SIEMENS

SIMATIC

Automation Systems
S7-300, ET 200M Ex I/O Modules

Manual

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Legal information

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

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

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

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

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Preface

Purpose of the manual

This manual will help you to

- plan,
- install,
- and operate a SIMATIC S7 ex module for an automation system in a hazardous area.

Basic knowledge required

General knowledge of automation engineering is required to understand this manual.

You should be familiar with the fundamentals of explosion protection, with the identification of explosion-protected equipment and with the regulations regarding explosion protection.

Validity of the manual

This manual is valid for all the SIMATIC S7 ex modules listed by order number in the following table.

Table 1 S7-300 I/O modules

SIMATIC S7 ex module	Order number
SM 321; DI 4 x NAMUR	6ES7321-7RD00-0AB0
SM 322; DO 4 x 24V/10mA	6ES7322-5SD00-0AB0
SM 322; DO 4 x 15V/20mA	6ES7322-5RD00-0AB0
SM 331; AI 8 x TC/4 x RTD	6ES7331-7SF00-0AB0
SM 331; AI 4 x 0/4...20mA	6ES7331-7RD00-0AB0
SM 332; AO 4 x 0/4...20mA	6ES7332-5RD00-0AB0
SM 331; AI 2 x 0/4...20mA HART	6ES7331-7TB00-0AB0
SM 331; AI 2 x 0/4…20mA HART	6ES7331-7TB10-0AB0
SM 332; AO 2 x 0/4...20mA HART	6ES7332-5TB00-0AB0
SM 332; AO 2 x 0/4...20mA HART	6ES7332-5TB10-0AB0

For information on CPUs or IM 153-x versions which support this module, refer to the STEP 7 Hardware Catalog.

Changes since the previous edition of the manual

The section below outlines the changes this manual contains compared to the previous version:

- The HART analog modules 6ES7331-7TB10-0AB0 and 6ES7332-5TB10-0AB0 have been added.

Position in the information scheme

Depending on the application, you will need the following documentation to understand this manual:

- **S7-300**: Hardware and Installation, CPU data, module specifications and instruction list
- **ET 200M**: Distributed I/O device
- **Distributed I/O Devices S7-300, M7-300, ET 200M**: Manual

Guide

The manual covers the following subject areas:

- At the beginning of this manual you will find a complete table of contents.
- Chapter 1 explains the mechanical configuration of an automation system with SIMATIC S7 Ex modules
- Chapter 2 describes the SIMATIC S7 Ex digital modules
- Chapter 3 describes the SIMATIC S7 Ex analog modules
- Chapter 4 describes the SIMATIC S7 HART analog modules
- Important terms are explained in the glossary.
- You can use the index to find the key parts of the manual.

Approvals

See Appendix Standards and approvals (Page 249)

CE marking

See Appendix Standards and approvals (Page 249)

Mark for Australia (C-Tick-Mark)

See Appendix Standards and approvals (Page 249)

Standards

See Appendix Standards and approvals (Page 249)

Recycling and disposal

You can recycle the Ex I/O modules because they are made of low-toxicity materials. To recycle and disposal of your old device in an environmentally friendly way, please contact a company certified to deal with electronic waste.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (http://www.siemens.com/industrialsecurity).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (http://support.automation.siemens.com).

Table of contents

Mechanical Configuration of an Automation System with SIMATIC S7 Ex Modules

1

1.1 Use

Overview

The SIMATIC S7 Ex modules can be used in the systems:

- S7-300,
- ET 200M.

The HART analog modules SM 331; AI 2 x 0/4…20mA HART and SM 332; AO 2 x 0/4...20mA HART can be used in the ET 200M system.

For installation purposes, you must therefore comply with the configuration guidelines as specified in the corresponding manuals. In addition, further reference guidelines for SIMATIC S7 Ex modules are provided in this section. These must be taken into consideration.

1.2 Fundamental Guidelines and Specifications

Note

Note

Ex systems may only be installed by authorized personnel.

Approvals

The SIMATIC S7 Ex modules have the following approval

II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc. This means they can be installed in a non-hazardous area and also in zone 2 (category 3G) if certain conditions are adhered to. Only intrinsically safe electrical equipment (actuators/sensors) permitted in zones 1 and 2 can be connected to the SIMATIC S7 Ex modules. The approval applies to all potentially explosive gas mixtures in Groups IIC. The safety-related limits can be found in the certificates of conformity.

The certificates of conformity and explanations of the designations can be found on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200).

FM approval

The SIMATIC S7 Ex modules have the following FM approvals:

- Class I, Division 2, Group A, B, C, D Tx;
- Class I, Zone 2, Group IIC Tx

Therefore, the modules can be used in areas that contain volatile flammable liquids or flammable gasses which are normally within closed vessels or systems, from which they can only escape under abnormal operating or fault conditions. The approval applies to all test gasses. A surface temperature no greater than 135 °C (T4) occurs at ambient temperatures of 60 °C.

Safe extra low voltage

SIMATIC S7 Ex modules must be operated with a "safe functional extra low voltage". The module may thus only be subject to a fault voltage of U < 60 V. You can find more detailed information on the safe extra low voltage in, for example, the data sheets for the power supplies to be used.

All system components which can supply electrical energy in any form whatsoever must fulfill this condition. This includes in particular:

- the power supply module PS307. It fulfills this condition.
- the MPI interface. It fulfills this condition when all users operate with safe extra low voltage. SIMATIC automation systems and programming units also fulfill this condition.
- 115/230 V modules. Even if they are used in another cell or in another programmable controller they must feature safe extra low voltage on the system side (i.e. towards the backplane bus).

Any other current circuit (24 VDC) integrated in the system must be operated with ESLV. Refer to the corresponding data sheets or consult the manufacturer.

Note that the I/O modules also support the connection of sensors and actuators with auxiliary power supply. Also ensure a safe extra low voltage is used in this case. The voltage level of the process signal at a 24 V digital module **may never reach a fault voltage U_m > 60V**. This also applies to non-intrinsically safe components.

Note

All power sources such as the internal or external 24 VDC load voltage supplies and the 5 V bus voltage must be appropriately interconnected galvanically, so that voltage addition as a result of potential differences is not liable to generate a fault voltage which exceeds U_m. You can achieve this state, for example, by referencing all power sources of the system to functional ground. Also refer to the instructions provided in the relevant manuals (see Foreword) for this purpose. The maximum possible fault voltage U_m in the system is 60V.

Minimum thread measure

A minimum thread measure of 50 mm must be maintained between connections with safe functional extra low voltage and intrinsically safe connections. The process connector features a cable chamber in order to meet this requirement.

Certain module components may prevent you from maintaining this thread measure. In this case, you should install a DM 370 dummy module, and set it up so that it does not use any address space. If you use the ET 200M Distributed I/O, you should observe the information regarding the configuration.

Also take care with regard to the wiring to ensure this specified spacing is maintained between intrinsically safe and non-intrinsically safe connections.

Combined use of Ex and non-Ex I/O modules

Combined use is possible, however, the minimum thread measure between conductive parts of Ex and non-Ex modules must be maintained in all cases. As a rule, you must install a DM 370 spacer module between Ex and non-Ex modules. Always separate the intrinsically safe from the non-intrinsically safe wiring. They must be routed in separate cable ducts. A mixed operation is therefore not recommended.

Partition

The Ex partition must be fitted to achieve the minimum thread measure of 50 mm between Ex and non-Ex modules when using the bus module of the active backplane bus.

Load current circuit

Power is supplied to the Ex sensors and actuators (to 4-wire transducers, for example) either from the Ex modules, or via separate, intrinsically safe power supply modules.

The Ex I/O modules receive their power supply via the backplane bus. The 24VDC load voltage input of the front connector is required for the power supply of the Ex sensors and the Ex actuators on the majority of modules.

Connecting Ex I/O modules

The Ex I/O modules are configured in the same way as standard modules from left to right. Wire the Ex sensors and actuators to the process connector, include any load voltage supply using the cable chamber, and then plug the connector into the module.

Note

If necessary, a safety assessment of this intrinsically safe power circuit should be carried out by an expert before a sensor or actuator is connected to an Ex module.

Replacing Ex I/O modules

After being plugged in for the first time, the front connector adopts the module type coding set at the factory. This setting prevents you from unintentionally replacing the module with a different type, i.e. the front connector's mechanical coding prevents snap-on mounting on an incorrect module type. thus fulfilling explosion protection requirements. When replacing Ex modules, carry out the necessary steps in the order described below:

- **Configuration**

1. Disconnect the L+ load voltage supply
2. Unplug the front connector
3. Remove the module

- **Mounting**

1. Install the module
2. Plug in the front connector
3. Connect the L+ load voltage supply

See also

Overview of diagnostic functions (Page 247)

The LK 393 line chamber (Page 14)

Configuration of an S7-300 with Ex I/O Modules (Page 17)

Configuration of an ET 200M with Ex I/O modules (Page 20)

1.3 The LK 393 line chamber

Scope of application

With the exception of the analog input module SM 331; AI 8 x TC/4 x RTD, all Ex I/O modules require a 24V DC load voltage supply via the process connector. Safety isolation of this signal in order to maintain the minimum thread measure between Ex and non-Ex areas is achieved by using the LK 393 line chamber (Order No. 6ES7393-4AA00-0AA0). Process signals are carried downward while the 24V supply is routed upward in separate ducts.

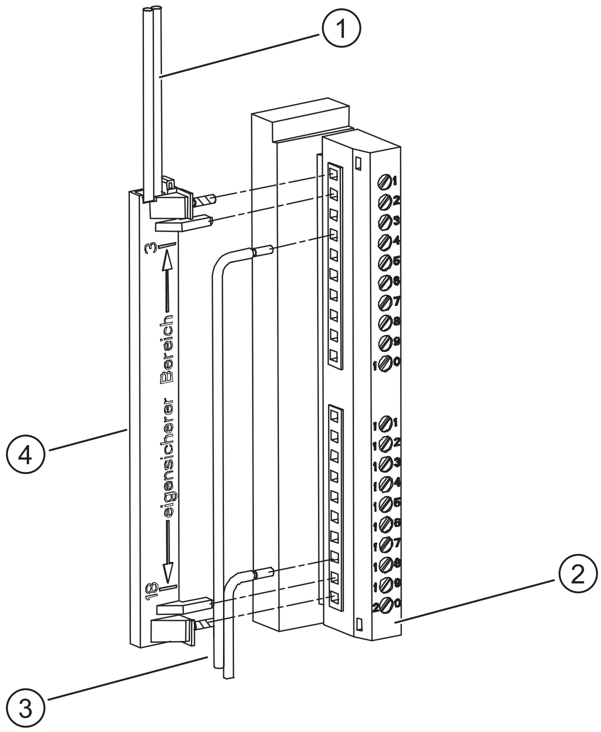
When using the LK 393 line chamber, you must always use the front connector with screw-type contacts. If you use the front connector with spring contacts, the front door of the module can no longer be closed.

Connecting the line chamber

1. The lines of the L+ and M connections are cut to the required length, their insulation is stripped and wire end ferrules are fitted.
2. The conductor ends with the ferrules are passed through the openings in the LK 393 line chamber until they are flush with the fastening pins.
3. The conductors are then pressed into the guide ducts of the LK 393 line chamber and routed upward (secure with hot-melt adhesive if necessary).
4. The line chamber pre-assembled in this way is now inserted in the terminals of the front connector.
5. The wire end ferrules of L+ and M are screwed to the terminals 1 and 20 and the fastening pins to terminals 2 and 19.

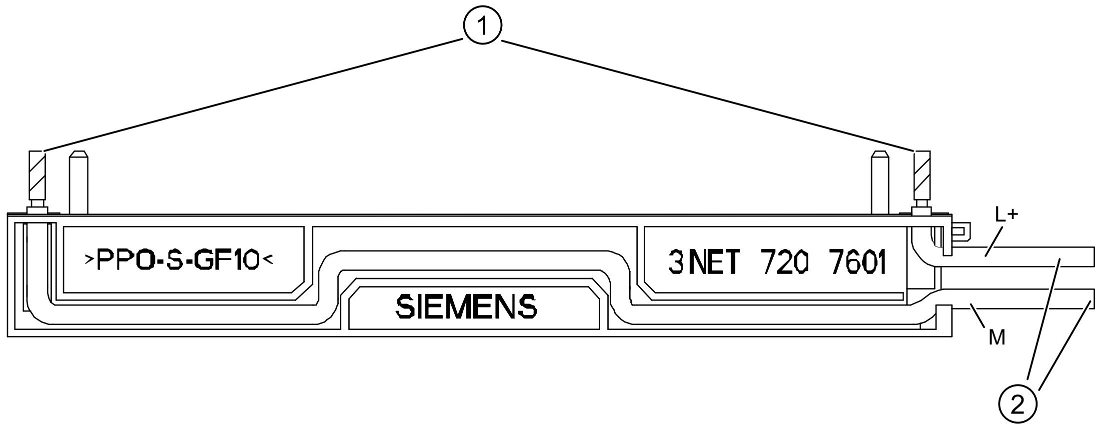
This ensures a firm connection of the line chamber with the front connector, thus fulfilling explosion protection safety requirements.

The following figs.illustrate the configuration.



①	Load voltage supply
②	Process connector with screw-type connection
③	Ex (i) process cables
④	Line chamber

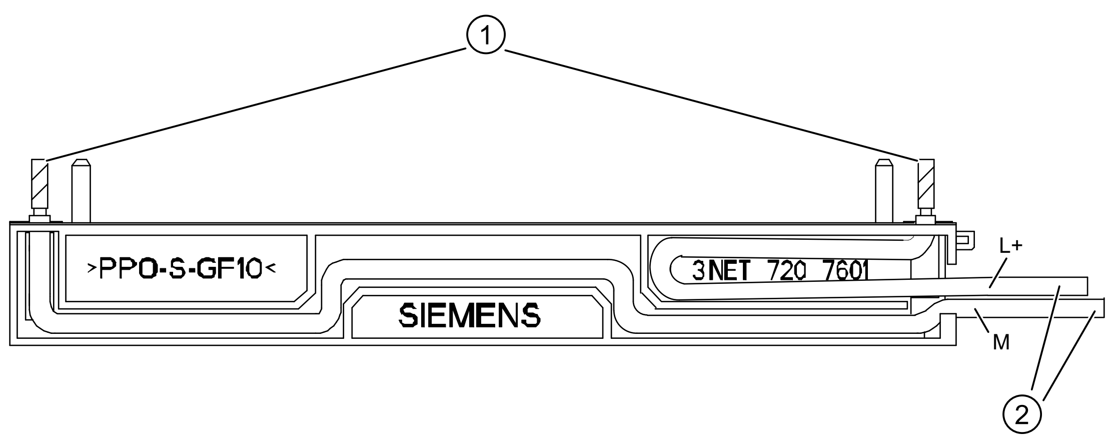
Image 1-1 Connecting the LK 393 line chamber



① Wire end ferrule

② Diameter > 2 mm

Image 1-2 Inserting the connecting cables of the load voltage in the line chamber. Outside diameter of the wires > 2 mm (viewed from below)



① Wire end ferrule

② Diameter < 2 mm

Image 1-3 Insert the L+ line in a loop in the line chamber. Outside diameter of the wires < 2 mm (viewed from below)

Note

Use Ex I/O modules which require a 24V load voltage exclusively with the LK 393 line chamber. It is necessary for ensuring the modules are used for their intended purpose.

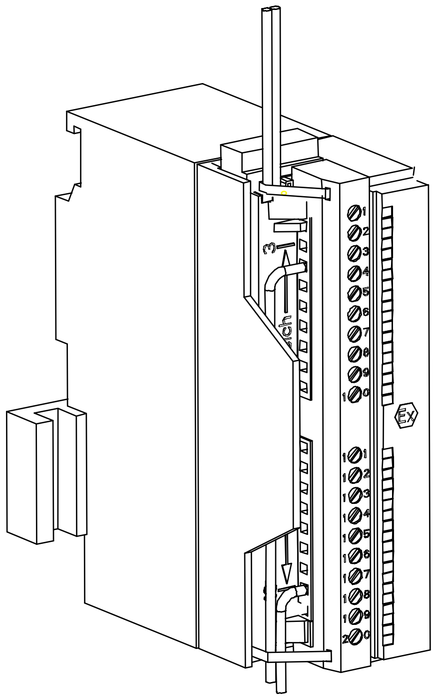


Image 1-4 LK 393 line chamber when connected

You can, of course, also use Ex I/O modules for non-intrinsically safe tasks. You will not need the line chamber in this case. However, you must then clearly and permanently cancel the Ex identification symbol. Subsequent use for Ex applications is no longer possible unless you return the module to the manufacturer for testing.

1.4 Configuration of an S7-300 with Ex I/O Modules

General information

Physical isolation of non-Ex signals from Ex signals corresponds to the requirements with regard to the configuration of explosion-protected automation technology. If the minimum distance of 50 mm between bare connection terminals of Ex modules and bare connection terminals of non-Ex modules **can not** be maintained, a DM 370 spacer module (order number 6ES7 370-0AA00-0AA0) must be fitted between these modules. Care must be taken to ensure that all automation systems are routed to a common ground.

This means:

- All earthing screws of the sectional rails must be referred to a common ground.
- The earthing clip of all CPUs must be locked in position.

Spacing for arrangement on several subracks

The following figure shows the spacing dimensions between the individual subracks as well as to adjacent items of apparatus, cable ducts, cabinet panels etc. for a two-tier S7-300 configuration.

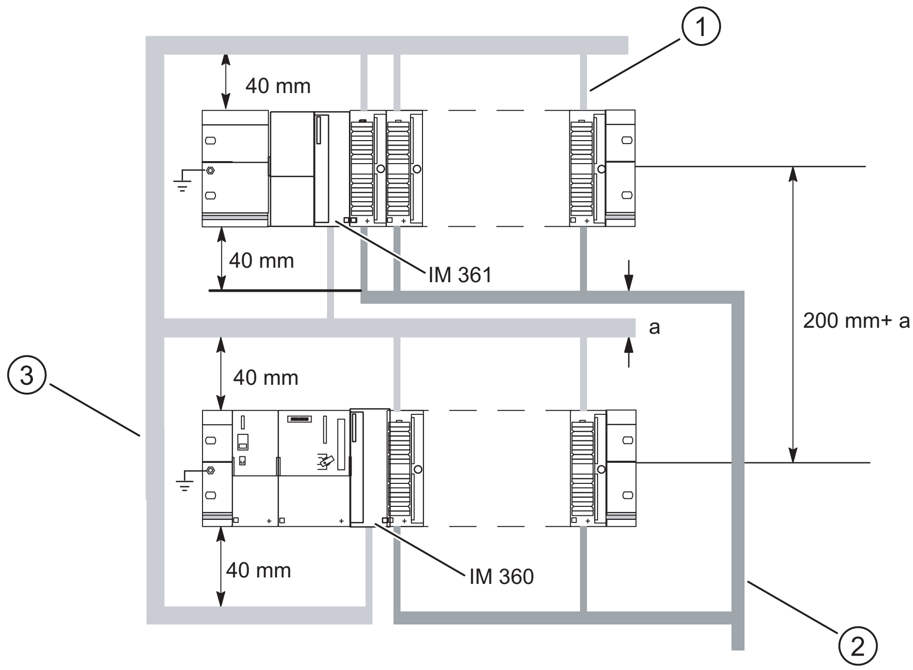


Image 1-5 Spacing dimensions for a two-tier S7-300 configuration

① L+ supply
② EX CABLE DUCT
③ NON-EX (24V) CABLE DUCT

If you maintain these minimum spacing dimensions then:

- you will guarantee heat dissipation of the S7-300 modules
- you will have sufficient space to insert and remove the S7-300 modules
- you will have sufficient space for installing lines

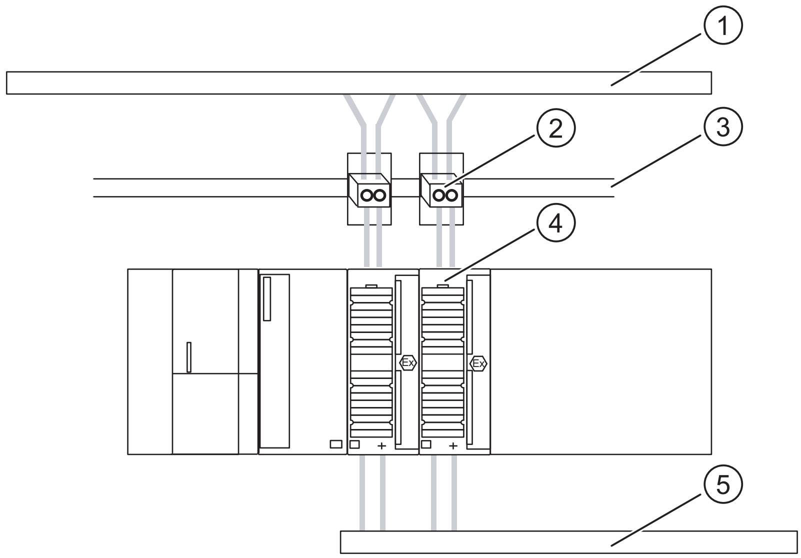
Note

If you use a shield support element, the specified dimensions apply as from the lower edge of the shield support element.

The L+/M lines on the Ex modules can be wired directly or via connection elements.

For direct wiring, route the L+/M lines from the cable duct (if a line chamber is used) directly to the terminals of the module front connector. You can route the Ex process lines directly from the front connector to the apparatus.

You can use commercially available clamp-type distributors for wiring via connection elements. You then have the option of disconnecting the L+/M supply lines module by module by means of a plug connector (see Fig. below).



① Non Ex-cable duct
② Connection elements
③ 15 mm top-hat rail
④ Ex modules
⑤ Ex cable duct

Image 1-6 Wiring between L+/M lines and Ex modules via connecting elements

See also

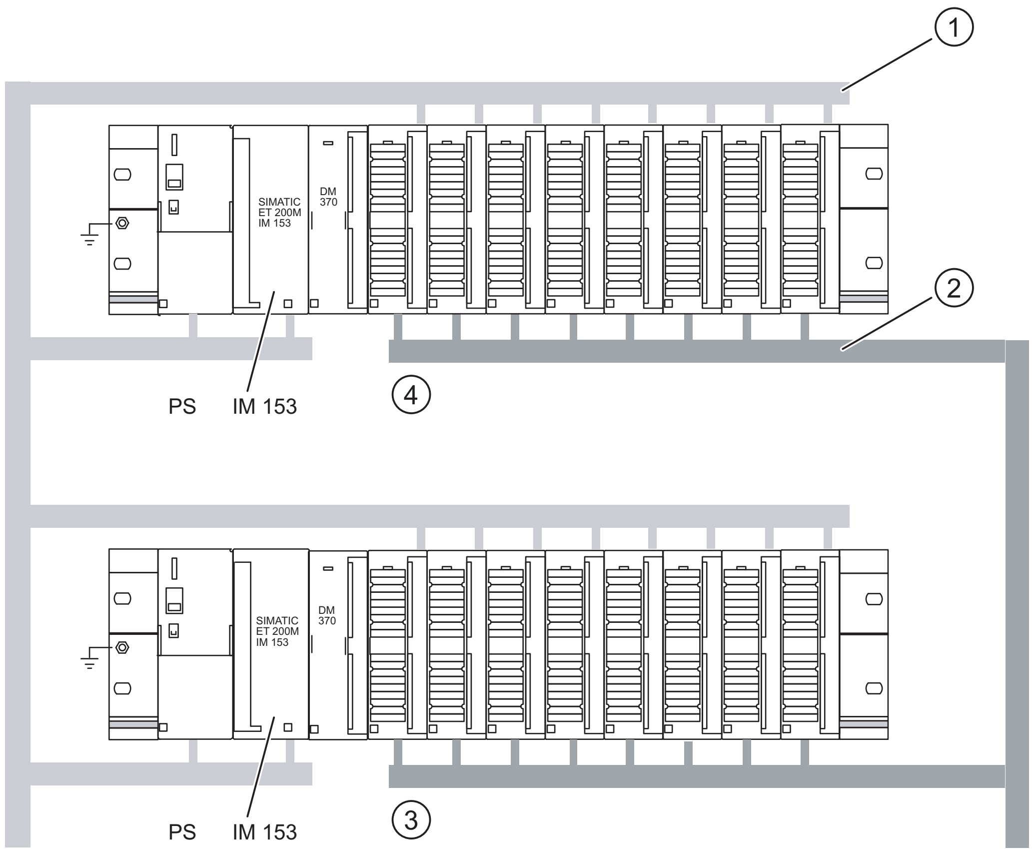
The LK 393 line chamber (Page 14)

Summary of Requirements of EN 60079-14 (Page 27)

1.5 Configuration of an ET 200M with Ex I/O modules

ET 200M configurations on two subracks

The Figure shows you two ET 200M configurations on two subracks. Place a DM 370 dummy module between the IM153 and the first Ex I/O module in such a way that it doesn't occupy any address area. If you are using an active backplane bus, use an Ex partition (order number 6ES7195-1KA00-0XA0) instead of the dummy module.



①	NON-EX CABLE DUCT
②	EX CABLE DUCT
③	S7-300 modules
④	S7-300 modules

Image 1-7 Two subracks with ET 200M

1.6 Equipotential bonding of explosion protected systems

General

Potential differences may develop between the bodies of electrical equipment which are bonded to a protective conductor and the conductive elements of the construction which do not belong to the electrical equipment, for example, the piping. The bridging of such potential differences may cause ignition sparks. Equipotential bonding requires that conductive metal parts which are not touch-protected are interconnected with the ground conductor. A practical central point for equipotential bonding is the distribution cabinet. The cross-section of the equipotential conductor should at least be equivalent to that of the corresponding protective conductor. In all other situations, the minimum cross-section of the equipotential conductor is 10 mm^2 Cu.

The backplane bus and I/O power circuits of Ex modules feature galvanically isolated, i.e. equipotential bonding is not required for these modules. Exception: Connection to the equipotential conductor if this is necessary for reasons of measuring technology. Where lightning protection devices are required in the intrinsically safe circuit, they must be connected to the EB conductor at the same point as the shield of the intrinsically safe circuits.

Generally speaking, the measures described in EN 60079-14 should be used or adhered to.

Generally, cable racks must be incorporated throughout the earthing system.

Equipotential bonding in buildings

All buildings must be equipped with an equipotential bonding facility, to VDE 0100, Parts 410 / 540 and to DIN VDE 0185, which is interconnected with the overall cabling of the automation system. Such facilities if missing must be installed.

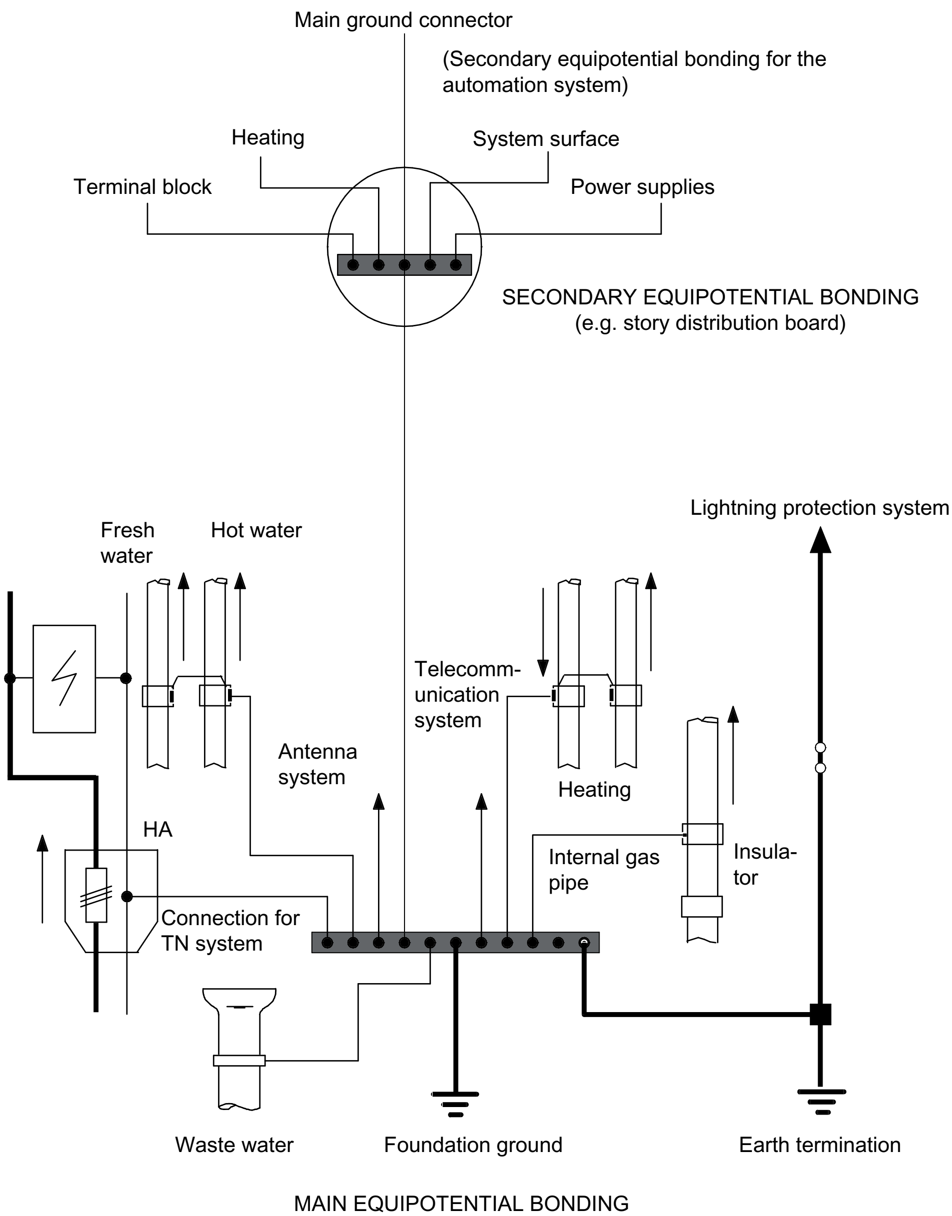


Image 1-8 Main and secondary equipotential bonding to VDE

Main equipotential bonding

This interconnects the following conductive elements by the EB conductor on the EB bus: A_{PA} = 0.5 x $_{APE\ main}$

- PE conductor
- Main ground conductor
- Earth termination
- Main water pipes
- Main gas pipes
- other metal piping systems
- Metal structural elements of the building (if possible)
- power and information system cables extending beyond the building, via lightning conductor.

Additional equipotential bonding

Connecting the following conductive elements by the EB conductor on the EB bus:

- All "extraneous conductive elements" such as structural elements, supports, containers, piping (these can themselves form EB conductors), A_{PA} = 0.5 x A_{PEmax} (A = cable cross section) from the distrib. board.
- The bodies of stationary electrical equipment which can be touched simultaneously, if interconnected with PEN (PE connection is sufficient otherwise), A_{EQ} = 0.5 x A_{PE} of both appliances.

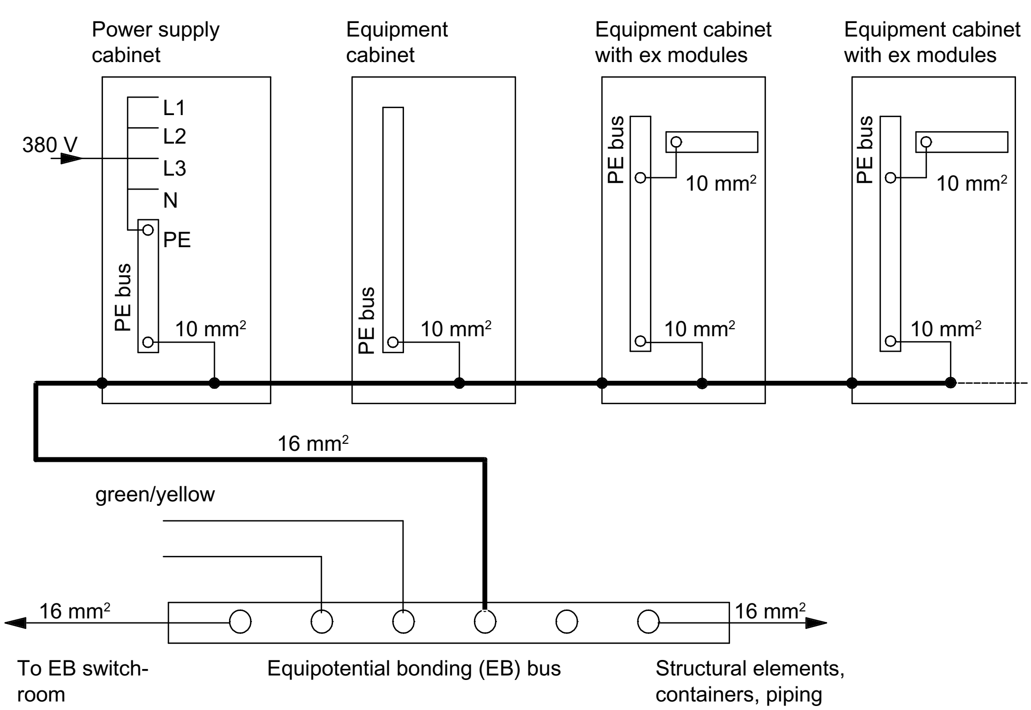


Image 1-9 Example of equipotential bonding in M&C systems

See also

Measures (Page 39)

1.7 Wiring and Cabling in Ex Systems

1.7.1 General information

Measures

Neither the electrical installation nor the required materials for this such as cables, lines and installation materials are subject to the special test procedure of ElexV with respect to their design. The responsibility of plant personnel or of an installation company for the proper installation of an Ex system is particularly high on account of the risk of explosion in the event of improper implementation.

General planning principles for cable routes are very similar to those for piping. At the drafting stage of installation plans and building layouts, areas with increased risk of fire and danger zones must be defined in accordance with ElexV and VbF. The focus should be set on cable and piping tray installations in low-risk areas. Furthermore, accessibility and ease of maintenance must be ensured, also for subsequent expansion. The cabling and line duct passages between the control rooms and operational danger areas must be sealed appropriately in order to prevent any ingress of dangerous gases or fumes into the control room.

Note

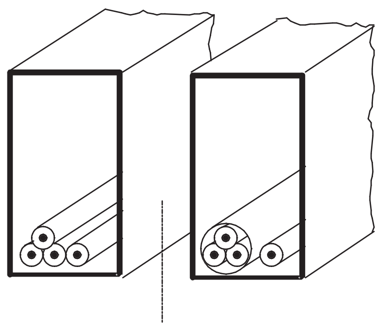
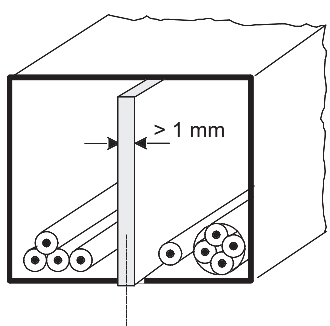
Laying cables in ducts in the floor should be avoided. There is the risk

- of the penetration or the formation of potentially explosive gas / air mixtures and their uncontrolled propagation,
- penetration of corrosive liquids.

The flexible multicore and single conductor cables used to install intrinsically safe power circuits only require a diameter of ≥ 0.1 mm. For implementation in the Ex area, cables and lines must primarily withstand the expected mechanical, chemical and thermal effects. It is therefore always necessary to lay considerably larger cross sections and use cables and lines that are flame-retardant and oil-resistant.

Intrinsically safe and non-intrinsically safe lines (conductors, non-sheathed cables) must be laid separately or with appropriate insulation. Common routing in cables, lines and conductor bundles is not permissible.

Special care must be taken to ensure full isolation in cable ducts. This can be achieved with a continuous intermediate 1 mm layer of insulating material or by laying sheathed cables (see following table).

Routing of cables for intrinsically safe circuits	
	Cable routed in separate, insulating cable ducts
	Cables routed in a common cable duct with an insulating intermediate layer (the solid insulating intermediate layer of > 1 mm provides reliable isolation of the intrinsically safe lines in accordance with EN 60079-11).

Any cables of intrinsically / not intrinsically safe circuits with common routing must be capable of withstanding a minimum test voltage of 500 V AC.

The high insulation voltage of 500 V AC can be dispensed with if the intrinsically safe or non-intrinsically safe circuits are enclosed in a grounded shield. However, the cables of intrinsically safe circuits must be capable of withstanding at least 500 VAC (conductor-conductor-ground).

Intrinsically safe lines must be clearly marked. If a color is used, it must be light-blue. An exception to this rule is the routing of lines within equipment, distribution panels and switchrooms. Cables and lines thus marked must not be used for other purposes.

In general, intrinsically safe circuits must be installed in a floating arrangement. A connection to ground via a 15 kOhm resistor, e.g. to discharge electrostatic charges, does not qualify as a ground. Intrinsically safe circuits must be bonded to ground if necessary for reasons of measuring technology or safety. The circuit may only be grounded once to the equipotential bonding system. Equipotential bonding must exist in the entire installation of intrinsically safe circuits.

The terminal elements of systems which contain intrinsically / not intrinsically safe circuits, for example, in measuring and control cabinets, must comply with EN 60079-11 directives. The connections of the intrinsically safe circuits must be marked as intrinsically safe. Light-blue must be used if color coding is preferred.

1.7.2 Marking of Cables and Lines of Intrinsically Safe Circuits

Marking

Cables and lines of intrinsically safe circuits must be marked. Where jackets or sheaths are color-coded, light-blue must be chosen as the color. Cables and lines thus marked must not be used for other purposes. Equalizing conductors for thermocouples with a plastic sheath may be provided with colored longitudinal stripes as follows, according to the type of thermocouple:

Copper/cupro-nickel (copper/constantan)	brown
Iron/cupro-nickel (iron/constantan)	dark blue
Nickel-chrome/nickel	green
Platinum-rhodium/platinum	white

In the case of equalizing conductors for thermocouples with a mineral sheath or metal braid, a light-blue strip of sufficient width must be woven in as the color code for intrinsic safety.

Within measurement and control cabinets and in the interior of switching and distribution systems, special measures must be taken where there is a risk of interchanging the lines of intrinsically safe and non-intrinsically safe circuits, e.g. where there is a blue neutral conductor in compliance with DIN 47002.

The following measures are acceptable:

- Bundling of conductors in a common light-blue sheath,
- Labeling,
- clear arrangement and physical separation.

1.7.3 Wiring and Cabling in Cable Bedding Made of Metal or in Conduits

Protection measures

Cable bedding made of metal must be incorporated in the protective measures to counteract indirect contact. This can be achieved by routing an existing ground conductor made of steel strip or with a good conductive connection between individual beds.

For single laying, conduits made of metal are now only usually used where particular mechanical or thermal stress is developed. In general, PVC conduits of two different types are used depending on the expected mechanical stress. Remember, however, that PVC exhibits a linear expansion which is about 8 times that of metal. The fixing points must therefore be such that the linear expansion is taken up.

1.7.4 Summary of Requirements of EN 60079-14

Overview

The table below once again highlights the most important cable and conductor specifications to EN 60079-14.

Table 1-1 Cables and lines

application	Requirements of cables and lines	
General requirements: note additional requirements for "i" and zone 0)	• Select according to mechanical, chemical and thermal influences (refer to DIN VDE 0298 and DIN VDE 0891)	
	• Protection against the distribution of fire. Cable routing in sand, for example. Proof of combustibility properties of cables in accordance with DIN VDE 0472 part 804, test type B.	
	• Cu or Al conductors. Al conductors should only be used when installing multicore cables starting at 25 mm^2, or single-conductor cables starting at 35 mm^2, using suitable terminal elements.	
(smaller cross section permissible for multicore lines with more than 5 cores, and lines for measurement and control)	• Minimum cross sections for copper conductor: single-core cable: multi-core cable:	1 mm fine, 1.5 mm solid conductor 0.75 mm fine, otherwise as above
Permissible types for portable/mobile apparatus (does not apply to intrinsically safe systems)	• U <= 750 V	Flexible cable H07RN or equivalent (e.g. NSHou)
	• U <= 250 V	flexible cable H07RN or equivalent
	• I <= 6 A	no severe mechanical stresses
	• in M&C systems, Wire remote control and telecommunications system	Plastic-sheathed flexible cable H05VV-F minimum cross section 1 mm^2 (not at ambient temperatures below 5 °C)

Table 1-2 Contents of EN 60079-14, continued

Application	Requirements of cables and lines
Laying cables and lines	• Sealing of cable passages in Ex and non-Ex areas, for example, by means of sand pockets, plastering or similar. • Sealing of unused cable inlets using certified caps (certification not required for Zone 2) • where there is particular thermal, mechanical or chemical stress, protect cables and lines, e.g. by laying in conduit, sheaths, metal tubing (not in enclosed conduits) • where routed into a pressure-resistant enclosure, use certified cable lead-in elements.
Connection of cables and lines	• Conductors outside the appliance may only be connected by crimping. • Conductor connections within apparatus should use suitable clamps, multicore or fine conductor ends should be secured against separation • Crimp connections can be protected with cast resin applications or heatshrink sleeves, provided these are not subject to mechanical stress.

See also

Types of cables (Page 29)

1.7.5 Selecting the cables and wires in accordance with EN 60079-14

Specification

Cables and wires laid in hazardous areas do not require a test certificate in accordance with Elex V. The electrical data of cables used for intrinsically safe M&C circuits must be specified (for example, capacitance at 200 nF/km, inductivity at 1 mH/km).

The following applies within a group cable:
The insulation between lines of intrinsically safe and non-intrinsically safe circuits must

withstand an alternating voltage of 2U + 1000 V, but at least 1500 V, where U is the sum of rms voltage values of the intrinsically safe and non-intrinsically safe circuits.

Table 1-3 Minimum cross sections of copper conductors in accordance with

Cable type	Number of cores	Flexible stranded conductor mm^2	Solid conductor mm^2	Conductor diameter mm
Power cables and lines in accordance with DIN VDE 0298, Part 1, 3	1 2 - 5 > 5	1 0,75 0,5	1,5 1,5 1	-
Wiring cables and lines in accordance with DIN VDE 0891, Parts 1, 5, 6 for voltages	> 1	0,5	0,5	0,8
< AC 60 V or 120 V DC	2 > 2 2 (shielded)	0,5 0,28 0,28	0,5 0,28 0,28	0,8 0,6 0,6

1.7.6 Types of cables

Overview

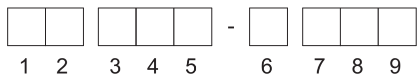
Suitable process signal cables are installation cables for industrial electronic systems (SIMATIC cable) with bundled twisted-pair, color-coded conductors. Cables with a solid conductor (0.5 mm^2 cross section, 0.8 mm diameter) have a static shield. Cables with flexible stranded conductors (J-LIYCY) have a braided shield (C) made of copper wires.

Table 1-4 Types of cables

Cable designation		Cable for
A-Y(St) YY	nx2x0.8/1.4 BdSi	Outdoor cable (burying in ground[1])
J-Y(St) Y	nx2x0.8/1.4 BdSi	Normal applications
J-LiYY	nx2x0.5/1.6 BdSi	Compact control stations
J-LiYCY	nx2x0.5/1.6 BdSi	Vibration and impact stresses
		Connector installation
[1] Direct burying in ground is not recommended.		

Type designations for lines in accordance with harmonized standards

The type designations for lines in accordance with harmonized standards are listed in the following:

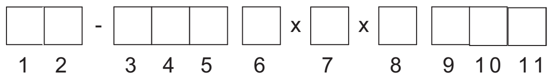


1	Basic type	H	harmonized type
		A	national type
2	rated voltage	03	300/300 Volt
		05	300/500 Volt
		07	450/750 Volt
3	insulating material	V	PVC
		R	Rubber
		S	silicon rubber
4	sheath material	V	PVC
		R	Rubber
		N	cloroprene rubber
		J	glass fiber braid
		T	fabric braid
5	Special features	H	ribbon cable, separable
		H2	ribbon cable, not separable
6	Conductor	U	single-core
		R	multi-core
		K	fine (permanently installed)
		F	fine (flexible)
		H	extra fine wire
		Y	tinsel
7	Number of cores	...	Number of cores
8	protective conductor	X	without protective conductor
		G	with protective conductor
9	conductor cross section	...	specified in mm^2

Image 1-10 Type designations for lines in accordance with harmonized standards

Type designations for telecommunication cables and lines

Type designations for telecommunication cables and lines are listed in the following:



1	Basic type	A	Outdoor cable
		G	Mining cable
		J	Wiring cable
		L	Sheathed cable
		S	Switchboard cable
2	Supplement	B	Lightning protection system
		J	Induction-protected
		E	Electronics
3	Insulating material	Y	PVC
		2Y	Polyethylene
		O2Y	Cellular PE
		5Y	PTFE
		6Y	FEP
		7Y	ETFE
		P	PAPER
4	Design features	F	Petrolatum filler
		L	Aluminum sheath
		LD	Corrugated aluminum
		(ST)	Aluminum tape
		(K)	Metal foil shield
		W	Copper tape shield
		M	Corrugated steel sheath
		Mz	Lead sheath
		B	Special lead sheath
		C	Armoring
		E	Jute sheath & ground
			Compound layer + tape
5	Sheath material		(refer to 3. Isolation)
6	Number of elements	n	Number of stranding elements
7	Stranding element	1	Single core
		2	Pair
8	Conductor diameter	...	in mm
9	Stranding element	F	Star quad (railway)
		St	Star quad (phantom)
		St I	Star quad (long distance cable)
		St III	Star quad (local cable)
		TF	Star quad for TF
		S	Signal cable (railway)

		PiMF	shielded pair
10	Type of stranding	Lg	Layer stranding
		Bd	Unit stranding
11	Sheath color	BL	blue

Table 1-5 Siemens cables for measurement and control to DIN VDE 0815

Cable designation		Order Number
JE-LIYCY	2x2x0.5 BD SI BL	V45483-F25-C15
JE-LIYCY	16x2x0.5 BD SI BL	V45483-F165-C15
JE-LIYCY	32x2x0.5 BD SI BL	V45483-F325-C55
JE-Y(ST)Y	2x2x0.8 BD SI BL	V45480-F25-C25
JE-Y(ST)Y	16x2x0.8 BD SI BL	V45480-F165-C35
JE-Y(ST)Y	32x2x0.8 BD SI BL	V45480-F325-C25
JE-Y(ST)Y	100x2x0.8 BD SI BL	V45480-F1005-C15

Characteristic values of cables for intrinsically safe circuits

Example: Cable type JE-LiYCY		
Coupling	200 pF/100 m	at 800 Hz
Working capacity	c. 200 nF/km	at 800 Hz
Working inductance	c. 1 mH/km	
Minimum bending radius for permanent installation		6 x line diameter
Temperature range, permanent installation		- 30 °C to 70 °C
	for moveable use	- 5 °C to 50 °C
Test voltage		core/core 2000 V, core/shield 500 V,
Loop resistance		c. 80 Ω/km

1.7.7 Requirements of Terminals for Intrinsically Safe Type of Protection

Requirements

These must be identifiable, for example by their type designation, and the following constructional requirements must be observed:

- Clearance in air and leakage path in accordance with EN 60079-0/EN 60079-11 between two connection elements of different intrinsically safe circuits must be at least 6 mm.
- Clearance in air and leakage path between connection elements of each intrinsically safe circuit and grounded metal parts must be not less than 3 mm.
- Marking of connection elements must be unambiguous and easily recognized. When a color is used for this purpose, it must be light blue.

The following must also be observed with regard to the use of terminals:

Connection terminals of intrinsically safe circuits must be at a distance of at least 50 mm from connection elements or bare conductors of any non-intrinsically safe circuit, or must be isolated from it by an insulating partition or grounded metal partition. When such partitions are used, they must extend at least by up to 1.5 mm from the housing panels, or must ensure a minimum clearance of 50 mm between connection elements, measured around the partition in all directions.

The insulation between an intrinsically safe circuit and the chassis of the electrical apparatus or parts which may be grounded must withstand an alternating rms voltage of twice the voltage value of the intrinsically safe circuit, but at least 500 V.

1.8 Shielding and Measures to Counteract Interference Voltage

1.8.1 Shielding

Definition

Shielding is a method of attenuating magnetic, electric or electromagnetic interference fields. Shielding can be subdivided into

- Equipment Shielding
- Line Shielding

1.8.2 Equipment Shielding

General information

Particularly observe the following when cabinets and housings are incorporated in control system shielding:

- Cabinet covers such as side panels, rear panels, top and bottom panels, must make contact in an overlapping arrangement at adequate distances (e.g. 50 mm).
- Doors must be given additional contact with the cabinet ground. Use several grounding strips.
- Lines exiting the shielded housing should either be shielded or routed via filters.
- Where the cabinet contains sources of severe interference (transformers, lines to motors, etc.), they must be partitioned from sensitive electronic areas with metal plates. The metal plates must have several low-impedance bolted joints to the cabinet ground.

Interference voltages picked up in the programmable controller via non-Ex signal and supply lines are diverted to the central ground point (standard sectional rail).

The central ground point should have a low-impedance connection to the PE conductor via a copper conductor (> = 10 mm^2) which is as short as possible.

1.8.3 Line Shielding

Non-Ex circuits

Both ends of the cable shields are usually bonded to cabinet potential at a suitable conductive point. Satisfactory suppression of all frequencies picked up can only be achieved by shielding at both ends.

Shielding of systems with optimal equipotential bonding

Vital aspects in the optimization of a system's EMC properties are the shielding of system components and, in particular, of their connecting cables, and that the system shielding forms an encompassing electrical shell. The significance of this requirement increases with the scope of signal frequencies processed in the systems. In ideal cases, the cable shields are connected to the housings which are often metal or corresponding shielding of the connected field devices. Since, as a rule, they are linked to chassis ground (or to the PE conductor), the shield of the signal cable is grounded at several points. This procedure is optimum for electromagnetic compatibility and personal protection. It can be applied in these systems without any restrictions.

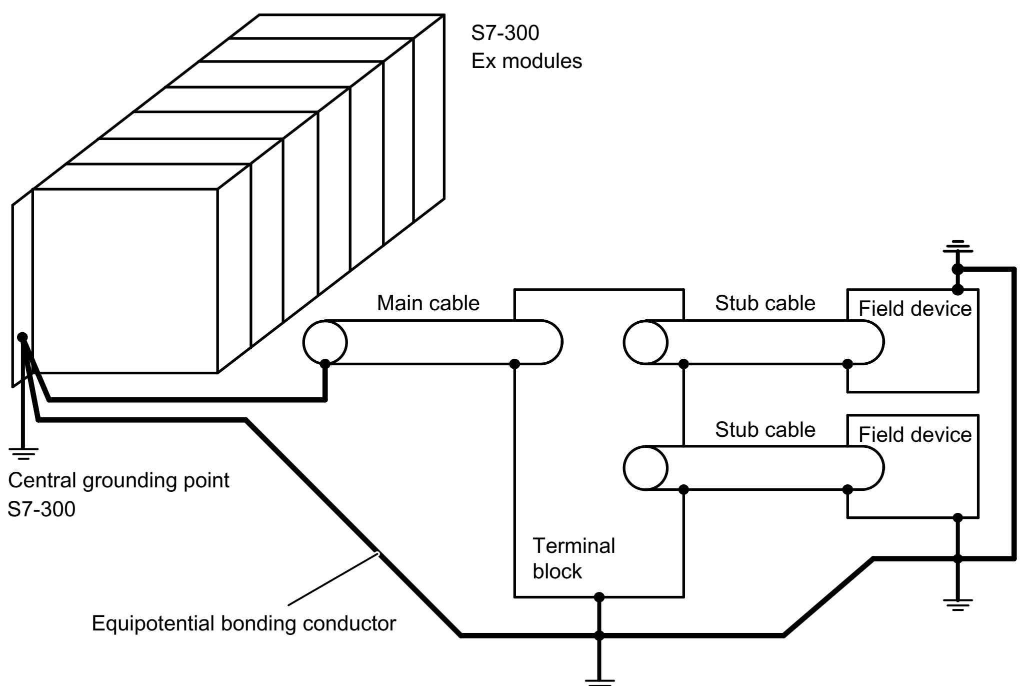


Image 1-11 Shielding and equipotential bonding conductors for non-Ex circuits

Ex circuits

Three aspects must be considered with regard to the design of shielding and grounding of an S7-300 system:

- Ensuring electromagnetic compatibility (EMC)
- Explosion protection
- Personal protection

Grounding and shielding of intrinsically safe circuits

EN 60079-14 stipulates general equipotential bonding in potentially explosive environments in order to prevent potential differences and resultant sparking. The equipotential bonding system must be designed and implemented to DIN VDE 0100!

In accordance with EN 60079-14, intrinsically safe circuits are generally not grounded. They must be grounded if this is required for safety reasons. They can be grounded if this is required for functional reasons. The circuit may only be grounded once to the equipotential bonding system.

Intrinsically safe signal lines and cables are shielded in order to meet measuring technology requirements or to prevent inductive coupling, because the system often generates low signal levels.

The section below outlines the procedures of planning the equipotential bonding of intrinsically safe signal lines:

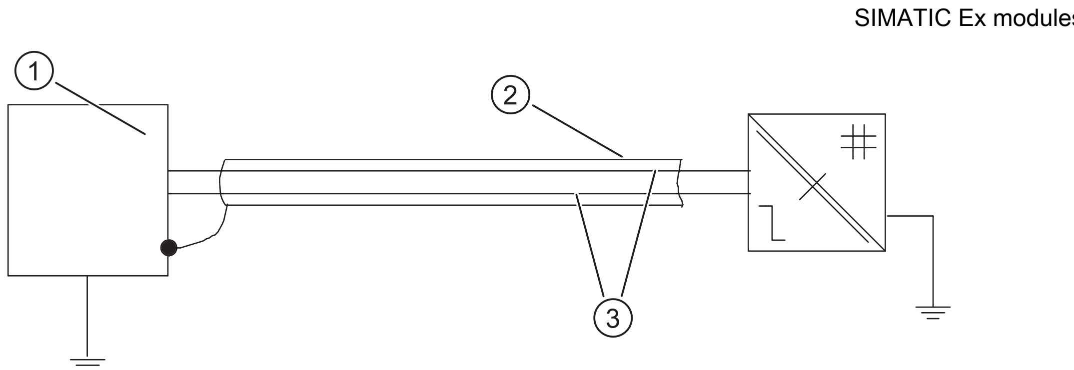
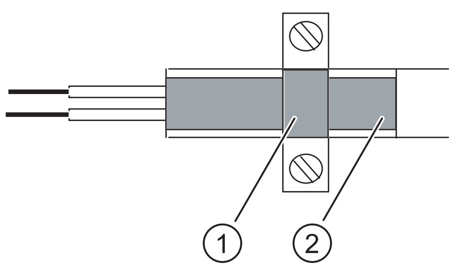
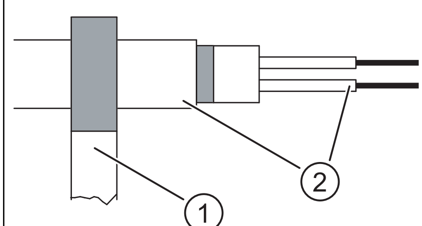
- Metal enclosures with safe contact to construction elements as a result of their mounting fixtures are integrated in the system's equipotential bonding circuit and thus do not require separate grounding.
- The shielding is grounded at only one point in order to avoid looping. In Zone 1, 2 and 21 systems, the shielding is grounded outside the danger area, i.e. ideally in the measurement control system.

The cable shields must be isolated from devices operated in the potentially explosive zone. The measured value is routed via twisted-pair signal cable (single cable) to a distribution cabinet, and from there to the measuring room via multicore cable. The shield is insulated at all intermediate points.

In Zone 0, the cable shield is connected to equipotential ground by wiring it directly to the device connection housing (usually Zone 1). The apparatus is grounded directly via the ground conductor.

Shielding of lines in the hazardous area

Table 1-6 Shielding of Ex lines in the hazardous area

Ex area	Non-Ex area
 (1) Sensor or actuator (2) shield (3) line	
 (1) Shield support with strain relief (2) cable shield	 (1) strain relief (2) insulation

1.8.4 Measures to Counteract Interference Voltages

Assembling the control system

Measures to suppress interference voltages are often only implemented when the control system is already in operation and proper reception of a useful signal is impaired. Expenditure involved with such measures (special relays, for example) can be reduced considerably when installing the control system by making allowances for the items outlined below.

Included here:

- favorable arrangement of equipment and lines
- grounding of all inactive metal elements
- filtering of power cables and signal lines

- shielding of equipment and lines
- special interference-suppression measures

Physical arrangement of equipment and lines

Magnetic DC or AC fields of low frequency, such as 50 Hz, can only be sufficiently attenuated at great expense. In such a case, however, you can often solve the problem by providing the greatest possible distance between the interference source and sink.

Note

The analog Ex modules operate based on a method which suppresses faults caused by AC system ripple.

Grounding of inactive metal elements

Well implemented grounding is an important factor for interference-free assembly. Grounding is understood to mean a good electrical connection of all inactive metal elements (VDE 0160). The principle of surface grounding should be followed. All conductive, inactive metal elements should be grounded!

Observe the following when grounding:

- All ground connections must have a low impedance.
- All metal elements should have a large-area connection. Use particularly wide grounding strips for the connection. The surface of the ground connection and not only its cross section is decisive.
- Screw-type connections should always have spring washers or lock washers.

Protection against electrostatic discharge

In order to protect the devices and modules against electrostatic discharge, these should be installed in fully enclosed metal housings or cabinets which feature proper conductive connections both to the grounding busbar at the installation location and to the main equipotential conductor.

You should preferably use cast iron or steel sheet enclosures. Plastic housings should always have a metallized surface.

Doors or covers of housings should be connected to the grounded body of the housing with ground strips or contact springs.

If you are working on the system with the cabinet open, observe the guidelines for protective measures for electrostatically sensitive devices (ESDs).

The risk of ignition as a result of electrostatic charge must be safely excluded in the system installation. Refer to "Guidelines for avoiding the risk of ignition resulting from electrostatic charges" laid down by the main association of Industrial Employers' Liability Insurance.

If electrostatic charges cannot be avoided, the charge should be kept as low as possible or safe discharge should be provided. The following measures, in particular, should be applied:

- Electrostatic grounding of all conductive elements. Solid materials can be considered as being electrostatically grounded if their leakage resistance at any point is not greater than 10^6 Ω. Under favorable conditions, 10^8 Ω is also satisfactory, particularly for small equipment of low capacitance.
- Reducing the electrical resistance of the material moved or parts moved with respect to each other.
- Incorporating grounded metal elements in material subject to electrostatic charging.
- Increasing the relative air humidity. By increasing the relative air humidity to about 65 % with air conditioning, sprays or by hanging moist cloths, the surface resistance of most non-conductive materials can be adequately reduced. However, if the surface of plastic material is water-repellent, this measure will not succeed.
- Ionization of the air.

1.8.5 The Most Important Basic Rules for Ensuring EMC

Overview

To ensure EMC, it is often sufficient to observe some elementary rules. When assembling the control system, take into consideration the five following basic rules.

1. **When installing the programmable controllers, ensure high quality surface grounding of the inactive metal elements**
   - Connect all inactive metal elements over a large area and at low impedance.
   - On painted and anodized metal elements, make screwed connections with special contact washers or remove the insulating protective layers.
   - Provide a central connection between chassis ground and the ground/protective conductor system.
2. **When wiring always follow the code of practice for line routing**
   - Subdivide the cabling into line groups.
   - (AC power cables, supply lines, Ex and non-Ex signal lines, data lines).
   - Always install power cables and signal or data lines in separate ducts or bundles.
   - Route the signal and data lines as closely as possible to grounded surfaces such as supporting bars, metal rails, cabinet sheet metal panels.
   - Install Ex and non-Ex signal lines in separate ducts.

3. **Ensure that line shields are properly secured**
   - Data lines should be shielded when laid. The shield should be connected accordingly, see chapter Line Shielding (Page 34).
   - Analog lines should be shielded when laid. When low-amplitude signals are transmitted, it may be advantageous if the shield is connected at only one end.
   - For Ex signal lines, connect the line shields only at the sensor or actuator end. Ensure the connected shield continues without interruption as far as the module, but do not connect it there.
   - Make sure the shield has a low-impedance connection to equipotential ground.
   - Use metal or metallized plug housings for shielded data lines.
4. **Implement special EMC measures for particular applications**
   - For all inductances, fit quenching elements provided they are not already contained in the output modules.
   - Use incandescent bulbs for lighting the cabinets and avoid fluorescent lamps.
5. **Harmonize the reference potential and, where possible, connect all electrical components to ground**
   - Take care to ensure specific grounding measures. Grounding of the control system is a protective and functional measure.
   - System elements and cabinets should be connected in star-configuration to the ground/ protective conductor system. In this way you can avoid the formation of ground loops.
   - Install equipotential conductors of sufficient size to compensate for any potential differences between the system components and cabinets.

1.9 Lightning Protection

1.9.1 Measures

Overview

In systems with hazardous areas, the most important task, not least for reasons of explosion protection, is to avoid overvoltages; where this is not possible, they must be reduced and safely discharged.

In addition to the provision of external lightning protection, these measures cover internal lightning protection and overvoltage protection. These measures must be coordinated with the equipment-related EMC.

You will find more detailed information on the subjects of lightning protection and overvoltage protection in the manuals of the individual systems as specified in the foreword. Here, you will also find an overview of the components which can be used for this purpose.

1.9.2 External Lightning Protection/Shielding of Buildings

Measures

External lightning protection is a measure for preventing damage to buildings and fire damage. For this task, a large-mesh wire cage consisting of lightning conductors and down conductors is sufficient.

On buildings with sensitive electronic equipment such as control rooms, the external lightning protection must be supplemented by a building shield. For these purposes, where possible, metal facades and reinforcements of walls, floors and ceilings on or in the building are connected to form shield cages. Where this is not possible, the lightning conductor and down conductor should have a reduced mesh size and, where applicable, the supporting structure of the intermediate floor should be electrically interconnected.

Electrical equipment protruding above roof level must be protected against direct lightning strikes. When such equipment is metallically connected to the external lightning protection system, a partial current is picked up by the building in the event of a lightning strike; this can result in destruction of the equipment sensitive to overvoltages. The pick-up of partial lightning currents can be prevented by protecting the electrical equipment protruding above the roof from direct lightning strikes by means of rods insulated from the equipment (45 degree protective area), or by cage-type tensioned wires or cables.

The down conductors for external lightning protection and, if applicable, the reinforcements and supporting structures, should be connected to the ground system. Each individual building has its own functioning ground system. The ground systems are meshed to create a common grounding network. The voltage between the buildings is thus reduced.

1.9.3 Creating distributed systems with S7-300 and ET 200M

Measures

The process engineering of a plant, such as gas supply, requires a wide-ranging exchange of information between the systems with the distributed Ex I/O devices and the central, electrical or electronic measurement and control system. This necessitates a great number of cable connections, sometimes extending over several hundred meters - in the case of gas storage systems, over several thousands of meters. In the event of a lightning strike, therefore, extensive voltage pick-up occurs.

A distributed arrangement of instrumentation and control equipment with relatively short cables to the plant, and the connection of distributed I/O stations to each other and to the central controller via a bus (PROFIBUS-DP) or fiber-optic cable, are an important measure for reducing overvoltages between sections of the plant.

You will find more detailed information on this arrangement in the *manuals* specified in the foreword.

1.9.4 Shielding of Cables and Buildings

Measures

Overvoltages between separate plant sections or buildings cannot be avoided in practice by meshing. In the event of a lightning strike, a circulating current will flow over the path created by metal connections between the buildings or between a building and I/O device. Cable cores are ideal for this purpose. The lightning or partial lightning current must therefore be offered other conductive connections. Shielding which can be implemented in different ways is particularly suitable, for example:

- a helical current-rated metal strip or metal braid as the cable shield, e.g. NYCY or A2Y(K)Y.
- By installing the cables in continuously connected metal conduits which are grounded at both ends.
- By installing the cables in reinforced concrete ducts with through-connected reinforcement or on closed metal cable racks.
- By laying conductors (shield conductors) in parallel with cables. This measure, however, only relieves the cables of partial lightning currents.
  or
- By laying fiber-optic cables.

Overvoltage-sensitive equipment must also be shielded to ensure the currents at the cable ends cannot destroy this equipment. This is achieved with metal housings or by installing the equipment in metal cabinets which are connected to the ground conductor.

1.9.5 Equipotential bonding for lightning protection

Measures

"Internal lightning protection" covers all the additional measures which prevent the magnetic and electrical effects of the lightning current within the building to be protected. These measures include in particular "equipotential bonding for lightning protection" in order to reduce potential differences caused by lightning current.

Internal lightning protection is based on the principle of the inclusion of all incoming and outgoing lines of a protected volume in the equipotential bonding system for lightning protection, i.e. in addition to the entire metal piping systems (gas, water and heating), this includes all power and IT cables which must be wired to corresponding protective devices. Since considerable, partial lightning currents can flow over such lines and must be discharged by the protective devices, they must be chosen for a suitable current carrying capacity (lightning current conductors).

1.9.6 Overvoltage Protection

General

Effectiveness depends very much on the connection and cable routing of the overvoltage protection devices. When the devices are used in hazardous areas or intrinsically safe circuits, EN60079-14 must be adhered to.

When the system is installed, the minimum igniting curves and maximum heating specified by EN 60079-11 must be adhered to.

Overvoltage protection in intrinsically safe circuits

Overvoltage protection devices can protect intrinsically safe circuits from overvoltage.

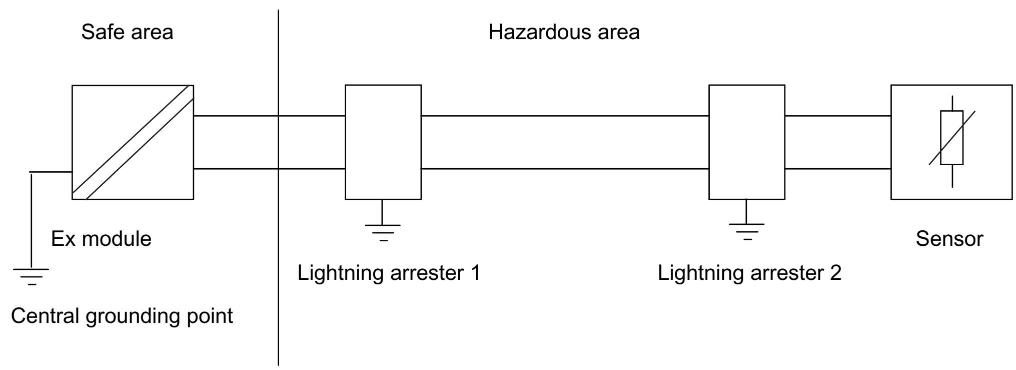


Image 1-12 Overvoltage protection in intrinsically safe circuits

The discussion of safety-relevant aspects is limited to the direct comparison of the data for inductance and capacity.

Table 1-7 Comparison of data for inductance and capacity

Ex module	Comparison	Lightning arrester 1	Line	Lightning arrester 2	Sensor/actuator
La	≥	L_{BD1}	$+L_{Ltg}$	$+L_{BD2}$	+Li
Ca	≥	C_{BD1}	$+C_{Ltg}$	$+C_{BD2}$	+Ci

Table 1-8 Example of the comparison of data for inductance and capacity

Ex module	Comparison	Lightning arrester 1	Line	Lightning arrester 2	Sensor/actuator
La = 4 mH	≥	< 0.5 μH	< 50 μH	< 0.5 mH	< 0.6 mH
Ca = 270 nF	≥	< 1 nF	< 10 nF	< 6 nF	< 6 nF

The overvoltage protection elements described in this section are only effective if used together with external lightning protection. External lightning protection measures reduce the effects of a lightning strike.

You can obtain suitable lightning conductors for Ex modules from:

DEHN + SÖHNE
GmbH + Co. KG
Elektrotechnische Fabrik
Hans-Dehn-Str. 1
D-92318 Neumarkt

http://www.dehn.de (http://www.dehn.de)

1.9.7 Example of Lightning and Overvoltage Protection

Lightning/overvoltage protection for a gas compressor station

Fig. "Lightning/overvoltage protection for a gas compressor station" shows an example of how protective devices can be used.

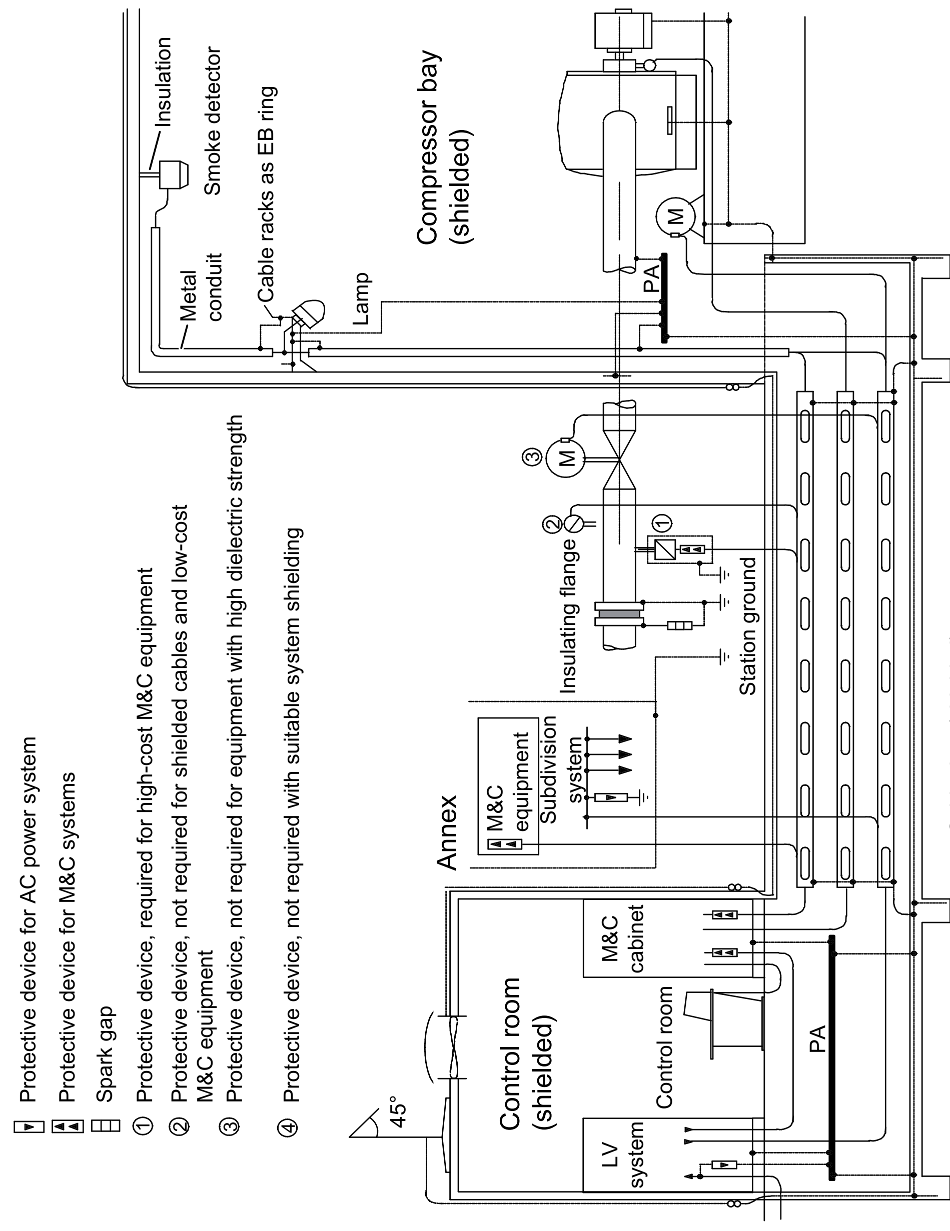


Image 1-13 Lightning/overvoltage protection for a gas compressor station

1.9.8 Lightning Strike

Measures

When lightning strikes an explosive atmosphere it always ignites. There is also a risk of ignition due to an excessive rise in temperature in the lightning discharge paths. In order to prevent, at Zones 0, 1 and 20 themselves, the harmful effects of lightning strikes occurring outside of these zones, surge diverters, for example, must be fitted at suitable points. Overground metal tank systems which are equipped with electrical appliances or electrically conductive components which are electrically isolated to the container require equipotential bonding, for example, of measuring and control equipment and of the filling tubes.

Note

Lightning protection equipment and grounding systems must be tested by an expert upon their completion and at regular intervals. In conjunction with ElexV, an inspection interval of three years is specified for electrical and lightning protection systems operated in potentially explosive rooms.

Summary:

- Enhanced external lightning protection (reduced mesh size, increased number of down conductors) on all buildings and systems.
- Meshing of grounding systems in the building to create area grounding.
- Meshed equipotential bonding.
- Fitting of lightning conductors and surge diverters in the power system.
- Fitting of overvoltage fine-protection devices at both ends of measurement and control cables.
- Shielding of M&C cables.
- M&C cables with twisted pairs of cores.

1.10 Installation Work in Hazardous Areas

1.10.1 Safety Measures

Introduction

All possible measures which eliminate the risk of explosion must be implemented not only when using programmable controllers in hazardous areas but also during the installation stage.

Sparks capable of causing ignition during mechanical work

Tools which tend to produce sparks must not be used for working in potentially explosive systems or system sections in operation. Copperberyllium is a suitable material for tools such as screwdrivers, pliers, wrenches, hammers and chisels. Since this material has low wear-resistance, the tools should be used with care.

Sparks capable of causing ignition during mechanical work

low	when bare steel elements strike each other
possible	when steel elements collide or drop
great	when striking rusty steel
very great	when striking rusty steel with an alloy coating (e.g. aluminum paint)

The possibility of creating sparks capable of causing ignition is substantially reduced by using non-sparking tools. Exception: when the tool is harder than the workpiece.

Measures for eliminating the risk of explosion

Safely closing off the working area, e.g. with dummy panels.

- Good ventilation of the rooms.
- Flushing with inert gas. Testing the effectiveness of the flushing (gas tester). Then working with a normal tool.

If the risk of explosion at the workplace cannot be eliminated, the following measures must be implemented:

- Avoidance of collisions and dropping of steel elements.
- Wearing antistatic shoes, e.g. leather shoes or using shoe grounding strips.
- Avoiding rust layers and aluminum coating at impact points. If this is not possible, eliminating the risk of explosion locally, e.g. with inert gas.
- Adequate air supply and waste air disposal.
- Removing or enclosing readily flammable substances in the vicinity.
- Keeping the workplace and, if applicable, floor moist.

Table 1-9 Safety Measures

Working area	Safety Measures
Installations with readily flammable gas and vapor-air mixtures, e.g. hydrogen, city gas, acetylene and hydrogen sulphide	Working only allowed after implementation of special safety measures and with written permission of plant manager. Only non-sparking tools to be used (tool softer than workpiece).
Installations with gas and vapor-air mixtures such as methane, propane, butane and petrol	Sufficient to use non-sparking tools. Exception: For materials with rust formation and aluminum coating or similar, special protective measures required.
Installations with risk of explosion from readily flammable dust	Remove dust deposits. Keep working area wet and protect against dust formation. Normal tools may be used.

Note

Working on energized electrical installations and apparatus in hazardous industrial premises is prohibited. This also includes the disconnection of live control lines for test purposes.

As an exception, work on intrinsically safe circuits is permitted; also, in special cases, work on other electrical systems where the user has certified in writing that there is no risk of explosion for the duration of the work at the site.

If necessary, a fire permit must also be obtained.

Grounding and short-circuiting may only be carried out in hazardous industrial premises when there is no risk of explosion at the point of grounding and short-circuiting.

Use measuring instruments which are approved for the zones to test for no voltages.

1.10.2 Use of Ex Assemblies in Hazardous Zone 2

License

SIMATIC S7 Ex modules are permitted for use in zone 2 (category 3G). Note in this case the specific conditions on the EU special test certificate (see certificates of conformity on theInternet (http://support.automation.siemens.com/WW/view/en/37217116/134200)).

1.10.3 Use of Ex Assemblies in Hazardous Zone 1

Types of protection

It is basically possible to install a SIMATIC assembly in a hazardous area zone 1. However, the system installer must implement additional measures in order to protect the modules. Two types of protection are available:

- the Ex assembly is installed in a "pressurized enclosure";
- the Ex assembly is installed in a "pressure-resistant, enclosed casing".

The following figure shows a possible configuration for zone 1 in a pressure-resistant, enclosed casing with a terminal housing that provides an increased level of safety.

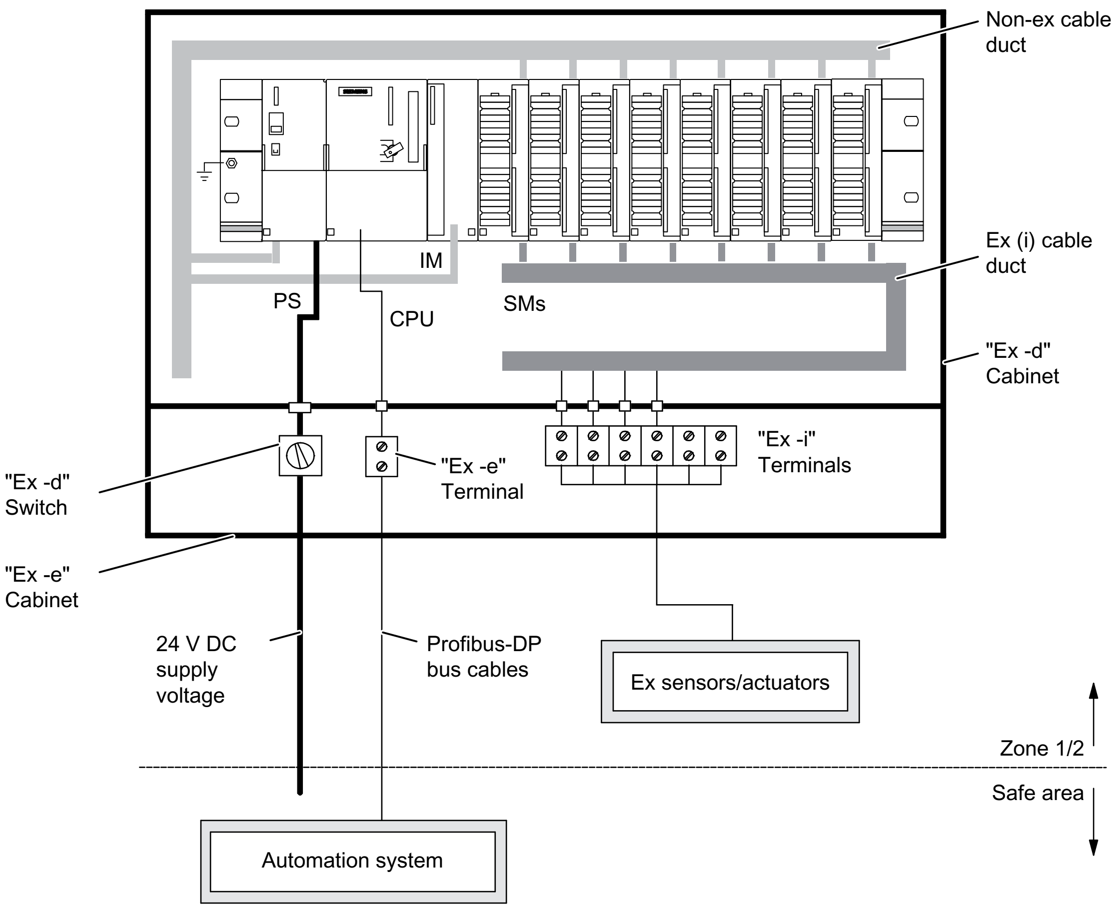


Image 1-14 SIMATIC Ex modules in hazardous area

Housing

The selected type of housing is characterized by the fact that it is able to withstand explosions occurring inside the housing and that an explosive gas/air mixture surrounding the housing is not ignited. In addition, the surface temperature does not exceed the limit values of the temperature classes. Cable glands that are protected against transmission of internal ignition and isolated against the housing wall must be used for routing the supply leads into the pressure-resistant, enclosed casing.

A housing with "increased safety" is used as a terminal compartment. Special screwed glands are used for the cable entries.

The housing must be certified by a testing authority to comply with the "Ex d" type of protection and the relevant design requirements.

Explosion protection of the housing: Ex de II T5 .. T6.

Cables

The cables used must comply with the EN 60079-0 and EN 60079-11 standards for intrinsically safe circuits or EN 60079-7 for circuits with increased safety.

The cables for the assembly are to be installed in such a way that they are endangered neither by thermal, mechanical nor chemical load or stress.

Note

If necessary, the cables should be installed in cable conduits.

Terminals

The terminal connectors for the power supply cable and the bus line should always meet the requirements of the "increased safety" tape of protection. The clamping points of the intrinsically safe circuits should always be implemented according to the guidelines of "Intrinsic safety".

Protective device

The assembly is connected to a 24 V DC supply circuit fed by a power supply unit with safe electrical isolation. The supply circuit must be protected by an appropriate circuit-breaker. This circuit-breaker is installed outside the Ex zone.

Switch

The switch for enabling the system should comply with the "Ex de II T6" type of protection.

Table 1-10 Working on systems to type of protection: Ex de [ib] T5 .. T6

Type of protection of apparatus used in system	Type of work to be carried out	Work within		Additional requirements and notes
Ex ib		**Zone 1**	**Zone 2**	
	Opening the housing, Ex i/e housing only	allowed	allowed	if no other apparatus is in the housing
	Connecting/disconnecting lines	allowed	allowed	
	Current, voltage and resistance measurement	allowed with certified apparatus	allowed	
	Soldering	prohibited	allowed if soldering temperature lower than ignition temperature	
Ex e		**Zone 1**	**Zone 2**	

Type of protection of apparatus used in system	Type of work to be carried out	Work within		Additional requirements and notes
	Opening the housing, Ex i/e housing only	allowed	allowed	if no other apparatus is in the housing
	Connecting/disconnecting lines	not allowed unless in de-energized state	only in de-energized state and if no risk of explosion	
	Current, voltage and resistance measurement	voltage measurement with certified apparatus only	voltage measurement with certified apparatus only	
	Soldering	prohibited	allowed in de-energized state if soldering temperature lower than ignition temperature	
Ex d		**Zone 1**	**Zone 2**	
	Opening the housing, Ex d housing only	prohibited	allowed if no risk of explosion	apparatus in pressure-resistant enclosure are no longer protected against explosion if housing is opened
	Connecting/disconnecting lines	not allowed unless in de-energized state	allowed if no risk of explosion	
	Current, voltage and resistance measurement	Work not possible	allowed if no risk of explosion	
	Soldering	prohibited	allowed in de-energized state if soldering temperature lower than ignition temperature	

1.11 Maintenance of Electrical Apparatus

Replacing equipment

Work on electrical systems or equipment can only be carried out if a "permit" has been granted. If electrical equipment is replaced, attention must be paid to the correct temperature class, explosion group, and corresponding (Ex) zone. Certificates of conformity, EU special test certificates, and design approval must be available.

Maintaining apparatus

Repaired electrical apparatus may only be placed in operation again after testing by a recognized expert in accordance with paragraph 15 of ElexV, and the test has been certified, unless explosion protection has not been affected by the repair. If the repair affects explosion protection, only original spare parts may be used. Improvised repairs which no longer ensure explosion protection of apparatus are not permitted.

SIMATIC S7 Ex Digital Modules 2

2.1 Chapter overview

Overview

The following SIMATIC S7 Ex digital modules are described in this chapter:

- Digital input SM 321; DI 4 x NAMUR,
  Order number: 6ES7321-7RD00-0AB0
- Digital output SM 322; DO 4 x 24V/10mA,
  Order number: 6ES7322-5SD00-0AB0
- Digital output SM 322; DO 4 x 15V/20mA,
  Order number: 6ES7322-5RD00-0AB0

Notes

You will find information on the relevant safety standards and on other safety regulations in the Appendix Standards and Licenses (Page 249).

The general technical specifications in the device manual S7-300 Module Specifications, see Internet (http://support.automation.siemens.com/WW/view/en/8859629).

2.2 Digital input module SM 321; DI 4 x NAMUR (6ES7321-7RD00-0AB0)

2.2.1 Features and technical specifications

Order Number

6ES7321-7RD00-0AB0

Features

SM 321; DI 4 x NAMUR has the following properties:

- 4 inputs
  - electrically isolated from the bus
  - electrically isolated from each other
- load voltage 24 V DC

- connectable sensors
  - to DIN EN 60947-5-6 or IEC 60947-5-6
  - interconnected mechanical contacts (with diagnostic evaluation)
  - open-circuited mechanical contacts (without diagnostics)
- 4 short circuit-proof outputs for the encoder power supply (8.2 V)
- Operating points:
  logic "1" ≥ 2.1 mA
  logic "0" ≤ 1.2 mA
- Status indication (0...3) = green LEDs
  Fault indications = red LEDs for
  - group fault indication (SF)
  - channel-related short-circuit and wire-break error message (F0 to F3)
- configurable diagnostics
- configurable diagnostic interrupt
- configurable process interrupt
- Intrinsic safety of inputs in accordance with EN 60079-11
- 2-wire encoder connection
- Supports time stamping
- Configuration in Run (CiR) supported

Wiring diagram of SM 321; DI 4 x NAMUR

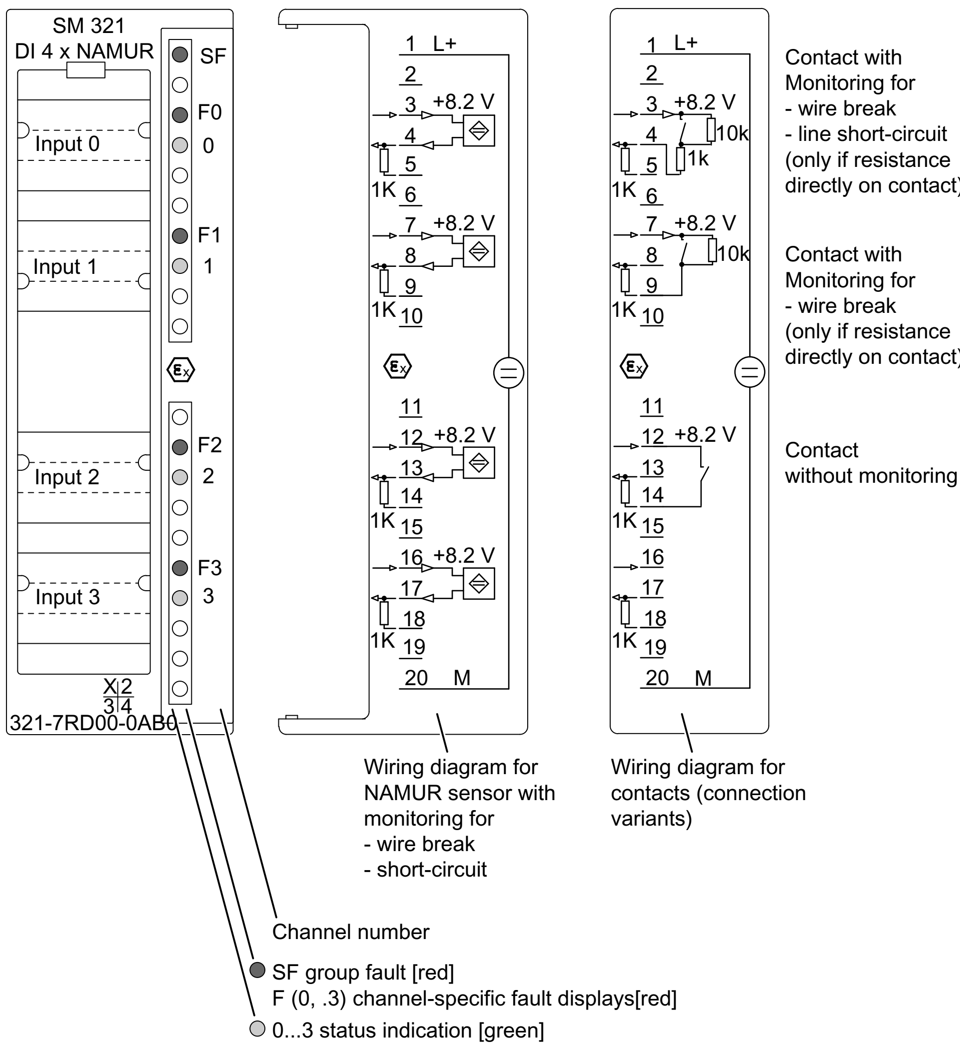


Image 2-1 Wiring diagram of digital input module SM 321; DI 4 x NAMUR

Notes on intrinsically-safe installation

You must connect the DM 370 dummy module between the CPU or IM 153 (in a distributed configuration) and the Ex I/O modules whose signal cables lead into the hazardous location. In a distributed configuration with an active backplane bus, you should use the ex dividing panel/ex barrier instead of the dummy module.

Power supply for an intrinsically-safe structure

In order to maintain the clearances and creepage distances, L+/M must be routed via the line chamber LK393 when operating modules with signal cables that lead to the hazardous location.

Block diagram SM 321; DI 4 x NAMUR

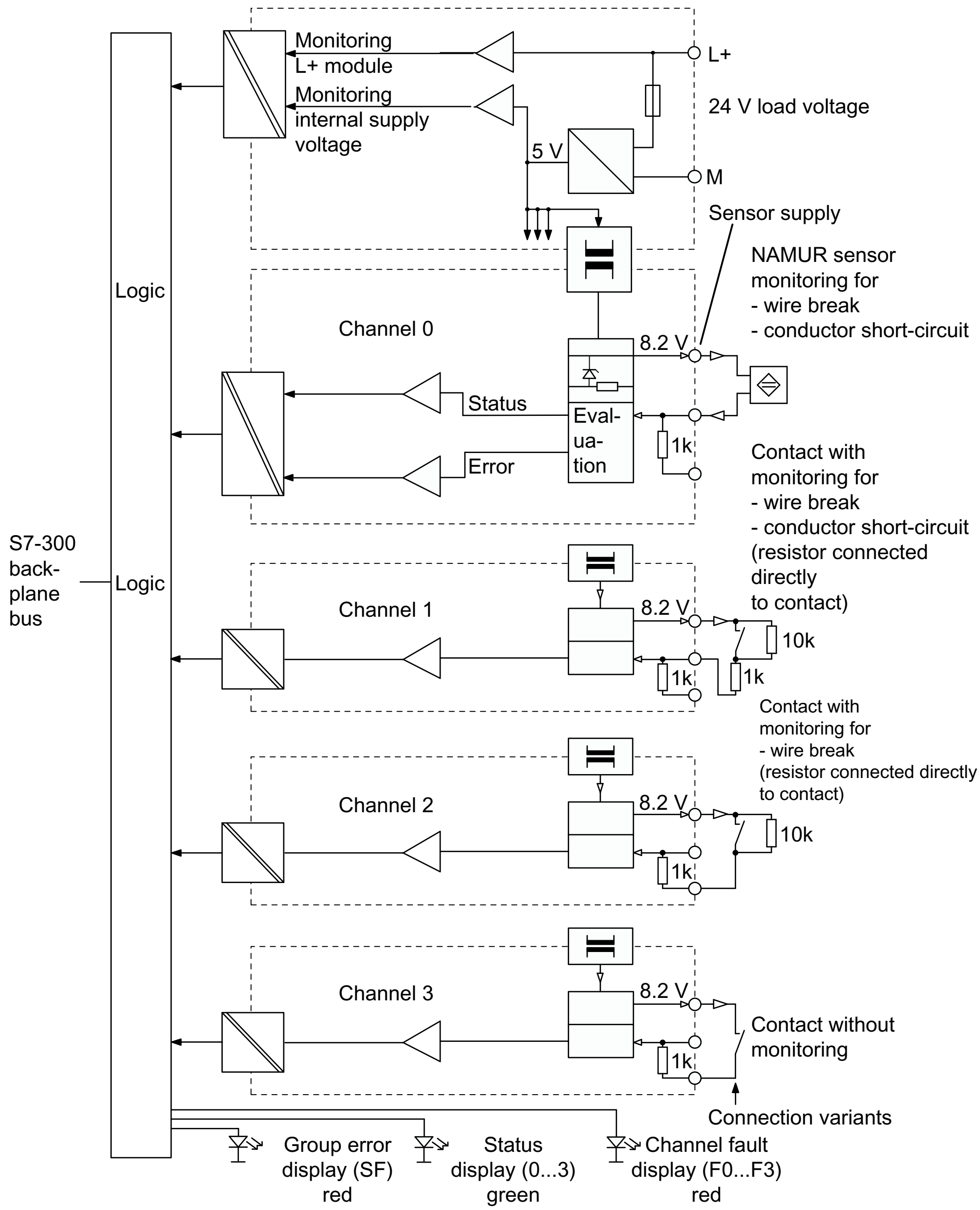


Image 2-2 Block diagram of the digital input module SM 321; DI 4 x NAMUR

Technical specifications of SM 321; DI 4 x NAMUR

Dimensions and Weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	approx. 230 g
Module-specific data	
Configuration in Run (CiR) supported	yes

• Behavior of non-configured inputs during CiR	They return the process value that applied before the parameters were set.
Supports time stamping	yes
Number of inputs	4
Line length, shielded	max. 200 m
ATEX approvals	II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 01ATEX1057 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply Rated load voltage L+ • Reverse voltage protection	5 V DC 24 V DC yes
Number of inputs which can be activated simultaneously	4
Electrical isolation	
• between the channels and backplane bus	yes
• between the channels and load voltage L+	yes
• between the channels	yes
• between the backplane bus and load voltage L+	yes
Permitted potential difference (V_{ISO}) of signals of the Ex area	
• between the channels and backplane bus	DC 60 V AC 30 V
• between the channels and load voltage L+	60 VDC 30 VAC
• between the channels	60 VDC 30 VAC
• between the backplane bus and load voltage L+	60 VDC 30 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area	
• between the channels and backplane bus	300 VDC 250 VAC
• between the channels and load voltage L+	300 VDC 250 VAC
• between the channels	300 VDC 250 VAC
• between the backplane bus and load voltage L+	75 VDC 60 VAC
Insulation tested	
• Channels to backplane bus and load voltage L_+	with 2500 V DC
• Channels to each other	with 2500 V DC

• between the backplane bus and load voltage L_+	with 500 V DC
Current input • from backplane bus • from load voltage L+	 max. 80 mA max. 50 mA
Module power loss	typical 1.1 W
Status, interrupts, diagnostics	
Status indication	
• Inputs	green LED per channel
Interrupts	
• Process interrupt • Diagnostic interrupt	Configurable Configurable
Diagnostic functions	
• Group fault indication	red LED (SF)
• Channel fault indication	red LED (F) per channel
• Diagnostic functions readout	possible
monitoring for	
• short-circuit	I > 8.5 mA
• Wire break	I ≤ 0.1 mA
Safety specifications (see EU special test certificate KEMA 01ATEX1057 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))	
Maximum values of input circuits (per channel)	
• U_0 (no-load output voltage)	max. 10 V
• I_0 (short-circuit current)	max. 14.1 mA
• P_0 (load power)	max. 33.7 mW
• L_0 (permissible external inductance)	max. 100 mH
• C_0 (permissible external capacity)	max. 3 μF
• U_m (fault voltage)	max. DC 60V AC 30V
• T_a (permissible ambient temperature)	max. 60°C
Data for sensor selection	
To DIN EN 60947-5-6 or IEC 60947-5-6	
Input current	
• at signal "1"	2.1 to 7 mA
• at signal "0"	0.35 to 1.2 mA
Time/frequency	
Interrupt conditioning time for	
• Interrupt conditioning only	max. 250 μs
• Interrupt and diagnostic conditioning	max. 250 μs
Input delay (EV)	
• Configurable	yes
• Nominal value	type 0.1/0.5/3/15/20 ms

Configuration in RUN (CiR)

If you use the Configuration in RUN function, the following special feature occurs.

SF LED is lit:

If a diagnostic event was pending before you started to reassign parameters, the SF LEDs (on the CPU, IM or module) may be lit even though the diagnostic event has been cleared and the module is operating properly.

Remedy:

- Only make new parameter settings when there is no diagnostic event pending on the module, or
- Inserting and removing modules

Additional information on Configuration in RUN (CiR)

...can be found in the online help for STEP7 and in the manual System modification in RUN by means of CiR on the Internet (http://support.automation.siemens.com/WW/view/en/14044916).

See also

The LK 393 line chamber (Page 14)

Configuration of an S7-300 with Ex I/O Modules (Page 17)

Configuration of an ET 200M with Ex I/O modules (Page 20)

2.2.2 Parameterization

Parameterization

You set the parameters of digital input module SM 321; DI 4 x NAMUR in STEP 7. You must implement the settings in CPU STOP mode. The parameters set in this way are stored in the CPU during transfer from PG to S7-300. These parameters are transferred to the digital module during the status change from STOP-->RUN.

You can also change some parameters in the user program with SFC 55 to 57.

The parameters for the 2 parameterization alternatives are subdivided into:

- static parameters
- dynamic parameters

The table below shows the characteristics of static and dynamic parameters.

Table 2-1 Static and dynamic parameters of SM 321; DI 4 x NAMUR

Parameter	can be set with	CPU operating status
static	Programming Devices	STOP
dynamic	Programming Devices	STOP
dynamic	SFCs 55 to 57 in user program	RUN

Default settings

The SM 321, DI 4 x NAMUR features default settings for diagnostics, interrupts etc..

These defaults apply to digital input modules which were not parameterized in STEP 7.

Configurable characteristics

The characteristics of the SM 321, DI 4 x NAMUR can be parameterized with the following parameter blocks:

- Basic settings
- Diagnostics
- Process interrupts

Channel group allocation

The table shows the allocation of the 4 channels to the channel groups of the SM 321; DI 4 x NAMUR.

Table 2-2 Allocation of 4 digital input channels to the 4 channel groups of SM 321; DI 4 x NAMUR

Channel	Allocated channel group
Channel 0	Channel group 0
Channel 1	Channel group 1
Channel 2	Channel group 2
Channel 3	Channel group 3

Parameters of the digital input module

The table below provides an overview of the parameters of the SM 321; DI 4 x NAMUR and shows what parameters

- are static or dynamic and
- can be used for the module as a whole or for a channel group.

Table 2-3 Parameters of SM 321; DI 4 x NAMUR

Parameter	SM 321; DI 4 x NAMUR			
	Range of values	Default	Type of	Effective range
Basic settings				
• Input delay (ms)	0.1/0.5/3/15/20	3	static	Module
• Process interrupt enable	yes/no	no	dynamic	Module
• Enable diagnostic interrupt	yes/no	no	dynamic	Module
Diagnostics				
• Wire-break monitoring	yes/no	no	static	Channel group
• Short-circuit to M	yes/no	no	static	Channel group
Process interrupts				
• with leading edge	yes/no	no	dynamic	Channel group
• at trailing edge	yes/no	no	dynamic	Channel group

Input delay

The table below shows the programmable input delay times of SM 321; DI 4 x NAMUR and their tolerances.

Table 2-4 Delay times of input signal for SM 321; DI 4 x NAMUR

Input delay	Tolerance
0.1 ms	75 to 150 µs
0.5 ms	0.4 to 0.8 ms
3 ms (default)	2.8 to 3.5 ms
15 ms	14.5 to 15.5 ms
20 ms	19 to 21 ms

2.2.3 Diagnostic messages

Introduction

You can use the diagnostic function to determine whether signal acquisition takes place without errors.

Parameterizing diagnostics

You program the diagnostics functions in STEP 7.

Diagnostic evaluation

We need to distinguish between programmable and non-programmable diagnostic messages when analyzing diagnostics data. Programmable diagnostic messages such as "wire break" or "short-circuit to M" are only output if diagnostics data analysis was enabled at the "wire break" or "short-circuit to M" parameters.

Non-configurable diagnostic messages are general, i.e. independent of parameterization.

A diagnostic signal results in a diagnostic interrupt being triggered providing the diagnostic interrupt has been enabled by way of parameterization.

Irrespective of the parameterization, known module errors always result in the SF LED and the corresponding channel fault LED lighting irrespective of the CPU operating status (at POWER ON).

Exception:

The SF LED and the corresponding channel fault LED light in the event of a wire break only when parameterization is enabled.

Diagnostics of the digital input module

The table below provides an overview of the diagnostic messages generated by SM 321; DI 4 x NAMUR. You enable the diagnostics functions in STEP 7.

The diagnostics information refers to either the channel groups or the entire module.

Table 2-5 Diagnostic messages of SM 321; DI 4 x NAMUR

Diagnostic message	Effective range of diagnostics	Configurable
Wire break	Channel group	Yes
Short-circuit to M		
incorrect parameters in module	Module	No
Module not configured		
external auxiliary voltage missing		
No internal auxiliary voltage		
Fuse blown		
Time watchdog tripped		
EPROM error		
RAM error		
CPU error		
Hardware interrupt lost		

Reading out diagnostic messages

You can read the system diagnostics data in STEP 7. You can read detailed diagnostic messages from the module in the user program with SFC 59 of SFC 53.

Causes of error and remedies

The table below provides a list of possible causes and corresponding corrective measures for individual diagnostic messages.

However, be aware that error detection must be enabled at the modules in order to output the relevant programmable diagnostic messages.

Table 2-6 Diagnostic messages as well as their causes and remedies in SM 321; DI 4 x NAMUR

Diagnostic message	Possible fault causes	Corrective measures
Short-circuit to M (I > 8.5 mA)	Short-circuit between the two encoder lines	Eliminate the short-circuit
	with contacts as sensor 1 kΩ series resistor not fitted in line to contact	Connect 1 kΩ resistor *directly at contact* in line
Wire break (I ≤ 0.1 m A)	Conductor break between module and NAMUR sensor	Connect line
	with contact as sensor (wire break monitoring enabled)	10 kΩ resistor not fitted or interrupted *directly at contact*
	with contact as sensor (without monitoring)	disable channel by parameterization "diagnostics wire break"
	Channel not used (open)	
Incorrect parameters in module	Invalid parameters loaded in module by means of SFC	Check parameterization of module and re-load valid parameters
Module not configured	Module not supplied with parameters	Include module in parameterization
external auxiliary voltage missing	No module supply voltage L+	Provide L+ supply
No internal auxiliary voltage	No module supply voltage L+	Provide L+ supply
	module-internal fuse defective	Replace module
Fuse blown	module-internal fuse defective	Replace module
Time watchdog tripped	partially high electromagnetic interference	Eliminate interference sources
	Module defective	Replace module
EPROM error RAM error CPU error	partially high electromagnetic interference	Eliminate interference sources and switch CPU supply voltage OFF/ON
	Module defective	Replace module
Hardware interrupt lost	The CPU is unable to process successive hardware interrupts at this rate	Change interrupt processing in CPU and reparameterize module if necessary

2.2.4 Interrupts

Introduction

In principle, a differentiation is made between the following interrupts:

- Diagnostic interrupt
- Process interrupt

Parameterizing interrupts

You program the interrupts in STEP 7.

Default setting

The interrupts are inhibited by way of default.

Diagnostic interrupt

The module triggers a diagnostics interrupt when it detects incoming or outgoing errors such as a wire break or short-circuit to M, provided this interrupt function is enabled. Diagnostic functions inhibited by parameterization cannot trigger an interrupt. The CPU interrupts processing of the user program or low-priority classes and processes the diagnostic interrupt module (OB82).

Process interrupt

The module supports triggering of process interrupts for each channel at the positive, negative or both edges of the signal transition, depending on parameter settings. You can determine which of the channels has triggered the interrupt from the local data of the OB 40 in the user program.

Active process interrupts trigger process interrupt execution (OB 40) at the CPU, i.e. the CPU interrupts execution of the user program or of jobs of a lower priority class. If there are no higher priority classes pending processing, the stored interrupts (of all modules) are processed one after the other corresponding to the order in which they occurred.

Process interrupt lost

Events (edge transitions) at a channel are written to the process interrupt stack and trigger a process interrupt. The event is lost if a further event is generated at this channel before the CPU has acknowledged the process interrupt, i.e. before OB 40 was executed. This status triggers a "process interrupt lost" diagnostics interrupt. The relevant diagnostics interrupt must be enabled.

Further events at this channel are not logged until interrupt processing is completed for this channel.

Influence of the supply voltage and of the operating state

The input values of the SM 321; DI 4 x NAMUR are dependent on the supply voltage and on the operating status of the CPU.

The table below provides an overview of these dependencies.

Table 2-7 Dependencies of the input values for CPU operating status and supply voltage L+ of SM 321; DI 4 x NAMUR

Operating status CPU		Supply voltage L+ at digital module	Input value of the digital module
POWER ON	RUN	L+ applied	Process value
		L+ not applied > 20 ms	0 signal
	STOP	L+ applied	Process value
		No L+	0 signal
POWER OFF	-	L+ applied	-
		No L+	-

Failure of the supply voltage L+ of the SM 321; DI 4 x NAMUR is always indicated by the SF-LED on the front of the module and additionally entered in diagnostics.

In the event of the module supply voltage L+ failing, the input value is initially held for 20 to 40 ms before the "0" signal is transferred to the CPU. Supply voltage dips < 20 ms do not influence the process value, but are reported by diagnostics interrupt and at the group error LED.

Interrupt-triggering channels

The relevant process interrupt-triggering channel is logged in the OB40_POINT_ADDR variable of the start information of OB40. The figure below shows the assignment of bits in DWORD 8 of local data.

Byte	Variable	Data type		Description
6/7	OB40_MDL_ADDR	WORD	B#16#0	Address of the interrupt-triggering module
As of 8	OB40_POINT_ADDR	DWORD	see the following figure	Indication of the interrupt-triggering inputs

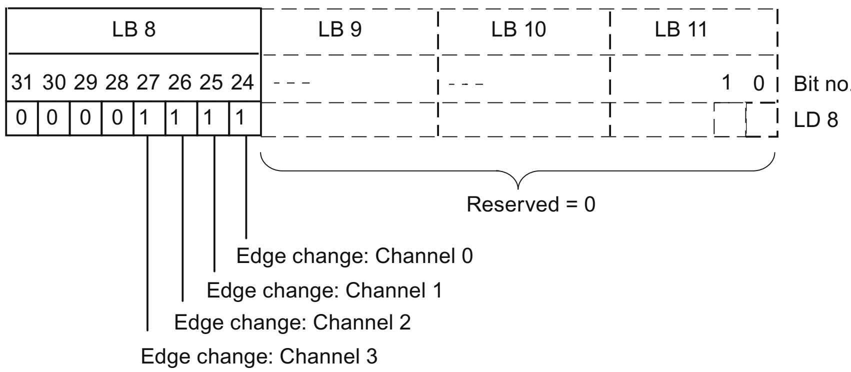


Image 2-3 Start Information of OB40: which event has triggered the process interrupt

2.3 Digital output module SM 322; DO 4 x 24V/10 mA (6ES7 322-5SD00-0AB0)

2.3.1 Features and technical specifications

Order Number

6ES7322-5SD00-0AB0

Features

SM 322; DO 4 x 24V/10mA has the following properties:

- 4 outputs
  - electrically isolated from the bus
  - electrically isolated from each other
- suitable for
  - intrinsically safe valves
  - acoustic interrupts
  - indicators
- configurable diagnostics
- configurable diagnostic interrupt
- configurable default output
- Status indication (0...3) = green LEDs
  Fault indications = red LEDs for
  - group fault indication (SF)
  - channel-related short-circuit and wire-break error message (F0 to F3)

- Intrinsic safety of outputs in accordance with 60079-11
- 2-wire actuator connection
- Configuration in Run (CiR) supported

Wiring diagram of SM 322; DO 4 x 24V/10mA

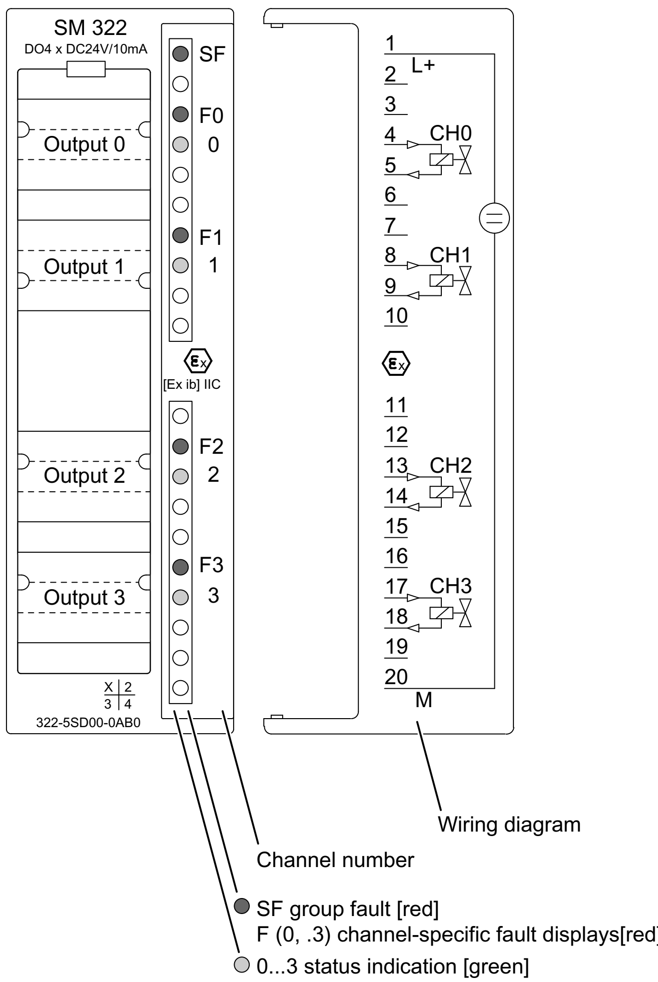


Image 2-4 Wiring diagram of SM 322; DO 4 x 24V/10mA

Notes on intrinsically-safe installation

You must connect the DM 370 dummy module between the CPU or IM 153 (in a distributed configuration) and the Ex I/O modules whose signal cables lead into the hazardous location. In a distributed configuration with an active backplane bus, you should use the ex dividing panel/ex barrier instead of the dummy module.

Power supply for an intrinsically-safe structure

In order to maintain the clearances and creepage distances, L+/M must be routed via the line chamber LK393 when operating modules with signal cables that lead to the hazardous location.

Block diagram of SM 322; DO 4 x 24V/10mA

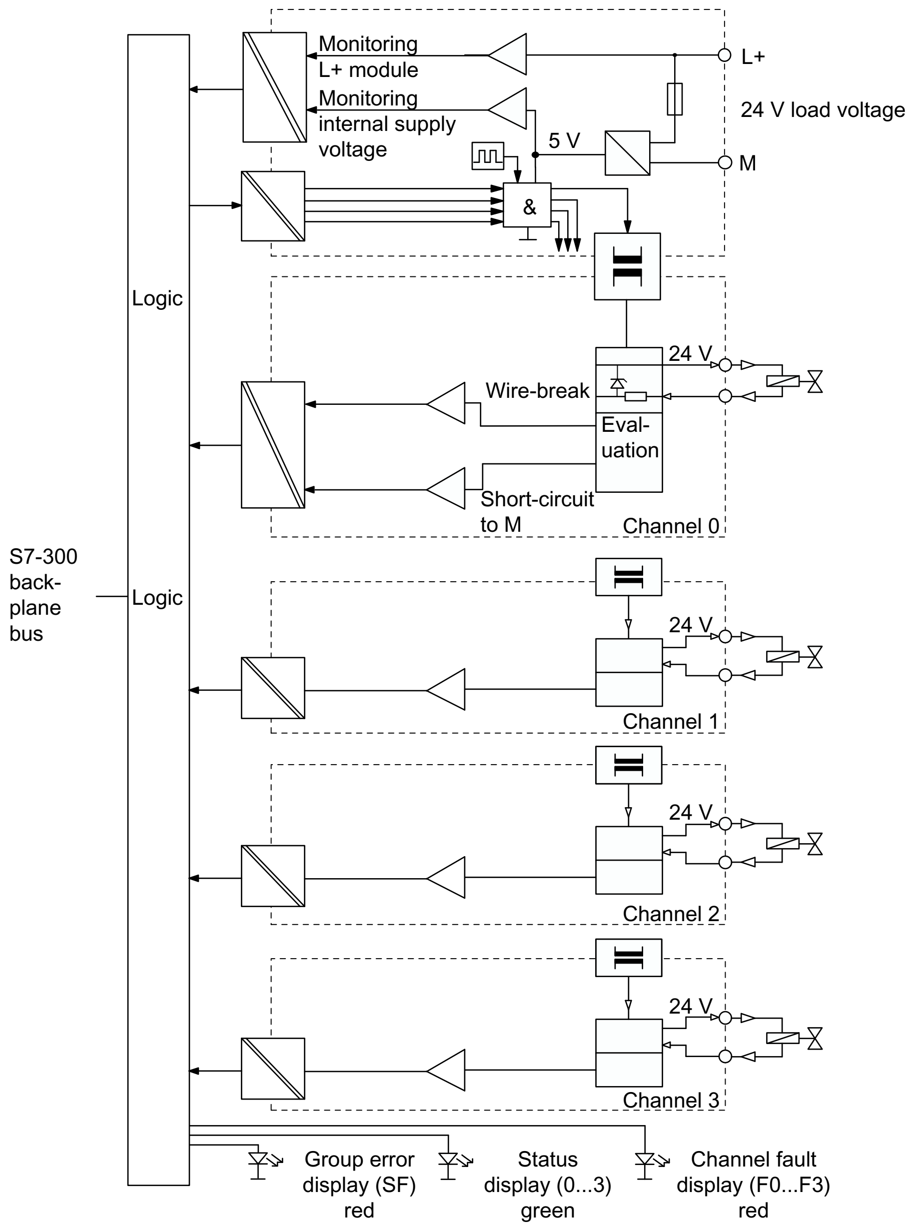


Image 2-5 Block diagram of digital output module SM 322; DO 4 x 24V/10 mA

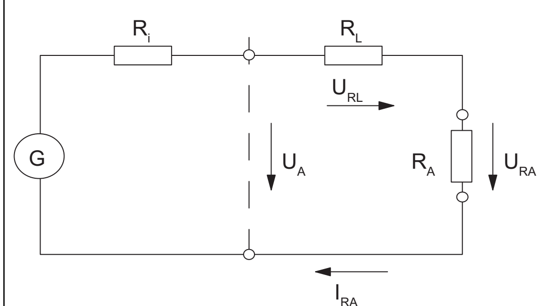
Technical specifications of the SM 322; DO 4 x 24V/10mA

Dimensions and Weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	approx. 230 g
Module-specific data	
Configuration in Run (CiR) supported	yes
• Behavior of non-configured inputs during CiR	specify the output value which was valid before the parameter-ization
Number of outputs	4
Line length, shielded	max. 200 m
ATEX approvals	II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 01ATEX1059 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply Rated load voltage L+ • Reverse voltage protection	5 V DC 24 V DC yes
Total current of outputs	
• horizontal arrangement up to 60 °C	no restrictions
• vertical installation to 40 °C	no restrictions
Electrical isolation	
• between the channels and backplane bus	yes
• between the channels and load voltage L+	yes
• between the channels	yes
• between the backplane bus and load voltage L+	yes
Permitted potential difference (V_{ISO}) of signals of the Ex area	
• between the channels and backplane bus	DC 60 V AC 30 V
• between the channels and load voltage L+	60 VDC 30 VAC
• between the channels	60 VDC 30 VAC
• between the backplane bus and load voltage L+	60 VDC 30 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area	
• between the channels and backplane bus	300 VDC 250 VAC

• between the channels and load voltage L+	300 VDC 250 VAC
• between the channels	300 VDC 250 VAC
• between the backplane bus and load voltage L+	75 VDC 60 VAC
Insulation tested	
• Channels to backplane bus and load voltage L_+	with 2500 V DC
• Channels to each other	with 2500 V DC
• between the backplane bus and load voltage L_+	with 500 V DC
Current input	
• from backplane bus • from load voltage L+ (at rated data)	Max. 85 mA max. 160 mA
Module power loss	typical 3 W
Status, interrupts, diagnostics	
Status indication	
• Outputs	green LED per channel
Interrupts	
• Diagnostic interrupt	configurable
Diagnostic functions	
• Group fault indication	red LED (SF)
• Channel fault indication	red LED (F) per channel
• Diagnostic functions readout	possible
monitoring for	
• short-circuit	I > 10 mA (±10%)
• Wire break	I ≤ 0.15 mA
Safety specifications (see EU special test certificate KEMA 01ATEX1059 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))	
Maximum values of the output circuits (per channel)	
• U_0 (no-load output voltage)	max.25.2 V
• I_0 (short-circuit current)	max. 70 mA
• P_0 (load power)	max. 440 mW
• L_0 (permissible external inductance)	max. 6.7 mH
• C_0 (permissible external capacity)	max. 90 nF
• U_m (fault voltage)	max. DC 60V AC 30V
• T_a (permissible ambient temperature)	max. 60°C
Data for sensor selection	
Outputs	
• No-load voltage U_{A0} • Internal resistance R_I	DC 24 V ±5% 390 Ω ±5%
Curve vertices E	

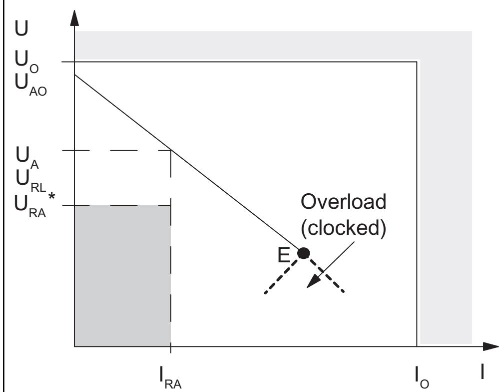
• Voltage U_E • Current I_E	DC 19 V ±10% 10 mA ±10%
Parallel wiring of two outputs	
• for redundant activation of a load	not possible
• for increasing power	possible
Switching frequency	
• at resistive load	100 Hz
• at inductive load (LLo)	100 Hz
Short-circuit protection of the output	yes, electronic
• Response threshold	Curve vertex E

Block diagram



G	Generator
R_i	Internal resistor
R_L	Line resistor
R_A	Load resistor
U_{AO}	No-load voltage
U_A	Output voltage
U_{RL}	Voltage drop at load resistor
U_{RA}	Output power at load
U_0	max. output voltage
I_0	max. output voltage
I_{RA}	Load current

Output characteristic

Block diagram	
 Range outside safety-relevant limits Load output power	
E	Curve vertice (U_E, I_E) U_E = 19V ± 10% I_E = 10 mA ± 10% Output current electronically clocked at overload. Clock ratio ~ 1:25

Additional information on Configuration in RUN (CiR)

...can be found in the online help for STEP7 and in the manual System modification in RUN by means of CiR on the Internet (http://support.automation.siemens.com/WW/view/en/14044916).

See also

The LK 393 line chamber (Page 14)

Configuration of an S7-300 with Ex I/O Modules (Page 17)

Configuration of an ET 200M with Ex I/O modules (Page 20)

2.3.2 Parameterization

Parameterization

You program the parameters in STEP 7. You must implement the settings in CPU STOP mode. During transfer from the PG to the S7-300, the parameters set in this way are stored in the CPU and then transferred by the CPU to the digital module.

Alternatively, you can also change several parameters in the user program with SFCs 55 to 57 (see *STEP 7-online help*).

The parameters for the 2 parameterization alternatives are subdivided into:

- static parameters
- dynamic parameters

The table below shows the characteristics of static and dynamic parameters.

Table 2-8 Static and dynamic parameters

Parameter	can be set with	CPU operating status
static	Programming Devices	STOP
dynamic	Programming Devices	STOP
	SFCs 55 to 57 in user program	RUN

Default settings

The digital output features default settings for diagnostics, substitute values, etc..

These defaults apply to digital modules which were not parameterized in STEP 7.

Configurable characteristics

The characteristics of the SM 322; DO 4 x 24V/10 mA can be parameterized with the following parameter blocks:

- Basic settings
- Diagnostics

Channel groups allocation

The table below shows the allocation of the 4 channels to the 4 channel groups of digital output.

Table 2-9 Assignment of the four channels to the four channel groups of SM 322; DO 4 x 24V/10mA and SM 322; DO 4 x 15V/20mA

Channel	Allocated channel group
Channel 0	Channel group 0
Channel 1	Channel group 1
Channel 2	Channel group 2
Channel 3	Channel group 3

Parameters of the digital output module

The table below provides an overview of the parameters and shows what parameters:

- are static or dynamic,
- can be used for the module as a whole or for a channel group.

Table 2-10 Parameters of SM 322; DO 4 x 24V/10 mA and SM 322; DO 4 x 15V/20 mA

Parameter	SM 322; DO 4 x DC 24V/10 mA / or 15V/20 mA			
	Range of values	Default	Type of	Effective range
Basic settings				
• Enable diagnostic interrupt	yes/no	no	dynamic	module
• retain last valid value	yes/no	no	dynamic	Module
• Switch to substitute value	yes/no	yes	dynamic	Module
• Substitute value	0 / 1	0	dynamic	Module
Diagnostics				
• Short-circuit to M	yes/no	no	static	Channel group
• Wire break monitoring [1]	yes/no	no	static	Channel group
• Supply voltage fault	yes/no	no	static	Channel group

[1] If wire break diagnostic enable is not parameterized there will be no indication by the channel fault LED in the event of a wire break.

2.3.3 Diagnostic messages

Introduction

You can use the diagnostic function to determine whether signal output takes place without errors.

Parameterizing diagnostics

You program the diagnostics functions in STEP 7.

Diagnostic evaluation

We need to distinguish between programmable and non-programmable diagnostic messages when analyzing diagnostics data. Programmable diagnostic messages such as "short-circuit to M" are only output if diagnostics data analysis was enabled at the "wire break" or "short-circuit to M" parameters.

Non-configurable diagnostic messages are general, i.e. independent of parameterization.

A diagnostic signal results in a diagnostic interrupt being triggered providing the diagnostic interrupt has been enabled by way of parameterization.

Irrespective of the parameterization, known module errors always result in the SF LED or the corresponding channel fault LED lighting irrespective of the CPU operating status (at POWER ON).

Exception:

The SF LED and the corresponding channel fault LED light in the event of a wire break only when parameterization is enabled.

Diagnostics of digital output module

The table below provides an overview of the diagnostic messages. You enable the diagnostics functions in STEP 7.

The diagnostic information refers to either the individual channels or the entire module.

Table 2-11 Parameters of SM 322; DO 4 x 24V/10mA and SM 322; DO 4 x 15V/20mA

Diagnostic message	Effective range of diagnostics	Configurable
Short-circuit to M	Channel group	Yes
Wire break		
No-load voltage		
Module not configured	Module	No
external auxiliary voltage missing		
No internal auxiliary voltage		
Fuse blown		
Time watchdog tripped		
EPROM error		
RAM error		
CPU error		

Wire break detection

A wire break is detected at a current ≤ 0.15 mA.

Reading out diagnostic messages

You can read the system diagnostics data in STEP 7. You can read detailed diagnostic messages from the module in the user program with SFC 59 of SFC 53.

Causes of error and remedies

The table below provides a list of possible causes, marginal conditions for fault recognition and corresponding corrective measures for individual diagnostic messages.

However, be aware that error detection must be programmed accordingly at the modules in order to output programmable diagnostic messages.

Table 2-12 Diagnostic messages as well as their causes of error and remedies for the SM 322; DO 4 x 24V/10mA and SM 322; DO 4 x 15V/20mA

Diagnostic message	Fault recognition at	Possible fault causes	Corrective measures
Short-circuit to M	only when output at "1"	output overload	Eliminate overload
		Short-circuit between the two output lines	Eliminate the short-circuit
Wire break	only when output at "1"	Break in line between module and actuator	Connect line
		Channel not used (open)	disable channel by parameterization "diagnostics wire break"
No-load voltage	only when output at "1"	Failure of internal channel supply voltage	Replace module
Incorrect parameters in module	general	Invalid parameters loaded in module by means of SFC	Check parameterization of module and re-load valid parameters
Module not configured	general	Invalid parameters loaded in module by means of SFC	Check parameterization of module and re-load valid parameters
external auxiliary voltage missing	general	No module supply voltage L+	Provide L+ supply
No internal auxiliary voltage	general	No module supply voltage L+	Provide L+ supply
		module-internal fuse defective	Replace module
Fuse blown	general	module-internal fuse defective	Replace module
Time watchdog tripped EPROM error CPU error	general	partially high electromagnetic interference	Eliminate interference sources and switch CPU supply voltage OFF/ON
		Module defective	Replace module

2.3.4 Interrupts

Introduction

The digital output can trigger a diagnostic interrupt.

Parameterizing interrupts

Interrupts can be configured in STEP 7.

Default setting

The interrupts are inhibited by way of default.

Diagnostic interrupt

The module triggers a diagnostics interrupt when it detects incoming or outgoing errors such as short-circuit to M, provided this interrupt function is enabled. Diagnostic functions inhibited by parameterization cannot trigger an interrupt. The CPU interrupts processing of the user program or low-priority classes and processes the diagnostic interrupt module (OB82).

Influence of the supply voltage and of the operating state

The output values are dependent on the supply voltages and CPU operating status.

The table below provides an overview of these dependencies.

Table 2-13 Dependencies of output values on the CPU operating status and supply voltage L+ of SM 322; DO 4 x 24V/10 mA and SM 322; DO 4 x 15V/20 mA

Operating status CPU		Supply voltage L+ at digital module	Output value of the digital module
POWER ON	RUN	L+ applied	CPU value
		No L+	0 signal
	STOP	L+ applied	Substitute value / last value Substitute value for 0-signal is default setting
		No L+	0 signal
POWER OFF	-	L+ applied	0 signal
		No L+	0 signal

Failure of the supply voltage is always indicated by the SF LED on the front of the module and additionally entered in diagnostics.

2.4 Digital output module SM 322; DO 4 x 15V/20 mA (6ES7322-5RD00-0AB0)

2.4.1 Features and technical specifications

Order Number

6ES7322-5RD00-0AB0

Features

SM 322; DO 4 x 15V/20mA has the following properties:

- 4 outputs
  - electrically isolated from the bus
  - electrically isolated from each other
- suitable for
  - intrinsically safe valves
  - acoustic interrupts
  - indicators
- configurable diagnostics
- configurable diagnostic interrupt
- configurable default output
- Status indication (0...3) = green LEDs
  Fault indications = red LEDs for
  - group fault indication (SF)
  - channel-related short-circuit and wire-break error message (F0 to F3)
- Intrinsic safety of outputs in accordance with 60079-11
- 2-wire actuator connection
- Configuration in Run (CiR) supported

Wiring diagram of SM 322; DO 4 x 15V/20mA

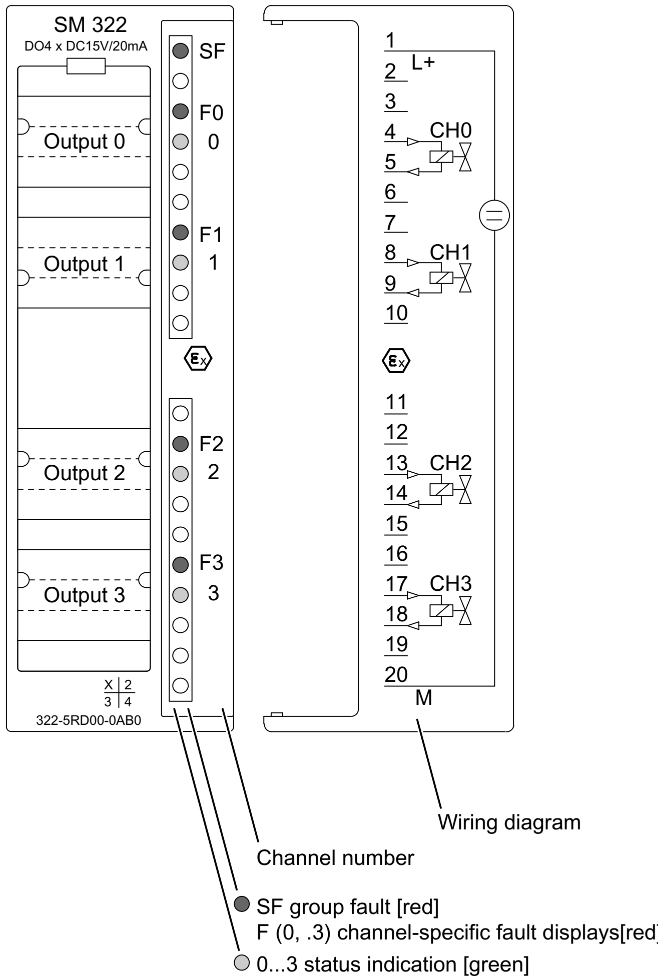


Image 2-6 Wiring diagram of SM 322; DO 4 x 15V/20mA

Notes on intrinsically-safe installation

You must connect the DM 370 dummy module between the CPU or IM 153 (in a distributed configuration) and the Ex I/O modules whose signal cables lead into the hazardous location. In a distributed configuration with an active backplane bus, you should use the ex dividing panel/ex barrier instead of the dummy module.

Power supply for an intrinsically-safe structure

In order to maintain the clearances and creepage distances, L+/M must be routed via the line chamber LK393 when operating modules with signal cables that lead to the hazardous location.

Block diagram of the SM 322; DO 4 x 15V/20 mA

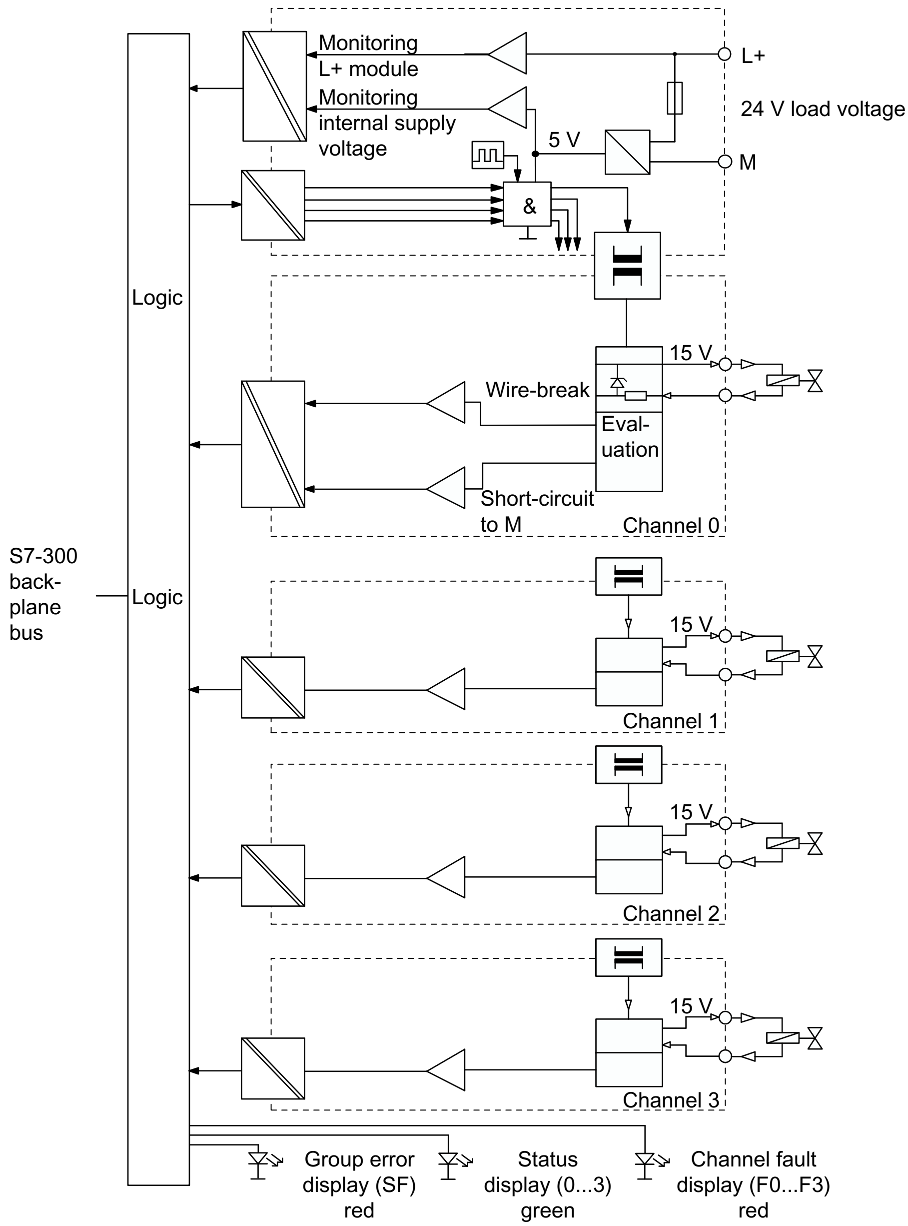


Image 2-7 Block diagram of digital output module SM 322; DO 4 x 15V/20 mA

Technical specifications of the SM 322; DO 4 x 15V/20 mA

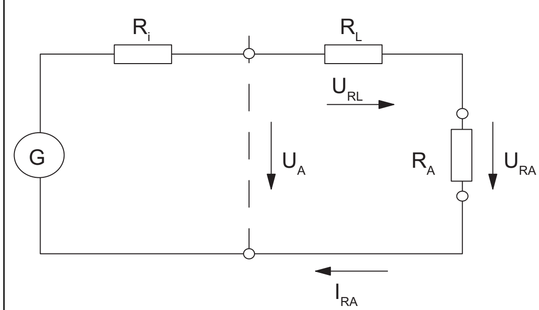
Dimensions and Weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	approx. 230 g
Module-specific data	
Configuration in Run (CiR) supported	yes

• Behavior of non-configured inputs during CiR	return the output value which was valid before the parameterization
Number of outputs	4
Line length, shielded	max. 200 m
ATEX approvals	II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 01ATEX1056 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply Rated load voltage L+ • Reverse voltage protection	1. 5 V DC 2. 24 V DC yes
Total current of outputs	
• horizontal arrangement up to 60 °C	no restrictions
• vertical installation to 40 °C	no restrictions
Electrical isolation	
• between the channels and backplane bus	yes
• between the channels and load voltage L+	yes
• between the channels	yes
• between the backplane bus and load voltage L+	yes
Permitted potential difference (V_{ISO}) of signals of the Ex area	
• between the channels and backplane bus	60 VDC 30 VAC
• between the channels and load voltage L+	60 VDC 30 VAC
• between the channels	60 VDC 30 VAC
• between the backplane bus and load voltage L+	60 VDC 30 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area	
• between the channels and backplane bus	300 VDC 250 VAC
• between the channels and load voltage L+	300 VDC 250 VAC
• between the channels	300 VDC 250 VAC
• between the backplane bus and load voltage L+	75 VDC 60 VAC
Insulation tested	
• Channels to backplane bus and load voltage L+	with 2500 V DC

• Channels to each other	with 2500 V DC
• between the backplane bus and load voltage L_+	with 500 V DC
Current input	
• from backplane bus • from load voltage L+ (at rated data)	Max. 85 mA max. 160 mA
Module power loss	typical 3 W
Status, interrupts, diagnostics	
Status indication	
• Outputs	green LED per channel
Interrupts	
• Diagnostic interrupt	Configurable
Diagnostic functions	
• Group fault indication	red LED (SF)
• Channel fault indication	red LED (F) per channel
• Diagnostic functions readout	possible
monitoring for	
• short-circuit	I > 20.5 mA (±10%)
• Wire break	I ≤ 0.15 mA
Safety specifications (see EU special test certificate KEMA 01ATEX1056 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))	
Maximum values of the output circuits (per channel)	
• U_0 (no-load output voltage)	max.15.75 V
• I_0 (short-circuit current)	max. 85 mA
• P_0 (load power)	max. 335 mW
• L_0 (permissible external inductance)	max. 5 mH
• C_0 (permissible external capacity)	max. 478 nF
• U_m (fault voltage)	max. 60 VDC 30 VAC
• T_a (permissible ambient temperature)	max. 60°C
Data for sensor selection	
Outputs	
• No-load voltage U_{A0} • Internal resistance R_I	DC 15 V ±5% 200 Ω ±5%
Curve vertices E	
• Voltage U_E • Current I_E	DC 10 V ±10% 20.5 mA ±10%
Parallel wiring of two outputs	
• for redundant activation of a load	not possible
• for increasing power	possible
Switching frequency	
• at resistive load	100 Hz
• at inductive load (L < Lo)	100 Hz

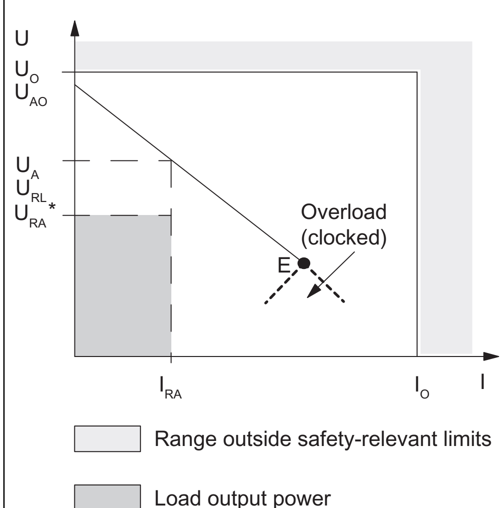
Short-circuit protection of the output	yes, electronic
• Response threshold	Curve vertex E

Block diagram



G	Generator
R_i	Internal resistance
R_L	Line resistor
R_A	Load resistor
U_{AO}	No-load voltage
U_A	Output voltage
U_{RL}	Voltage drop at load resistor
U_{RA}	Output power at load
U_0	max. output voltage
I_0	max. output voltage
I_{RA}	Load current

Output characteristic



E	Curve vertice (U_E, I_E) U_E = 10 V ± 10% I_E = 20.5 mA ± 10% Output current electronically clocked at overload. Clock ratio ~ 1:25

Additional information on Configuration in RUN (CiR)

...can be found in the online help for STEP7 and in the manual System modification in RUN by means of CiR on the Internet (http://support.automation.siemens.com/WW/view/en/14044916).

See also

The LK 393 line chamber (Page 14)

Configuration of an S7-300 with Ex I/O Modules (Page 17)

Configuration of an ET 200M with Ex I/O modules (Page 20)

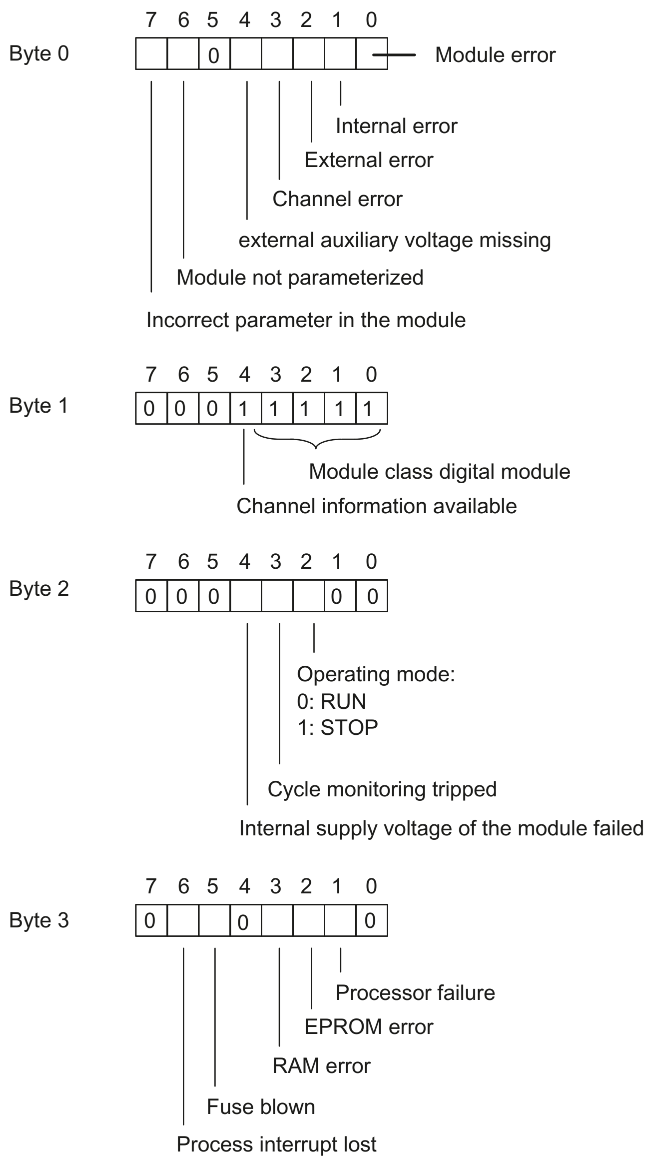
2.5 Diagnostic data records of the S7 Ex digital modules

Structure and contents of the diagnostic data records

The diagnostics data for a module is stored in data records 0 and 1.

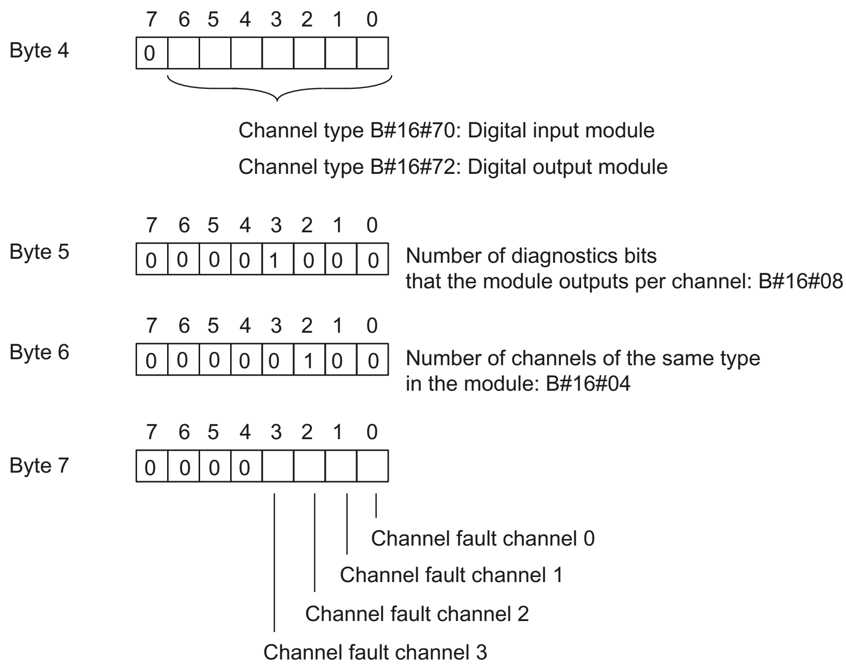
- Data record 0 contains 4 bytes of diagnostics data describing the current status of the module.
- Data record 1 contains the 4 bytes of diagnostics data also stored in data record 0, plus additional module-specific diagnostics data that describe the status of a channel of the module.

Byte 0 to 3 (data records 0 and 1)

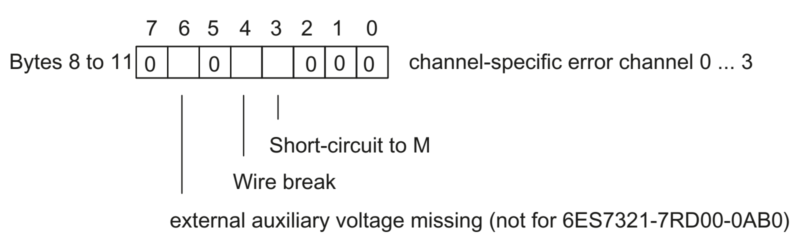


Byte 4 to byte 6 infoblock (data record 1)

Bytes 4 to 6 form the infoblock with the information about channel type, length of diagnostics information and the length of the channels.



The channel error vector is followed by the channel-specific diagnostics data.



3 SIMATIC S7 Ex Analog Modules

3.1 Analog value representation

3.1.1 Analog Value Representation of Analog Input and Output Values

Conversion of analog values

The CPU processes the analog values only in binary form.

Analog input modules convert the analog process signal into digital form.

Analog output modules convert the digital output value into an analog signal.

Analog value representation

The digitized analog value is the same for both input and output values with the same rated range.

The analog values are represented as two's complement.

Table 3-1 Characteristics of Analog Modules

Resolution	Analog value															
Bit number	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit significance	sign	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

sign

The sign of the analog value is always in bit number 15:

- "0" → +
- "1" → -

3.1.2 General information about the display of analog values within the measuring ranges of analog inputs

Introduction

This section contains the tables of digitized analog values for the measurement ranges of analog modules

Reading measured value tables

The tables represent the digitized analog values of the various measurement ranges of analog input modules.

As the binary notation of analog values is always the same, these tables only contain a comparison of measuring ranges with the units.

Measured value resolution

Deviating from this, a Sigma Delta AD converter is used with the analog input modules described in the *manual*. Irrespective of the configurable integration time, this converter always makes available the maximum representable 15 Bit +sign. Lower resolution ratings than indicated in the specifications are due to conversion noise based on the shorter integration times (2.5, $16^2/_3$, 20 ms). The different integration times do not influence the numeric notation of measured values. The number of stable bits is specified in the technical specifications.

The number of stable bits is the resolution at which, despite noise, the "no missing code"characteristics of the AD converter are guaranteed.

The bits that are no longer stable at shorter integration times are marked with "x" in the following tables.

Table 3-2 Representation of the smallest stable unit of the analog value

Stable bits (+ sign)	Smallest stable unit		Analog value	
	decimal	hexadecimal	High-Byte	Low-Byte
9	64	40_H	Sign 0 0 0 0 0 0 0	0 1 x x x x x x
10	32	20_H	Sign 0 0 0 0 0 0 0	0 0 1 x x x x x
12	8	8_H	Sign 0 0 0 0 0 0 0	0 0 0 0 1 x x x
13	4	4_H	Sign 0 0 0 0 0 0 0	0 0 0 0 0 1 x x
15	1	1_H	Sign 0 0 0 0 0 0 0	0 0 0 0 0 0 0 1

Noise-prone bits

At a constant input voltage, noise causes distribution of the supplied value by more than ± 1 digit. In the majority of cases, these "unsteady" values can be used as they are. In any case, this is the most effective option when subsequent processing has integral action characteristics (integrator, controller, etc.) in any form whatsoever. If this "unsteady state" is undesirable (e.g. for displays), you can

- mask out the "x" bits
- round up to "stable" bits
- filter the successive values

When choosing these options, you first have to scan the values in order to prevent any change or filtering of the coding of invalid measured values (-32768 / 8000_H and 32767 / $7FFF_H$).

3.1.3 Analog value notation of the voltage measurement ranges

Voltage measuring ranges ± 25 mV, ± 50 mV, ± 80 mV, ± 250 mV, ± 500 mV and ± 1 V.

Table 3-3 Notation of the digitized measured value of an analog input module (voltage measuring range)

Measuring ranges						Units		Location
± 25 mV	± 50 mV	± 80 mV	± 250 mV	± 500 mV	± 1 V	decimal	hexadec-imal	
> 29.397	> 58.794	> 94.071	>293.96	>587.94	> 1.1750	32767	7FFF$_H$	Overflow
29.397	58.794	94.071	293.96	587.94	1.1750	32511	7EFF$_H$	Over-range
:	:	:	:	:	:	:	:	
25.001	50.002	80.003	250.02	500.02	1.0001	27649	6C01$_H$	
25.000	50.000	80.000	250.00	500.00	1.0000	27648	6C00$_H$	Rated range
18.750	37.500	60.000	187.50	375.00	0.7500	20736	5100$_H$	
:	:	:	:	:	:	:	:	
- 18.750	- 37.500	- 60.000	- 187.50	- 375.00	0.7500	-20736	AF00$_H$	
- 25.000	- 50.000	- 80.000	- 250.00	- 500.00	- 1.0000	-27648	9400$_H$	
- 25.001	- 50.002	- 80.003	- 250.01	- 500.02	- 1.0001	-27649	93FF$_H$	Under-range
:	:	:	:	:	:	:	:	
- 29.398	- 58.796	- 94.074	- 293.98	- 587.96	- 1.1750	-32512	8100$_H$	
<- 29.398	<- 58.796	<- 94.074	<- 293.98	<- 587.96	<- 1.1750	-32768	8000$_H$	Under-flow

3.1.4 Analog value notation of the current measurement ranges

0 mA to 20 mA and 4 mA to 20 mA current measuring ranges

Table 3-4 Displaying the digitized measured values SM 331; AI 4 x 0/4.... .20mA and AI 2 x 0/4 ... . 20mA HART analog input modules

Measuring range from 0 to 20 mA	Measuring range from 4 to 20 mA	Units		Location
		Decimal	Hexadeci-mal	
> 23.515	>22.810	32767	7FFF$_H$	Overflow
23.515	22.810	32511	7EFF$_H$	Overrange
:	:	:	:	
20.0007	20.0005	27649	6C01$_H$	

Measuring range from 0 to 20 mA	Measuring range from 4 to 20 mA	Units		Location
		Decimal	Hexadecimal	
20.000	20.000	27648	$6C00_H$	Rated range
14.998	16.000	20736	5100_H	
:	:	:	:	
0.0	4.000	0	0_H	
<0.0 [2]	3.9995	-1	$FFFF_H$	
	3.800	-345	$FEA7_H$	
	3.600	-691	$FD4D_H$	Wire break limit I ≦ 3.60 mA in accordance with NAMUR [1]
	:	:	:	Underrange
	1.1852	-4864	$ED00_H$	
	<1.1852	32767	$7FFF_H$	Underflow
	0[3]	58624	$E500_H$	

[1] NAMUR limits are evaluated only if wire break diagnostics is enabled. When wire break diagnostics is enabled, $7FFF_H$ is output if the current value drops below 3.6 mA. If the value increases again to above 3.8 mA, the wire break signal is canceled and the current value is output again.

[2] Negative measured values cannot be acquired. For analog values < 0 mA each display of the digital measured value of 0 mA remains.

[3] If wire break monitoring is not enabled, the measured value can fall to 0 mA and the module returns $E500_H$.

3.1.5 Analog value notation of the measurement ranges of resistive encoders

Resistance sensor with measurement ranges 150 Ω, 300 Ω and 600 Ω

Table 3-5 Notation of the digitized measured value of an analog input module (resistance sensor)

Measuring range 150 Ω	Measuring range 300 Ω	Measuring range 600 Ω	Units		Location
			Decimal	Hexadecimal	
> 176.383	> 352.767	> 705.534	32767	$7FFF_H$	Overflow
176.383	352.767	705.534	32511	$7EFF_H$	Overrange [1]
:	:	:	:	:	
150.005	300.011	600.022	27649	$6C01_H$	

Measuring range 150 Ω	Measuring range 300 Ω	Measuring range 600 Ω	Units		Location
			Deci-mal	Hexa-deci-mal	
150.000	300.000	600.000	27648	$6C00_H$	Rated range
112.500	225.000	450.000	20736	5100_H	
:	:	:	:	:	
0.000	0.000	0.000	0	0_H	
(negative values physically not possible)					
[1] The same degree of accuracy as in the rated range is guaranteed in the overrange.					

3.1.6 Analog value representation for the standard temperature range

Standard temperature range of the sensor Pt 100, Pt 200 in accordance with DIN 43760 and IEC 751

Table 3-6 Notation of the digitized measured value of an analog input module (temperature range standard; Pt 100, Pt200)

Temperature range standard 850 °C Pt 100, Pt 200 in °C	decimal	hexadecimal	location
> 1300.0	32767	$7FFF_H$	Overflow
1300.0 : 850.1	13000 : 8501	$32C8_H$: 2135_H	Overrange [1]
850.0 : -200.0	8500 : -2000	2134_H : $F830_H$	Rated range
-200.1 : -240.0	-2001 : -2400	$F82F_H$: $F6A0_H$	Underrange[2]
< -240.0	-32768	8000_H	Underflow

[1] The characteristic of the Pt 100, Pt 200 sensor is not defined in the overrange. The overrange has been extended to 1300˚C in order to be able to incorporate future technical developments of platinum thermal resistors (thermistors). It is not possible to specify the accuracy of this range.

[2] The characteristic of the Pt 100, Pt 200 sensor is not defined in the overrange. The rise of the characteristic curve is retained on leaving the linearized rated range. It is not possible to specify the accuracy of this range.

3.1.7 Analog value representation for the standard temperature range Ni 100

Standard temperature range Ni 100 in accordance with DIN 43760

Table 3-7 Notation of the digitized measured value of an analog input module (temperature range standard; Ni 100)

Temperature range standard Ni 100 in °C	decimal	hex	Location
> 295.0	32767	$7FFF_H$	Overflow
295.0 : 250.1	2950 : 2501	686_H : $9C5_H$	Overrange [1]
250.0 : -60.0	2500 : -600	$9C4_H$: $FDA8_H$	Rated range
-60.1 : -105.0	-601 : -1050	$FDA7_H$: $FF97_H$	Underrange[1]
< - 105.0	-32768	8000_H	Underflow
[1] The characteristic of the Ni 100 sensor is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized rated range. It is not possible to specify the accuracy of these ranges.			

3.1.8 Analog value representation for the climatic temperature range

Climatic temperature range of the sensor Pt 100, Pt 200 in accordance with DIN 43760 and IEC 751

Table 3-8 Notation of the digitized measured value of an analog input module (temperature range climatic; Pt 100, Pt200)

Climatic temperature range Pt 100, Pt 200 in °C	decimal	hex	Location
> 325.12	32767	$7FFF_H$	Overflow
325.12 : 276.49	32512 : 27649	$7F00_H$: $6C01_H$	Overrange [1]
276.48 : -200.00	27648 : -20000	$6C00_H$: B1E0	Rated range

Climatic temperature range Pt 100, Pt 200 in °C	decimal	hex	Location
-200.01 : -240.00	-20001 : -24000	B1E1 : $A240_H$	Underrange[2]
< - 240.00	-32768	8000_H	Underflow
[1] The same degree of accuracy as in the rated range is guaranteed in the overrange Pt 100, Pt 200 climatic. [2] The characteristic of the Pt 100, Pt 200 sensor is not defined in the overrange. The rise of the characteristic curve is retained on leaving the linearized rated range. It is not possible to specify the accuracy of these ranges.			

3.1.9 Analog value representation for the climatic temperature range Ni 100

Climatic temperature range Ni 100 in accordance with DIN 43760

The same value range as in the standard range of the Ni 100 sensor applies in the climatic range Ni 100 only with a higher resolution of 0.01°C instead of 0.1°C.

Table 3-9 Notation of the digitized measured value of an analog input module (temperature range climatic Ni 100)

Climatic temperature range Ni 100 in °C	decimal	hex	Location
> 295.00	32767	$7FFF_H$	Overflow
295.00 : 250.01	29500 : 25001	$733C_H$: $61A9_H$	Overrange [1]
250.00 : -60.00	25000 : -6000	$61A8_H$: $E890_H$	Rated range
-60.01 : -105.00	-6001 : -10500	$E88F_H$: $D6FC_H$	Underrange[1]
< - 105.00	-32768	8000_H	Underflow
[1] The characteristic of the Ni 100 sensor is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized rated range. It is not possible to specify the accuracy of these ranges.			

3.1.10 Analog value representation for the temperature range type B

Temperature range sensor type B

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-10 Notation of the digitized measured value of an analog input module (temperature range, type B)

Temperature range in °C Type B	decimal	hexadecimal	location
> 2070.0	32767	$7FFF_H$	Overflow
2070.0	20700	$50DC_H$	Overrange [2]
:	:	:	
1820.1	18201	4719_H	
1820.0	18200	4718_H	Rated range
:	:	:	
:	:	:	
200.0[1]	2000	$7D0_H$	
:	:	:	
0.0	0	0_H	
-0.1	-1	$FFFF_H$	Underrange[2]
:	:	:	
-150.0	-1500	$FF24_H$	
< -150.0	-32768	8000_H	Underflow

In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below $FA24_H$ the analog input module signals underflow and outputs 8000_H.

[1] The module linearizes the range +1820 °C to +200°C for type B. The gradient of the curve deteriorates below +200°C to an extent which no longer allows any precise analysis. The rise in the characteristic curve at this point is retained until underrange is reached.

The characteristic curve of the type B thermocouple does not feature monotone characteristics *in the temperature range between 0 and 40° C. Values measured in this range cannot be allocated to a specific temperature.*

[2] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized range. It is not possible to specify the accuracy of these ranges.

3.1.11 Analog value representation for the temperature range type E

Temperature range sensor type E

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-11 Notation of the digitized measured value of an analog input module (temperature range, type E)

Temperature range in °C	decimal	hexadecimal	location
> 1200.0	32767	$7FFF_H$	Overflow
1200.0 : 1000.1	12000 : 10001	$2EE0_H$: 2711_H	Overrange [2]
1000.0 : : -150.0[1] : -270.0	10000 : : -1500 : -2700	2710_H : : $FA24_H$: $F574_H$	Rated range
≦-270.1	≦-2701	≦$F573_H$	Underrange[2]

In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below $F0C4_H$ the analog input module signals underflow and outputs 8000_H.

[1] The module will linearize the range +1000 °C to -150 °C for type E. The gradient of the curve deteriorates below -150 °C to an extent which no longer allows any precise analysis. The rise in the characteristic curve at this point is retained until underrange is reached.

[2] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized range. It is not possible to specify the accuracy of these ranges.

3.1.12 Analog value representation for the temperature range type J

Temperature range sensor type J

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-12 Notation of the digitized measured value of an analog input module (temperature range, type J)

Temperature range in °C	decimal	hexadecimal	location
> 1360.0	32767	$7FFF_H$	Overflow
1360.0 : 1200.1	13600 : 12001	3520_H : $2EE1_H$	Overrange [1]
1200.0 : : -210.0	12000 : : -2100	$2EE0_H$: : $F7CC_H$	Rated range
≦-210.1	≦-2101	≦$F7CB_H$	Underrange[1]
In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below $F31C_H$ the analog input module signals underflow and outputs 8000_H. [1] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized rated range. It is not possible to specify the accuracy of these ranges.			

3.1.13 Analog value representation for the temperature range type K

Temperature range sensor type K

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-13 Notation of the digitized measured value of an analog input module (temperature range, type K)

Temperature range in °C	decimal	hexadecimal	location
> 1622.0	32767	$7FFF_H$	Overflow
1622.0 : 1372.1	16220 : 13721	$3F5C_H$: 3599_H	Overrange [2]

Temperature range in °C	decimal	hexadecimal	location
1372.0 : : -220.0[1] : -270.0	13720 : : -2200 : -2700	3598_H : : $F768_H$: $F574_H$	Rated range
≦-270.1	≦-2701	≦$F573_H$	Underrange[2]
In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below $F0C4_H$ the analog input module signals underflow and outputs 8000_H. [1] The module linearizes the range +1372 °C to -220°C for type K. The gradient of the curve deteriorates below -220°C to an extent which no longer allows any precise analysis. The rise in the characteristic curve at this point is retained until underrange is reached. [2] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the rated range. It is not possible to specify the accuracy of these ranges.			

3.1.14 Analog value representation for the temperature range type L

Temperature range sensor type L

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-14 Notation of the digitized measured value of an analog input module (temperature range, type L)

Temperature range in °C	decimal	hexadecimal	location
> 1150.0	32767	$7FFF_H$	Overflow
1150.0 : 900.1	13500 : 9001	$2CEC_H$: 2329_H	Overrange [1]
900.0 : : -200.0	9000 : : -2000	2328_H : : $F830_H$	Rated range
≦-200.1	≦-2001	≦$F82F_H$	Underrange[1]
In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below $F380_H$ the analog input module signals underflow and outputs 8000_H. [1] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized rated range. It is not possible to specify the accuracy of these ranges.			

3.1.15 Analog value representation for the temperature range type N

Temperature range sensor type N

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-15 Notation of the digitized measured value of an analog input module (temperature range, type N)

Temperature range in°C	decimal	hexadecimal	location
> 1550.0	32767	$7FFF_H$	Overflow
1550.0 : 1300.1	15500 : 13001	$3C8C_H$: $32C9_H$	Overrange [2]
1300.0 : : -220.0[1] : -270.0	13000 : : -2200 : -2700	$32C8_H$: : $F768_H$: $F574_H$	Rated range
≦-270.1	≦-2701	≦$F573_H$	Underrange[2]

In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below $F0C4_H$ the analog input module signals underflow and outputs 8000_H.

[1] The module linearizes the range +1300 °C to -220°C for type N. The gradient of the curve deteriorates below -220°C to an extent which no longer allows any precise analysis. The rise in the characteristic curve at this point is retained until underrange is reached.

[2] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the rated range. It is not possible to specify the accuracy of these ranges.

3.1.16 Analog value representation for the temperature range type R

Temperature range sensor type R

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-16 Notation of the digitized measured value of an analog input module (temperature range, type R)

Temperature range in °C	decimal	hexadecimal	location
> 2019.0	32767	$7FFF_H$	Overflow
2019.0 : 1769.1	20190 : 17691	$4EDE_H$: $451B_H$	Overrange [1]
1769.0 : : -50.0	17690 : : -500	$451A_H$: : $FE0C_H$	Rated range
-50.1 : -170.0	-501 : -1700	$FE0B_H$: $F95C_H$	Underrange[1]
< -170.0	-32768	8000_H	Underflow
In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below $F95C_H$ the analog input module signals underflow and outputs 8000_H. [1] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized rated range. It is not possible to specify the accuracy of these ranges.			

3.1.17 Analog value representation for the temperature range type S

Temperature range sensor type S

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-17 Notation of the digitized measured value of an analog input module (temperature range, type S)

Temperature range in °C	decimal	hexadecimal	location
> 1850.0	32767	$7FFF_H$	Overflow
1850.0 : 1769.1	18500 : 17691	4844_H : $451B_H$	Overrange [1]

Temperature range in °C	decimal	hexadecimal	location
1769.0 : : -50.0	17690 : : -500	$451A_H$: : $FE0C_H$	Rated range
-50.1 : -170.0	-501 : -1700	$FE0B_H$: $F95C_H$	Underrange[1]
< -170.0	-32768	8000_H	Underflow
In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below $F95C_H$ the analog input module signals underflow and outputs 8000_H. [1] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized range. It is not possible to specify the accuracy of these ranges.			

3.1.18 Representation of the analog values of the temperature range type T

Temperature range sensor type T

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-18 Notation of the digitized measured value of an analog input module (temperature range, type T)

Temperature range in °C	decimal	hex	Location
> 540.0	32767	$7FFF_H$	Overflow
540.0 : 400.1	5400 : 4001	1518_H : $0FA1_H$	Overrange [2]
400.0 : : -230.0 [1)] : -270.0	4000 : : -2300 : -2700	$0FA0_H$: : $F704_H$: $F574_H$	Rated range

Temperature range in °C	decimal	hex	Location
≦-270.1	≦-2701	≦F573$_H$	Underrange[2]
In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below F0C4$_H$ the analog input module signals underflow and outputs 8000$_H$.			
[1] The module will linearize the range +400 °C to -230°C for type T. The gradient of the curve deteriorates below -230°C to an extent which no longer allows any precise analysis. The rise in the characteristic curve at this point is retained until underrange is reached.			
[2] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized range. It is not possible to specify the accuracy of these ranges.			

3.1.19 Analog value representation for the temperature range type U

Temperature range sensor type U

The basic values of thermal voltages defined below conform to DIN IEC 584.

Table 3-19 Notation of the digitized measured value of an analog input module (temperature range, type U)

Temperature range in°C	decimal	hexadecimal	location
> 850.0	32767	7FFF$_H$	Overflow
850.0 : 600.1	8500 : 6001	2134$_H$: 0FA1$_H$	Overrange [1]
600.0 : : -200.0	6000 : : -2000	0FA0$_H$: : F830$_H$	Rated range
≦-200.1	≦-2001	≦F82F$_H$	Underrange[1]
In the case of incorrect wiring (e.g. polarity reversal, open inputs) or a sensor fault in the negative range (e.g. incorrect type of thermocouple), when dropping below F380$_H$ the analog input module signals underflow and outputs 8000$_H$.			
[1] The characteristic of the thermocouple is not defined in the overrange and underrange. The rise of the characteristic curve is retained on leaving the linearized range. It is not possible to specify the accuracy of these ranges.			

3.1.20 Analog Value Representation for the Output Ranges of Analog Outputs

Current output ranges from 0 to 20 mA and 4 to 20 mA

Table 3-20 Representation of analog output range of analog output modules (current output ranges)

Output range 0 to 20 mA	Output range 4 to 20 mA	Units		Location
		decimal	hex	
0.0	0.0	≥32512	≥7F00$_H$	Overflow
23.515	22.81	32511	7EFF$_H$	Overrange
:	:	:	:	
20.0007	20.005	27649	6C01$_H$	
20.000	20.000	27648	6C00$_H$	Rated range
:	:	:	:	
0.0	4.000	0	0$_H$	
0.0	3.9995	-1	FFFF$_H$	Underrange
	:	:	:	
	0.0	- 6912	E500$_H$	
	0.0	- 6913	E4FF$_H$	Underflow
		:	:	
		- 32768	8000$_H$	

Note

For the analog output SM 332; AO 4 x 0/4 ... 20mA the linearity can be reduced in the overrange for load impedances > 425 Ω .

3.2 General information on wiring technology

Abbreviations used

The diagrams in the next section show the various options of wiring encoders. The abbreviations used in the diagrams have the following meanings:

Abbreviation	Meaning
I_C+	Positive terminal of the constant current output
I_{C-}	Negative terminal of the constant current output
M+	Positive measuring line
M-	Negative measuring line
U_{ISO}	Potential difference between the inputs and grounding terminal M
U_{CM}	Potential difference between the inputs

Abbreviation	Meaning
L +	24 VDC power supply terminal
M	24 VDC power supply ground terminal
P5V	Supply voltage of module logic
$M_{internal}$	Module logic ground
U_V	Electrically isolated supply voltage of the compensating box
L_0+ to L_3+	Electrically isolated transducer supply per channel
U_M	Measurement voltage
R_S	Measuring resistor
U_V+; U_V-	External supply voltage of the transducer
QI_0- to QI_3-	Analog outputs current (output current)
M_0- to M_3-	Reference potentials of the analog output circuit
R_L	Resistance of the load/actuator
U_{ISO}	Potential difference between the reference potential of channels M_0- to M_3-, or between the channels and the M terminal of the CPU

See also

Wiring transducers to analog inputs (Page 103)

Connecting thermocouples to the analog input SM 331; AI 8 x TC/4 x RTD (Page 106)

Connection of resistance thermometers (e.g. Pt100) and resistance sensors (Page 111)

3.3 Wiring transducers to analog inputs

Transducers

The analog input modules support the connection of different transducers to suit a specific type of measurement:

- Voltage sensor
- Current sensor as
  - 2-wire transducer
  - 4-wire transducer
- Resistance sensor

Lines for analog signals

Shielded conductors twisted in pairs are used for the analog signals.

Electrically isolated analog input modules

A galvanic connection of measuring circuit ground M- to CPU ground M does not exist on electrically isolated analog input modules.

Electrically isolated analog input modules are used if there is any risk of potential difference V_{ISO} developing between reference ground M- of the measuring circuit and CPU ground M. Take appropriate measures to prevent any overshoot of the permitted potential difference V_{ISO}. Interconnect the reference potential M- of the measuring circuit with reference potential M of the CPU if the permitted value of V_{ISO} is actually exceeded or if you cannot precisely determine the potential difference. This also refers to unused inputs.

Electrical isolation between channels

The channels are electrically isolated by means of separate power transformers, and the signals are transferred via optocoupler. This electrical isolation tolerates high potential differences between the channels. In addition, very good values are achieved with regard to interference voltage rejection and crosstalk between the channels.

SM 331; AI 4 x 0/4...20mA features electrically isolated channels.

To facilitate channel isolation, The SM 331; AI 8 x TC/4 x RTD is equipped with optical semiconductor multiplexers that ensure a high common-mode range of $U_{CM} \leq$ DC 60 V. This represents a virtually equivalent solution in practical applications.

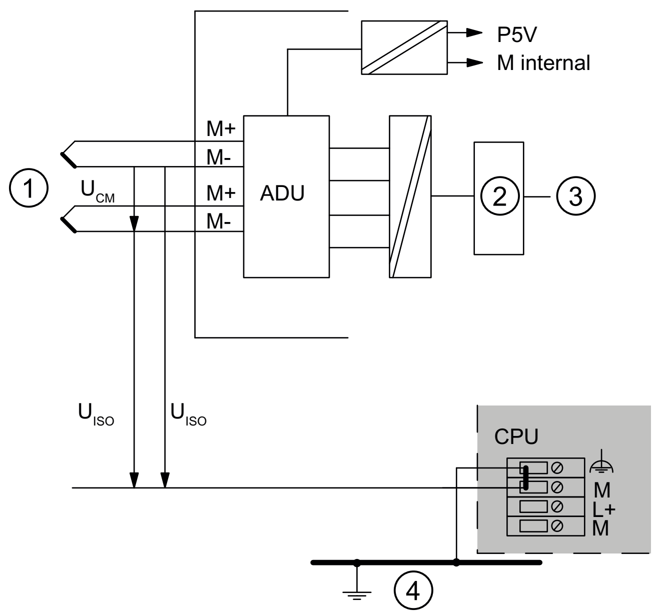
Higher potential differences can be tolerated if the modules are used to process signals from the non-Ex area.

Insulated transducers

Insulated transducers are not wired to local ground potential. These transducers can be operated in electrically isolated mode. Potential differences V_{CM} (static or dynamic) may develop between the input channels as a result of local conditions or interference. However, such potential differences may not exceed the permitted value of V_{CM}. If there is a possibility that the permissible value may be exceeded, the M- terminals of the input channels must be interconnected.

Interconnect M- of the input channels and M of the CPU if you expect any violation of V_{ISO} limits (inputs to the backplane bus).

The diagram below shows the basic wiring of insulated transducers to an electrically isolated analog input module.



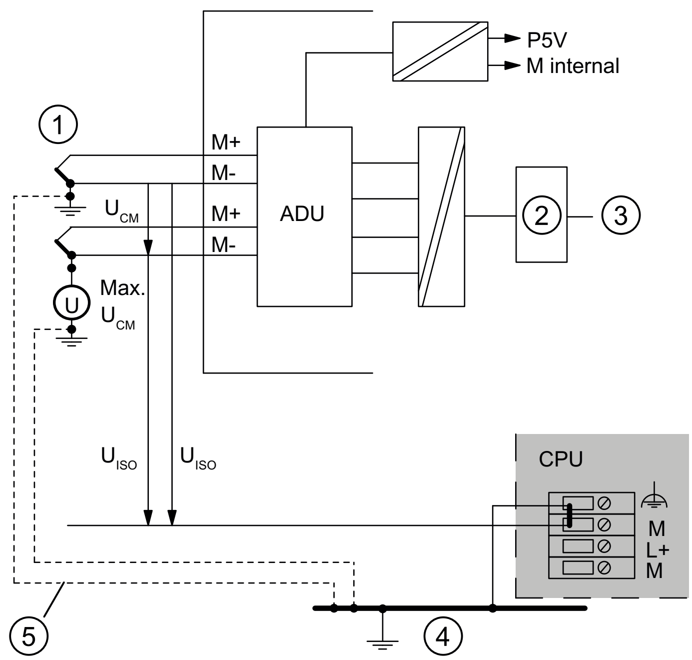
① Insulated transducers
② Logic
③ Backplane bus
④ Ground bus

Image 3-1 Connection of insulated transducers to an isolated analog input module

Non-insulated transducers

Non-insulated transducers are wired to local ground potential. Potential differences VCM (static or dynamic) may develop between locally distributed measuring points as a result of local conditions or interference. Install equipotential conductors between the measuring points in order to avoid such potential differences.

The diagram below shows the basic wiring of non-insulated transducers to an electrically isolated analog input module.



① Non-insulated transducers

② Logic

③ Backplane bus

④ Ground bus

⑤ Equipotential conductor

Image 3-2 Connection of non-insulated transducers to an electrically isolated analog input module

See also

Shielding (Page 33)

Using thermocouples (Page 112)

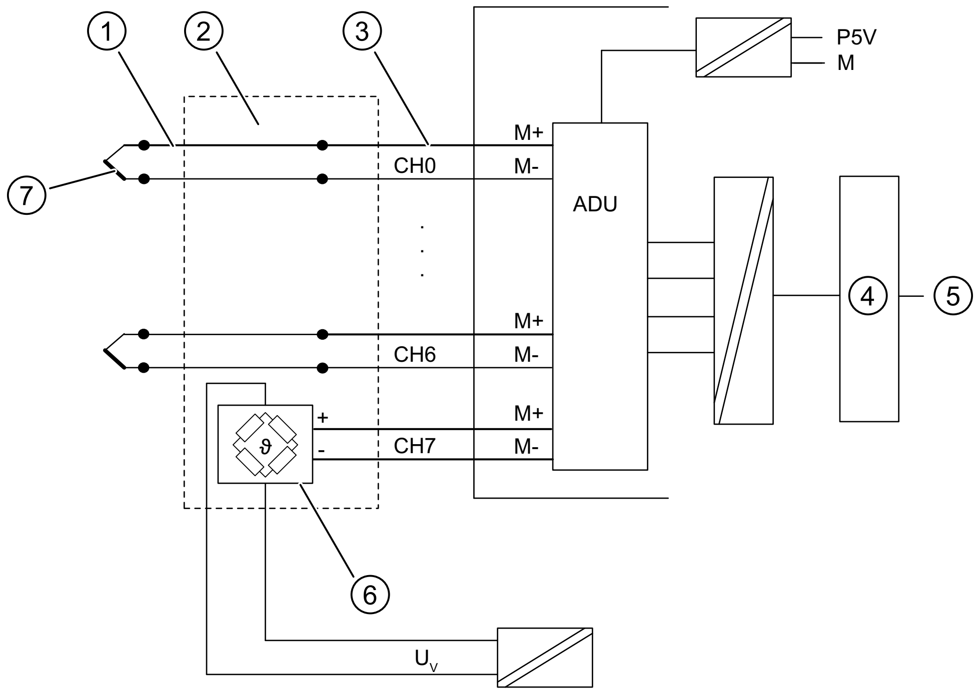
3.4 Connecting thermocouples to the analog input SM 331; AI 8 x TC/4 x RTD

Options of wiring thermocouples

The diagrams below show the various options of wiring thermocouples with external or internal compensation. The potential differences V_{CM} and V_{ISO} defined in the relevant chapters also apply to these circuits.

Thermocouples with compensation box

All thermocouples that are connected to the inputs of a module and which have the same reference junction compensate as follows. The thermocouples which use a compensation box must be of the **same** type. Each of the thermocouples can **be grounded at any arbitrary point**.



①	Equalizing conductor (material with same thermal e.m.f. as thermocouple)
②	Reference junction
③	Supply conductor (copper)
④	Logic
⑤	Backplane bus
⑥	Compensation box with reference junction temperature of 0 °C
⑦	Thermocouple

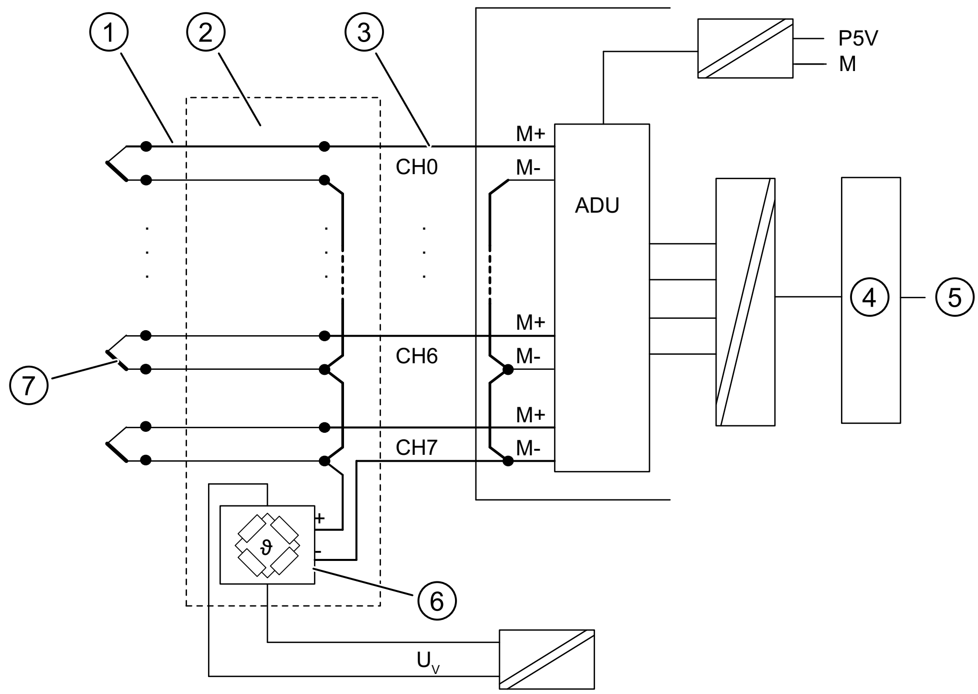
Image 3-3 Wiring of thermocouples with external compensation box to the electrically isolated analog input module SM 331; AI 8 x TC/4 x RTD

Thermocouples with direct looping-in of compensation box

The compensation box can be directly interconnected with the measuring circuit if the wiring of all thermocouples is **electrically isolated**.

Compensation channel CH 7 is thus not required and is now available as additional measuring input.

The **"Thermocouples with linearization and 0°C compensation"** type of measurement must be set for all channels. In doing so, the thermocouples that use a compensation box must be of the **same** type.



①	Equalizing conductor (material with same thermal e.m.f. as thermocouple)
②	Reference junction
③	Supply conductor (copper)
④	Logic
⑤	Backplane bus
⑥	Compensation box with reference junction temperature of 0 °C
⑦	Thermocouple

Image 3-4 Wiring of electrically isolated thermocouples to a compensation box and "0 °C compensation" measurement type with analog input module SM 331; AI 8 x TC/4 x RTD

Advantages

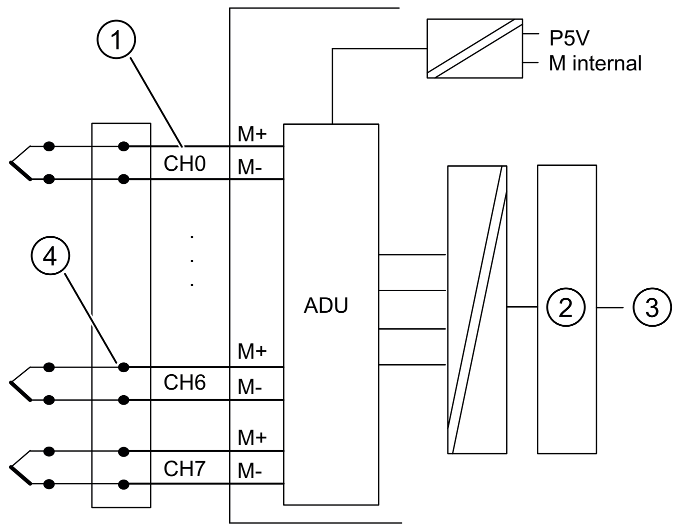
- When using a compensation box with a reference junction temperature of 0 °C, the voltage corresponding to the reference junction temperature is subtracted **directly**.
- **Channel 7** can be used **as additional measuring channel** in this circuit variant.
- The number of connecting cables between the compensation box and the analog input module is reduced.
- The faults, which are attributed to isolated compensation measurement do not occur.

Conditions

The thermocouples that are routed to the same compensation box **must only be grounded once at one point.**

Thermocouples with temperature compensation at the terminals

All eight inputs of the measuring channels are available if the thermocouples are wired via a reference junction regulated to 0 °C or 50 °C.

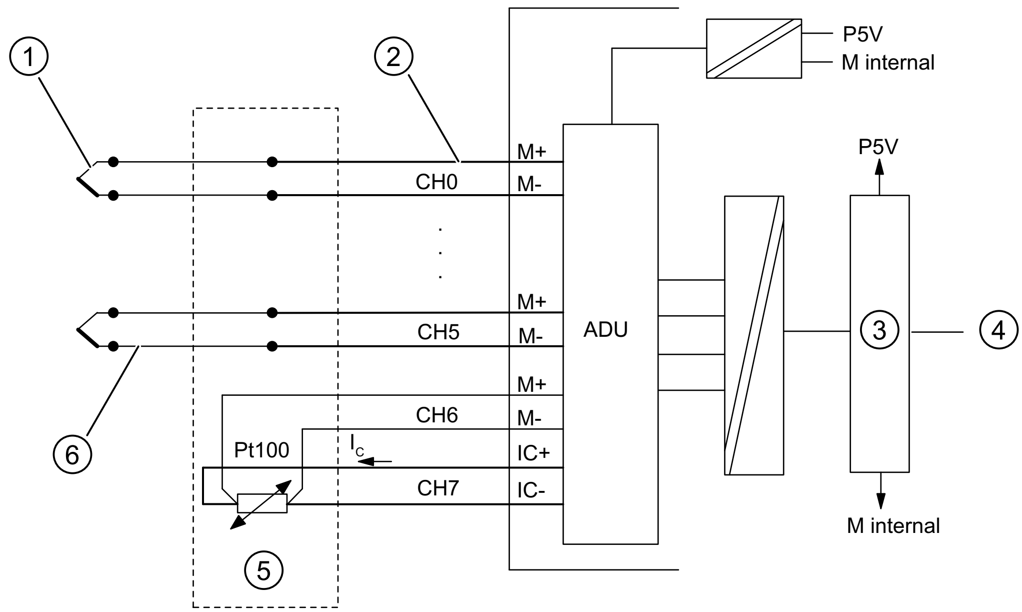


①	Supply conductor (copper)
②	Logic
③	Backplane bus
④	Reference junction regulated to 0 °C or 50 °C

Image 3-5 Wiring of thermocouples to analog input module SM 331; AI 8 x TC/4 x RTD via a reference junction regulated to 0°C or 50°C

Thermocouples with thermal resistor compensation

In this type of compensation, the terminal temperature of the reference junction is determined by a thermal resistance-type sensor in the climatic range.



①	Thermocouple
②	Supply conductor (copper)
③	Logic
④	S7-300 backplane bus
⑤	Reference junction e.g. Pt100
⑥	Equalizing conductor (material with same thermal e.m.f. as thermocouple)

Image 3-6 Wiring of thermocouples with external compensation by means of thermal resistance-type sensors (Pt100, for example)

Note

The two last channels (channel 6 and 7) of the analog input module SM 331; AI 8 x TC/4 x RTD are used for temperature compensation by means of a thermal resistor.

Thermocouples with internal compensation

The internal terminal temperature sensor must be used where thermocouples are wired directly or via compensating lines to the module. Each channel group can use one of the supported types of thermocouple independent of the other channel groups.

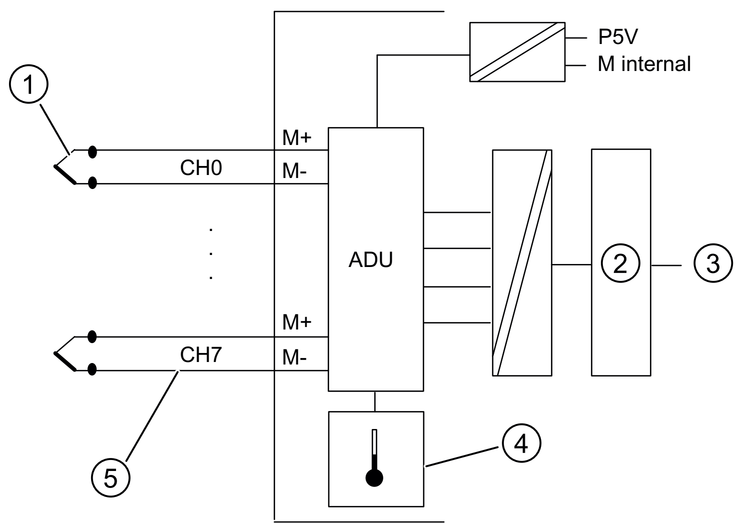


Image 3-7 Wiring of thermocouples with internal compensation to an electrically isolated analog input module

①	Thermocouple
②	Logic
③	Backplane bus
④	Internal recording of terminal temperature
⑤	Equalizing conductor (material with same thermal e.m.f. as thermocouple)

3.5 Connection of resistance thermometers (e.g. Pt100) and resistance sensors

Measurement

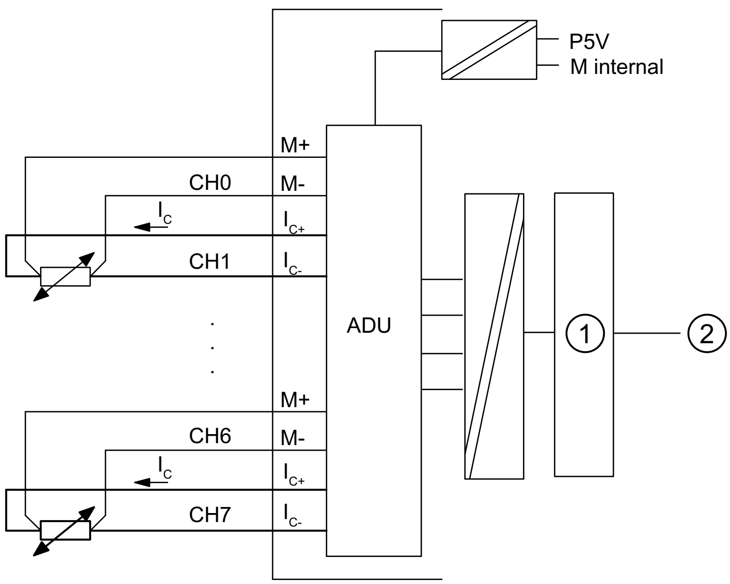
The values of resistance thermometers and resistance transducers are measured using the 4-wire technique. The resistance thermometers/resistance sensors are fed a constant current via terminals I_{C+} and I_C. The voltage generated at the resistance thermometers / transducers is measured at the M_+ and M_- terminals. This method returns a high accuracy of measurement results with 4-wire technology.

Lines for analog signals

Shielded lines twisted in pairs are used for analog signals. So as to reduce interference influence.

When using the 4-wire technique to connect resistance thermometers, wire the constant current line I_{c+} and sense line M_+ using one of the twisted pairs, and the second pair for I_{c+} / M_+. You will achieve a further improvement if you also twist these two twisted-pair wires with each other (star-quad).

The potential differences V_{CM} and V_{ISO} defined in the relevant chapters also apply to these circuits.



① Logic

② Backplane bus

Image 3-8 Wiring of resistance thermometers to the electrically isolated analog input module SM 331; AI 8 x TC/4 x RTD

For 2- and 3-wire connections you need to insert corresponding bridges between the module terminals M_+ and I_{C+} or M_- and I_{C-}. However, certain losses of measurement accuracy must be expected when using such connections, because you cannot measure the voltage loss at the relevant feed lines.

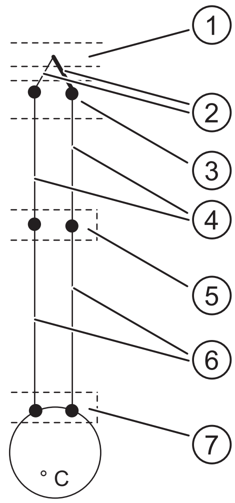
3.6 Using thermocouples

Installation of thermocouples

A thermocouple consists of

- the pair of thermal elements (sensors) and
- of the mounting and terminal elements required.

The thermocouple consists of two wire elements made of different metals or metal alloys which are joint at their ends by soldering or welding. The different material compounds return different thermocouple types such as K, J or N. The principle of measurement is the same for all thermocouple types.



①	Measuring point
②	Thermocouple with positive and negative thermal elements
③	Terminal
④	Equalizing conductor (material with same thermal e.m.f. as thermocouple)
⑤	Reference junction
⑥	Copper conductor
⑦	Thermal e.m.f. acquisition point

Image 3-9 Measuring circuit with thermocouple

Operating principle of thermocouples

A difference of the temperature between the measuring point and the free ends of the thermocouple (terminal) generates a voltage at these electrodes, namely the thermal voltage.

The value of this thermal voltage is determined by the temperature difference between the measuring point and the electrodes, and by the material combination of the pair of thermal elements. As the pair of thermal elements always records a temperature difference, the free ends of the thermocouple always have to be kept at a known temperature in order to determine the temperature at a measuring point.

Extension to a reference junction

The pair of thermal elements can be extended using compensating lines in order to interconnect these with a reference which has a known temperature.

The material of the equalizing conductors has the same thermal e.m.f. as the wires of the thermocouple. The conductors leading from the reference junction up to the analog module are made of copper.

Using thermostatically controlled terminal boxes

It is possible to use temperature-compensated terminal boxes. Use boxes with reference junction temperatures of 0 °C or 50 °C when using thermostatically controlled terminal boxes.

Compensation of thermocouples

External or internal compensation can be adopted depending on where (locally) you require the reference junction.

In the case of external compensation, the temperature of the reference junction for thermocouples is taken into consideration by means of a compensation box or thermal resistor.

In the case of internal compensation, the internal terminal temperature of the module is used for the comparison.

External compensation

The temperature of the reference junction can be compensated by means of a compensating circuit, e.g. by a compensation box.

The compensation box contains a bridge circuit which is calibrated for a certain reference junction temperature (compensating temperature). The terminal connections for the ends of the equalizing conductor of the thermocouple form the reference junction.

If the actual reference temperature deviates from the compensating temperature the temperature-dependent bridge resistance will change. A positive or negative compensation voltage is produced which is added to the thermal e.m.f.

Compensation boxes with a **reference junction temperature of 0 °C** must be used for the purpose of compensating the analog input modules.

A further external compensation option is to record the reference junction temperature with a thermal resistor in the climatic range (e.g. Pt 100).

The following conditions must be observed:

- External compensation by means of a compensation box can only be carried out for one specific type of thermocouple. This means that all channels of this module operating with external compensation must be parameterized for the same type of thermocouple. Module diagnostic signals "incorrect parameters in module" and "reference channel error" for the corresponding channels (0..5) in the case of incorrect parameterization.
- The parameters of a channel group apply to both channels of this channel group (e.g. type of thermocouple, integration time, etc.)

Internal compensation

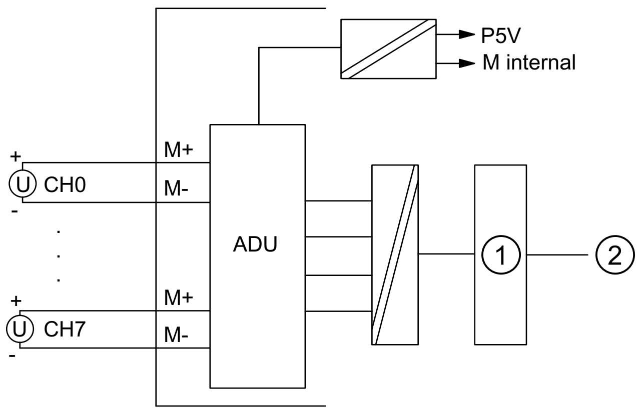
For the purposes of internal compensation, you can form the reference junction at the terminals of the analog input module. In this case, you must route the compensating conductors to the analog module. The internal temperature sensor senses the terminal temperature of the module. The thermocouples (also different types) connected to the module are compensated with this temperature.

Note

For the analog input module SM 331; SI 8 x TC/4 x RTD, the compensation box is connected to terminals 18 and 19. The thermal resistor is connected to terminals 16, 17, 18 and 19 in order to register the reference junction temperature.

3.7 Connecting voltage sensors

Wiring voltage sensors to the electrically isolated analog input module SM 331; AI 8 x TC/4 x RTD



① Logic

② Backplane bus

Image 3-10 Wiring of voltage sensors to the electrically isolated analog input module SM 331; AI 8 x TC/4 x RTD

The potential differences V_{CM} and V_{ISO} defined in the chapter "Wiring transducers to analog inputs" also apply to these circuits.

3.8 Wiring current transducers or measuring transducers to the analog inputs SM 331; AI 4 x 0/4...20 mA

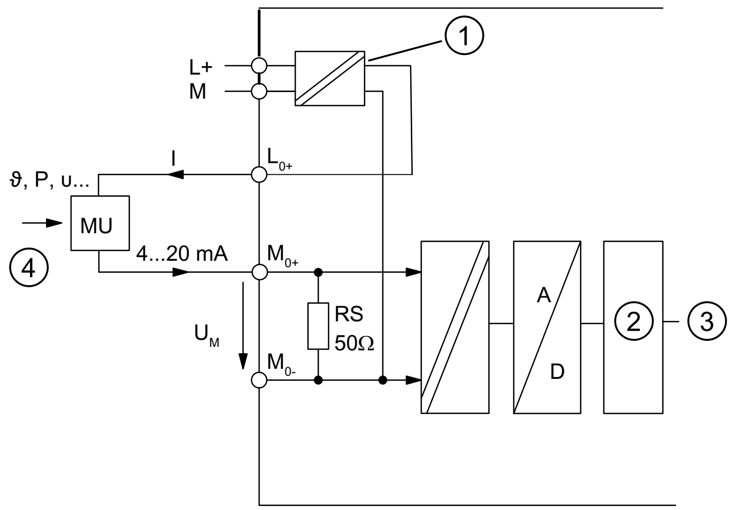
Wiring current transducers as 2-wire and 4-wire transducer

The next section describes the operation of transducers on analog input module SM 331; AI 4 x 0/4...20 mA.

The relevant analog channel supplies the electrically isolated and short circuit-proof transducer voltage L0+ to L3+ to the 2-wire transducer. The 2-wire transducer converts the input process variable into a current from 4 mA to 20 mA.

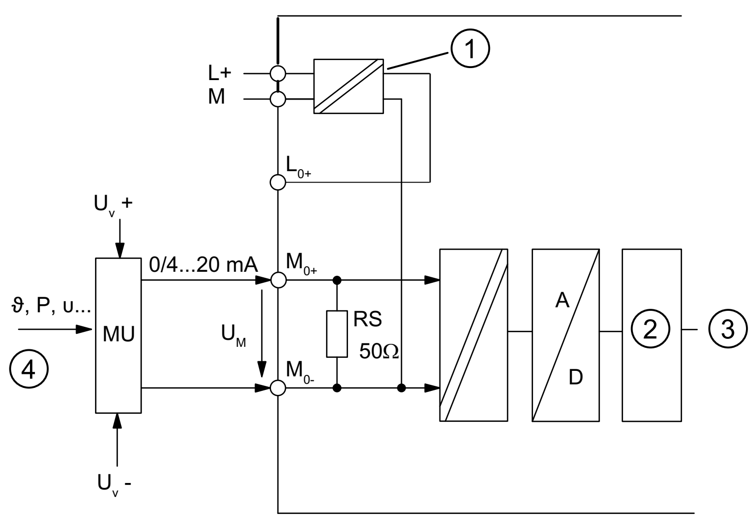
4-wire transducers feature a separate power supply which must be taken from an external PS module.

The potential differences V_{CM} and V_{ISO} defined in the chapter "Wiring transducers to analog inputs" also apply to these circuits.



①	Transducer power supply
②	Logic
③	Backplane bus
④	e.g. pressure, temperature

Image 3-11 Wiring 2-wire transducers to the SM 331; AI 4 x 0/4 .... 20mA and AI 2 x 0/4 ... 20mA HART analog input modules



①	Transducer power supply
②	Logic
③	Backplane bus
④	e.g. pressure, temperature

Image 3-12 Wiring 4-wire transducers with external power supply to the SM 331; AI 4 x 0/4 .... 20mA and AI 2 x 0/4 ... 20mA HART analog input modules

3.9 Connecting Loads/Actuators to the Analog Output Module SM 332; AO 4 x 0/4...20 mA

Introduction

The analog output modules can be used to supply loads/actuators with current.

Lines for analog signals

Shielded lines twisted in pairs are used for analog signals. So as to reduce interference influence.

You should ground the shield of the analog lines at both ends. Any potential difference between the cable ends may cause an equipotential current which interferes with the analog signals. In this case, the shield should only be grounded at one end of the line.

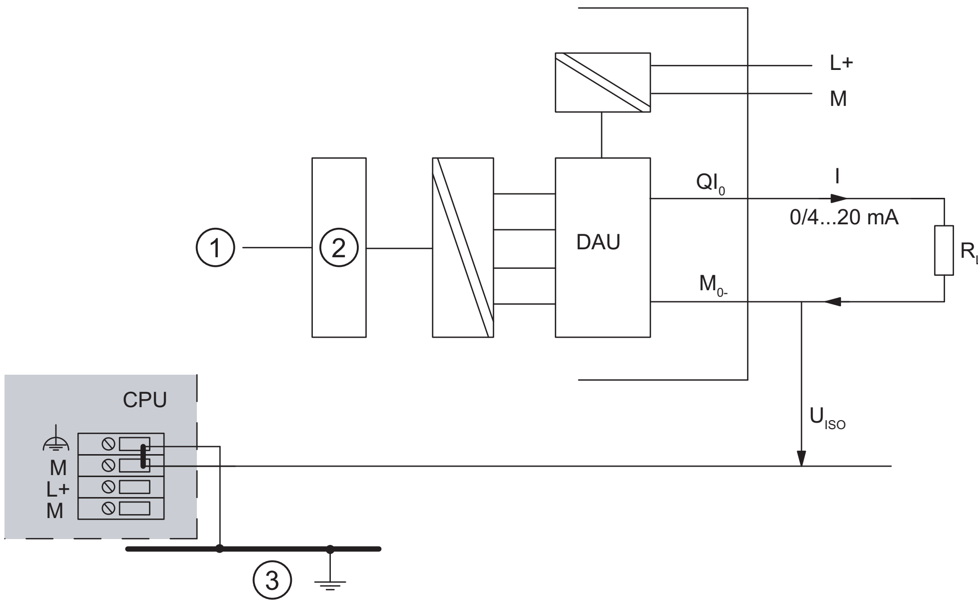
Electrically isolated analog output modules

Electrically isolated analog input modules do not have a galvanic connection between their reference ground M0- to M3- and CPU reference ground M.

Electrically isolated analog input modules are used if there is any risk of potential difference d U_{ISO} developing between reference ground $M_{0- \text{ to}}$ M_{3-} of the analog circuit and reference ground M of the CPU. Take appropriate measures to prevent any overshoot of the permitted potential difference V_{ISO}. You should always interconnect the terminals $M_{0- \text{ to}}$ M_{3-} with the M terminal of the CPU if you expect any overshoot of permitted limits.

Wiring loads to a current output

You must connect loads to an output current at, e.g., QI_0 and the reference point M_{0-} of the analog circuit.



① Backplane bus
② Logic
③ Ground bus

Image 3-13 Connection of loads to a current output of the electrically isolated analog output module SM 332; AO 4 x 0/4...20mA

3.10 Basic Requirements for the Use of Analog Modules

3.10.1 Conversion and Cycle Time of Analog Input Channels

Conversion time

The conversion time is made up of the basic conversion time and additional processing times for wire break monitoring.

The basic conversion time depends directly on the conversion method (integral action, successive approximation or sigma-delta method) of the analog input channel. In the case of integral action conversion, the integration time is included directly in the conversion time. The integration time influences the resolution. The integration times of the individual analog modules are specified in the respective chapter. You set up the conversion functions in STEP 7.

Cycle time

Analog-to-digital conversion and the transfer of digitized measured values to memory or to the S7-300 backplane bus is handled sequentially, i.e. the analog input channels are converted successively. The cycle time, i.e. the time required until an analog input value has been converted again, is the sum of the conversion times of all activated analog input channels of the analog input module. The conversion time is based on channel groups when the analog input channels are combined in channel groups by means of parameterization. In the analog input modules SM 331; AI 8 x TC/4 x RTD, 2 analog input channels are combined to form one channel group. You must therefore subdivide the cycle time into steps of 2. You should disable all unused analog input channels in your STEP 7 program in order to reduce cycle times.

The diagram shows an overview of how the cycle time is made up for an n-channel analog input module.

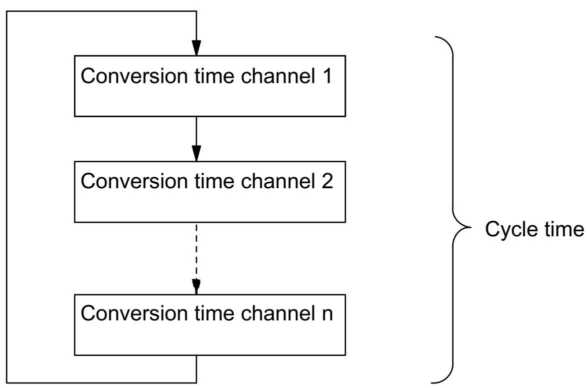


Image 3-14 Cycle time of an analog input module

3.10.2 Conversion, Cycle, Transient Recovery and Response Times of Analog Output Channels

Conversion time

The conversion time of analog output channels includes the transfer of digitized output values and digital/analog conversion.

Cycle time

In the SM 332; AO 4 x 0/4...20 mA, conversion of the analog output channels takes place in parallel, i.e. on receipt of the data, all four analog output channels are converted simultaneously.

The cycle time, i.e. the time required until an analog output value is re-converted, is constant and equals the conversion time.

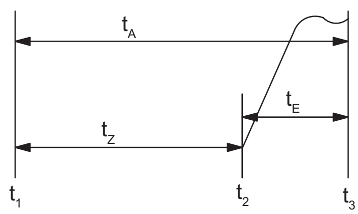
Transient recovery time

The transient recovery time (t_2 to t_3), i.e. the time from applying the converted value up to achieving the specified value at the analog output is dependent on load. In this context we have to distinguish between resistive, capacitive and inductive loads.

Response time

In the most unfavorable case, the response time (t_1 to t_3), i.e. the time from receiving the digital output values in the module up to obtaining the specified value at the analog output is the sum of the cycle time and transient recovery time. The most unfavorable case is when channel conversion begins just before transfer of a new output value.

The digitized output values are connected simultaneously to all output channels.



t_A	Response time
t_Z	Cycle time
t_E	Transient recovery time
t_1	New digitized output value applied
t_2	Output value accepted and converted
t_3	Specified output value obtained

Image 3-15 Response time of the analog input channels

3.10.3 Parameters of Analog Modules

Parameterization

You program the parameters of analog modules in STEP 7. These settings must then be transferred in STOP mode to the CPU. During the status change from STOP-->RUN, the CPU then transfers the parameters to the relevant analog modules.

You can also change some parameters in the user program with SFC 55. You can find out which parameters can be changed in this way in Appendix A of the S7-300, Modules Device Manual (http://support.automation.siemens.com/WW/view/en/8859629). Call SFC 56 and 57 when the CPU is in RUN in order to transfer the parameters set in STEP 7 to the analog module.

The parameters are subdivided as follows for the 2 parameterization alternatives:

- static parameters and
- dynamic parameters

The table below shows the characteristics of static and dynamic parameters.

Parameter	Can be set with	CPU operating status
static	Programming Devices	STOP
dynamic	Programming Devices	STOP
	SFC 55 in user program	RUN

Configurable characteristics

The properties of the analog modules can be programmed in STEP 7 at the parameter blocks listed below:

- for input channels
  - Basic settings (enables)
  - Limits (process interrupt triggers)
  - Diagnostics
  - Measurement
- for output channels
  - Basic settings
  - Diagnostics
  - Default values
  - Output

Parameters of analog input modules

The tables provide an overview of the parameters for analog input modules and show what parameters

- are static or dynamic and
- can be set for the modules as a whole or for a channel group or a channel.

Table 3-21 Parameters of the analog input module SM 331; AI 8 x TC/4 x RTD

Parameter	Range of values	Default setting	Type of parameter	Effective range
Basic settings Enable				
• Diagnostic interrupt	yes/no	no	dynamic	Module
• Process interrupt triggered by violation of limits	yes/no	no		
• End-of-cycle process interrupt	yes/no	no		
Limit				

Parameter	Range of values	Default setting	Type of parameter	Effective range
• Upper limit	from 32511 to -35512	32767	dynamic	Channel
• Lower limit	from -32512 to 32511	-32768		
Diagnostics				
• Group diagnostics	yes/no	no	static	Channel group
• with wire break monitoring	yes/no	no		
Measurement				
• Interference frequency suppression	400 Hz; 60 Hz; 50 Hz; 10 Hz	50 Hz	dynamic	Channel group
• Measurement type	- deactivated - Voltage - resistor with 4-wire connection - thermoresistor (RTD) with linearization, 4-wire connection - Thermocouple with linearization and compensation at 0 ˚C - Thermocouple with linearization and compensation at 50 ˚C - Thermocouple with linearization and internal compensation - Thermocouple with linearization and external compensation [1]	Voltage	dynamic	Channel group
• Range of measurement		±1V	dynamic	Channel group

[1] This type of measurement supports the following compensations:

- Use of a compensation box
  The compensation box must be compatible with the type of thermocouple connected.
  All thermocouples must be of the same type.
- Use of a thermal resistor for compensation (e.g. Pt100)

The absolute terminal temperature is determined for compensation with a Pt100 resistor in the climatic range. In this case, the thermocouples to be compensated can be of different types.

Table 3-22 Parameters of the analog input module SM 331; AI 4 x 0/4...20 mA

parameter	Range of values	Default setting	Type of parameter	Effective range
Basic settings Enable				
• Diagnostic interrupt	yes/no	no	dynamic	module
• Process interrupt triggered by violation of limits	yes/no	no		
• End-of-cycle process interrupt	yes/no	no		
Limit				
• Upper limit	from 32511 to -32512	32767	dynamic	Channel
• Lower limit	from -32512 to 32511	-32768		
Diagnostics				
• Group diagnostics	yes/no	no	static	Channel group
• with wire break monitoring	yes/no	no		
Measurement				
• Interference frequency suppression	400 Hz; 60 Hz; 50 Hz; 10 Hz	50Hz	dynamic	Channel group
• Measurement mode	4DMU Current (4-wire transducer) 2DMU Current (2-wire transducer)	4-wire transducer	dynamic	Channel group
• Range of measurement	0...20 mA, 4...20 mA	4...20 mA	dynamic	Channel group

Parameters of the analog output module

The following table provides an overview of the parameters of the analog output module that are

- static or dynamic and
- can be set for the modules as a whole or for a channel.

Table 3-23 Parameters of the analog output module SM 332; AO 4 x 0/4...20 mA

Parameter	Range of values	Default setting	Type of parameter	Effective range
Basic settings • Enable diagnostic interrupt	yes/no	no	dynamic	Module
Diagnostics • Group diagnostics and wire break monitoring	yes/no	no	static	Channel
Substitute value				
• retain last value	yes/no	no	dynamic	Channel
• Value	-32512...32511	-6912 (0 mA)		
Output				
• Output mode	deactivated Current	Current	dynamic	Channel
• Output range	4...20 mA 0...20 mA	4...20mA	dynamic	Channel

3.10.4 Diagnostics of the Analog Modules

Definition

With the aid of the diagnostics function you can determine whether analog processing is faulty or free of faults and which faults have occurred. On detecting a fault, the analog modules output the signal value "$7FFF_H$" irrespective of the parameterization.

Parameterizing diagnostics

You program the diagnostics functions in STEP 7.

Diagnostic evaluation

With regard to diagnostic evaluation, differentiation is made between configurable and non-configurable diagnostic messages. In the case of configurable diagnostic messages, evaluation only takes place when diagnostics has been enabled by means of parameterization ("diagnostic enable" parameter). The non-parameterizable diagnostic messages are always evaluated irrespective of the diagnostic enable.

Diagnostic messages trigger following actions:

- SF LED on analog module lights,
- if applicable channel fault LED,

- Transfer of diagnostic message to CPU,
- Diagnostic interrupt triggered (only if diagnostic interrupt has been enabled in the parameterization).

Diagnostics of the analog input modules

The table below provides an overview of the parameterizable diagnostic messages of the analog input modules. The enable is set in the "diagnostics" parameter block. The diagnostic information refers to either the individual channels or the entire module.

Table 3-24 Diagnostic messages of the analog input modules SM 331; AI 8 x TC/4 x RTD, AI 4 x 0/4...20mA and AI 2 x 0/4...20mA HART

Diagnostic message	Effective range of diagnostics	Configurable
Wire break [1]	Channel	Yes
Undershoot of the measuring range		Yes, (group error)
Overshoot of the measuring range		
Reference channel fault [2]		
Incorrect parameters in module		No
Incorrect parameters in module	Module	No
Module not configured		
external auxiliary voltage missing [3]		
internal auxiliary voltage missing [3]		
Fuse blown [3]		
Time watchdog tripped		
EPROM error [4]		
RAM error [4]		
CPU error [4]		
ADU error [4]		
Hardware interrupt lost		

[1] If wire-break monitoring is enabled and a wire break is detected at the 2-wire transducer (4 to 20mA), the AI 4 x 0 / 4 to 20mA and AI 2 x 0/4...20mA HART modules output a wire-break message when the input current drops below $I \leq 3.6$ mA (wire-break limit to NAMUR). The wire break message is only deactivated (hysteresis), when the input current rises above 3.8 mA again.

In the case of the module AI 8 x TC/4 x RTD the line is checked by connecting a test current if wire break diagnostics is enabled.

[2] Only for thermocouples with external compensation and compensation fault.

[3] Only for AI 4 x 0/4...20mA and AI 2 x 0/4...20mA HART with 24 volt supply from L+.

[4] The tests are conducted during start-up and on-line.

Causes of error and remedies

However, be aware that error detection must be enabled at the modules in order to output the relevant programmable diagnostic messages.

Table 3-25 Diagnostic messages of the analog input modules SM 331; AI 8 x TC/4 x RTD, AI 4 x 0/4...20mA and AI 2 x 0/4...20mA HART - their possible causes of fault and remedies

Diagnostic message	Possible fault causes	Corrective measures
Wire break	Break in the line between the module and sensor	Connect line
	Channel not connected (open)	Deactivate channel group ("Measurement mode" parameter)
Undershoot of the measuring range	Input value below underflow range, error possibly caused by:	
• on AI 8 x TC/4 x RTD	• incorrect type of thermocouple • Reversal of polarity at the sensor connection. Incorrect measuring range setting	• Check type of thermocouple • Check connection terminals • Configure a different measuring range
• on AI 4 x 0/4...20mA	• Module does not report measuring range undershoot • Sensor connected with reverse polarity; (a digitized value is output for 0 mA)	
Overshoot of the measuring range	Input value exceeds overflow range	Configure a different measuring range
Reference channel fault	A different sensor type is set as reference channel in the measuring channels parameters	Parameterize different type of sensor
	Reference channel error (wire break, for example. All measuring channels values are $7FFF_H$	Eliminate fault in reference channel
Incorrect parameters in module	Module supplied with invalid parameters	Check parameterization of module and re-load valid parameters
Module not configured	Module not supplied with parameters	Include module in parameterization
external auxiliary voltage missing	No module supply voltage L+	Provide L+ supply
No internal auxiliary voltage	No module supply voltage L+	Provide L+ supply
	module-internal fuse defective	Replace module
Fuse blown	module-internal fuse defective	Replace module
Time watchdog tripped	partially high electromagnetic interference	Eliminate interference sources
	Module defective	Replace module

Diagnostic message	Possible fault causes	Corrective measures
EPROM error RAM error CPU error ADU error	partially high electromagnetic interference	Eliminate interference sources and switch CPU supply voltage OFF/ON
	Module defective	Replace module
Hardware interrupt lost	The CPU is unable to process successive hardware interrupts (violation of limits, end-of-cycle interrupts) at this rate	Change interrupt processing in CPU and reparameterize module if necessary

Diagnostics of the analog output module

Table 3-26 Diagnostic message of the analog output module SM 332; AO 4 x 0/4...20mA

Diagnostic message	Effective range of diagnostics	configurable
Wire break [2]	Channel group	Yes
incorrect parameters in module		No
incorrect parameters in module	Module	No
Module not configured		
No internal auxiliary voltage		
external auxiliary voltage missing		
Fuse blown		
Time watchdog tripped		
EPROM error [1]		
RAM error [1]		
CPU error [1]		
[1] The tests are conducted during start-up and on-line.		
[2] Wire break recognition at output values I > 100 µA *and* output voltage > 12V		

Causes of error and remedies

However, be aware that error detection must be enabled at the modules in order to output the relevant programmable diagnostic messages.

Table 3-27 Diagnostic messages of analog output module SM 332; AO 4x0/4...20mA and their possible causes and remedies

Diagnostic message	Possible fault causes	Corrective measures
Wire break	Break in line between module and actuator	Connect line
	Voltage at load resistor > 12V	Lower load resistance to ≤500 Ω
	Channel not connected (open)	Deactivate channel ("Measurement mode" parameter)
incorrect parameters in module	Module supplied with invalid parameters	Check parameterization of module and re-load valid parameters

Diagnostic message	Possible fault causes	Corrective measures
Module not configured	Module not supplied with parameters	Include module in parameterization
external auxiliary voltage missing	No module supply voltage L+	Provide L+ supply
No internal auxiliary voltage	No module supply voltage L+	Provide L+ supply
	module-internal fuse defective	Replace module
Fuse blown	module-internal fuse defective	Replace module
Time watchdog tripped	partially high electromagnetic interference	Eliminate interference sources
	Module defective	Replace module
EPROM error CPU error RAM error	partially high electromagnetic interference	Eliminate interference sources and switch CPU supply voltage OFF/ON
	Module defective	Replace module

Reading out diagnostic messages

You can read detailed diagnostic messages in STEP 7 by enabling the diagnostics functions at the analog modules.

See also

Parameters of Analog Modules (Page 120)

3.10.5 Interrupts of analog modules

Types of interrupts

In principle, a differentiation is made between the following interrupts:

- Diagnostic interrupt
- Process interrupt

Parameterizing interrupts

You program the interrupts in STEP 7.

Default setting

The interrupts are inhibited by way of default.

Diagnostic interrupt

The module triggers a diagnostics interrupt when it detects incoming or outgoing errors such as a wire break or short-circuit to M, provided this interrupt function is enabled. Diagnostic functions inhibited by parameterization cannot trigger an interrupt. The CPU interrupts processing of the user program or low-priority classes and processes the diagnostic interrupt module (OB82).

Process interrupt

The working range is defined by programming a high and low limit. The module triggers a process interrupt if the process signal, such as the temperature of an analog signal module, is out of this working range, provided limit value interrupts are enabled. The interrupt-triggering channel can be identified based on the local data of OB 40 in the user program.

Active process interrupts trigger process interrupt execution (OB 40) at the CPU, i.e. the CPU interrupts execution of the user program or of jobs of a lower priority class. If there are no higher priority classes pending processing, the stored interrupts (of all modules) are processed one after the other corresponding to the order in which they occurred.

Process interrupt lost

Channel events such as overshoot/undershoot of limits are saved to memory and trigger a process interrupt. The event is lost if a further event is generated at this channel before the CPU has acknowledged the process interrupt, i.e. before OB 40 was executed. This status triggers a "process interrupt lost" diagnostics interrupt. The relevant diagnostics interrupt must be enabled.

Further events at this channel are not logged until interrupt processing is completed for this channel.

Structure of the start information tag OB40_POINT_ADDR of OB 40

The limit values exceeded by the different channels are entered in the start information of OB 40 in the tag OB40_POINT_ADDR. The figure below shows the assignment of bits in word 8 of local data.

Byte	Variable	Data type		Description
6/7	OB40_MDL_ADDR	WORD	B#16#0	Address of the interrupt-triggering module
As of 8	OB40_POINT_ADDR	DWORD	see the follow-ing figure	Indication of the interrupt-triggering inputs

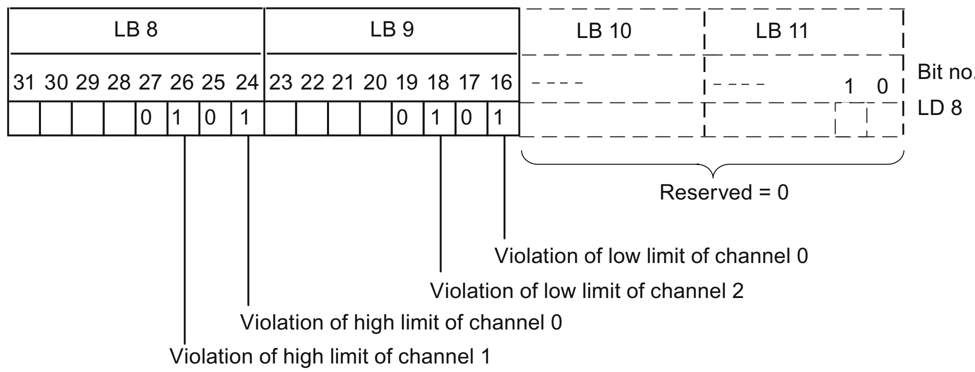


Image 3-16 Start Information of OB40: Which event has violated limits and triggered a hardware interrupt

A hardware interrupt programmed to be triggered at the end of scan cycles allows you to synchronize a process with the scan cycle of the analog input module. A scan cycle includes the conversion of the measured values of all active channels of the analog input module. The module processes the channels in succession. When all measured values are successfully converted, the module reports the existence of new measurement data at its channels to the CPU by means of an interrupt.

With an end-of-cycle interrupt, bits 20 ... 23 and 28 ... 31 are set to 1. You can always use this interrupt to load the actual, converted analog values.

3.10.6 Characteristics of Analog Modules

Influence of the supply voltage and of the operating state

The input and output values of the analog modules are dependent on the supply voltage of the analog module and on the operating status of the CPU.

Table 3-28 Dependencies of analog input/output values on the CPU operating status and the supply voltage L+

CPU operating status		Supply voltage L+ at analog module	Parameters of analog input modules	Output value of the analog output module
POWER ON	RUN	L+ applied	Process value	CPU value
			$7FFF_H$ up to first conversion after switching on or after module parameterization has been completed	Up to first conversion ... • **after switch-on** has been completed if signal of 0 mA is output. • **after parameterization** has been completed, previous value is output.
		No L+	Overflow value [1]	0 mA

CPU operating status		Supply voltage L+ at analog module	Parameters of analog input modules	Output value of the analog output module
POW-ER ON	STOP	L+ applied	Process value	Default/last value
			$7FFF_H$ up to first conversion after switching on or after module parameterization has been completed	at 0...20 mA: 0 mA default at 4...20 mA: 4 mA default
		No L+	Overflow value [1]	0 mA
POW-ER OFF	-	L+ applied	-	0 mA
		No L+	-	0 mA

[1] only applies to SM 331; AI 8xT C/4 x RTD as no L+ supply voltage is required.

Failure of the L+ supply voltage for the analog modules is always indicated by the group fault LED on the module and additionally entered in diagnostics.

Triggering of a diagnostic interrupt is dependent on the parameterization.

Table 3-29 Characteristics of analog modules dependent on the position of analog input value in value range

The process value lies within the	Input value	SF LED	Diagnostics	Interrupt	Channel fault LED
Rated range	Process value	-	-	-	-
Overrange/ underrange	Process value	-	-	-	-
Overflow	$7FFF_H$	lit	Entry made [1]	Diagnostic interrupt [1]	lit
Underflow	8000_H	lit			lit
Wire break	$7FFF_H$	lit [1]			lit [1]
outside parameterized limit	Process value	-	-	Process interrupt[1, 2]	-

[1] depending on parameterization

[2] An active diagnostics error prevents the limit value process interrupt.

Example: An enabled wire break diagnostics renders limits below the wire break threshold ineffective.

Impact of the range of values on the output

The characteristics of the output modules depend on what part of the value range the output values are in.

Table 3-30 Characteristics of analog modules dependent on position of analog output value in value range

Output value in	Output value	SF LED	Diagnostics	Interrupt	Channel fault LED
Rated range	CPU value	-	-	-	-
Overrange/ underrange	CPU value	-	-	-	-
Overflow	0 mA	-	-	-	-

Output value in	Output value	SF LED	Diagnostics	Interrupt	Channel fault LED
Wire break	CPU value	lit [1]	Entry made [1]	Entry made [1]	lit [1]
[1] depending on parameterization					

Influence of errors

Faults occurring in analog modules with diagnostic capabilities and corresponding parameterization result in diagnostic entry and diagnostic interrupt. Refer to the respective chapter for a list of faults.

The SF LED and, if applicable, the channel fault LED light on the analog module.

Faults which cannot be parameterized in diagnostics (e.g. fuse blown) result in an entry being made in the diagnostic range and the fault LED lighting irrespective of the CPU operating status.

See also

Diagnostics of the Analog Modules (Page 124)

Parameters of Analog Modules (Page 120)

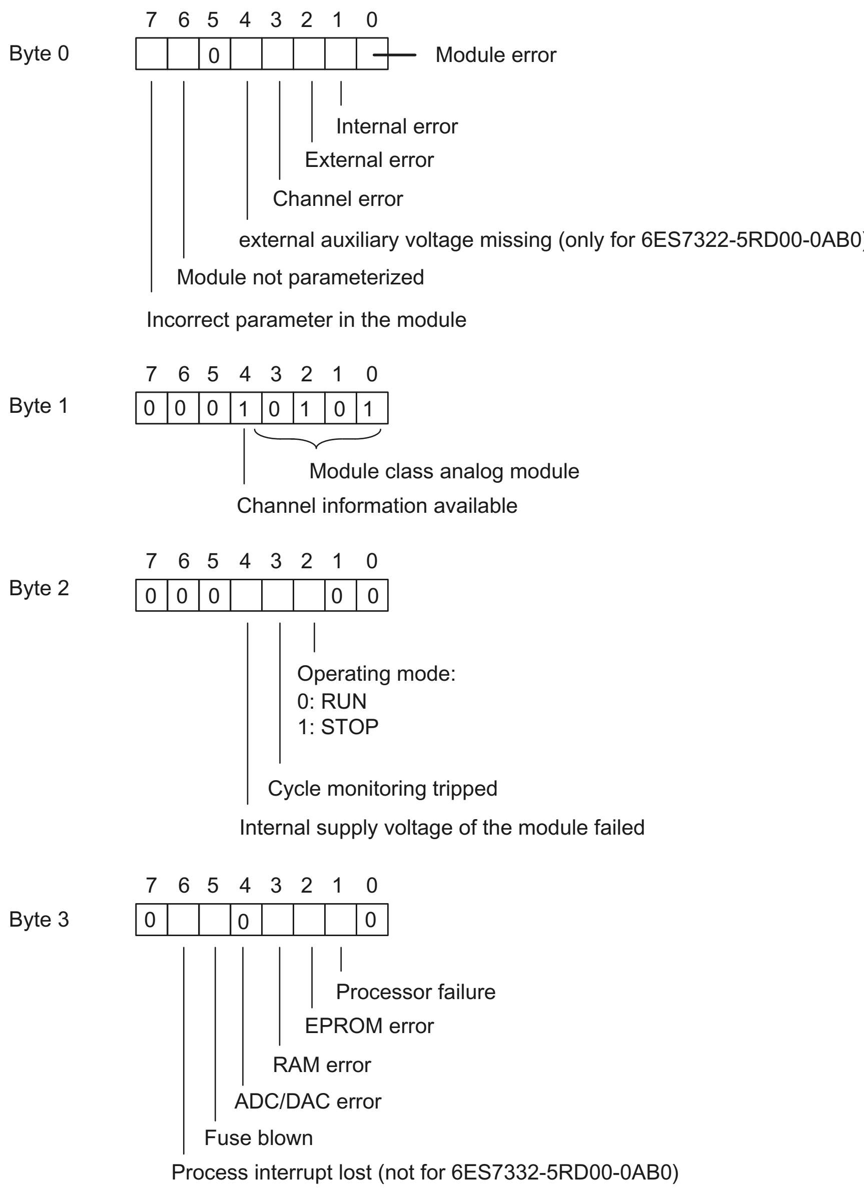
3.10.7 Diagnostic data records of the S7 Ex analog modules

Structure and contents of the diagnostic data records

The diagnostics data for a module is stored in data records 0 and 1:

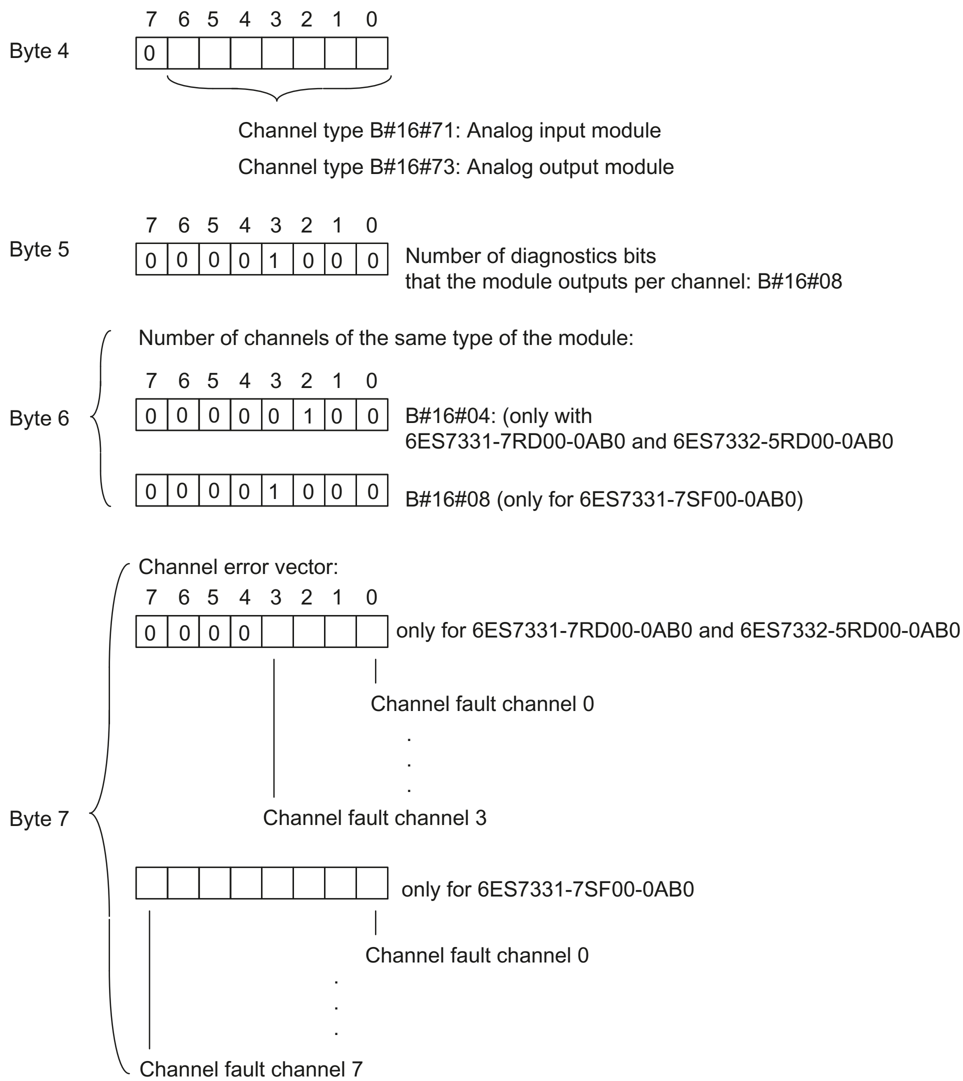
- Data record 0 contains 4 bytes of diagnostics data describing the current status of the module.
- Data record 1 contains the 4 bytes of diagnostics data also stored in data record 0, plus additional module-specific diagnostics data that describe the status of a channel of the module.

Byte 0 to byte 3 (data records 0 and 1)

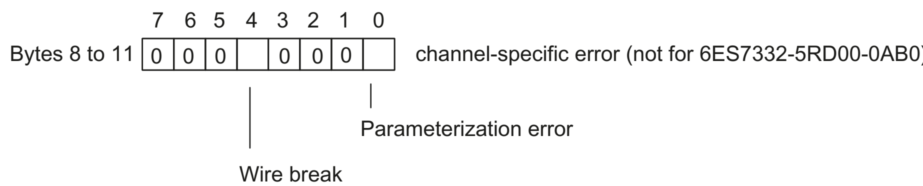


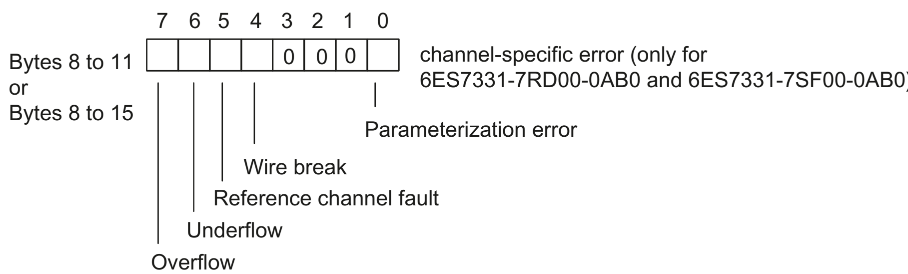
Byte 4 to byte 6 infoblock (data record 1)

Bytes 4 to 6 form the infoblock with the information about channel type, length of diagnostics information and the length of the channels.



The channel error vector is followed by the channel-specific diagnostics data.





3.11 Analog input module SM 331; AI 8 x TC/4 x RTD (6ES7331-7SF00-0AB0)

Order Number

6ES7331-7SF00-0AB0

Features

Properties of the analog input module SM 331; AI 8 x TC/4 x RTD:

- 8 inputs in 4 channel groups
- Measured value resolution, can be adjusted separately at each channel group, depending on the settings of interference frequency suppression
  - 9 Bit + sign (integration time 2.5 ms) ≙ 400 Hz
  - 12 Bit + sign (integration time $16^2/_3$ / 20 ms) ≙ 60/50 Hz
  - 15 Bit + sign (integration time 100 ms) ≙ 10 Hz
- Mode of measurement, selectable for each channel group:
  - Voltage
  - Resistance
  - Temperature
- user-specific measurement range per channel group
- configurable diagnostics
- configurable diagnostic interrupt
- 2 channels with limit monitoring

- configurable limit interrupt
- electrically isolated from the CPU
- Common mode < 60 V between the channels
- Configuration in Run (CiR) supported

Resolution

The resolution of the measured value is directly proportional to the integration time selected, i.e. longer integration times at an analog input channel increase resolution accuracy of the measured value.

Wiring diagram

View and wiring diagram of analog input module SM 331; AI 8 x TC/4 x RTD

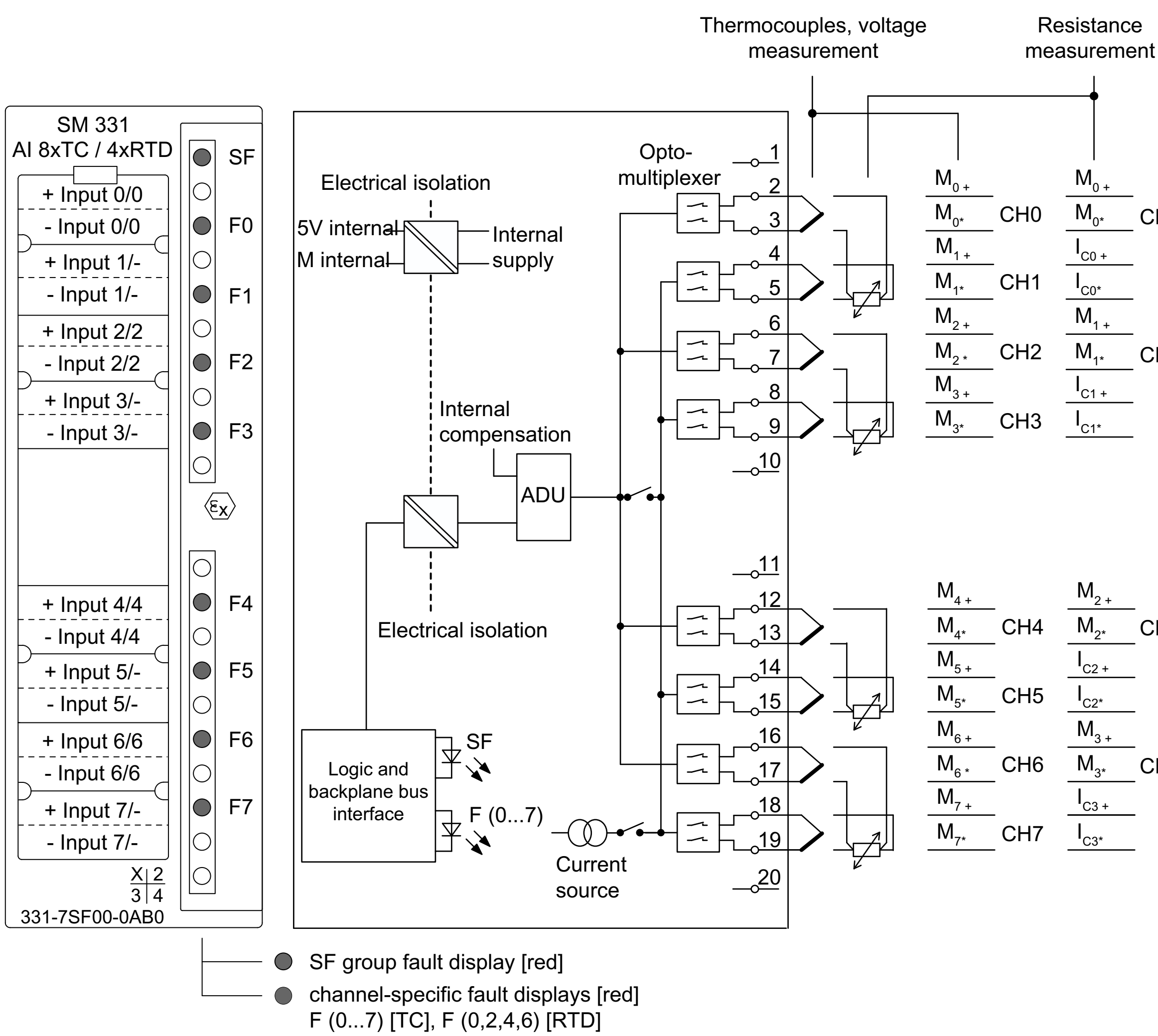


Image 3-17 Module view and block diagram of SM 331; AI 8 x TC/4 x RTD

Notes on intrinsically-safe installation

You must connect the DM 370 dummy module between the CPU or IM 153 (in a distributed configuration) and the Ex I/O modules whose signal cables lead into the hazardous location. In a distributed configuration with an active backplane bus, you should use the ex dividing panel/ex barrier instead of the dummy module.

Notes on the module

An external voltage supply L+ (24V) is not required for the analog input module SM 331; AI 8 x TC/4 x RTD.

If thermal resistors (e.g. Pt100) are used for external compensation, connect them to channels 6 and 7.

If a compensation box is used for external compensation, connect it to channel 7.

Notes on the front connector

You can use the front connector 6ES7392-1AJ20-0AA0 only for the analog input module 6ES7331-7SF00-0AB0.

If you use a front connector, you attain a higher accuracy of temperature measurements with thermocouples in the measurement mode "Internal compensation". The accuracy of the internal reference junction temperature is ± 1.5 K when this front connector is used at ambient temperatures from 0 to 60 °C.

You can connect lines of 0.25 mm^2 to 1 mm^2.

The use of this front connector results in no restrictions regarding the licenses of the module.

Alternatively, you can use the front connector 6ES7392-1AJ00-0AA0, but without the increased accuracy.

Parameterization

The functions of the analog input module SM 331; AI 8 x TC/4 x RTD are set

- with STEP 7 (refer to the STEP 7 online help), or
- in the user program with SFCs.

Default settings

The analog input module features default settings for integration time, diagnostics, interrupts etc..

These defaults apply to modules which were not reprogrammed in STEP 7.

Channel groups

In the analog input module SM 331; AI 8 x TC/4 x RTD, 2 analog input channels are combined to form one channel group. Parameters can always only be assigned to one channel group, i.e. parameters which are specified for a channel group are always valid for both channels of this channel group.

Table 3-31 Allocating analog input channels of the SM 331; AI 8 x TC/4 x RTD to channel groups

Channel	Allocated channel group
Channel 0	Channel group 0
Channel 1	
Channel 2	Channel group 1
Channel 3	
Channel 4	Channel group 2
Channel 5	
Channel 6	Channel group 3
Channel 7	

Special feature of resistant measurement

Only one channel per channel group is required for the "resistance measurement". The "2nd" of the group is used for current sinking (I_C).

With access to the "1st" to read the measured value. The "2nd" channel of the group is preset with the overflow value "$7FFF_H$".

During diagnostics, the 1st channel provides the actual status (in compliance with parameterization) and the 2nd channel "free of faults".

Non-connected input channels

You must short-circuit activated and non-connected channels of the analog input module SM 331; AI 8 x TC/4 x RTD. This way you ensure optimum interference immunity for the analog input module. Deactivate all non-connected channels in STEP 7 in order to reduce module cycle times.

Configurable measuring modes

You can set the following measuring modes on the analog input module SM 331; AI 8 x TC/4 x RTD, make the setting in STEP 7.

- Voltage measurement
- Resistance measurement
- Temperature measurement

Supported ranges of measurement

The measuring ranges for which you can use the analog input module SM 331; AI 8 x TC/4 x RTD can be found in the following tables. Define the relevant ranges of measurement in STEP 7.

Wire-break monitoring

The analog input module SM 331; AI 8 x TC/4 x RTD carries out wire-break monitoring for all ranges if it is enabled via parameterization. The four wires used in resistance thermometer mode (RTD) are monitored for wire break.

Voltage measurement ranges

measurement mode selected	Explanation	Measuring range
Voltage	The digitalized analog values can be found in chapter Analog Representation for Voltage Measuring Ranges of Analog Inputs (Page 89).	± 25 mV ± 50 mV ± 80 mV ± 250 mV ± 500 mV ± 1 V

Resistance measurement ranges

measurement mode selected	Explanation	Measuring range
Resistor 4-wire connection	The digitized analog values are listed in the chapter Analog value representation of the measurement ranges of resistance sensors (Page 90).	150 ohms 300 ohms 600 ohms

Connectable types of thermocouple

The linearization of characteristic curves is specified for thermocouples in accordance with **DIN IEC 584**.

For thermal resistor measurements, linearization of the characteristic curves is based on **DIN 43760** and **IEC 751**.

Table 3-32 Connectable thermocouples and thermal resistors

Measurement type	Explanation	Measuring range
• Linearization and compensation at 0 ˚C • Linearization and compensation at 50 ˚C • Linearization and compensation internal comparison [1] • Linearization and compensation external comparison [2]	The digitized analog values for the thermocouples listed are found in the chapter Analog value representation (Page 87). (one unit corresponds to 0.1 ˚C)	Type T [Cu-CuNi] Type U [Cu-CuNi] Type E [NiCr-CuNi] Type J [Fe-CuNi] Type L [Fe-CuNi] Type K [NiCr-Ni] Type N [NiCr-SiNiSi] Type R [Pt13Rh-Pt] Type S [Pt10Rh-Pt] Type B [Pt30Rh-Pt6Rh]
Thermal resistance+ Linearization, 4-wire connection (temperature measurement)	The digitized analog values for the thermal resistors listed are found in the chapter Analog value representation (Page 87).	Pt100, Pt200, Ni 100 standard range Pt100, Pt200, Ni 100 climatic range
[1] In the case of internal compensation in the module, all 8 channels are available for temperature measurements also with different times of thermocouples. • The module returns the terminal temperature when the input is short-circuited. This does not apply to thermocouple type B, which is not suitable for measurements in the ambient temperature range. [2] This type of measurement supports the following compensations: • Use of a compensation box The compensation box must be compatible with the type of thermocouple connected. Terminated at channel 7. • Use of thermal resistors in climatic range (e.g. Pt100) for compensation. The absolute terminal temperature is determined in the climatic range with a thermal resistor (e.g. Pt 100) for compensation purposes. In this case, the thermocouples to be compensated can be of different types. Terminated at channels 6 and 7.		

technical specifications

Dimensions and Weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	approx. 210 g
Module-specific data	
Configuration in Run (CiR) supported	yes
• Behavior of non-configured inputs during CiR	They return the value that applied before the parameters were set.
Number of inputs • with resistance sensor	8 4

Line length, shielded	max. 200 m max. 50 m for voltage ranges ≤ 80 mV and thermocouples
ATEX approvals	II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 01ATEX1061 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply	5 V DC
Electrical isolation	
• between the channels and backplane bus	yes
• between the channels	no
Permitted potential difference of signals of the Ex area	
• between the channels and backplane bus (U_{ISO})	60 V DC 30 V AC
• between the channels (U_{CM})	60 V DC 30 V AC
Insulation tested	
• Channels with respect to backplane bus	with 2500 V DC
Current input from backplane bus	max. 120 mA
Module power loss	typical 0.6 W
Permitted potential difference of signals of the non-Ex area	
• between the channels and backplane bus (U_{ISO})	300 V DC 250 V AC
• between the channels (U_{CM})	75 V DC 60 V AC
Safety specifications (see EU special test certificate KEMA 01ATEX1061 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))	
Maximum values per channel for thermocouples and thermal resistors	
• U_0 (no-load output voltage)	max. 5.9 V
• I_0 (short-circuit current)	max. 28.8 mA
• P_0 (load power)	max. 41.4 mW
• L_0 (permissible external inductance)	max. 40 mH
• C_0 (permissible external capacity)	max. 43 µF
• U_m (error voltage)	max. 60 VDC 30 V AC
• T_a (permissible ambient temperature)	max. 60°°C

Connection of active encoders with the following limit values U_i = ± 1.2V I_i = 20 mA deviating from the above-specified values					
• L_0	(permissible external inductance)	max. 15 mH			
• C_0	(permissible external capacity)	max. 14.6 µF			
Analog value formation					
Principle of measurement		SIGMA-DELTA			
Integration time/conversion time/resolution (per channel) • Configurable • Integration time in ms		yes 2.5	yes $16^2/_3$	yes 20	yes 100
• Basic conversion time = • 3 x integration time + • Transient recover time optomultiplexer in ms		7.5 + 2.5	50 + 2.5	60 + 2.5	300 + 2.5
• additional conversion time for wire break recognition in ms		2.5	2.5	2.5	2.5
• Resolution in bit (incl. overrange)		9+sign	12+sign	12+sign	15+sign
• Interference voltage suppression for interference frequency f1 in Hz		400	60	50	10
Interference suppression, error limits					
Interference voltage suppression for f = n x (f1 ± 1 %), (f1 = interference frequency)					
• Common-mode rejection (U_{ISO} < 60 V)		> 130 dB			
• Normal-mode rejection (interference peak value < rated value of input range)		> 40 dB			
Crosstalk attenuation between inputs (U_{ISO} < 60 V)		> 70 dB			
Operational limit (in total temperature range, referred to input range)					
• ± 25 mV • ± 50 mV • ± 80 mV • ±250 mV/±500 mV/±1V		± 0.09 % ± 0.06 % ± 0.05% ± 0.04%			
Basic error limit (operational limit at 25 °C, referred to input range)					
• ± 25 mV • ± 50 mV • ± 80 mV • ±250 mV/±500 mV/±1V		± 0.018% ± 0.014% ± 0.011% ± 0.008%			
Temperature error (referred to input range)					
• ± 25 mV • ± 50 mV • ± 80 mV • ±250 mV/±500 mV/±1V		± 0.0019 %/K ± 0.0013 %/K ± 0.0011 %/K ± 0.0010 %/K			
Linearity error (referred to input range)		± 0.003%			

Repeatability (in steady-state condition at 25 °C, referred to input range)	± 0.003%
The accuracy of temperature measurement with *external compensation with thermal resistors* is derived from:	• Error for the analog input of the type of thermocouple used • Accuracy [1] of the type of thermal resistor used for compensation • Error [1] of the compensation input
The accuracy of temperature measurement with *external compensation with compensation box* is derived from:	• Error for the analog input of the type of thermocouple used • Accuracy [1] of the compensation box • Error [1] of the compensation input
The accuracy of temperature measurement with *compensation of the external reference junction maintained at 0 °C / 50 °C* is derived from:	• Error for the analog input of the type of thermocouple used • Accuracy [1] of the reference junction temperature
The accuracy of temperature measurement with *internal compensation (terminal temperature)* results from:	• Error for the analog input of the type of thermocouple used • Accuracy [1] of the internal reference junction temperature ± 2.5 K (in the range 0 to 60 °C
[1] Due to the constant increase in the thermocouple characteristic at higher temperatures, the error in the compensation element is less effective than at temperatures in the vicinity of the compensation temperature. Exception: Thermocouple types J and E (relative linear progression) Due to the little increase in the range from approx. 0 °C to 40 °C, the *lack of compensation of the reference junction temperature* has only a negligible effect in the case of **thermocouple type B**. Deviation of measuring temperatures when using thermocouples type B without compensation and measurement type "0 °C compensation" setting: 700°C and 1820°C < 0.5°C 500 °C and 700 °C < 0.7°C. "Internal compensation" should be set if the reference junction temperature closely corresponds to the module temperature. This reduces the error for the temperature range from 500 °C to 1820 °C to < 0.5 °C.	

Error limits of analog inputs for thermocouples			
(at 25 °C ambient temperature and 100 ms integration time)			
Type	Temperature range	Basic error [1]	Temperature error [2] [°C/K]
T	-150 °C...+400 °C -230 °C ... -150°C	±0.2K ±1K	± 0.006
U	-50 °C...+400 °C 200 °C....-50 °C	± 0.2K ±1K	± 0.006
E	-100 °C....+1000 °C -200 °C....-100 °C	±0.2K ± 1K	± 0.0075
J	-150 °C....+1200 °C -210 °C ... -150 °C	±0.2K ±0.5K	± 0.02
L	-50 °C...+1200 °C -200 °C....-50 °C	±0.2K ± 1K	± 0.02

Error limits of analog inputs for thermocouples			
K	-100 °C....+1372 °C 220 °C....-100 °C	±0.2K ± 1K	± 0.018
N	-50 °C...+1300 °C 150 °C....-50 °C	±0.2K ± 1K	± 0.025
R	+200 °C....+1769 °C -50 °C...+200 °C	±0.3K ± 1K	± 0.025
S	+100 °C....+1769 °C -50 °C...+100 °C	±0.3K ± 1K	± 0.025
B	+700 °C....+1820 °C +500 °C....+700 °C +200 °C....+500 °C	±0.3K ±0.5K ±3K	± 0.04

Error limits of analog inputs for thermal resistors			
(at 25 ˚C ambient temperature and 100 ms integration time)			
Type	Temperature range	Basic error [1]	Temperature error [2] [°C/K]
Pt100 climatic	-200 °C....+325 °C	± 0.05K	± 0.006
Pt200 climatic	-200 °C....+325 °C	± 0.05K	± 0.006
Ni 100 climatic	-60 °C....+250 °C	± 0.05K	± 0.003
Pt100 standard	-200° C....+850 °C	± 0.2K	± 0.01
Pt200 standard	-200 °C....+850 °C	± 0.2K	± 0.01
Ni 100 standard	-60 °C....+250 °C	± 0.1K	± 0.003

Error limits of analog inputs for resistance sensors			
(at 25 °C ambient temperature and 100 ms integration time)			
Type	Resistance sensor	Basic error [3]	Temperature error [2] [°C/K]
150 Ω	0.000 Ω .176.383 Ω	± 0.006%	± 0.001
300 Ω	0.000 Ω .352.767 Ω	± 0.006%	± 0.001
600 Ω	0.000 Ω .705.534 Ω	± 0.006%	± 0.001
[1] The basic error includes the linearization error of the voltage temperature conversion and the basic error of the analog/digital conversion at T_u = 25°C. [2] The total temperature error = temperature error x max. ambient temperature change DT_u as a temperature difference with respect to 25°C . [3] The basic error includes ADC error as a % value of the measuring range at T_a = 25 °C.			

The operating error for the use of **thermocouples / thermal resistors** consists of:

- Basic error of the analog input at T_u = 25°C
- Total temperature error
- Errors which occur due to the compensation of the reference junction temperature
- Errors of the thermocouple / thermal resistor used

The operating error for the use of **thermal resistors** consists of:

- Basic error of the analog input at T_u = 25°C
- Total temperature error
- Error for the sensor used

Interrupts, diagnostics		
Interrupts		
• Limit interrupt	configurable channels 0 and 2	
• Diagnostic interrupt	Configurable	
Diagnostic functions	Configurable	
• Group fault indication	red LED (SF)	
• Channel fault indication	red LED (F) per channel	
• Diagnostic information readout	possible	
Data for sensor selection		
Input ranges (rated values) / input resistance • Voltage	± 25 mV ± 50 mV ± 80 mV ± 250 mV ± 500 mV ± 1 V	/10 MΩ /10 MΩ /10 MΩ /10 MΩ /10 MΩ /10 MΩ
• Resistance	150 Ω 300 Ω 600 Ω	/10 MΩ /10 MΩ /10 MΩ
• Thermocouples	Type: T, U, E, J, L, K, N, R, S, B	/10 MΩ
• Resistance thermometer	Pt100, Pt200, Ni100	/10 MΩ
Measuring current for thermoresistors and wire-break checks	c. 0.5 mA	
Permissible input voltage for voltage input (destruction limit)	Max. 35 V permanent; 75 V for max. 1 s (pulse duty factor 1:10)	
Connection of signal transducers		
• for voltage measurement	possible	
• for resistance measurement with 4-wire connection, with 3-wire connection[1] with 2-wire connection[1]	possible	
Characteristic linearization	Configurable	
• for thermocouples	• Type : T, U, E, J, L, K, N, R, S, B	
• for thermal resistors	• Pt100, Pt200, Ni 100 (standard and climatic range)	
Temperature compensation	Configurable	
• Internal temperature compensation	possible	

Interrupts, diagnostics	
• external temperature compensation with compensation box	possible
• external temperature compensation with thermal resistors (e.g. Pt100)	possible
• Compensation for 0 °C reference junction temperature	possible
• Compensation for 50 °C reference junction temperature	possible
[1] without line resistance correction	

Additional information on Configuration in RUN (CiR)

...can be found in the online help for STEP7 and in the manual System modification in RUN by means of CiR on the Internet (http://support.automation.siemens.com/WW/view/en/14044916).

See also

Configuration of an S7-300 with Ex I/O Modules (Page 17)

Configuration of an ET 200M with Ex I/O modules (Page 20)

Parameters of Analog Modules (Page 120)

3.12 Analog input module SM 331; AI 4 x 0/4...20 mA (6ES7331-7RD00-0AB0)

Order Number

6ES7331-7RD00-0AB0

Features

Properties of the analog input module SM 331; AI 4 x 0/4...20mA:

- 4 inputs in 4 channel groups
- Measured value resolution, can be adjusted separately at each channel group, depending on the integration time set
  - 10 Bit (integration time 2.5 ms)
  - 13 Bit (integration time $16^2/_3$ / 20 ms)
  - 15 Bit (integration time 100 ms)

- Mode of measurement, selectable for each channel group:
  - Current
  - Channel deactivated
- User-specific measurement range per channel
  - 0 ... 20 mA
  - 4 ... 20 mA
- configurable diagnostics and configurable diagnostic interrupt
- Channel 0 and 2 with limit value monitoring and configurable limit interrupt
- The channels are electrically isolated from each other, from the CPU, and from load voltage L+
- The analog inputs are HART-compatible
- Configuration in Run (CiR) supported

Resolution

The resolution of the measured value is directly proportional to the integration time selected, i.e. longer integration times at an analog input channel increase resolution accuracy of the measured value.

Wiring diagram of SM 331; AI 4 x 0/4...20 mA

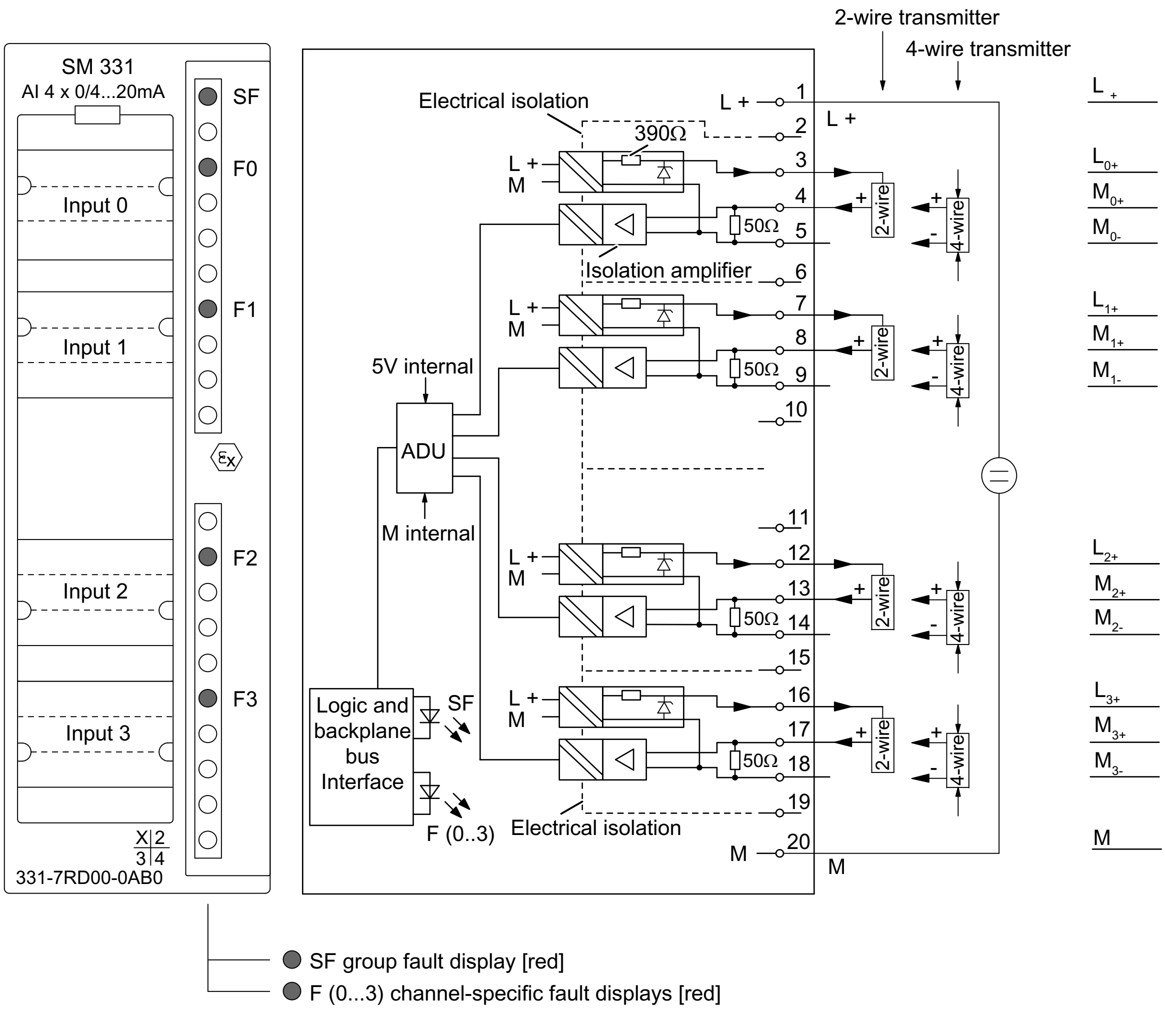


Image 3-18 Module view and block diagram of the SM 331; AI 4 x 0/4...20mA

Notes on intrinsically-safe installation

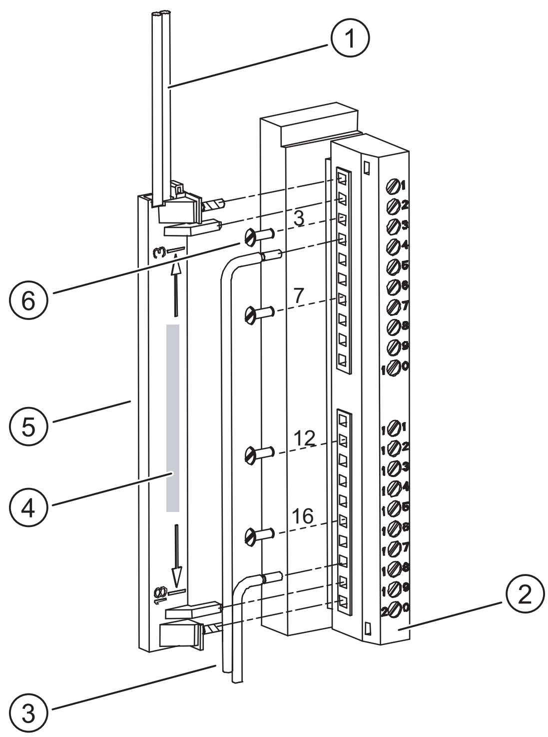
You must connect the DM 370 dummy module between the CPU or IM 153 (in a distributed configuration) and the Ex I/O modules whose signal cables lead into the hazardous location. In a distributed configuration with an active backplane bus, you should use the ex dividing panel/ex barrier instead of the dummy module.

Power supply for an intrinsically-safe structure

In order to maintain the clearances and creepage distances, L+/M must be routed via the line chamber LK393 when operating modules with signal cables that lead to the hazardous location.

Additional measures

The SM 331-7RD00 (6ES7 331-7RD00-0AB0) module reaches lower safety-relevant technical data for the connection of active encoders (see the first amendment of the certificate) if the unused transducer outputs (terminals 3, 7, 12 and 16) are locked with plastic bolts. Use for example M3 x 8 plastic screws for this (see diagram below).



① Load voltage supply
② Process connector with screw-type connection
③ Ex (i) process cable
④ Intrinsically safe area
⑤ Line chamber
⑥ Plastic screw M 3 x 8

Parameterization

The functions of the analog input module SM 331; AI 4 x 0/4...20 mA are set

- in STEP 7
- in the user program with SFCs.

Default settings

The analog input module features default settings for integration time, diagnostics, interrupts, etc. These defaults apply to modules which were not reprogrammed in STEP 7.

Channel groups

The channel group is allocated to each input channel for parameterization of the analog input module SM 331; AI 4 x 0/4...20 mA. Advantage: You can specify separate parameters for each channel! The table shows the allocation of the channels to channel groups:

Table 3-33 Allocation of analog input channels of the SM 331; AI 4 x 0/4...20 mA to channel groups

channel	Allocated channel group
Channel 0	Channel group 0
Channel 1	Channel group 1
Channel 2	Channel group 2
Channel 3	Channel group 3

Configurable measuring modes

You set up the measurement types in STEP 7. You can set up the following measurement types:

- Current measurement
- Channel deactivated

Measurement ranges for 2-wire and 4-wire transducers

The table below shows the current measurement ranges for 2-wire and 4-wire transducers. Define the relevant ranges of measurement in STEP 7.

Table 3-34 Measurement ranges for 2-wire and 4-wire transducers

measurement mode selected	Explanation	Measuring range
2-wire transducer	The digitalized analog values can be found in chapter Analog Representation for Current Measurement Ranges (Page 89).	from 4 to 20 mA
4-wire transducer		from 0 to 20 mA from 4 to 20 mA

Wire-break monitoring

Wire break recognition is not possible for the current range 0 to 20 mA. For the current range from 4 to 20 mA, the input current dropping below I x 3.6 mA is interpreted as a wire break and, if enabled, an appropriate diagnostic interrupt is triggered.

Influencing by HART signals

When implementing transducers with HART protocol, you should preferably program integration times of $16^2/_3$, 20 or 100 ms in order to keep the influence of AC modulation on the measuring signal to minimum.

Technical specifications of the SM 331; AI 4 x 0/4...20 mA

Dimensions and Weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	approx. 290 g
Module-specific data	
Configuration in Run (CiR) supported	yes
• Behavior of non-configured inputs during CiR	They return the process value that applied before the parameters were set.
Number of inputs	4
Line length, shielded	max. 200 m
ATEX approvals	II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 01ATEX1060 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply Rated load voltage L+ • Reverse voltage protection	5 V DC 24 V DC yes
Transducer power supply • short circuit-proof	yes
Electrical isolation	
• between the channels and backplane bus	yes
• between the channels and load voltage L+	yes
• between the channels	yes
• between the backplane bus and load voltage L +	yes
Permitted potential difference (V_{ISO}) of signals of the Ex area	
• between the channels and backplane bus	DC 60 V AC 30 V
• between the channels	DC 60 V AC 30 V
• between the channels and load voltage L+	DC 60 V AC 30 V
• between the backplane bus and load voltage L +	DC 60 V AC 30 V
Permitted potential difference (V_{ISO}) of signals of the non-Ex area	
• between the channels and backplane bus	300 VDC 250 VAC
• between the channels and load voltage L+	300 VDC 250 VAC

• between the channels	300 VDC 250 VAC			
• between the backplane bus and load voltage L +	DC 75 V AC 60 V			
Insulation tested				
• Channels to backplane bus and load voltage L +	with 2500 V DC			
• Channels to each other	with 2500 V DC			
• Backplane bus with respect to load voltage L+	with 500 V DC			
Current input • from backplane bus • from load voltage L+	 max. 60 mA max. 250 mA			
Module power loss	typical 3 W			
Safety specifications (see EU special test certificate KEMA 01ATEX1060 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))				
Maximum values per channel				
• U_0 (no-load output voltage)	max. 25.2 V			
• I_0 (short-circuit current)	max. 68.5 mA			
• P_0 (load power)	max. 431 mW			
• L_0 (permissible external inductance)	max. 7.5 mH			
• C_0 (permissible external capacity)	max. 90 nF			
• U_m (fault voltage)	max. DC 60V AC 30V			
• T_a (permissible ambient temperature)	max. 60°C			
Analog value formation				
Principle of measurement	SIGMA-DELTA			
Integration time/conversion time/resolution (per channel) • configurable • Integration time in ms	yes 2.5	yes $16^2/_3$	yes 20	yes 100
• Basic conversion time including integration time in ms (several channels enabled)	7.5	50	60	300
• Basic conversion time including integration time in ms (one channel enabled)	2.5	$16^2/_3$	20	100
• Resolution in bit + sign (incl. overrange)	10+ sign	13+ sign	13+ sign	15+sign
• Interference voltage suppression for interference frequency f1 in Hz	400	60	50	10
Interference suppression, error limits				
Interference voltage suppression for f = n x (f1 ± 1 %), (f1 = interference frequency)				
• Common mode interference between channels and reference ground M of the CPU (V_{ISO} < 60 V)	> 130 dB			

• Series mode interference (measured value + interference signal must lie within the 0 mA to 22 mA input range)	> 60 dB	
Crosstalk attenuation between inputs (U_{ISO} < 60 V)	> 130 dB	
Operational limit (in total temperature range, referred to input range)		
• from 0/4 to 20 mA	± 0.45%	
Basic error limit (operational limit at 25 °C, referred to input range)		
• from 0/4 to 20 mA	± 0.1%	
Temperature error (referred to input range)	± 0.01%/K	
Linearity error (referred to input range)	± 0.01%	
Repeatability (in steady-state condition at 25 °C, referred to input range)	± 0.05%	
Influence of a HART signal modulated on an input signal relative to the input range		
Error at integration time	± 0.25%	
• 2.5 ms	± 0.05%	
• $16^2/_3$ ms	± 0.04%	
• 20 ms	± 0.02%	
• 100 ms		
Interrupts, diagnostics		
Interrupts		
• Limit interrupt	configurable channels 0 and 2	
• Diagnostic interrupt	Configurable	
Diagnostic functions	Configurable	
• Group fault indication	red LED (SF)	
• Channel fault indication	red LED (F) per channel	
• Diagnostic information readout	possible	
Technical date of the transducer power supply		
• No-load voltage • Output voltage for transducer and cable at a transducer current of 22 mA (50 Ω reference resistor on the module included)	< 25.2 V > 13 V	
Data for sensor selection		
Input ranges (rated values / input resistance)		
• Current	0 to 20 mA 4 to 20 mA	/50 Ω /50 Ω
Permissible input current for current input (destruction limit)	40 mA	
Connection of signal transducers		
• for current measurement as 2-wire transducer as 4-wire transducer	 possible possible	

Additional information on Configuration in RUN (CiR)

...can be found in the online help for STEP7 and in the manual System modification in RUN by means of CiR on the Internet (http://support.automation.siemens.com/WW/view/en/14044916).

See also

Analog value notation of the measurement ranges of resistive encoders (Page 90)

The LK 393 line chamber (Page 14)

Configuration of an S7-300 with Ex I/O Modules (Page 17)

Configuration of an ET 200M with Ex I/O modules (Page 20)

Parameters of Analog Modules (Page 120)

3.13 Analog output module SM 332; AO 4 x 0/4...20 mA (6ES7332-5RD00-0AB0)

Order Number

6ES7332-5RD00-0AB0

Features

The analog output module SM 332, AO 4 x 0/4 ... 20 mA is characterized by the following features:

- 4 current outputs in 4 groups
- Resolution 15 bit
- Configuration in Run (CiR) supported
- configurable diagnostics
- Channels electrically isolated
- Channels electrically isolated from the CPU and from load voltage L+

Note

When switching the load voltage (L+) on and off, incorrect intermediate values can occur at the output for approx. 10 ms.

Block diagram of SM 332; AO 4 x 0/4...20mA

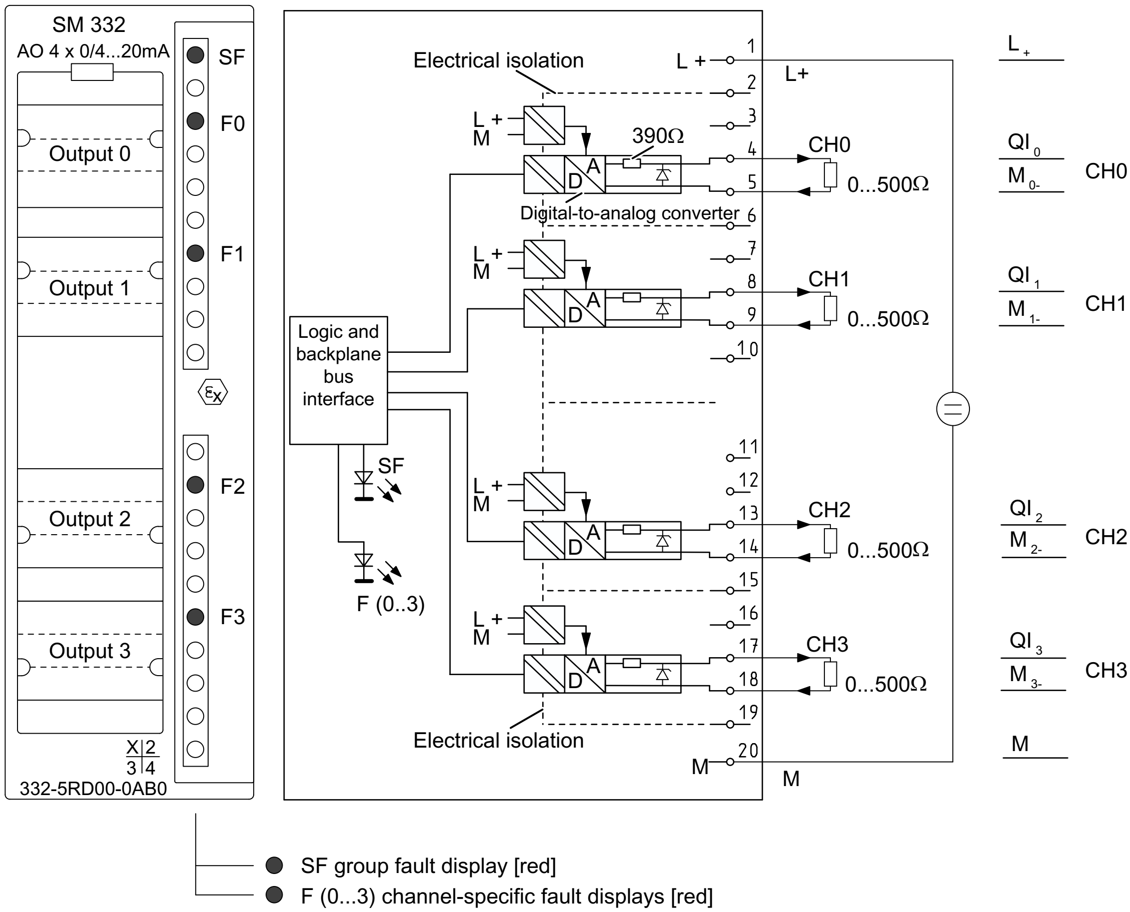


Image 3-19 Module view and block diagram of SM 332; AO 4 x 0/4...20 mA

Notes on intrinsically-safe installation

You must connect the DM 370 dummy module between the CPU or IM 153 (in a distributed configuration) and the Ex I/O modules whose signal cables lead into the hazardous location. In a distributed configuration with an active backplane bus, you should use the ex dividing panel/ex barrier instead of the dummy module.

Power supply for an intrinsically-safe structure

In order to maintain the clearances and creepage distances, L+/M must be routed via the line chamber LK393 when operating modules with signal cables that lead to the hazardous location.

Parameterization

You set up the functionality designed for analog output module SM 332; AO 4 x 0/4...20 mA

- in STEP 7 or
- in the user program with SFCs.

Default settings

The analog output module features default settings for output type, interrupts, default settings etc..

These defaults apply to modules which were not reprogrammed with STEP 7.

Channel groups

Table 3-35 Allocation of 4 channels to 4 channel groups of the SM 332; AO 4 x 0/4...20 mA

Channel	Allocated channel group
Channel 0	Channel group 0
Channel 1	Channel group 1
Channel 2	Channel group 2
Channel 3	Channel group 3

Unswitched output channels

To ensure that the unswitched output channels of the analog output module SM 332; AO 4 x 0/4...20 mA are without voltage, you must deactivate them. You deactivate an output channel using STEP 7 by means of the "Output" parameter block.

Analog outputs

You can connect the outputs as:

- Current outputs

The outputs can be set channel by channel. You program the output type in STEP 7.

Output ranges

Configure the various current output ranges in STEP 7.

Table 3-36 Output ranges of the analog output module SM 332; AO 4 x 0/4...20 mA

selected output mode	Explanation	Output range
Current	The digitized analog values are listed in the chapter Analog value representation of the output range of the analog outputs (Page 102).	from 0 to 20 mA from 4 to 20 mA

Wire-break monitoring

The analog output module SM 332; AO 4 x 0/4...20 mA carries out a wire break check.

Conditions:

A wire break can only be signaled if the minimum output current > 100 μA and the voltage generated at the load > 12 V.

Influence of load voltage dips on diagnostics messages

If the 24 V load voltage falls below the permitted rated range (< 20.4 V), there may be a reduction in the output current at connected loads > 400 Ω and output currents > 18 mA before a diagnostic message is transmitted.

Technical specifications of the SM 332; AO 4 x 0/4...20 mA

Dimensions and Weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	approx. 280 g
Module-specific data	
Configuration in Run (CiR) supported	yes
• Behavior of non-configured outputs during CiR	They specify the output value that applied before the parameters were set.
Number of outputs	4
Line length, shielded	max. 200 m
ATEX approvals	Ex II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 01ATEX1062 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply Rated load voltage L+	5 V DC 24 V DC
• Reverse voltage protection	yes
Electrical isolation	
• between channels and backplane bus	yes
• between channels and load voltage L+	yes
• between the channels	yes
• between the backplane bus and load voltage L+	yes
Permitted potential difference (V_{ISO}) of signals of the Ex area	
• between channels and backplane bus	DC 60 V AC 30 V
• between channels and load voltage L+	DC 60 V AC 30 V
• between the channels	DC 60 V AC 30 V
• between the backplane bus and load voltage L+	DC 60 V AC 30 V
Permitted potential difference (V_{ISO}) of signals of the non-Ex area	
• between channels and backplane bus	300 VDC 250 VAC

• between channels and load voltage L+	300 VDC 250 VAC
• between the channels	300 VDC 250 VAC
• between the backplane bus and load voltage L+	DC 75 V AC 60 V
Insulation tested	
• between the backplane bus and load voltage L_+	with 2500 V DC
• Channels to each other	with 2500 V DC
• Backplane bus with respect to load voltage L_+	with 500 V DC
Current input • from backplane bus • from load voltage L+ (at rated data)	 max. 80 mA max. 200 mA
Module power loss	typical 4 W
Analog value formation	
Resolution (incl. overrange)	15 Bit
Cycle time (all channels)	9.5 ms
Transient recovery time	
• for resistive load	0.2 ms
• for capacitive load	0.5 ms
• for inductive load	0.2 ms
Switch substitute values	yes, configurable
Interference suppression, error limits	
Crosstalk attenuation between outputs	> 130 dB
Operational limit (in total temperature range, referred to output range)	± 0.55%
Basic error limit (operational limit at 25 °C, referred to output range)	± 0.2%
Temperature error (referred to output range)	± 0.01 %/K
Linearity error (referred to output range)	± 0.02%
Repeatability (in steady-state condition at 25 °C, referred to output range)	± 0.005%
Output ripple; range 0 to 50 kHz (referred to output range)	± 0.02%
Interrupts, diagnostics	
Interrupts	
• Diagnostic interrupt	Configurable
Diagnostic functions	Configurable
• Group fault indication	red LED (SF)
• Channel fault indication	red LED (F) per channel
• Diagnostic information readout	possible
monitoring for	
• Wire break	yes
as of output value *and*	> 0.1 mA
Output voltage	> 12 V

Safety specifications (see EU special test certificate KEMA 01ATEX1062 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))	
Maximum values of the output circuits (per channel)	
• U_0 (no-load output voltage)	max. 14 V
• I_0 (short-circuit current)	max. 70 mA
• P_0 (load power)	max. 440 mW
• L_0 (permissible external inductance)	max. 6.6 mH
• C_0 (permissible external capacity)	max. 730 nF
• U_m (fault voltage)	max. 60 VDC 30 VAC
• T_a (permissible ambient temperature)	max. 60°C
Data for sensor selection	
Output ranges (rated values) • Current	from 0 to 20 mA from 4 to 20 mA
Load impedance (in rated range of output) • for current outputs – resistive load – inductive load – capacitive load	max. 500 Ω max. 6.6 mH[1] max. 730 nF[1]
Current output • No-load voltage	max. 14 V
Destruction limit for externally applied voltages / currents • Voltages • Current	max. + 12 V / - 0.5V max. + 60 mA / - 1A
Wiring of actuators • for current output 2-wire connection	yes
[1] KEMA approval limitations When used in a non-Ex areas, the following • resistive load max. 500 Ω • inductive load max. 15 mH • capacitive load max. 3 μF can be set as the load impedance.	

Configuration in RUN (CiR)

If you use the Configuration in RUN function, the following special feature occurs.

SF LED is lit:

If a diagnostic event was pending before you started to reassign parameters, the SF LEDs (on the CPU, IM or module) may be lit even though the diagnostic event has been cleared and the module is operating properly.

Remedy:

- Only make new parameter settings when there is no diagnostic event pending on the module, or
- Inserting and removing modules

Additional information on Configuration in RUN (CiR)

...can be found in the online help for STEP7 and in the manual System modification in RUN by means of CiR on the Internet (http://support.automation.siemens.com/WW/view/en/14044916).

See also

The LK 393 line chamber (Page 14)

Configuration of an S7-300 with Ex I/O Modules (Page 17)

Configuration of an ET 200M with Ex I/O modules (Page 20)

Parameters of Analog Modules (Page 120)

Analog value notation of the current measurement ranges (Page 89)

SIMATIC S7 HART Analog Modules 4

Most of the examples listed in this manual refer to the use of HART analog modules with PROFIBUS DP interface modules.

Overview

There are two analog input modules and two analog output modules each with HART functions in the product range of the SIMATIC S7 Ex-HART analog modules.

- SM 331; AI 2 x 0/4...20mA HART (HART analog input module),

Order number: 6ES7 331-7TB00-0AB0 (Revision 5)

Order number: 6ES7 331-7TB10-0AB0 (Revision 7)

- SM 332; AO 2 x 0/4...20mA HART (HART analog output module),

Order number: 6ES7 332-5TB00-0AB0 (Revision 5)

Order number: 6ES7 332-5TB10-0AB0 (Revision 7)

The electrical properties of Revision 5 and Revision 7 modules are identical. The modules differ only in the interfaces (parameters, diagnostics, user data and HART request interface) and in the HART functionality and the supported HART version.

4.1 Using HART analog modules

Basic characteristics

The SIMATIC S7 HART analog modules belong to the category of SIMATIC S7-Ex analog modules. Their basic properties were described in section "Simatic S7 Ex analog modules" and also apply here.

You can operate the HART analog modules as part of the distributed I/O ET 200M with the interface modules:

- As of IM153-2BA00 or as of IM153-2BB00 as coupling to PROFIBUS DP.
- As of IM153-2BA20 as coupling to PROFIBUS DP for the modules 6ES7 331-7TB10-0AB0 and 6ES7 332-5TB10-0AB0.
- As of IM153-4BA00 as coupling to PROFINET IO.

In this application, the ET 200M is the HART master for HART devices (intelligent field devices). The IM153 directs the commands (for example, parameter assignment) that come from the HART client
(for example, SIMATIC PDM or programmed via the data record interface of the HART analog modules) through the HART analog module to the intelligent field devices. The reply comes back the same way. In the figure below, the gray line represents the communication path in an application with PROFIBUS DP.

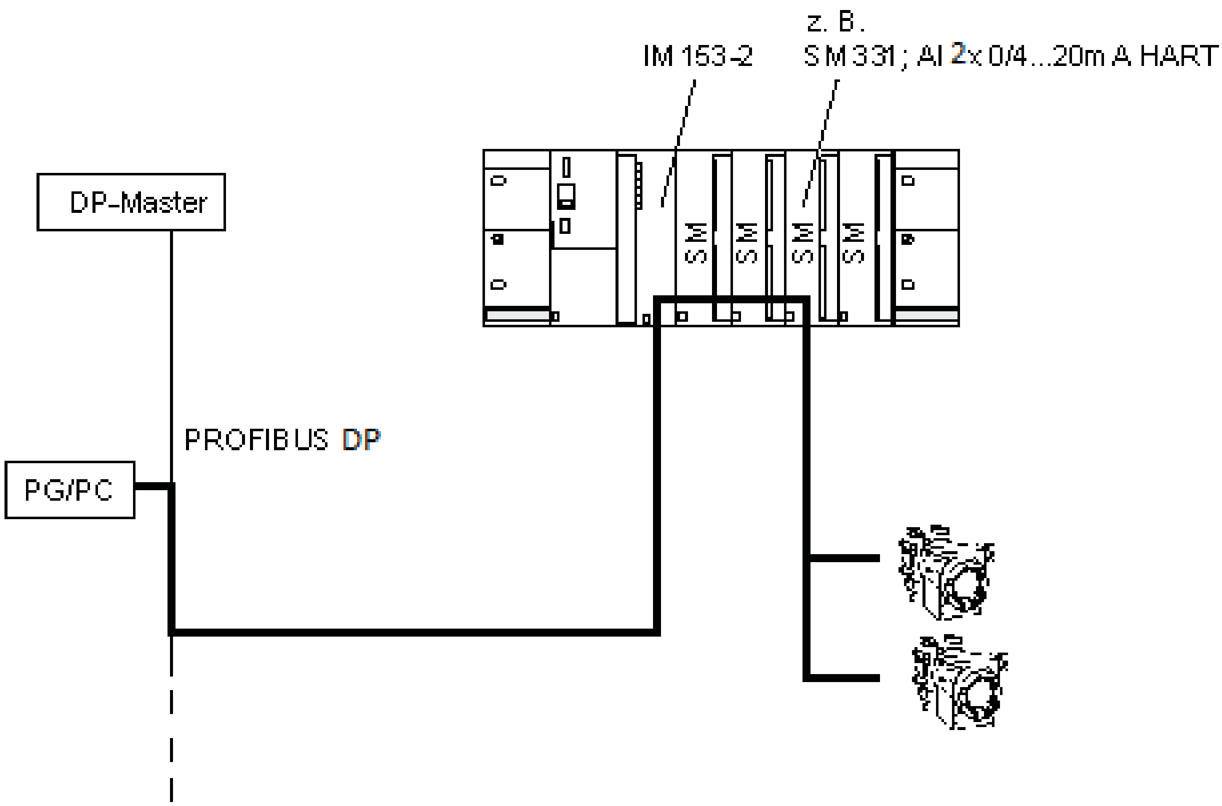


Image 4-1 Location of the HART analog modules in the distributed system

Application in the system

The HART analog modules are used in the distributed I/O connected to the PROFIBUS DP or PROFINET IO.

You can connect one field device to each of the two channels on a HART analog module: the module acts as a HART master, the field devices as HART slaves.

Various software applications, such as SIMATIC PDM, can send or receive data to or from a transducer via a HART analog module. They can be compared to clients for which the HART analog module is the server.

4.2 Introduction to HART

4.2.1 Definition of HART

Introduction

This section provides you with an introduction to HART from a user's perspective:

- Definition of HART
- Advantages of HART analog modules
- Typical applications of HART

Definition

"HART" stands for "Highway Addressable Remote Transducer"

The HART functions enable you to operate the analog modules in conjunction with digital communication. The HART protocol is generally accepted as a standard protocol for communication with smart field devices: Hart is a registered trademark of the "HART Communication Foundation" (HCF), which retains all rights for the HART protocol. You can find detailed information about HART in the HART specification.

Advantages of HART

The use of HART analog modules has the following advantages:

- Compatible connection to analog modules: current loop 4 - 20 mA
- additional digital communication with the HART protocol
- low power requirements with HART, important for use in hazardous areas
- a wide range of field devices with HART functions are now available
- integration of the HART functionality in the S7 system when using HART analog modules

Typical applications

The following are typical applications of HART:

- Installation of field devices (central assignment of parameters)
- Modification of field device parameters online
- Display of information, maintenance data and diagnostic data for field devices
- Integration of configuration tools for field devices via the HART interface

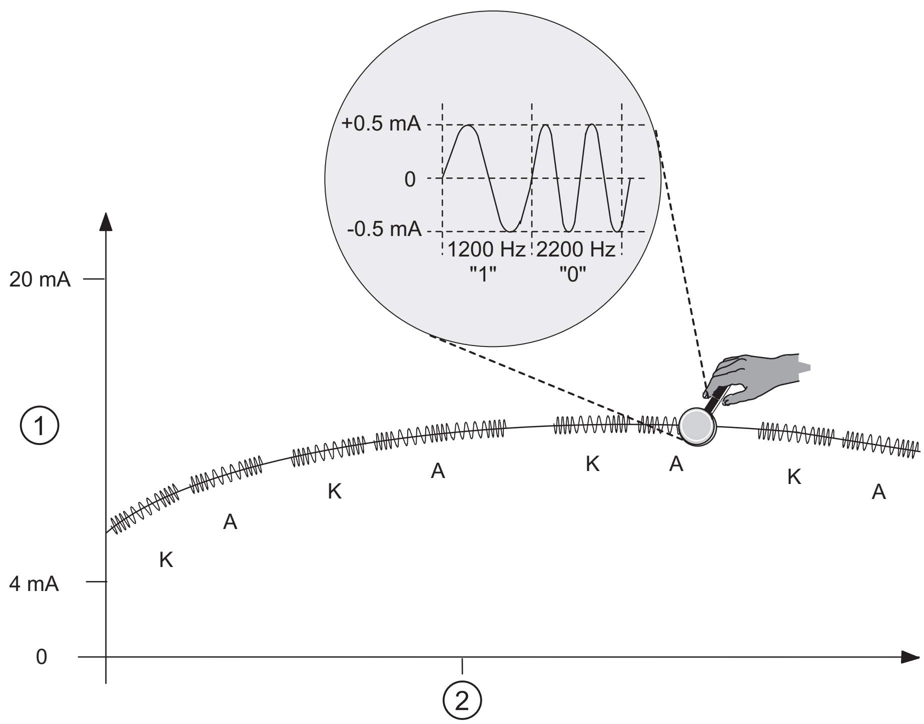
4.2.2 HART functions

Introduction

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

HART signal

The following diagram shows the analog signal with the modulating HART signal (FSK procedure). The HART signal is composed of sine waves at 1200 Hz and 2200 Hz and has a mean value of zero. It can be filtered out with an input filter, leaving the original analog signal unaffected.



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

Image 4-2 The HART signal

HART commands and parameters

The adjustable properties of the HART field devices (HART parameters) can be set with HART commands and read using HART responses. The HART commands and their parameters are defined in three groups with the following properties:

- universal
- common-practice
- device-specific

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

Examples of HART parameters

The following table shows the HART parameters of the different groups:

Table 4-1 Examples of HART parameters

Parameter group	HART field device parameters
universal	Measured or manipulated value (primary variable), manufacturer name, process tags or final control element ID, additional measured values or manipulated values
common-practice	Measuring range, filter time, interrupt parameters (message, alarm and warning limits), output range
device-specific	special diagnostic information

Examples of HART commands

The following two tables provide examples of commands:

Table 4-2 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
2	Read current and percentage of the 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 measuring point tag, description and date (data included in transmission)

Table 4-3 Examples of common-practice commands

Command	Function
36	Sets the upper limit of the range
37	Sets the lower limit of the range
41	Carries out the device self-test
43	Sets the primary variable to zero
109	Switch burst mode on or off

Burst mode

Burst mode means that a command initiates cyclic response of the slave. This response is sent repeatedly until the mode is deactivated by the master device.

Data and status

HART commands are often transmitted without data, because they are used to start a processing function. HART responses always contain data. The HART response frame always includes status data which you should evaluate in order to validate the response.

4.2.3 Application of HART

System environment for HART use

To use a smart field device with HART functionality, you require the following system environment (see diagram below):

- **current loop 4 - 20 mA**
- **HART configuration tool:**
  You can assign the HART parameters either with an external HART handheld device or with the configuration tool, SIMATIC PDM. The configuration tool accesses the HART analog module directly, whereas the HART hand-held device is connected parallel to the field device. SIMATIC PDM (Process Device Manager) is available as autonomous (stand-alone) tool or embedded in STEP 7 HW Config or PCS 7.

- **HART system connection:**
  The HART analog module assumes the function of a "master," in that it receives the commands from the HART configuration tool, forwards them to the field device, and then sends back the responses. The interface of the HART analog module comprises data records which are transmitted via the I/O bus. The data records must be created and interpreted by the HART configuration tool.
- **Interface IM153-2 (PROFIBUS DP) and IM153-4 (PROFINET IO) for HART configuration tool:**
  DP Connection which is capable of master class 1 as well as master class 2 functionality.

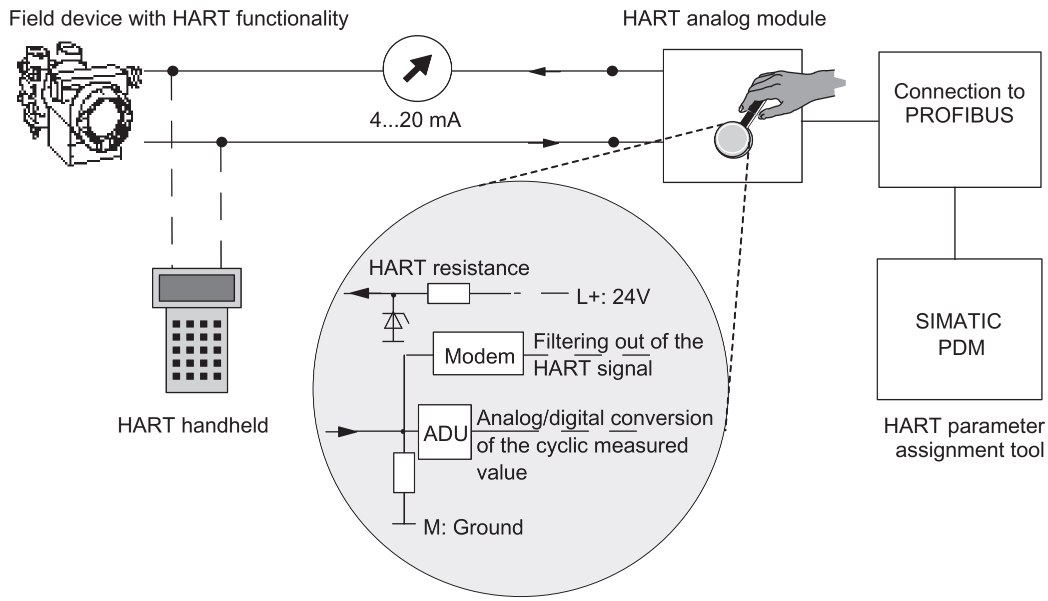


Image 4-3 System environment required for HART

Error handling

The two HART status bytes transmitted with each response of the field device contain error information relating to HART communication, HART commands and device status, (see "HART communication data records").

These are evaluated by the HART analog module, among other devices, and made available in the system via the S7 diagnostic mechanisms.

See also

HART Communication Data Records (Page 194)

4.3 Guidelines for Installation and Operation

4.3.1 Example configuration

Application in the system

A sample configuration is used to show you how to start up a HART analog module with the field devices connected, and the points you should take into consideration during operation. You can find more information on the operation of the field devices in the *integrated help for SIMATIC PDM*.

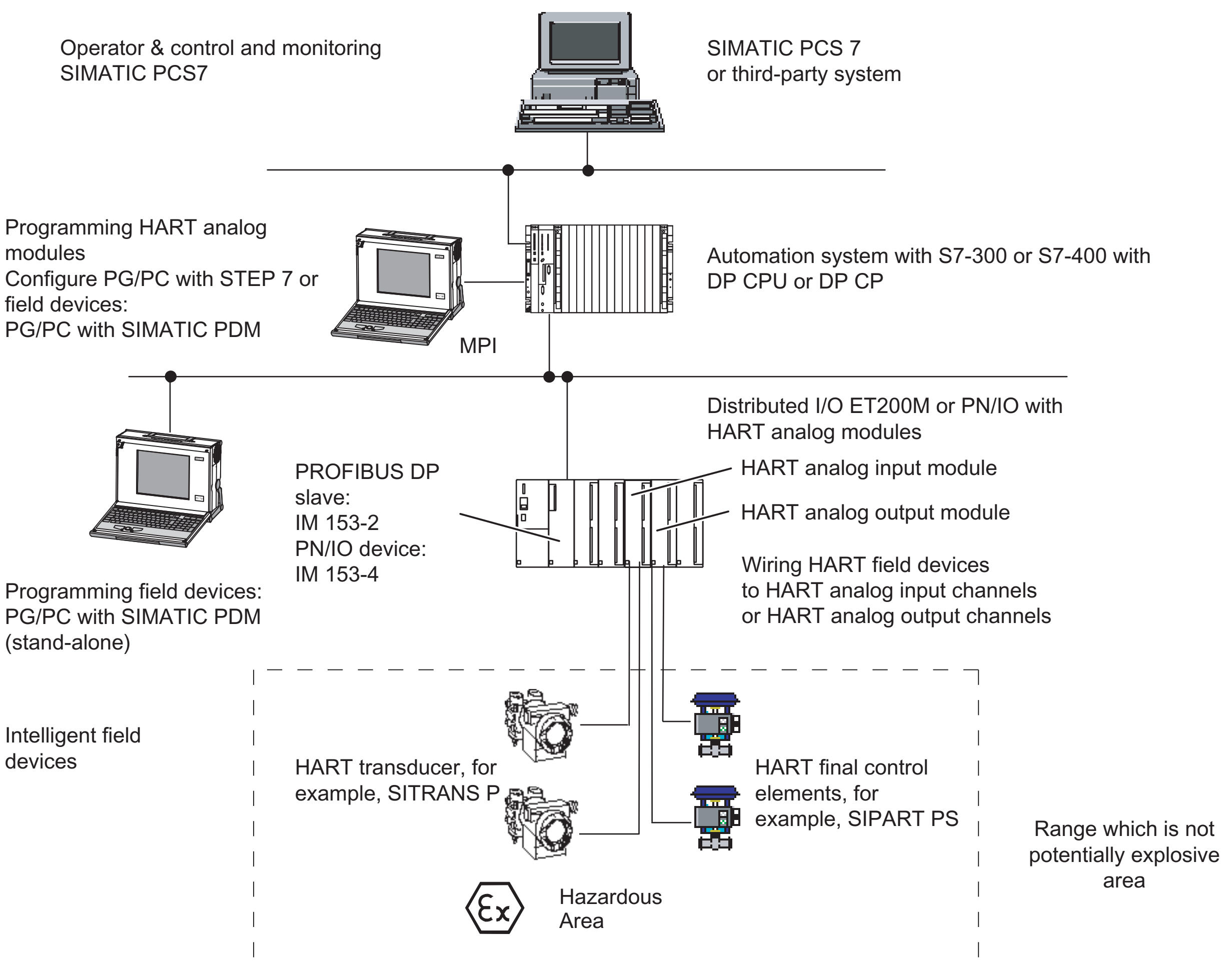


Image 4-4 Use of a HART analog module in a sample configuration

Note

Notes on intrinsically-safe installation

You must connect the DM 370 dummy module between the IM 153 interface module and explosion-proof I/O modules, which include HART I/O modules, whose signal cables lead into the hazardous area. In a distributed configuration with an active backplane bus, you should use the explosion-proof partition (6ES7 195-1KA00-0XA0) instead of the dummy module.

4.3.2 Setting Up the HART Analog Module and Field Devices

Installation

Commission the HART analog modules using STEP 7, and the intelligent field devices connected using the SIMATIC PDM programming tool:

Configuring and assigning parameters

1. Plug the HART analog module into the ET200M distributed I/O system. "Configuring and assigning parameters" to the associated station in the SIMATIC Manager with STEP 7: Start by double-clicking on the "Hardware" icon.
2. Select the ET 200M distributed I/O with a High Feature IM153 from the module catalog and attach this to the PROFIBUS (note the DP slave address) or PROFINET IO network.
3. Insert the HART analog module in the desired slot and assign the module parameters: You start the parameter assignment dialog by double-clicking the HART analog module in the selected slot.
   With HART Revision 7 analog modules, you can also configure up to 8 additional HART variables in the user data area of the module using the parameter assignment dialog in HW Config. See 4.5.1 for more on this.
4. Insert the HART field devices in the corresponding channels.
   When you insert a HART field device, the field device already connected in the "Device Selection (Reassign)" configuration dialog is identified via the "Device identification".
5. Download the configuration for the station which also contains the parameters for the HART analog module, to the programmable logic controller.
6. The field devices are configured with SIMATIC PDM via the channel to which the field device is connected:
   You start by double-clicking the HART field device configured on the channel.
7. Now you can configure the field devices using the SIMATIC PDM configuration tool: Within SIMATIC PDM, you see a device-specific configuration interface based on the type of the connected field device. You must have installed the EDD of the field device, the IM 153, and the HART analog module beforehand.

Modifying the parameters of the field devices

Note that the field devices report a configuration change to the HART module whenever you edit their parameters. This leads to a diagnostic interrupt on the programmable logic controller, provided this option is enabled. During commissioning it can be advantageous to disable the diagnostic interrupt when you assign parameters to the HART analog module.

A diagnostic interrupt can also be triggered, if enabled, during parameter modification with the handheld.

See also

Parameters of HART Analog Modules (Page 171)

4.3.3 Operating Phase of the HART Analog Module and Field Devices

Operating phase

In the operating phase you must distinguish between the cyclic return of user data, the acyclic HART operation and the cyclic HART communication.

- Cyclic process data such as the measured values can be requested from the automation system PROFIBUS DP master class 1) The user data area with input and output data is available for this.
- the acyclic operation for diagnostics and modifying the parameters of the field devices is carried out with the SIMATIC PDM parameter assignment tool or with a HART hand-held device using HART commands and HART responses.
- You can establish HART communication via read/write data record.

The operating phase

1. Switch the programmable logic controller to "RUN": User data are transmitted cyclically via PROFIBUS DP or PROFINET IO.
2. You can evaluate the user data cyclically in your user program. With HART Revision 7 analog modules, up to four HART variables of the connected transducer are provided for evaluation in the user data.
3. You can perform diagnostics and re-configuration of field devices with the configuration tool, SIMATIC PDM:
   You start by double-clicking the HART field device configured on the channel.
4. You can send HART commands to the connected transducers at any time via the data record interface of the HART analog modules. For example, you can re-configure the transducers or read data from the transducers.
   See 4.4.6.3 for Revision 5 modules or 4.5.7.3 for Revision 7 modules.

Access to the field devices

The HART analog module generally accepts the modification of parameters for the field devices. Access rights can only be allocated using the configuration tool.

Modifying the parameters of the field devices

To modify the parameters of the field devices connected to the HART analog modules, proceed as follows:

1. To modify the parameters of a field device, enter a HART command using the SIMATIC PDM configuration tool.
2. The HART analog module triggers a diagnostics interrupt when it detects new field device parameters, provided diagnostics interrupts are enabled.

Information on status

After you have modified the parameters of a HART field device, the corresponding bit is set in the device status of the connected field device (= HART status byte). This should be regarded as an indicator and not as an error and is reset by the module. For more information, see the "HART status bytes" section.

See also

Diagnostic Functions of HART Analog Modules (Page 174)

4.4 HART Analog Modules - Revision 5

Overview

The following SIMATIC S7 HART analog modules are described in this section:

- SM 331; AI 2 x 0/4...20mA HART (HART analog input module),
  Order number: 6ES7 331-7TB00-0AB0
- SM 332; AO 2 x 0/4...20mA HART (HART analog output module),
  Order number: 6ES7 332-5TB00-0AB0

This section provides the information you need to use the modules as a HART interface.

4.4.1 Parameters of HART Analog Modules

Overview of the parameters

The following table lists the parameters for the HART analog input module, the next table lists the parameters for the HART analog output module. The tables show which parameters can be set for the module as a whole and which parameters can be set separately for each channel. General information on assigning parameters can be found in the description of the SIMATIC-Ex analog modules.

Parameters of the analog input module SM 331; AI 2 x 0/4...20mA HART

Table 4-4 Parameters of the analog input module SM 331; AI 2 x 0/4...20mA HART

Parameter	Value range	Default setting	Type of parameter	Effective range
Basic settings enables				
• Diagnostic interrupt	Yes/no	No	Dynamic	Module
• Hardware interrupt triggered by limit violation	Yes/no	No		
• End-of-cycle hardware interrupt	Yes/no	No		
Limit for hardware interrupt				
• High limit	20 ...0/4 mA (from 32511 to - 32512)	Overflow (32767)	Dynamic	Channel
• Low limit	0/4 ...20 mA (from - 32512 to 32511)	Underflow (-32767)		
Diagnostics				
• Group diagnostics	Yes/no	No	Static	Channel
• with wire break monitoring	Yes/no	No		
Measurement				
• Measurement type	Deactivated 4DMU Current (4-wire transducer) 2DMU Current (2-wire transducer) HART (connected to 2DMU or 4DMU)	HART	Dynamic	Channel
• Measuring range	0 to 20 mA (can only be set with 4DMU), 4 to 20 mA	4 to 20 mA		
• Integration time / interference frequency suppression	2.5 ms; 16.6 ms; 20 ms; 100 ms corresponds to interference frequency suppression From 400 Hz; 60 Hz; 50 Hz; 10 Hz	20 ms		

HART measurement

The green HART status display indicates that HART measurement is enabled at a channel and that HART communication is active. When HART starts up, the HART analog module transmits the HART command 0 to the field device, followed by HART command 13. The resulting HART response data (for example "long frame" address and "tag"), are entered in the diagnostic data record 131 or 151. When it is operating, the HART analog module continually sends the HART command 1 to update the value of the primary variable. This value is entered in the user data area.

Parameters of the analog output module SM 332; AO 2 x 0/4...20mA HART

Table 4-5 Parameters of the analog output module SM 332; AO 2 x 0/4...20mA HART

Parameter	Value range	Default setting	Type of parameter	Effective range
Basic settings enable				
• Diagnostic interrupt	Yes/no	No	Dynamic	Module
Diagnostics				
• Group diagnostics	Yes/no	No	Static	Channel
Output				
Output mode	Deactivated Current HART	HART	Dynamic	Channel
Output range	4 to 20 mA 0 to 20 mA	4 to 20 mA		
Reaction to CPU STOP	Output with zero current and voltage (OCV) Keep last value (KLV) Set substitution value (SSV)	Set substitution value (SSV)		
Substitute value	0 to 20mA	0 mA		

HART output mode

If you have activated the HART output mode for a channel and HART communication is running, the green HART status display lights up. When HART starts up, the HART analog module transmits the HART command 0 to the field device, followed by HART command 13. The resulting HART response data (for example "long frame" address and "tag"), is entered in the diagnostic data record 131 or 151. When it is operating, the HART analog module continually sends the HART command 1 to update the value of the primary variable. This value is entered in the user data area.

See also

Additional diagnostic data records (Page 198)

Input area (read) (Page 202)

Parameters of Analog Modules (Page 120)

4.4.2 Diagnostic Functions of HART Analog Modules

Overview of diagnostic functions

If errors occur during configuration or parameter assignment, or during the operating phase, you can use diagnostics to determine the cause of the error. The general diagnostic behavior of the HART analog module corresponds to that of the other SIMATIC S7-Ex analog modules.

Diagnostic messages

The diagnostic messages for the analog input modules are shown in the table "Diagnostic messages of the analog input module SM 331"; the diagnostic messages for the analog output modules are shown in the table "Diagnostic messages of the analog output module SM 332". The additional diagnostic messages are listed in the following table:

Table 4-6 Additional diagnostic messages for the analog input module SM 331; AI 2 x 0/4...20mA HART and the analog output module SM 332; AO 2 x 0/4...20mA HART

Diagnostic message	Effective range of diagnostics	configurable with group diagnostics
Modification of HART parameters reported by the connected field device	Channel	Yes
HART group error		Yes

Causes of error

The following table provides a list of possible causes and corresponding corrective measures for the individual diagnostic messages.

Table 4-7 Additional diagnostic messages, possible causes of the errors, and remedies

Diagnostic message	Possible cause of error / diagnostics	Corrective measures
Modification of HART parameters reported by the connected field device	The identifier for the modification of parameters to the HART field device was set in the HART device status.	If you do not want diagnostic interrupts to be triggered when parameters are modified, you should disable the diagnostic interrupt.
HART group error	Communication and command error during HART operation affecting the connected HART field devices.	For detailed information, evaluate the response data record of the relevant client or the additional diagnostic data record.

HART status bytes

Each HART command is followed by a HART response containing data and status bytes. The status bytes provide information regarding

- Device status of the connected field device (e.g. modification of parameters)
- Communication error during transmission between HART analog module and the connected field device
- Command error during interpretation of the HART command by the connected field device (warning, rather than error)

The HART status bytes are entered in the response data record unchanged. Their significance is described in the technical specifications for HART. You can read the device status in your user program by using SFC59 or SFB 53 to read the corresponding data records.

See also

Diagnostics of the Analog Modules (Page 124)

HART Communication Data Records (Page 194)

Additional diagnostic data records (Page 198)

4.4.3 Interrupts of the HART Analog Modules

Overview of the interrupts

The interrupt response of the HART analog module is similar to that of SIMATIC S7 Ex analog modules. You can set parameters to enable or disable any interrupt.

Hardware interrupts with AI-HART

In this context we distinguish between the "out-of-limits hardware interrupt" and the "end-of-cycle hardware interrupt". You can evaluate the local data in OB40 when a hardware interrupt is active.

Table 4-8 Local data in OB40

Local data OB40	Bit 7 ...2	Bit 1	Bit 0	Limit
Byte 0	'0'	Channel 1	Channel 0	High limit exceeded
Byte 1	'0'	Channel 1	Channel 0	Low limit exceeded
Byte 2	'0'	'0'	'0'	Not relevant
Byte 3	'0'	'0'	'0'	Not relevant

At the end of the cycle all the bits in bytes 0-3 of the additional information for OB 40 which are not reserved for channels 0 and 1 are set to "1". You can use the reserved bits to evaluate whether the upper or lower limit set has been exceeded for a particular channel: if a limit has been exceeded, a "1" is displayed instead of a "0".

See also

Interrupts of analog modules (Page 128)

Parameters of HART Analog Modules (Page 171)

4.4.4 HART analog input module SM 331; AI 2 x 0/4...20mA HART (6ES7331-7TB00-0AB0)

Order number

6ES7331-7TB00-0AB0

Features

The analog input module SM 331; AI 2 x 0/4...20mA HART is characterized by the following features:

- 2 inputs in 2 channel groups
- 2 encoder supply outputs for 2-wire transducers
- The resolution of the measured value can be set separately at each channel (see "Analog values and resolution")
- Mode of measurement, selectable for each channel group:
  - 2-wire or 4-wire current transducers (with HART function)
  - 2-wire or 4-wire current transducers (no HART function)
  - Channel deactivated
- User-specific measuring range per channel
  - 0 ... 20 mA (no HART function)
  - 4 ... 20 mA
- Settings for diagnostics and diagnostic interrupt
  - Group diagnostics
  - Additional wire break monitoring
  - Diagnostic interrupt
- Programmable hardware interrupt
  - Channels 0 and 1 with limit monitoring: Programmable generation of out-of-limits hardware interrupts
  - Programmable end-of-cycle hardware interrupt

- Electrical isolation
  - Channels electrically isolated
  - Channels electrically isolated from the CPU and from load voltage L+
- Configuration in Run (CiR) supported

Analog values and resolution

The representation of the analog values is the same as for the analog input module SM 331; AI 4 x 0/4...20mA. The resolution of the input value for the HART analog input module is 15 bits + sign.

Table 4-9 Measuring types of the analog input module SM 331; AI 2 x 0/4...20mA HART

Selected measuring type	Measuring range
2-wire transducer	4 to 20 mA
4-wire transducer	0 to 20 mA 4 to 20 mA

Integration times when HART is used

When implementing transducers with HART protocol, you should preferably program integration times of 100 ms to keep the influence of AC modulation on the measuring signal to a minimum.

Default settings

HART measurement is set by default. There are other default settings for integration time, diagnostics, interrupts. The HART analog module uses these settings when no parameter modification is carried out in STEP 7.

Wire break check

Wire break recognition is not possible for the current range 0 to 20 mA.

For the current range from 4 to 20 mA, undershooting the input current of I ≤ 3.6 mA is interpreted as a wire break. When diagnostic interrupts are enabled, the module also triggers a diagnostic interrupt.

Wiring diagram of SM 331; AI 2 x 0/4...20mA

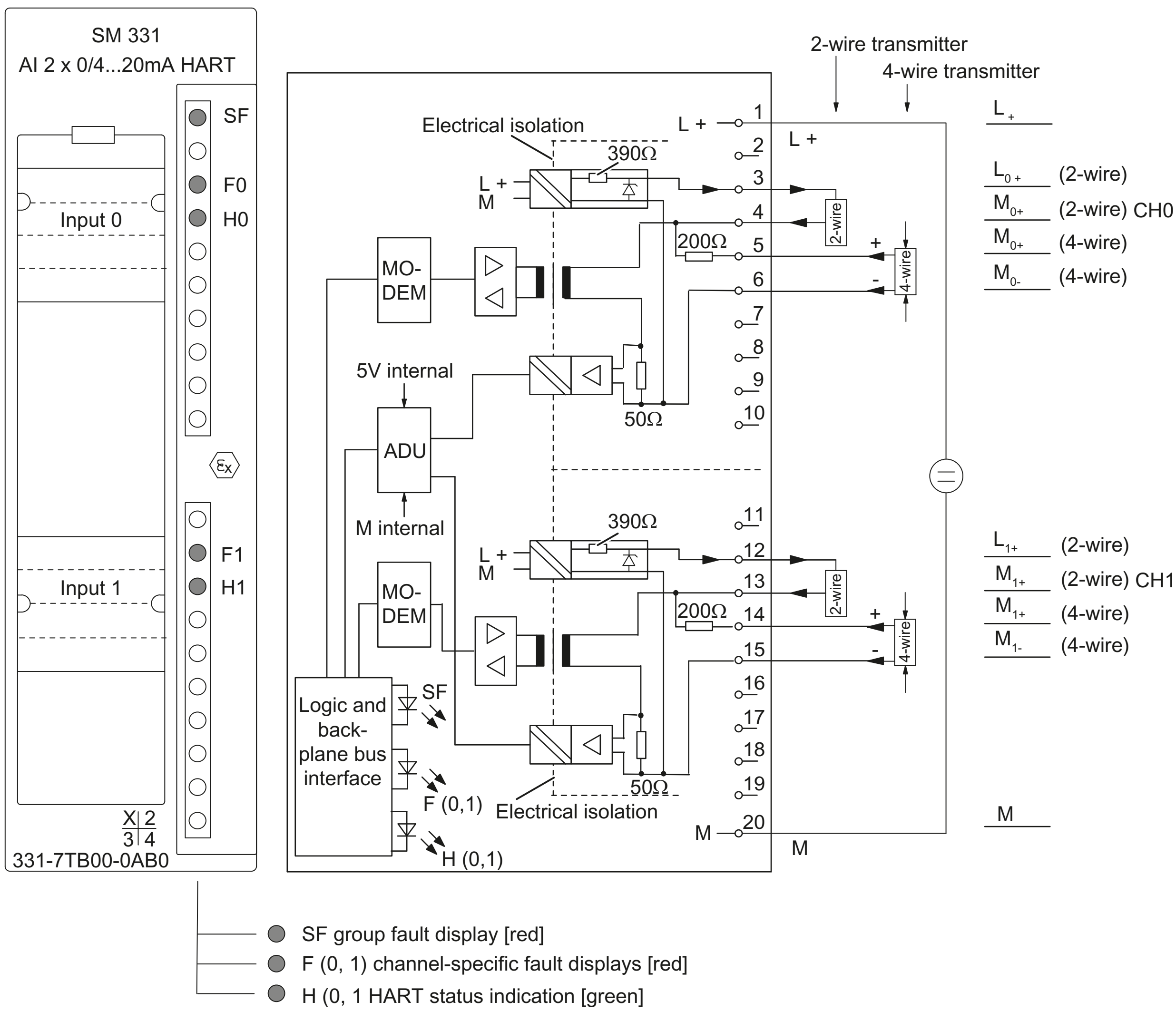


Image 4-5 Module view and block diagram of SM 331; AI 2 x 0/4...20mA HART

Note

The 200 ohm resistor must be in the measuring circuit when using HART transducers. This means that a 2-wire HART transducer must be connected to terminals 3 and 5 (12 and 14) and a 4-wire HART transducer to terminals 5 and 6 (14 and 15).

The 200 ohm resistor is optional in the measuring circuit for standard transducers without HART.

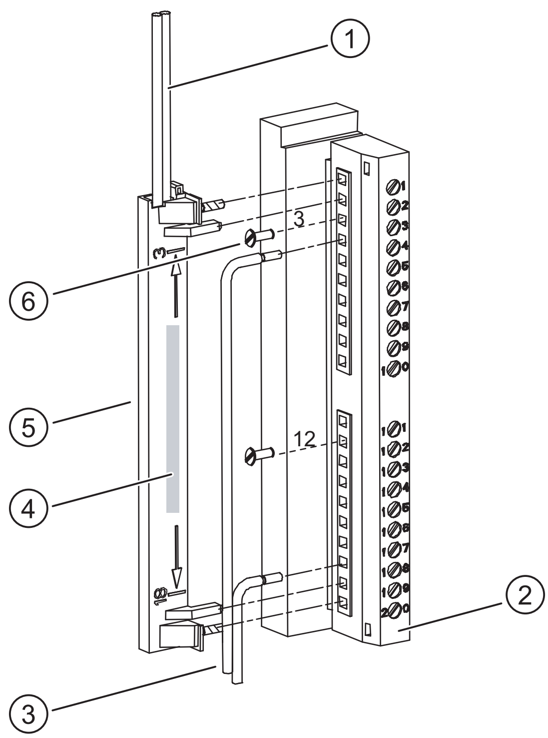
Note

Observe the prerequisites for an intrinsically safe installation.

Special feature for the connection of active encoders

Lock the unused transducer outputs at terminals 3 and 12 with plastic bolts if you connect active encoders to the SM 331-7TB00 module (6ES7 331-7TB00-0AB0). You can use M3 x 8 plastic screws, for example (see the diagram below).

Note that these measures reduce safety-relevant data of the module. For information on safety data, refer to the first amendment of the certificate.



① Load voltage supply
② Process connector with screw-type connection
③ Ex (i) process cable
④ Intrinsically safe area
⑤ Line chamber
⑥ Plastic screw M 3 x 8

Power supply for an intrinsically-safe structure

In order to maintain the clearances and creepage distances, L+/M must be routed via the line chamber LK393 when operating modules with signal cables that lead to the hazardous location.

Technical specifications of SM 331; AI 2 x 0/4...20mA HART (6ES7331-7TB00-0AB0)

Dimensions and weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	approx. 260 g
Module-specific data	

Configuration in Run (CiR) supported	Yes
• Behavior of non-configured inputs during CiR	They return the process value that applied before the parameters were set.
Number of inputs Number of power outputs	2 2
Line length, shielded	Max. 400 m
ATEX approvals	Ex II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 97ATEX3039 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply Rated load voltage L+ • Reverse voltage protection	5 VDC 24 VDC Yes
2-wire transducer power supply • short circuit-proof	 Yes (approx. 30 mA)
Electrical isolation	
• Between the channels and backplane bus	Yes
• Between the channels	Yes
• Between the channels and load voltage L+	Yes
• Between the backplane bus and load voltage L+	Yes
Permitted potential difference (V_{ISO}) of signals of the Ex area	
• Between the channels and backplane bus	60 VDC 30 VAC
• Between the channels and load voltage L+	60 VDC 30 VAC
• Between the channels	60 VDC 30 VAC
• Between the backplane bus and load voltage L+	60 VDC 30 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area	
• Between the channels and backplane bus	300 VDC 250 VAC
• Between the channels and load voltage L+	300 VDC 250 VAC
• Between channels	300 VDC 250 VAC
• Between the backplane bus and load voltage L+	75 VDC 60 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area for shared operation with F-modules	

• Between the channels and backplane bus	150 VDC 150 VAC			
• Between the channels and load voltage L+	150 VDC 150 VAC			
• Between the channels	150 VDC 150 VAC			
• Between the backplane bus and load voltage L +	75 VDC 60 VAC			
Insulation tested				
• Channels to backplane bus and load voltage L +	With 2500 VDC			
• Channels to each other	With 2500 VDC			
• Backplane bus to load voltage L+	With 500 VDC			
Current input				
• From backplane bus	Max. 100 mA			
• From load voltage L +	max. 180 mA			
Module power loss	typical 4.5 W			
Safety specifications (see EU special test certificate 97ATEX3039 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))				
Maximum values per channel				
• U_0 (no-load output voltage)	Max. 26 V			
• I_0 (short-circuit current)	Max. 96.1 mA			
• P_0 (power under load)	Max. 511 mW			
• L_0 (permissible external inductance)	Max. 3 mH			
• C_0 (permissible external capacity)	Max. 62 nF			
• U_m (fault voltage)	Max. DC 250V			
• T_a (permissible ambient temperature)	0 to 60°C			
Analog value formation				
Principle of measurement	SIGMA-DELTA			
Integration time/conversion time/ resolution (per channel)				
• Configurable	Yes	Yes	Yes	Yes
• Integration time in ms	2.5	16 2/3	20	100
• Basic conversion time plus integration time in ms (one channel enabled)	2.5	16 2/3	20	100
• Basic conversion time including integration time in ms (2 channels enabled)	7.5	50	60	300
• Resolution in bits +sign (including the overshoot range)	10 +sign	13+ sign	13+ sign	15+sign
• Interference voltage suppression for interference frequency f1 in Hz	400	60	50	10

Interference suppression, error limits		
Interference voltage suppression for f = n x (f1 ± 1 %), (f1 = interference frequency)		
• Common mode interference between channels and reference ground M of the CPU (V_{ISO} < 60 V)	> 130 dB	
• Series mode interference (measured value + interference signal must lie within the 0 mA to 22 mA input range)	> 60 dB	
Crosstalk attenuation between inputs (V_{ISO} < 60 V)	> 130 dB	
Operational limit (in total temperature range, based on input range)		
• from 0/4...20mA	± 0.45%	
Basic error limit (operational limit at 25 °C, based on input range)		
• from 0/4...20mA	± 0.1%	
Temperature error (based on input range)	± 0.01%/K	
Linearity error (based on input range)	± 0.01%	
Repeatability (in steady-state condition at 25°C, based on input range)	± 0.05%	
Influence of a HART signal modulated on an input signal relative to the input range		
Error at integration time		
• 2.5 ms	± 0.25%	
• 16 2/3 ms	± 0.05%	
• 20 ms	± 0.04%	
• 100 ms	± 0.02%	
Interrupts, diagnostics		
Interrupts		
• Limit interrupt	configurable channels 0 and 1	
• Diagnostic interrupt	Configurable	
Diagnostic functions	Configurable	
• Group error display	Red LED (SF)	
• Channel error display	Red LED (F) per channel	
• Diagnostic information readable	Possible	
• HART communication active and OK	Green LED (H)	
Technical date of the transducer power supply		
• No-load voltage	< 29.6 V	
• Output voltage for transducers and cables at 22 mA transducer current (50 W measurement resistance on module included)	> 15 V	
Data for sensor selection		
Input ranges (rated values / input resistance)		
• Current	0 to 20 mA; 4 to 20 mA:	/50 Ω /50 Ω
Permissible input current for current input (destruction limit)	40 mA	

Connection of signal transducers	
• for current measurement	
as 2-wire transducer as 4-wire transducer	Possible Possible

See also

Analog value notation of the measurement ranges of resistive encoders (Page 90)

The LK 393 line chamber (Page 14)

HB_Umparametrieren im RUN (http://support.automation.siemens.com/WW/view/en/14044916)

4.4.5 HART analog output module SM 332; AO 2 x 0/4...20mA HART (6ES7332-5TB00-0AB0)

Order number

6ES7332-5TB00-0AB0

Features

The HART analog output module has the following features:

- 2 current outputs in 2 channel groups
- Resolution 12 bit (+ sign)
- Output type selectable per channel:
  - Current output with HART
  - Current without HART
  - Channel deactivated
- Selection of any output range per channel
  - 0 to 20 mA (no HART function)
  - 4 to 20 mA
- Settings for diagnostics and diagnostic interrupt
  - Group diagnostics
  - Diagnostic interrupt
- Electrical isolation
  - Channels electrically isolated
  - Channels electrically isolated from the CPU and from load voltage L+

- Read-back capability of the analog outputs
- Configuration in Run (CiR) supported

Analog values and resolution

The representation of the analog values is the same as for the analog output module SM 332; AO 4 x 0/4...20mA. The resolution of the output value for the HART analog output module is, however, 12 bit.

Table 4-10 Output ranges of analog output module SM 332; AO 4 x 0/4...20mA

Selected output mode	Output range
Current	0 to 20 mA 4 to 20 mA

Default settings

The output type HART is the default setting. There are also default settings for substitute value, diagnostics, interrupts. The HART analog output module uses these settings when no parameters have been changed in STEP 7.

Wire break check

Wire break monitoring is possible for the current range 0/4 to 20mA.

Condition: Minimum output current > 500 μA

Effect of a falling load voltage on the diagnostic message

When the 24 V load voltage falls under the permissible rated range (< 20.4 V), if loads > 650 Ω are connected and there are output currents > 20 mA, the output current may be reduced before a diagnostic message is issued.

Readback capability

The analog outputs can be read back in the user data range (+ sign) with a resolution of 8 bit. Note that the value read back from the analog output is only available at the corresponding accuracy when the conversion cycle is completed.

Wiring diagram of SM 332; AO 2 x 0/4...20mA HART

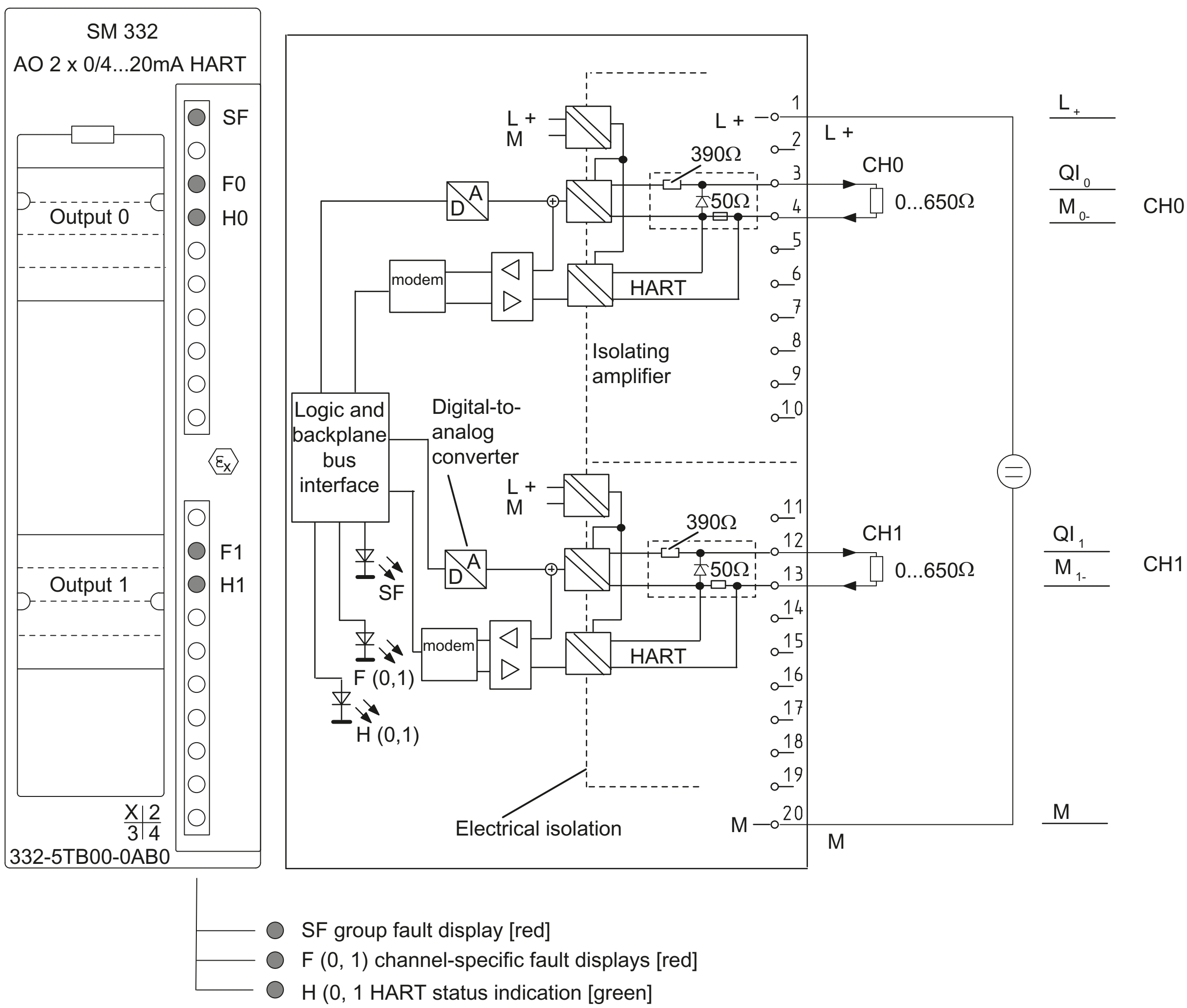


Image 4-6 Module view and block diagram of the SM 332; AO 2 x 0/4...20mA HART

Note

Observe the prerequisites for an intrinsically safe installation.

Power supply for an intrinsically-safe structure

In order to maintain the clearances and creepage distances, L+/M must be routed via the line chamber LK393 when operating modules with signal cables that lead to the hazardous location.

Non-wired output channels

To ensure that non-wired output channels of the analog output module SM 332; AO 2 x 0/4...20mA HART are deenergized, you have to deactivate them. You deactivate an output channel using STEP 7 by means of the "Output" parameter block.

Technical specifications of SM 332; AO 2 x 0/4...20mA HART (6ES7332-5TB00-0AB0)

Dimensions and weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	Approx. 280 g
Module-specific data	
Configuration in Run (CiR) supported	Yes
Behavior of non-configured outputs during CiR	They output the output value that applied before the parameters were set.
Number of outputs	2
Line length, shielded	Max. 400 m
ATEX approvals	II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 97ATEX2359 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply Rated load voltage • Reverse voltage protection	5 VDC 24 VDC Yes
Electrical isolation	
• Between the channels and backplane bus	Yes
• Between the channels	Yes
• Between the channels and load voltage L+	Yes
• Between the backplane bus and load voltage L+	Yes
Permitted potential difference (V_{ISO}) of signals of the Ex area	
• Between the channels and backplane bus	60 VDC 30 VAC
• Between the channels and load voltage L+	60 VDC 30 VAC
• Between the channels	60 VDC 30 VAC
• Between the backplane bus and load voltage L+	60 VDC 30 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area	

• Between channels and backplane bus	300 VDC 250 VAC
• Between channels and load voltage L+	300 VDC 250 VAC
• Between channels	300 VDC 250 VAC
• Between the backplane bus and load voltage L+	75 VDC 60 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area for shared operation with F-modules	
• Between the channels and backplane bus	150 VDC 150 VAC
• Between the channels and load voltage L+	150 VDC 150 VAC
• Between the channels	150 VDC 150 VAC
• Between the backplane bus and load voltage L+	75 VDC 60 VAC
Insulation tested	
• Channels to backplane bus and load voltage L +	With 2500 VDC
• Channels to each other	With 2500 VDC
• Backplane bus to load voltage L+	With 500 VDC
• Channels with respect to shield	With 500 VDC
Current input	
From backplane bus	Max. 100 mA
From load voltage L+ (at rated data)	Max. 150 mA
Module power loss	Typical 3.5 W
Analog value formation	
Output value	
Resolution (including overrange)	12 bit (+ sign)
Cycle time (all channels)	5 ms
Transient recovery time	
• for resistive load	2.5 ms
• For inductive load	2.5 ms
• For capacitive load	4 ms
Set substitute values	Yes, configurable
Readback value	
Resolution	8 bit (+ sign)
Conversion time (per channel)	40 ms
Interference suppression, error limits	
Crosstalk attenuation between the outputs	>130 dB
Operational limit (across temperature range, relative to output range)	± 0.55%
Intrinsic error limit (operating error limit at 25°C relative to the output range)	± 0.15%

Temperature error (relative to the output range)	± 0.01%/K
Linearity error (based on output range)	± 0.03%
Repeatability (in steady-state condition at 25°C, based on output range)	± 0.005%
Output ripple; range 0 to 50 kHz (based on output range)	± 0.02%
Interrupts, diagnostics	
Interrupts	
• Diagnostic interrupt	Configurable
Diagnostic functions	Configurable
• Group error display	Red LED (SF)
• Channel error display	Red LED (F) per channel
• Diagnostic information readable	Possible
Monitoring for	
• Wire break From output value	Yes > 0.5 mA
HART communication active and OK	Green LED (H)
Safety specifications (see EU special test certificate KEMA 97ATEX2359 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))	
Maximum values of the output circuits (per channel)	
• U_0 (no-load output voltage)	Max. 19 V
• I_0 (short-circuit current)	Max. 66 mA
• P_0 (power under load)	Max. 506 mW
• L_0 (permissible external inductance)	Max. 7.5 mH
• C_0 (permissible external capacity)	Max. 230 nF
• U_m (fault voltage)	Max. 60 VDC
• T_a (permissible ambient temperature)	Max. 60°C
Data for actuator selection	
Output ranges (rated values)	
• Current	0 to 20 mA 4 to 20 mA
Load impedance (in rated range of output)	
• for current outputs – Resistive load – Inductive load	 Max. 650 Ω Max. 7.5 mH[1]
• Capacitive load	Max. 230 nF[1]
Current output	
• No-load voltage	Max. 19 V
Destruction limit for externally applied voltages / currents	
Voltages	Max. + 17 V / - 0.5 V
Current	Max. + 60 mA / - 1A

Wiring of actuators	
• For current output 2-wire connection	Yes
[1] KEMA approval limitations can be set as the load when used in non-ex areas • Inductive load max. 15 mH • Capacitive load max. 3 μF *) *) HART communication no longer possible, however	

See also

The LK 393 line chamber (Page 14)

Analog Value Representation for the Output Ranges of Analog Outputs (Page 102)

Parameters of HART Analog Modules (Page 171)

HB_Umparametrieren im RUN (http://support.automation.siemens.com/WW/view/en/14044916)

4.4.6 Data record interface

Introduction

This section contains specific data you need for programming, diagnostics and HART communication if you want to extend the functionality of STEP7 standard applications or deploy your own software tool for HART communication.

Configuration and parameter assignment with STEP 7

You can configure and assign parameters of the HART analog modules with STEP 7. The integrated help system supports you in this.

You can integrate certain additional functions for writing parameters and reading diagnostic data in your user program by means of SFCs.

4.4.6.1 Parameter Data Records

Structure of the parameter data records for the HART analog input

The figures below show data record 0 for the static parameters and data record 1 for the dynamic parameters for AI-HART and AO-HART.

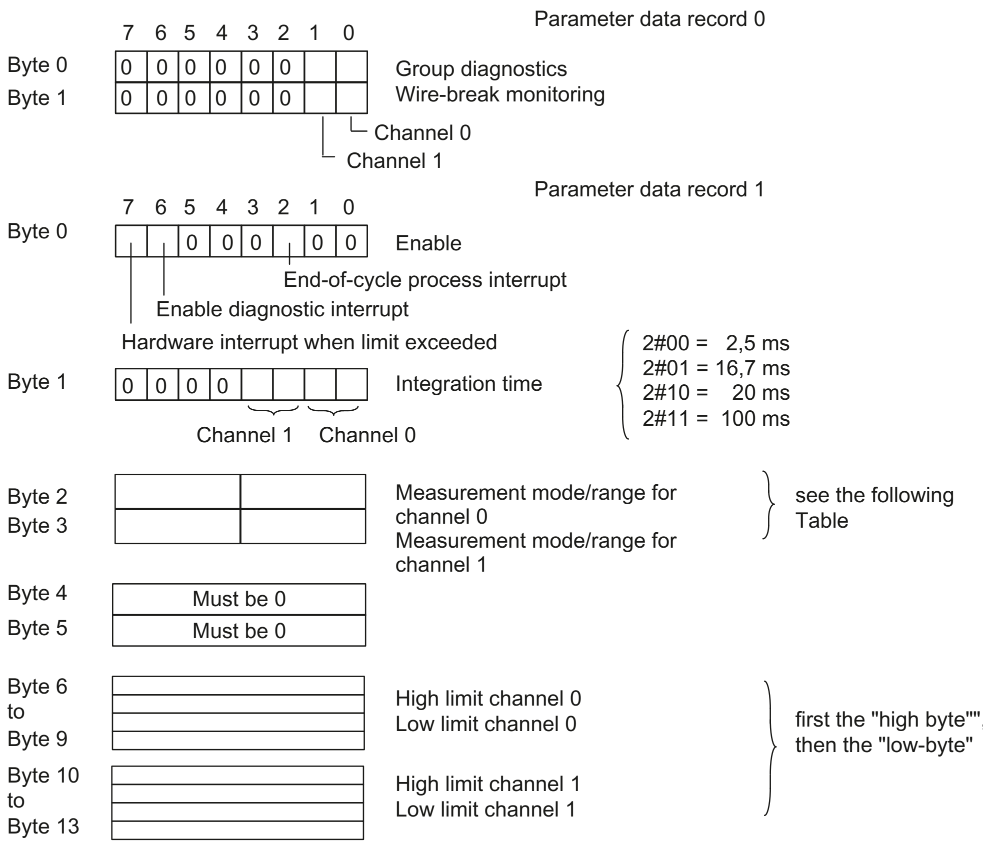


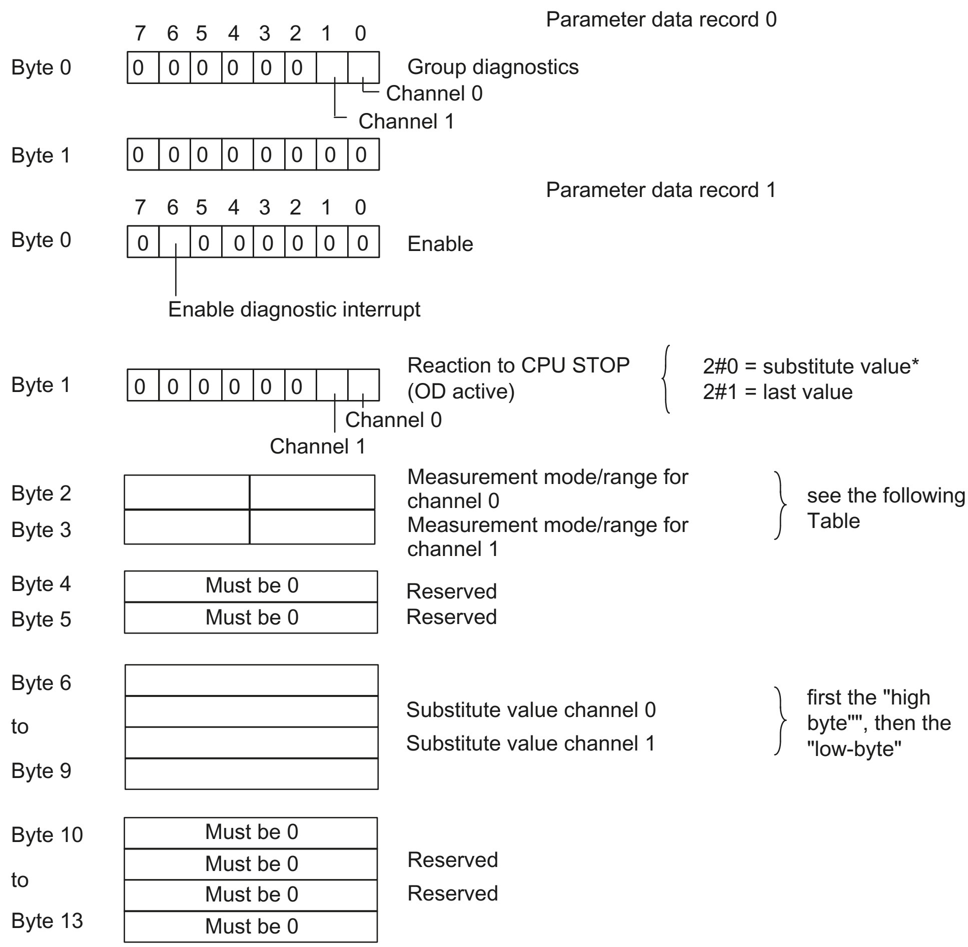
Image 4-7 Parameters of the HART analog input module

Table 4-11 Codes for the measuring type and measuring range of the HART analog input module

Measurement type	Code	Measuring range	Code
Deactivated	2#0000	Deactivated	2#0000
4-wire transducer	2#0010	0 to 20 mA 4 to 20 mA	2#0010 2#0011
2-wire transducer	2#0011	4 to 20 mA	2#0011
HART (2-wire or 4-wire transducers can be connected)	2#0111	4 to 20 mA HART	2#1100

Structure of the parameter data records for the HART analog output

The figure below shows data record 0 for the static parameters and data record 1 for the dynamic parameters.



* For the substitute value - 6912 (E500 Hex) the outputs will be disabled.

Image 4-8 Parameters of the HART analog output module

Table 4-12 Code for the measurement type / range of the HART analog output module

Output mode	Code	Output range	Code
Deactivated	2#0000	Deactivated	2#0000
Current output without HART	2#0010	0 to 20 mA 4 to 20 mA	2#0010 2#0011
Current output with HART	2#0111	4 to 20 mA HART	2#1100

4.4.6.2 Diagnostic data records

Structure and contents of the diagnostic data

The diagnostic data for a module can be up to 16 bytes long and consist of data records 0 and 1:

- Data record 0 contains system-specific diagnostic data: 4 bytes that are set on a system-wide basis and apply to both HART analog inputs and outputs.
- Data record 1 contains the 4 bytes of diagnostic data of an S7-300 that are also in data record 0 **and** 6 bytes of module class-specific diagnostic data.

Diagnostic data record DS0 / DS1

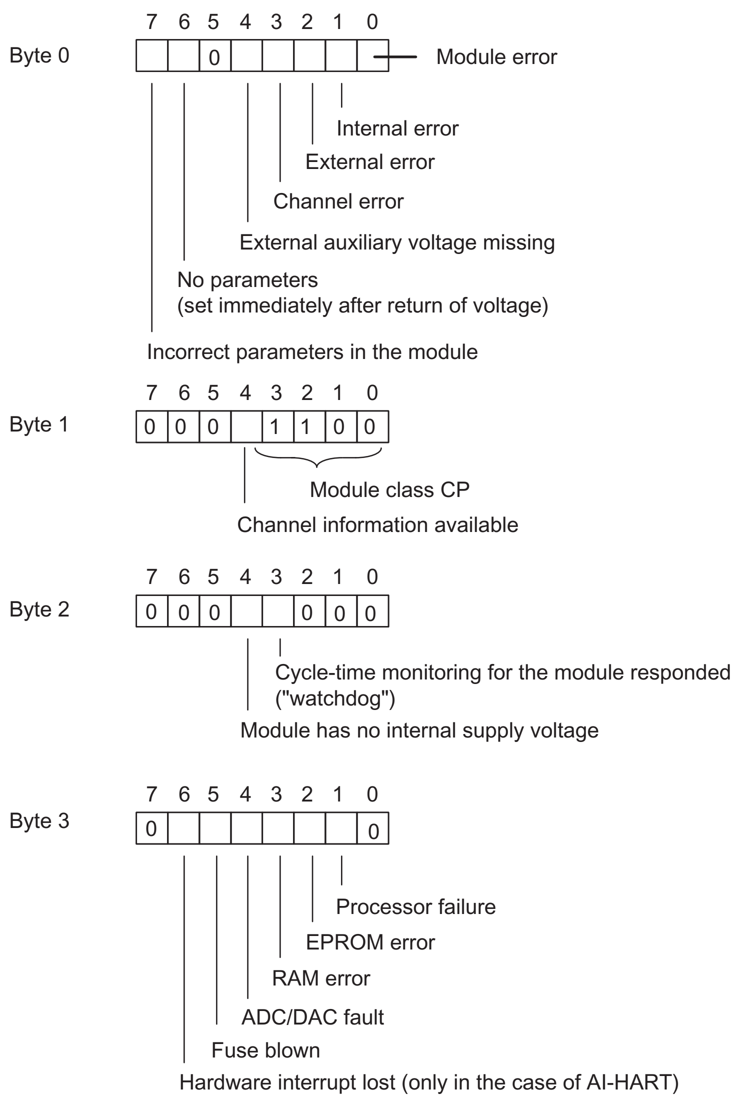


Image 4-9 Diagnostic data: data record 0/1

Diagnostic data: data record DS1

The following diagram shows the contents of bytes 4 to 9 of the diagnostic data.

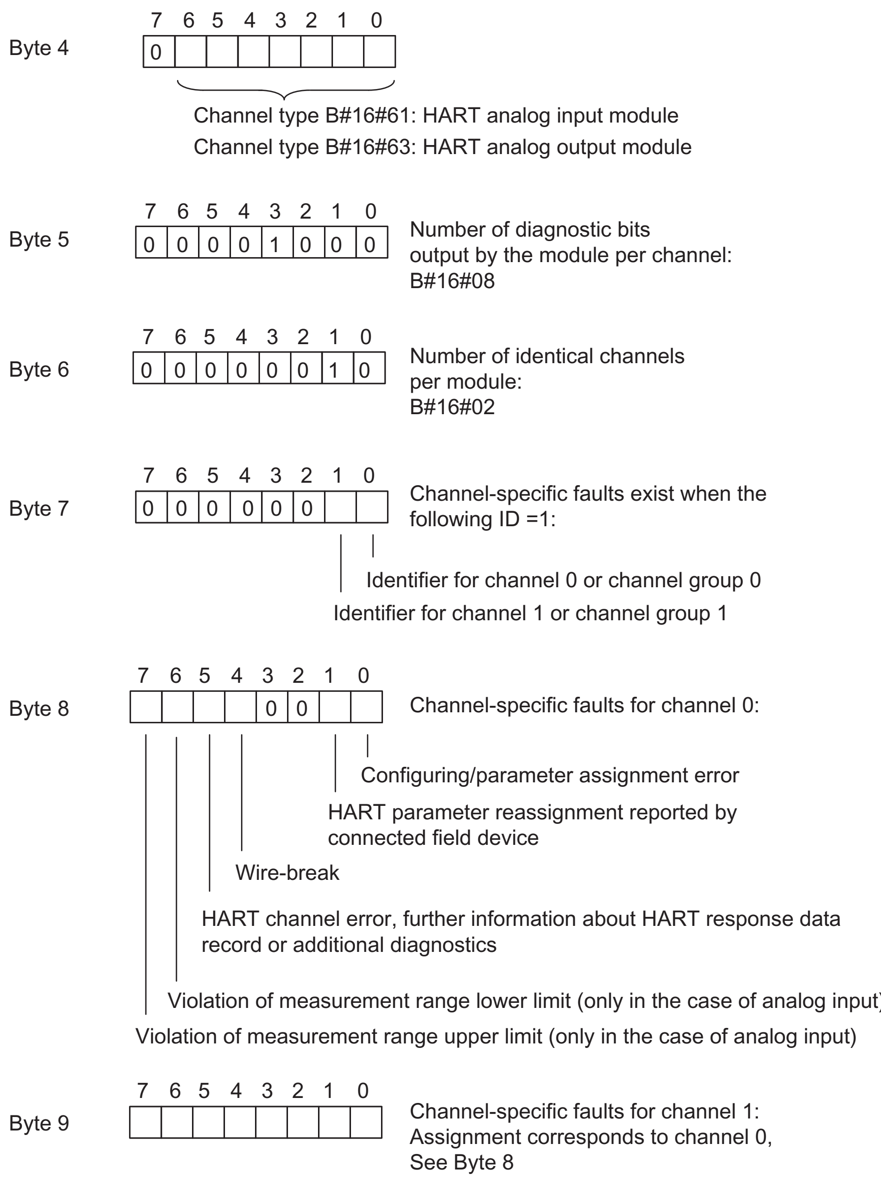


Image 4-10 Diagnostic data: data record 1

Note

Please note the following points regarding diagnostic data:

If a HART channel error occurs, you can obtain further information by using SFC59 or SFB 53 to read the status in the HART response data record for the relevant client or the additional diagnostic data record for the relevant channel.

See also

HART Communication Data Records (Page 194)

Additional diagnostic data records (Page 198)

4.4.6.3 HART Communication Data Records

Transfer data records

HART communication can be operated by up to 7 clients each using two separate channels. There are 14 separate data transfer areas for this purpose, 7 for channel 0 and 7 for channel 1. Each transfer area consists of a command data record and a response data record.

Coordination rules for HART communication

- Each client / channel is allocated fixed data record numbers:

Chan-nel	Client / data record	1	2	3	4	5	6	7
0	Command	10	14	18	22	26	30	34
0	Response	12	16	20	24	28	32	36
1	Command	50	54	58	62	66	70	74
1	Response	52	56	60	64	68	72	76

- Each client may only use the data record numbers allocated to its transfer area.
- For example, for client 6, channel 0: the command is data record 30 and the response is data record 32.
- After having written a command data record, the client must read the response data record before it writes the next command data record.
- The transfer area of each client is allocated a data ready bit in the user data area, which is set when new data can be collected.
- In Master Class 2 the client can evaluate the "processing state" in the response data record: if the "processing state" indicates "successful" or "error," the data record contains current response data or error bits respectively.
- All data must be read, because the module can modify the data record if the initial read operation returns a successful or faulty state.
- The status section of the response data record provides information on any errors that have occurred.
- The HART burst mode cannot be used by more than one client at any one time (that is, only one client can set this operating mode with a command).

Structure of the command data record

The following diagram shows the structure of the data record, which you can use to write a command in the transfer area of a client. The HART analog module transmits the command to the connected HART field device.

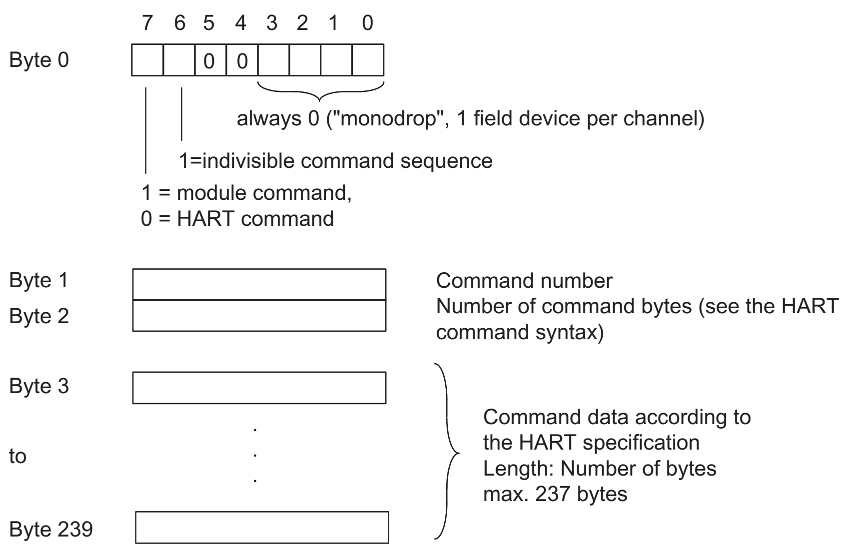


Image 4-11 Command data record of the HART analog module

Notes on the command

The same client must not send a second command until the **response** to any previous command has been read. In order to prevent interim execution of the commands of other clients, the client must set the "indivisible command sequence" bit in its command:

- The inseparable command sequence is maintained as long as the bit "inseparable command sequence" is set.
- The inseparable command sequence is terminated if the bit "inseparable command sequence" is not set, or automatically after 10 seconds by the module.
- While an inseparable command sequence is set for one client, one command from each of the other clients can be stored temporarily in the buffer. The stored commands are processed once the inseparable command sequence has been terminated.

Notes on response

Always make sure that you are reading the current response data record.

- If the processing state in the response data record indicates "successful" or "error," the data record contains current response data or error messages respectively.
- Alternatively you can evaluate the "data ready" in the user data area: the transfer area of each client is allocated a bit in the user data area which is set when new data arrives.

Structure of the response data record

The following figure shows the structure of the response data record, which contains the response to the HART command you sent previously and any error or status bits.

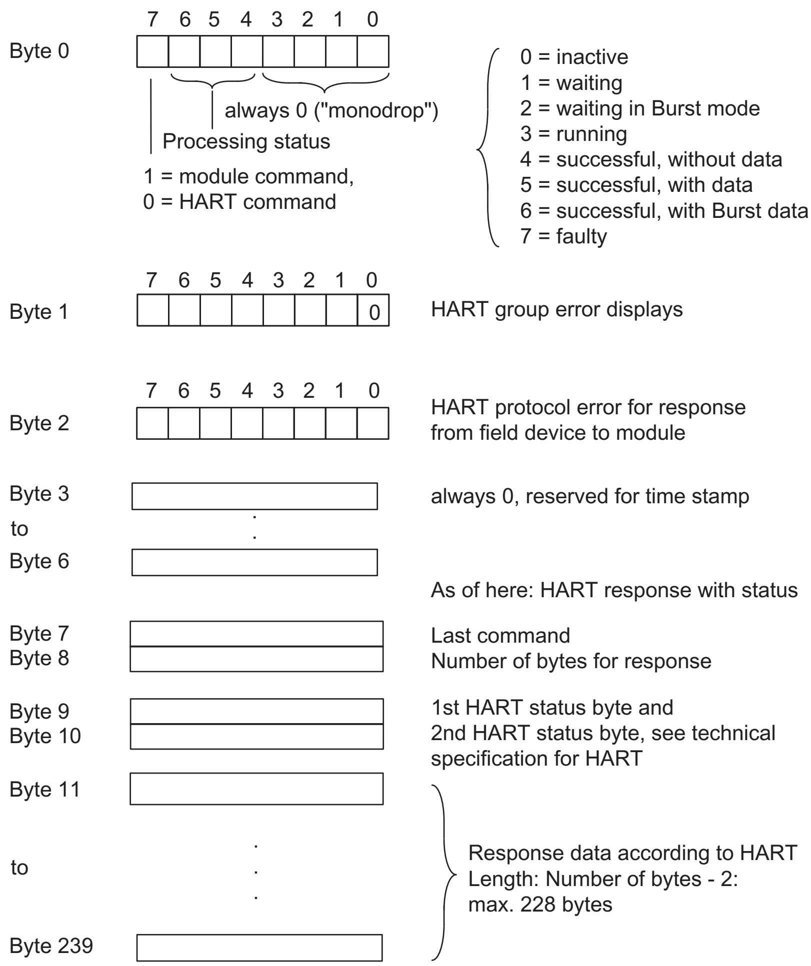


Image 4-12 Response data record of the HART analog modules

Evaluating the response data

When you have an up-to-date response data record, you can check the following:

- Look for the "last command" entry to verify that the response belongs to the command sent.
- You can evaluate the "Group error bits" (see following table) to locate individual errors.
- You can obtain more information from "HART protocol errors during response" (see following table) and both HART status bytes.
- In the group error bytes the corresponding bits will be set to "1".

Table 4-13 HART group error displays

Bit No.	HART group error display	Meaning
0	always 0	not used
1	command rejected	Used in the following cases: For a module command which does not exist. If you try to activate the burst mode when it is already activated. If you try to deactivate the burst mode when it was activated by another client. If you try to change the polling address of the HART field device.
2	further status information available.	Corresponds to bit 4 in the 2nd HART status byte. You can obtain further status information with the HART command 48.
3	HART device status--> "Modification of parameters" entry in diagnostic data, data record 1	The field device transmits its device state. This information is found in the **2nd HART status byte** which is accepted unchanged.
4	HART command status	The field device transmits displays on the receipt of the command. Information on this can be found in the **1st HART status byte**.
5	Error during HART communication--> "HART group error" entry in diagnostic data, data record 1	The field device has detected a communication error while receiving the command. Information on the error can be found in the **1st HART status byte** which is accepted unchanged.
6	HART protocol error during response--> "HART group error" entry in diagnostic data, data record 1	Error during HART communication between field device and module, i.e. the response was incorrectly received. Information on the cause of the error can be found in the next byte. See following **table**.
7	Wire break--> parallel entry "Wire break" in diagnostic data, data record 1	The connection to the transducer or final control element is interrupted.

Table 4-14 HART protocol error during response from field device to module

Bit No.	HART protocol error in byte 2	Meaning
0	bad frame timing	Waiting time elapsed without response being received from field device.
1	always 0	not used
2	bad character transmission timing	The pause between two bytes was not observed.
3	checksum error in response	The checksum calculated does not match the checksum transmitted.
4	Response frame error	Error receiving HART signal (in UART)
5	Response overrun error	Error receiving HART signal (in UART)
6	Response parity error	Error receiving HART signal (in UART)
7	HART access not possible	The connection to the field device is permanently used. This error is registered if the transmission time exceeds 10 seconds.

4.4.6.4 Additional diagnostic data records

Additional diagnostic data

The additional diagnostic data provide information on the state of the HART communication following the last command.

- Additional diagnostic data record 128 for channel 0, 129 for channel 1
- Additional diagnostic data record 130 for channels 0 and 1: When the module starts up the recognized connected HART field devices and their identifiers ("tags") are entered here.
- Additional diagnostic data records 131 for channel 0 and 151 for channel 1 with the data for the identifiers found in the additional diagnostic data record 130.

Structure of the diagnostic data records 128 and 129

The following figure shows the structure of the diagnostic data records 128 and 129.

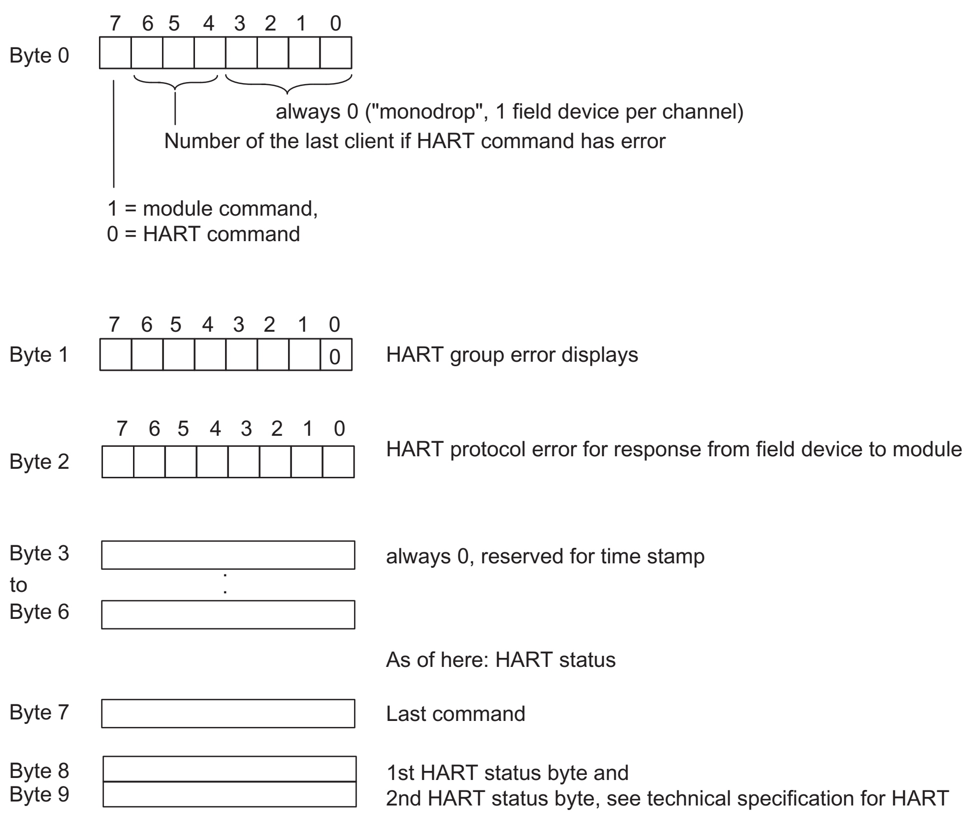


Image 4-13 Diagnostic data records 128 and 129 of the HART analog modules

Structure of the diagnostic data record 130

The diagram below shows the structure of diagnostics data record 130 from which you can request the identification of connected HART transducers or final control elements.

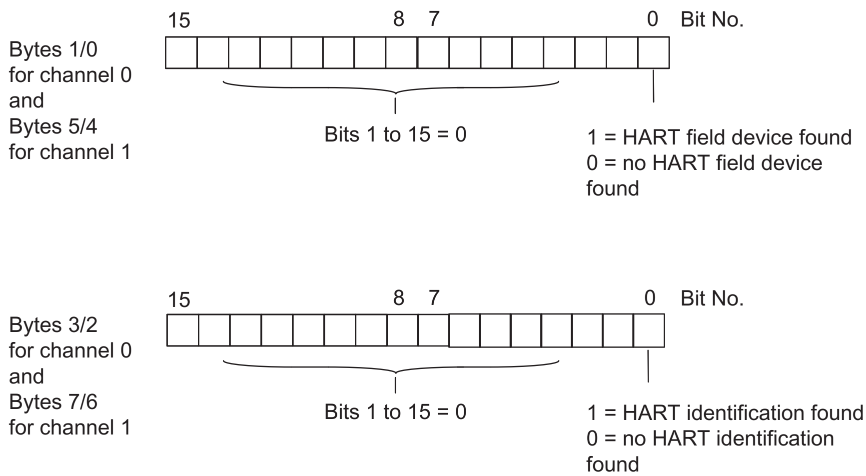


Image 4-14 Diagnostic data record 130 of the HART analog modules

Structure of the diagnostic data records 131 and 151

These contain the data corresponding to the identifiers marked in data record 130: The address of the HART field device found and the HART identifier with measuring point tag or final control element identifier. The structure is illustrated in the following diagram.

- Data record 131 for channel 0 (length: 38 bytes)
- Data record 151 for channel 1 (length: 38 bytes)

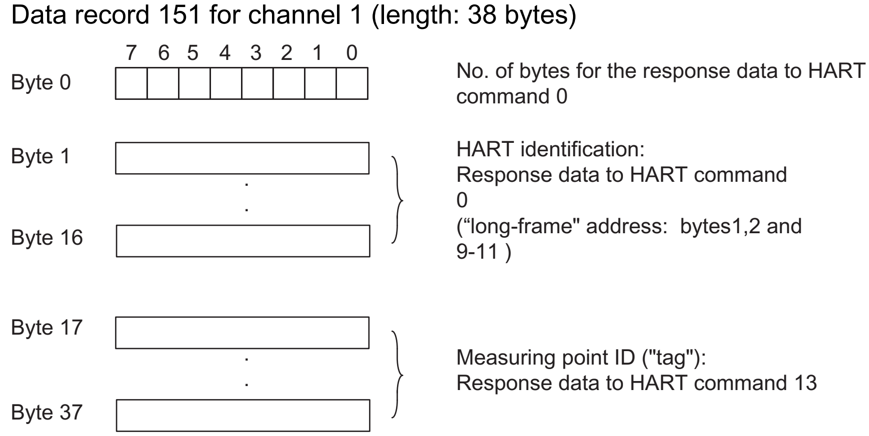


Image 4-15 Diagnostic data records 131 and 151 of the HART analog module

4.4.6.5 Additional parameter data records

Structure of the parameter data records 128 and 129

The following diagram shows the structure of the additional parameter data records 128 for channel 0 and 129 for channel 1. The settings affect the assigned channel:

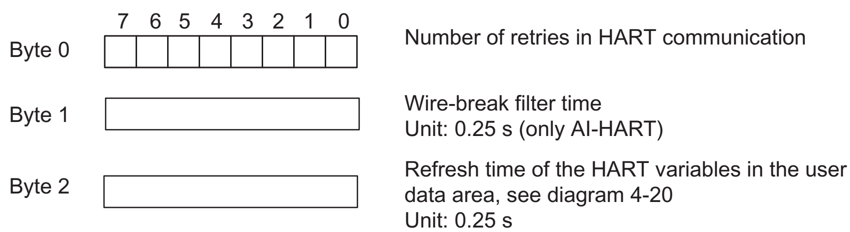


Image 4-16 Parameter data records 128 and 129 of the HART analog modules

Notes on the additional parameters

The additional parameters comprise parameters which you do not normally need to change, as they have already been set to an optimized value: The following table provides explanations of the parameters and the default values.

Table 4-15 Additional parameters of the HART analog modules

Parameter	Explanation	Value range and default setting	
Repeated attempts	The HART analog modules initiate the configured retry sequence when sending a command to a field device whose port is in use by another function.	Value range: Default setting: No repeat attempts:	0 to 127 3 0
Wire break filter time [1]	A wire break is only signaled if it occurs for longer than the set filter time.	Value range: Default setting: no filter time:	0 to 20 3 ≙ 0.75 s 0
Update time	The HART modules send the HART command 1 automatically, to read the present value of the primary variable.	Value range: Default setting: no filter time:	0 to 255, 12 ≙ 3 s 0

[1] Several diagnostics interrupts may be generated during startup due to differences in the time-related startup characteristics of transducers. The wire break filter time was introduced to avoid this problem.

Default parameter assignment for DP master class 2

HART analog modules which are not in parameterized state, for example after power failure, can receive default parameters from PROFIBUS DP master class 2 when the PLC is in OFF state. This is carried out with the aid of parameter data record No. 250 which consists of one byte with the value unequal 0. However, the assignment of default parameters can only be initiated when the module is in an unparameterized state. You can determine the state of the module by reading the diagnostic data record.

4.4.6.6 User data interface

Overview of the user data

The user data range of the HART analog modules includes the following for both channel 0 and channel 1:

- Current as analog input value or analog output value
- Primary variable in HART format (measured value or manipulated variable)
- Identifiers for clients to indicate that new data can be collected.

Relative addresses are specified in the description of the user data. Determine the module address offset using the "Configuring and programming" application in STEP7.

Input area (read)

Structure of the user data

The following figure shows the structure of the user data area for the HART analog input module. The data for the user data area can be read in the desired format using "Read peripheral data" (for example, L PIW 256) and evaluated in your user program.

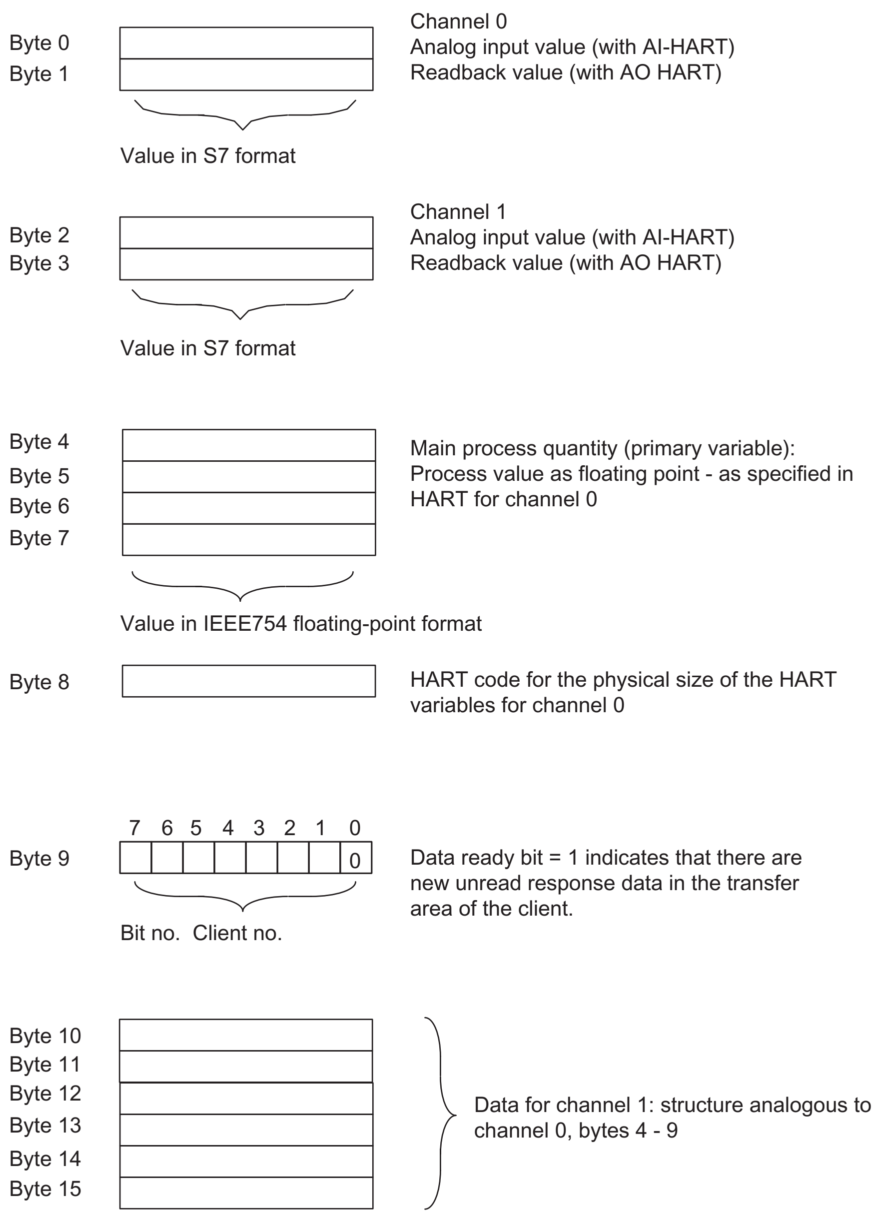


Image 4-17 Input user data area of the HART analog modules

Output Area (write)

Structure of the user data

The following diagram shows the structure of the user data area for the HART analog output modules. The data for the user data area can be read in the desired format using "Write peripheral data" (for example, L POW 256) and evaluated in your user program.

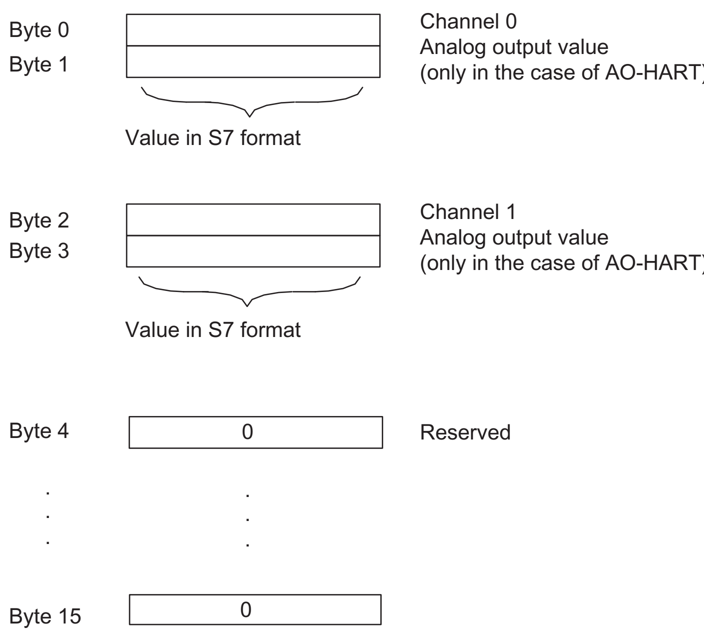


Image 4-18 User data area of the HART analog output module

4.5 HART Analog Modules - Revision 7

Overview

The following SIMATIC S7 HART analog modules are described in this section:

- SM 331; AI 2 x 0/4...20mA HART (HART analog input module),
  Order number: 6ES7 331-7TB10-0AB0
- SM 332; AO 2 x 0/4...20mA HART (HART analog output module),
  Order number: 6ES7 332-5TB10-0AB0

This section provides the information you need to use the modules as a HART interface.

The HART Analog Modules – Revision 7 offer the following in comparison to Revision 5 modules:

- You can use HART 5, HART 6 and HART 7 transducers.
- You can also configure up to 8 additional HART variables in the user data area of the module using the parameter assignment dialog in HW Config.
- The mapping of HART commands and HART responses to S7 data records is based on the *PROFIBUS Profile HART Version 1.0*. See 4.5.7.3.

Requirement

The HART Analog Modules – Revision 7 can be used as of STEP7 V5.5 + SP4 and SIMATIC PCS 7 V8.1.

The modules can be used on PROIFIBUS DP or PROFINET IO in connection with the respective High Feature interface modules
IM 153-2, 6ES7153-2BA02-0XB0 or
IM 153-4, 6ES7153-4BA00-0XB0.

Integration of the HART analog modules based on the PROFINET IO standard is possible with the current GSDML file (as of GSDML V2.3 Siemens ET200M 20140124.xml) for IM153-4.

Field devices can be configured with SIMATIC PDM V6.1 and higher or SIMATIC PDM V 8.1 SP 1.
You need the EDD for the ET 200M for this. For PROFIBUS DP as of EDD V1.1.17 and PROFINET IO as of EDD V770.1.2.

4.5.1 Configuring HART variables

Introduction

Numerous HART field devices make available additional measurement variables (e.g. sensor temperature). These can be read if they are set accordingly in the field device configuration in SIMATIC PDM.

Using the HART variables it is possible to adopt the set measured values directly from the field device into the I/O area of your automation system.

A maximum of 8 HART variables can be configured for HART modules. You assign the HART variables to a channel in the properties dialog for the module.

Address assignment

The HART modules use 16 input/output bytes (user data). If you configure HART variables, the modules use an additional 5 bytes of input data for each HART variable.

If you use all 8 HART variables, the HART modules use a total of 56 input bytes (16 bytes + 8 x 5 bytes = 56 bytes).

The "None" configuration occupies no additional input bytes.

No HART variables are placed in the user data area for configuration in run (CIR). However, an additional 5 bytes of address space are reserved for a subsequent re-configuration.

Configuration of HART variables

You assign the HART variables in STEP 7 HW Config.

You can configure up to 4 HART variables for each channel

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

If you want to assign the HART variable later in the user program, use the CiR parameter. CiR is a placeholder that reserves the address space for a HART variable. You must configure the HART variables you are not using with the "None" parameter.

Example of a configuration of HART variables

The figure below shows an example for the configuration of HART variables.

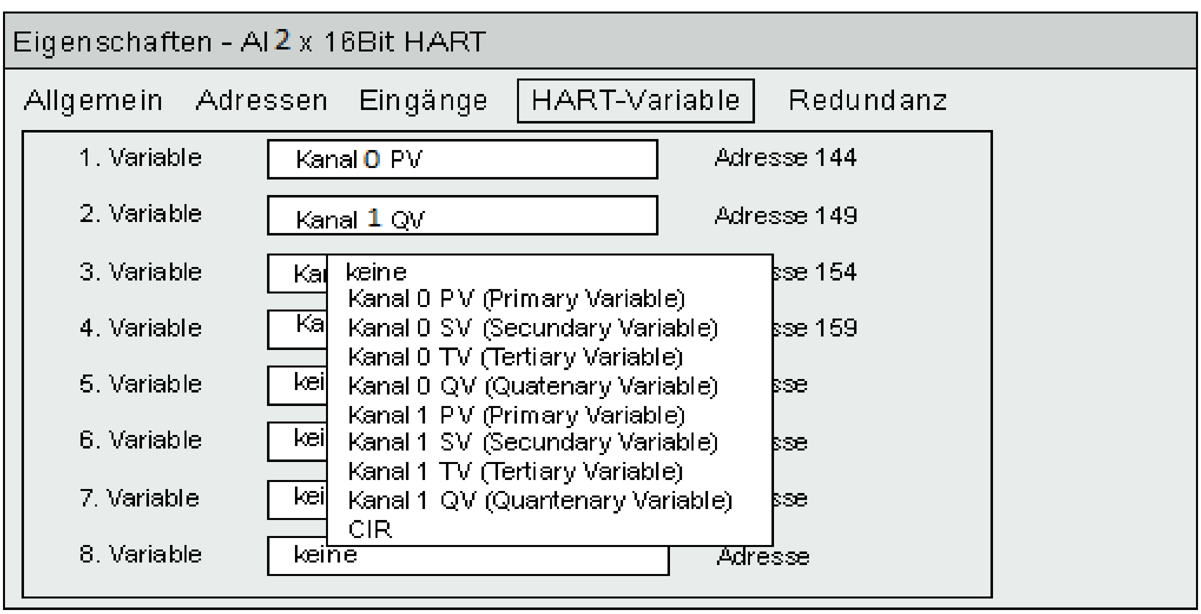
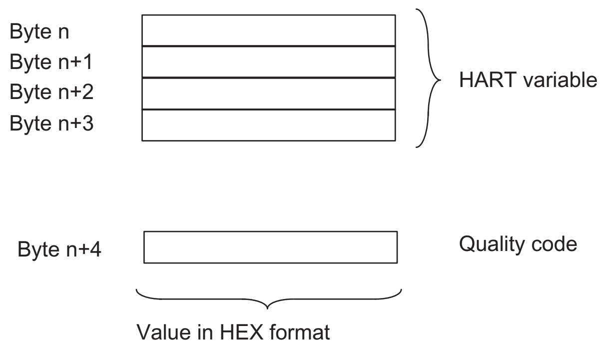


Image 4-19 Example of a configuration of HART variables

Structure of HART variables

Each HART variable uses 5 bytes of input data and is structured as follows:



Structure of the "Quality Code" byte

The Quality Code (QC) can assume the following values:

Quality Code (QC)	Meaning
0x4C or 0	Initialization: 0 value of IM and 4C of module
0x18	Communication cancelled / no communication
0x0C	Fault in HART device
0x47	HART device is busy
0x84	OK "Configuration changed"
0x80	OK

Reassign HART variables in RUN mode

You can reassign HART variables in RUN mode in S7-400 automation systems with CiR capability and also in S7-400H systems.

Requirement: HART variable must already be configured in HW Config as PV, SV, TV, QV, or CiR.

4.5.2 Parameters of HART Analog Modules

Overview

The following tables contain the parameters of the HART analog input module and the parameters of the HART analog output module. The tables show which parameters can be set for the module as a whole and which parameters can be set separately for each channel. You can find general information on parameter assignment in the description of the SIMATIC analog modules in the Manual *Automation System SIMATIC S7-300 Module Data*.

Parameters of the SM 331; AI 2 x 0/4...20mA HART

Table 4-16 Parameters of the analog input module SM 331; AI 2 x 0/4...20mA HART

Parameter	Value range	Default setting	Type of parameter	Effective range
Basic settings enables				
• Diagnostic interrupt	Yes/no	No	Dynamic	Module
• Hardware interrupt triggered by limit violation	Yes/no	No		
• End-of-cycle hardware interrupt	Yes/no	No		
Limit for hardware interrupt				
• High limit	At 0 to 20mA: 23.52 to -3.52mA At 4 to 20mA: 22.81 to 1.185mA	Overflow (32767)	Dynamic	Channel
• Low limit	At 0 to 20mA: -3.52 to 23.52mA At 4 to 20mA: 1.185 to 22.81mA	Underflow (-32768)		
Diagnostics				
• Group diagnostics	Yes/no	No	Static	Channel
• with wire break monitoring	Yes/no	No		
• HART group diagnostics	Yes/no	No		
Measurement				
• Measurement type	Deactivated 4DMU (4-wire transducer) 2DMU (2-wire transducer)	4DMU (4-wire transducer)	Dynamic	Channel
• Measuring range	Deactivated 0...20 mA (can only be set with 4DMU) 4 to 20mA	4 to 20 mA		
• Integration time / Interference frequency suppression	2.5 ms; 16.6 ms; 20 ms; 100 ms Corresponds to Interference frequency suppression From 400 Hz; 60 Hz; 50 Hz; 10 Hz	20 ms		
HART				
• HART function	Yes/no	Yes	Dynamic	Channel
• Retries	0-255	10		

Wire break check

The wire break check is only possible if group diagnostics is enabled and the measuring range is 4 to 20mA.

HART function

The HART functionality is only possible in the measuring range 4 to 20 mA. When the HART function is activated, the HART analog module transmits the HART command 0 to the field device, cyclically followed by HART command 3. Once a correct communication with the HART field device is established, the green HART status display lights up.

HART group diagnostics

HART group diagnostics refers to the HART communication and is possible for a selected HART function even when group diagnostics are not activated. If the HART function is not selected, no HART group diagnostics are possible.

Parameters of the SM 332; AO 2 x 0/4...20mA HART

Table 4-17 Parameters of the analog output module SM 332; AO 2 x 0/4...20mA HART

Parameter	Value range	Default setting	Type of parameter	Effective range
Basic settings enable				
• Diagnostic interrupt	Yes/no	No	Dynamic	Module
Diagnostics				
Group diagnostics	Yes/no	No	Static	Channel
HART group diagnostics	Yes/no	No		
Output				
Output mode	Deactivated Current	Current	Dynamic	Channel
Output range	4 to 20 mA 0 to 20 mA	4 to 20 mA		
Reaction to CPU STOP	Output with zero current and voltage (OCV) Keep last value (KLV) Set substitution value (SSV)	Set substitution value (SSV)		
Substitute value	0 to 20mA	0mA		
HART				
• HART function	Yes/no	Yes	Dynamic	Channel
• Retries	0-255	10		

HART function

HART is only possible in the output range 4 to 20mA. When the HART function is activated, the HART analog module transmits the HART command 0 to the field device, cyclically followed by HART command 3. Once a correct communication with the HART field device is established, the green HART status display lights up.

HART group diagnostics

HART group diagnostics refers to the HART communication and is possible for a selected HART function even when group diagnostics are not activated. If the HART function is not selected, no HART group diagnostics are possible.

4.5.3 Diagnostic Functions of HART Analog Modules

Overview of diagnostic functions

If errors occur during configuration or parameter assignment, or during the operating phase, you can use diagnostics to determine the cause of the error. The general diagnostic behavior of the HART analog module corresponds to that of the other SIMATIC S7-Ex analog modules.

Diagnostic messages to which parameters can and cannot be assigned

We distinguish between diagnostic messages to which parameters can be assigned and those to which they cannot be assigned.

You only obtain configurable diagnostic messages if you have enabled diagnostics at the relevant parameters. Assign the parameters in the "Diagnostics" configuration dialog in *STEP 7*.

The analog module always provides non-configurable diagnostic messages, regardless of the enable state of diagnostic functions.

Actions after a diagnostic message in STEP 7

Every diagnostic message initiates the following actions:

- The diagnostic message is entered into the diagnostics of the analog module.
- The group error LED (SF LED) on the analog module is lit.
- The channel error LED also lights for channel-specific errors.
- When "Enable Diagnostic Interrupt" is set in STEP 7, the system triggers a diagnostic interrupt and calls the OB 82 in the CPU.

Diagnostic message in the measured value of analog input modules

All analog input modules return the measured value 7FFFH as a reaction to errors, regardless of parameter settings. This measured value indicates either overflow, error, or a disabled channel.

Diagnostic message via LED

The analog modules indicate module-specific as well as channel-specific errors with their SF LED (group error LED). The SF LED lights up as soon as the analog module detects an error. It goes out once all errors are resolved.

In addition, channel-specific errors are displayed via the corresponding channel error LED.

"Analog" diagnostic messages

Table 4-18 "Analog" diagnostic messages

Diagnostic message	Effective range of diagnostics	Configurable
External auxiliary voltage missing	Module	No
Module not configured		
Incorrect parameters		
Time watchdog tripped		
EPROM error		
RAM error		
ADC/DAC error		
Hardware interrupt lost		
Parameter assignment error	Channel	No
Wire break	Channel	Yes
Underflow (only with analog input and if no wire break check is enabled)	Channel	Yes
Overflow (only with analog input)	Channel	Yes

Overflow

Acquired analog values above 23.52 mA (for measuring range 0 to 20 mA) or 22.81 mA (for the measuring range 4 to 20mA) are reported as "overflow" if group diagnostics are enabled. The analog value is set to 0x7FFF. It has no effect on the HART communication.

Underflow

A current less than 1.1845 mA is reported as "underflow" if group diagnostics are enabled and wire break diagnostics are disabled. The analog value is set to 0x8000. No HART communication is possible below 1.1845 mA.

Wire break

A current less than 3.6 mA is reported as "wire break" with analog input if group diagnostics and wire break diagnostics are enabled. Wire break is reported as cleared for a current higher than 3.8 mA. The analog value is set to 0x7FFF for "wire break". HART communication is active up to 1.1845 mA.

A wire break check is performed for analog output in the measuring range 4 to 20mA if group diagnostics are enabled . A wire break is reported for a current lower than approximately 500 μA. No HART communication is possible with "wire break".

Causes of error and remedies for "analog" diagnostic messages

Table 4-19 Diagnostic messages of analog input module, causes of error and remedies

Diagnostic message	Possible cause of error	Remedy
external auxiliary voltage missing	No load voltage L+ in the module	Provide L+ supply
Module not configured	Startup error	Program the module
Incorrect parameters	Implausible parameter or combination thereof	Program the module
Time watchdog tripped	partially high electromagnetic interference Module defective	Eliminate interference sources Replace the module
EPROM error		
RAM error		
ADC/DAC error	Module defective	Replace the module
Hardware interrupt lost	Hardware interrupts are triggered faster than the CPU can process them	Check the system, if necessary, use a more powerful CPU
Parameter assignment error	A parameter or combination of parameters of parameter data record 1 is implausible A parameter of the HART parameter data records (131/132) is incorrect	Check parameters and transfer them to the module again
Wire break	Resistance of transducer circuit too high	Use a different type of sensor or modify the wiring, for example, using a larger conductor cross-section
	Break in the line between the module and sensor	Connect line
	Channel not connected (open)	Disable channel ("Measuring type" parameter)
		Wire the channel
Underflow	Input value below underflow range, error possibly caused by: Wrong measuring range setting	Configure a different measuring range
	The sensor could be connected the wrong way in the measuring range 4 to 20 mA	Check connection terminals
Overflow	Input value exceeds overflow range	Configure a different measuring range

"HART" diagnostic messages

Table 4-20 Additional HART diagnostic messages of the analog input module

Diagnostic message	Effective range of diagnostics	Configurable
HART communication error	Channel	Yes
Main variable outside limits		
Secondary value outside of limits		
Analog output saturated		
Analog output fixed current intensity		
Further status information available		
Configuration changed		
Field device malfunction		

HART communication error

Communication error with HART field device of HART group diagnostics are enabled.
All remaining HART diagnostic messages are reported by the connected field device in the HART status bytes and displayed by the analog module as a diagnostic result.

HART status bytes

Each HART command is followed by a HART reply that contains data and two status bytes. The status bytes provide information regarding

- Device status of the connected field device (e.g. parameter modification)
- Communication error during transmission between the HART analog module and the connected field device
- Command error in the interpretation of the HART command through the connected field device (warning rather than error message).

The HART status bytes are accepted unchanged in the HART reply record. Their significance is described in the technical specifications for HART.

Causes of error and remedies with "HART" diagnostic messages

The following table contains the possible causes of the errors described in the additional diagnostic messages and the remedies.

Table 4-21 Additional HART diagnostic messages, possible causes of errors and remedies

Diagnostic message	Possible cause of error / diagnostics	Corrective measures
HART communication error	• HART field device not responding • Timing error	• Check the process wiring • Correct the parameter assignment. • Current less than 1.1845 mA • Increase number of assigned retries • Analog input: Connect a capacitor of approximately 150 nF in parallel to the transducer

Main variable outside limits	• Incorrect parameters in the HART device • HART device has simulation, and simulation is set to "Primary variable outside the limits" • Incorrect measuring point • Primary variable parameterized outside the limits	• Check the parameter assignment of the HART device • Correct simulation • Check whether the correct sensor is connected
Secondary value outside of limits	• Incorrect parameters in the HART device • HART device has simulation, and simulation is set to "Non-primary variable outside the limits" • Incorrect measuring point • Primary variable parameterized outside the limits	
Analog output saturated	• Incorrect parameters in the HART device • HART device has simulation, and the measured value set for the simulation is too high • Incorrect measuring point • Primary variable parameterized outside the limits	
Analog output fixed current intensity	• Incorrect parameters in the HART device • HART device has simulation, and the measured value set for the simulation is too high • Incorrect measuring point • Primary variable parameterized outside the limits	
Further status information available (deleted after 3 s)	• HART device supplies further status.	• Read out status and correct, if necessary
Configuration changed	The identifier for the parameter modification of the HART field device was set in the HART device status (= HART status bytes).	If you do not want diagnostic interrupts to be triggered when parameters are modified, you should disable the diagnostic interrupt.
Field device malfunction	Communication and command error during HART operation affecting the connected HART field devices.	For detailed information analyze the reply record of the corresponding client or the diagnostic data record.

See also

Diagnostics of the Analog Modules (Page 124)

HART Communication Data Records (Page 194)

Additional diagnostic data records (Page 198)

Diagnostic data records (Page 192)

4.5.4 Interrupts of the HART Analog Modules

Overview of the interrupts

The interrupt response of the HART analog module is similar to that of SIMATIC S7 Ex analog modules. You can set parameters to enable or disable any interrupt.

Hardware interrupts with AI-HART

In this context we distinguish between the "out-of-limits hardware interrupt" and the "end-of-cycle hardware interrupt". You can evaluate the local data in OB40 when a hardware interrupt is active.

Table 4-22 Local data in OB40

Local data OB40	Bit 7 ...2	Bit 1	Bit 0	Limit
Byte 0	'0'	Channel 1	Channel 0	High limit exceeded
Byte 1	'0'	Channel 1	Channel 0	Low limit exceeded
Byte 2	'0'	'0'	'0'	Not relevant
Byte 3	'0'	'0'	'0'	Not relevant

At the end of the cycle all the bits in bytes 0-3 of the additional information for OB 40 which are not reserved for channels 0 and 1 are set to "1". You can use the reserved bits to evaluate whether the upper or lower limit set has been exceeded for a particular channel: if a limit has been exceeded, a "1" is displayed instead of a "0".

See also

Interrupts of analog modules (Page 128)

Parameters of HART Analog Modules (Page 171)

4.5.5 HART Analog Input Module SM 331; AI 2 x 0/4...20mA HART (6ES7331-7TB10-0AB0)

Order number

6ES7331-7TB10-0AB0

Features

The analog input module SM 331; AI 2 x 0/4...20mA HART is characterized by the following features:

- 2 inputs in 2 channel groups
- 2 encoder supply outputs for 2-wire transducers
- The resolution of the measured value can be set separately at each channel (see "Analog values and resolution")
- Mode of measurement, selectable for each channel group:
  - 2-wire transducer current
  - 4-wire transducer current
  - Channel deactivated
- User-specific measuring range per channel
  - 0 ... 20 mA (only for 4-wire transducer)
  - 4 ... 20 mA
- HART functionality (only for 4 to 20 mA)
  - Support for HART 5 to HART 7
  - Configuring HART variables
- Settings for diagnostics and diagnostic interrupt
  - Group diagnostics
  - Additional wire break monitoring
  - Diagnostic interrupt
- Programmable hardware interrupt
  - Channels 0 and 1 with limit monitoring: Programmable generation of out-of-limits hardware interrupts
  - Programmable end-of-cycle hardware interrupt
- Electrical isolation
  - Channels electrically isolated
  - Channels electrically isolated from the CPU and from load voltage L+
- Configuration in Run (CiR) supported

Analog values and resolution

The representation of the analog values is the same as for the analog input module SM 331; AI 4 x 0/4...20mA. The resolution of the input value for the HART analog input module is 15 bits + sign.

Table 4-23 Measuring types of the analog input module SM 331; AI 2 x 0/4...20mA HART

Selected measuring type	Measuring range
2-wire transducer	4 to 20 mA
4-wire transducer	0 to 20 mA 4 to 20 mA

Integration times when HART is used

When implementing transducers with HART protocol, you should preferably program integration times of 100 ms to keep the influence of AC modulation on the measuring signal to a minimum.

Default settings

HART measurement is set by default. There are other default settings for integration time, diagnostics, interrupts. The HART analog module uses these settings when no parameter modification is carried out in STEP 7.

Wire break check

Wire break recognition is not possible for the current range 0 to 20 mA.

For the current range from 4 to 20 mA, undershooting the input current of I ≤ 3.6 mA is interpreted as a wire break. When diagnostic interrupts are enabled, the module also triggers a diagnostic interrupt.

Wiring diagram of SM 331; AI 2 x 0/4...20mA

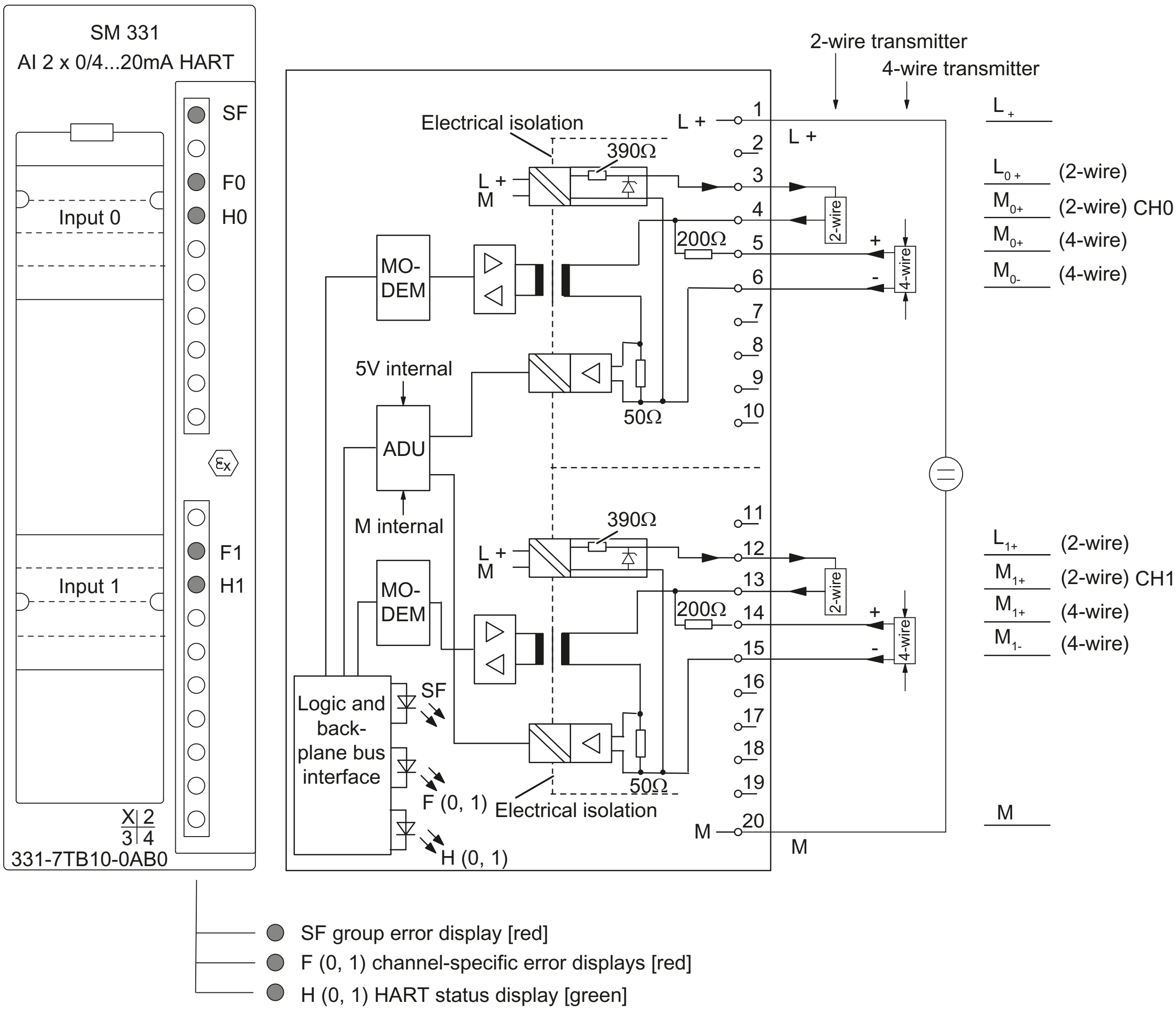


Image 4-20 Module view and block diagram of SM 331; AI 2 x 0/4...20mA HART

Note

The 200 ohm resistor must be in the measuring circuit when using HART transducers. This means that a 2-wire HART transducer must be connected to terminals 3 and 5 (12 and 14) and a 4-wire HART transducer to terminals 5 and 6 (14 and 15).

The 200 ohm resistor is optional in the measuring circuit for standard transducers without HART.

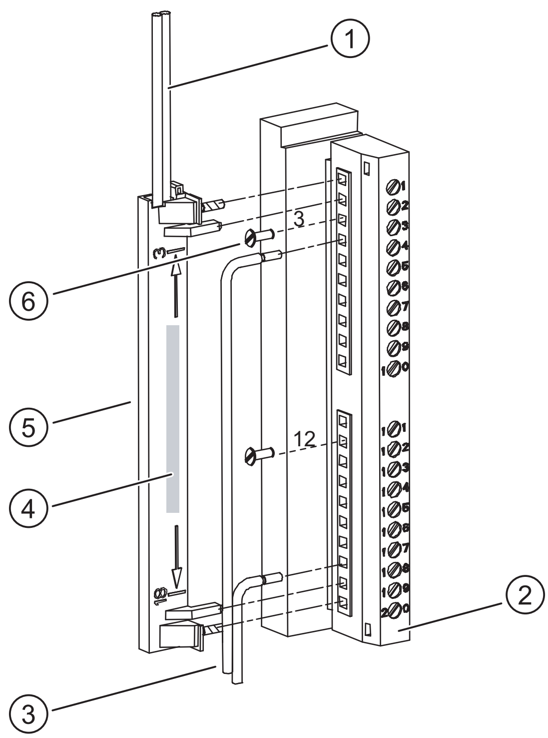
Note

Observe the prerequisites for an intrinsically safe installation.

Special feature for the connection of active encoders

Lock the unused transducer outputs at terminals 3 and 12 with plastic bolts if you connect active encoders to the SM 331-7TB00 module (6ES7 331-7TB00-0AB0). You can use M3 x 8 plastic screws, for example (see the diagram below).

Note that these measures reduce safety-relevant data of the module. For information on safety data, refer to the first amendment of the certificate.



① Load voltage supply
② Process connector with screw-type connection
③ Ex (i) process cable
④ Intrinsically safe area
⑤ Line chamber
⑥ Plastic screw M 3 x 8

Power supply for an intrinsically-safe structure

In order to maintain the clearances and creepage distances, L+/M must be routed via the line chamber LK393 when operating modules with signal cables that lead to the hazardous location.

Technical specifications of SM 331; AI 2 x 0/4...20mA HART (6ES7331-7TB10-0AB0)

Dimensions and weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	approx. 260 g
Module-specific data	

Configuration in Run (CiR) supported	Yes
• Behavior of non-configured inputs during CiR	They return the process value that applied before the parameters were set.
Number of inputs Number of power outputs	2 2
Line length, shielded	Max. 400 m
ATEX approvals	II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 97ATEX3039 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply Rated load voltage L+ • Reverse voltage protection	5 VDC 24 VDC Yes
2-wire transducer power supply • short circuit-proof	 Yes (approx. 30 mA)
Electrical isolation	
• Between the channels and backplane bus	Yes
• Between the channels	Yes
• Between the channels and load voltage L+	Yes
• Between the backplane bus and load voltage L+	Yes
Permitted potential difference (V_{ISO}) of signals of the Ex area	
• Between the channels and backplane bus	60 VDC 30 VAC
• Between the channels and load voltage L+	60 VDC 30 VAC
• Between the channels	60 VDC 30 VAC
• Between the backplane bus and load voltage L+	60 VDC 30 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area	
• Between the channels and backplane bus	300 VDC 250 VAC
• Between the channels and load voltage L+	300 VDC 250 VAC
• Between channels	300 VDC 250 VAC
• Between the backplane bus and load voltage L+	75 VDC 60 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area for shared operation with F-modules	

• Between the channels and backplane bus	150 VDC 150 VAC
• Between the channels and load voltage L+	150 VDC 150 VAC
• Between the channels	150 VDC 150 VAC
• Between the backplane bus and load voltage L +	75 VDC 60 VAC
Insulation tested	
• Channels to backplane bus and load voltage L +	With 2500 VDC
• Channels to each other	With 2500 VDC
• Backplane bus to load voltage L+	With 500 VDC
Current input	
• From backplane bus	Max. 100 mA
• From load voltage L +	Max. 180 mA
Module power loss	typical 4.5 W
Safety specifications (see EU special test certificate 97ATEX3039 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))	
Maximum values per channel	
• U_0 (no-load output voltage)	Max. 26 V
• I_0 (short-circuit current)	Max. 96.1 mA
• P_0 (power under load)	Max. 511 mW
• L_0 (permissible external inductance)	Max. 3 mH
• C_0 (permissible external capacity)	Max. 62 nF
• U_m (fault voltage)	Max. DC 250V
• T_a (permissible ambient temperature)	0 to 60°C

Analog value formation				
Principle of measurement	SIGMA-DELTA			
Integration time/conversion time/ resolution (per channel)				
• Configurable	Yes	Yes	Yes	Yes
• Integration time in ms	2.5	16 2/3	20	100
• Basic conversion time plus integration time in ms (one channel enabled)	2.5	16 2/3	20	100
• Basic conversion time including integration time in ms (2 channels enabled)	7.5	50	60	300
• Resolution in bits +sign (including the overshoot range)	10 +sign	13+ sign	13+ sign	15+sign
• Interference voltage suppression for interference frequency f1 in Hz	400	60	50	10

Interference suppression, error limits		
Interference voltage suppression for f = n x (f1 ± 1 %), (f1 = interference frequency)		
• Common mode interference between channels and reference ground M of the CPU (V_{ISO} < 60 V)	> 130 dB	
• Series mode interference (measured value + interference signal must lie within the 0 mA to 22 mA input range)	> 60 dB	
Crosstalk attenuation between inputs (V_{ISO} < 60 V)	> 130 dB	
Operational limit (in total temperature range, based on input range)		
• from 0/4...20mA	± 0.45%	
Basic error limit (operational limit at 25 °C, based on input range)		
• from 0/4...20mA	± 0.1%	
Temperature error (based on input range)	± 0.01%/K	
Linearity error (based on input range)	± 0.01%	
Repeatability (in steady-state condition at 25°C, based on input range)	± 0.05%	
Influence of a HART signal modulated on an input signal relative to the input range		
Error at integration time		
• 2.5 ms	± 0.25%	
• 16 2/3 ms	± 0.05%	
• 20 ms	± 0.04%	
• 100 ms	± 0.02%	
Interrupts, diagnostics		
Interrupts		
• Limit interrupt	configurable channels 0 and 1	
• Diagnostic interrupt	Configurable	
Diagnostic functions	Configurable	
• Group error display	Red LED (SF)	
• Channel error display	Red LED (F) per channel	
• Diagnostic information readable	Possible	
• HART communication active and OK	Green LED (H)	
Technical date of the transducer power supply		
• No-load voltage	< 29.6 V	
• Output voltage for transducers and cables at 22 mA transducer current (50 W measurement resistance on module included)	> 15 V	
Data for sensor selection		
Input ranges (rated values / input resistance)		
• Current	0 to 20 mA; 4 to 20 mA:	/50 Ω /50 Ω
Permissible input current for current input (destruction limit)	40 mA	

Connection of signal transducers	
• for current measurement	
as 2-wire transducer	Possible
as 4-wire transducer	Possible

See also

Analog value notation of the measurement ranges of resistive encoders (Page 90)

The LK 393 line chamber (Page 14)

HB_Umparametrieren im RUN (http://support.automation.siemens.com/WW/view/en/14044916)

4.5.6 HART Analog Output Module SM 332; AO 2 x 0/4...20mA HART (6ES7332-5TB10-0AB0)

Order number

6ES7332-5TB10-0AB0

Features

The HART analog output module has the following features:

- 2 current outputs in 2 channel groups
- Resolution 12 bit (+ sign)
- Output type selectable per channel:
  - Current output
  - Channel deactivated
- Selection of any output range per channel
  - 0 to 20 mA
  - 4 to 20 mA
- HART functionality
  - Support for HART 5 to HART 7
  - Configuring HART variables
- Settings for diagnostics and diagnostic interrupt
  - Group diagnostics
  - Diagnostic interrupt

- Electrical isolation
  - Channels electrically isolated
  - Channels electrically isolated from the CPU and from load voltage L+
- Read-back capability of the analog outputs
- Configuration in Run (CiR) supported

Analog values and resolution

The representation of the analog values is the same as for the analog output module SM 332; AO 4 x 0/4...20mA. The resolution of the output value for the HART analog output module is, however, 12 bit.

Table 4-24 Output ranges of analog output module SM 332; AO 4 x 0/4...20mA

Selected output mode	Output range
Current	0 to 20 mA 4 to 20 mA

Default settings

The output type HART is the default setting. There are also default settings for substitute value, diagnostics, interrupts. The HART analog output module uses these settings when no parameters have been changed in STEP 7.

Wire break check

Wire break check is possible for the output range 4 to 20 mA.

Effect of a falling load voltage on the diagnostic message

When the 24 V load voltage falls under the permissible rated range (< 20.4 V), if loads > 650 Ω are connected and there are output currents > 20 mA, the output current may be reduced before a diagnostic message is issued.

Readback capability

The analog outputs can be read back in the user data range (+ sign) with a resolution of 8 bit. Note that the value read back from the analog output is only available at the corresponding accuracy when the conversion cycle is completed.

Wiring diagram of SM 332; AO 2 x 0/4...20mA HART

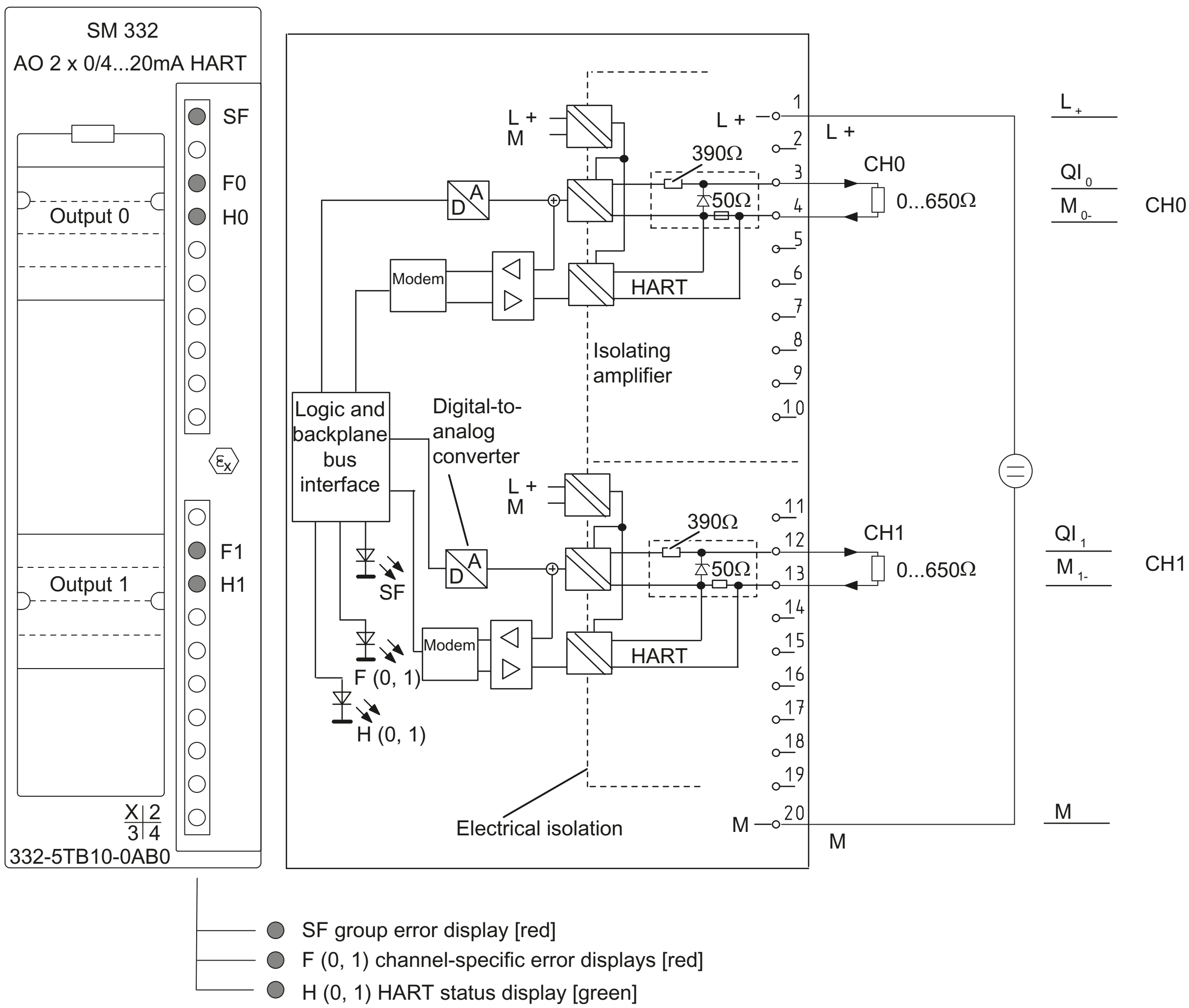


Image 4-21 Module view and block diagram of the SM 332; AO 2 x 0/4...20mA HART

Note

Observe the prerequisites for an intrinsically safe installation.

Power supply for an intrinsically-safe structure

In order to maintain the clearances and creepage distances, L+/M must be routed via the line chamber LK393 when operating modules with signal cables that lead to the hazardous location.

Non-wired output channels

To ensure that non-wired output channels of the analog output module SM 332; AO 2 x 0/4...20mA HART are deenergized, you have to deactivate them. You deactivate an output channel using STEP 7 by means of the "Output" parameter block.

Technical specifications of SM 332; AO 2 x 0/4...20mA HART (6ES7332-5TB10-0AB0)

Dimensions and weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	Approx. 280 g
Module-specific data	
Configuration in Run (CiR) supported	Yes
Behavior of non-configured outputs during CiR	They output the output value that applied before the parameters were set.
Number of outputs	2
Line length, shielded	Max. 400 m
ATEX approvals	II 3 G (2) GD Ex nA [ib Gb] [ib Db] IIC T4 Gc
Test number	KEMA 97ATEX2359 X
FM/UL approvals	Class I, Division 2, Group A, B, C, D T4 Class I, Zone 2, Group IIC T4
Voltages, currents, potentials	
Bus power supply Rated load voltage • Reverse voltage protection	5 VDC 24 VDC Yes
Electrical isolation	
• Between the channels and backplane bus	Yes
• Between the channels	Yes
• Between the channels and load voltage L+	Yes
• Between the backplane bus and load voltage L+	Yes
Permitted potential difference (V_{ISO}) of signals of the Ex area	
• Between the channels and backplane bus	60 VDC 30 VAC
• Between the channels and load voltage L+	60 VDC 30 VAC
• Between the channels	60 VDC 30 VAC
• Between the backplane bus and load voltage L+	60 VDC 30 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area	

• Between channels and backplane bus	300 VDC 250 VAC
• Between channels and load voltage L+	300 VDC 250 VAC
• Between channels	300 VDC 250 VAC
• Between the backplane bus and load voltage L+	75 VDC 60 VAC
Permitted potential difference (V_{ISO}) of signals of the non-Ex area for shared operation with F-modules	
• Between the channels and backplane bus	150 VDC 150 VAC
• Between the channels and load voltage L+	150 VDC 150 VAC
• Between the channels	150 VDC 150 VAC
• Between the backplane bus and load voltage L+	75 VDC 60 VAC
Insulation tested	
• Channels to backplane bus and load voltage L +	With 2500 VDC
• Channels to each other	With 2500 VDC
• Backplane bus to load voltage L+	With 500 VDC
• Channels with respect to shield	With 500 VDC
Current input	
From backplane bus	Max. 100 mA
From load voltage L+ (at rated data)	Max. 150 mA
Module power loss	Typical 3.5 W
Analog value formation	
Output value	
Resolution (including overrange)	12 bit (+ sign)
Cycle time (all channels)	5 ms
Transient recovery time	
• for resistive load	2.5 ms
• For inductive load	2.5 ms
• For capacitive load	4 ms
Set substitute values	Yes, configurable
Readback value	
Resolution	8 bit (+ sign)
Conversion time (per channel)	40 ms
Interference suppression, error limits	
Crosstalk attenuation between the outputs	>130 dB
Operational limit (across temperature range, relative to output range)	± 0.55%
Intrinsic error limit (operating error limit at 25°C relative to the output range)	± 0.15%

Temperature error (relative to the output range)	± 0.01%/K
Linearity error (based on output range)	± 0.03%
Repeatability (in steady-state condition at 25°C, based on output range)	± 0.005%
Output ripple; range 0 to 50 kHz (based on output range)	± 0.02%
Interrupts, diagnostics	
Interrupts	
• Diagnostic interrupt	Configurable
Diagnostic functions	Configurable
• Group error display	Red LED (SF)
• Channel error display	Red LED (F) per channel
• Diagnostic information readable	Possible
Monitoring for	
• Wire break From output value	Yes > 0.5 mA
HART communication active and OK	Green LED (H)
Safety specifications (see EU special test certificate KEMA 97ATEX2359 X under certificates of conformity on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200))	
Maximum values of the output circuits (per channel)	
• U_0 (no-load output voltage)	Max. 19 V
• I_0 (short-circuit current)	Max. 66 mA
• P_0 (power under load)	Max. 506 mW
• L_0 (permissible external inductance)	Max. 7.5 mH
• C_0 (permissible external capacity)	Max. 230 nF
• U_m (fault voltage)	Max. 60 VDC
• T_a (permissible ambient temperature)	Max. 60°C
Data for actuator selection	
Output ranges (rated values)	
• Current	0 to 20 mA 4 to 20 mA
Load impedance (in rated range of output)	
• for current outputs – Resistive load – Inductive load	 Max. 650 Ω Max. 7.5 mH[1]
• Capacitive load	Max. 230 nF[1]
Current output	
• No-load voltage	Max. 19 V
Destruction limit for externally applied voltages / currents	
Voltages	Max. + 17 V / - 0.5 V
Current	Max. + 60 mA / - 1A

Wiring of actuators	
• For current output 2-wire connection	Yes
[1] KEMA approval limitations can be set as the load when used in non-ex areas • Inductive load max. 15 mH • Capacitive load max. 3 μF *) *) HART communication no longer possible, however	

See also

The LK 393 line chamber (Page 14)

Analog Value Representation for the Output Ranges of Analog Outputs (Page 102)

Parameters of HART Analog Modules (Page 171)

HB_Umparametrieren im RUN (http://support.automation.siemens.com/WW/view/en/14044916)

4.5.7 Data record interface

Introduction

This section contains specific data you need for programming, diagnostics and HART communication if you want to extend the functionality of STEP7 standard applications or deploy your own software tool for HART communication.

Configuration and parameter assignment with STEP 7

You can configure and parameterize the HART analog modules with STEP 7. The integrated help system supports you in this.

You can integrate certain additional functions for writing parameters and reading diagnostic data in your user program by means of SFCs.

Reading and writing records

To read and write records, use the following SFCs / SFBs:

- Read record:
  - SFC 59 "RD_REC
  - SFB 52 "RDREC" (mandatory for Profinet !)
- Write record:
  - SFB 53 "WRREC" (mandatory for Profinet !)
  - SFC 55 "WR_PARAM"
  - SFC 58 "WR_REC"

4.5.7.1 Parameter Data Records

Structure of the parameter records 0/1 for the HART analog input

The figures below show data record 0 for the static parameters and data record 1 for the dynamic parameters for AI-HART and AO-HART.

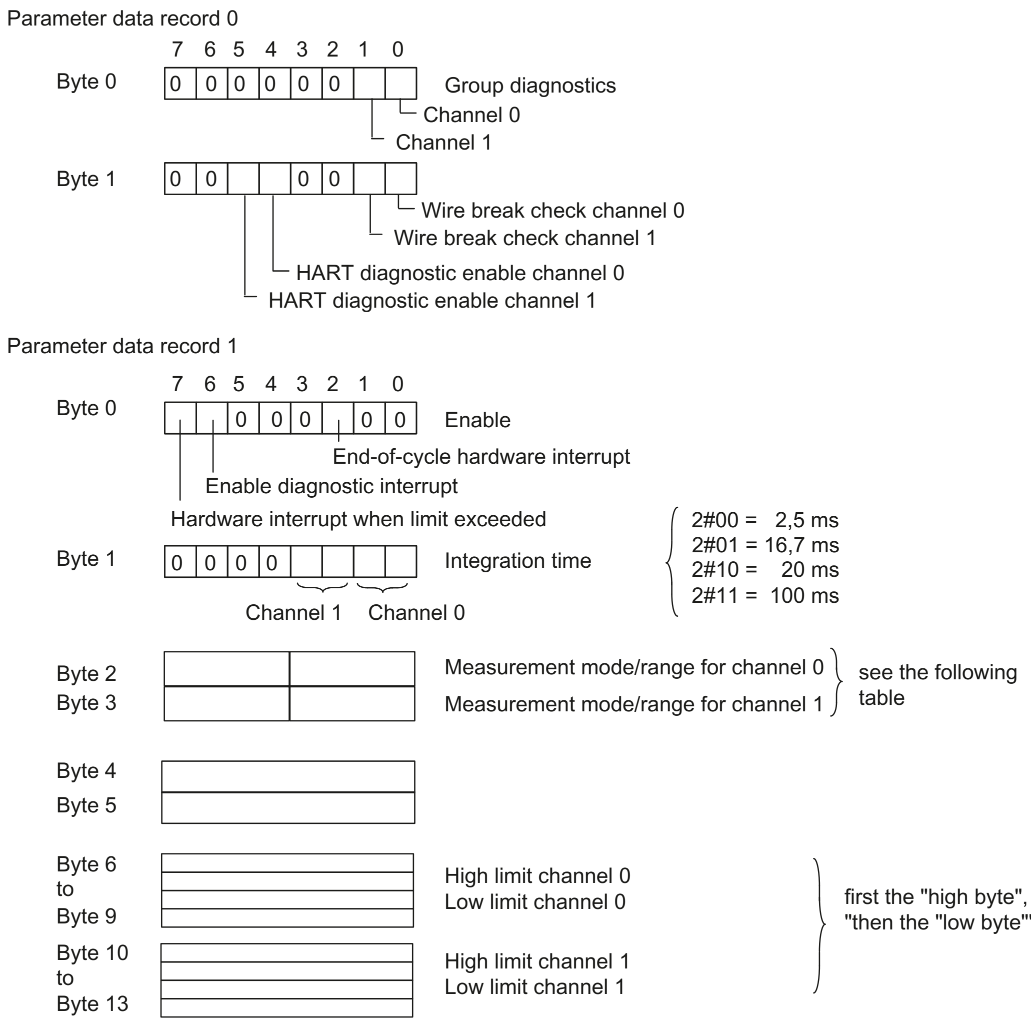


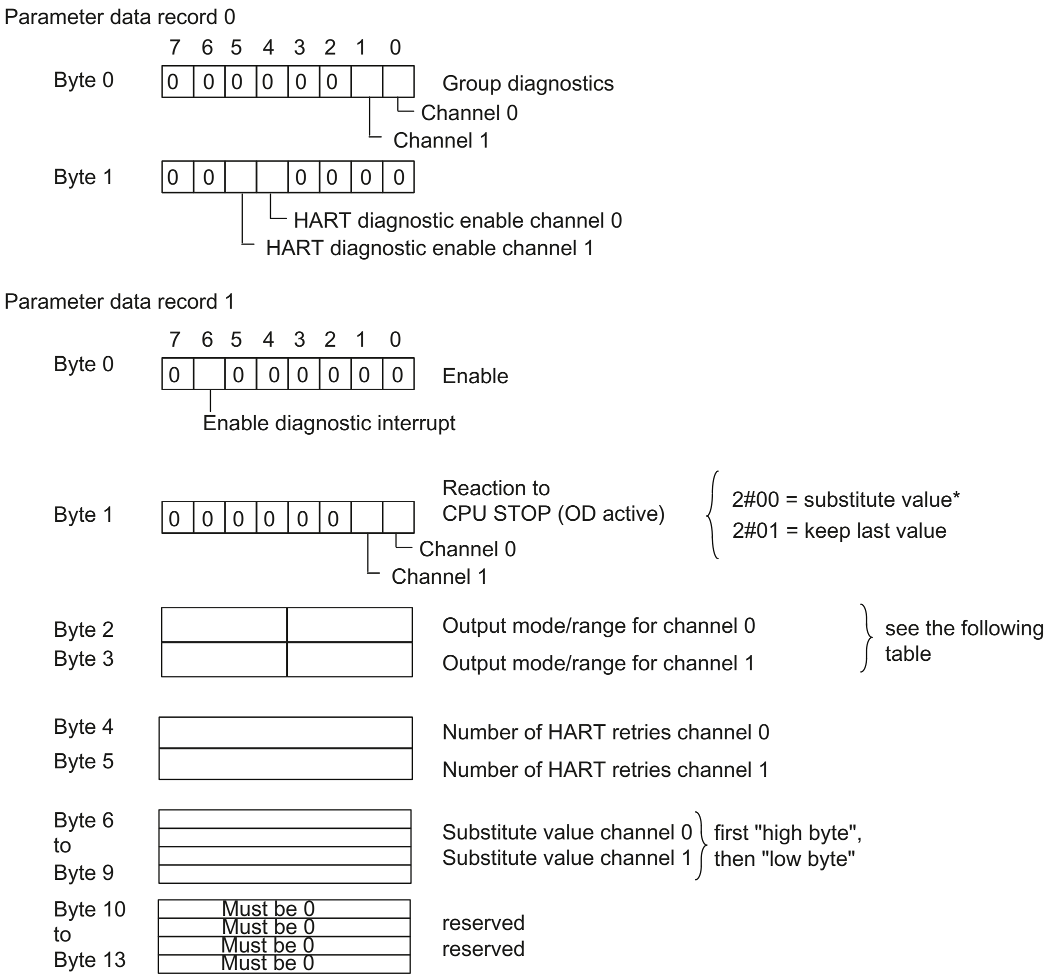
Image 4-22 Parameters of the HART analog input module

Table 4-25 Codes for the measuring type and measuring range of the HART analog input module

Measurement type	Code	Measuring range	Code
Deactivated	2#0000	Deactivated	2#0000
4-wire transducer	2#0010	0 to 20 mA 4 to 20 mA 4 to 20 mA with HART	2#0010 2#0011 2#0111
2-wire transducer	2#0011	4 to 20 mA 4 to 20 mA with HART	2#0011 2#0111

Structure of the parameter data records for the HART analog output

The figure below shows data record 0 for the static parameters and data record 1 for the dynamic parameters.



* The outputs are deenergized with a substitute value of 6912 (E500Hex).

Image 4-23 Parameters of the HART analog output module

Table 4-26 Code for the measurement type / range of the HART analog output module

Output mode	Code	Output range	Code
Deactivated	2#0000	Deactivated	2#0000
Current output	2#0010	0 to 20 mA 4 to 20 mA 4 to 20 mA with HART	2#0010 2#0011 2#0111

Structure of the HART parameter data records 131/132

There is a specific HART parameter data record for each channel:

- Data record 131: HART parameter data for channel 0
- Data record 132: HART parameter data for channel 1

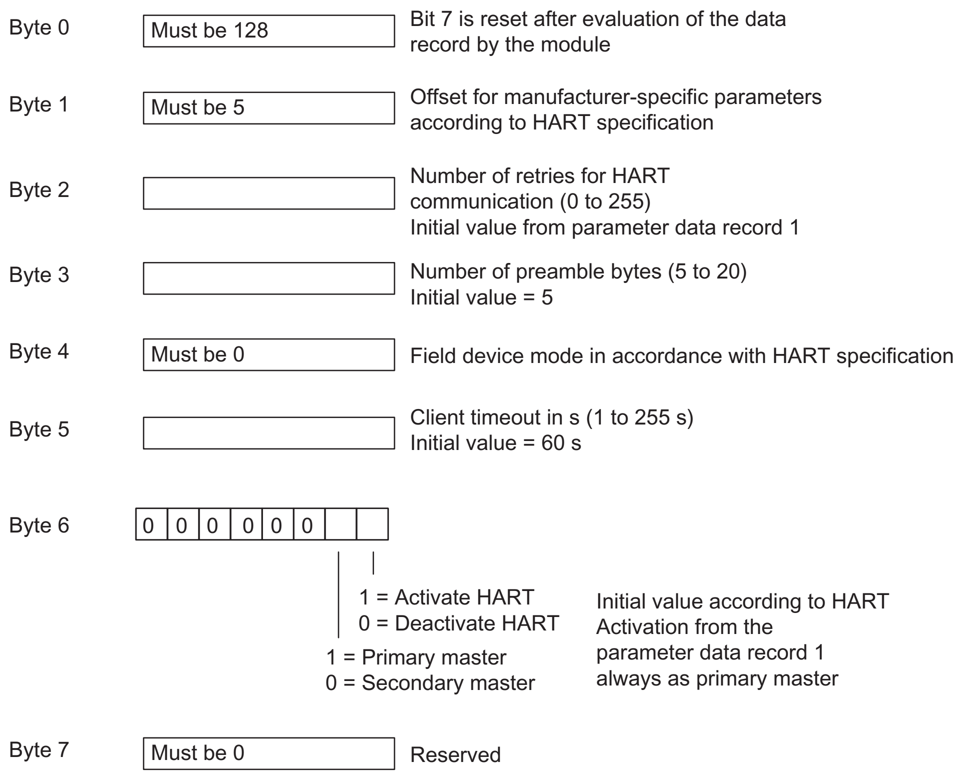


Image 4-24 Data record

These records are not absolutely necessary for the HART operation.

If these records are not transferred to the module after module startup, the HART interface works with the specified initial values. The number of HART retries and the HART enable are used in accordance with the parameter data record 1.

However, both HART parameter data records can write to the module at any time during operation for each data record (for example, using SFC 58 "WR_REC"). The parameters are applied accordingly by the respective HART channel and overwrite the values currently in effect.

This way you can also adjust the "Number of preamble bytes", the "Client timeout" as well as the HART mode to suit your needs.

The transferred HART parameters are not used if an error occurs in DR131 / DR132. The previous values remain in effect. The error is reported as channel-specific parameter assignment error in diagnostic data record 1.

Each new parameter assignment with parameter data record 1 sets the HART parameters back to the "initial values".

4.5.7.2 Diagnostic data records

Structure and contents of the diagnostic data

The diagnostic data of a module consists of the data records 0 and 1:

- Data record 0 has a length of 4 bytes and contains system-specific diagnostic data: 4 bytes that are defined system-wide and are valid for HART analog input and output.
- Data record 1 has a length of 16 bytes and contains
  - 4 bytes of diagnostic data for an S7-300, which are also in data record 0 **and** another
  - 8 bytes of module-specific diagnostic data

Diagnostic data record DS0 / DS1

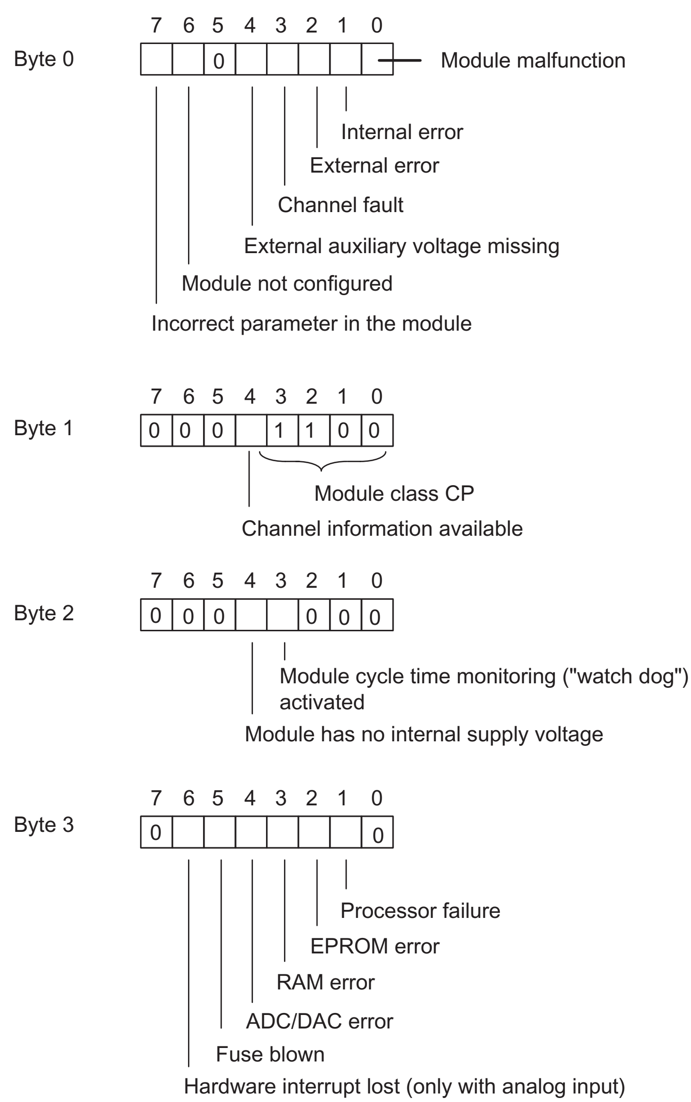


Image 4-25 Diagnostic data: data record 0

Diagnostic data: data record DS1

The following diagram shows the contents of bytes 4 to 11 of the diagnostic data. Bytes 12 to 15 are always zero.

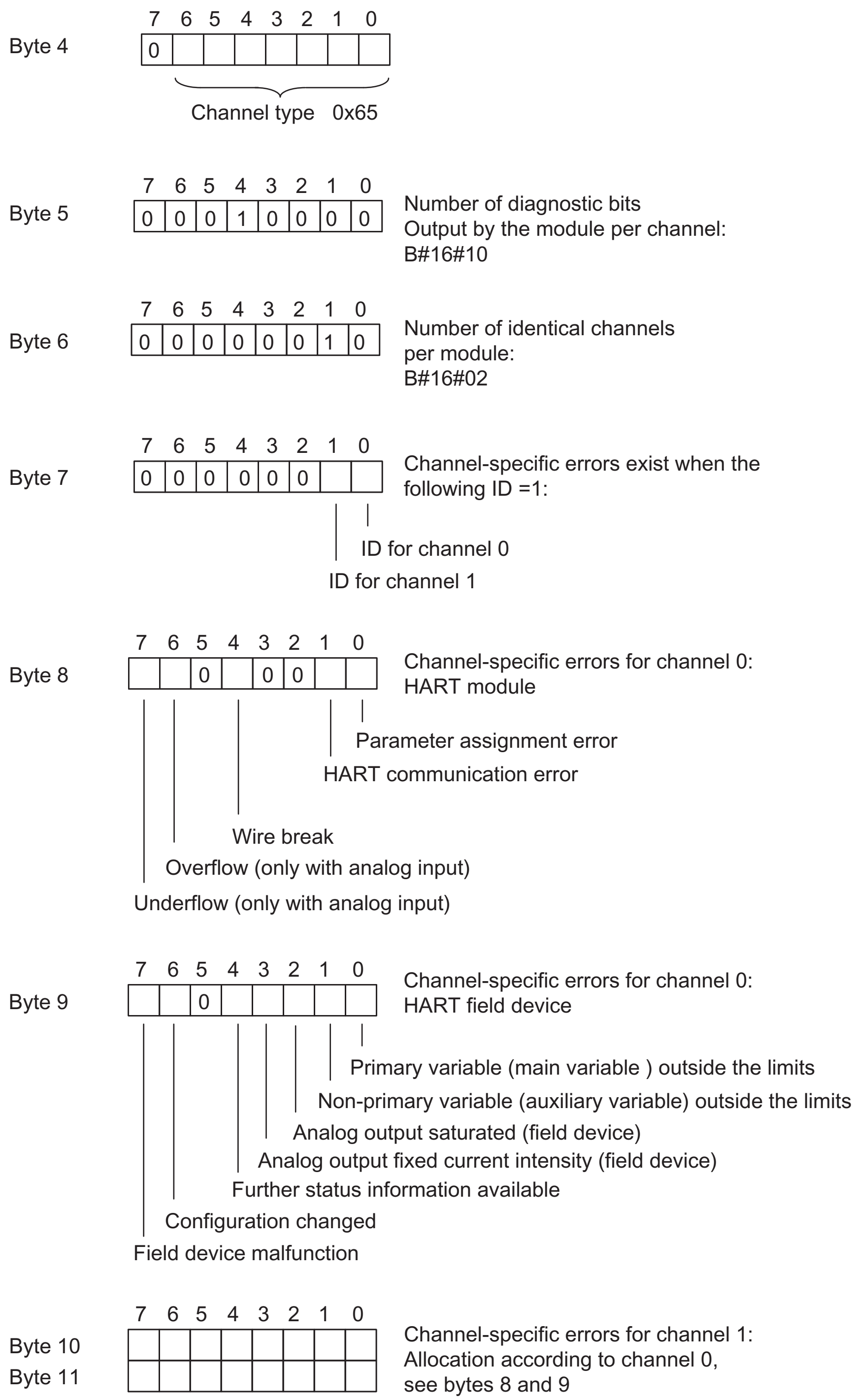


Image 4-26 Diagnostic data: data record 1

Note

Please note the following points regarding diagnostic data:

If a HART channel error occurs, you can obtain further information by using SFC59 / SFB 52 to read the status in the HART response data record for the relevant client or the additional diagnostic data record for the relevant channel.

See also

HART communication and information data records (Page 236)

4.5.7.3 HART communication and information data records

Overview

The mapping of HART commands and HART responses to S7 data records is based on the *PROFIBUS Profile HART Version 1.0*. You can find more information on the HART protocol in the *PROFIBUS DP HART Profile Application Guidelines*.

You can obtain this documentation from the PNO (PROFIBUS Users Organization) on the Internet at http://www.profibus.com.

Table 4-27 Overview

<table>
<tr><th>Data record number</th><th>Read/write</th><th>Size in bytes</th><th>Name</th></tr>
<tr><td>148</td><td>Read</td><td>13</td><td>Directory Process Data</td></tr>
<tr><td></td><td colspan="3">DR information (directory record): This data record contains the record numbers (index) of all HART data records and information on numbers and revisions.</td></tr>
<tr><td>149</td><td>Read</td><td>3</td><td>HMD Feature Parameter Process Data</td></tr>
<tr><td></td><td colspan="3">Optional HART functions (HART feature flags): This data record describes which optional HART functions are supported and specifies the maximum data field length of the request/response records.</td></tr>
<tr><td>80, 82</td><td>Write</td><td>240</td><td>HART Request Write Process Data</td></tr>
<tr><td></td><td colspan="3">HART request records to field devices: These records contain by channel (0 - 1) the transfer data for the command from the client to the HART field device.</td></tr>
<tr><td>81, 83</td><td>Read</td><td>240</td><td>HART Response Read Process Data</td></tr>
<tr><td></td><td colspan="3">HART response records from field devices: These records contain by channel (0 - 1) the transfer data for the reply from the HART field device to the client.</td></tr>
</table>

Coordination rules for HART communication

HART communication can be operated only by one client per channel. Each channel has a separate transfer area available. Each transfer area consists of the command and reply data records.

If a channel is operated by several clients, the reply made available by the module cannot be securely allocated to one client. The module does not support client management, refer to data record number 149 (HMD Feature Parameter Process Data).

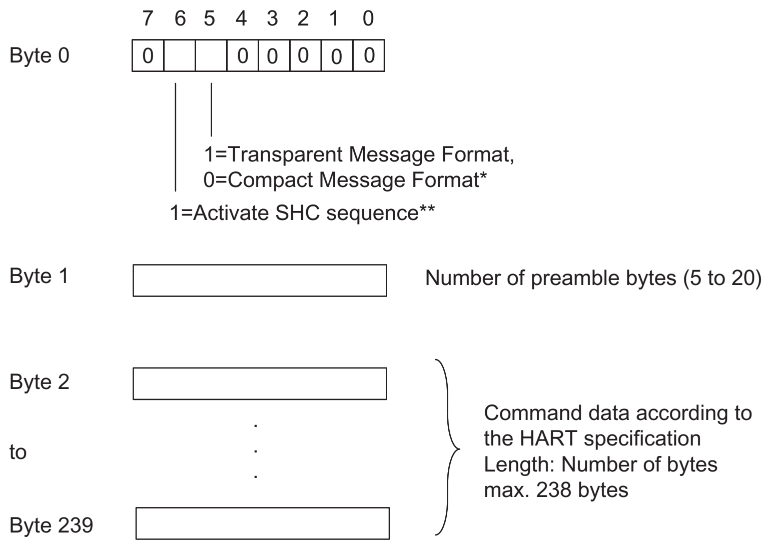
- Each client / channel is allocated fixed data record numbers:

Channel	Client	Data record
0	Command	80
0	Response	81
1	Command	82
1	Response	83

- After having written a command data record, the client must read the response data record before it writes the next command data record.
- The client can evaluate the "processing status" in the reply data record: if the "processing state" indicates "successful" or "error," the data record contains current response data or error bits respectively.
- All data must be read, because the module can modify the data record if the initial read operation returns a successful or faulty state.
- The status component in the reply record (= HART status bytes) provides information on whether and which errors have occurred.

Structure of the command data record

The following diagram shows the structure of the data record, which you can use to write a command in the transfer area of a client. The HART analog module transmits the command to the connected HART field device.



* HART commands are processed both in Transparent Message Format and in the Compact Message Format, see technical specification for HART. The response data from the module, however, is always provided in the transparent format.

** Processing a sequence of HART commands as a SHC sequence (Successive HART Command Mode)

Image 4-27 Command data record of the HART analog module

SHC sequence

If a HART command is sent to the module with a set SHC bit, then this channel is reserved for HART commands for 2 seconds. This means that no internal HART command (command 3) is sent to the transducer with this channel.

Each time a HART command with a set SHC bit is sent, the module once again reserves this channel for another 2 seconds for the HART commands. If a HART command without a set SHC bit is detected for this channel, or if no further command for this channel occurs within 2 seconds after the previous HART command, then command 3 is cyclically sent to the transducer for reading the HART variables for the channel.

Notes on the command

The same client must not send a second command until the **response** to any previous command has been read.

Notes on response

Always make sure that you are reading the current response data record.

- If the processing state in the response data record indicates "successful" or "error," the data record contains current response data or error messages respectively.

Structure of the response data record

The following figure shows the structure of the response data record, which contains the response to the HART command you sent previously and any error or status bits.

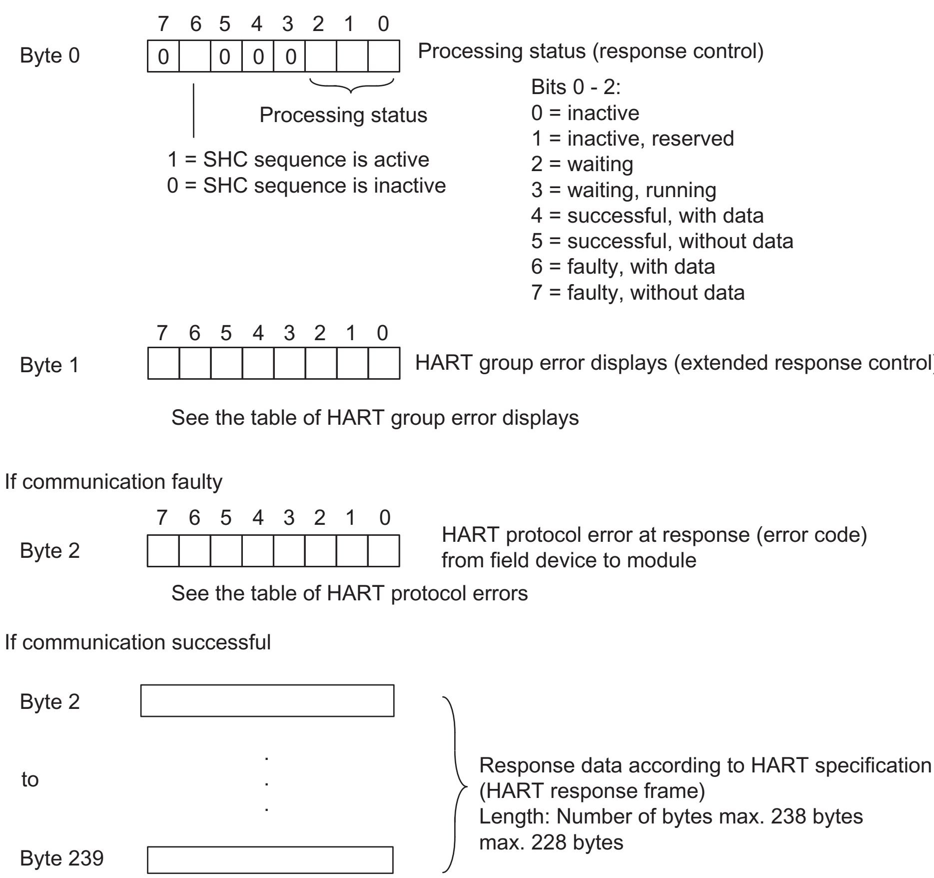


Image 4-28 Response data record of the HART analog modules

Evaluating the response data

When you have an up-to-date response data record, you can check the following:

- Look for the "last command" entry to verify that the response belongs to the command sent.
- You can evaluate the "Group error bits" (see following table) to locate individual errors.
- You can obtain more information from "HART protocol errors during response" (see following table) and both HART status bytes.
- In the group error bytes the corresponding bits will be set to "1".

Table 4-28 HART group error displays in response byte 1 (extended response control)

Bit no.	HART group error display	Meaning
0	Further status information available	Corresponds to bit 4 in the channel-specific error bytes in diagnostic data record 1 (2nd HART status byte). The HART command 48 provides you with further status information, if required.
1	HART communication error --> HART communication error entry in diagnostic data record 1	The field device has detected a communication error while receiving the command. The error information is contained in the 1st HART status byte (in the reply record or diagnostic data record 1) which is accepted without changes.
2	Parameter check	0: HMD parameters unchanged 1: Check HMD parameters
3	Always 0	Reserved
4 - 7	HART protocol error for reply --> HART communication error entry in diagnostic data record 1	Error during HART communication between field device and module, i.e. the response was incorrectly received. 0: Unspecified error 1: HMD error 2: Channel error 3: Command error 4: Query error 5: Response error 6: Query rejected 7: Profile query rejected 8: Vendor-specific query rejected 9 - 15: Not used You can find information on the cause of the error in response byte 2. See the table below.

Table 4-29 HART protocol error in response byte 2 for the response from the field device to the module (error code)

Error	HART protocol error in byte 2	Meaning
0	Unspecified error	0: Not specified
1	HMD error	0: Unspecified 1: Internal communication error 2: Parameter assignment error 3: HW error 4: Wait time expired 5: HART timer expired
2	Channel fault	0: Unspecified 1: Line error 2: Short circuit 3: Open line 4: Low current output 5: Parameter assignment error
3	Command error	0-127: HART protocol, Bit 7=0

Error	HART protocol error in byte 2	Meaning
4	Query error	HART protocol, Bit 7=1 Bit 0: Reserved Bit 1: Receive buffer overflow Bit 2: Reserved Bit 3: Checksum error Bit 4: Frame error Bit 5: Overflow error Bit 6: Parity error Bit 7: 1
5	Reply error	HART protocol, Bit 7=1 Bit 0: GAP timeout Bit 1: Receive buffer overflow Bit 2: Timeout Bit 3: Checksum error Bit 4: Frame error Bit 5: Overflow error Bit 6: Parity error Bit 7: 1
6	Query rejected	0: Unspecified 1: Short format not supported 2: SHC not supported 3: Impermissible command 4: No resources
7	Profile query rejected	0: Not specified (not supported)
8	Vendor-specific query rejected	0: Not specified (not supported)

4.5.7.4 Example of HART programming

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

The following assumptions are made:

- The module address of the HART analog module in the ET 200M is 512 (200H).
- The record is stored in DB80: starting at address 0.0, length 11 bytes.
- In this example, DB80 (request record for channel 0) consists of 11 bytes.

Table 4-30 FC80: Writing of the record to DB80 with SFC 58

STL	Explanation
A I 4.0	
FP M 101.0	
= M 104.0	
m2: CALL SFC 58	
REQ :=M104.0	Write request
IOID :=B#16#54	Address range ID
LADDR :=W#16#200	Module address of the HART-AI
RECNUM :=B#16#50	Data record number 80

STL	Explanation
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)
RET_VAL :=MW93	RET_VAL of SFC 58 (OK/error/...)
BUSY :=M51.0	Write operation not yet completed
U M 51.0	
SPB m2	
BE	

Table 4-31 DB80: Transparent Message Format

Byte	Initial value (hex)	Comment (Hex)
0	00	Req_Control (00 = Transparent Message Format. 40 = Transparent Message Format with SHC sequence)
1	05	Number of preamble bytes (05-14)
2	82	Start character (02 = Short Frame with command 0) (82 = Long Frame with other commands)
3	98	Address (with command 0, the address is exactly 1 byte long and has the value 0.)
4	CF	
5	38	
6	84	
7	F0	
8	01	Command (CMD)
9	00	Length in bytes
10	98	Check sum (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 that is to be transferred via DB 80 is reduced to 4 bytes.

Table 4-32 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 find out when the reply was received by cyclically reading record DS81 for HART channel 0. The response is always supplied in Transparent Message Format.

Table 4-33 FC81: Reading of the reply to DB81 with SFC 59

STL	Explanation
m3: CALL SFC 59	
REQ :=1	Read request
IOID :=B#16#54	Address range ID
LADDR :=W#16#200	Module address of the HART-AI
RECNUM :=B#16#51	Data record number 81
RECORD :=P#DB81.DBX0.0 BYTE 75	Data record
RET_VAL :=MW100	RET_VAL of SFC 59 (OK/error/...)
BUSY :=M49.1	Read operation not yet completed
U M 49.1	
SPB m3	
BE	

The program part U M 49.1 to SPB m3 is only required if reading is to occur synchronously.

As long as "0x03" is in byte 0 of DB81, the reply has not been received from the field device. Once bit 2 = 1 in byte 0, positive response data are available from field devices, which you can evaluate.

If the response data is invalid, see Tables "HART group error displays in response byte 1 (extended response control)" or "HART protocol error in response byte 2 in response from the field device to the module (error code)" in this manual.

4.5.7.5 User data interface

User data interface - input area (read)

Structure of the user data

The figure below shows the structure of the input user data area of the HART analog modules beginning with the correspondingly configured module address.

If you have configured HART variables, then these are made available justified after byte 15. Each configured HART variable uses 5 input bytes, see section 4.5.1.

You can read in the data of the user data area (e.g. with L PEW 256) and evaluate it in your user program.

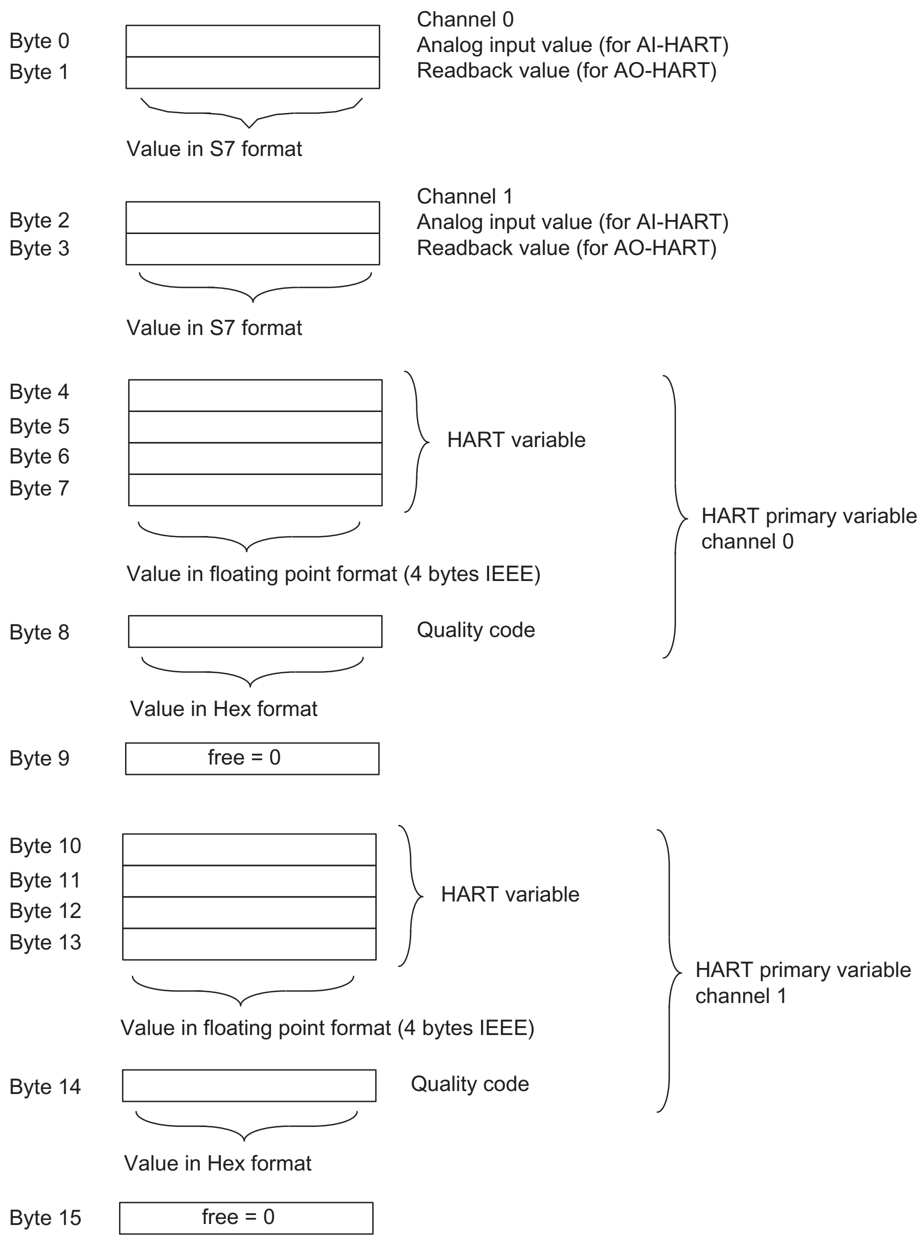


Image 4-29 Input user data area of the HART analog modules

User data interface, output range (writing)

Structure of the user data

The figure below shows the structure of the output user data area of the HART analog output module beginning with the correspondingly configured module address. You can transfer the data to the user data area in a permissible format (e.g. with T PAW 256).

Both the analog input as well as the analog output occupy 16 bytes in the output area. In the case of the analog input, writing has no effect.

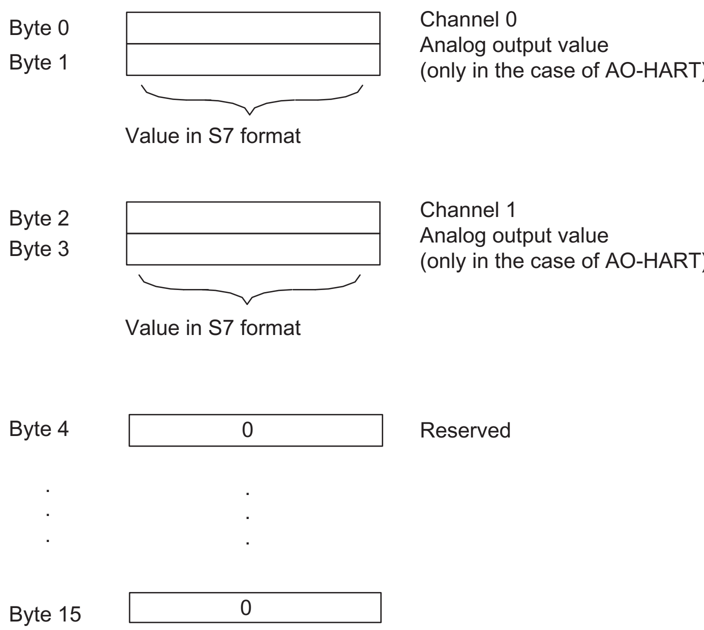


Image 4-30 User data area of the HART analog output module

Certificates A

A.1 Overview of diagnostic functions

Introduction

The EU special test certificates and EU certificates of conformity for the modules described in this manual can be found on the Internet: (http://support.automation.siemens.com/WW/view/en/37217116/134200)

Example

In the "Entry list" tab, select under filter settings:

- Entry type: Certificates
- Certificate Type: Certificates of conformity
- Search item(s): 6ES7321-7RB00-0AB0

Standards and licenses B

B.1 Standards and licenses

Introduction

In this section you will find

- standards and test values satisfied by modules of the S7-300 automation system and ET 200M.
- test criteria according to which the S7-300/ET 200M Ex I/O modules were tested.

CE mark

0344

The automation system S7-300/ET 200M satisfies the requirements and protection goals of the following EC directives, and conforms with the harmonized European standards (EN) for programmable logic controllers announced in the Official Journals of the European Community:

- 2006/95/EC "Electrical Equipment Designed for Use within Certain Voltage Limits" (Low-voltage Directive)
- 2004/108/EC "Electromagnetic Compatibility" (EMC Directive)
- 94/9/EC "Equipment and Protective Systems for Use in Potentially Explosive Atmospheres" (Directive for Explosion Protection)

The EC Declarations of Conformity are available to the responsible authorities at:

Siemens Aktiengesellschaft
Bereich Automatisierungs- und Antriebstechnik
Industry Sector I IA AS R&D DH A
Postfach 1963
D-92209 Amberg, Germany

These files are also available for download on the Customer Support Internet pages, under "Declaration of Conformity" on the Internet (http://support.automation.siemens.com/WW/view/en/37217116/134200).

Safety standards used

The following safety standards apply to all EX modules:

- EN 60079-0:
  Electrical equipment for hazardous locations:
  General specifications.
- EN 60079-11:
  Electrical equipment for hazardous locations:
  Intrinsic safety "i".
- DIN EN 61010 (part 1 v. 3/94):
  Safety regulations for electrical measuring and control devices and
  laboratory equipment.
- DIN EN 61131 (part 2 v. 5/95):
  Programmable logic controllers, operational equipment requirements and testing.
- DIN EN 60204 (part 1 v. 6/93):
  Electrical equipment of machines:
  General requirements.

Safety-related characteristic values:

U_o	Maximum output voltage
I_o	Maximum output current
U_m	Maximum r.m.s. power-frequency voltage or maximum direct voltage
C_o	Maximum external capacitance
L_o	Maximum external inductance
P_o	Maximum output power
C_i	Maximum internal capacitance
L_i	Maximum internal inductance

cULus HAZ. LOC. approval

HAZ. LOC.

Underwriters Laboratories Inc. in accordance with

- UL 508 (Industrial Control Equipment)
- UL 1604 (Hazardous Location)
- CSA C22.2 No. 142 (Process Control Equipment)
- CSA C22.2 No. 213 (Hazardous Location)

APPROVED for use in
Class I, Division 2, Group A, B, C, D T4;
Class I, Zone 2, Group IIC T4

Note the following information.

Note

This product must be installed according to the NEC (National Electric Code) stipulations.

When used in environments according to class I, division 2 (see above), ET 200M must be mounted in an enclosure that corresponds to at least IP54 according to EN 60529.

WARNING

Installation Instructions according cULus

WARNING – Explosion Hazard - Do not disconnect while circuit is live unless area is known to be non-hazardous.

WARNING – Explosion Hazard - Substitution of components may impair suitability for Class I, Division 2 or Class I, Zone 2

This equipment is suitable for use in Class I, Division 2, Groups A, B, C or D; Class I, Zone 2, Group IIC, or non-hazardous locations only.

FM approval

FM
APPROVED

Factory Mutual Research (FM) in accordance with
Approval Standard Class Number 3611, 3600, 3810
APPROVED for use in
Class I, Division 2, Group A, B, C, D T4;
Class I, Zone 2, Group IIC T4

Note

This product must be installed according to the NEC (National Electric Code) CEC (Canadian Electric Code) stipulations.

> **WARNING**
>
> **Installation Instructions according cULus**
>
> WARNING – Explosion Hazard - Do not disconnect while circuit is live unless area is known to be non-hazardous.
>
> WARNING – Explosion Hazard - Substitution of components may impair suitability for Class I, Division 2 or Class I, Zone 2
>
> This equipment is suitable for use in Class I, Division 2, Groups A, B, C or D; Class I, Zone 2, Group IIC, or non-hazardous locations only.

ATEX approval

In accordance with EN 60079-15 (Electrical apparatus for potentially explosive atmospheres; Type of protection "n") and EN 60079-11 (Type of protection "i") and EN 60079-0 (Electrical apparatus for potentially explosive gas atmospheres - Part 0: General Requirements)

II 3G (2) GD
Ex nA [ib Gb] [ib Db] IIC T4 Gc

Marking for Australia

or

The S7-300/ET 200M automation system meets the requirements of the EN 61000-6-4 standard.

IEC 61131

The S7-300/ET 200M automation system meets the requirements and criteria of the IEC 61131-2 standard (programmable controllers, Part 2: Equipment Requirements and Tests).

Marine approval

Classification authorities:

- ABS (American Bureau of Shipping)
- BV (Bureau Veritas)
- DNV (Det Norske Veritas)
- GL (Germanischer Lloyd)
- LRS (Lloyds Register of Shipping)
- Class NK (Nippon Kaiji Kyokai)

Use in industrial environment

SIMATIC products are designed for use in industrial environments.

Table B-1 Use in industrial environment

Area of application	Requirement for	
	Interference emission	Interference immunity
Industry	EN 61000-6-4: 2007	EN 61000-6-2: 2005

Use in residential areas

Note

The S7-300/Et 200M is designed for use in industrial areas; using it in residential areas could disturb radio and TV reception.

If you use the S7-300/ET 200M in residential areas, you must ensure that the radio interference emissions comply with limit value class B in accordance with EN 61000-6-3.

Suitable measures for achieving RF interference Limit Class B include, for example:

- Install S7-300/ET 200M in grounded switching cabinets/boxes
- Use of filters in supply lines

Service & support

C

C.1 Service & support

Technical support

You can contact technical support for all A&D products using the online (http://www.siemens.com/automation/support-request) Support Request form.

Additional information on our technical support is available on the Internet (http://www.siemens.com/automation/service).

Service & support on the Internet

In addition to our documentation, we offer a comprehensive knowledge base on the Internet.

On the Internet (http://www.siemens.com/automation/service&support).

There you will find:

- Our Newsletter, which constantly provides you with the latest information about your products.
- The documents you require, via our service & support search facility.
- A forum, where users and experts from all over the world exchange their experiences.
- Your local contact for Automation & Drives from our contact database.
- Information about on-site service, repairs, spare parts, and much more.

Additional support

If you have any questions relating to the products described in this manual and cannot find the answers in this documentation, please contact your Siemens partner at the appropriate office or sales and service location.

The contact details for your partner are available on the Internet (http://www.automation.siemens.com/partner/).

A guide to the technical documentation provided for the various SIMATIC products and systems is available on the Internet (http://www.siemens.com/simatic-tech-doku-portal).

The online catalog and order system is available on the Internet (http://www.siemens.com/automation/mall).

Training center

Siemens offers various courses to get you started with the S7-300 and the SIMATIC S7 automation system. Please contact your regional training center or the central training center in Nuremberg (ZIP code: 90327).
Additional information is available on the Internet (http://www.siemens.com/sitrain).

Glossary

AS

--> Automation system

Automation system

An automation system is a programmable logic controller which consists at least of one → CPU, various I/O modules, and operating and monitoring devices.

Backplane bus

The backplane bus is a serial data bus through which the modules communicate with one another and through which they are supplied with the necessary voltage. The connection between the modules is created by the bus connector.

The --> I/O bus is a component of the backplane bus.

Backplane bus active

Backplane bus of the distributed I/O system --> ET 200M, which is made of active bus modules. This is the prerequisite for a configuration with which "inserting and removing" is permitted during operation.

Baud rate

The baud rate is the speed at which data is transferred. It indicates the number of bits transferred per second (baud rate = bit rate).

With → ET 200 baud rates of 9.6 kBaud up to 12 MBaud are possible.

Bus

Transmission path with two defined ends, shared by all interconnected nodes.

With → ET 200 the bus is a two-wire line or a fiber-optic cable.

Bus user

Device which can send, receive and amplify signals via the → bus, for example; → DP master, → DP slave, RS485 Repeater, active star coupler.

CELENEC

European Committee for Electrical Standards

CiR

CiR (Configuration in RUN) stands for system modification in RUN. System modification in RUN by means of CiR allows the configuration of units of an active system with distributed I/O. Process execution is interrupted for the duration of a brief, assignable period. The process inputs retain their last value during this time period.

Client

A client can request a service from a --> server. A client can, for example, be a program, a central module (CPU) or a station (e.g. PC). The client and server can exchange data via →PROFIBUS DP by means of →master-slave process, for example. A separate transfer channel can be assigned to each client to coordinate data exchange between several clients and the server, for example.

Configuration

Assigning modules to subracks / slots and addresses. A distinction is made between actual configuration (= actual inserted modules) and calculated configuration. You stipulate the calculated configuration with the help of STEP 7, COM PROFIBUS. The operating system can thus detect any incorrect assembly at startup.

Configuring (initialize, assign parameters to)

Included in parameterization is the setting of the behavior of a module or a --> field device by parameters.

CPU

Central processing unit = CPU of the S7 automation system with a control and arithmetic unit, memory, operating system, and interface for programming device.

Diagnostic interrupt

Modules which support diagnostics interrupts report system errors detected to the central → CPU.

In SIMATIC S7/M7: With the detection or disappearance of an error (e.g. wire break), the module triggers a diagnostics interrupt provided this interrupt is enabled. The --> CPU interrupts the processing of the user program or low-priority classes and processes the diagnostic interrupt module (OB82).

In SIMATIC S5: The diagnostic interrupt is reproduced within the device-related --> diagnostics. It can detect errors, like for example, wire breaks, by means of the cyclic querying of the diagnostics bit in the device-related diagnostics.

Diagnostics

The detection, localization, classification, visualization and further evaluation of errors, disturbances and messages.

Diagnostics offers monitoring functions that automatically run while the system is in operation. This hence increases the availability of systems by reducing the installation and down times.

Diagnostics buffer

The diagnostics buffer is a buffered memory area in the CPU in which diagnostics events can be stored in the order of occurrence.

Distributed I/Os

Represent I/O units which are installed at distributed locations at a greater distance to the → CPU, instead of being implemented in the central rack. Examples:

- ET 200M, ET 200B, ET 200C, ET 200U
- DP/AS-I Link
- S5-95U with PROFIBUS-DP slave interface
- further → DP slaves by Siemens or other manufacturers

The distributed I/Os are connected via --> PROFIBUS-DP with the --> DP master.

DP address

Each → bus node must be assigned a unique DP address for → PROFIBUS DP.

PC/PG or the ET 200 hand-helds have the DP address "0".

→ DP-Master and → DP slaves have a DP address from the range 1 to 125.

DP master

A master that complies with the *IEC 61784–1:2002 Ed1 CP 3/1* standard is known as a DP master.

DP slave

A slave running on the PROFIBUS using the PROFIBUS DP protocol in accordance with *IEC 61784-1:2002 Ed1 CP 3/1* is known as a DP slave.

DP standard

The DP standard is the bus protocol of the ET 200 distributed I/O system in accordance with *IEC 61784-1:2002 Ed1 CP 3/1*.

Dynamic parameters

In contrast to static parameters, dynamic parameters of modules can be changed dynamically by the user program.

Electrically isolated

Electrically isolated I/O modules are isolated from the → reference potentials of the control and load circuit by means of optocoupler, relay contact or transformer circuits. I/O circuits can be interconnected with a root circuit.

Error handling via OB

If the operating system detects a specific error (e.g. →access fault with STEP 7), it calls up the respective --> organization block (error OB) for this case, in which the further behavior --> of the CPU can be established.

ET 200

The distributed I/O system ET 200 with → PROFIBUS DP protocol is a → bus system for interconnecting distributed I/O with a → CPU or for interconnecting adequate → DP master. ET 200 features high-speed → reaction times as the system only transfers a low data volume (bytes).

ET 200 is based on the standard EN 50170, Volume 2, --> PROFIBUS.

ET 200 works in accordance with the master slave principle. → DP-Masters can, for example, be the master connection IM 308-C or the CPU 315-2 DP.

→ DP slaves can be distributed I/Os ET 200B, ET 200C, ET 200M, ET 200U or DP slaves by Siemens or other manufacturers.

Fault indication

The fault indication is one of the possible reactions of the operating system to a --> runtime error. The other reaction possibilities are: → Error reaction in the user program, STOP state of the → CPU or of IM 153-1.

Fault reaction

Reaction to a runtime error. The operating system can react in the following ways: Put the programmable controller in the STOP state, call up a --> organization block, whereby the user can program a reaction, or display an error.

Field

This can be an area of the plant outside the control room where measured values can be obtained through communication or manipulated values can be sent to actuators.

Or part of a message, e.g. address field or command field, that is dedicated to a particular function. The dimensions or other regulations for the interpretation of each field are part of the protocol specification.

Field device

A → transducer, that is located on the → field and exchanges communication data with the central system.

Field device, intelligent (smart device)

A field device with more complex functionality, which includes a microprocessor and the functions of which can be set via a respective --> parameter assignment toll by the control room.

FM

FM Approvals, American certification organization for products

frequency shift keying (FSK)

is a data modulation technique that is suitable for the data transport via normal lines. Two audio frequencies are used for this, in order to code the binary "0" and "1" in the frequency range 300 - 3000 Hz. With → HART protocol the FSK signal is transmitted via a current loop.

FSK

Frequency Shift Keying →Frequency shift keying

Ground

The conductive earth whose electrical potential can be set equal to zero at any point.

Ground potential may be different from zero in the area of grounding electrodes. The term reference ground is frequently used to describe this situation.

One or more conductive parts that can have very good contact with the ground.

Chassis ground is the totality of all the interconnected passive parts of a piece of equipment on which dangerous fault-voltage cannot occur.

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The conductive earth whose electrical potential can be set equal to zero at any point.

Ground potential may be different from zero in the area of grounding electrodes. The term reference ground is frequently used to describe this situation.

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One or more conductive parts that can have very good contact with the ground.

Chassis ground is the totality of all the interconnected passive parts of a piece of equipment on which dangerous fault-voltage cannot occur.

HART

Highway Addressable Remote Transducer. HART is a registered trademark of the --> HART Communication Foundation.

HART analog modules

Analog modules which, in addition to their analog value, can carry out --> HART communication. HART analog modules can be used as --> HART interfaces for HART field devices.

HART commands

The HART field device works as a slave and is controlled by the master by means of HART commands. The master sets the --> HART parameters or requests data in the form of --> HART responses.

HART communication

Transmitting data between a master (e.g. HART analog module) and a slave (--> HART field device) via the --> HART protocol.

HART Communication Foundation

The HART Communication Foundation (HCF) was founded in 1993 in order to market and further develop the HART protocol. The HCF is an establishment that is not focused on profits and it is financed by its members.

HART field device

Smart device with additional → HART-compatible functionality to enable interpretation of the → HART communication functions.

HART hand-held

The HART hand-held includes the original parameter assignment tool by Fisher-Rosemount Ltd. for --> HART field devices, which is directly linked to its connections. The --> HART parameters are set using the HART hand-held.

HART interface

Part of a system with which a --> HART field device can be connected. The HART interface represents the master for the field device. With reference to the system, the HART interface however is a slave that can supply the system via various masters. A master represents, e.g. the --> HART parameter assignment tool. The programmable controller is itself a different master.

HART parameter

The HART parameters call the configurable features of --> HART field devices, which can be changed via the --> HART protocol. The setting takes place via a --> HART parameter assignment tool.

HART parameter assignment tool

The HART parameter assignment tool is used to comfortably set the --> HART parameters. It can be a --> HART hand-held or a parameter assignment tool that is integrated in the system, e.g. SIMATIC SIPROM.

HART protocol

The → HART protocol is the industry standard for expanded communication with --> HART field devices. It includes the --> HART commands and the --> HART responses.

HART responses

The HART field devices transmits data upon the request of the master. These data represent measurement results, manipulated values or the values of → HART parameters. A HART response always includes a status information, the --> HART status byte.

HART signal

Analog signal on a current loop from 4 - 20 mA, where the aid of the --> FSK procedure, the sinus waves for the --> HART protocol, 1200 Hz for the binary "1" and 2200 Hz for the binary "0" can be modulated.

HART status byte

The status information that consists of the 1st and 2nd status byte of the --> HART response and with which the HART field device offers information via the --> HART communication, the receipt of the --> HART command and the device status.

HART transfer area

Area of data records that are established for writing HART commands and reading HART responses with the HART analog modules. The HART transfer area consists of records. Each --> client is assigned its own range of data records, with which the --> server can exchange data with the client.

HCF

--A HART Communication Foundation

I/O bus

Component of the --> S7-300 backplane bus in the --> programmable controller system, optimized at the fast exchange of signals between the IM 153 and the signal modules. The I/O bus is used to transfer → process data, such as digital input signals of a signal module and system data, such as the → default parameter records of a signal module.

Interrupt

The operating system of the --> CPU recognizes 10 different priority classes that regulate the editing of the user program. These priority classes include interrupts (e.g. hardware interrupts). When an interrupt is triggered, the operating system automatically calls an assigned OB in which the user can program the desired reaction.

KEMA

Certification office for products

Load mains device

Power supply to the signal / function modules and the process I/O connected to them.

Master class 1

--> Master that carries out the user data traffic and with which the configuration and diagnostics of the distributed I/Os takes place.

Master class 2

--> Master for controlling / installing and configuration tasks, e.g. configuring and diagnostics of the field devices that are connected to the distribution I/Os.

Master slave procedure

Bus access method where only one node is → DP master, and all other nodes are → DP slaves.

Masters

A master station which is in possession of the token can send data to other nodes and request data from those (= active node.)

→ DP-Masters can, for example, be the master connection IM 308-C or the CPU 315-2 DP.

Measuring-point tag

Unique identifier for the measuring point, consisting of 8 characters. It is saved in the --> HART field device and can be changed and read off via the --> HART command.

modem

A modem (modulator / demodulator) is a device that converts binary digital signals into --> FSK signals and vice-versa. A modem doesn´t code data, it offers a conversion of the physical form of the signals.

Module parameters

Module parameters are values using which the behavior of the module can be modified. We distinguish between static and dynamic module parameters.

Monodrop

In a monodrop communication system a maximum of two devices are linked to the same transmission path, e.g. channel of the HART analog module and --> HART field device. The --> HART protocol and the analog signal can be used simultaneously with this procedure. (By contrast, a communication system with more than two devices has the multidrop feature)

Non-isolated

The → reference potentials of non-isolated I/O modules and of the control and load circuit are interconnected electrically.

OB

--> organization block

organization blocks

form the interface between the operating system of the S7-CPU and the user program. The sequence of processing the user program is established in the organization blocks.

Parameter assignment tool

A SW tool using which the parameters e.g. of an --> intelligent field device can be set.

Potentially explosive atmosphere

This is an area in which there is an explosion hazard or where due to local and operating conditions a dangerous explosive atmosphere can occur.

Primary variable

Variable for the master measured value of a HART analog input, for example, pressure. The →HART field devices also support the implementation of other measuring processes, for example temperature measurements, and save the results to the second, third, or fourth variable and so forth. With a HART analog output the primary variable includes the manipulated variable.

Process image

Special memory area of the → automation system. At the start of the cyclic program the signal states of the input modules are transferred to the process image of the inputs. At the end of the cyclic program the process image of the outputs is transferred as a signal state to the output modules.

Process interrupt

A hardware interrupt is triggered by interrupt-capable S7-300 modules due to a certain event in the process. Process interrupts are reported to the central → CPU. The assigned organization block is then processed according to the priority of this interrupt.

In SIMATIC S7/M7: The range is defined by parameterization of an upper and a lower limit. The module triggers a process interrupt if the process signal of an analog signal module such as the temperature is out of this working range, provided limit value interrupts are enabled. The → CPU interrupts execution of the user program or of jobs of a lower priority class in order to execute process interrupt OB 40.

In SIMATIC S5: The process interrupt is mapped within the device-specific → diagnostics function. You can identify errors such as violation of limits by means of cyclic polling of the diagnostics bits in the device-specific diagnostics data.

PROFIBUS

PROcess FIeld BUS. This is an international process and fieldbus standard as defined in *IEC 61784-1:2002 Ed1 CP 3/1*. Specifies the functional, electrical and mechanical characteristics of a serial bit stream field bus system.

PROFIBUS is a bus system that connects PROFIBUS compatible automation systems and field devices on a cell and field level.

PROFIBUS is available with the protocols DP (= Distributed Peripherals), FMS (= Fieldbus Message Specification), PA (= Process Automation), or TF (= Technological Functions).

PTB

Physical Technical Federal Organization, Certification Office for Products

Reaction time

The reaction time is the average time that elapses between the changing of an input and the associated changing of an output.

Reference potential

Reference potential for the evaluation / measuring of the voltages of participating circuits.

Runtime error

Error that occurs during the editing of the user program in the --> programmable controller (also no in the process).

S7-300 backplane bus

Backplane bus for the S7-300 system. The same backplane bus can also be used for the distributed I/O system --> ET 200M. There the use of the active backplane bus is also possible (--> backplane bus, active)

Server

A server provides a service upon request. A server can, for example, be a program, a module or a station (e.g. PC). The data exchange between the --> A client and server can, for example, take place via PROFIBUS-DP in the --> master slave procedure.

SFC

--> system function

Signal module

Signal modules form the interface between the process and the automation system. There are digital input and output modules as well as analog input and output modules.

Slave

A slave can only exchange data with the master upon request from the same.

SM

--> signal module

Static parameters

Unlike dynamic parameters, static parameters of modules cannot be changed by the user program. You can only modify these parameters in STEP 7 or COM PROFIBUS.

Structure, central

In a centralized configuration, the process I/O devices and central module are located in the same rack or in expansion units in the same or a neighboring cabinet.

Structure, distributed

The process I/O of a distributed configuration is not installed directly alongside with the CPU in the same rack or in the same/adjacent cabinet. Distributed I/Os are installed at remote locations and interconnected via communication bus system.

Substitute value

Substitute values are values which are output by faulty signal output modules to the process, or used to substitute a process value of a faulty signal input module in the user program. The substitute values can be set by the user (for example, retain old values)

System diagnostics

System diagnostics is the detection, evaluation and the report of errors that occur within the programmable controller. Examples for such errors are: Program errors or failure of modules. System errors can be displayed with LED displays or in the STEP 7.

System function

A system function is a function integrated in the operating system of the --> CPU which upon request can be called up in the STEP 7 user program.

Terminating resistor

power adaptation resistor connected to the bus cable. Always required at the end of cables or segments.

The → ET 200 bus connectors are equipped with switched terminating resistors.

Timeout

If an expected event does not occur within a specified time, this time is known as a "timeout". In the --> HART protocol there is a timeout for the response of a slave to a message from the master and for the pause after each transaction.

Transducer

Sensor, measuring transducer, actuator or final control element. A transducer can be implemented by means of a →smart device.

User data

User data is exchanged between a central module and signal module, function module and communication modules via the process image or via direct access. User data could be: digital and analog input/output signals from signal modules, control and status information from function modules.

Index

D

E

F

G

H

I

L

M

O

T

U

V

W