BECKHOFF New Automation Technology

Short information EMC | EN

AX5000

Servo drive

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1 Foreword

1.1 Notes on the documentation

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 the 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.

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1.2 Documentation issue status

Issue	Comment
1.1	**Chapter update:** 4.1
1.0	First edition

2 Safety

2.1 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 symbols

In this documentation the following symbols are used with an accompanying safety instruction or note. The safety instructions must be read carefully and followed without fail!

⚠ DANGER

Serious risk of injury!

Failure to follow the safety instructions associated with this symbol directly endangers the life and health of persons.

⚠ WARNING

Risk of injury!

Failure to follow the safety instructions associated with this symbol endangers the life and health of persons.

⚠ CAUTION

Personal injuries!

Failure to follow the safety instructions associated with this symbol can lead to injuries to persons.

NOTE

Damage to the environment or devices

Failure to follow the instructions associated with this symbol can lead to damage to the environment or equipment.

Tip or pointer

This symbol indicates information that contributes to better understanding.

3 General Information

Earthing

Earthing is an electrically conductive connection to the electrical potential of the ground. Earthing is a form of ground connection. The neutral potential is not necessarily the earth potential. Ground connection creates a conductive connection to the environment. Earthing or grounding refers to a situation where this environment includes the ground (e.g. steel reinforcement in a concrete floor) or is conductively connected to it. On the one hand there is the live conductor, also referred to as the phase (L), on the other hand the neutral conductor (N) and the protective earth conductor (PE), also referred to as earthing conductor, earthing or earth in short. Together with a residual current device (RCD) or residual current circuit breaker (RCCB), the sole purpose of the earthing conductor is personal protection in relation to electrical wires and systems. Earthing refers to the entirety of all earthing means for the purpose of discharging electrical currents into the foundation earthing.

Grounding

Ground (GND) refers to a conductive body, which is usually assigned zero potential. This represents the reference potential for all signal and operating voltages. In principle, any node of an electrical circuit can serve as ground and be used as reference potential for the specification of all voltages in the respective network. The ground can be potential-free and is in any case connected directly to the protective conductor with the electrical potential of the conductive foundation earthing, as required.
In many case the negative terminal of the power supply also acts as ground. The positive terminal of the power supply and all other voltage and electrical signals of a circuit refer to the neutral (ground) potential. Ground is the common connection for most components.

Protective conductor

In order to be able to establish an effective protective earth conductor system, in addition to the protective conductors and all electronic components all conductive components of a machine must be included in the protective earth conductor system through equipotential bonding.

NOTE

Installation of electrical systems and components!

When installing electrical systems and components, the protective earth conductors should always be connected first and removed last. The specifications for the protective earth conductor connections depend on the level of leakage currents. The minimum requirement for the protective earth conductor is a KU value[1)] of 4.5 for leakage currents I_L < 10 mA or KU = 6 for I_L > 10 mA.

[1)] The KU-value is a variable for the classification of safety-related types of failure for protection against dangerous shock current and excessive heating. A value of KU = 4.5 in relation to interruption is attained:

- with a permanently attached protective conductor ≥ 1.5 mm²
- for protective earth conductor connections ≥ 2.5 mm² with plug connectors for industrial systems (IEC 60309−2).

KU = 6 in relation to interruption is attained with permanently connected conductors ≥ 10 mm², wherein the type of connection and routing must comply with the standards applicable to PE conductors.

Measuring leakage currents!

The full cable lengths must be connected for measuring leakage currents. The measurement can take place without load. Further information can be found in section: “Leakage currents”.

4 Potential equalization

Potential equalization is used to create electrical connections between conductive components, in order to achieve potential equality. Furthermore, a conductive connection ensures equalization of charge differences between two bodies or components. All protective conductors and equipotential bonding conductors come together at the main earthing bar (PE bar) and are connected to the foundations earthing (steel reinforcement in concrete slabs) via the earthing conductor.

Potential equalization is also intended as protection against dangerous electrostatic discharge (ESD). To this end persons and equipment are connected to the foundation earthing through special devices to ensure that potential differences are rendered harmless.

This potential equalization can fulfil two different tasks in the electrical installation of a machine:

1. Protection

- Personal protection against electric shock in the event of a fault in the machine or system, by means of a protective conductor system.

2. Functional potential equalization

- To prevent malfunctions (as a result of shield faults) and to improve electromagnetic compatibility (EMC) of sensitive electronic components.

The following schematic diagram illustrates the purpose of potential equalization:

Potential equalization is also a “requirement for protection against electric shock”. It is specified in the international IEC 60364-4-41:2005 standard and the German DIN VDE 0100-410:2007-06 standard.

Connection of all conductive bodies (housings) of electrical components to a grounded protective conductor and the main earthing bar is the basis for protection against electric shock. The main protective measure specified in the VDE standard, i.e. automatic disconnection of the power supply in the event of a fault, is ensured through standard-compliant installation and subsequent testing of the system. The test also serves to verify adequately small loop impedance for automatic switch-off in the event of a fault.

The technical implementation of the potential equalization, the dimensioning of the cross-sections and the standardized terminology are specified in the international IEC 60364-5-54:2011 standard and the German DIN VDE 0100-540:2012-06 standard.

NOTE

Separation of protective and neutral conductor!

Please ensure that the network has **separate** protective (PE) and neutral (N) conductors and that the two conductors are not connected to the same potential (protective and neutral conductor = PEN).

Mains systems

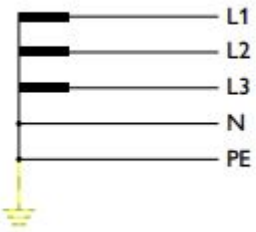
TN-C system

In a TN-C system the star point of all cables (L1, L2, L3 and PEN) is grounded directly. The neutral conductor (N) and the protective conductor (PE) are consolidated in a single conductor (PEN).

In a three-phase power supply four cables are used, as shown in the sample on the left:
L1, L2, L3 and PEN.

The following section describes TN-S systems, which are recommended by Beckhoff Automation GmbH & Co. KG from the perspective of **E**lectro **M**agnetic **C**ompatibility (EMC).

TN-S system

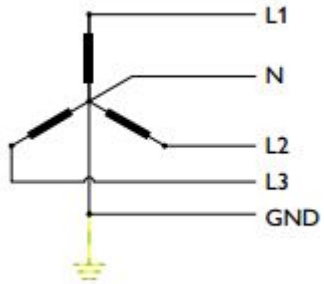


Similar to a TN-C system, in a TN-S system the star point of all cables (L1, L2, L3, N and PE) is also grounded directly. The neutral conductor (N) and the protective conductor (PE) are connected separately to the consumer.

In a three-phase power supply five cables are used, as shown in the sample on the left:
L1, L2, L3, N and PE.

The transition from a TN-C system to a TN-S system is indicated with a blue cable.

Wye system (Solidly Grounded Wye)

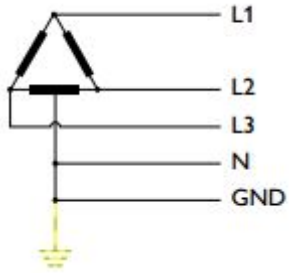


In a Wye system the star point of all cables (L1, L2, L3, N and GND) is grounded and brought together in the center. In this mains system the protective earth conductor (GND) must not carry any current. The neutral conductor N (grounded conductor) must be separate and should only be tapped within the consumer system. In Germany TN-C-S mains systems are used.

In many cases such systems are also used in the US as standard.

In a three-phase power supply five cables are used, as shown in the sample on the left:
L1, L2, L3, optionally N and GND.

Delta system (Corner Grounded Delta)

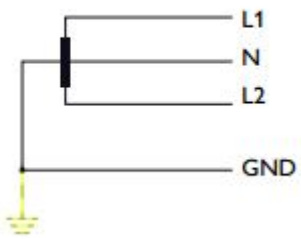


In a delta system all connected components are grounded directly. This is done independent of the current source earthing. The protective earth conductor (GND) must not carry any current! The neutral conductor N (grounded conductor) must be separate and should only be tapped within the consumer system. Special measures, e.g. mains filters, must be applied in order to meet EMC requirements.

These systems have no direct counterpart in the IEC standard. Earthing takes place either via one of the phases (Corner Grounded) or via a center tap between two phases (High-Leg).

In a three-phase power supply five cables are used, as shown in the sample on the left:
L1, L2, L3, optionally N and GND.

Split-phase system



In a split-phase system earthing takes place via a center tap between the two phases. The neutral conductor is carried from there.

In a three-phase power supply four cables are used, as shown in the sample on the left:
L1, N, L2 and GND.

Potential differences:

- Several spatially separated mounting plates within a control cabinet
- Several control cabinets, which are spatially separated within the application
- Operation of several local servo drives (AX5000 / AX8000)
- Feeding of the control cabinet components from different suppliers

All potential differences result in leakage currents (potential equalization currents). For further information please refer to section: “Leakage currents” in the system manual for the AX5000 servo drive.

Potential differences also affect control and feedback signals, cause interference in communication devices and can render electronic components inoperable.

To reduce potential differences you have to:

- Establish a potential equalization. Earthing straps with a large surface and a large contact area should be used for connecting unpainted mounting plates and control cabinets.
- Establish a power supply with a common potential.
- Provide large-surface shield connections.

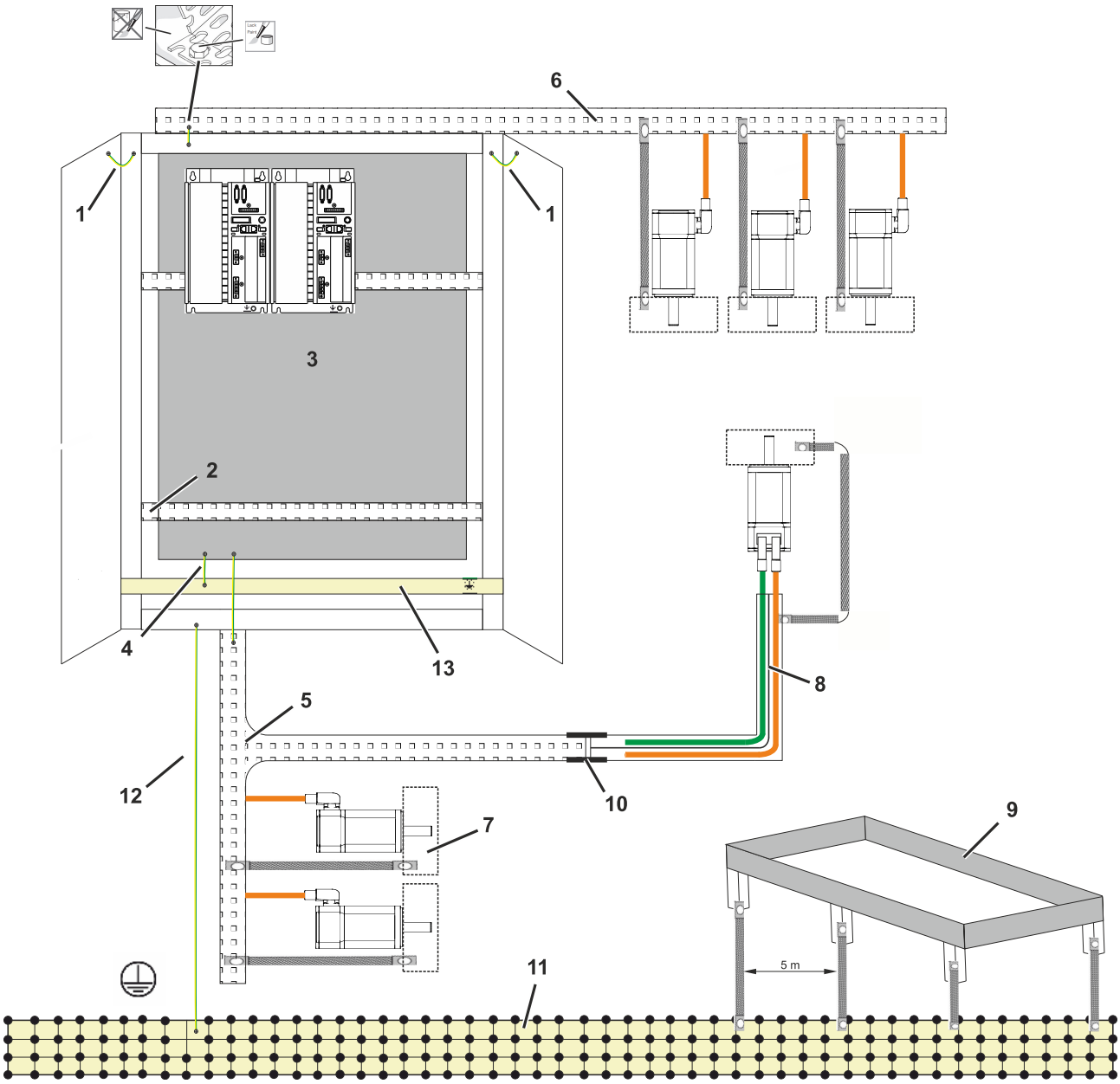
Electrical safety and EMC considerations

- From a personal protection measures (PPM) perspective, the PE bar in the control cabinet is used as star point.
- From an EMC perspective, Beckhoff Automation GmbH & Co. KG recommends using the unpainted mounting plate in the control cabinet as star point for potential equalization.

Conductor cross-sections for potential equalization cables

The potential equalization cables should be as short as possible. The conductor cross-section should be rectangular and flat. The cross-section of your potential equalization cable must be adequately dimensioned.

The following diagram shows an exemplary potential equalization configuration with different components. Note that potential equalization is application-specific, and the following sample should therefore not be regarded as a standard solution!



Item number	Explanation
1	Control cabinet door with earthing strap connection
2	DIN rail for component mounting
3	Unpainted mounting plate in the control cabinet
4	Earthing strap connection between PE bar and unpainted mounting plate
5	Large-surface cable duct connection
6	Cable duct made of sheet metal
7	Potential equalization between motor (OCT) and cable duct (HF-compatible) via flanged adapter plate
8	Separating bar in the cable duct for signal (green) and power cable (orange)
9	Potential equalization between machine frame and foundation earthing
10	Conductive connection of the metallic cable duct
11	Foundations earthing with steel reinforcement in the concrete slab
12	Earthing strap connection between control cabinet and foundation earthing
13	PE bar in the control cabinet

Installation of potential equalization

Note the following when installing potential equalization:

- **Protective conductor connection**
  Connect the control cabinet doors (1) to the control cabinet via a protective earth conductor cable (cross-section ≥ 10 mm² Cu).
  Connect the mounting plate of the control cabinet (3) to the PE bar (13) via a protective earth conductor cable (cross-section ≥ 10 mm² Cu).
  Connect the control cabinet to the foundation earthing (11) via a protective earth conductor cable (cross-section ≥ 10 mm² Cu). In addition, all cable ducts must connected to the control cabinet via a protective earth conductor cable (cross-section ≥ 10 mm² Cu).
- **Connection of motors and gear units**
  Connect all motors and gear units of your application to the metallic cable ducts via earthing straps.
- **Connection of metallic cable ducts**
  Metallic cable ducts should always be connected to each other over a large area.
  The connections of the protective earth conductor cables should be a short as possible. All connections must be metallically pure! Never connect the protective conductors to painted surfaces! Clean all joints with a commercial industrial cleaner before connecting components.

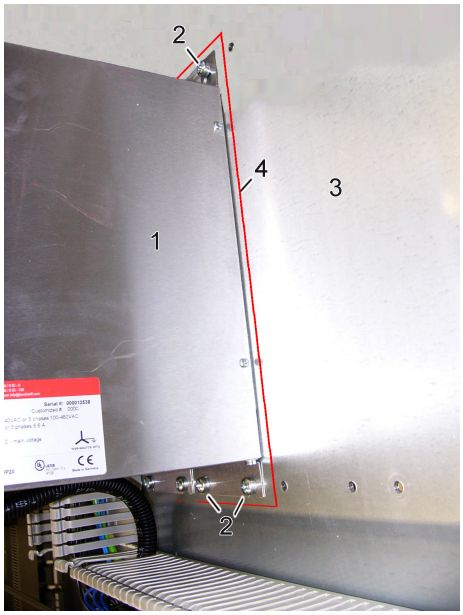
4.1 Installation in the control cabinet

We recommend installing the control electronics and the power electronics spatially separated in two metallic control cabinets. Both control cabinets should be connected to the ground potential with low-resistance, in order to ensure maximum interference immunity. A metallic cable duct between the two control cabinets mounted near the floor ensures that potential equalization can take place between them. If only one control cabinet is feasible, ensure that components susceptible to interference are shielded from strong interference emitters through a low-resistance grounded metallic partition.

Potential equalization!

System-wide safety can only be ensured if all drivetrain components are on the same potential.
Please refer to section: “Potential equalization” of this documentation.

Installing the AX5000



The AX5000 (1) must be installed on a metallic mounting plate (3) with four M6 threaded screws (2). The mounting plate must be connected to the metallic control cabinet via a low-resistance connection. If the mounting plate (3) is painted, remove the paint in the area where the AX5000 (4) is connected.

Earthing bolt!

If painted mounting plates are used, the servo drive can be earthed with the earthing bolt and an earthing strap at a painted point of the mounting plate.

5 Shielding concept

Why do cables have to be shielded?

Cables are equipped with shielding in order to keep electrical or magnetic fields away from technical devices, buildings or rooms. This shielding protects the environment from interference emanating from the cables.

Electromagnetic waves are a combination of electrical and magnetic fields. These waves have magnetic and electrical components. Cables are shielded in order to prevent interference within the cable and outside the cable.

Shielding is used to improve electromagnetic compatibility (EMC) and to ensure trouble-free signal transfers.

The effect of motor or signal line shields can be measured as impedance. The impedance indicates the relationship between sinusoidal alternating voltage and sinusoidal alternating current. The temporal shift of the phase angle between the these parameters (current and voltage) is the phase shift angle (power factor).

Loop impedance

The loop impedance is the sum of all impedance values in a closed circuit through which interference currents flow.

The interference currents of the loop impedance are composed of:

- the current source
- the non-grounded conductor between the current source and the fault location
- the return wire to the current source

Line connection to the AX5000

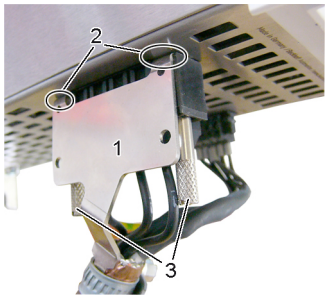
A further cause of electromagnetic interference is incorrect line connection. As already mentioned in section “Cables”, the shield braid should be connected to the metallic housing of the plug connector or a special shroud via a surface that is as large as possible. When the plug connector is screwed to the servo drive, ensure that low-resistance contact to the shield-carrying components with the metallic housing (potential) of the servo drive is created.

Cable lengths

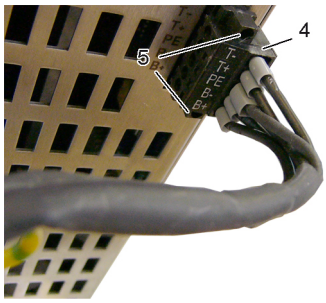
With longer motor cables the resulting commutation currents can lead to EMC faults. Mains chokes or mains filters may have to be used, depending on the application. The fitting dimensions for any mains chokes or mains filters etc. that may be required should be taken into account when dimensioning the control cabinet. Run the power and signal cables in separate metallic cable ducts, as shown in our Potential equalization [▶ 9] sample. If a common cable duct is used, a grounded, metallic partition between the cables should be used, as shown in our Potential equalization [▶ 9] sample.

More detailed information and overview tables for the cable lengths can be found in section 9.15: “Motors and cables for servo drives” of the AX5000 system manual!

Motor connector, brake and temperature contact

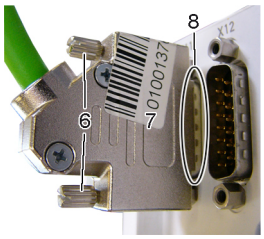


For the motor connector the connection of the shroud (1) is particularly important in terms of interference immunity. The shroud (1) is connected to the metallic housing of the AX5000 via two straps (2). To ensure safe contact, tighten the two screws (3) with a suitable tool.



The brake temperature plug (4) must be securely connected with the two screws (5). The shield connection is established via the PE pin, which is internally connected to the metallic housing of the AX5000.

Feedback connector



The shield is connected via the trapezoidal sheet (8), which is connected to the metallic housing (7). In the AX5000 the counterpart is internally connected to the metallic housing of the AX5000. The screws (6) must be tightened securely, in order to ensure that the trapezoidal sheet (8) is connected to the counterpart with low resistance.

Tightening torques

Please note the tightening torques for the motor and feedback connectors! Detailed information can be found in sections: “Motors” and “Feedback” of the AX5000 system manual!

Shield concept

NOTE

Pre-assembled power and signal cables!

The company Beckhoff Automation offers pre-assembled power and signal cables. The cables are tested with regard to material, shielding and connection type. If such pre-assembled cables are used, Beckhoff guarantees proper functioning and compliance with statutory regulations such as EMC, UL etc.
The use of other cables or application of custom cable shield can result in unexpected interference and may void the warranty!
Please refer to other relevant sections in this chapter!

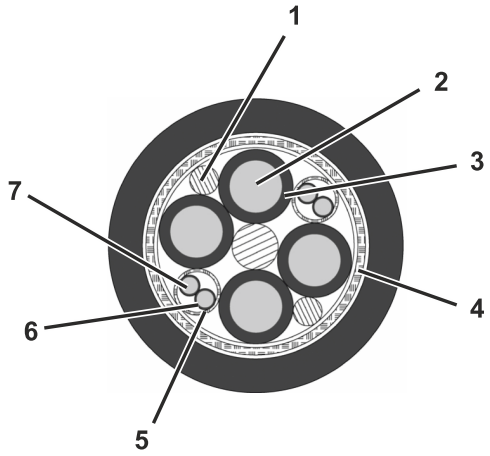
In practice, pre-assembled Beckhoff motor and signal cables are often shortened or re-configured on site.

Re-configuration or shortening of the cables can lead to the following problems:

- the shielding effect of the cables becomes inadequate;
- high-frequency interference currents enter brake lines etc.

If the motor cable is only connected on one side, the shielding effect is inadequate!

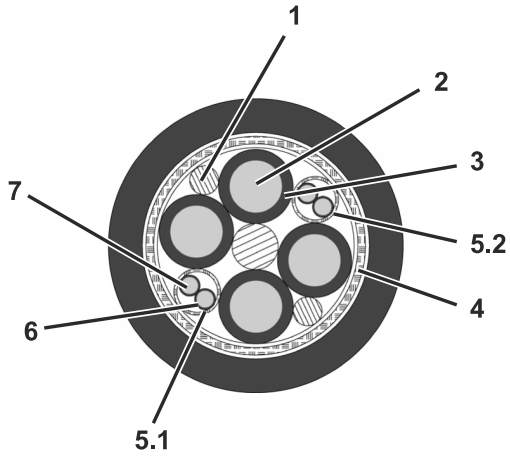
Motor cable ZK4509-0019-xxxx



Item no. with explanation

1	Filling material
2	Stranded power wire
3	Wire isolation (power)
4	External shield
5	Highly flexible inner shield for particularly dynamic requirements
6	External shield for the brake line
7	Stranded brake wire

Feedback cable ZK4509-0019-xxxx



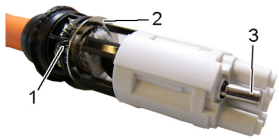
Item no. with explanation

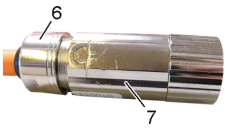
1	Filling material
2	Stranded power wire
3	Wire isolation (power)
4	External shield
5.1	Highly flexible inner brake shield for particularly dynamic requirements
5.2	Highly flexible inner shields for the thermal contact / OCT for particularly dynamic requirements
6	Wire isolation (thermal contact / OCT)
7	Stranded signal wire

Motor cable

Motor cables of servo drives are inherently subjected to strong EMC interference sources and belong to cable category 1. The precise specifications of the motor cable can be found in the “AX5000 user manual → Accessories → Cables”. The main characteristics of EMC-compliant cables are described below.

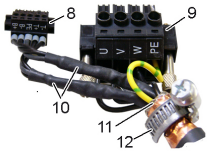
View “X”

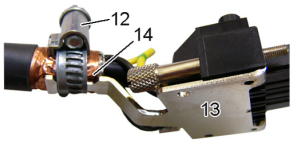


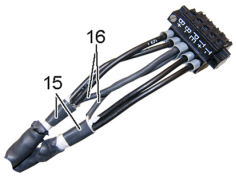


The surrounding shield braid (1) is flush with the metallic shielding ring (2). The PE conductor ends in a metallic sleeve (3). Ensure the sleeve (3) is fitted securely in the receptacle (4) when fitting the inner part to the outer part. The shielding ring (2) should be flush with the perimeter edge (5). The joint (6) must be screwed securely to the outer part (7), in order to ensure that the shielding ring (2) and the sleeve (3) have maximum contact with the outer part (7).

View “Y”







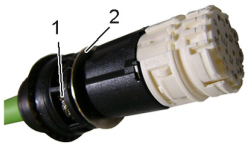
The wires of the motor connector (9) and the two pairs of wires (10) of the brake temperature connector (8) are brought together in one line (11). The whole line (11) is covered by a shield braid (1) and secured to the shroud with a shield clamp (12).

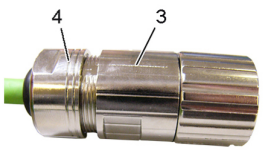
Ensure that the shield braid (1) is protected with copper foil (14) and secured with the shield clamp (12) on the shroud (13). The two pairs of wires (10) of the brake temperature connector (8) are pairwise twisted and covered with a shield braid (15). Two wires are soldered to this shield braid and screwed to the PE pin of the brake temperature connector.

Feedback cable

Feedback cables of servo drives are inherently non-interfering and EMC sensitive and belong to cable category 4. The precise specifications of the feedback cables can be found in the “AX5000 user manual → Accessories → Cables”. The main characteristics of EMC-compliant cables are described below, using an encoder cable as an sample.

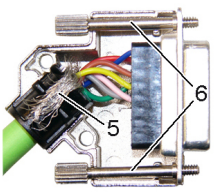
View “X”

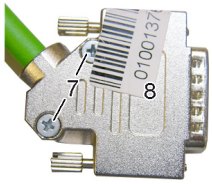




The surrounding shield braid (1) is flush with the metallic shielding ring (2). The joint (4) must be screwed securely to the outer part (3), in order to ensure that the shielding ring (2) has maximum contact with the outer part (3).

View “Y”





Ensure that the surrounding shield braid (5) has maximum contact with the strain relief. Both screws (6) must be flush in the housing. The two screws (7) must be tightened securely, in order to ensure that the shield braid (5) has maximum contact with the housing (8) via the strain relief.

Single-sided connection of the inner shield of the motor cable can lead to damage of the servo drive in the long term and result in damage to the brake coil as a consequence.

A TF line with shielding that is not grounded on both sides can trigger a feedback error.

Apply the shields of the motor and signal cables on both sides!

NOTE

Intermediate shield!

In general it is not recommended to apply an additional shield at the earthing points (intermediate shield).

Using motors with OCT feedback

Only pre-assembled OCT cables from Beckhoff Automation GmbH & Co. KG must be used in conjunction with motors with OCT feedback. Please note that the use of custom-assembled OCT cables voids any warranty offered by Beckhoff Automation GmbH & Co. KG!

6 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:
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You will also find further documentation for Beckhoff components there.

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