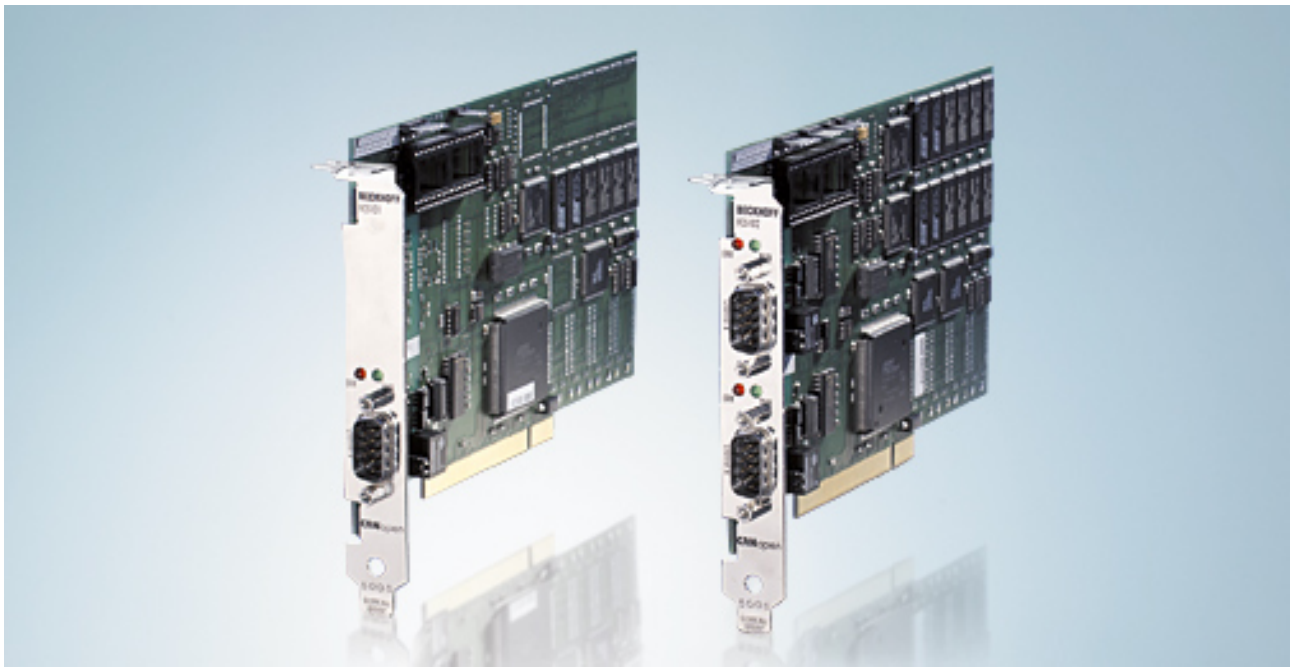


Documentation

FC5101 and FC5102

PCI Cards for CANopen

Version: 2.0
Date: 2017-11-17

BECKHOFF

Table of contents

1 Foreword

1.1 Notes on the documentation

Intended audience

This description is only intended for the use of trained specialists in control and automation engineering who are familiar with the applicable national standards.
It is essential that the documentation and the following notes and explanations are followed when installing and commissioning these components.
It is the duty of the technical personnel to use the documentation published at the respective time of each installation and commissioning.

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, 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 prior announcement.

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

Trademarks

Beckhoff®, TwinCAT®, EtherCAT®, EtherCAT P®, Safety over EtherCAT®, TwinSAFE®, XFC® and XTS® are registered trademarks of and licensed by Beckhoff Automation GmbH.
Other designations used in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owners.

Patent Pending

The EtherCAT Technology is covered, including but not limited to the following patent applications and patents: EP1590927, EP1789857, DE102004044764, DE102007017835 with corresponding applications or registrations in various other countries.

The TwinCAT Technology is covered, including but not limited to the following patent applications and patents: EP0851348, US6167425 with corresponding applications or registrations in various other countries.

EtherCAT® is registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

Copyright

1.2 Safety instructions

Safety regulations

Please note the following safety instructions and explanations!
Product-specific safety instructions can be found on following pages or in the areas mounting, wiring, commissioning etc.

Exclusion of liability

All the components are supplied in particular hardware and software configurations appropriate for the application. Modifications to hardware or software configurations other than those described in the documentation are not permitted, and nullify the liability of Beckhoff Automation GmbH & Co. KG.

Personnel qualification

This description is only intended for trained specialists in control, automation and drive engineering who are familiar with the applicable national standards.

Description of instructions

In this documentation the following instructions are used.
These instructions must be read carefully and followed without fail!

⚠ DANGER

Serious risk of injury!

Failure to follow this safety instruction directly endangers the life and health of persons.

⚠ WARNING

Risk of injury!

Failure to follow this safety instruction endangers the life and health of persons.

⚠ CAUTION

Personal injuries!

Failure to follow this safety instruction can lead to injuries to persons.

NOTE

Damage to environment/equipment or data loss

Failure to follow this instruction can lead to environmental damage, equipment damage or data loss.

Tip or pointer

This symbol indicates information that contributes to better understanding.

1.3 Documentation Issue Status

Version	Comment
2.0	• Migration
1.0	• completely revised ◦ FC510x Monitor Software documented ◦ CANopen Protocol description revised
0.9 (Pre-Release)	• Preliminary version, 11.03.2002

The using of the FC5101 in slave mode is described separately (FC510x Slave.chm resp. -.pdf).

2 Product Overview

2.1 Hardware overview

CAN Terminating Resistor

The card features CAN terminating resistors (120 ohm). These can be activated via a jumper (up to hardware version 3) or a slide switch (from hardware version 4) near the CAN connectors.

The Flash Disk socket is currently not in use.

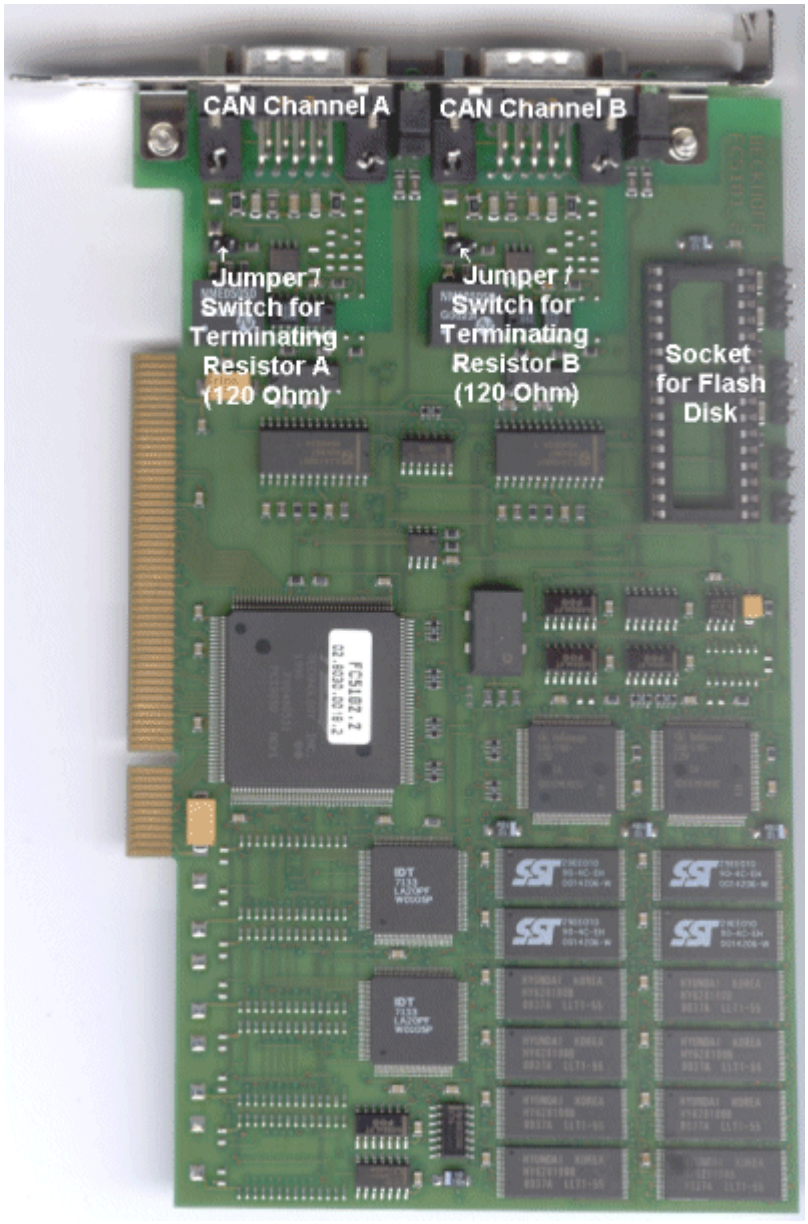


Fig. 1: FC5102

Pinout

The CAN bus line is connected via 9-pin Sub-D sockets with the following pinout.

Pin	Pinout
2	CAN low (CAN-)
3	CAN Ground (internally connected to pin 6)
5	Shield
6	CAN Ground (internally connected to pin 3)
7	CAN high (CAN+)

The unlisted pins are not connected.

Note: an auxiliary voltage of up to 30 V_{DC} may be connected to pin 9. Some CAN devices use this to supply the transceiver.

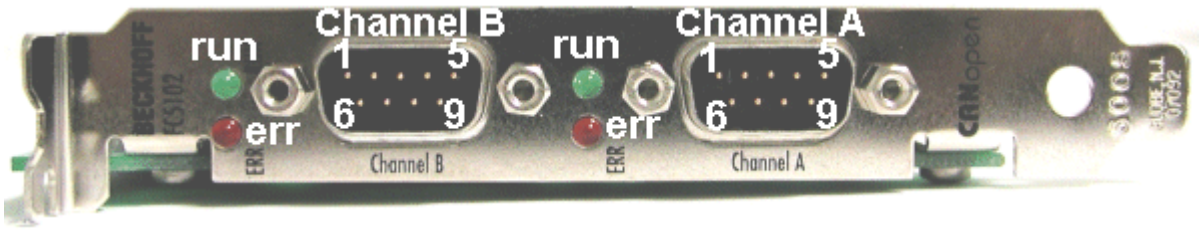


Fig. 2: FC5102 panel

2.2 Technical data

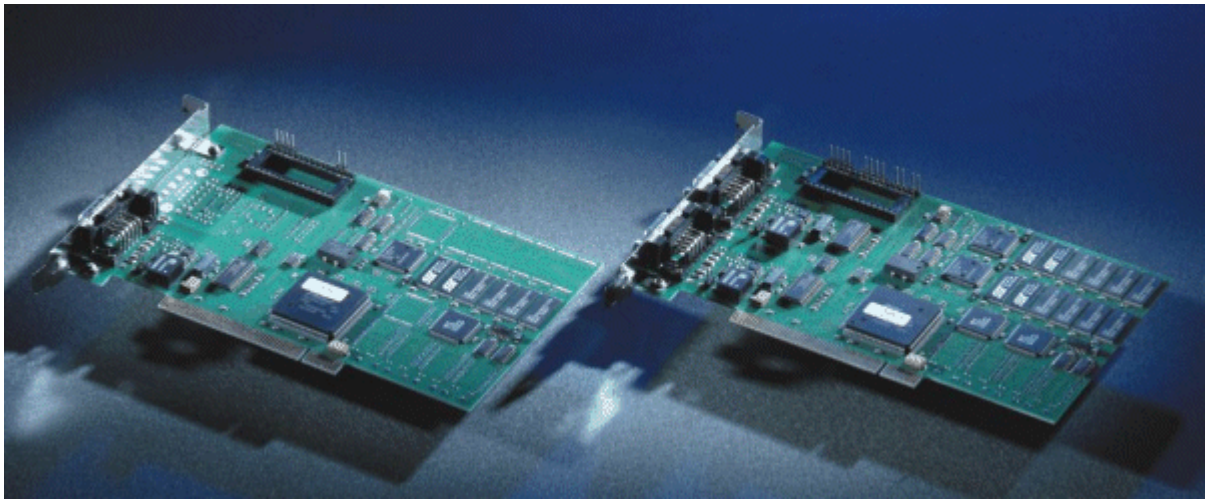


Fig. 3: FC510x

The FC510x is a CANopen [▶ 11] master card with the following features:

- One (FC5101) or two (FC5102) CAN channels, each with its own processor, memory, etc.
- Optionally CANopen master or slave.
- All PDO communication types are supported.
- Process image: max. 3 kbytes input and output data in total.
- Each PDO can be individually monitored.
- Host communication may be free running, synchronized or equidistant.
- Equidistant mode for drive control over the bus: SYNC objects are transmitted with a mean timing having the accuracy of the quartz oscillator, while process data exchange with the application is synchronized throughout (only with TwinCAT).
- Emergency messages are stored by the card.
- Error handling can be set individually for each bus node.
- General CAN messages (CAN layer 2) can be sent and received.
- Powerful parameter and diagnostics interface.
- Integrated bus loading display.
- CAN interfaces are electrically isolated.
- Meets CANopen specification DS301 V4.01.
- Boot-up according to DS302.
- Drivers: TwinCAT I/O for WinNT, Win2k, WinXP;
- Driver Construction Kit for other operating systems by request.

See the appropriate separate documentation for details of slave functionality.

2.3 CANopen Introduction

Fig. 4: CANopenLogo

CANopen is a widely used CAN application layer, developed by the CAN-in-Automation association (CiA, http://www.can-cia.org), and which has meanwhile been adopted for international standardization.

Device Model

CANopen consists of the protocol definitions (communication profile) and of the device profiles that standardize the data contents for the various device classes. Process data objects (PDO) [▶ 44] are used for fast communication of input and output data. The CANopen device parameters and process data are stored in a structured object directory. Any data in this object directory is accessed via service data objects (SDO). There are, additionally, a few special objects (such as telegram types) for network management (NMT), synchronization, error messages and so on.

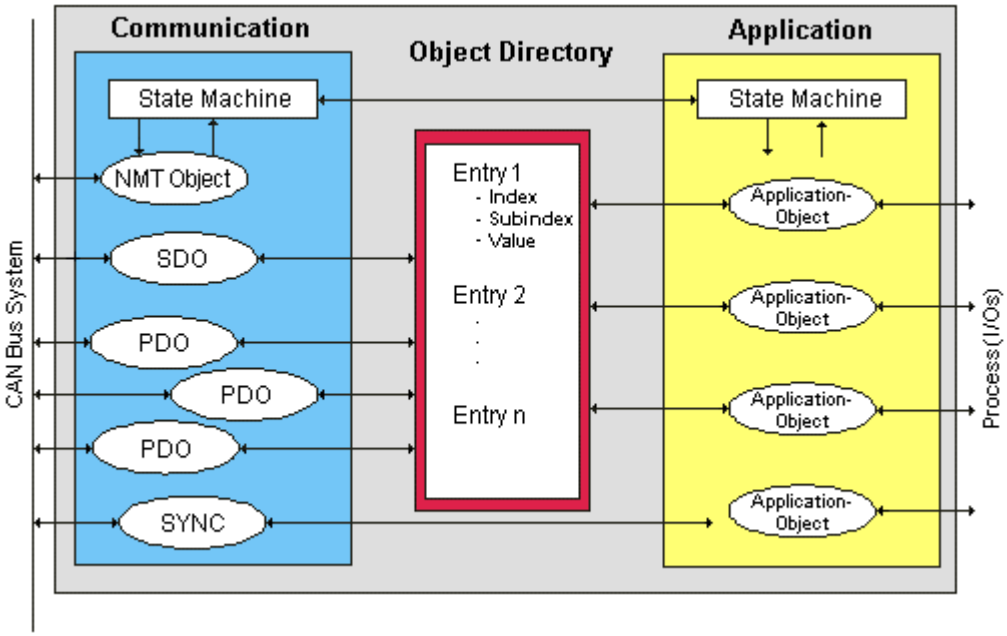


Fig. 5: CANopen Device Model

Communication Types

CANopen defines a number of communication classes for the input and output data (process data objects):

- Event driven [▶ 46]: Telegrams are sent as soon as their contents have changed. This means that the process image as a whole is not continuously transmitted, only its changes.
- Cyclic synchronous [▶ 46]: A SYNC telegram causes the modules to accept the output data that was previously received, and to send new input data.
- Requested (polled) [▶ 44]: A CAN data request telegram causes the modules to send their input data.

The desired communication type is set by the Transmission Type [▶ 44] parameter.

Device Profile

The BECKHOFF CANopen devices support all types of I/O communication, and correspond to the device profile for digital and analog input/output modules (DS401 Version 1). For reasons of backwards compatibility, the default mapping was not adapted to the DS401 V2 profile version.

Data transfer rates

Nine transmission rates from 10 kbaud up to 1 Mbaud are available for different bus lengths. The effective utilization of the bus bandwidth allows CANopen to achieve short system reaction times at relatively low data rates.

Topology

CAN is based on a linear topology [▶ 14]. The number of devices participating in each network is logically limited by CANopen to 128, but physically the present generation of drivers allows up to 64 nodes in one network segment. The maximum possible size of the network for any particular data rate is limited by the signal propagation delay required on the bus medium. For 1 Mbaud, for instance, the network may extend 25 m, whereas at 50 kbaud the network may reach up to 1000 m. At low data rates the size of the network can be increased by repeaters, which also allow the construction of tree structures.

Bus access procedures

CAN utilizes the Carrier Sense Multiple Access (CSMA) procedure, i.e. all participating devices have the same right of access to the bus and may access it as soon as it is free (multi-master bus access). The exchange of messages is thus not device-oriented but message-oriented. This means that every message is unambiguously marked with a prioritized identifier. In order to avoid collisions on the bus when messages are sent by different devices, a bit-wise bus arbitration is carried out at the start of the data transmission. The bus arbitration assigns bus bandwidth to the messages in the sequence of their priority. At the end of the arbitration phase only one bus device occupies the bus, collisions are avoided and the bandwidth is optimally exploited.

Configuration and parameterization

The TwinCAT System Manager allows all the CANopen parameters to be set conveniently. An "eds" file (an electronic data sheet) is available on the Beckhoff website (http://www.beckhoff.de) for the parameterization of Beckhoff CANopen devices using configuration tools from other manufacturers.

Certification

The Beckhoff CANopen devices have a powerful implementation of the protocol, and are certified by the CAN in Automation Association (http://www.can-cia.org).

3 Fitting and wiring

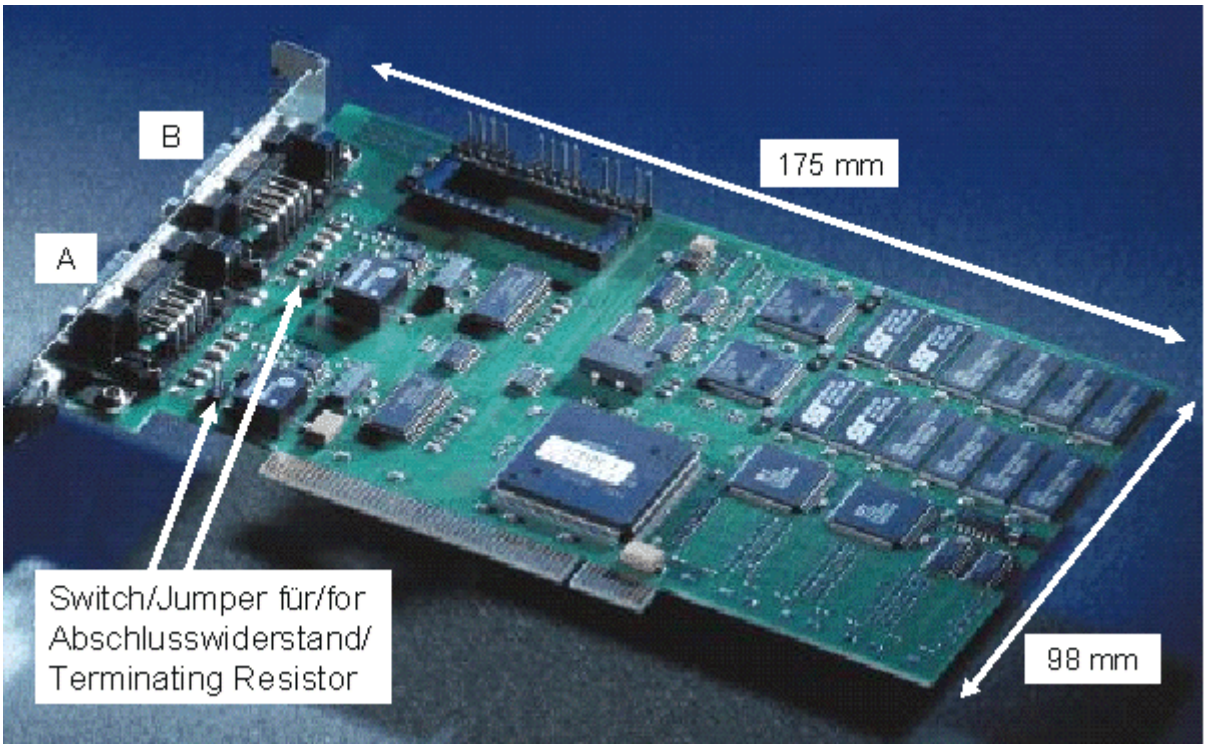
3.1 Installation

NOTE

Qualified installation

Fieldbus PCI cards may only be fitted by qualified personnel and the following points must be observed.

- In order to protect the card from electrostatic discharge the user must be discharged before handling the card or the PC.
- Before opening the PC housing it must be switched off, and the mains plug must be removed.



In may be necessary before fitting to set the jumper in order to activate the internal CAN bus terminating resistors, or to set the switches (as from hardware version 3). Jumper set or switch on [ON] means: terminating resistor connected.

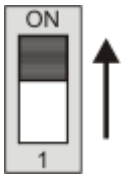


Fig. 6: DIP switch ON = terminating resistor connected

The card can be fitted into any free PCI slot. Ensure that the PCI bus connector is making good contact, and that the module is seated firmly. Secure the board to the PC slot housing with the mounting bolt.

3.2 CANopen cabling

Notes related to checking the CAN wiring can be found in the Trouble Shooting [▶ 71] section.

3.2.1 CAN topology

CAN is a 2-wire bus system, to which all participating devices are connected in parallel (i.e. using short drop lines). The bus must be terminated at each end with a 120 (or 121) Ohm terminating resistor to prevent reflections. This is also necessary even if the cable lengths are very short!

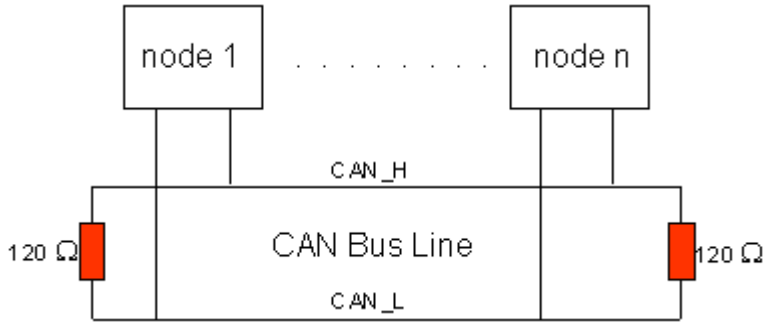


Fig. 7: Termination of the bus with a 120 Ohm termination resistor

Since the CAN signals are represented on the bus as the difference between the two levels, the CAN leads are not very sensitive to incoming interference (EMI): Both leads are affected, so the interference has very little effect on the difference.

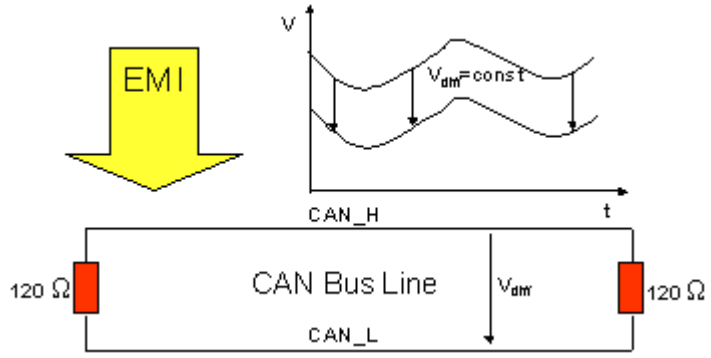


Fig. 8: Insensitivity to incoming interference

3.2.2 Bus length

The maximum length of a CAN bus is primarily limited by the signal propagation delay. The multi-master bus access procedure (arbitration) requires signals to reach all the nodes at effectively the same time (before the sampling within a bit period). Since the signal propagation delays in the CAN connecting equipment (transceivers, opto-couplers, CAN controllers) are almost constant, the line length must be chosen in accordance with the baud rate:

Baud rate	Bus length
1 Mbit/s	< 20 m*
500 kbit/s	< 100 m
250 kbit/s	< 250 m
125 kbit/s	< 500 m
50 kbit/s	< 1000 m
20 kbit/s	< 2500 m
10 kbit/s	< 5000 m

*) A figure of 40 m at 1 Mbit/s is often found in the CAN literature. This does not, however, apply to networks with optically isolated CAN controllers. The worst case calculation for opto-couplers yields a figure 5 m at 1 Mbit/s - in practice, however, 20 m can be reached without difficulty.

It may be necessary to use repeaters for bus lengths greater than 1000 m.

3.2.3 Drop lines

Drop lines must always be avoided as far as possible, since they inevitably cause reflections. The reflections caused by drop lines are not however usually critical, provided they have decayed fully before the sampling time. In the case of the bit timing settings selected in the Bus Couplers it can be assumed that this is the case, provided the following drop line lengths are not exceeded:

Baud rate	Drop line length	Total length of all drop lines
1 Mbit/s	< 1 m	< 5 m
500 kbit/s	< 5 m	< 25 m
250 kbit/s	< 10 m	< 50 m
125 kbit/s	< 20 m	< 100 m
50 kbit/s	< 50 m	< 250 m

Drop lines must not have terminating resistors.

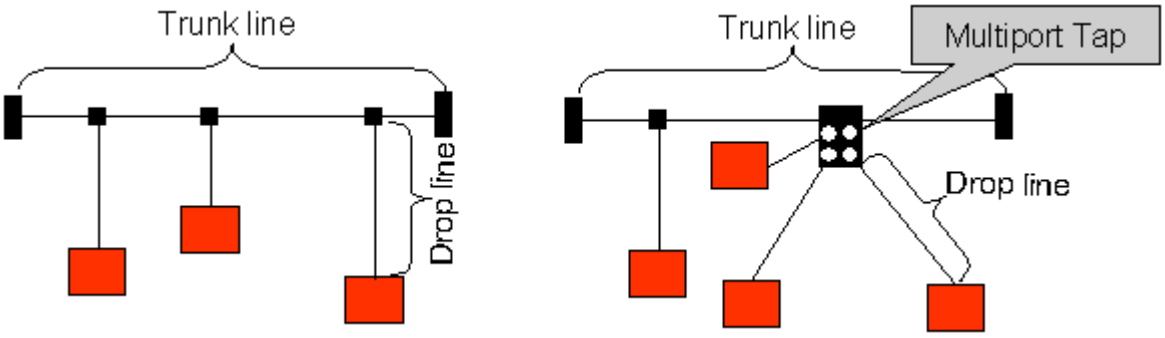


Fig. 9: Sample topology of drop lines

3.2.4 Star Hub (Multiport Tap)

Shorter drop line lengths must be maintained when passive distributors ("multiport taps"), such as the Beckhoff ZS5052-4500 Distributor Box. The following table indicates the maximum drop line lengths and the maximum length of the trunk line (without the drop lines):

Baud rate	Drop line length with multiport topology	Trunk line length (without drop lines)
1 Mbit/s	< 0,3 m	< 25 m
500 kbit/s	< 1,2 m	< 66 m
250 kbit/s	< 2,4 m	< 120 m
125 kbit/s	< 4,8 m	< 310 m

3.2.5 CAN cable

Screened twisted-pair cables (2x2) with a characteristic impedance of between 108 and 132 Ohm is recommended for the CAN wiring. If the CAN transceiver’s reference potential (CAN ground) is not to be connected, the second pair of conductors can be omitted. (This is only recommended for networks of small physical size with a common power supply for all the participating devices).

ZB5100 CAN Cable

A high quality CAN cable with the following properties is included in Beckhoff's range:

- 2 x 2 x 0.25 mm² (AWG 24) twisted pairs, cable colors: red/black + white/black
- double screened
- braided screen with filler strand (can be attached directly to pin 3 of the 5-pin connection terminal)
- flexible (minimum bending radius 35 mm when bent once, 70 mm for repeated bending)
- characteristic impedance (60 kHz): 120 ohm
- conductor resistance < 80 Ohm/km
- sheath: grey PVC, outside diameter 7.3 +/- 0.4 mm
- Weight: 64 kg/km.
- printed with "Beckhoff ZB5100 CAN-BUS 2x2x0.25" and meter marking (length data every 20cm)

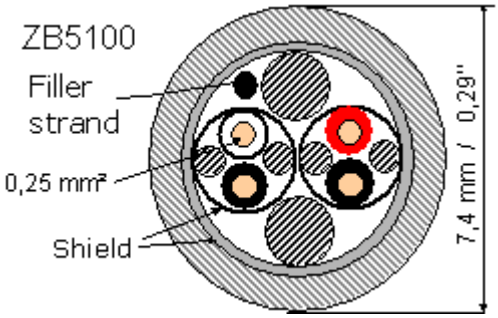


Fig. 10: Structure of CAN cable ZB5100

ZB5200 CAN/DeviceNet Cable

The ZB5200 cable material corresponds to the DeviceNet specification, and is also suitable for CANopen systems. The ready-made ZK1052-xxxx-xxxx bus cables for the Fieldbus Box modules are made from this cable material. It has the following specification:

- 2 x 2 x 0.34 mm² (AWG 22) twisted pairs
- double screened, braided screen with filler strand
- characteristic impedance (1 MHz): 126 ohm
- Conductor resistance 54 Ohm/km
- sheath: grey PVC, outside diameter 7.3 mm
- printed with "InterlinkBT DeviceNet Type 572" as well as UL and CSA ratings
- stranded wire colors correspond to the DeviceNet specification
- UL recognized AWM Type 2476 rating
- CSA AWM I/II A/B 80°C 300V FT1
- corresponds to the DeviceNet "Thin Cable" specification

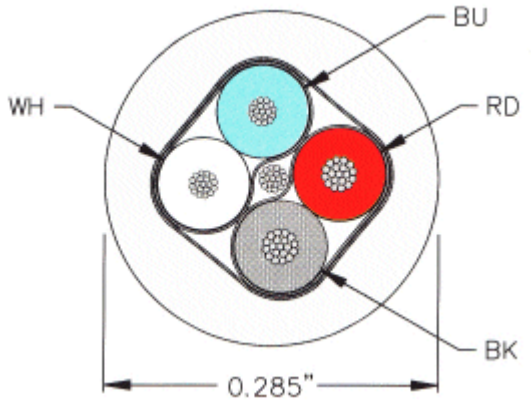


Fig. 11: Structure of CAN/DeviceNet cable ZB5200

3.2.6 Shielding

The screen is to be connected over the entire length of the bus cable, and only galvanically grounded at one point, in order to avoid ground loops.
The design of the screening, in which HF interference is diverted through R/C elements to the mounting rail assumes that the rail is appropriately earthed and free from interference. If this is not the case, it is possible that HF interference will be transmitted from the mounting rail to the screen of the bus cable. In that case the screen should not be attached to the couplers - it should nevertheless still be fully connected through.

Notes related to checking the CAN wiring can be found in the Trouble Shooting [▶ 71] section.

3.2.7 Cable colors

Suggested method of using the Beckhoff CAN cable on Bus Terminal and Fieldbus Box:

BK51x0 pin PIN BX5100 (X510)	Pin BK5151 CX8050, CX8051, CXxxxx-B510/M510	Fieldbus Box pin	Pin FC51xx	Function	ZB5100 cable color	ZB5200 cable color
1	3	3	3	CAN Ground	**black/** (red)	**black**
2	2	5	2	CAN Low	**black**	**blue**
3	5	1	5	Shield	Filler strand	Filler strand
4	7	4	7	CAN high	**white**	**white**
5	9	2	9	not used	**(red)**	**(red)**

3.2.8 BK5151, FC51xx, CX with CAN interface and EL6751: D-sub, 9 pin

The CANbus cable is connected to the FC51x1, FC51x2 CANopen cards and in the case of the EL6751 CANopen master/slave terminal via 9-pin Sub-D sockets with the following pin assignment.

Pin	Assignment
2	CAN low (CAN-)
3	CAN ground (internally connected to pin 6)
6	CAN ground (internally connected to pin 3)
7	CAN high (CAN+)

The unlisted pins are not connected.
The mounting rail contact spring and the plug shield are connected together.

Note: an auxiliary voltage of up to 30 V_{DC} may be connected to pin 9. Some CAN devices use this to supply the transceiver.

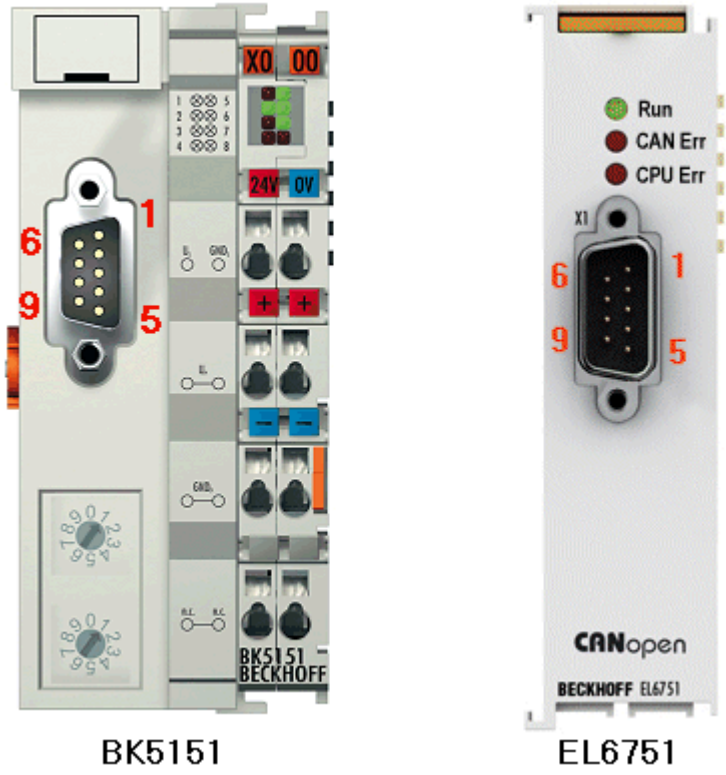


Fig. 12: BK5151, EL6751 pin assignment

FC51x2:

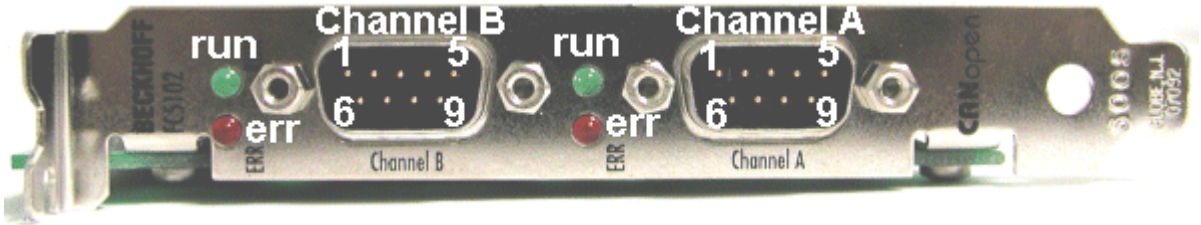


Fig. 13: FC51x2

3.2.9 BK51x0/BX5100: 5-pin open style connector

The BK51x0/BX5100 (X510) Bus Couplers have a recessed front surface on the left hand side with a five pin connector.
The supplied CANopen socket can be inserted here.

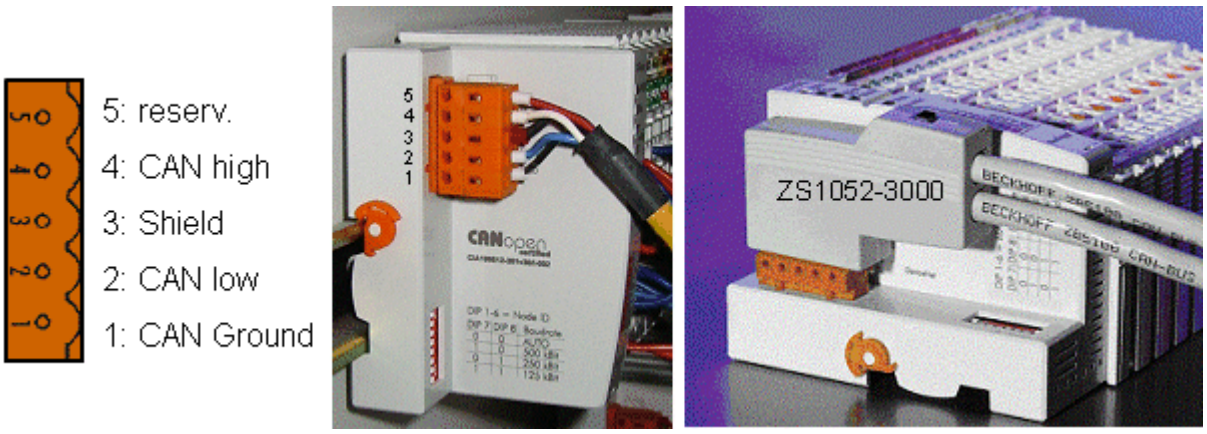


Fig. 14: BK51x0/BX5100 socket assignment

The left figure shows the socket in the BK51x0/BX5100 Bus Coupler. Pin 5 is the connection strip's top most pin. Pin 5 is not used. Pin 4 is the CAN high connection, pin 2 is the CAN low connection, and the screen is connected to pin 3 (which is connected to the mounting rail via an R/C network). CAN-GND can optionally be connected to pin 1. If all the CAN ground pins are connected, this provides a common reference potential for the CAN transceivers in the network. It is recommended that the CAN GND be connected to earth at one location, so that the common CAN reference potential is close to the supply potential. Since the CANopen BK51X0/BX5100 Bus Couplers provide full electrical isolation of the bus connection, it may in appropriate cases be possible to omit wiring up the CAN ground.

ZS1052-3000 Bus Interface Connector

The ZS1052-3000 CAN Interface Connector can be used as an alternative to the supplied connector. This makes the wiring significantly easier. There are separate terminals for incoming and outgoing leads and a large area of the screen is connected via the strain relief. The integrated terminating resistor can be switched externally. When it is switched on, the outgoing bus lead is electrically isolated - this allows rapid wiring fault location and guarantees that no more than two resistors are active in the network.

3.2.10 LC5100: Bus connection via spring-loaded terminals

In the low cost LC5100 Coupler, the CAN wires are connected directly to the contact points 1 (CAN-H, marked with C+) and 5 (CAN-L, marked with C-). The screen can optionally be connected to contact points 4 or 8, which are connected to the mounting rail via an R/C network.

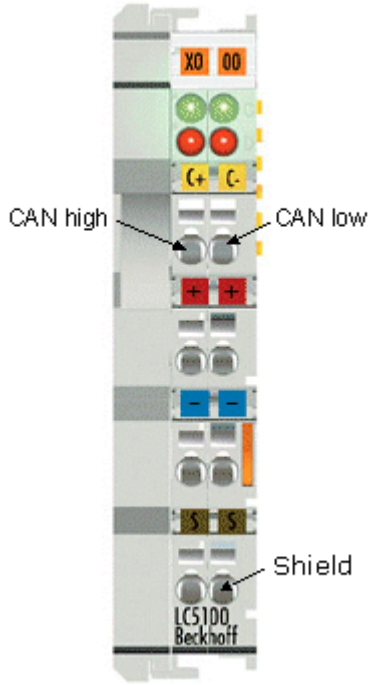


Fig. 15: LC5100

NOTE

Risk of device damage!

On account of the lack of electrical isolation, the CAN driver can be destroyed or damaged due to incorrect cabling. Always carry out the cabling in the switched-off condition.
First connect the power supply and then the CAN. Check the cabling and only then switch on the voltage.

3.2.11 Fieldbus Box: M12 CAN socket

The IPxxxx-B510, IL230x-B510 and IL230x-C510 Fieldbus Boxes are connected to the bus using 5-pin M12 plug-in connectors.

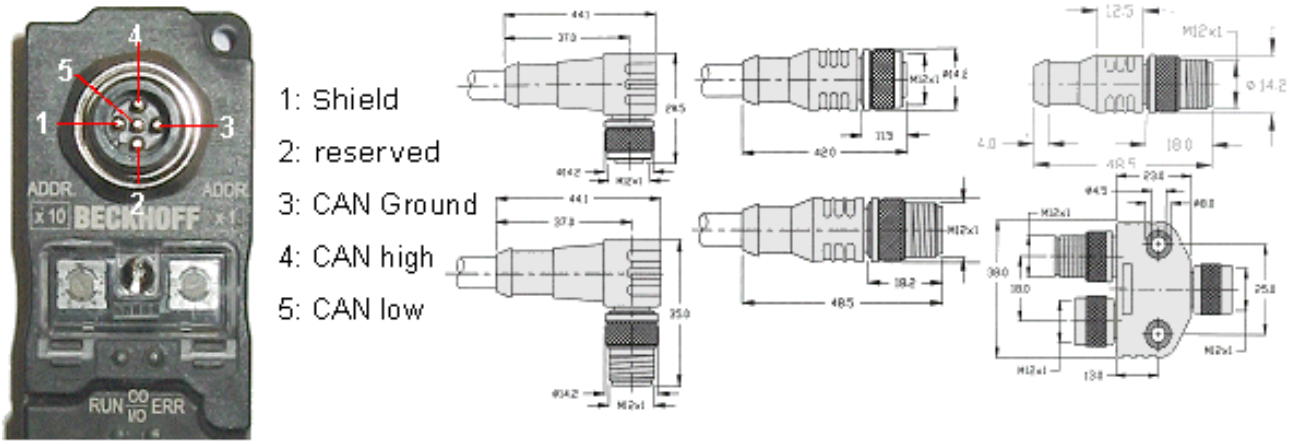


Fig. 16: Pin assignment: M12 plug, fieldbus box

Beckhoff offer plugs for field assembly, passive distributor's, terminating resistors and a wide range of pre-assembled cables for the Fieldbus Box system. Details be found in the catalogue, or under www.beckhoff.de.

4 Parameterization and Commissioning

4.1 Configuration: TwinCAT System Manager

The TwinCAT System Manager Tool is used to configure the FC510x CANopen PCI card. The System Manager provides a representation of the number of programs of the TwinCAT PLC systems, the configuration of the axis control and of the connected I/O channels as a structure, and organizes the mapping of the data traffic.

Fig. 17: TwinCAT System Manager

For applications without TwinCAT PLC or NC, the TwinCAT System Manager Tool configures the programming interfaces for a wide range of application programs:

- ActiveX control (ADS-OCX) for e.g. Visual Basic, Visual C++, Delphi, etc.
- DLL interface (ADS-DLL) for e.g. Visual C++ projects
- Script interface (ADS script DLL) for e.g. VBScript, JScript, etc.

System Manager – Features

- Bit-wise association of server process images and I/O channels
- Standard data formats such as arrays and structures
- User defined data formats
- Continuous variable linking
- Drag and Drop
- Import and export at all levels

The procedure and the configuration facilities in the System Manager are described below.

Context menu

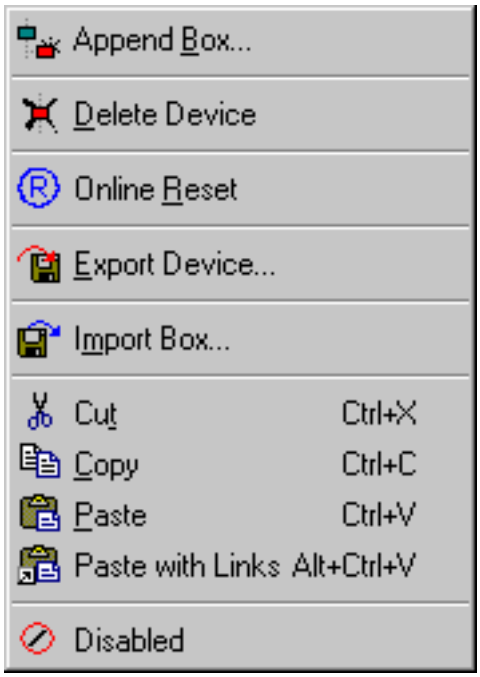


Fig. 18: Context menu

Append Box... <Insert>

Adds CANopen slaves (boxes). The following boxes are currently supported (more detailed description of the boxes is given further down):

Supported boxes	Description
BK5100 [▶ 29]	Bus Coupler
BK5110 [▶ 29]	Economy Bus Coupler
BK5120 [▶ 29]	Bus Coupler (successor of BK5100)
LC5100 [▶ 29]	Low-cost Bus Couplers
IPxxxx-B510 [▶ 29]	Fieldbus compact box: CANopen in/output module, protection class IP67
CANopen Node [▶ 31]	General CANopen device or general CAN device (access via CAN layer 2)

Delete Device... <Del>

Removes the FC510x fieldbus card and all subsidiary elements from the I/O configuration.

Online Reset

Initiates an online reset on the CANopen bus.

FC510x tab

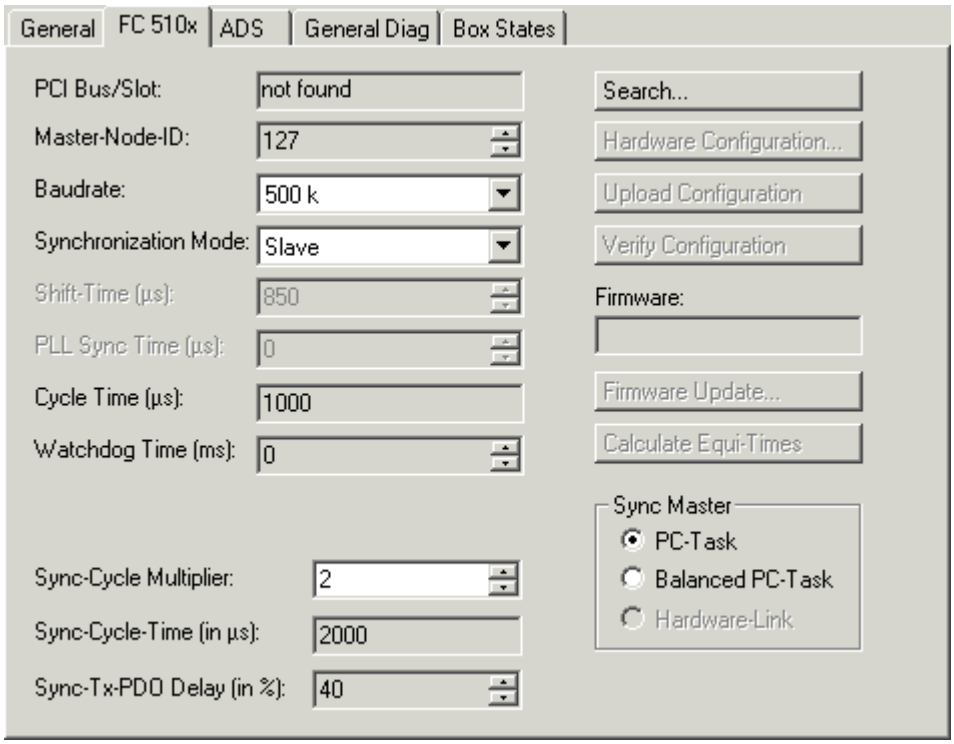


Fig. 19: FC510x tab

PCI Bus/Slot

Indicates in which logical PCI slot the card was found.

Master-Node-ID

Node address for the FC5100. Range of values: 1...127. Determines the identifier of the master heartbeat telegram. Ensure that it is not the same as a slave node address.

Baud rate

Set the baud rate [▶ 51] here. Automatically tests whether the connected slave also supports this baud rate.

Synchronization Mode

The Synchronization Mode determines the accuracy with which the CANopen SYNC [▶ 44] telegram is generated.

The highest-priority task linked to the FC510x card handles the control of the CANopen card and is thus synchronized with the CANopen bus. All other tasks are served asynchronously via corresponding buffers. For all operation modes you can individually set the communication type for each process data object (PDO) - event driven or synchronized (in each PDO tab). If one of the PDOs has been configured for a synchronous operation mode, a SYNC telegram is sent at the start of the cycle, which the slaves use to synchronize their actions with the master cycle.

Different modes can be selected, depending on the SYNC accuracy requirements. Note that individual SYNC telegrams in CAN systems inherently jitter by one telegram length if the bus is occupied at the time of the SYNC. The SYNC accuracy therefore primarily refers to the long-term stability. Bus nodes that synchronize via a PLL procedure are particularly dependent on good long-term stability.

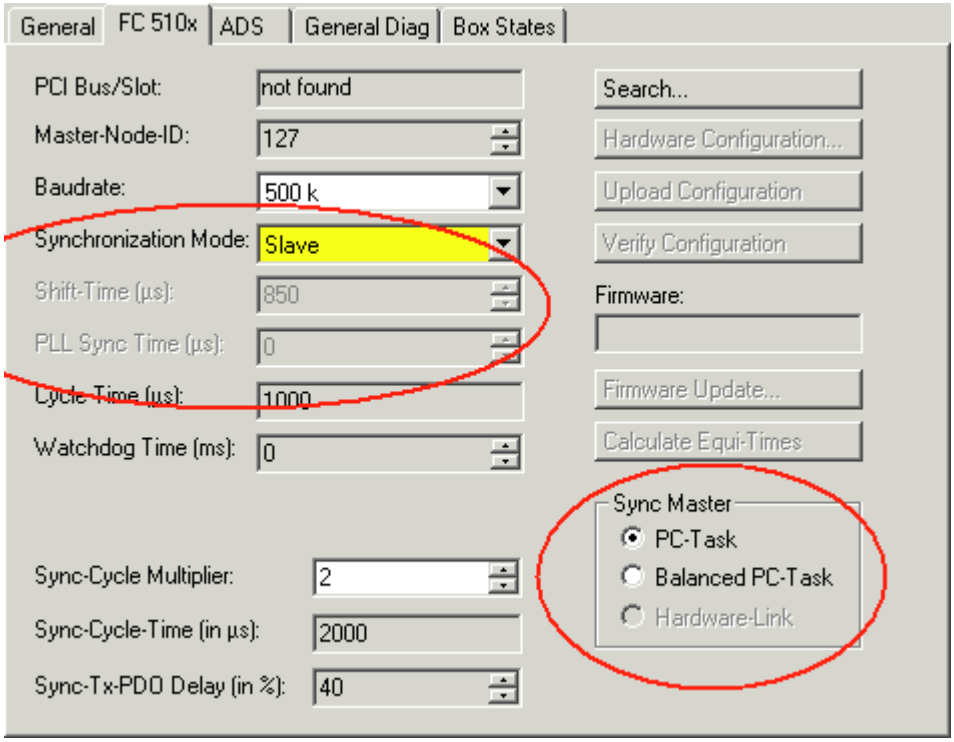


Fig. 20: **Synchronization Mode**

Slave

In slave mode, the card receives its time base from a SYNC master. The Sync Master is selected via the corresponding field.

- **Sync Master: PC Task**. This is the default setting. The PC sets the timebase based on the TwinCAT real-time. Depending on the setting, the task start (default for TwinCAT NC) or task end (default for TwinCAT PLC) triggers the SYNC telegram.
- **Sync Master: Balanced PC Task**. In this operation mode, the sync cycle is also generated with the accuracy of the PC time base on average. However, the interval between two SYNC telegrams is more accurate than with the Sync Master "PC task":
  - runtime differences (e.g. due to case-dependent program branches) are compensated,
  - the FC510x card delays pending send telegrams until after the SYNC telegram,
  - the individual SYNC distances are determined by the crystal-precise timer of the FC510x card.

If necessary, the card timer is readjusted in small steps to the PC timer if it the latter deviates from the card timer by the value set in "PLL Sync Time".
In this mode, the sync telegram is delayed by the **shift time** relative to the completion of the TwinCAT task. The shift time should be as small as possible in this mode, but sufficiently large to ensure that the TwinCAT task can access the process data. The function "Calculate Equi-Times", which is triggered by clicking on the corresponding button after the mappings have been created, helps to set the optimum shift time.

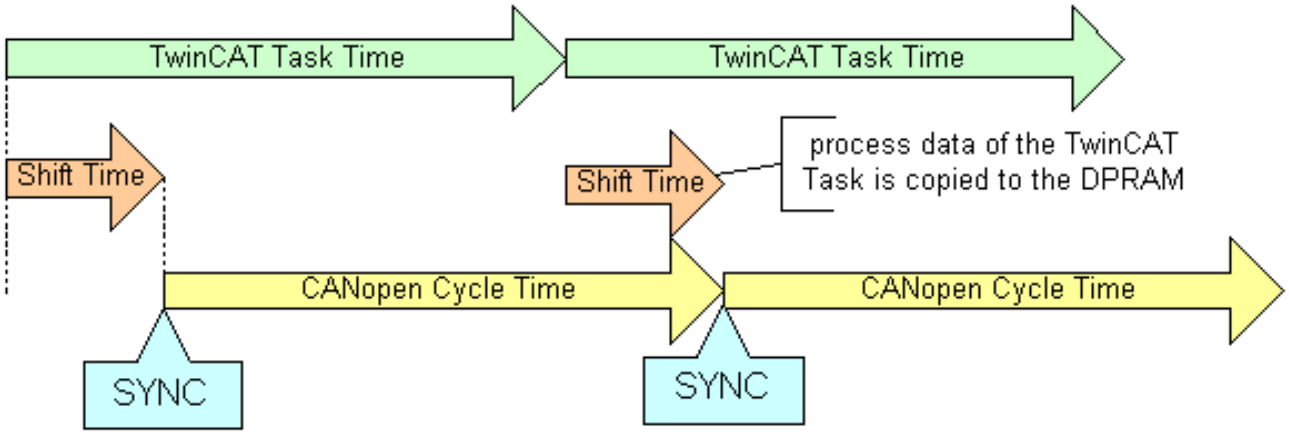


Fig. 21: Synchronization Mode: Slave (sync master: balanced PC clock)

Master

In master mode the card generates its time base locally. The SNYC telegram is crystal-precise on average. The start of the TwinCAT task is specified by the card and is delayed by the shift time relative to the SYNC telegram. In this mode, the shift time should be selected as large as possible. The function "Calculate Equi-Times", which is triggered by clicking on the corresponding button after the mappings have been created, helps to set the optimum shift time.

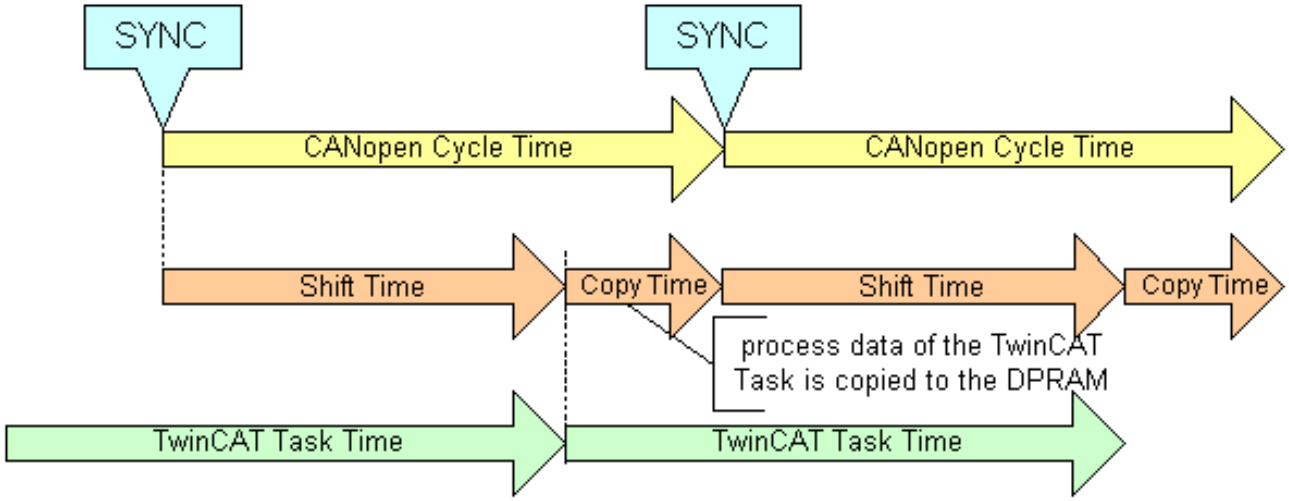


Fig. 22: Synchronization Mode: Master

Cycle Time

Displays the cycle time of the corresponding highest priority task. The display is updated when the mapping is generated.

Watchdog Time

Here, a watchdog can be activated, which means that the FC510x enters STOP mode in the event of a PC crash and also transfers all projected slaves to this state.

Sync-Cycle Multiplier

CANopen SYNC Cycle Time = (Task) Cycle Time x Sync-Cycle Multiplier. Event driven PDO communications and cyclical synchronized PDO communication are frequently combined when used in conjunction with CANopen. In order to be able to respond rapidly to an event, the TwinCAT task cycle time has to be less than the CANopen SYNC cycle time. If the sync cycle multiplier is set to values > 1, the TwinCAT task is called repeatedly before the SYNC telegram is sent again.

Sync-Cycle Time

The cycle time of the CANopen snyc telegram is displayed here. It results from the cycle time of the highest-priority task, whose process data are linked with the card, and from the sync cycle multiplier.

Sync-Tx-PDO Delay

Directly after the SYNC telegram, the synchronized slaves send their input data/actual values. The FC510x can delay the sending of the output data / set value (TxPDOs from the perspective of the card) in order to minimize the telegram burst directly after the SYNC. This delay is set in percent of the SYNC cycle time with the parameter Sync-Tx-PDO -Delay.

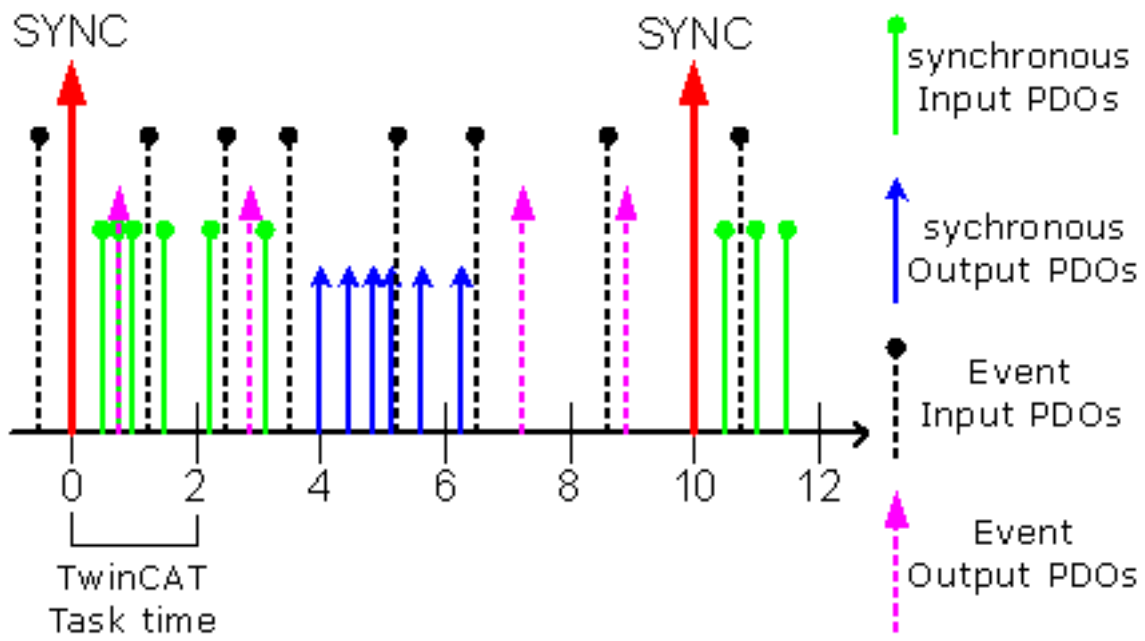


Fig. 23: Example

Task Cycle Time = 2000 µs, Sync-Cycle Multiplier = 5, Sync Tx-PDO Delay =40. The PLC task can process event-driven PDOs every 2 ms; the CANopen sync cycle is 10 ms; the FC510x sends its synchronous PDOs 4 ms (=40% of 10 ms) after the SYNC.

Search...

This is used to search all existing FC510x channels; the required channel can be selected. In the case of an FC5102 both channels A and B appear. These behave in logical terms like two FC5101 cards.

Hardware Configuration...

In which the address of the FC510x is set in the lower memory area (below 1 MB) of the PC.

Upload Configuration

Scans the CANopen network and adds all detected equipment to the device (FC510x) (boxes cannot be added). In the case of Beckhoff boxes, reads the configuration precisely. In the case of external devices, the PDO configuration and the identity object are read and evaluated.

Verify Configuration

Allows a comparison of the expected (entered) network configuration with the devices actually found in the network. The data from the CANopen Identify Object are read and compared. In the case of Beckhoff boxes the connected Bus Terminals or extension modules are read and compared (under preparation).

Firmware

Shows the current firmware version of the FC510x.

Firmware Update...

Update the FC510x card firmware version here. Attention: The TwinCAT System must be stopped for this function.

ADS tab

The FC510x is an ADS device with its own net ID, which can be changed here. All ADS services (diagnostics, acyclic communication) intended for the FC510x, have to address the card via this Net-ID.

Box States tab

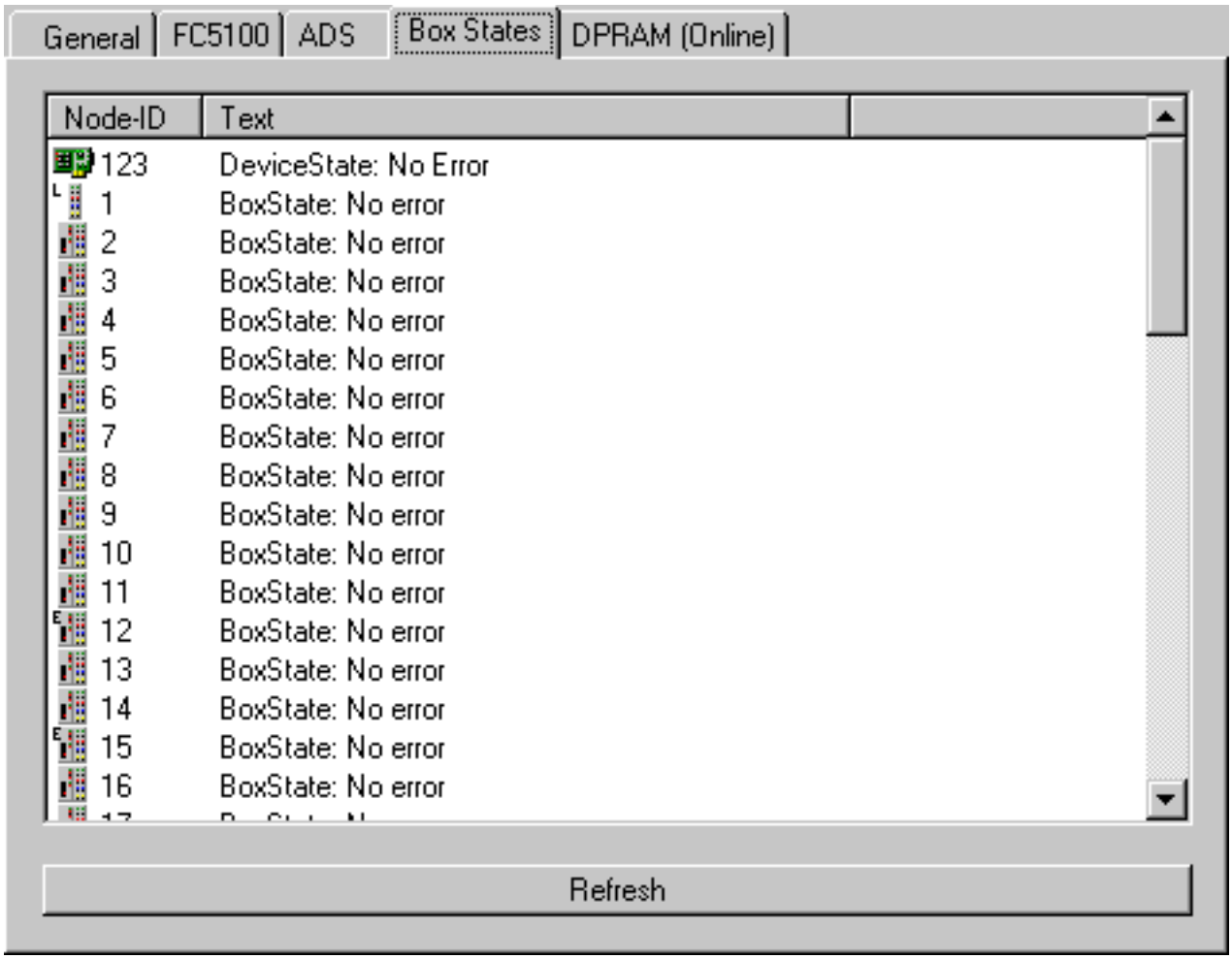


Fig. 24: Box States tab

Displays an overview of all current box states.

DPRAM (Online) tab

Refer to "Online display of DPRAM" in the System Manager documentation.

Diagnostic Inputs

The FC510x automatically provides various diagnostic variables which describe the status of the card and the CANopen network:

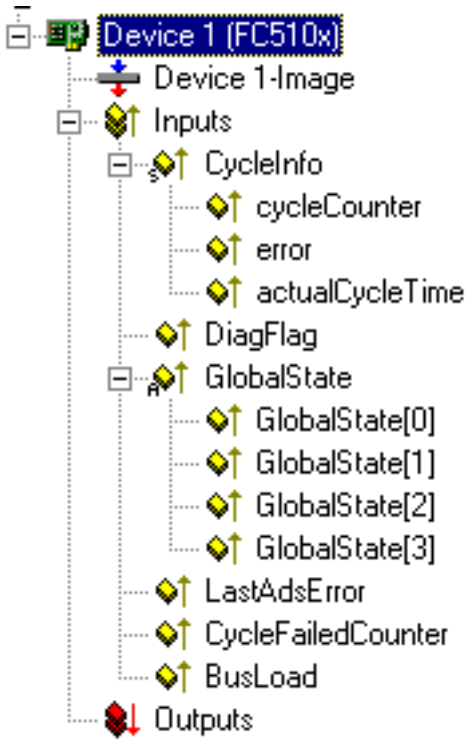


Fig. 25: FC510x - diagnostic variables

cycleCounter: Is incremented at the end of each firmware cycle in order that this variable can indicate whether the last cycle was completed before the task was started

error: Shows the number of slaves whose Box State is not equal to zero. Only check the BoxState of the slaves if this value is other than 0

actualCycleTime: Shows the current cycle time in 4/25 µs. This variable is only updated when all slaves are involved in the data exchange (and when error is 0)

DiagFlag: Shows whether the diagnostics information on the card has changed. This can be read off using ADS-Read. For that purpose, specify the net ID of the FC510x, the port number 200 and the IndexGroup 0xF100. The IndexOffset and the length then relate to the diagnostic data. (Note: the Box States are also directly available as variables.)

Offset 1-127: BusStatus List, 1-127 one byte each station address which contains the station status (see BoxState for CANopen boxes)

Global State: Various diagnostic and status displays for the FC510x. The byte in GlobalState(0) shows the status of the card in relation to the TwinCAT system: RUN, RESET, OFFLINE and STOP are distinguished. GlobalState(2) gives information about the status of the CAN controller: "CAN Warning Limit Reached" and "Bus Off" are displayed. Warning limit reached means that the send/receive error counter on the CAN controller has exceeded the value 96. BusOff means that the CAN controller can no longer participate in bus communication; this is caused by an excessive number of CAN errors (Error Frames). In this case there is a serious physical error in the CAN network. (e.g. too few or too many termination resistors, at least one device with incorrect baud rate, short circuit, etc.) The "bus off" state can only be exited through a card reset. Details about further global state data, see comments in "Online" tab.

LastAdsError: Shows the error code of the last ADS access error, e.g. if an attempt has been made to read the diagnostic data for a deactivated node.

CycleFailedCounter: Counts the number of firmware cycles, which could not be completed before the corresponding task tried to read or write the process image again. If this counter is incremented, the task cycle time has been set too low for the actual network configuration.

BusLoad: Shows the current bus load in %. The Bus Load [▶ 51] is an important design criterion for CAN networks. The value shown is an average value over 100 ms.

4.2 Beckhoff Bus Coupler

The BK51x0 Bus Coupler and the IPxxx-B510 Fieldbus Box are installed in the **CANopen** bus. The specific properties which distinguish them from other Bus Couplers and/or Fieldbus Box modules are then described below.

Types	Description
BK5100	Bus Coupler
BK5110	Economy Bus Coupler
BK5120	Bus Coupler, successor of BK5100
LC5100	Low-cost Bus Couplers
IPxxxx-B510	Fieldbus compact box: CANopen in/output module, protection class IP67
ILxxxx-B510	Fieldbus Coupler Box: Expandable CANopen input/output module in protection class IP67

BK51x0/IX-B510 tab

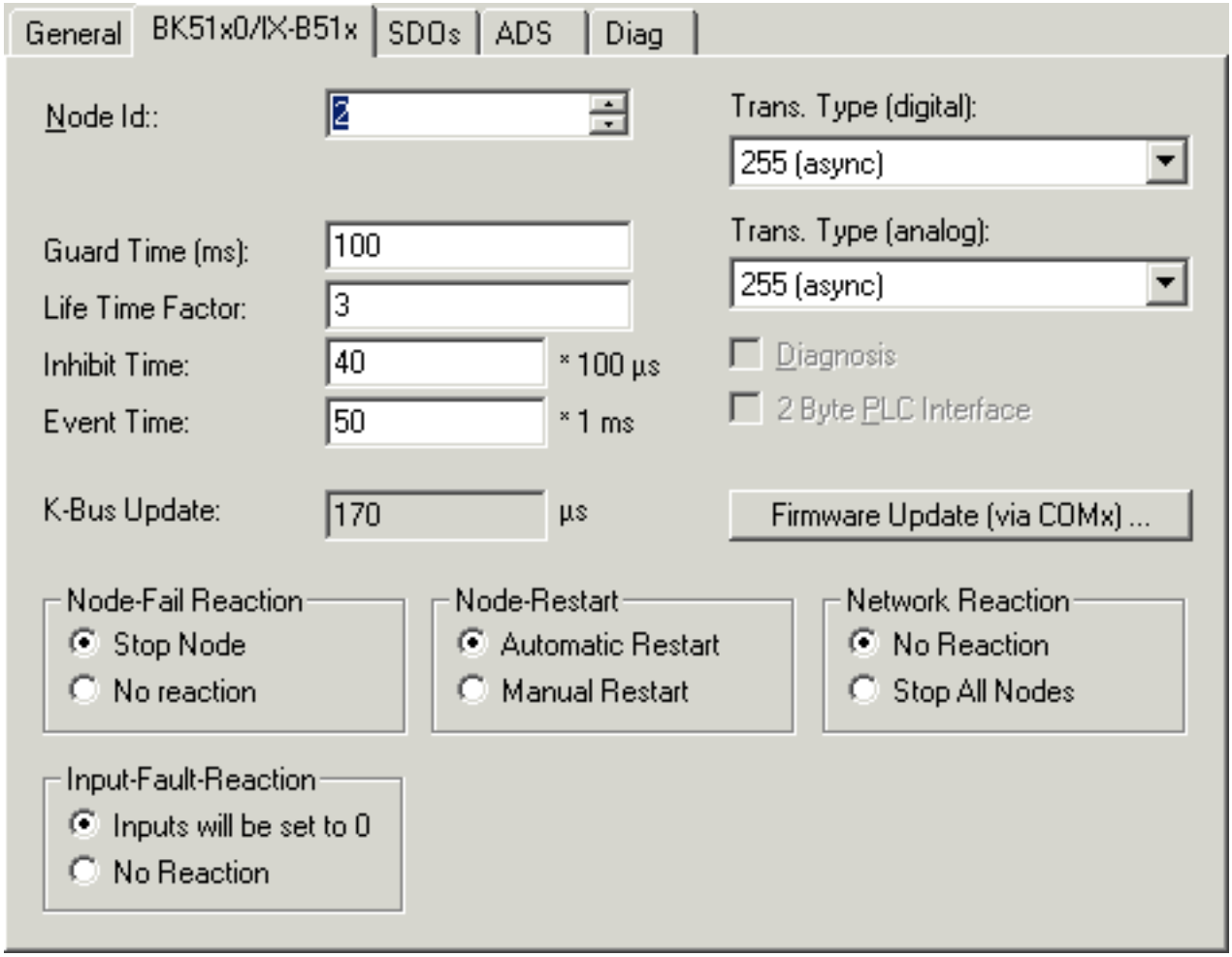


Fig. 26: BK51x0/IX-B510 tab

Node Id: Sets the node ID of the CAN bus device (between 1 and 63 (BK51x0) and/or 1 and 99 (IPxxxx-B510)). This value must comply with the value set at the Bus Coupler and/or at the compact box.

Guard Time: Cycle time for the node monitoring (node guarding).

Life Time Factor: Guard time multiplied produces the watchdog time for the monitoring of the master by the coupler (life guarding). Life guarding is deactivated if the lifetime factor is set to zero.

Inhibit Time: Displays the minimum send interval for PDOs (telegrams) with analog and special signals. If more than 64 digital signals are present, they also furnished with this inhibit time [▶ 48].

Event Time: Event timer for transmit PDOs. Expiry of this timer is treated as an additional event for the corresponding PDO, so that the PDO will then be transmitted. If the application event occurs during a timer period, it will also be transmitted, and the timer is reset.

K-Bus Update: Calculates the anticipated duration of a complete update of the terminal bus (according to type and number of connected terminals).

Trans.Type: Gives the Transmission Type [▶ 44] for digital / analog input telegrams. 254 + 255 corresponds to the event-driven transmission, 1...240 are synchronous transmission types. For further details see also BK51X0 manual.

Firmware Update: Enables the updating of the coupler firmware via the serial interface (requires KS2000 software package interface cable).

SDOs tab

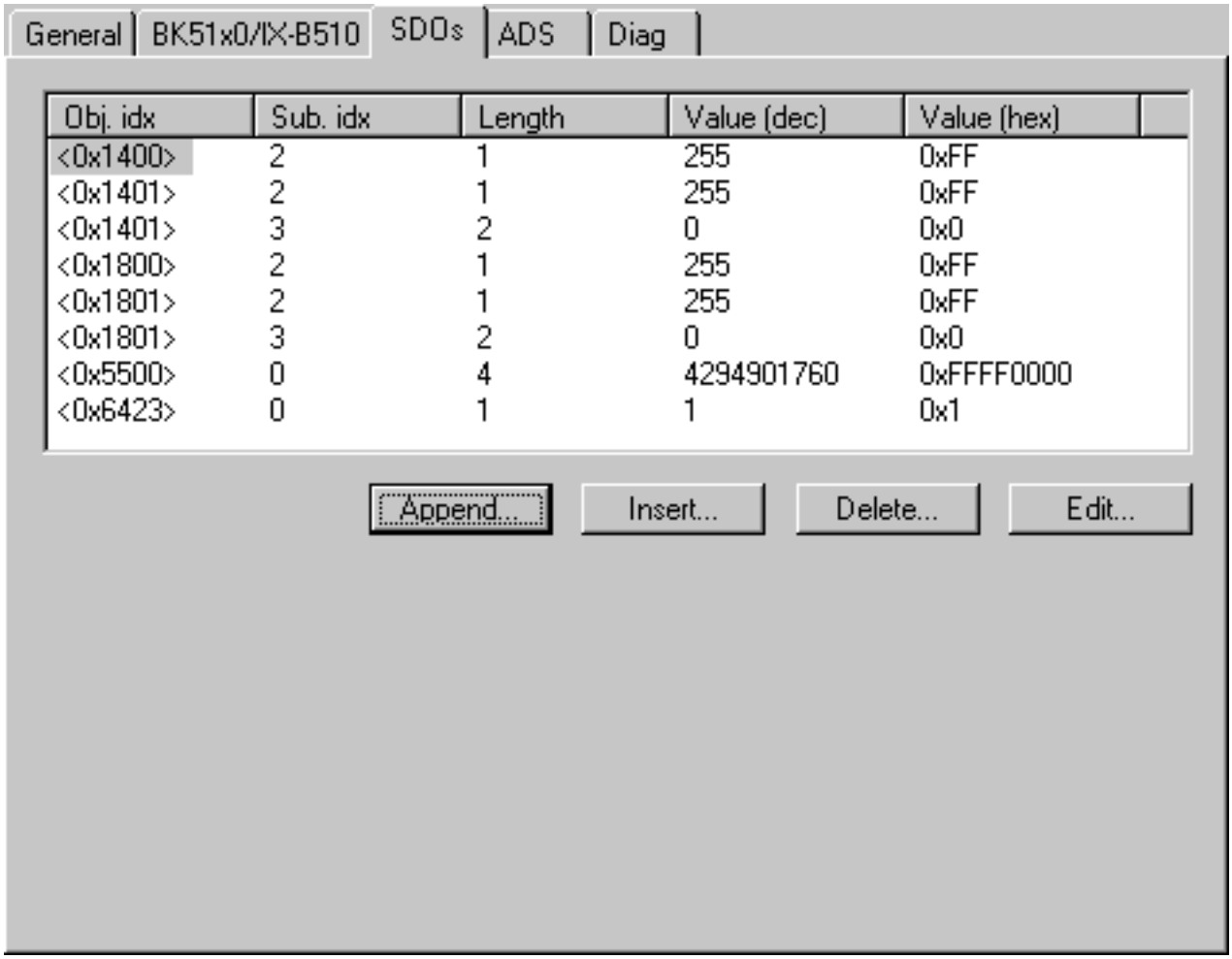


Fig. 27: SDOs tab

SDO inputs sent to the node at StartUp are displayed/managed on this page. Inputs with an object index in straight brackets are automatically created on the basis of the updated terminal configuration. Other inputs can be managed using "Append", "Insert", "Delete" and "Edit".

ADS tab

The node (Bus Coupler) is assigned an ADS port to enable writing and reading of SDO objects at runtime (e.g. from the PLC). It can be changed if required. The ADS IndexGroup contains the CANopen object index and the ADS IndexOffset contains the CANopen SubIndex. See chapter SDO communication [▶ 56] for details of SDO communication via ADS.

Diag tab

Diagnostic information is displayed here. The window contents are not cyclically refreshed; select the "Refresh" button if necessary. The diagnostic information displayed can also be queried by ADS [▶ 62].

4.3 CANopen node

CANopen devices which are not recognized by the TwinCAT System Manager can be incorporated into the network by selecting the box "CANopen Node". The CAN(open) messages (PDOs) can be configured directly for these devices. This will guarantee the optimum flexibility of this general CANopen interface.

When using the FC510x / EL6751, this box also enables you to receive and send any CAN identifier - this enables communication with any CAN node. The only condition is the support of at least one of the baud rates [▶ 60] supported by the FC510x / EL6751.

CAN Node tab

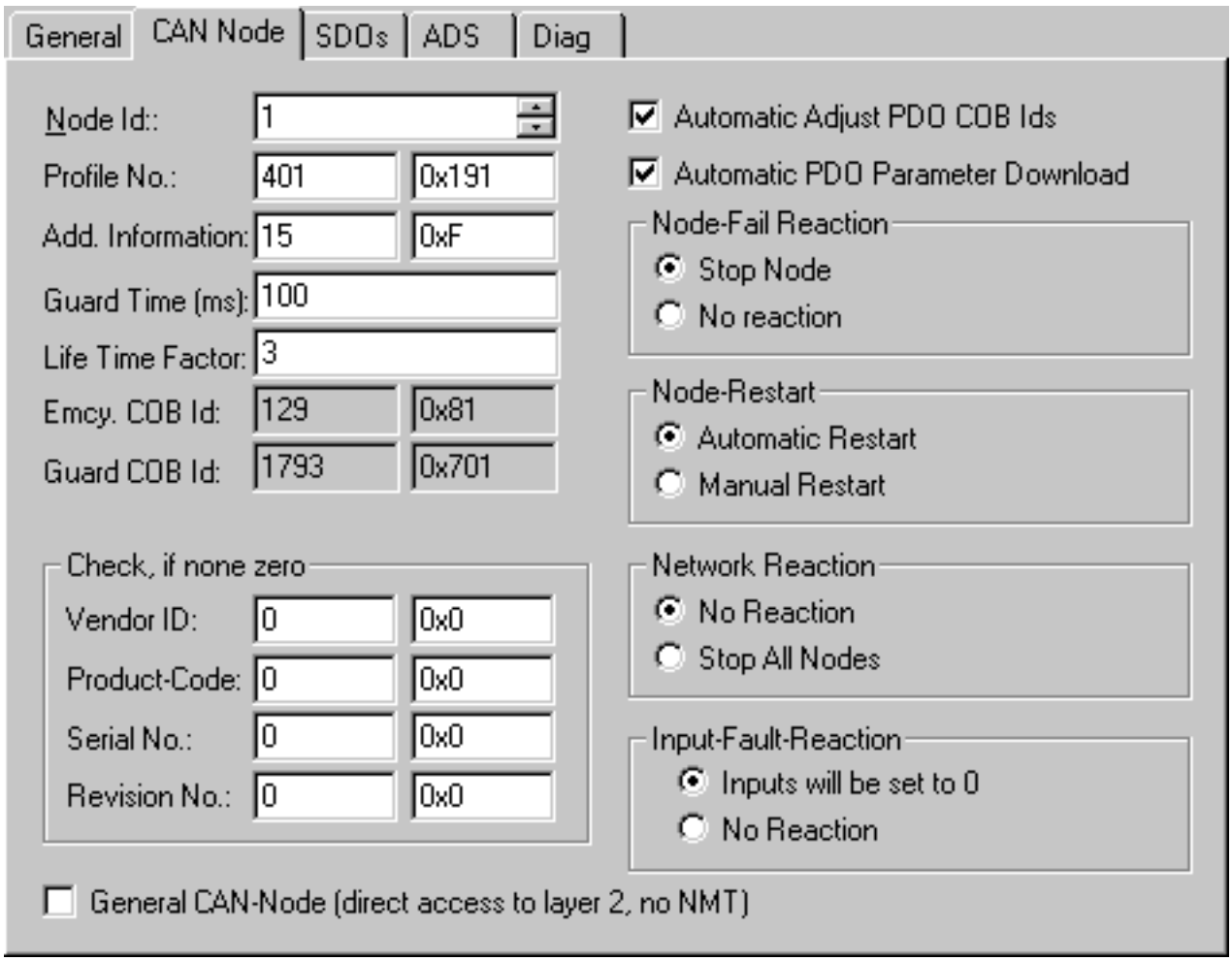


Fig. 28: CAN Node tab

Node ID
Enter the general CANopen device node address here. If you select the "Auto Adapt PDO COB Ids" box, the default identifier for the process data object can also be carried out after changing the node ID.

Profile no.
After CANopen, the parameter 0x1000 "Device Type" contains the number of the supported device profile in both the lowest value bytes. These are entered here and compared at the system StartUp with the device parameters present. If no device profile is supported, the parameter will contain the value 0

Add info
The additional info is located in both the highest value bytes of the object directory entry 0x1000 (device type).

The set/actual configuration comparison only takes place if Profile No. or Add. Info (i.e. object directory entry 0x1000) is set to a value that is not zero. If the expected data at the system start do not comply with the values present, the StartUp of this node will be interrupted and a corresponding error message will appear in the Diag Tab.

Guard Time
The Guard Time determines the interval at which the node is monitored (node guarding). 0 means no monitoring. The value entered is rounded up to the next multiple of 10 ms.

Life Time Factor
Guard Time x Life Time Factor determines the watchdog length for the mutual monitoring of card and CANopen nodes. 0 indicates that the CANopen node is not monitoring the card. At 0 the card takes the Guard Time directly as the watchdog length.

The FC 510x / EL6751 also support the Heartbeat protocol and initially attempt to start this form of node monitoring on the CANopen node (write access to the objects 0x1016 and 0x1017 in the object dictionary). If this attempt fails, guarding is activated. The guard time as producer heartbeat time and (guard time x lifetime factor) as consumer heartbeat time are entered. In this case a Heartbeat telegram is transmitted with the smallest configurable guard time (the guard times can be individually set for each node).

Emcy COB Id / Guard COB ID
Identifier for emergency messages or guarding protocol. They result from the node address.

Use Heartbeat
Heartbeat is used for monitoring of the node. If this is deactivated, the guarding is used for monitoring.

Auto-adjust PDO...
Specifies whether TwinCAT should download the PDO communications parameters to the node at the system start.

If the download of the PDOs Parameter Identifier and Transmission Type fails, the card attempts to read these parameters and compare them with the configured values. In this way, it supports only those nodes which, e.g. have implemented the default identifiers as read-only values.

Vendor ID, Product Code, Serial No., Revision No.
If values other than zero are entered here, these identity object inputs (0x1018 in the object directory) are read off at the system StartUp and compared with the configured values. The corresponding node will be started only if the values coincide. It is also possible to compare one part of the value (e.g. vendor ID and product code) - in this case set the not desired parameters to zero.

Node error reaction

Stop Node
After a recognized node error, the node is set to "Stopped" mode (NMT command "Stop Remote Node"). The node (according to each device profile) can then be switched to a safe state via the network status machine - SDO addressing is not possible in this mode.

No Reaction
No NMT stop remote node command after node error

Node Restart

Automatic Restart
After a recognized node error the card automatically attempts to restart the node. The StartUp attempt is initiated by a node reset command.

Manual Restart
After a node error, this node remains in error state and is not restarted automatically. You can actuate a restart via "I/O-Reset".

Network Reaction

No Reaction
The failure of a node has no effect on the other bus devices

Stop All Nodes
After the failure of a node, all other previously started nodes are stopped (NMT stop remote node command). You then need to restart the system.

General CAN Node
If you have selected this checkbox, the entire CANopen network management for this device is deactivated. It is not started, monitored etc. The PDO entries are regarded as pure CAN telegrams (layer 2) and made available to the controller on an event-driven basis.

CANopen terminology

As the CANopen terminology is retained, even in the case of the general CAN nodes, you need to take into account the fact that RxPDOs are the telegrams sent by the FC510x / EL6751 and TxPDOs are the received telegrams.

This option allows any CAN node to be connected to the TwinCAT, if the Baud Rate [▶ 60] and the bit timing parameters comply. The respective protocol can then be simulated within the PLC program. It is also possible to run CANopen devices and general CAN nodes within the same network - if there are no identifier overlaps (the system structure is such that you cannot use an identifier twice).

CANopen PDOs

Process Data Objects [▶ 44] (PDOs) are CAN telegrams which transport process data without a protocol overhead. RxPDOs are received by node, TxPDOs are sent by the node. This description is contained in the System Manager from the perspective of the configured node, i.e. RxPDOs are sent by TwinCAT, TxPDOs are received by TwinCAT.

PDO tab

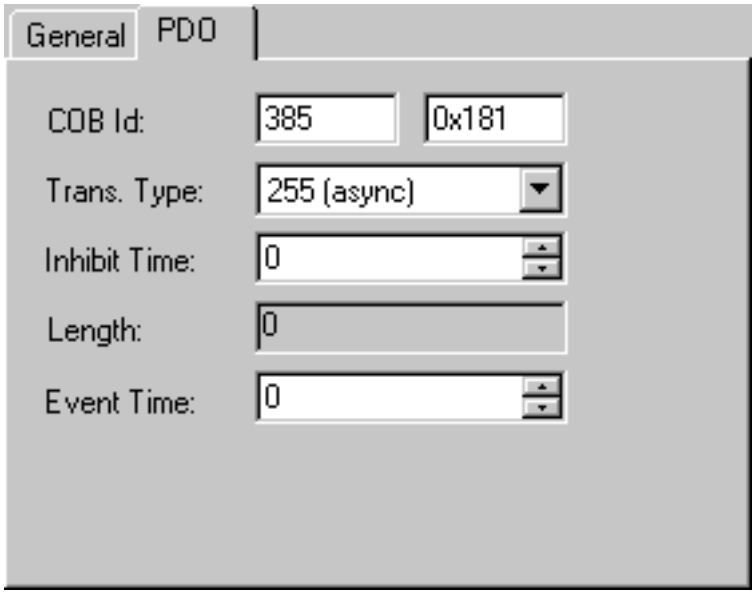


Fig. 29: PDO tab

COB Id
The CAN identifier of this PDO. For every two send and receive PDOs per node, CANopen provides Default Identifiers [▶ 61]. These can then be changed.

Trans.Type
The Transmission Type [▶ 44] determines the send behavior of the PDO. 255 corresponds to the event driven send.

Inhibit Time
Send Delay [▶ 44] between two identical PDOs. Is entered in multiples of 0.1 ms.

Length
The length of the PDO is based on the mapped variables and cannot therefore be edit here.

Event Time (FC510x and EL6751 only)
Enter the value for the Event Timer [▶ 49] in ms. For Send PDOs (here: RxPDOs, see above) an additional sending of the PDO is triggered, for Receive PDOs (here: TxPDOs) the arrival of a PDO within the pre-set value is monitored and the box state of the node is changed as appropriate. If 0, the parameter is not transferred to the node.

TwinCAT creates corresponding inputs in the node object directory on the basis of the parameters entered here. These are transferred via SDO at the system start. You can view the inputs at the SDO tab. If this behavior is not required, you can deactivate "Auto Download of PDO Parameters" by selecting the checkbox at the CAN node tab.

Deactivate checking of the PDO size
Checkbox for deactivation of the length check of the PDO size.

Tree Representation

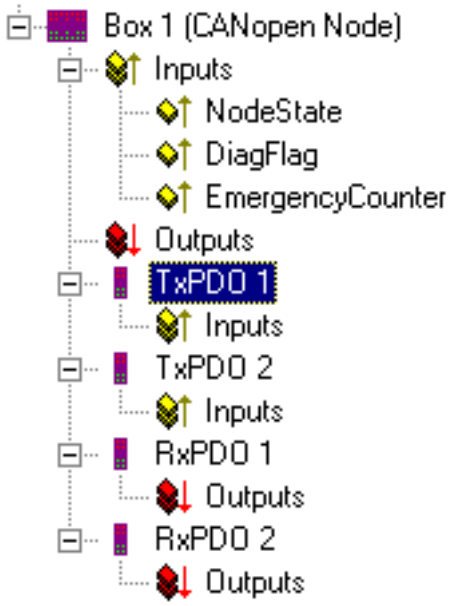


Fig. 30: Tree Representation

TwinCAT firstly provides two send and receive PDOs, with Default Identifiers [▶ 61], for a general CANopen node. Superfluous PDOs can be selected and removed.

TxPDOs are sent by the CANopen node and generally contain inputs. RxPDOs are received by the node, i.e., sent by TwinCAT

Add variables to the PDOs by right clicking on "Inputs" and/or "Outputs" and selecting the corresponding variable(s). If several variables of the same type are inserted with a single action, the offset within the PDO will be created automatically. If variables are inserted one after another, you need to set the corresponding offset (start address within the CAN telegram) for each variable.

Object dictionary entries in TwinCAT

TwinCAT places the PDOs in the displayed order according to the object dictionary entries in the node. This way, for example, the PDO communication parameters of the third listed TxPDO are always written to index 0x1802 – independent of the designation of the PDO in the System Manager. Thus, if only PDO1 and PDO3 are to be used, a PDO2 must also be entered – in this case without assigning variables. PDOs without variables are not transmitted and also not expected.

Context menu

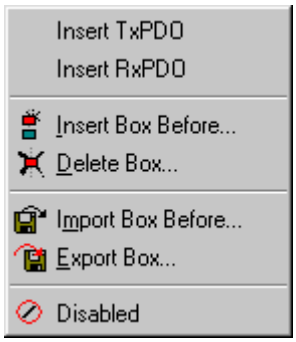


Fig. 31: Context menu

The menu above is obtained by right clicking on the general CANopen node. Here you can insert further Tx PDOs and/or Rx PDOs.

SDOs tab

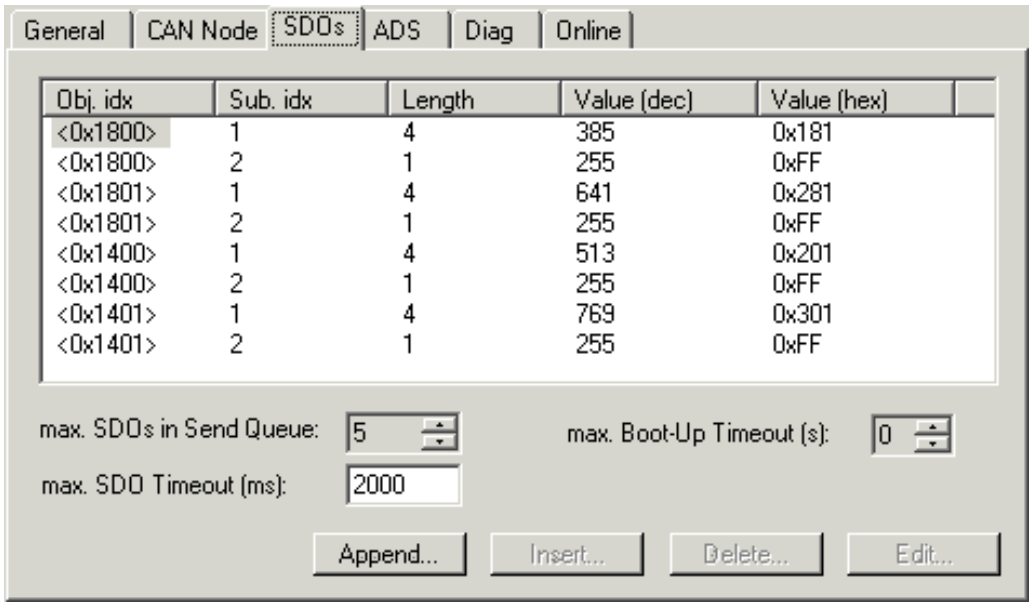


Fig. 32: SDOs tab

SDO inputs sent to the node at StartUp are displayed/managed on this page. Inputs with an object index in straight brackets are automatically created on the basis of the updated terminal configuration. Other inputs can be managed using "Append", "Insert", "Delete" and "Edit".

ADS tab

In order to be able to read and write SDO objects during the runtime (e.g. from the PLC), the node (Bus Coupler) can be allocated an ADS port (CIFx0-CAN). The FC510x / EL6751 provides an ADS port at all times for every node since the diagnostic information is transported via ADS. These ports can be used to read and write SDO objects using ADS read requests and/or write requests.

The ADS IndexGroup contains the CANopen object index and the ADS IndexOffset contains the CANopen SubIndex.

4.4 Configuration Files

The configuration options for a CANopen device are available in eds files (electronic data sheets) in a standard data format. The data format is specified in CiA DSP 306. A tool is available from the CAN-in-Automation e.V. user association with which this data format can be checked.

eds files for the Beckhoff CANopen slave devices are available for download from the Beckhoff website.

Since it was found that a large number of eds files do not properly observe the standard, Beckhoff have until now not supported eds files in the System Manager. The direct configuration of PDO parameters makes it possible to adapt to the devices that are to be incorporated, and also to use devices that do not entirely meet the standard.

5 CANopen Communication

5.1 Network Management

Simple Boot-Up

CANopen allows the distributed network to boot in a very simple way. After initialization, the modules are automatically in the *Pre-Operational* state. In this state it is already possible to access the object directory using service data objects (SDOs) with default identifiers, so that the modules can be configured. Since default settings exist for all the entries in the object directory, it is in most cases possible to omit any explicit configuration.

Only one CAN message is then required to start the module: Start_Remote_Node: Identifier *0*, two data bytes: 0x01, 0x00. It switches the node into the *Operational* state.

Network Status

The states and the state transitions involved as CANopen boots up can be seen from the state diagram:

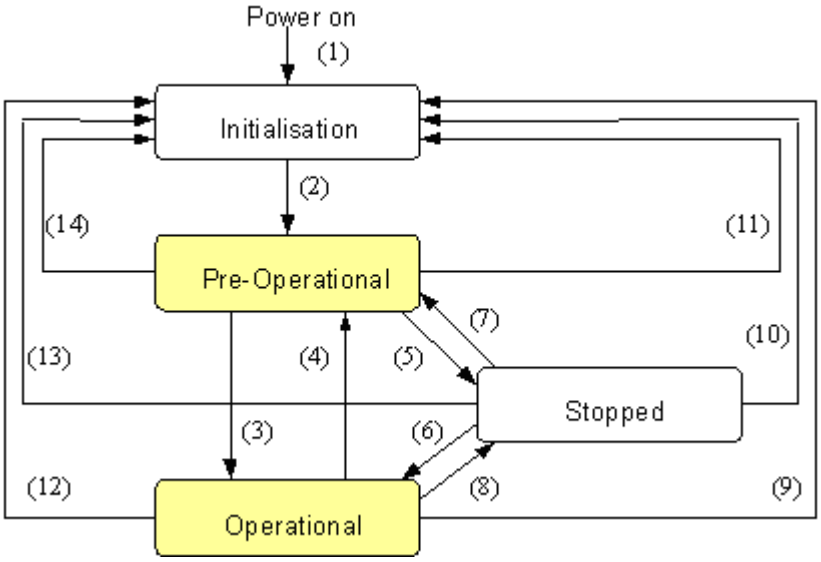


Fig. 33: CANopen bootup state diagram

Pre-Operational

After initialization the Bus Coupler goes automatically (i.e. without the need for any external command) into the *Pre-Operational* state. In this state it can be configured, since the service data objects (SDOs) are already active. The process data objects, on the other hand, are still locked.

Operational

In the *Operational* state the process data objects are also active.

If external influences (such as a CAN error, or absence of output voltage) or internal influences (such as a K-Bus error) mean that it is no longer possible for the Bus Coupler to set outputs, to read inputs or to communicate, it attempts to send an appropriate emergency message, goes into the error state, and thus returns to the *Pre-Operational* state. In this way the NMT status machine in the network master can also immediately detect fatal errors.

Stopped

In the *Stopped* state (formerly: *Prepared*) data communication with the Coupler is no longer possible - only NMT messages are received. The outputs go into the fault state.

State Transitions

The network management messages have a very simple structure: CAN identifier *0*, with two bytes of data content. The first data byte contains what is known as the command specifier (cs), and the second data byte contains the node address, the node address *0* applying to all nodes (broadcast).

11 bit identifier	2 byte user data							
0x00	cs	Node ID						

The following table gives an overview of all the CANopen state transitions and the associated commands (command specifier in the NMT master telegram):

Status transition	Command Specifier cs	Explanation
(1)	-	The initialization state is reached automatically at power-up
(2)	-	After initialization the pre-operational state is reached automatically - this involves sending the boot-up message.
(3), (6)	cs = 1 = 0x01	Start_Remote_Node. Starts the module, enables outputs, starts transmission of PDOs.
(4), (7)	cs = 128 = 0x80	Enter_Pre-Operational. Stops PDO transmission, SDO still active.
(5), (8)	cs = 2 = 0x02	Stop_Remote_Node. Outputs go into the fault state, SDO and PDO switched off.
(9), (10), (11)	cs = 129 = 0x81	Reset_Node. Carries out a reset. All objects are reset to their power-on defaults.
(12), (13), (14)	cs = 130 = 0x82	Reset_Communication. Carries out a reset of the communication functions. Objects 0x1000 - 0x1FFF are reset to their power-on defaults.

Sample 1

The following telegram puts all the modules in the network into the error state (outputs in a safe state):

11 bit identifier	2 byte of user data							
0x00	0x02	0x00						

Sample 2

The following telegram resets node 17:

11 bit identifier	2 byte of user data							
0x00	0x81	0x11						

Boot-up message

After the initialization phase and the self-test the Bus Coupler sends the boot-up message, which is a CAN message with a data byte (0) on the identifier of the guarding or heartbeat message: CAN-ID = 0x700 + node ID. In this way temporary failure of a module during operation (e.g. due to a voltage drop), or a module that is switched on at a later stage, can be reliably detected, even without Node Guarding. The sender can be determined from the message identifier (see default identifier allocation).

It is also possible, with the aid of the boot-up message, to recognize the nodes present in the network at start-up with a simple CAN monitor, without having to make write access to the bus (such as a scan of the network by reading out parameter 0x1000).

Finally, the boot-up message communicates the end of the initialization phase; the Bus Coupler signals that it can now be configured or started.

Firmware version BA

Up to firmware version BA the emergency identifier was used for the boot up message.

Format of the Boot-up message

11 bit identifier	1 byte of user data							
0x700 (=1792)+ node ID	0x00							

Node Monitoring

Heartbeat and guarding mechanisms are available to monitor failures in the CANopen network. These are of particular importance for CANopen, since modules do not regularly speak in the event-driven mode of operation. In the case of "guarding", the devices are cyclically interrogated about their status by means of a data request telegram (remote frame), whereas with "heartbeat" the nodes transmit their status on their own initiative.

Guarding: Node Guarding and Life Guarding

Node Guarding is used to monitor the non-central peripheral modules, while they themselves can use Life Guarding to detect the failure of the guarding master. Guarding involves the master sending remote frames (remote transmit requests) to the guarding identifier of the slaves that are to be monitored. These reply with the guarding message. This contains the slave's status code and a toggle bit that has to change after every message. If either the status or the toggle bit do not agree with that expected by the NMT master, or if there is no answer at all, the master assumes that there is a slave fault.

Guarding procedure

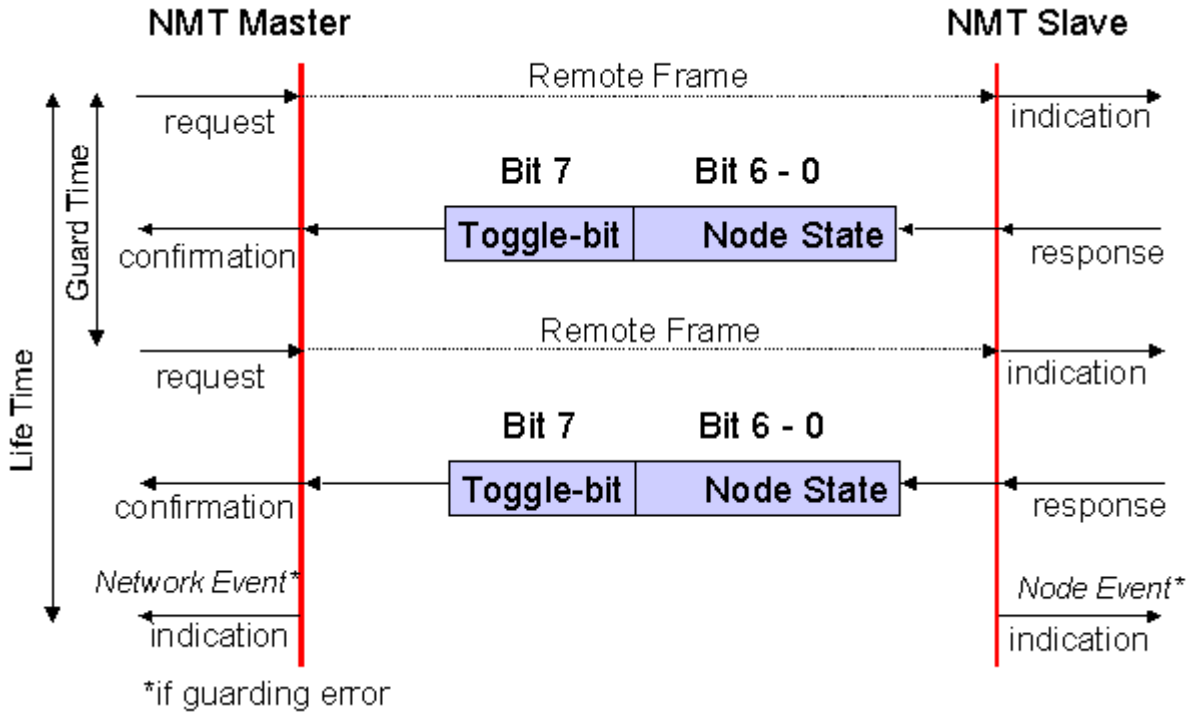


Fig. 34: Schematic diagram: "Guarding procedure"

Protocol

The toggle bit (t) transmitted in the first guarding telegram has the value *0*. After this, the bit must change (toggle) in every guarding telegram so that the loss of a telegram can be detected. The node uses the remaining seven bits to transmit its network status (s):

s	Status
4 = 0x04	Stopped (previously: Prepared)
5 = 0x05	Operational
127 = 0x7F	Pre-Operational

Sample

The guarding message for node 27 (0x1B) must be requested by a remote frame having identifier 0x71B (1819_{dec}). If the node is *Operational*, the first data byte of the answer message alternates between 0x05 and 0x85, whereas in the *Pre-Operational* state it alternates between 0x7F and 0xFF.

Guard time and life time factor

If the master requests the guard messages in a strict cycle, the slave can detect the failure of the master. In this case, if the slave fails to receive a message request from the master within the set *Node Life Time* (a guarding error), it assumes that the master has failed (the watchdog function). It then puts its outputs into the error state, sends an emergency telegram, and returns to the pre-operational state. After a guarding time-out the procedure can be re-started by transmitting a guarding telegram again.

The node life time is calculated from the guard time (object 0x100C) and life time factor (object 0x100D) parameters:

Life time = guard time x life time factor

If either of these two parameters is "0" (the default setting), the master will not be monitored (no life guarding).

Heartbeat: Node Monitoring without Remote Frame

In the heart beat procedure, each node transmits its status message cyclically on its own initiative. There is therefore no need to use remote frames, and the bus is less heavily loaded than under the guarding procedure.

The master also regularly transmits its heartbeat telegram, so that the slaves are also able to detect failure of the master.

Heartbeat procedure

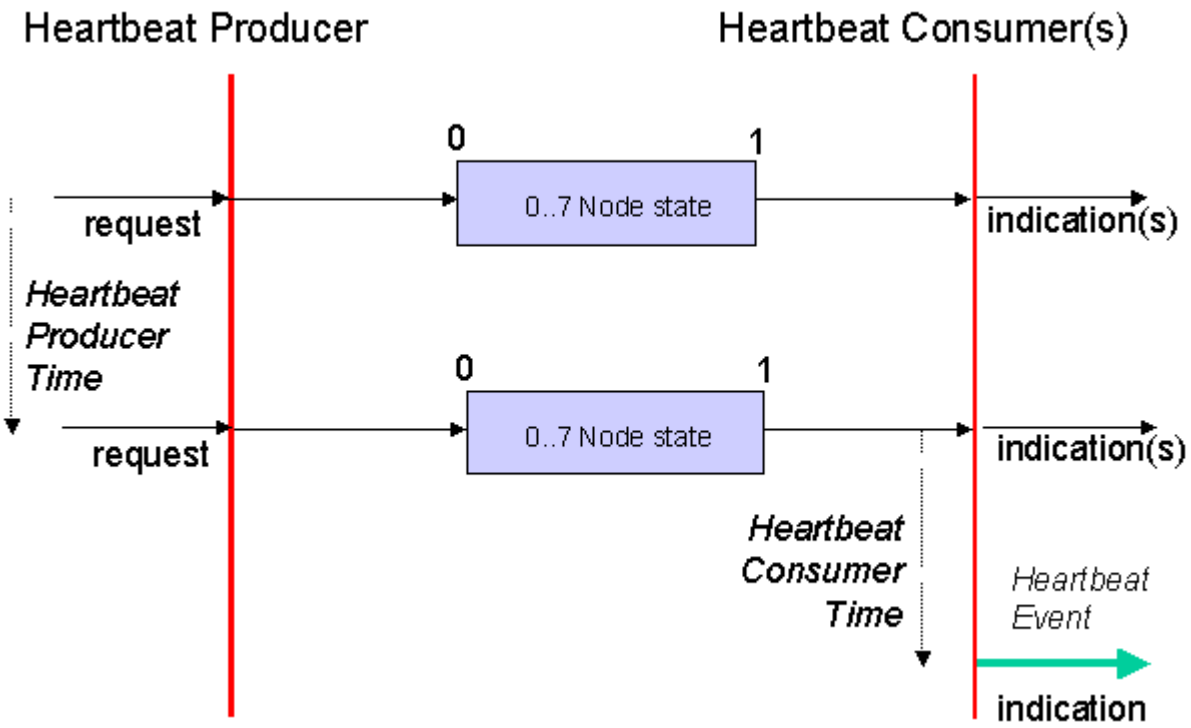


Fig. 35: Schematic diagram: "Heartbeat procedure"

Protocol

The toggle bit is not used in the heart beat procedure. The nodes send their status cyclically (s). See Guarding [▶ 39].

5.2 BootUp of the FC510x

Introduction

The firmware in the FC510x CANopen PCI card treats each individual node separately. The first action following the system start is to check for the presence of the expected nodes, and whether they basically correspond to the devices that have been configured. Following this, each node is parameterized and started, independently of the others. The starting behavior of a node is described below.

1. Reset All Nodes

The starting sequence begins with the global Reset Communication telegram, so that all nodes are brought in to a defined initial state

2. Identify Node

Presence of the nodes is first established through an SDO upload of the object 0x1000 (Device Type). The content supplied by a node is checked for agreement with the expected value. Object 0x1000 is composed of the profile number and of the additional information - both values can be found on the CAN Node tab.

If both the additional information and the profile number are set to "0", the contents returned for object 0x1000 is not checked. An answer containing an SDO abort protocol cannot be tolerated; the process is interrupted.

For values other than zero, the next step is only taken if the value is as expected. Otherwise the process is aborted and the node enters state 0x04 (SDO syntax error at start-up if an SDO abort message has been received or if the data length is incorrect) or state 0x05 (if there is an SDO data mismatch at start-up or the value do not comply) and an appropriate error message is displayed in the dialog box.

If the node does not answer the SDO upload telegram, then the SDO protocol is interrupted after a timeout (approx. 2 seconds) and then repeated after a waiting time (of approx. 1 second) until the node answers. In this phase, the node is in state 0x02 (node not found).

If the vendor ID, the product code, the serial no. or the revision no. have been configured to values other than zero on the CAN Node's tab, then the corresponding values are read and compared in the node's object 0x1018. The booting process is only continued if they are as expected.

3. Set SYNC Time

If synchronous PDOs have been configured, an attempt is now made to enter the given Sync Cycle Time into object 0x1006 (SYNC interval). Because this object is optional, the boot up is still continued even if the node acknowledges negatively - it is, however, necessary for the node to answer.

4. Set PDO Parameter

If the "Auto-download PDO parameters" checkbox on the CAN node's tab has been selected (which it is by default) then the PDO parameters for all the configured PDOs are now written. These are the identifier and the transmission type. The Inhibit Time and the Event Time are only written at this stage if they have been configured to have values other than zero.

If a node answers an SDO download of the PDO parameters with an SDO abort protocol, then the corresponding entry is then read (SDO upload) and compared with the value to be written. If they are in agreement, the process continues. In this way it is possible for read-only PDO parameters to be tolerated, provided they agree with the configured values.

The next step is only taken if the download, or the comparison with existing values, is successful. Otherwise the process is aborted, and the node enters state 0x04 or 0x05, and the appropriate error message is displayed in the dialog box.

5. Set Guarding/Heartbeat

If a value other than zero has been configured for the Guard Time, the appropriate parameters are now written to the nodes. Because the heartbeat process generates less bus loading than guarding, an attempt is first made to start this form of node monitoring on the CANopen nodes.

Heartbeat: The guard time is entered as the producer heartbeat time (0x1017) and the product of (guard time x life time factor) is entered as the consumer heartbeat time (0x1016). The FC510x card then transmits cyclically its heartbeat telegram with the smallest configured guard time (the guard times can be set individually for each node). If the node refuses the entry of the consumer heartbeat time, then it is assumed that the node does not support monitoring of the master - this is tolerated. If entry of the producer heartbeat time also fails, then the guarding protocol is configured.

Guarding: If the node does not support the heartbeat, then the guarding parameters (guard time, 0x100C and life time factor, 0x100D) are entered.

If this attempt also fails, then the start-up process is aborted, and the node enters state 0x04, with an appropriate error message being sent to the dialog box.

6. Download User Parameter

The objects added manually on the SDO tab are now transmitted to the node by SDO download. Once again, if the SDO is interrupted the value is fed back and checked for agreement, so that read-only parameters can be tolerated. The process only continues if successful, and otherwise is aborted.

7. Start Node

After all the parameters have successfully been downloaded, the node is switched into the operational state by means of an individual Start_Remote_Node telegram. RxPDOs are first sent to the nodes about 1 s after this start telegram, and the guarding or heartbeat protocol begins. Node monitoring by heartbeat does not start until the node's producer heartbeat telegram has been received for the first time.

Because CANopen does not provide explicit confirmation of the start process, it is only possible to evaluate the first arrival of the transmit PDOs. Until all the configured TxPDOs have arrived, the state of the node remains set to 0x17 (expected TxPDO is missing).

After all configured nodes have been found, successfully parameterized and individually started, the FC510x card again sends a global Start_Remote_Node telegram (with node ID=0).

8. SYNC

SYNC telegrams are first sent after the linked task with the highest priority has been started. Synchronous TxPDOs are also therefore triggered until this task is running - this can also be a reason for the node state remaining at 0x17.

Example of a boot up sequence:

Node with node ID1, identifier in hex code.

```
Time    ID DLC DATA                     Description
0.1244 00 2  82 00                      Reset communication all nodes
    All nodes are moved into source state
0.1252 601 8 40 00 10 00 00 00 00 00  [1000,00] Initiate Upload Rq.
   First attempt to find knot 1 - node is still in Reset
2.1316 601 8 80 00 00 00 00 00 04 05 05040000 [0000,00] Abort: SDO protocol timed out
   Node has not answered within SDO Time-out (2 sec), SDO is broken off
2.7875 701 1 00                         Boot-up
   Node has carried out reset and contacts with Boot-Up message
4.1391 601 8 40 00 10 00 00 00 00 00 [1000,00] Initiate Upload Rq.
   Second attempt to find node 1. Reading access to object 0x1000
4.1411 581 8 43 00 10 00 91 01 07 00 91 01 07 00 [1000,00] Initiate Upload Rsp. expedited
   Node 1 answers with Profile No. 0x191 (401dez) and Add. Info 0x07
4.1418 601 8 40 18 10 01 00 00 00 00 [1018,01] Initiate Upload Rq.
   The Vendor ID is read
4.1434 581 8 43 18 10 01 02 00 00 00 02 00 00 00 [1018,01] Initiate Upload Rsp. expedited
   Node 1 answers with Vendor ID 0x02 (= Beckhoff)
4.1442 601 8 23 00 18 01 81 01 00 00 81 01 00 00 [1800,01] Initiate Download Rq. expedited
   Now the Identifier for of TxPDO1 is written: 0x181
4.1831 581 8 60 00 18 01 00 00 00 00 00 [1800,01] Initiate Download Rsp
   Node 1 confirms the download
4.1840 601 8 23 01 18 01 81 02 00 00 81 02 00 00 [1801,01] Initiate Download Rq. expedited
   Identifier for TxPDO2 is 0x281
4.2223 581 8 60 01 18 01 00 00 00 00 00 [1801,01] Initiate Download Rsp
4.2230 601 8 23 00 14 01 01 02 00 00 01 02 00 00 [1400,01] Initiate Download Rq. expedited
    Identifier for RxPDO1 is 0x201
4.2347 581 8 60 00 14 01 00 00 00 00 00 [1400,01] Initiate Download Rsp
4.2356 601 8 2f 00 18 02 ff 00 00 00 ff [1800,02] Initiate Download Rq. expedited
   Transmission type for TxPRO1 is 0xFF=255
4.2737 581 8 60 00 18 02 00 00 00 00 00 [1800,02] Initiate Download Rsp
4.2744 601 8 2f 01 18 02 ff 00 00 00 ff [1801,02] Initiate Download Rq. expedited
   Transmission type for TxPRO2 is 0xFF=255
4.3133 581 8 60 01 18 02 00 00 00 00 00 [1801,02] Initiate Download Rsp
4.3141 601 8 2f 00 14 02 ff 00 00 00 ff [1400,02] Initiate Download Rq. expedited
   Transmission type for RxPRO1 is 0xFF=255
4.3252 581 8 60 00 14 02 00 00 00 00 00 [1400,02] Initiate Download Rsp
4.3264 601 8 2b 17 10 00 64 00 00 00 64 00 [1017,00] Initiate Download Rq. expedited
   Heartbeat Producer Time is 0x64=100ms
4.3279 581 8 60 17 10 00 00 00 00 00 00 [1017,00] Initiate Download Rsp
4.3287 601 8 23 16 10 01 2c 01 7f 00 2c 01 7f 00 [1016,01] Initiate Download Rq. expedited
   Heartbeat Consumer Time ist 0x012C=300ms, Node ID des Heartbeat Producers (hier: FC5101) ist 0x7F
4.3304 581 8 60 16 10 01 00 00 00 00 00 [1016,01] Initiate Download Rsp
4.3312 601 8 23 00 55 00 00 00 ff ff 00 00 ff ff [5500,00] Initiate Download Rq. expedited
   User Parameter: Index 0x5500, SI 0, Wert 0x00 00 FF FF
4.3321 701 1 7f                         T0 Preoperational
   Node 1 sends first heartbeat telegram, FC5101 starts controlling
4.4679 581 8 60 00 55 00 00 00 00 00 [5500,00] Initiate Download Rsp
4.4686 601 8 2f 23 64 00 01 00 00 00 01 [6423,00] Initiate Download Rq. expedited
   User Parameter: Index 0x6423, SI 0, Wert 0x01
4.4700 581 8 60 23 64 00 00 00 00 00 [6423,00] Initiate Download Rsp
4.4707 00 2 01 01                       Start Node
   Node 1 is transferred individually in operational
4.4717 701 1 7f                         T0 Preoperational
   The next heartbeat telegram is sent before the status crossing is concluded
4.4986 181 1 00 00
   Node 1 is operational and sends his TxPDO1 and TxPDO2
4.4989 281 4 00 00 00 00 00 00 00 00
4.5786 701 1 05                         T0 Operational
4.6390 281 4 00 00 08 00 00 00 08 00
4.6411 281 4 00 00 00 00 00 00 00 00
4.6891 701 1 05                         T0 Operational
4.7951 701 1 05                         T0 Operational
4.9032 701 1 05                         T0 Operational
5.0048 281 4 00 00 08 00 00 00 08 00
```

```
5.0070 281 4 00 00 00 00 00 00 00 00
5.0094 701 1 05                      T0 Operational
5.0153 281 4 00 00 08 00 00 00 08 00
5.0174 281 4 00 00 00 00 00 00 00 00
5.1129 701 1 05                      T0 Operational
....
5.4755 00 2 01 00                    Start all nodes
   Now all nodes are started
5.4847 201 1 00 00
   approx. 1 sec after start of node 1 the RxPDO1 is sent for the first time
```

5.3 Process Data Objects (PDO)

Introduction

In many fieldbus systems the entire process image is continuously transferred - usually in a more or less cyclic manner. CANopen is not limited to this communication principle, since the multi-master bus access protocol allows CAN to offer other methods. Under CANopen the process data is not transferred in a master/slave procedure, but follows instead the producer-consumer model. In this model, a bus node transmits its data, as a producer, on its own accord. This might, for example, be triggered by an event. All the other nodes listen, and use the identifier to decide whether they are interested in this telegram, and handle it accordingly. These are the consumers.

The process data in CANopen is divided into segments with a maximum of 8 bytes. These segments are known as process data objects (PDOs). The PDOs each correspond to a CAN telegram, whose specific CAN identifier is used to allocate them and to determine their priority. Receive PDOs (RxPDOs) and transmit PDOs (TxPDOs) are distinguished, the name being chosen from the point of view of the device: an input/output module sends its input data with TxPDOs and receives its output data in the RxPDOs. **This naming convention is retained in the TwinCAT System Manager.**

Communication parameters

The PDOs can be given different communication parameters according to the requirements of the application. Like all the CANopen parameters, these are also available in the device's object directory, and can be accessed by means of the service data objects. The parameters for the receive PDOs are at index 0x1400 (RxPDO1) onwards. There can be up to 512 RxPDOs (ranging up to index 0x15FF). In the same way, the entries for the transmit PDOs are located from index 0x1800 (TxPDO1) to 0x19FF (TxPDO512).

The Beckhoff Bus Couplers or Fieldbus Coupler Box modules make 16 RxPDO and TxPDOs available for the exchange of process data (although the figure for Economy and LowCost BK5110 and LC5100 Couplers and the Fieldbus Boxes is 5 PDOs each, since these devices manage a lower quantity of process data). The FC510x CANopen master card supports up to 192 transmit and 192 receive PDOs for each channel - although this is restricted by the size of the DPRAM. The EL6751 CANopen terminal dynamically organizes the process image; i.e. the process data are written in succession, enabling a higher data transmission rate. Up to 32 TxPDOs and 32 RxPDOs can be handled in slave mode.

For each existing process data object there is an associated communication parameter object. The TwinCAT System Manager automatically assigns the set parameters to the relevant object directory entries. These entries and their significance for the communication of process data are explained below.

PDO Identifier

The most important communication parameter in a PDO is the CAN identifier (also known as the communication object identifier, or COB-ID). It is used to identify the data, and determines their priority for bus access. For each CAN data telegram there may only be one sender node (producer), although all messages sent in the CAN broadcast procedure can be received, as described, by any number of nodes (consumers). Thus a node can make its input information available to a number of bus devices at the same time - even without transferring them through a logical bus master. The identifier is located in sub-index 1 of the communication parameter set. It is coded as a 32-bit value in which the least significant 11 bits (bits 0...10) contain the identifier itself. The data width of the object of 32 bits also allows 29-bit identifiers in accordance with CAN 2.0B to be entered, although the default identifiers always refer to the more usual 11-bit versions. Generally speaking, CANopen is economical it its use of the available identifiers, so that the use

of the 29-bit versions remains limited to unusual applications. It is therefore also not supported by a Beckhoff's CANopen devices. The highest bit (bit 31) can be used to activate the process data object or to turn it off.

A complete identifier list [▶ 80] is provided in the appendix.

PDO linking

In the system of default identifiers, all the nodes (here: slaves) communicate with one central station (the master), since slave nodes do not listen by default to the transmit identifier of any other slave node.

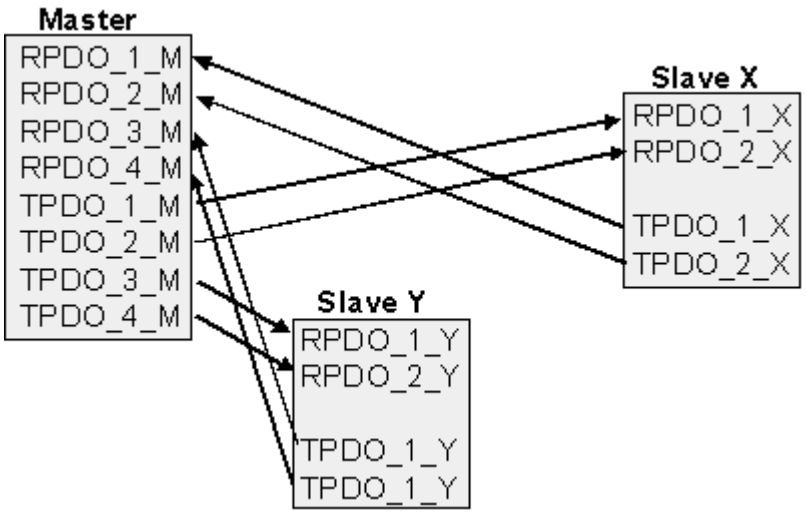


Fig. 36: Default identifier allocation: Master/Slave

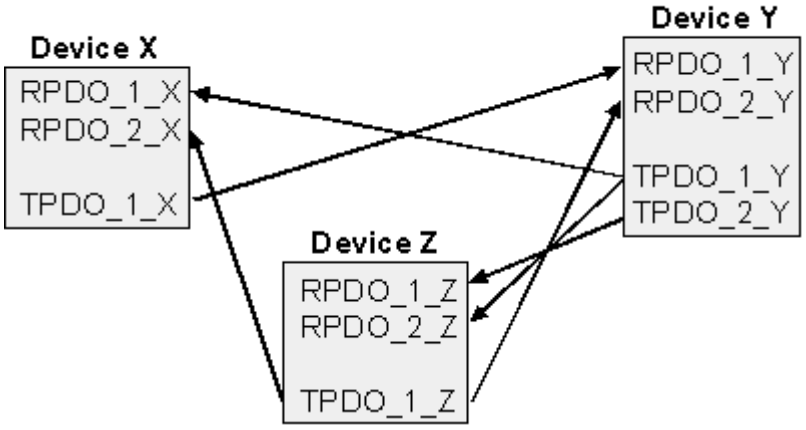


Fig. 37: PDO linking: Peer to Peer

If the consumer-producer model of CANopen PDOs is to be used for direct data exchange between nodes (without a master), the identifier allocation must be appropriately adapted, so that the TxPDO identifier of the producer agrees with the RxPDO identifier of the consumer: This procedure is known as PDO linking. It permits, for sample, easy construction of electronic drives in which several slave axes simultaneously listen to the actual value in the master axis TxPDO.

PDO Communication Types: Overview

CANopen offers a number of possible ways to transmit process data (see also: Notes on PDO Parameterization [▶ 51]).

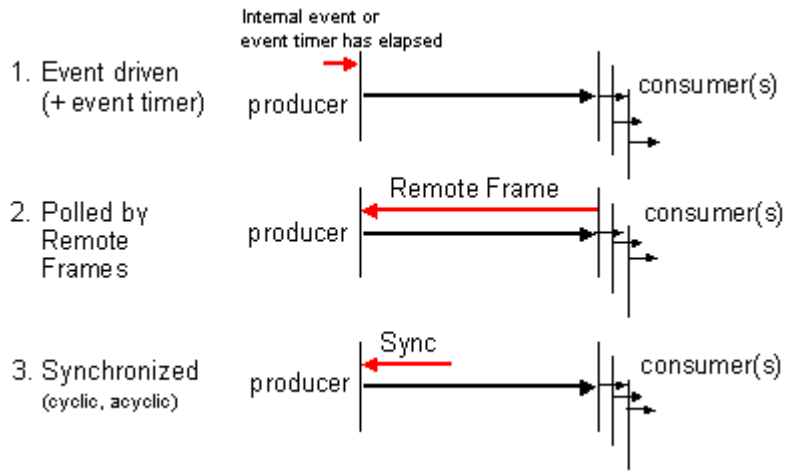


Fig. 38: Diagram: CAN process data transmission

Event driven

The ”event" is the alteration of an input value, the data being transmitted immediately after this change. The event-driven flow can make optimal use of the bus bandwidth, since instead of the whole process image it is only the changes in it that are transmitted. A short reaction time is achieved at the same time, since when an input value changes it is not necessary to wait for the next interrogation from a master.

As from CANopen Version 4 it is possible to combine the event driven type of communication with a cyclic update. Even if an event has not just occurred, event driven TxPDOs are sent after the event timer has elapsed. If an event does occur, the event timer is reset. For RxPDOs the event timer is used as a watchdog in order to monitor the arrival of event driven PDOs . If a PDO does not arrive within a set period of time, the bus node adopts the error state.

Polled

The PDOs can also be polled by data request telegrams (remote frames). In this way it is possible to get the input process image of event-driven inputs onto the bus, even when they do not change, for instance through a monitoring or diagnostic device brought into the network while it is running. The time behavior of remote frame and response telegrams depends on what CAN controller is in use. Components with full integrated message filtering ("FullCAN") usually answer a data request telegram immediately, transmitting data that is waiting in the appropriate transmit buffer - it is the responsibility of the application to see that the data there is continuously updated. CAN controllers with simple message filtering (BasicCAN) on the other hand pass the request on to the application which can now compose the telegram with the latest data. This does take longer, but does mean that the data is up-to-date. Beckhoff use CAN controllers following the principle of Basic CAN.

Since this device behavior is usually not transparent to the user, and because there are CAN controllers still in use that do not support remote frames at all, polled communication can only with reservation be recommended for operative running.

Synchronized

It is not only for drive applications that it is worthwhile to synchronize the determination of the input information and the setting the outputs. For this purpose CANopen provides the SYNC object, a CAN telegram of high priority but containing no user data, whose reception is used by the synchronized nodes as a trigger for reading the inputs or for setting the outputs.

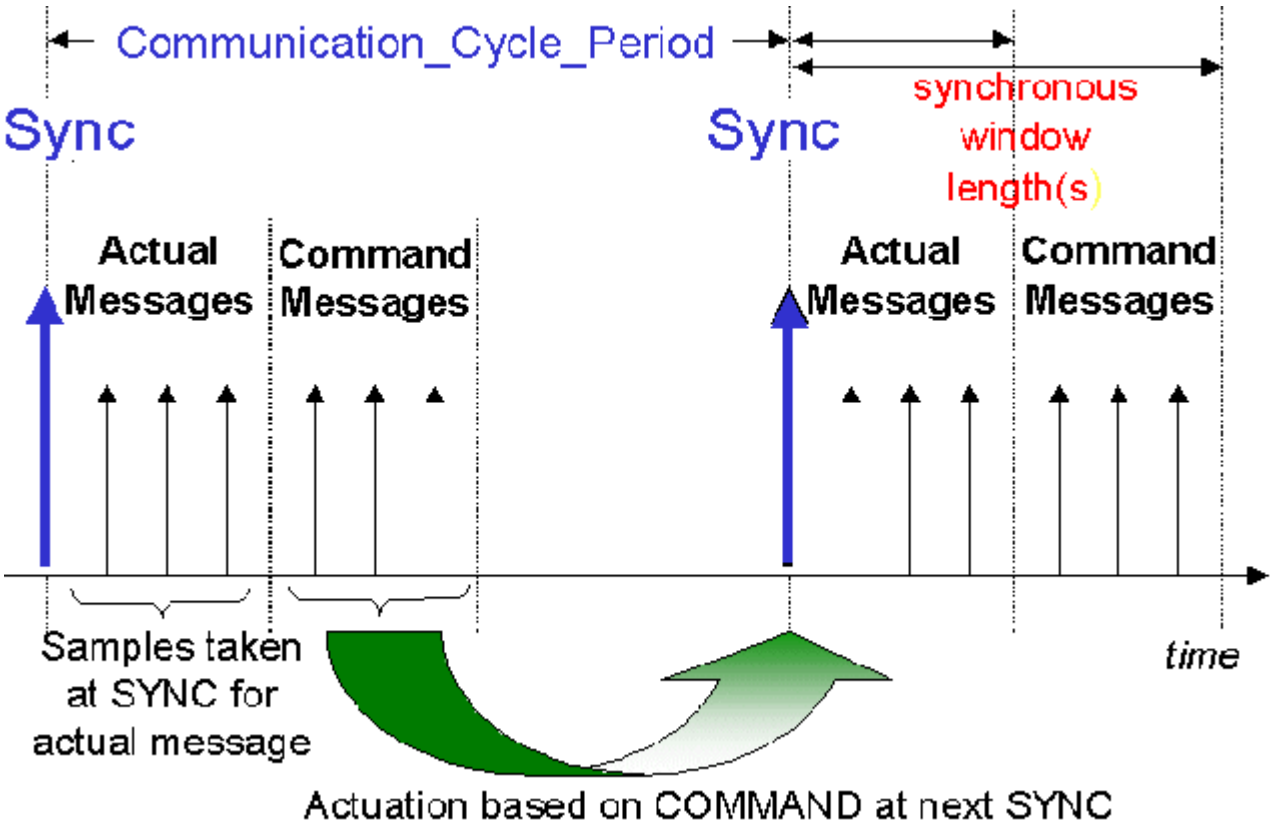


Fig. 39: Diagram: CAN "SYNC" telegram

PDO transmission types: Parameterization

The PDO transmission type parameter specifies how the transmission of the PDO is triggered, or how received PDOs are handled.

Transmission type	Cyclical	Acyclical	Synchronous	Asynchronous	Only RTR
0		X	X		
1-240	X		X		
241-251	- reserved -				
252			X		X
253				X	X
254, 255				X	

The type of transmission is parameterized for RxPDOs in the objects at 0x1400ff, sub-index 2, and for TxPDOs in the objects at 0x1800ff, sub-index 2.

Acyclic Synchronous

PDOs of transmission type 0 function synchronously, but not cyclically. An RxPDO is only evaluated after the next SYNC telegram has been received. In this way, for instance, axis groups can be given new target positions one after another, but these positions only become valid at the next SYNC - without the need to be constantly outputting reference points. A device whose TxPDO is configured for transmission type 0 acquires its input data when it receives the SYNC (synchronous process image) and then transmits it if the data correspond to an event (such as a change in input) having occurred. Transmission type 0 thus combines transmission for reasons that are event driven with a time for transmission (and, as far as possible, sampling) and processing given by the reception of "SYNC".

Cyclic Synchronous

In transmission types 1-240 the PDO is transmitted cyclically: after every ”nth" SYNC (n = 1...240). Since transmission types can be combined on a device as well as in the network, it is possible, for example, for a fast cycle to be agreed for digital inputs (n = 1), whereas the data for analog inputs is transmitted in a slower

cycle (e.g. n = 10). RxPDOs do not generally distinguish between transmission types 0...240: a PDO that has been received is set to valid when the next SYNC is received. The cycle time (SYNC rate) can be monitored (object 0x1006), so that if the SYNC fails the device reacts in accordance with the definition in the device profile, and switches, for sample, its outputs into the error state.

The FC510x card / EL6751 terminal fully support the synchronous communication method: transmitting the SYNC telegram is coupled to the linked task, so that new input data is available every time the task begins. If a synchronous PDO does not arrive, this is detected and reported to the application.

Only RTR

Transmission types 252 and 253 apply to process data objects that are transmitted exclusively on request by a remote frame. 252 is synchronous: when the SYNC is received the process data is acquired. It is only transmitted on request. 253 is asynchronous. The data here is acquired continuously, and transmitted on request. This type of transmission is not generally recommended, because fetching input data from some CAN controllers is only partially supported. Because, furthermore, the CAN controllers sometimes answer remote frames automatically (without first requesting up-to-date input data), there are circumstances in which it is questionable whether the polled data is up-to-date. Transmission types 252 and 253 are for this reason not supported by the Beckhoff PC cards / terminals.

Asynchronous

The transmission types 254 + 255 are asynchronous, but may also be event-driven. In transmission type 254, the event is specific to the manufacturer, whereas for type 255 it is defined in the device profile. In the simplest case, the event is the change of an input value - this means that every change in the value is transmitted. The asynchronous transmission type can be coupled with the event timer, thus also providing input data when no event has just occurred.

Inhibit time

The ”inhibit time" parameter can be used to implement a ”transmit filter" that does not increase the reaction time for relatively new input alterations, but is active for changes that follow immediately afterwards. The inhibit time (transmit delay time) specifies the minimum length of time that must be allowed to elapse between the transmission of two of the same telegrams. If the inhibit time is used, the maximum bus loading can be determined, so that the worst case latency can then be found.

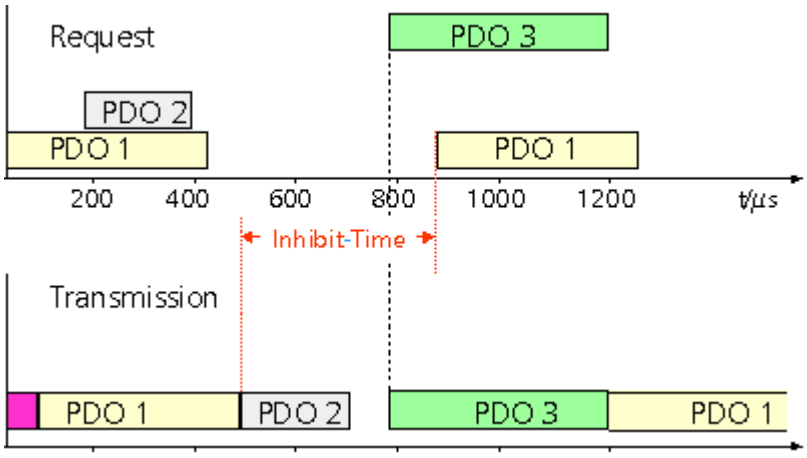


Fig. 40: Timing diagram: "Inhibit time"

Although the Beckhoff FC510x PC cards / EL6751 terminal can parameterize the inhibit time on slave devices, they do not themselves support it. The transmitted PDOs become automatically spread out (transmit delay) as a result of the selected PLC cycle time - and there is little value in having the PLC run faster than the bus bandwidth permits. The bus loading, furthermore, can be significantly affected by the synchronous communication.

Event Timer

An event timer for transmit PDOs can be specified by sub-index 5 in the communication parameters. Expiry of this timer is treated as an additional event for the corresponding PDO, so that the PDO will then be transmitted. If the application event occurs during a timer period, it will also be transmitted, and the timer is reset.

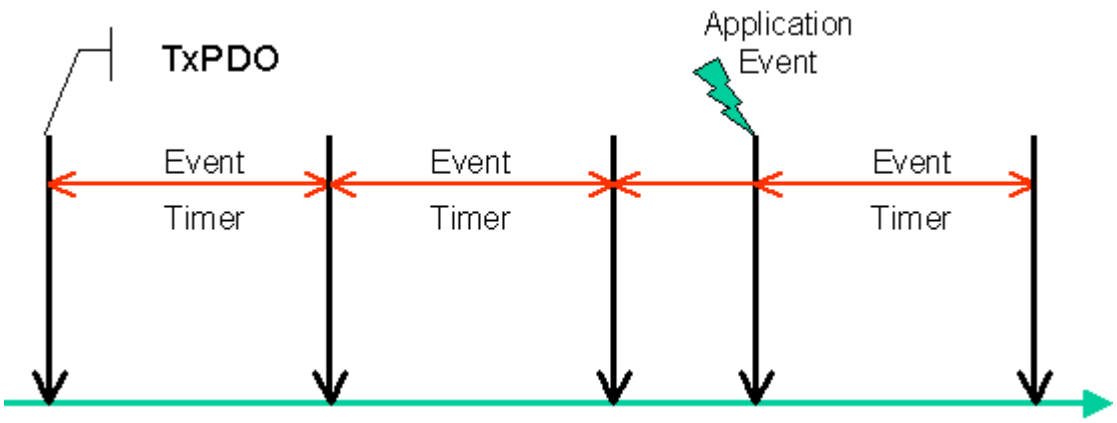


Fig. 41: Time representation of the event timer

In the case of receive PDOs, the timer is used to set a watchdog interval for the PDO: the application is informed if no corresponding PDO has been received within the set period. The FC510x / EL6751 can in this way monitor each individual PDO.

Notes on PDO Parameterization [▶ 51]

PDO Mapping

PDO mapping refers to mapping of the application objects (real time data) from the object directory to the process data objects. The CANopen device profile provide a default mapping for every device type, and this is appropriate for most applications. Thus the default mapping for digital I/O simply represents the inputs and outputs in their physical sequence in the transmit and receive process data objects.

The default PDOs for drives contain 2 bytes each of a control and status word and a set or actual value for the relevant axis.

The current mapping can be read by means of corresponding entries in the object directory. These are known as the mapping tables. The first location in the mapping table (sub-index 0) contains the number of mapped objects that are listed after it. The tables are located in the object directory at index 0x1600ff for the RxPDOs and at 0x1A00ff for the TxPDOs.

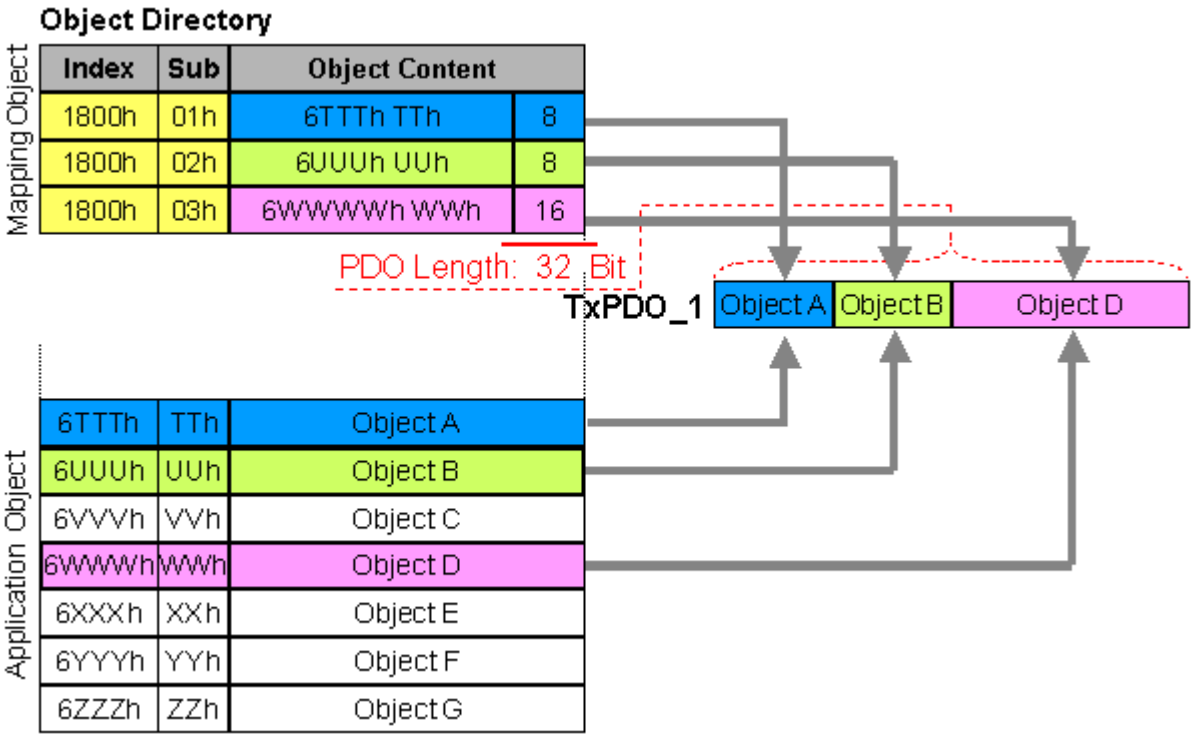


Fig. 42: Mapping representation

Digital and analog input/output modules: Read out the I/O number

The current number of digital and analog inputs and outputs can be determined or verified by reading out the corresponding application objects in the object directory:

Parameter	Object directory address
Number of digital input bytes	Index 0x6000, sub-index 0
Number of digital output bytes	Index 0x6200, sub-index 0
Number of analog inputs	Index 0x6401, sub-index 0
Number of analog outputs	Index 0x6411, sub-index 0

Variable mapping

As a rule, the default mapping of the process data objects already satisfies the requirements. For special types of application the mapping can nevertheless be altered: the Beckhoff CANopen Bus Couplers, for instance, thus support variable mapping, in which the application objects (input and output data) can be freely allocated to the PDOs. The mapping tables must be configured for this: as from Version 4 of CANopen, only the following procedure is permitted, and must be followed precisely:

1. First delete the PDO (set 0x1400ff, or 0x1800ff, sub-index 1, bit 31 to "1")
2. Set sub-index 0 in the mapping parameters (0x1600ff or 0x1A00ff) to "0"
3. Change mapping entries (0x1600ff or 0x1A00ff, SI 1..8)
4. Set sub-index 0 in the mapping parameters to the valid value. The device then checks the entries for consistency.
5. Create PDO by entering the identifier (0x1400ff or 0x1800ff, sub-index 1).

Dummy Mapping

A further feature of CANopen is the mapping of placeholders, or dummy entries. The data type entries stored in the object directory, which do not themselves have data, are used as placeholders. If such entries are contained in the mapping table, the corresponding data from the device is not evaluated. In this way, for instance, a number of drives can be supplied with new set values using a single CAN telegram, or outputs on a number of nodes can be set simultaneously, even in event-driven mode.

5.4 PDO Parameterization

Even though the majority of CANopen networks operate satisfactorily with the default settings, i.e. with the minimum of configuration effort, it is wise at least to check whether the existing bus loading is reasonable: 80% bus loading may be acceptable for a network operating purely in cyclic synchronous modes, but for a network with event-driven traffic this value would generally be too high, as there is hardly any bandwidth available for additional events.

Consider the Requirements of the Application

The communication of the process data must be optimized in the light of application requirements which are likely to be to some extent in conflict. These include

- Little work on parameterization - useable default values are optimal
- Guaranteed reaction time for specific events
- Cycle time for regulation processes over the bus
- Safety reserves for bus malfunctions (enough bandwidth for the repetition of messages)
- Maximum baud rate - depends on the maximum bus length
- Desired communication paths - who is speaking with whom

The determining factor often turns out to be the available bus bandwidth (bus load).

Baud rate

We generally begin by choosing the highest baud rate that the bus will permit. It should be borne in mind that serial bus systems are fundamentally more sensitive to interference as the baud rate is increased. The following rule therefore applies: just as fast as necessary. 1000 kbit/s are not usually necessary, and only to be unreservedly recommended on networks within a control cabinet where there is no electrical isolation between the bus nodes. Experience also tends to show that estimates of the length of bus cable laid are often over-optimistic - the length actually laid tends to be longer.

Determine the Communication Type

Once the baud rate has been chosen it is appropriate to specify the PDO communication type(s). These have different advantages and disadvantages:

- Cyclic synchronous communication provides an accurately predictable bus loading, and therefore a defined time behavior - you could say that the standard case is the worst case. It is easy to configure: The SYNC rate parameter sets the bus loading globally. The process images are synchronized: Inputs are read at the same time, output data is set valid simultaneously, although the quality of the synchronization depends on the implementation. The BECKHOFF FC510x PC cards / EL6751 CANopen terminal are capable of synchronizing the CANopen bus system with the cycles of the application program (PLC or NC).

  The guaranteed reaction time under cyclic synchronous communication is always at least as long as the cycle time, and the bus bandwidth is not exploited optimally, since old data, i.e. data that has not changed, is continuously transmitted. It is however possible to optimize the network through the selection of different SYNC multiples (transmission types 1...240), so that data that changes slowly is transmitted less often than, for instance, time-critical inputs. It must, however, be borne in mind that input states that last for a time that is shorter than the cycle time will not necessarily be communicated. If it is necessary for such conditions to be registered, the associated PDOs for asynchronous communication should be provided.
- Event-driven asynchronous communication is optimal from the point of view of reaction time and the exploitation of bus bandwidth - it can be described as "pure CAN". Your choice must, however, also take account of the fact that it is not impossible for a large number of events to occur simultaneously, leading to corresponding delays before a PDO with a relatively low priority can be sent. Proper network planning therefore necessitates a worst-case analysis. Through the use of, for instance, inhibit time [▶ 44], it is also necessary to prevent a constantly changing input with a high PDO priority from blocking the bus (technically known as a "babbling idiot"). It is for this reason that event driving is switched off by

default in the device profile of analog inputs, and must be turned on specifically. Time windows for the transmit PDOs can be set using progress timers: the telegram is not sent again before the inhibit time [▶ 44] has elapsed, and not later than the time required for the progress timer to complete.

- The communication type is parameterized by means of the transmission type [▶ 44].

It is also possible to combine the two PDO principles. It can, for instance, be helpful to exchange the set and actual values of an axis controller synchronously, while limit switches, or motor temperatures with limit values are monitored with event-driven PDOs. This combines the advantages of the two principles: synchronicity for the axis communication and short reaction times for limit switches. In spite of being event-driven, the distributed limit value monitoring avoids a constant addition to the bus load from the analog temperature value.

In this sample it can also be of value to deliberately manipulate the identifier allocation, in order to optimize bus access by means of priority allocation: the highest priority is given to the PDO with the limit switch data, and the lowest to that with the temperature values.

Optimization of bus access latency time through modification of the identifier allocation is not, however, normally required. On the other hand the identifiers must be altered if masterless communication is to be made possible (PDO linking [▶ 44]). In this sample it would be possible for one RxPDO for each axis to be allocated the same identifier as the limit switch TxPDO, so that alterations of the input value can be received without delay.

Determining the Bus Loading

It is always worth determining the bus loading. But what bus loading values are permitted, or indeed sensible? It is first necessary to distinguish a short burst of telegrams in which a number of CAN messages follow one another immediately - a temporary 100% bus loading. This is only a problem if the sequence of receive interrupts that it caused at the CAN nodes cannot be handled. This would constitute a data overflow (or CAN queue overrun). This can occur at very high baud rates (> 500 kbit/s) at nodes with software telegram filtering and relatively slow or heavily loaded microcontrollers if, for instance, a series of remote frames (which do not contain data bytes, and are therefore very short) follow each other closely on the bus (at 1 Mbit/s this can generate an interrupt every 40 µs; for example, an NMT master might transmit all its guarding requests in an unbroken sequence). This can be avoided through skilled implementation, and the user should be able to assume that the device suppliers have taken the necessary trouble. A burst condition is entirely normal immediately after the SYNC telegram, for instance: triggered by the SYNC, all the nodes that are operating synchronously try to send their data at almost the same time. A large number of arbitration processes take place, and the telegrams are sorted in order of priority for transmission on the bus. This is not usually critical, since these telegrams do contain some data bytes, and the telegrams trigger a sequence of receive interrupts at the CAN nodes which is indeed rapid, but is nevertheless manageable.

Bus loading most often refers to the value averaged over several primary cycles, that is the mean value over 100-500 ms. CAN, and therefore CANopen, is indeed capable of managing a bus loading of close to 100% over long periods, but this implies that no bandwidth is available for any repetitions that may be necessitated by interference, for asynchronous error messages, parameterization and so on. Clearly, the dominant type of communication will have a large influence on the appropriate level of bus loading: a network with entirely cyclic synchronous operation is always in any case near to the worst case state, and can therefore be operated with values in the 70-80% range. The figure is very hard to state for an entirely event-driven network: an estimate must be made of how many events additional to the current state of the system might occur, and of how long the resulting burst might last - in other words, for how long the lowest priority message will be delayed. If this value is acceptable to the application, then the current bus loading is acceptable. As a rule of thumb it can usually be assumed that an event-driven network running with a base loading of 30-40% has enough reserve for worst-case scenarios, but this assumption does not obviate the need for a careful analysis if delays could have critical results for the plant.

The BECKHOFF FC510x CANopen master cards / EL6751 CANopen master terminal display the bus load via the System Manager. This variable can also be processed in the PLC, or can be displayed in the visualization system.

The amount data in the process data objects is of course as relevant as the communication parameters: the PDO mapping. [▶ 49]

5.5 Service Data Objects (SDO)

The parameters listed in the object directory are read and written by means of service data objects. These SDOs are *Multiplexed Domains*, i.e. data structures of any size that have a multiplexer (address). The multiplexer consists of a 16-bit index and an 8-bit sub-index that address the corresponding entries in the object directory.

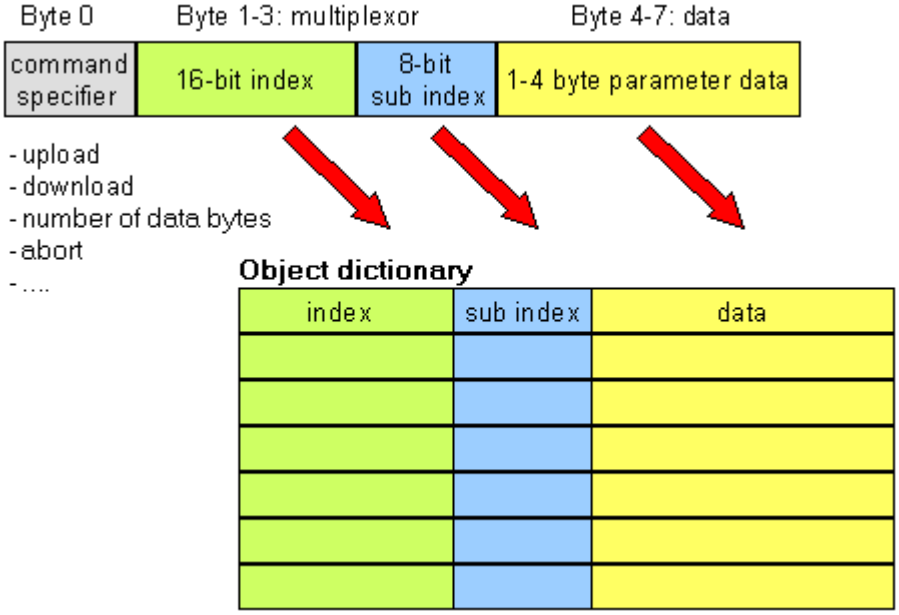


Fig. 43: SDO protocol: access to the object directory

The CANopen Bus Couplers are servers for the SDO, which means that at the request of a client (e.g. of the IPC or the PLC) they make data available (upload), or they receive data from the client (download). This involves a handshake between the client and the server.

When the size of the parameter to be transferred is not more than 4 bytes, a single handshake is sufficient (one telegram pair): For a download, the client sends the data together with its index and sub-index, and the server confirms reception. For an upload, the client requests the data by transmitting the index and sub-index of the desired parameter, and the server sends the parameter (including index and sub-index) in its answer telegram.

The same pair of identifiers is used for both upload and download. The telegrams, which are always 8 bytes long, encode the various services in the first data byte. All parameters with the exception of objects 1008h, 1009h and 100Ah (device name, hardware and software versions) are only at most 4 bytes long, so this description is restricted to transmission in expedited transfer.

Protocol

The structure of the SDO telegrams is described below.

Client -> Server, Upload Request

11 bit identifier	8 byte user data							
0x600 (=1536dec) + node ID	0x40	Index0	Index1	SubIdx	0x00	0x00	0x00	0x00

Parameter	Explanation
Index0	Index low byte (Unsigned16, LSB)
Index1	Index high byte (Unsigned16, MSB)
SubIdx	Sub-index (Unsigned8)

Client -> Server, Upload Response

11 bit identifier	8 byte user data							
0x580 (=1408dec) + node ID	0x4x	Index0	Index1	SubIdx	Data0	Data1	Data2	Data3

Parameter	Explanation
Index0	Index low byte (Unsigned16, LSB)
Index1	Index high byte (Unsigned16, MSB)
SubIdx	Sub-index (Unsigned8)
Data0	Data low low byte (LLSB)
Data3	Data high high byte (MMSB)

Parameters whose data type is Unsigned8 are transmitted in byte D0, parameters whose type is Unsigned16 use D0 and D1.

The number of valid data bytes is coded as follows in the first CAN data byte (0x4x):

Number of parameter bytes	1	2	3	4
First CAN data byte	0x4F	0x4B	0x47	0x43

Client -> Server, Download Request

11 bit identifier	8 byte user data							
0x600 (=1536dec) + node ID	0x22	Index0	Index1	SubIdx	Data0	Data1	Data2	Data3

Parameter	Explanation
Index0	Index low byte (Unsigned16, LSB)
Index1	Index high byte (Unsigned16, MSB)
SubIdx	Sub-index (Unsigned8)
Data0	Data low low byte (LLSB)
Data3	Data high high byte (MMSB)

It is optionally possible to give the number of valid parameter data bytes in the first CAN data byte

Number of parameter bytes	1	2	3	4
First CAN data byte	0x2F	0x2B	0x27	0x23

This is, however, not generally necessary, since only the less significant data bytes up to the length of the object directory entry that is to be written are evaluated. A download of data up to 4 bytes in length can therefore always be achieved in BECKHOFF bus nodes with 22 h in the first CAN data byte.

Client -> Server, Download Response

11 bit identifier	8 byte user data							
0x580 (=1408dec) + node ID	0x60	Index0	Index1	SubIdx	0x00	0x00	0x00	0x00

Parameter	Explanation
Index0	Index low byte (Unsigned16, LSB)
Index1	Index high byte (Unsigned16, MSB)
SubIdx	Sub-index (Unsigned8)

Breakdown of Parameter Communication

Parameter communication is interrupted if it is faulty. The client or server send an SDO telegram with the following structure for this purpose:

11 bit identifier	8 byte user data							
0x580 (client) or 0x600(server) + node ID	0x80	Index0	Index1	SubIdx	Error0	Error1	Error2	Error3

Parameter	Explanation
Index0	Index low byte (Unsigned16, LSB)
Index1	Index high byte (Unsigned16, MSB)
SubIdx	Sub-index (Unsigned8)
Error0	SDO error code low low byte (LLSB)
Error3	SDO error code high high byte (MMSB)

List of SDO error codes (reason for abortion of the SDO transfer):

SDO error code	Explanation
0x05 03 00 00	Toggle bit not changed
0x05 04 00 01	SDO command specifier invalid or unknown
0x06 01 00 00	Access to this object is not supported
0x06 01 00 02	Attempt to write to a Read_Only parameter
0x06 02 00 00	The object is not found in the object directory
0x06 04 00 41	The object cannot be mapped into the PDO
0x06 04 00 42	The number and/or length of mapped objects would exceed the PDO length
0x06 04 00 43	General parameter incompatibility
0x06 04 00 47	General internal error in device
0x06 06 00 00	Access interrupted due to hardware error
0x06 07 00 10	Data type or parameter length do not agree or are unknown
0x06 07 00 12	Data type does not agree, parameter length too great
0x06 07 00 13	Data type does not agree, parameter length too short
0x06 09 00 11	Sub-index not present
0x06 09 00 30	General value range error
0x06 09 00 31	Value range error: parameter value too great
0x06 09 00 32	Value range error: parameter value too small
0x06 0A 00 23	Resource not available
0x08 00 00 21	Access not possible due to local application
0x08 00 00 22	Access not possible due to current device status

Further, manufacturer-specific error codes have been introduced for register communication (index 0x4500, 0x4501):

SDO error code	Explanation
0x06 02 00 11	Invalid table: Table or channel not present
0x06 02 00 10	Invalid register: table not present
0x06 01 00 22	Write protection still set
0x06 07 00 43	Incorrect number of function arguments
0x06 01 00 21	Function still active, try again later
0x05 04 00 40	General routing error
0x06 06 00 21	Error accessing BC table
0x06 09 00 10	General error communicating with terminal
0x05 04 00 47	Time-out communicating with terminal

5.6 SDO communication with FC510x

CANopen SDO (Service Data Object) communication is used to read or write any parameters in the CANopen bus node's object directory. The FC5101CANopen PCI card uses SDO communication to configure the communication parameters when starting up. Two types of application-specific SDO communication are additionally possible:

1. Downloading Application-Specific Parameters when Starting Up

The appropriate parameters are to be entered here in the System Manager for the corresponding node under "SDO". The objects that result from the configuration under CAN node appear in square brackets. Any desired number of object directory entries can then be added.

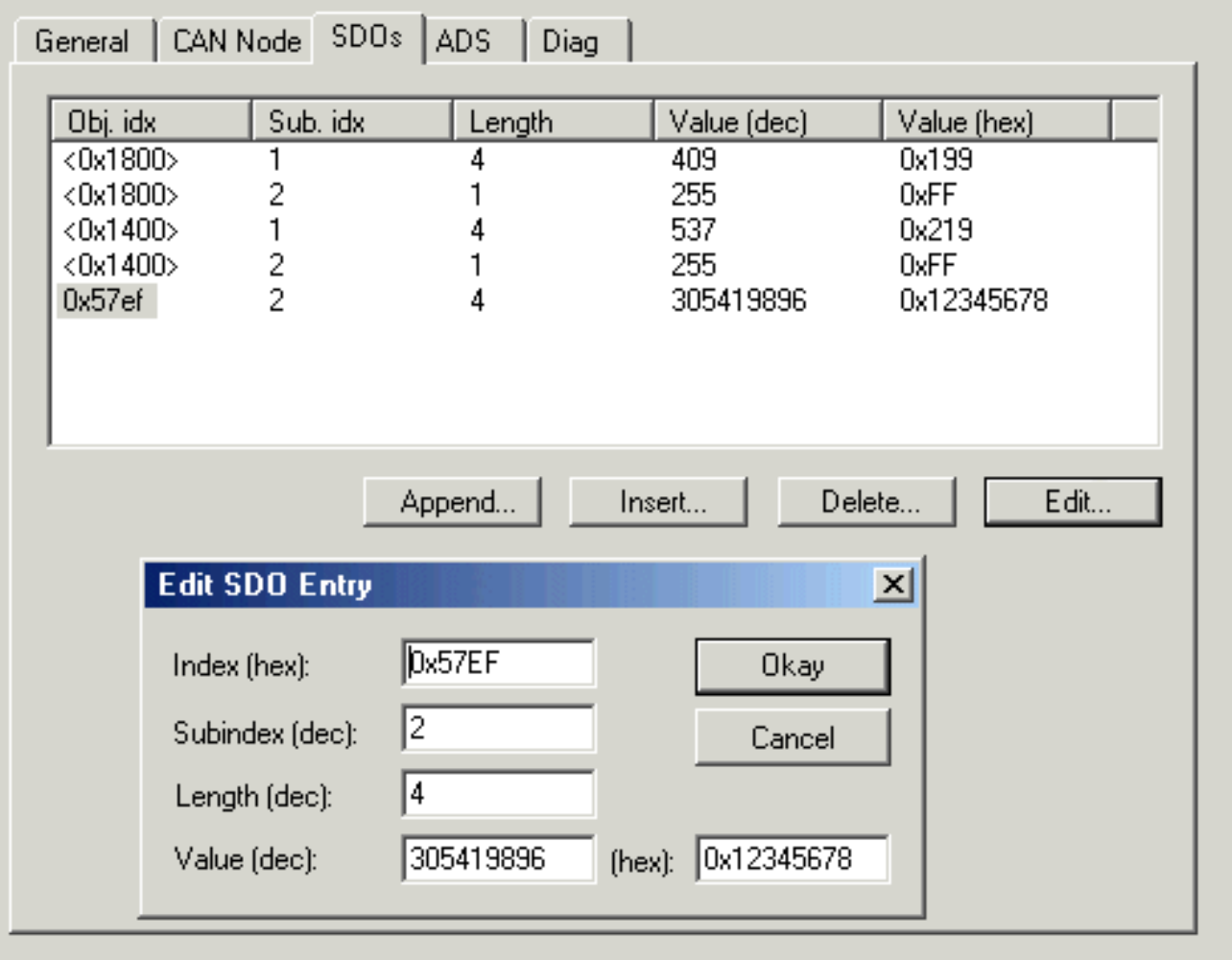


Fig. 44: Edit SDO entry

The card expects a positive acknowledgement of the parameter download from the relevant bus device. If it was not possible to write a parameter (the bus device has aborted the SDO) the card then attempts to read the corresponding value back and to compare it with the value that was to be written. This is because it could, for instance, be a read-only value, and therefore already correctly configured within the bus device. If they agree with one another, the card moves onto the next parameter entry.

2. Upload and download at runtime via ADS

It is possible to perform SDO accesses to the bus devices' object directories using Beckhoff's ADS communication when the system is running. This is also possible from the PLC, from the NC, from the OPC server, from ActiveX controls or from any other ADS device.

The whole SDO protocol is handled by the card. Using the ADS Write or ADS Read functions the parameters are transferred to the card, and the data is transferred (write) or fetched (read). The "IDXGRP" parameter here corresponds to the 16 bit index in the CANopen object directory, while "IDXOFFS" corresponds to the 8 bit subindex in the CANopen object directory. Details about the ADS function blocks can be found in the TwinCAT documentation (Beckhoff Information System).

The ADS function block parameters are represented as follows in the SDO parameters:

ADSREAD / ADSWRITE

Parameter	Description
NETID	The NetID is a string, 23 bytes in length, and is formed by default from the IP address of the computer with an additional two bytes. It addresses the FC5101 card and can be found under "ADS" in the System Manager.
PORT	Contains the ADS device's port number - this is the port number of the CANopen bus device that is to be addressed.
IDXGRP	**Corresponds to the 16 bit index in the CANopen object directory.**
IDXOFFS	**Corresponds to the 8 bit subindex in the CANopen object directory.**
LEN	The length of the parameter that is to be read or written, in bytes.
DESTADDR (only ADSREAD)	Contains the address of the buffer which is to receive the data that has been read. The programmer is himself responsible for dimensioning the buffer to a size that can accept 'LEN' bytes. The buffer can be a single variable, an array or a structure, whose address can be found with the ADR operator.
SRCADDR (only ADSWRITE)	Contains the address of the buffer from which the data to be written is to be fetched. The programmer is himself responsible for dimensioning the buffer to such a size that 'LEN' bytes can be taken from it. The buffer can be a single variable, an array or a structure, whose address can be found with the ADR operator.
READ	The ADS command is triggered by a rising edge at this input
TIMEOUT	States the time before the function is canceled
BUSY	This output remains TRUE until the function block has executed a command, but at the longest for the duration supplied to the 'Timeout' input. While Busy = TRUE, no new command will be accepted at the inputs. Please note that it is not the execution of the service but its acceptance whose time is monitored.
ERR	This output is switched to TRUE if an error occurs during the execution of the command.
ERRID	Contains the command-specific error code of the most recently executed command. Is reset to 0 by the execution of a command at the inputs.

The ERRID is a 32 bit value. The Low word (bits 0...15) contains the general ADS ERROR CODES, while the High word (bits 16...31) returns SDO-specific error codes:

MSB				LSB
Bit 31	Bits 30...24	Bits 23...20	Bits 19...16	Bit 15...0
1	Bits 6..0 of the SDO error code	Bits 19...16 of the SDO error code	Bits 27...24 of the SDO error code	ADS ERROR code, see chapter Error handling and diagnostics [▶ 67] for meaning

If one of the values SDO Additional Code, SDO Error Code or SDO Error Class is larger than the available data width (hidden bits set), then the value 0x2115 is returned in the High word (bits 16...31).

Example: SDO Read via ADS

In the following sample program (structured text) for the use of ADS services for SDO communication, object 0x1000, subindex 0, from the node with port number 0x1001 is read. The DeviceType is CANopen. This is coded as UnSigned32, and is therefore 4 bytes long.

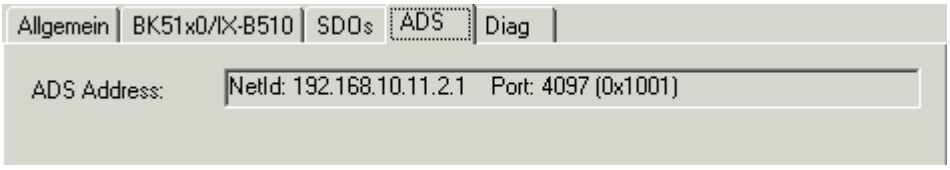


Fig. 45: SDO Read via ADS

```
SDO_READ(
        StartReading :=ReadStart,
        CO_Index :=16#1000,
        CO_SubIndex :=16#0,
        DataLength := 4,
        PortNr := 16#1001,
       ADSNetID:='192.168.10.11.2.1'
        );
IF SDO_READ.ReadDataAvailable THEN
        ReadStart :=FALSE;
        ReadError :=SDO_READ.Error;
        ReadData :=SDO_READ.ReadData;
END_IF
```

The SDO_READ function block that has been called in turn calls the ADSREAD function a number of times. It looks like this (starting with the variable declaration):

```
FUNCTION_BLOCK SDO_READ
VAR_INPUT
    ADSNetID:STRING(23); (* The AMSNetID addresses the FC5101 card. Can be empty if only one local s
ingle channel card is present*)
   PortNr:WORD;         (*This Port No. addresses the CANopen Node (see System Manager)*)
    CO_Index:DWORD;      (*This is the Index of the CANopen Object Dictionary Entry*)
    CO_SubIndex:DWORD;   (* This is the Sub-Index of the CANopen Object Dictionary Entry*)
    DataLength:DWORD;    (* This is the Length of the CANopen Object Dictionary Entry*)
    StartReading:BOOL;   (* only reset to FALSE after ReadDataAvailable=TRUE*)
END_VAR
VAR_OUTPUT
    ReadData:ARRAY[0..255] OF BYTE;
    ReadDataAvailable:BOOL;
    Error:DWORD;
END_VAR
VAR
    state:BYTE := 0;
    ADSREAD:ADSREAD;
END_VAR
```

```
CASE
state OF
    0:
        IF StartReading THEN
           ReadDataAvailable := FALSE;
           Error := 0;
           ADSRead(
               NETID:= ADSNetID,
               PORT:= PortNr,
               IDXGRP:= CO_Index,
               IDXOFFS:= CO_SubIndex,
               LEN:= DataLength,
               DESTADDR:= ADR(ReadData),
               READ:= TRUE,
               TMOUT := T#1s
               );
           IF ADSRead.err THEN
               state := 2;
               ReadDataAvailable := TRUE;
               Error := ADSRead.ErrId;
           ELSE
               state := 1;
           END_IF
        ELSE
           ADSRead(
               NETID:= ADSNetID,
               PORT:= PortNr,
               IDXGRP:= CO_Index,
               IDXOFFS:= CO_SubIndex,
               LEN:= DataLength,
               DESTADDR:= ADR(ReadData),
               READ:= FALSE,
```

```
                TMOUT := T#1s
            );
        END_IF
    1:
        ADSRead(READ:=FALSE);
        IF ADSRead.err THEN
            state := 2;
            ReadDataAvailable := TRUE;
            Error := ADSRead.ErrId;
        ELSE
            IF NOT ADSRead.busy THEN
                state := 2;
                ReadDataAvailable := TRUE;
            END_IF
        END_IF
    2:
        ADSRead(READ:=FALSE);
        state := 0;
END_CASE
```

Sample: SDO Write via ADS

In the following sample program (structured text) for the use of ADS services for SDO communication, object 0x6200, Subindex3, from the node with port number 0x1001 is written. It concerns digital outputs to an I/O node.

```
(* Data to be written *)
WriteData[0] := 16#55;

(* write Object *)
    SDO_WRITE(
    StartWriting := WriteStart,
    CO_Index := 16#6200,
    CO_SubIndex := 3,
    DataLength := 1,
    PortNr := 16#1001,
    WriteData := WriteData,
    ADSNetID:='192.168.10.11.2.1'
    );
IF SDO_WRITE.WriteDataFinished THEN
    WriteStart := FALSE;
    WriteError := SDO_WRITE.Error;
END_IF
```

The SDO_WRITE function block that has been called in turn calls the ADSWRITE function a number of times. It looks like this (starting with the variable declaration):

```
FUNCTION_BLOCK SDO_WRITE
VAR_INPUT
    ADSNetID:STRING(23);   (* The AMSNetID addresses the FC5101 card. Can be empty if only one local
 single
channel card is present*)
   PortNr:WORD;          (* The Port No. addresses the CANopen Node (see System Manager)*)
   CO_Index:DWORD;        (* This is the Index of the CANopen Object Dictionary Entry*)
    CO_SubIndex:DWORD;     (*This is the Sub-Index of the CANopen Object Dictionary Entry*)
    DataLength:DWORD;     (* This is the Length of the CANopen Object Dictionary Entry*)
    StartWriting:BOOL;     (*only reset to FALSE after WriteDataFinished=TRUE*)
    WriteData:ARRAY[0..255] OF BYTE; (*This array contains the data to be written to the CANopen Obj
ect Dictionary*)
END_VAR
VAR_OUTPUT
    WriteDataFinished:BOOL;
    Error:DWORD;
END_VAR
VAR
    state:BYTE := 0;
    ADSWRITE:ADSWRITE;
END_VAR
```

```
CASE
state OF
    0:
        IF StartWriting THEN
            WriteDataFinished := FALSE;
            Error := 0;
```

```
            ADSWrite(
                NETID:= ADSNetID,
                PORT:= PortNr,
                IDXGRP:= CO_Index,
                IDXOFFS:= CO_SubIndex,
                LEN:= DataLength,
                SRCADDR:= ADR(WriteData),
                WRITE:= TRUE,
                TMOUT := T#1s
                );
            IF ADSWrite.err THEN
                state := 2;
                WriteDataFinished := TRUE;
                Error := ADSWrite.ErrId;
            ELSE
                state := 1;
            END_IF
        ELSE
            ADSWrite(
                NETID:= '',
                PORT:= PortNr,
                IDXGRP:= CO_Index,
                IDXOFFS:= CO_SubIndex,
                LEN:= DataLength,
                SRCADDR:= ADR(WriteData),
                WRITE:= FALSE,
                TMOUT := T#1s
                );
        END_IF
    1:
        ADSWrite(WRITE:=FALSE);
        IF ADSWrite.err THEN
            state := 2;
            WriteDataFinished := TRUE;
            Error := ADSWrite.ErrId;
        ELSE
            IF NOT ADSWrite.busy THEN
                state := 2;
                WriteDataFinished := TRUE;
            END_IF
        END_IF
    2:
        ADSWrite(WRITE:=FALSE);
        state := 0;
END_CASE
```

5.7 Baud rate and bit timing

The following baud rates and entries in the bit-timing register are supported by the CANopen devices:

Baud rate [kbaud]	BTR0	BTR1	Sampling Point
1000	0x00	0x14	75%
800	0x00	0x16	80%
500	0x00	0x1C	87%
250	0x01	0x1C	87%
125	0x03	0x1C	87%
100	0x04	0x1C	87%
50	0x09	0x1C	87%
20	0x18	0x1C	87%
10	0x31	0x1C	87%

The bit-timing register settings given (BTR0, BTR1) apply, for example, for the Philips 82C200, SJA1000, Intel 80C527, Siemens 80C167 and other CAN controllers. They are optimized for the maximum bus length.

5.8 Identifier distribution

Default identifier

CANopen provides default identifiers for the most important communication objects, and these are derived from the 7-bit node address (the node ID) and a 4-bit function code in accordance with the following scheme:

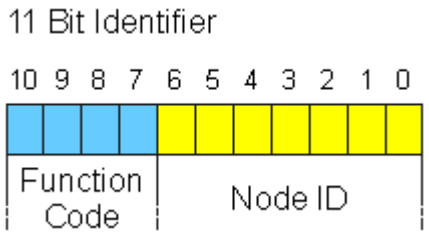


Fig. 46: Structure of the default identifier

For broadcast objects the node ID is set to *0*. This gives rise to the following default identifiers:

Broadcast objects

Object	Function	Function code	resulting COB ID hex / dec	Object for comm. Parameter / mapping
NMT	Boot-Up	0	0x00 / 0	- / -
SYNC	Synchronization	1	0x80 / 128	0x1005 + 0x1006 / -

Peer-to-peer objects

Object	Function with I/O devices	Function code	resulting COB ID hex / dec	Object for comm. Parameter / mapping
Emergency	Status / error	1	0x81 - 0xFF/ 129 - 255	- / -
PDO1 (tx)	dig. inputs	11	0x181 - 0x1FF / 385 - 511	0x1800 / 0x1A00
PDO1 (rx)	digital outputs	100	0x201 - 0x27F/ 513-639	0x1400 / 0x1600
PDO2 (tx)	analog inputs	101	0x281 - 0x2FF/ 641-767	0x1801 / 0x1A01
PDO2 (rx)	analog outputs	110	0x301 - 0x37F/ 769-895	0x1401 / 0x1601
PDO3 (tx)	analog inputs*	111	0x381 - 0x3FF / 897 - 1023	0x1802 / 0x1A02
PDO3 (rx)	analog outputs*	1000	0x401 - 0x47F/ 1025 - 1151	0x1402 / 0x1602
PDO4 (tx)	analog inputs*	1001	0x481 - 0x4FF/ 1153 - 1279	0x1803 / 0x1A03
PDO4 (rx)	analog outputs*	1010	0x501 - 0x57F/ 1281 - 1407	0x1403 / 0x1603
SDO (tx)	Parameter	1011	0x581 - 0x5FF/ 1409-1535	- / -
SDO (rx)	Parameter	1100	0x601 - 0x67F/ 1537-1663	- / -
Guarding	Life/node guarding, Heartbeat, Boot-up message	1110	0x701 - 0x77F/ 1793-1919	(0x100C, 0x100D, 0x100E, 0x1016, 0x1017)

* For historical reasons, the Beckhoff default mapping applies to PDOs 3 and 4 in Beckhoff I/O devices. In most configurations, PDOs 3+4 contain data related to analog inputs and outputs, but there can also be "excess" data from digital I/Os, or data from special terminals. Details may be found in the Bus Coupler documentation.

Up until version 3 of the CANopen specification, default identifiers were assigned to 2 PDOs at a time. The Beckhoff Bus Couplers up to firmware status BA correspond to this issue of the specification. After firmware version C0 (CANopen version 4), default identifiers are provided for up to 4 PDOs.

6 Error handling and diagnostics

6.1 LEDs

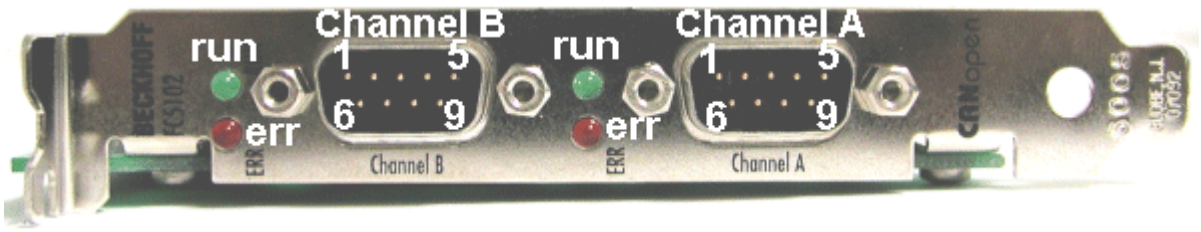


Fig. 47: FC510x - LEDs

LED behavior

The main card states can be quickly diagnosed by means of the red Error LED and the green Run LED:

Error LED (red)	Run LED (green)	Meaning
off	off	TwinCAT is stopped
off	on	All configured bus devices are error-free (box state = 0); TwinCAT task or process is running.
off	flashes at 2 Hz	The task whose process data are linked to the card is not running. All configured bus devices found and error-free (box state = 0)
flashes at 2 Hz	on	At least one box state is not zero (e.g. device not found, wrong configuration, device fault), TwinCAT task is running
flashes at 2 Hz	off	At least one box state is not zero (e.g. device not found, wrong configuration, device fault), TwinCAT task is not running.
on	off	TwinCAT is running, CAN controller is Bus OFF. Physical CAN problem. Possible causes: e.g. missing termination resistor, bus line too long, wrong baud rate, node address assigned twice, wiring fault, short circuit. Restart required
flashes at 20 Hz	flashes at 20 Hz	Configuration upload being carried out
flashes at 20 Hz	off	Card is in STOP mode

6.2 Bus Node Diagnostics

The CANopen fieldbus card FC510x has a comprehensive range of diagnostic options for connected network nodes.

For each CANopen fieldbus node there is a node state input variable, which signals the status of the current slave during the runtime and can be linked, for example with the PLC.

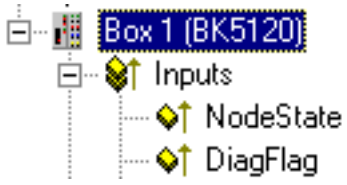


Fig. 48: Input variable Node State

Node State (Box-State)

Node State	Meaning	Explanation
0 = 0x00	No error	Bus node is operational, communication is running correctly
1 = 0x01	Node deactivated	The node is subject to one or more of the following errors: • guarding/heartbeat error (failure, toggle bit error, node has changed state) • expected TxPDO has not been received • TxPDO length shorter than expected Node has been stopped, because "Manual restart [▶ 31]" following a node failure has been selected.
2 = 0x02	Node not found	Node not found: no answer to SDO read access to object 0x1000 at the expected node address. Check the following at the node: what node address is set, and what baud rate. Check network (terminating resistors, connectors, bus length, crossed wiring etc.)
4 = 0x04	SDO syntax error at StartUp	Error during SDO write access: SDO abort by node. See the "Diag" tab for details. or: the length of an object read by SDO does not agree with the expected length.
5 = 0x05	SDO data mismatch at StartUp	Expected data do not match the data read via SDO (e.g. Device Profile and/or Add. Info does not match object 0x1000). Can also occur if the value to be written (e.g. PDO COB-ID) is read back due to refusal of write access, and does not agree. See the "Diag" tab for details.
8 = 0x08	Node StartUp in progress	Node was found and has been started.
11 = 0x0B	FC510x Bus-OFF	CAN chip has entered the "Bus-OFF" state: transmit error counter is running
12 = 0x0C	Pre-Operational	Node has gone pre-operational (on its own account).
13 = 0x0D	Severe bus fault	General firmware error.
14 = 0x0E	Guarding: toggle error	Guarding error: Toggle bit has not changed.
20 = 0x14	TxPDO too short	Received TxPDO shorter than expected.
22 = 0x16	Expected TxPDO is missing	TxPDO has not been received within the expected time interval: • sync interval with synchronous TxPDOs, • event timer with event-driven PDOs.
23 = 0x17	Node is Operational but not all TxPDOs were received	Node has been started, but at least one TxPDO has not yet been received from the node. Possible causes (e.g.): • The node only sends event-driven PDOs after the first event (this is not the intention of the CANopen specification, but is quite usual). • Too many TxPDOs have been configured. • A TxPDO is present at the node, but no process data has been mapped. • The TxPDO has transmission type 1...120 (synchronous), but SYNC has not yet been sent because the associated task has not been started.

DiagFlag

Shows whether the box diagnostic information has changed.

Reading the Diagnostic Data via ADS

CANopen emergencies and other diagnostic data can be read out via ADS read (new data present as soon as you see the DiagFlag). You need to enter the FC510x ADS Net-ID. Further ADS parameters:

Port: 200

IndexGroup: Lo-Word = 0xF180, Hi-Word = Node-Number.

IndexOffset: See below

Length: See below

If more than 26 bytes of diagnostic data have been read out the emergency memory is reset. The DiagFlag is reset as soon as at least 108 bytes have been read starting from offset 0. Alternatively, the flag is reset after each read access, if IndexGroup 0xF181 (instead of 0xF180) is used for reading.

The diagnostic data have the following definitions:

Offset 0,1:	Bit 1:	Boot up message not received or incorrect
	Bit 2:	Emergency-Overflow
	Bit 0, Bits 3-15:	reserved
Offset 2,3:	Bits 0-14:	TX-PDO (i+1) received
	Bit 15:	All TX PDOs 16-n received
Offset 4,5:	Bits 0-4:	1. Incorrect TX PDO length 2. Synchronous TX PDO absent 3. Node signaling PRE-OPERATIONAL 4. Event timer timed out for one TX PDO 5. No response during guarding 6. Toggling missed several times during guarding
	Bits 5-15:	Associated COB ID
Offset 6:	Bits 0-7:	1. Incorrect value during SDO upload 2. Incorrect length during SDO upload 3. Abort during SDO up/download 4. Incorrect date during a boot-up message 5. Timeout while waiting for a boot-up message
Offset 7:	Bits 0-7:	2: Incorrect SDO command specifier 3: SDO toggle bit has not changed 4: SDO length too great 5: SDO-Abort 6: SDO-Timeout
Offset 8,9	Bits 0-7:	SDO up/download index
Offset 10:	Bits 0-7:	SDO up/download subindex
Offset 11:	Bits 0-7:	reserved
Offset 12:	Bits 0-7:	Abort errorClass
Offset 13:	Bits 0-7:	Abort errorCode
Offset 14,15:	Bits 0-15:	Abort additionalCode
Offset 16-19:		Read value (if offset 6 = 1)
Offset 20-23:		Expected value (if offset 6 = 1)
Offset 24-25:		Number of consecutive emergencies
Offset 26 - n:		Emergencies (8 bytes each)

6.3 FC510x Diagnostics

The FC510x CANopen fieldbus card makes extensive diagnostic facilities available for the input variables.

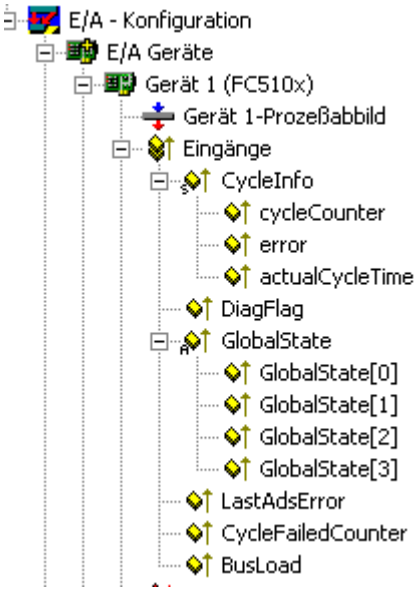


Fig. 49: FC510x - diagnostic inputs

cycleCounter

Is incremented after each firmware cycle. The PLC task can use this to establish whether new input data is being handled - if the cycleCounter has not been incremented since the last time the PLC task was called, the task time is too short.

error

The number of nodes whose state is not zero.

actualCycleTime

Current cycle time of the card firmware in 4/25 µs. Depends on the quantity of data and the bus loading.

DiagFlag

Is set to 1 if new diagnostic data (such as emergency) has been placed in the card's memory.

GlobalState

Reserved for internal evaluations.

LastAdsError

Last ADS error to have occurred. See also ADS Error Codes [▶ 67].

CycleFailedCounter

This counter is incremented if it was not possible to complete the card's firmware cycle before the highest priority linked task accessed the DPRAM again. In this case, the task does not receive any new input data, nor are new synchronous PDOs issued in the previous cycle. Because the CycleFailedCounter is not incremented until *after* the corresponding task start, it cannot be used for diagnostics within that task. It is recommended that the cycleCounter be used here, as it is not incremented in these cases.

Busload

Indicates the current bus loading in %.

General Diag

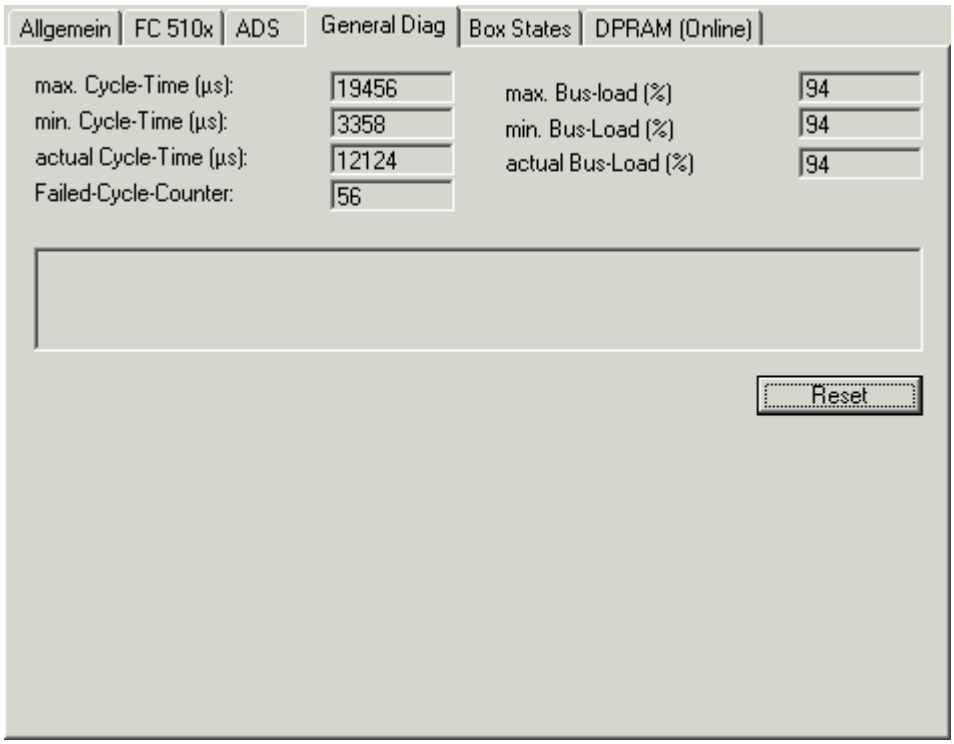


Fig. 50: "General Diag" tab

The minimum and maximum bus load are also displayed on the General Diag tab in addition to the current bus load, as are the cycle time and the Failed Cycle Counter. In the example illustrated above, about 5000 CAN frames are handled each second, and a corresponding number of PDOs are sent. Because the firmware sends all the pending PDOs in each cycle, the firmware cycle time in this case primarily depends on the time required to transmit the PDOs.

6.4 Error telegrams: Emergency

The CANopen FC510x fieldbus card stores arriving emergency messages in the diagnostic area starting at offset 26 (see below). Up to 10 emergencies can be stored for each bus node. The oldest message is replaced if more emergencies than this arrive.

New diagnostic data (emergencies or other diagnostic data) is present as soon as the DiagFlag is set.

Fig. 51: Node State

CANopen emergencies and other diagnostic data can be read via ADS. You need to enter the FC510x ADS Net-ID. Further ADS parameters:

Port: 200

IndexGroup: Lo-Word = 0xF180, Hi-Word = Node-Number.

IndexOffset: See below

Length: See below

If more than 26 bytes of diagnostic data have been read out the emergency memory is reset. The DiagFlag is reset as soon as at least 108 bytes have been read starting from offset 0. Alternatively, the flag is reset after each read access, if IndexGroup 0xF181 (instead of 0xF180) is used for reading.

A description of the diagnostic data at offset 0...23 is to be found in the corresponding Chapter [▶ 62]. The diagnostic area starting at offset 24 is organized as follows:

Offset 24-25:	Number of consecutive emergencies
Offset 26 - n:	Emergencies (8 bytes each)

The significance of the emergency data is to be found in the technical documentation for the particular CANopen device.

6.5 ADS error codes

The ADS error codes have the following meaning:

Error	Description
0x1001	Insufficient memory for AMS command
0x1101	Incorrect data length at StartFieldbus
0x1102	Incorrect DeviceState at StartFieldbus
0x1103	Device cannot change from INIT to RUN
0x1104	Incorrect AdsState in INIT state
0x1105	Incorrect DeviceState at StopFieldbus
0x1106	Device cannot change from STOP to RUN if a CDL is not defined
0x1107	Device cannot change from STOP to RUN if a box is not defined
0x1108	Incorrect data length at StartDataTransfer
0x1109	Incorrect DeviceState at StartDataTransfer
0x110A	Incorrect AdsState in STOP state
0x110B	Device cannot change from RUN to INIT
0x110C	Incorrect data length at StopDataTransfer
0x110D	Incorrect DeviceState at StopDataTransfer
0x1110	Incorrect AdsState in RUN state
0x1111	Loading the device parameters is only permitted in the INIT state
0x1112	Incorrect data length at SetDeviceState
0x1113	AddBox not allowed in INIT state
0x1114	Incorrect data length at AddBox
0x1115	DeleteBox not allowed in INIT state
0x1116	Incorrect IndexOffset at DeleteBox
0x1117	Incorrect data length at DeleteBox
0x1118	ReadBox only with AdsRead
0x1119	AddCdl not allowed in INIT state
0x111A	Incorrect data length at AddCdl
0x111B	DeleteCdl not allowed in INIT state
0x111C	Incorrect IndexOffset at DeleteCdl
0x111D	Incorrect data length at DeleteCdl
0x111E	Incorrect IndexGroup at AdsWrite
0x111F	Device parameters cannot be read

Error	Description
0x1120	Box parameters cannot be read
0x1121	Cdl parameters cannot be read
0x1122	DeleteBox or DeleteCdl only with AdsWrite
0x1123	ReadBox only possible in STOP state
0x1124	Incorrect IndexOffset at ReadBox
0x1125	Incorrect data length at ReadBox
0x1126	Incorrect IndexGroup at AdsRead
0x1127	AddDeviceNotification not allowed in INIT state
0x1128	DelDeviceNotification not allowed in INIT state
0x1129	IndexOffset too large during reading of the device diagnostic data
0x112B	IndexOffset too large during reading of the box diagnostic data
0x112F	Insufficient memory for ReadBox response
0x113E	FC card is in a status in which the status state cannot be changed
0x1201	AddCdl: CDL no. is too large
0x1202	DeleteCdl only possible when CDL is stopped
0x1203	DeleteCdl not possible as no CDL defined
0x1204	Cycle could not be completed within the internal watchdog time
0x1301	AddCdl: I/O access multiplier is too large
0x1302	AddCdl: Start cycle must be smaller than I/O access multiplier
0x1303	AddCdl: Incorrect data length for output area
0x1304	AddCdl: Incorrect data offset for output area
0x1305	AddCdl: Output area is already defined
0x1306	AddCdl: Incorrect data length for input area
0x1307	AddCdl: Incorrect data offset for input area
0x1308	AddCdl: Input area is already defined
0x1309	AddCdl: Incorrect area type
0x130A	AddCdl: BoxNo has not been defined with AddBox
0x130B	AddCdl: Incorrect action type
0x130C	AddCdl: Insufficient memory for poll list
0x130D	AddCdl: Insufficient memory for poll list array
0x130E	AddCdl: Insufficient memory for actions
0x130F	AddCdl: CdlNo already exists
0x1310	DeleteCdl: CDL is not stopped
0x1311	AddCdl: Insufficient memory for asynchronous transmit list
0x1312	AddCdl: Insufficient memory for synchronous receive list
0x1313	AddCdl: Insufficient memory for asynchronous receive list
0x1316	AddCdl: Insufficient memory for synchronous receive list
0x1318	AddCdl: Only slave action allowed
0x1319	AddCdl: Insufficient memory for slave list

Error	Description
0x1601	AddBox: BoxNo is too large
0x1602	AddBox: Insufficient memory for ADS StartUp telegram
0x1604	DeleteBox: Box is not stopped
0x1605	AddBox: Insufficient memory for CDL telegram
0x1606	AddBox: Number of CDL telegrams is too large
0x1607	BoxRestart: Box is not stopped
0x1608	BoxRestart: AdsWriteControl syntax error
0x1609	BoxRestart: Incorrect AdsState
0x160A	Syntax error in AdsWrite to box port
0x160B	AMS CmdId is not supported by box port
0x160E	AdsReadState is not supported by box port
0x160F	AddBox: Insufficient memory for the ADS interface
0x1610	AddBox: AMS channel is invalid
0x1611	Error communicating with an AMS box
0x1613	Error communicating with an AMS box: Incorrect offset
0x1614	Error communicating with an AMS box: Data packet is too large
0x1615	Error communicating with an AMS box: AMS command is too large
0x1616	Error communicating with an AMS box: First data packet is too large
0x1617	Error communicating with an AMS box: First offset is incorrect
0x1701	AddDeviceNotification: Length of device diagnostic data to small
0x1702	AddDeviceNotification: Length of device diagnostic data to large
0x1703	AddDeviceNotification: Length of box diagnostic data to small
0x1704	AddDeviceNotification: Length of box diagnostic data to large
0x1705	AddDeviceNotification: Box is not defined
0x1706	AddDeviceNotification: Incorrect IndexGroup
0x1707	AddDeviceNotification: No more resources for client
0x1708	DelDeviceNotification: Incorrect handle
0x1801	StartFieldbus: In equidistant operation, shift time + safety time + 2*PLL sync. time must be greater than the cycle time
0x1802	StartFieldbus: Cycle time is too large
0x1803	StartFieldbus: Cycle time is too large
0x1804	StartFieldbus: Shift time is too large
0x1805	StartFieldbus: PLL sync time is too large
0x1806	StartFieldbus: Safety time is too large
0x1807	StartFieldbus: Cycle times shorter than 1 ms must be integral divisors of 1 ms

Error	Description
0x1A01	Memory could not be allocated from the huge heap, because it is larger than 0x8000 bytes
0x1A02	Memory could not be allocated from the near heap, because it is larger than 0x1000 bytes
0x1A03	Memory could not be allocated from the huge heap, because it is 0 byte
0x1A04	Memory could not be allocated from the near heap, because it is 0 byte
0x2001	StartFieldbus: Initialization of the CAN controller failed
0x2002	AddBox: Incorrect box parameter length
0x2003	AddBox: Incorrect box number
0x2004	AddBox: Syntax error in ADS StartUp parameters
0x2005	AddBox: Syntax errors in PDO parameters
0x2006	AddBox: Syntax error in data length
0x2007	AddBox: Insufficient memory
0x2008	AddCdl: Incorrect receive data length
0x2009	AddCdl: Incorrect transmit data length
0x200A	AddCdl: PDO is not defined
0x200B	AddCdl: PDO Id is already defined
0x200C	AddBox: Syntax error in ADS StartUp parameters
0x200D	AddBox: Syntax error in ADS StartUp parameters
0x200E	AddBox: Emergency Id is already defined
0x200F	AddBox: Too many PDOs defined
0x2010	AddCdl: Incorrect telegram index
0x2011	AddBox: Too many Rx or Tx PDOs
0x2012	AdsRead: Incorrect IndexGroup
0x2013	AdsRead: Incorrect IndexOffset
0x2014	AdsRead: Incorrect length
0x2015	AdsWrite: Incorrect IndexGroup
0x2016	AdsWrite: Incorrect IndexOffset
0x2017	AdsWrite: Incorrect length
0x2018	AddBox: Guarding time smaller than 10 is not possible
0x2019	AddBox: Incorrect transmission type in CAN Layer 2 node
0x201A	AdsRead: not possible at CAN Layer 2 node
0x201B	AdsWrite: not possible at CAN Layer 2 node
0x201C	AddBox: BootUp Id is already defined
0x201D	AddBox: BoxNo 0 is not possible
0x201E	StartFieldbus: Loading the device parameters is only possible in the OFFLINE state
0x201F	StartDataTransfer: No memory for copy queue
0x2020	ReadBox: no more memory
0x2021	ReadBox: SDO error or timeout
0x2022	ReadBox: SDO cannot be initialized
0x2023	StartFieldbus: reserved device parameter not equal to 0

Error	Description
0x2101	Insufficient memory for low-priority queues
0x2102	Insufficient memory for low-priority queues
0x2103	Insufficient memory at node boot-up
0x2104	Insufficient memory at node boot-up
0x2105	Insufficient memory at node boot-up
0x2106	Insufficient memory at node boot-up
0x2107	Insufficient memory at node boot-up
0x2108	Insufficient memory at node boot-up
0x2109	Insufficient memory at node boot-up
0x210A	Insufficient memory at node boot-up
0x210B	Insufficient memory at node boot-up
0x210C	Insufficient memory at node boot-up
0x210D	Insufficient memory at node boot-up
0x210E	Insufficient memory at node boot-up
0x210F	Insufficient memory at node boot-up
0x2110	Insufficient memory at node boot-up
0x2111	Insufficient memory at node boot-up
0x2112	Insufficient memory at node boot-up
0x2113	Insufficient memory at node boot-up
0x2114	Insufficient memory at node boot-up
0x2301	Insufficient memory for low-priority queues
0x2302	Insufficient memory for low-priority queues

6.6 CANopen Trouble Shooting

Error Frames

One sign of errors in the CAN wiring, the address assignment or the setting of the baud rate is an increased number of error frames: the diagnostic LEDs then show *Warning Limit exceeded* or *Bus-off state entered*.

Error Frames

Warning limit exceeded, passive error or bus-off state are indicated first of all at those nodes that have detected the most errors. These nodes are not necessarily the cause for the occurrence of error frames!
If, for instance, one node contributes unusually heavily to the bus traffic (e.g. because it is the only one with analog inputs, the data for which triggers event-driven PDOs at a high rate), then the probability of its telegrams being damaged increases. Its error counter will, correspondingly, be the first to reach a critical level.

Node ID / Setting the Baud Rate

Care must be taken to ensure that node addresses are not assigned twice: there may only be one sender for each CAN data telegram.

Test 1

Check node addresses. If the CAN communication functions at least some of the time, and if all the devices support the boot up message, then the address assignment can also be examined by recording the boot up messages after the devices are switched on. This will not, however, recognize node addresses that have been swapped.

Test 2

Check that the same baud rate has been set everywhere. For special devices, if the bit timing parameters are accessible, do they agree with the CANopen definitions (sampling time, SJW, oscillator).

Testing the CAN wiring

These tests should not be carried out if the network is active: No communication should take place during the tests. The following tests should be carried out in the stated sequence, because some of the tests assume that the previous test was successful. Not all the tests are generally necessary.

Network terminator and signal leads

The nodes should be switched off or the CAN cable unplugged for this test, because the results of the measurements can otherwise be distorted by the active CAN transceiver.

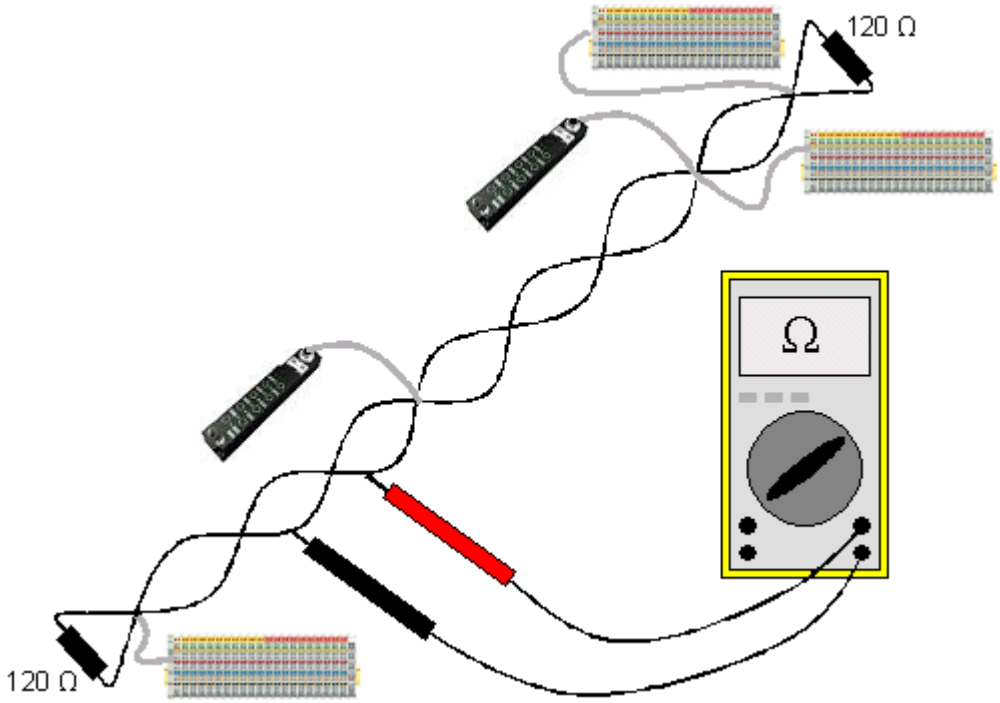


Fig. 52: Wiring diagram for test setup

Test 3

Determine the resistance between CAN high and CAN low - at each device, if necessary.

If the measured value is greater than 65 Ohms, it indicates the absence of a terminating resistor or a break in a signal lead. If the measured value is less than 50 Ohms, look for a short circuit between the CAN lines, more than the correct number of terminating resistors, or faulty transceivers.

Test 4

Check for a short circuit between the CAN ground and the signal leads, or between the screen and signal leads.

Test 5

Remove the earth connection from the CAN ground and screen. Check for a short circuit between the CAN ground and screen.

Topology

The possible cable length in CAN networks depends heavily on the selected baud rate. CAN will tolerate short drop lines - although this again depends on the baud rate. The maximum permitted drop line length should not be exceeded. The length of cable that has been installed is often underestimated - estimates can even be a factor of 10 less than the actual length. The following test is therefore recommended:

Test 6

Measure the lengths of the drop lines and the total bus lengths (do not just make rough estimates!) and compare them with the topology rules for the relevant baud rate.

Screening and earthing

The power supply and the screen should be carefully earthed at the power supply unit, once only and with low resistance. At all connecting points, branches and so forth the screen of the CAN cable (and possibly the CAN GND) must also be connected, as well as the signal leads. In the Beckhoff IP20 Bus Couplers, the screen is grounded for high frequencies via an R/C element.

Test 7

Use a DC ammeter (16 amp max.) to measure the current between the power supply ground and the shield at the end of the network most remote from the power supply unit. An equalization current should be present. If there is no current, then either the screen is not connected all the way through, or the power supply unit is not properly earthed. If the power supply unit is somewhere in the middle of the network, the measurement should be performed at both ends. When appropriate, this test can also be carried out at the ends of the drop line.

Test 8

Interrupt the screen at a number of locations and measure the connection current. If current is flowing, the screen is earthed at more than one place, creating a ground loop.

Potential differences

The screen must be connected all the way through for this test, and must not be carrying any current - this has previously been tested.

Test 9

Measure and record the voltage between the screen and the power supply ground at each node. The maximum potential difference between any two devices should be less than 5 volts.

Detect and localize faults

The "low-tech approach" usually works best: disconnect parts of the network, and observe when the fault disappears.

However, this does not work well for problems such as excessive potential differences, ground loops, EMC or signal distortion, since the reduction in the size of the network often solves the problem without the "missing" piece being the cause. The bus load also changes as the network is reduced in size, which can mean that external interference "hits" CAN telegrams less often.

Diagnosis with an oscilloscope is not usually successful: even when they are in good condition, CAN signals can look really chaotic. It may be possible to trigger on error frames using a storage oscilloscope - this type of diagnosis, however, is only possible for expert technicians.

Protocol problems

In rare cases, protocol problems (e.g. faulty or incomplete CANopen implementation, unfavorable timing at boot up, etc.) can be the cause of faults. In this case it is necessary to trace the bus traffic for evaluation by a CANopen experts - the Beckhoff support team can help here.
A free channel on a Beckhoff FC5102 CANopen PCI card is appropriate for such a trace - Beckhoff make the necessary trace software available on the internet. Alternatively, it is of course possible to use a normal commercial CAN analysis tool.

Protocol problems can be avoided if devices that have not been conformance tested are not used. The official CANopen Conformance Test (and the appropriate certificate) can be obtained from the CAN in Automation Association (http://www.can-cia.de).

7 Bus Trace function

7.1 FC510x as bus monitor

From firmware version 1.00 and TwinCAT 2.8 (build 740), the FC5101 or FC5102 can also be used as CANopen monitor instead of master or slave.

For example, the second channel of the FC5102 can be used for this purpose, in which case the first channel continues to function as CANopen master or slave, or vice versa. In such a case, both channels must be connected to the same CAN network. (Data exchange within the card is not provided, since this cannot take place in a non-reactive manner).

The telegrams recorded by the FC510x are temporarily stored in a ring buffer by the task linked with the FC510x; the stored telegrams can then be accessed by ADS. Beckhoff offers a CANopen monitoring program (CANMON) with filter [▶ 76] and trigger [▶ 76]options as freeware (see Download section at http://www.beckhoff.com).

Inserting the FC510x as a CANopen Monitor

In the **Append Device** context menu: insert CANopen monitor

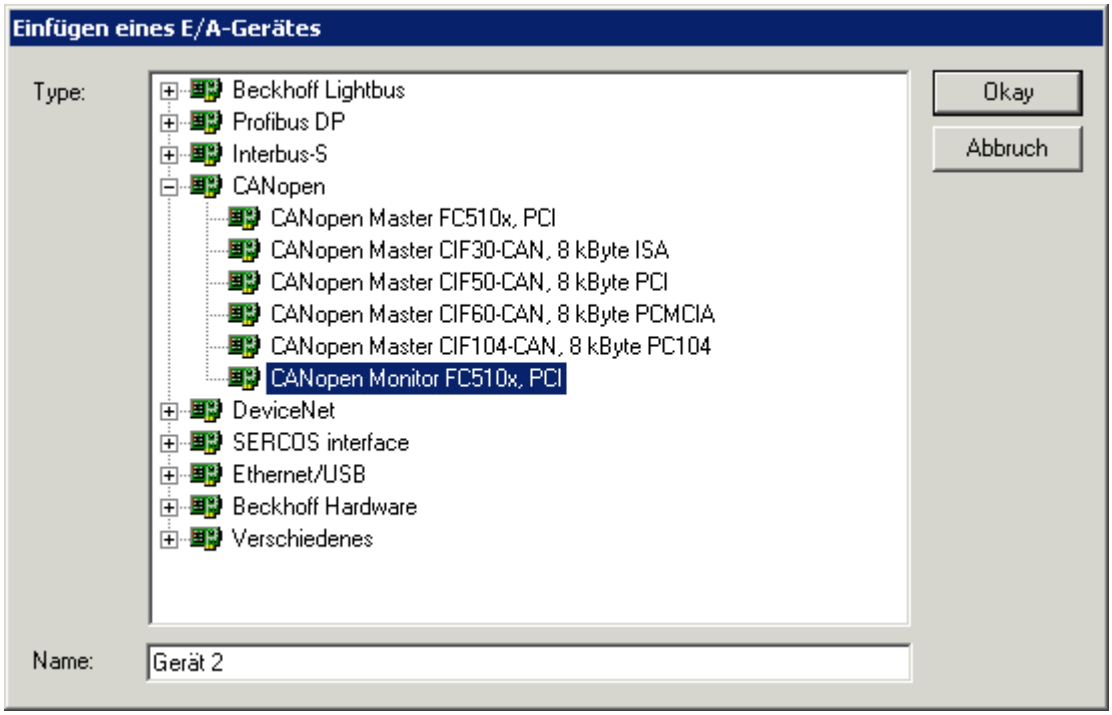


Fig. 53: Inserting the FC510x as a CANopen Monitor

After this it is necessary to select the appropriate channel (PCI memory address).

Linking the FC510x with a task

The monitor data is accessed at the start of a task from real-time TwinCAT. For this purpose it is necessary to create an additional task in the System Manager, containing at least one UINT16 input variable that is to be linked to one of the variables in the FC510x.

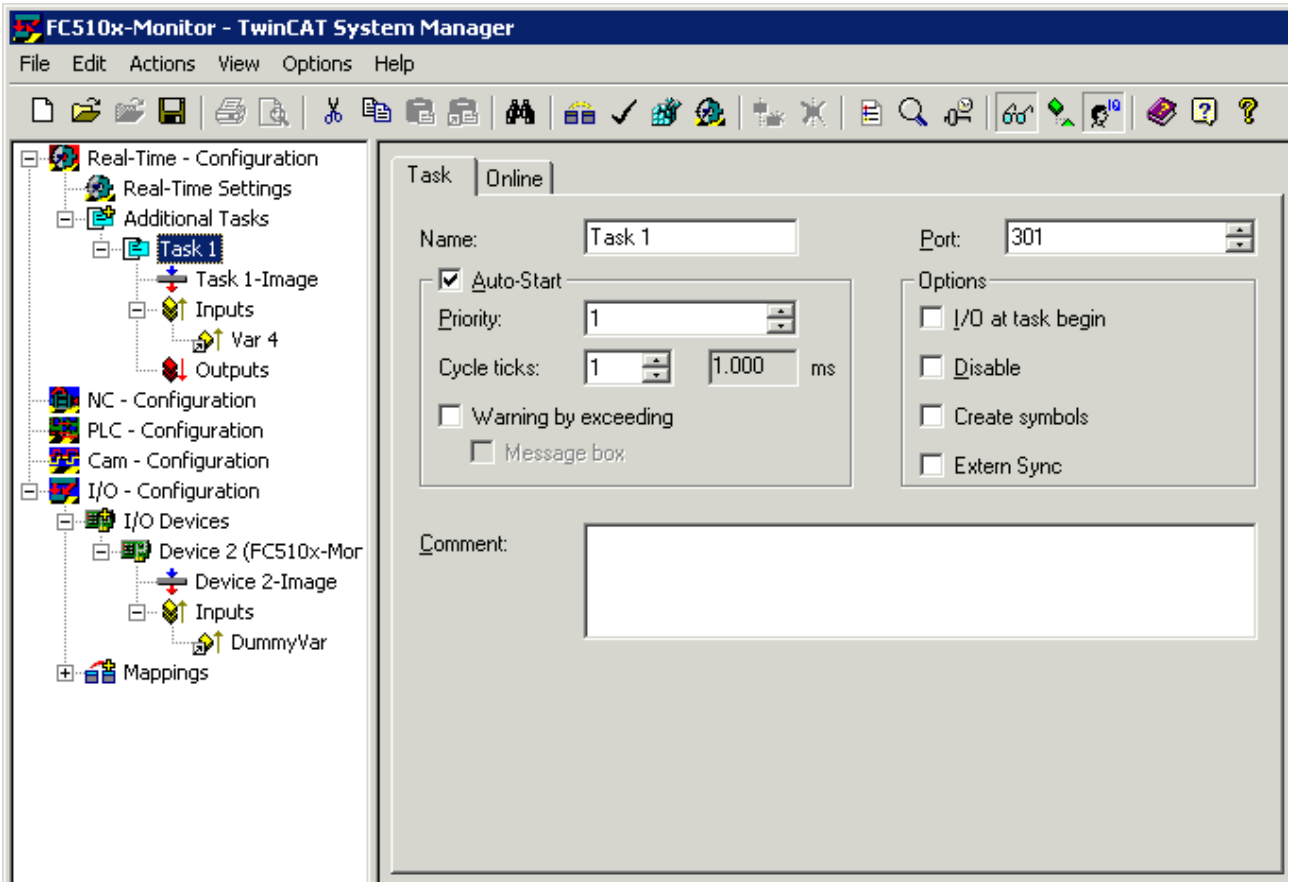


Fig. 54: Linking the FC510x with a task

The only purpose of this linking is to make it possible for the real-time system to access the FC510x in the cycle time of the task. The cycle time of the additional task is to be set as follows, depending on the baud rate:

Baud rate	Cycle time of the additional task
1 Mbaud	<= 10 ms
800 kbaud	<= 12 ms
500 kbaud	<= 20 ms
250 kbaud	<= 40 ms
125 kbaud	<= 80 ms
100 kbaud	<= 100 ms
50 kbaud	<= 200 ms
20 kbaud	<= 500 ms
10 kbaud	<= 1000 ms

The Autostart checkbox is also to be set (see illustration above).

FCxxxx Monitor tab

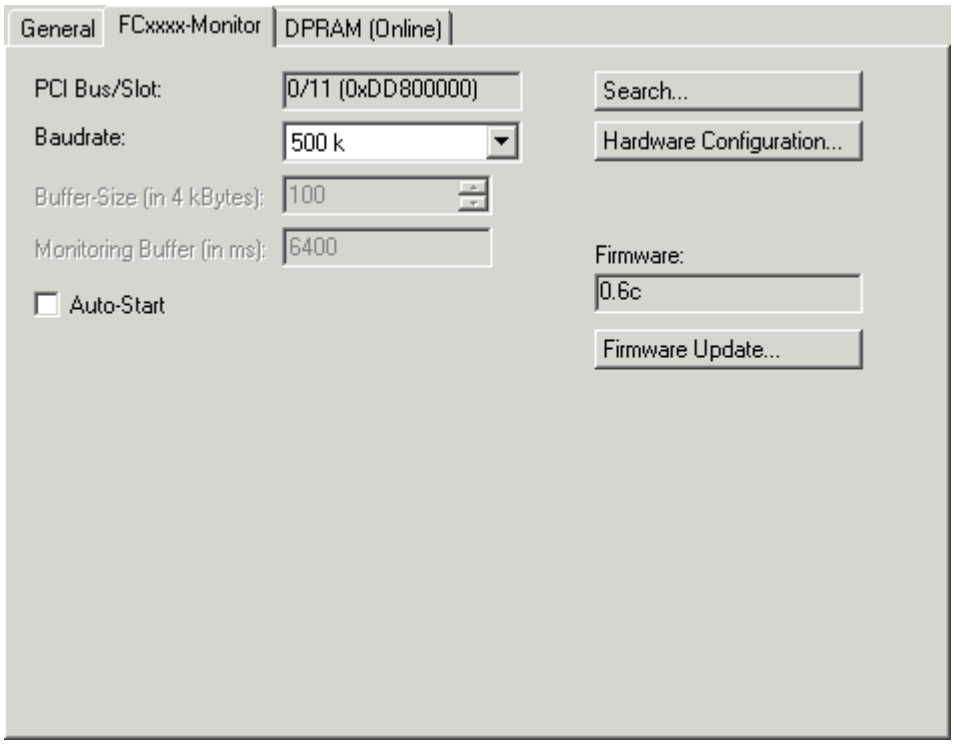


Fig. 55: FCxxxx Monitor tab

PCI Slot/Irq: Indicates in which logical PCI slot the card was found.

Search...: Searches for all connected FC510x channels. Select those desired. In the case of an FC5102 both channels A and B appear. These behave in logical terms like two FC5101 cards.

Hardware Configuration...: The hardware version number of the FC510x can be displayed here

Firmware: Shows the current firmware version of the FC510x.

Firmware Update...: Update the FC510x card firmware version here.

Baud rate: The CAN baud rate is set here.

Ring buffer: The size of the ring buffer is set here. The recording time for the ring buffer size that has been set when the bus is fully loaded is also given.

Autostart: If the Autostart checkbox is ticked, the monitor recording can be started when TwinCAT starts. Otherwise the monitor software must be used to start it via ADS.

Monitor Software

The monitor software fetches the trace data from the FC510x card and places it as a file in the desired mass storage. Only the DLL (TcRouterHelper.dll) is required in addition to the monitor program itself (CAN-Monitor.exe). This must be placed in the same directory as the monitor program.

After starting the monitor program, the device ID of the FC5101 channel that will be used for the monitoring must be selected.

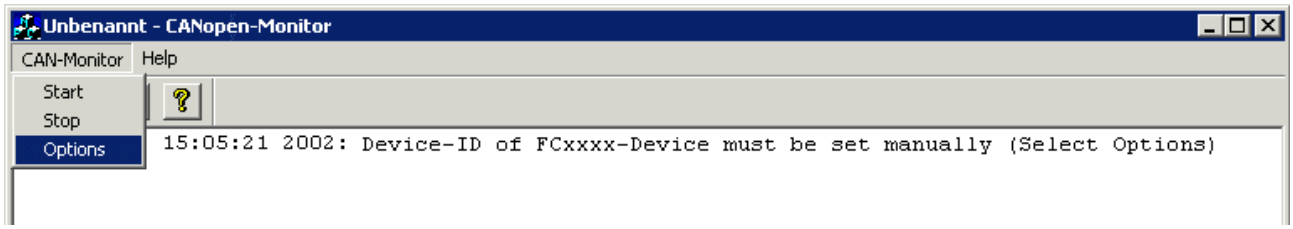


Fig. 56: CAN Monitor - calling the options

The following window opens:

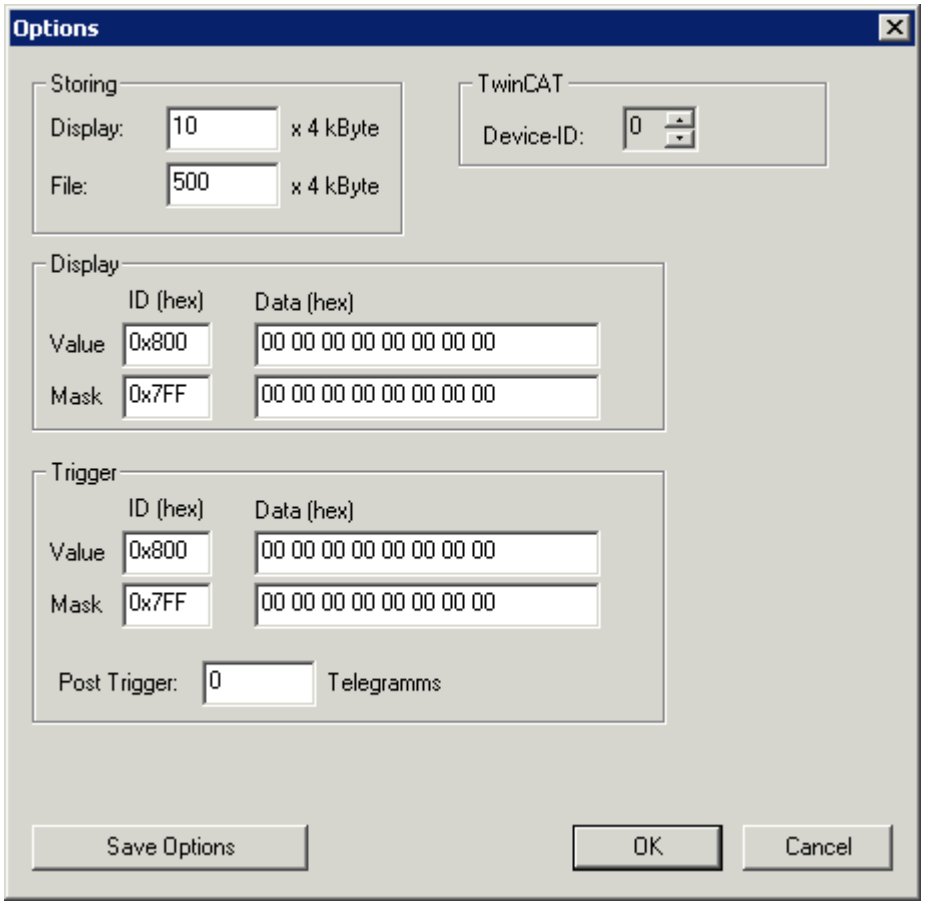


Fig. 57: CAN Monitor - options

Device-ID: The ID that the System Manager has assigned to the FC510x monitor channel must be entered here:

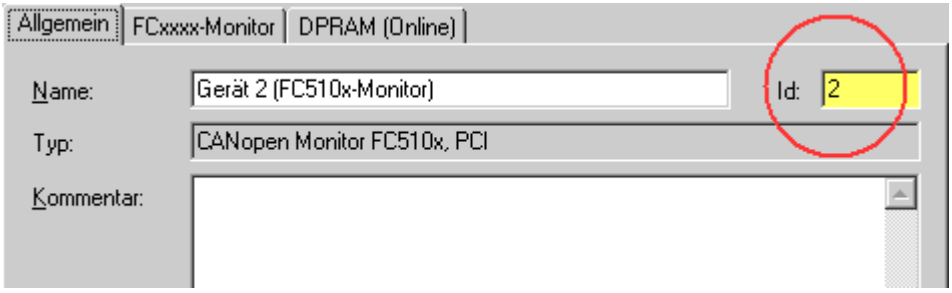


Fig. 58: Entering the device ID

Storing: The size of the ring buffer memory for the screen display (**Display**) and for that file output (**File**) can be set here.

Display: A filter for the display output can be specified here.

Trigger: Trigger conditions that will stop the measurement can be specified here. It is possible, for instance, for a specific otherwise unused output to be set when an error occurs, and to trigger off this bit in the output module's RxPDO.

Post Trigger: This can be used to specify how many telegrams are still to be recorded after the trigger condition has occurred. The number of telegrams recorded prior to occurrence of the trigger condition is only restricted by the specified buffer size.

Trigger and display filters function in such a way that only those bits for which the mask is set to 1 are considered when selecting the identifier (ID) or the data bytes (Data). These bits are then checked for conformity with the values specified in Value. The default setting (mask ID = 0x7FF and mask data = 0x00) is relevant if the identifier (ID) specified in Value is to be recognized, regardless of the data. If an identifier (ID) greater than 0x7FF (e.g. 0x800, default) is entered under Value, the filter or trigger is disabled.

Example:
The measurement is to be stopped after 250 telegrams, after bit 0 in the second data byte of a telegram with identifier 0x210 equal to 1 has been found. The following entries are to be made to achieve this:

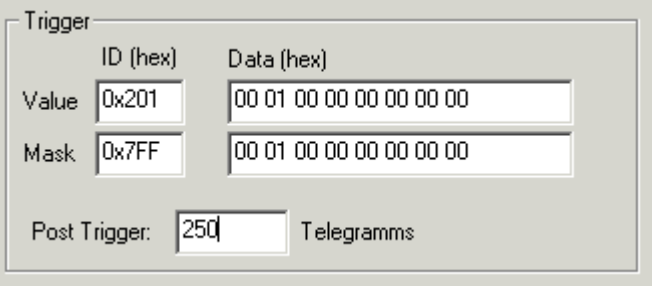


Fig. 59: Entering 250 telegrams

Starting the Recording

TwinCAT must be started, and a variable in a cyclic task (such as the Autostart task) must be linked with the dummy variable of the FC510x in monitoring mode. The recording can now be started by clicking the green traffic light symbol.

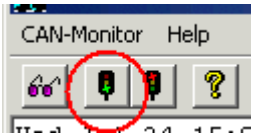


Fig. 60: Starting the recording

If the start-up procedure associated with another CANopen channel in the system is to be recorded, then the "Autostart" checkbox on the System Manager's FC Monitor [▶ 76] tab is to be selected. The card can then buffer up to 25,000 CAN messages. It is then only necessary to start the recording via monitor software before the CAN card's buffer overflows.

Stopping the Recording

Click the red traffic light symbol to stop the recording. The following dialog box opens:

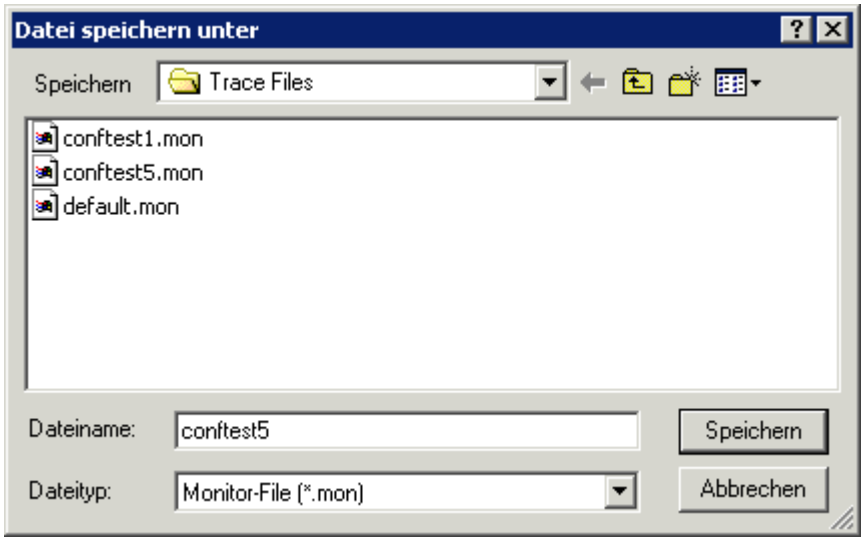


Fig. 61: Stopping the recording

Two trace files are created automatically. One is an ASCII file with the ending *.mon, readable by any text editor. A file with the ending *.ASC is also created: this can be read for further processing by the CANalyzer® tool from Vector Informatik.

Trace example

The beginning of a CANopen boot up with two nodes (node ID 1 and node ID 50) is illustrated.

Number Time (100 µs) telegram
0 0.0638 ID: 000 Len: 2 Data: 82 00
1 0.0649 ID: 632 Len: 8 Data: 40 00 10 00 00 00 00 00
2 0.0653 ID: 601 Len: 8 Data: 40 00 10 00 00 00 00 00
3 2.0722 ID: 632 Len: 8 Data: 80 00 00 00 00 00 04 05
4 2.0725 ID: 601 Len: 8 Data: 80 00 00 00 00 00 04 05
5 2.2686 ID: 732 Len: 1 Data: 00
6 2.7440 ID: 701 Len: 1 Data: 00
7 4.0802 ID: 632 Len: 8 Data: 40 00 10 00 00 00 00 00
8 4.0806 ID: 601 Len: 8 Data: 40 00 10 00 00 00 00 00
9 4.0813 ID: 5b2 Len: 8 Data: 43 00 10 00 91 01 02 00
10 4.0823 ID: 632 Len: 8 Data: 40 18 10 01 00 00 00 00
11 4.0826 ID: 581 Len: 8 Data: 43 00 10 00 91 01 07 00
12 4.0835 ID: 601 Len: 8 Data: 40 18 10 01 00 00 00 00
13 4.0838 ID: 5b2 Len: 8 Data: 43 18 10 01 02 00 00 00
14 4.0848 ID: 632 Len: 8 Data: 23 00 14 01 32 02 00 00
15 4.0853 ID: 581 Len: 8 Data: 43 18 10 01 02 00 00 00
16 4.0863 ID: 601 Len: 8 Data: 23 00 18 01 81 01 00 00

8 Appendix

8.1 CAN Identifier List

The list provided here should assist in identifying and assigning CANopen messages. All the identifiers allocated by the CANopen default identifier allocation are listed, as well as the manufacturer-specific default identifiers issued by BECKHOFF via object 0x5500 (only to be used in networks with node addresses less than 64).

The following values can be used as search aids and "entry points" in the extensive identifier table in the *chm edition of the documentation:

Decimal: 400 [▶ 81], 500 [▶ 88], 600 [▶ 88], 700 [▶ 83], 800 [▶ 84], 900 [▶ 85], 1000 [▶ 90], 1100 [▶ 90], 1200 [▶ 86], 1300 [▶ 86], 1400 [▶ 91], 1500 [▶ 92], 1600 [▶ 92], 1700 [▶ 87], 1800 [▶ 95], 1900 [▶ 87]

Hexadecimal: 0x181 [▶ 81], 0x1C1 [▶ 88], 0x201 [▶ 82], 0x301 [▶ 84], 0x401 [▶ 85], 0x501 [▶ 86], 0x601 [▶ 94], 0x701 [▶ 95]

The identifier distribution via object 0x5500 follows this pattern:

Object	Resulting COB ID (dec)	Resulting COB ID (hex)
Emergency [▶ 81]	129 to 191 [255]	0x81 to 0xBF [0xFF]
TxPDO1 [▶ 81]	385 to 447 [511]	0x181 to 0x1BF [0x1FF]
RxPDO1 [▶ 82]	513 to 575 [639]	0x201 to 0x23F [0x27F]
TxPDO2 [▶ 83]	641 to 676 [767]	0x281 to 0x2BF [0x2FF]
RxPDO2 [▶ 84]	769 to 831 [895]	0x301 to 0x33F [0x37F]
TxDPO3 [▶ 85]	897 to 959 [1023]	0x381 to 0x3BF [0x3FF]
RxPDO3 [▶ 85]	1025 to 1087 [1151]	0x401 to 0x43F [0x47F]
TxPDO4 [▶ 86]	1153 to 1215 [1279]	0x481 to 0x4BF [0x4FF]
RxPDO4 [▶ 86]	1281 to 1343 [1407]	0x501 to 0x53F [0x57F]
TxPDO5 [▶ 87]	1665 to 1727	0x681 to 0x6BF
RxPDO5 [▶ 87]	1921 to 1983	0x781 to 0x7BF
TxPDO6 [▶ 88]	449 to 511	0x1C1 to 0x1FF
RxPDO6 [▶ 88]	577 to 639	0x241 to 0x27F
TxDPO7 [▶ 89]	705 to 767	0x2C1 to 0x2FF
RxPDO7 [▶ 89]	833 to 895	0x341 to 0x37F
TxPDO8 [▶ 90]	961 to 1023	0x3C1 to 0x3FF
RxPDO8 [▶ 90]	1089 to 1151	0x441 to 0x47F
TxPDO9 [▶ 91]	1217 to 1279	0x4C1 to 0x4FF
RxPDO9 [▶ 91]	1345 to 1407	0x541 to 0x57F
TxDPO10 [▶ 92]	1473 to 1535	0x5C1 to 0x5FF
RxPDO10 [▶ 92]	1601 to 1663	0x641 to 0x67F
TxPDO11 [▶ 93]	1729 to 1791	0x6C1 to 0x6FF
RxPDO11 [▶ 93]	1857 to 1919	0x741 to 0x77F
SDO (Tx) [▶ 94]	1409 to 1471 [1535]	0x581 to 0x5BF [0x5FF]
SDO (Rx) [▶ 94]	1537 to 1599 [1663]	0x601 to 0x63F [0x67F]
Guarding / Heartbeat/ Bootup [▶ 95]	1793 to 1855 [1919]	0x701 to 0x73F [0x77F]

Identifier List

Identifiers marked with * are given manufacturer-specific assignments on the Bus Couplers after writing index 0x5500

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
0	0x00	NMT	149	0x95	EMCY Nd.21	171	0xAB	EMCY Nd.43
128	0x80	SYNC	150	0x96	EMCY Nd.22	172	0xAC	EMCY Nd.44
129	0x81	EMCY Nd.1	151	0x97	EMCY Nd.23	173	0xAD	EMCY Nd.45
130	0x82	EMCY Nd.2	152	0x98	EMCY Nd.24	174	0xAE	EMCY Nd.46
131	0x83	EMCY Nd.3	153	0x99	EMCY Nd.25	175	0xAF	EMCY Nd.47
132	0x84	EMCY Nd.4	154	0x9A	EMCY Nd.26	176	0xB0	EMCY Nd.48
133	0x85	EMCY Nd.5	155	0x9B	EMCY Nd.27	177	0xB1	EMCY Nd.49
134	0x86	EMCY Nd.6	156	0x9C	EMCY Nd.28	178	0xB2	EMCY Nd.50
135	0x87	EMCY Nd.7	157	0x9D	EMCY Nd.29	179	0xB3	EMCY Nd.51
136	0x88	EMCY Nd.8	158	0x9E	EMCY Nd.30	180	0xB4	EMCY Nd.52
137	0x89	EMCY Nd.9	159	0x9F	EMCY Nd.31	181	0xB5	EMCY Nd.53
138	0x8A	EMCY Nd.10	160	0xA0	EMCY Nd.32	182	0xB6	EMCY Nd.54
139	0x8B	EMCY Nd.11	161	0xA1	EMCY Nd.33	183	0xB7	EMCY Nd.55
140	0x8C	EMCY Nd.12	162	0xA2	EMCY Nd.34	184	0xB8	EMCY Nd.56
141	0x8D	EMCY Nd.13	163	0xA3	EMCY Nd.35	185	0xB9	EMCY Nd.57
142	0x8E	EMCY Nd.14	164	0xA4	EMCY Nd.36	186	0xBA	EMCY Nd.58
143	0x8F	EMCY Nd.15	165	0xA5	EMCY Nd.37	187	0xBB	EMCY Nd.59
144	0x90	EMCY Nd.16	166	0xA6	EMCY Nd.38	188	0xBC	EMCY Nd.60
145	0x91	EMCY Nd.17	167	0xA7	EMCY Nd.39	189	0xBD	EMCY Nd.61
146	0x92	EMCY Nd.18	168	0xA8	EMCY Nd.40	190	0xBE	EMCY Nd.62
147	0x93	EMCY Nd.19	169	0xA9	EMCY Nd.41	191	0xBF	EMCY Nd.63
148	0x94	EMCY Nd.20	170	0xAA	EMCY Nd.42			

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
385	0x181	TxPDO1, DI, Nd.1	406	0x196	TxPDO1, DI, Nd.22	427	0x1AB	TxPDO1, DI, Nd.43
386	0x182	TxPDO1, DI, Nd.2	407	0x197	TxPDO1, DI, Nd.23	428	0x1AC	TxPDO1, DI, Nd.44
387	0x183	TxPDO1, DI, Nd.3	408	0x198	TxPDO1, DI, Nd.24	429	0x1AD	TxPDO1, DI, Nd.45
388	0x184	TxPDO1, DI, Nd.4	409	0x199	TxPDO1, DI, Nd.25	430	0x1AE	TxPDO1, DI, Nd.46
389	0x185	TxPDO1, DI, Nd.5	410	0x19A	TxPDO1, DI, Nd.26	431	0x1AF	TxPDO1, DI, Nd.47
390	0x186	TxPDO1, DI, Nd.6	411	0x19B	TxPDO1, DI, Nd.27	432	0x1B0	TxPDO1, DI, Nd.48
391	0x187	TxPDO1, DI, Nd.7	412	0x19C	TxPDO1, DI, Nd.28	433	0x1B1	TxPDO1, DI, Nd.49
392	0x188	TxPDO1, DI, Nd.8	413	0x19D	TxPDO1, DI, Nd.29	434	0x1B2	TxPDO1, DI, Nd.50
393	0x189	TxPDO1, DI, Nd.9	414	0x19E	TxPDO1, DI, Nd.30	435	0x1B3	TxPDO1, DI, Nd.51
394	0x18A	TxPDO1, DI, Nd.10	415	0x19F	TxPDO1, DI, Nd.31	436	0x1B4	TxPDO1, DI, Nd.52
395	0x18B	TxPDO1, DI, Nd.11	416	0x1A0	TxPDO1, DI, Nd.32	437	0x1B5	TxPDO1, DI, Nd.53
396	0x18C	TxPDO1, DI, Nd.12	417	0x1A1	TxPDO1, DI, Nd.33	438	0x1B6	TxPDO1, DI, Nd.54
397	0x18D	TxPDO1, DI, Nd.13	418	0x1A2	TxPDO1, DI, Nd.34	439	0x1B7	TxPDO1, DI, Nd.55
398	0x18E	TxPDO1, DI, Nd.14	419	0x1A3	TxPDO1, DI, Nd.35	440	0x1B8	TxPDO1, DI, Nd.56
399	0x18F	TxPDO1, DI, Nd.15	420	0x1A4	TxPDO1, DI, Nd.36	441	0x1B9	TxPDO1, DI, Nd.57
400	0x190	TxPDO1, DI, Nd.16	421	0x1A5	TxPDO1, DI, Nd.37	442	0x1BA	TxPDO1, DI, Nd.58
401	0x191	TxPDO1, DI, Nd.17	422	0x1A6	TxPDO1, DI, Nd.38	443	0x1BB	TxPDO1, DI, Nd.59
402	0x192	TxPDO1, DI, Nd.18	423	0x1A7	TxPDO1, DI, Nd.39	444	0x1BC	TxPDO1, DI, Nd.60
403	0x193	TxPDO1, DI, Nd.19	424	0x1A8	TxPDO1, DI, Nd.40	445	0x1BD	TxPDO1, DI, Nd.61
404	0x194	TxPDO1, DI, Nd.20	425	0x1A9	TxPDO1, DI, Nd.41	446	0x1BE	TxPDO1, DI, Nd.62
405	0x195	TxPDO1, DI, Nd.21	426	0x1AA	TxPDO1, DI, Nd.42	447	0x1BF	TxPDO1, DI, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
513	0x201	RxPDO1, DO, Nd.1	534	0x216	RxPDO1, DO, Nd.22	555	0x22B	RxPDO1, DO, Nd.43
514	0x202	RxPDO1, DO, Nd.2	535	0x217	RxPDO1, DO, Nd.23	556	0x22C	RxPDO1, DO, Nd.44
515	0x203	RxPDO1, DO, Nd.3	536	0x218	RxPDO1, DO, Nd.24	557	0x22D	RxPDO1, DO, Nd.45
516	0x204	RxPDO1, DO, Nd.4	537	0x219	RxPDO1, DO, Nd.25	558	0x22E	RxPDO1, DO, Nd.46
517	0x205	RxPDO1, DO, Nd.5	538	0x21A	RxPDO1, DO, Nd.26	559	0x22F	RxPDO1, DO, Nd.47
518	0x206	RxPDO1, DO, Nd.6	539	0x21B	RxPDO1, DO, Nd.27	560	0x230	RxPDO1, DO, Nd.48
519	0x207	RxPDO1, DO, Nd.7	540	0x21C	RxPDO1, DO, Nd.28	561	0x231	RxPDO1, DO, Nd.49
520	0x208	RxPDO1, DO, Nd.8	541	0x21D	RxPDO1, DO, Nd.29	562	0x232	RxPDO1, DO, Nd.50
521	0x209	RxPDO1, DO, Nd.9	542	0x21E	RxPDO1, DO, Nd.30	563	0x233	RxPDO1, DO, Nd.51
522	0x20A	RxPDO1, DO, Nd.10	543	0x21F	RxPDO1, DO, Nd.31	564	0x234	RxPDO1, DO, Nd.52
523	0x20B	RxPDO1, DO, Nd.11	544	0x220	RxPDO1, DO, Nd.32	565	0x235	RxPDO1, DO, Nd.53
524	0x20C	RxPDO1, DO, Nd.12	545	0x221	RxPDO1, DO, Nd.33	566	0x236	RxPDO1, DO, Nd.54
525	0x20D	RxPDO1, DO, Nd.13	546	0x222	RxPDO1, DO, Nd.34	567	0x237	RxPDO1, DO, Nd.55
526	0x20E	RxPDO1, DO, Nd.14	547	0x223	RxPDO1, DO, Nd.35	568	0x238	RxPDO1, DO, Nd.56
527	0x20F	RxPDO1, DO, Nd.15	548	0x224	RxPDO1, DO, Nd.36	569	0x239	RxPDO1, DO, Nd.57
528	0x210	RxPDO1, DO, Nd.16	549	0x225	RxPDO1, DO, Nd.37	570	0x23A	RxPDO1, DO, Nd.58
529	0x211	RxPDO1, DO, Nd.17	550	0x226	RxPDO1, DO, Nd.38	571	0x23B	RxPDO1, DO, Nd.59
530	0x212	RxPDO1, DO, Nd.18	551	0x227	RxPDO1, DO, Nd.39	572	0x23C	RxPDO1, DO, Nd.60
531	0x213	RxPDO1, DO, Nd.19	552	0x228	RxPDO1, DO, Nd.40	573	0x23D	RxPDO1, DO, Nd.61
532	0x214	RxPDO1, DO, Nd.20	553	0x229	RxPDO1, DO, Nd.41	574	0x23E	RxPDO1, DO, Nd.62
533	0x215	RxPDO1, DO, Nd.21	554	0x22A	RxPDO1, DO, Nd.42	575	0x23F	RxPDO1, DO, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
641	0x281	TxPDO2, AI, Nd.1	662	0x296	TxPDO2, AI, Nd.22	683	0x2AB	TxPDO2, AI, Nd.43
642	0x282	TxPDO2, AI, Nd.2	663	0x297	TxPDO2, AI, Nd.23	684	0x2AC	TxPDO2, AI, Nd.44
643	0x283	TxPDO2, AI, Nd.3	664	0x298	TxPDO2, AI, Nd.24	685	0x2AD	TxPDO2, AI, Nd.45
644	0x284	TxPDO2, AI, Nd.4	665	0x299	TxPDO2, AI, Nd.25	686	0x2AE	TxPDO2, AI, Nd.46
645	0x285	TxPDO2, AI, Nd.5	666	0x29A	TxPDO2, AI, Nd.26	687	0x2AF	TxPDO2, AI, Nd.47
646	0x286	TxPDO2, AI, Nd.6	667	0x29B	TxPDO2, AI, Nd.27	688	0x2B0	TxPDO2, AI, Nd.48
647	0x287	TxPDO2, AI, Nd.7	668	0x29C	TxPDO2, AI, Nd.28	689	0x2B1	TxPDO2, AI, Nd.49
648	0x288	TxPDO2, AI, Nd.8	669	0x29D	TxPDO2, AI, Nd.29	690	0x2B2	TxPDO2, AI, Nd.50
649	0x289	TxPDO2, AI, Nd.9	670	0x29E	TxPDO2, AI, Nd.30	691	0x2B3	TxPDO2, AI, Nd.51
650	0x28A	TxPDO2, AI, Nd.10	671	0x29F	TxPDO2, AI, Nd.31	692	0x2B4	TxPDO2, AI, Nd.52
651	0x28B	TxPDO2, AI, Nd.11	672	0x2A0	TxPDO2, AI, Nd.32	693	0x2B5	TxPDO2, AI, Nd.53
652	0x28C	TxPDO2, AI, Nd.12	673	0x2A1	TxPDO2, AI, Nd.33	694	0x2B6	TxPDO2, AI, Nd.54
653	0x28D	TxPDO2, AI, Nd.13	674	0x2A2	TxPDO2, AI, Nd.34	695	0x2B7	TxPDO2, AI, Nd.55
654	0x28E	TxPDO2, AI, Nd.14	675	0x2A3	TxPDO2, AI, Nd.35	696	0x2B8	TxPDO2, AI, Nd.56
655	0x28F	TxPDO2, AI, Nd.15	676	0x2A4	TxPDO2, AI, Nd.36	697	0x2B9	TxPDO2, AI, Nd.57
656	0x290	TxPDO2, AI, Nd.16	677	0x2A5	TxPDO2, AI, Nd.37	698	0x2BA	TxPDO2, AI, Nd.58
657	0x291	TxPDO2, AI, Nd.17	678	0x2A6	TxPDO2, AI, Nd.38	699	0x2BB	TxPDO2, AI, Nd.59
658	0x292	TxPDO2, AI, Nd.18	679	0x2A7	TxPDO2, AI, Nd.39	700	0x2BC	TxPDO2, AI, Nd.60
659	0x293	TxPDO2, AI, Nd.19	680	0x2A8	TxPDO2, AI, Nd.40	701	0x2BD	TxPDO2, AI, Nd.61
660	0x294	TxPDO2, AI, Nd.20	681	0x2A9	TxPDO2, AI, Nd.41	702	0x2BE	TxPDO2, AI, Nd.62
661	0x295	TxPDO2, AI, Nd.21	682	0x2AA	TxPDO2, AI, Nd.42	703	0x2BF	TxPDO2, AI, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
769	0x301	RxPDO2, AO, Nd.1	790	0x316	RxPDO2, AO, Nd.22	811	0x32B	RxPDO2, AO, Nd.43
770	0x302	RxPDO2, AO, Nd.2	791	0x317	RxPDO2, AO, Nd.23	812	0x32C	RxPDO2, AO, Nd.44
771	0x303	RxPDO2, AO, Nd.3	792	0x318	RxPDO2, AO, Nd.24	813	0x32D	RxPDO2, AO, Nd.45
772	0x304	RxPDO2, AO, Nd.4	793	0x319	RxPDO2, AO, Nd.25	814	0x32E	RxPDO2, AO, Nd.46
773	0x305	RxPDO2, AO, Nd.5	794	0x31A	RxPDO2, AO, Nd.26	815	0x32F	RxPDO2, AO, Nd.47
774	0x306	RxPDO2, AO, Nd.6	795	0x31B	RxPDO2, AO, Nd.27	816	0x330	RxPDO2, AO, Nd.48
775	0x307	RxPDO2, AO, Nd.7	796	0x31C	RxPDO2, AO, Nd.28	817	0x331	RxPDO2, AO, Nd.49
776	0x308	RxPDO2, AO, Nd.8	797	0x31D	RxPDO2, AO, Nd.29	818	0x332	RxPDO2, AO, Nd.50
777	0x309	RxPDO2, AO, Nd.9	798	0x31E	RxPDO2, AO, Nd.30	819	0x333	RxPDO2, AO, Nd.51
778	0x30A	RxPDO2, AO, Nd.10	799	0x31F	RxPDO2, AO, Nd.31	820	0x334	RxPDO2, AO, Nd.52
779	0x30B	RxPDO2, AO, Nd.11	800	0x320	RxPDO2, AO, Nd.32	821	0x335	RxPDO2, AO, Nd.53
780	0x30C	RxPDO2, AO, Nd.12	801	0x321	RxPDO2, AO, Nd.33	822	0x336	RxPDO2, AO, Nd.54
781	0x30D	RxPDO2, AO, Nd.13	802	0x322	RxPDO2, AO, Nd.34	823	0x337	RxPDO2, AO, Nd.55
782	0x30E	RxPDO2, AO, Nd.14	803	0x323	RxPDO2, AO, Nd.35	824	0x338	RxPDO2, AO, Nd.56
783	0x30F	RxPDO2, AO, Nd.15	804	0x324	RxPDO2, AO, Nd.36	825	0x339	RxPDO2, AO, Nd.57
784	0x310	RxPDO2, AO, Nd.16	805	0x325	RxPDO2, AO, Nd.37	826	0x33A	RxPDO2, AO, Nd.58
785	0x311	RxPDO2, AO, Nd.17	806	0x326	RxPDO2, AO, Nd.38	827	0x33B	RxPDO2, AO, Nd.59
786	0x312	RxPDO2, AO, Nd.18	807	0x327	RxPDO2, AO, Nd.39	828	0x33C	RxPDO2, AO, Nd.60
787	0x313	RxPDO2, AO, Nd.19	808	0x328	RxPDO2, AO, Nd.40	829	0x33D	RxPDO2, AO, Nd.61
788	0x314	RxPDO2, AO, Nd.20	809	0x329	RxPDO2, AO, Nd.41	830	0x33E	RxPDO2, AO, Nd.62
789	0x315	RxPDO2, AO, Nd.21	810	0x32A	RxPDO2, AO, Nd.42	831	0x33F	RxPDO2, AO, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
897	0x381	TxPDO3*, Nd.1	918	0x396	TxPDO3*, Nd.22	939	0x3AB	TxPDO3*, Nd.43
898	0x382	TxPDO3*, Nd.2	919	0x397	TxPDO3*, Nd.23	940	0x3AC	TxPDO3*, Nd.44
899	0x383	TxPDO3*, Nd.3	920	0x398	TxPDO3*, Nd.24	941	0x3AD	TxPDO3*, Nd.45
900	0x384	TxPDO3*, Nd.4	921	0x399	TxPDO3*, Nd.25	942	0x3AE	TxPDO3*, Nd.46
901	0x385	TxPDO3*, Nd.5	922	0x39A	TxPDO3*, Nd.26	943	0x3AF	TxPDO3*, Nd.47
902	0x386	TxPDO3*, Nd.6	923	0x39B	TxPDO3*, Nd.27	944	0x3B0	TxPDO3*, Nd.48
903	0x387	TxPDO3*, Nd.7	924	0x39C	TxPDO3*, Nd.28	945	0x3B1	TxPDO3*, Nd.49
904	0x388	TxPDO3*, Nd.8	925	0x39D	TxPDO3*, Nd.29	946	0x3B2	TxPDO3*, Nd.50
905	0x389	TxPDO3*, Nd.9	926	0x39E	TxPDO3*, Nd.30	947	0x3B3	TxPDO3*, Nd.51
906	0x38A	TxPDO3*, Nd.10	927	0x39F	TxPDO3*, Nd.31	948	0x3B4	TxPDO3*, Nd.52
907	0x38B	TxPDO3*, Nd.11	928	0x3A0	TxPDO3*, Nd.32	949	0x3B5	TxPDO3*, Nd.53
908	0x38C	TxPDO3*, Nd.12	929	0x3A1	TxPDO3*, Nd.33	950	0x3B6	TxPDO3*, Nd.54
909	0x38D	TxPDO3*, Nd.13	930	0x3A2	TxPDO3*, Nd.34	951	0x3B7	TxPDO3*, Nd.55
910	0x38E	TxPDO3*, Nd.14	931	0x3A3	TxPDO3*, Nd.35	952	0x3B8	TxPDO3*, Nd.56
911	0x38F	TxPDO3*, Nd.15	932	0x3A4	TxPDO3*, Nd.36	953	0x3B9	TxPDO3*, Nd.57
912	0x390	TxPDO3*, Nd.16	933	0x3A5	TxPDO3*, Nd.37	954	0x3BA	TxPDO3*, Nd.58
913	0x391	TxPDO3*, Nd.17	934	0x3A6	TxPDO3*, Nd.38	955	0x3BB	TxPDO3*, Nd.59
914	0x392	TxPDO3*, Nd.18	935	0x3A7	TxPDO3*, Nd.39	956	0x3BC	TxPDO3*, Nd.60
915	0x393	TxPDO3*, Nd.19	936	0x3A8	TxPDO3*, Nd.40	957	0x3BD	TxPDO3*, Nd.61
916	0x394	TxPDO3*, Nd.20	937	0x3A9	TxPDO3*, Nd.41	958	0x3BE	TxPDO3*, Nd.62
917	0x395	TxPDO3*, Nd.21	938	0x3AA	TxPDO3*, Nd.42	959	0x3BF	TxPDO3*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1025	0x401	RxPDO3*, Nd.1	1046	0x416	RxPDO3*, Nd.22	1067	0x42B	RxPDO3*, Nd.43
1026	0x402	RxPDO3*, Nd.2	1047	0x417	RxPDO3*, Nd.23	1068	0x42C	RxPDO3*, Nd.44
1027	0x403	RxPDO3*, Nd.3	1048	0x418	RxPDO3*, Nd.24	1069	0x42D	RxPDO3*, Nd.45
1028	0x404	RxPDO3*, Nd.4	1049	0x419	RxPDO3*, Nd.25	1070	0x42E	RxPDO3*, Nd.46
1029	0x405	RxPDO3*, Nd.5	1050	0x41A	RxPDO3*, Nd.26	1071	0x42F	RxPDO3*, Nd.47
1030	0x406	RxPDO3*, Nd.6	1051	0x41B	RxPDO3*, Nd.27	1072	0x430	RxPDO3*, Nd.48
1031	0x407	RxPDO3*, Nd.7	1052	0x41C	RxPDO3*, Nd.28	1073	0x431	RxPDO3*, Nd.49
1032	0x408	RxPDO3*, Nd.8	1053	0x41D	RxPDO3*, Nd.29	1074	0x432	RxPDO3*, Nd.50
1033	0x409	RxPDO3*, Nd.9	1054	0x41E	RxPDO3*, Nd.30	1075	0x433	RxPDO3*, Nd.51
1034	0x40A	RxPDO3*, Nd.10	1055	0x41F	RxPDO3*, Nd.31	1076	0x434	RxPDO3*, Nd.52
1035	0x40B	RxPDO3*, Nd.11	1056	0x420	RxPDO3*, Nd.32	1077	0x435	RxPDO3*, Nd.53
1036	0x40C	RxPDO3*, Nd.12	1057	0x421	RxPDO3*, Nd.33	1078	0x436	RxPDO3*, Nd.54
1037	0x40D	RxPDO3*, Nd.13	1058	0x422	RxPDO3*, Nd.34	1079	0x437	RxPDO3*, Nd.55
1038	0x40E	RxPDO3*, Nd.14	1059	0x423	RxPDO3*, Nd.35	1080	0x438	RxPDO3*, Nd.56
1039	0x40F	RxPDO3*, Nd.15	1060	0x424	RxPDO3*, Nd.36	1081	0x439	RxPDO3*, Nd.57
1040	0x410	RxPDO3*, Nd.16	1061	0x425	RxPDO3*, Nd.37	1082	0x43A	RxPDO3*, Nd.58
1041	0x411	RxPDO3*, Nd.17	1062	0x426	RxPDO3*, Nd.38	1083	0x43B	RxPDO3*, Nd.59
1042	0x412	RxPDO3*, Nd.18	1063	0x427	RxPDO3*, Nd.39	1084	0x43C	RxPDO3*, Nd.60
1043	0x413	RxPDO3*, Nd.19	1064	0x428	RxPDO3*, Nd.40	1085	0x43D	RxPDO3*, Nd.61
1044	0x414	RxPDO3*, Nd.20	1065	0x429	RxPDO3*, Nd.41	1086	0x43E	RxPDO3*, Nd.62
1045	0x415	RxPDO3*, Nd.21	1066	0x42A	RxPDO3*, Nd.42	1087	0x43F	RxPDO3*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1153	0x481	TxPDO4*, Nd.1	1174	0x496	TxPDO4*, Nd.22	1195	0x4AB	TxPDO4*, Nd.43
1154	0x482	TxPDO4*, Nd.2	1175	0x497	TxPDO4*, Nd.23	1196	0x4AC	TxPDO4*, Nd.44
1155	0x483	TxPDO4*, Nd.3	1176	0x498	TxPDO4*, Nd.24	1197	0x4AD	TxPDO4*, Nd.45
1156	0x484	TxPDO4*, Nd.4	1177	0x499	TxPDO4*, Nd.25	1198	0x4AE	TxPDO4*, Nd.46
1157	0x485	TxPDO4*, Nd.5	1178	0x49A	TxPDO4*, Nd.26	1199	0x4AF	TxPDO4*, Nd.47
1158	0x486	TxPDO4*, Nd.6	1179	0x49B	TxPDO4*, Nd.27	1200	0x4B0	TxPDO4*, Nd.48
1159	0x487	TxPDO4*, Nd.7	1180	0x49C	TxPDO4*, Nd.28	1201	0x4B1	TxPDO4*, Nd.49
1160	0x488	TxPDO4*, Nd.8	1181	0x49D	TxPDO4*, Nd.29	1202	0x4B2	TxPDO4*, Nd.50
1161	0x489	TxPDO4*, Nd.9	1182	0x49E	TxPDO4*, Nd.30	1203	0x4B3	TxPDO4*, Nd.51
1162	0x48A	TxPDO4*, Nd.10	1183	0x49F	TxPDO4*, Nd.31	1204	0x4B4	TxPDO4*, Nd.52
1163	0x48B	TxPDO4*, Nd.11	1184	0x4A0	TxPDO4*, Nd.32	1205	0x4B5	TxPDO4*, Nd.53
1164	0x48C	TxPDO4*, Nd.12	1185	0x4A1	TxPDO4*, Nd.33	1206	0x4B6	TxPDO4*, Nd.54
1165	0x48D	TxPDO4*, Nd.13	1186	0x4A2	TxPDO4*, Nd.34	1207	0x4B7	TxPDO4*, Nd.55
1166	0x48E	TxPDO4*, Nd.14	1187	0x4A3	TxPDO4*, Nd.35	1208	0x4B8	TxPDO4*, Nd.56
1167	0x48F	TxPDO4*, Nd.15	1188	0x4A4	TxPDO4*, Nd.36	1209	0x4B9	TxPDO4*, Nd.57
1168	0x490	TxPDO4*, Nd.16	1189	0x4A5	TxPDO4*, Nd.37	1210	0x4BA	TxPDO4*, Nd.58
1169	0x491	TxPDO4*, Nd.17	1190	0x4A6	TxPDO4*, Nd.48	1211	0x4BB	TxPDO4*, Nd.59
1170	0x492	TxPDO4*, Nd.18	1191	0x4A7	TxPDO4*, Nd.49	1212	0x4BC	TxPDO4*, Nd.60
1171	0x493	TxPDO4*, Nd.19	1192	0x4A8	TxPDO4*, Nd.40	1213	0x4BD	TxPDO4*, Nd.61
1172	0x494	TxPDO4*, Nd.20	1193	0x4A9	TxPDO4*, Nd.41	1214	0x4BE	TxPDO4*, Nd.62
1173	0x495	TxPDO4*, Nd.21	1194	0x4AA	TxPDO4*, Nd.42	1215	0x4BF	TxPDO4*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1281	0x501	RxPDO4*, Nd.1	1302	0x516	RxPDO4*, Nd.22	1323	0x52B	RxPDO4*, Nd.43
1282	0x502	RxPDO4*, Nd.2	1303	0x517	RxPDO4*, Nd.23	1324	0x52C	RxPDO4*, Nd.44
1283	0x503	RxPDO4*, Nd.3	1304	0x518	RxPDO4*, Nd.24	1325	0x52D	RxPDO4*, Nd.45
1284	0x504	RxPDO4*, Nd.4	1305	0x519	RxPDO4*, Nd.25	1326	0x52E	RxPDO4*, Nd.46
1285	0x505	RxPDO4*, Nd.5	1306	0x51A	RxPDO4*, Nd.26	1327	0x52F	RxPDO4*, Nd.47
1286	0x506	RxPDO4*, Nd.6	1307	0x51B	RxPDO4*, Nd.27	1328	0x530	RxPDO4*, Nd.48
1287	0x507	RxPDO4*, Nd.7	1308	0x51C	RxPDO4*, Nd.28	1329	0x531	RxPDO4*, Nd.49
1288	0x508	RxPDO4*, Nd.8	1309	0x51D	RxPDO4*, Nd.29	1330	0x532	RxPDO4*, Nd.50
1289	0x509	RxPDO4*, Nd.9	1310	0x51E	RxPDO4*, Nd.30	1331	0x533	RxPDO4*, Nd.51
1290	0x50A	RxPDO4*, Nd.10	1311	0x51F	RxPDO4*, Nd.31	1332	0x534	RxPDO4*, Nd.52
1291	0x50B	RxPDO4*, Nd.11	1312	0x520	RxPDO4*, Nd.32	1333	0x535	RxPDO4*, Nd.53
1292	0x50C	RxPDO4*, Nd.12	1313	0x521	RxPDO4*, Nd.33	1334	0x536	RxPDO4*, Nd.54
1293	0x50D	RxPDO4*, Nd.13	1314	0x522	RxPDO4*, Nd.34	1335	0x537	RxPDO4*, Nd.55
1294	0x50E	RxPDO4*, Nd.14	1315	0x523	RxPDO4*, Nd.35	1336	0x538	RxPDO4*, Nd.56
1295	0x50F	RxPDO4*, Nd.15	1316	0x524	RxPDO4*, Nd.36	1337	0x539	RxPDO4*, Nd.57
1296	0x510	RxPDO4*, Nd.16	1317	0x525	RxPDO4*, Nd.37	1338	0x53A	RxPDO4*, Nd.58
1297	0x511	RxPDO4*, Nd.17	1318	0x526	RxPDO4*, Nd.38	1339	0x53B	RxPDO4*, Nd.59
1298	0x512	RxPDO4*, Nd.18	1319	0x527	RxPDO4*, Nd.39	1340	0x53C	RxPDO4*, Nd.60
1299	0x513	RxPDO4*, Nd.19	1320	0x528	RxPDO4*, Nd.40	1341	0x53D	RxPDO4*, Nd.61
1300	0x514	RxPDO4*, Nd.20	1321	0x529	RxPDO4*, Nd.41	1342	0x53E	RxPDO4*, Nd.62
1301	0x515	RxPDO4*, Nd.21	1322	0x52A	RxPDO4*, Nd.42	1343	0x53F	RxPDO4*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1665	0x681	TxPDO5*, Nd.1	1686	0x696	TxPDO5*, Nd.22	1707	0x6AB	TxPDO5*, Nd.43
1666	0x682	TxPDO5*, Nd.2	1687	0x697	TxPDO5*, Nd.23	1708	0x6AC	TxPDO5*, Nd.44
1667	0x683	TxPDO5*, Nd.3	1688	0x698	TxPDO5*, Nd.24	1709	0x6AD	TxPDO5*, Nd.45
1668	0x684	TxPDO5*, Nd.4	1689	0x699	TxPDO5*, Nd.25	1710	0x6AE	TxPDO5*, Nd.46
1669	0x685	TxPDO5*, Nd.5	1690	0x69A	TxPDO5*, Nd.26	1711	0x6AF	TxPDO5*, Nd.47
1670	0x686	TxPDO5*, Nd.6	1691	0x69B	TxPDO5*, Nd.27	1712	0x6B0	TxPDO5*, Nd.48
1671	0x687	TxPDO5*, Nd.7	1692	0x69C	TxPDO5*, Nd.28	1713	0x6B1	TxPDO5*, Nd.49
1672	0x688	TxPDO5*, Nd.8	1693	0x69D	TxPDO5*, Nd.29	1714	0x6B2	TxPDO5*, Nd.50
1673	0x689	TxPDO5*, Nd.9	1694	0x69E	TxPDO5*, Nd.30	1715	0x6B3	TxPDO5*, Nd.51
1674	0x68A	TxPDO5*, Nd.10	1695	0x69F	TxPDO5*, Nd.31	1716	0x6B4	TxPDO5*, Nd.52
1675	0x68B	TxPDO5*, Nd.11	1696	0x6A0	TxPDO5*, Nd.32	1717	0x6B5	TxPDO5*, Nd.53
1676	0x68C	TxPDO5*, Nd.12	1697	0x6A1	TxPDO5*, Nd.33	1718	0x6B6	TxPDO5*, Nd.54
1677	0x68D	TxPDO5*, Nd.13	1698	0x6A2	TxPDO5*, Nd.34	1719	0x6B7	TxPDO5*, Nd.55
1678	0x68E	TxPDO5*, Nd.14	1699	0x6A3	TxPDO5*, Nd.35	1720	0x6B8	TxPDO5*, Nd.56
1679	0x68F	TxPDO5*, Nd.15	1700	0x6A4	TxPDO5*, Nd.36	1721	0x6B9	TxPDO5*, Nd.57
1680	0x690	TxPDO5*, Nd.16	1701	0x6A5	TxPDO5*, Nd.37	1722	0x6BA	TxPDO5*, Nd.58
1681	0x691	TxPDO5*, Nd.17	1702	0x6A6	TxPDO5*, Nd.38	1723	0x6BB	TxPDO5*, Nd.59
1682	0x692	TxPDO5*, Nd.18	1703	0x6A7	TxPDO5*, Nd.39	1724	0x6BC	TxPDO5*, Nd.60
1683	0x693	TxPDO5*, Nd.19	1704	0x6A8	TxPDO5*, Nd.40	1725	0x6BD	TxPDO5*, Nd.61
1684	0x694	TxPDO5*, Nd.20	1705	0x6A9	TxPDO5*, Nd.41	1726	0x6BE	TxPDO5*, Nd.62
1685	0x695	TxPDO5*, Nd.21	1706	0x6AA	TxPDO5*, Nd.42	1727	0x6BF	TxPDO5*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1921	0x781	RxPDO5*, Nd.1	1942	0x796	RxPDO5*, Nd.22	1963	0x7AB	RxPDO5*, Nd.43
1922	0x782	RxPDO5*, Nd.2	1943	0x797	RxPDO5*, Nd.23	1964	0x7AC	RxPDO5*, Nd.44
1923	0x783	RxPDO5*, Nd.3	1944	0x798	RxPDO5*, Nd.24	1965	0x7AD	RxPDO5*, Nd.45
1924	0x784	RxPDO5*, Nd.4	1945	0x799	RxPDO5*, Nd.25	1966	0x7AE	RxPDO5*, Nd.46
1925	0x785	RxPDO5*, Nd.5	1946	0x79A	RxPDO5*, Nd.26	1967	0x7AF	RxPDO5*, Nd.47
1926	0x786	RxPDO5*, Nd.6	1947	0x79B	RxPDO5*, Nd.27	1968	0x7B0	RxPDO5*, Nd.48
1927	0x787	RxPDO5*, Nd.7	1948	0x79C	RxPDO5*, Nd.28	1969	0x7B1	RxPDO5*, Nd.49
1928	0x788	RxPDO5*, Nd.8	1949	0x79D	RxPDO5*, Nd.29	1970	0x7B2	RxPDO5*, Nd.50
1929	0x789	RxPDO5*, Nd.9	1950	0x79E	RxPDO5*, Nd.30	1971	0x7B3	RxPDO5*, Nd.51
1930	0x78A	RxPDO5*, Nd.10	1951	0x79F	RxPDO5*, Nd.31	1972	0x7B4	RxPDO5*, Nd.52
1931	0x78B	RxPDO5*, Nd.11	1952	0x7A0	RxPDO5*, Nd.32	1973	0x7B5	RxPDO5*, Nd.53
1932	0x78C	RxPDO5*, Nd.12	1953	0x7A1	RxPDO5*, Nd.33	1974	0x7B6	RxPDO5*, Nd.54
1933	0x78D	RxPDO5*, Nd.13	1954	0x7A2	RxPDO5*, Nd.34	1975	0x7B7	RxPDO5*, Nd.55
1934	0x78E	RxPDO5*, Nd.14	1955	0x7A3	RxPDO5*, Nd.35	1976	0x7B8	RxPDO5*, Nd.56
1935	0x78F	RxPDO5*, Nd.15	1956	0x7A4	RxPDO5*, Nd.36	1977	0x7B9	RxPDO5*, Nd.57
1936	0x790	RxPDO5*, Nd.16	1957	0x7A5	RxPDO5*, Nd.37	1978	0x7BA	RxPDO5*, Nd.58
1937	0x791	RxPDO5*, Nd.17	1958	0x7A6	RxPDO5*, Nd.38	1979	0x7BB	RxPDO5*, Nd.59
1938	0x792	RxPDO5*, Nd.18	1959	0x7A7	RxPDO5*, Nd.39	1980	0x7BC	RxPDO5*, Nd.60
1939	0x793	RxPDO5*, Nd.19	1960	0x7A8	RxPDO5*, Nd.40	1981	0x7BD	RxPDO5*, Nd.61
1940	0x794	RxPDO5*, Nd.20	1961	0x7A9	RxPDO5*, Nd.41	1982	0x7BE	RxPDO5*, Nd.62
1941	0x795	RxPDO5*, Nd.21	1962	0x7AA	RxPDO5*, Nd.42	1983	0x7BF	RxPDO5*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
449	0x1C1	TxPDO6*, Nd.1	470	0x1D6	TxPDO6*, Nd.22	491	0x1EB	TxPDO6*, Nd.43
450	0x1C2	TxPDO6*, Nd.2	471	0x1D7	TxPDO6*, Nd.23	492	0x1EC	TxPDO6*, Nd.44
451	0x1C3	TxPDO6*, Nd.3	472	0x1D8	TxPDO6*, Nd.24	493	0x1ED	TxPDO6*, Nd.45
452	0x1C4	TxPDO6*, Nd.4	473	0x1D9	TxPDO6*, Nd.25	494	0x1EE	TxPDO6*, Nd.46
453	0x1C5	TxPDO6*, Nd.5	474	0x1DA	TxPDO6*, Nd.26	495	0x1EF	TxPDO6*, Nd.47
454	0x1C6	TxPDO6*, Nd.6	475	0x1DB	TxPDO6*, Nd.27	496	0x1F0	TxPDO6*, Nd.48
455	0x1C7	TxPDO6*, Nd.7	476	0x1DC	TxPDO6*, Nd.28	497	0x1F1	TxPDO6*, Nd.49
456	0x1C8	TxPDO6*, Nd.8	477	0x1DD	TxPDO6*, Nd.29	498	0x1F2	TxPDO6*, Nd.50
457	0x1C9	TxPDO6*, Nd.9	478	0x1DE	TxPDO6*, Nd.30	499	0x1F3	TxPDO6*, Nd.51
458	0x1CA	TxPDO6*, Nd.10	479	0x1DF	TxPDO6*, Nd.31	500	0x1F4	TxPDO6*, Nd.52
459	0x1CB	TxPDO6*, Nd.11	480	0x1E0	TxPDO6*, Nd.32	501	0x1F5	TxPDO6*, Nd.53
460	0x1CC	TxPDO6*, Nd.12	481	0x1E1	TxPDO6*, Nd.33	502	0x1F6	TxPDO6*, Nd.54
461	0x1CD	TxPDO6*, Nd.13	482	0x1E2	TxPDO6*, Nd.34	503	0x1F7	TxPDO6*, Nd.55
462	0x1CE	TxPDO6*, Nd.14	483	0x1E3	TxPDO6*, Nd.35	504	0x1F8	TxPDO6*, Nd.56
463	0x1CF	TxPDO6*, Nd.15	484	0x1E4	TxPDO6*, Nd.36	505	0x1F9	TxPDO6*, Nd.57
464	0x1D0	TxPDO6*, Nd.16	485	0x1E5	TxPDO6*, Nd.37	506	0x1FA	TxPDO6*, Nd.58
465	0x1D1	TxPDO6*, Nd.17	486	0x1E6	TxPDO6*, Nd.38	507	0x1FB	TxPDO6*, Nd.59
466	0x1D2	TxPDO6*, Nd.18	487	0x1E7	TxPDO6*, Nd.39	508	0x1FC	TxPDO6*, Nd.60
467	0x1D3	TxPDO6*, Nd.19	488	0x1E8	TxPDO6*, Nd.40	509	0x1FD	TxPDO6*, Nd.61
468	0x1D4	TxPDO6*, Nd.20	489	0x1E9	TxPDO6*, Nd.41	510	0x1FE	TxPDO6*, Nd.62
469	0x1D5	TxPDO6*, Nd.21	490	0x1EA	TxPDO6*, Nd.42	511	0x1FF	TxPDO6*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
577	0x241	RxPDO6*, Nd.1	598	0x256	RxPDO6*, Nd.22	619	0x26B	RxPDO6* Nd.43
578	0x242	RxPDO6*, Nd.2	599	0x257	RxPDO6*, Nd.23	620	0x26C	RxPDO6, Nd.44
579	0x243	RxPDO6*, Nd.3	600	0x258	RxPDO6*, Nd.24	621	0x26D	RxPDO6*, Nd.45
580	0x244	RxPDO6*, Nd.4	601	0x259	RxPDO6*, Nd.25	622	0x26E	RxPDO6*, Nd.46
581	0x245	RxPDO6*, Nd.5	602	0x25A	RxPDO6*, Nd.26	623	0x26F	RxPDO6*, Nd.47
582	0x246	RxPDO6*, Nd.6	603	0x25B	RxPDO6*, Nd.27	624	0x270	RxPDO6*, Nd.48
583	0x247	RxPDO6*, Nd.7	604	0x25C	RxPDO6*, Nd.28	625	0x271	RxPDO6*, Nd.49
584	0x248	RxPDO6*, Nd.8	605	0x25D	RxPDO6*, Nd.29	626	0x272	RxPDO6*, Nd.50
585	0x249	RxPDO6*, Nd.9	606	0x25E	RxPDO6*, Nd.30	627	0x273	RxPDO6*, Nd.51
586	0x24A	RxPDO6*, Nd.10	607	0x25F	RxPDO6*, Nd.31	628	0x274	RxPDO6*, Nd.52
587	0x24B	RxPDO6*, Nd.11	608	0x260	RxPDO6*, Nd.32	629	0x275	RxPDO6*, Nd.53
588	0x24C	RxPDO6*, Nd.12	609	0x261	RxPDO6*, Nd.33	630	0x276	RxPDO6*, Nd.54
589	0x24D	RxPDO6*, Nd.13	610	0x262	RxPDO6*, Nd.34	631	0x277	RxPDO6*, Nd.55
590	0x24E	RxPDO6*, Nd.14	611	0x263	RxPDO6*, Nd.35	632	0x278	RxPDO6*, Nd.56
591	0x24F	RxPDO6*, Nd.15	612	0x264	RxPDO6*, Nd.36	633	0x279	RxPDO6*, Nd.57
592	0x250	RxPDO6*, Nd.16	613	0x265	RxPDO6*, Nd.3	634	0x27A	RxPDO6*, Nd.58
593	0x251	RxPDO6*, Nd.17	614	0x266	RxPDO6*, Nd.8	635	0x27B	RxPDO6*, Nd.59
594	0x252	RxPDO6*, Nd.18	615	0x267	RxPDO6*, Nd39	636	0x27C	RxPDO6*, Nd.60
595	0x253	RxPDO6*, Nd.19	616	0x268	RxPDO6*, N.40	637	0x27D	RxPDO6*, Nd.61
596	0x254	RxPDO6*, Nd.20	617	0x269	RxPDO6*, d.41	638	0x27E	RxPDO6*, Nd.62
597	0x255	RxPDO6*, Nd.21	618	0x26A	RxPDO6*,Nd.42	639	0x27F	RxPDO6*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
705	0x2C1	TxPDO7*, Nd.1	726	0x2D6	TxPDO7*, Nd.22	747	0x2EB	TxPDO7*, Nd.43
706	0x2C2	TxPDO7*, Nd.2	727	0x2D7	TxPDO7*, Nd.23	748	0x2EC	TxPDO7*, Nd.44
707	0x2C3	TxPDO7*, Nd.3	728	0x2D8	TxPDO7*, Nd.24	749	0x2ED	TxPDO7*, Nd.45
708	0x2C4	TxPDO7*, Nd.4	729	0x2D9	TxPDO7*, Nd.25	750	0x2EE	TxPDO7*, Nd.46
709	0x2C5	TxPDO7*, Nd.5	730	0x2DA	TxPDO7*, Nd.26	751	0x2EF	TxPDO7*, Nd.47
710	0x2C6	TxPDO7*, Nd.6	731	0x2DB	TxPDO7*, Nd.27	752	0x2F0	TxPDO7*, Nd.48
711	0x2C7	TxPDO7*, Nd.7	732	0x2DC	TxPDO7*, Nd.28	753	0x2F1	TxPDO7*, Nd.49
712	0x2C8	TxPDO7*, Nd.8	733	0x2DD	TxPDO7*, Nd.29	754	0x2F2	TxPDO7*, Nd.50
713	0x2C9	TxPDO7*, Nd.9	734	0x2DE	TxPDO7*, Nd.30	755	0x2F3	TxPDO7*, Nd.51
714	0x2CA	TxPDO7*, Nd.10	735	0x2DF	TxPDO7*, Nd.31	756	0x2F4	TxPDO7*, Nd.52
715	0x2CB	TxPDO7*, Nd.11	736	0x2E0	TxPDO7*, Nd.32	757	0x2F5	TxPDO7*, Nd.53
716	0x2CC	TxPDO7*, Nd.12	737	0x2E1	TxPDO7*, Nd.33	758	0x2F6	TxPDO7*, Nd.54
717	0x2CD	TxPDO7*, Nd.13	738	0x2E2	TxPDO7*, Nd.34	759	0x2F7	TxPDO7*, Nd.55
718	0x2CE	TxPDO7*, Nd.14	739	0x2E3	TxPDO7*, Nd.35	760	0x2F8	TxPDO7*, Nd.56
719	0x2CF	TxPDO7*, Nd.15	740	0x2E4	TxPDO7*, Nd.36	761	0x2F9	TxPDO7*, Nd.57
720	0x2D0	TxPDO7*, Nd.16	741	0x2E5	TxPDO7*, Nd.37	762	0x2FA	TxPDO7*, Nd.58
721	0x2D1	TxPDO7*, Nd.17	742	0x2E6	TxPDO7*, Nd.38	763	0x2FB	TxPDO7*, Nd.59
722	0x2D2	TxPDO7*, Nd.18	743	0x2E7	TxPDO7*, Nd.39	764	0x2FC	TxPDO7*, Nd.60
723	0x2D3	TxPDO7*, Nd.19	744	0x2E8	TxPDO7*, Nd.40	765	0x2FD	TxPDO7*, Nd.61
724	0x2D4	TxPDO7*, Nd.20	745	0x2E9	TxPDO7*, Nd.41	766	0x2FE	TxPDO7*, Nd.62
725	0x2D5	TxPDO7*, Nd.21	746	0x2EA	TxPDO7*, Nd.42	767	0x2FF	TxPDO7*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
833	0x341	RxPDO7*, Nd.1	854	0x356	RxPDO7*, Nd.22	875	0x36B	RxPDO7*, Nd.43
834	0x342	RxPDO7*, Nd.2	855	0x357	RxPDO7*, Nd.23	876	0x36C	RxPDO7*, Nd.44
835	0x343	RxPDO7*, Nd.3	856	0x358	RxPDO7*, Nd.24	877	0x36D	RxPDO7*, Nd.45
836	0x344	RxPDO7*, Nd.4	857	0x359	RxPDO7*, Nd.25	878	0x36E	RxPDO7*, Nd.46
837	0x345	RxPDO7*, Nd.5	858	0x35A	RxPDO7*, Nd.26	879	0x36F	RxPDO7*, Nd.47
838	0x346	RxPDO7*, Nd.6	859	0x35B	RxPDO7*, Nd.27	880	0x370	RxPDO7*, Nd.48
839	0x347	RxPDO7*, Nd.7	860	0x35C	RxPDO7*, Nd.28	881	0x371	RxPDO7*, Nd.49
840	0x348	RxPDO7*, Nd.8	861	0x35D	RxPDO7*, Nd.29	882	0x372	RxPDO7*, Nd.50
841	0x349	RxPDO7*, Nd.9	862	0x35E	RxPDO7*, Nd.30	883	0x373	RxPDO7*, Nd.51
842	0x34A	RxPDO7*, Nd.10	863	0x35F	RxPDO7*, Nd.31	884	0x374	RxPDO7*, Nd.52
843	0x34B	RxPDO7*, Nd.11	864	0x360	RxPDO7*, Nd.32	885	0x375	RxPDO7*, Nd.53
844	0x34C	RxPDO7*, Nd.12	865	0x361	RxPDO7*, Nd.33	886	0x376	RxPDO7*, Nd.54
845	0x34D	RxPDO7*, Nd.13	866	0x362	RxPDO7*, Nd.34	887	0x377	RxPDO7*, Nd.55
846	0x34E	RxPDO7*, Nd.14	867	0x363	RxPDO7*, Nd.35	888	0x378	RxPDO7*, Nd.56
847	0x34F	RxPDO7*, Nd.15	868	0x364	RxPDO7*, Nd.36	889	0x379	RxPDO7*, Nd.57
848	0x350	RxPDO7*, Nd.16	869	0x365	RxPDO7*, Nd.37	890	0x37A	RxPDO7*, Nd.58
849	0x351	RxPDO7*, Nd.17	870	0x366	RxPDO7*, Nd.38	891	0x37B	RxPDO7*, Nd.59
850	0x352	RxPDO7*, Nd.18	871	0x367	RxPDO7*, Nd.39	892	0x37C	RxPDO7*, Nd.60
851	0x353	RxPDO7*, Nd.19	872	0x368	RxPDO7*, Nd.40	893	0x37D	RxPDO7*, Nd.61
852	0x354	RxPDO7*, Nd.20	873	0x369	RxPDO7*, Nd.41	894	0x37E	RxPDO7*, Nd.62
853	0x355	RxPDO7*, Nd.21	874	0x36A	RxPDO7*, Nd.42	895	0x37F	RxPDO7*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
961	0x3C1	TxPDO8*, Nd.1	982	0x3D6	TxPDO8*, Nd.22	1003	0x3EB	TxPDO8*, Nd.43
962	0x3C2	TxPDO8*, Nd.2	983	0x3D7	TxPDO8*, Nd.23	1004	0x3EC	TxPDO8*, Nd.44
963	0x3C3	TxPDO8*, Nd.3	984	0x3D8	TxPDO8*, Nd.24	1005	0x3ED	TxPDO8*, Nd.45
964	0x3C4	TxPDO8*, Nd.4	985	0x3D9	TxPDO8*, Nd.25	1006	0x3EE	TxPDO8*, Nd.46
965	0x3C5	TxPDO8*, Nd.5	986	0x3DA	TxPDO8*, Nd.26	1007	0x3EF	TxPDO8*, Nd.47
966	0x3C6	TxPDO8*, Nd.6	987	0x3DB	TxPDO8*, Nd.27	1008	0x3F0	TxPDO8*, Nd.48
967	0x3C7	TxPDO8*, Nd.7	988	0x3DC	TxPDO8*, Nd.28	1009	0x3F1	TxPDO8*, Nd.49
968	0x3C8	TxPDO8*, Nd.8	989	0x3DD	TxPDO8*, Nd.29	1010	0x3F2	TxPDO8*, Nd.50
969	0x3C9	TxPDO8*, Nd.9	990	0x3DE	TxPDO8*, Nd.30	1011	0x3F3	TxPDO8*, Nd.51
970	0x3CA	TxPDO8*, Nd.10	991	0x3DF	TxPDO8*, Nd.31	1012	0x3F4	TxPDO8*, Nd.52
971	0x3CB	TxPDO8*, Nd.11	992	0x3E0	TxPDO8*, Nd.32	1013	0x3F5	TxPDO8*, Nd.53
972	0x3CC	TxPDO8*, Nd.12	993	0x3E1	TxPDO8*, Nd.33	1014	0x3F6	TxPDO8*, Nd.54
973	0x3CD	TxPDO8*, Nd.13	994	0x3E2	TxPDO8*, Nd.34	1015	0x3F7	TxPDO8*, Nd.55
974	0x3CE	TxPDO8*, Nd.14	995	0x3E3	TxPDO8*, Nd.35	1016	0x3F8	TxPDO8*, Nd.56
975	0x3CF	TxPDO8*, Nd.15	996	0x3E4	TxPDO8*, Nd.36	1017	0x3F9	TxPDO8*, Nd.57
976	0x3D0	TxPDO8*, Nd.16	997	0x3E5	TxPDO8*, Nd.37	1018	0x3FA	TxPDO8*, Nd.58
977	0x3D1	TxPDO8*, Nd.17	998	0x3E6	TxPDO8*, Nd.38	1019	0x3FB	TxPDO8*, Nd.59
978	0x3D2	TxPDO8*, Nd.18	999	0x3E7	TxPDO8*, Nd.39	1020	0x3FC	TxPDO8*, Nd.60
979	0x3D3	TxPDO8*, Nd.19	1000	0x3E8	TxPDO8*, Nd.40	1021	0x3FD	TxPDO8*, Nd.61
980	0x3D4	TxPDO8*, Nd.20	1001	0x3E9	TxPDO8*, Nd.41	1022	0x3FE	TxPDO8*, Nd.62
981	0x3D5	TxPDO8*, Nd.21	1002	0x3EA	TxPDO8*, Nd.42	1023	0x3FF	TxPDO8*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1089	0x441	RxPDO8*, Nd.1	1110	0x456	RxPDO8*, Nd.22	1131	0x46B	RxPDO8*, Nd.43
1090	0x442	RxPDO8*, Nd.2	1111	0x457	RxPDO8*, Nd.23	1132	0x46C	RxPDO8*, Nd.44
1091	0x443	RxPDO8*, Nd.3	1112	0x458	RxPDO8*, Nd.24	1133	0x46D	RxPDO8*, Nd.45
1092	0x444	RxPDO8*, Nd.4	1113	0x459	RxPDO8*, Nd.25	1134	0x46E	RxPDO8*, Nd.46
1093	0x445	RxPDO8*, Nd.5	1114	0x45A	RxPDO8*, Nd.26	1135	0x46F	RxPDO8*, Nd.47
1094	0x446	RxPDO8*, Nd.6	1115	0x45B	RxPDO8*, Nd.27	1136	0x470	RxPDO8*, Nd.48
1095	0x447	RxPDO8*, Nd.7	1116	0x45C	RxPDO8*, Nd.28	1137	0x471	RxPDO8*, Nd.49
1096	0x448	RxPDO8*, Nd.8	1117	0x45D	RxPDO8*, Nd.29	1138	0x472	RxPDO8*, Nd.50
1097	0x449	RxPDO8*, Nd.9	1118	0x45E	RxPDO8*, Nd.30	1139	0x473	RxPDO8*, Nd.51
1098	0x44A	RxPDO8*, Nd.10	1119	0x45F	RxPDO8*, Nd.31	1140	0x474	RxPDO8*, Nd.52
1099	0x44B	RxPDO8*, Nd.11	1120	0x460	RxPDO8*, Nd.32	1141	0x475	RxPDO8*, Nd.53
1100	0x44C	RxPDO8*, Nd.12	1121	0x461	RxPDO8*, Nd.33	1142	0x476	RxPDO8*, Nd.54
1101	0x44D	RxPDO8*, Nd.13	1122	0x462	RxPDO8*, Nd.34	1143	0x477	RxPDO8*, Nd.55
1102	0x44E	RxPDO8*, Nd.14	1123	0x463	RxPDO8*, Nd.35	1144	0x478	RxPDO8*, Nd.56
1103	0x44F	RxPDO8*, Nd.15	1124	0x464	RxPDO8*, Nd.36	1145	0x479	RxPDO8*, Nd.57
1104	0x450	RxPDO8*, Nd.16	1125	0x465	RxPDO8*, Nd.37	1146	0x47A	RxPDO8*, Nd.58
1105	0x451	RxPDO8*, Nd.17	1126	0x466	RxPDO8*, Nd.38	1147	0x47B	RxPDO8*, Nd.59
1106	0x452	RxPDO8*, Nd.18	1127	0x467	RxPDO8*, Nd.39	1148	0x47C	RxPDO8*, Nd.60
1107	0x453	RxPDO8*, Nd.19	1128	0x468	RxPDO8*, Nd.40	1149	0x47D	RxPDO8*, Nd.61
1108	0x454	RxPDO8*, Nd.20	1129	0x469	RxPDO8*, Nd.41	1150	0x47E	RxPDO8*, Nd.62
1109	0x455	RxPDO8*, Nd.21	1130	0x46A	RxPDO8*, Nd.42	1151	0x47F	RxPDO8*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1217	0x4C1	TxPDO9*, Nd.1	1238	0x4D6	TxPDO9*, Nd.22	1259	0x4EB	TxPDO9*, Nd.43
1218	0x4C2	TxPDO9*, Nd.2	1239	0x4D7	TxPDO9*, Nd.23	1260	0x4EC	TxPDO9*, Nd.44
1219	0x4C3	TxPDO9*, Nd.3	1240	0x4D8	TxPDO9*, Nd.24	1261	0x4ED	TxPDO9*, Nd.45
1220	0x4C4	TxPDO9*, Nd.4	1241	0x4D9	TxPDO9*, Nd.25	1262	0x4EE	TxPDO9*, Nd.46
1221	0x4C5	TxPDO9*, Nd.5	1242	0x4DA	TxPDO9*, Nd.26	1263	0x4EF	TxPDO9*, Nd.47
1222	0x4C6	TxPDO9*, Nd.6	1243	0x4DB	TxPDO9*, Nd.27	1264	0x4F0	TxPDO9*, Nd.48
1223	0x4C7	TxPDO9*, Nd.7	1244	0x4DC	TxPDO9*, Nd.28	1265	0x4F1	TxPDO9*, Nd.49
1224	0x4C8	TxPDO9*, Nd.8	1245	0x4DD	TxPDO9*, Nd.29	1266	0x4F2	TxPDO9*, Nd.50
1225	0x4C9	TxPDO9*, Nd.9	1246	0x4DE	TxPDO9*, Nd.30	1267	0x4F3	TxPDO9*, Nd.51
1226	0x4CA	TxPDO9*, Nd.10	1247	0x4DF	TxPDO9*, Nd.31	1268	0x4F4	TxPDO9*, Nd.52
1227	0x4CB	TxPDO9*, Nd.11	1248	0x4E0	TxPDO9*, Nd.32	1269	0x4F5	TxPDO9*, Nd.53
1228	0x4CC	TxPDO9*, Nd.12	1249	0x4E1	TxPDO9*, Nd.33	1270	0x4F6	TxPDO9*, Nd.54
1229	0x4CD	TxPDO9*, Nd.13	1250	0x4E2	TxPDO9*, Nd.34	1271	0x4F7	TxPDO9*, Nd.55
1230	0x4CE	TxPDO9*, Nd.14	1251	0x4E3	TxPDO9*, Nd.35	1272	0x4F8	TxPDO9*, Nd.56
1231	0x4CF	TxPDO9*, Nd.15	1252	0x4E4	TxPDO9*, Nd.36	1273	0x4F9	TxPDO9*, Nd.57
1232	0x4D0	TxPDO9*, Nd.16	1253	0x4E5	TxPDO9*, Nd.37	1274	0x4FA	TxPDO9*, Nd.58
1233	0x4D1	TxPDO9*, Nd.17	1254	0x4E6	TxPDO9*, Nd.38	1275	0x4FB	TxPDO9*, Nd.59
1234	0x4D2	TxPDO9*, Nd.18	1255	0x4E7	TxPDO9*, Nd.39	1276	0x4FC	TxPDO9*, Nd.60
1235	0x4D3	TxPDO9*, Nd.19	1256	0x4E8	TxPDO9*, Nd.40	1277	0x4FD	TxPDO9*, Nd.61
1236	0x4D4	TxPDO9*, Nd.20	1257	0x4E9	TxPDO9*, Nd.41	1278	0x4FE	TxPDO9*, Nd.62
1237	0x4D5	TxPDO9*, Nd.21	1258	0x4EA	TxPDO9*, Nd.42	1279	0x4FF	TxPDO9*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1345	0x541	RxPDO9*, Nd.1	1366	0x556	RxPDO9*, Nd.22	1387	0x56B	RxPDO9*, Nd.43
1346	0x542	RxPDO9*, Nd.2	1367	0x557	RxPDO9*, Nd.23	1388	0x56C	RxPDO9*, Nd.44
1347	0x543	RxPDO9*, Nd.3	1368	0x558	RxPDO9*, Nd.24	1389	0x56D	RxPDO9*, Nd.45
1348	0x544	RxPDO9*, Nd.4	1369	0x559	RxPDO9*, Nd.25	1390	0x56E	RxPDO9*, Nd.46
1349	0x545	RxPDO9*, Nd.5	1370	0x55A	RxPDO9*, Nd.26	1391	0x56F	RxPDO9*, Nd.47
1350	0x546	RxPDO9*, Nd.6	1371	0x55B	RxPDO9*, Nd.27	1392	0x570	RxPDO9*, Nd.48
1351	0x547	RxPDO9*, Nd.7	1372	0x55C	RxPDO9*, Nd.28	1393	0x571	RxPDO9*, Nd.49
1352	0x548	RxPDO9*, Nd.8	1373	0x55D	RxPDO9*, Nd.29	1394	0x572	RxPDO9*, Nd.50
1353	0x549	RxPDO9*, Nd.9	1374	0x55E	RxPDO9*, Nd.30	1395	0x573	RxPDO9*, Nd.51
1354	0x54A	RxPDO9*, Nd.10	1375	0x55F	RxPDO9*, Nd.31	1396	0x574	RxPDO9*, Nd.52
1355	0x54B	RxPDO9*, Nd.11	1376	0x560	RxPDO9*, Nd.32	1397	0x575	RxPDO9*, Nd.53
1356	0x54C	RxPDO9*, Nd.12	1377	0x561	RxPDO9*, Nd.33	1398	0x576	RxPDO9*, Nd.54
1357	0x54D	RxPDO9*, Nd.13	1378	0x562	RxPDO9*, Nd.34	1399	0x577	RxPDO9*, Nd.55
1358	0x54E	RxPDO9*, Nd.14	1379	0x563	RxPDO9*, Nd.35	1400	0x578	RxPDO9*, Nd.56
1359	0x54F	RxPDO9*, Nd.15	1380	0x564	RxPDO9*, Nd.36	1401	0x579	RxPDO9*, Nd.57
1360	0x550	RxPDO9*, Nd.16	1381	0x565	RxPDO9*, Nd.37	1402	0x57A	RxPDO9*, Nd.58
1361	0x551	RxPDO9*, Nd.17	1382	0x566	RxPDO9*, Nd.38	1403	0x57B	RxPDO9*, Nd.59
1362	0x552	RxPDO9*, Nd.18	1383	0x567	RxPDO9*, Nd.39	1404	0x57C	RxPDO9*, Nd.60
1363	0x553	RxPDO9*, Nd.19	1384	0x568	RxPDO9*, Nd.40	1405	0x57D	RxPDO9*, Nd.61
1364	0x554	RxPDO9*, Nd.20	1385	0x569	RxPDO9*, Nd.41	1406	0x57E	RxPDO9*, Nd.62
1365	0x555	RxPDO9*, Nd.21	1386	0x56A	RxPDO9*, Nd.42	1407	0x57F	RxPDO9*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1473	0x5C1	TxPDO10*, Nd.1	1494	0x5D6	TxPDO10*, Nd.22	1515	0x5EB	TxPDO10*, Nd.43
1474	0x5C2	TxPDO10*, Nd.2	1495	0x5D7	TxPDO10*, Nd.23	1516	0x5EC	TxPDO10*, Nd.44
1475	0x5C3	TxPDO10*, Nd.3	1496	0x5D8	TxPDO10*, Nd.24	1517	0x5ED	TxPDO10*, Nd.45
1476	0x5C4	TxPDO10*, Nd.4	1497	0x5D9	TxPDO10*, Nd.25	1518	0x5EE	TxPDO10*, Nd.46
1477	0x5C5	TxPDO10*, Nd.5	1498	0x5DA	TxPDO10*, Nd.26	1519	0x5EF	TxPDO10*, Nd.47
1478	0x5C6	TxPDO10*, Nd.6	1499	0x5DB	TxPDO10*, Nd.27	1520	0x5F0	TxPDO10*, Nd.48
1479	0x5C7	TxPDO10*, Nd.7	1500	0x5DC	TxPDO10*, Nd.28	1521	0x5F1	TxPDO10*, Nd.49
1480	0x5C8	TxPDO10*, Nd.8	1501	0xDE	TxPDO10*, Nd.29	1522	0x5F2	TxPDO10*, Nd.50
1481	0x5C9	TxPDO10*, Nd.9	1502	0x5DE	TxPDO10*, Nd.30	1523	0x5F3	TxPDO10*, Nd.51
1482	0x5CA	TxPDO10*, Nd.10	1503	0x5DF	TxPDO10*, Nd.31	1524	0x5F4	TxPDO10*, Nd.52
1483	0x5CB	TxPDO10*, Nd.11	1504	0x5E0	TxPDO10*, Nd.32	1525	0x5F5	TxPDO10*, Nd.53
1484	0x5CC	TxPDO10*, Nd.12	1505	0x5E1	TxPDO10*, Nd.33	1526	0x5F6	TxPDO10*, Nd.54
1485	0x5CD	TxPDO10*, Nd.13	1506	0x5E2	TxPDO10*, Nd.34	1527	0x5F7	TxPDO10*, Nd.55
1486	0x5CE	TxPDO10*, Nd.14	1507	0x5E3	TxPDO10*, Nd.35	1528	0x5F8	TxPDO10*, Nd.56
1487	0x5CF	TxPDO10*, Nd.15	1508	0x5E4	TxPDO10*, Nd.36	1529	0x5F9	TxPDO10*, Nd.57
1488	0x5D0	TxPDO10*, Nd.16	1509	0x5E5	TxPDO10*, Nd.37	1530	0x5FA	TxPDO10*, Nd.58
1489	0x5D1	TxPDO10*, Nd.17	1510	0x5E6	TxPDO10*, Nd.38	1531	0x5FB	TxPDO10*, Nd.59
1490	0x5D2	TxPDO10*, Nd.18	1511	0x5E7	TxPDO10*, Nd.39	1532	0x5FC	TxPDO10*, Nd.60
1491	0x5D3	TxPDO10*, Nd.19	1512	0x5E8	TxPDO10*, Nd.40	1533	0x5FD	TxPDO10*, Nd.61
1492	0x5D4	TxPDO10*, Nd.20	1513	0x5E9	TxPDO10*, Nd.41	1534	0x5FE	TxPDO10*, Nd.62
1493	0x5D5	TxPDO10*, Nd.21	1514	0x5EA	TxPDO10*, Nd.42	1535	0x5FF	TxPDO10*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1601	0x641	RxPDO10*, Nd.1	1622	0x656	RxPDO10*, Nd.22	1643	0x66B	RxPDO10*, Nd.43
1602	0x642	RxPDO10*, Nd.2	1623	0x657	RxPDO10*, Nd.23	1644	0x66C	RxPDO10*, Nd.44
1603	0x643	RxPDO10*, Nd.3	1624	0x658	RxPDO10*, Nd.24	1645	0x66D	RxPDO10*, Nd.45
1604	0x644	RxPDO10*, Nd.4	1625	0x659	RxPDO10*, Nd.25	1646	0x66E	RxPDO10*, Nd.46
1605	0x645	RxPDO10*, Nd.5	1626	0x65A	RxPDO10*, Nd.26	1647	0x66F	RxPDO10*, Nd.47
1606	0x646	RxPDO10*, Nd.6	1627	0x65B	RxPDO10*, Nd.27	1648	0x670	RxPDO10*, Nd.48
1607	0x647	RxPDO10*, Nd.7	1628	0x65C	RxPDO10*, Nd.28	1649	0x671	RxPDO10*, Nd.49
1608	0x648	RxPDO10*, Nd.8	1629	0x65D	RxPDO10*, Nd.29	1650	0x672	RxPDO10*, Nd.50
1609	0x649	RxPDO10*, Nd.9	1630	0x65E	RxPDO10*, Nd.30	1651	0x673	RxPDO10*, Nd.51
1610	0x64A	RxPDO10*, Nd.10	1631	0x65F	RxPDO10*, Nd.31	1652	0x674	RxPDO10*, Nd.52
1611	0x64B	RxPDO10*, Nd.11	1632	0x660	RxPDO10*, Nd.32	1653	0x675	RxPDO10*, Nd.53
1612	0x64C	RxPDO10*, Nd.12	1633	0x661	RxPDO10*, Nd.33	1654	0x676	RxPDO10*, Nd.54
1613	0x64D	RxPDO10*, Nd.13	1634	0x662	RxPDO10*, Nd.34	1655	0x677	RxPDO10*, Nd.55
1614	0x64E	RxPDO10*, Nd.14	1635	0x663	RxPDO10*, Nd.35	1656	0x678	RxPDO10*, Nd.56
1615	0x64F	RxPDO10*, Nd.15	1636	0x664	RxPDO10*, Nd.36	1657	0x679	RxPDO10*, Nd.57
1616	0x650	RxPDO10*, Nd.16	1637	0x665	RxPDO10*, Nd.37	1658	0x67A	RxPDO10*, Nd.58
1617	0x651	RxPDO10*, Nd.17	1638	0x666	RxPDO10*, Nd.38	1659	0x67B	RxPDO10*, Nd.59
1618	0x652	RxPDO10*, Nd.18	1639	0x667	RxPDO10*, Nd.39	1660	0x67C	RxPDO10*, Nd.60
1619	0x653	RxPDO10*, Nd.19	1640	0x668	RxPDO10*, Nd.40	1661	0x67D	RxPDO10*, Nd.61
1620	0x654	RxPDO10*, Nd.20	1641	0x669	RxPDO10*, Nd.41	1662	0x67E	RxPDO10*, Nd.62
1621	0x655	RxPDO10*, Nd.21	1642	0x66A	RxPDO10*, Nd.42	1663	0x67F	RxPDO10*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1729	0x6C1	TxPDO11*, Nd.1	1750	0x6D6	TxPDO11*, Nd.22	1771	0x6EB	TxPDO11*, Nd.43
1730	0x6C2	TxPDO11*, Nd.2	1751	0x6D7	TxPDO11*, Nd.23	1772	0x6EC	TxPDO11*, Nd.44
1731	0x6C3	TxPDO11*, Nd.3	1752	0x6D8	TxPDO11*, Nd.24	1773	0x6ED	TxPDO11*, Nd.45
1732	0x6C4	TxPDO11*, Nd.4	1753	0x6D9	TxPDO11*, Nd.25	1774	0x6EE	TxPDO11*, Nd.46
1733	0x6C5	TxPDO11*, Nd.5	1754	0x6DA	TxPDO11*, Nd.26	1775	0x6EF	TxPDO11*, Nd.47
1734	0x6C6	TxPDO11*, Nd.6	1755	0x6DB	TxPDO11*, Nd.27	1776	0x6F0	TxPDO11*, Nd.48
1735	0x6C7	TxPDO11*, Nd.7	1756	0x6DC	TxPDO11*, Nd.28	1777	0x6F1	TxPDO11*, Nd.49
1736	0x6C8	TxPDO11*, Nd.8	1757	0x6DD	TxPDO11*, Nd.29	1778	0x6F2	TxPDO11*, Nd.50
1737	0x6C9	TxPDO11*, Nd.9	1758	0x6DE	TxPDO11*, Nd.30	1779	0x6F3	TxPDO11*, Nd.51
1738	0x6CA	TxPDO11*, Nd.10	1759	0x6DF	TxPDO11*, Nd.31	1780	0x6F4	TxPDO11*, Nd.52
1739	0x6CB	TxPDO11*, Nd.11	1760	0x6E0	TxPDO11*, Nd.32	1781	0x6F5	TxPDO11*, Nd.53
1740	0x6CC	TxPDO11*, Nd.12	1761	0x6E1	TxPDO11*, Nd.33	1782	0x6F6	TxPDO11*, Nd.54
1741	0x6CD	TxPDO11*, Nd.13	1762	0x6E2	TxPDO11*, Nd.34	1783	0x6F7	TxPDO11*, Nd.55
1742	0x6CE	TxPDO11*, Nd.14	1763	0x6E3	TxPDO11*, Nd.35	1784	0x6F8	TxPDO11*, Nd.56
1743	0x6CF	TxPDO11*, Nd.15	1764	0x6E4	TxPDO11*, Nd.36	1785	0x6F9	TxPDO11*, Nd.57
1744	0x6D0	TxPDO11*, Nd.16	1765	0x6E5	TxPDO11*, Nd.37	1786	0x6FA	TxPDO11*, Nd.58
1745	0x6D1	TxPDO11*, Nd.17	1766	0x6E6	TxPDO11*, Nd.38	1787	0x6FB	TxPDO11*, Nd.59
1746	0x6D2	TxPDO11*, Nd.18	1767	0x6E7	TxPDO11*, Nd.39	1788	0x6FC	TxPDO11*, Nd.60
1747	0x6D3	TxPDO11*, Nd.19	1768	0x6E8	TxPDO11*, Nd.40	1789	0x6FD	TxPDO11*, Nd.61
1748	0x6D4	TxPDO11*, Nd.20	1769	0x6E9	TxPDO11*, Nd.41	1790	0x6FE	TxPDO11*, Nd.62
1749	0x6D5	TxPDO11*, Nd.21	1770	0x6EA	TxPDO11*, Nd.42	1791	0x6FF	TxPDO11*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1857	0x741	RxPDO11*, Nd.1	1878	0x756	RxPDO11*, Nd.22	1899	0x76B	RxPDO11*, Nd.43
1858	0x742	RxPDO11*, Nd.2	1879	0x757	RxPDO11*, Nd.23	1900	0x76C	RxPDO11*, Nd.44
1859	0x743	RxPDO11*, Nd.3	1880	0x758	RxPDO11*, Nd.24	1901	0x76D	RxPDO11*, Nd.45
1860	0x744	RxPDO11*, Nd.4	1881	0x759	RxPDO11*, Nd.25	1902	0x76E	RxPDO11*, Nd.46
1861	0x745	RxPDO11*, Nd.5	1882	0x75A	RxPDO11*, Nd.26	1903	0x76F	RxPDO11*, Nd.47
1862	0x746	RxPDO11*, Nd.6	1883	0x75B	RxPDO11*, Nd.27	1904	0x770	RxPDO11*, Nd.48
1863	0x747	RxPDO11*, Nd.7	1884	0x75C	RxPDO11*, Nd.28	1905	0x771	RxPDO11*, Nd.49
1864	0x748	RxPDO11*, Nd.8	1885	0x75D	RxPDO11*, Nd.29	1906	0x772	RxPDO11*, Nd.50
1865	0x749	RxPDO11*, Nd.9	1886	0x75E	RxPDO11*, Nd.30	1907	0x773	RxPDO11*, Nd.51
1866	0x74A	RxPDO11*, Nd.10	1887	0x75F	RxPDO11*, Nd.31	1908	0x774	RxPDO11*, Nd.52
1867	0x74B	RxPDO11*, Nd.11	1888	0x760	RxPDO11*, Nd.32	1909	0x775	RxPDO11*, Nd.53
1868	0x74C	RxPDO11*, Nd.12	1889	0x761	RxPDO11*, Nd.33	1910	0x776	RxPDO11*, Nd.54
1869	0x74D	RxPDO11*, Nd.13	1890	0x762	RxPDO11*, Nd.34	1911	0x777	RxPDO11*, Nd.55
1870	0x74E	RxPDO11*, Nd.14	1891	0x763	RxPDO11*, Nd.35	1912	0x778	RxPDO11*, Nd.56
1871	0x74F	RxPDO11*, Nd.15	1892	0x764	RxPDO11*, Nd.36	1913	0x779	RxPDO11*, Nd.57
1872	0x750	RxPDO11*, Nd.16	1893	0x765	RxPDO11*, Nd.37	1914	0x77A	RxPDO11*, Nd.58
1873	0x751	RxPDO11*, Nd.17	1894	0x766	RxPDO11*, Nd.38	1915	0x77B	RxPDO11*, Nd.59
1874	0x752	RxPDO11*, Nd.18	1895	0x767	RxPDO11*, Nd.39	1916	0x77C	RxPDO11*, Nd.60
1875	0x753	RxPDO11*, Nd.19	1896	0x768	RxPDO11*, Nd.40	1917	0x77D	RxPDO11*, Nd.61
1876	0x754	RxPDO11*, Nd.20	1897	0x769	RxPDO11*, Nd.41	1918	0x77E	RxPDO11*, Nd.62
1877	0x755	RxPDO11*, Nd.21	1898	0x76A	RxPDO11*, Nd.42	1919	0x77F	RxPDO11*, Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1409	0x581	SDO Tx Nd.1	1430	0x596	SDO Tx Nd.22	1451	0x5AB	SDO Tx Nd.43
1410	0x582	SDO Tx Nd.2	1431	0x597	SDO Tx Nd.23	1452	0x5AC	SDO Tx Nd.44
1411	0x583	SDO Tx Nd.3	1432	0x598	SDO Tx Nd.24	1453	0x5AD	SDO Tx Nd.45
1412	0x584	SDO Tx Nd.4	1433	0x599	SDO Tx Nd.25	1454	0x5AE	SDO Tx Nd.46
1413	0x585	SDO Tx Nd.5	1434	0x59A	SDO Tx Nd.26	1455	0x5AF	SDO Tx Nd.47
1414	0x586	SDO Tx Nd.6	1435	0x59B	SDO Tx Nd.27	1456	0x5B0	SDO Tx Nd.48
1415	0x587	SDO Tx Nd.7	1436	0x59C	SDO Tx Nd.28	1457	0x5B1	SDO Tx Nd.49
1416	0x588	SDO Tx Nd.8	1437	0x59D	SDO Tx Nd.29	1458	0x5B2	SDO Tx Nd.50
1417	0x589	SDO Tx Nd.9	1438	0x59E	SDO Tx Nd.30	1459	0x5B3	SDO Tx Nd.51
1418	0x58A	SDO Tx Nd.10	1439	0x59F	SDO Tx Nd.31	1460	0x5B4	SDO Tx Nd.52
1419	0x58B	SDO Tx Nd.11	1440	0x5A0	SDO Tx Nd.32	1461	0x5B5	SDO Tx Nd.53
1420	0x58C	SDO Tx Nd.12	1441	0x5A1	SDO Tx Nd.33	1462	0x5B6	SDO Tx Nd.54
1421	0x58D	SDO Tx Nd.13	1442	0x5A2	SDO Tx Nd.34	1463	0x5B7	SDO Tx Nd.55
1422	0x58E	SDO Tx Nd.14	1443	0x5A3	SDO Tx Nd.35	1464	0x5B8	SDO Tx Nd.56
1423	0x58F	SDO Tx Nd.15	1444	0x5A4	SDO Tx Nd.36	1465	0x5B9	SDO Tx Nd.57
1424	0x590	SDO Tx Nd.16	1445	0x5A5	SDO Tx Nd.37	1466	0x5BA	SDO Tx Nd.58
1425	0x591	SDO Tx Nd.17	1446	0x5A6	SDO Tx Nd.38	1467	0x5BB	SDO Tx Nd.59
1426	0x592	SDO Tx Nd.18	1447	0x5A7	SDO Tx Nd.39	1468	0x5BC	SDO Tx Nd.60
1427	0x593	SDO Tx Nd.19	1448	0x5A8	SDO Tx Nd.40	1469	0x5BD	SDO Tx Nd.61
1428	0x594	SDO Tx Nd.20	1449	0x5A9	SDO Tx Nd.41	1470	0x5BE	SDO Tx Nd.62
1429	0x595	SDO Tx Nd.21	1450	0x5AA	SDO Tx Nd.42	1471	0x5BF	SDO Tx Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1537	0x601	SDO Rx Nd.1	1558	0x616	SDO Rx Nd.22	1579	0x62B	SDO Rx Nd.43
1538	0x602	SDO Rx Nd.2	1559	0x617	SDO Rx Nd.23	1580	0x62C	SDO Rx Nd.44
1539	0x603	SDO Rx Nd.3	1560	0x618	SDO Rx Nd.24	1581	0x62D	SDO Rx Nd.45
1540	0x604	SDO Rx Nd.4	1561	0x619	SDO Rx Nd.25	1582	0x62E	SDO Rx Nd.46
1541	0x605	SDO Rx Nd.5	1562	0x61A	SDO Rx Nd.26	1583	0x62F	SDO Rx Nd.47
1542	0x606	SDO Rx Nd.6	1563	0x61B	SDO Rx Nd.27	1584	0x630	SDO Rx Nd.48
1543	0x607	SDO Rx Nd.7	1564	0x61C	SDO Rx Nd.28	1585	0x631	SDO Rx Nd.49
1544	0x608	SDO Rx Nd.8	1565	0x61D	SDO Rx Nd.29	1586	0x632	SDO Rx Nd.50
1545	0x609	SDO Rx Nd.9	1566	0x61E	SDO Rx Nd.30	1587	0x633	SDO Rx Nd.51
1546	0x60A	SDO Rx Nd.10	1567	0x61F	SDO Rx Nd.31	1588	0x634	SDO Rx Nd.52
1547	0x60B	SDO Rx Nd.11	1568	0x620	SDO Rx Nd.32	1589	0x635	SDO Rx Nd.53
1548	0x60C	SDO Rx Nd.12	1569	0x621	SDO Rx Nd.33	1590	0x636	SDO Rx Nd.54
1549	0x60D	SDO Rx Nd.13	1570	0x622	SDO Rx Nd.34	1591	0x637	SDO Rx Nd.55
1550	0x60E	SDO Rx Nd.14	1571	0x623	SDO Rx Nd.35	1592	0x638	SDO Rx Nd.56
1551	0x60F	SDO Rx Nd.15	1572	0x624	SDO Rx Nd.36	1593	0x639	SDO Rx Nd.57
1552	0x610	SDO Rx Nd.16	1573	0x625	SDO Rx Nd.37	1594	0x63A	SDO Rx Nd.58
1553	0x611	SDO Rx Nd.17	1574	0x626	SDO Rx Nd.38	1595	0x63B	SDO Rx Nd.59
1554	0x612	SDO Rx Nd.18	1575	0x627	SDO Rx Nd.39	1596	0x63C	SDO Rx Nd.60
1555	0x613	SDO Rx Nd.19	1576	0x628	SDO Rx Nd.40	1597	0x63D	SDO Rx Nd.61
1556	0x614	SDO Rx Nd.20	1577	0x629	SDO Rx Nd.41	1598	0x63E	SDO Rx Nd.62
1557	0x615	SDO Rx Nd.21	1578	0x62A	SDO Rx Nd.42	1599	0x63F	SDO Rx Nd.63

dec	hex	Telegram type	dec	hex	Telegram type	dec	hex	Telegram type
1793	0x701	Guarding Nd.1	1814	0x716	Guarding Nd.22	1835	0x72B	Guarding Nd.43
1794	0x702	Guarding Nd.2	1815	0x717	Guarding Nd.23	1836	0x72C	Guarding Nd.44
1795	0x703	Guarding Nd.3	1816	0x718	Guarding Nd.24	1837	0x72D	Guarding Nd.45
1796	0x704	Guarding Nd.4	1817	0x719	Guarding Nd.25	1838	0x72E	Guarding Nd.46
1797	0x705	Guarding Nd.5	1818	0x71A	Guarding Nd.26	1839	0x72F	Guarding Nd.47
1798	0x706	Guarding Nd.6	1819	0x71B	Guarding Nd.27	1840	0x730	Guarding Nd.48
1799	0x707	Guarding Nd.7	1820	0x71C	Guarding Nd.28	1841	0x731	Guarding Nd.49
1800	0x708	Guarding Nd.8	1821	0x71D	Guarding Nd.29	1842	0x732	Guarding Nd.50
1801	0x709	Guarding Nd.9	1822	0x71E	Guarding Nd.30	1843	0x733	Guarding Nd.51
1802	0x70A	Guarding Nd.10	1823	0x71F	Guarding Nd.31	1844	0x734	Guarding Nd.52
1803	0x70B	Guarding Nd.11	1824	0x720	Guarding Nd.32	1845	0x735	Guarding Nd.53
1804	0x70C	Guarding Nd.12	1825	0x721	Guarding Nd.33	1846	0x736	Guarding Nd.54
1805	0x70D	Guarding Nd.13	1826	0x722	Guarding Nd.34	1847	0x737	Guarding Nd.55
1806	0x70E	Guarding Nd.14	1827	0x723	Guarding Nd.35	1848	0x738	Guarding Nd.56
1807	0x70F	Guarding Nd.15	1828	0x724	Guarding Nd.36	1849	0x739	Guarding Nd.57
1808	0x710	Guarding Nd.16	1829	0x725	Guarding Nd.37	1850	0x73A	Guarding Nd.58
1809	0x711	Guarding Nd.17	1830	0x726	Guarding Nd.38	1851	0x73B	Guarding Nd.59
1810	0x712	Guarding Nd.18	1831	0x727	Guarding Nd.39	1852	0x73C	Guarding Nd.60
1811	0x713	Guarding Nd.19	1832	0x728	Guarding Nd.40	1853	0x73D	Guarding Nd.61
1812	0x714	Guarding Nd.20	1833	0x729	Guarding Nd.41	1854	0x73E	Guarding Nd.62
1813	0x715	Guarding Nd.21	1834	0x72A	Guarding Nd.42	1855	0x73F	Guarding Nd.63

8.2 Approvals

(in preparation)

8.3 Bibliography

German books

- Holger Zeltwander (Pub.):
  CANopen,
  VDE Verlag, 2001. 197 pages,
  ISBN 3-800-72448-0

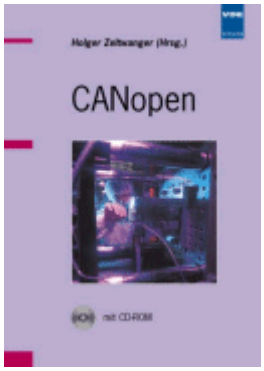


Fig. 62: CANopen

- Konrad Etschberger:
  Controller Area Network, Grundlagen, Protokolle, Bausteine, Anwendungen. (Principles, protocols, components, applications.)
  Hanser Verlag, 2000. 431 pages.
  ISBN 3-446-19431-2

General fieldbus technology

- Gerhard Gruhler (Pub.):
  Feldbusse und Geräte-Kommunikationssysteme, Praktisches Know-How mit Vergleichsmöglichkeiten. (Fieldbus and Device Communication Systems, Practical Know-how with Comparative Resources).
  Franzis Verlag, 2001. 244 pages.
  ISBN 3-7723-5745-8

English books

- Konrad Etschberger:
  Controller Area Network,
  Ixxat Press, 2001. 440 pages.
  ISBN 3-00-007376-0
- M. Farsi, M. Barbosa:
  CANopen Implementation,
  RSP 2000. 210 pages.
  ISBN 00-86380-247-8

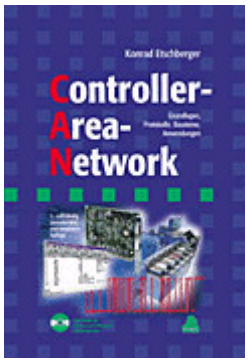


Fig. 63: Controller Area Network,

Standards

- ISO 11898:
  Road Vehicles - Interchange of digital information - Controller Area Network (CAN) for high speed communication.
- CiA DS 301:
  CANopen Application Layer and Communication Profile.
  Available from the CAN in Automation Association.
- CiA DS 401:
  CANopen Device Profile for Generic I/O Modules.
  Available from the CAN in Automation Association.

8.4 List of Abbreviations

CAN

Controller Area Network. Serial bus system standardized in ISO 11898 that is used as the basic technology for CANopen.

CiA

CAN in Automation e.V.. An international association of manufacturers and users based in Erlangen, Germany.

COB

Communication Object. A CAN telegram with up to 8 data bytes.

COB-ID

Communication Object Identifier. Telegram address (not to be confused with the node address). CANopen uses the 11-bit identifier according to CAN 2.0A.

NMT

Network Management. One of the service primitives of the CANopen specification. Network management is used to initialize the network and to monitor nodes.

PDO

Process Data Object. A CAN telegram for the transfer of process data (e.g. I/O data).

RxPDO

Receive PDO. PDOs are always identified from the point of view of the device under consideration. Thus a TxPDO with input data from an I/O module becomes an RxPDO from the controller's point of view.

SDO

Service Data Object. A CAN telegram with a protocol for communication with data in the object directory (typically parameter data).

TxPDO

Transmit PDO (named from the point of view of the CAN node).

8.5 Support and Service

Beckhoff and their partners around the world offer comprehensive support and service, making available fast and competent assistance with all questions related to Beckhoff products and system solutions.

Beckhoff's branch offices and representatives

Please contact your Beckhoff branch office or representative for local support and service on Beckhoff products!

The addresses of Beckhoff's branch offices and representatives round the world can be found on her internet pages:
http://www.beckhoff.com

You will also find further documentation for Beckhoff components there.

Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG

Huelshorstweg 20
33415 Verl
Germany

Phone:	+49(0)5246/963-0
Fax:	+49(0)5246/963-198
e-mail:	info@beckhoff.com

Beckhoff Support

Support offers you comprehensive technical assistance, helping you not only with the application of individual Beckhoff products, but also with other, wide-ranging services:

- support
- design, programming and commissioning of complex automation systems
- and extensive training program for Beckhoff system components

Hotline:	+49(0)5246/963-157
Fax:	+49(0)5246/963-9157
e-mail:	support@beckhoff.com

Beckhoff Service

The Beckhoff Service Center supports you in all matters of after-sales service:

- on-site service
- repair service
- spare parts service
- hotline service

Hotline:	+49(0)5246/963-460
Fax:	+49(0)5246/963-479
e-mail:	service@beckhoff.com

List of illustrations