

AKD™

EtherCAT Communication



Edition December 2009

Valid for Hardware Revision A

Original Documentation

EtherCAT®

Keep all manuals as a product component during the life span of the product.
Pass all manuals to future users / owners of the product.

KOLLMORGEN®

Record of Document Revisions:

| Revision | Remarks |
|----------|--------------------------|
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| | |
| | |
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| Hardware Revision | Firmware | WorkBench | Remarks |
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| | | | |

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Current patents:

US Patent 5,646,496 (used in control card R/D and 1 Vp-p feedback interface)
US Patent 5,162,798 (used in control card R/D)
US Patent 6,118,241 (used in control card simple dynamic braking)

Technical changes which improve the performance of the device may be made without prior notice!

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1 General

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1.1 About this Manual

This manual, *AKD EtherCAT Communication*, describes the installation, setup, range of functions, and software protocol for the EtherCAT AKD product series. All AKD EtherCAT drives have built-in EtherCAT functionality; therefore an additional option card is not required.

A digital version of this manual (pdf format) is available on the CD-ROM included with your drive. Manual updates can be downloaded from the Kollmorgen website.

Related documents for the AKD series include:

- *AKD Quick Start* (also provided in hard copy). This guide provides instructions for basic drive setup and connection to a network.
- *AKD Installation Manual* (also provided in hard copy). This manual provides instructions for installation and drive setup.
- *AKD Parameter and Command Reference Guide*. This guide provides documentation for the parameters and commands used to program the AKD.
- *AKD Accessories Manual*. This manual includes technical data and dimensional drawings of accessories such as cables, brake resistors, and mains supplies.
- *AKD CANopen Communication*. This manual includes setup information for the CAN interface and describes the CANopen profile.


1.2 Target Group

This manual addresses personnel with the following qualifications:






- Installation: only by electrically qualified personnel.
- Setup : only by qualified personnel with extensive knowledge of electrical engineering and drive technology
- Programming: Software developers, project-planners

The qualified personnel must know and observe the following standards:











- ISO 12100, IEC 60364 and IEC 60664
- National accident prevention regulations

| |
|---|
|  WARNING During operation there are deadly hazards, with the possibility of death, severe injury or material damage. The operator must ensure that the safety instructions in this manual are followed. The operator must ensure that all personnel responsible for working with the servo drive have read and understand the manual. |
|---|

1.3 Warning Symbols

| Symbol | Indication |
|---|--|
|  | Indicates a hazardous situation which, if not avoided, will result in death or serious injury. |
|  | Indicates a hazardous situation which, if not avoided, could result in death or serious injury. |
|  | Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury. |
|  | Indicates situations which, if not avoided, could result in property damage. |
|  | This is not a safety symbol. This symbol indicates important notes. |

Drawing symbols

| Symbol | Description | Symbol | Description |
|---|------------------|---|---------------------------|
|  | Signal ground |  | Diode |
|  | Chassis ground |  | Relays |
|  | Protective earth |  | Relays switch off delayed |
|  | Resistor |  | Normal open contact |
|  | Fuse |  | Normal closed contact |

1.4 Abbreviations used

| Abbreviation | Meaning |
|--------------|--|
| AL | Application Layer: the protocol that directly used by the process entities. |
| Cat | Category – classification for cables that is also used in Ethernet. |
| DC | Distributed Clocks Mechanism to synchronize EtherCAT slaves and master |
| DL | Data Link(=Layer 2). EtherCAT uses Ethernet, which is standardized as IEEE 802.3. |
| FPGA | Field Programmable Gate Array |
| FTP | File Transfer Protocol |
| HW | Hardware |
| ICMP | Internet Control Message Protocol: Mechanisms for signaling IP errors. |
| IEC | International Electrotechnical Commission: The international standards |
| IEEE | Institute of Electrical and Electronics Engineers, Inc. |
| LLDP | Lower Layer Discovery Protocol |
| MAC | Media Access Control |
| MII | Media Independent Interface: Standardized interface Ethernet controller <-> routing equipment. |
| MDI | Media Dependant Interface: Use of connector Pins and Signaling. |
| MDI-X | Media Dependant Interface (crossed): Use of connector Pins and Signaling with crossed lines. |
| OSI | Open System Interconnect |
| OUI | Organizationally Unique Identifier – the first 3 Bytes of an Ethernet-Address, that will be assign to companies or organizations and can be used for protocoll identifiers as well (e.g. LLDP) |
| PDI | Physical Device Interface: set of elements that allows access to ESC from the process side. |
| PDO | Process Data Object |
| PDU | Protocol Data Unit: Contains protocol information transferred from a protocol instance of transparent data to a subordinate level |
| PHY | Physical interface that converts data from the Ethernet controller to electric or optical signals. |
| PLL | Phase Locked Loop |
| PTP | Precision Time Protocol in accordance with IEEE 1588 |
| RSTP | Rapid Spanning Tree Protocol |
| RT | Real-time, can be run in Ethernet controllers without special support. |
| RX | Receive |
| RXPDO | Receive PDO |
| SNMP | Simple Network Management Protocol |
| SPI | Serial Peripheral Interface |
| Src Addr | Source Address: Source address of a message. |
| STP | Shielded Twisted Pair |
| TCP | Transmission Control Protocol |
| TX | Transmit |
| TXPDO | Transmit PDO |
| UDP | User Datagram Protocol: Non-secure multicast/broadcast frame. |
| UTP | Unshielded Twisted Pair |
| ZA ECAT | Access mode EtherCAT |
| ZA Drive | Acces mode Drive |

2 Safety

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2.1 Safety Instructions

| | |
|-------------------------|---|
| <p>⚠ DANGER</p> | <p>During operation there are deadly hazards, with the possibility of death, severe injury or material damage. Do not open or touch the equipment during operation. Keep all covers and cabinet doors closed during operation. Touching the equipment is allowed during installation and commissioning for properly qualified persons only.</p> <ul style="list-style-type: none"> • During operation, drives may have uncovered live components, depending on their level of enclosure protection. • Control and power connections may be live, even though the motor is not rotating. • Drives may have hot surfaces during operation. Heat sink can reach temperatures above 80°C. |
| <p>⚠ WARNING</p> | <p>Electronic equipment is basically not failure-proof. The user is responsible for ensuring that, in the event of a failure of the servo amplifier, the drive is set to a state that is safe for both machinery and personnel, for instance with the aid of a mechanical brake.</p> <p>Drives with servo amplifiers and EtherCAT expansion cards are remote-controlled machines. They can start to move at any time without previous warning. Take appropriate measures to ensure that the operating and service personnel is aware of this danger.</p> <p>Implement appropriate protective measures to ensure that any unintended start-up of the machines cannot result in dangerous situations for personnel or machinery. Software limit-switches are not a substitute for the hardware limit-switches in the machine.</p> |
| <p>NOTICE</p> | <p>Install the drive as described in the <i>Installation Manual</i>. The wiring for the analog setpoint input and the positioning interface, as shown in the wiring diagram in the <i>Installation Manual</i>, is not required. Never break any of the electrical connections to the drive while it is live. This action can result in destruction of the electronics</p> |
| <p>NOTICE</p> | <p>Do not connect the Ethernet line for the PC with the set up software to the EtherCAT interface X5/X6. The set up Ethernet cable must be connected to the service interface on X11</p> |

2.2 Use as directed

Drives are components that are built into electrical plants or machines and can only be operated as integral components of these plants or machines. The manufacturer of the machine used with a drive must generate a hazard analysis for the machine and take appropriate measures to ensure that unforeseen movements cannot cause personnel injury or property damage.

Please observe the chapters "Use as directed" and "Prohibited use" in the *AKD Installation Manual*.

The EtherCAT interface serves only for the connection of the *AKD Drive* to a master with EtherCAT connectivity.

2.3 Prohibited use

Other use than that described in chapter "Use as directed" is not intended and can lead to personnel injuries and equipment damage. The drive may not be used with a machine that does not comply with appropriate national directives or standards. The use of the drive in the following environments is also prohibited:

- potentially explosive areas
- environments with corrosive and/or electrically conductive acids, alkaline solutions, oils, vapors, dusts
- ships or offshore applications

The connectors X5 and X6 of the AKD EtherCAT drive may not be used for any ethernet protocol except EtherCAT (CoE, Can over EtherCAT).

3 Installation and Setup

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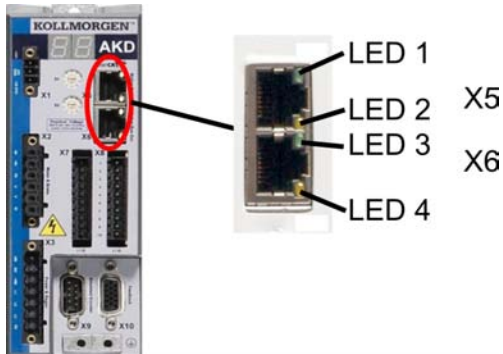
3.1 Safety Instructions

| | |
|------------------|---|
| ⚠ DANGER | <p>Never undo any electrical connections to the drive while it is live. There is a danger of electrical arcing with damage to contacts and serious personal injury. Wait at least seven minutes after disconnecting the drive from the main supply power before touching potentially live sections of the equipment (e.g. contacts) or undoing any connections. Capacitors can still have dangerous voltages present up to 7 minutes after switching off the supply power. To be sure, measure the voltage in the DC Bus link and wait until it has fallen below 40 V.</p> <p>Control and power connections can still be live, even if the motor is not rotating.</p> |
| ⚠ WARNING | <p>Electronic equipment is basically not failure-proof. The user is responsible for ensuring that, in the event of a failure of the servo amplifier, the drive is set to a state that is safe for both machinery and personnel, for instance with the aid of a mechanical brake. Drives with servo amplifiers and EtherCAT are remote-controlled machines. They can start to move at any time without previous warning. Take appropriate measures to ensure that the operating and service personnel is aware of this danger. Implement appropriate protective measures to ensure that any unintended start-up of the machines cannot result in dangerous situations for personnel or machinery. Software limit-switches are not a substitute for the hardware limit-switches in the machine.</p> |
| NOTICE | <p>Install the drive as described in the <i>Installation Manual</i>. The wiring for the analog setpoint input and the positioning interface, as shown in the wiring diagram in the <i>Installation Manual</i>, is not required. Never break any of the electrical connections to the drive while it is live. This action can result in destruction of the electronics.</p> |
| NOTICE | <p>The drive's status must be monitored by the PLC to acknowledge critical situations. Wire the FAULT contact in series into the emergency stop circuit of the installation. The emergency stop circuit must operate the supply contactor.</p> |

| | |
|-------------|--|
| NOTE | <p>It is permissible to use WorkBench to alter the settings of the drive. Any other alterations will invalidate the warranty.</p> |
| NOTE | <p>Because of the internal representation of the position-control parameters, the position controller can only be operated if the final limit speed of the drive does not exceed:</p> <p>rotatory at sinusoidal² commutation: 7500 rpm at trapezoidal commutation: 12000 rpm.</p> <p>linear at sinusoidal² commutation: 4 m/s at trapezoidal commutation: 6.25 m/s</p> |
| NOTE | <p>All the data on resolution, step size, positioning accuracy etc. refer to calculatory values. Non-linearities in the mechanism (backlash, flexing, etc.) are not taken into account. If the final limit speed of the motor must be altered, then all the parameters that were previously entered for position control and motion blocks must be adapted.</p> |

3.2 EtherCAT Onboard

Connection to the EtherCAT Network via X5 (in port) and X6 (out port).



3.2.1 LED functions

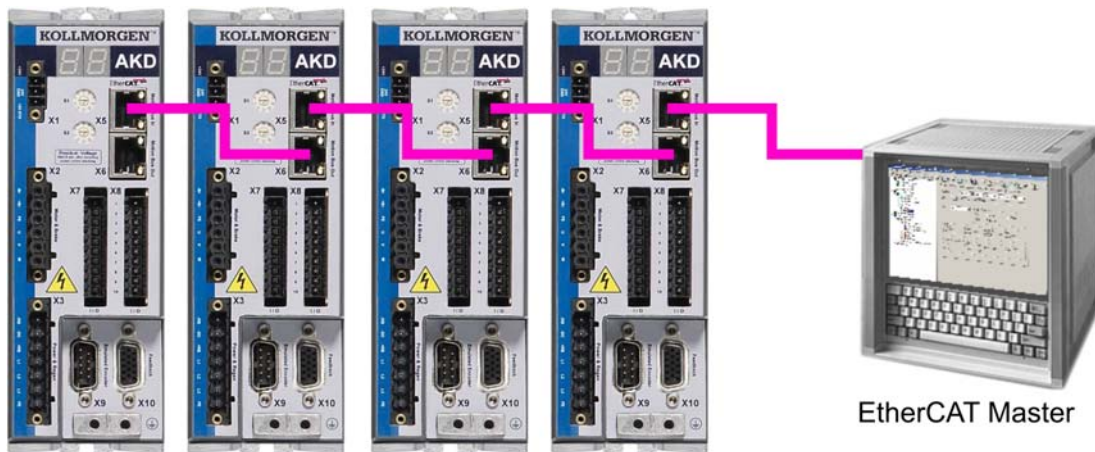
The communication status is indicated by the built-in LEDs.

| Connector | LED# | Name | Function |
|-----------|------|---------------|-----------------------------------|
| X5 | LED1 | IN port Link | ON = active OFF = not active |
| | LED2 | RUN | ON = running OFF = not running |
| X6 | LED3 | OUT port Link | ON = active OFF = not active |
| | LED4 | - | - |

3.2.2 Connection technology

You can connect to the EtherCAT network using RJ-45 connectors.

3.2.3 Network Connection Example



EtherCAT Master

3.3 Guide to Setup

| | |
|------------------|---|
| ⚠ WARNING | Only professional personnel with extensive knowledge of control and drive technology are allowed to setup the drive. |
| ⚠ CAUTION | Make sure that any unintended movement of the drive cannot endanger machinery or personnel. |

1. Check assembly/installation. Check that all the safety instructions in the product manual for the drive and this manual have been observed and implemented. Check the setting for the station address and baud rate.
2. Connect PC, start WorkBench. Use the setup software WorkBench to set the parameters for the drive.
3. Setup basic functions. Start up the basic functions of the drive and optimize the current, speed and position controllers. This section of the setup is described in the in the online help of the setup software.
4. Save parameters. When the parameters have been optimized, save them in the drive.

3.4 Setup via TwinCAT NC/PTP System Manager

Before you set up the drive, make sure the following have been completed:

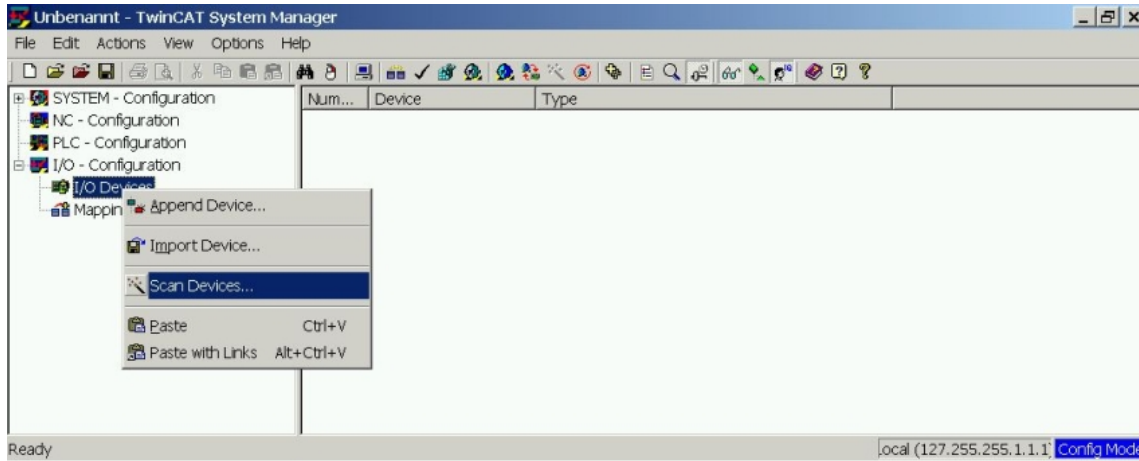
- The AKD is configured with WorkBench and the servomotor is able to move
- A correctly configured EtherCAT card is present in the master.
- TwinCAT software from Beckhoff (NC/PTP-Mode setup) is installed. Install first the TwinCAT System Manager, restart your PC, then install the option package NC/PTP-Mode.
- The XML description of the Drive is available (the XML file on the CD-ROM or on the Kollmorgen website).
- An AKD EtherCAT slave is connected to the EtherCAT master PC.
- The TwinCAT system manager resides in Config-Mode. The current mode of the system manager is displayed of the bottom right side of the TwinCAT main-screen window.

Copy the XML description of the drive to the TwinCAT system (usually to the folder c:\TwinCAT\IO\EtherCAT) and restart the TwinCAT system since TwinCAT analyzes all device description files during start-up.

The following example explains the automatic EtherCAT network setup. The network setup can also be done manually; please refer to the TwinCAT manual for more details.

3.4.1 Scan devices

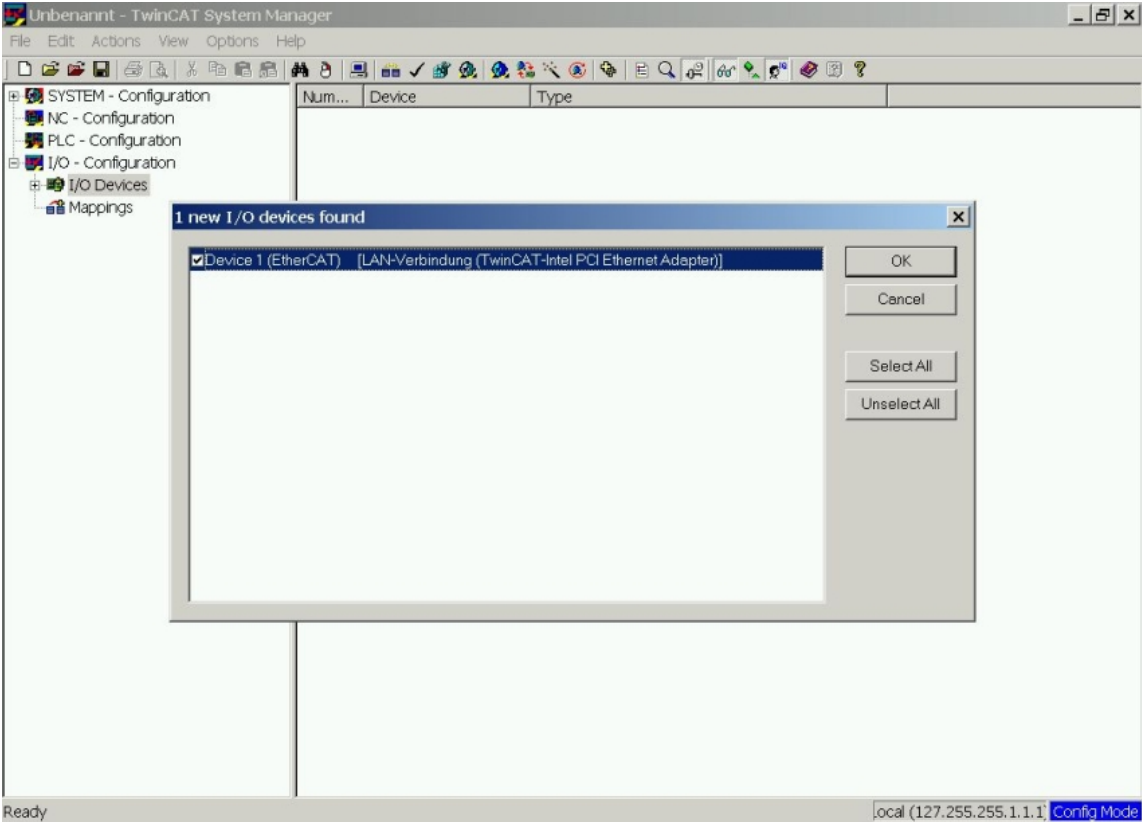
First ensure that the EtherCAT master is physically connected to the EtherCAT AKD Drive. Create a new (empty) project. Right click I/O-Devices and scan for the devices. An example is included in the EtherCAT network card, which is plugged into the PC.



A pop-up window informs you that not all devices can be detected by the TwinCAT software. Click **OK** to continue.

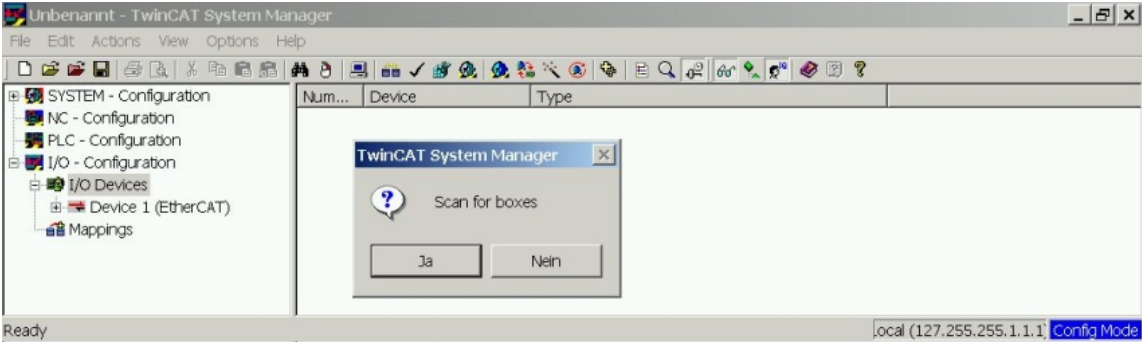
3.4.2 Select the device

TwinCAT must be able to find the EtherCAT network card. An EtherCAT slave must be connected to the network card; otherwise TwinCAT will find a real-time EtherNET card instead of the EtherCAT card. Press the **OK** button.



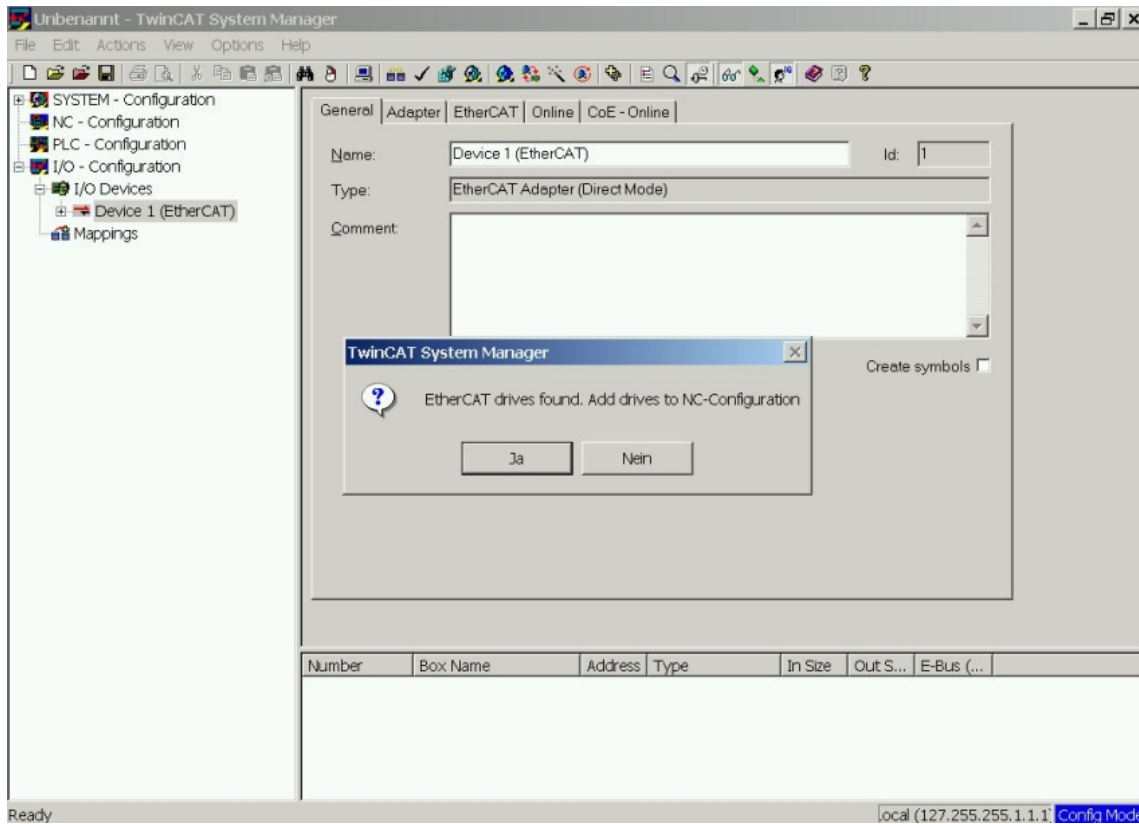
3.4.3 Scan for boxes

Click **Yes** to allow TwinCat to scan for boxes. A *box* is an alias for a slave device and is always used in Beckhoff software products.






3.4.4 Add Slaves to NC tasks

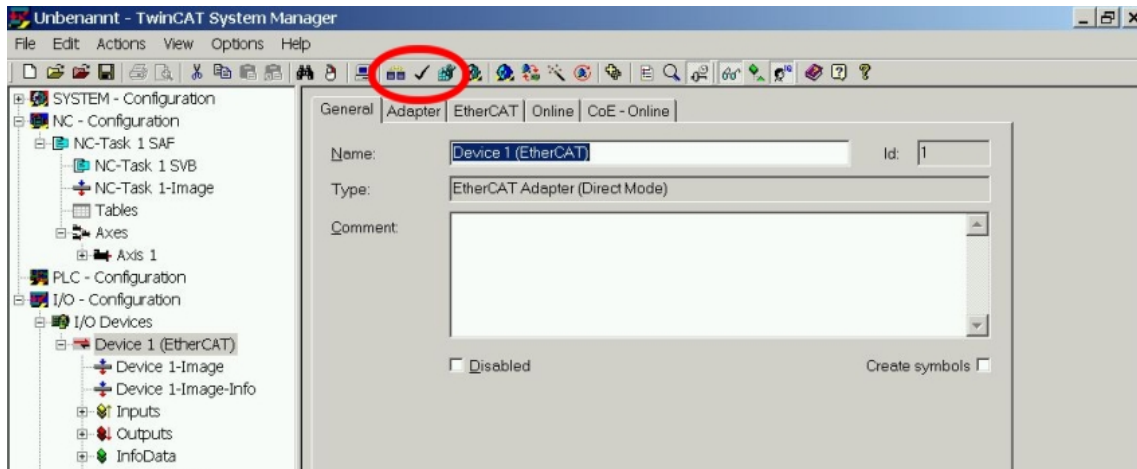
TwinCAT should now have identified the AKD according to the Device Description file. TwinCAT next asks if the slaves should be connected to NC tasks. Click **Yes** to continue. An NC task can, for example, contain a PLC program, which can be programmed by the user.



3.4.5 Enable the network configuration

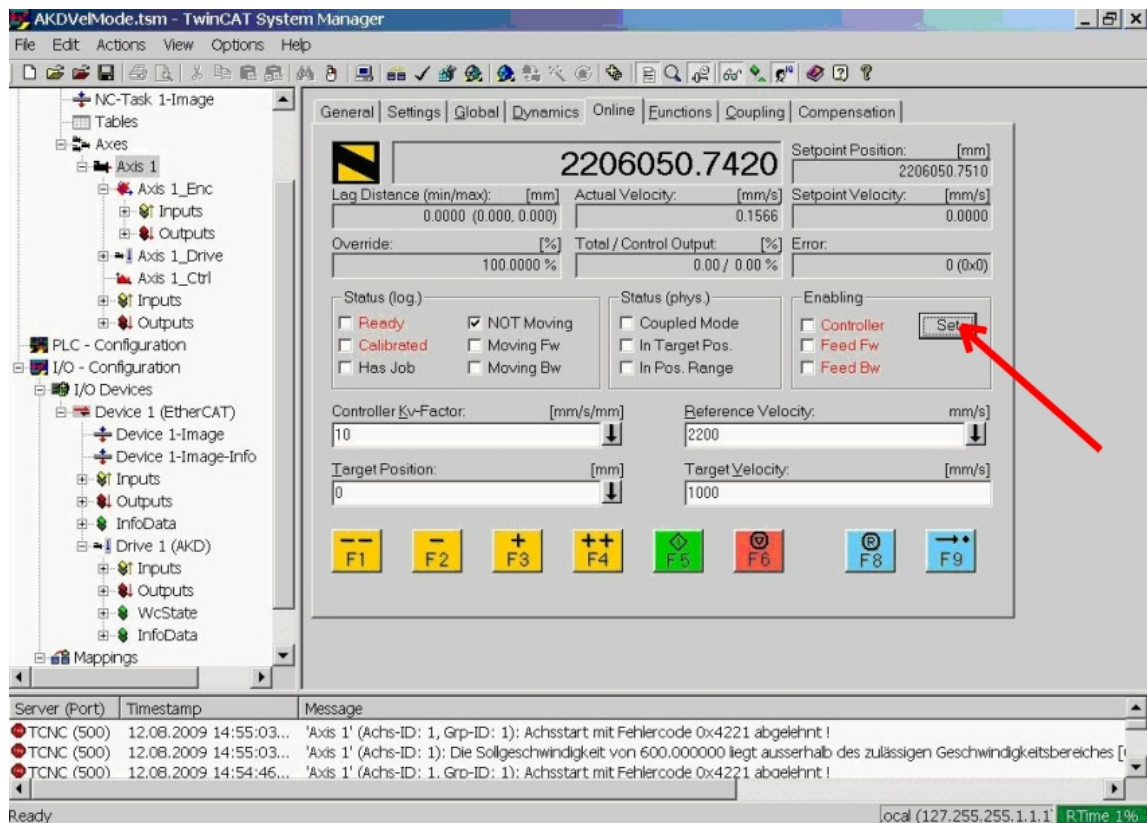
Confirm that the AKD appears in the device tree. Next, enable the network configuration. Press first the  button in order to generate the mappings, afterwards press the  button in order to let TwinCAT check the configuration and use finally the  button in order to step into run-mode.

Confirm afterwards that TwinCAT is allowed to jump into run-mode.



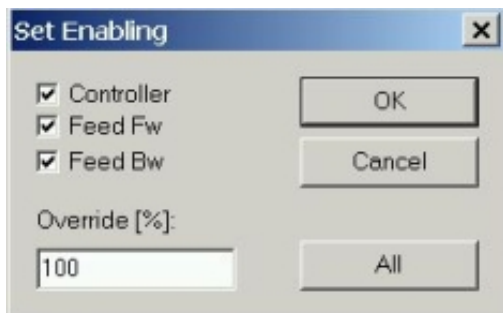
3.4.6 Enable the axis and move the axis

The Axis can be enabled by a mouse-click on the Set button within the Online window inside of each Axis, see also the next picture.



Afterwards a pop-up window appears.

The following setting enables the drive and allows command values in both directions.



Afterwards the motor should move in positive or negative direction as soon as the clicks on the following yellow buttons within the Online window:



4 EtherCAT Profile

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4.1 Slave Register

The table below gives the addresses of individual registers in the FPGA memory. The data is provided in little-endian format, with the 'least significant byte' occupying the lowest address. A detailed description of all registers and FPGA memory locations is available in the "EtherCAT Slave Controller" description of the EtherCAT user organization (www.EtherCAT.org).

| Address | Length (Byte) | Description | ZA ECAT* | ZA Drive* |
|---------|---------------|---|----------|-----------|
| 0x0120 | 2 | AL Control | R/W | R/O |
| 0x0130 | 2 | AL Status | R/O | R/W |
| 0x0134 | 2 | AL Status Code | R/O | R/W |
| 0x0204 | 2 | Interrupt Enable Register | R/O | R/W |
| 0x0220 | 2 | AL Event (IRQ Event) | R/W | R/O |
| 0x0800 | 8 | Sync Manager 0 (Mail Out Control Register) | R/W | R/O |
| 0x0808 | 8 | Sync Manager 1 (Mail In Control Register) | R/W | R/O |
| 0x0810 | 8 | Sync Manager 2 (Process data Output Control Register) | R/W | R/O |
| 0x0818 | 8 | Sync Manager 3 (Process data Input Control Register) | R/W | R/O |
| 0x0820 | 8 | Sync Manager 4 | R/W | R/O |
| 0x0828 | 8 | Sync Manager 5 | R/W | R/O |
| 0x0830 | 8 | Sync Manager 6 | R/W | R/O |
| 0x0838 | 8 | Sync Manager 7 | R/W | R/O |
| 0x0840 | 8 | Sync Manager 8 | R/W | R/O |
| 0x1100 | Max. 64 | ProOut Buffer (Process data Output, setpoints ECAT) | R/W | R/O |
| 0x1140 | Max. 64 | ProIn (Process data Input, act. values ECAT) | R/O | R/W |
| 0x1800 | 512 | Mail Out Buffer (Object Channel Buffer ECAT, byte-length is specified in the device description file) | R/W | R/O |
| 0x1C00 | 512 | Mail In Buffer (Object Channel Buffer Drive, byte-length is specified in the device description file) | R/O | R/W |

* ZA ECAT = Access mode EtherCAT

* ZA Drive = Access mode Drive

4.2 AL Event (Interrupt Event) and Interrupt Enable

Communication between the drive and the EtherCAT FPGA can be interrupt-driven. The interrupt enable register and the AL event register are responsible for the EtherCAT interface interrupt functionality.

There are two events which lead also to a HW interrupt within the Drive, the EEPROM emulation event and the SyncManager 2 event. The actual values of the Drive (SyncManager 3 data) are written without any AL event request during each HW IRQ, e.g. triggered by a SyncManager 2 event. The Mailbox exchange between the master and the AKD is completely handled by polling the AL event register within the background task of the Drive.

The drive activates individual EtherCAT interface events when the corresponding bit of the interrupt enable register is set to 1. When it is set to 0, the hardware interrupts for the specific events are deactivated.

4.2.1 Interrupt Enable Register (Address 0x0204:0x0205)

| Parameter | Address | Bit | ZA Drive | ZA ECAT | Description |
|--|---------|--------|-------------|------------|---|
| AL Control Event | 0x204 | 0 | R/W | R/O | Activation of AL control event for phase run-up |
| - | 0x204 | 1 | R/W | R/O | Reserved |
| Sync0 DC Distributed Clock | 0x204 | 2 | R/W | R/O | Activation of distributed clock (DC) sync 0 interrupts for entire communication |
| Sync1 DC Distributed Clock | 0x204 | 3 | R/W | R/O | Activation of distributed clock (DC) sync 1 interrupts for entire communication |
| SyncManager activation register change | 0x204 | 4 | R/W | R/O | Activation of 'SyncManager activation register change' IRQ. |
| EEPROM emulation event | 0x204 | 5 | R/W | R/O | Activation of the EEPROM emulation interrupts. |
| - | 0x204 | 3 to 7 | R/W | R/O | Reserved |
| Sync Manager 0 Event (Mail Out Event) | 0x205 | 0 | R/W | R/O | Activation of output event mailbox (SDO, Sync Manager 0) for object channel. |
| Sync Manager 1 Event (Mail In Event) | 0x205 | 1 | R/W | R/O | Activation of input event mailbox (SDO, Sync Manager 1) for object channel. |
| Sync Manager 2 Event (Pro Out Event) | 0x205 | 2 | R/W | R/O | Activation of output event process data (PDO, card's cyclical setpoints) |
| Sync Manager 3 Event (Pro In Event) | 0x205 | 3 | R/W | R/O | Activation of input event process data (PDO, drive's cyclical actual values) |
| - | 0x205 | 4 to 7 | R/W | R/O | Reserved |

4.2.2 AL Event Request (Address 0x0220:0x0221)

When the relevant bit of the AL event request register is set to 1, the EtherCAT interface tells the drive which event it should process by the AKD.

| Parameter | Address | Bit | ZA Drive | ZA ECAT | Description |
|--|---------|--------|-------------|------------|--|
| AL Control Event | 0x220 | 0 | R/O | R/W | Processing of AL control event for phase run-up |
| Sync0 Distributed Clock (DC) Event | 0x220 | 2 | R/O | R/W | Processing of a distributed clock (DC) event |
| Sync1 Distributed Clock (DC) Event | 0x220 | 3 | R/O | R/W | Processing of a distributed clock (DC) event |
| SyncManager activation register change | 0x220 | 4 | R/O | R/W | The content of the SyncManager activation register has been changed. |
| EEPROM emulation event | 0x220 | 5 | R/O | R/W | Processing of an EEPROM emulation event in order to identify the AKD within the network. |
| - | 0x220 | 6 to 7 | R/O | R/W | Reserved |
| Sync Manager 0 Event | 0x221 | 0 | R/O | R/W | Mailbox request (SDO, Sync Manager 0) for object channel. |
| Sync Manager 1 Event | 0x221 | 1 | R/O | R/W | Mailbox response (SDO, Sync Manager 1) for object channel. |
| Sync Manager 2 Event | 0x201 | 2 | R/O | R/W | Process data output (PDO, card's cyclical set-points) |
| Sync Manager 3 Event | 0x201 | 3 | R/O | R/W | Process data input (PDO, drive's cyclical actual values) |
| Sync Manager 4 – | | | | | |
| Sync Manager 7 Event | 0x221 | 4 to 7 | R/O | R/W | Reserved |
| Sync Manager 8 – | | | | | |
| Sync Manager 15 Event | 0x222 | 0...7 | R/O | R/W | Reserved |

4.3 Phase Run-Up

The AL control, AL status and AL status code registers are responsible for communication phase run-up (also referred to as EtherCAT status change), for current status display and for any fault messages. The drive responds to every EtherCAT interface transition request made by the AL control register via the AL Status and AL Status Code registers. Any fault messages are displayed in the AL status code register.

A status change within the AL control register is polled within the AKD, which means that an AL control event does not lead to a HW interrupt within the Drive.

4.3.1 AL Control (Address 0x0120:0x0121)

| Parameter | Address | Bit | ZA Drive | ZA ECAT | Description |
|--------------------------------|---------|---------|-------------|------------|---|
| Status | 0x120 | 3 to 0 | R/O | W/O | 0x01: Init Request |
| 0x02: PreOperational Request | | | | | |
| 0x03: Bootstrap Mode Request | | | | | |
| 0x04: Safe Operational Request | | | | | |
| 0x08: Operational Request | | | | | |
| Acknowledgement | 0x120 | 4 | R/O | W/O | 0x00: No fault acknowledgement 0x01: Fault acknowledgement (positive edge) |
| Reserved | 0x120 | 7 to 5 | R/O | W/O | - |
| Applic. specific | 0x120 | 15 to 8 | R/O | W/O | - |

4.3.2 AL Status (Address 0x0130:0x0131)

| Parameter | Address | Bit | ZA Drive | ZA ECAT | Description |
|------------------------|---------|---------|-------------|------------|---|
| Status | 0x130 | 3 to 0 | W/O | R/O | 0x01: Init |
| 0x02: PreOperational | | | | | |
| 0x03: Bootstrap Mode | | | | | |
| 0x04: Safe Operational | | | | | |
| 0x08: Operational | | | | | |
| Status change | 0x130 | 4 | W/O | R/O | 0x00: Acknowledgement 0x01: Error, e.g. forbidden transition |
| Reserved | 0x130 | 7 to 5 | W/O | R/O | - |
| Applic. specific | 0x130 | 15 to 8 | W/O | R/O | - |

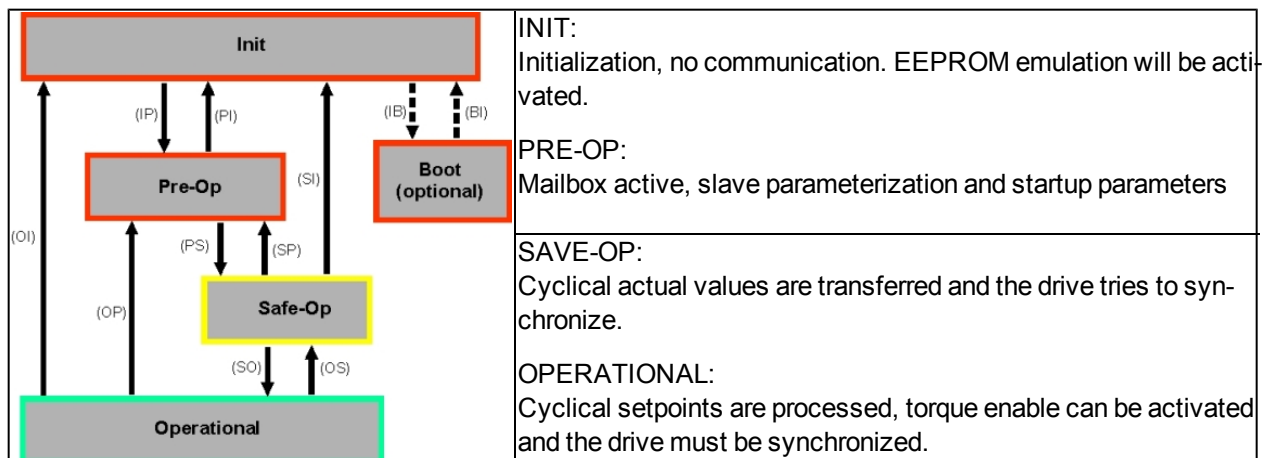
4.3.3 AL Status Code (Address 0x0134:0x0135)

| Parameter | Address | Bit | ZA Drive | ZA ECAT | Description |
|-----------|---------|--------|----------|---------|-----------------|
| Status | 0x134 | 7 to 0 | W/O | R/O | See table below |
| Status | 0x135 | 7 to 0 | W/O | R/O | See table below |

| Code | Description | Current Status (Status change) | Resulting Status |
|--------|------------------------------------|---|--------------------|
| 0x0000 | No error | All | Current Status |
| 0x0011 | Invalid requested state change | I -> S, I -> O, P -> O, O -> B, S -> B, P -> B | Current Status + E |
| 0x0017 | Invalid sync manager configuration | I -> P, P -> S | Current Status + E |

No other codes are supported.

4.3.4 EtherCAT communication phases

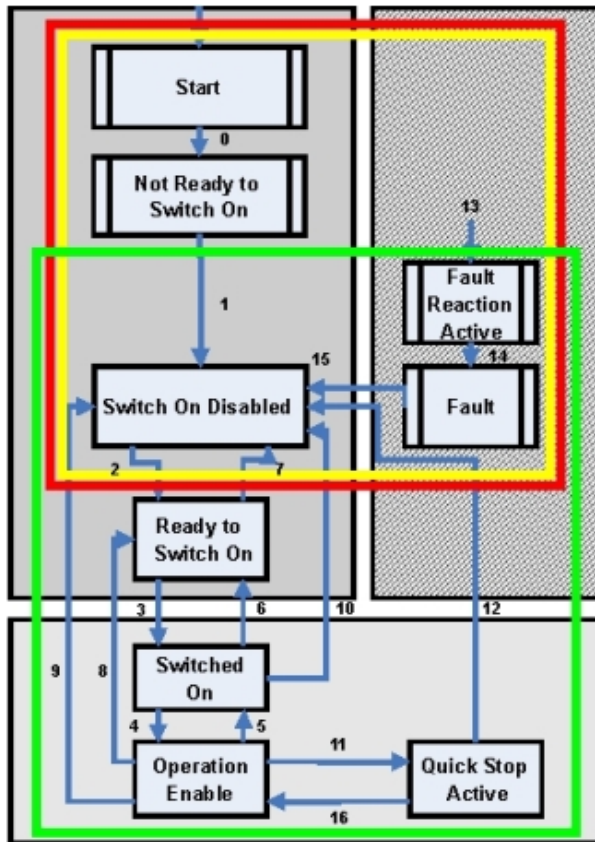


Individual communication transitions

| Transition | AL Control (Bit 3 to 0) | Description |
|------------|-------------------------|--|
| (IB) | 0x03 | - |
| (BI) | - | - |
| (IP) | 0x02 | AKD reads the SyncManager 0 & 1 configuration and verifies the value of the start-address and the length. The AKD prepares itself for handling SyncManager 0 events. |
| (PI) | 0x01 | - |
| (PS) | 0x04 | AKD reads the SyncManager 2 & 3 configuration and verifies the value of the start-address and the length. |
| (SP) | 0x02 | - |
| (SI) | 0x01 | - |
| (SO) | 0x08 | The SnycManager 2 hardware interrupt will be enabled by the Drive. |
| (OS) | 0x04 | Deactivation of SyncManager 2 hardware interrupt. |
| (OP) | 0x02 | Deactivation of SyncManager 2 hardware interrupt.. |
| (OI) | 0x01 | Deactivation of SyncManager 2 hardware interrupt. |

4.4 CANopen over EtherCAT (CoE) Status Machine

The status machine for the control and status words corresponds to the CANopen status machine in accordance with DS402. CANopen control and status words are captured in every instance of fixed PDO mapping (see chapter entitled 'Fixed PDO Mapping', page).



4.4.1 Status Description

| Status | Description |
|------------------------|--|
| Not Ready to Switch On | The drive is not ready to switch on; the controller has not indicated readiness for service. The drive is still in the boot phase or in fault status. |
| Switch On Disable | In 'Switch On Disable' status, the amplifier cannot be enabled via the EtherCAT interface, because (for example) there is no connection to a power source. |
| Ready to Switch On | In 'Ready to Switch On' status, the drive can be enabled via the control word. |
| Switched On | In 'Switched On' status, the amplifier is enabled, but the setpoints of the EtherCAT-interface are not yet transferred. The amplifier is idle, and a positive edge in bit 3 of the control word activates setpoint transfer (transition to 'Operation Enable' status). |
| Operation Enable | In this status, the drive is enabled and setpoints are transferred from the EtherCAT interface. |
| Quick Stop Active | The drive follows a quick stop ramp. |
| Fault Reaction Active | The drive responds to a fault with an emergency stop ramp. |
| Fault | A fault is pending, the drive is stopped and disabled. |

4.4.2 Commands in the Control Word

Bit assignment in the control word

| Bit | Name | Bit | Name |
|-----|---|-----|-----------------------|
| 0 | Switch on | 8 | Pause/halt |
| 1 | Disable Voltage | 9 | reserved |
| 2 | Quick Stop | 10 | reserved |
| 3 | Enable Operation | 11 | reserved |
| 4 | Operation mode specific | 12 | reserved |
| 5 | Operation mode specific | 13 | Manufacturer-specific |
| 6 | Operation mode specific | 14 | Manufacturer-specific |
| 7 | Reset Fault (only effective for faults) | 15 | Manufacturer-specific |

Commands in the control word

| Command | Bit 7 Fault Reset | Bit 3 Enable Operation | Bit 2 Quick Stop | Bit 1 Disable Voltage | Bit 0 Switch on | Transitions |
|-------------------|----------------------|---------------------------|---------------------|--------------------------|--------------------|--------------|
| Shutdown | X | X | 1 | 1 | 0 | 2, 6, 8 |
| Switch on | X | X | 1 | 1 | 1 | 3 |
| Disable Voltage | X | X | X | 0 | X | 7, 9, 10, 12 |
| Quick Stop | X | X | 0 | 1 | X | 7, 10, 11 |
| Disable Operation | X | 0 | 1 | 1 | 1 | 5 |
| Enable Operation | X | 1 | 1 | 1 | 1 | 4, 16 |
| Fault Reset | 1 | X | X | X | X | 15 |

Bits labeled **X** are irrelevant. **0** and **1** indicate the status of individual bits.

Mode-dependent bits in the control word

The following table shows the mode-dependent bits in the control word. Only manufacturer-specific modes are supported at present. The individual modes are set by Object 6060h Modes of operation.

| Operation mode | No. | Bit 4 | Bit 5 | Bit 6 |
|----------------------------------|-----|------------------------|------------------------|-------------------|
| Profile Position Mode (pp) | 01h | new_set_point | change_set_immediately | absolute/relative |
| Profile Velocity Mode (pv) | 03h | reserved | reserved | reserved |
| Profile Torque Mode (tq) | 04h | reserved | reserved | reserved |
| Homing Mode (hm) | 06h | homing_operation_start | reserved | reserved |
| Interpolated Position Mode (ip) | 07h | | reserved | reserved |
| Cyclic synchronous position mode | 08h | reserved | reserved | reserved |

Description of the remaining bits in the control word

Bit 8: (Pause) If Bit 8 is set, then the drive halts (pauses) in all modes. The setpoints (speed for homing or jogging, motion task number, setpoints for digital mode) for the individual modes are retained.

Bit 9,10: These bits are reserved for the drive profile (DS402).

Bit 13, 14, 15: These bits are manufacturer-specific, and reserved at present.

4.4.3 Status Machine Bits (status word)

Bit assignment in the status word

| Bit | Name | Bit | Name |
|-----|--------------------|-----|------------------------------------|
| 0 | Ready to switch on | 8 | Manufacturer-specific (reserved) |
| 1 | Switched on | 9 | Remote (always 1) |
| 2 | Operation enable | 10 | Target reached |
| 3 | Fault | 11 | Internal limit active |
| 4 | Voltage enabled | 12 | Operation mode specific (reserved) |
| 5 | Quick stop | 13 | Operation mode specific (reserved) |
| 6 | Switch on disabled | 14 | Manufacturer-specific (reserved) |
| 7 | Warning | 15 | Manufacturer-specific (reserved) |

States of the status machine

| State | Bit 6 switch on disable | Bit 5 quick stop | Bit 3 fault | Bit 2 operation enable | Bit 1 switched on | Bit 0 ready to switch on |
|------------------------|-------------------------------|------------------------|----------------|------------------------------|-------------------------|--------------------------------|
| Not ready to switch on | 0 | X | 0 | 0 | 0 | 0 |
| Switch on disabled | 1 | X | 0 | 0 | 0 | 0 |
| Ready to switch on | 0 | 1 | 0 | 0 | 0 | 1 |
| Switched on | 0 | 1 | 0 | 0 | 1 | 1 |
| Operation enabled | 0 | 1 | 0 | 1 | 1 | 1 |
| Fault | 0 | X | 1 | 0 | 0 | 0 |
| Fault reaction active | 0 | X | 1 | 1 | 1 | 1 |
| Quick stop active | 0 | 0 | 0 | 1 | 1 | 1 |

Bits labeled **X** are irrelevant. **0** and **1** indicate the status of individual bits.

Description of the remaining bits in the status word

Bit 4: `voltage_enabled` The DC-link voltage is present if this bit is set.

Bit 7: `warning` There are several possible reasons for Bit 7 being set and this warning being produced. The reason for this warning can be revealed by using the Object 20subindex `manufacturer warnings`.

Bit 9: `remoteis always` set to 1, i.e. the drive can always communicate and be influenced via the RS232-interface.

Bit 10: `target_reached` This is set when the drive has reached the target position.

Bit 11: `internal_limit_active` This bit specifies that a movement was or is limited. In different modes, different warnings cause the bit to be set.

4.5 Fixed PDO Mappings

Various ready-to-use mappings can be selected for cyclic data exchange via SDO's of the object 0x1C12 and 0x1C13. Using object 0x1C12 subindex 1 (Sync Manager 2 assignment), a fixed mapping for the cyclic command values can be set with the values 0x1701 ... 0x1702. Using object 0x1C13 subindex 1 (Sync Manager 3 assignment), a fixed mapping for the cyclic actual values can be set via the data 0x1B01 ... 0x1B02.

The following sequence describes how to select the fixed command value mapping 0x1701 via SDO's:

1. SDO write access to object 0x1C12Sub0 Data:0x00
2. SDO write access to object 0x1C12Sub1 Data:0x1701
3. SDO write access to object 0x1C12Sub0 Data:0x01

The following fixed mappings are supported:

Position interface:

0x1701: Position command value (4 bytes), Control word (2 bytes), total (6 bytes)

0x1B01: Position actual value (4 bytes), Status word (2 bytes), total (6 bytes)

Velocity interface:

0x1702: Velocity command value (4 bytes), Control word (2 bytes), total (6 bytes)

0x1B02: Position actual value (4 bytes), Status word (2 bytes), total (6 bytes)

4.6 Supported Cyclical Setpoint- and Actual Values

Supported cyclical setpoint values

| Name | CANopen object number | Data type | Description |
|------------------------|-----------------------|-----------|--------------------------------------|
| Position command value | 0x60C1 sub 1 | INT32 | interpolation data record in IP-mode |
| Velocity command value | 0x60FF sub 0 | INT32 | |
| CANopen control-word | 0x6040 Sub 0 | UINT16 | CANopen control word. |

Supported cyclical actual values

| Name | CANopen object number | Data type | Description |
|-----------------------|-----------------------|-----------|----------------------|
| Position actual value | 0x6063 sub 0 | INT32 | |
| Velocity actual value | 0x606c sub 0 | INT32 | |
| CANopen status-word | 0x6041 Sub 0 | UINT16 | CANopen status word. |

4.7 Supported Operation Modes

| CANopen mode of operation | AKD mode of operation | Description |
|---------------------------|---------------------------------|--|
| Profile velocity | DRV.OPMODE 2 DRC.CMDSOURCE 1 | 0x6060Sub0 Data: 3 In this mode of operation the EtherCAT master sends cyclic velocity command values to the AKD. |
| Interpolated position | DRV.OPMODE 2 DRV.CMDSOURCE 1 | 0x6060Sub0 Data: 7 In this mode of operation the EtherCAT master sends cyclic position command values to the AKD. These command values are interpolated by the AKD according to the fieldbus sample rate. |

4.8 Adjusting EtherCAT Cycle Time

The cycle time to be used in the drive for the cyclical setpoints and actual values can either be stored in the FBUS.SAMPLEPERIOD parameter in the amplifier or configured in the startup phase.

This takes place via SDO mailbox access (see chapter) to CANopen objects 60C2 subindex 1 and 2.

Subindex 2, known as the interpolation time index, defines the power of ten of the time value (e.g. -3 means 10⁻³ or milliseconds) while subindex 1, known as interpolation time units, gives the number of units (e.g. 4 means 4 units).

If you wish to run a 2 ms cycle, this can be achieved by means of various combinations. For example,

Index = -3, Units = 2

or

Index = -4, Units = 20 etc.

The FBUS.SAMPLEPERIOD parameter is counted in multiples of 62.5us microseconds within the device. This means, for example that 2 ms equates to FBUS.SAMPLEPERIOD value of 32.

4.9 Maximum Cycle Times depending on operation mode

The minimum cycle time for the drive is largely dependent on the drive configuration (second actual position value encoder latch functionality enabled and so on)

| Interface | Cycle time AKD |
|-----------|----------------------|
| Position | ≥ 0.25 ms (≥ 250 μs) |
| Velocity | ≥ 0.25 ms (≥ 250 μs) |
| Torque | ≥ 0.25 ms (≥ 250 μs) |

4.10 Synchronization

On all drives, the internal PLL is theoretically able to even out an average deviation of up to 4800 ppm in the cycle time provided by the master. The Drive checks once per fieldbus cycle a counter within the Drive internal FPGA, which is cleared by a Sync0 (Distributed clock) event. Depending of the counter value, the Drive extends or decrease the 62.5[μs] MTS signal within the Drive by a maximum of 300[ns].

The theoretical maximum allowed deviation can be calculated by using the following formula:

$$\max_{dev} = \frac{300[\text{ns}]}{62.5[\mu\text{s}]} \cdot 1,000,000 = 4800 [\text{ppm}]$$

The synchronization functionality within the Drive can be enabled via setting bit 0 of the FBUS.PARAM02 parameter to high. Therefore FBUS.PARAM02 must be set to the value of 1. Furthermore the distributed clock functionality must be enabled by the EtherCAT master in order to activate cyclic Sync0 events.

4.11 Latch Control Word and Latch Status Word

Latch Control word (2 Byte)

| Bit | Value (bin) | Value (hex) | Description |
|-------|-------------------|-------------|---------------------------------------|
| 0 | 00000000 00000001 | xx01 | Enable extern latch 1 (positive rise) |
| 1 | 00000000 00000010 | xx02 | Enable extern latch 1 (negative rise) |
| 2 | 00000000 00000100 | xx04 | Enable extern latch 2 (positive rise) |
| 3 | 00000000 00001000 | xx08 | Enable extern latch 2 (negative rise) |
| 4 | | | |
| 5-7 | | | Reserve |
| 8-12 | 00000001 00000000 | 01xx | Read external latch 1 (positive rise) |
| | 00000010 00000000 | 02xx | Read external latch 1 (negative rise) |
| | 00000011 00000000 | 03xx | Read external latch 2 (positive rise) |
| | 00000100 00000000 | 04xx | Read external latch 2 (negative rise) |
| 13-15 | | | Reserve |

Latch Status word (2 Byte)

| Bit | Value (bin) | Value (hex) | Description |
|-------|-------------------|-------------|--|
| 0 | 00000000 00000001 | xx01 | External latch 1 valid (positive rise) |
| 1 | 00000000 00000010 | xx02 | External latch 1 valid (negative rise) |
| 2 | 00000000 00000100 | xx04 | External latch 2 valid (positive rise) |
| 3 | 00000000 00001000 | xx08 | External latch 2 valid (negative rise) |
| 4 | | | |
| 5-7 | | | Reserve |
| 8-11 | 00000001 00000000 | X1xx | Acknowledge value external latch 1 (positive rise) |
| | 00000010 00000000 | X2xx | Acknowledge value external latch 1 (negative rise) |
| | 00000011 00000000 | X3xx | Acknowledge value external latch 2 (positive rise) |
| | 00000100 00000000 | X4xx | Acknowledge value external latch 2 (negative rise) |
| 12-15 | 00010000 00000000 | 1xxx | Zustand Digital Input 4 |
| | 00100000 00000000 | 2xxx | Zustand Digital Input 3 |
| | 01000000 00000000 | 4xxx | Zustand Digital Input 2 |
| | 10000000 00000000 | 8xxx | Zustand Digital Input 1 |

4.12 Mailbox Handling

With EtherCAT, acyclical data traffic (object channel or SDO channel) is called mailbox. This system is based around the master:

Mailbox Output:

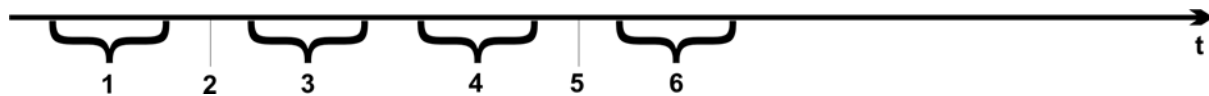
The master (EtherCAT controller) sends data to the slave (drive). This is essentially a (read/write) request from the master. Mailbox output operates via Sync Manager 0.

Mailbox Input:

The slave (drive) sends data to the master (EtherCAT controller). The master reads the slave's response. Mailbox input operates via Sync Manager 1.

Timing diagram

The timing diagram illustrates the mailbox access process:



1. The EtherCAT master writes the mailbox request to the mail-out buffer.
2. On the next interrupt, the EtherCAT interface activates a Sync Manager 0 event (mailbox output event) in the AL event register.
3. The drive reads 16 bytes from the mail-out buffer and copies them to the internal mailbox output array.
4. The drive identifies new data in the internal mailbox output array and performs an SDO access to the object requested by the EtherCAT interface. The response from the drive is written to an internal mailbox input array.
5. The drive deletes all data in the internal mailbox output array so that a new mailbox access attempt can be made.
6. The drive copies the response telegram from the internal mailbox input array to the mail-in buffer of the EtherCAT interface.

4.12.1 Mailbox Output

An interrupt by the EtherCAT-interface with a Sync Manager 0 - Event starts a Mailbox Output Process. A 1 in the Mail Out Event-Bit of the AL Event register signalizes the drive, that the EtherCAT-interface wants to send a Mailbox message and that it has already stored the required data in the Mail Out Buffer. Now 16 Byte data are read by the drive with the IRQ process. The bytes are defined as follows

| Address 0x1800 | | | | | | | | Address 0x180F | | | | | | | |
|---|---|---|---|--|---|---|---|---|---|----|----|----|----|----|----|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| CAN over EtherCAT specific data (CoE Header) | | | | | | | | CAN specific data (standard CAN SDO) | | | | | | | |
| Byte 0 | Length of the data (Low Byte) | | | | | | | | | | | | | | |
| Byte 1 | Length of the data (High Byte) | | | | | | | | | | | | | | |
| Byte 2 | Address (Low Byte) | | | | | | | | | | | | | | |
| Byte 3 | Address (High Byte) | | | | | | | | | | | | | | |
| Byte 4 | Bit 0 to 5: Channel Bit 6 to 7: Priority | | | | | | | | | | | | | | |
| Byte 5 | Bit 0 to 3: Type | | | 1 = Reserved: ADS over EtherCAT 2 = Reserved: Ethernet over EtherCAT 3 = Can over EtherCAT...) | | | | | | | | | | | |
| | Bit 4 to 7: Reserved | | | | | | | | | | | | | | |
| Byte 6 | PDO Number (with PDO transmissions only, Bit 0 = LSB of the PDO number, see Byte 7 for MSB) | | | | | | | | | | | | | | |
| Byte 7 | Bit 0: MSB of the PDO number, see Byte 6 | | | | | | | | | | | | | | |
| | Bit 1 to 3: Reserved | | | | | | | | | | | | | | |
| | Bit 4 to 7: CoE specific type | | | 0: Reserved | | | | | | | | | | | |
| | | | | 1: Emergency message | | | | | | | | | | | |
| | | | | 2: SDO request | | | | | | | | | | | |
| | | | | 3: SDO answer | | | | | | | | | | | |
| | | | | 4: TXPDO | | | | | | | | | | | |
| | | | | 5: RxPDO | | | | | | | | | | | |
| | | | | 6: Remote transmission request of a TxPDO | | | | | | | | | | | |
| | | | | 7: Remote transmission request of a RxPDO | | | | | | | | | | | |
| | | | | 8...15: reserved | | | | | | | | | | | |
| Byte 8 | Control-Byte in the CAN telegram: | | | | | | | | | | | | | | |
| | write access: | | | 0x23=4Byte, 0x27=3Byte, 0x2B=2Byte, 0x2F=1Byte | | | | | | | | | | | |
| | read access: | | | 0x40 | | | | | | | | | | | |
| Byte 9 | Low Byte of the CAN object number (Index) | | | | | | | | | | | | | | |
| Byte 10 | High Byte of the CAN object number (Index) | | | | | | | | | | | | | | |
| Byte 11 | Subindex according to CANopen Specification for the drive | | | | | | | | | | | | | | |
| Byte 12 | Data with a write access (Low Byte) | | | | | | | | | | | | | | |
| Byte 13 | Data with a write access | | | | | | | | | | | | | | |
| Byte 14 | Data with a write access | | | | | | | | | | | | | | |
| Byte 15 | Data with a write access (High Byte) | | | | | | | | | | | | | | |

The drive answers every telegram with an answer in the Mailbox Input buffer.

4.12.2 Mailbox Input

The drive answers every CoE telegram with a 16 byte answer telegram in the Mailbox Input buffer. The bytes are defined as follows:

| Address 0x1C00 | | | | | | | | Address 0x1C0F | | | | | | | |
|---|---|---|---|--|---|---|---|---|---|----|----|----|----|----|----|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| CAN over EtherCAT specific data (CoE Header) | | | | | | | | CAN specific data (standard CAN SDO) | | | | | | | |
| Byte 0 | Length of the data (Low Byte) | | | | | | | | | | | | | | |
| Byte 1 | Length of the data (High Byte) | | | | | | | | | | | | | | |
| Byte 2 | Address (Low Byte) | | | | | | | | | | | | | | |
| Byte 3 | Address (High Byte) | | | | | | | | | | | | | | |
| Byte 4 | Bit 0 to 5: Channel Bit 6 to 7: Priority | | | | | | | | | | | | | | |
| Byte 5 | Bit 0 to 3: Type | | | 1 = Reserved: ADS over EtherCAT 2 = Reserved: Ethernet over EtherCAT 3 = Can over EtherCAT... | | | | | | | | | | | |
| | Bit 4 to 7: Reserved | | | | | | | | | | | | | | |
| Byte 6 | PDO Number (with PDO transmissions only, Bit 0 = LSB of the PDO number, see Byte 7 for MSB) | | | | | | | | | | | | | | |
| Byte 7 | Bit 0: MSB of the PDO number, see Byte 6 | | | | | | | | | | | | | | |
| | Bit 1 to 3: Reserved | | | | | | | | | | | | | | |
| | Bit 4 to 7: CoE specific type | | | 0: Reserved 1: Emergency message 2: SDO request 3: SDO answer 4: TXPDO 5: RxPDO 6: Remote transmission request of a TxPDO 7: Remote transmission request of a RxPDO 8...15: reserved | | | | | | | | | | | |
| Byte 8 | Control-Byte in the CAN telegram: | | | | | | | | | | | | | | |
| | write access OK: | | | 0x60 | | | | | | | | | | | |
| | read access OK + length of answer: | | | 0x43 (4 Byte), 0x47 (3 Byte), 0x4B (2Byte), 0x4F (1Byte) | | | | | | | | | | | |
| | error with read- or write access: | | | 0x80 | | | | | | | | | | | |
| Byte 9 | Low Byte of the CAN object number (Index) | | | | | | | | | | | | | | |
| Byte 10 | High Byte of the CAN object number (Index) | | | | | | | | | | | | | | |
| Byte 11 | Subindex according to CANopen Specification for Kollmorgen drive | | | | | | | | | | | | | | |
| Byte 12 | Data (Low Byte) | | | | | | | | | | | | | | |
| Byte 13 | Data | | | error code Fehlercode according to CANopen Specification in case of an error | | | | | | | | | | | |
| Byte 14 | Data | | | data value of the object in case of successfull read access | | | | | | | | | | | |
| Byte 15 | Data (High Byte) | | | | | | | | | | | | | | |

4.12.3 Example: Mailbox Access

In the example below, PDOs 0x1704 are mapped (see Chapter # “Fixed PDO Mappings”):

The master sends this mailbox output message:

| | | |
|----------------|------|--|
| Byte 0 | 0x0A | The next 10 Bytes contain data (Byte 2 to Byte 11) |
| Byte 1 | 0x00 | The next 10 Bytes contain data (Byte 2 to Byte 11) |
| Byte 2 | 0x00 | Address 0 |
| Byte 3 | 0x00 | Address 0 |
| Byte 4 | 0x00 | Channel 0 and Priority 0 |
| Byte 5 | 0x03 | CoE Object |
| Byte 6 | 0x00 | PDO Number 0 |
| Byte 7 | 0x20 | PDO Number 0 and SDO-Request |
| Byte 8 | 0x2B | 2 Byte write access |
| Byte 9 | 0x12 | SDO-Object 0x1C12 |
| Byte 10 | 0x1C | SDO-Object 0x1C12 |
| Byte 11 | 0x01 | Subindex 1 |
| Byte 12 | 0x04 | Data value 0x00001704 |
| Byte 13 | 0x17 | Data value 0x00001704 |
| Byte 14 | 0x00 | Data value 0x00001704 |
| Byte 15 | 0x00 | Data value 0x00001704 |

The drive returns the following message:

| | | |
|----------------|------|--|
| Byte 0 | 0x0E | The next 14 Bytes contain data (Byte 2 to Byte 15) |
| Byte 1 | 0x00 | The next 14 Bytes contain data (Byte 2 to Byte 15) |
| Byte 2 | 0x00 | Address 0 |
| Byte 3 | 0x00 | Address 0 |
| Byte 4 | 0x00 | Channel 0 and Priority 0 |
| Byte 5 | 0x03 | CoE Object |
| Byte 6 | 0x00 | PDO Number 0 |
| Byte 7 | 0x20 | PDO Number 0 and SDO-Answer |
| Byte 8 | 0x60 | Successful write access |
| Byte 9 | 0x12 | SDO-Object 0x1C12 |
| Byte 10 | 0x1C | SDO-Object 0x1C12 |
| Byte 11 | 0x01 | Subindex 1 |
| Byte 12 | 0x00 | Data value 0x00000000 |
| Byte 13 | 0x00 | Data value 0x00000000 |
| Byte 14 | 0x00 | Data value 0x00000000 |
| Byte 15 | 0x00 | Data value 0x00000000 |

4.13 Fieldbus Parameters

The AKD Drive holds several fieldbus specific general purpose parameter. Some of them contain the following EtherCAT relevant data:

FBUS.PARAM02: This parameter activates the synchronization feature of the AKD. The DC feature must be activated in order to allow the AKD to get synchronized with the master. A value of 1 enables the Drive internal PLL functionality, a value of 0 deactivates this feature.

FBUS.PARAM03: This parameter contains the Configured Station Alias address of the AKD. An EEPROM emulation write access to the Configured Station Alias address forces the AKD to store the Drive parameters automatically via a DRV.NVSAVE command.

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