SIEMENS

SIMATIC

ET 200SP HA
F-AI 8xI 2-/4-wire HART HA

Equipment Manual

6DL1136-6AA00-0PH1

09/2021
A5E50557845-AA

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.

⚠ DANGER

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

⚠ 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.

Qualified Personnel

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.

Proper use of Siemens products

Note the following:

⚠ WARNING

Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

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.

Siemens AG
Digital Industries
Postfach 48 48
90026 NÜRNBERG
GERMANY

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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.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions constitute one element of such a concept.

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https://www.siemens.com/industrialsecurity.

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customer's exposure to cyber threats.

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Preface

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Validity of the documentation

This equipment manual describes the F-AI 8xI 2-/4-wire HART HA I/O module with part number 6DL1 136-6AA00-0PH1.

It supplements the system manual "Distributed I/O System ET 200SP HA (https://support.industry.siemens.com/cs/de/en/view/109781000)".

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

The information in this manual and in the system and function manuals enables you to commission the ET 200SP HA.

You can find additional information in the programming and operating manual "SIMATIC Industrial Software S7 F/FH Systems - Configuring and Programming (https://support.industry.siemens.com/cs/ww/en/view/109773062)

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.

Important notes for maintaining operational safety of your plant

Note

Operation of systems with safety aspects in mind

Safety-related systems are subject to special operational safety requirements on the part of the operator. The supplier is also obliged to comply with special product monitoring measures. For this reason, we provide you with information on product developments and features that are (or could be) relevant to operation of systems with safety aspects in mind. In order to obtain the latest information and to enable you to undertake any necessary modifications to your system, you must subscribe to the corresponding notifications To subscribe, go to the Internet (https://support.industry.siemens.com/My/ww/en/).

Log on to this website and under "My Notifications" select the notifications for the following topics, for example:

- S7-400 / S7-400H / S7-400F/FH
- Distributed I/O
- SIMATIC Industrial Software
- S7 F/FH Systems
- Configuration tool of the process control system
- ET 200SP HA

You can find additional information on setting up notifications on the page "Helpful Functions in Online Support (https://support.industry.siemens.com/cs/ww/en/sc/2063)".

Product overview

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3.1 Properties of I/O module

Definition

The I/O module F-AI 8xI 2-/4-wire HART HA is an analog input module with 8 current inputs for process control.

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

- Fail-safe analog module
- PROFIsafe profile V2.6.1
- PROFIsafe address type 2
- 8 fail-safe analog inputs (up to SIL3/Cat.3/PLd or SIL3/Cat.4/PLe with CPU voting)
- Measuring range: 0..20 mA and 4..20 mA
- Resolution: 16 bits including sign
- Short-circuit proof internal sensor supply Uv for 2-wire transmitter
- External sensor supply possible
- Configurable diagnostics
- Diagnostics display LED DIAG (red/green)
- Maintenance messages and maintenance display LED MT (yellow)
- Channel-specific status display LED "Channel status" (green)
- Channel-specific fault display LED "Channel fault" (red)
- Diagnostics
  - e.g. short-circuit/ wire break, channel-by-channel
  - e.g. supply voltage missing, module-by-module
- Channel-wide and module-wide passivation
- HART communication (Rev. 5 to Rev. 7)

The module supports the following functions:

- Firmware upgrade
- I&M identification data
- Value status
- IO redundancy

WARNING

Validity of safety parameters

The safety parameters in the technical specifications are valid for a mission time of 20 years and a repair time of 100 hours. If a repair is not possible within 100 hours, remove the relevant module from the terminal block or switch off its supply voltage before 100 hours elapse. After 100 hours elapse, the module switches off on its own.

For repairs, follow the procedure described in section "Diagnostic messages (Page 67)".

(FAIW-001)

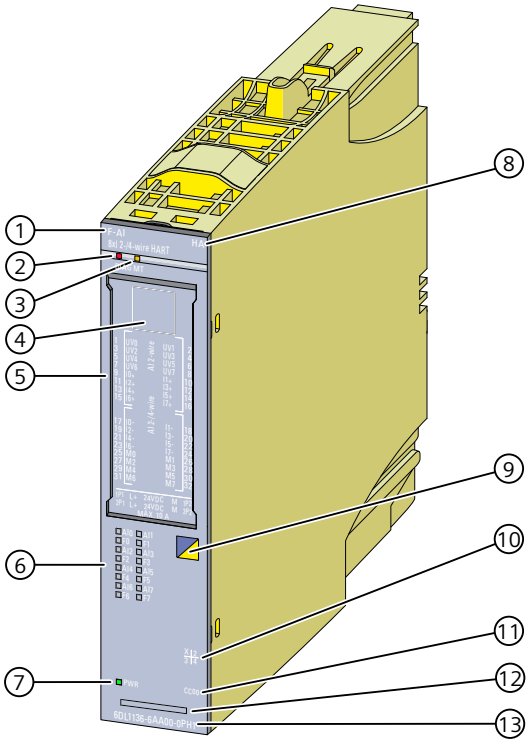
Note

Cyclic reading of I&M data

Cyclic reading of I&M data can put a strain on the timing of the F-modules. Therefore, avoid fast read cycles lower than 500 ms.

Description

The I/O module consists of the following components:



① Module type and designation
② LED for diagnostics
③ LED for maintenance
④ 2D matrix code
⑤ Wiring diagram
⑥ LEDs for channel status/error
⑦ LED for supply voltage
⑧ Function class
⑨ Module type color coding
- Basic type: "Blue" = Analog input module
- Supplemental type information: "Yellow" = Fail-safe I/O module

⑩ Product version
⑪ Color code for selection of the color-coded labels
⑫ Serial number
⑬ Article No.

3.2 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

You can find additional information in the system manual "Distributed I/O System ET 200SP HA (https://support.industry.siemens.com/cs/de/en/view/109781000)".

Connection

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4.1 Terminal blocks

Definition

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

Description

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

Article No.	Color	Description
6DL1193-6TP00-0DH1	Light gray	For single mode "Enable new potential group"
6DL1193-6TP00-0BH1	Dark gray	For single mode "Use potential group of the left module"
6DL1193-6TP00-0DP0	Light gray	Double-width terminal block with L+ potential distributor For single operation only "Enable new potential group"
6DL1193-6TP00-0BP0	Dark gray	Double-width terminal block with L+ potential distributor For single operation only "Use potential group of the left module"
6DL1193-6TP00-0DN0	Light gray	Double-width terminal block with M potential distributor For single operation only "Enable new potential group"
6DL1193-6TP00-0BN0	Dark gray	Double-width terminal block with M potential distributor For single operation only "Use potential group of the left module"
6DL1193-6TP00-0DF1	Black	Only for redundant interconnection of two F-AI 8xI 2-/4-wire HART HA F-modules "Mo potential group"

WARNING

Structure with redundant terminal block

No terminal block (color: dark gray) may be inserted to the right of a redundant terminal block (6DL1193-6TP00-0DF1; color black) to continue a potential group.

If this is not observed, reaction-free behavior between non-fail-safe and fail-safe modules can no longer be guaranteed.

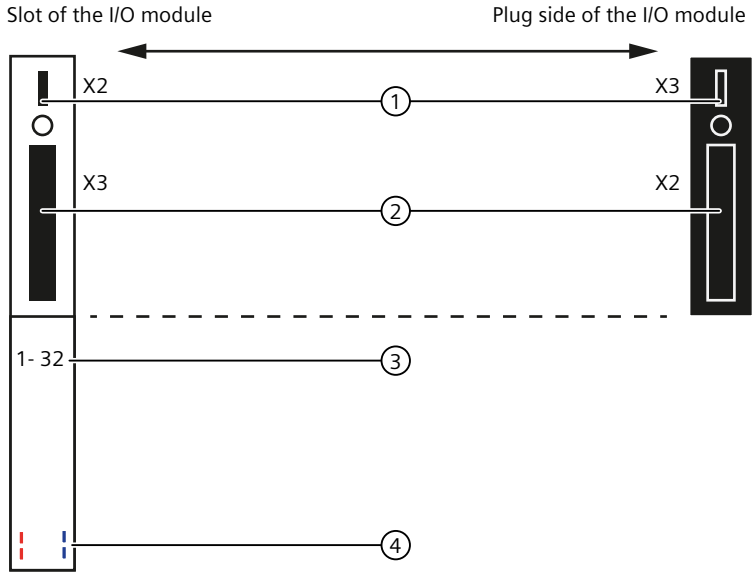
(FAIW-018)

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.

Connections on the slot and in the I/O module



① Carrier module contacts of the backplane bus:
Maximum 50 mA
Maximum 3.5 V DC ⎓

② Terminal block contacts of the I/O module:
Maximum 30 V DC ⎓
Maximum 30 mA per pin / maximum 0.24 A per module

③ Process terminals on the terminal block

④ Supply voltage of the I/O module

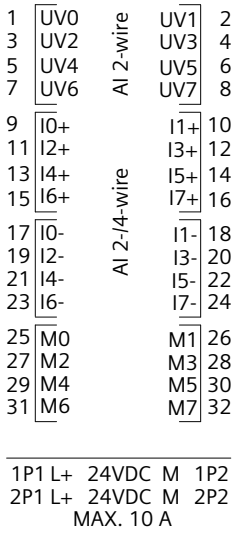
4.2 Terminal assignment

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	Explanations
1	UV0	2	UV1	• Terminal 1 to 8: UVn: Sensor supply, channel n • Terminal 9 to 16: In+: Current input positive, channel n • Terminal 17 to 24: In-: Current input negative, channel n • Terminal 25 to 32: Mn: Ground; channel n 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 
3	UV2	4	UV3	
5	UV4	6	UV5	
7	UV6	8	UV7	
9	I0+	10	I1+	
11	I2+	12	I3+	
13	I4+	14	I5+	
15	I6+	16	I7+	
17	I0-	18	I1-	
19	I2-	20	I3-	
21	I4-	22	I5-	
23	I6-	24	I7-	
25	M0	26	M1	
27	M2	28	M3	
29	M4	30	M5	
31	M6	32	M7	
1P1	L+	1P2	M	
2P1[1]	L+	2P2	M	

[1] If the module is inserted in a TB45R-P32+A0+4D terminal block (6DL1193-6TP00-0DF1) suitable for IO redundancy, the potential at this terminal is 1P3.

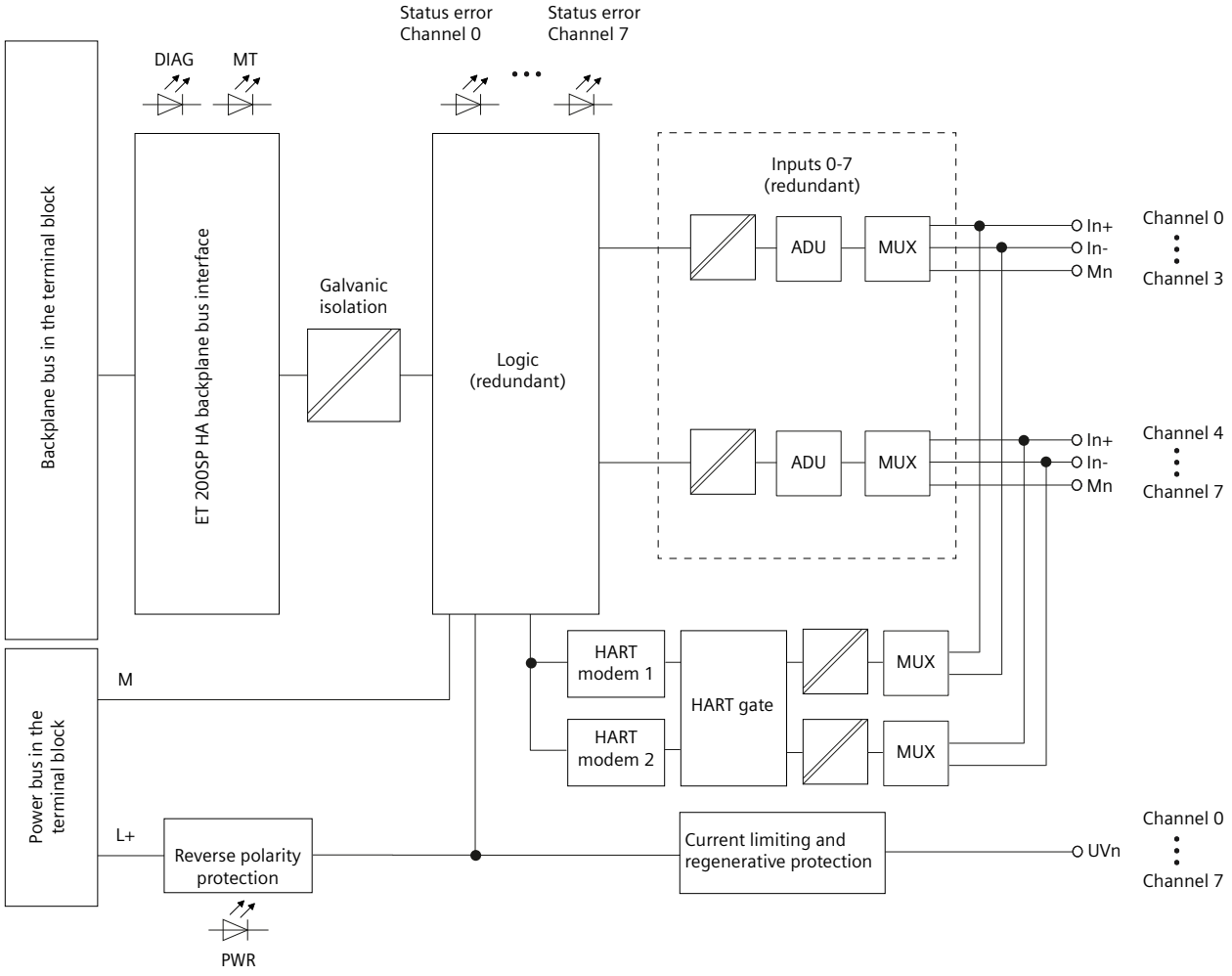
4.3 Schematic circuit diagram

Definition

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

Description

The block diagram for the I/O module is structured as follows:



Supply voltage

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

Firmware update

The supply voltage L+ must be available on the I/O module at the start of firmware updates and during the update.

The firmware can only be updated in the STOP mode of the F-CPU.

Recommendation: Internal sensor supply

We recommend to always use the short-circuit proof internal sensor supply of the F-module.

In the event of an error when using the internal sensor supply, the channel is passivated and the diagnostics provide information about the cause.

If there are short-circuits in the wiring or at the sensor, the input is also protected.

To guarantee the correct channel-specific reaction in the event of an error of the internal sensor supply, you must use the sensor supply assigned to the channel. If you do not observe this assignment, channels that are not affected may be influenced or passivated.

Note

The internal sensor supply is switched off if there is a short-circuit to ground.

The sensor supply is also switched off when the channel detects an overflow.

A check is made as to whether the error is still persisting after about 30 seconds.

External/internal sensor supply

The pictures in "Applications cases of the I/O module (Page 37)" section show how you can supply the sensors via an external sensor supply (e.g. via another module).

WARNING

Short-circuit from L+ to I_n+ or I_n-

If there is a short-circuit from I_n+ or I_n-, the input resistors may be destroyed, depending on the selected type of circuit.

This can be avoided by an appropriate short-circuit-proof circuit or by using the internal sensor supply. When using an external sensor supply, other suitable measures are required to protect the input resistors (external 50 mA "Fast-acting" fuse in the input circuit of the F-module).

(FAIW-016)

⚠ WARNING

External sensor supply

If you use an external sensor supply, you must take voltage dips and voltage supply deviation into account when determining the safety function.

To ensure proper functioning of the sensor, we recommend one of the following options:

- Use transmitters with appropriate buffering or diagnostics.
  or
- Use a redundant external sensor supply
  or
- Monitoring of the external sensor supply for undervoltage/overvoltage including shutdown of the sensor supply in the event of a fault.

(FAIW-017)

Parameters/address space

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5.1 Configuration options

Definition

There are fixed input and output address ranges that are used in the I/O system.

Configuring

The following software is required to configure the I/O module:

- S7 F-Systems V6.4 (or higher)

Configuration options

When configuring is done in HW Config, the configuration is carried out indirectly in the parameter assignment dialog of the module.

5.2 Parameter types

Definition

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

Description

The parameters are divided into three types:

- F-parameters (data record 128)
- "i" parameters (data record 129) e.g. module/channel parameters, system parameters, redundancy
- Potential group parameters (data record 243)

5.3 Module/channel parameters

Definition

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

Description

The parameters of the I/O module are displayed in the "Properties" dialog of the module in HW Config on the following tabs:

- "Parameters" tab
- "Redundancy" tab
  This tab is displayed for redundant I/O modules.

The following module/channel parameters are available.

"Parameters" tab

Parameter	Value range	Default	Re-parameterization in RUN	Efficiency range
F-parameters				
F_source_address (Page 27)	1 (display only)[a]	1	No	Module
F_destination_address (Page 27)	1 to 65534	Preset automatically[b]	No	Module
F_monitoring time (ms) (Page 28)	10 ms to 65535 ms	2500	No	Module
Cross-channel Cross-channel parameters act on all identically named parameters of the channels of the module and thus allow a higher-level setting.				
Measurement type (Page 31)	• deactivated • 2-wire • 4-wire	2-wire	No	Channel
Measuring range (Page 31)	• 0..20mA • 4..20mA	4..20mA	No	Channel
Smoothing (Page 29)	• 1 (none) • 4 • 16 • 64	1	No	Channel
Diagnostics wire break (Page 32)	• deactivated • activated	activated	No	Channel

Parameter	Value range	Default	Re-parameterization in RUN	Efficiency range
HART activated (Page 31)	• deactivated • activated Can only be configured when the "HART gate" is activated and the measuring range "4..20mA" is set.	deactivated	No	Channel
Number HART message frame repetitions (Page 28)	0 to 10 Only relevant when the "HART activated" parameter is activated.	5	No	Channel
Diagnostics HART (Page 32)	• deactivated • activated Only relevant when the "HART activated" parameter is activated.	activated	No	Channel
Module parameters				
Diagnostics: missing power supply voltage L+ (Page 29)	Activated (display only)	activated	No	Module
Behavior after channel fault (Page 34)	• Passivate the entire module • Passivate channel	Passivate channel	No	Module
HART gate (Page 30)	• Off • On	Off	No	Module
Interference frequency suppression (Page 34)	• 60 Hz (integration time 16.6 ms) • 50 Hz (integration time 20 ms) When 50 Hz is set, the 400 Hz interfering signals are also filtered automatically.	50 Hz	No	Module
Channel n				
Measurement type (Page 31)	• deactivated • 2-wire • 4-wire	2-wire	No	Channel
Measuring range (Page 31)	• 0..20mA • 4..20mA	4..20mA	No	Channel
Smoothing (Page 29)	• 1 (none) • 4 • 16 • 64	1	No	Channel
Diagnostics wire break (Page 32)	• deactivated • activated	activated	No	Channel

Parameter	Value range	Default	Re-parameterization in RUN	Efficiency range
HART activated (Page 31)	• deactivated • activated Can only be configured when the "HART gate" is activated and the measuring range "4..20mA" is set.	deactivated	No	Channel
Number HART message frame repetitions (Page 28)	0 to 10 Only relevant when the "HART activated" parameter is activated.	5	No	Channel
Diagnostics HART (Page 32)	• deactivated • activated Only relevant when the "HART activated" parameter is activated.	activated	No	Channel
Terminal block				
Double-width terminal block (Page 29)	• no • yes	No	No	Module
Potential group				
Potential group (Page 33)	• Potential group of the left module (dark gray terminal block) • New potential group (light gray terminal block) • No potential group (black terminal block)	New potential group (light gray terminal block)	No	Module

[a] The F_source_address is automatically preset with the value "1" in S7 F/FH Systems and cannot be changed in the properties of the I/O module.

[b] The F_destination_address is automatically preset uniquely station-wide.

Note

Unused channels

"Disable" unused channels in the parameter assignment to improve the cycle time of the module.

You can find more information on this in the section "Response times (Page 113)".

A deactivated channel always returns the analog value 0x0000 and QI = 0 ("Substitute value is output").

"Redundancy" tab

Define additional settings on the "Redundancy" tab for redundant analog input modules.

Parameter	Value range	Default	Re-parameterization in RUN	Efficiency range
"Redundancy General Settings" group				
Selection box "Redundancy (Page 33)"	• None • 2 modules	None	No	Redundant modules

5.4 Explanation of the module/channel parameters

5.4.1 F_source_address

Definition

Together, the F-source address "F_source_address" and the F-destination address "F_destination_address" form the PROFIsafe address. The PROFIsafe address is used for the unique identification of the F-I/O modules.

The F-source address is a unique address of the fail-safe CPU for the entire network. In S7 F/FH systems, it is automatically preset with the value "1" and cannot be changed in the properties of the I/O module.

5.4.2 F_destination_address

Definition

Together, the F-destination address "F_destination_address" and the F-source address "F_source_address" form the PROFIsafe address. The PROFIsafe address is used for the unique identification of the F-I/O modules.

Station-wide uniqueness:

- The F-source address "F_source_address" of the F-CPU is unique station-wide. In S7 F/FH systems, it is automatically preset with the value "1".
- The F-destination address of the F-I/O module is automatically unique station-wide.
  To prevent an incorrect parameter assignment, a station-wide unique F-destination address is automatically assigned when the F-I/O module is placed in HW Config.
  If you change F-destination address, the station-wide uniqueness of F-destination address is automatically checked.
  You must assign the F-destination address to the F-I/O module before you commission it.

Note

Requirement for type R1 system redundancy

With type R1 system redundancy for distributed I/O, the left interface module must be plugged in so that a new F_destination_address can be assigned to the module.

WARNING

PROFIsafe addresses have to be unique for the station

- Station-wide uniqueness:
  Fail-safe I/O modules of the ET 200SP HA are uniquely addressed station-wide by a combination of F-source address (PROFIsafe start address of the assigned F-CPU) and F-destination address. The F-system itself ensures that the F-destination addresses of all F-I/O modules within the assigned F-CPU are unique.
- Cross-station uniqueness:
  To guarantee uniqueness across stations, you must verify that the PROFIsafe addresses ("F_source_address" + "F_destination_address") of the F-I/O modules are unique across stations.
- Verification following a change:
  Because the F-source address "F_source_address" of the PROFIsafe address of the F-CPU is automatically set to "1", you can only change the preset address "F_destination_address" for F-I/O modules of the ET 200SP HA.
  Note that the PROFIsafe address of the F-I/O module must be unique across all stations!

For Ethernet subnets and mixed configurations of PROFIBUS and Ethernet subnets, the following also applies:

The combination of F-source address and F-destination address of all F-I/O modules only has to be unique throughout the Ethernet subnet including all lower-level PROFIBUS subnets, under the exclusion of cyclic PROFINET IO communication between Ethernet subnets.

(FAIW-002)

5.4.3 F_monitoring time (ms)

Definition

You use this parameter to set the monitoring time for safety-related communication between the F-CPU and F-I/O (PROFIsafe monitoring time) for safety mode.

The parameter is assigned a default value, but you can change it.

The configured F-monitoring time influences the response time of the system to a system error. For this reason, the selected time must be as short as possible, but still long enough to prevent timeouts in error-free conditions.

5.4.4 Number HART message frame repetitions

Definition

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

The parameter is only relevant when the "HART enabled" parameter is activated.

5.4.5 Diagnostics: missing power supply voltage L+

Definition

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

This parameter is "activated" by default, cannot be changed and is for display purposes only.

5.4.6 Double-width terminal block

Definition

Specifies that a double-width terminal block is used in this slot.

This parameter is only active if the module is plugged into an even-numbered slot.

If set to "Yes", it is not possible to configure an additional module on the slot to the right of the current slot.

When using the terminal blocks with potential distributors, you have to activate the parameter "Double-width terminal block".

This parameter only affects the configuration in HW Config.

5.4.7 Smoothing

Definition

Compensates for measured value fluctuations.

The individual measured values are smoothed by filtering.

Description

The measured values are smoothed by a digital filter. Smoothing is achieved by the F-I/O module calculating the moving average from a number of digitalized analog values specified with the "Smoothing" parameter.

Smoothing can be set in 4 levels (1, 4, 16, 64 conversion cycles). The level determines the number of analog signals to be used for generating the moving average.

When "1" is set, smoothing is deactivated.

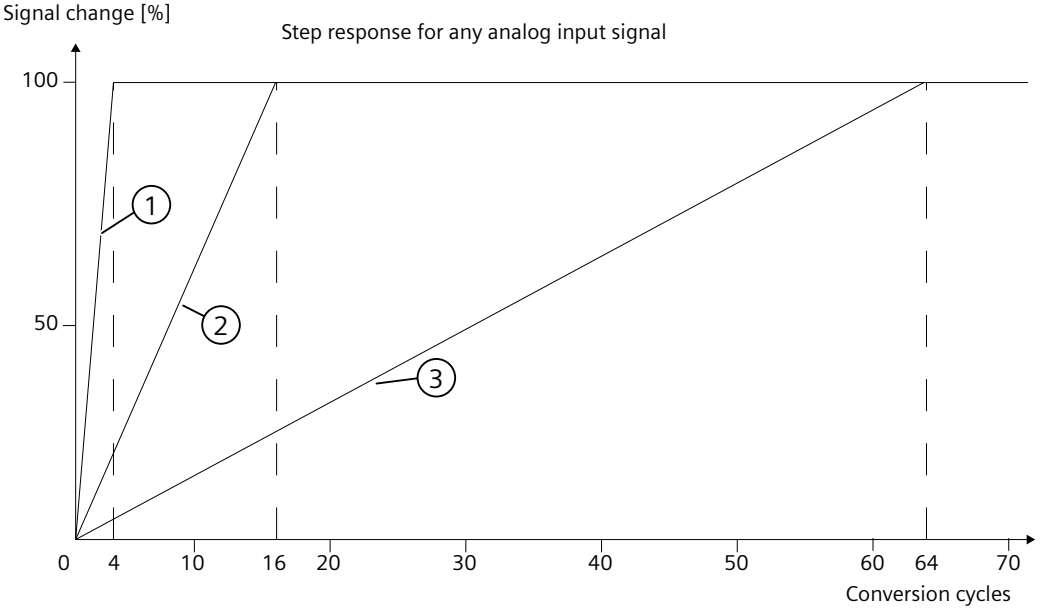
The higher the smoothing is selected, the more stable the smoothed analog value is and the longer it takes until the smoothed analog signal is applied after a unit jump.

Note

After start-up, short circuit, wire break or other channel fault, the smoothing is restarted.

If, for example, the smoothing is parameterized with 16 conversion cycles and all channels are active, then, with a set interference frequency suppression of 50 Hz, it takes up to 2400 ms until the process value is reported.
Up to the first valid process value, the peripheral module for the channel reports a value of 0 and QI = 0.

The following figure shows how many conversion cycles it takes for the smoothed analog value to be completely available, depending on the configured smoothing. This applies to every signal change at the analog input.



① k = 4: Weak smoothing
② k = 16: Medium smoothing
③ k = 64: Strong smoothing

5.4.8 HART gate

Definition

This parameter is used to enable the HART communication for the I/O module.

The "HART gate" parameter acts as a fail-safe "main switch" for the complete module.

The following parameter assignments are possible:

- "On": HART communication is enabled.
- "Off": HART communication is disabled.

HART communication is then activated on a channel-specific basis with the "HART enabled" parameter.

You can find additional information on this parameter in the section "HART for safety-related applications (Page 77)".

5.4.9 HART activated

Definition

This parameter is used to enable the HART communication for the respective channel.

This parameter can only be configured when the "HART gate" is activated and the measuring range "4 to 20 mA" is set.

The parameter is not safety-related, meaning that fail-safe deactivation of the HART communication is not possible with this parameter.

5.4.10 Measurement type/measuring range

Definition

- "Measurement type" parameter
  The "Measurement type" parameter can be used to select between 2-wire and 4-wire transducers or to deactivate the channel.
  With a 2-wire transmitter, the sensor supply is internal, with a 4-wire transmitter it is external.
  You can find more information on this in the section "Applications cases of the I/O module (Page 37)".
  You can deactivate an unused channel with this parameter (measurement type "deactivated").
  If you deactivate unused channels, the response time of the F-I/O module is reduced.
  You can find more information on this in the section "Response times (Page 113)".
- "Measuring range" parameter
  With an active channel, i.e. the "Measurement type" parameter is not "deactivated", you can select between different measuring ranges using the "Measuring range" parameter.

An overview of the measuring ranges and the overflow, overrange, etc. can be found in appendix "Analog value representation (Page 109)".

Description

The I/O module has the following measuring ranges:

Measurement type	Measuring range	Resolution with interference frequency suppression for 50 and 60 Hz
"deactivated"	--	--
"2-wire"	4 to 20 mA	16 bits including sign
"4-wire"	0 to 20 mA	
	4 to 20 mA	

HART mode is only possible with a measuring range of 4 to 20 mA. HART communication is not deactivated even at currents below 4 mA.

Note

Response of the internal sensor supply with "2-wire" measurement type

After activation of the internal sensor supply (e.g. during module startup or after a short-circuit of the sensor supply), the "Wire break" and "Low limit violated" diagnostic events are suppressed for 3 seconds to avoid passivation of the channel involved in the ramp-up of the sensor.

During this time, the module provides the safe process value 0 on all channels.

5.4.11 Diagnostics HART

Definition

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

The parameter is only relevant when the "HART enabled" parameter is activated.

The HART diagnostics are reported as maintenance events.

Maintenance events (Page 72)

5.4.12 Diagnostics wire break

Definition

Enable the wire break detection. The module can only detect a wire break if this parameter is activated.

You can activate the wire break detection with a parameterized measuring range of 4 to 20 mA here.

- Parameterized measuring range from 4 to 20 mA:
  - In the case of parameterized diagnostics wire break and currents < 3.6 mA, a wire break is detected and a diagnostic interrupt is triggered in the F-CPU.
  - Without parameterized diagnostics wire break and with currents < 0.4444 mA, an "underflow" is detected and a diagnostic interrupt is triggered in the F-CPU.
- Parameterized measuring range from 0 to 20 mA:
  Diagnostics wire break is preset by default. With currents < 0.4442 mA, a wire break is detected and a diagnostic interrupt is triggered in the F-CPU.

If you do not need a channel, deactivate the channel. No wire break detection is then available.

5.4.13 Potential group

Definition

Specifies whether the I/O module is located on a terminal block with supply voltage infeed.

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 to the right of 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*.

5.4.14 Redundancy

Definition

You can configure two identical modules redundantly. To do so, plug both modules directly side by side into the redundant terminal block specified below. 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.

Both redundant modules measure the process simultaneously and independently. Similarly, both redundant modules form diagnostics, interrupts and process values.

The HART communication takes place exclusively via one of the two redundant channels.

Description

The acquired process value is made available on both the modules in error-free, redundant operation.

IO redundancy is only possible with the I/O module F-AI 8xI 2-/4-wire HART HA with the terminal block type F1 ("TB45R-P32"; 6DL1193-6TP00-0DF1).

5.4.15 Interference frequency suppression

Definition

Suppresses the interference that is caused by the frequency of the AC voltage network used.

The following parameter assignments are possible:

- 50 Hz (integration time 20 ms)
- 60 Hz (integration time 16.6 ms)

When 50 Hz is set, the 400 Hz interfering signals are also filtered automatically.

5.4.16 Behavior after channel fault

Definition

With this parameter you specify whether the entire F-module is passivated after channel faults or just the faulty channels:

- "Passivate entire module"
- "Passivate channel"

5.5 Address space

Abbreviations

- "IB" stands for input byte, i.e. the module start address in the input area
- "QB" stands for output byte, i.e. the module start address in the output area
- "QAIn" stands for value status (QI) of the analog input "n"

"Value status" bit

For each input signal, the F-AI 8xI 2-/4-wire HART HA module provides information on its validity, the "value status" (qualifier bit). The value status is stored in the process image of the inputs.

In S7 F/FH systems, you may only access the addresses occupied by user data (AIx). The value status is automatically processed by the F-channel drivers.

Regardless of the diagnostics enables, each "value status" provides information about the validity of the corresponding process value.

Address space

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

Input area

IB x +	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
0...1	Analog value, analog input 0							
: :	: :							
14...15	Analog value, analog input 7							
16	QAI7	QAI6	QAI5	QAI4	QAI3	QAI2	QAI1	QAI0
17...21	PROFIsafe trailer (PROFIsafe profile V2.6.1)							

x = module start address

Output range

QB x + 0...4	PROFIsafe trailer (PROFIsafe profile V2.6.1)

x = module start address

Note

- You may only access the addresses occupied by user data.
- In S7 F/FH systems, the value status is automatically processed by the F-channel drivers.
- With I/O redundancy, you only access the channels of the left I/O module. The input values of the corresponding channels of the redundant I/O module are automatically processed by the F-channel drivers.
- The other address areas occupied by the F-modules are assigned for functions including safety-related communication between the F-modules and F-CPU in accordance with PROFIsafe.

Applications of the F-I/O module

6

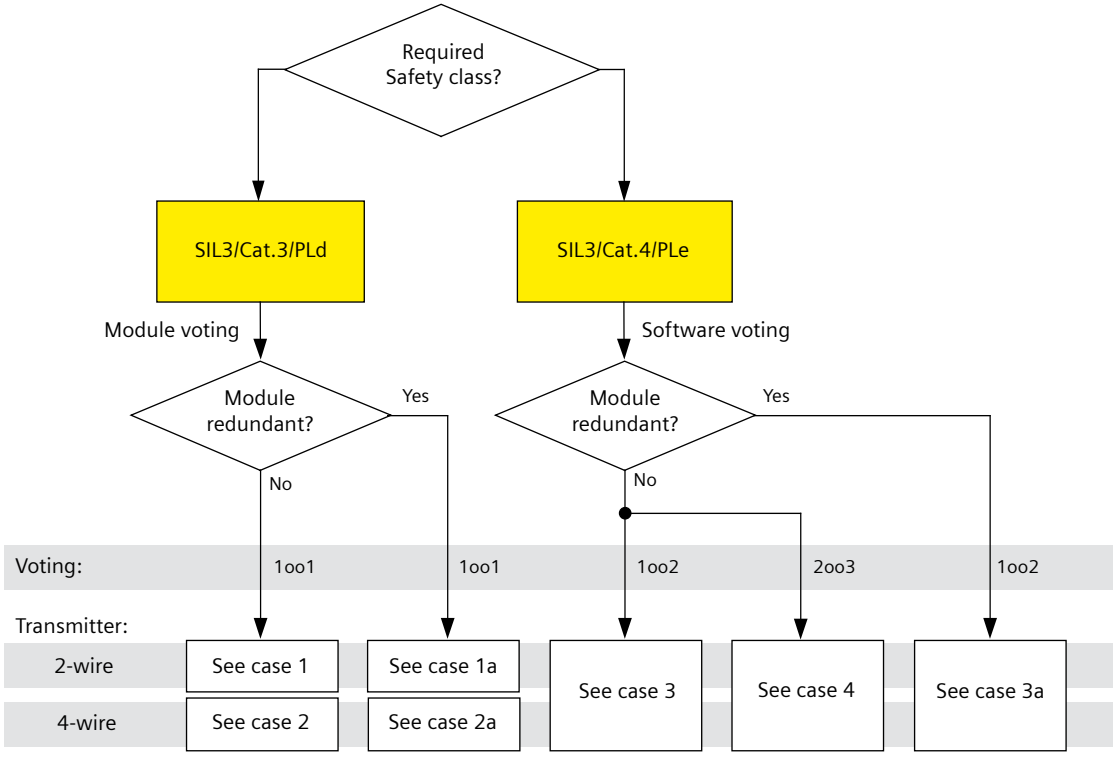
6.1 Applications cases of the I/O module

Definition

In the following sections, you will learn how to wire the F-I/O module for each application, which specific parameters you need to set in STEP 7.

Selecting the application

The diagram below supports you in selecting the application that suits your fail-safe requirements.



Conditions for achieving SIL/Cat./PL

The table below lists the conditions which have to be met for achieving at least the corresponding safety requirements.

Application	Sensor evaluation	Sensor supply	Achievable SIL/Cat./PL
1	1oo1	Internal, since 2-wire transmitter	3 / 3 / d
1a	1oo1	Internal, since 2-wire transmitter	
2	1oo1	External, since 4-wire transmitter	
2a	1oo1	External, since 4-wire transmitter	
3	1oo2 (2v2) (not on the module, only in the F-program)	• Internal, if 2-wire transmitter • External, if 4-wire transmitter	3 / 4 / e
3a	1oo2 (2v2) (not on the module, only in the F-program)	• Internal, if 2-wire transmitter • External, if 4-wire transmitter	
4	2oo3 (not on the module, only in the F-program)	• Internal, if 2-wire transmitter • External, if 4-wire transmitter	

WARNING

Achievable safety class

The achievable safety class depends on the sensor quality and the proof-test interval according to the standard IEC 61508:2010. If the sensor quality is not as high as required by the required safety class, the sensor must be used redundantly, have a 2-channel connection and 2-channel evaluation.

(FAIW-003)

Note

You can operate the different inputs of an F-I/O module simultaneously in SIL3/Cat.3/PLd **and** in SIL3/Cat.4/PLe. You only have to interconnect the inputs and assign parameters as described in the following sections.

Sensor requirements

You can find information on the requirements placed on sensors for F-I/O modules in safety-related use in section "Requirements placed on sensors for fail-safe modules (Page 57)".

Calculation of the remaining supply voltage at the transmitter

You can find additional information on this in the section "Calculation of the remaining supply voltage at the sensor (Page 60)".

See also

Application case 1: SIL3/Cat.3/PLd, 2-wire transmitter, 1oo1 (Page 40)

Application case 1a: SIL3/Cat.3/PLd, 2-wire transmitter, 1oo1 (high availability) (Page 42)

Application case 2: SIL3/Cat.3/PLd, 4-wire transducer, 1oo1 (Page 44)

Application case 2a: SIL3/Cat.3/PLd, 4-wire transmitter, 1oo1 (high availability) (Page 46)

Application case 3: SIL3/Cat.4/PLe, 2- or 4-wire transducer, 1oo2 (Page 48)

Application case 3a: SIL3/Cat.4/PLe, 2- or 4-wire transmitter, 1oo2 (high availability) (Page 51)

Application case 4: SIL3/Cat.4/PLe, 2- or 4-wire transmitter, 2oo3 (Page 54)

IO redundancy (Page 58)

6.2 Application case 1: SIL3/Cat.3/PLd, 2-wire transmitter, 1oo1

Definition

In the following, you can find the wiring diagram and the configuration of the I/O module F-AI 8xI 2-/4-wire HART HA for application case 1:

- SIL3/Cat.3/PLd
- 1oo1 evaluation
- 2-wire transmitter

You can find possible diagnostic messages, their causes and remedies in the "Diagnostic messages" section.

Wiring

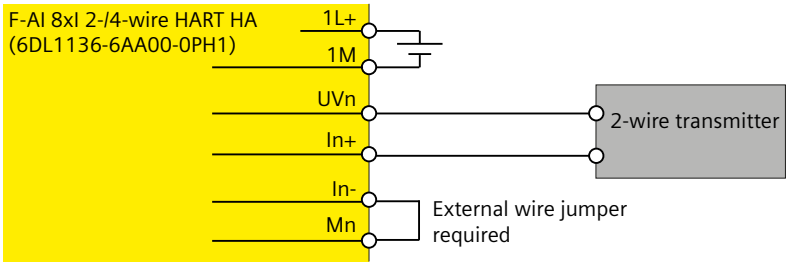
You perform the wiring on the appropriate terminal block. You can find additional information on this in the section "Terminal assignment (Page 17)".

Sensor supply

The sensor supply is internal for a 2-wire transmitter.

The sensor supply UVn is provided by the F-module for 8 channels.

Wiring scheme



WARNING

Requirement for sensor

To achieve SIL3/Cat.3/PLd using this wiring, you must use a qualified sensor.

(FAIW-004)

⚠ WARNING

Cabling

You must use shielded cables to ensure installation free of interference voltage.

(FAIW-005)

Parameter assignment

Set the following parameters for the corresponding channel:

Parameter	Channel with internal sensor supply
Measurement type	Current (2-wire transmitter)
Measuring range	4 to 20 mA
Behavior after channel fault	Passivate the channel / passivate the entire module
Interference frequency suppression	50 Hz / 60 Hz
HART gate	On / Off
Diagnostics, Wire break	Activated / deactivated
Smoothing	1 / 4 / 16 / 64
HART enabled	Activated / deactivated
Number HART message frame repetitions	0 to 10
Diagnostics HART	Activated / deactivated

6.3 Application case 1a: SIL3/Cat.3/PLd, 2-wire transmitter, 1oo1 (high availability)

Definition

In the following, you can find the wiring diagram and the configuration of the I/O module F-AI 8xI 2-/4-wire HART HA for application case 1a:

- SIL3/Cat.3/PLd
- 1oo1 evaluation
- 2-wire transmitter
- Redundant I/O module

You can find possible diagnostic messages, their causes and remedies in the "Diagnostic messages" section.

Wiring

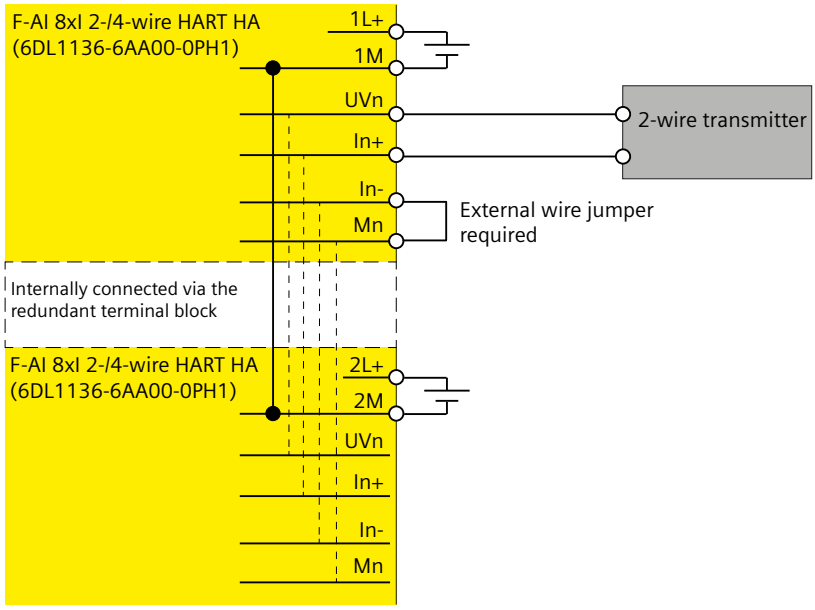
You perform the wiring on the appropriate terminal block. You can find additional information on this in the section "Terminal assignment (Page 17)".

Sensor supply

The sensor supply is internal for a 2-wire transmitter.

The sensor supply UVn is provided by the F-module for 8 channels.

Wiring scheme



WARNING

Requirement for sensor

To achieve SIL3/Cat.3/PLd using this wiring, you must use a qualified sensor.

(FAIW-004)

WARNING

Cabling

You must use shielded cables to ensure installation free of interference voltage.

(FAIW-005)

Parameter assignment

Set the following parameters for the corresponding channel:

Parameter	Channel with internal sensor supply
Measurement type	Current (2-wire transmitter)
Measuring range	4 to 20 mA
Behavior after channel fault	Passivate the channel / passivate the entire module
Interference frequency suppression	50 Hz / 60 Hz
HART gate	On / Off
Diagnostics, Wire break	Activated / deactivated
Smoothing	1 / 4 / 16 / 64
HART enabled	Activated / deactivated
Number HART message frame repetitions	0 to 10
Diagnostics HART	Activated / deactivated

6.4 Application case 2: SIL3/Cat.3/PLd, 4-wire transducer, 1oo1

Definition

In the following, you can find the wiring diagram and the configuration of the I/O module F-AI 8xI 2-/4-wire HART HA for application case 2:

- SIL3/Cat.3/PLd
- 1oo1 evaluation
- 4-wire transmitter

You can find possible diagnostic messages, their causes and remedies in the "Diagnostic messages" section.

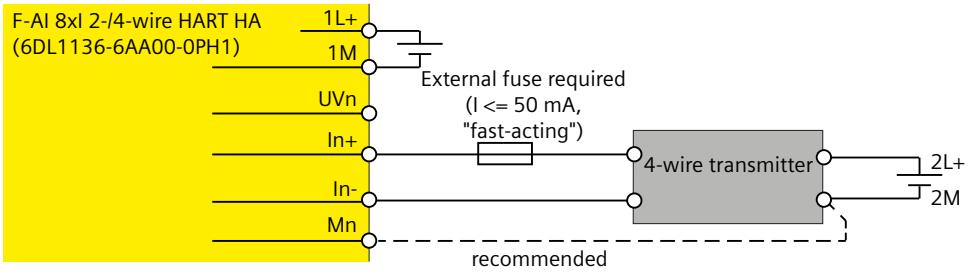
Wiring

You perform the wiring on the appropriate terminal block. You can find more information on this in the section "Terminal assignment (Page 17)".

Sensor supply

The sensor supply is external for a 4-wire transmitter.

Wiring scheme



WARNING

Requirement for sensor

To achieve SIL3/Cat.3/PLd using this wiring, you must use a qualified sensor.

(FAIW-004)

⚠ WARNING

Cabling

You must use shielded cables to ensure installation free of interference voltage.

(FAIW-005)

Parameter assignment

Set the following parameters for the corresponding channel:

Parameter	Channel with external sensor supply
Measurement type	Current (4-wire transmitter)
Measuring range	0 to 20 mA / 4 to 20 mA
Behavior after channel fault	Passivate the channel / passivate the entire module
Interference frequency suppression	50 Hz / 60 Hz
HART gate	On / Off
Diagnostics, Wire break	In the measuring range 4 to 20 mA: Activated / deactivated
Smoothing	1 / 4 / 16 / 64
HART enabled	In the measuring range 4 to 20 mA: Activated / deactivated
Number HART message frame repetitions	In the measuring range 4 to 20 mA: 0 to 10
Diagnostics HART	In the measuring range 4 to 20 mA: Activated / deactivated

6.5 Application case 2a: SIL3/Cat.3/PLd, 4-wire transmitter, 1oo1 (high availability)

Definition

In the following, you can find the wiring diagram and the configuration of the I/O module F-AI 8xI 2-/4-wire HART HA for application case 2a:

- SIL3/Cat.3/PLd
- 1oo1 evaluation
- 4-wire transmitter
- Redundant I/O module

You can find possible diagnostic messages, their causes and remedies in the "Diagnostic messages" section.

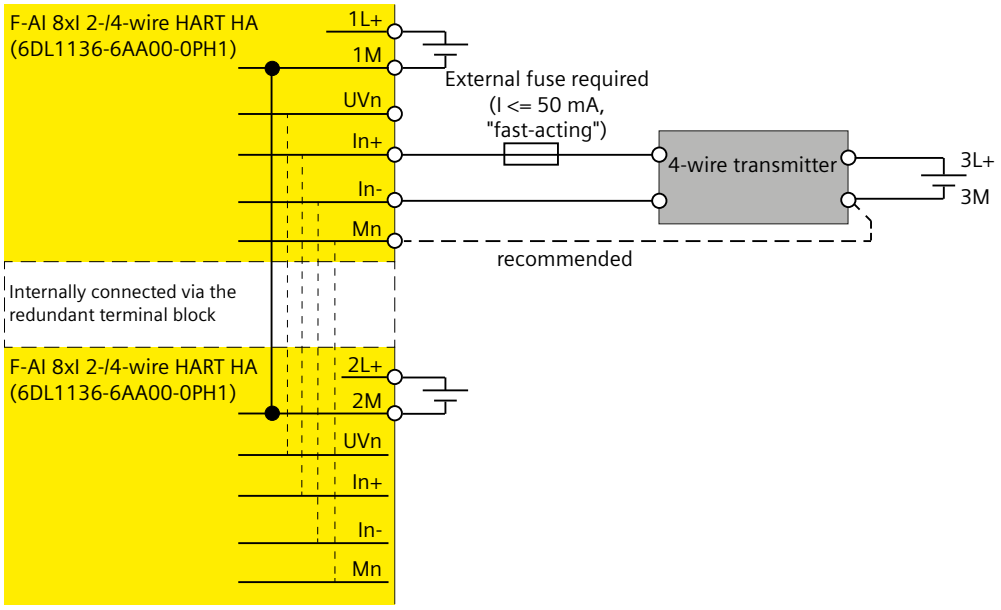
Wiring

You perform the wiring on the appropriate terminal block. You can find additional information on this in the section "Terminal assignment (Page 17)".

Sensor supply

The sensor supply is external for a 4-wire transmitter.

Wiring scheme



WARNING

Requirement for sensor

To achieve SIL3/Cat.3/PLd using this wiring, you must use a qualified sensor.

(FAIW-004)

WARNING

Cabling

You must use shielded cables to ensure installation free of interference voltage.

(FAIW-005)

Parameter assignment

Set the following parameters for the corresponding channel:

Parameter	Channel with external sensor supply
Measurement type	Current (4-wire transmitter)
Measuring range	0 to 20 mA / 4 to 20 mA
Behavior after channel fault	Passivate the channel / passivate the entire module
Interference frequency suppression	50 Hz / 60 Hz
HART gate	On / Off
Diagnostics, Wire break	In the measuring range 4 to 20 mA: Activated / deactivated
Smoothing	1 / 4 / 16 / 64
HART enabled	In the measuring range 4 to 20 mA: Activated / deactivated
Number HART message frame repetitions	In the measuring range 4 to 20 mA: 0 to 10
Diagnostics HART	In the measuring range 4 to 20 mA: Activated / deactivated

6.6 Application case 3: SIL3/Cat.4/PLe, 2- or 4-wire transducer, 1oo2

Definition

In the following, you can find the wiring diagram and the configuration of the I/O module F-AI 8xI 2-/4-wire HART HA for application case 3:

- SIL3/Cat.4/PLe
- 1oo2 evaluation
- Application for a two-channel or for two single-channel qualified sensors

You can find possible diagnostic messages, their causes and remedies in the "Diagnostic messages" section.

Wiring

You perform the wiring on the appropriate terminal block. You can find more information on this in the section "Terminal assignment (Page 17)".

Sensor supply

The sensor supply can be powered internally (2-wire transmitter) or externally (4-wire transmitter).

Wiring scheme

Please note application case 1 or 2.

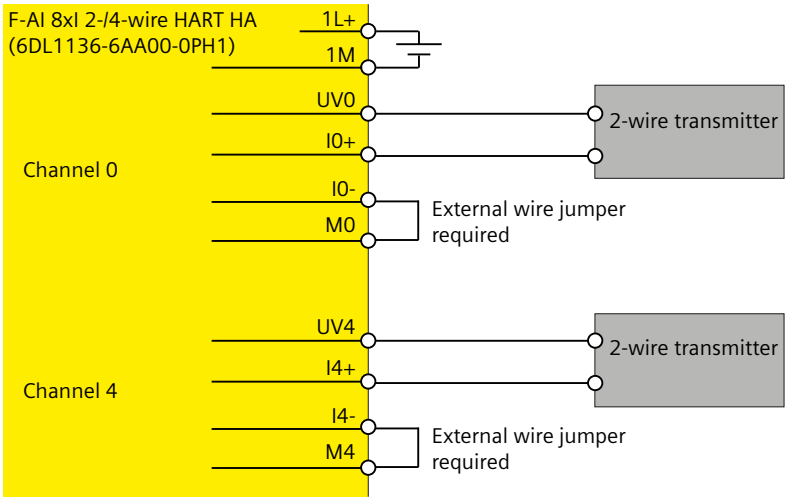
One of these application cases is set up in pairs.

It is recommended to pair the following inputs for the 1oo2 evaluation in the CPU:

- Channel 0 and 4
- Channel 1 and 5
- Channel 2 and 6
- Channel 3 and 7

You can combine the channels for the 1oo2 evaluation in the CPU as you like. However, the mentioned combinations represent the most favorable channel pairings, because these channel pairs are read in simultaneously by the F-module and therefore you can set the lowest possible discrepancy time.

In the following figure, application case 1 and channels 0 and 4 have been selected as an example.



WARNING

Requirement for sensor

To achieve SIL3/Kat.4/PLe with this wiring, a two-channel or two single-channel qualified sensor is required.

(FAIW-007)

WARNING

Cabling

You must use shielded cables to ensure installation free of interference voltage.

(FAIW-005)

Parameter assignment

Set the following parameters for the corresponding channel:

Parameter	Channel / sensor supply
Measurement type	• Current (2 wire transmitter); internal sensor supply (Application case 1) • Current (4-wire transmitter); external sensor supply (Application case 2)
Measuring range	0 to 20 mA / 4 to 20 mA
Behavior after channel fault	Passivate the channel / passivate the entire module
Interference frequency suppression	50 Hz / 60 Hz
HART gate	On / Off
Diagnostics, Wire break	In the measuring range 4 to 20 mA: Activated / deactivated
Smoothing	1 / 4 / 16 / 64

Parameter	Channel / sensor supply
HART enabled	In the measuring range 4 to 20 mA: Activated / deactivated
Number HART message frame repetitions	In the measuring range 4 to 20 mA: 0 to 10
Diagnostics HART	In the measuring range 4 to 20 mA: Activated / deactivated

Configuration in the safety program

For safety-oriented applications according to SIL3/Cat.4/PLe, perform a discrepancy analysis with 1oo2 evaluation (in S7 F Systems with the F-block F_1oo2AI) in your safety program.

You can find more information in the programming and operating manual "SIMATIC Industrial Software S7 F/FH Systems - Configuring and Programming (https://support.industry.siemens.com/cs/ww/en/view/109773062)".

6.7 Application case 3a: SIL3/Cat.4/PLe, 2- or 4-wire transmitter, 1oo2 (high availability)

Definition

In the following, you can find the wiring diagram and the configuration of the I/O module F-AI 8xI 2-/4-wire HART HA for the application case 3a:

- SIL3/Cat.4/PLe
- 1oo2 evaluation
- Redundant I/O module
- Application for a two-channel or for two single-channel qualified sensors

You can find possible diagnostic messages, their causes and remedies in the "Diagnostic messages" section.

Wiring

You perform the wiring on the appropriate terminal block. You can find additional information on this in the section "Terminal assignment (Page 17)".

Sensor supply

The sensor supply can be powered internally (2-wire transmitter) or externally (4-wire transmitter).

Wiring scheme

Refer to application case 1a or 2a.

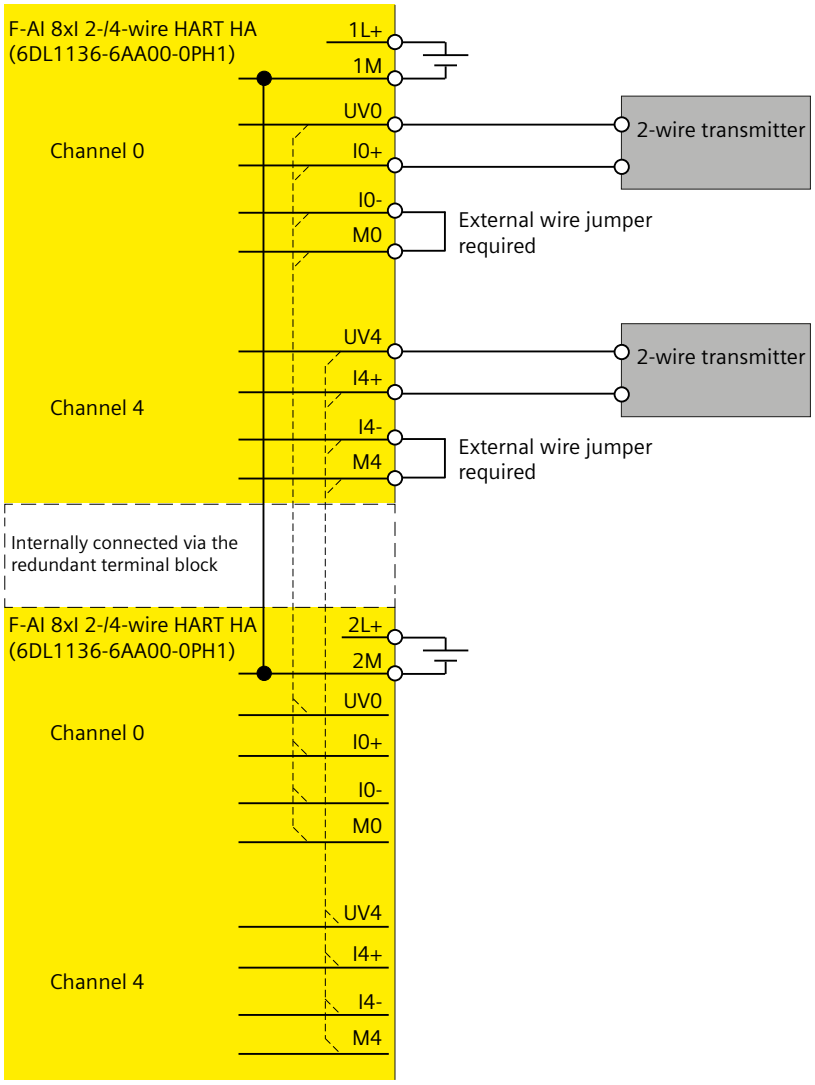
One of these application cases is set up in pairs.

It is recommended to pair the following inputs for the 1oo2 evaluation in the CPU:

- Channel 0 and 4
- Channel 1 and 5
- Channel 2 and 6
- Channel 3 and 7

You can combine the channels for the 1oo2 evaluation in the CPU as you like. However, the mentioned combinations represent the most favorable channel pairings, because these channel pairs are read in simultaneously by the F-module and therefore you can set the lowest possible discrepancy time.

In the following figure, application case 1a and channels 0 and 4 have selected as an example.



WARNING

Requirement for sensor

To achieve SIL3/Kat.4/PLe with this wiring, a two-channel or two single-channel qualified sensor is required.

(FAIW-007)

WARNING

Cabling

You must use shielded cables to ensure installation free of interference voltage.

(FAIW-005)

Parameter assignment

Set the following parameters for the corresponding channel:

Parameter	Channel / sensor supply
Measurement type	• Current (2 wire transmitter); internal sensor supply (Application case 1a) • Current (4-wire transmitter); external sensor supply (application case 2a)
Measuring range	0 to 20 mA / 4 to 20 mA
Behavior after channel fault	Passivate the channel / passivate the entire module
Interference frequency suppression	50 Hz / 60 Hz
HART gate	On / Off
Diagnostics, Wire break	In the measuring range 4 to 20 mA: Activated / deactivated
Smoothing	1 / 4 / 16 / 64
HART enabled	In the measuring range 4 to 20 mA: Activated / deactivated
Number HART message frame repetitions	In the measuring range 4 to 20 mA: 0 to 10
Diagnostics HART	In the measuring range 4 to 20 mA: Activated / deactivated

Configuration in the safety program

For safety-related applications according to SIL3/Cat.4/PLe, perform a discrepancy analysis with 1oo2 evaluation (in S7 F Systems with the F-block F_1oo2AI) in your safety program.

You can find additional information in the programming and operating manual "SIMATIC Industrial Software S7 F/FH Systems - Configuring and Programming (https://support.industry.siemens.com/cs/ww/en/view/109773062)".

6.8 Application case 4: SIL3/Cat.4/PLe, 2- or 4-wire transmitter, 2oo3

Definition

Below you can find the wiring diagram and the configuration of the I/O module F-AI 8xI 2-/4-wire HART HA for application case 4:

- SIL3/Cat.4/PLe
- 2oo3 evaluation
- Application for three single-channel qualified sensors on input channels of 3 I/O modules.

You can find possible diagnostic messages, their causes and remedies in the "Diagnostic messages" section.

Wiring

You perform the wiring on the appropriate terminal block. You can find additional information on this in the section "Terminal assignment (Page 17)".

Sensor supply

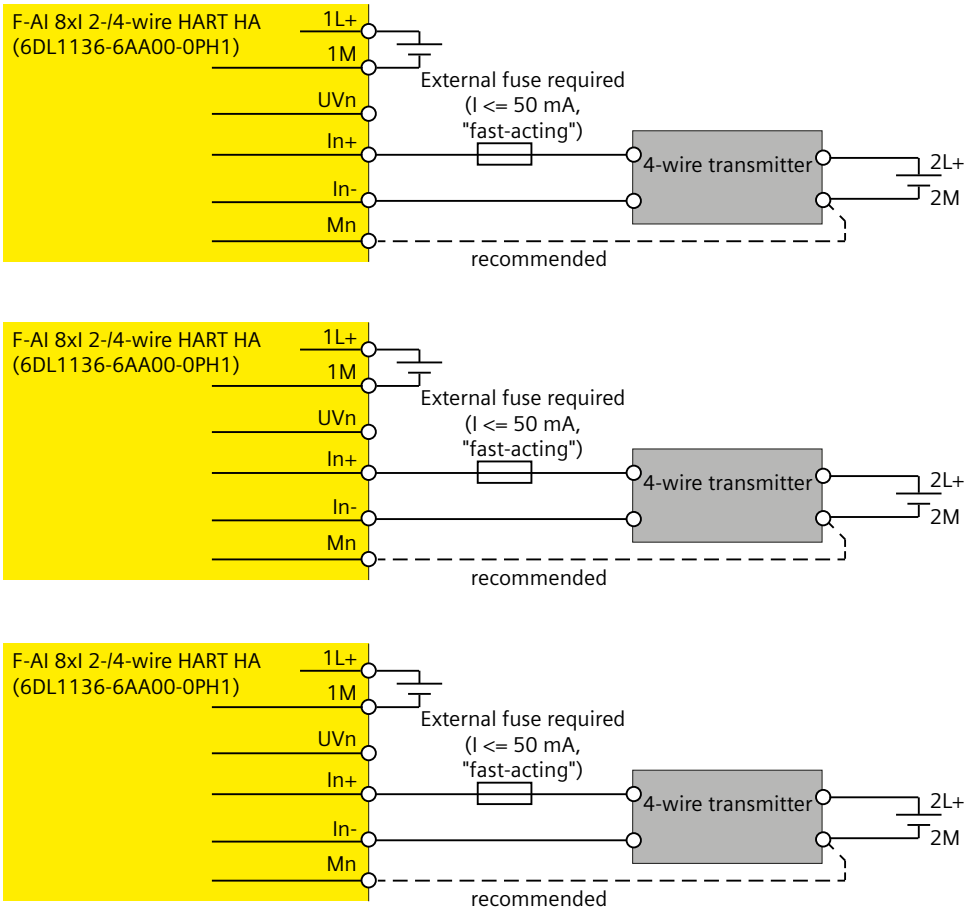
The sensor supply can be powered internally (2-wire transmitter) or externally (4-wire transmitter).

Wiring scheme

Please note application case 1 or 2.

One of these application cases is set up three times and three I/O modules are used.

In the following figure, application case 2 was selected as an example and set up in triplicate.



WARNING

Requirement for sensor

To achieve SIL3/Kat.4/PLe with this wiring, three single-channel qualified sensors are required.

(FAIW-008)

WARNING

Cabling

You must use shielded cables to ensure installation free of interference voltage.

(FAIW-005)

Parameter assignment

Set the following parameters for the corresponding channel:

Parameter	Channel / sensor supply
Measurement type	• Current (2-wire transmitter); internal sensor supply (application case 1) • Current (4-wire transmitter); external sensor supply (application case 2)
Measuring range	0 to 20 mA / 4 to 20 mA
Behavior after channel fault	Passivate the channel / passivate the entire module
Interference frequency suppression	50 Hz / 60 Hz
HART gate	On / Off
Diagnostics, Wire break	In the measuring range 4 to 20 mA: Activated / deactivated
Smoothing	1 / 4 / 16 / 64
HART enabled	In the measuring range 4 to 20 mA: Activated / deactivated
Number HART message frame repetitions	In the measuring range 4 to 20 mA: 0 to 10
Diagnostics HART	In the measuring range 4 to 20 mA: Activated / deactivated

Configuration in the safety program

For safety-related applications according to SIL3/Cat.4/PLe, perform a discrepancy analysis with 1oo2 evaluation (in S7 F Systems with the F-block F_1oo2AI) in your safety program.

You can find additional information in the programming and operating manual "SIMATIC Industrial Software S7 F/FH Systems - Configuring and Programming (https://support.industry.siemens.com/cs/ww/en/view/109773062)".

6.9 Requirements placed on sensors for fail-safe modules

Definition

There are certain requirements for the safety-related use of sensors, which are briefly described below.

General sensor requirements

For safety-related use of sensors, you must observe the following important warning:

WARNING

Sensor requirements

Note that a significant responsibility for safety of instrumentation lies with the sensors. Also keep in mind that sensors generally do not have proof-test intervals of 20 years according to IEC 61508:2010 without a significant loss of safety.

The probability of dangerous faults or the rate of dangerous faults of a safety function must adhere to an SIL-dependent upper limit.

You will find the values achieved by the F-modules in their technical specifications.

To achieve the respective safety class, correspondingly qualified sensors are required.

(FAIW-010)

Additional sensor requirements

WARNING

Safe reaction of the safety program in case of sensor error

With the fail-safe analog input modules, the affected input is passivated and the substitute value is forwarded to the F-CPU after errors have been detected. You therefore need to take care that the safe reaction of the safety program is achieved with the substitute value.

(FAIW-011)

6.10 IO redundancy

Definition

To set up IO redundancy, plug 2 F-AI 8xI 2-/4-wire HART HA I/O modules of the same type next to each other in a redundant terminal block. You can find additional information on the possible terminal blocks in section "Terminal blocks (Page 15)".

This terminal block connects the respective process signals of the two modules to a common process terminal.

- The wiring work is lower compared to connecting separate I/O modules, because the interconnection of the process signals is integrated into the system.
- The redundant signal processing of the sensors at module level increases the availability of the system.

Note

IO redundancy is briefly described below.

You can find more detailed information in the *Distributed I/O System; ET 200SP HA* System Manual, "IO redundancy" chapter.

Configuration and use

The following conditions apply to the setup and use of F-AI 8xI 2-/4-wire HART HA I/O modules in IO redundancy:

Selection of hardware**:**

- Redundantly used I/O modules must be identical. This means they must have the same article number, the same firmware version, and a compatible hardware release.

Installation**:**

- I/O modules of the same type are plugged in pairs next to each other in the same redundant terminal block (type "TB45R-P32"; 6DL1193-6TP00-0DF1).

IO redundancy:

- The master module must always be configured at an even slot, the slave module at the following odd slot.
- The two redundant I/O modules operate simultaneously and independently. Both modules generate diagnostics, interrupts, messages, process values, etc.

WARNING

Provisions for IO redundancy

- With a redundant configuration, you need to ensure that not only one I/O module is permanently operated on the terminal block.
- When plugging a I/O module in a redundant configuration, you must ensure that you use identical module types.
- The correct function of the diodes located in the terminal block and required for redundancy switchover must be ensured at regular intervals. This can be achieved, for example, by the discrepancy evaluation of the fail-safe channel driver from F-systems.
  You can find more information on discrepancy analysis in the description of the channel driver in the "SIMATIC Industrial Software S7 F/FH Systems - Configuring and Programming (https://support.industry.siemens.com/cs/ww/en/view/109773062)" Programming and Operating Manual.

(FAIW-013)

Configuration:

- Assign the redundancy parameters for the I/O module.
- Settings that you make on a I/O module always apply to the module pair, with the exception of the F-destination address.

Response to failure

In the event of a channel failure in the redundant I/O modules or one of the two I/O modules, the following applies:

- Error-free inputs remain available in the system.

6.11 Calculation of the remaining supply voltage at the sensor

To ensure the function of the connected sensor, the remaining supply voltage U_{min} must be greater than/equal to the minimum supply voltage of the sensor.

To calculate the remaining supply voltage on the sensor, determine the following voltages depending on the wiring scheme used:

- Determine the minimum supply voltage (UV_{min}):
  Power supply unit e.g. for SITOP 24 V ± 2%
  UV_{min} = UV – [Tolerance] = 24 V – 2% = 23.5 V
  (Voltage drop on the supply line to the I/O module was neglected).
- Calculate the maximum voltage drop on the signal line (U_{line}):
  For example, for copper cable 500 m with ∅ = 0.5 mm²; at I_{max} = 25 mA

$$R_{Cable} = \frac{500\ m}{0.5\ mm^2 \times 56\ m/(mm^2\Omega)} \times 2 = 35.7\ \Omega$$

  U_{line} = 35.7 Ω × 25 mA = 0.9 V
- Calculate the voltage drop (U_{Ri}) at the input resistance "Ri" of the I/O module:
  - With Ri_{max} = 150 Ω; at I_{max} = 25 mA
    U_{Ri} = 150 Ω × 25 mA = 3.8 V
  - In a high-availability application case, the voltage of the Z diodes used in the redundant terminal block (U_Z = 6.2 V) must also be considered with a tolerance of 5%.
    $U_{Z\_6V2} = U_Z$ + Tolerance = 6.2 V + 5% = 6.5 V
- Determine the voltage drop at the sensor supply $U_{sensor\ supply}$:
  $U_{sensor\ supply}$ = 1.2 V

Calculation examples

Example for the calculation of the remaining supply voltage (U_{min}) on a 2-wire transmitter in an application case with no high-availability:

- $U_{min} = UV_{min} – U_{line} – U_{Ri} – U_{sensor\ supply}$
- U_{min} = 23.5 V – 0.9 V – 3.8 V – 1.2 V = 17.6 V

Example for the calculation of the remaining supply voltage (U_{min}) on a 2-wire transmitter in an application case with high availability:

- $U_{min} = UV_{min} – U_{line} – U_{Z\_6V2} – U_{Ri} – U_{sensor\ supply}$
- U_{min} = 23.5 V – 0.9 V – 6.5 V – 3.8 V – 1.2 V = 11.1 V

Displays, alarms and messages

7

7.1 Status and error displays

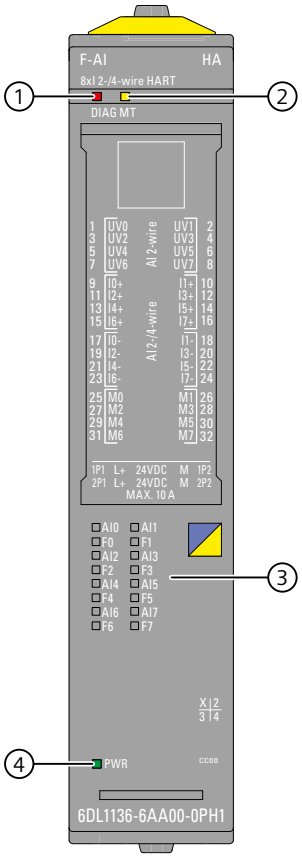
Definition

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.

Description

The following figure identifies the LED displays of the F-AI 8xI 2-/4-wire HART HA I/O module.



① DIAG LED (Page 62) (green / red)
② MT LED (Page 62) (yellow)
③ Channel status / fault LEDs (Page 63) Channel status (green) / channel fault (red)
④ PWR LED (Page 64) (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.
Alternately flashing	Module is waiting for user acknowledgment.

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 disabled or module switched off.
■ On	☐ Off	Channel activated and no channel diagnostics pending.
☐ Off	■ On	Channel activated and channel diagnostics or module diagnostics pending.

7.2.4 Channel status/DIAG/Channel fault LEDs

Definition

The combination of the Channel status, DIAG and Channel fault LEDs provide you information about status and error information of the module.

Description

The combination of the status and fault displays of the Channel status, DIAG and Channel fault LEDs is as follows:

Channel status LED	DIAG LED	Channel fault LED	Meaning
☐ Off	☼ Flashes	■ All On	• The PROFIsafe address is different from the configured PROFIsafe address. • Module fault/defect • Fault on all channels
☼ Flashes	☼ Flashes	☐ Off	Identification of the module for assignment of the PROFIsafe address

7.2.5 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 P (L+) missing.
■ On	Supply voltage P (L+) available.

7.3 Interrupts

Definition

The fail-safe analog input module F-AI 8xI 2-/4-wire HART HA supports diagnostic interrupts and maintenance messages.

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

Diagnostic interrupts are used by the I/O module to output both diagnostic messages and maintenance events.

Diagnostic interrupts

The F-module generates a diagnostic interrupt for each diagnostic message described in section "Diagnostic messages (Page 67)".

The following table provides an overview of the diagnostics interrupts of the F-module. The diagnostics interrupts are assigned either to one channel or to the entire F-module.

Diagnostic interrupts of F-AI 8xI 2-/4-wire HART HA

Diagnostic interrupt	Error code	Effective range of diagnostic interrupt	Configurable
Overtemperature	5_H	F-module	No
Wire break	6_H	Channel	Yes
High limit exceeded	7_H	Channel	No
Low limit violated	8_H	Channel	No
Parameter error	10_H	F-module	No
Supply voltage missing	11_H	F-module	No
Communication error	13_H	F-module	No
Channel/component temporarily unavailable	$1F_H$	F-module	No
Mismatch of safety destination address (F_Dest_Add)	40_H	F-module	No
Safety destination address not valid (F_Dest_Add)	41_H	F-module	No
Safety source address not valid (F_Source_Add)	42_H	F-module	No
Safety watchdog timer value is 0 ms (F_WD_Time)	43_H	F-module	No
Parameter F_SIL exceeds SIL from specific device application	44_H	F-module	No
Parameter F_CRC_Length does not match the generated values	45_H	F-module	No
Version of F-parameter set incorrect	46_H	F-module	No
CRC1 fault	47_H	F-module	No
Device-specific diagnostic information, see manual	48_H	F-module	No
Inconsistent iParameters (iParCRC error)	$4B_H$	F-module	No
F_Block_ID not supported	$4C_H$	F-module	No
Transmission error: Inconsistent data (CRC error)	$4D_H$	F-module	No
Transmission error: Timeout (monitoring time 1 or 2 expired)	$4E_H$	F-module	No
Module is defective	100_H	F-module	No
Watchdog tripped	103_H	F-module	No

Diagnostic interrupt	Error code	Effective range of diagnostic interrupt	Configurable
Internal supply voltage fault	104_H	F-module	No
Invalid/inconsistent firmware present	$11B_H$	F-module	No
Redundancy partner has different hardware/firmware version	120_H	F-module	No
IO redundancy warning	121_H	F-module	No
Diagnostic queue overflow	$13E_H$	F-module	No
Invalid terminal block	152_H	F-module	No
Carrier module or memory in carrier module is defective	154_H	F-module	No
Terminal block (TB) or memory in terminal block is defective	155_H	F-module	No
Overload or internal sensor supply short-circuit to ground	307_H	Channel	No
F-address memory not accessible	$30D_H$	F-module	No
No valid F-address available	$30E_H$	F-module	No
Undertemperature	312_H	F-module	No
Internal discrepancy failure	315_H	Channel	No
Supply voltage too high	321_H	F-module	No
Supply voltage too low	322_H	F-module	No
Safety-related HART shutoff defective	$32A_H$	F-module	No
ADC error	331_H	F-module	No
Error in the test circuit	332_H	F-module	No

Maintenance messages

The I/O module generates a maintenance message for the following events:

- Redundancy partner has different hardware/firmware version
- IO redundancy warning
- Carrier module or memory in carrier module is defective
- Terminal block (TB) or memory in terminal block is defective
- Internal temperature limit reached
- Internal malfunction of HART communication detected
- In addition, all HART diagnostics are reported as maintenance messages.

You can find more information on this in the section "Maintenance events (Page 72)".

7.4 Diagnostic messages

Diagnostic messages

The F-module generates a diagnostics interrupt for each diagnostic message described in the following table. In addition, the DIAG LED on the I/O module flashes red or the MT LED lights up yellow.

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

The diagnostic messages can, for example, be read out in the diagnostic buffer of the CPU.

Module faults are indicated as diagnostics (module status).

After fault correction, you must reintegrate the F-module in the safety program.

You can find additional information on passivation and reintegration of F-I/O in the programming and operating manual "SIMATIC Industrial Software S7 F/FH Systems - Configuring and Programming (https://support.industry.siemens.com/cs/ww/en/view/109773062)".

Diagnostic messages are assigned either to one input on a channel-specific basis or to all inputs as a module message.

All channels are switched off for diagnostic messages that affect the entire module.

Only the corresponding analog input is affected for diagnostic messages that relate to individual channels.

Diagnostic messages, their meaning and possible remedies

Diagnostic message	Error code	Assignment	Meaning	Remedy
Overtemperature	5_H	F-module	An excessive temperature rise was measured in the F-module.	Operate the F-module in the specified temperature range. (See section "Technical specifications") After reducing the temperature and returning to the specified range, you need to pull and plug the F-module or perform POWER OFF – POWER ON.
Wire break	6_H	Channel	• Impedance of sensor circuitry is too high • Wire break between the module and sensor • Channel not connected (open)	• Use a different sensor type or modify the wiring, for example, using cables with a larger cross-section • Connect the cable • Disable diagnostics • Connect the sensor contacts
High limit exceeded	7_H	Channel	• The analog value is above the overrange. • Short-circuit of input to L+	Correct the module/sensor tuning

Diagnostic message	Error code	Assignment	Meaning	Remedy
Low limit violated	8_H	Channel	The analog value is below the underrange.	Correct the module/sensor tuning
Parameter error	10_H	F-module	• Incorrect parameter assignment • Parameter assignment does not match the terminal block used	• Correct the parameter assignment • Check terminal block[1]
Supply voltage missing	11_H	F-module	Supply voltage missing or too low	• Check the supply voltage on the terminal block • Check the terminal block type
Communication error	13_H	F-module	The F-module has detected an internal communication error. Possible causes: Electromagnetic interference is too high.	• Eliminate the interference. Removal and insertion of the F-module or a POWER OFF – POWER ON is then required. • If the error occurs again, consider replacement.
Channel/component temporarily unavailable	$1F_H$	F-module	Update of the firmware is being performed or has been canceled. The F-module does not perform any measurements during this time.	• Restart firmware update • Wait for firmware update
Mismatch of safety destination address (F_Dest_Add)	40_H	F-module	The F-module has detected a different F-destination address.	Check the parameter assignment of the PROFIsafe driver and the address setting of the F-module.
Safety destination address not valid (F_Dest_Add)	41_H	F-module	The F-module has detected an invalid F-destination address.	Check the parameter assignment of the PROFIsafe driver.
Safety source address not valid (F_Source_Add)	42_H	F-module	The F-module has detected an invalid F-source address.	
Safety monitoring time value is 0 ms (F_WD_Time)	43_H	F-module	The F-module has detected an invalid monitoring time.	
Parameter F_SIL exceeds SIL from specific device application	44_H	F-module	The F-module has detected a discrepancy between the SIL setting of the communication and the application.	
Parameter F_CRC_Length does not match the generated values	45_H	F-module	The F-module has detected a discrepancy in the CRC length.	
Version of F-parameter set incorrect	46_H	F-module	The F-module has detected an invalid version of the F-parameters.	
CRC1 fault	47_H	F-module	The F-module has detected inconsistent F-parameters.	
Device-specific diagnostic information, see manual	48_H	F-module	The F-module has detected inconsistent F-parameters.	

Diagnostic message	Error code	Assignment	Meaning	Remedy
Inconsistent iParameters (iParCRC error)	$4B_H$	F-module	The F-module has detected inconsistent iParameters.	Check the parameter assignment.
F_Block_ID not supported	$4C_H$	F-module	The F-module has detected an incorrect block ID.	Check the parameter assignment of the PROFIsafe driver.
Transmission error: Inconsistent data (CRC error)	$4D_H$	F-module	The F-module has detected a CRC error. Possible causes: • The communication between F-CPU and F-module is disturbed. • Electromagnetic interference is too high. • An error has occurred in the sign-of-life monitoring.	• Check the communication connection between F-module and F-CPU. • Eliminate the electromagnetic interference.
Transmission error: Timeout (monitoring time 1 or 2 expired)	$4E_H$	F-module	The F-module has detected a timeout. Possible causes: • The F-monitoring time is set incorrectly. • There is a bus fault.	• Check the parameter assignment. • Ensure that communication is functional.
Module is defective	100_H	F-module	Possible causes: • Electromagnetic interference is too high. • The F-module has detected an internal fault and responded to it in a safety-related manner. • Wrong terminal block	• Eliminate the interference. Removal and insertion of the F-module or a POWER OFF – POWER ON is then required. • Use a suitable terminal block. • Replace the F-module.
Watchdog tripped	103_H	F-module	Possible causes: • Electromagnetic interference is too high. • The F-module has detected an internal fault and responded to it in a safety-related manner. • Wrong terminal block	• Eliminate the interference. Removal and insertion of the F-module or a POWER OFF – POWER ON is then required. • Replace the F-module.
Internal supply voltage fault	104_H	F-module	Internal voltage is too low.	Replace the F-module.
Invalid/inconsistent firmware present	$11B_H$	Channel	The firmware is incomplete and/or firmware extensions of the F-module are incompatible. This leads to errors or functional limitations when operating the F-modules.	• Perform a firmware upgrade of the F-module and watch out for any error messages. • Use only the firmware versions released for this F-module.
Diagnostic queue overflow	$13E_H$	F-module	Overflow of the diagnostics memory. Not all pending diagnostics information could be sent. This error can lead to disabling of the F-module until the supply voltage is switched off/on.	Correct the cause of the diagnostics surge.

Diagnostic message	Error code	Assignment	Meaning	Remedy
Invalid terminal block	152_H	F-module	The terminal block cannot be used with the current F-module.	Replace the terminal block.
Carrier module or memory in carrier module is defective	154_H	F-module	An error of the carrier module or of the memory module on the carrier module was detected during operation.	Replace carrier module
Terminal block (TB) or memory in terminal block is defective	155_H	F-module	An error of the terminal block or the memory chip on the terminal block was detected during operation.	Replace terminal block
Overload or internal sensor supply short-circuit to ground	307_H	Channel	• The internal sensor supply is overloaded. • Missing or insufficient supply voltage L+	• Eliminate the short-circuit in the process wiring. • Check the L+ supply voltage at the terminal block. • Check the terminal block.
F-address memory not accessible	$30D_H$	F-module	No valid PROFIsafe address is stored in the retentive memory. Possible causes: • Initial commissioning • Deliberate parameter change of the PROFIsafe address • Conformity error between set and actual configuration of the plant	• Assign the PROFIsafe address during initial commissioning or when deliberately changing parameters. • Check the consistency between the set and actual configuration.
No valid F-address available	$30E_H$	F-module	F_source_address and F_destination_address parameters invalid	Check F_source_address and F_destination_address parameters
Undertemperature	312_H	F-module	The minimum permissible temperature was fallen below.	Operate the F-module in the specified temperature range. (See section "Technical specifications") After increase of the temperature and return to the specified range, removal and insertion of the F-module or a POWER OFF – POWER ON is required.
Internal discrepancy failure	315_H	Channel	The module has detected an internal error. Possible causes: • Electromagnetic interference is too high. • Module is defective	If the fault occurs persistently, replace the F-module.
Supply voltage too high	321_H	F-module	The supply voltage is too high.	Check the supply voltage.
Supply voltage too low	322_H	F-module	The supply voltage is too low.	Check the supply voltage.
Safety-related HART shutoff defective	$32A_H$	F-module	The F-module has a malfunction in the safety-related HART shutdown. Cause: Error in the F-module	Replace the F-module.

Diagnostic message	Error code	Assignment	Meaning	Remedy
ADC error	331_H	F-module	Internal error in analog-to-digital conversion. Possible causes: • Increased EMC • F-module defective	If the fault occurs persistently, replace the F-module.
Error in the test circuit	332_H	F-module	The F-module has detected an internal error in the test circuit. Possible causes: • Increased EMC • F-module defective	If the fault occurs persistently, replace the F-module.

[1] Only the terminal block TB45R-P32+A0+4D (6DL1193-6TP00-0DF1) is suitable for using the I/O module F-AI 8xI 2-/4-wire HART HA (6DL1 136-6AA00-0PH1) in IO redundancy.

7.5 Maintenance events

Maintenance events

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

Maintenance messages are assigned either to one input on a channel-specific basis (HART error) or to inputs as a module message affecting all inputs.

Maintenance messages have no direct effect on the function of the module or the analog value acquisition. Maintenance events of the HART communication do not affect the analog value acquisition of the module.

Maintenance messages, their meaning and possible remedies

Maintenance message	Error code	Assignment	Meaning / Cause	Remedy
Error (000B)	B_H	Module	The F-module has detected an internal malfunction of the HART communication and therefore shut down the HART communication. Possible cause: Electromagnetic interference is too high.	• Eliminate the interference. Removal and insertion of the F-module or a POWER OFF – POWER ON is then required. • If the error occurs again, consider replacement.
Error (000C)	C_H	Module	The internal temperature of the F-module leaves the permissible range. This condition must be corrected within the repair time of the module, otherwise a safety-related shutdown of the entire module occurs. Possible causes: • Ambient temperature is too high • Operation of the F-module outside the permissible specification • External heating by adjacent modules	Operate the F-module within the specified temperature range. (see "Technical specifications" section) After reducing the temperature and returning to the specified range, this maintenance message is automatically reset.
Redundancy partner has different hardware/firmware version	120_H	Module	The redundantly configured and interconnected I/O modules are not compatible	Check the operating status and firmware version of the modules and replace modules or perform a firmware upgrade.
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 *ET 200SP HA Distributed I/O System*, section "Communication errors", "I/O redundancy warning" (Maintenance event: Error code 121H)"

Maintenance message	Error code	Assignment	Meaning / Cause	Remedy
HART communication error	141_H	Analog input	• 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
HART primary variable out of range	142_H	Analog input	• Incorrect parameters in the HART field device • HART field device is set to "Primary variable out of range" in simulation mode • Incorrect measuring point • Parameter assignment of primary variable out of range	• Check the parameter assignment of the HART device • Correct the simulation • Check whether the correct measuring transmitter is connected
HART analog output current of field device saturated	143_H	Analog input	• The output current of the HART field device is saturated: • Incorrect parameters in the HART field device • HART field device is set to a measured value that is too high in simulation mode • Incorrect measuring point	
HART output current of the field device fixed	144_H	Analog input	• The output current of the HART field device is fixed: • Incorrect parameters in the HART field device • HART field device is set to a measured value that is too high in simulation mode • Incorrect measuring point	
HART error - additional status information available	145_H	Analog input	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 input	In the HART device status (in the 2nd status byte), the identifier for "re-parameterization" 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 input	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 the field device

Maintenance message	Error code	Assignment	Meaning / Cause	Remedy
HART - non-primary variable out of limits	149_H	Analog input	• Incorrect parameters in the HART field device • HART field device is set to "Non-primary variable out of range" in simulation mode • Incorrect measuring point • Parameter assignment of non-primary variable out of range	• Check the parameter assignment of the HART device • Correct the simulation • Check whether the correct measuring transmitter is connected
Carrier module or memory in carrier module is defective	154_H	Module	An error of the carrier module or of the memory module on the carrier module was detected during operation.	Replace carrier module
Terminal block (TB) or memory in terminal block is defective	155_H	Module	A fault of the terminal block or the memory chip 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 "re-parameterization" (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.

HART function

8

8.1 Use

8.1.1 Notes 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 76)

Advantages of HART

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

- Connection compatibility with 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 76)

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 HART

Definition

"HART" stands for "Highway Addressable Remote Transducer" and enables the digital communication of several field devices (sensor or transmitter or actuator) via a common data bus.

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.

8.1.3 HART protocol

Definition

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

WARNING

Special properties of the HART protocol

The HART protocol is not safety-related!

(FAIW-014)

Description

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

PREAMBLE	STRT	ADDR	COM	BCNT	STATUS	DATA	CHK

PREAMBLE: Bytes (0xFF) for synchronizing.
5 bytes

STRT: Start character (start delimiter)

ADDR: Address of the field device (1-byte; short address or 5-byte; 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 81)

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 request and response data records (Page 97)

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

8.1.4 HART for safety-related applications

Overview

WARNING

SIL-3 application for channels with HART devices without write protection

For SIL-3 applications for channels with HART devices without write protection, please note that as soon as you activate the "HART-Tor" parameter, the input values of the channels must be checked for plausibility, for example by comparison with the equivalent value of another I/O module in the user program.

Optionally, the I/O module can also be removed from the safety function of the plant for this time.

FAIW-022

- "HART gate" parameter
  You can use the "HART gate" parameter to switch on the HART function (HART communication) for the I/O module. The "HART gate" parameter acts as a fail-safe "main switch" for the complete module.

WARNING

Activation of HART communication

Release the HART communication only if your system is in a state in which a possible reconfiguration of a HART field device is safe.

FAIW-021

WARNING

Impact of a connected HART handheld

Note that the "Off" setting of the "HART gate" parameter is bridged by a connected HART handheld.

FAIW-020

- "HART activated" parameter
  You can use the "HART activated" parameter to enable or disable the HART communication from the affected channel of the I/O module to the HART field device.
  The parameter is not safety-related, meaning that fail-safe deactivation of the HART communication is not possible with this parameter.

8.2 HART system connection

8.2.1 Notes on system connection

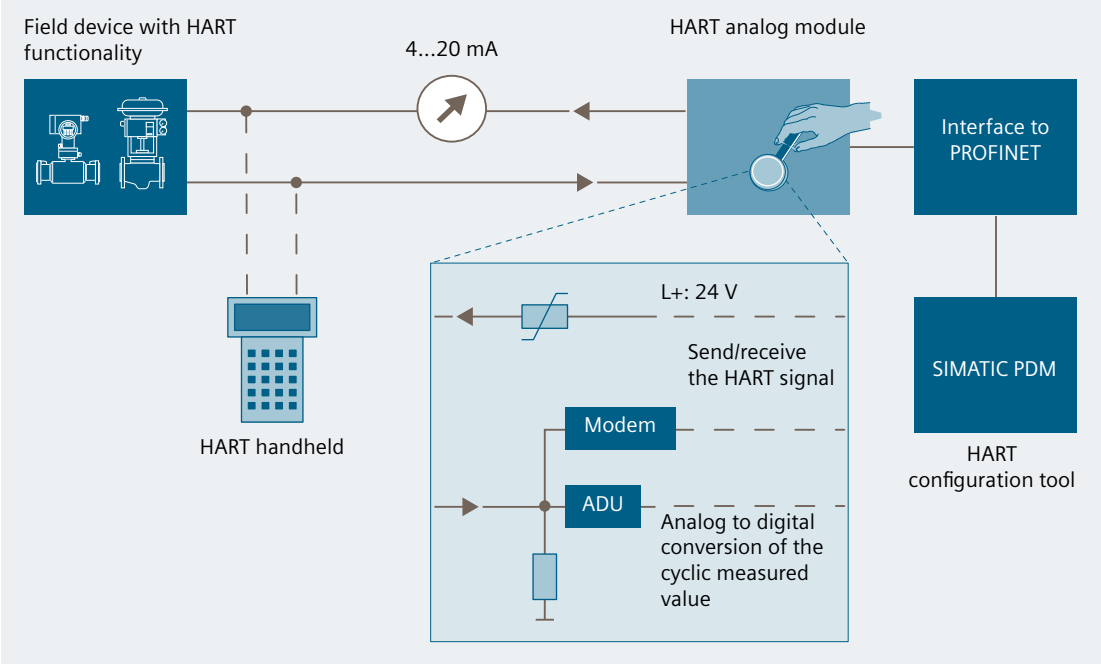
The following describes the system connection and configuration of the field devices.

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 81)
- HART configuration tool (Page 80)
- HART device status (Page 81)

Configuration

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.

Re-parameterization 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.

To reassign parameters of the field devices connected to the I/O module, proceed as follows:

1. You start the re-parameterization of a field device using a HART command that you enter using the SIMATIC PDM parameter assignment tool.
2. After you complete re-parameterization of a HART field device, the corresponding bit is set in the HART device status of the connected field device (in the 2nd status byte).
3. The re-parameterization 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.

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

WARNING

Impact of a connected HART handheld

Note that the "Off" setting of the "HART gate" parameter is bridged by a connected HART handheld.

FAIW-020

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.

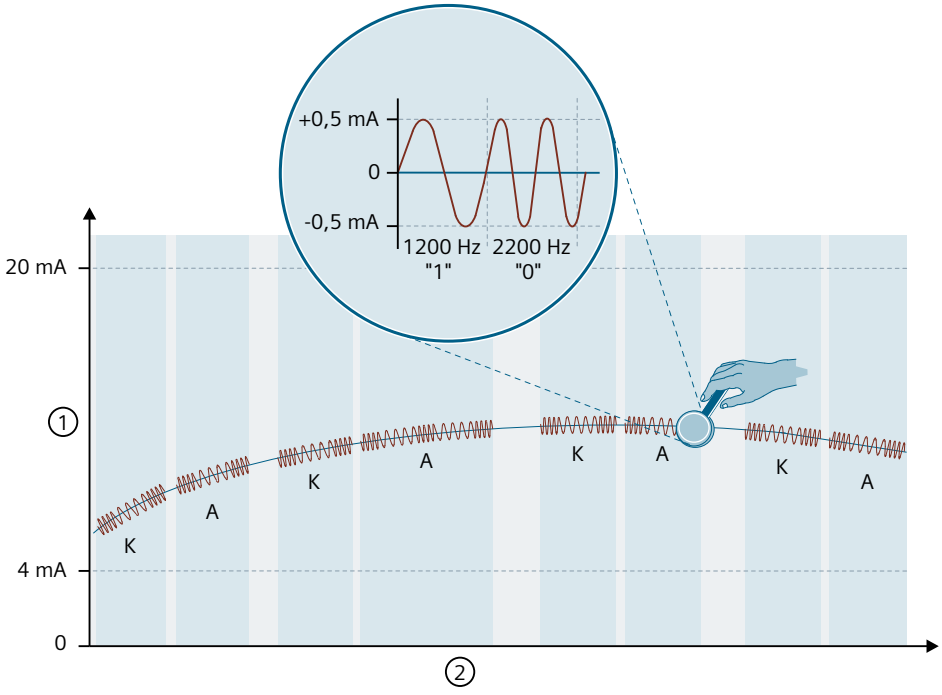
8.2.3 HART signal

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) transferred with each response of the field device contain error information about the HART communication, the HART command and the 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:

1st status byte

With 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
With bit 7 = 0: Bit 0 to 6 Specific according to the response frame	

2nd status byte

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

8.3 Communication

8.3.1 Notes on communication with HART

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.

- HART command (Page 83)
- HART command interface (Page 95)

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 85)

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.

8.3.2 HART command

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 84)
- General purpose HART commands (Page 84)
- Device-specific HART commands (Page 85)

8.3.3 Explanation of the HART commands

8.3.3.1 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
1	Reads primary variable and unit
2	Reads current and percentage of range, digitally as floating-point number (IEEE 754)
3	Read up to four pre-defined dynamic variables (primary variable, secondary variable, etc.)
9	Read up to four pre-defined dynamic variables (primary variable, secondary variable, etc.)
11	Reads manufacturer and device type
13, 18	Reads or writes tag, descriptor and date (data included in transmission)

8.3.3.2 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

8.3.3.3 Device-specific HART commands

Definition

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

8.3.4 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.

8.4 Tags

8.4.1 Notes on HART variables

Introduction

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

HART variables (Page 86)

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 105)

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 87)
- Field devices with HART revision 7 and higher (Page 88)

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

Quality code	Meaning (process status)	
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 startup or after redundancy failover to the standby channel[1]
00_H	Initialization value from S7 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 startup or after redundancy failover to the standby channel[1]
40_H	Read alternatively via command 3	
00_H	Initialization value from S7 system	

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

Technical specifications

9

9.1 Technical specifications

Technical specifications of the F-AI 8xI 2-/4-wire HART HA

Note

Power supply

The supply and input voltages of the ET 200SP HA system must always be generated with voltage/current supplies with safe electrical isolation (SELV/PELV according to IEC/UL61010-2-201) with a rated value of 24 V DC ±20% (⎓).

Note

Power failure bridging

For compliance with IEC 61131-2, EN 298 and the NAMUR Recommendation NE 21, use only power supplies (230 V AC --> 24 V DC) with bridging of power failures of at least 20 ms (NE21, IEC 61131-2), or at least 30 ms (EN 298).

You can find up-to-date information on SV components on the internet (https://mall.automation.siemens.com).

You can find more information on power supplies in the *ET 200SP HA Distributed I/O System* Equipment Manual in the following sections:

- Notes on the power supply (SELV/PELV)
- Notes on fail-safe I/O modules (F-I/O modules)

Note

The terms "sensor supply" and "encoder supply" or "sensor" and "encoder" are synonymous in the context of this manual.

Article number	6DL1136-6AA00-0PH1
General information	
Product type designation	F-AI 8xI 2-/4-wire HART HA
Firmware version	V1.0.0
• FW update possible	Yes
Color code for module-specific color identification plate	CC00
Product function	
• I&M data	Yes; I&M0 to I&M3
Redundancy	
• Redundancy capability	Yes; with TB type F1
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)	90 mA; without sensor supply
Encoder supply	
Number of outputs	8
Short-circuit protection	Yes
24 V encoder supply	
• 24 V	Yes
• Short-circuit protection	Yes
• Output current per channel, max.	30 mA
Power	
Power available from the backplane bus	90 mW
Power loss	
Power loss, typ.	2.8 W
Address area	
Address space per module	
• Inputs	22 byte
• Outputs	5 byte
Analog inputs	
Number of analog inputs	
• For current measurement	8; destruction limit for current input 35 mA
Input ranges (rated values), currents	
• 0 to 20 mA	Yes
– Input resistance (0 to 20 mA)	150 Ω
• 4 mA to 20 mA	Yes
– Input resistance (4 mA to 20 mA)	150 Ω
HART communication	
• Primary Master	Yes

Article number	**6DL1136-6AA00-0PH1**
• Secondary Master	No
• input resistance (with HART communication)	150 Ω; for operation with an external secondary master (e.g. communicator), an external load may be necessary to achieve a total impedance of 230 - 600 Ω.
Cable length	
• shielded, max.	1 000 m; shielded, twisted pair
Analog value generation for the inputs	
Measurement principle	Sigma Delta
Integration and conversion time/resolution per channel	
• Resolution with overrange (bit including sign), max.	16 bit
• Integration time, parameterizable	Yes
• Integration time (ms)	20 ms (at 50 Hz); 16.66 ms (at 60 Hz)
• Interference voltage suppression for interference frequency f1 in Hz	50 / 60 Hz
Smoothing of measured values	
• parameterizable	Yes; in 4 stages (1, 4, 16, 64 conversion cycles), channel-by-channel
Encoder	
Connection of signal encoders	
• for current measurement as 2-wire transducer	Yes
• for current measurement as 4-wire transducer	Yes
Errors/accuracies	
Crosstalk between the inputs, min.	-70 dB
Repeat accuracy in steady state at 25 °C (relative to input range), (+/-)	0.008 %
safety-relevant accuracy	
• up to 40 °C, max.	0.6 %; (0.7% in vertical installation)
• up to 70 °C, max.	0.9 %
note regarding accuracy	the safety-relevant accuracy consists of a basic error, a temperature-dependent drift, aging and internal safety measures
Influence of a HART signal modulated on the input signal in relation to input range	
• error at 16.6 ms integration time	0.11 %
• error at 20 ms integration time	0.11 %
Interference voltage suppression for f = n x (f1 +/- 1 %), f1 = interference frequency	
• Series mode interference (peak value of interference < rated value of input range), min.	40 dB
• Common mode voltage, max.	35 V
• Common mode interference, min.	80 dB

Article number	6DL1136-6AA00-0PH1
Protocols	
HART protocol	Yes
• Protocol version	up to Revision 7
Interrupts/diagnostics/status information	
Alarms	
• Diagnostic alarm	Yes
Diagnoses	
• Monitoring the supply voltage	Yes
• Wire-break	Yes
• Short-circuit	Yes
• Overflow/underflow	Yes
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+	No
Permissible potential difference	
between the inputs (UCM)	30 V DC / 25 V AC
Isolation	
tested with	
• between backplane bus and load voltage	1 500 V DC (load voltage L+ and channels I+n bridged)
• between the backplane bus and functional ground (FE)	1 500 V DC
• between load voltage and functional ground (FE)	1 500 V DC (load voltage L+ and channels I+n bridged)
• between the channels and load voltage	370 V AC
• between the potential groups of the channels	370 V AC
Standards, approvals, certificates	
Highest safety class achievable in safety mode	
• Performance level according to ISO 13849-1	PLd (PLe for 1oo2 voting on the F-CPU)
• Category according to ISO 13849-1	cat. 3 (cat. 4 for 1oo2 voting on the F-CPU)
• SIL acc. to IEC 61508	Up to SIL 3
Probability of failure (for service life of 20 years and repair time of 100 hours)	
– Low demand mode: PFDavg in accordance with SIL3	< 27E-05 (< 9E-05 for 1oo2 voting on the F-CPU)

Article number	**6DL1136-6AA00-0PH1**
– High demand/continuous mode: PFH in accordance with SIL3	< 4E-09 1/h (< 1E-09 1/h for 1oo2 voting on the F-CPU)
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.	220 g

HART operating data records

A

A.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 in full as the data record can be changed by the I/O module after it is first read with a 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 fault 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.

A.2 HART operating data records

Reading/writing data in RUN

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".

The following HART operating data records are available:

Data record number	Description	Length (bytes)	Writable	Readable
80	HART request channel 0	240	yes	yes
81	HART response channel 0	240	no	yes
82	HART request 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 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

A.3 HART request 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
4	88	89
5	90	91
6	92	93
7	94	95

Structure of request data records 80 to 94

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

"Request control" coding:

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 activated.

HART command interface (Page 95)

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 106)

Structure of response data records 81 to 95

In case of response error

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

In case of error-free response

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

"Response control" coding

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 is not active
1 = SHC mode active

Bit 7: 0 = HART response

"HART group fault display" coding

Bit number	Meaning	Explanation
0	More status information available	(2nd HART status byte) You obtain more 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
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

"HART protocol error during response" coding

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: Not specified 1: Short format (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 does not have to be sent with the request.)

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").

A.4 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.

A.5 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	= 240 (maximum length of the HART request data records)

A.6 HART variable data record

The I/O module supports a maximum of 4 HART variables per channel in enabled HART operation. These variables are read cyclically, provided they are supported by the connected field device.

These 32 HART variables are available to be read in HART variable data record 121.

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).

A.7 HART-specific settings

HART communication is available via standard parameter assignment.

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

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.

Every new parameter assignment of the analog module resets the HART-specific settings back to the initial values from parameter data record 129.

The I/O module does not apply the HART-specific settings if there is missing supply voltage L+.

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.

Note

Each parameter data record (131...138) of the HART channels is checked by the I/O module. If a faulty parameter is detected, then the entire data record is discarded and the parameters of the HART channel remain unchanged.

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

Structure of the HART-specific settings

Byte 0	7 6 5 4 3 2 1 0 must be 128	Bit 7 is reset after evaluation of data record by module
Byte 1	7 6 5 4 3 2 1 0 must be 5	Offset for manufacturer-specific parameter according to HART specification
Byte 2	7 6 5 4 3 2 1 0	Number of HART repetitions (0...10), initial value from parameter data record
Byte 3	7 6 5 4 3 2 1 0	Number of HART preamble bytes (0, 5...20, 255) initial value = 5*
Byte 4	7 6 5 4 3 2 1 0 must be 0	Field device mode according to HART specification
Byte 5	7 6 5 4 3 2 1 0	Client timeout in s (1...255 s), initial value = 60 s
Byte 6	7 6 5 4 3 2 1 0 0 0 0 0 0 0	Initial value according to HART activation from parameter data record always as primary master 1 = Switch on HART 0 = Switch off HART 1 = Primary master 0 = Secondary master
Byte 7	7 6 5 4 3 2 1 0 must be 0	Reserved

* 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 representation

B

B.1 Analog value representation in the current measurement range 0 to 20 mA

Display / current measuring range 0 to 20 mA

Values		Current measuring range	Ranges	Diagnostic message
Dec.	**Hex.**	**0 to 20 mA**		
32512	7F00	>23.518 mA	Overflow[1]	Overflow
32511	7EFF	23.518 mA	Overrange	-
...	...	...		
27649	6C01	20.007 mA		
27648	6C00	20 mA	Nominal range	-
...	...	...		
614	266	0.4442 mA		
613	265	<0.4442 mA	Wire break[1]	Wire break
...	...	...		
1	1	723.4 nA		
0	0	0 mA		

[1] Substitute value 0 and QI = 0 is provided by the F-module. In S7 F/FH systems, the substitute value is output as configured at the SUBS_V input of the F-channel driver.

B.2 Analog value representation with activated "Wire break diagnostics" in current measuring range 4...20 mA

Display / current measuring range with activated "Wire break diagnostics" parameter (current measuring range 4 to 20 mA)

Values		Current measuring range	Ranges	Diagnostic message
Dec.	Hex.	4 to 20 mA		
32512	7F00	>22.814 mA	Overflow[1]	Overflow
32511	7EFF	22.814 mA	Overrange	-
...	...	...		
27649	6C01	20.0006 mA		
27648	6C00	20 mA	Nominal range	-
...	...	...		
1	1	4 mA + 578.7 nA		
0	0	4 mA		
-1	FFFF	3.9994 mA	Underrange	-
...	...	...		
-691	FD4F	3.6 mA		
-692	FD4C	< 3.6 mA	Wire break[1]	Wire break
...	...	...		
-6144	E800	0.4444 mA		
-6145	E7FF	< 0.4444 mA		

[1] Substitute value 0 and QI = 0 is provided by the F-module. In S7 F/FH systems, the substitute value is output as configured at the SUBS_V input of the F-channel driver.

B.3 Analog value representation with deactivated "Wire break diagnostics" in the current measuring range 4...20 mA

Display / current measuring range with deactivated "Wire break diagnostics" parameter (current measuring range 4 to 20 mA)

Values		Current measuring range	Ranges	Diagnostic message
Dec.	Hex.	4 to 20 mA		
32512	7F00	>22.814 mA	Overflow[1]	Overflow
32511	7EFF	22.814 mA	Overrange	-
...	...	...		
27649	6C01	20.0006 mA		
27648	6C00	20 mA	Nominal range	-
...	...	...		
1	1	4 mA + 578.7 nA		
0	0	4 mA		
-1	FFFF	3.9994 mA	Underrange	-
...	...	...		
-691	FD4F	3.6 mA		
-692	FD4C	< 3.6 mA		
...	...	...		
-6144	E800	0.4444 mA		
-6145	E7FF	< 0.4444 mA	Underflow[1]	Underflow

[1] Substitute value 0 and QI = 0 is provided by the F-module. In S7 F/FH systems, the substitute value is output as configured at the SUBS_V input of the F-channel driver.

B.3 Analog value representation with deactivated "Wire break diagnostics" in the current measuring range 4...20 mA

Response times

C

C.1 Response times

Introduction

Below you can find the response times of the analog input module F-AI 8xI 2-/4-wire HART HA. The response times of the analog input module are included in the calculation of the response time of the F System.

Definition of response time for fail-safe analog inputs

The response time specifies the time between a signal change at the analog input and the safe provision of the safety message frame at the backplane bus.

The response time results from the number of activated channels/channel pairs, the response time per channel/channel pair, the basic response time and from the configured smoothing.

Times required for the calculation

- Max. acknowledgment time (Device Acknowledgment Time): T_{DAT} = 50 ms
- Dependency of the response time per channel/channel pair:
  The module works with 2 channel groups (channels 0-3 and channels 4-7). The channels in a group are converted simultaneously. See also Chapter 4.3
  . Channels are processed as channel pairs. If at least one channel of a channel pair is activated, this channel pair must be taken into account for the response time.
  Channel pairs:
  - Channel 0 and channel 4
  - Channel 1 and channel 5
  - Channel 2 and channel 6
  - Channel 3 and channel 7

  Response time per channel/channel pair
  - At 50 Hz: 30 ms
  - At 60 Hz: 27 ms
- Basic response time: 25 ms

Typically response time

The typical response time can be calculated according to the following formula:

Typical response time = (N * Response time per channel/channel pair + Basic response time) * Smoothing

N Number of activated channel pairs

Examples:

- Channel 0 activated, all other channels deactivated: N = 1
- Channel 0 and 4 activated, all other channels deactivated: N = 1
- Channel 0 and 1 activated, all other channels deactivated: N = 2
- Channels 0, 1, 4, 5 activated, all other channels deactivated: N = 2

Maximum response time under error-free conditions (Worst Case Delay Time, WCDT)

The maximum response time in the error-free scenario (Worst Case Delay Time, WCDT) can be calculated according to the following formula:

Max. response time = (2 * N * Response time per channel + 3 * Basic response time) * Smoothing

N Number of activated channel pairs

Maximum response time when a fault is present (One Fault Delay Time, OFDT)

The maximum response time in the presence of a fault (One Fault Delay Time, OFDT) can be calculated according to the following formula:

Max. response time (to channel fault) = 2 * N * Response time per channel + 3 * Basic response time

N Number of activated channel pairs