SIEMENS

Edition 08/2023

Equipment manual

SIMATIC

S7-1500/ET 200MP

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

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SIMATIC

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

Equipment Manual

Original operating instructions

08/2023
A5E51970360-AA

Legal information

Warning notice system

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

⚠ DANGER

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

⚠ WARNING

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

⚠ CAUTION

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

NOTICE

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

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A5E51970360-AA
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Preface

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 configuration and programming software "STEP 7 (TIA Portal)".
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)

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For legal reasons, we are obliged to publish the original text of the license conditions and copyright notices. Read the information on this in the Internet (https://support.industry.siemens.com/cs/ww/en/view/109805059).

Table of contents

Documentation Guide for S7-1500/ET 200MP

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1.1 Information classes S7-1500/ET 200MP

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 200MPsystems.
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.
(https://support.industry.siemens.com/cs/de/en/view/109806400)

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).

1.2 Basic tools

Tools

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)

SIMATIC Automation Tool

You can use the SIMATIC Automation Tool to perform commissioning and maintenance activities on various SIMATIC S7 stations as bulk operations independent of TIA Portal.
The SIMATIC Automation Tool offers a wide range of functions:

- Scanning of a PROFINET/Ethernet system network and identification of all connected CPUs
- Assignment of addresses (IP, subnet, Gateway) and device name (PROFINET device) to a CPU
- Transfer of the date and the programming device/PC time converted to UTC time to the module
- Program download to CPU
- RUN/STOP mode switchover
- CPU localization through LED flashing
- Reading out of CPU error information
- Reading the CPU diagnostic buffer
- Reset to factory settings
- Firmware update of the CPU and connected modules

You can find the SIMATIC Automation Tool on the Internet.
(https://support.industry.siemens.com/cs/ww/en/view/98161300)

PRONETA

SIEMENS PRONETA (PROFINET network analysis) is a commissioning and diagnostic tool for PROFINET networks. PRONETA Basic has two core functions:

- In the network analysis, you get an overview of the PROFINET topology. Compare a real configuration with a reference installation or make simple parameter changes, e.g. to the names and IP addresses of the devices.
- The "IO test" is a simple and rapid test of the wiring and the module configuration of a plant, including documentation of the test results.

You can find SIEMENS PRONETA Basic on the Internet:
(https://support.industry.siemens.com/cs/ww/en/view/67460624)
SIEMENS PRONETA Professional is a licensed product that offers you additional functions. It offers you simple asset management in PROFINET networks and supports operators of automation systems in automatic data collection/acquisition of the components used through various functions:

- The user interface (API) offers an access point to the automation cell to automate the scan functions using MQTT or a command line.
- With PROFIenergy diagnostics, you can quickly detect the current pause mode or the readiness for operation of devices that support PROFIenergy and change these as needed.
- The data record wizard supports PROFINET developers in reading and writing acyclic PROFINET data records quickly and easily without PLC and engineering.

You can find SIEMENS PRONETA Professional on the Internet.
(https://www.siemens.com/proneta-professional)

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).

1.3 S7 Failsafe Configuration Tool (S7-FCT)

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).

1.4 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/TwLSxxRQQsA)

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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)

Product overview

2

2.1 Properties

Article number

6ES7536-1MF00-0AB0

View of the module

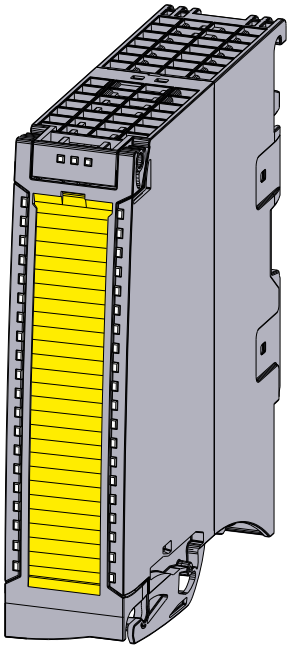


Figure 2-1 View of the F-AI 8xI 0(4)..20mA module

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-CPUs 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 (AI_0 ... AI_3, AI_4 ... AI_7)
- 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; as of firmware version 2.0 supported)

⚠ 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 51).

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.

2.2 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 and SIMATIC Safety V18 with HSP0394

Connecting

3

3.1 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 23).
You can find more information on the various connection options in the section Applications of the F-I/O module (Page 39).
You can find information on wiring the front connectors and providing the cable shielding, etc., in the Wiring section of the system manual Automation System S7-1500 (https://support.industry.siemens.com/cs/ww/en/view/59191792).

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).

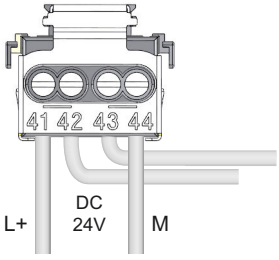
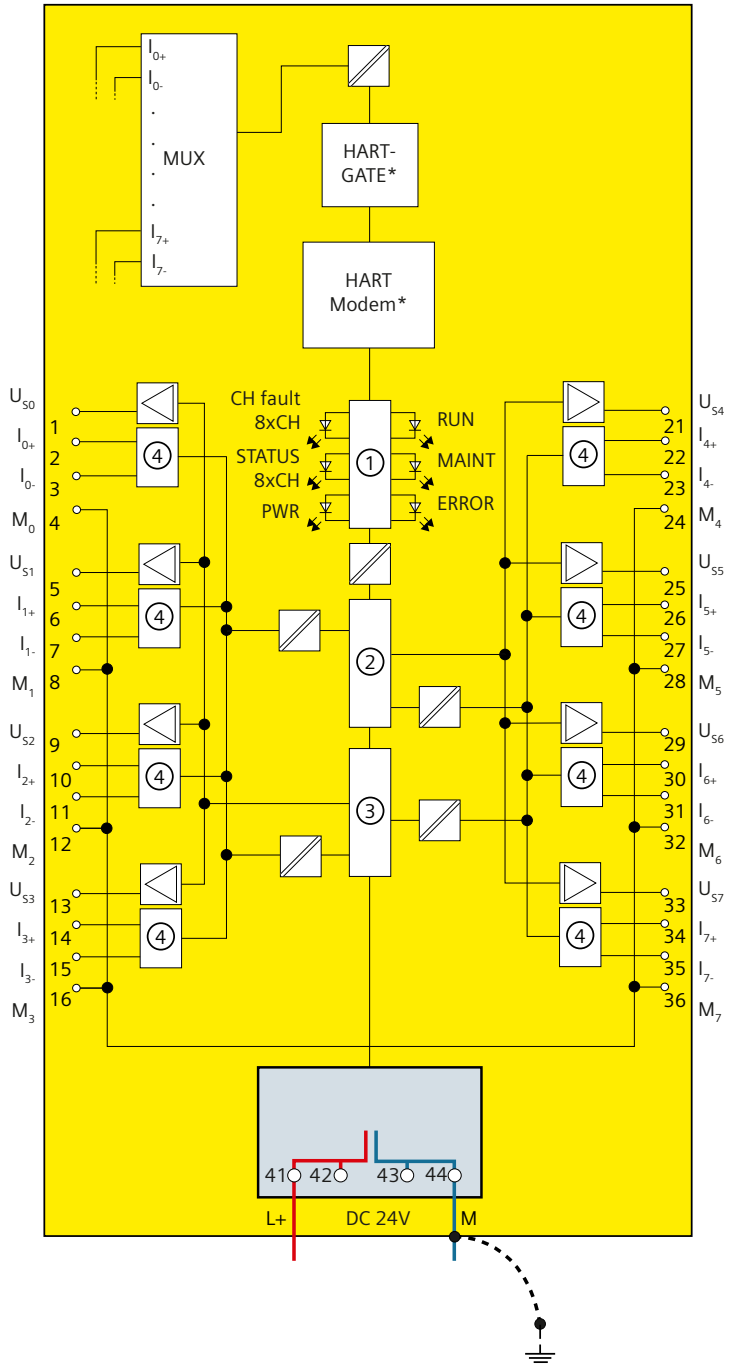


Figure 3-1 Connection of power supply element

Block diagram

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



①	Backplane bus interface	RUN	LED status display (green)
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 version 2.0.

Figure 3-2 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 39) 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+ 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 fast 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 - under development

4

NOTE

HART communication (Rev. 5 to Rev. 7) is supported as of firmware version 2.0.

Parameters/address space

5

5.1 Measurement types and measuring ranges

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

Table 5-1 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 63).

5.2 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 39).

The following parameters are possible:

Table 5-2 Configurable parameters

Parameter	Value range	Default	Parameter reassignment 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 address)	0 to 65535	Calculated by F-system	No	Module

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

*- Can only be set with 4 to 20 mA measuring range

*)

Parameter	Value range	Default	Parameter reassignment 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	—	Suggested by F-system	No	Module
F-I/O DB name	—	Suggested by F-system	No	Module
AI parameters				
Interference frequency suppression	• 50 Hz • 60 Hz	50 Hz	No	Module
Channel parameters:				
Channel n				
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
Standard value	• MIN • MAX	MIN	No	Channel
Discrepancy time *	100 to 30000 ms	100 ms	No	Channel
Tolerance window % absolute	0.3 to 20.0%	2.5%	No	Channel
Tolerance window % relative	0.3 to 20.0%	2.5%	No	Channel
Activated	• Disable • Enable	Enable	No	Channel
Channel failure acknowledge	• Manual • Automatically	Manual	No	Channel
Measuring range	• 0 to 20 mA • 4 to 20 mA	4 to 20 mA	No	Channel
Diagnostics: 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"

*- Can only be set with 4 to 20 mA measuring range
*)

5.3 Explanation of parameters

5.3.1 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).

5.3.1.1 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"

5.3.1.2 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.

5.3.1.3 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).

5.3.2 Parameters of the channels

5.3.2.1 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"

5.3.2.2 Standard 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 standard value prior to the occurrence of the discrepancy is made available to the F-CPU.

5.3.2.3 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 standard 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 28).

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.

5.3.2.4 Tolerance window %, absolute

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 28).

Example

You have assigned the following:

- The "Tolerance window % absolute" 10%
- A measuring range of 0 to 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 27)

5.3.2.5 Tolerance window %, relative

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 standard 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 % absolute" and "Tolerance window % relative" are combined. The "Tolerance window % absolute" parameter is decisive in 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 28).

Example

You have assigned the following:

- The "tolerance window % relative" is set at 10%
- A measuring range of 0 to 20 mA
- A discrepancy time of 200 ms
- The standard 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 27)

5.3.2.6 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 standard 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 standard value at an instant and is within the tolerance window, **no** discrepancy exists.

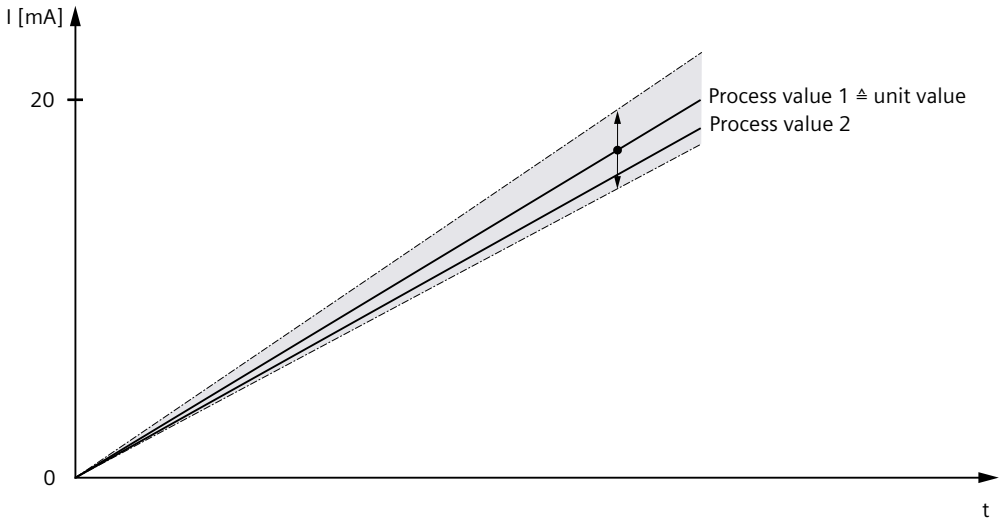


Figure 5-1 Example of a relative tolerance window *without* discrepancy (parameter assignment: standard value = MAX)

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

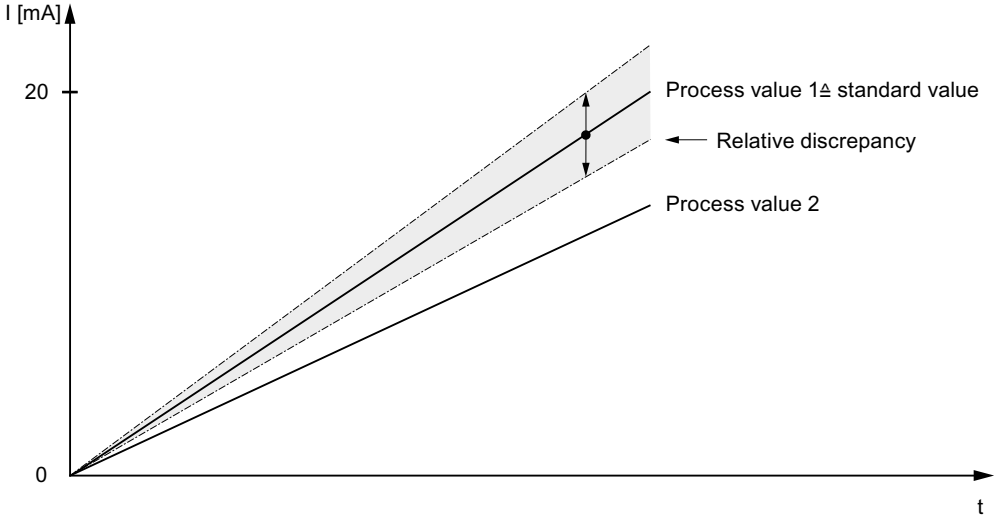


Figure 5-2 Example of a relative tolerance window *with* discrepancy (parameter assignment: standard value = MAX)

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 standard 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 standard 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
- Standard value
- Tolerance window %, absolute
- Tolerance window %, relative

"Discrepancy time" parameter

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

- The process value that does not represent the standard 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 standard 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 61) in the above equation.

You can assign the discrepancy time for each channel pair.

"Standard 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 standard 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 standard value.
- "MAX": The higher of the two values is signaled to the F-CPU as the standard value.

"Tolerance window %, absolute" parameter

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

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

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

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

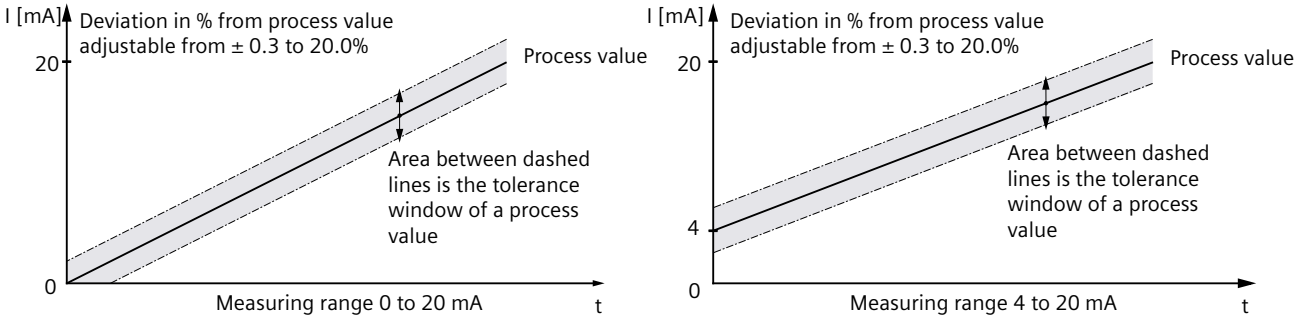


Figure 5-3 Absolute deviation in % of the nominal range for measuring range 0 to 20 mA or 4 to 20 mA

"Tolerance window %, relative" 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 standard value) in this instant.
You can calculate the relative tolerance window using the following formula:

$$\mathbf{T}_{rel} = \frac{|\Delta \mathbf{I}_{rel}|}{|\mathbf{I}_{EW} - \mathbf{I}_{MA}|} \times 100 \ [\%]$$

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

$$\Delta I_{rel} = \pm \frac{|\mathbf{I}_{EW} - \mathbf{I}_{MA}| \times \mathbf{T}_{rel}}{100} \ [mA]$$

With

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

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

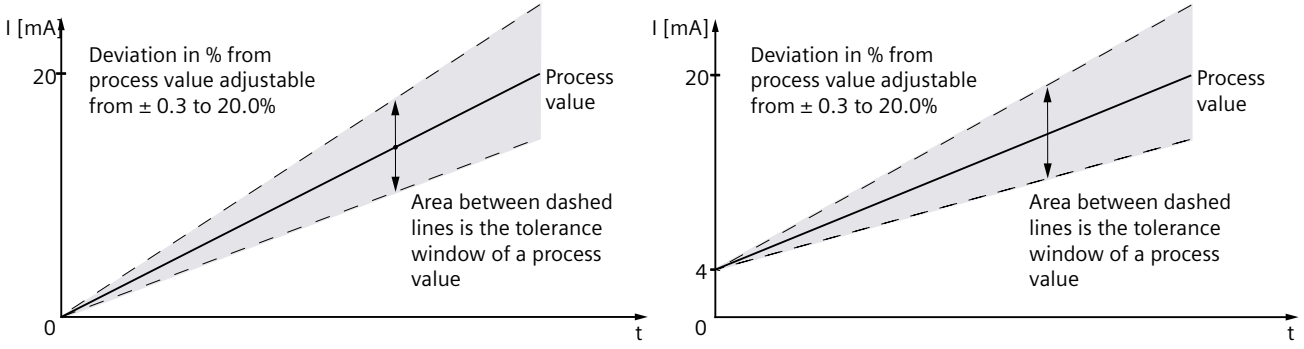
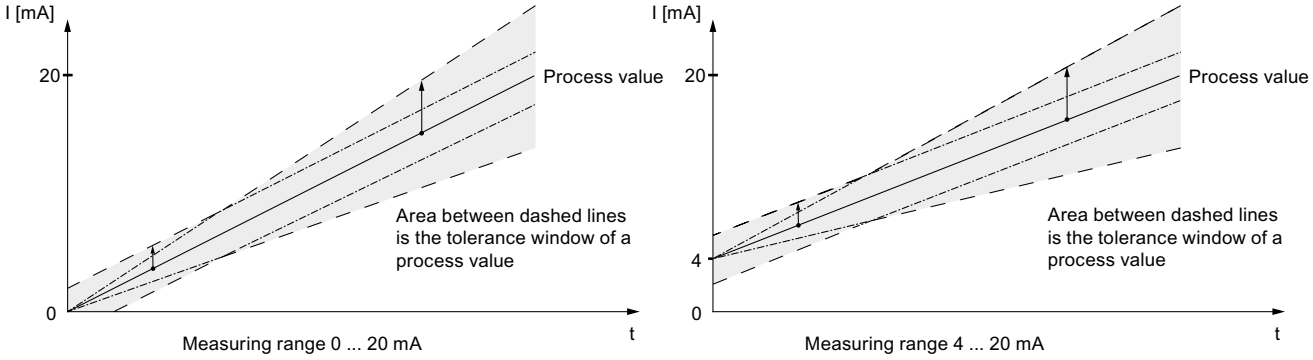


Figure 5-4 Relative deviation in % of the nominal range for measuring range 0 to 20 mA or 4 to 20 mA

Combination of the "Tolerance window %, absolute" and "Tolerance window %, relative" parameters

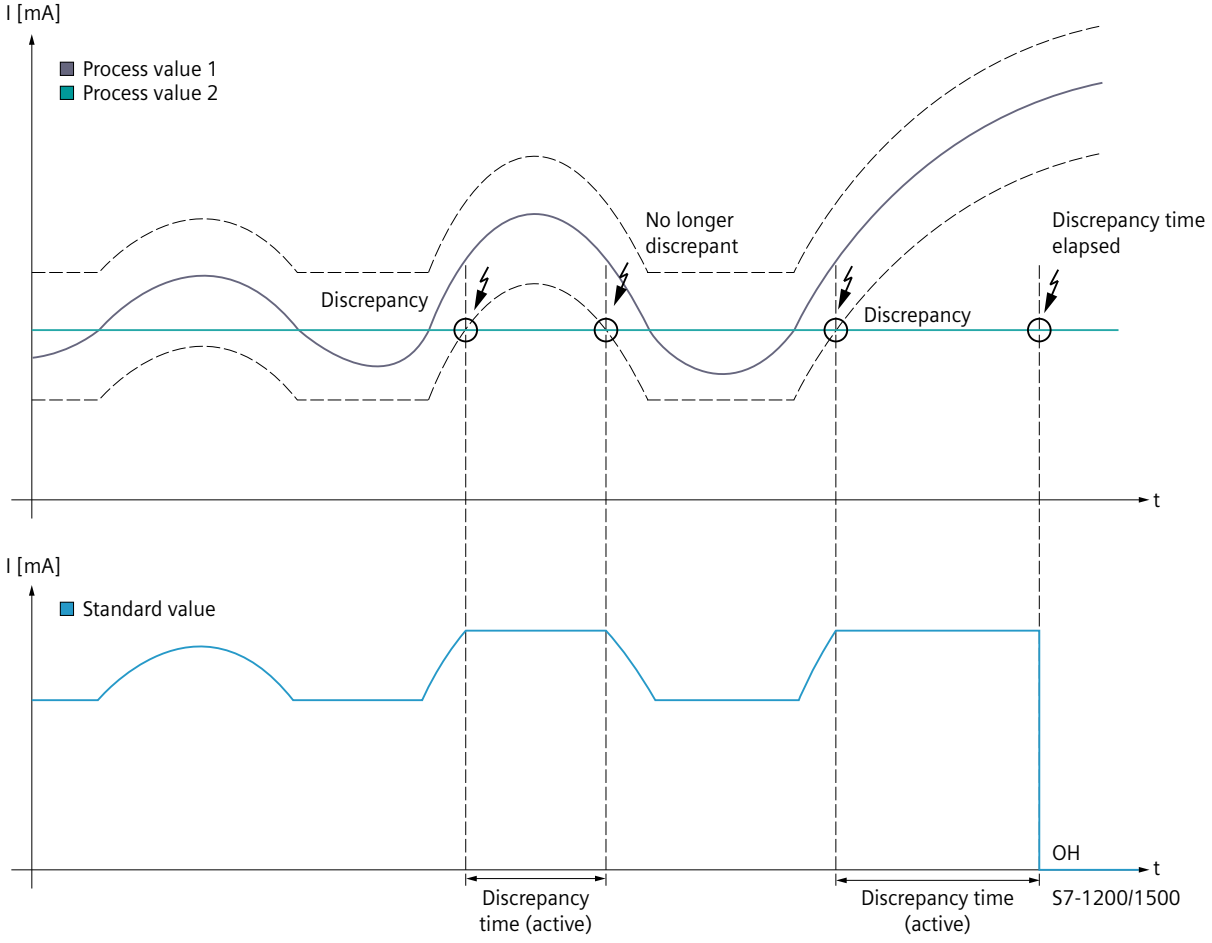
You can combine the "Tolerance window %, absolute" and "Tolerance window %, relative" parameters as needed. The combined tolerance window (shown in gray in the figure below) is the maximum of T_{rel} and T_{abs}.
$T = MAX \{ T_{rel}, T_{abs} \}$
$\Delta I = MAX \{ \Delta I_{rel}, \Delta I_{abs} \}$
With

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



Example

The following diagrams show you the behavior of the discrepancy evaluation when standard 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 standard 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.

5.3.2.7 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 61).

5.3.2.8 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)

5.3.2.9 Measuring range

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

- 0 to 20 mA
- 4 to 20 mA

5.3.2.10 Diagnostics: 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.

5.3.2.11 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

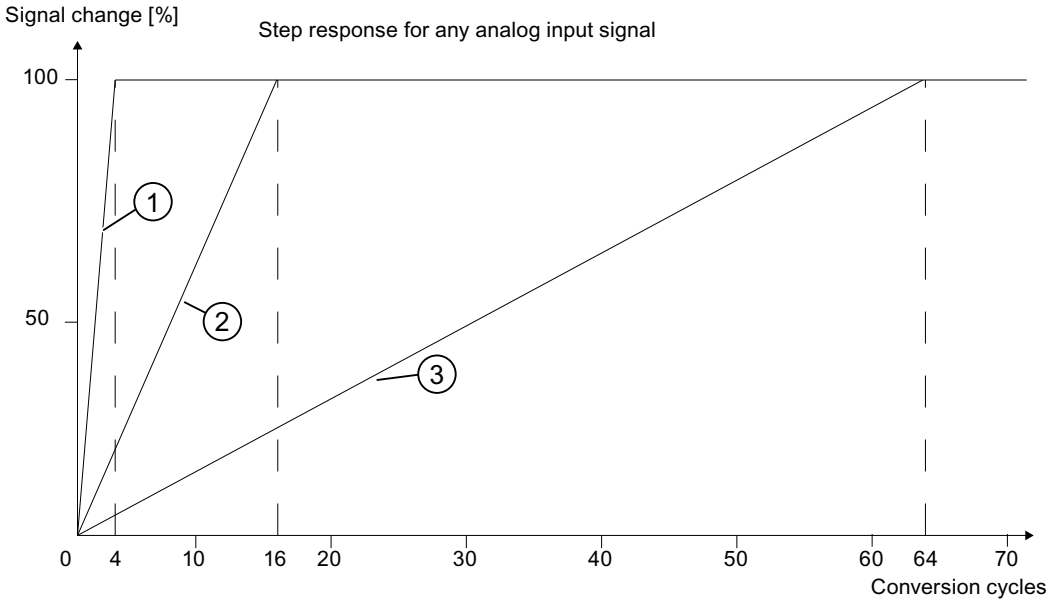
Smoothing is reset after startup, short-circuit, wire break or another channel fault. If, for example, smoothing with 16 conversion cycles is assigned and all channels are active, it takes up to 1600 ms until the process value is signaled with a configured interference frequency suppression of 50 Hz.

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 × Conversion cycle time × Smoothing + Discrepancy time + 2 × 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 61):

Max. response time (in case of discrepancy error) = 2 × 31 ms × 16 + 2000 ms + 2 × 31 ms = 3054 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.

5.4 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 5-3 Address assignment in the F-CPU

Occupied bytes in the F-CPU:		
F-CPU	**In input range**	**In output range**
F-CPUs 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 Analog input module F-AI 8xI 0(4)..20mA

The user data occupies 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 5-4 User data 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								

x = Module start address

Byte in the F-CPU	Assigned bits in F-CPU per F-module:							
	7	**6**	**5**	**4**	**3**	**2**	**1**	**0**
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
IB x + 18	PROFIsafe driver - 5 bytes							

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 AI_0) with channel 4 (input word AI_4). In this example, you may only access the input bit AI_0 in the safety program with 1oo2 evaluation of the sensors.

Table 5-5 Address space for output byte

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*
QB x + 1	PROFIsafe driver - 5 bytes							

* The function is supported as of firmware version 2.0.

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.

Applications of the F-I/O module

6

6.1 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.

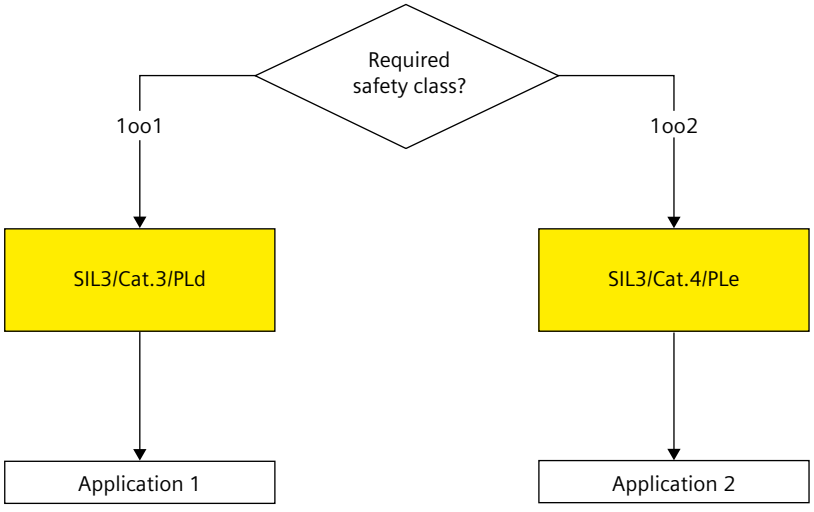


Figure 6-1 Select application case - Analog input module F-AI 8xI 0(4)..20mA

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 6-1 Conditions for achieving SIL/Cat./PL

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

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).

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

Wiring

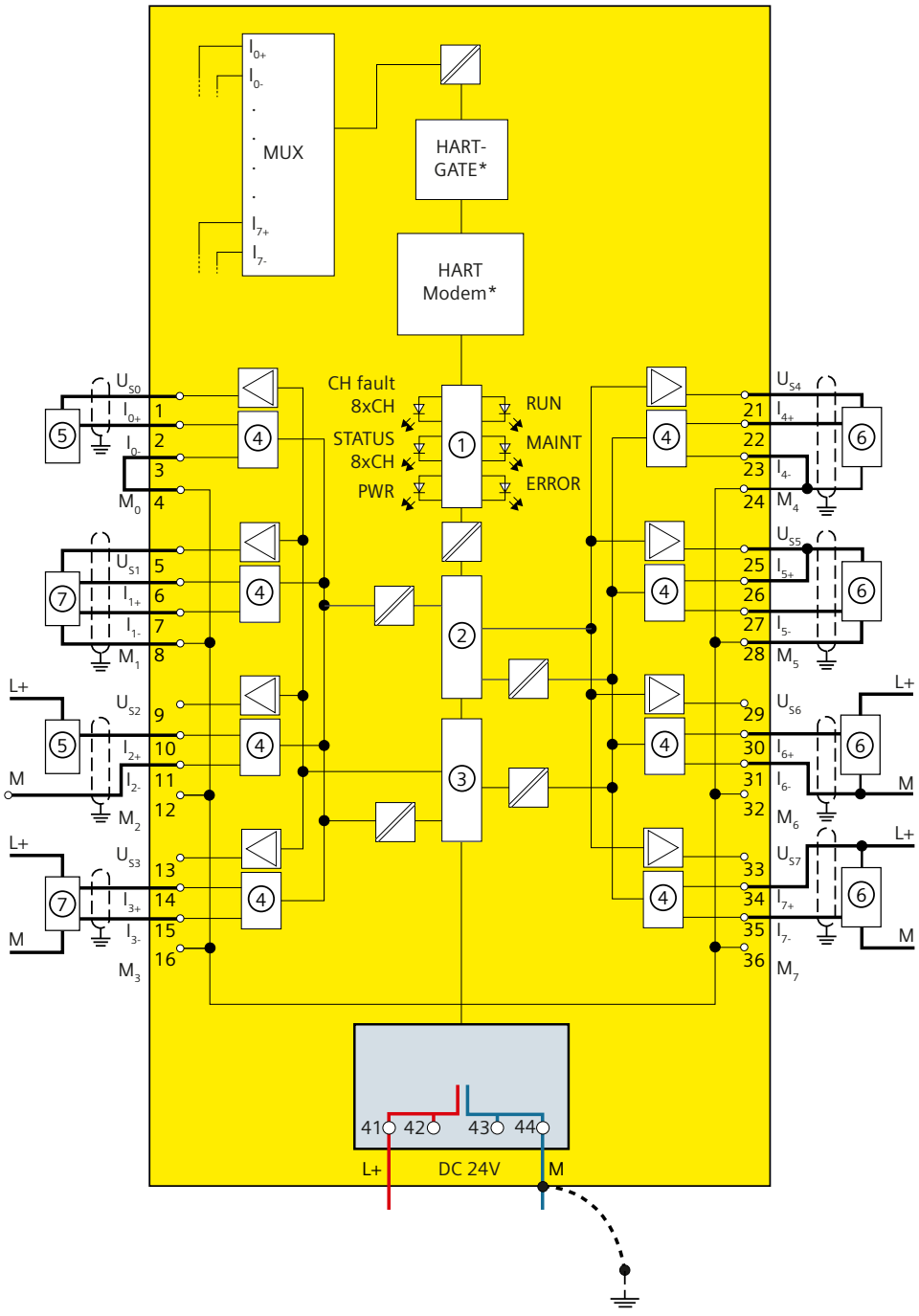
The wiring is carried out on the front connector of the module. Refer to the "Wiring" section in the S7-1500 Automation System (https://support.industry.siemens.com/cs/ww/en/view/59191792) system manual.

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	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	3-wire transducer	STATUS	LED for channel status (green)
⑦	4-wire transducer	*	The function is supported as of firmware version 2.0.

Figure 6-2 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 6-2 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
Diagnostics: Wire break	(in the measuring range 4 to 20 mA) • Disable • Enable
Smoothing	1 / 2 / 4 / 8 / 16 / 32 / 64 conversion cycles

6.3 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 AI_0 to AI_7 (SIL3). You can combine two of these inputs each to one input.
You can combine the following inputs:

- AI_0 and AI_4
- AI_1 and AI_5
- AI_2 and AI_6
- AI_3 and AI_7

The process signals are provided by channels AI_0, AI_1, AI_2 and AI_3

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

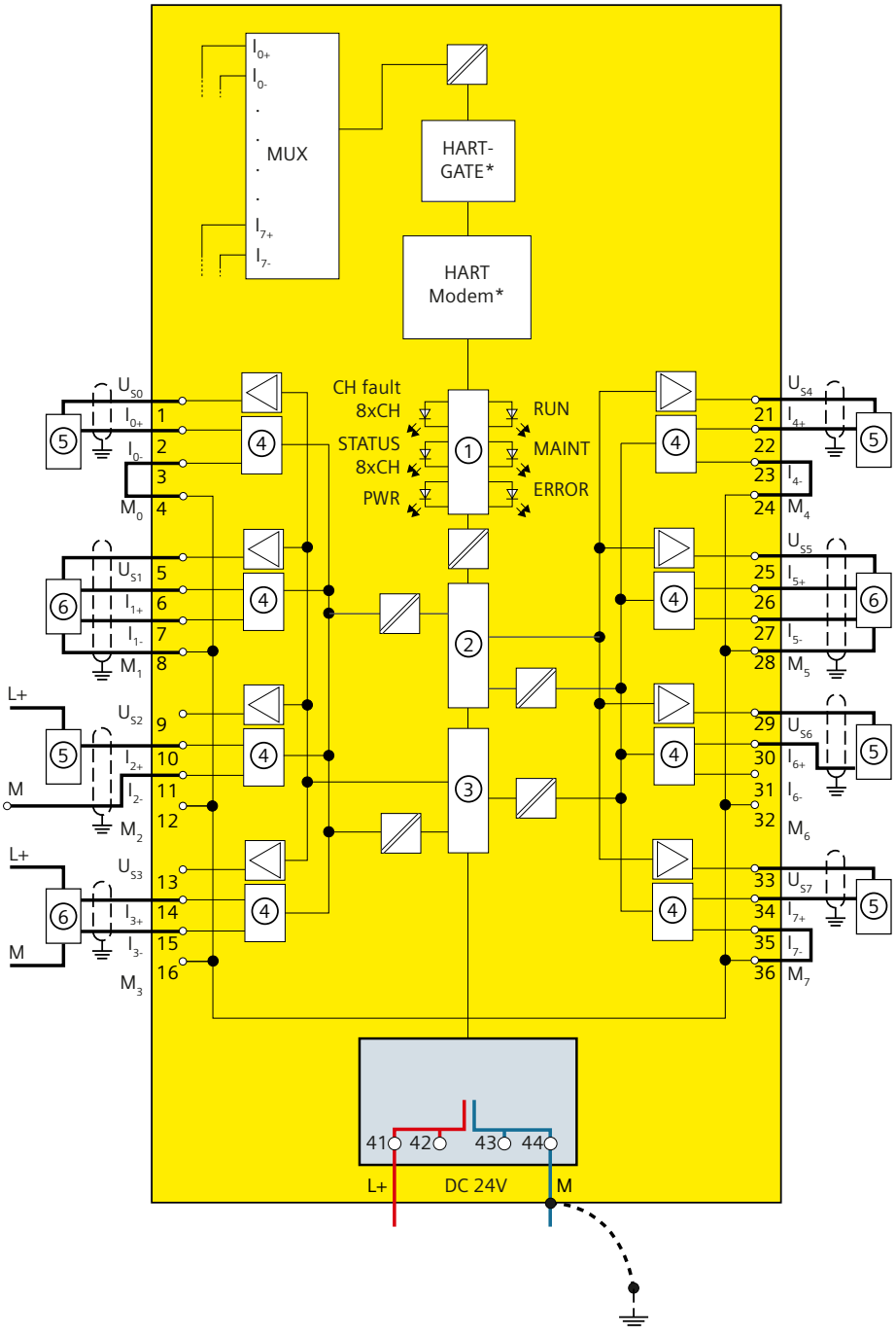
The sensor supply can be powered internally or externally.

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 version 2.0.

Figure 6-3 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 6-3 Parameters for application case 2 of F-AI 8xI 0(4)..20mA

Parameter	Value range in safety mode
Standard value	• MIN • MAX
Discrepancy time	100 to 30000 ms
Tolerance window % absolute	0.3 to 20.0%
Tolerance window % relative	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 to 20 mA • 4 to 20 mA
Diagnostics: Wire break	(in the measuring range 4 to 20 mA) • Disable • Enable
Smoothing	1 / 2 / 4 / 8 / 16 / 32 / 64 conversion cycles

Interrupts/diagnostic messages

7

7.1 Status and error displays

LED displays

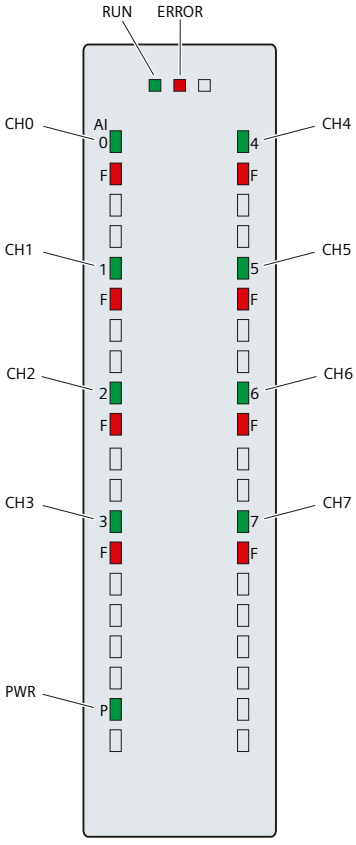


Figure 7-1 **LED displays of the F-AI 8xI 0(4)..20mA** module

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 51).

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 7-1 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)).

PWR LED

Table 7-2 PWR status display

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

CHx LED

Table 7-3 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 7-4 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 7-5 Channel status/channel diagnostics/RUN/ERROR display if power supply error occurs

CHx status	Diagnostics CHx	RUN	ERROR	Meaning
□ Off	■ On	■ On	☼ Flashing	• Supply voltage too high or too low. • Module is waiting for user acknowledgment.

7.2 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 51).

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 51)

Table 7-6 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		F-module	
Supply voltage missing	11_H			
Communication fault	13_H			
Channel/component temporarily not available	$1F_H$		Channel	
Mismatch of safety destination address (F_Dest_Add)	40_H		F-module	
Safety destination address not valid (F_Dest_Add)	41_H			
Safety source address not valid (F_Source_Add)	42_H			
Safety watchdog time value is 0 ms (F_WD_Time)	43_H			
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)	$4B_H$			

Diagnostic interrupt	Fault code	Signaled in application case	Scope of diagnostic interrupt	Configurable
F_Block_ID not supported	$4C_H$	1, 2	F-module	No
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	$13E_H$			
Analog input signal not recorded unique	304_H			
Internal sensor supply short-circuit to P	306_H		Channel	Yes
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			
Supply voltage too high	321_H			
Supply voltage too low	322_H			
Safety related HART shutoff defective	$32A_H$			
F module error (0x032F)	$32F_H$			
ADC failure	331_H		Channel	No
Failure in the test circuit	332_H			

7.3 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 7-7 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 56)) 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
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.
Safety destination address not valid (F_Dest_Add)	41_H	The firmware of the F-module has detected an illegal different F-destination address.	

Diagnostic alarm	Fault code	Meaning	Remedy
Safety source address not valid (F_Source_Add)	42_H	The firmware of the F-module has detected a different F-source address.	• Assign the PROFIsafe address to the F-module (again).
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.
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.

Diagnostic alarm	Fault code	Meaning	Remedy
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.
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.
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 56))

Diagnostic alarm	Fault code	Meaning	Remedy
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 signal module	Replace the signal 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.

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 56)), 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 39)

7.4 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 signal. 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 37).

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

8

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

The table below shows the technical specifications as of 08/2023. 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 or higher
Operating mode	
• MSI	No
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
Power	
Power available from the backplane bus	0.5 W

Article number	6ES7536-1MF00-0AB0
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; Differential inputs
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 %
Basic error limit (operational limit at 25 °C)	
• Current, relative to input range, (+/-)	0.05 %
Interference voltage suppression for f = n x (f1 +/- 1 %), f1 = interference frequency	
• Series mode interference (peak value of interference < rated value of input range), min.	40 dB
• Common mode voltage, max.	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 limit in complete temperature range

⚠ WARNING

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

Dimension drawing

See system manual S7-1500 Automation System (https://support.industry.siemens.com/cs/ww/en/view/59191792).

Response times

A

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 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 × Conversion cycle time × 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 × Smoothing + Discrepancy time + Conversion cycle time
  Maximum response time = 2 × Conversion cycle time × Smoothing + Discrepancy time + 2 × Conversion cycle time
- According to the following formula if a channel fault is present:
  Typical response time = Conversion cycle time
  Max. response time = 2 × 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

B

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 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 . . 27649	$7EFF_H$ . . $6C01_H$	23.518 mA . . 20.0007 mA	Overrange
27648 . . 614	$6C00_H$ . . 266_H	20 mA . . 0.4442 mA	Nominal range
613 . . 1 0	265_H . . 1_H 0_H	< 0.4442 mA . . 723.4 nA 0 mA	Wire break

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

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	