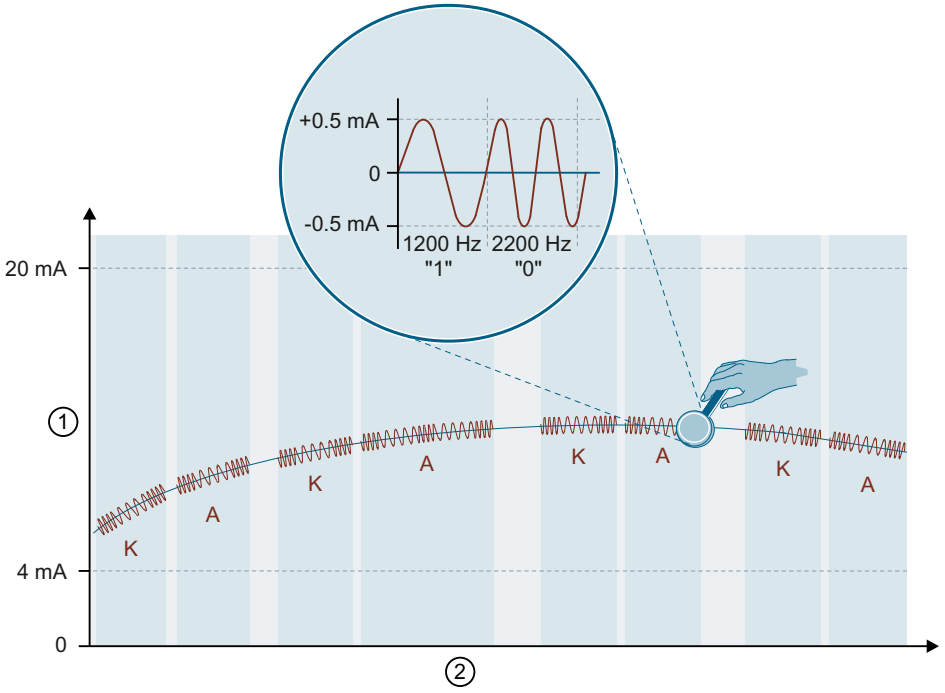
8.2.3 HART signal

Definition

A HART signal consists of sine waves of 1200 Hz and 2200 Hz and has an average value of 0.

Description

The following figure shows the analog signal with the modulated HART signal (FSK method). It can be filtered out using an input filter so that the original analog signal is available again.



①	Analog signal
②	Time (seconds)
K	Command
A	Response

8.2.4 HART device status

Definition

The two HART status bytes (HART device status) that are transferred with each response of the field device contain error information about the HART communication, HART command and device status.
Among other things, this information is evaluated by the I/O module and signaled to the CPU via maintenance messages.

Description

The 1st and 2nd status byte is structured as follows:

Table 8-1 1st status byte

When bit 7 = 1: Communication error	
Bit 6 = 1	Parity error
Bit 5 = 1	Overflow
Bit 4 = 1	Framing error
Bit 3 = 1	Checksum error
Bit 2 = 0	Reserved
Bit 1 = 1	Overflow in the receive buffer
Bit 0 = 0	Reserved
When Bit 7 = 0: Bit 0 to 6 Specific according to the response frame	

Table 8-2 2nd status byte

Bit 7 = 1	Device fault
Bit 6 = 1	Configuration changed
Bit 5 = 1	Startup (cold start)
Bit 4 = 1	Additional status information available
Bit 3 = 1	Fixed analog output current setting
Bit 2 = 1	Analog output current saturated
Bit 1 = 1	Secondary variable outside the limits
Bit 0 = 1	Primary variable outside the range

8.3 Communication

8.3.1 Notes on communication

Reference is made to communication with HART in the following.

HART communication

With enabled HART operation, the analog module independently sends HART commands to the connected field devices. This always occurs alternately on a channel-specific basis with any pending external HART commands that arrive via the command interface of the module.

- Notes on communication (Page 41)
- HART command interface (Page 71)

The I/O module is used in the following operation:

Multiplex operation (Page 44)

Fast mode

When processing HART commands as an SHC sequence (Successive HART Command), HART processing is reserved for the current channel.

If a HART command with set SHC bit is recognized by the I/O module for a channel, the complete HART command processing on the I/O module is reserved for this channel for approx. 2 seconds. There is no processing of internal HART requests, and there is no HART command processing for all other channels of the I/O module during this time.

SHC sequence (Page 44)

Note

- While a HART channel of the I/O module is processing an SHC sequence, and thus the complete HART processing is reserved for this channel, the HART variables of all HART channels are no longer updated. They remain unchanged in terms of value and quality code.
- HART commands for other channels are not processed and are acknowledged correspondingly.

Burst mode

The I/O module does not support burst mode. HART commands with set burst bit are ignored and are not forwarded to the connected field device.

Definition

HART commands are used to set the configurable properties of HART field devices (HART parameters). HART responses are used to read out the HART parameters.

Description

The HART commands and their parameters are divided into three groups:

- Universal HART commands (Page 42)
- General purpose HART commands (Page 43)
- Device-specific HART commands (Page 43)

8.3.2 Explanation of the HART commands

8.3.2.1 Universal HART commands

Definition

Universal commands must be supported by all manufacturers of HART field devices.

Description

Examples of universal HART commands:

Command	Function
0	Reads manufacturer and device type - only with this command 0 can field devices be addressed by means of a short frame address
11	Reads manufacturer and device type
1	Reads primary variable and unit
2	Reads current and percentage of range, digitally as floating-point number (IEEE 754)
3	Reads up to four pre-defined dynamic variables (primary variables, secondary variables, etc.)
9	Reads up to four pre-defined dynamic variables (primary variables, secondary variables, etc.)
13, 18	Reads or writes tag, descriptor and date (data included in transmission)

8.3.2.2 General purpose HART commands

Definition

General purpose commands should be supported by all manufacturers of HART field devices.

Description

Examples of usable HART commands:

Command	Function
36	Sets high range limit
37	Sets low range limit
41	Perform self-test
43	Sets the primary variable to zero

8.3.2.3 Device-specific HART commands

Definition

Device-specific commands only apply to the respective field device.

8.3.3 SHC sequence

Definition

If a HART command with set SHC bit is sent to the I/O module, this channel is reserved for HART commands for 2 seconds.

For each additional HART command with SHC bit set, the I/O module reserves this channel again for HART commands for an additional 2 seconds. Command 3 or 9 for reading the HART variables starts being sent cyclically to the field device again if a HART command without a set SHC bit is detected for this channel, or if no further command is received for the channel within 2 seconds of the previous HART command.

See also

HART command interface (Page 71)

8.3.4 Multiplex operation

Definition

The I/O module processes the HART communication in multiplex mode, i.e. one channel after the other. HART commands of the individual channels therefore influence the speed of HART processing of the other channels.

8.4 Tags

8.4.1 Notes on HART variables

HART variables, the properties dialog and address assignment are explained below.

Properties dialog of the I/O module

In the properties dialog of the I/O module, you can configure up to 8 HART variables directly in the input address area of the I/O module. You select these from the four HART variables provided by each channel:

HART variables (Page 45)

You can refer to the quality code for information on the process status of a HART variable.

Quality code (Page 46)

The HART variables are assigned to a channel in the properties dialog of the module. The HART variables are configured via parameter data record 130. This allows you to process measured values directly from the field device as input data in the automation device.

Parameter assignment and structure of the HART mapping parameters (Page 61)

You also determine the use of the multiHART range and its properties in the properties dialog box of the I/O module.

multiHART range (Page 48)

Address assignment

You can choose to configure the following:

- Maximum 8 HART variables
  Each HART variable occupies 5 bytes of input data. As soon as you configure (map) at least one HART variable in the input address space, the addresses for all 8 variables are assigned (40 bytes).
- A multiHART range
  If the multiHART range is used, an additional 6 bytes of input address space and 1 byte of output address space is allocated.

8.4.2 HART variables

Definition

Each HART variable consists of a 4-byte real value and one byte of quality code. A maximum of four HART variables supported by the connected field device are read cyclically for each channel with enabled HART functionality. The HART variables are read automatically via the HART command 3 (for field devices with HART Rev. 5 and 6) or via command 9 (for field devices with HART Rev. 7 or later).

These four HART variables are always stored in the HART variable data record 121 for each channel and can be read at any time.

HART variable data record (Page 80)

Description

The following HART variables are available:

- PV (Primary Variable)
- SV (Secondary Variable)
- TV (Tertiary Variable)
- QV (Quaternary Variable)

8.4.3 Quality code

Definition

The quality code describes the process status of the corresponding HART variable.

Description

The quality code is structured as follows:

Bit	7....6	5....2	1...0
	Quality 0 0: Bad 0 1: Uncertain 1 0: Good 1 1: Good	Sub-status Coded according to "PROFIBUS PA Profile for Process Control Devices"	Limits 0 0: OK 0 1: Low limit 1 0: High limit 1 1: Constant

The quality codes generated by the I/O module conform to the HART revision of the field device used.

- Field devices with HART revision 5 and 6 (Page 46)
- Field devices with HART revision 7 and higher (Page 47)

8.4.4 HART revision

8.4.4.1 Field devices with HART revision 5 and 6

Definition

The quality code is formed exclusively from the 1st and 2nd status byte (HART device status) of the response frames (HART command 3).

Description

The quality code of field devices with HART revision 5 and 6 is structured as follows:

Quality code	Meaning (process status)	
80_H	Value is okay	Also applies when the following bits are set in the 2nd status byte of the HART response frame: • Configuration changed • Startup (cold start) • Fixed analog output current setting
78_H	Value is uncertain	Also applies when the following bits are set in the 2nd status byte of the HART response frame: • Additional status information available • Analog output current saturated • Secondary variable outside the limits • Primary variable outside the range
84_H	Response code RC8: Update error	
24_H	Response code RC16: Access restricted	Request from field device refused
23_H	Communication error or HART variable not present in the field device	
37_H	Initialization value from analog module	After module start-up, after incorrect operation of the multiHART interface or after redundancy failover to the standby channel[1]
00_H	Initialization value from system	

[1] A channel is in standby mode when a redundancy failover occurs due to a fault in an IO-redundant module.

8.4.4.2 Field devices with HART revision 7 and higher

Definition

The quality code is formed from the 1st status byte (HART device status) and the "Device variable status" (DVS) of the response frames (HART command 9).

Description

The quality code of field devices with HART revision 7 or higher is structured as follows:

Quality code	Meaning (process status)	
80_H	Value is okay	
89_H	"Good" with "low limit"	Process status, formed from the "Device variable status" (DVS) of the response frames with corresponding limits (see above).
$8A_H$	"Good" with "high limit"	
$28_{H...}2B_H$	"Bad"	
$68_{H...}6B_H$	"Poor accuracy"	
$78_{H...}7B_H$	"Manual" or "Fixed" (manually controlled or fixed value)	
$88_{H...}8B_H$	"More device variable state available" (additional status information available)	
84_H	Response code RC8: Update error	
24_H	Response code RC16: Access restricted	Request from field device refused
23_H	Communication error or HART variable not present in the field device	
37_H	Initialization value from analog module	After module start-up, after incorrect operation of the multiHART interface or after redundancy failover to the standby channel[1]
40_H	Read alternatively via command 3	
00_H	Initialization value from system	

[1] A channel is in standby mode when a redundancy failover occurs due to a fault in an IO-redundant module.

8.4.5 multiHART range

Definition

You can access any of the configured HART variables in the I/O module via the multiHART range.

When HART mode is enabled, the I/O module cyclically reads the variables provided by the connected field devices itself and makes them available in the configured input address space. You can request and read one of these HART variables via the multiHART range.

Technical specifications

9

Technical data of the AQ 8xI HART HA

Article number	6DL1135-6TF00-0PH1
General information	
Product type designation	AQ 8 x I HART HA
Firmware version	V1.0
• FW update possible	Yes
Usable terminal block	TB type H1, M1 and N0
Color code for module-specific color identification plate	CC00
Product function	
• I&M data	Yes; I&M0 to I&M3
Engineering with	
• PCS 7 configurable/integrated as of version	V9.0
Redundancy	
• Redundancy capability	Yes; With TB type M1
CiR – Configuration in RUN	
Reparameterization possible in RUN	Yes
Supply voltage	
Rated value (DC)	24 V
permissible range, lower limit (DC)	19.2 V
permissible range, upper limit (DC)	28.8 V
Reverse polarity protection	Yes
Input current	
Current consumption (rated value)	230 mA; 8x 20 mA with 750 ohm load resistance
Current consumption, max.	350 mA; 8x 24 mA with 750 ohm load resistance
Power loss	
Power loss, typ.	3.2 W
Address area	
Address space per module	
• Address space per module, max.	17 byte; 16-byte outputs and 1 byte for QI information
• Address space per module with HART, max.	57 byte; 40-byte inputs for HART and 1 byte for QI information, 16-byte outputs
• Address space per module with MultiHART, max.	24 byte; 6-byte inputs for HART and 1 byte for QI information, 16-byte outputs, and 1-byte output for MultiHART command
Analog outputs	
Number of analog outputs	8
Current output, no-load voltage, max.	26 V

Article number	6DL1135-6TF00-0PH1
Output ranges, current	
• 0 to 10 mA	Yes; 14 bit
• 0 to 20 mA	Yes; 15 bit
• -20 mA to +20 mA	No
• 4 mA to 20 mA	Yes; 16 bit incl. sign
Connection of actuators	
• for current output two-wire connection	Yes
Load impedance (in rated range of output)	
• with current outputs, max.	750 Ω
• with current outputs, inductive load, max.	10 mH
Destruction limits against externally applied voltages and currents	
• Voltages at the outputs	36 V; Minus 0.3 V lower limit
Cable length	
• shielded, max.	1 000 m; With unshielded cables up to 800 m, remember that (external) EMC loads can cause incorrect measured values.
Settling time	
• for resistive load	1.2 ms; 750 ohm
• for inductive load	1.2 ms
Errors/accuracies	
Linearity error (relative to output range), (+/-)	0.01 %
Temperature error (relative to output range), (+/-)	0.002 %/K
Crosstalk between the outputs, min.	70 dB
Repeat accuracy in steady state at 25 °C (relative to output range), (+/-)	0.02 %
Operational error limit in overall temperature range	
• Current, relative to output range, (+/-)	0.5 %; 0 ... 60 °C: 0.2 %
Basic error limit (operational limit at 25 °C)	
• Current, relative to output range, (+/-)	0.1 %
Interrupts/diagnostics/status information	
Diagnostics function	Yes
Substitute values connectable	Yes
Alarms	
• Diagnostic alarm	Yes
Diagnostic messages	
• Monitoring the supply voltage	Yes
• Wire-break	Yes; channel by channel
• Short-circuit	Yes; channel by channel
• Overflow/underflow	Yes; channel by channel
Diagnostics indication LED	
• MAINT LED	Yes; Yellow LED

Article number	**6DL1135-6TF00-0PH1**
• Monitoring of the supply voltage (PWR-LED)	Yes; Green PWR LED
• Channel status display	Yes; Green LED
• for channel diagnostics	Yes; Red LED
• for module diagnostics	Yes; green/red DIAG LED
Potential separation	
Potential separation channels	
• between the channels	No
• between the channels and backplane bus	Yes
• Between the channels and load voltage L+	Yes
Isolation	
Isolation tested with	1 500 V DC/1 min, type test
Ambient conditions	
Ambient temperature during operation	
• horizontal installation, min.	-40 °C
• horizontal installation, max.	70 °C
• vertical installation, min.	-40 °C
• vertical installation, max.	60 °C
Dimensions	
Width	22.5 mm
Height	115 mm
Depth	138 mm
Weights	
Weight, approx.	160 g

Article number	6DL1135-6TF00-0EH1
General information	
Product type designation	AQ 8 x I HART HA
Firmware version	V1.0
• FW update possible	Yes
Usable terminal block	TB type H1 and M1
Color code for module-specific color identification plate	CC00
Product function	
• I&M data	Yes; I&M0 to I&M3
Engineering with	
• SPPA-T3000 can be configured/integrated from version	V8.0
Redundancy	
• Redundancy capability	Yes; With TB type M1
Supply voltage	
Rated value (DC)	24 V
permissible range, lower limit (DC)	19.2 V
permissible range, upper limit (DC)	28.8 V
Reverse polarity protection	Yes
Input current	
Current consumption (rated value)	230 mA; 8x 20 mA with 750 ohm load resistance
Current consumption, max.	350 mA; 8x 24 mA with 750 ohm load resistance
Power loss	
Power loss, typ.	3.2 W
Address area	
Address space per module	
• Address space per module with MultiHART, max.	28 byte; PII: 0 bytes, +1 byte for QI information, +6 bytes for HART, +2 bytes of PROFINET status data; PIO: 16 bytes, +1 byte for HART, +2 bytes of PROFINET status data
Analog outputs	
Current output, no-load voltage, max.	26 V
Output ranges, current	
• 0 to 10 mA	Yes; 14 bit
• 0 to 20 mA	Yes; 15 bit
• -20 mA to +20 mA	No
• 4 mA to 20 mA	Yes; 16 bit incl. sign
Connection of actuators	
• for current output two-wire connection	Yes
Load impedance (in rated range of output)	
• with current outputs, max.	750 Ω
• with current outputs, inductive load, max.	10 mH

Article number	6DL1135-6TF00-0EH1
Destruction limits against externally applied voltages and currents	
• Voltages at the outputs	36 V; Minus 0.3 V lower limit
Cable length	
• shielded, max.	1 000 m
Analog value generation for the outputs	
Settling time	
• for resistive load	1.2 ms; 750 ohm
• for inductive load	1.2 ms
Errors/accuracies	
Linearity error (relative to output range), (+/-)	0.01 %
Temperature error (relative to output range), (+/-)	0.002 %/K
Crosstalk between the outputs, min.	70 dB
Repeat accuracy in steady state at 25 °C (relative to output range), (+/-)	0.02 %
Operational error limit in overall temperature range	
• Current, relative to output range, (+/-)	0.5 %; 0 ... 60 °C: 0.2 %
Basic error limit (operational limit at 25 °C)	
• Current, relative to output range, (+/-)	0.1 %
Interrupts/diagnostics/status information	
Substitute values connectable	Yes
Diagnoses	
• Monitoring the supply voltage	Yes
• Wire-break	Yes; channel by channel
• Short-circuit	Yes; channel by channel
• Overflow/underflow	Yes; channel by channel
Diagnostics indication LED	
• MAINT LED	Yes; Yellow LED
• Monitoring of the supply voltage (PWR-LED)	Yes; green PWR LED
• Channel status display	Yes; green LED
• for channel diagnostics	Yes; red LED
• for module diagnostics	Yes; green/red DIAG LED
Potential separation	
Potential separation channels	
• between the channels	No
• between the channels and backplane bus	Yes
• Between the channels and load voltage L+	Yes
Ambient conditions	
Ambient temperature during operation	
• horizontal installation, min.	-40 °C
• horizontal installation, max.	70 °C

Article number	6DL1135-6TF00-0EH1
• vertical installation, min.	-40 °C
• vertical installation, max.	60 °C
Fire resistance	
Dimensions	
Height	115 mm
Depth	138 mm

Cycle time

The cycle time describes the time slice in which new process values are output.

The cycle time is the sum of the basic cycle times and the channel processing times (independent of parameter assignment).

	Without HART protocol	With HART protocol and multiHART	With HART protocol and 8 HART variables
Basic cycle time	4.7 ms	4.9 ms	7.8 ms
Channel processing time	0.75 ms	0.875 ms	1.5 ms

Cycle time = Basic cycle time + n × Channel processing time

Redundancy failover time

In error-free IO redundancy mode, both I/O modules output half the specified current. If one I/O module fails, failover to the partner module occurs and the partner module outputs the full current.
The maximum redundancy failover time of the I/O module is 20 ms.

Drivers, parameters, diagnostics messages and address space

A

A.1 Parameter assignment

Parameter assignment in the user program

You can reconfigure individual channels of the module and HART variable mapping in RUN without affecting the other channels.

Changing parameters in RUN

The "WRREC" instruction is used to transfer the parameters to the module.

- Module/channel parameters using data record 128
- HART mapping via data record 130

The parameters assigned with STEP 7 are not changed permanently in the CPU, which means the parameters assigned with STEP 7 are valid again after a restart.

Output parameter STATUS

If errors occur when transferring parameters with the "WRREC" instruction, the module continues operation with the previous parameter assignment. The STATUS output parameter contains a corresponding error code.

The STATUS output parameter is 4 bytes long and is configured as followed:

- Byte1: Function_Num, general error code
- Byte2: Error_Decode, location of the error code
- Byte3: Error_Code_1, error code
- Byte4: Error_Code_2, manufacturer-specific extension of the error code

Module-specific errors are displayed via Error_Decode = 0x80 and Error_Code_1 / Error_Code_2.

Error_ Code_ 1	Error_ Code_ 2	Cause	Remedy
0xB0	0x00	Number of the data record unknown	Enter valid number for data record
0xB1	0x01	Length of the data record is incorrect	Enter permissible value for data record length
0xB2	variable	Module cannot be reached	• Check station - is the module plugged in correctly? • Check the parameters of the WRREC instruction
0xE0	0x01	incorrect version in the header	Correct version number of the parameter block
0xE0	0x02	Header error (number or length of parameter block)	Correct length and number of parameter blocks

Error_ Code_ 1	Error_ Code_ 2	Cause	Remedy
0xE1	0x01	Reserved bit set	Check and correct the parameters
0xE1	0x05	invalid coding for output range/type	
0xE1	0x06	Invalid coding for substitute value reaction	
0xE1	0x0A	Invalid value for substitute value	
0xE1	0x0E	Invalid redundancy parameter assignment	

Valid parameters

Only the values specified in the following are permitted. Values that are not listed are rejected by the module.

Each parameter data record is checked by the analog module. If an incorrect parameter is detected, the entire data record is rejected and the parameters of the module remain unchanged.

A.2 Parameter assignment and structure of the module/channel parameters

Structure of data record 128

Data record 128 has a length of 76 bytes.

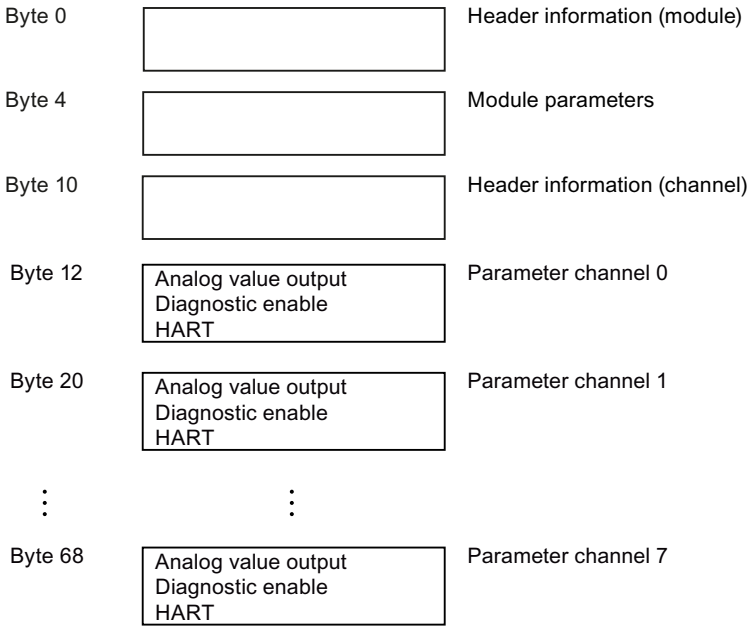
It contains module parameters and the module/channel parameters of the 8 channels, 8 bytes per channel.

The module/channel parameters are divided into parameters which influence the actual analog value output, diagnostic enables and basic parameters of the HART communication.

You can specify and change other parameters and HART-specific settings with data records 131 to 138.

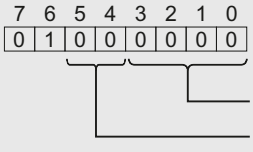
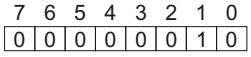
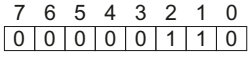
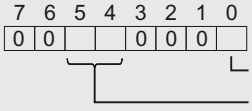
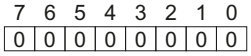
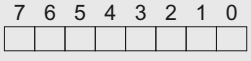
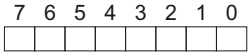
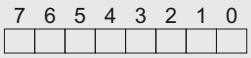
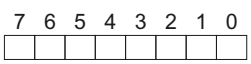
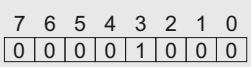
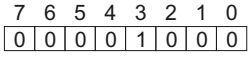
HART-specific settings (Page 81)

The data block 128 is structured as follows:


Byte 0
Header information (module)
Byte 4
Module parameters
Byte 10
Header information (channel)
Byte 12
Analog value output
Diagnostic enable
HART
Parameter channel 0
Byte 20
Analog value output
Diagnostic enable
HART
Parameter channel 1
Byte 68
Analog value output
Diagnostic enable
HART
Parameter channel 7

Header information and module parameters

The header information and module parameters of the data block 128 are structured as follows:

Byte 0		
Byte 1		Number of subsequent parameter structures
Byte 2		Number of subsequent parameter blocks
Byte 3		Length of subsequent module parameter block
Byte 4		Diagnostics for missing supply voltage L+ Redundancy role: 0="Off" 2="Master (station-internal)" 3="Slave (station-internal)"
Byte 5		Reserved
Byte 6		Non-redundant mode: irrelevant Redundancy mode: Logical base address, high byte
Byte 7		Non-redundant mode: irrelevant Redundancy mode: Logical base address, low byte
Byte 8		Non-redundant mode: irrelevant Redundancy mode: Logical base address of partner module, high byte
Byte 9		Non-redundant mode: irrelevant Redundancy mode: Logical base address of partner module, low byte
Byte 10		Number of subsequent channel parameter blocks = 8
Byte 11		Length of a channel parameter block = 8

Channel parameters

The following figure shows the configuration of the channel parameters for channels 0 to 7.

x = 12 + (channel number * 8); with channel number 0...7

All unused bits and the bits or bytes marked as "reserved" must be set to zero.
You activate a channel parameter by setting the corresponding bit to "1" or the corresponding value.

Structure of byte x to x+n for channels 0 to 7

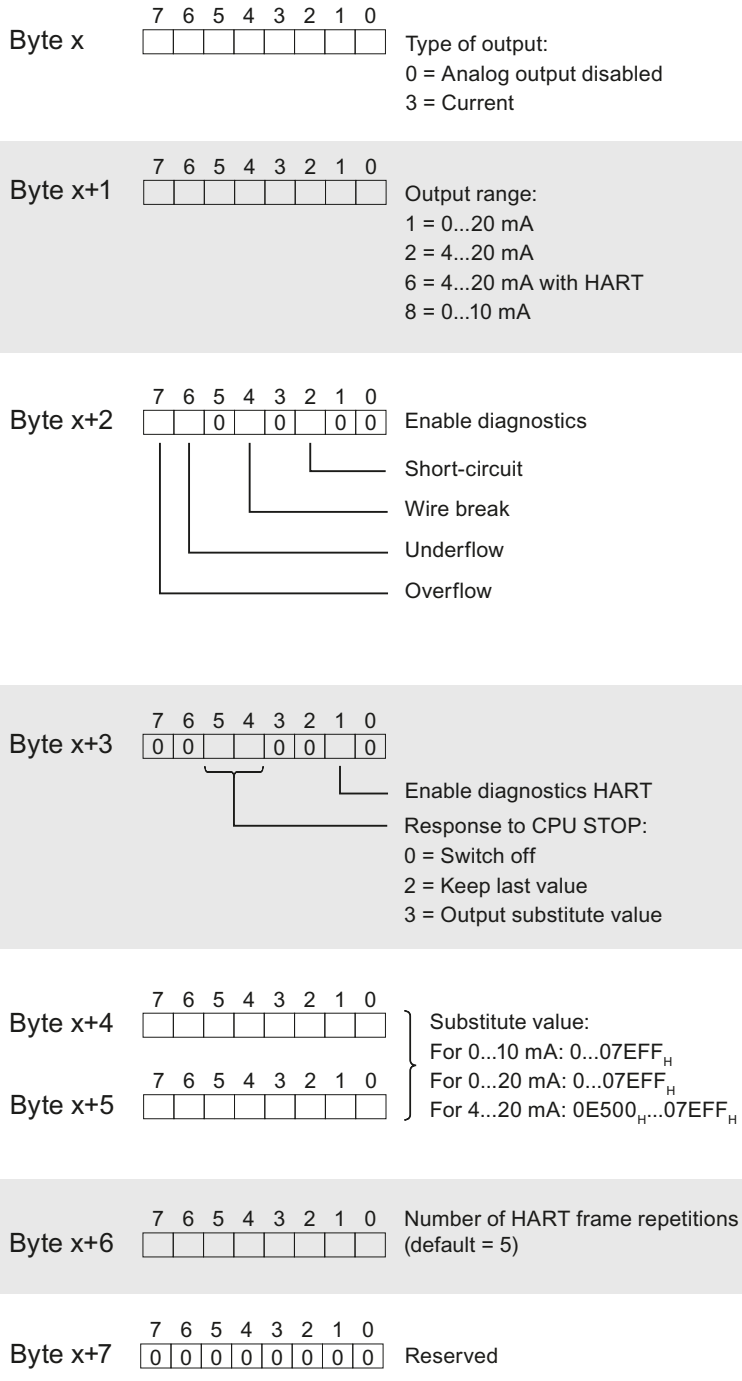


Figure A-1 Structure of byte x to x+n for channels 0 to 7

A.3 Parameter assignment and structure of the HART mapping parameters

Structure of data record 130

Data record 130 has a total length of 20 bytes.

You can configure/map up to 8 HART variables of the individual channels in the input address space of the module using the parameters of data record 130 if configuration with HART variables in the input range is selected, see section Configuration options (Page 21).

Header information

The figure below shows the structure of the header information.

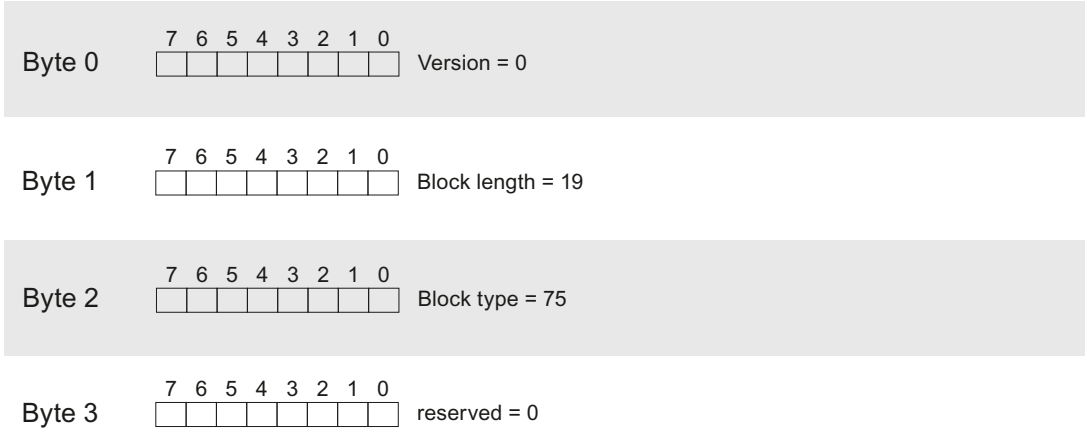


Figure A-2 Header information of data record 130

Parameters

The figure below shows the parameter assignment of the 8 HART variables.

x = 4, 6, 8, 10, ..., 18

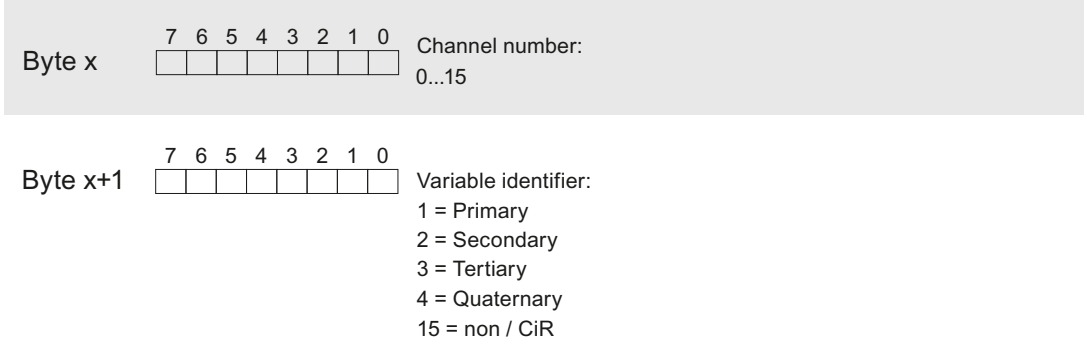


Figure A-3 Parameters of data record 130

The effect of variable identifier 15 = non / CiR on the I/O module is that no HART variable is configured or mapped; that is, the corresponding memory area in the input address area remains unallocated.

A.4 Diagnostics alarms

Diagnostic messages

A diagnostic message is generated for each detected diagnostic event, and the DIAG LED flashes on the I/O module.

There is additionally a channel-specific display of the diagnostics through the corresponding channel fault/channel status LEDs.

The diagnostics messages can, for example, be read from the diagnostic buffer of the CPU.

Diagnostics messages are either assigned to an output for specific channels or to all outputs as a module message. For diagnostics messages which affect the entire module, all channels are switched off. For diagnostics messages which refer to individual channels, only the corresponding analog output is affected.

Table A-1 Diagnostics messages, their meaning and how to deal with them

Diagnostics message	Error code	Assignment	Meaning/cause	Remedy
Short-circuit	1_H	Analog output	Short-circuit of cable to the actuator or impedance too low	• Correct the process wiring • Check the connected actuator
Overtemperature	5_H	Module	• Ambient temperature is too high • Total current of the analog outputs too high • Short circuit of one or more analog outputs	Check wiring
Wire break	6_H	Analog output	• Wire break between the module and actuator • Channel not connected (open)	• Connect the cable • Disable diagnostics
High limit violated	7_H	Analog output	The analog value is above the overrange.	Correct the output value
Low limit violated	8_H	Analog output	The analog value is below the underrange.	Correct the output value
Parameter assignment error	10_H	Module	• Parameter assignment does not match the terminal block used • Incorrect parameter assignment	• Correct the parameter assignment • Check terminal block[1]
Supply voltage missing	11_H	Module	Missing or insufficient supply voltage L+	• Check wiring of the supply voltage L+ on the terminal block • Check the terminal block type

Diagnostics message	Error code	Assignment	Meaning/cause	Remedy
Channel/component temporarily unavailable	$1F_H$	Module	Update of the firmware is being performed or has been canceled. The module does not perform any processing during this time	• Restart firmware update • Wait for firmware update
Module is faulty	100_H	Module	Internal module error has occurred	Replace module
Inconsistent parameter assignment	123_H	Module	Error in the redundancy parameters transferred to the module	• Check the parameter assignment • Check the slot and terminal block
Retentive memory in carrier module defective	154_H	Module	An error of the memory block on the support module was detected during start-up	Replace carrier module
Retentive memory in the terminal block defective	155_H	Module	An error of the memory block on the terminal block was detected during start-up	Replace terminal block

[1] Only the terminal blocks (TB 45R ...) are suitable for use with I/O modules in IO redundancy.

A.5 Maintenance events

Maintenance events

A maintenance event is generated whenever a maintenance requirement is determined. The MT LED lights up on the module.

Maintenance messages are assigned channel-specific to an output or as a module message to all outputs.

Maintenance messages do not have a direct influence on the functioning of the module or the analog outputs.

Table A-2 Maintenance messages, their meaning and possible solutions

Maintenance message	Error code	Assignment	Meaning / Cause	Solution
Redundancy partner has different hardware/firmware version	120_H	Module	The redundantly configured and interconnected I/O modules are not compatible	• Check and replace modules • Update firmware
IO redundancy warning	121_H	Module	Unable to correctly communicate with the partner module	• Check/replace right module • Check/replace left module • Check/replace terminal block See also system manual *Distributed I/O System; ET 200SP HA*", section "Replacing an I/O module for I/O redundancy"
HART communication error	141_H	Analog output	• HART field device is not responding • Timing error • HART field device did not understand the command that was sent (1st status byte)	• Check the process wiring • Correct the parameter assignment • Set current ≥4 mA • Increase number of configured repetitions

Maintenance message	Error code	Assignment	Meaning / Cause	Solution
HART primary variable outside of limits	142_H	Analog output	• Wrong parameters in the HART field device • HART field device is set to "Primary variable outside of limits" in simulation mode • Wrong measuring point • Parameter assignment of primary variable outside of limits	• Check the parameter assignment of the HART device • Correct the simulation • Check whether the correct measuring transducer is connected
HART analog output current of field device saturated	143_H	Analog output	• The output current of the HART field device is saturated: • Wrong parameters in the HART field device • HART field device is set to an excessively high measuring value in simulation mode • Wrong measuring point	
HART output current of the field device specified	144_H	Analog output	• The output current of the HART field device is fixed: • Wrong parameters in the HART field device • HART field device is set to an excessively high measuring value in simulation mode • Wrong measuring point	
HART additional status information available	145_H	Analog output	In the HART device status (in the 2nd status byte), the HART field device identifier for "further status information available" has been set	Read out status with HART command 48 and clear error/cause if necessary
HART configuration changed[1]	146_H	Analog output	In the HART device status (in the 2nd status byte), the identifier for "parameter reassignment" of the HART field device has been set	If no diagnostics interrupt is to be triggered by reconfiguration, the HART diagnostics must be disabled.
HART malfunction in the field device	147_H	Analog output	In the HART device status (in the 2nd status byte) the field device reports a malfunction	• Read out status with HART command 48 and clear error/cause if necessary • Replace field device
HART secondary variable outside the limits	149_H	Analog output	• Wrong parameters in the HART field device • HART field device is set to "Non-primary variable outside limits" in simulation mode • Wrong measuring point • Parameter assignment of non-primary variable is outside the limits	• Check the parameter assignment of the HART device • Correct the simulation • Check whether the correct measuring transducer is connected

Maintenance message	Error code	Assignment	Meaning / Cause	Solution
Retentive memory in carrier module defective	154_H	Module	Fault detected in the data block on the carrier module during operation	Replace carrier module
Retentive memory in the terminal block defective	155_H	Module	An error of the memory block on the terminal block was detected during operation	Replace terminal block

[1] **Response of the "HART configuration changed" maintenance message**

If the HART field device signals "parameter reassignment" (configuration changed) in the 2nd status byte, the module generates the maintenance message "HART configuration changed". If the field device withdraws the message in the 2nd status byte within a minute, the maintenance message is also deleted again by the module. If the message in the 2nd status byte is still set after a minute, the module then independently sends HART command 38 for resetting the message in the field device.

A.6 Address space

Abbreviations

- "IB" stands for input byte, that is, the module start address in the input area
- "QB" stands for output byte, that is the module start address in the output area
- "AQ" stands for analog output
- "QAQn" stands for value status (QI) of the analog output n
- "QC"stands for Quality Code

Evaluate value status

There is one bit value status for each analog output in the input address space.

Irrespective of the diagnostics enables, each value status (each QI bit) provides information on the validity of the corresponding process value.

- Value status = 1: Process value okay, "good"
- Value status = 0: Process value not okay, "bad"

Generally, the value status is set to "good" if the analog value can be output without errors. The value status is set to "bad" in the following cases:

- The analog value cannot be output due to an error.
- The analog output is deactivated.
- The substitute value is output at the analog output.

Address space

The following tables show the allocation of the address space of the I/O module.

The addresses for the HART variables or the addresses of the multiHART range are only available if the HART variables or the multiHART range were configured/parameterized.

Output range

If the HART variables or the multiHART range are configured or parameterized, then HART variables or the multiHART range begin directly after the value status, i.e. from IB x + 1.

IB x +	**Meaning**							
0	QAQ7	QAQ6	QAQ5	QAQ4	QAQ3	QAQ2	QAQ1	QAQ0
1	HART range							
:								
:								

The structure of the HART range is dependent on the configuration:

- With the configuration with 8 variables, the range is 40 bytes long and always contains 8 HART variables, each with 4 bytes value and a byte quality code.

IB x +	**HART range**	
1 : 4	Value	Configured HART variable 0
5	QC	
6 : 9	Value	Configured HART variable 1
10	QC	
: : :		
36 : 39	Value	Configured HART variable 7
40	QC	

- With the configuration with a multiHART range, the range is 6 bytes long:

IB x +	**multiHART range**		
1	Acknowledgment		multiHART range
2 : 5	Value	HART variable	
6	QC		

Output range

The HART range is only available if you have configured multiHART.

QB x +	Meaning
0...1	Analog value of analog output 0 (AQ0)
2...3	Analog value of analog output 1 (AQ1)
4...5	Analog value of analog output 2 (AQ2)
6...7	Analog value of analog output 3 (AQ3)
8...9	Analog value of analog output 4 (AQ4)
10...11	Analog value of analog output 5 (AQ5)
12...13	Analog value of analog output 6 (AQ6)
14...15	Analog value of analog output 7 (AQ7)
16	HART range

There is one byte in the output range in the configuration with a multiHART range.

QB x	Command	multiHART range

Evaluating HART variables

If you have configured (mapped) HART variables for the I/O module, then 8 HART variables with 5 bytes each are stored in the input address space.

Each HART variable consists of a 4 byte real value and a byte quality code. The quality code describes the validity of the value.

The assigned HART variables are automatically updated by the I/O module and can be used directly in the user program.

Evaluate multiHART range

If you use the I/O module from the module catalog and select the multiHART range via the parameter assignment dialog, a multiHART range is created.

The multiHART range occupies 1 byte in the output range (command) and 6 bytes in the input range (1 byte acknowledgment + 5 bytes HART variable).

You can read all the HART variables available in the module via the multiHART range. To do so, you must request a HART variable from the module via the command byte in the output range.

The command byte marks the requested HART variable (HART variable reference):

HART variable reference	
Bit 0 to 3: Variable identifier 1 = Primary 2 = Secondary 3 = Tertiary 4 = Quaternary	Bit 4 to 7: Channel number 0 to 7

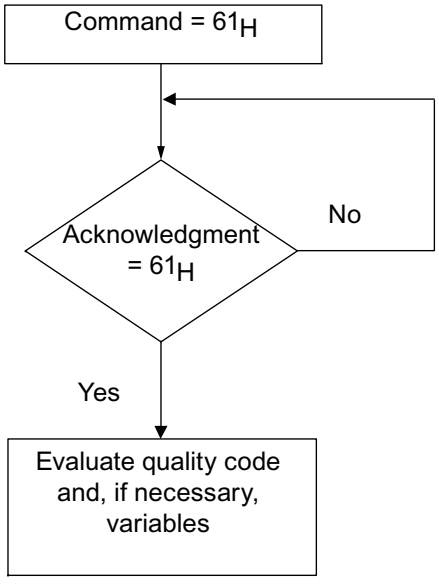
The command is acknowledged via the acknowledgment byte in the input range. As soon as the HART variable reference requested using the command can be read, the requested HART variable can be evaluated.

If you leave the command byte of the multiHART range unchanged, the module will continuously update the corresponding HART variable.

If an invalid HART variable reference is requested, this is also acknowledged accordingly. The value of the corresponding HART variable is then zero and the quality code is signaled with $0x37_H$ (initialization value of the analog module).

Example:

The primary variable should be read from channel 6. Command = 0x61



HART operating data records

B

B.1 HART command interface

Data records

The HART commands are sent as external HART orders to the connected field device from the client, e.g. PDM, via data records. The response of the field device is made available again in the system via data records.

HART communication may only be handled by one client per channel. If a channel is handled by several clients, the response made available by the module cannot be allocated to one client with certainty. The I/O module does not support client management.

Rules

- After having written a request data record, a client must read the response data record before it may write another request data record.
- The client can evaluate the "processing status" in the response data record: If the "processing status" indicates "successful" or "error," the response data record contains current response data or error indications, respectively.
- The response data record must always be read completely because the I/O module may modify the data record after the initial reading with "successful" or "error" status.
  If the processing status in the response data record indicates "successful" or "error", the data record contains current response data or error displays.
- The client may only write a request data record to the I/O module again when it has read the response to the previously written request data record via the corresponding response data record. Otherwise, the response from the I/O module is overwritten.
- The STATUS component in the response frame (HART device status in the response data) provides information on whether errors have occurred and, if so, which errors.

Each request is stored on a channel-specific basis, and the corresponding request data record is locked. Another writing of the same request data record is thus not possible and is acknowledged with BUSY.
The disable of the request data record is reset after the termination or completion of the requested HART command.

HART operating data records are transferred to the module with the instruction "WRREC" and read by the module with the instruction "RDREC".

Errors during the transfer are indicated at output parameter STATUS of the "WRREC" or "RDREC".

Reading/writing data in RUN

The following HART operating data records are available:

Data record number	Description	Length (bytes)	Writable	Readable
80	HART job channel 0	240	Yes	Yes
81	HART response channel 0	240	No	Yes
82	HART job channel 1	240	Yes	Yes
83	HART response channel 1	240	No	Yes
84	HART request channel 2	240	Yes	Yes
85	HART response channel 2	240	No	Yes
86	HART request channel 3	240	Yes	Yes
87	HART response channel 3	240	No	Yes
88	HART request channel 4	240	Yes	Yes
89	HART response channel 4	240	No	Yes
90	HART request channel 5	240	Yes	Yes
91	HART response channel 5	240	No	Yes
92	HART request channel 6	240	Yes	Yes
93	HART response channel 6	240	No	Yes
94	HART request channel 7	240	Yes	Yes
95	HART response channel 7	240	No	Yes
121	HART additional variables	160	No	Yes
131	HART parameter channel 0	8	Yes	Yes
132	HART parameter channel 1	8	Yes	Yes
133	HART parameter channel 2	8	Yes	Yes
134	HART parameter channel 3	8	Yes	Yes
135	HART parameter channel 4	8	Yes	Yes
136	HART parameter channel 5	8	Yes	Yes
137	HART parameter channel 6	8	Yes	Yes
138	HART parameter channel 7	8	Yes	Yes
148	HART directory	25	No	Yes
149	HART feature data	3	No	Yes

B.2 HART job and response data records

HART commands are processed on a channel-specific basis via a separate command interface with one request data record and one response data record in each case.

Channel	Data record number	
	Request to the field device	Response from the field device
0	80	81
1	82	83
2	84	85
3	86	87

Channel	Data record number	
	Request to the field device	Response from the field device
4	88	89
5	90	91
6	92	93
7	94	95

Structure of response data records 80 bis 94

Byte	Meaning	Comment
0	Request control	
1	Number of preamble bytes	5...20, 255
2...239	Communication data according to HART specification	

Coding "Request control":

Bit 0...1: Reserved = 0
Bit 2: 0 = Parameters are not checked
Bit 3...4: Reserved = 0
Bit 5: 0 = Transparent format [1]
1 = Compact format
Bit 6: 1 = Enable SHC mode [2]
Bit 7: 0 = HART Request

[1] HART commands are processed by the I/O module in both transparent message format and compact message format. However, the response data from the module is always made available in transparent message format.

[2] Processing of a sequence of HART commands as an SHC sequence affects all other channels with HART enabled.

HART command interface (Page 71)

Note

When "Number of Preamble Bytes" = 255, the number of preambles set with the parameters is used. The default setting is five. You can reconfigure the number of preamble bytes using the HART-specific settings.

HART-specific settings (Page 81)

Structure of response data records 81 bis 95

In case of response error

Byte	Meaning	Comment
0	Response control	
1	HART group error display	
2	Protocol error	
3...239	Response data according to HART specification	Only present when "Response result" = 6 = "Error, with data"

In case of response error

Byte	Meaning	Comment
0	Response control	
1	HART group error display	
2...239	Response data according to HART specification	Only present when "Response result" = 4 = "Successful, with data"

Coding "Response control":

Bits 0-2: Response result (processing status)
0 = Inactive
1 = Inactive (reserved)
2 = Waiting
3 = Waiting, executing
4 = Successful, with data
5 = Successful, without data
6 = Error, with data
7 = Error, without data

Bit 3: 0 = Burst mode not active;

Bit 4: 0 = Response data come directly from the HART device

Bit 5: 0 = Response data in transparent message format

Bit 6: 0 = SHC mode not active
1 = SHC mode active

Bit 7: 0 = HART response

Coding "HART group error display"

Bit number	Meaning	Explanation
0	Additional status information available	(2nd HART status byte) You obtain additional status information, if required, with HART command 48.
1	HART communication error	The field device has detected a communication error when receiving the command. The error information is in the first HART status byte
2	Parameter check	0: HMD parameters unchanged 1: Check HMD parameters

Bit number	Meaning	Explanation
3	Reserved	Always 0
4...7	HART protocol error during response	0: Unspecified error 1: HMD error 2: Channel fault 3: Command error 4: Query error 5: Response error 6: Query rejected 7: Profile query rejected 8: Manufacturer-specific query rejected 9 - 15: Not used

Coding "HART protocol error during response"

HART protocol error during response	Meaning	Explanation
0	Unspecified error	Always 0
1	HMD error	0: Not specified 1: Internal communication error 2: Parameter assignment error 3: HW fault 4: Wait time expired 5: HART timer expired 6...127: Reserved 128...255: Manufacturer-specific
2	Channel fault	0: Not specified 1: Line fault 2: Short-circuit 3: Open line 4: Low current output 5: Parameter assignment error 6...127: Reserved 128...255: Manufacturer-specific
3	Command error	0-127: HART protocol, Bit 7 = Always 0

HART protocol error during response	Meaning	Explanation
4	Query error	Bit 0 = 0: Reserved Bit 1 = 1: Receive buffer overflow Bit 2 = 0: Reserved Bit 3 = 1: Checksum error Bit 4 = 1: Framing error Bit 5 = 1: Overflow error Bit 6 = 1: Parity error Bit 7 = 1: Reserved
5	Response error	Bit 0 = 1: GAP timeout Bit 1 = 1: Receive buffer overflow Bit 2 = 1: Timeout Bit 3 = 1: Checksum error Bit 4 = 1: Framing error Bit 5 = 1: Overflow error Bit 6 = 1: Parity error Bit 7 = 1: Reserved
6	Query rejected	0: Unspecified 1: Compact format not supported 2: SHC not supported 3: Impermissible command 4: No resources 5: Channel in standby mode [1] 6...127: Reserved 128...255: Manufacturer-specific
7	Profile query rejected	0: Not specified (not supported)
8	Manufacturer-specific query rejected	0: Not specified (not supported)

[1] An external HART request has been rejected because the channel is not the active channel of a redundancy pair. The request must be sent to the connected field device via the partner module.

Example of HART programming (HART command interface)

For HART channel 0, command 01 is to be sent in transparent message format to the HART field device with address "98 CF 38 84 F0".
A positive edge at input 4.0 of a digital input module leads to the writing of the HART command.

The following assumptions are made:

- The module address of the I/O module is 512 (200_H).
- The data record is stored in DB80: starting from address 0.0, length of 11 bytes.
- In this example, DB80 (request data record for channel 0) consists of 11 bytes.

```
                                    Explanation
```

```
    A I 4.0
    FP M 101.0
    = M 104.0
m2: CALL SFB53, DB53
    REQ :=M104.0                        Write request
    ID :=DW#16#200                      Module address
    INDEX :=80                          Data record number 80
    LEN :=11                            Length 11 bytes
    DONE :=M51.7
    BUSY :=M51.0
    ERROR :=M51.6
    STATUS :=MD92                       Block status or error information
    RECORD :=P#DB80.DBX0.0 BYTE 11      Source area in DB80
    A M 51.0
    SPB m2
    BE
```

DB80: Transparent message format

Byte	Initial value (hex)	Comment (Hex)
0	00	Req_Control (00 = Transparent message format. 40 = Transparent message format with SHC sequence)
1	05	Number of preamble bytes (05-14)
2	82	Start character (02 = Short Frame with command 0) (82 = Long Frame with other commands)
3	98	Address (with command 0, the address is exactly 1 byte long and has the value 0.)
4	CF	
5	38	
6	84	
7	F0	
8	01	Command (CMD)
9	00	Length in bytes
10	98	Checksum (CHK) (calculated as EXOR addition starting from byte 2 "Start character" up to the last byte of the command) The checksum must not be sent with the job.)

A HART command can also be sent in compact message format. In this case, the data transmitted via DB 80 is reduced to 4 bytes.

DB80: Compact message format

Byte	Initial value (hex)	Comment (Hex)
0	20	Req_Control (20 = Compact message format 60 = Compact message format with SHC string)
1	05	Number of preamble bytes (5...20, 255)
2	01	Command (CMD)
3	00	Length in bytes

You can learn when the response from the field device was received by cyclically reading data record DS81 for HART channel 0. The response is always supplied in transparent message format.

FC81: Read the response with SFB 52 to DB81

```
                                        Explanation
m3: CALL SFB52, DB52
    REQ :=M1                            Read request
    ID :=DW#16#200                      Module address
    INDEX :=81                          Data record number 81
    MLEN :=200                          Target length
    VALID :=M49.7
    BUSY :=M49.1
    ERROR :=M49.6
    STATUS :=MD100                      Block status or error information
    LEN :=MW104
    RECORD :=P#DB81.DBX0.0 BYTE 200     Target area in DB81
    A M 49.1
    SPB m3
    BE
```

The program part A M 49.1 to SPB m3 is only required if reading is to occur within a block cycle.

As long as the processing status (byte 0 of DB81) is at 3 (waiting, executing), the response has not yet been received from the field device. As soon as the processing status changes to greater than 3, the HART request is finished.

With a processing status of 4, the request finished without errors and the response data can be evaluated.

With a processing status of 5, the request also finished without errors but without response data from the field device.

With a processing status of 6 or 7, the request finished with errors. You can find more detailed information in byte 1 of DB81 (see table "HART group fault display") and for a HART protocol error also in byte 2 of DB81 (see table "HART protocol error during response").

B.3 HART directory

Structure of the HART directory

Byte	Meaning	Comment
0	Profile Revision Number	= 2, 0 (Revision 2.0)
1		
2	Index of Client Management	= 255 (not relevant)
3	Number of Clients	= 1
4	Number of Channels	= 8
5	Write Read Index Offset	= 1 (The response to a job data record is made with the data record number of the request data record + 1)
6	Index of HMD Feature Parameter	= 149
7	Index of HMD Module Parameter	= 255 (not relevant)
8	Start Index of Burst Buffer Area	= 255 (not relevant)
9+n	Index of HMD Channel Parameter (Channel n)	= 131+n
9+n+4	Index of HART Client Channel Message Data	= 80+(2*n) The HART request data records cannot be configured. Data records starting from data record number 80 (80, 82, 84, 86, 88, 90, 92, 94) are used.

B.4 HART feature data

Structure of the HART feature data

Byte	Meaning	Comment
0	Byte 0	= 0x62 Bit 1 = 1: "Parameter check result is given with a read response" Bit 5 = 1: "Compact format is supported" Bit 6 = 1: "SHC mode is supported"
1	Byte 1	= 0
2	Max Length Data Unit	= 230 (maximum length of the HART request data records)

B.5 HART variable data record

The I/O module supports a maximum of 4 HART variables per channel when HART mode is enabled. Provided they are supported by the connected field device, these variables are ready cyclically.
The total of 32 HART variables are made available in HART variable data record 121 as readable variables.

Each HART variable consists of a 4-byte real value and 1-byte quality code.

In IO redundancy mode, the HART variables are only updated if the HART interface is on the corresponding module/channel. The channel may not be in standby mode. If the HART interface is on the partner module/partner channel, the corresponding HART variable is initialized (quality code = 0x37).

Structure of the HART variable data record

Byte	Meaning	
Channel 0		
0...3	Value	Primary Variable (PV)
4	Quality Code	
5...8	Value	Secondary Variable (SV)
9	Quality Code	
10...13	Value	Tertiary Variable (TV)
14	Quality Code	
15...18	Value	Quaternary Variable (QV)
19	Quality Code	
Channel 1		
20...39	HART variables same as for channel 0	
Channel 2		
40...59	HART variables same as for channel 0	
Channel 3		
60...79	HART variables same as for channel 0	
Channel 4		
80...99	HART variables same as for channel 0	
Channel 5		
100...119	HART variables same as for channel 0	
Channel 6		
120...139	HART variables same as for channel 0	
Channel 7		
140...159	HART variables same as for channel 0	

If HART is not enabled or the respective HART variable is not supplied from the connected field device, the corresponding variable = 0 and the QC = 0x37 (initialization value from the analog module).

B.6 HART-specific settings

The HART communication is available using standard parameter assignment (see section 9.1 "Parameter assignment and structure of the channel/technology parameters").

Additional HART-specific settings can be specified on a channel-specific basis using data records 131 to 138.

Every new parameter assignment of the analog module resets the HART-specific settings back to the initial values from parameter data record 128.

If you make changes in IO redundancy mode using the HART-specific settings, these changes only apply to the addressed module or the addressed channel. There is no synchronization with the partner channel.

Channel	Data record number
0	131
1	132
2	133
3	134
4	135
5	136
6	137
7	138

If there is missing supply voltage L+, the HART-specific settings are not adopted by the module.

Structure of the HART-specific settings

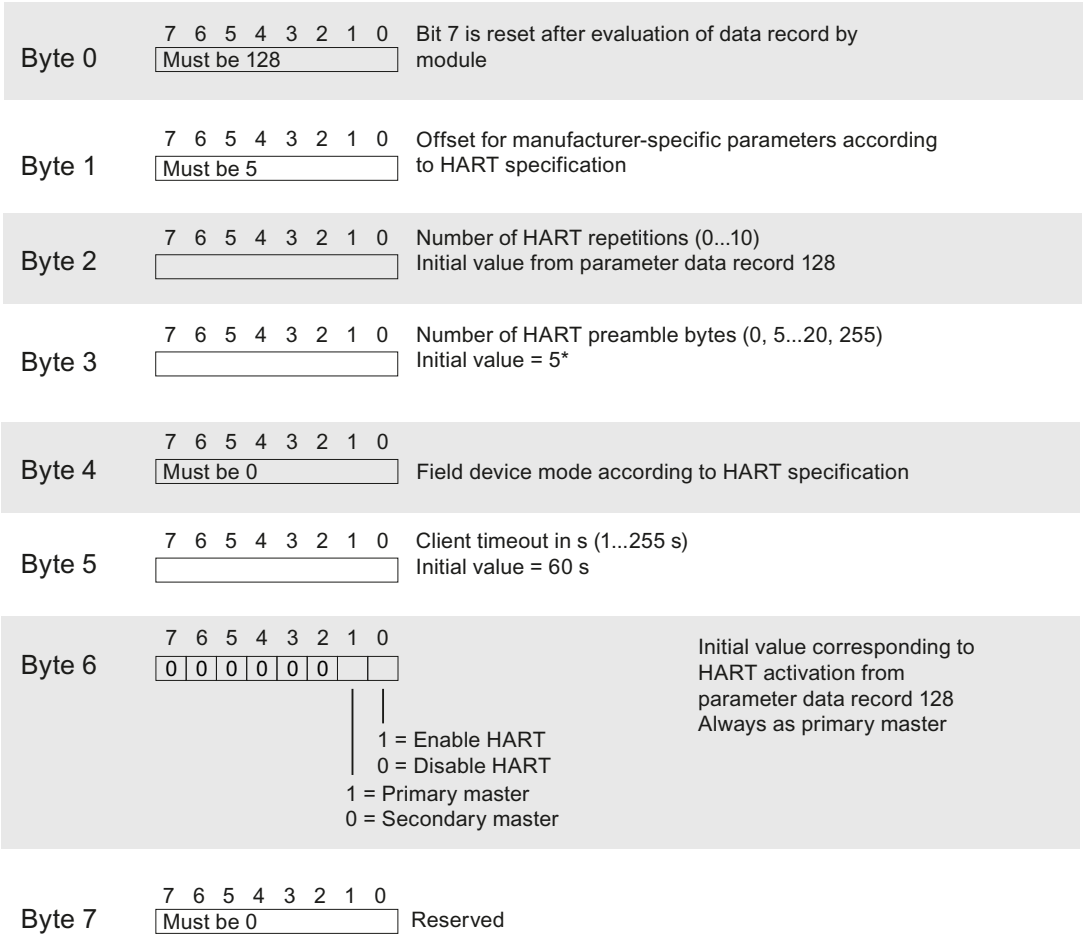


Figure B-1 Settings

* When the number of HART preamble bytes = 0, the number of preamble bytes required by the connected field device are used, but no fewer than 5.
When the number of HART preamble bytes = 255, then 20 preamble bytes are used.

Analog value display

C

C.1 Representation of analog values in the current output ranges

In the following tables, you can find the digitized representation of the unipolar output ranges. The resolution is 16 bits.

Display of analog value of current output ranges

The tables below list the decimal and hexadecimal values (codes) of the possible current output ranges.

Table C-1 Current output range 0 to 10 mA

Values			Current output range	Range
	Dec.	Hex.	0 to 10 mA	
118.5149%	32767	7FFF	11.76 mA	Overflow
	32512	7F00		
117.589%	32511	7EFF	11.76 mA	Overrange
	27649	6C01	10 mA + 361.7 nA	
100 %	27648	6C00	10 mA	Nominal range
75 %	20736	5100	7.5 mA	
0.003617%	1	1	361.7 nA	
0 %	0	0	0 mA	
	-1	FFFF	0 mA	Underflow
-118.519%	-32768	8000		

Table C-2 Current output range 0 to 20 mA

Values			Current output range	Range
	Dec.	Hex.	0 to 20 mA	
118.5149%	32767	7FFF	23.52 mA	Overflow
	32512	7F00		
117.589%	32511	7EFF	23.52 mA	Overrange
	27649	6C01	20 mA + 723.4 nA	
100 %	27648	6C00	20 mA	Nominal range
75 %	20736	5100	15 mA	
0.003617%	1	1	723.4 nA	
0 %	0	0	0 mA	
	-1	FFFF	0 mA	Underflow
-118.519%	-32768	8000		

Table C-3 Current output ranges 4 to 20 mA

Values			Current output range	Range
	Dec.	**Hex.**	**4 to 20 mA**	
118.5149%	32767	7FFF	22.81 mA	Overflow
	32512	7F00		
117.589%	32511	7EFF	22.81 mA	Overrange
	27649	6C01	20 mA + 578.7 nA	
100 %	27648	6C00	20 mA	Nominal range
75 %	20736	5100	16 mA	
0.003617%	1	1	4 mA + 578.7 nA	
0 %	0	0	4 mA	
	-1	FFFF	4 mA – 578.7 nA	Underrange
-25 %	-6912	E500	0 mA	
	-6913	E4FF	0 mA	Underflow
-118.519%	-32768	8000		