



► Safety over EtherCAT (FSoE)

PILZ
THE SPIRIT OF SAFETY

System Description-1006821-EN-01

- Configurable, safe small controllers PNOZmulti 2



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SD means Secure Digital

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1 Introduction

1.1 Terminology

EtherCAT® and Safety over EtherCAT® are registered trademarks and patented technology, licensed by Beckhoff Automation GmbH, Germany.

► Bus system terminology

The description contains various technical terms, which are established and defined by the bus system's user organisation. These include the terms "Master" and "Slave".

1.2 Definition of symbols

Information that is particularly important is identified as follows:



DANGER!

This warning must be heeded! It warns of a hazardous situation that poses an immediate threat of serious injury and death and indicates preventive measures that can be taken.



WARNING!

This warning must be heeded! It warns of a hazardous situation that could lead to serious injury and death and indicates preventive measures that can be taken.



CAUTION!

This refers to a hazard that can lead to a less serious or minor injury plus material damage, and also provides information on preventive measures that can be taken.



NOTICE

This describes a situation in which the product or devices could be damaged and also provides information on preventive measures that can be taken. It also highlights areas within the text that are of particular importance.



INFORMATION

This gives advice on applications and provides information on special features.

2 Safety

2.1 Intended use

With PNOZmulti, a secure communication connection can be established via FSoE. The PNOZmulti FSoE module **PNOZ m EF EtherCAT FSoE** is used for this purpose. It can be used as FSoE Master and FSoE Slave.

2.2 System requirements

Please refer to the "Product Modifications" document in the "Version overview" section for details of which versions of the PNOZmulti Configurator can be used for this product.

2.3 Safety regulations

2.3.1 Safety assessment

Before using a device, a safety assessment in accordance with the Machinery Directive is required.

The product as an individual component fulfils the functional safety requirements in accordance with EN ISO 13849 and EN IEC 62061. However, this does not guarantee the functional safety of the overall plant/machine. To achieve the relevant safety level of the overall plant/machine's required safety functions, each safety function needs to be considered separately.

2.3.2 Use of qualified personnel

The products may only be assembled, installed, programmed, commissioned, operated, maintained and decommissioned by persons who are competent to do so.

A competent person is a qualified and knowledgeable person who, because of their training, experience and current professional activity, has the specialist knowledge required. In order to inspect, assess and handle products, devices, systems, plant and machinery, this person must be familiar with the state of the art and the applicable national, European and international laws, directives and standards.

It is the company's responsibility only to employ personnel who

- ▶ Are familiar with the basic regulations concerning health and safety / accident prevention,
- ▶ Have read and understood the information provided in the section entitled Safety
- ▶ Have a good knowledge of the generic and specialist standards applicable to the specific application.

2.3.3 Warranty and liability

All claims to warranty and liability will be rendered invalid if

- ▶ The product was used contrary to the purpose for which it is intended,
- ▶ Damage can be attributed to not having followed the guidelines in the manual,
- ▶ Operating personnel are not suitably qualified,

- ▶ Any type of modification has been made (e.g. exchanging components on the PCB boards, soldering work etc.).

2.3.4 Disposal

- ▶ In safety-related applications, please comply with the mission time T_M in the safety-related characteristic data.
- ▶ When decommissioning, please comply with local regulations regarding the disposal of electronic devices (e.g. Electrical and Electronic Equipment Act).

2.3.5 For your safety

The unit meets all the necessary conditions for safe operation. However, you should always ensure that the following safety requirements are met:

- ▶ This operating manual only describes the basic functions of the unit. Advanced functions are described in the online help for the PNOZmulti Configurator, in the "PNOZmulti Communication Interfaces" document and in "PNOZmulti Special Applications". Only use these functions once you have read and understood the documentation.
- ▶ Please note the "PNOZmulti Installation Manual".
- ▶ You must note the information stated in the "PNOZmulti Safety Manual".
- ▶ Adequate protection circuit must be provided for all inductive consumers.
- ▶ Do not open the housing or make any unauthorised modifications.
- ▶ Please make sure you shut down the supply voltage when performing maintenance work (e.g. exchanging contactors).

3 Security

To secure plants, systems, machines and networks against cyberthreats it is necessary to implement (and continuously maintain) an overall industrial security concept that is state of the art.

Perform a risk assessment in accordance with VDI/VDE 2182 or IEC 62443-3-2 and plan the security measures with care. If necessary, seek advice from Pilz Customer Support.

3.1 Required security measures

- ▶ The product is not protected against physical manipulation. Use appropriate measures to ensure that there is no physical access by unauthorised persons. You should also use security seals so that you can detect any manipulation of the product or interfaces. Installation inside a lockable control cabinet is recommended as a minimum measure.
- ▶ Make sure that the product is in a closed, secured EtherCAT network.

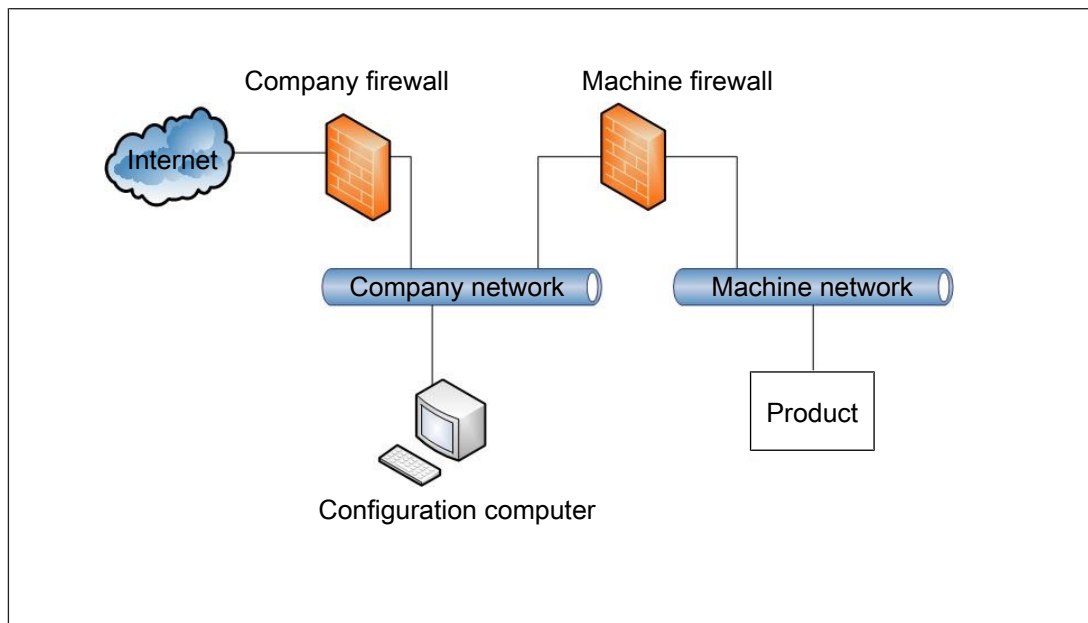


Fig.: Example network topology

- ▶ Note the network data for risk analysis and the security measures.

4 EtherCAT and FSoE

The basic communication functions with EtherCAT conform to the System Description from the EtherCAT User Group.

The EtherCAT network consists of an EtherCAT Master and one or several slaves. The EtherCAT telegram includes standard data, and also safe data (FSoE data) can be transferred via this.

The module PNOZ m EF EtherCAT FSoE can be used as FSoE Master and as FSoE Slave. Also, it is an EtherCAT Slave subscriber.

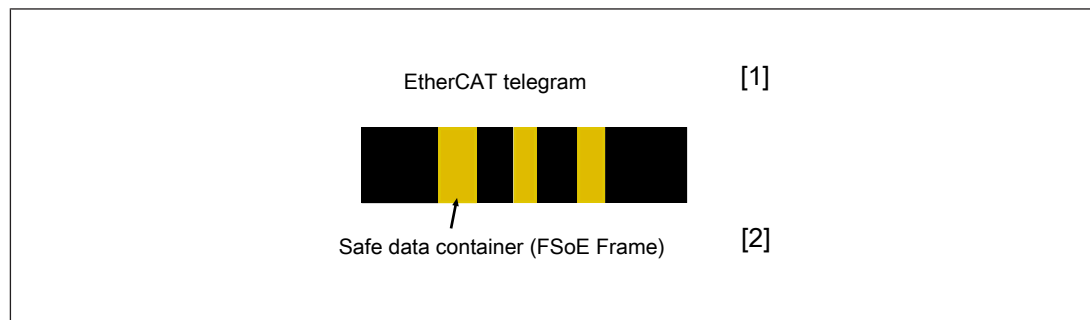
The module PNOZ m EF EtherCAT FSoE can transfer safe data via FSoE and send and receive non-safety-related data via EtherCAT.

The FSoE log is standardised in the standard IEC 61784-3 international and marks a safe communication system to transfer safe process data between FSoE modules. FS is an open technology, supported by the EtherCAT Technology Group (ETG).

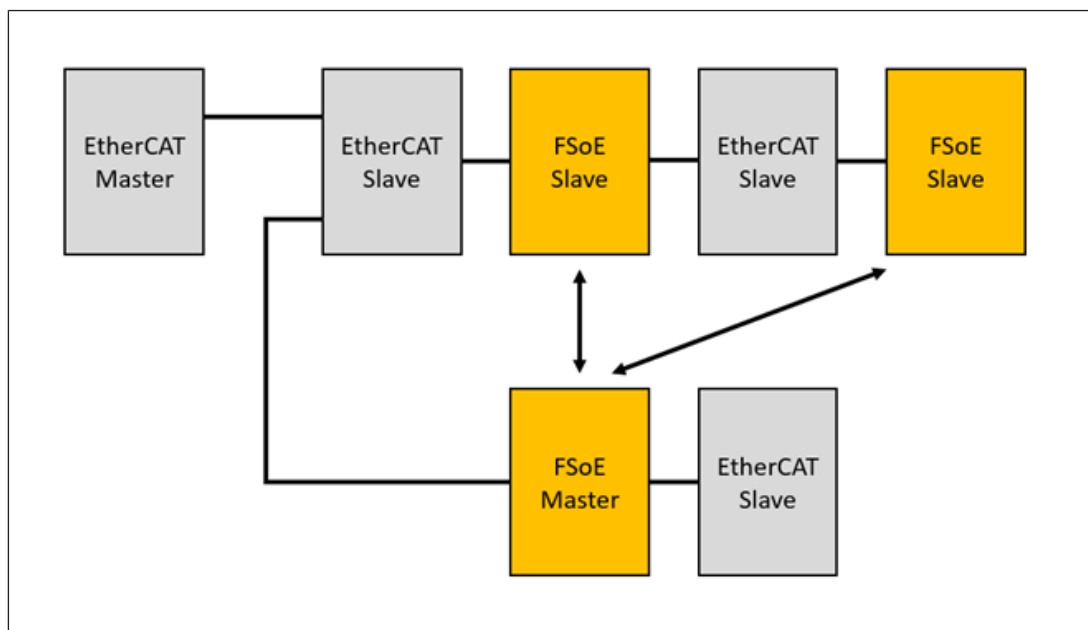
A prerequisite for FSoE communication via the EtherCAT network is a functioning EtherCAT network with an EtherCAT Master.

Within the Standard EtherCAT telegram [1] FSoE data are transported in a safe data container (FSoE Frame) [2].

The FSoE Master initiates communication with a request telegram. The FSoE Master receives the FSoE data from the FSoE Slaves and evaluates them safety-related. The data are available in the PNOZmulti module program PNOZ m EF EtherCAT FSoE.



The FSoE cycle time of the module PNOZ m EF EtherCAT FSoE is a max. of 10 ms. The FSoE connections are monitored using a watchdog to be able to detect interruptions.



An EtherCAT Network requires an EtherCAT Master, it communicates with the EtherCAT Slaves. When failsafe data is to be exchanged via FSoE, an FSoE Master (such as the module PNOZ m EF EtherCAT FSoE) and at least one FSoE Slave are required. The FSoE Master is also an EtherCAT Slave.

The expansion module PNOZ m EF EtherCAT FSoE can be configured as FSoE Master or FSoE Slave.

All the data from the EtherCAT Slaves (also the FSoE subscribers) is transferred via the EtherCAT Master.

Connections to the FSoE Slaves are created in the PNOZmulti Configurator. The corresponding data must be copied or mapped in EtherCAT Master so that the corresponding data from the FSoE Slaves is available to the FSoE Master and vice versa.

5 Network planning

Before the network is configured and installed, a plan of the FSoE network should be created.

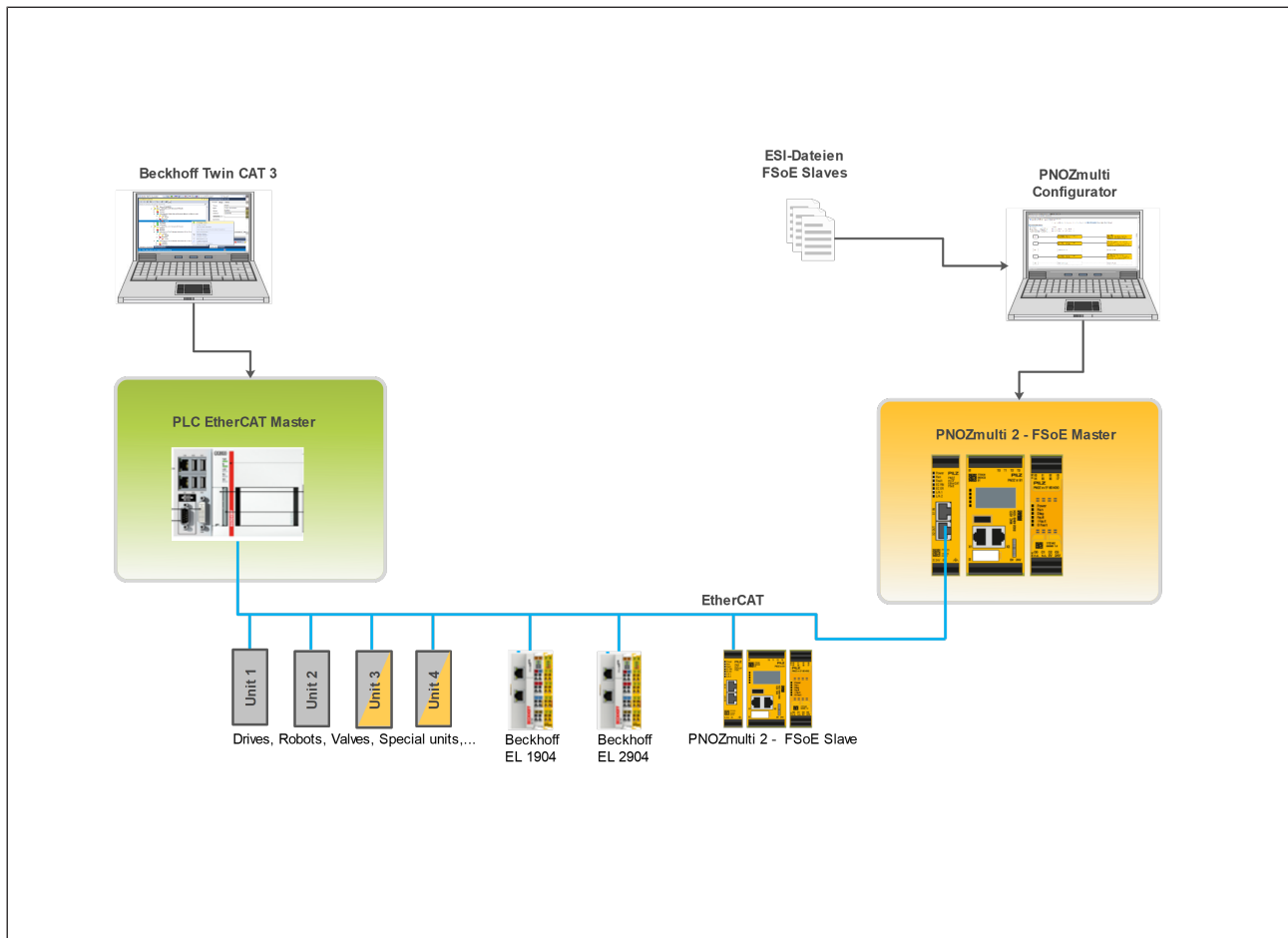
- ▶ Define EtherCAT Master
- ▶ Define FSoE Master
- ▶ Define FSoE Slaves
- ▶ Define FSoE network structure
- ▶ EtherCAT cycle time (corresponds to the slowest module in the network)
- ▶ Define FSoE safety parameters
 - FSoE address
A unique FSoE address must be assigned to each FSoE subscriber
 - Connection ID
A unique Connection ID, independent from the FSoE address, must be assigned to each FSoE subscriber.
 - Watchdog timeout [ms]
The data transfer of a connection is monitored using a watchdog timer. Each subscriber monitors that the communication partner sends a new FSoE frame within the watchdog timeout. When the watchdog timeout has elapsed, the connection will reset. Incoming and outgoing data are set to safe values.
A watchdog timeout must be assigned to each connection (see also [Reaction times](#)  22).

6 EtherCAT and FSoE application example

The following sections use an example to describe how to plan and configure an FSoE application.

In this example, a plant with 4 FSoE subscribers is planned. We recommend that you start with the FSoE configuration, as the slot assignment can be transferred over when configuring the EtherCAT network.

6.1 System overview



The EtherCAT/FSOE network in the example consists of the following components:

► **EtherCAT Master**

- PLC Beckhoff TwinCAT 3 Runtime

► **FSoE subscribers**

- PNOZmulti 2 – FSoE Master
Base unit PNOZ m B1, FSoE module PNOZ m EF EtherCAT FSoE, input/output module PNOZ m EF 8DI4DO
- PNOZmulti 2 – FSoE Slave
Base unit PNOZ m B1, FSoE module PNOZ m EF EtherCAT FSoE, input/output module PNOZ m EF 8DI4DO
- Input module Beckhoff EL1904 – FSoE Slave

– Output module Beckhoff EL2904 – FSoE Slave

6.2 Define network parameters

FSoE addresses

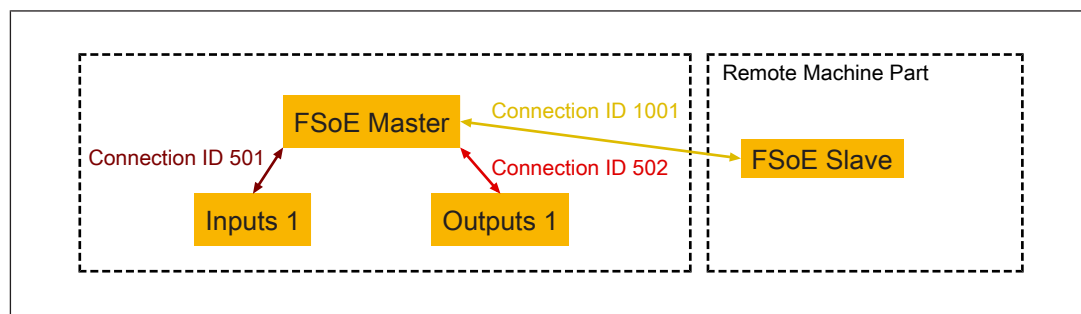
The following FSoE addresses were assigned for the example application:

Device name	FSoE address	Product name
FSoE Master	(no Slave instance)	PNOZ m EF EtherCAT FSoE
Inputs 1	10	EL1904
Outputs 1	20	EL2904
FSoE Slave	100	PNOZ m EF EtherCAT FSoE

Connection IDs and watchdog times

The following values were selected for the FSoE connections in the example application:

Connection Master	Connection Slave	Connection ID	Watchdog
FSoE Master	Inputs 1	501	100 ms
FSoE Master	Outputs 1	502	100 ms
FSoE Master	FSoE Slave	1001	100 ms



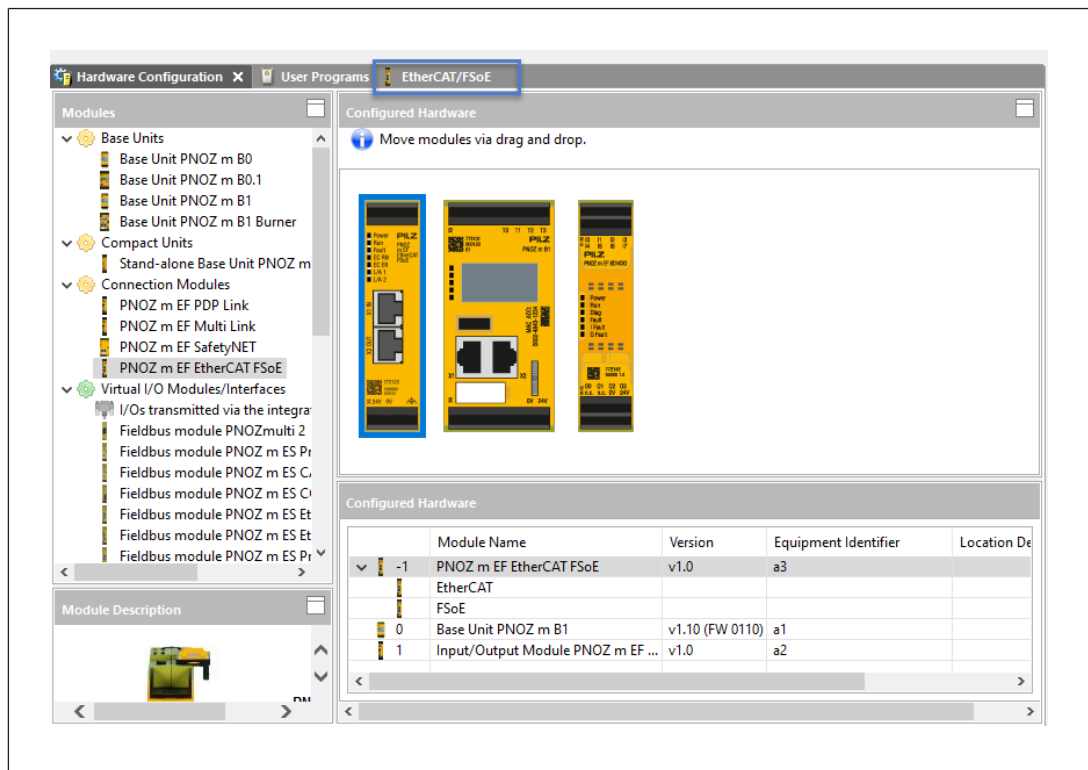
6.3 Configuration of the FSoE project in the PNOZmulti Configurator

6.3.1 Create hardware configuration

Open the hardware configuration and insert the following modules in the **Configured hardware** area:

- ▶ Base unit PNOZ m B1
- ▶ Input/output module PNOZ m EF 8DI4DO
- ▶ Link module PNOZ m EF EtherCAT FSoE

As soon as you insert the module PNOZ m EF EtherCAT FSoE, the **EtherCAT/FSoE** tab appears.



The window can be opened at any time via the menu: **Tools->EtherCAT/FSoE->EtherCAT/FSoE configuration.**

The FSoE connections are then configured in the **EtherCAT/FSoE** window.

6.3.2 Create FSoE Master configuration

The connections with the FSoE slaves are configured in the **EtherCAT/FSoE Master configuration** window. Each FSoE connection is assigned to a slot.

In the example, these are the connections to the FSoE Slaves Beckhoff EL 1904, Beckhoff EL 2904 and the PNOZmulti 2 System - FSoE Slave.

Import and edit FSoE modules in the EtherCAT/FSoE Slave library

► Import ESI file(s)

An ESI file must be imported for FSoE Slave module types that are unknown to the PNOZmulti Configurator.

In the EtherCAT/FSoE Slave library, click on  and select the required file. After the import, the modules from the ESI file are shown in the library.

► Delete ESI files

The imported ESI files are not saved in the project, but in the installation directory of the PNOZmulti Configurator.

To delete ESI files, proceed as follows:

From the **Tools** menu, select **EtherCAT/FSoE -> Open ESI library** and delete the required files.

To update the EtherCAT/FSoE Slave library in the PNOZmulti Configurator, click on .

► Create user-defined FSoE connection

If no ESI file is present, the connection for an EtherCAT/FSoE module can also be created by the user.

To do this, click on .

Please note:

The details, such as the number of safety parameters and their content, must be obtained from the FSoE Slave manufacturer.

Create FSoE connections

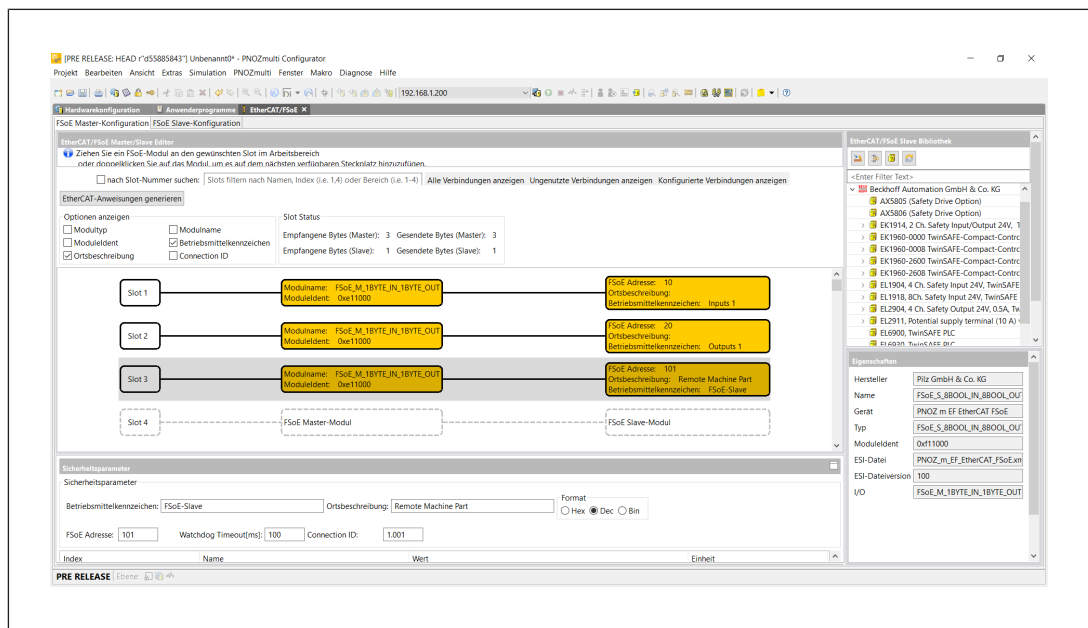
To create the FSoE Slave connections, drag the required FSoE modules from the EtherCAT/FSoE Slave library to the relevant required slots in the workspace.

The slot plays a role when setting up communication via EtherCAT in the EtherCAT Master's tool.

A max. of 60 connections can be created to FSoE Slave devices.

The module PNOZ m EF EtherCAT FSoE can use only the data types "Bit" and "Bool" of the FSoE Slave devices.

The maximum number of application parameters for all the configured FSoE Slave connections is 6000 Bytes.



Parameters and settings options for the connections

For each connection, various parameters and properties are displayed, which can be edited.

Display options

You can select what information is to be shown in the workspace on the connection at the slot.

Slot status

Here it is shown how many received and sent Bytes are already assigned by the configured connections (max. 60 Bytes).

Safety parameters

The safety parameters must be configured for each connection.

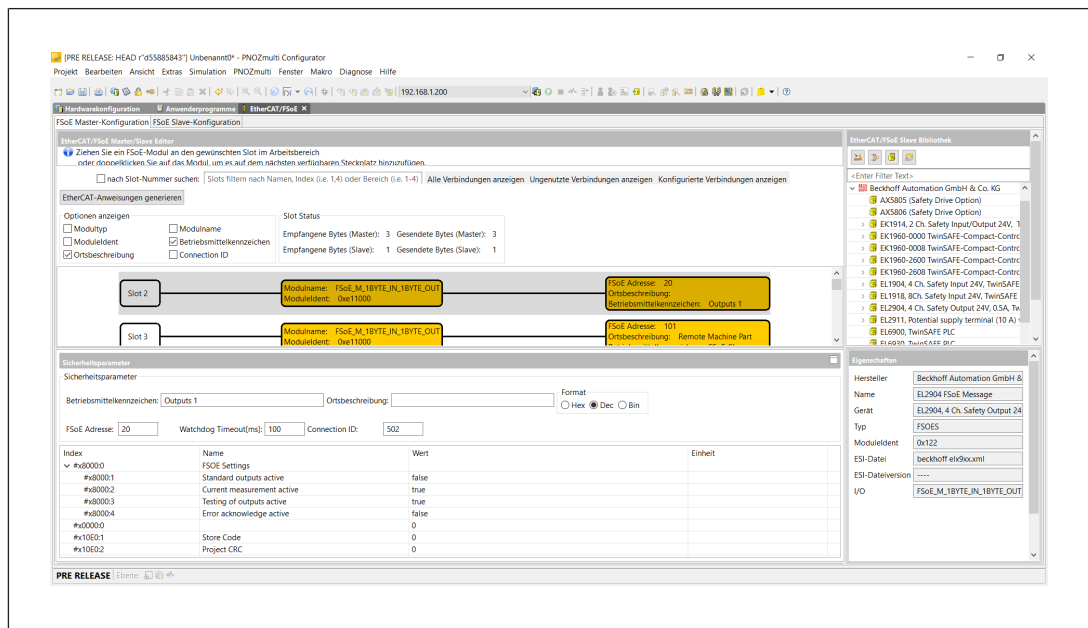
To do this, click on a connection and enter the values stated in the section entitled [Define network parameters](#) [12].

Application parameters

The table contains manufacturer-defined safe application parameters for an EtherCAT/FSoE module.

Click on a connection to display and configure the parameters.

Under **Format** the value can be displayed in binary, decimal or hexadecimal.



6.3.3

Create FSoE Slave configuration

In the window EtherCAT/FSoE Slave configuration, the connections to a PNOZmulti as an FSoE slave are created and configured. Each FSoE connection is assigned to a slot. In the example, this step is taken when the PNOZmulti 2 System - FSoE Slave is configured.



CAUTION!

Please note:

After the connection is interrupted or after an error on an FSoE Slave, the FSoE connection restarts automatically.

An automatic start-up can be prevented in the user program using the FSoE status elements.

Create FSoE connections

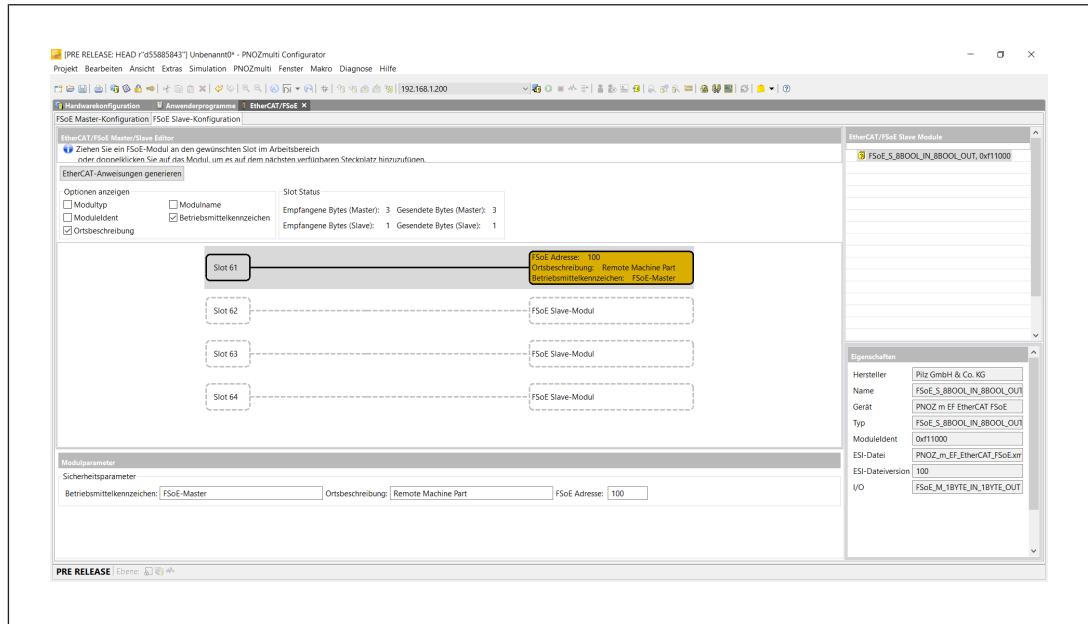
To create the FSoE connections, drag the required FSoE modules from the EtherCAT/FSoE Slave library to the relevant required slots in the workspace.

Later on, the slot will be important again when setting up communication via EtherCAT in the EtherCAT Master's tool.

The FSoE Slave function is implemented by the "Modular Device Profile" ETG 5001 - 195.

The FSoE Slave function does not include safety parameters.

A max. of 4 connections to FSoE Master devices can be created.



Parameters and settings options for the connections

For each connection, various parameters and properties are shown, which can partly be edited.

Display options

You can select what information is to be shown in the workspace on the connection at the slot.

Slot status

Here it is shown how many received and sent Bytes are already assigned by the configured connections.

Safety parameters

The safety parameters must be configured for each connection.

To do this, click on the connection and enter the FSoE address in the section entitled [Define network parameters](#) [12].

Watchdog and Connection ID are set on the connection's FSoE Master.

The FSoE Slaves provide the safety parameters in the ESI file. The safety parameters are described in the documentation for the respective device (FSoE Slave).

6.3.4 Generate EtherCAT instructions

After the FSoE connections have been configured, an EtherCAT instruction file can be generated. This contains all the data for the FSoE connections and helps with the configuration of the EtherCAT network.

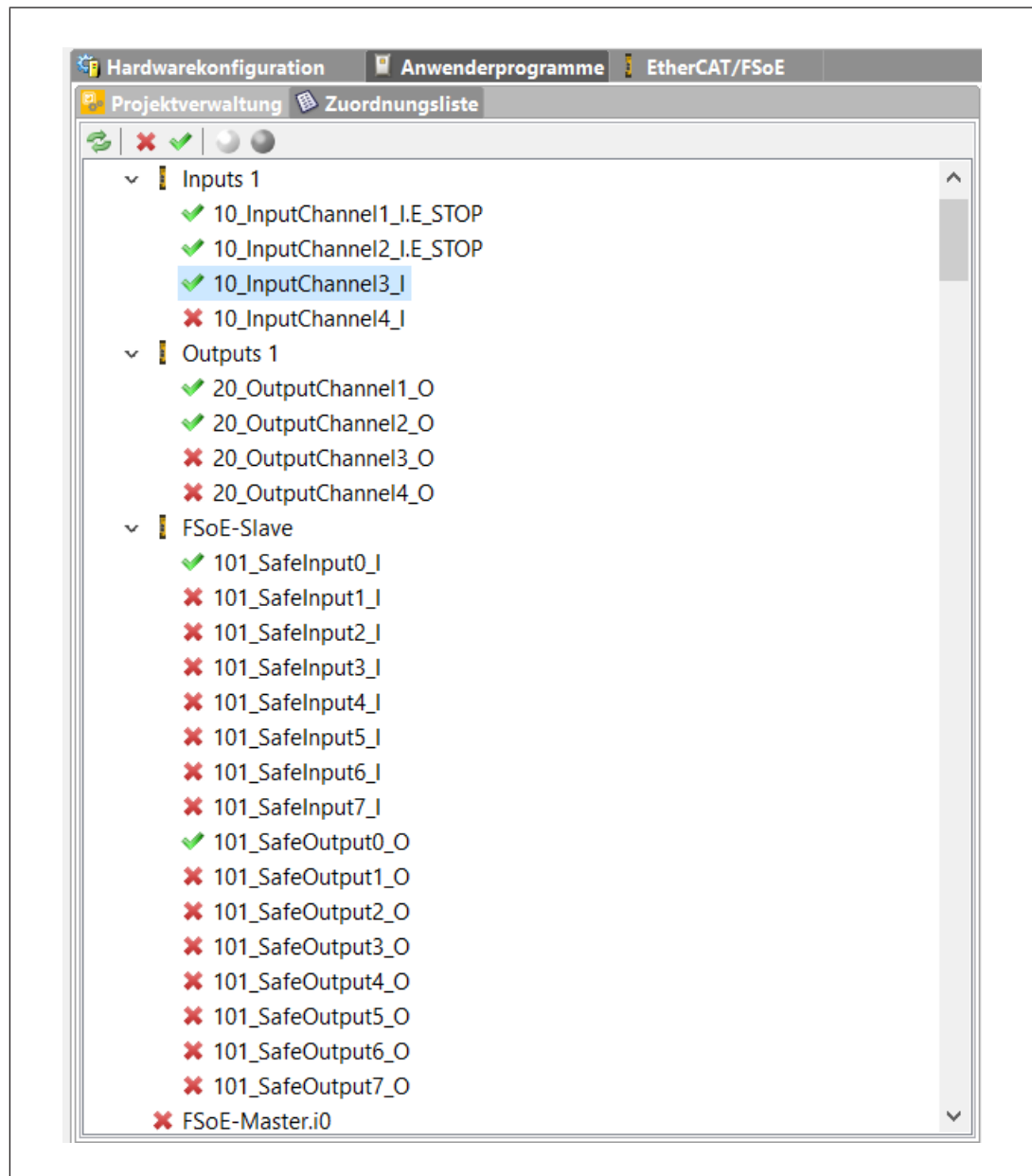
- ⇒ Click on Generate EtherCAT instructions and save the file or copy the text to the clipboard.

6.3.5 Create FSoE user program

After the FSoE is configured, the FSoE user program can be created.

Edit assignment list

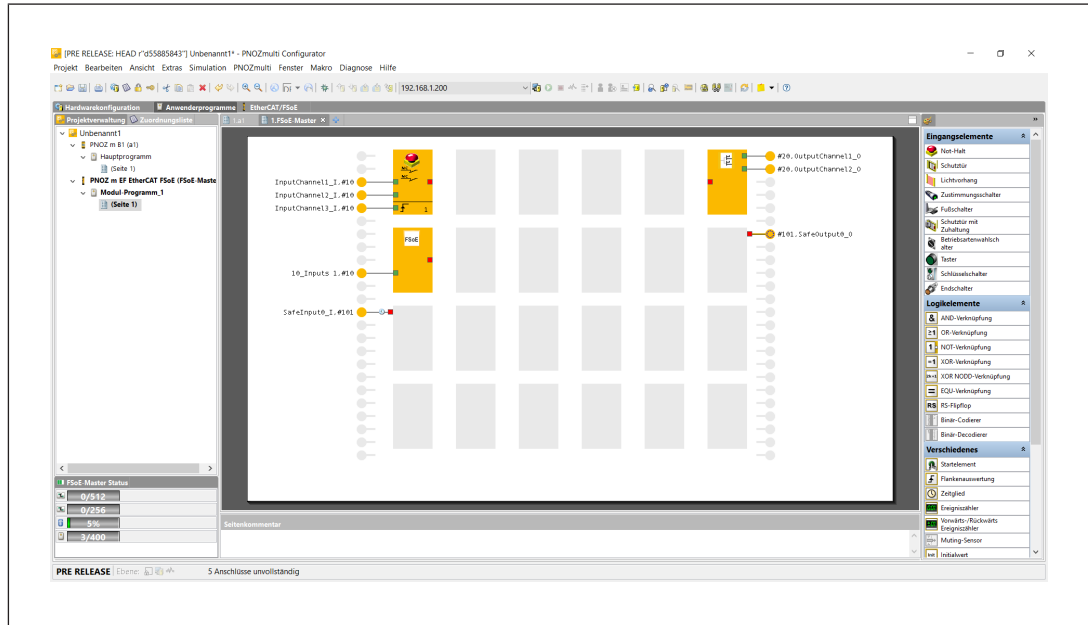
In the assignment list you can define a separate equipment identifier and location description for each bit.



Create FSoE user program in the module program PNOZ m EF EtherCAT FSoE

Create the FSoE user program in the module program of the PNOZ m EF EtherCAT FSoE, by activating the FSoE inputs and outputs of the configured FSoE modules using the inputs and outputs to the far left or right in the user program, or by configuring function elements.

You can link the PNOZ m EF EtherCAT FSoE to the main program via the program connector inputs and outputs.



Configure FSoE status element

A status element can be configured for each FSoE connection. With the element you can evaluate the status of the connection. The output of the element is "1", when safe data is received and sent in the connection. Otherwise, the output is "0".

1. Establish FSoE connections

⇒ In the list of icons under **Miscellaneous**, click on the icon .

2. Place FSoE status

⇒ Drag the icon to an empty cell on the far left of the middle workspace.

A window appears, in which the FSoE status can be configured.

3. Configure FSoE status

⇒ Select the required FSoE connection and enter an Equip-ID and a location description.

6.4

Set FSoE addresses on the FSoE Slaves

The FSoE addresses must be set on the FSoE Slaves, as defined in the section entitled [Define network parameters](#)  12]. For details of the procedure, read the documentation for the FSoE Slaves.

6.5 Incorporate FSoE subscribers in the EtherCAT network using TwinCAT

Now the FSoE subscribers must be incorporated in the EtherCAT network.
In the example, the configuration is made using the TwinCAT 3 tool

Prerequisites:

- ▶ An EtherCAT network has been set up.
The creation of an EtherCAT network is not addressed in this System Description. Knowledge of how to build an EtherCAT network is assumed.
- ▶ The EtherCAT/FSoE configuration was downloaded from the PNOZmulti Configurator to the PNOZmulti.
- ▶ The EtherCAT/FSoE subscribers are connected within the EtherCAT network, switched on and connected to the PC that is running the configuration tool TwinCAT 3.
- ▶ The Beckhoff configuration tool TwinCAT 3 is open.
- ▶ The EtherCAT Master is inserted and configured in TwinCAT 3

Insert FSoE Slaves into the EtherCAT Master configuration

When the EtherCAT Master (PLC Beckhoff TwinCAT 3 Runtime) is incorporated and the EtherCAT network is connected, you can search for EtherCAT Slaves in TwinCAT 3.

⇒ Navigate to the EtherCAT Master in the **Project folder explorer** and select **Scan** from the context menu.

The EtherCAT Slaves in the EtherCAT network are incorporated into the EtherCAT Master configuration. On the PNOZ m EF EtherCAT FSoE, the FSoE modules used in the slots are recognised and assigned.

Connect EtherCAT process data objects (PDOs) from FSoE Slaves and FSoE Master

The PDOs from the FSoE Slaves must now be connected to the PDOs from the FSoE Master. Each FSoE subscriber has TxPDOs and RxPDOs

The PDOs must be connected for both directions. To send the data from the FSoE Master to the FSoE Slave and vice-versa.

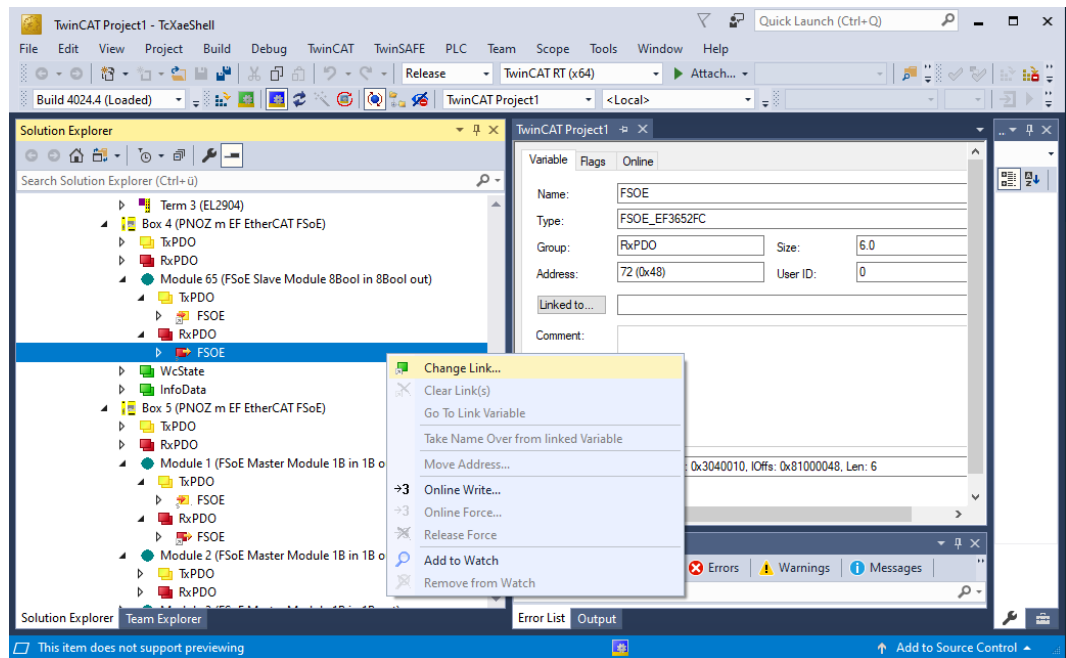
This means that the TxPDO from the FSoE Master must be connected to the RxPDO from the FSoE Slave and vice-versa.

Details of which PDOs to connect can be taken from the **EtherCAT instructions** generated in the PNOZmulti Configurator under: **FSoE Master – FSoE Slave connections**.

See also [Generate EtherCAT instructions](#)  17].

To connect the PDOs, follow the instructions below:

- Right-click on which RxPDO or TxPDO from an FSoE Slave is to be connected, and select **Change Link** from the context menu.

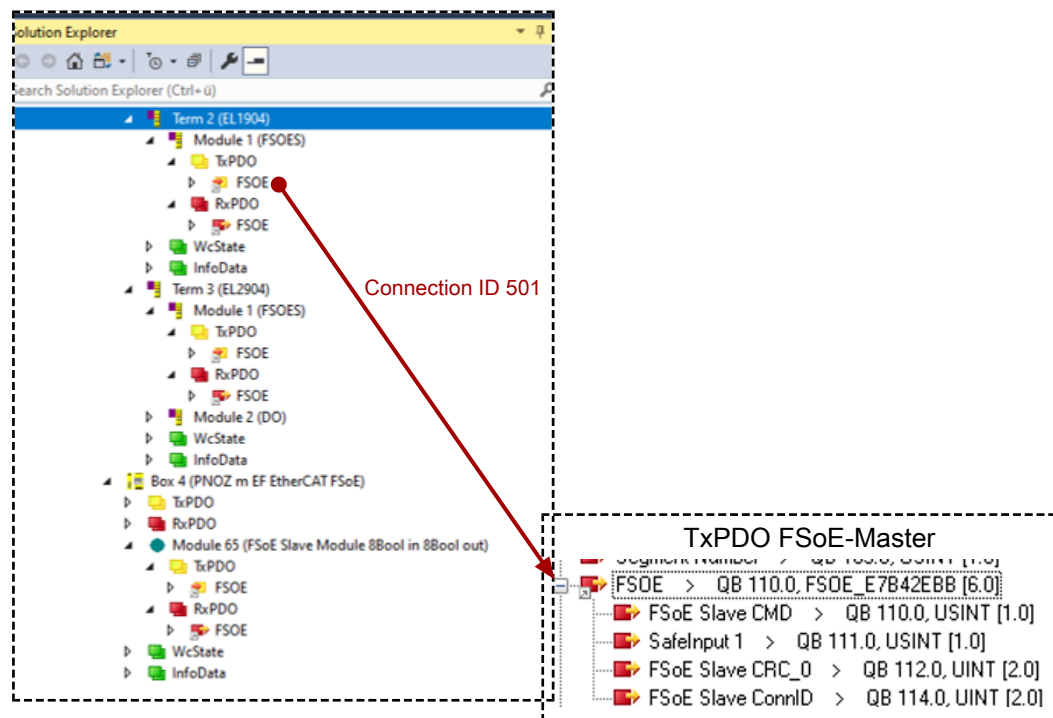


The **Add FSoE variable** window will open. This is where the PDOs from the FSoE Master are listed.

- In the **Add FSoE variable** window, select which TxPDO or RxPDO from the FSoE Master is to be connected.

Please note the following when connecting the PDOs:

- To display the required PDOs, the **Exclude same Image** option must be deselected
- When several devices of the same type are used, take care when linking the FSoE address.
- The PDOs must be linked for both directions. To send the data from the FSoE Master to the FSoE Slave and vice-versa.
TxPDO < - - - > RxPDO and RxPDO < - - - > TxPDO



7 Reaction times

The maximum EtherCAT FSoE reaction time consists of the delay times of the components involved, including communication.

The following times must be included in the calculation:

- ▶ EtherCAT cycle time
- ▶ Delay time PNOZ m EF EtherCAT FSoE
- ▶ Delay time FSoE Slave
- ▶ FSoE Master watchdog time

The detailed reaction times are described in the System Expansion document.



WARNING!

Hazard due to loss of the safety function

When calculating, note that the FSoE reaction time is influenced by a change in the EtherCAT cycle time!

8 Troubleshooting

If an error occurs in the FSoE connection, proceed as follows:

Problem / Status	Remedy
Determine the affected FSoE connection	▶ Start dynamic program display and determine the affected FSoE connection
Watchdog error	▶ Adapt EtherCAT cycle time ▶ Check the watchdog times of the FSoE Slave ▶ Adapt the watchdog times in the FSoE Master ▶ Check the project size and examine the load on the FSoE devices.
Determine the state of the FSoE connection	In the CANopen EtherCAT Master, query the objects 0xAnn0
FSoE connection in the state RESET + SESSION	▶ Check whether the FSoE Slave is signalling a failsafe problem ▶ Check whether the FSoE frames in the EtherCAT Master are compatible and are copied correctly
FSoE connection in the state CONNECTION	▶ Check whether the FSoE address in the FSoE Master is set correctly ▶ Check that the Connection ID has not already been configured for another connection.
FSoE connection in the state PARAMETER	With the following checks, refer to the documentation of the third-party manufacturer. ▶ Check whether the right FSoE Slave module has been selected. ▶ Check whether the watchdog time of the FSoE Slave has a valid value. ▶ In the case of a custom connection, check whether the safety parameters are correct.
FSoE connection in the state FAILSAFE	▶ Check whether the FSoE Slave requires an acknowledgement in order to switch to a run state ▶ Check whether the FSoE Slave is signalling a failsafe problem
FSoE connection in the state DATA	▶ The FSoE connection is established ▶ No errors are present.

Read CANopen objects 0xAnn0

The state of the FSoE connection can be queried via the EtherCAT Master with the help of the CANopen objects 0xAnn0.

The digits **nn** stand for the number of the FSoE connection (e.g. 0xA010 for the FSoE connection numbered 1).

There are two entries in the object 0xAnn0:

Connection State

indicates the state of the FSoE connection (e.g. **RESET + SESSION**)

Connection Diagnosis

The bits are divided as follows:

Connection Dia- gnosis	Bit 7 ... 5	Bit 4 ... 5	Bit 0 ... 3
	0:No Error 2:Establishing Con- nection FSoE Connection in Failsafe State 1:FSoE Slave 4:FSoE Master 5:Both	0:No Error or 0>Error in Master Connection 1>Error in Slave Con- nection	0:No Error 1:Wrong Command 2:Unknown Com- mand 3:Wrong Connection ID 4:Wrong CRC 5:Watchdog Expired 6:Wrong FSoE Ad- dress 7:Wrong Data 8:Wrong Communic- ation Parameter Length 9:Wrong Communic- ation Parameter Length 10:Wrong Application Parameter Length 11: Wrong Applica- tion Parameter 12:Unexpected Ses- sion Command 13:Failsafe Data Re- ceived

Support

Technical support is available from Pilz round the clock.

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