

Manual | EN

FC1428

PCIe EtherCAT Master Card

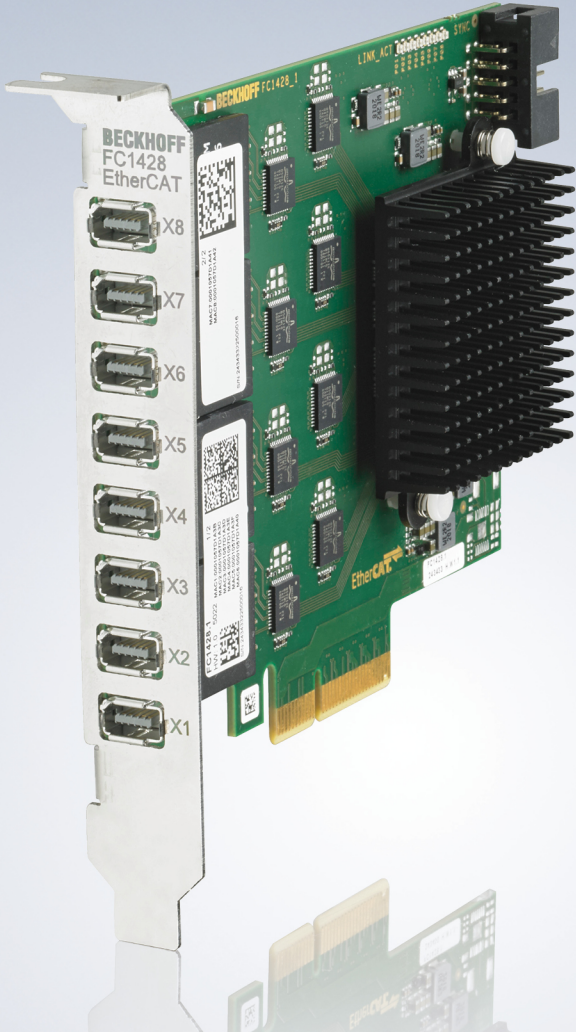


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1 Notes on the documentation

This description is intended exclusively for trained specialists in control and automation technology who are familiar with the applicable national standards.

For installation and commissioning of the components, it is absolutely necessary to comply with the documentation and the following notes and explanations.

The qualified personnel is always obliged to use the currently valid documentation.

The responsible staff must ensure that the application or use of the products described satisfies all safety requirements, including all the relevant laws, regulations, guidelines, and standards.

Disclaimer

The documentation has been prepared with care. The products described are, however, constantly under development.

We reserve the right to revise and change the documentation at any time and without notice.

No claims to modify products that have already been supplied may be made on the basis of the data, diagrams, and descriptions in this documentation.

Trademarks

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Patents

The EtherCAT Technology is covered by the following patent applications and patents, without this constituting an exhaustive list:

EP1590927, EP1789857, EP1456722, EP2137893, DE102015105702

and similar applications and registrations in several other countries.

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1.1 Representation and structure of warnings

The following warnings are used in the documentation. Read and follow the warnings.

Warnings relating to personal injury:

⚠ DANGER

Hazard with high risk of death or serious injury.

⚠ WARNING

Hazard with medium risk of death or serious injury.

⚠ CAUTION

There is a low-risk hazard that can result in minor injury.

Warnings relating to damage to property or the environment:

NOTICE

There is a potential hazard to the environment and equipment.

Notes showing further information or tips:



This notice provides important information that will be of assistance in dealing with the product or software. There is no immediate danger to product, people or environment.

1.2 Documentation issue status

Version	Comment
1.0	First version

2 Product overview

The FC1428 EtherCAT card can be used to integrate an industrial PC into an EtherCAT G network as a master. The card has over 8 EtherCAT G channels and a total of eight ix-Industrial® type A connectors. Adapter cables are required to connect the EtherCAT devices (see: [Accessories \[▶ 27\]](#)).

A total of 8 EtherCAT G masters are available with the FC1428 EtherCAT card. The EtherCAT masters are fully DC synchronous. No external synchronization is necessary in order to synchronize the EtherCAT masters or EtherCAT segments with one another. This function is particularly useful for XPlanar systems that require synchronously running EtherCAT masters. The FC1428 EtherCAT card can also be used to provide EtherCAT redundancy.

2.1 Structure

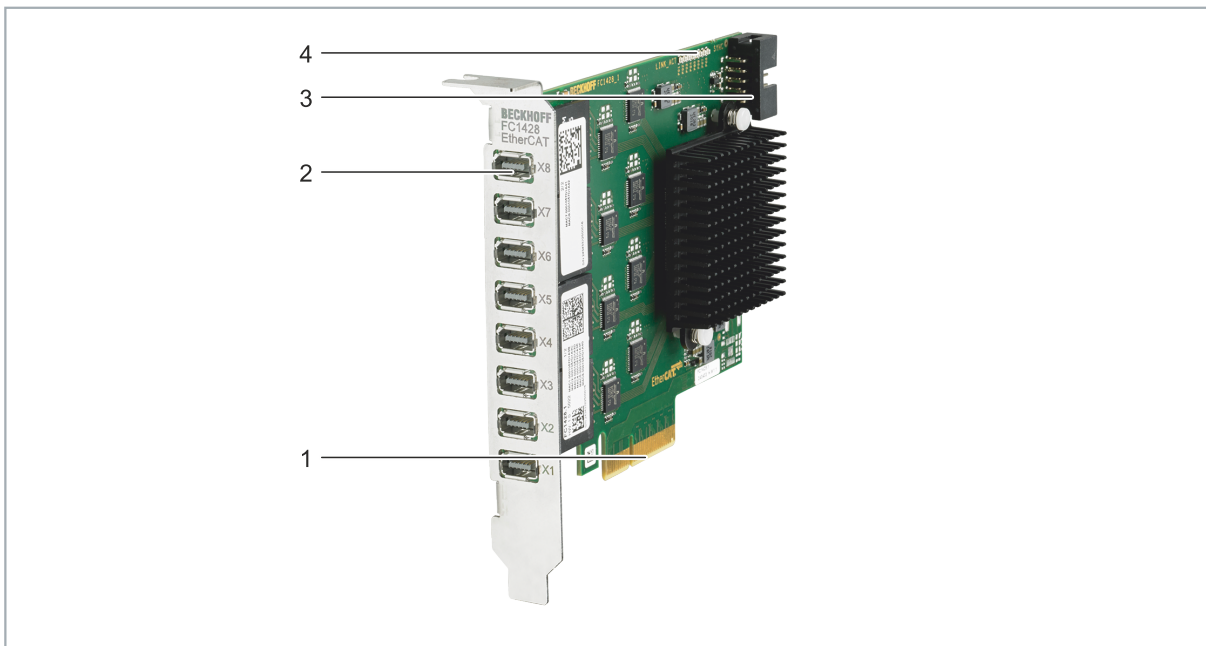


Fig. 1: Example structure of a FC1428 EtherCAT card.

Table 1: Key for the structure of the FC1428 EtherCAT card.

No.	Component	Description
1	PCI Express x4 bus	Requires a PCIe x4 slot that meets the PCIe 2.0 standard.
2	ix Industrial® interface	8 x ix-Industrial® type A interfaces. A total of 8 EtherCAT masters can be executed per interface.
3	2 x 5-pin contact strip	Synchronization interface for synchronization of multiple FC1428 EtherCAT cards.
4	Diagnostic LEDs	The P01 to P08 LEDs indicate the status of the connection (see: Diagnostic LEDs [▶ 25]).

2.2 Interfaces

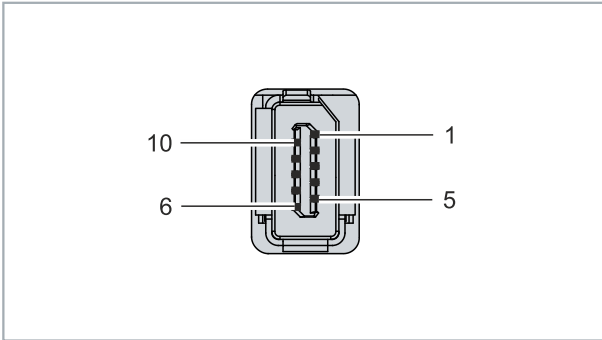


Fig. 2: EtherCAT interfaces, X1 to X8.

Table 2: EtherCAT interfaces X1 to X8, PIN assignment.

PIN	Signal	Assignment according to EIA/TIA-568B
1	BI_DA+	white/orange
2	BI_DA-	orange
3	GND	-
4	BI_DC+	blue
5	BI_DC-	white/blue
6	BI_DB+	white/green
7	BI_DB-	green
8	GND	-
9	BI_DD+	white/brown
10	BI_DD-	brown

ZK1096-969A-0005 connection cable

The ZK1096-969A-0005 connection cable is used to convert an x-Industrial® plug (P1) into an RJ45 socket (P2). For other cable variants, see: [Accessories](#) [▶ 27].

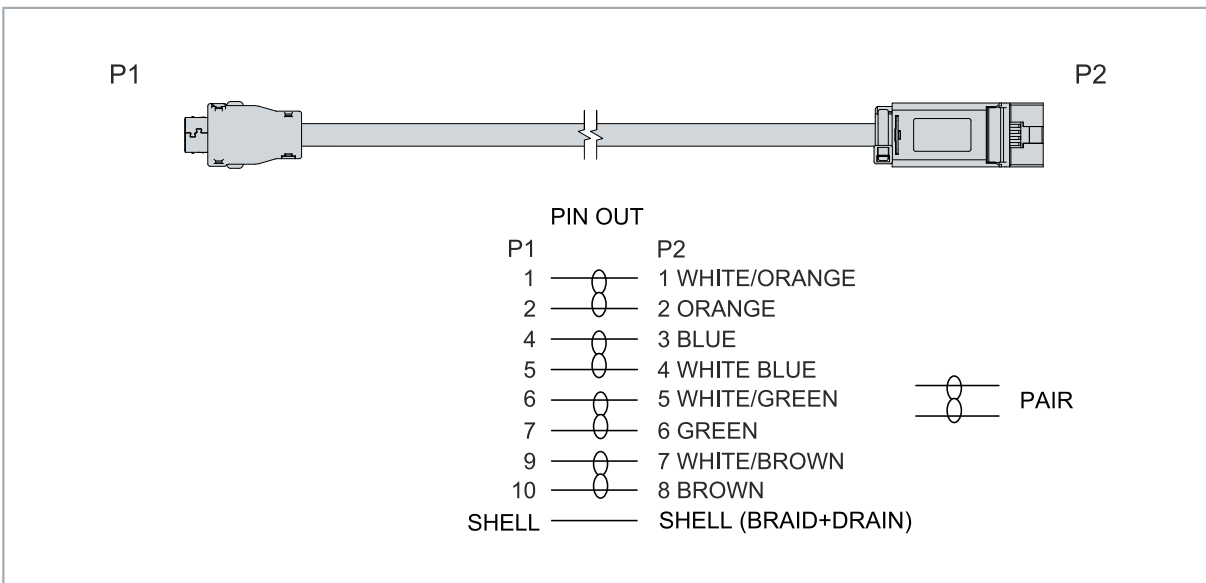


Fig. 3: ZK1096-969A-0005 connection cable, structure and PIN assignment.

3 Commissioning

3.1 Assembly

NOTICE

Electrostatic discharge

Electrical components can be damaged by electrostatic discharge. Observe ESD protection measures during assembly. Ensure the environment is well-grounded with ESD-compliant floors, gloves, clothing and workstations.

The FC1428 EtherCAT card requires a PCIe x4 slot that complies with the PCIe 2.0 standard. In principle, the card can also be operated in longer slots, i.e. in PCIe x8 or PCIe x16 slots. The slots simply need to support four PCIe lanes.

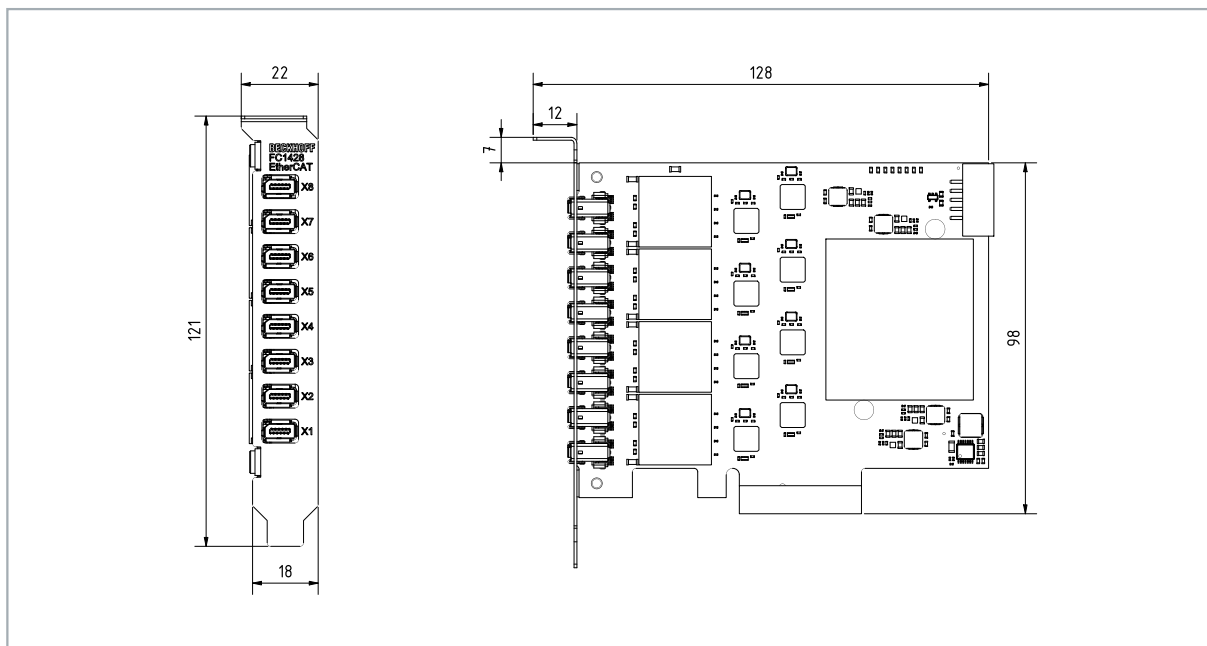


Fig. 4: FC1428 EtherCAT card, dimensions.

The EtherCAT card does not require an external power supply. The card is supplied directly from the industrial PC via the PCIe bus. The power supply of the industrial PC has to be sufficient in order to meet the power requirement of the EtherCAT cards, particularly if several EtherCAT cards are installed.

Proceed as follows:

1. Before installing the EtherCAT card, switch off the industrial PC and any external power supplies, and disconnect the PC from the mains.
 2. Open the housing of the industrial PC and remove the cover plate on a free PCIe slot in the motherboard in the housing wall of the industrial PC.
 3. Insert the EtherCAT card into the free PCIe slot and fix it with the screw or device provided. Make sure that there is enough space between the EtherCAT card and other PC components so that the EtherCAT card cannot touch any other plug-in cards or motherboard components.
- ⇒ After a restart, the EtherCAT card is automatically detected. No additional drivers need to be installed.

3.2 Wiring

Type C9900-K918 connection cables are required to connect the EtherCAT devices. The connection cable is a cable with an ix-Industrial® type A plug to 1 x Cat.6 RJ45 socket.

Table 3: Accessories connection cable, ordering information.

Ordering information	Description
ZK1096-969A-0005	Industrial Ethernet/EtherCAT G/G10 cable, Cat.6A, PUR, 4 x 2 x AWG26, fixed installation, RJ45, coupling, straight, female, 8-pin - ix Industrial® type A, plug, straight, male, 10-pin, 0.5 m
ZK1096-819A-0xxx	Industrial Ethernet/EtherCAT G/G10 cable, Cat.7, PUR, 4 x 2 x AWG26, fixed installation, M12, plug, straight, male, 8-pin, X-coded - ix Industrial® type A 10-pin plug
ZK1096-9191-0xxx	Industrial Ethernet/EtherCAT G/G10 patch cable, Cat.6A, PUR, 4 x 2 x AWG26, fixed installation, RJ45, plug, straight, male, 8-pin - RJ45, plug, straight, male, 8-pin
ZK1096-9191-3xxx	Industrial Ethernet/EtherCAT G/G10 patch cable, Cat.6A, PVC, 4 x 2 x AWG26, fixed installation, RJ45, plug, straight, male, 8-pin - RJ45, plug, straight, male, 8-pin

The card has a total of eight ix-Industrial® type A interfaces, allowing up to 8 EtherCAT networks to be connected to the eight interfaces.

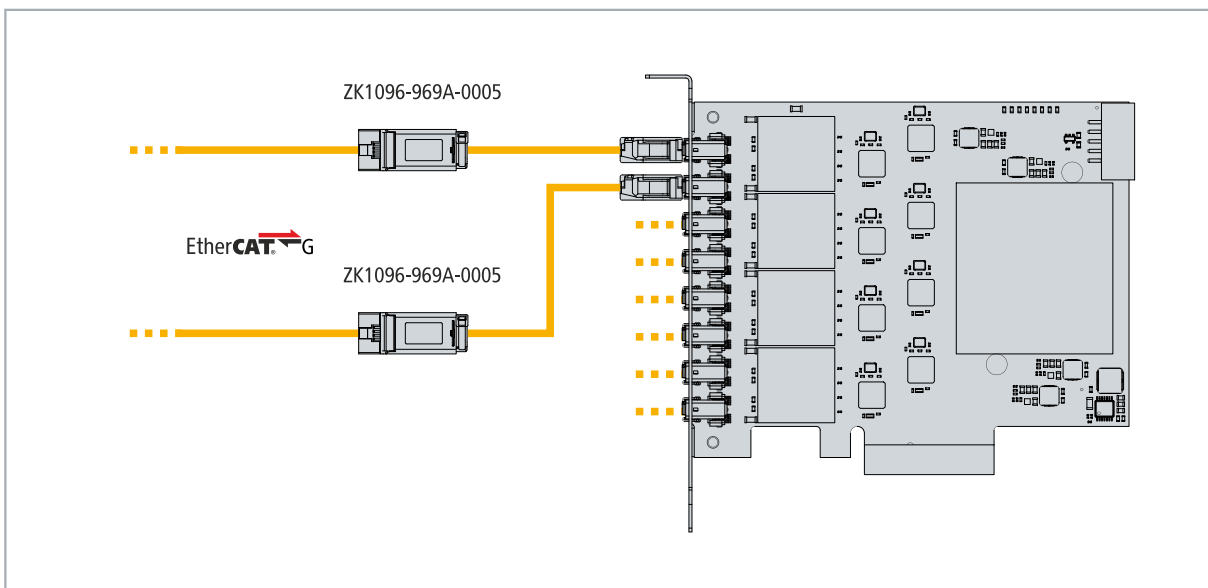


Fig. 5: Connection example with two adapter cables of type ZK1096-969A-0005.

3.3 Driver note

No drivers have to be installed for the operation of the FC1428 EtherCAT card. The card is ready for operation immediately after mounting. Note that the card is not displayed in the Device Manager or as a network interface under Windows, but the card can be used under TwinCAT (see: [TwinCAT configuration](#) [► 13]).

3.4 BIOS settings

For industrial PCs that are delivered ex factory with the FC1428 EtherCAT card, the BIOS is configured appropriately so that the card functions properly.

If you retrofit a Beckhoff Industrial PC with a FC1428, you must adjust or check the settings in the BIOS to ensure that the EtherCAT card functions properly. Without the appropriate BIOS settings, the card will not be ready for operation and cannot be used in TwinCAT.

Adjust BIOS settings:

1. Restart your industrial PC and press **[Del]** to start the BIOS setup.

2. If the **[Del]** key does not work, another key is displayed on the screen in all cases, and this key can be used to access the BIOS setup.
 3. Navigate to the PCI Configuration menu
 4. Disable the **Memory Mapped I/O above 4 GB** option.
 5. Press **[F4]** to save the settings and exit the BIOS setup.
- ⇒ The industrial PC is restarted. With these settings, the FC1428 EtherCAT card is ready for operation and can be used under TwinCAT.

4 TwinCAT configuration

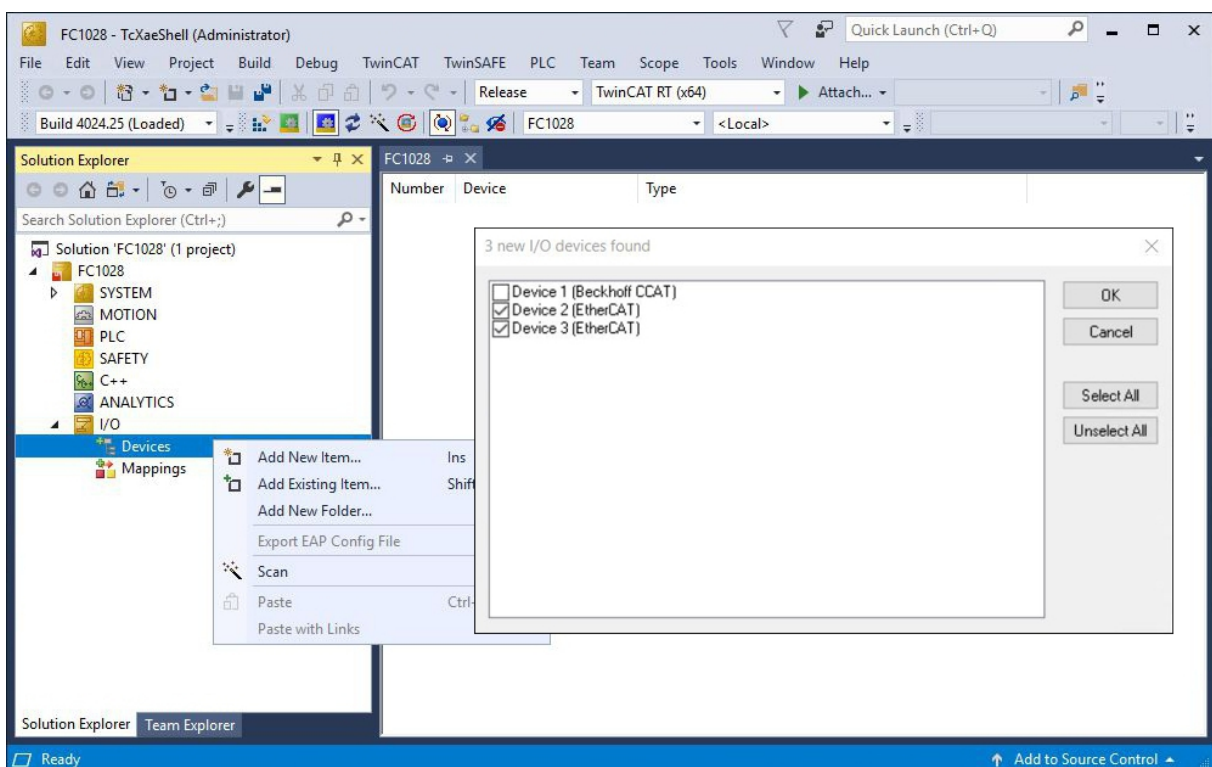
4.1 Scan card in TwinCAT

This step shows how to scan an FC1428 EtherCAT card in TwinCAT and how to create the EtherCAT masters automatically. For the scan to be successful, active EtherCAT slaves must already be connected to the interfaces of the card. Otherwise the EtherCAT telegram from an inactive slave is not answered and the EtherCAT master is not created in TwinCAT.

You should have completed the hardware configuration, so that the scan runs successfully and all EtherCAT masters and the EtherCAT slaves connected to them are created in TwinCAT.

Proceed as follows:

1. Start TwinCAT and open an empty project.
2. In the tree view on the left, right-click on **I/O Devices**.
3. Click on **Scan** in the context menu.



In this example, two EtherCAT masters are found because active EtherCAT slaves are connected to them.

4. Select the devices that you want to use and confirm the selection with **OK**.
Devices that are actually available are always available for selection.
 5. Confirm the request with Yes in order to look for box modules.
 6. Confirm the request on whether FreeRun should be enabled with Yes.
- ⇒ The FC1428 card has been scanned successfully in TwinCAT and is displayed with the available EtherCAT masters.

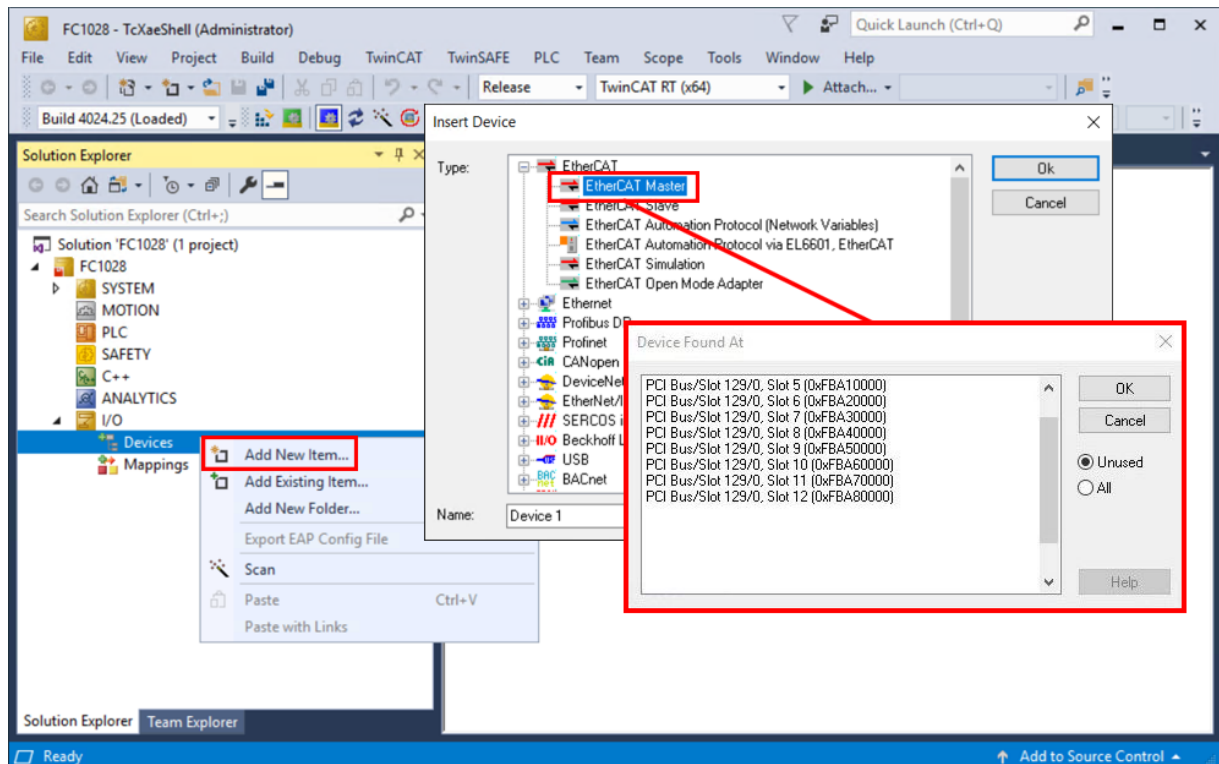
4.2 Insert EtherCAT master manually

This chapter shows how you can manually create an FC1428 EtherCAT card and its EtherCAT master if no active EtherCAT slaves are connected to the card. This is particularly necessary if you already want to start with the project planning and the complete hardware configuration is not available.

This is in contrast to the automatic scanning of the card in TwinCAT (see: [Scan card in TwinCAT](#) [▶ 13]).

Proceed as follows:

1. Start TwinCAT and open an empty project.
2. In the tree view on the left, right-click on **I/O Devices**.
3. Click **Add New Item** and select **EtherCAT master** to create an EtherCAT master. The window **Device Found At** appears.

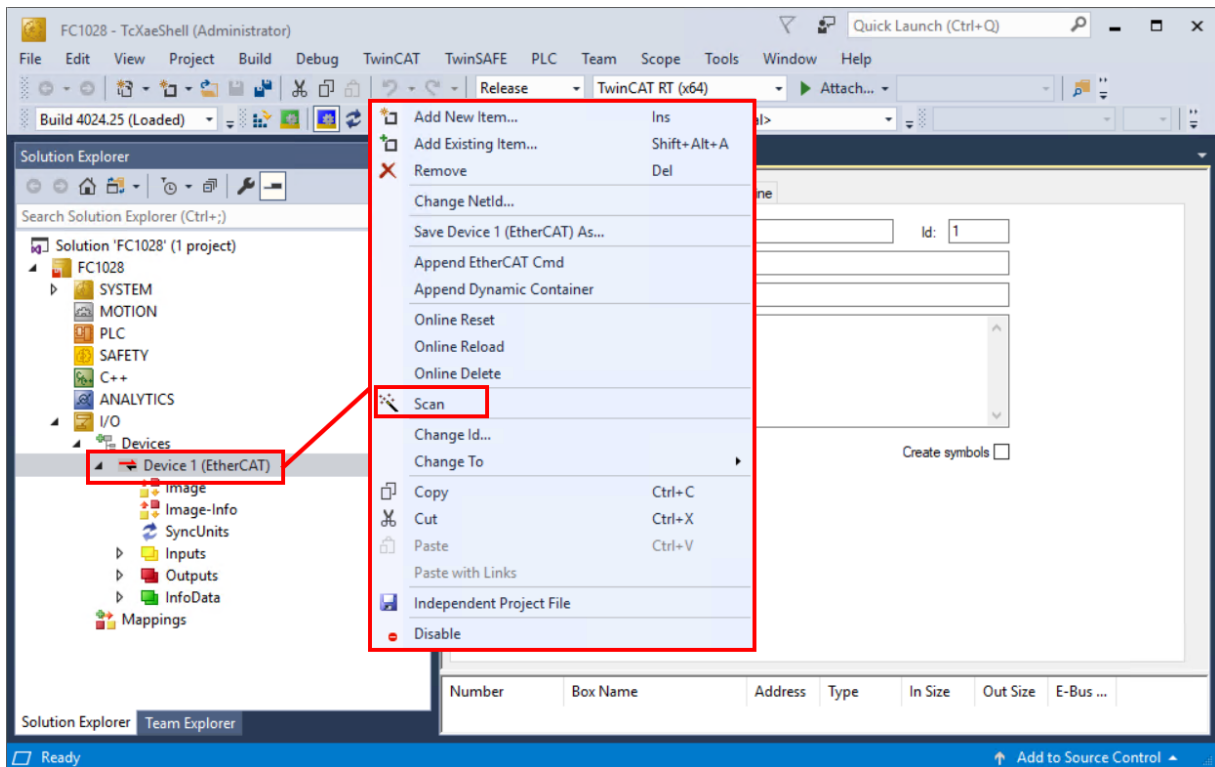


4. Select the appropriate interface from the list according to the subsequent cabling. The list of interfaces is continued chronologically from 5 to 20, which corresponds to the total of 16 EtherCAT masters of the card.

Note: The card has a total of eight ix-Industrial® type A interfaces, thus up to 16 EtherCAT devices can be connected to the eight interfaces.

5. Create additional or required EtherCAT masters in TwinCAT in this way.

- ⇒ You can start project planning at this point. As soon as the complete hardware configuration is available, you can scan each EtherCAT master and thus start the search for the EtherCAT slaves connected to it.



The EtherCAT slaves are created in TwinCAT according to your hardware configuration and the cabling under the respective EtherCAT masters.

4.3 Use cable redundancy

The FC1428 EtherCAT card has independent EtherCAT interfaces that can be used for EtherCAT cable redundancy. Cable redundancy offers resilience for cabling. Interruptions of the EtherCAT communication due to wire break or unplugged LAN cables are avoided. Interference at the individual terminals is not intercepted by the cable redundancy.

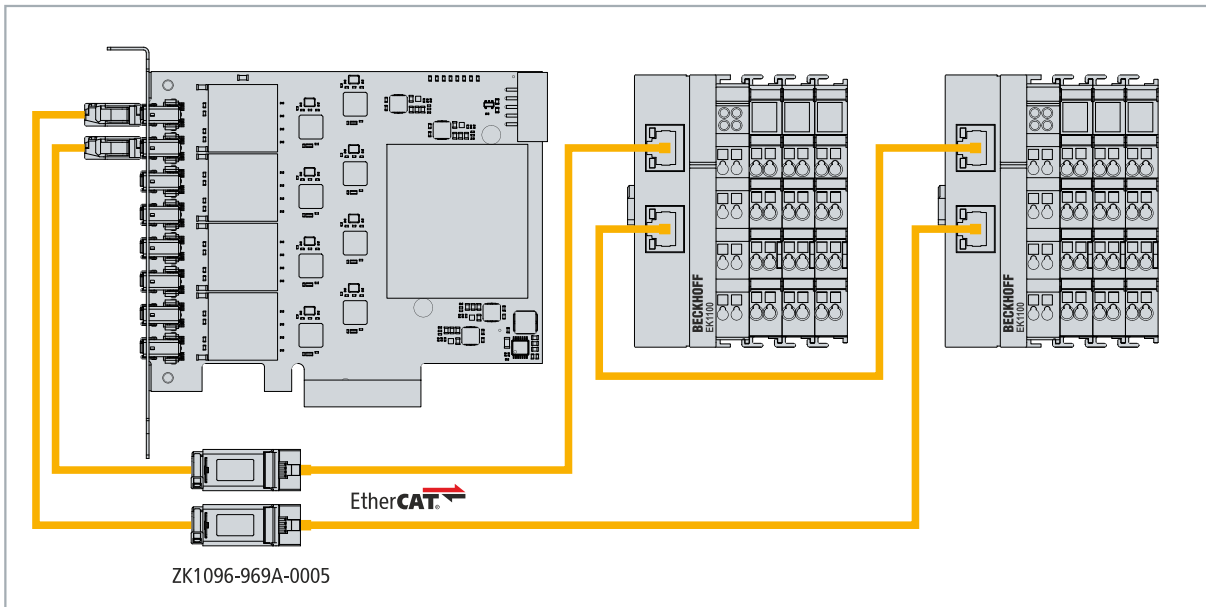


Fig. 6: Example configuration of a FC1428 with EtherCAT cable redundancy.

In the example configuration the hardware is wired as an EtherCAT ring. For this EtherCAT ring, two EtherCAT masters of the FC1428 are occupied. This intercepts failures in the cabling beyond the adapter cable. In this way, for example, a wire break between the two EtherCAT Couplers has no effect on the EtherCAT communication.

Table 4: Cable redundancy, hardware for sample configuration.

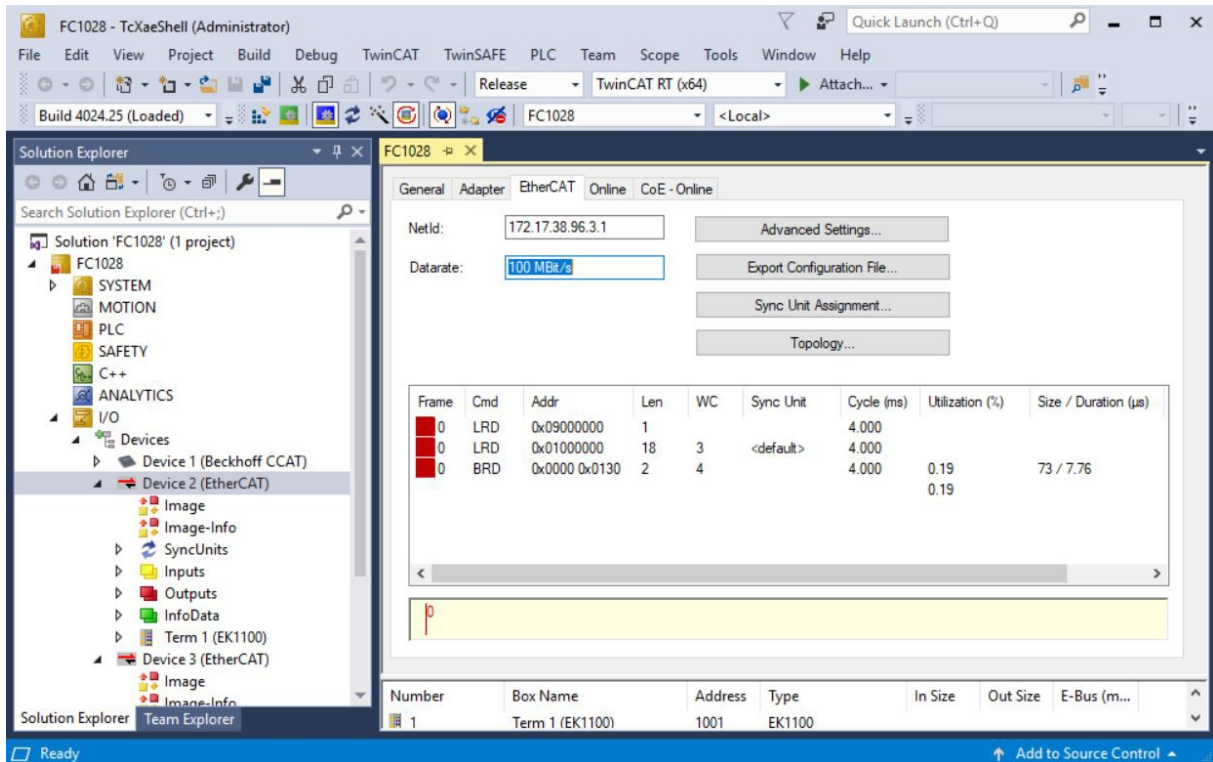
Type	Description
FC1428	Is the EtherCAT master in the example.
ZK1096-969A-0005	Adapter cable for FC1428. Cable with one ix-Industrial® type A plug to 1 x Cat.6 RJ45 socket.
2 x EK1100 EtherCAT Couplers	The first EtherCAT Coupler forwards the EtherCAT signal to connected EtherCAT Terminals and to the second EK1100 EtherCAT Coupler via the second Ethernet interface. The second EtherCAT Coupler is connected to the adapter cable via the second Ethernet interface and thus to another EtherCAT master.
EtherCAT Terminals	Any number of EtherCAT Terminals connected to the EtherCAT Coupler.

Requirements:

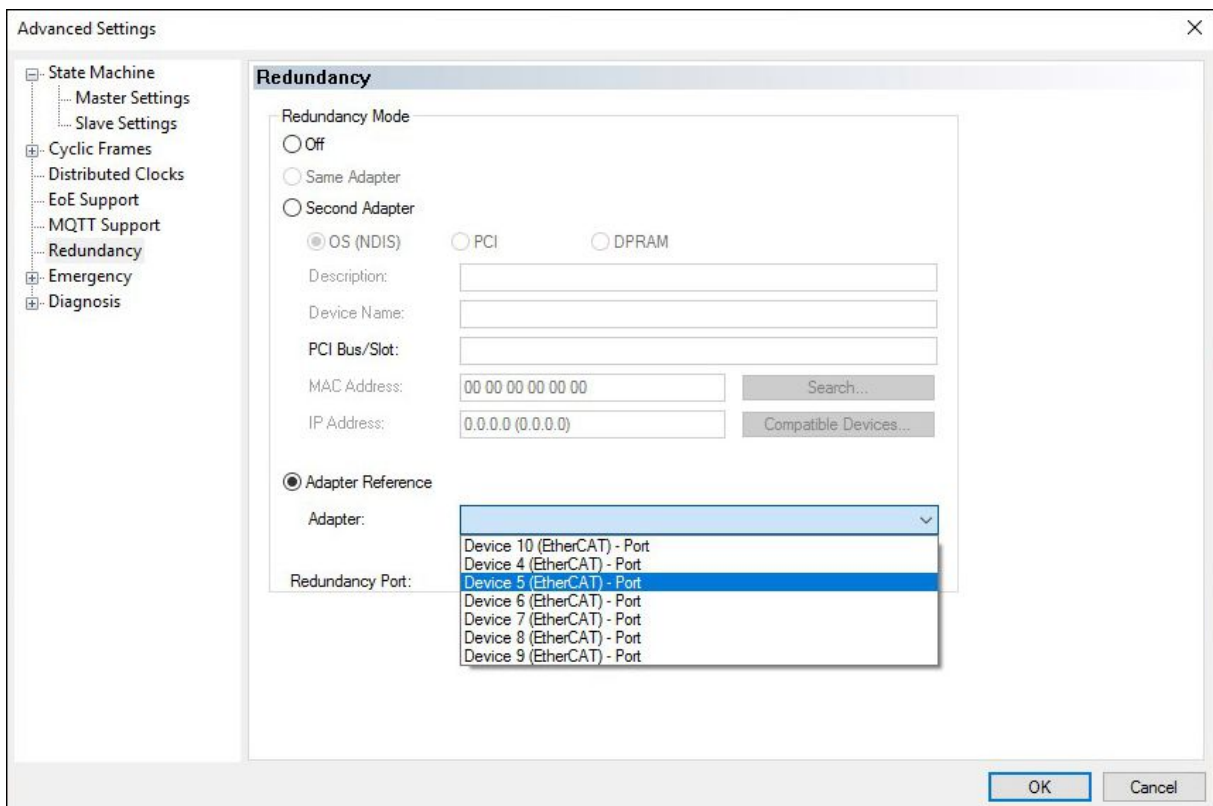
- For TwinCAT 2, you have to install and license the TS622x | TwinCAT EtherCAT Redundancy supplement on the Embedded PC: <https://www.beckhoff.com/TS622x>
- In TwinCAT 3, the supplement is already included and only has to be licensed.
- Hardware wired as EtherCAT ring (see Fig.: Example configuration of a FC1428 with EtherCAT cable redundancy).

Configure EtherCAT cable redundancy as follows:

1. Click on an EtherCAT master that you want to configure for cable redundancy on the left side in the tree view.



2. Click on the **EtherCAT** tab, then **Advanced Settings**.
3. Click on **Redundancy** on the left in the tree structure.



4. Click on the **Adapter Reference** option and then select a second EtherCAT master from the drop-down menu.
- ⇒ You have successfully configured cable redundancy. The EtherCAT slaves configured for cable redundancy are displayed in the **Online** tab.

The state of the individual EtherCAT slaves can be found in the **State** column. If, for example, the cable connection between the two EK1100 EtherCAT Couplers is interrupted, their state changes. The message "LINK_MIS C" and "LINK_MIS A" then appears in the State column.

No	Addr	Name	State	CRC
1	1001	Term 1 (EK1100)	OP LNK_MIS C	0, 0
2	1002	Term 2 (EL2004)	OP	0, 0
3	1003	Term 3 (EL4032)	OP	0, 0
4	1004	Term 4 (EL3154)	OP	0
5	1005	Term 5 (EK1100)	OP LNK_MIS A	0, 0, 0
6	1006	Term 6 (EL3044)	OP	0, 0
7	1007	Term 7 (EL1008)	OP	0, 0
8	1008	Term 8 (EL1008)	OP	0

Although the connection between the EtherCAT Couplers is interrupted, the EtherCAT Terminals connected to the EK1100 EtherCAT Couplers do not have a fault.

If the cable connection is interrupted at the same point without cable redundancy, a fault is displayed for the terminals in the State column.

No	Addr	Name	State	CRC
1	1001	Term 1 (EK1100)	OP LNK_MIS C	0, 0
2	1002	Term 2 (EL2004)	OP	0, 0
3	1003	Term 3 (EL4032)	OP	0, 0
4	1004	Term 4 (EL3154)	OP	0
5	1005	Term 5 (EK1100)	INIT NO_COMM	0, 0
6	1006	Term 6 (EL3044)	INIT NO_COMM	0, 0
7	1007	Term 7 (EL1008)	INIT NO_COMM	0, 0
8	1008	Term 8 (EL1008)	INIT NO_COMM	0

4.4 Enabling Distributed Clocks

Distributed clocks are a common part of EtherCAT communication. They enable distributed, absolute system synchronization for the CPU, I/O, and drive units. This enables time-based and simultaneous data processing of all distributed clocks-capable EtherCAT devices.

Principle of operation

Without distributed clocks the devices would no longer work simultaneously in extended EtherCAT networks, because EtherCAT works on the pass-through principle. In the pass-through principle, the first devices receive the EtherCAT frame first and the latter devices receive it significantly later. This would mean, for example, that all inputs could not be read at the same time or all outputs could not be set at the same time.

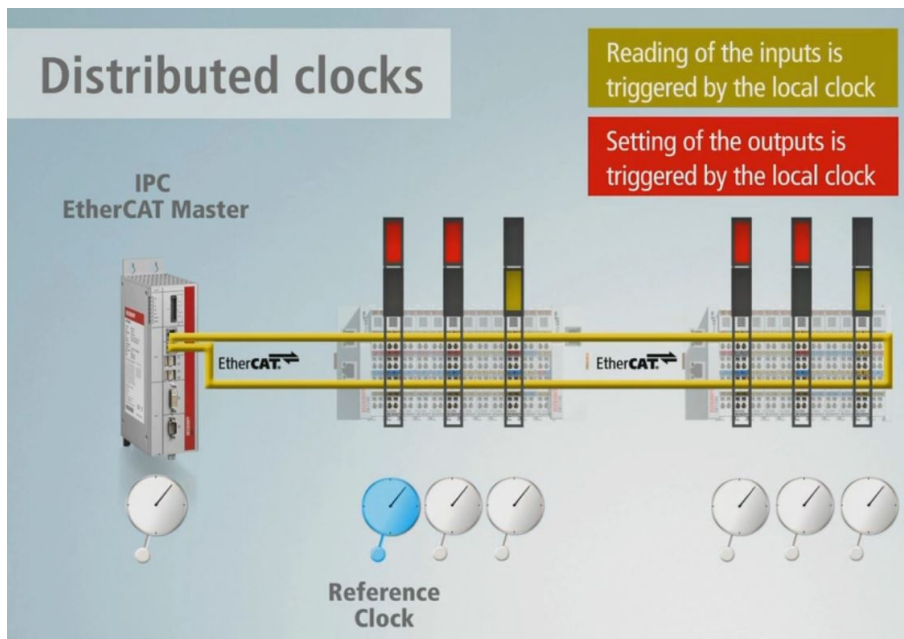


Fig. 7: Example structure of an EtherCAT communication with distributed clocks.

For this purpose a distributed clock is integrated in some specially designed EtherCAT devices. This distributed clock is an electronic mechanism that runs in this device and is synchronized with other devices with distributed clocks. Hierarchically, the structure looks like this: there is a master clock or a reference clock and all other devices with distributed clocks support are then the slave clocks. The EtherCAT master sends a special telegram through the EtherCAT network in each I/O cycle, which distributes the time from the master clock to all following slave clocks. For this reason, the master clock must also be at the beginning before all other slave clocks. By default, TwinCAT therefore selects the first distributed clocks-capable device as reference clock.

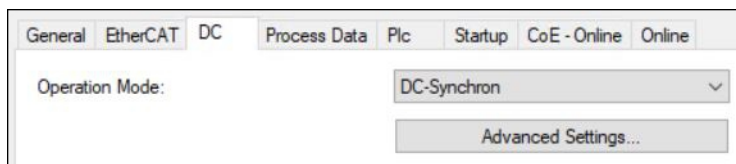


Fig. 8: Distributed clocks functionality of an EtherCAT slave.

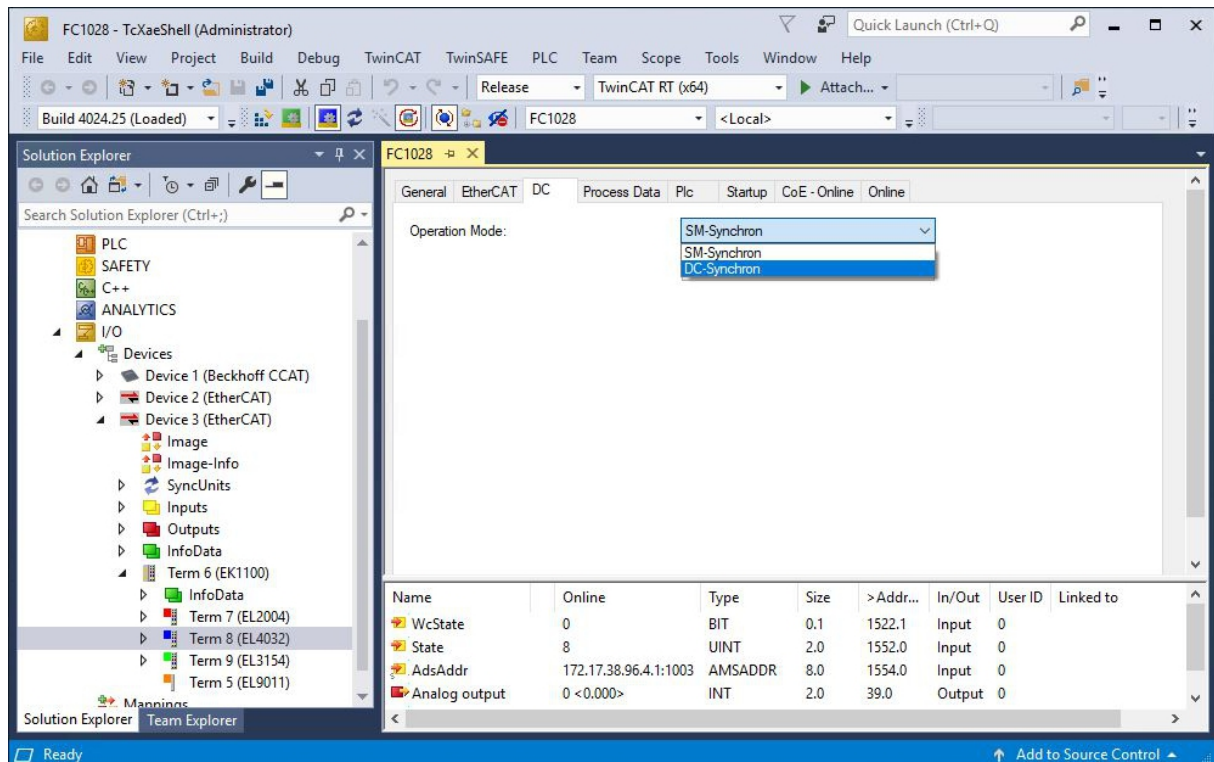
Not all EtherCAT slaves support the distributed clocks method. An EtherCAT slave shows its distributed clocks functionality in TwinCAT by having a **DC** tab.

Example structure with FC1428

The activation of the distributed clocks is shown in a small example structure, with an FC1428 as EtherCAT master and an EK1100 EtherCAT Coupler connected to it with EtherCAT Terminals, including two terminals with distributed clocks functionality.

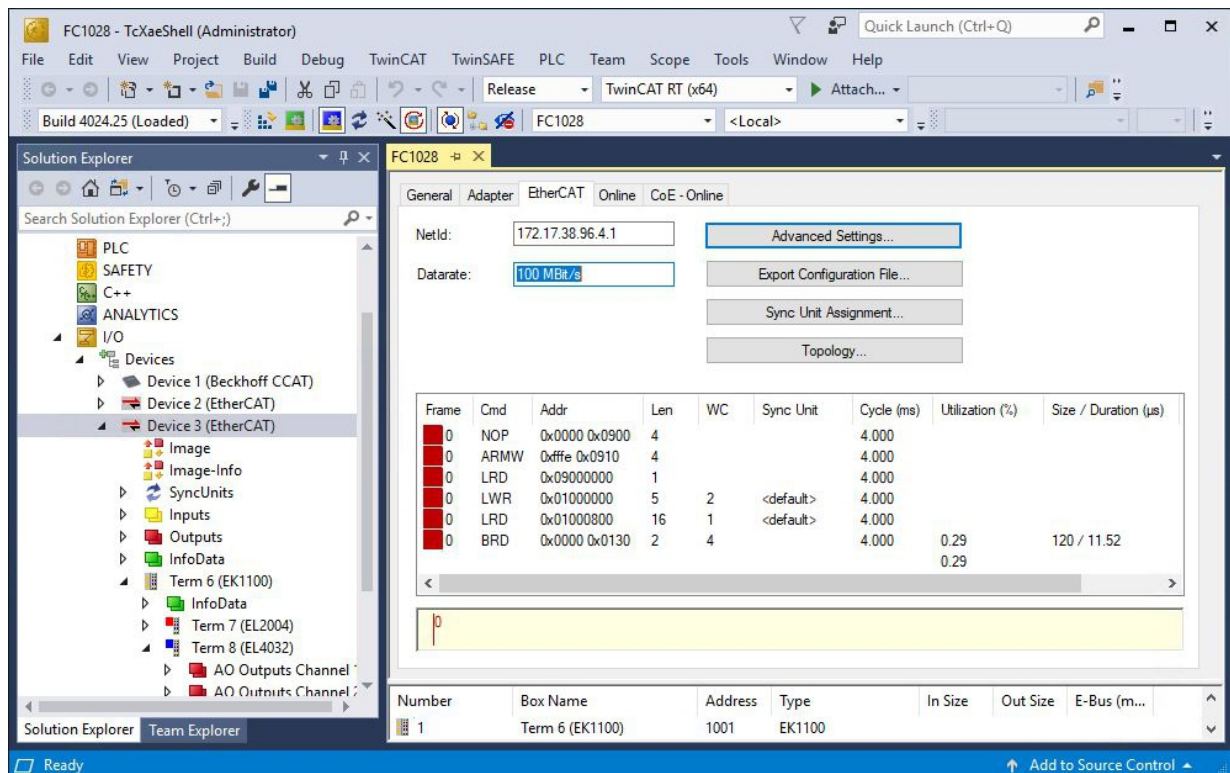
Activate the distributed clocks as follows:

1. Click on the first EtherCAT slave with distributed clocks support on the left side in the tree view. In this example it is the EL4032.
2. Click the **DC** tab and select the **DC-Synchron** option under **Operation Mode**.

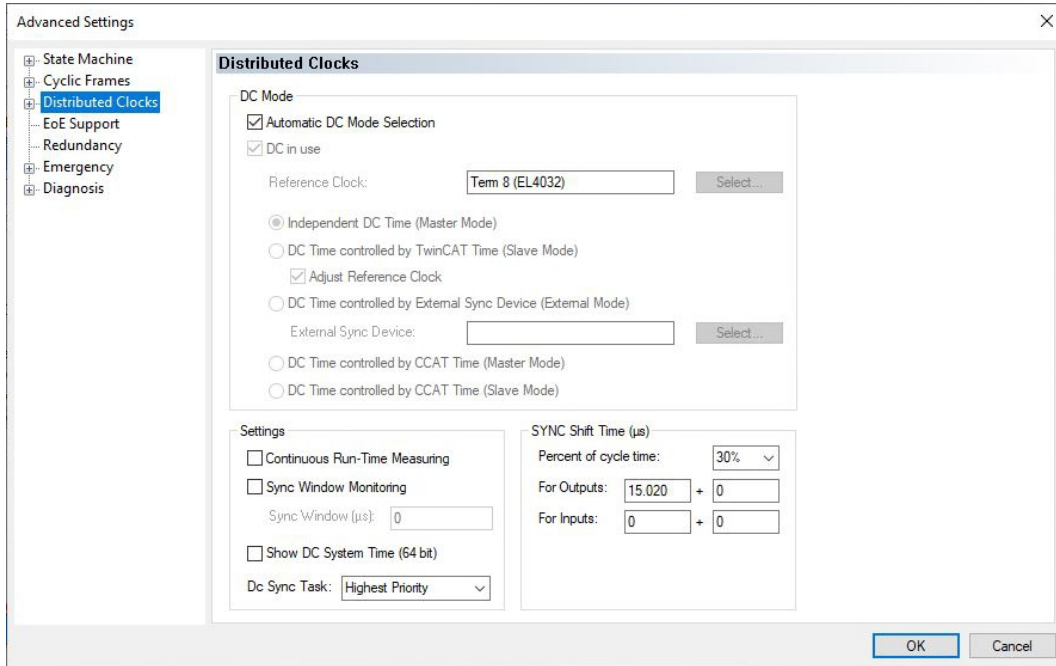


Since it is the first EtherCAT device with distributed clocks support in this example, this EtherCAT device is used as reference clock for all subsequent EtherCAT devices.

3. Activate further EtherCAT devices with distributed clocks support in your system as shown.
4. Click on the EtherCAT master on the left in the tree view and then on the **Advanced Settings** button in the **EtherCAT** tab.



5. The EL4032 EtherCAT Terminal is automatically adopted by TwinCAT as master clock or reference clock.



⇒ This means that the distributed clocks functionality is active in this example.

4.5 Coupling distributed clocks – EtherCAT master

This chapter shows how two or more EtherCAT masters can be coupled and synchronized. The first EtherCAT master is changed to master mode in the DC settings during this process. The first DC-capable EtherCAT slave connected to this EtherCAT master continues to set the reference clock. The TwinCAT real time of this clock is synchronized based on frequency.

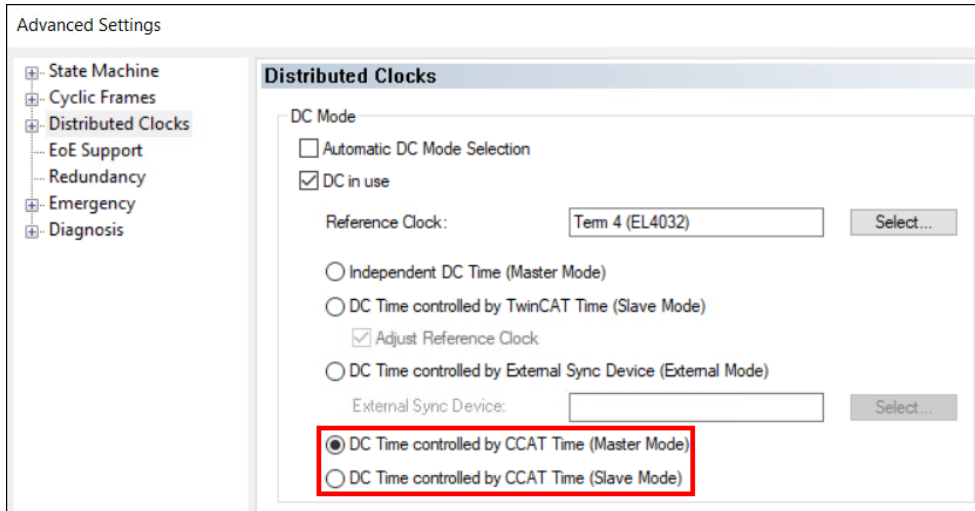


Fig. 9: Settings for EtherCAT master in master or slave mode.

The other EtherCAT masters are synchronized with the first master and are switched to slave mode for this. These EtherCAT masters still keep their local reference clock for synchronization of the subsequent devices. During the EtherCAT startup and continuously afterwards, this reference clock itself is synchronized based on the TwinCAT time and is referred to as "tracking reference clock".

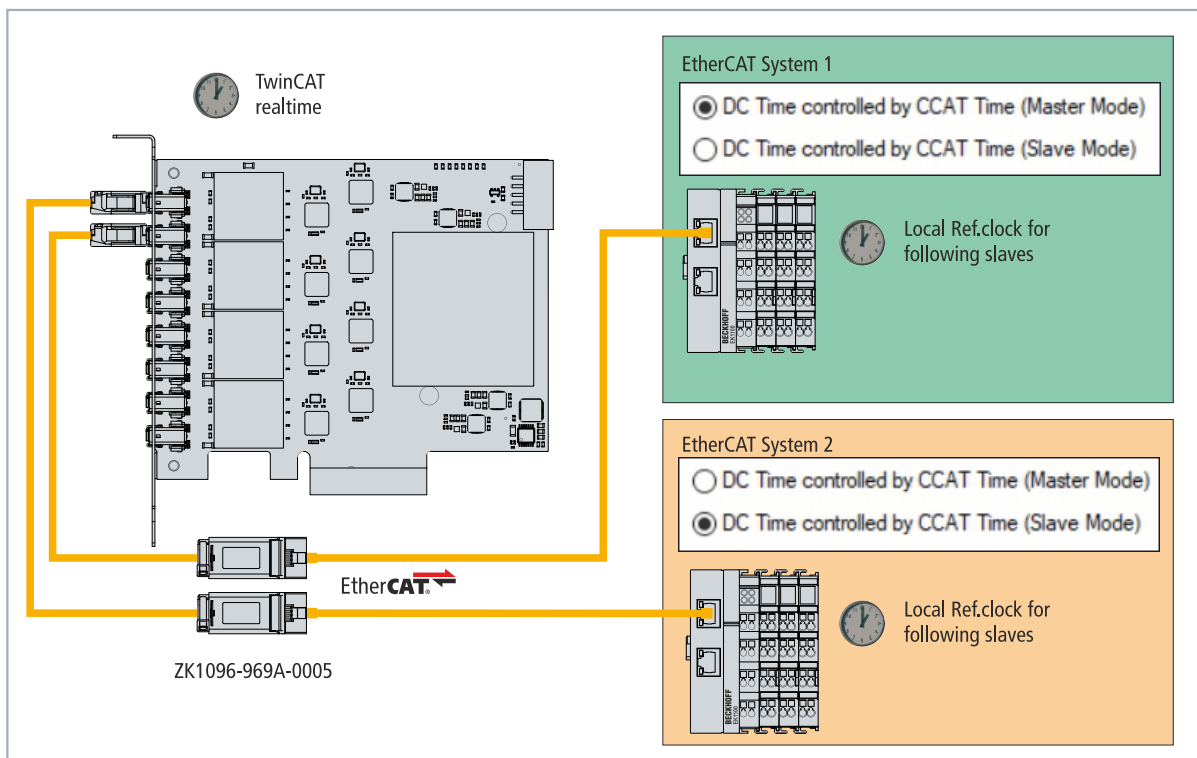
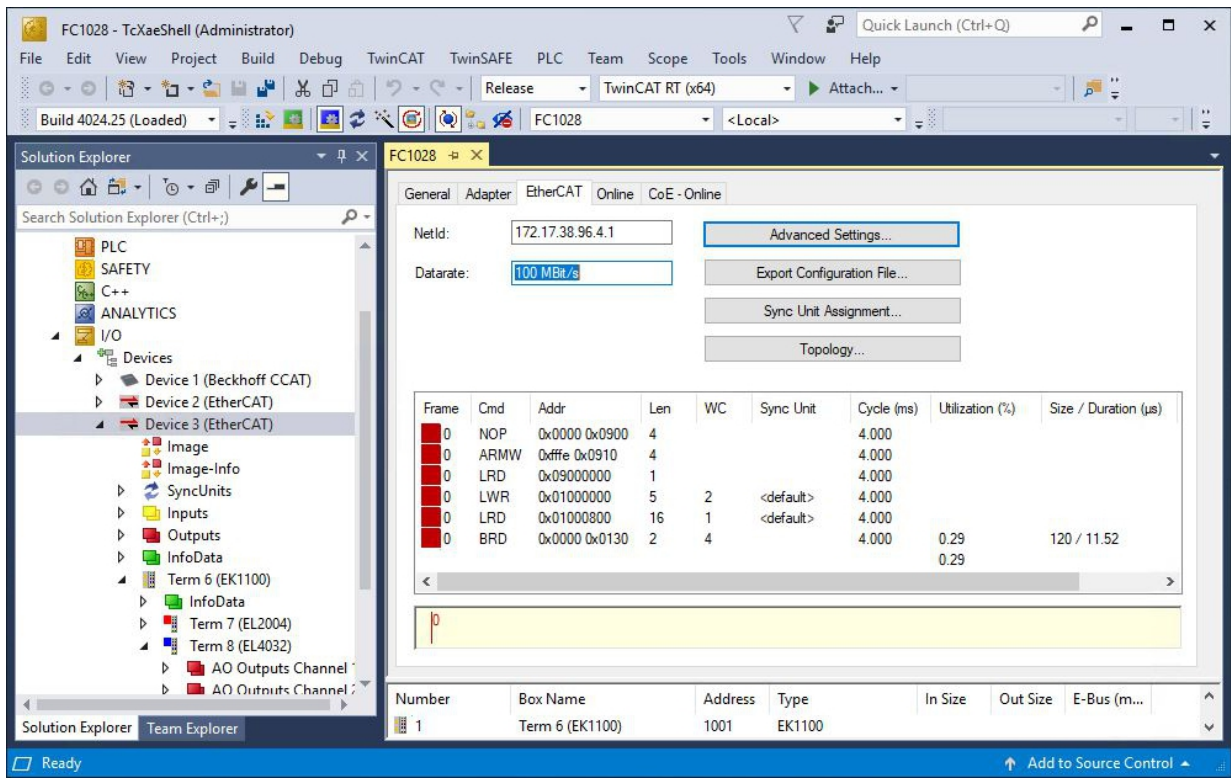


Fig. 10: Example configuration with coupled EtherCAT masters.

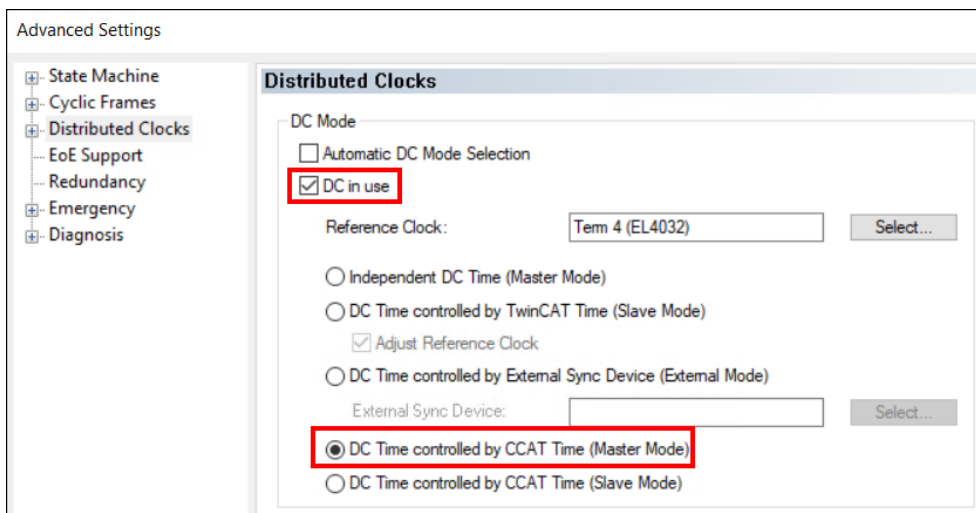
For more information, please visit: https://download.beckhoff.com/download/Document/io/ethercat-terminals/ethercatsystem_en.pdf

Proceed as follows:

1. Activate the distributed clocks for all EtherCAT masters that you want to synchronize with each other (see: [Enabling Distributed Clocks \[▶ 19\]](#)).
2. Activate a reference clock for each of these EtherCAT masters.
3. Click on the EtherCAT master at the first EtherCAT master on the left side in the tree view and then on the button **Advanced Settings** under the **EtherCAT** tab.

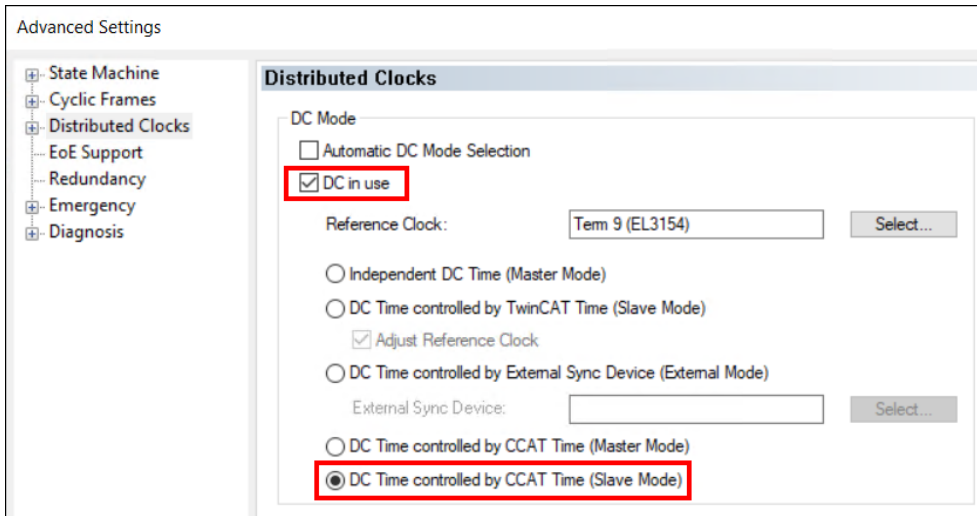


4. Deactivate the **Automatic DC Mode Selection** option.
5. Activate the option **DC in use** in **Distributed Clocks** and also the option **DC Time controlled by CCAT Time (Master Mode)**



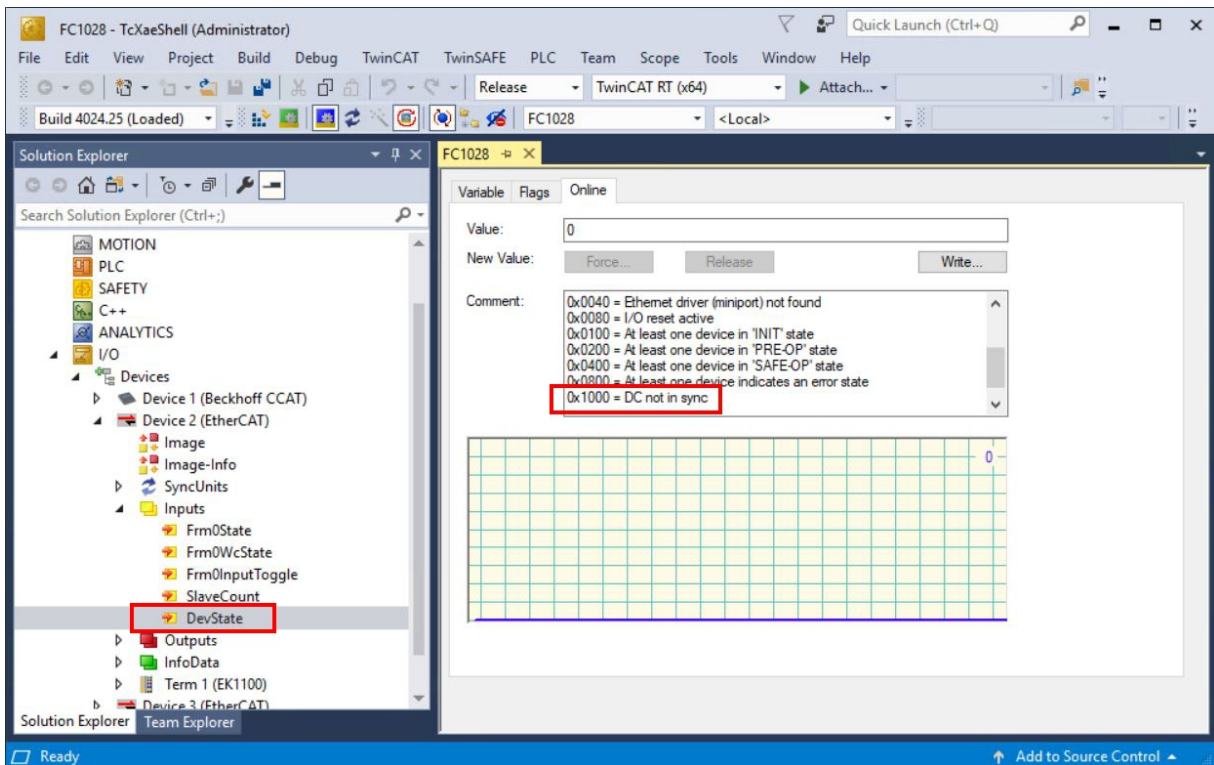
All following EtherCAT masters are synchronized with this EtherCAT master.

- For all following EtherCAT masters that you want to synchronize with the first master, activate the option **DC in use** in **Distributed Clocks** and then the option **DC Time controlled by CCAT Time (Slave Mode)**.



- Repeat this setting for all further EtherCAT masters.

⇒ Synchronization is successful when the distributed clocks devices in the lower-level systems change to OP state. In addition, the **DevState** variable shows the state of the distributed clock communication.



5 Error handling and diagnostics

5.1 Diagnostic LEDs

The LEDs on the FC1428 EtherCAT card indicate the status of the connection. The LEDs are numbered from P01 to P08 and correspond to interfaces X1 to X8.

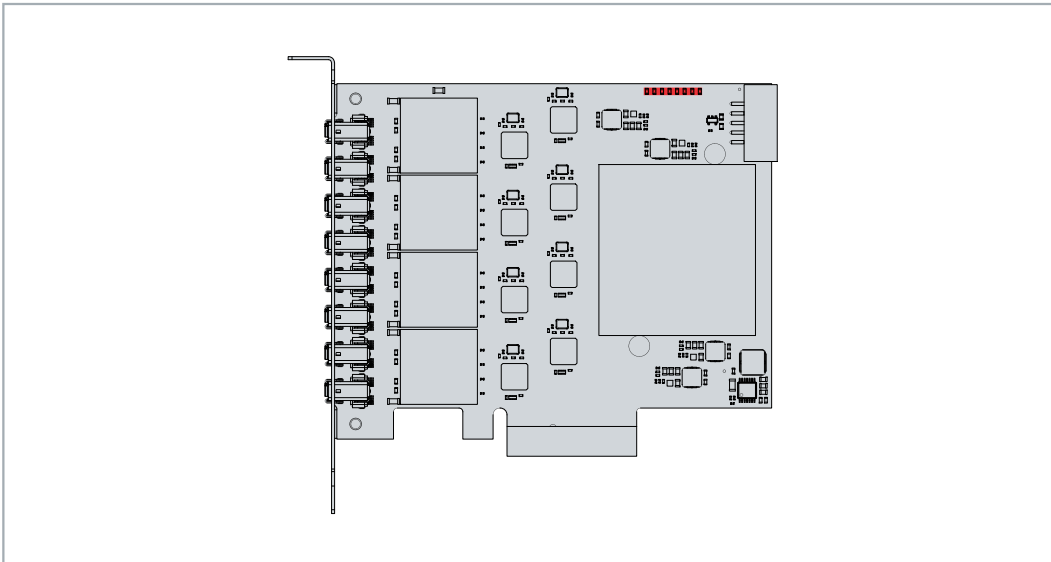


Fig. 11: Diagnostic LEDs for the EtherCAT card.

An LED (LINK/ACT) lights up green when there is a connection to a network. The LED flashes when data transfer is underway on the interface.

5.2 Faults

Table 5: Possible faults and their correction.

Fault	Cause	Measures
The EtherCAT card cannot be scanned under TwinCAT.	BIOS settings not configured correctly.	Disable the Memory Mapped I/O above 4 GB option in the BIOS (see: BIOS settings [▶_11]).

6 Technical data

Table 6: Technical data, general data.

Technical data	FC1428
Fieldbus	EtherCAT
Number of channels	8 EtherCAT master channels
Interfaces	8 x ix Industrial® Type A
Data transfer rate	10/100/1000 Mbit/s
Design	PCIe
Interface to the PC	PCIe x4 (PCIe 2.0)
Control software	TwinCAT 3 Runtime (XAR) from 3.1 4026
Max. power consumption	7.5 W
Dimensions (W x H x D)	116 mm x 98 mm x 22 mm
Operating/storage temperature	0...+55 °C/-20...+65 °C
Relative humidity	95% no condensation
Vibration/shock resistance	conforms to EN 60068-2-6/EN 60068-2-27
EMC immunity/emission	conforms to EN 61000-6-2/EN 61000-6-4
Approvals/markings	CE

7 Appendix

7.1 Accessories

Table 7: Accessories connection cable, ordering information.

Ordering information	Description
ZK1096-969A-0005	Industrial Ethernet/EtherCAT G/G10 cable, Cat.6A, PUR, 4 x 2 x AWG26, fixed installation, RJ45, coupling, straight, female, 8-pin - ix Industrial® type A, plug, straight, male, 10-pin, 0.5 m
ZK1096-819A-0xxx	Industrial Ethernet/EtherCAT G/G10 cable, Cat.7, PUR, 4 x 2 x AWG26, fixed installation, M12, plug, straight, male, 8-pin, X-coded - ix Industrial® type A 10-pin plug
ZK1096-9191-0xxx	Industrial Ethernet/EtherCAT G/G10 patch cable, Cat.6A, PUR, 4 x 2 x AWG26, fixed installation, RJ45, plug, straight, male, 8-pin - RJ45, plug, straight, male, 8-pin
ZK1096-9191-3xxx	Industrial Ethernet/EtherCAT G/G10 patch cable, Cat.6A, PVC, 4 x 2 x AWG26, fixed installation, RJ45, plug, straight, male, 8-pin - RJ45, plug, straight, male, 8-pin

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Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG

Huelshorstweg 20
33415 Verl
Germany

Phone: +49 5246 963-0
e-mail: info@beckhoff.com
web: www.beckhoff.com

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More Information:
www.beckhoff.com/FC1428

Beckhoff Automation GmbH & Co. KG
Hülshorstweg 20
33415 Verl
Germany
Phone: +49 5246 9630
info@beckhoff.com
www.beckhoff.com

