



IO-Link System Description

Technology and Application



Contents

Preface	3
1 Benefits of IO-Link.....	4
2 System Overview	5
2.1 Overview of IO-Link.....	5
2.2 IO-Link interface.....	6
2.3 IO-Link protocol	7
2.4 Device profiles.....	9
2.5 IODD and engineering.....	9
2.6 Differences of IO-Link Specifications V1.0 and V1.1	10
3 Integration into the automation system.....	11
3.1 Configuration of the IO-Link system	11
3.2 Data access from the automation system and HMI device	15
3.3 Changing and backing up device settings during plant operation	15
3.4 Replacement of a device or master during operation	16
4 Glossary	18

List of Figures

Fig. 1: Example of system architecture with IO-Link	5
Fig. 2: IO-Link point-to-point connection	6
Fig. 3: Pin assignment of IO-Link device.	6
Fig. 4: Pin assignment Port Class A	6
Fig. 5: Pin assignment Port Class B	7
Fig. 6: Configuration tool with IODD of a device and the device information it contains.....	10
Fig. 7: Configuration of a PROFINET network with lower-level IO-Link masters.....	11
Fig. 8: Device view of the PROFINET device with setting of the IO-Link address range.....	12
Fig. 9: Configuration of an IO-Link master in the configuration tool.	13
Fig. 10: Assignment of the parameter values of the IO-Link device	14
Fig.11: Setting backup level	16

Preface

IO-Link is the first I/O technology for communicating with sensors and actuators to be adopted as an international standard (IEC 61131-9). The goal of the IO-Link Community is to develop and market IO-Link technology.

Purpose of the documentation

This system description provides an overview for the IO-Link I/O technology.

It presents the interaction of the various components of an IO-Link system and serves to increase the general understanding of IO-Link.

Target audience of the application description

This system description is aimed at the following individuals involved with automation systems:

- Mechanical and plant engineers
- System integrators
- Plant owners
- Non-automation specialists, e.g., design engineers

Additional information regarding IO-Link

Additional information about IO-Link can be found on the Internet: www.io-link.com



1 Benefits of IO-Link

The IO-Link system offers the following benefits for the connection of complex (intelligent) sensors/actuators:

- Open standard according to IEC 61131-9
 - Devices can be integrated in the same way in all commonly used fieldbus systems and automation systems
- Tool-supported parameter assignment and central data management
 - Fast configuring and commissioning
 - Easy creation of up-to-date plant documentation, including for sensors/actuators
- Simple, standardized wiring and a significantly reduced variety of interfaces for sensors/actuators
 - Standardized uniform interface for sensors and actuators irrespective of their complexity (switching, measuring, multi-channel binary, mixed signal, etc.)
 - Reduced variations and inventory
 - Fast commissioning
 - Reduced space requirement
 - Any combination of IO-Link devices and sensors/actuators without IO-Link on the IO-Link master
- Consistent communication between sensors/actuators and the controller
 - Access to all process data, diagnostic data, and device information
 - Access to device-specific data
 - Remote diagnostics supported
- Consistent diagnostic information down to the sensor/actuator level
 - Reduced effort for troubleshooting
 - Minimized failure risks
 - Preventive maintenance and optimization of maintenance and maintenance scheduling
- Dynamic change of sensor/actuator parameters by the controller or the operator on the HMI
 - Reduced downtimes for product changeover
 - Increased product diversity of the machine
- Automatic parameter reassignment for device replacement during operation
 - Minimized downtimes
 - Device replacement by untrained personnel without additional tools
 - Prevention of incorrect settings
- Integrated device identification
 - Identification of the embedded devices
 - Securing machine quality during device replacement

2 System overview

2.1 Overview of IO-Link

Components

An IO-Link system consists of the following basic components:

- IO-Link master
- IO-Link device (e.g., sensors, RFID readers, valves, motor starters, I/O modules)
- Unshielded 3- or 5-conductor standard cables
- Engineering tool for configuring and assigning parameters of IO-Link

The IO-Link master establishes the connection between the IO-Link devices and the automation system. As a component of an I/O system, the IO-Link master is installed either in the control cabinet or as remote I/O, with enclosure rating of IP65/67, directly in the field. The IO-Link master communicates over various fieldbuses or product-specific backplane buses. An IO-Link master can have several IO-Link ports (channels). An IO-Link device can be connected to each port (point-to-point communication). Hence, IO-Link is a point-to-point communication and not a fieldbus.

Figure 1 shows an example of a system architecture with IO-Link.

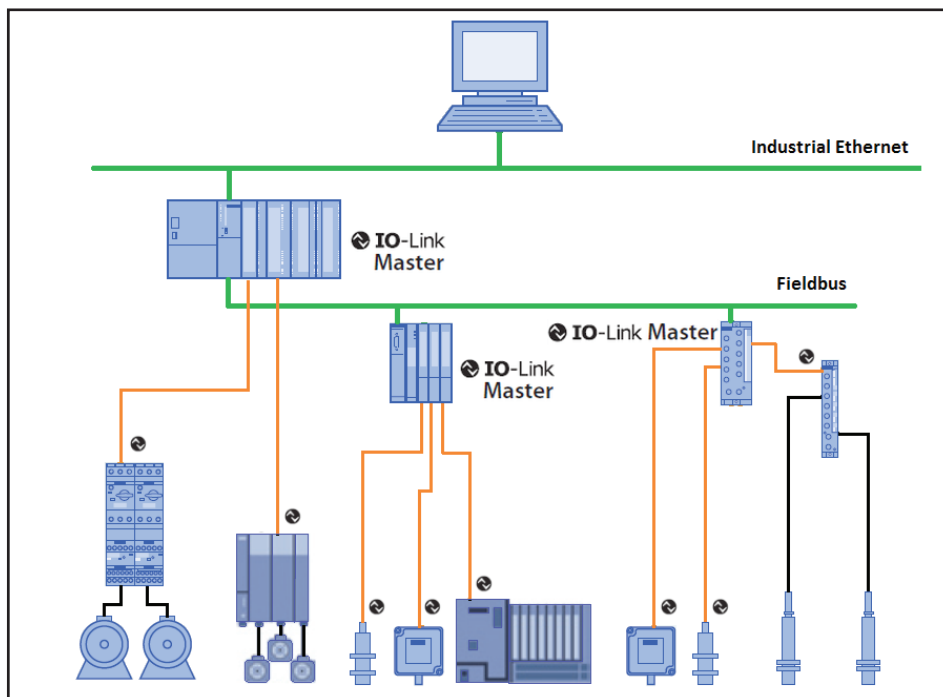


Figure 1: Example of system architecture with IO-Link

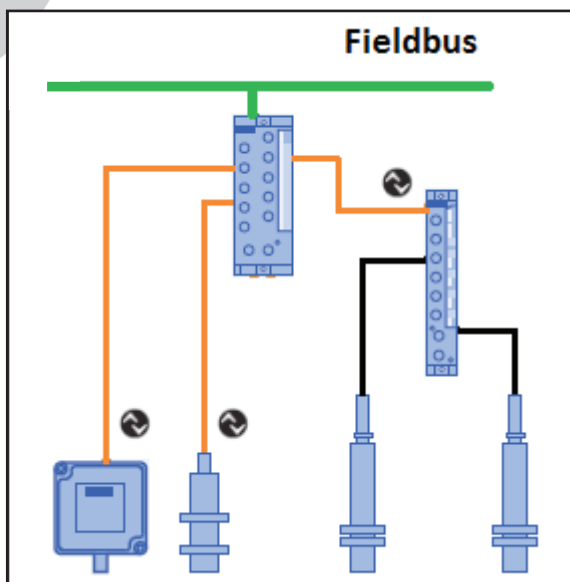


Figure 2: IO-Link point-to-point connection

Engineering

The engineering of the IO-Link system is performed in parallel with the engineering of the overall automation system and can be embedded in and meshed with this engineering.

2.2 IO-Link interface

IO-Link is a serial, bi-directional point-to-point connection for signal transmission and energy supply under any networks, fieldbuses, or backplane buses.

Connection technology in IP65/67

For the connection technology in IP65/67, one possibility that has been defined is an M12 plug connector, in which sensors usually have a 4-pin plug and actuators a 5-pin plug. IO-Link masters generally have a 5-pin M12 socket.

The pin assignment is specified according to IEC 60974-5-2 as follows:

- Pin 1: 24 V
- Pin 3: 0 V
- Pin 4: Switching and communication line (C/Q)

These 3 pins are used for the IO-Link communication as well as for supplying a maximum of 200 mA to the device (see Figure 3).

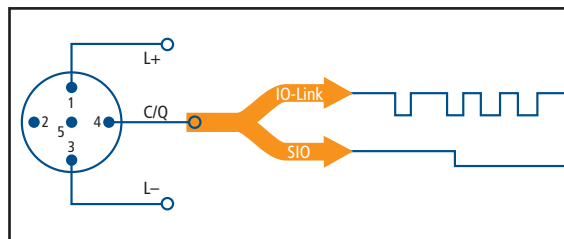


Figure 3: Pin assignment of IO-Link device

Port types in IP65/67

The specification distinguishes two types of ports for the IO-Link master:

Port Class A (Type A)

In this type, the functions of pins 2 and 5 are not specified. The manufacturer defines these functions. Pin 2 is usually assigned with an additional digital channel.

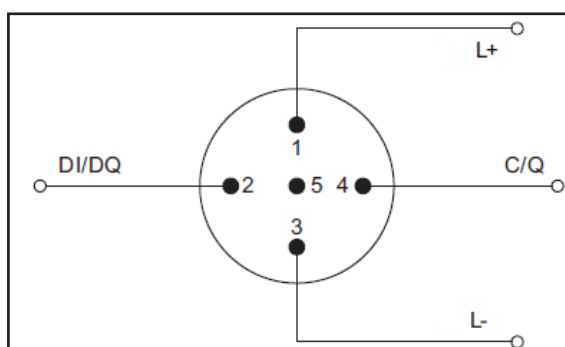


Figure 4: Pin assignment Port Class A

Port Class B (Type B)

This type provides additional supply voltage and is suitable for the connection of devices that have an

increased power demand. In this case, pins 2 and 5 are used to provide additional (galvanically isolated) supply voltage. A 5-conductor standard cable is required in order to use this additional supply voltage.

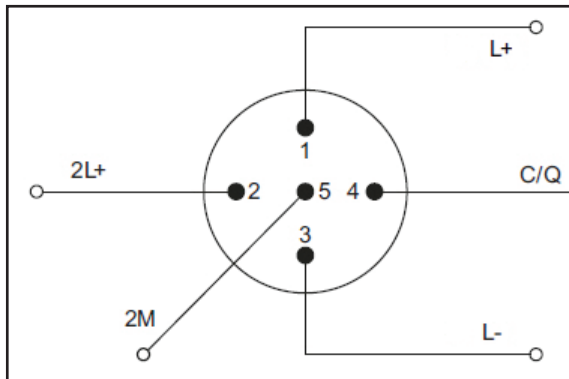


Figure 5: Pin assignment Port Class B

Connecting cable

The devices are connected to the master using unshielded 3- or 5-conductor standard cables up to 20 m long. Shielding is not necessary. Likewise, no specific guidelines have to be followed when laying the cables.

2.3 IO-Link protocol

Operating modes

The IO-Link ports of the master can be operated in the following modes:

- **IO-Link:**
In "IO-Link" mode, the port is used for IO-Link communication.
- **DI:**
In "DI" mode, the port behaves like a digital input.
- **DQ:**
In "DQ" mode, the port behaves like a digital output.
- **Deactivated:**
"Deactivated" mode can be used for unused ports.

Transmission rate

Three transmission rates (baud rates) are specified for IO-Link mode in IO-Link Specification V1.1:

- COM 1 = 4.8 kbaud
- COM 2 = 38.4 kbaud
- COM 3 = 230.4 kbaud (optional according to Specification V1.0)

An IO-Link device supports only one of the defined data transmission rates. According to Specification V1.1, the IO-Link master supports all data transmission rates and adapts itself automatically to the data transmission rate supported by the device.

Response time of the IO-Link system

The response time of the IO-Link system provides information about the frequency and speed of the data transmission between the device and master. The response time depends on various factors. The device description file IODD of the device contains a value for the minimum cycle time of the device. This value indicates the time intervals at which the master may address the device. The value has a large influence on the response time. In addition, the master has an internal processing time that is included in the calculation of the response time.

Devices with different minimum cycle times can be configured on one master. The response time differs accordingly for these devices. That is, the response time of the different devices on a master can differ significantly.

When configuring the master, you can specify a fixed cycle time in addition to the device-specific minimum cycle time stored in the IODD. The master then addresses the device based on this specification. The typical response time for a device therefore results from the effective cycle time of the device and the typical internal processing time of the master.



Transmission quality

IO-Link is a very robust communication system. This communication system operates with a 24 V level. If transmissions fail, the frame is repeated two more times. Only after the failure of the second retry does the IO-Link master recognize a communication failure and signal this to the higher-level controller.

Data types

Four basic data types are available:

- Process data → Cyclic data
- Value status → Cyclic data
- Device data → Acyclic data
- Events → Acyclic data

Process data

The process data of the devices are transmitted cyclically in a data frame in which the size of the process data is specified by the device. Depending on the device, 0 to 32 bytes of process data are possible (for each input and output). The consistency width of the transmission is not fixed and is thus dependent on the master.

Value status

Each port has a value status (PortQualifier). The value status indicates whether the process data are valid or invalid. The value status can be transmitted cyclically with the process data.

Device data

Device data can be parameters, identification data, and diagnostic information.

They are exchanged acyclically and at the request of the IO-Link master. Device data can be written to the device (Write) and also read from the device (Read).

Events

When an event occurs, the device signals the presence of the event to the master. The master then reads out the event. Events can be error messages (e.g., short-circuit) and warnings/maintenance data (e.g., soiling, overheating).

Error messages are transmitted from the device to the controller or the HMI via the IO-Link master. The IO-Link master can also transmit events and statuses on its behalf. Examples of such events are wire breaks or communication failures.

The transmission of device parameters or events occurs independently from the cyclic transmission of process data. These transmissions do not influence or impair each other.

Startup of the I/O system

If the port of the master is set to IO-Link mode, the IO-Link master attempts to communicate with the connected IO-Link device. To do so, the IO-Link master sends a defined signal (wake up pulse) and waits for the IO-Link device to reply.

The IO-Link master initially attempts to communicate at the highest defined data transmission rate. If unsuccessful, the IO-Link master then attempts to communicate at the next lower data transmission rate. The device always supports only one defined data transmission rate.

If the master receives a reply, the communication begins. Next, it exchanges the communication parameters. If necessary, parameters saved in the system will be transmitted to the device. Then, the cyclic exchange of the process data and value status begins.

2.4 Device profiles

To standardize how the user program on the controller accesses the devices, device profiles are defined for IO-Link.

The device profiles specify the data structure, data contents, and basic functionality. As a result, a uniform user view and an identical access by the program on the controller is achieved for a variety of different devices that conform to the same device profile.

Profiles for IO-Link

At present, the “Smart Sensor Profile” is defined for IO-Link. This profile is particularly suitable for measuring sensors, i.e., sensors that transmit measured values in addition to switching points.

IO-Link configuration tool

In order to configure the entire IO-Link system, configuration tools are required. The IO-Link configuration tools of the master manufacturers are able to read in IODDs. The main tasks of the IO-Link configuration tool include:

- Assignment of the devices to the ports of the master
- Address assignment (I/O addresses of the process data) to the ports within the address area of the master
- Parameter assignment of the IO-Link devices

In addition, the connected devices must have diagnostics capability.

This allows the IO-Link configuration tool to provide a transparent representation of the IO-Link system down to the field level.

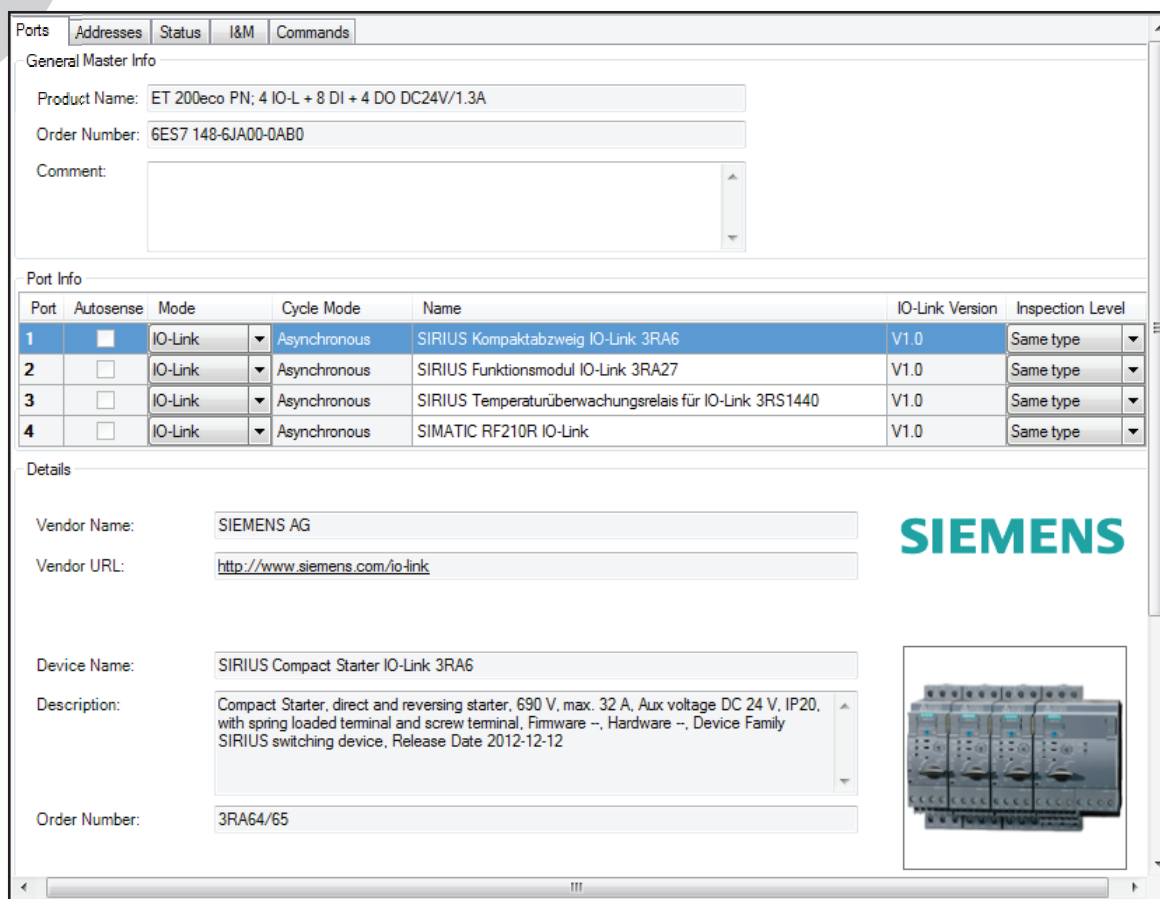
2.5 IODD and engineering

Device description IODD

An electronic device description – the IODD file (IO Device Description) – is available for each device. The IODD stores a variety of information for the system integration:

- Communication properties
- Device parameters with value range and default value
- Identification, process, and diagnostic data
- Device data
- Text description
- Illustration of the device
- Logo of the manufacturer

The structure of the IODD is the same for all devices of all manufacturers. The structure of the IODD is always represented in the same way by the IO-Link configuration tools of the master manufacturers. This ensures the same handling of all IO-Link devices irrespective of the manufacturer. For devices that support both V1.0 and V1.1 functionality, two different IODD versions are available.



The screenshot shows the Siemens IODD configuration tool interface. It has tabs for Ports, Addresses, Status, I&M, and Commands. The 'Ports' tab is active, displaying 'General Master Info' and 'Port Info'.

General Master Info:

- Product Name: ET 200eco PN; 4 IO-L + 8 DI + 4 DO DC24V/1.3A
- Order Number: 6ES7 148-6JA00-0AB0
- Comment: (empty text area)

Port Info:

Port	Autosense	Mode	Cycle Mode	Name	IO-Link Version	Inspection Level
1	<input checked="" type="checkbox"/>	IO-Link	Asynchronous	SIRIUS Kompaktabzweig IO-Link 3RA6	V1.0	Same type
2	<input type="checkbox"/>	IO-Link	Asynchronous	SIRIUS Funktionsmodul IO-Link 3RA27	V1.0	Same type
3	<input type="checkbox"/>	IO-Link	Asynchronous	SIRIUS Temperaturüberwachungsrelais für IO-Link 3RS1440	V1.0	Same type
4	<input type="checkbox"/>	IO-Link	Asynchronous	SIMATIC RF210R IO-Link	V1.0	Same type

Details:

- Vendor Name: SIEMENS AG
- Vendor URL: <http://www.siemens.com/io-link>
- Device Name: SIRIUS Compact Starter IO-Link 3RA6
- Description: Compact Starter, direct and reversing starter, 690 V, max. 32 A, Aux voltage DC 24 V, IP20, with spring loaded terminal and screw terminal, Firmware --, Hardware --, Device Family SIRIUS switching device, Release Date 2012-12-12
- Order Number: 3RA64/65

On the right side, there is a Siemens logo and a photograph of the SIRIUS Compact Starter IO-Link 3RA6 device.

Figure 6: Configuration tool with IODD of a device and the device information it contains

2.6 Differences of IO-Link Specifications V1.0 and V1.1

Specification

The technical definition of the IO-Link system is described in a specification of the IO-Link Community. Version 1.0 of the Specification was prepared in the first step. As a result of further development and the addition of functions to the IO-Link system, Version 1.1 was prepared.

The important additions in Version 1.1. are:

- Parameter assignment server function (data storage)
- Data transmission rate of 230.4 kbaud is mandatory for IO-Link master
- Process data width per port up to 32 bytes

Combination of IO-Link devices

In principle, any combination of masters and devices is possible. However, the limits of the particular system must be noted (e.g., maximum size of user data of the master).

If IO-Link devices of a different IO-Link specification are combined, the following must be noted:

- Only IO-Link devices according to V1.0 can be operated on the IO-Link master according to V1.0.
- IO-Link devices according to V1.0 and V1.1 can be operated on the IO-Link master according to V1.1.
- The parameter assignment server function and the data transmission rate of 230.4 kbaud of the IO-Link master according to V1.1 can only be used if these functions are also supported by the IO-Link device.

3 Integration into the automation system

3.1 Configuration of the IO-Link system

The IO-Link system is configured in several steps. In the first step, the IO-Link master is integrated in the automation system and configured. In the second step, the IO-Link device parameters are assigned.

are described in the device description of the IO-Link master. However, at this point there is no other information about the IO-Link system, e.g., regarding the IO-Link devices to be connected.

Example configuration in STEP 7 TIA Portal

The following figure shows a PROFINET configuration in which PROFINET devices with IO-Link masters are integrated.

Integration into the automation system

In the configuration of the automation system or fieldbus, the IO-Link system is represented by the IO-Link master and integrated using the appropriate device description (e.g., GSD file for PROFINET). The IO-Link master itself can be a fieldbus node or a module of a modular IO system formatting issue that is connected to the fieldbus. In both cases, the number of ports, the address range, and the module properties

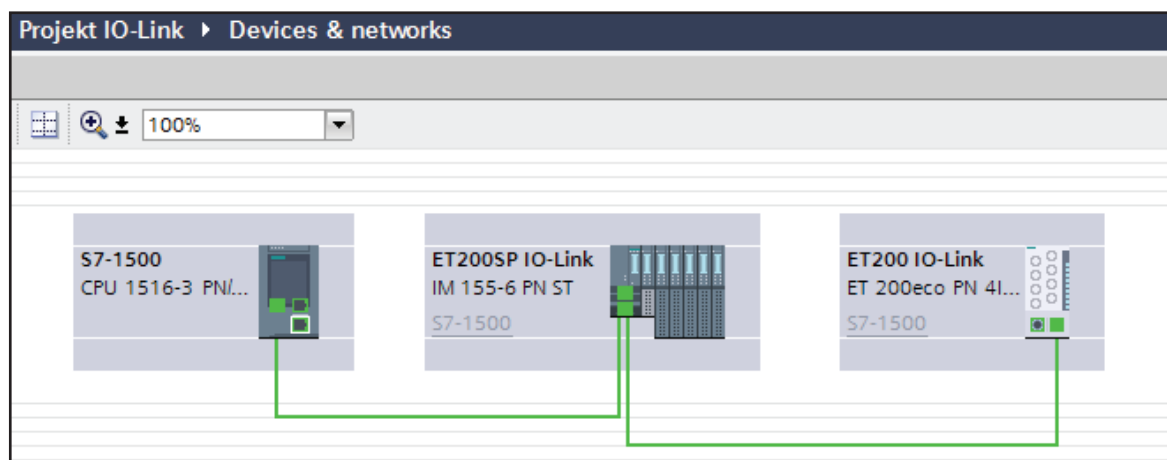


Figure 7: Configuration of a PROFINET network with lower-level IO-Link masters

At this point the address ranges for the exchange of cyclic data (process values) of IO-Link are specified.

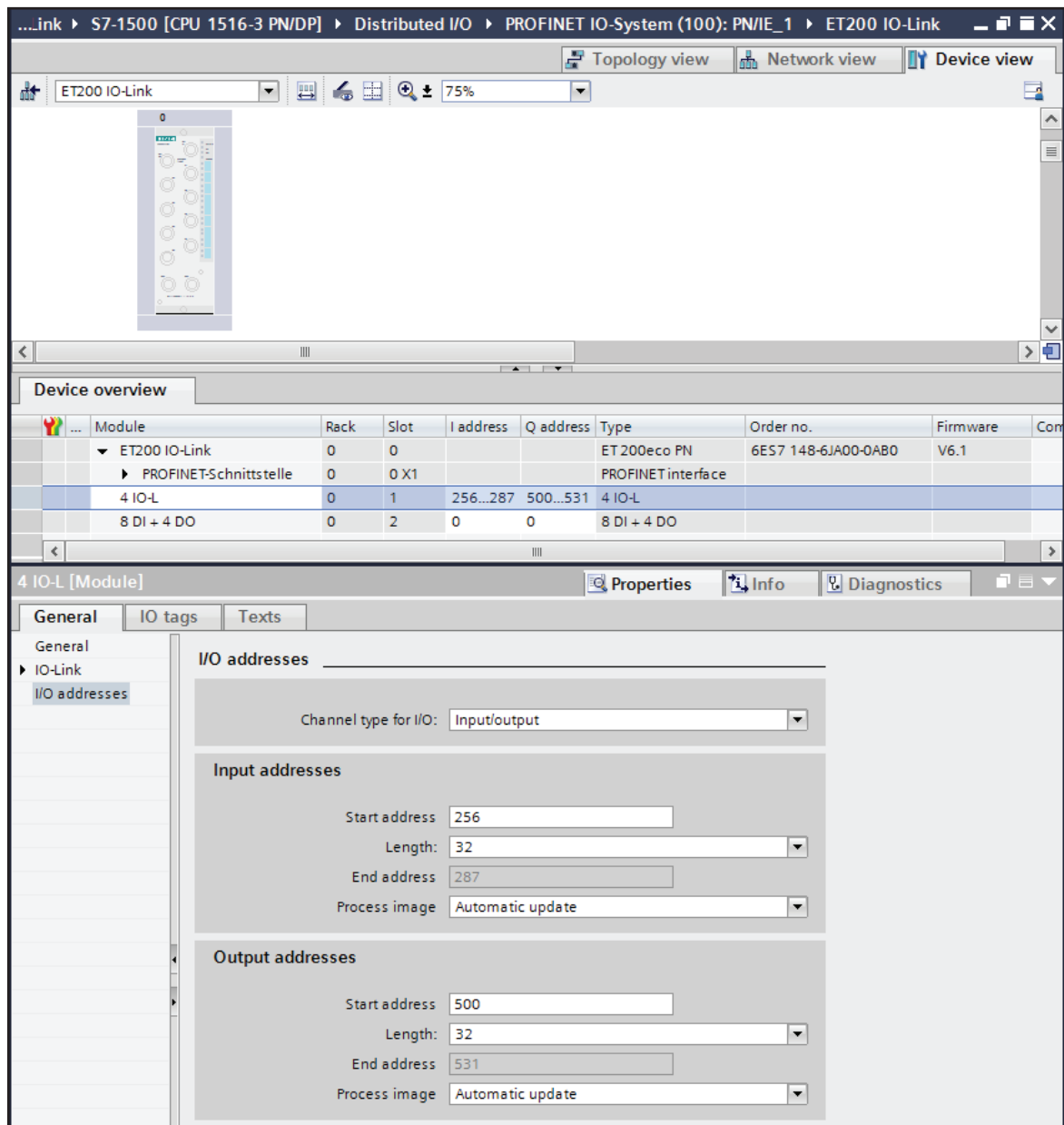


Figure 8: Device view of the PROFINET device with setting of the IO-Link address range

IO-Link configuration tool

In order to represent the system architecture completely and transparently down to the IO-Link device and in order to configure the IO-Link system in detail and assign its parameters, the IO-Link configuration tool of the IO-Link master is necessary. The configuration tool shows all the IO-Link masters of the relevant manufacturer configured in the automation. After you select an IO-Link master, you can assign the desired IO-Link devices to its IO-Link ports. To do so, you select the appropriate devices (or their IODDs) from the device catalog and drag them onto the IO-Link master port.

Example configuration

Figure 9 shows the configuration of an IO-Link master in an IO-Link configuration tool.

A variety of information is displayed in this view of the configuration tool:

- Higher-level fieldbus and overview or structure of the lower-level IO-Link master (left tree)
- Detailed information of the selected IO-Link master
- Current configuration of the IO-Link ports of the selected IO-Link master
- Detailed information of the selected IO-Link device
- Device catalog with the IODDs of the IO-Link devices of different manufacturers (right tree)

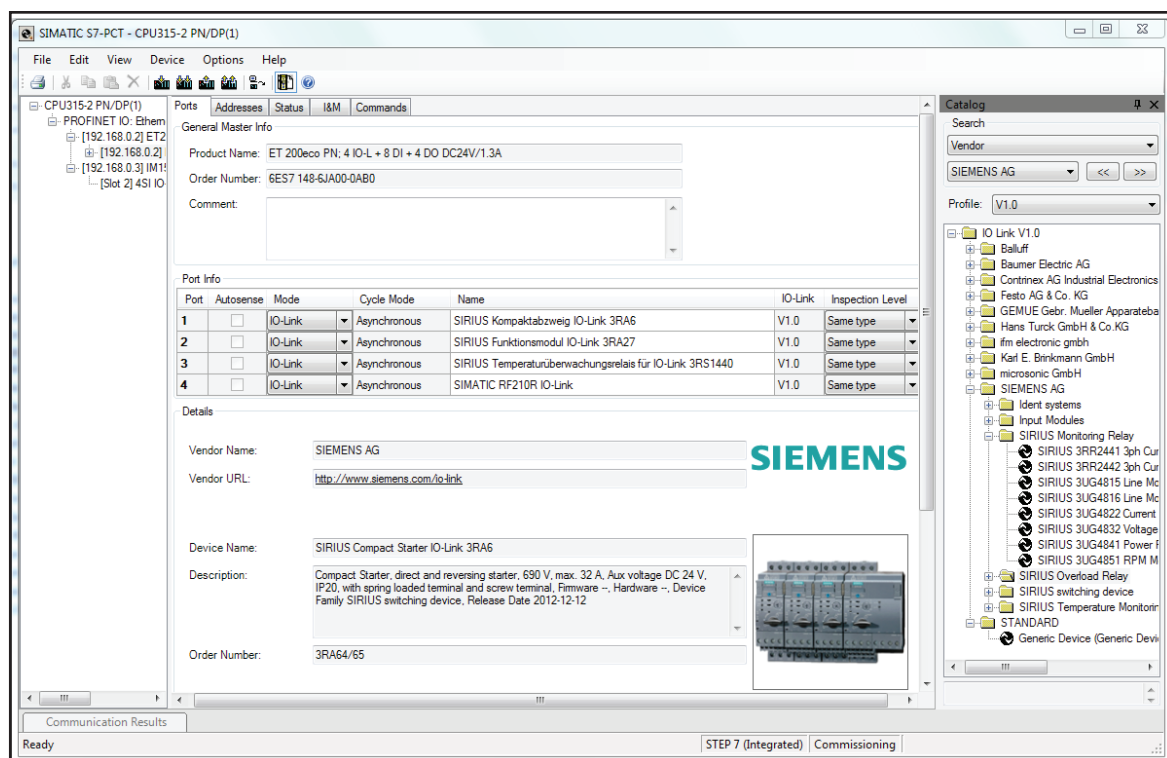


Figure 9: Configuration of an IO-Link master in the configuration tool

Address range of the ports

In addition to assigning the IO-Link devices to the IO-Link master ports, it is also possible to change the previously pre-assigned address ranges of the ports. Within these address ranges, the IO-Link master transmits the process values it receives from the IO-Link device and makes them available to the higher-level automation system.

The address range can be set on the “Addresses” tab.

Assigning the device parameters

Adapting the devices to the particular application task requires specific parameter settings. The possible parameters and setting values are contained in the IODD of the device. After selection of the appropriate device in the project tree (left tree), the device parameters can be assigned on the “Parameters” tab.

Example parameter assignment

Figure 10 shows the parameter assignment screen form of an IO-Link device.

Starting from the pre-assigned settings shown, the values can be changed within the defined value range and saved.

The configuration of the IO-Link system and the parameters of the devices are available to the IO-Link system as well as to the overall automation project. You have the option of saving and printing the configuration and the parameters.

Identification	Parameters	Monitoring	Diagnostics
Parameter	Value	Unit	Status
Parameters			
Parameter Data			
Operating system functions			
index131 - Group diagnostics	enabled		
index131 - Group error diagnos...	enabled		
index131 - Local threshold cha...	enabled		
index131 - Local parameter ch...	enabled		
index131 - Local reset	enabled	!	changed
index131 - Retentive error mem...	enabled	!	changed
index131 - Analog value coding	Tmin [°C] (4)	!	changed
Temperature monitoring			
index131 - Temperature monito...	Overshoot		
index131 - Temperature unit	°C	!	changed
index131 - ON-delay time (at P...	enabled		
index131 - ON-delay time (at m...	enabled		
index131 - ON-delay time	0.0	s	
index131 - Tripping delay time (...)	0.0	s	
index131 - Temperature sensor...	PT1000	!	changed
index131 - Hysteresis	5		
index131 - Relay switching res...	Closed-circuit principle (NC)		
Thresholds			
index131 - Threshold θ1	100	!	changed
index131 - Threshold θ2	40	!	changed
index131 - Warning threshold f...	90	!	changed
index131 - Warning threshold f...	43	!	changed

Figure 10: Assignment of the parameter values of the IO-Link device

3.2 Data access from the automation system and HMI device

Cyclic data exchange

In order to exchange the cyclic process data between an IO-Link device and a controller, the IO-Link data from the IO-Link master is placed on the address ranges assigned beforehand. The user program on the controller accesses the process values using these addresses and processes them. The cyclic data exchange from the controller to the IO-Link device (e.g., IO-Link actuator) is performed in reverse.

Acyclic data exchange

Acyclic data, such as device parameters or events, are exchanged using a specified index and sub-index range. The controller accesses these using system mechanisms (e.g., in the case of online functions such as the reading out of the status). The use of the index and sub-index ranges allows a targeted access to the device data (e.g., for reassigning the device or master parameters during operation).

Programming the user program

In addition to configuring and assigning parameters of the IO-Link system and its integration in the overall automation, it is also necessary to write the user program of the controller. Controller and device manufacturers offer IO-Link function blocks to assist users in the programming of acyclic accesses.

3.3 Changing and backing up device settings during plant operation

Changing the device settings

Device settings can be changed during operation. These settings (parameters) take effect on the device and are retentively saved in the device.

Parameters can be changed during plant operation by:

- Engineering tool (e.g., when commissioning the plant)
- User program of the PLC (program-controlled)
- HMI (by the plant operator for a batch changeover, process optimization)
- Local operator input on the device (through a local operator control unit on the device)

Backing up the device settings

The parameters that are set during engineering or changed during plant operation can also be saved additionally in the master. This backup is carried out according the behavior setting (Backup Level) of the master ports. The following settings are available:

- **OFF**
No backup of the device parameters is made in the master.
- **BACKUP/RESTORE**
After every change of the device parameters, a backup of these data is made automatically in the master (see Section Initiating a backup).
- **RESTORE**
No automatic backup of the device parameters is made in the master.

IO-Link Version	Inspection Level	Backup Level
V1.0	Same type	Off
V1.1	No check	Off
V1.1	Type compatible	Backup&Restore
V1.1	Type compatible	Restore
		Off
		Backup&Restore
		Restore

Figure 11: Setting backup level

Masters and devices according to IO-Link Specification V1.1 provide this backup behavior for backing up device parameters in the master. Masters and devices according to IO-Link Specification V1.0 do not have this function. A data backup cannot be set for these (Backup Level is "OFF").

The behavior during device replacement is also directly dependent on this setting (see Section *Replacement of a device*).

Initiating a backup

Prerequisites for a backup are the correct setting of the backup level of the master port and basic support of this function by the master and device. Backups can be initiated from different places:

- **Engineering tool**
After an engineering download to the device, the device initiates the backup immediately.
- **User program of the PLC**
Parameters of the device can be changed by the user program one after the other. Initiation of a backup requires a system command, however. This system command must be issued by the program at the end of the parameter changes. The transmission of parameter changes and the system command is supported by function blocks of the PLC.
- **HMI**
The same process and behavior applies here as for the user program of the PLC. The plant operator can initiate the necessary system command on the HMI (confirmation of input).

- **Local operator input on the device**
After confirmation of the input on the device, the backup is initiated by the device.

3.4 Replacement of a device or master during operation


Replacement of a device

Device replacement during operation is a common scenario and must not cause an extended downtime of the plant. It should be possible for operating personnel without special knowledge or tools to replace devices quickly and without errors.

When the backup function of the master is used (see Section *Backing up the device settings*), the master automatically provides the saved parameters to the new device again after replacement. The following cases must be distinguished here:

- **BACKUP/RESTORE**
If the backup level of the master port was set to "BACKUP/RESTORE", the new device takes up the same behavior as the replaced device because the master had stored the last parameter change by a "Backup".
- **RESTORE**
If the backup level of the master port was set to "RESTORE", the new device takes up the behavior according to the parameters saved in the master at the time of the last backup. Because possible parameter changes were not saved in the master, a different behavior from the behavior before the replacement may be realized. This can be useful if plant optimizations are enabled temporarily but these are not to be transferred to the plant backup.

It must be generally noted that sensors often have to be adapted to the specific local use conditions (field calibration). These types of adaptations that are not included in the backup



must be restored after device replacement by performing another field calibration. Only then can the replacement device behave completely identically to its predecessor.

Replacement of a master

The replacement of a master during operation represents a less common scenario. Nevertheless, it must not result in extended plant downtimes either, and operating personnel should be able to replace devices quickly and without errors without special knowledge or tools.

Because the master has both its own configuration and parameter data as well as the data of the connected devices, these data can be backed up together in the PLC and be reloaded on the newly installed master after master replacement. PLC providers offer methods (e.g., function blocks) that support upload and download of a complete master backup. For details refer to the documentation of the PLC system or IO-Link master manufacturer.



4 Glossary

Acyclic data	Data transmitted from the controller only after a request (e.g., parameter data, diagnostic data).
COM1-3	IO-Link data transmission rates
Cyclic data	Data that is transmitted by the controller automatically and at regular intervals (process data, value status).
DI	Digital input
DQ	Digital output
GSD file	The properties of a PROFINET device are described in a GSD file (<i>Generic Station Description</i>), which contains all information required for configuring.
HMI	Human machine interface of the automation system
IEC 61131-9	International standard that deals with the basics of programmable controllers. Part 9 describes IO-Link under the designation <i>Single-drop digital communication interface for small sensors and actuators</i> (SDCI).
IODD	Electronic device description of devices (<i>IO Device Description</i>)
IO-Link device	Field device that is monitored and controlled by an IO-Link master.
IO-Link master	Represents the connection between a higher-level fieldbus and the IO-Link devices. The IO-Link master monitors and controls the IO-Link devices.
Parameter Assignment server	An IO-Link master according to IO-Link Specification 1.1 can act as a parameter assignment server for the IO-Link device.
Port	A port is an IO-Link communication channel.

IO-Link System Description – Technology and Application

Version February 2016

Order number 4.392

Publisher

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