



Edition

09/2024

EQUIPMENT MANUAL

SIMATIC

S7-1500/ET 200MP

Analog input module F-AI 8xI 0(4)..20mA
6ES7536-1MF00-0AB0

SIMATIC

S7-1500/ET 200MP Analog Input Module F-AI 8xI 0(4)..20mA (6ES7536-1MF00-0AB0)

Equipment Manual

Original operating instructions

09/2024

A5E51970360-AC

Introduction

1

Industrial cybersecurity

2

Product overview

3

Connecting

4

HART function

5

Parameters/address space

6

Applications of the F-I/O
module

7

Interrupts/diagnostic
messages

8

Technical specifications

9

Response times

A

Representation of analog
values

B

HART operating data records

C

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.

Trademarks

All names identified by ® are registered trademarks of Siemens Aktiengesellschaft. The remaining trademarks in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owner.

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.

Table of contents

1	Introduction.....	7
1.1	S7-1500/ET 200MP Documentation Guide.....	9
1.1.1	S7-1500/ET 200MP documentation guide.....	9
1.1.2	SIMATIC Technical Documentation.....	11
1.1.3	Tool support.....	13
2	Industrial cybersecurity.....	15
2.1	Introduction to industrial cybersecurity.....	15
2.2	Cybersecurity information.....	15
3	Product overview.....	16
3.1	Properties.....	16
3.2	F-CPU and Engineering.....	19
4	Connecting.....	20
4.1	Block diagram.....	20
5	HART function.....	24
5.1	Usage of HART.....	24
5.2	HART operating principle.....	26
5.3	Using HART.....	30
5.4	HART for safety-related applications.....	33
5.5	HART command interface.....	34
5.6	HART variables.....	36
6	Parameters/address space.....	40
6.1	Measurement types and measuring ranges.....	40
6.2	Parameters.....	40
6.3	Explanation of parameters.....	43
6.3.1	F-parameters.....	43
6.3.1.1	Behavior after channel fault.....	43
6.3.1.2	Reintegration after channel fault.....	43
6.3.1.3	HART gate.....	44
6.3.1.4	Interference frequency suppression.....	44
6.3.2	Parameters of the channels.....	45
6.3.2.1	Evaluation of the sensors.....	45
6.3.2.2	Unit value.....	45
6.3.2.3	Discrepancy time.....	46

6.3.2.4	Tolerance window abs.....	46
6.3.2.5	Tolerance window rel.....	47
6.3.2.6	Parameter assignment of discrepancy analysis for 1oo2 evaluation.....	48
6.3.2.7	Activated.....	54
6.3.2.8	Channel failure acknowledge.....	54
6.3.2.9	Measuring range.....	54
6.3.2.10	Diagnosis: Wire break.....	54
6.3.2.11	Smoothing.....	55
6.3.3	AI configuration.....	57
6.3.3.1	Additional submodules.....	57
6.3.4	HART.....	58
6.3.4.1	HART function.....	58
6.3.4.2	HART preamble bytes.....	58
6.3.4.3	HART repetitions.....	58
6.3.4.4	HART diagnostics.....	59
6.3.4.5	HART variables.....	59
6.3.4.6	HART mapping.....	60
6.3.5	Submodule type.....	61
6.4	Address space.....	61
6.5	Address space of additional submodules.....	63
7	Applications of the F-I/O module.....	68
7.1	Application cases of the F-AI 8xI 0(4)..20mA.....	68
7.2	Application 1: Safety mode SIL3/Cat.3/PLd.....	70
7.3	Application 2: Safety mode SIL3/Cat.4/PLe.....	75
8	Interrupts/diagnostic messages.....	78
8.1	Status and error displays.....	78
8.2	Interrupts.....	81
8.3	Diagnostic alarms.....	83
8.4	Value status.....	88
9	Technical specifications.....	90
A	Response times.....	95
B	Representation of analog values.....	97
B.1	Representation of analog values.....	97
C	HART operating data records.....	99
C.1	HART operating data records.....	99
C.2	HART directory (DS 148).....	100
C.3	HART feature data (DS 149).....	100
C.4	HART variable data record (DS 121).....	101

C.5 HART-specific settings (DS 131 to DS 138)..... 102

C.6 HART request and response data records (DS 80 to DS 95)..... 104

C.7 Parameter assignment and structure of the HART mapping parameters (DS 140)..... 112

Introduction

Purpose of the documentation

This manual supplements the system manual S7-1500 Automation System. You can find information on the functions that apply generally to the S7-1500 automation system and the ET 200MP distributed I/O system in the system manual S7-1500 Automation System (<https://support.industry.siemens.com/cs/ww/en/view/59191792>).

The information provided in this manual and the system manual enables you to commission the S7-1500 automation system and ET 200MP distributed I/O system.

Conventions

STEP 7: In this documentation, "STEP 7" is used as a synonym for all versions of the "STEP 7 (TIA Portal)" configuration and programming software.

Please also observe the notes identified as follows:

NOTE

A note includes important information on the product described in the documentation, on handling the product or on the part of the documentation to which particular attention should be paid.

Important note for maintaining the operational safety of your system

NOTE

The operators of systems with safety-related characteristics must adhere to specific operational safety requirements. The supplier is also obliged to comply with special product monitoring measures. Siemens informs system operators by means of personal notifications about product developments and properties which may be or become important issues in terms of operational safety.

You should subscribe to the corresponding notifications in order to obtain the latest information and to allow you to make any necessary modifications to your system.

Log in to Industry Online Support. Follow the links below and click on "Email on update" on the right-hand side in each case:

- SIMATIC S7-1500/SIMATIC S7-1500F (<https://support.industry.siemens.com/cs/products?pnid=13716&lc=en-WW>)
 - SIMATIC S7-1200/SIMATIC S7-1200F (<https://support.industry.siemens.com/cs/products?pnid=13683&lc=en-WW>)
 - Distributed I/O (<https://support.industry.siemens.com/cs/products?pnid=14029&lc=en-WW>)
 - STEP 7 (TIA Portal) (<https://support.industry.siemens.com/cs/ww/en/ps/24471>)
-

Open source software

Open source software is used in the firmware of the product described. The open source software is provided free of charge. We are liable for the product described, including the open source software contained in it, pursuant to the conditions applicable to the product. Siemens accepts no liability for the use of the open source software over and above the intended program sequence, or for any faults caused by modifications to the software.

For legal reasons, we are obliged to publish the original text of the license conditions and copyright notices. Read the information on this on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109823569>).

1.1 S7-1500/ET 200MP Documentation Guide

1.1.1 S7-1500/ET 200MP documentation guide



The documentation for the SIMATIC S7-1500 automation system and the ET 200MP distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require. Changes and supplements to the manuals are documented in a Product Information.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742691>).

Basic information



The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC S7-1500 and ET 200MP systems.

The STEP 7 online help supports you in the configuration and programming.

Examples:

- Getting Started S7-1500
- S7-1500/ET 200MP System Manual
- Online help TIA Portal

Device information



Equipment manuals contain a compact description of the module-specific information, such as properties, wiring diagrams, characteristics and technical specifications.

Examples:

- Equipment Manuals CPUs
- Equipment Manuals Interface Modules
- Equipment Manuals Digital Modules
- Equipment Manuals Analog Modules
- Equipment Manuals Communications Modules
- Equipment Manuals Technology Modules
- Equipment Manuals Power Supply Modules

General information



The function manuals contain detailed descriptions on general topics relating to the SIMATIC S7-1500 and ET 200MP systems.

Examples:

- Function Manual Diagnostics
- Function Manual Communication
- Function Manual Motion Control
- Function Manual Web Server
- Function Manual Cycle and Response Times
- PROFINET Function Manual
- PROFIBUS Function Manual

Product Information

Changes and supplements to the manuals are documented in a Product Information. The Product Information takes precedence over the device and system manuals.

You can find the latest Product Information on the S7-1500 and ET 200MP systems on the Internet (<https://support.industry.siemens.com/cs/de/en/view/68052815>).

Manual Collection S7-1500/ET 200MP

The Manual Collection contains the complete documentation on the SIMATIC S7-1500 automation system and the ET 200MP distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet.
(<https://support.industry.siemens.com/cs/ww/en/view/86140384>)

Manual Collection fail-safe modules

The Manual Collection contains the complete documentation on the fail-safe SIMATIC modules, gathered together in one file.

You can find the Manual Collection on the Internet.

SIMATIC S7-1500 comparison list for programming languages

The comparison list contains an overview of which instructions and functions you can use for which controller families.

You can find the comparison list on the Internet
(<https://support.industry.siemens.com/cs/ww/en/view/86630375>).

1.1.2 SIMATIC Technical Documentation

Additional SIMATIC documents will complete your information. You can find these documents and their use at the following links and QR codes.

The Industry Online Support gives you the option to get information on all topics. Application examples support you in solving your automation tasks.

Overview of the SIMATIC Technical Documentation

Here you will find an overview of the SIMATIC documentation available in Siemens Industry Online Support:



Industry Online Support International
(<https://support.industry.siemens.com/cs/ww/en/view/109742705>)

Watch this short video to find out where you can find the overview directly in Siemens Industry Online Support and how to use Siemens Industry Online Support on your mobile device:



Quick introduction to the technical documentation of automation products per video (<https://support.industry.siemens.com/cs/us/en/view/109780491>)



YouTube video: Siemens Automation Products - Technical Documentation at a Glance (<https://youtu.be/TwLSxxRQsA>)

Retention of the documentation

Retain the documentation for later use.

For documentation provided in digital form:

1. Download the associated documentation after receiving your product and before initial installation/commissioning. Use the following download options:
 - Industry Online Support International: (<https://support.industry.siemens.com>)
The article number is used to assign the documentation to the product. The article number is specified on the product and on the packaging label. Products with new, non-compatible functions are provided with a new article number and documentation.
 - ID link:
Your product may have an ID link. The ID link is a QR code with a frame and a black frame corner at the bottom right. The ID link takes you to the digital nameplate of your product. Scan the QR code on the product or on the packaging label with a smartphone camera, barcode scanner, or reader app. Call up the ID link.
2. Retain this version of the documentation.

Updating the documentation

The documentation of the product is updated in digital form. In particular in the case of function extensions, the new performance features are provided in an updated version.

1. Download the current version as described above via the Industry Online Support or the ID link.
2. Also retain this version of the documentation.

mySupport

With "mySupport" you can get the most out of your Industry Online Support.

Registration	You must register once to use the full functionality of "mySupport". After registration, you can create filters, favorites and tabs in your personal workspace.
Support requests	Your data is already filled out in support requests, and you can get an overview of your current requests at any time.
Documentation	In the Documentation area you can build your personal library.
Favorites	You can use the "Add to mySupport favorites" to flag especially interesting or frequently needed content. Under "Favorites", you will find a list of your flagged entries.
Recently viewed articles	The most recently viewed pages in mySupport are available under "Recently viewed articles".
CAX data	The CAX data area gives you access to the latest product data for your CAX or CAE system. You configure your own download package with a few clicks: • Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files • Manuals, characteristics, operating manuals, certificates • Product master data

You can find "mySupport" on the Internet. (<https://support.industry.siemens.com/My/ww/en>)

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You can find the application examples on the Internet.
(<https://support.industry.siemens.com/cs/ww/en/ps/ae>)

1.1.3 Tool support

The tools described below support you in all steps: from planning, over commissioning, all the way to analysis of your system.

TIA Selection Tool

The TIA Selection Tool tool supports you in the selection, configuration, and ordering of devices for Totally Integrated Automation (TIA).

As successor of the SIMATIC Selection Tools, the TIA Selection Tool assembles the already known configurators for automation technology into a single tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet.

(<https://support.industry.siemens.com/cs/ww/en/view/109767888>)

SINETPLAN

SINETPLAN, the Siemens Network Planner, supports you in planning automation systems and networks based on PROFINET. The tool facilitates professional and predictive dimensioning of your PROFINET installation as early as in the planning stage. In addition, SINETPLAN supports you during network optimization and helps you to exploit network resources optimally and to plan reserves. This helps to prevent problems in commissioning or failures during productive operation even in advance of a planned operation. This increases the availability of the production plant and helps improve operational safety.

The advantages at a glance

- Network optimization thanks to port-specific calculation of the network load
- Increased production availability thanks to online scan and verification of existing systems
- Transparency before commissioning through importing and simulation of existing STEP 7 projects
- Efficiency through securing existing investments in the long term and the optimal use of resources

You can find SINETPLAN on the Internet

(<https://new.siemens.com/global/en/products/automation/industrial-communication/profinet/sinetplan.html>).

See also

PRONETA Professional (<https://support.industry.siemens.com/cs/ww/en/view/109781283>)

SIMATIC S7-FCT

Failsafe Configuration Tool (FCT) enables you to GSD configure the following devices in third-party engineering systems:

- Selected, functionally fail-safe SIMATIC I/O devices
- Functionally fail-safe SIRIUS ACT PROFINET interfaces

The engineering system must meet the following requirements for this:

- Support of the CPD system integration acc. to "PROFIsafe - Profile for Safety Technology on PROFIBUS DP and PROFINET IO"
- TCI implementation to Conformance Class C3

Additional information on S7-FCT can be found on the Internet

(<https://support.industry.siemens.com/cs/ww/en/view/109762827>).

Industrial cybersecurity

2.1 Introduction to industrial cybersecurity

Due to the digitalization and increasing networking of machines and industrial plants, the risk of cyber attacks is also growing. Appropriate protective measures are therefore mandatory, particularly in the case of critical infrastructure facilities.

You can find general information and measures relating to industrial cybersecurity in the system manual (<https://support.industry.siemens.com/cs/ww/en/view/59191792>).

This section provides an overview of security-related information about your SIEMENS device.

NOTE

Security-related changes to software or devices are documented in the "New functions" section.

2.2 Cybersecurity information

Siemens provides products and solutions with industrial cybersecurity 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 cybersecurity concept. Siemens' products and solutions constitute one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For additional information on industrial cybersecurity measures that may be implemented, please visit <https://www.siemens.com/cybersecurity-industry>.

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.

To stay informed about product updates, subscribe to the Siemens Industrial Cybersecurity RSS Feed under <https://new.siemens.com/cert>.

Product overview

3.1 Properties

Article number

6ES7536-1MF00-0AB0

View of the module

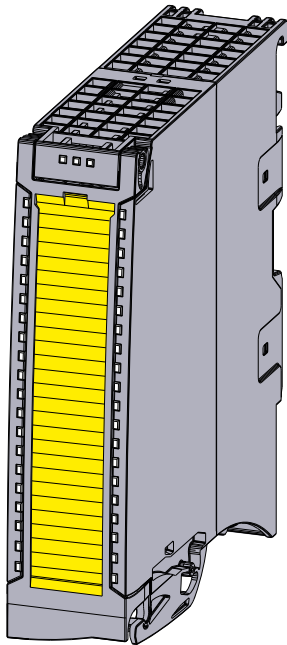


Figure 3-1 View of the F-AI 8xI 0(4)..20mA module

Properties

The module has the following technical properties:

- Fail-safe analog module for use in the S7-1500 automation system and in the ET 200MP distributed I/O system.
- PROFIsafe profile V2.6.1
- PROFIsafe address type 2
- Supports the profile RIOforFA-Safety (on F-CPU S7-1200 and S7-1500)
- Measurement type current adjustable per channel
 - 0 to 20 mA
 - 4 to 20 mA
- Interference frequency suppression: 50/60 Hz
- 8 analog inputs (SIL3/Cat.3/PLd) or 4 inputs (SIL3/Cat.4/PLe)
- Use of various interconnection types are possible (1oo1 & 1oo2)
- External sensor supply possible
- Internal short-circuit-proof sensor supplies for each channel
- Electrical isolation
 - From backplane bus
 - In groups of 4 channels (AI₀ ... AI₃, AI₄ ... AI₇)
- Status display RUN (green LED)
- Status display module diagnostics (red LED)
- Status display channel status (green LED)
- Status display power supply (green LED)
- Channel diagnostics per input (red LED)
- Resolution 16 bits including sign
- Channel-specific or module-wide passivation

Supported functions:

- Firmware update
- I&M identification data
- Service data
- Value status
- HART communication (Rev. 5 to Rev. 7; is supported as of firmware V2.0)
- Up to 3 additional submodules can be configured as module-internal shared input (MSI) or as HART variables (supported as of firmware V2.0)

 WARNING

The fail-safe performance characteristics in the technical specifications apply for a mission time of 20 years and a repair time of 100 hours. If a repair within 100 hours is not possible, switch off the power supply of the affected module before 100 hours expires. Follow the repair procedure described in section Diagnostic alarms (Page 83).

Accessories

The following accessories are supplied with the module and can also be ordered as spare part:

- Labeling strips
- U-connector
- Universal front cover
- Electronic coding element
- Shielding bracket
- Shield terminal
- Power supply element

Additional components

The following component must be ordered separately:

- Front connector and cable tie

You can find more information on accessories in the S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/ww/en/view/59191792>) system manual.

3.2 F-CPU and Engineering

Requirement

- F-CPU 15xxF as of firmware V2.0
- F-CPU 12xxF as of firmware V4.2
- Safety system version as of V2.5
- PROFIsafe driver profile V2.6.1
- As of TIA Portal V18 SP1 with HSP0394 (firmware V1.0)
- As of TIA Portal V19 with HSP0451 (firmware V2.0)

Connecting

4.1 Block diagram

This section includes the block diagram with the general pin assignment of the F-module.

You can find more information on the parameter assignment of the F-module in the section Parameters/address space (Page 40).

You can find more information on the various connection options in the section Applications of the F-I/O module (Page 68).

You can find information on wiring the front connectors and providing the cable shielding, etc., in the Wiring section of the Automation System S7-1500

(<https://support.industry.siemens.com/cs/ww/en/view/59191792>) System Manual.

Abbreviations used

In the following images, the abbreviations used mean:

I_{n+}/I_{n-}	Analog input channel n (current only)
L+	Connection to power supply
M	Connection to ground
U_{Sn}	Sensor supply

Pin assignment for the power supply element

The power supply element is plugged onto the front connector and serves as the shield connection. For this, you must connect the power supply to terminal 41 (L+) and terminal 44 (M).

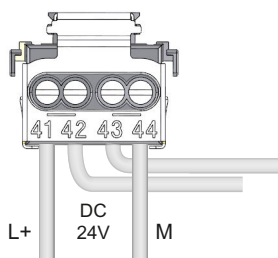
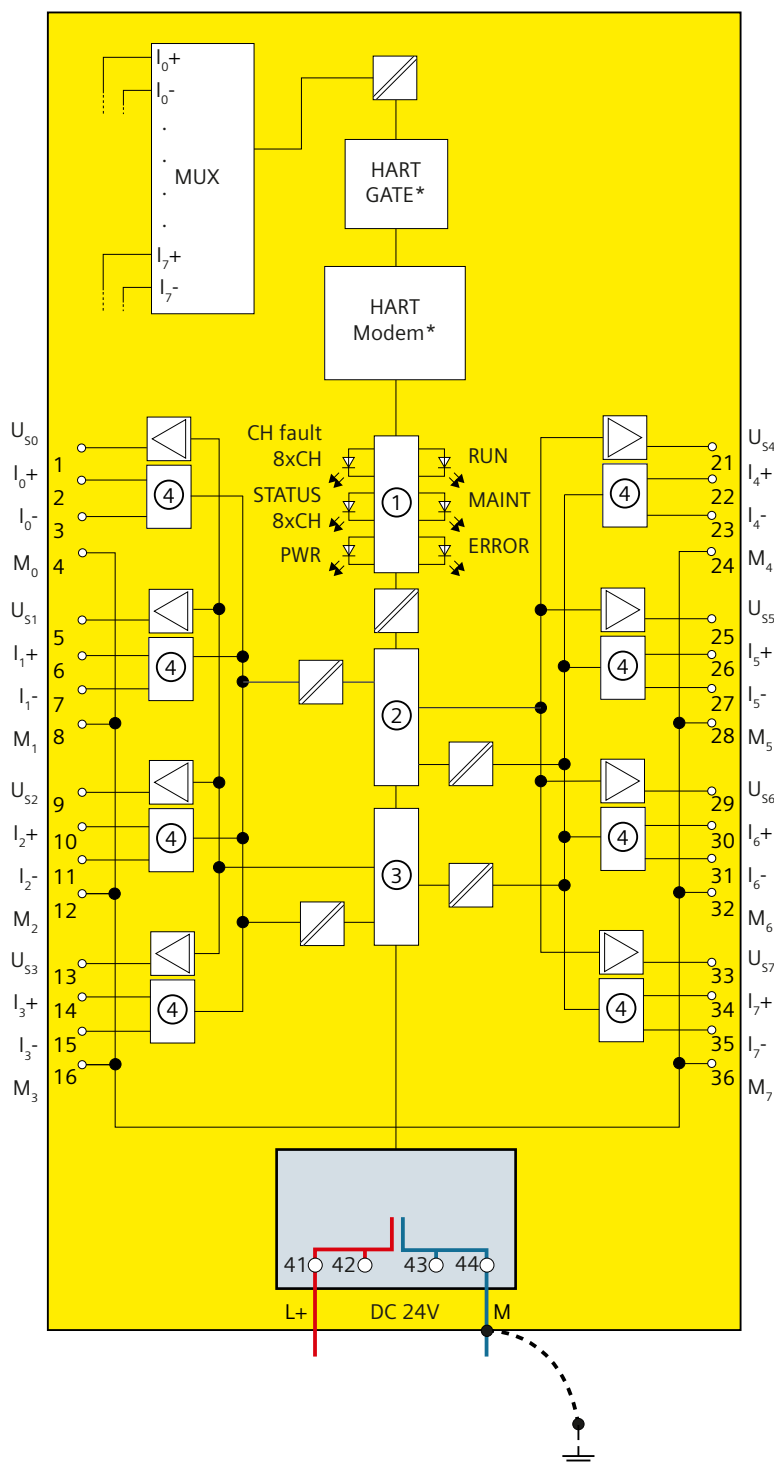


Figure 4-1 Connection of power supply element

Block diagram

The following figure shows the assignment of channels to addresses (input word).



① Backplane bus interface

RUN

LED status display (green)

4.1 Block diagram

②	Microcontroller 1	ERROR	LED for fault display (red)
③	Microcontroller 2	PWR	LED for power supply (green)
④	Signal evaluation	MAINT	LED for MAINT ALARM (yellow)
		CH fault	LED for channel fault (red)
		STATUS	LED for channel status (green)
		*	The function is supported as of firmware V2.0.

Figure 4-2 Block diagram

Sensor supply

 **WARNING**

Voltage dips and voltage fluctuations of the power supply are not buffered by the F-module and therefore affect the sensor supply.
This can cause the measured value to be falsified and must be taken into account when determining the safety function.
To ensure that the sensor functions without problems, we recommend one of the following options:

- You can avoid voltage dips by using a voltage supply according to the NAMUR recommendation NE 21.

or

- Use a transmitter with an appropriate battery backup or diagnostics.

Recommendation: Internal sensor supply

You are strongly advised to use the short-circuit-proof internal sensor supply of the F-module. This internal sensor supply is monitored and its status is indicated by the Fn LED. The input is also protected in the event of short-circuits in the wiring or at the sensor.

NOTE

The internal sensor supply is switched off in case of a short-circuit to ground or during power-up in the event of short-circuit to L+.
The sensor supply is also switched off at input currents > 35 mA.
A check is made approximately 1 minute later to determine if the error has gone.

NOTE

Behavior of process values and diagnostics evaluation

Sensor startup during module startup:

After the internal sensor supply is activated, the evaluation of wire break and underflow diagnostics is suppressed for 3 seconds. During this time, the module makes the secure process value 0 available at all channels. This suppresses a possible wire break or underflow diagnostics caused by the sensor startup. If the sensor startup is not yet complete after the 3 seconds have elapsed, it is possible that the module might detect wire break or underflow and passivate the affected channel. In this case, the channel fault must be acknowledged during startup.

Sensor startup during operation:

If a sensor startup takes place during operation, e.g. the sensor supply is reactivated after a short-circuit, all analog values are invalid and wire break or underflow diagnostics can occur on the sensors connected to the internal sensor supply.

External/internal sensor supply

The figures in section Applications of the F-I/O module (Page 68) show how you can supply power to the sensors via an external sensor supply (for example, from another module).

WARNING

A short-circuit from L+ to I_n+ might destroy the input resistors, depending on the selected interconnection type.

You can avoid this problem through proper wiring and use of the internal sensor supply. When an external sensor supply is used, other suitable measures are necessary to protect the input resistors (e.g. external quick-response 50 mA fuse in the input circuit of the F-module).

WARNING

External sensor supply

If you use an external sensor supply, you need to take into consideration the voltage dips and voltage fluctuations when determining the safety function.

To ensure that the sensor functions without problems, we recommend one of the following options:

- Use a transmitter with an appropriate battery backup or diagnostics.
or
- Use a **redundant** external sensor supply
or
- **Monitor** the external sensor supply for undervoltage/overvoltage, including shutdown of the sensor supply in the event of a fault (1-channel for SIL2; 2-channel for SIL3).

HART function

5.1 Usage of HART

Definition

"HART" stands for "Highway Addressable Remote Transducer" = Remote-controlled field devices (sensors or transmitters) that can be addressed via communication.

Using the HART functionality, you can also use the analog input module F-AI 8xI 0(4)..20mA 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.

NOTE

HART communication (Rev. 5 to Rev. 7) is supported as of firmware V2.0.

Advantages of HART

Using the analog input module F-AI 8xI 0(4)..20mA offers the following advantages:

- Additional digital communication using the HART protocol
- Numerous field devices with HART functions are in use
- Analog input module F-AI 8xI 0(4)..20mA is used to integrate HART into the S7 system.

Use in the system

Analog input module F-AI 8xI 0(4)..20mA is used in the central I/O as well as in the distributed structure, which is connected to PROFIBUS DP or PROFINET IO.

You can connect a field device to any channel: The analog input module F-AI 8xI 0(4)..20mA operates as a HART master, monodrop; field devices as HART devices.

Typical applications

The following applications are typical:

- Commissioning of field devices (centralized parameter assignment)
- Field device parameters can be changed online
- Information, maintenance, and diagnostics displays for the field devices
- Integration of configuration tools for field devices via the HART interface

WARNING
The HART protocol is not a safety-related protocol.

Use of HART communication with marine applications

NOTE

Power supply requirements with marine applications

To meet the requirements of the marine approvals specified in the S7-1500 automation system (<https://support.industry.siemens.com/cs/ww/en/view/59191792>) System Manual, you must install the F-AI 8xI 0(4)..20mA analog input module and the associated power supply unit in the same control cabinet if HART communication is enabled. Only F-AI 8xI 0(4)..20mA analog input modules may be supplied with the power supply unit.

If HART communication is disabled, these restrictions do not apply.

5.2 HART operating principle

Introduction

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

HART signal

The figure below shows the analog signal with the modulated HART signal (FSK method), which consists of sine waves of 1200 Hz and 2200 Hz and has a mean value of 0. It can be filtered out using an input filter so that the original analog signal is available again.

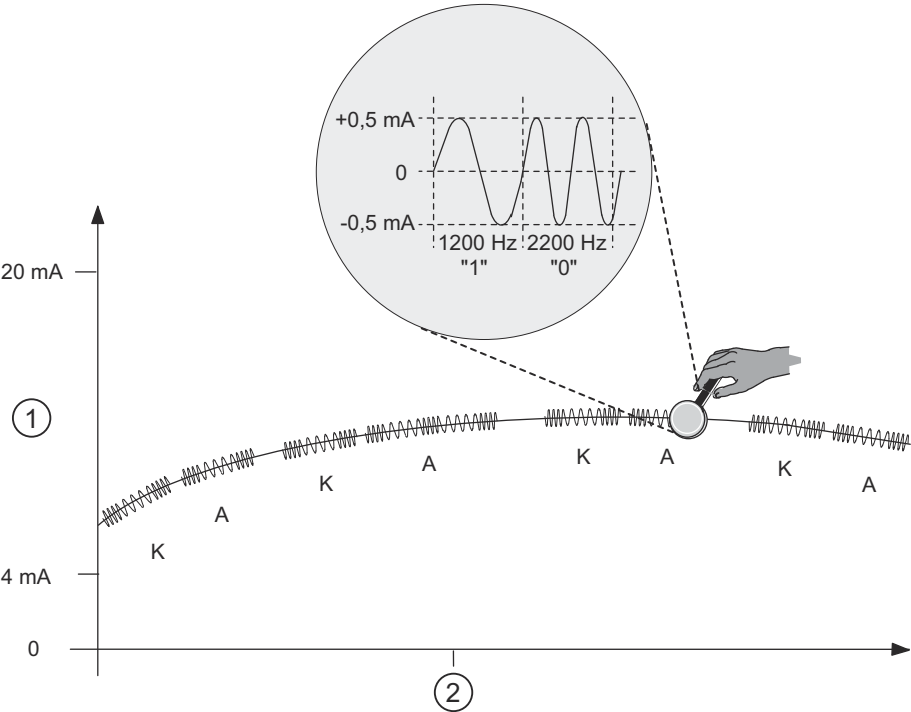


Figure 5-1 The HART signal

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

HART communication

The analog input module F-AI 8xI 0(4)..20mA processes the HART communication sequentially in multiplex mode, i.e. channel-by-channel one after the other. HART commands of the individual channels therefore influence the speed of HART processing of the other channels.

When HART mode is enabled, the analog module independently sends HART commands to the connected field devices. This always takes place on a channel-specific basis, alternating with any pending external HART commands that arrive via the module's command interface, see HART command interface (Page 34).

Commissioning a HART field device

Only HART field devices that are set to the 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.

HART commands

The assignable properties of the HART field devices (HART parameters) can be set with HART commands and read by means of HART replies. The HART commands and their parameters are divided into 3 groups with the following properties:

- Universal
- Common practice
- Device-specific

Universal commands must be supported by all manufacturers of HART field devices and common practice commands should be supported. There are also device-specific commands that apply only to the particular field device.

Examples of HART commands

The following two tables show examples of HART commands:

Table 5-1 Examples of universal commands

Command	Function
0	Read manufacturer and device type - only with this command 0 can field devices be addressed by means of a short frame address
11	Read manufacturer and device type
1	Read primary variable and unit

5.2 HART operating principle

2	Read current output and percent of range, digitally as floating-point number (IEEE 754)
3	Read up to four pre-defined dynamic variables (primary variables, secondary variables, etc.)
13, 18	Read or write tag, descriptor and date (data included in transmission)

Table 5-2 Examples of common practice commands

Command	Function
36	Set upper range value
37	Set lower range value
41	Perform self-test
43	Set the primary variable to zero
109	Switch burst mode on or off

Structure of the HART protocol

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

PREAMBLE	STRT	ADDR	COM	BCNT	STATUS	DATA	CHK
----------	------	------	-----	------	--------	------	-----

PREAMBLE:	Bytes (0xFF) for synchronization. 5 to 20 bytes depending on parameter assignment
STRT:	Start character (start delimiter)
ADDR:	Address of the field device (1 byte; short address or 5 bytes; long address)
COM:	HART command number
BCNT:	Byte count, number of bytes to follow without checksum
STATUS:	HART device status (1st and 2nd status byte). Only present for a response frame. For structure of HART device status, see below.
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. See section HART request and response data records (DS 80 to DS 95) (Page 104).

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

Structure of HART device status (1st and 2nd status bytes).

Table 5-3 1st status byte

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

Table 5-4 2nd status byte

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

HART Fast Mode

The analog input module F-AI 8xI 0(4)..20mA supports processing of HART commands as SHC sequence ("Successive HART Command").

When a HART command with a set SHC bit for a channel is detected by the analog module, the complete HART command processing is reserved on the analog module for that channel for about 2 seconds. For all other channels of the analog module, no HART frame processing occurs during this time, see section HART command interface [\(Page 34\)](#)

NOTE

- While a HART channel of the HART module of the analog input module F-AI 8xI 0(4)..20mA processes an SHC sequence, i.e. the HART processing for this channel is reserved, the HART variables of all HART channels are no longer updated. They remain unchanged in the value and quality code.
- HART requests for other channels of the HART module are not processed and acknowledged accordingly.

Burst mode

Analog input module F-AI 8xI 0(4)..20mA does not support burst mode. HART commands with set burst bit are ignored and are not forwarded to the connected field device.

5.3 Using HART

System environment for the use of HART

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

- Current loop 4 to 20 mA

Connection of the transmitters to the analog input module F-AI 8xI 0(4)..20mA

- HART configuration tool "Client":

You can assign the HART parameters using an external hand-held operating device (HART handheld) or a HART configuration tool (PDM). Both assume the function of a "client":

The configuration tool accesses through the analog input module F-AI 8xI 0(4)..20mA while the HART handheld is connected directly in parallel to the field device.

PDM (Process Device Manager) is available as a stand-alone unit or integrated in *STEP 7 HW Config*.

- HART system integration:

The analog input module F-AI 8xI 0(4)..20mA assumes the function of a "master" by receiving the commands from the HART configuration tool or programmed from an S7 user program, passing them on to the intelligent field device and then returning the replies. The interface of the analog input module F-AI 8xI 0(4)..20mA is represented by data records that are transferred via the S7-1500 I/O bus. The data records must be created and interpreted by the client.

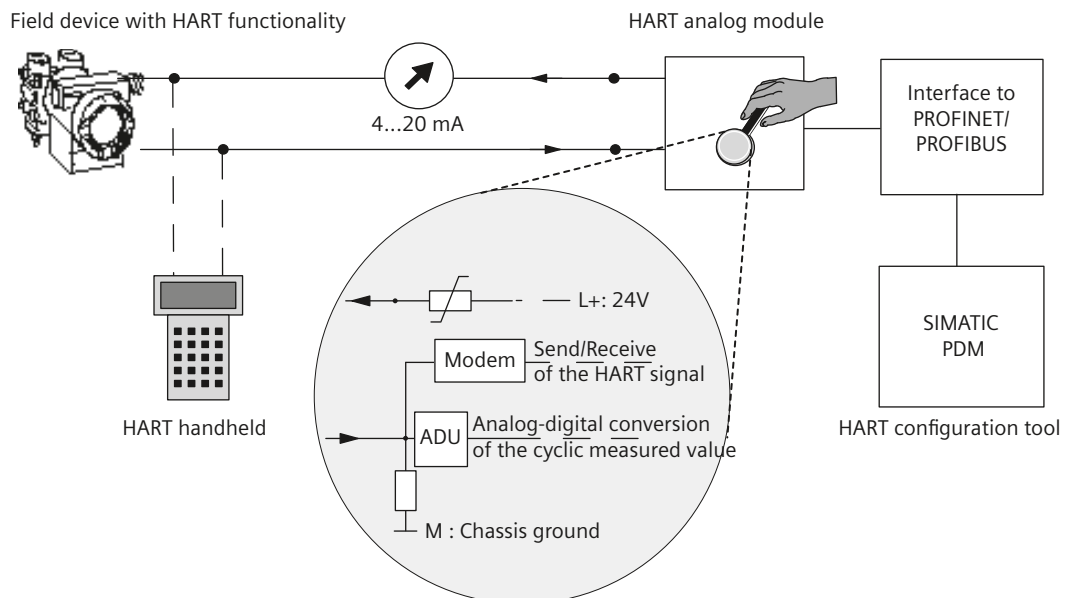


Figure 5-2 System environment for the use of HART

Error management

The two HART status bytes (HART device status), which are transmitted with each response from the field device, contain error messages about the HART communication, HART command and device status.

Among other things, these are evaluated by the analog input module F-AI 8xI 0(4)..20mA and made available in the system via the S7 diagnostic alarms.

Configuration/commissioning

You configure the analog input module F-AI 8xI 0(4)..20mA in the SIMATIC system with STEP 7 or the TIA Portal. You configure the individual channels with respect to the actual analog value acquisition and the use of the HART variables in the input address space of the additional submodules of the module.

You can configure one field device per channel. By means of this configured field device, the configuration/parameter assignment of the connected field device is then carried out using PDM or the EDD for the S7-1500/ET 200MP. You will find the current EDD for download in Siemens Industry Online Support under entry ID 109822354 (<https://support.industry.siemens.com/cs/ww/en/view/109822354>).

With PROFINET IO, analog input module F-AI 8xI 0(4)..20mA can be configured via a GSD file. However, in this case, direct configuration / parameter assignment of the connected field devices is not possible.

Parameter reassignment of the field devices

The analog input module F-AI 8xI 0(4)..20mA generally accepts triggered parameter reassignment for field devices. Access rights can only be allocated in the configuration tool.

For parameter reassignment of the field devices connected to analog input module F-AI 8xI 0(4)..20mA, proceed as follows:

1. You trigger parameter reassignment of a field device with a HART command entered using the SIMATIC PDM configuration tool or programmed via the STEP 7 user program.
2. The corresponding bit is set in the HART device status of the connected field device (in the 2nd status byte) after you have reassigned the parameters of a HART field device.
3. The parameter reassignment of the field device causes the analog input module F-AI 8xI 0(4)..20mA to trigger a "HART configuration changed" diagnostic interrupt, if this is enabled. See Diagnostic alarms (Page 83). This diagnostic interrupt is to be regarded as information and not as an error and is automatically deleted again by the analog module after approximately 1 minute.

A diagnostic interrupt can also be triggered, if enabled, when parameters are reassigned with the handheld.

 WARNING

An external operating device (e.g. HART handheld or HART modem) may only be used if one of the following requirements is met:

- The input signals (i.e. process values or user data in the input range in section Address space (Page 61)) are checked for plausibility. For example, by comparison in the fail-safe user program with the equivalent value of another F-I/O module.
- Your system is in a state in which parameter reassignment of a HART field device is possible without risk.

See also

[Block diagram \(Page 20\)](#)

5.4 HART for safety-related applications

Overview

- "HART gate" parameter
You 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.
- "HART function" parameter
You use the "HART function" parameter to enable or disable HART communication with the HART field device for the relevant channel of the I/O module.
The parameter is not safety-related. In other words, this parameter cannot be used for fail-safe shutdown of HART communication.

WARNING

Write protection of the connected HART field devices should always be enabled as soon as the "HART gate" is switched on.

This measure guarantees both protection from unauthorized access or manipulation of the HART sensors and compliance with the requirements for using HART field devices in safety-related applications.

If write protection is not enabled and the "HART gate" is switched on, one of the following conditions must be met:

- The input signals (i.e. input values or user data in the input range in the section Address space (Page 61)) are checked for plausibility. For example, by comparison in the fail-safe user program with the equivalent value of another F-I/O module.
- Your system is in a state in which parameter reassignment of a HART field device is possible without risk.

WARNING

If the "HART gate" is switched on, the additional error of the input signal (i.e. input values or user data in the input range in section Address space (Page 61)) specified in the Technical specifications (Page 90) of the F-I/O module must be taken into account by the HART signal modulated on the input signal depending on the configured interference frequency suppression.

⚠ WARNING

An external operating device (e.g. HART handheld or HART modem) may only be used if one of the following requirements is met:

- The input signals (i.e. input values or user data in the input range in the section Address space (Page 61)) are checked for plausibility. For example, by comparison in the fail-safe user program with the equivalent value of another F-I/O module.
- Your system is in a state in which parameter reassignment of a HART field device is possible without risk.

5.5 HART command interface

Data records

The HART commands are sent as "external" HART requests from the client (e.g. PDM or the STEP 7 user program) via data records to the connected field device. The response from the field device is then made available in the system via data records.

HART communication may be controlled by only one client (e.g. PDM) 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. Analog input module F-AI 8xI 0(4)..20mA does not support client management.

Fixed data records are assigned to each client/channel:

Table 5-5 Structure of the data records

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

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

Errors during the transfer are indicated at output parameter STATUS.

Errors during interpretation of the request data record are signaled in the corresponding response data record. The faulty request can be read back again using the request data record.

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 displays.
- The response data record must always be read completely because the analog module may modify the data record after the initial reading with "successful" or "error" status. If the processing status in the response data record indicates "successful" or "error", the data record contains current response data or error displays.
- The client may only write a request data record to the 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 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 disabled. 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.

SHC sequence

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

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

5.6 HART variables

Introduction

Numerous HART field devices provide additional measured quantities (e.g. sensor temperature).

For each channel with activated HART functionality, a maximum of 4 HART variables supported by the connected field device are read cyclically. The HART variables are read automatically via HART command 3 (for field devices with HART Rev. 5 and 6) or via command 9 (for field devices from HART Rev. 7).

These 4 HART variables per channel are always stored in the HART variable data record 121 and can be read at any time. See section HART variable data record (DS 121) (Page 101).

In addition, a maximum of 8 HART variables can be configured directly in the input address space of the additional submodules of the analog input module F-AI 8xI 0(4)..20mA. See section Additional submodules (Page 57). You assign the respective HART variables to a channel in the "HART variables configuration" properties dialog of the module. Parameter assignment is performed via parameter data record 140. See section Parameter assignment and structure of the HART mapping parameters (DS 140) (Page 112). This enables you to easily process measured values directly from the field device as input data in the automation device.

Evaluating the multiHART area

You can select the multiHART area via the parameter assignment dialog.

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

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

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

HART variable reference	
Bit 4 ... 7: Channel number 0 ... 7	Bit 0 ... 3: Variable identification 1 = PV (Primary Variable) 2 = SV (Secondary Variable) 3 = TV (Tertiary Variable) 4 = QV (Quaternary Variable)

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

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

Example:
The primary variable of channel 6 is to be read.

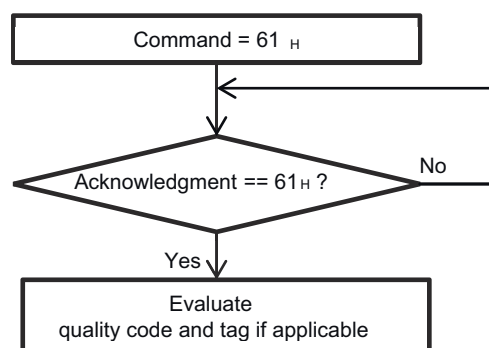


Figure 5-3 Command = 0x61

Address assignment

You can configure up to three additional submodules and access the HART variables in the input address space of these additional submodules (see section Additional submodules (Page 57)).

You can find the address assignment in section Address space of additional submodules (Page 63).

Configuration of HART variables

You can configure up to 4 HART variables for each channel:

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

When HART mode is activated, the analog input module F-AI 8xI 0(4)..20mA automatically reads the variables supplied by the connected field devices cyclically and makes them available in the input address space of the module's additional submodules in accordance with the configuration.

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

Quality code

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

Basic structure of the quality code

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 analog input module F-AI 8xI 0(4)..20mA depend on the HART revision of the field device used.

For field devices with HART Revision 5 and 6

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

Quality code	Meaning (process status)	
80 _H	Value is okay	Also applies if 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 if the following bits are set in the 2nd status byte of the HART response frame: • Additional status information available • Analog output current saturated • Non primary variable outside the limits • Primary variable outside the range
84 _H	Response code RC8: Update error	
24 _H	Response code RC16: Access restricted	Request from field device refused
23 _H	Communication error or HART variable not present in the field device	
37 _H	Initialization value from analog module	• After module startup • After incorrect operation of the multiHART interface
00 _H	Initialization value from S7 system	

For field devices from HART Revision 7

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

Quality code	Meaning (process status)	
80 _H	Value is okay	
28 _H ... 2B _H	"Bad"	Process status, formed from the "Device variable status" (DVS) of the response frames with corresponding limits (see above)
68 _H ... 6B _H	"Poor accuracy"	
78 _H ... 7B _H	"Manual" or "Fixed" (manually controlled or fixed value)	
88 _H	"More device variable state available" (additional status information available)	
89 _H	"Good" with "Low limit"	
8A _H	"Good" with "High limit"	
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 • After incorrect operation of the multiHART interface
40 _H	Alternatively read via command 3	
00 _H	Initialization value from S7 system	

Parameters/address space

6.1 Measurement types and measuring ranges

The following table shows the measurement types and the respective measuring range.

Table 6-1 Measurement types and measuring ranges

Measurement type	Measuring range	Resolution
Current	0 to 20 mA (2- and 3-/4-wire transducer) 4 to 20 mA (2- and 3-/4-wire transducer)	16 bits including sign 16 bits including sign

You can find the tables of the measuring ranges as well as overflow, overrange, etc. in the Appendix Representation of analog values (Page 97).

6.2 Parameters

Parameters for F-AI 8xI 0(4)..20mA

WARNING

Diagnostic functions must be activated or deactivated in accordance with the application; see section Applications of the F-I/O module (Page 68).

The following parameters are possible:

Table 6-2 Configurable parameters

Parameter	Value range	Default	Configuration in RUN	Scope
F-parameters:				
Manual assignment of F-monitoring time	- Disable - Enable	Disable	No	Module
F-monitoring time	1 to 65535 ms	150 ms	No	Module
F-source address	1 to 65534	Dependent on parameter assignment of the F-CPU	No	Module
F-destination address	1 to 65534	Suggested by F-system	No	Module
F-parameter signature (without addresses)	0 to 65535	Calculated by F-system	No	Module

*) See formula in the section "Parameter assignment of discrepancy analysis for 1oo2 evaluation"

Parameter	Value range	Default	Configuration in RUN	Scope
Behavior after channel fault	- Passivate the entire module - Passivate channel	Passivate channel	No	Module
Reintegration after channel fault	- Adjustable - All channels automatically - All channels manually	All channels manually	No	Module
F-I/O DB manual number assignment	- Disable - Enable	Disable	No	Module
F-I/O DB-number	Value range depending on parameter assignment of the F-CPU	Suggested by F-system	No	Module
F-I/O DB-name	—	Suggested by F-system	No	Module
AI parameters:				
HART gate	- On - Off - Switchable	Off	No	Module
Interference frequency suppression	50 Hz 60 Hz	50 Hz	No	Module
Channel parameters				
Channel n, n+4				
Sensor evaluation	1oo1 evaluation (max. SIL3/Cat.3/PLd) 1oo2 evaluation (max. SIL3/Cat.4/PLe)	1oo2 evaluation (max. SIL3/Cat.4/PLe)	No	Channel
Unit value	- MIN - MAX	MIN	No	Channel
Discrepancy time *	100 to 30000 ms	100 ms	No	Channel
Tolerance window abs.	0.3 to 20.0%	2.5%	No	Channel
Tolerance window rel.	0.3 to 20.0%	2.5%	No	Channel
Channel n				
Activated	- Disable - Enable	Enable	No	Channel
Channel fault acknowledge	- Manual - Automatic	Manual	No	Channel

*) See formula in the section "Parameter assignment of discrepancy analysis for 1oo2 evaluation"

6.2 Parameters

Parameter	Value range	Default	Configuration in RUN	Scope
Measuring range	0...20 mA 4...20 mA	4...20 mA	No	Channel
Diagnosis: Wire break **	- Disable - Enable	Enable	No	Channel
Smoothing	1 2 4 8 16 32 64	1	No	Channel

*) See formula in the section "Parameter assignment of discrepancy analysis for 1oo2 evaluation"

Table 6-3 HART/MSI/HART variables parameter

Parameter	Value range	Default	Configuration in RUN	Scope
Module parameters:				
AI configuration				
Number of additional submodules (for MSI / HART variables)				
Additional submodules	- None 1 2 3	None	No	Module
HART:				
Channel n				
HART function	- Disable - Enable	Disable	Yes	Channel
HART preamble bytes	5 to 20	5	Yes	Channel
HART repetitions	1 to 10	5	Yes	Channel
HART diagnostics	- Disable - Enable	Disable	Yes	Channel
HART variables configuration				
HART variables	- None 4 HART 8 HART 1 multiHART	None	No	Module
Submodule_n: *				
Submodule type				
Submodule type	- MSI - HART variables	MSI	No	Module

*) Only present if the "Additional submodules" parameter is configured with 1, 2 or 3

6.3 Explanation of parameters

6.3.1 F-parameters

You must assign the PROFIsafe address (F-destination address together with F-source address) to the F-module before you put it into operation.

- You define the F-source address using the "Basis for PROFIsafe addresses" parameter in the F-CPU.
- An F-destination address unique throughout the CPU is automatically assigned for each F-module. You can manually change the F-destination addresses set in the hardware configuration.

You can find information on F-parameters for the F-monitoring time, the PROFIsafe address assignment (F-source address, F-destination address) and the F I/O DB in the manual SIMATIC Safety - Configuring and Programming

(<https://support.industry.siemens.com/cs/ww/en/view/54110126>).

6.3.1.1 Behavior after channel fault

This parameter is used to specify whether the entire F-module is passivated or just the faulty channel(s) in the event of channel faults:

- "Passivate the entire module"
- "Passivate channel"

6.3.1.2 Reintegration after channel fault

Use this parameter to select how the channels of the fail-safe module are reintegrated after a fault.

If you have set the "Behavior after channel fault" parameter to "Passivate channel", you enable individual setting of the reintegration type per channel with the parameter assignment "Adjustable". The reintegration type of the respective channel is specified with the "Channel failure acknowledge" channel parameter.

If you have set the "Behavior after channel fault" parameter to "Passivate the entire module", you can only select the same reintegration type for all channels.

6.3.1.3 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.
- "Switchable": If the module is in RUN, HART communication can be switched on and off from the safety program via the process output byte QB x + 0. This means that the HART communication with HART field devices can be activated and deactivated during operation of the F-CPU (e.g. for maintenance purposes). You can find more information about the address assignment in the section Address space ([Page 61](#)).

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

You can find more information on this parameter in the section "HART for safety-related applications ([Page 33](#))".

6.3.1.4 Interference frequency suppression

Here you set the interference frequency suppression for the line frequency:

- 50 Hz
- 60 Hz

You can find more information on this in the Analog value processing function manual (<https://support.industry.siemens.com/cs/ww/en/view/67989094>).

6.3.2 Parameters of the channels

6.3.2.1 Evaluation of the sensors

Overview

Here you select the type of sensor evaluation:

- "1oo1 evaluation (max. SIL3/Cat.3/PLd)"
- "1oo2 evaluation (max. SIL3/Cat.4/PLe)"

If you do not want to measure with a channel or channel pair, disable the channel or the channel pair.

1oo1 evaluation (max. SIL3/Cat.3/PLd)

With the 1oo1 evaluation, there is one sensor, and it is connected to the F-module via a single channel.

1oo2 evaluation (max. SIL3/Cat.4/PLe)

With the 1oo2 evaluation, two input channels are occupied by:

- Two single-channel sensors
- One two-channel sensor

Note that in 1oo2 evaluation, two channels are combined into a channel pair.

Achievable safety class

Depending on the selected sensor evaluation, you achieve the following safety classes with a sensor that is qualified accordingly:

- SIL3/Cat.3/PLd for "1oo1 evaluation" or
- SIL3/Cat.4/PLe for "1oo2 evaluation"

6.3.2.2 Unit value

Function

If you have selected "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you can choose for each input channel pair which of the two F-CPU values is provided.

- "MIN": the lesser of the two values.
- "MAX": the greater of the two values.

During a discrepancy between the two input channels, the last valid unit value prior to the occurrence of the discrepancy is made available to the F-CPU.

6.3.2.3 Discrepancy time

Function

If you have selected "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you can enter the discrepancy time for each channel pair here in milliseconds.

The discrepancy time does not start until the unit value is outside the assigned tolerance window (relative or absolute). If the two redundant input channels of the channel pair differ by more than the specified tolerance and for longer than the specified discrepancy time but no longer than the duration of the maximum response time, the F-module detects a discrepancy error and triggers a diagnostic interrupt. If the input channels fall below the specified tolerance prior to expiration of the discrepancy time (input channels are no longer discrepant), the discrepancy time is cleared and is restarted only when a new discrepancy is detected.

For more information regarding configuring the discrepancy analysis refer to Parameter assignment of discrepancy analysis for 1oo2 evaluation (Page 48).

A discrepancy error is handled by the safety program in the same way as a channel fault. More information is available in the SIMATIC Safety – Configuring and Programming (<https://support.industry.siemens.com/cs/ww/en/view/54110126>) manual.

6.3.2.4 Tolerance window abs.

Function

If you have selected "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you can enter the size of a tolerance window for the discrepancy here for the channel pair. You specify the tolerance window as a percentage of the full-scale value. The reference value is the full-scale value, i.e. 20 mA. The entered value is rounded to one decimal place.

If two redundant input channels of the channel pair differ by more than the tolerance specified here and for longer than the specified discrepancy time, the F-module detects a discrepancy error and triggers a diagnostic interrupt.

You can find more information on setting the tolerance window under Parameter assignment of discrepancy analysis for 1oo2 evaluation (Page 48).

Example

You have assigned the following:

- "Tolerance window abs." at 10%
- The measuring range of 0...20 mA
- A discrepancy time of 100 ms

The input channels may differ from the configured discrepancy time (100 ms) up to the max. reaction time for a time window with a difference of more than 2 mA.

See also

[Discrepancy time \(Page 46\)](#)

6.3.2.5 Tolerance window rel.

Function

If you have selected "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you can enter the size of a tolerance window for the discrepancy here for each channel pair. You specify the tolerance window as a percentage of the assigned unit value. The entered value is rounded to one decimal place.

If two redundant input channels of the channel pair differ by more than the tolerance specified here and for longer than the specified discrepancy time, the F-module detects a discrepancy error and triggers a diagnostic interrupt.

The two parameters "Tolerance window abs." and "Tolerance window rel." are combined. The "Tolerance window abs." parameter is decisive in the case of low process values.

You can find more information on setting the tolerance window under Parameter assignment of discrepancy analysis for 1oo2 evaluation ([Page 48](#)).

Example

You have assigned the following:

- "Tolerance window rel." at 10%
- The measuring range of 0...20 mA
- A discrepancy time of 200 ms
- The unit value to MIN

With a measured value of 20 mA a difference of more than 2 mA from the configured discrepancy time (200 ms) up to the max. response time may occur.

See also

[Discrepancy time \(Page 46\)](#)

6.3.2.6 Parameter assignment of discrepancy analysis for 1oo2 evaluation

Operating principle of discrepancy analysis

A discrepancy analysis is performed with a configured 1oo2 evaluation. **Smoothed** process values are used for the discrepancy analysis.

An assignable tolerance window is formed around the process value that represents the instantaneous unit value (value that is signaled to the F-CPU).

The tolerance window is formed relative to the process value or as an absolute value relative to the measuring range end value. Relative and absolute tolerance windows are combined.

If the process value does not represent the unit value at an instant and is within the tolerance window, **no** discrepancy exists.

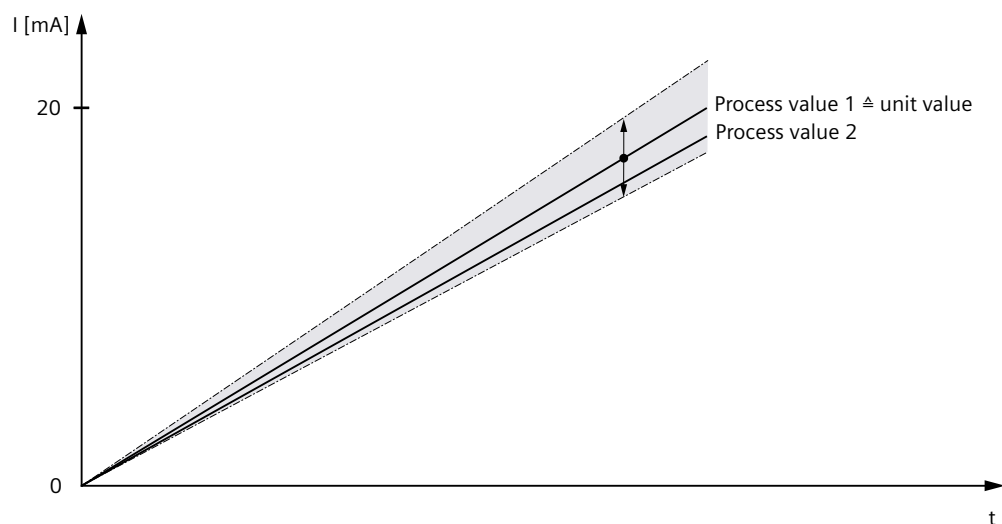


Figure 6-1 Example of a relative tolerance window *without* discrepancy (parameter assignment: unit value = MAX)

If the process value does not represent the unit value at an instant but is outside the tolerance window, a discrepancy exists.

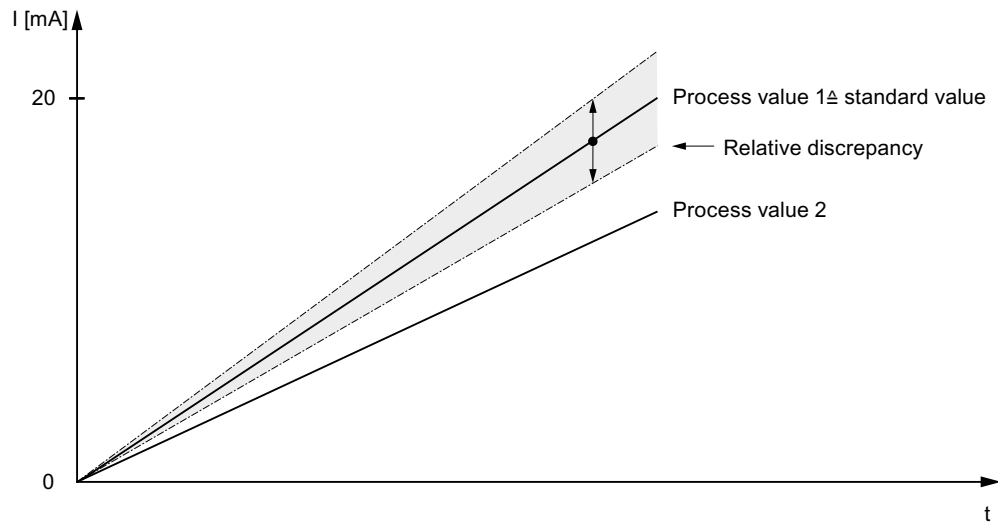


Figure 6-2 Example of a relative tolerance window *with* discrepancy (parameter assignment: unit value = MAX)

The assigned discrepancy time starts as soon as a discrepancy is detected. The discrepancy time runs as long as the discrepancy exists.

- During a discrepancy between the two input channels, the last valid unit value prior to occurrence of the discrepancy is signaled to the F-CPU.
If the input channels fall below the specified tolerance prior to expiration of the discrepancy time (input channels are no longer discrepant), the discrepancy time is cleared and is restarted only when a new discrepancy is detected.
- There is no valid old value after startup. If the discrepancy is detected during this time, 0 is output and the discrepancy time is started.
If there is no longer a discrepancy between the input channels when the discrepancy time expires, the unit value is output.

If the discrepancy time expires, an error is signaled and the process value is set to 0. In the PII, the substitute value 0 is set for the safety program.

A discrepancy error is handled by the safety program in the same way as a channel fault. More information is available in the STEP 7 Safety – Configuring and Programming (<https://support.industry.siemens.com/cs/ww/en/view/54110126>) manual.

Configuring the discrepancy analysis parameters

The following four parameters for the discrepancy analysis are assigned for each channel pair:

- Discrepancy time
- Unit value
- Tolerance window abs.
- Tolerance window rel.

"Discrepancy time" parameter

If the following is true, the F-module detects a discrepancy error:

- The process value that does not represent the unit value is outside the configured tolerance window.
- Lasts longer than the configured discrepancy time.
- Lasts at maximum the duration of the maximum response time.

In the case of a discrepancy error, the F-module triggers a diagnostic interrupt and sets the process value to 0. The discrepancy time is reset if the unit value lies within the tolerance window again.

In the PII, the substitute value 0 is set for the safety program.

You calculate the maximum discrepancy time that is permitted in the respective application using the following formula:

Discrepancy time = Maximum response time (in case of discrepancy error) – 2 × Conversion cycle time × Smoothing – 2 × Conversion cycle time

NOTE

You calculate the discrepancy time by using the values from the appendix Response times (Page 95) in the above equation.

You can assign the discrepancy time for each channel pair.

"Unit value" parameter

You can select which of the two values is to be signaled to the F-CPU for each input channel pair. During a discrepancy between the two input channels, the last valid unit value prior to occurrence of the discrepancy is signaled to the F-CPU.

- "MIN": The lower of the two values is signaled to the F-CPU as the unit value.
- "MAX": The higher of the two values is signaled to the F-CPU as the unit value.

"Tolerance window abs." parameter

You can calculate the absolute tolerance window using the following formula:

$$T_{abs} = \frac{|\Delta I_{abs}|}{I_{ME} - I_{MA}} \times 100 \text{ [%]}$$

Calculate the maximum deviation of the current using the following formula:

$$\Delta I_{abs} = \pm \frac{(I_{ME} - I_{MA}) \times T_{abs}}{100} \text{ [mA]}$$

With

- $I_{ME} = 20 \text{ mA}$ (full-scale value)
- $I_{MA} = 0 \text{ mA}$ for measuring range 0 ... 20 mA (start-of-scale value)
- $I_{MA} = 4 \text{ mA}$ for measuring range 4 ... 20 mA (start-of-scale value)
- $T_{abs} = \text{Tolerance in \%}$
- $\Delta I_{abs} = \text{Maximum deviation of current (+/-)}$

You can assign a value of 0.3 to 20.0% for the "Tolerance window abs." parameter for each channel pair.

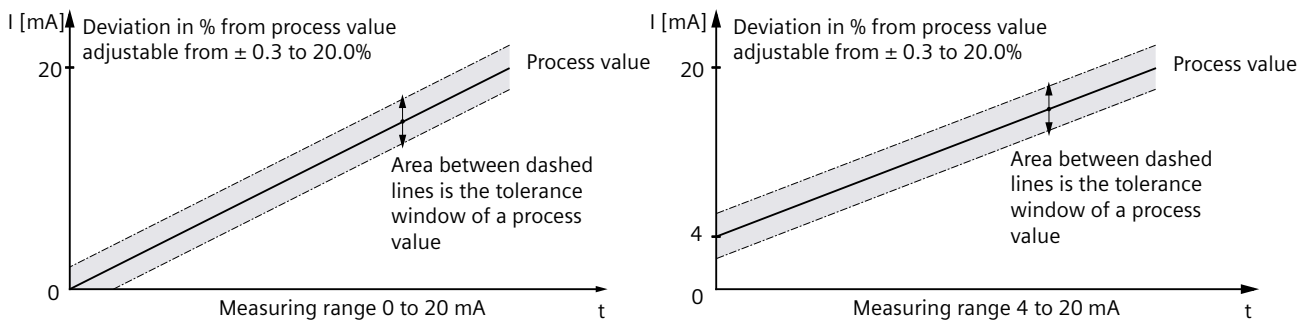


Figure 6-3 Absolute deviation in % of the nominal range for measuring range 0 to 20 mA or 4 to 20 mA

"Tolerance window rel." parameter

The tolerance window is calculated as a percentage of the **smoothed** process value that represents the MIN or MAX value (depending on the parameter assignment of the unit value) in this instant.

You can calculate the relative tolerance window using the following formula:

$$T_{rel} = \frac{|\Delta I_{rel}|}{|I_{EW} - I_{MA}|} \times 100 \text{ [\%]}$$

Calculate the maximum deviation of the current using the following formula:

$$\Delta I_{rel} = \pm \frac{|I_{EW} - I_{MA}| \times T_{rel}}{100} \text{ [mA]}$$

With

- $I_{EW} = \text{Process unit value (min./max.)}$
- $I_{MA} = 0 \text{ mA}$ for measuring range 0 ... 20 mA
- $I_{MA} = 4 \text{ mA}$ for measuring range 4 ... 20 mA
- $T_{rel} = \text{Tolerance in \%}$
- $\Delta I_{rel} = \text{Maximum deviation of current (+/-)}$

You can assign a value of 0.3 to 20.0% for the "Tolerance window rel." parameter for each channel pair.

6.3 Explanation of parameters

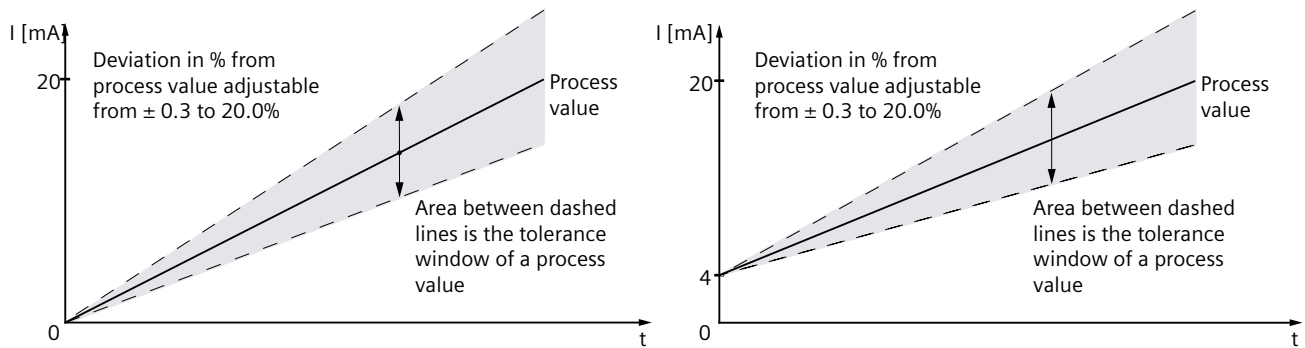


Figure 6-4 Relative deviation in % of the nominal range for measuring range 0 to 20 mA or 4 to 20 mA

Combination of the "Tolerance window abs." and "Tolerance window rel." parameters

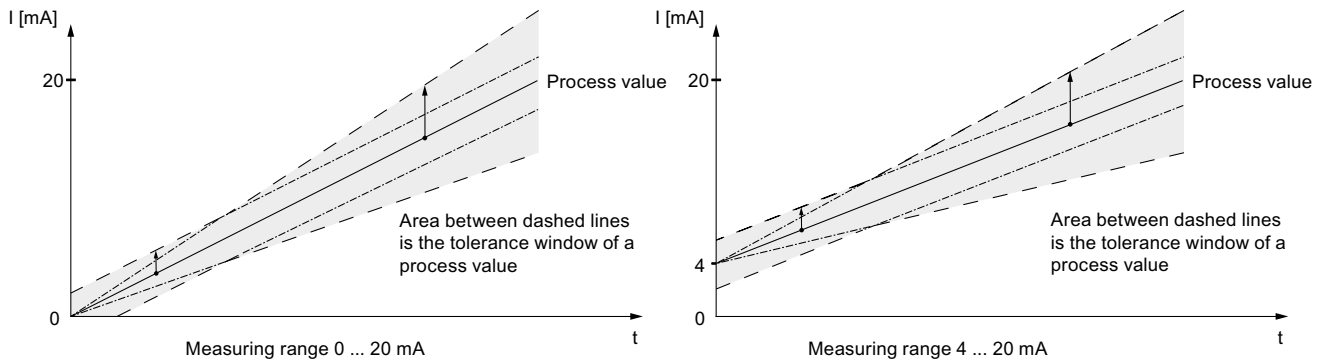
You can combine the "Tolerance window abs." and "Tolerance window rel." parameters as needed. The combined tolerance window (shown in gray in the figure below) is the maximum of T_{rel} and T_{abs} .

$$T = \text{MAX} \{ T_{rel}, T_{abs} \}$$

$$\Delta I = \text{MAX} \{ \Delta I_{rel}, \Delta I_{abs} \}$$

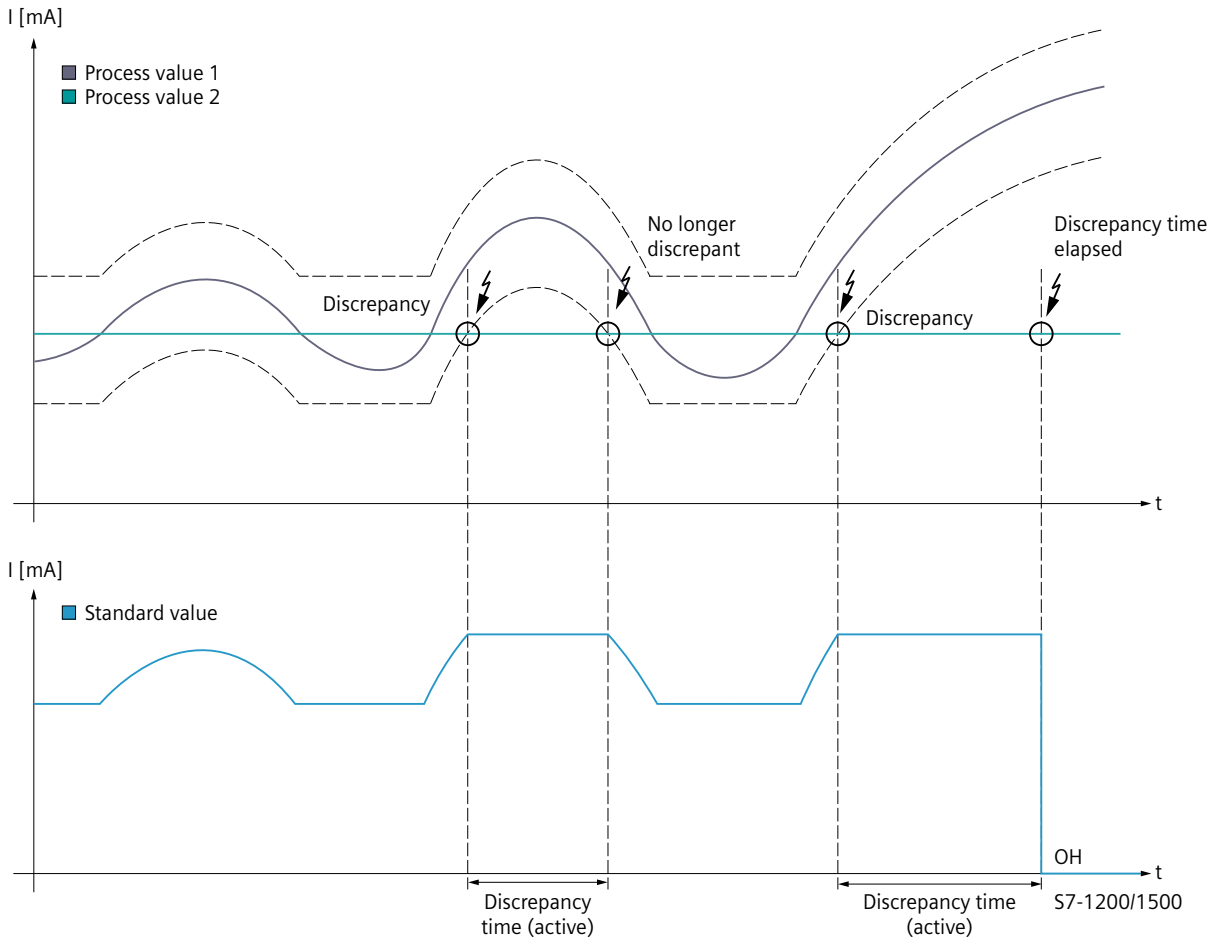
With

- T = Tolerance, in %
- ΔI = Maximum deviation of current (+/-)



Example

The following diagrams show you the behavior of the discrepancy evaluation when unit value = MAX.



The upper of the two diagrams shows you the characteristic curve of the two process values. The dashed line represents the absolute tolerance range configured in this example.

The lower of the two diagrams shows you the unit value signaled to the F-CPU.

In this example, on the first occurrence of a discrepancy, process value 1 is **within** the tolerance range again **before** expiration of the discrepancy time. This means the discrepancy error is not signaled.

In this example, on the second occurrence of a discrepancy, process value 1 is **outside** the tolerance range when the discrepancy time expires. As a result, a discrepancy error is signaled after expiration of the discrepancy time. In the PII, the substitute value 0 is set for the safety program.

6.3.2.7 Activated

If you select this check box, the corresponding channel is enabled for signal processing.

You can deactivate an unused channel with this parameter.

If you deactivate unused channels, the response time of the F-module is reduced.

You can find more information on the response times of the F-module in the appendix Response times ([Page 95](#)).

6.3.2.8 Channel failure acknowledge

The parameter can only be set if the F-parameter "Behavior after channel fault" is set to "Passivate channel" and the F-parameter "Reintegration after channel fault" is set to "Adjustable".

The value of this parameter specifies how the channel reacts after a channel fault:

- Manual: A channel failure is reintegrated after manual acknowledgment.
- Automatically: The channel is reintegrated automatically after a channel fault. Manual acknowledgment is not necessary.

See also

SIMATIC Safety - Configuring and Programming
(<https://support.industry.siemens.com/cs/ww/en/view/54110126>)

6.3.2.9 Measuring range

You select the measuring range for the channel with this parameter:

- 0...20 mA
- 4...20 mA

6.3.2.10 Diagnosis: Wire break

Function

Here you activate wire break detection for a configured measuring range of 4 to 20 mA.

With an assigned measuring range of 4 to 20 mA:

- With assigned wire break diagnostics and currents < 3.6 mA, a wire break is detected and a diagnostic interrupt is triggered in the F-CPU.
- Without configured wire break and currents diagnostics < 0.4444 mA detects "underflow" and triggers a diagnostic interrupt in the F-CPU.

With an assigned measuring range of 0 to 20 mA, the wire break diagnostics is permanently set 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. Then, a wire break is not detected.

6.3.2.11 Smoothing

Using smoothing

Smoothing of analog values provides a stabilized analog signal for further processing. Smoothed values are always used for discrepancy analysis.

WARNING

The smoothing takes place as a result of averaging over the selected number of most recently converted analog values of a channel, e.g. 64.

The mean value generation causes a discrepancy to be delayed with a configured "1oo2 evaluation (max. SIL3/Cat.4/PLe)". You can find an example below.

Smoothing principle

The measured values are smoothed by a digital filter. Smoothing is achieved by the F-module forming the mean of a number of converted (digitized) analog values determined by the "Smoothing" parameter.

You assign smoothing in 7 levels (1, 2, 4, 8, 16, 32, 64 conversion cycles). The level determines the number of analog signals that are averaged. If smoothing = 1 is configured, the smoothing is deactivated.

A higher smoothing provides a more stable analog value, and prolongs the time it takes to apply a smoothed analog signal following a unit step. You can find an example below.

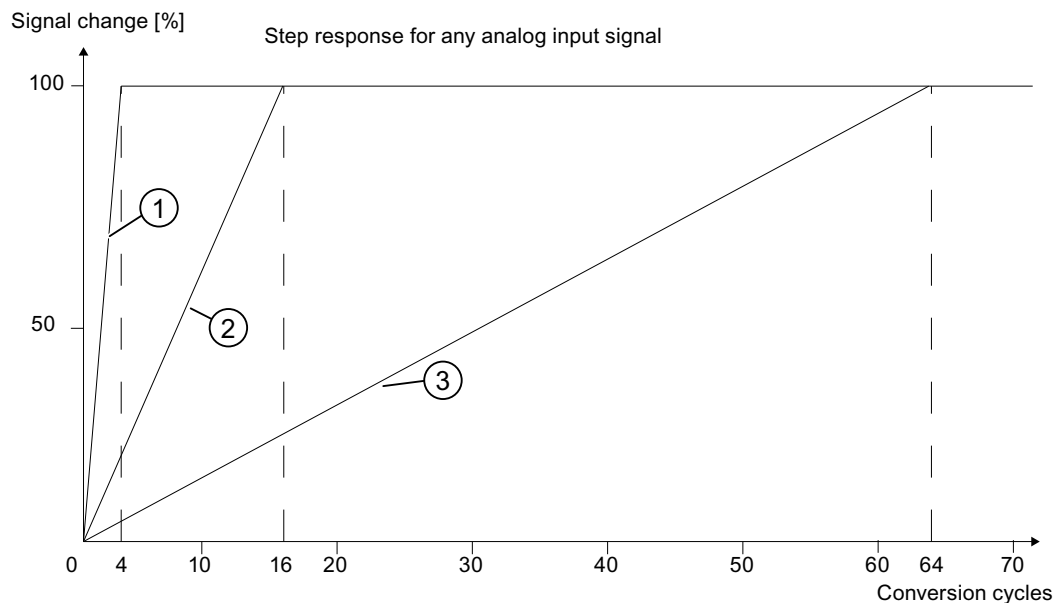
NOTE

Smoothing is reset after startup, short-circuit, wire break or another channel fault. If, for example, smoothing with 16 conversion cycles is assigned and all channels are active, it takes up to 1600 ms until the process value is signaled with a configured interference frequency suppression of 50 Hz.

Until the first valid process value, the F-module reports the process value 0 for the channel. If a discrepancy occurs, measuring and smoothing continues and is not restarted.

Example

The figure below shows the number of conversion cycles, depending on the smoothing setting, after which the analog value is completely smoothed and available in the case of a unit step. The figure applies to all signal changes at the analog input.



- ① Smoothing - 4 conversion cycles
- ② Smoothing - 16 conversion cycles
- ③ Smoothing - 64 conversion cycles

Example: Effect of smoothing on the maximum response time for a configured "1oo2 evaluation (max. SIL3/Cat.4/PLe)" in case of error

If an error (One Fault Delay Time, OFDT) occurred with a configured "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you calculate the maximum response time according to the following formula:

Maximum response time (in case of discrepancy error) = $2 \times \text{Conversion cycle time} \times \text{Smoothing} + \text{Discrepancy time} + 2 \times \text{Conversion cycle time}$

For example, one channel pair connected and configured (activated), interference frequency 50 Hz, smoothing = 16 conversion cycles, discrepancy time = 2000 ms, conversion cycle time calculated with the formula from the appendix Response times (Page 95):

Max. response time (in case of discrepancy error) = $2 \times 31 \text{ ms} \times 16 + 2000 \text{ ms} + 2 \times 31 \text{ ms} = 3054 \text{ ms}$

If a discrepancy exists between the two input channels, it can take 4380 ms until the F-module signals a discrepancy error to the F-CPU.

If the discrepancy time expires, an error is signaled and the process value is set to 0. In the PII, the substitute value 0 is set for the safety program.

6.3.3 AI configuration

6.3.3.1 Additional submodules

In addition to the basic submodule, you can create up to 3 additional submodules. You can find more information about the address assignment in the section Address space of the additional submodules (Page 63).

Use this parameter to specify the number of additional submodules:

- None
- 1
- 2
- 3

The additional submodules are only available when the module is used in a distributed setup that is connected to PROFINET.

When using the module in a Shared Device, you can assign the additional submodules to up to 3 IO controllers (fail-safe or non-fail-safe). Each IO controller has read access to the same data. The number of IO controllers depends on the interface module used. Follow the instructions in the respective manual for the interface module.

The additional submodules are preset to module-internal shared input (MSI). Channels 0 to 7 are copied to the additional submodules. Channels 0 to 7 are then available with identical input values in all submodules configured as MSI. Alternatively, you can copy the HART variables (8 HART, 4 HART or 1 multiHART) into the additional submodules; see section HART variables (Page 36). The change from MSI (default setting) to the HART variables is possible in TIA Portal within the additional submodules.

You can use MSI and HART variables simultaneously in up to three additional submodules. For example, MSI in the 1st additional submodule and HART variables in the 2nd and 3rd additional submodule. The HART variables used in the up to 3 additional submodules are defined once and are therefore identical in all additional submodules (i.e. 8 HART, 4 HART or 1 multiHART).

You can find the assignment of the address space of the additional submodules in the section Address space of the additional submodules (Page 63).

WARNING

All values in the additional submodules are not safety-related and must therefore not be used for safety-related activities.

NOTE

Procedure when assigning the PROFIsafe address

Assignment of the PROFIsafe address in TIA Portal is only possible when the value "None" is set for the "Additional submodules" parameter.

If you want to use 1, 2 or 3 additional submodules, we recommend that you proceed as follows:

1. Set "Additional submodules" to "None" initially.
 2. Assign the PROFIsafe address.
 3. Set the desired number of additional submodules (1, 2 or 3).
 4. Configure the set additional submodules.
-

NOTE

Displaying diagnostics alarms

If you have set the "Additional submodules" parameter to 1, 2 or 3 in the settings, diagnostics with the F-module scope are not displayed correctly in the TIA Portal (see sections Interrupts (Page 81) and Diagnostics alarms (Page 83)). Instead, only a PROFIsafe communication error (channel diagnostics) is shown. You can refer to the diagnostics buffer of the F-CPU for the correct diagnostics alarm in this case.

6.3.4 HART

6.3.4.1 HART function

Use this parameter to enable HART communication for the relevant channel.

This parameter can only be configured if the "HART gate" parameter is configured as "On" or "Switchable" and measuring range "4...20 mA" is set.

This parameter is not safety-related, i.e. it cannot be used for fail-safe shutdown of HART communication.

6.3.4.2 HART preamble bytes

Use this parameter to specify the number of preamble bytes sent.

6.3.4.3 HART repetitions

Use this parameter to specify the number of HART frame repetitions. If the analog input module F-AI 8xI 0(4)..20mA receives no response or a response with errors to a HART frame sent to the field device, the frame is repeated. It is therefore sent again to the field device.

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

6.3.4.4 HART diagnostics

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

The parameter is only relevant if the "HART function" parameter is activated.

The HART diagnostics are reported as maintenance events.

6.3.4.5 HART variables

Use this parameter to specify which HART variables can be copied to the additional submodules:

- None
- 8 HART
- 4 HART
- 1 multiHART

This parameter is only relevant if at least one additional submodule with "HART variables" is configured with the "Submodule type" parameter.

You can find information on the additional submodules in the section Additional submodules (Page 57).



WARNING

The HART variables are not safety-related and must therefore not be used for safety-related activities.

Use of "1 multiHART"

If you have configured the value "HART variables" as the "Submodule type" for more than one additional submodule and set the "HART variables" parameter to "1 multiHART", all these additional submodules read and write to the same multiHART area in the module.

By evaluating the acknowledgment byte in the input range of the submodule, you can determine if the HART variable requested by the respective submodule is available in the input range. See example under "Evaluating the multiHART area" in the section HART variables (Page 36). To ensure data consistency, read the acknowledgment byte and the HART variable from the input range of the submodule at the same time.

6.3.4.6 HART mapping

A maximum of 8 HART variables can be configured (mapped) in the address space of the additional submodules via the HART mapping parameters.

Each HART variable occupies 5 bytes of input data. Depending on the configuration, the addresses are assigned for 4 variables (20 bytes) or 8 variables (40 bytes).

You can find the assignment of the address space in section Address space of additional submodules (Page 63).

If required, this can be changed via data record 140; see section Parameter assignment and structure of the HART mapping parameters (DS 140) (Page 112).

Parameters

Table 6-4 Configurable HART mapping parameters

Parameter		Value range	Default	Configuration in RUN
Variable 1	Channel	0 ... 7	0	Yes
	Type	- None - PV (Primary Variable) - SV (Secondary Variable) - TV (Tertiary Variable) - QV (Quaternary Variable)	None	Yes
Variable 2	Channel	0 ... 7	0	Yes
	Type	- None - PV (Primary Variable) - SV (Secondary Variable) - TV (Tertiary Variable) - QV (Quaternary Variable)	None	Yes
Variable 3	Channel	0 ... 7	0	Yes
	Type	- None - PV (Primary Variable) - SV (Secondary Variable) - TV (Tertiary Variable) - QV (Quaternary Variable)	None	Yes
Variable 4	Channel	0 ... 7	0	Yes
	Type	- None - PV (Primary Variable) - SV (Secondary Variable) - TV (Tertiary Variable) - QV (Quaternary Variable)	None	Yes
The following variables only apply to a configuration with 8 HART variables:				
Variable 5	Channel	0 ... 7	0	Yes
	Type	- None - PV (Primary Variable) - SV (Secondary Variable) - TV (Tertiary Variable) - QV (Quaternary Variable)	None	Yes
Variable 6	Channel	0 ... 7	0	Yes

Parameter		Value range	Default	Configuration in RUN
Variable 6	Type	• None • PV (Primary Variable) • SV (Secondary Variable) • TV (Tertiary Variable) • QV (Quaternary Variable)	None	Yes
	Channel	0 ... 7	0	Yes
Variable 7	Type	• None • PV (Primary Variable) • SV (Secondary Variable) • TV (Tertiary Variable) • QV (Quaternary Variable)	None	Yes
	Channel	0 ... 7	0	Yes
Variable 8	Type	• None • PV (Primary Variable) • SV (Secondary Variable) • TV (Tertiary Variable) • QV (Quaternary Variable)	None	Yes
	Channel	0 ... 7	0	Yes

See also

[Address space \(Page 61\)](#)

6.3.5 Submodule type

Use this parameter to specify whether module-internal shared input (MSI) is available in the additional Submodule_n or the HART variables are copied into the additional Submodule_n.

The parameter is only present if the "Additional submodules" parameter is configured with 1, 2 or 3.

6.4 Address space

Address assignment of the analog input module F-AI 8xI 0(4)..20mA

The analog input module F-AI 8xI 0(4)..20mA occupies the following address ranges in the F-CPU:

Table 6-5 Address assignment in the F-CPU

Occupied bytes in the F-CPU:		
F-CPU	In the input range	In the output range
F-CPU S7-1200 and S7-1500	IB x + 0 to x + 22	QB x + 0 to x + 5

x = Module start address

Address assignment of the user data and the value status of the analog input module F-AI 8xI 0(4)..20mA

The user data and the value status occupy the following addresses in the F-CPU out of all the assigned addresses of the analog input module F-AI 8xI 0(4)..20mA:

Table 6-6 Address assignment in the input range

Byte in the F-CPU	Assigned bits in F-CPU per F-module:							
	7	6	5	4	3	2	1	0
IB x + 0	Input value at channel 0 (Result of the 1oo2 evaluation channel 0/4)							
IB x + 1								
IB x + 2	Input value at channel 1 (Result of the 1oo2 evaluation channel 1/5)							
IB x + 3								
IB x + 4	Input value at channel 2 (Result of the 1oo2 evaluation channel 2/6)							
IB x + 5								
IB x + 6	Input value at channel 3 (Result of the 1oo2 evaluation channel 3/7)							
IB x + 7								
IB x + 8	Input value at channel 4							
IB x + 9								
IB x + 10	Input value at channel 5							
IB x + 11								
IB x + 12	Input value at channel 6							
IB x + 13								
IB x + 14	Input value at channel 7							
IB x + 15								
IB x + 16	Value status for AI ₇	Value status for AI ₆	Value status for AI ₅	Value status for AI ₄	Value status for AI ₃	Value status for AI ₂	Value status for AI ₁	Value status for AI ₀
IB x + 17	-	-	-	-	-	-	-	Value status for HART gate

x = Module start address

NOTE

You only have read access to the addresses occupied by user data and value status.

The other address ranges occupied by the F-modules are assigned for functions including safety-related communication between the F-modules and F-CPU in accordance with PROFIsafe.

With 1oo2 evaluation of the sensors, two channels are combined, e.g. channel 0 (input word AI₀) with channel 4 (input word AI₄). In this example, you may only access the input bit AI₀ in the safety program with 1oo2 evaluation of the sensors.

Table 6-7 Address assignment in the output range

Byte in the F-CPU	Assigned bits in F-CPU per F-module:							
	7	6	5	4	3	2	1	0
QB x + 0								HART gate*

* The function is supported as of firmware V2.0. Only evaluated if HART gate is configured as "Switchable".

x = Module start address

More information

For detailed information about F-I/O access and for evaluation and processing of the value status, refer to the SIMATIC Safety – Configuring and Programming (<https://support.industry.siemens.com/cs/ww/en/view/54110126>) manual.

6.5 Address space of additional submodules

WARNING

All values in the additional submodules are not safety-related and must therefore not be used for safety-related activities.

Address assignment of the additional submodule for configuration MSI

The following table shows the allocation of the address space:

Table 6-8 Address assignment in the input range of the additional submodule

Byte	Assigned bits per F-module							
	7	6	5	4	3	2	1	0
IB a + 0	Input value at channel 0 (Result of the 1oo2 evaluation channel 0/4)							
IB a + 1								
IB a + 2	Input value at channel 1 (Result of the 1oo2 evaluation channel 1/5)							
IB a + 3								
IB a + 4	Input value at channel 2 (Result of the 1oo2 evaluation channel 2/6)							
IB a + 5								
IB a + 6	Input value at channel 3 (Result of the 1oo2 evaluation channel 3/7)							
IB a + 7								
IB a + 8	Input value at channel 4							
IB a + 9								
IB a + 10	Input value at channel 5							
IB a + 11								

a = Start address of the additional submodule

6.5 Address space of additional submodules

IB a + 12	Input value at channel 6							
IB a + 13								
IB a + 14	Input value at channel 7							
IB a + 15								
IB a + 16	Value status for AI ₇	Value status for AI ₆	Value status for AI ₅	Value status for AI ₄	Value status for AI ₃	Value status for AI ₂	Value status for AI ₁	Value status for AI ₀
IB a + 17	-	-	-	-	-	-	-	Value status for HART gate

a = Start address of the additional submodule

Reference

You can find information on the Shared Input/Output (MSI/MSO) functionality in the PROFINET with STEP 7 (<https://support.industry.siemens.com/cs/ww/en/view/49948856>) Function Manual in the Module-internal shared input/shared output (MSI/MSO) section.

NOTE

If the module is in the reintegration state (ACK_REQ = true), the following scenario can occur:
The input values and value status of the channels can have the value 0 in the basic submodule (see section Address space (Page 61)). At the same time, the input values and value status of the channels in the additional submodule configured with MSI can have a value not equal to 0.

In this case, the substitute values are output instead of the input values in the basic submodule. By contrast, the valid input values are already present in the additional submodule configured with MSI.

Address assignment of the additional submodule for HART configuration with 8 variables

The following table shows the allocation of the address space:

Table 6-9 Address assignment in the input range of the additional submodule

Byte	Assigned bits per F-module							
	7	6	5	4	3	2	1	0
IB a + 0	HART variable 1							
IB a + 1								
IB a + 2								
IB a + 3								
IB a + 4	Quality code HART variable 1							
IB a + 5	HART variable 2							
IB a + 6								

a = Start address of the additional submodule

6.5 Address space of additional submodules

IB a + 7	HART variable 2
IB a + 8	
IB a + 9	Quality code HART variable 2
IB a + 10	HART variable 3
IB a + 11	
IB a + 12	
IB a + 13	
IB a + 14	Quality code HART variable 3
IB a + 15	HART variable 4
IB a + 16	
IB a + 17	
IB a + 18	
IB a + 19	Quality code HART variable 4
IB a + 20	HART variable 5
IB a + 21	
IB a + 22	
IB a + 23	
IB a + 24	Quality code HART variable 5
IB a + 25	HART variable 6
IB a + 26	
IB a + 27	
IB a + 28	
IB a + 29	Quality code HART variable 6
IB a + 30	HART variable 7
IB a + 31	
IB a + 32	
IB a + 33	
IB a + 34	Quality code HART variable 7
IB a + 35	HART variable 8
IB a + 36	
IB a + 37	
IB a + 38	
IB a + 39	Quality code HART variable 8

a = Start address of the additional submodule

6.5 Address space of additional submodules

Address assignment of the additional submodule for HART configuration with 4 variables

The following table shows the allocation of the address space:

Table 6-10 Address assignment in the input range of the additional submodule

Byte	Assigned bits per F-module							
	7	6	5	4	3	2	1	0
IB a + 0	HART variable 1							
IB a + 1								
IB a + 2								
IB a + 3								
IB a + 4	Quality code HART variable 1							
IB a + 5	HART variable 2							
IB a + 6								
IB a + 7								
IB a + 8								
IB a + 9	Quality code HART variable 2							
IB a + 10	HART variable 3							
IB a + 11								
IB a + 12								
IB a + 13								
IB a + 14	Quality code HART variable 3							
IB a + 15	HART variable 4							
IB a + 16								
IB a + 17								
IB a + 18								
IB a + 19	Quality code HART variable 4							

a = Start address of the additional submodule

Address assignment of the additional submodule for configuration with multiHART

The following table shows the allocation of the address space:

Table 6-11 Address assignment in the input range of the additional submodule

Byte	Assigned bits per F-module							
	7	6	5	4	3	2	1	0
IB a + 0	Channel number 0 ... 7				Variable identification			
IB a + 1	HART variable							
IB a + 2								

a = Start address of the additional submodule (input range)

IB a + 3	HART variable
IB a + 4	
IB a + 5	Quality code HART variable

a = Start address of the additional submodule (input range)

Table 6-12 Address assignment in the output range of the additional submodule

Byte	Assigned bits per F-module							
	7	6	5	4	3	2	1	0
QB b + 0	Channel number 0 ... 7				Variable identification			

b = Start address of the additional submodule (output range)

Applications of the F-I/O module

7.1 Application cases of the F-AI 8xI 0(4)..20mA

Selecting the application

The diagram below supports you in selecting the application that suits your fail-safe requirements. In the following sections, you will learn how to wire the F-module, the specific parameters you must assign in STEP 7 Safety and the errors that are detected.

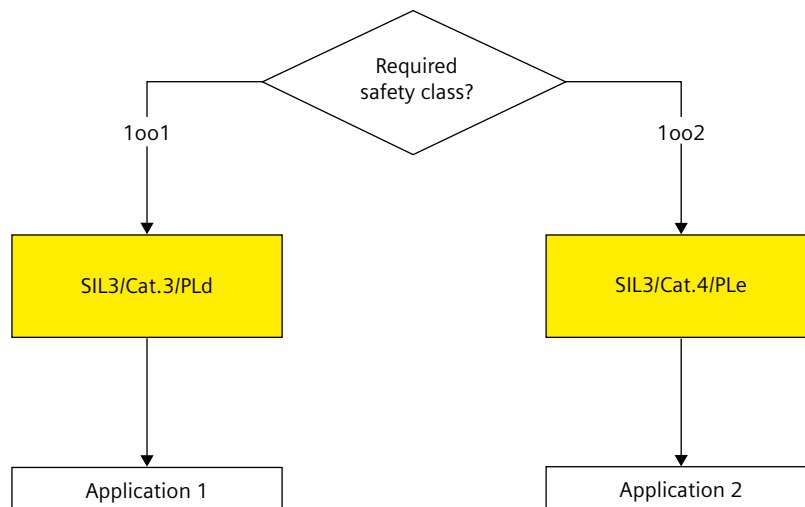


Figure 7-1 Select application case - Analog input module F-AI 8xI 0(4)..20mA

WARNING

The achievable safety class depends on the quality of the sensor and the duration of the mission time in accordance with IEC 61508:2010. If the quality of the sensor is lower than the quality required by the safety class, redundant sensors connected via two channels must be used and evaluated.

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.

Table 7-1 Conditions for achieving SIL/Cat./PL

Application	Sensor evaluation	Achievable SIL/Cat./PL
1	1oo1	3/3/d
2	1oo2	3/4/e

NOTE

You can operate the various inputs of an F-AI 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

Information on the safety-related use of sensors is available in the section Requirements for sensors and actuators for fail-safe modules of the system manual S7-1500 Automation System (<https://support.industry.siemens.com/cs/ww/en/view/59191792>).

7.2 Application 1: Safety mode SIL3/Cat.3/PLd

Wiring

The wiring is carried out on the front connector of the module. Refer to the "Wiring" section in the S7-1500 Automation System

(<https://support.industry.siemens.com/cs/ww/en/view/59191792>) system manual.

Sensor supply

The sensor supply can be powered internally or externally.

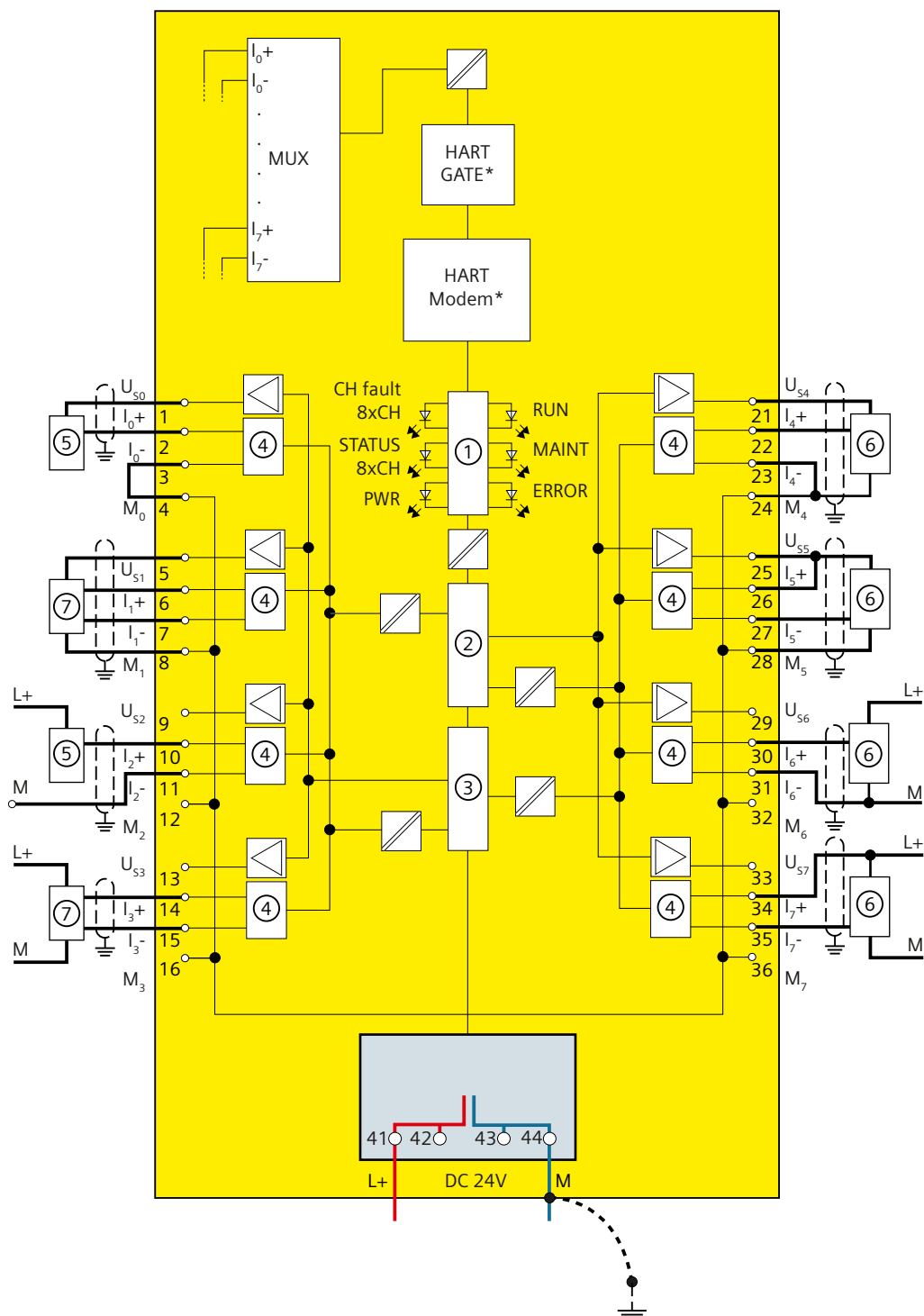
Wiring diagram – connecting one sensor via one channel

One sensor is connected via one channel (1oo1 evaluation) for each process signal.

The assignment of the sensor supply is defined by the terminals. There is one fused sensor supply per channel.

You can also supply the sensors by means of an external sensor supply.

The figure below shows an example of the pin assignment of the fail-safe analog input module F-AI 8xI 0(4)..20mA for connecting 1-channel sensors.



- ① Backplane bus interface
- ② Microcontroller 1
- ③ Microcontroller 2

- RUN LED status display (green)
- ERROR LED for fault display (red)
- PWR LED for power supply (green)

7.2 Application 1: Safety mode SIL3/Cat.3/PLd

④	Signal evaluation	MAINT	LED for MAINT ALARM (yellow)
⑤	2-wire transducer	CH fault	LED for channel fault (red)
⑥	3-wire transducer	STATUS	LED for channel status (green)
⑦	4-wire transducer	*	The function is supported as of firmware V2.0.

Figure 7-2 One sensor connected via one channel

 **WARNING**

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

 **WARNING**

All cables need to be laid in such a way that they are resistant to interference voltage. Use shielded cables.

 **WARNING**

With 1oo1 evaluation, faults with the sensor or wiring of the F-AI module are not detected.

Assignable parameters for application 1

Table 7-2 Parameters for application case 1 of F-AI 8xI 0(4)..20mA

Parameter	Value range in safety mode
Behavior after channel faults	- Passivate the entire module - Passivate channel
Interference frequency suppression	50 Hz 60 Hz
Sensor evaluation	1oo1 evaluation (max. SIL3/Cat.3/PLd)
Measuring range	0...20 mA 4...20 mA
Diagnosis: Wire break	(in measuring range 4...20 mA) - Disable - Enable
Smoothing	1/2/4/8/16/32/64 conversion cycles

7.3 Application 2: Safety mode SIL3/Cat.4/PLe

Assigning inputs to each other

The analog input module F-AI 8xI 0(4)..20mA has 8 fail-safe inputs AI₀ to AI₇ (SIL3). You can combine two of these inputs each to one input.

You can combine the following inputs:

- AI₀ and AI₄
- AI₁ and AI₅
- AI₂ and AI₆
- AI₃ and AI₇

The process signals are provided by channels AI₀, AI₁, AI₂ and AI₃.

NOTE

You can mix 1oo1 evaluation and 1oo2 evaluation in an F-AI module. You must interconnect and configure the inputs according to the fail-safe requirements (SIL3/Cat.3/PLd and SIL3/Cat.4/PLe).

Wiring

The wiring is carried out on the front connector of the module. Refer to the "Wiring" section in the S7-1500 Automation System

(<https://support.industry.siemens.com/cs/ww/en/view/59191792>) system manual.

Sensor supply

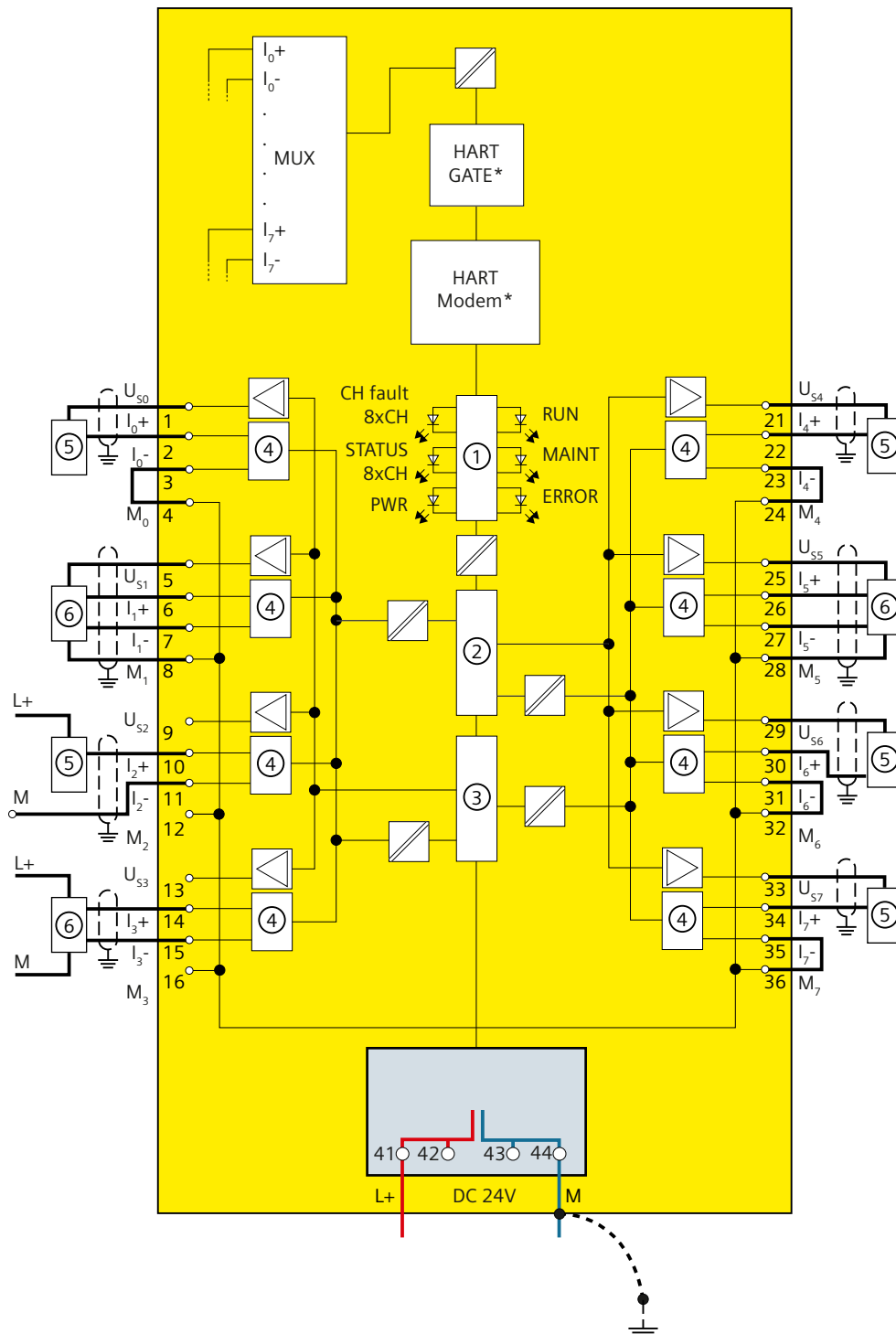
The sensor supply can be powered internally or externally.

Wiring diagram – connecting two single-channel sensors via two channels

Two single-channel sensors that capture the same process value are connected to two inputs of the F-module for each process signal (1oo2 evaluation).

You can also supply the sensors by means of an external sensor supply.

The figure below shows an example of the pin assignment of the fail-safe analog input module F-AI 8xI 0(4)..20mA for connecting 2-channel sensors.



①	Backplane bus interface	RUN	LED status display (green)
②	Microcontroller 1	ERROR	LED for fault display (red)
③	Microcontroller 2	PWR	LED for power supply (green)
④	Signal evaluation	MAINT	LED for MAINT ALARM (yellow)
⑤	2-wire transducer	CH fault	LED for channel fault (red)
⑥	4-wire transducer	STATUS	LED for channel status (green)
		*	The function is supported as of firmware V2.0.

Figure 7-3 Two single-channel sensors connected via 2 channels

 WARNING
To achieve SIL3/Cat.4/PLe with this wiring, you must use suitably qualified sensors.

 WARNING
All cables need to be laid in such a way that they are resistant to interference voltage. Use shielded cables.

Assignable parameters for application 2

Table 7-3 Parameters for application case 2 of F-AI 8xI 0(4)..20mA

Parameter	Value range in safety mode
Unit value	- MIN - MAX
Discrepancy time	100 to 30000 ms
Tolerance window abs.	0.3 to 20.0%
Tolerance window rel.	0.3 to 20.0%
Behavior after channel faults	- Passivate the entire module - Passivate channel
Interference frequency suppression	50 Hz 60 Hz
Sensor evaluation	1oo2 evaluation (max. SIL3/Cat.4/PLe)
Measuring range	0...20 mA 4...20 mA
Diagnosis: Wire break	(in measuring range 4...20 mA) - Disable - Enable
Smoothing	1/2/4/8/16/32/64 conversion cycles

Interrupts/diagnostic messages

8.1 Status and error displays

LED displays

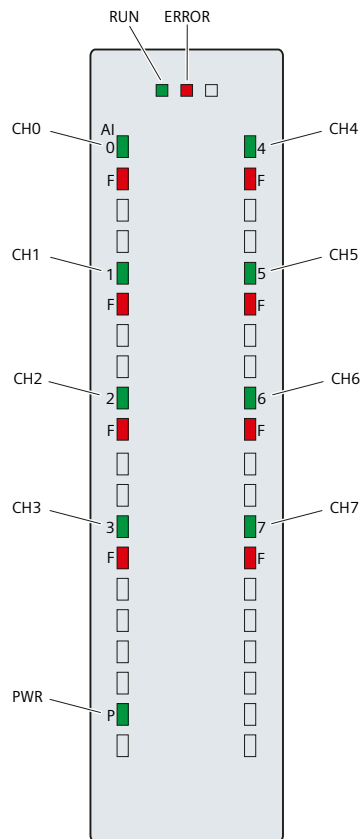


Figure 8-1 LED displays of the F-AI 8xI 0(4)..20mA module

Meaning of the LED displays

The following tables explain the meaning of the status and error displays. Remedies for diagnostic alarms can be found in section Diagnostic alarms (Page 83).

WARNING

The RUN, ERROR LEDs and channel status/channel diagnostics LEDs of the inputs are not designed as safety-related LEDs and therefore may not be evaluated for safety-related activities.

RUN and ERROR LEDs

Table 8-1 RUN and ERROR status and error displays

LED		Meaning	Remedy
RUN	ERROR		
 Off	 Off	Missing or insufficient voltage on the backplane bus	- Switch on the CPU and/or the system power supply modules. - Check whether the module is correctly plugged into the U-connector. - Check whether too many modules are plugged in.
 Flashing	 Off	Module starts up and flashes up to the valid parameter assignment.	---
 On	 Off	Module parameters are assigned and module addressed.	
 Off	 Flashing	Firmware is being updated.	
 On	 Flashing	Indicates diagnostic interrupts: - Module fault (for example, supply voltage too high) - Channel fault (e.g. wire break) - PROFIsafe communication fault - At least one channel is waiting for user acknowledgment.	Evaluate the diagnostics and eliminate or acknowledge the error. It may be necessary to remove and re-insert the module.
 Flashing	 Flashing	Hardware defective.	Replace the module.
  Alternately flashing		The F-module expects user acknowledgment after a module fault.	Acknowledge the error (see manual SIMATIC Safety - Configuring and Programming (https://support.industry.siemens.com/cs/ww/en/view/54110126)).

8.1 Status and error displays

PWR LED

Table 8-2 PWR status display

PWR LED	Meaning
 Off	Power supply L+ missing
 On	Power supply L+ available

CHx LED

Table 8-3 Display channel status/channel diagnostics

Status CHx	Diagnostics CHx	Meaning
 Off	 Off	Channel deactivated or power supply L+ missing.
 On	 Off	Channel activated and no channel diagnostics
 Off	 On	Channel activated and channel diagnostics
 On	 On	Channel activated and diagnostics with HART protocol
 Alternately flashing		Channel waiting for user acknowledgment

CHx/Error LED with PROFIsafe address assignment

Table 8-4 Channel status/channel diagnostics/Error display with PROFIsafe address assignment

Status CHx	Diagnostics CHx	ERROR	Meaning
 Off	 All on	 Flashing	The PROFIsafe address does not match the configured PROFIsafe address
 All are flashing	 Off	 Flashing	Identification of the F-module when assigning the PROFIsafe address

CHx/RUN/ERROR LED if power supply error occurs

Table 8-5 Channel status/channel diagnostics/RUN/ERROR display if power supply error occurs

CHx status	Dia- gnostics CHx	RUN	ERROR	Meaning
 Off	 On	 On	 Flashing	- Supply voltage too high or too low. - Module is waiting for user acknowledgment.

8.2 Interrupts

Introduction

The fail-safe analog input module F-AI 8xI 0(4)..20mA supports diagnostic interrupts.

Diagnostic interrupt

The F-module generates a diagnostic interrupt for each diagnostic alarm described in section Diagnostic alarms (Page 83).

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

 WARNING
Diagnostics Short-circuit Before acknowledging the short-circuit diagnostic message, remedy the respective fault and validate your safety function. Follow the troubleshooting procedure described in section Diagnostic alarms (Page 83)

Table 8-6 Diagnostic interrupts of the F-AI 8xI 0(4)..20mA

Diagnostic interrupt	Fault code	Signaled in application case	Scope of diagnostic interrupt	Configurable
Overtemperature	5 _H	1, 2	F-module	No
Wire break	6 _H		Channel	Yes
High limit exceeded	7 _H			No
Low limit violated	8 _H			
Parameter error	10 _H			
Supply voltage missing	11 _H			
Communication fault	13 _H			
Channel/component temporarily not available	1F _H		F-module	
Mismatch of safety destination address (F_Dest_Add)	40 _H			
Safety destination address not valid (F_Dest_Add)	41 _H			
Safety source address not valid (F_Source_Add)	42 _H			

8.2 Interrupts

Diagnostic interrupt	Fault code	Signaled in application case	Scope of diagnostic interrupt	Configurable
Safety watchdog time value is 0 ms (F_WD_Time)	43 _H	1, 2	F-module	No
Parameter F_SIL exceeds SIL from specific device application	44 _H			
Parameter F_CRC_Length does not match the generated values	45 _H			
Version of F parameter set incorrect	46 _H			
CRC1 fault	47 _H			
Device-specific diagnostics information, see manual	48 _H			
Save iParameter watchdog time exceeded	49 _H			
Restore iParameter watchdog time exceeded	4A _H			
Inconsistent iParameters (iParCRC error)	4B _H			
F_Block_ID not supported	4C _H			
Transmission error: Inconsistent data (CRC error)	4D _H			
Transmission error: Timeout (watchdog time 1 or 2 expired)	4E _H			
Acknowledge required to enable channel(s) - as channel error(s) are remedied.	4F _H			
Watchdog tripped	103 _H			
Internal supply voltage fault	104 _H			
Invalid/inconsistent firmware present	11B _H			
Diagnostics queue overflow	13E _H			
HART parameter error	140 _H		Channel	Yes
HART communication error	141 _H			
HART primary variable out of range	142 _H			
HART analog output current saturated	143 _H			
HART output current of the field device fixed	144 _H			
HART - more status available	145 _H			
HART configuration changed	146 _H			
HART field device malfunction	147 _H			
HART - non primary variable out of limits	149 _H			
Analog input signal not recorded unique	304 _H		Channel	No
Internal sensor supply short-circuit to P	306 _H		Channel	No
Overload or internal sensor supply short-circuit to ground	307 _H		Channel	No
Channel failure acknowledgment	30B _H		Channel	No
F-address memory not accessible	30D _H		F-module	No
No valid F-address available	30E _H			
Undertemperature	312 _H			
Discrepancy failure	314 _H		Channel	No
Supply voltage too high	321 _H		F-module	No
Supply voltage too low	322 _H			

Diagnostic interrupt	Fault code	Signaled in application case	Scope of diagnostic interrupt	Configurable
Safety related HART shutoff defective	32A _H	1, 2	F-module	No
F module error (0x032F)	32F _H			
ADC failure	331 _H		Channel	No
Failure in the test circuit	332 _H			

8.3 Diagnostic alarms

Diagnostic alarms

Module faults are indicated as diagnostics (module status).

Once the fault is eliminated, the F-module must be reintegrated in the safety program. For more information on passivation and reintegration of F-I/O, refer to the SIMATIC Safety – Configuring and Programming

(<https://support.industry.siemens.com/cs/ww/en/view/54110126>) manual.

Table 8-7 Diagnostic alarms of the F-AI 8xI 0(4)..20mA

Diagnostic alarm	Fault code	Meaning	Remedy
Overtemperature	5 _H	An excessively high temperature was measured in the F-module.	Operate the F-module within the specified temperature range (see Technical specifications (Page 90)) Once the temperature has been reduced and returns to the specified range, the F-module must be removed and inserted or the power switched OFF and ON.
Wire break	6 _H	Possible causes: • A cable to the sensor is broken. • Fault at the external circuit • Defective sensor • Wrong sensor type set in the parameters • Input channel not used • Measurement resistance too high	Check the possible causes and eliminate the fault.
High limit exceeded	7 _H	The measured value exceeds the measuring range.	Check the interaction between the module and the sensor.
Low limit violated	8 _H	The measured input value is below a measuring range.	Check the interaction between the module and the sensor.
Parameter error	10 _H	Parameter errors include: • The F-module cannot use the parameters (unknown, invalid combination, etc.). • The F-module parameters have not been configured.	Correct the parameter assignment.
Supply voltage missing	11 _H	Missing or insufficient power supply L+	• Check power supply L+ at the front connector • Check the front connector

8.3 Diagnostic alarms

Diagnostic alarm	Fault code	Meaning	Remedy
Communication fault	13 _H	The module is defective.	Replace the module.
Channel/component temporarily not available	1F _H	Possible causes: - Internal fault in the F-module - Firmware update error	- Replace the F-module. - Repeat the firmware update.
Mismatch of safety destination address (F_Dest_Add)	40 _H	The firmware of the F-module has detected a different F-destination address.	- Check the parameter assignment of the PROFIsafe driver and the PROFIsafe address assigned to the F-module. - Assign the PROFIsafe address to the F-module (again).
Safety destination address not valid (F_Dest_Add)	41 _H	The firmware of the F-module has detected an illegal different F-destination address.	
Safety source address not valid (F_Source_Add)	42 _H	The firmware of the F-module has detected a different F-source address.	
Safety watchdog time value is 0 ms (F_WD_Time)	43 _H	The firmware of the F-module has detected an invalid watchdog time.	
Parameter F_SIL exceeds SIL from specific device application	44 _H	The firmware of 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	The firmware of the F-module has detected a discrepancy in the CRC length.	
Version of F parameter set incorrect	46 _H	The firmware of the F-module has detected an incorrect F_Par_Version or an invalid F_Block_ID.	
CRC1 fault	47 _H	The firmware of the F-module has detected inconsistent F-parameters.	
Device-specific diagnostics information, see manual	48 _H	The PROFIsafe driver has received inconsistent fail-safe parameters.	Check the parameter assignment of the PROFIsafe driver.
Save iParameter watchdog time exceeded	49 _H	iPar server does not respond to "save iPar" within 4.4 minutes.	Check the parameter assignment of the iPar server.
Restore iParameter watchdog time exceeded	4A _H	iPar server does not respond to "restore iPar" within 4.4 minutes.	Check the parameter assignment of the iPar server.
Inconsistent iParameters (iParCRC error)	4B _H	The firmware of the F-module has detected inconsistent iParameters.	Check the parameter assignment.
F_Block_ID not supported	4C _H	The firmware of the F-module has detected an incorrect F_block_ID.	Check the parameter assignment of the PROFIsafe driver.
Transmission error: Inconsistent data (CRC error)	4D _H	The firmware of the F-module has detected a CRC error. Possible causes: - The communication between the F-CPU and F-module is disturbed. - Impermissibly high electromagnetic interference is present. - An error occurred in the sign-of-life monitoring.	- Check the communication connection between the F-module and F-CPU. - Eliminate the electromagnetic interference.

Diagnostic alarm	Fault code	Meaning	Remedy
Transmission error: Timeout (watchdog time 1 or 2 expired)	4E _H	The firmware of the F-module has detected a timeout. Possible causes: - The F-monitoring time is set incorrectly. - A bus fault is present.	- Check the parameter assignment. - Ensure that communication is functioning correctly.
Acknowledge required to enable channel(s) - as channel error(s) are remedied.	4F _H	A channel fault was detected. Confirmation is required to enable the channel.	Confirm the channel fault.
Watchdog tripped	103 _H	Possible causes: - Impermissibly high electromagnetic interference is present. - The F-module has detected an internal error and has reacted in a safety-related manner.	- Eliminate the interference. The module must then be pulled and plugged, or the power switched OFF and ON. - If the F-module cannot be put back into operation, consider replacing it.
Internal supply voltage fault	104 _H	Internal voltage is too low.	Replace the F-module.
Invalid/inconsistent firmware present	11B _H	The firmware is incomplete and/or firmware added to the F-module is incompatible. This leads to errors or functional limitations when operating the F-module.	- Perform a firmware update for all parts of the F-module and note any error messages. - Use only firmware versions released for this F-module.
Diagnostics queue overflow	13E _H	Overflow of the diagnostics memory. It was not possible to send all pending diagnostics. This error can lead to deactivation of the F-module and even to switch off/on of the power supply.	Remedy the cause of the diagnostics surge.
HART parameter error	140 _H	The module has detected an error in a HART parameter data record.	Check and correct the HART-specific parameters.
HART communication error	141 _H	- HART field device does not reply - 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 output current ≥ 4 mA - Increase number of configured repetitions
HART primary variable out of range	142 _H	- Incorrect parameters in the HART field device - HART field device is set to "Primary variable out of limits" in simulation mode - Incorrect measuring point - Assigned primary variable is outside the limits	- Check the parameter assignment of the HART device - Correct the simulation - Check whether the correct measuring transducer is connected
HART analog output current saturated	143 _H	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	

8.3 Diagnostic alarms

Diagnostic alarm	Fault code	Meaning	Remedy
HART output current of the field device fixed	144 _H	The output current of the HART field device is permanently set: - 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	- Check the parameter assignment of the HART device - Correct the simulation - Check whether the correct measuring transducer is connected
HART - more status available	145 _H	The HART field device identifier for "Additional status information available" has been set in the HART device status (in the 2nd status byte).	Read out status with HART command 48 and clear error/cause if necessary
HART configuration changed	146 _H	The identifier for "re-parameterization" of the HART field device has been set in the HART device status (in the 2nd status byte).	If a diagnostic interrupt is not to be triggered for the re-parameterization, the diagnostic interrupt must not be enabled.
HART field device malfunction	147 _H	In the HART device status (in the 2nd status byte), the field device reports a malfunction.	- Read out status with HART command 48 and clear error/cause if necessary - Replace field device
HART - non primary variable out of limits	149 _H	- Incorrect parameters in the HART field device - HART field device is set to "Non primary variable out of limits" in simulation mode - Incorrect measuring point - Assigned non primary variable is outside the limits	- Check the parameter assignment of the HART device - Correct the simulation - Check whether the correct measuring transducer is connected
Analog input signal not recorded unique	304 _H	Measured values from the sensor are not plausible. Possible causes: - Increased EMC - F-module defective	Check the interaction between the F-module and the sensor.
Internal sensor supply short-circuit to P	306 _H	Possible causes: - There is a short-circuit of the internal sensor supply with L+. - There is a short-circuit of two sensor supplies. - The sensor is defective.	- Eliminate the short-circuit in the process wiring. - Replace the sensor.
Overload or internal sensor supply short-circuit to ground	307 _H	- The internal sensor supply is overloaded. - Missing or insufficient power supply L+.	Eliminate the short-circuit in the process wiring.
Channel failure acknowledgment	30B _H	A channel fault was detected. Confirmation is required to enable the channel.	Confirm the channel fault.
F-address memory not accessible	30D _H	The F-source address and F-destination address stored in the electronic coding element cannot be accessed.	Verify that the coding element is present. Replace the coding element, if necessary.

Diagnostic alarm	Fault code	Meaning	Remedy
No valid F-address available	30E _H	No valid PROFIsafe address is saved in the retentive memory. Possible causes: - Initial commissioning - Deliberate parameter change of the PROFIsafe address - Deviation between target and actual configuration of the plant.	- In the case of initial commissioning or deliberate parameter change, assign the PROFIsafe address. - Check the consistency of the target and actual configuration.
Undertemperature	312 _H	The minimum permissible temperature limit has been violated.	Operate the F-module within the specified temperature range (see Technical specifications (Page 90))
Discrepancy failure	314 _H	The discrepancy time set for 1oo2 operation has been exceeded. Possible causes of the discrepancy failure: - Incorrect parameter assignment - Wire break in the sensor's supply cable	Check the discrepancy time, the sensors and the cabling.
Supply voltage too high	321 _H	The power supply is too high.	Check the power supply.
Supply voltage too low	322 _H	The power supply is too low.	Check the power supply.
Safety related HART shutoff defective	32A _H	The signal module has a malfunction in the safety-related HART shutoff. Cause: Fault in the F-module	Replace the F-module.
F module error (0x032F)	32F _H	Possible causes: - Impermissibly high electromagnetic interference is present. - The F-module is defective.	- The internal diagnostics has detected an error. The module must be pulled and plugged, or the power switched OFF and ON. - If the F-module cannot be put back into operation, consider replacing it.
ADC failure	331 _H	Internal error during analog-digital conversion. Possible causes: - Increased EMC - F-module defective	If the error persists, replace the F-module.
Failure in the test circuit	332 _H	The F-module detected an internal error in the test connection. Possible causes: - Increased EMC - F-module defective	If the error persists, replace the F-module.

NOTE**HART diagnostics for PROFIBUS IM with GSD file**

For PROFIBUS IM with GSD file, the HART diagnostics are represented by "External error".

NOTE**HART diagnostics**

HART diagnostics are generated in parallel and additionally in the event of wire break and over/underflow.

Power supply outside the nominal range

If the power supply L+ is outside the specified value range, the ERROR LED flashes and the module is passivated.

When the voltage is then recovered (level must remain within the specified value for at least 1 minute, see Technical specifications (Page 90)), the ERROR LED stops flashing. The module remains passivated and waits for user acknowledgment.

Generally applicable information on diagnostics

Information on diagnostics that pertains to all F-modules (for example, readout of diagnostics functions or passivation of channels) is available in the SIMATIC Safety – Configuring and Programming (<https://support.industry.siemens.com/cs/ww/en/view/54110126>) manual.

See also

[Applications of the F-I/O module \(Page 68\)](#)

8.4 Value status

Properties

In addition to the diagnostic messages and the status and fault display, the F-module provides information about the validity of each analog input signal – the value status. The value status is entered in the process image along with the input signal.

Value status for analog input and output modules

The value status is the binary additional information of an analog input signal. The value status is entered in the process image of the inputs at the same time as the process value. It provides information about the validity of the analog input signal.

The value status is affected by all faults.

- 1_B: A valid process value is output for the channel.
- 0_B: A substitute value is output for the channel, or the channel is deactivated.

NOTE

You may only access the addresses occupied by user data and value status.

The other address ranges occupied by the F-modules are assigned for functions including safety-related communication between the F-modules and F-CPU in accordance with PROFIsafe.

1oo2 evaluation of the sensors combines the two channels. With 1oo2 evaluation of the sensors, you can only access the low order channel in the safety program, e.g. channel 0.

Assignment of the inputs and value status in the PII

Each channel of the F-module is assigned a value status in the process image inputs. You can find the assignment in section Address space (Page 61).

Reference

A detailed description of the evaluation and processing of the respective input signals can be found in the SIMATIC Safety – Configuring and Programming (<https://support.industry.siemens.com/cs/ww/en/view/54110126>) manual.

Technical specifications

Technical specifications of F-AI 8xI 0(4)..20mA

The table below shows the technical specifications as of 06/2024. A data sheet with technical specifications updated on a daily basis can be found on the Internet

(<https://support.industry.siemens.com/cs/ww/en/pv/6ES7536-1MF00-0AB0/td?dl=en>).

Article number	6ES7536-1MF00-0AB0
General information	
Product type designation	F-AI 8xI 0(4) ... 20 mA
Firmware version	
• FW update possible	Yes
Product function	
• I&M data	Yes; I&M0 to I&M3
Engineering with	
• STEP 7 TIA Portal configurable/integrated from version	V18 with HSP0394 (FW V1.0) / V19 with HSP0451 (FW V2.0)
• PROFINET from GSD version/GSD revision	V2.42 / -
Operating mode	
• MSI	Yes; firmware V2.0 or higher
CiR - Configuration in RUN	
Reparameterization possible in RUN	No
Calibration possible in RUN	No
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)	75 mA
Current consumption, max.	2.5 A; All channels are supplied from the encoder supply
Encoder supply	
Number of outputs	8
Short-circuit protection	Yes
24 V encoder supply	
• 24 V	Yes; min. L+ (-1.5 V)
• Short-circuit protection	Yes
• Output current per channel, max.	300 mA

Article number	6ES7536-1MF00-0AB0
Power	
Power available from the backplane bus	0.5 W
Power loss	
Power loss, typ.	2.5 W
Address area	
Address space per module	
• Inputs	23 byte
• Outputs	6 byte
Hardware configuration	
Automatic encoding	Yes
Analog inputs	
Number of analog inputs	8
permissible input current for current input (destruction limit), max.	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
Cable length	
• shielded, max.	1 000 m
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 / 16,667
• Interference voltage suppression for interference frequency f1 in Hz	50 / 60 Hz
Smoothing of measured values	
• Number of smoothing levels	7
• parameterizable	Yes
• Step: None	Yes; 1x conversion time
• Step: low	Yes; 2x / 4x conversion cycle time
• Step: Medium	Yes; 8x / 16x conversion cycle time
• Step: High	Yes; 32x / 64x conversion cycle time

Article number	6ES7536-1MF00-0AB0
Encoder	
Connection of signal encoders	
for current measurement as 2-wire transducer	Yes
– Burden of 2-wire transmitter, max.	650 Ω
for current measurement as 4-wire transducer	Yes
Errors/accuracies	
Linearity error (relative to input range), (+/-)	0.05 %
Temperature error (relative to input range), (+/-)	0.005 %/K
Crosstalk between the inputs, max.	-70 dB
Repeat accuracy in steady state at 25 °C (relative to input range), (+/-)	0.05 %
Operational error limit in overall temperature range	
Current, relative to input range, (+/-)	0.3 %; without HART communication
Basic error limit (operational limit at 25 °C)	
Current, relative to input range, (+/-)	0.05 %; without HART communication
Influence of a HART signal modulated on the input signal in relation to input range	
error occurred at interference frequency suppression: 60 Hz	0.12 %
error occurred at interference frequency suppression: 50 Hz	0.12 %
Interference voltage suppression for $f = n \times (f_1 \pm 1 \%)$, f_1 = interference frequency	
Series mode interference (peak value of interference < rated value of input range), min.	40 dB
Common mode voltage, max.	60 V DC/30 V AC
Common mode interference, min.	70 dB
Interrupts/diagnostics/status information	
Diagnostics function	Yes
Alarms	
Diagnostic alarm	Yes
Limit value alarm	No
Diagnoses	
Monitoring the supply voltage	Yes
Wire-break	Yes
Short-circuit	Yes
Overflow/underflow	Yes

Article number	6ES7536-1MF00-0AB0
Diagnostics indication LED	
• RUN LED	Yes; green LED
• ERROR LED	Yes; red LED
• Monitoring of the supply voltage (PWR-LED)	Yes; green PWR LED
• Channel status display	Yes; green LED
• for channel diagnostics	Yes; red LED
Potential separation	
Potential separation analog inputs	
• between the channels	No
• between the channels, in groups of	4
• between the channels and backplane bus	Yes
• between the channels and the power supply of the electronics	Yes
Permissible potential difference	
between the inputs (UCM)	60 V DC/30 V AC
Isolation	
Isolation tested with	707 V DC (type test)
Standards, approvals, certificates	
Highest safety class achievable in safety mode	
• Performance level according to ISO 13849-1	PLe
• Category according to ISO 13849-1	Cat. 4
• SIL acc. to IEC 61508	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	< 4.00E-05
– High demand/continuous mode: PFH in accordance with SIL3	< 1.00E-09 1/h
Ambient conditions	
Ambient temperature during operation	
• horizontal installation, min.	0 °C
• horizontal installation, max.	60 °C
• vertical installation, min.	0 °C
• vertical installation, max.	40 °C
Dimensions	
Width	35 mm
Height	147 mm
Depth	129 mm
Weights	
Weight, approx.	290 g

Operational error limit in overall temperature range

WARNING

When designing the safety function, you must take into account the "Operational error limit in overall temperature range" information for the entire mission time.

Dimension drawing

See S7-1500 Automation System

(<https://support.industry.siemens.com/cs/ww/en/view/59191792>) System Manual.

Response times

Introduction

The next section shows the response times of the analog input module F-AI 8xI 0(4)..20mA. The response times of F-AI 8xI 0(4)..20mA analog input module are included in the calculation of the F-system response time.

Definition of cycle time for fail-safe analog inputs

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

Times required for the calculation

- Max. acknowledgment time (Device Acknowledgment Time): $T_{DAT} = 25 \text{ ms}$
- Basic response time: 8 ms
- Response time per channel pair
 - At 50 Hz: 23 ms
 - At 60 Hz: 20 ms

Conversion cycle time = Basic response time + (N × Response time per channel pair)

(N = Number of active channel pairs)

The conversion cycle time is the time in which all activated channels are processed/converted once.

Channel pairs are: 0-4, 1-5, 2-6, 3-7

If you use only one channel of the channel pair, the channel pair is considered used.

Example:

Activated channels: 0, 4, 1, 5 => N = 2

Activated channels: 0, 4, 1, 2 => N = 3

Typical response time

You can calculate the typical response time of F-AI 8xI 0(4)..20mA using the following formula:

Typical response time = Conversion cycle time × Smoothing

Maximum response time with no faults (Worst Case Delay Time, WCDT)

You can calculate the maximum response time of F-AI 8xI 0(4)..20mA (Worst Case Delay Time, WCDT) using the following formula:

Max. response time = $2 \times \text{Conversion cycle time} \times \text{Smoothing}$

Response time in the case of a fault (one fault delay time, OFDT)

You calculate the response time of the F-AI 8xI 0(4)..20mA (One Fault Delay Time, OFDT):

- According to the following formula if a discrepancy error is present:

Typical response time = Conversion cycle time $\times$ Smoothing + Discrepancy time + Conversion cycle time

Maximum response time = $2 \times \text{Conversion cycle time} \times \text{Smoothing} + \text{Discrepancy time} + 2 \times \text{Conversion cycle time}$

- According to the following formula if a channel fault is present:

Typical response time = Conversion cycle time

Max. response time = $2 \times \text{Conversion cycle time}$

This means that, for OFDT, the time on occurrence of a discrepancy error should be taken with parameter assignment "1oo2 evaluation (max. SIL3/Cat.4/PLe)" and the time on occurrence of a channel fault should be taken with parameter assignment "1oo1 evaluation (max. SIL3/Cat.3/PLd)".

Representation of analog values

This section shows the analog values for all measuring ranges that you can use with the F-AI 8xI 0(4)..20mA analog input module.

Measured value resolution

The analog values are shown as fixed-point number in two's complement.

The resolutions shown here are 16 bits including sign.

Table B-1 Resolution of the analog values

Resolution in bits	Values		Analog value	
	Decimal	Hexadecimal	High byte	Low byte
16	1	1 _H	Sign 0 0 0 0 0 0 0	0 0 0 0 0 0 1

B.1 Representation of analog values

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

Table B-2 Current measuring range 0 to 20 mA

Values		Current measuring range	Range
Dec.	Hex.	0 to 20 mA	
32512	7F00 _H	> 23.518 mA	Overflow
32511	7EFF _H	23.518 mA	Overrange
.	.	.	
27649	6C01 _H	20.0007 mA	
27648	6C00 _H	20 mA	Nominal range
.	.	.	
614	266 _H	0.4442 mA	
613	265 _H	< 0.4442 mA	Wire break
.	.	.	
1	1 _H	723.4 nA	
0	0 _H	0 mA	

Table B-3 Current measuring range 4 to 20 mA

Values		Current measuring range	Range	
Dec.	Hex.	4 to 20 mA	Diagnostics wire break: No	Diagnostics wire break: Yes
32512	7F00 _H	> 22.814 mA	Overflow	Overflow

B.1 Representation of analog values

Values		Current measuring range	Range	
32511 . . 27649	7EFF _H . . 6C01 _H	22.814 mA . . 20.0006 mA	Overrange	Overrange
27648 . . 1 0	6C00 _H . . 1 _H 0 _H	20 mA . . 4 mA + 578.7 nA 4 mA	Nominal range	Nominal range
-1 . . -691	FFFF _H . . FD4D _H	3.9994 mA . . 3.6 mA	Underrange	Underrange
-692 . . -6144	FD4C _H . . E800 _H	< 3.6 mA . . 0.4444 mA		Wire break
-6145	E7FF _H	< 0.4444 mA		
			Underflow	

HART operating data records

C.1 HART operating data records

Read/write data in RUN

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

Errors during transmission are indicated at the 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 parameters Channel 0	8	Yes	Yes
132	HART parameters Channel 1	8	Yes	Yes
133	HART parameters Channel 2	8	Yes	Yes
134	HART parameters Channel 3	8	Yes	Yes
135	HART parameters Channel 4	8	Yes	Yes
136	HART parameters Channel 5	8	Yes	Yes
137	HART parameters Channel 6	8	Yes	Yes
138	HART parameters Channel 7	8	Yes	Yes

Data record number	Description	Length (bytes)	Writable	Readable
140	HART mapping parameters	12 or 20	Yes	Yes
148	HART directory	25	No	Yes
149	HART feature data	3	No	Yes

C.2 HART directory (DS 148)

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 request 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 are not configurable. Data records starting from data record number 80 (80, 82, 84, 86, 88, 90, 92, 94) are always used.

C.3 HART feature data (DS 149)

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" Bit5 = 1: "compact format is supported"
1	Byte 1	= 0
2	Max Length Data Unit	= 230 (maximum length of the HART request data)

C.4 HART variable data record (DS 121)

The analog module F-AI 8xI 0(4)..20mA supports a maximum of 4 HART variables per channel. Provided they are supported by the connected field device, these variables are read cyclically.

These 32 HART variables are made available as readable variables in HART variable data record 121.

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

Structure of the HART variable data record

Byte	Meaning	
Channel 0		
0 ... 3	Value	PV (Primary Variable)
4	Quality code	
5 ... 8	Value	SV (Secondary Variable)
9	Quality code	
10 ... 13	Value	TV (Tertiary Variable)
14	Quality code	
15 ... 18	Value	QV (Quaternary Variable)
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).

C.5 HART-specific settings (DS 131 to DS 138)

HART communication is available via the standard configuration (see Parameters [\(Page 40\)](#)). Additional HART-specific settings can be specified channel-specifically via 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.

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

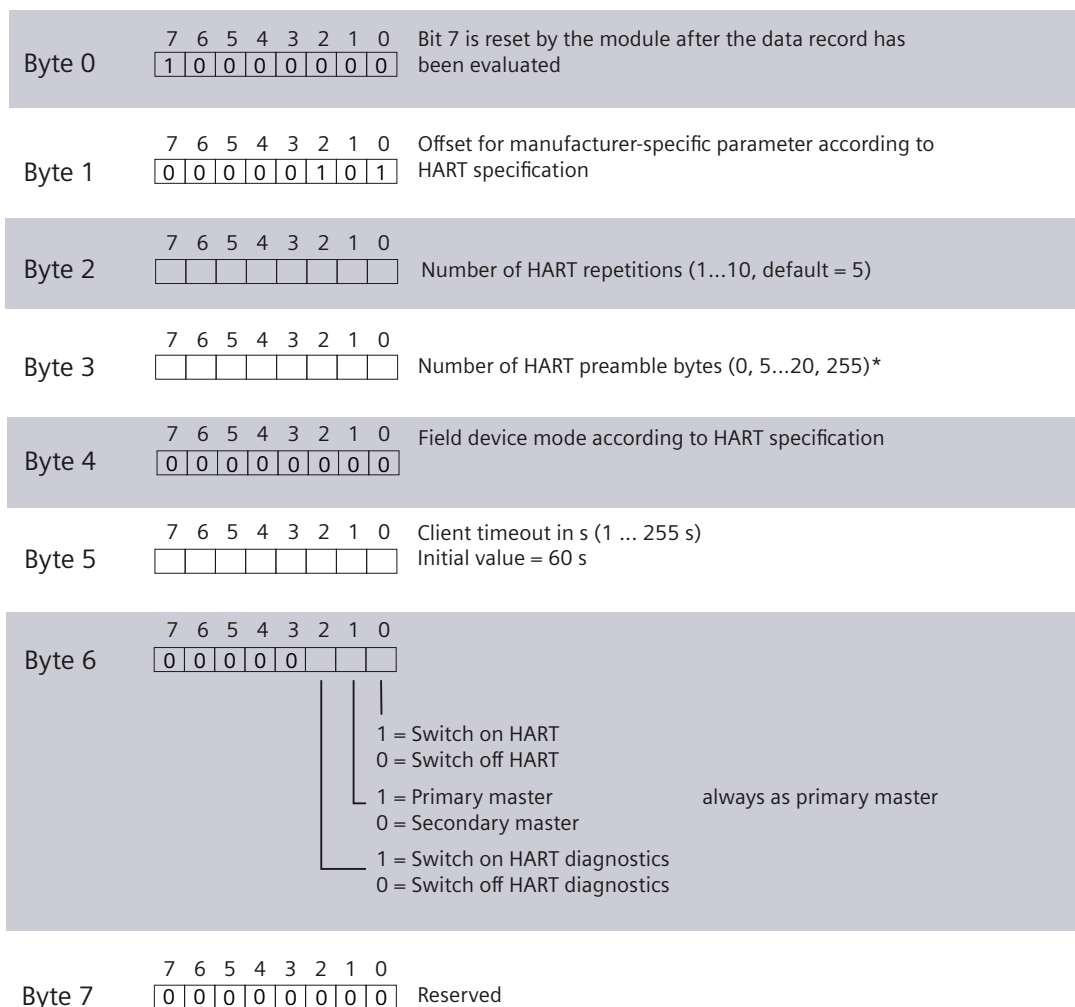


Figure C-1 Settings

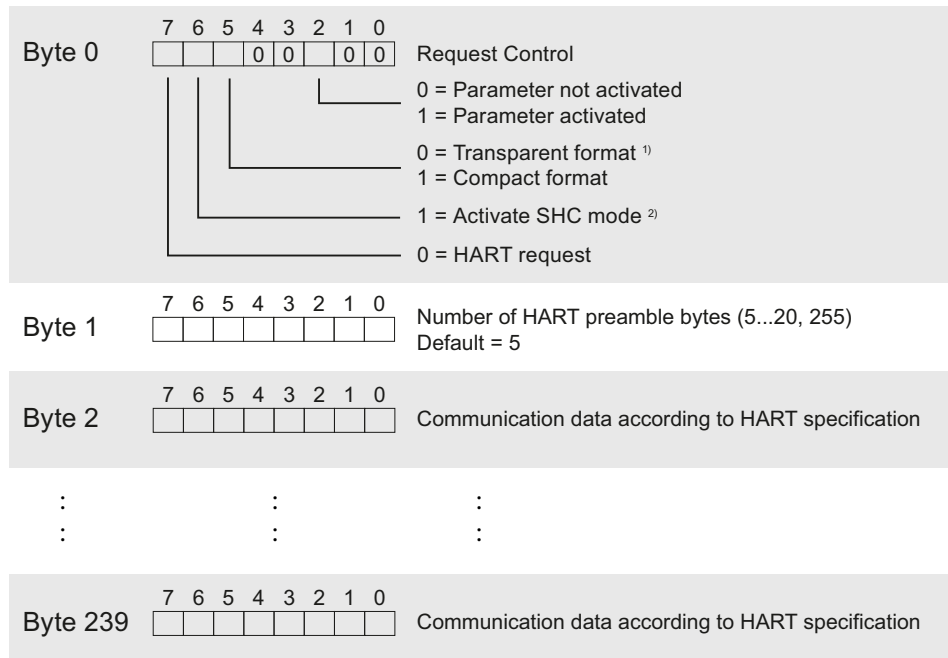
* If the number of HART preamble bytes = 0, the number of preamble bytes required by the connected field device is used, but at least 5.

If the number of HART preamble bytes = 255, 20 preamble bytes are used.

C.6 HART request and response data records (DS 80 to DS 95)

HART commands are processed channel-specifically via a separate command interface, each with a request data record and a response data record.

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 the request data records 80, 82, 84, 86, 88, 90, 92, 94

- 1) HART commands are processed by the analog module in transparent message format and in compact message format. However, the response data from the module is always made available in transparent message format.
- 2) When a sequence of HART commands in the form of an SHC sequence is processed, this affects all other channels with activated HART. See HART command interface (Page 34) SHC sequence.

Figure C-2 Request data record

NOTE

If "Number of HART preamble bytes" = 255, the number of preambles set via the parameters is used. 5 are set by default. You can change the configured number of preamble bytes via the parameters as well as via the HART-specific settings (see HART-specific settings (DS 131 to DS 138) (Page 102)).

Structure of the response data records 81, 83, 85, 87, 89, 91, 93, 95

In case of successful response

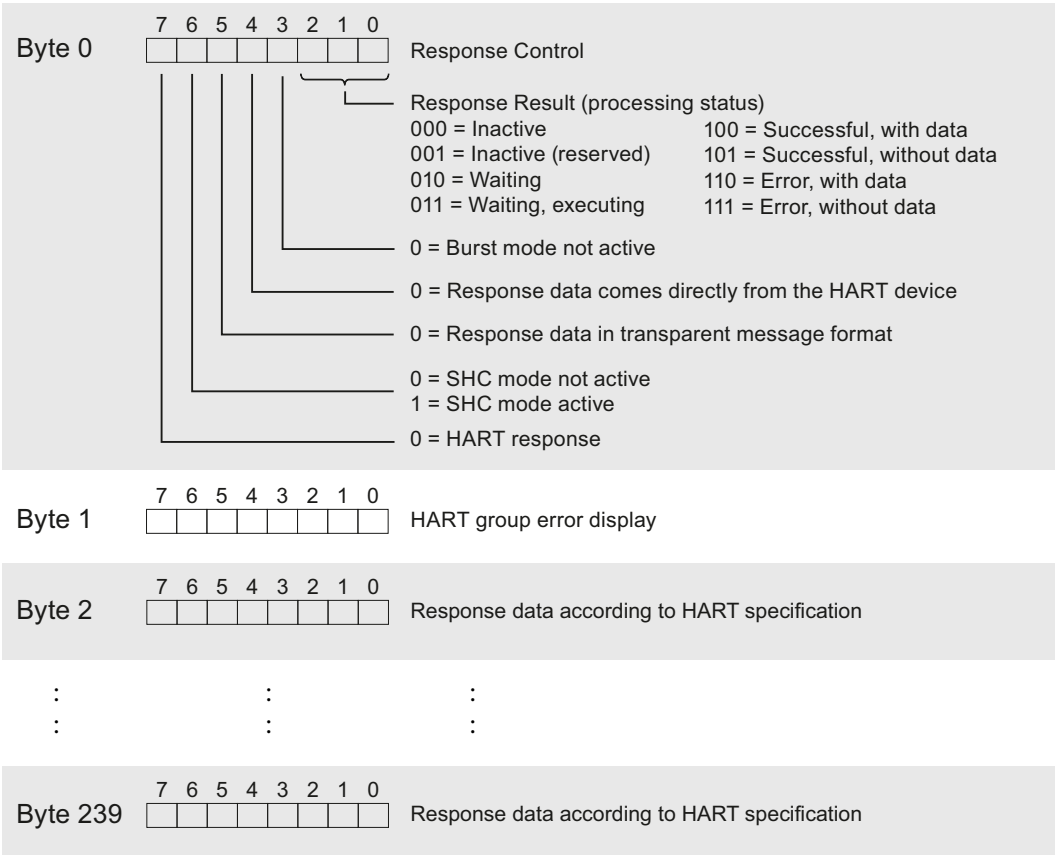
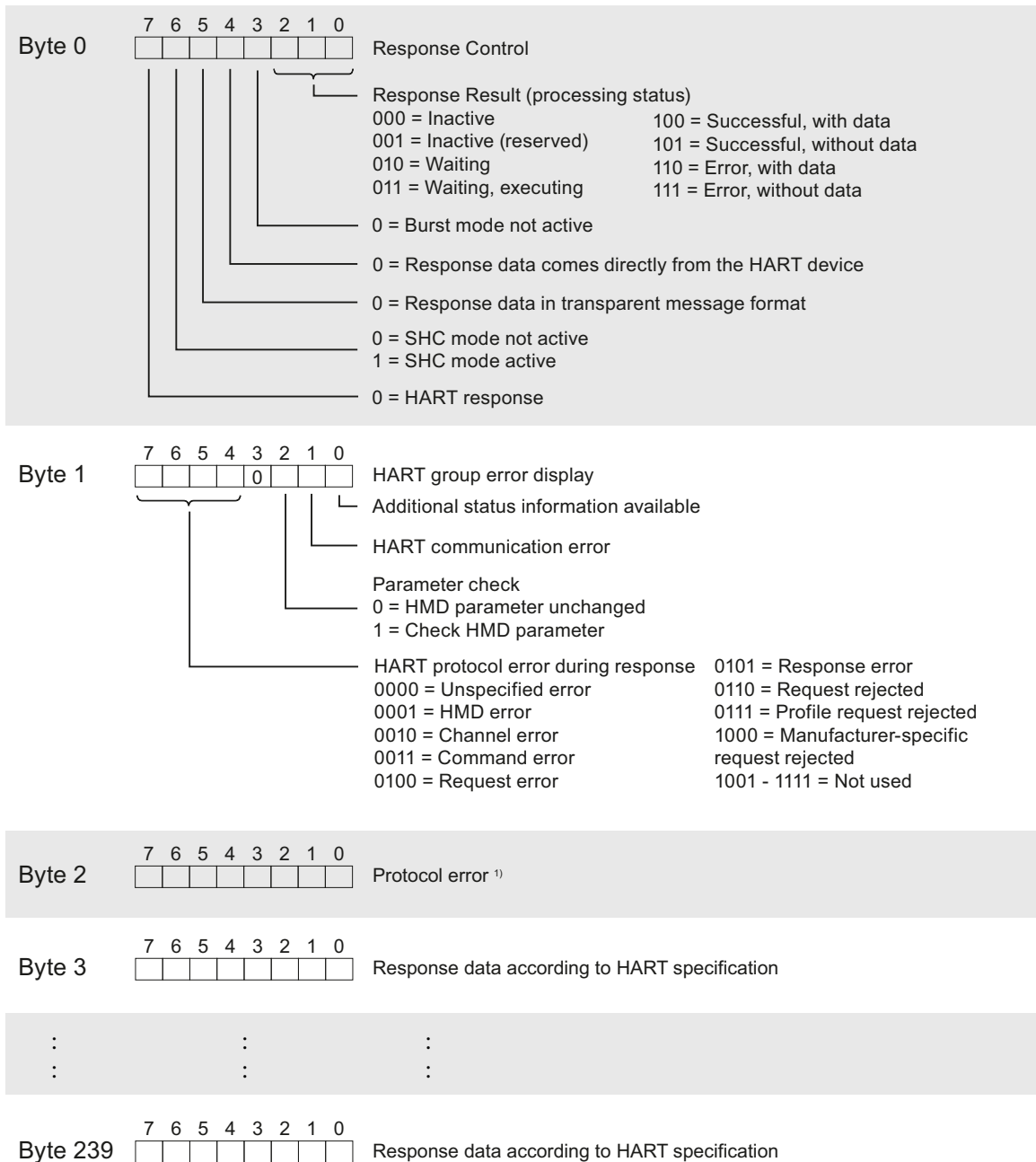


Figure C-3 Response data record in case of successful response

In case of response error

1) See table: "HART protocol error during response" coding

Figure C-4 Response data record in case of response error

Table C-1 "HART protocol error during response" coding

HART protocol error with 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 error	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
4	Query error	Bit 0 = 0: Reserved Bit 1 = 1: Receive buffer overflow Bit 2 = 0: Reserved Bit 3 = 1: Checksum error Bit 4 = 1: Framing error Bit 5 = 1: Overflow error Bit 6 = 1: Parity error Bit 7 = 1: Reserved
5	Response error	Bit 0 = 1: GAP timeout Bit 1 = 1: Receive buffer overflow Bit 2 = 1: Timeout Bit 3 = 1: Checksum error Bit 4 = 1: Framing error Bit 5 = 1: Overflow error Bit 6 = 1: Parity error Bit 7 = 1: Reserved
6	Query rejected	0: Unspecified 1: Compact format not supported 2: SHC not supported 3: Impermissible command 4: No resources 5 ... 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)

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 the address "2A 2F 00 59 D3".

A positive edge at input 4.0 of a digital input module causes the HART command to be written.

The following assumptions are made:

- The identification number of the hardware component of the analog module F-AI 8xI 0(4)..20mA is 266 (10A_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.

Symbol	Address	Data type	Comment
T_DS80	I 4.0	Bool	Button of DS80
M_PF_WR	M 104.0	Bool	Positive edges auxiliary flag WRREC
M_WR_Done	M 51.0	Bool	Flag =1 : Data record was transferred
M_WR_Busy	M 51.1	Bool	Flag =1 : Writing has not yet finished
M_WR_Error	M 51.2	Bool	Flag =1 : An error occurred when writing.
MD_WR_Status	MD 93	DWord	WRREC block status or error information
DB80	DB80	DB80	The data record is stored in DB80

SCL	Explanation
"R_TRIG_DB" (CLK:="T_DS80", Q=>"M_PF_WR");	
WHILE "M_PF_WR" DO	
"WRREC_DB" (REQ := TRUE,	
ID := 266,	Identification number of the hardware component
INDEX := 80,	Data record number 80
LEN := 11,	Data record length 11 bytes
DONE => "M_WR_Done",	Done= True: Data record was transferred
BUSY => "M_WR_Busy",	BUSY= True: Writing has not yet finished
ERROR => "M_WR_Error",	ERROR = True: An error occurred when writing.
STATUS => "MD_WR_Status",	Block status or error information
RECORD := P#DB80.DBX0.0 BYTE 11	Data record with length of 11 bytes (must correspond to the exact length that is to be transferred)
);	
IF ("M_WR_Done"	
OR "M_WR_Error") THEN	Exit loop immediately if data record was transferred or an error occurred.
EXIT;	
;	
END_IF;	
;	
END_WHILE;	

Table C-2 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	2A	Address (with command 0, the address is exactly 1 byte long and has the value 0.)
4	2F	
5	00	
6	59	
7	D3	
8	01	Command (CMD)
9	00	Length in bytes
10	0D	Checksum (CHK) (calculated starting from byte 2 "Start character" up to the next to last byte)

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.

Table C-3 DB80: Compact message format

Byte	Initial value (hex)	Comment (Hex)
0	20	Req_Control (20 = Compact message format. 60 = Compact message format with SHC sequence)
1	05	Number of preamble bytes (05-14)
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.

Symbol	Address	Data type	Comment
T_DS81	I 4.1	Bool	Button of DS81
M_PF_RD	M 104.1	Bool	Positive edges auxiliary flag RDREC
M_RD_Done	M 49.0	Bool	Flag = True : New data record was received and is valid
M_RD_Busy	M 49.1	Bool	Flag = True : Reading has not yet finished.
M_RD_Error	M 49.2	Bool	Flag = True : An error occurred when reading
MD_RD_Status	MD 100	DWord	RDREC block status or error information
MW_RD_Len	MW104	Word	The read length of the data record
DB81	DB81	DB81	The read data record is stored in DB81

SCL	Explanation
"R_TRIG_DB_1" (CLK:="T_DS81",	
Q=>"M_PF_RD");	
WHILE "M_PF_RD" DO	
"RDREC_DB" (REQ:=TRUE,	
ID:=266,	Identification number of the hardware component
INDEX:=81,	Data record number 81
MLEN:=255,	Maximum length in bytes of the data record information to be read
VALID=>"M_RD_Done",	New data record was received and is valid
BUSY=>"M_RD_Busy",	BUSY = True: Reading has not yet finished.
ERROR=>"M_RD_Error",	ERROR = True: An error occurred when reading
STATUS=>"MD_RD_Status",	Block status or error information
LEN=>"MW_RD_Len",	Read length of the data record
RECORD:=P#DB81.DBX0.0 BYTE	Data record
255	
IF ("M_RD_Done"	Exit loop immediately if data record was transferred or an error occurred.
OR "M_RD_Error") THEN	
EXIT;	
;	
END_IF;	
;	
END_WHILE;	

As long as "0x03" is in byte 0 of DB81, the response has not been received from the field device. As soon as bit 2 = 1 in byte 0, there is positive response data from the field device that you can evaluate.

In the event of incorrect response data, see the tables "HART group error display" in byte 1 or "HART protocol error on response" in byte 2 of the response from the field device.

C.7 Parameter assignment and structure of the HART mapping parameters (DS 140)

Structure of data record 140

Data record 140 has a length of 20 bytes.

You can use the parameters of data record 140 to configure/map up to 8 HART variables in the additional submodules of the module, provided the corresponding configuration is selected, see "HART mapping (Page 60)".

Data record 140 is then only evaluated by the module if 4 HART or 8 HART variables are configured.

Header information

The figure below shows the structure of the header information.

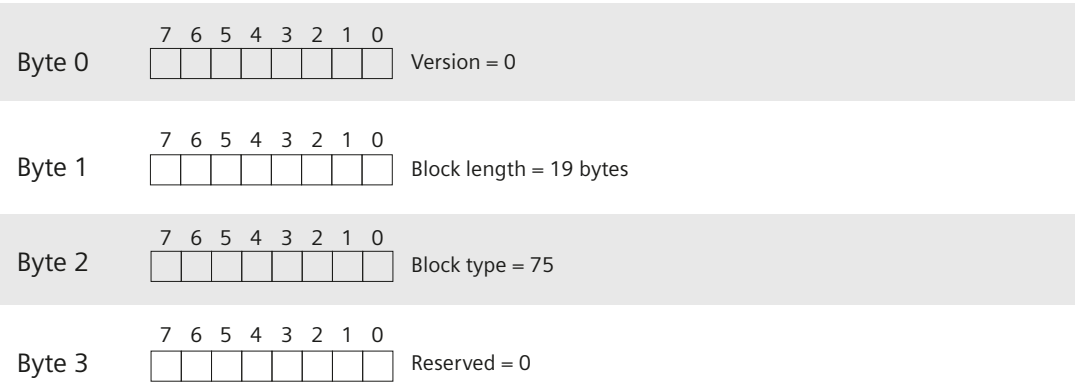
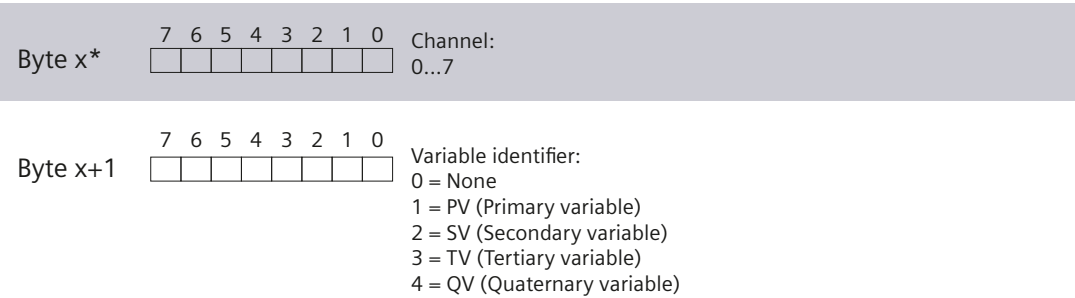


Figure C-5 Header information

Parameters

The following figure shows the configuration of the 8 HART variables 1 ... 8.



* $x = 4 + (\text{HART variable} - 1) * 2$; with HART variable 1 ... 8

Figure C-6 Parameters