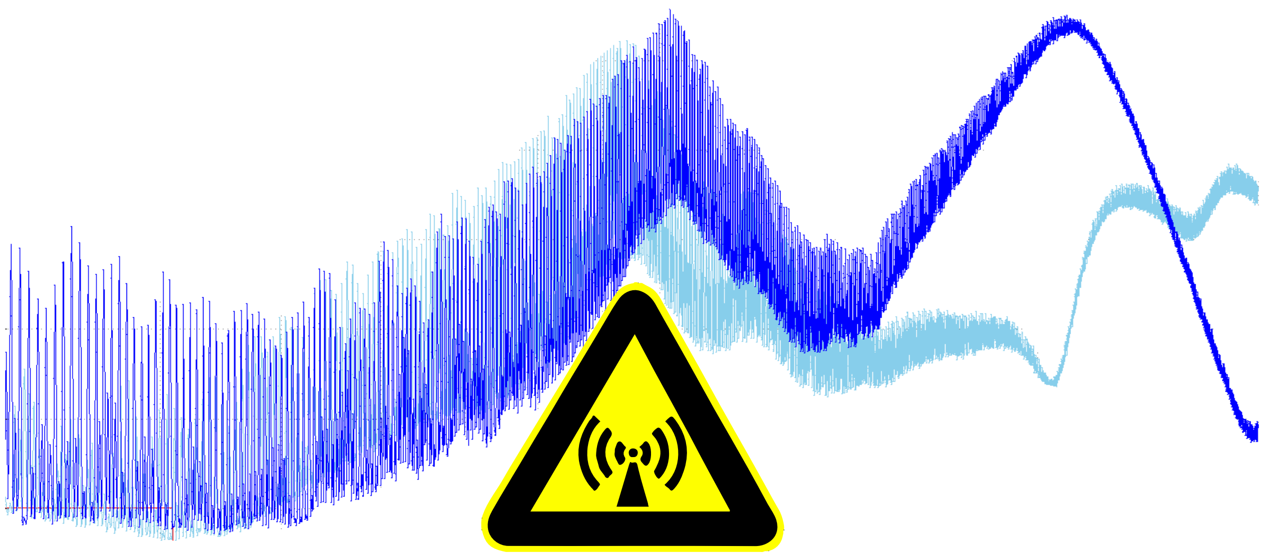
Technical Info | Technic Note

EMC Compliant Installation

for KEB drive controllers



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1 Preface

The Technic Notes contain additional information about the units and accessories. They are helping constructors and developers to use KEB products in their applications. However, they are considered for information only without responsibility. The selection with regard to their suitability for the intended use can only be made by the user. If you have any questions, please contact KEB Automation KG or your area representative.

The use of our devices in the target products is beyond of our control and therefore exclusively the responsibility of the machine manufacturer, system integrator or customer.

This document is not legally part of the certified device documentation. The functions described in the current KEB documentation must always be given priority. The enclosed documents correspond to conditions valid at printing. Misprint, mistakes and technical changes reserved.

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2 Introduction

This guideline is intended to provide basic knowledge of electromagnetic compatibility (EMC). It contains information on how to avoid interference and how to install the device correctly in order to obtain EMC-compatible conformity.

2.1 About the content

The constantly increasing use of electronic circuits and systems, especially in the industrial sector, is increasingly leading to problems with electromagnetic compatibility (EMC).

In order to be able to counteract this, the causes and effects need to be recognised and understood.

The responsibility for an EMC-compatible design of a system is mainly borne by the system manufacturer. Subsequent adjustments are often only possible to a limited extent and usually not without a high financial expense. For this reason, appropriate EMC measures should already be included in the planning and construction of systems.

According to the currently valid regulations, there must be an EMC plan for each system / machine and for the safety considerations.

This must include:
- Description / specification of the EMC requirements
- Instructions from the component manufacturers and how these are observed
- Assurance in production how this is implemented
- Proof of compliance (measurement, assessment)

2.2 What is EMC?

The operation of electronic devices can generate electromagnetic fields which can penetrate and interfere with the application range of other electronics. An example of this would be the limited use of mobile phones in airplanes. These can emit electromagnetic fields which can significantly affect the electronics of the airplane.

EMC is the term used to describe the electromagnetic compatibility of electronic devices with each other. If an electrical device has electromagnetic compatibility, this device can operate without interfering with or being interfered by other electronic devices.

In EMC, a distinction is made between interference sources and interference sinks. The strength of this interferences is influenced by the transmission path.

The **interference source** is a component or assembly which generates the interference signal.

The **interference sink** is a component or assembly which reacts sensitively to the interference signal. Their operating behaviour is influenced by the interference signal.

The **transmission path** is the coupling between the interference source and the interference sink, which transmits the interference signal from its source to the location of its undesired effect.

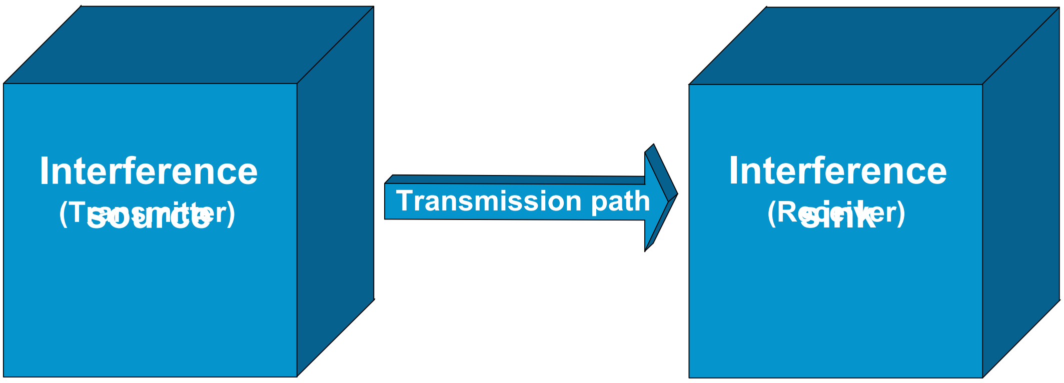


Fig. 1: Interference source, interference sink and transmission path

Simplified, the greater the distance between the interference source and the interference sink, the lower the interference. If the distance is too short and there is no other shielding, interference sources can influence interference sinks.

Location	Interference source	Transmission path	Interference sink
Target	Limitation of the generation of interferences	Limitation of the transmission of interferences	Limitation of the effect of interferences
Possible measures	Circuit concept Ground connection Separation Arrangement Interference suppression Switching frequencies Shielding	Ground connection Filtering Separation Arrangement Twisting Transmission Line topology Galvanic isolation Shielding	Circuit concept Ground connection Filtering Separation Arrangement Shielding

Tab. 1: Measures to reduce interferences

3 EMC fundamentals

3.1 Use of drive controllers

Drive controllers are electrical equipment for the use in industrial and commercial systems. According to the Directive 2014/30/EU, these devices do not require labelling, as they are components for further processing by the competent machine and system manufacturer in the sense of the EMC Directive and cannot be operated independently. The installer / operator of a machine / system must provide proof of compliance with the protection targets required by the EMC Directive. Using the radio interference suppression filters measured by KEB, as well as observing the following measures and installation guidelines, compliance with the specified limit values is usually given.

3.2 Operation site

According EN 61800-3 to, the operation site can be divided into two environmental areas.

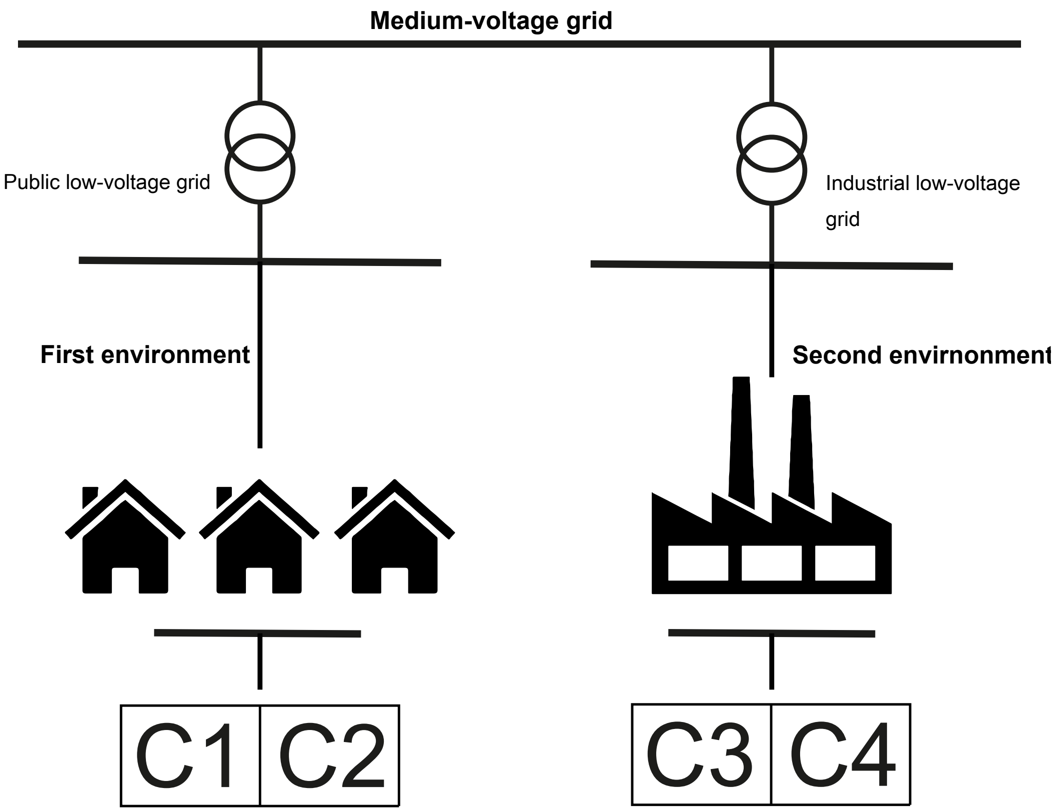


Fig. 2: Overview of the operation sites

3.2.1 First environment

3.2.1.1 Residential areas

A residential area is a spatial area intended for the construction of residential buildings. Residential buildings are places where one or more people can live. A residential building may be a single building (such as a single-family home), a separate building, or a single, detached part of a larger building (such as an apartment in an apartment block). The electrical mains power at such a location is drawn by a direct connection to the public low-voltage grid.

Notes on the residential area:

- Examples of residential areas are houses, apartments or farmhouses that are used to live in.

- It is expected that in residential areas radio receivers are operated at a distance of 10 m from the device.
- DC-powered or battery-powered devices intended for residential use included.

3.2.1.2 Business and commercial areas and small businesses

Places that are not residential areas but they receive their electrical mains power by a direct connection from the public low-voltage grid.

Notes on business and commercial areas:

Examples of such areas are:
- Stores, wholesale markets
- Business premises (offices, banks and financial institutions, hotels, data centers)
- Areas used for public entertainment (cinemas, public restaurants, dance halls or discotheques)
- Places used for religious practice (temples, churches, mosques, synagogues)
- Outdoor locations (gas stations, parking lots, amusement and sports facilities)
- Places for the general public (parks, amusement facilities, offices, service centers)
- Hospitals, educational institutions (schools, universities)
- Public transport areas, train stations and airports

These areas exclude the industrial area defined in IEC 61000-6-4.

3.2.2 Second environment

Locations outside of residential areas and industrial areas which are supplied by their own transformer from the medium-voltage grid.

Examples of second environment locations are industrial areas and technical areas of buildings which are supplied by their own transformer.

3.2.2.1 Industrial area

Industrial areas are characterized by the connection to their own power supply grid. The power supply grid is supplied by its own high or medium voltage distribution transformer, which is responsible for the power supply of the system.

Notes on industrial areas

Examples of industrial sectors include metal processing, pulp and paper processing, chemical plants and motor vehicle production.

These include:
- Use of industrial, scientific and / or medical devices.
- Use of large inductive or capacitive loads that are switched frequently.
- High voltages and / or currents and associated high electromagnetic fields.

4 The drive controller as interference sink

4.1 Possible interference coupling

Interference generated by interference sources can influence the interference sink via different transmission paths. A basic distinction is made between galvanic, capacitive, inductive and electromagnetic interference couplings.

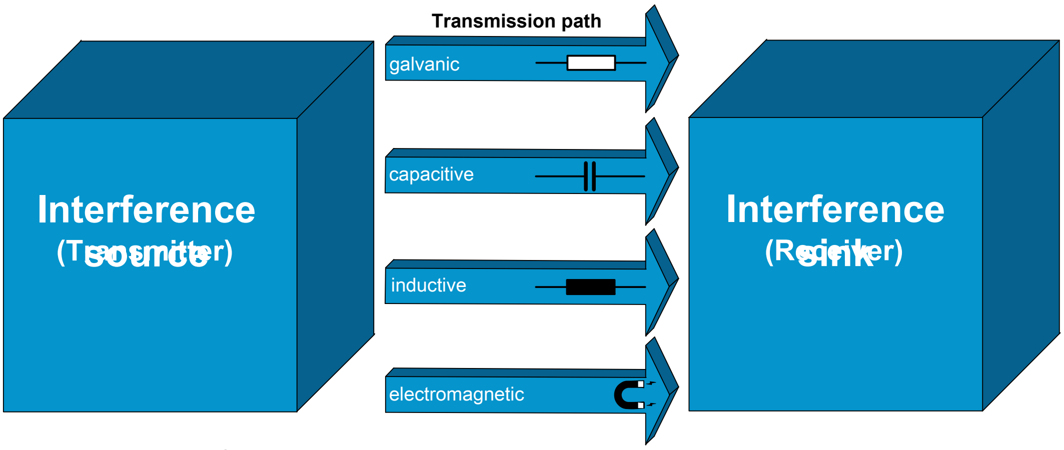


Fig. 3: Possible interference coupling

4.1.1 Galvanic interference coupling

A galvanic interference coupling occurs when several circuits use a common conductor. For example, a common ground line or ground connection. The current *I1* in component 1 generates at the impedance *Z* of the common conductor a voltage drop ΔU1, by which the voltage at the terminals of component 2 will be changed. Conversely, the current *I2* of component 2 generates a voltage drop ΔU2 at the impedance *Z* of the common conductor, by which the voltage at the terminals of component 1 will be changed.

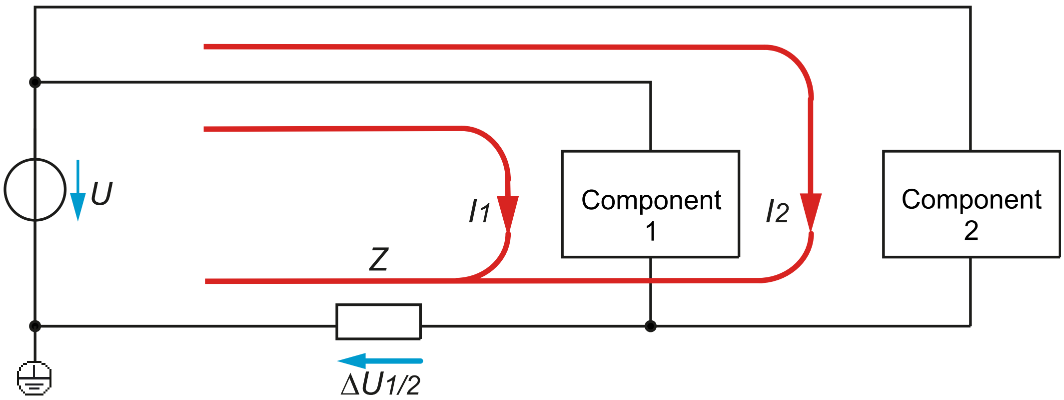


Fig. 4: Galvanic interference coupling

If, for example, the voltage source *U* is a 24V power supply unit which supplies two assemblies with DC voltage, component 1 is a switching power supply with a periodic, pulse-shaped current consumption and component 2 is a sensitive interface assembly for analog signal transmission, then component 1 acts as interference source. This interfere source disturbs via the galvanic coupling, i.e. via the voltage drop *ΔU* at the common impedance *Z* the supply voltage at the terminals of the interface module acting as interference sink, which can negatively affect the quality of the analog signal transmission.

4.1.1.1 Measures to reduce galvanic interference coupling

- Keep the length of shared conductors as short as possible.

- Use of large cable cross-sections if the common impedance has a predominantly ohmic character.
- Use of a separate supply and return conductor per circuit.

4.1.2 Capacitive interference coupling

A capacitive interference coupling occurs between mutually insulated conductors which are at different potentials. Due to the potential difference, there is an electric field between the conductors, which is described by the capacitance *Ck*. The size of the capacitance *Ck* depends on the geometry and the distance of the conductors at different potentials.

Figure 5, "Capacitive interference coupling" , shows a source of interference that couples an interference current *IS* into the interference sink via capacitive interference coupling. The interference current *IS* generates a voltage drop at the impedance *Zi* of the interference sink and thus an interference voltage *US*.

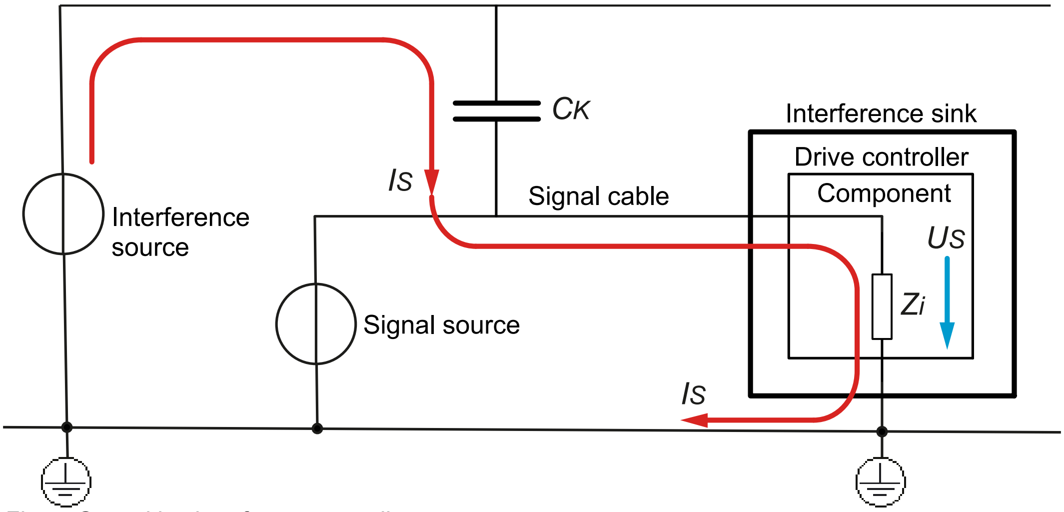


Fig. 5: Capacitive interference coupling

If, for example, a motor cable and an unshielded signal cable are laid in parallel on a cable rack in a short distance over a longer distance, the short distance results in a very large coupling capacitance *Ck*. The inverter on the motor side of the drive controller, which acts as source of interference, couples with each switching edge a pulsed interference current via the capacitance *Ck* into the signal cable. If this interference current flows e.g. via the digital inputs into the control unit of the drive controller, even small interference pulses lasting a few microseconds and an amplitude of a few volts can disturb the digital control of the drive controller executed via microprocessors and this can lead to a malfunction.

4.1.2.1 Measures to reduce capacitive interference coupling

- Keep the distance between the disturbing and the disturbed cable as large as possible.
- Keep the length of the parallel cable routing as short as possible.
- Use of shielded signal cables.

The most effective measure is the consistent separation of power and signal cables in combination with shielding of the signal cables. The interference current *Is* is now coupled into the shield and flows via the shield and housing of the device or drive controller to ground without disturbing the internal circuits.

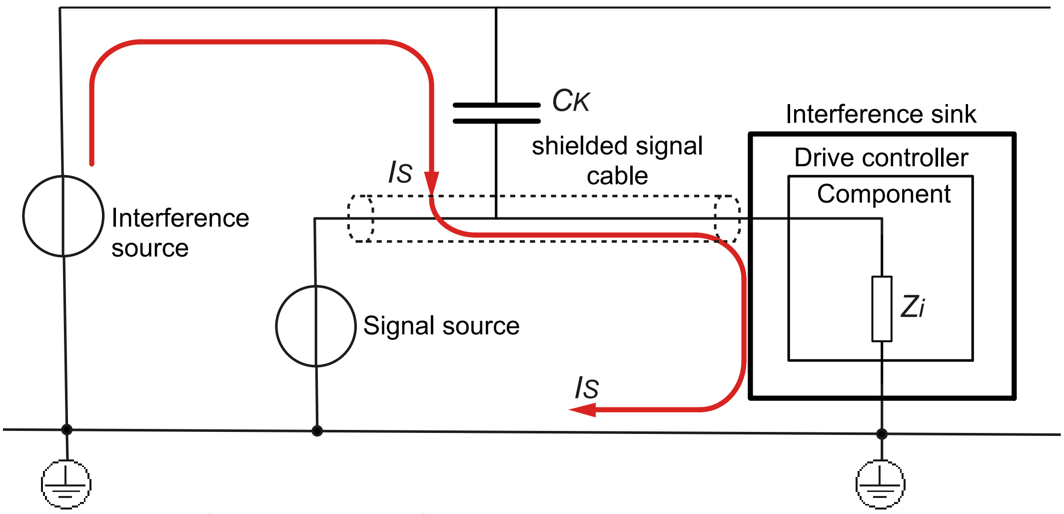


Fig. 6: Reduction of the capacitive interference coupling due to shielded signal cable

The condition for an optimum effect of the shield is a large-area, low-inductance shield connection.

- For digital signal cables, the shield must always be applied over a large-area on both sides (at the transmitter and at the receiver).
- For analog signal cables, low-frequency interferences (ground loops) can result if the shield is applied on both sides. In this case, the shield must only be applied to one side of the drive controller.

4.1.3 Inductive interference coupling

Inductive interference coupling occurs between current active circuits or conductor loops. If an AC current is flowing in a conductor loop, this current generates a magnetic alternating field. This interfuses the other conductor loop and induces a voltage there. The magnitude of the inductive interference coupling is described by the mutual inductance *Mk* and depends on the geometry and the distance between the conductor loops.

Figure 7, "Inductive interference coupling," shows a circuit fed by an interference source that induces an interference voltage *US* in a signal circuit through a magnetic interference field *BS* . The interference voltage *US* generates an interference current *IS* and this induces a voltage drop at the impedance *Zi* of the interference sink and thus a disturbance.

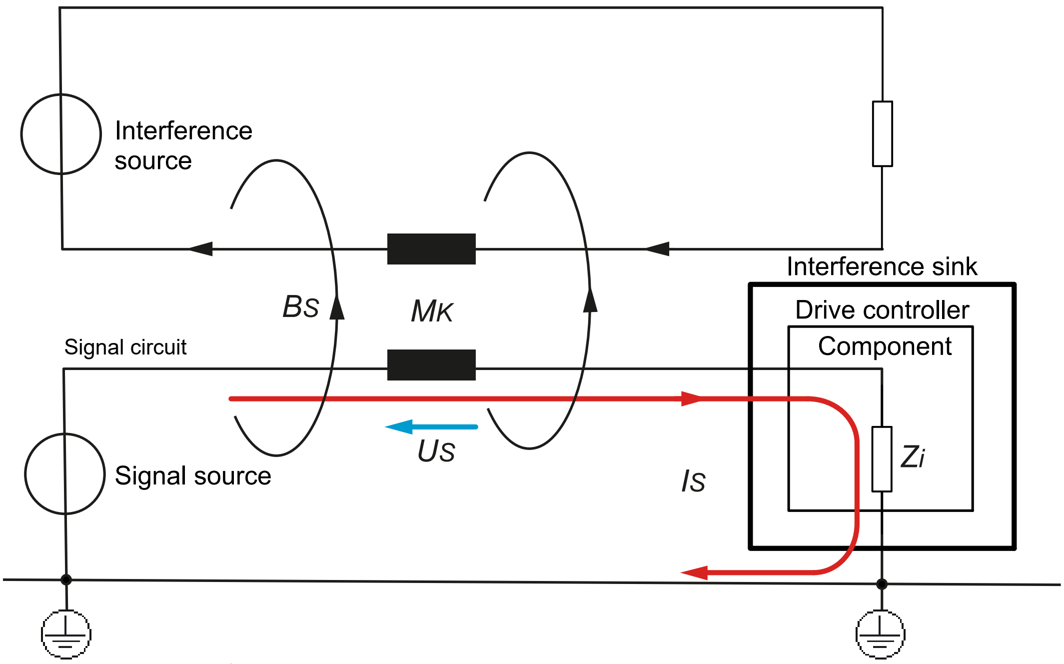


Fig. 7: Inductive interference coupling

If, for example, the interference source is a braking resistor connected to the DC link of the drive controller, a high, pulsed current flows to the braking resistor during braking operation. Due to its size and its high rate of current increase *di/dt*, this pulsed current induces a pulsed interference voltage in the signal circuit, which causes an interference current. If this interference current flows e.g. via the digital inputs into the interface module of the drive controller, malfunctions such as sporadic interference shutdowns can be triggered.

4.1.3.1 Measures to reduce inductive interference coupling

- Keep the distance between the conductor loops as large as possible.
- Keep the area of the conductor loops as small as possible, i.e. apply the supply and return conductors in parallel as close together as possible or use twisted cables for signal cables.
- Symmetrical signal routing (twisted pair) with common mode filtering.

4.1.4 Electromagnetic interference coupling

Electromagnetic interference coupling or radiation coupling is a disturbance caused by a radiated electromagnetic field.

Typical interference sources are:

- Mobile phones
- Mobile phones (smartwatches, wireless headphones, devices with Bluetooth function)
- Devices that operate with spark gaps (spark plugs, welding equipment, contactors and
- switches during opening of the switch contacts)

Figure 8, "Electromagnetic interference coupling" , shows a circuit fed by an interference source, which induces an interference voltage *US* in a signal circuit through an electromagnetic interference field *BS* . The interference voltage *US* generates an interference current *IS* , which generates a voltage drop at the impedance *Zi* of the interference sink, thereby causing interference.

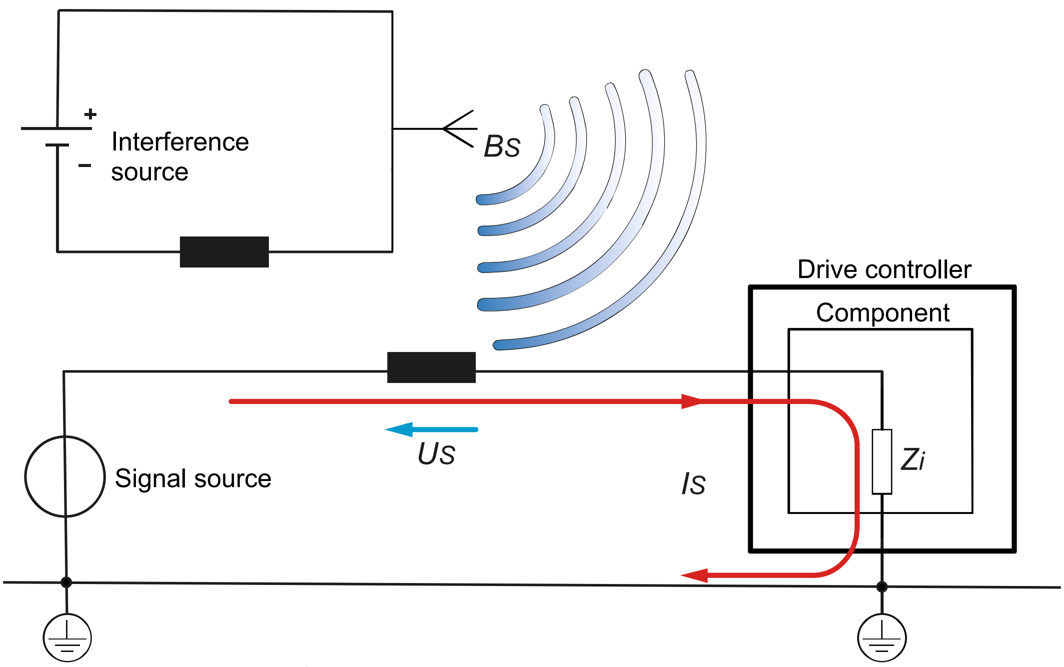


Fig. 8: Electromagnetic interference coupling

4.1.4.1 Measures to reduce electromagnetic interference coupling

The electromagnetic fields are in the high-frequency range. Therefore, the shielding measures listed below for the reduction of interference radiation couplings must be designed by way that they are also effective at high frequencies.

The following should be used:

- Metal control cabinets whose individual parts (cabinet framework, walls, doors, etc.) are connected to each other in a well-conducting manner.
- Metallic housings for devices and assemblies that are well connected to each other and to the control cabinet housing.
- Shielded cables with fine-wire braided shields suitable for high frequencies.
- Ferrite cores (braid-breaker filter) e.g. folding ferrites on signal, supply and output lines.

5 Power Drive System (PDS)

A Power Drive System (PDS) consists of a complete drive module including system control and sequence control system (e.g. KEB COMBIVERT), as well as a motor and measuring sensor.

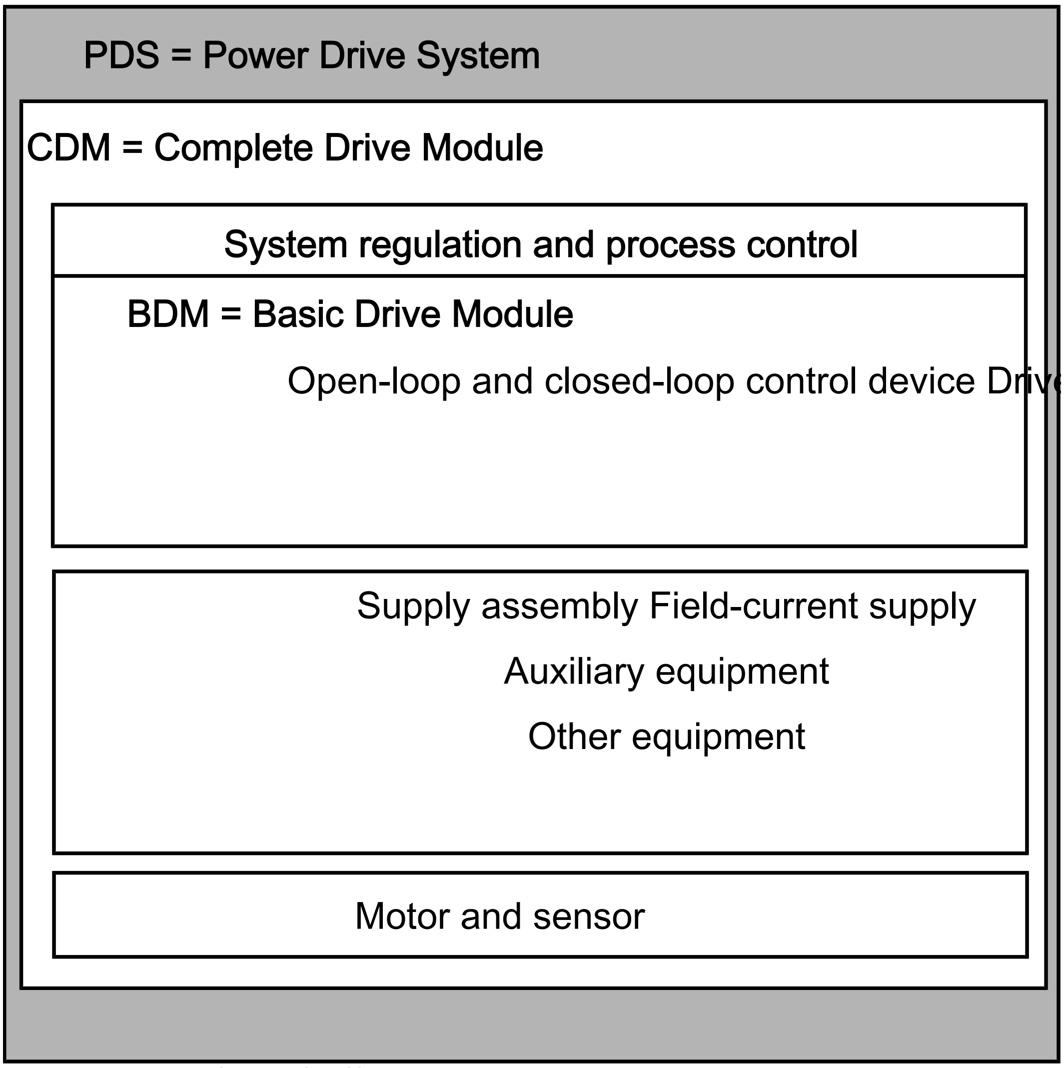


Fig. 9: Power Drive System (PDS)

5.1 Categories for PDS

Depending on the installation environment and power variable speed drives (PDS), the following four categories are defined in EN 61800-3.

Category	**C1**	**C2**	**C3**	**C4**
Environment	First environment		Second environment	
Voltage range	< 1000 V			≥ 1000 V / ≥ 400 A
Required competence	–	Installation and start-up must be carried out by qualified personnel.		

Tab. 2: Categories

5.1.1 PDS of category C1

PDS with a rated voltage lower than 1000 V, intended for the use in the first environment. No specialist knowledge is required for the installation and start-up.

5.1.2 PDS of category C2

PDS with a rated voltage lower than 1000 V, which is neither a plug-in device nor a movable device and which, when used in the first environment, is intended only for installation and start-up by qualified personnel.

5.1.3 PDS of category C3

PDS with a rated voltage lower than 1000 V intended for the use in the second environment and not intended for the use in the first environment. Installation and start-up may only be carried out by qualified personnel.

5.1.4 PDS of category C4

PDS with rated voltage from 1000 V and 400 A, intended for the use in the second environment and not for the use in the first environment. Installation and start-up may only be carried out by qualified personnel.

Expert within the meaning of this technical information

A specialist is a person or organisation with the necessary experience for the installation and/or commissioning of drive systems.

5.2 Definition of a PDS (Power Drive System)

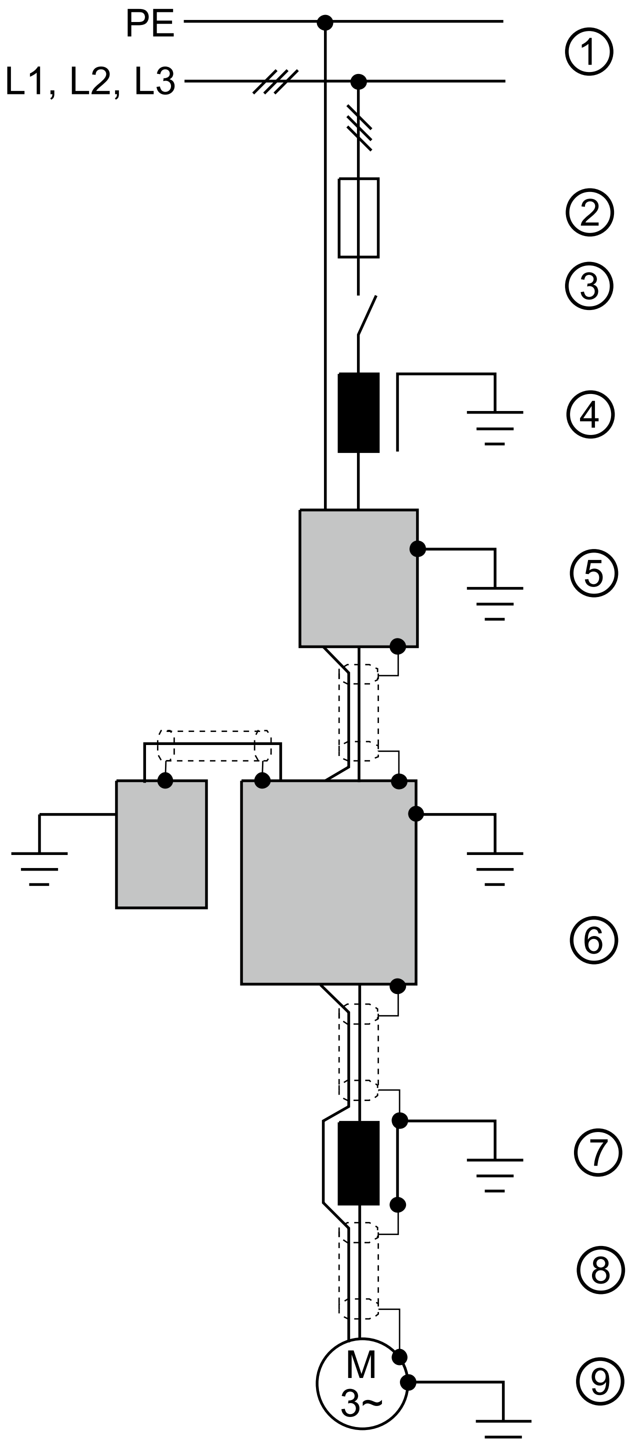
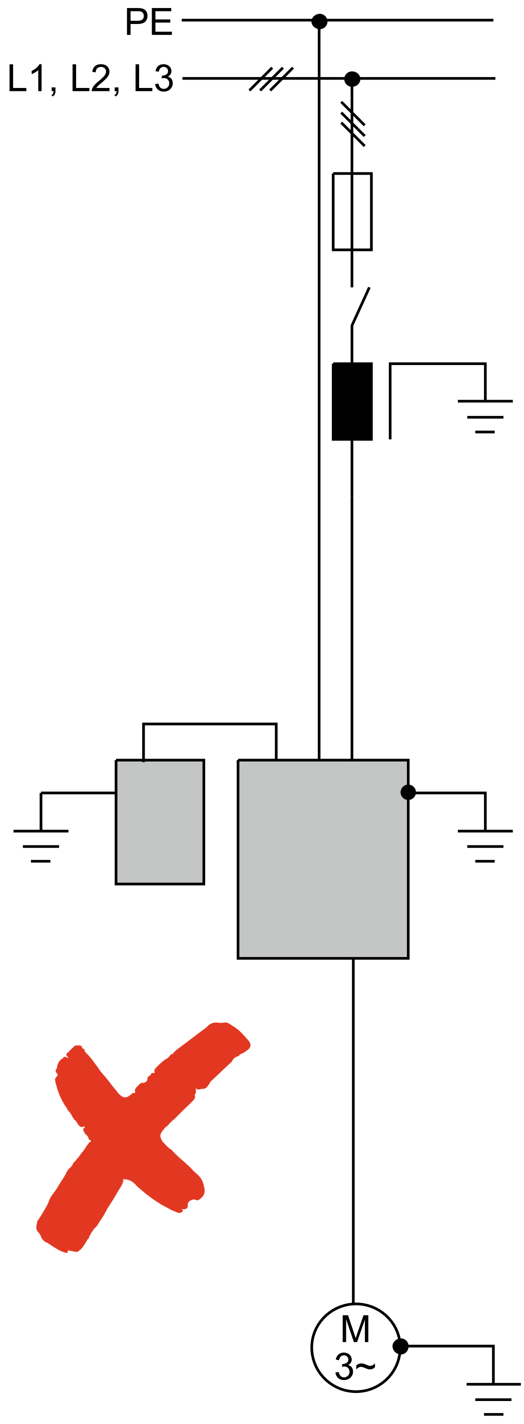


Fig. 10: Definition of a PDS (Power Drive System)

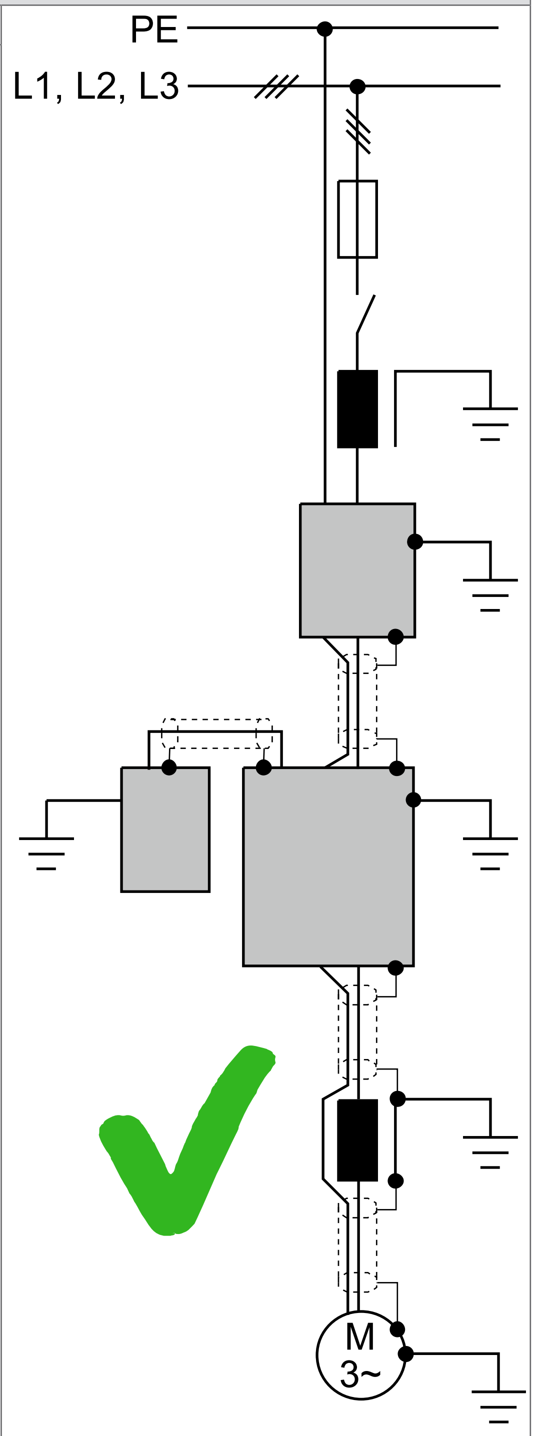
1 Mains with protective earth conductor	2 Protection of mains input
3 Main contactor	4 Mains choke
5 Radio interference filter (if not part of the drive controller)	6 Drive controller with braking resistor
7 Motor choke or output filter	8 Shielded cable
9 Motor	

5.2.1 PDS EMC installation

Incorrect installation
Error
• Missing filter measures • No EMC-compatible installation • shielding • No functional grounding
Possible problems
• Malfunction of measuring equipment • Malfunction of communication equipment • Unsteady control • Radiation of high-frequency interference signals due to clocked output voltage • High-frequency interferences are coupled into the mains from drive controllers • Other electrical devices operated on the high-voltage current system will be dis-turbed • High-frequency leakage currents to ground cause interference voltages in adjacent cables



Tab. 3: PDS EMC installation

Correct installation	
Checklist	
• Mains input filter connected to the drive controller? • Output circuit of the drive controller equipped with? • All connecting cables as short as possible and shielded? • All components and shields connected to PE over a large area? • Filter and drive controller mounted over large area on the same control cabinet potential?	

Tab. 4: PDS EMC installation

6 EMC measures

- The contact point of the motor shield and the HF filter must form a unit. Connect these together over a large area on the bare metal mounting plate.
- The connecting cable between the radio interference filter and the drive controller must be a shielded cable on both sides. Maximum length 30 cm.
- The mounting plate of the drive controller is to be seen as star point for the entire earthing and shield connection in the machine or system. Check the HF connection in case of interferences. In error case, perform parallel equipotential bonding.
- A good connection of the shield to the motor terminal box is only given on metal with metal PG screw connection. For plastic boxes, the shield must be fitted with a crimp connector without extension and connected directly to the earthing point.
- Consumers that generate electric or magnetic fields or influence the voltage supply must be placed far away from each other.

6.1 Cable laying

The cable laying contributes significantly to the electromagnetic compatibility of a system.

To prevent interference, the following cables must be separated and laid at a distance of at least 15 cm from each other:
- Netz- / Versorgungsleitungen
- Motor cables from drive controllers [1)]
- Control and data cables (low-voltage level < 48 V)

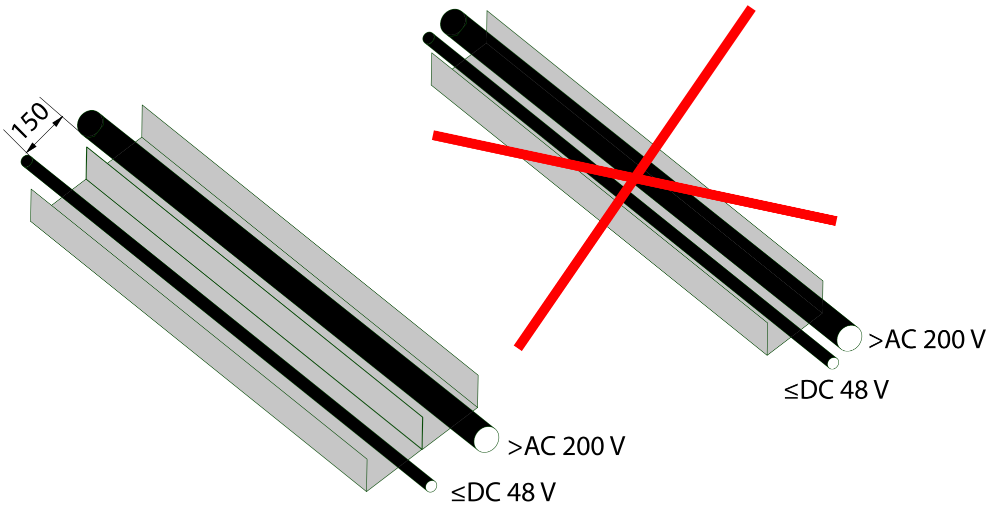


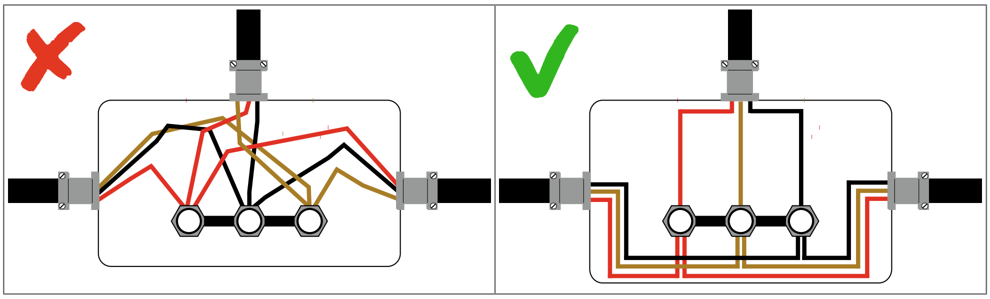
Fig. 11: Cable laying

1) *Observation of the informative measures against electromagnetic influences presented in* EN 60204 in Annex H.

6.1.1 Notes on cable laying

The following points must be observed when laying the cable:
- Use shielded cables only with copper or tinned copper braiding. Steel braiding in the HF range is not suitable. Lay the shield with clamps on the compensating rails or guided through the housing wall with metal screw connections. Pigtails should generally be avoided.
- When using external radio interference filters, these must be installed with a maximum distance of 30 cm from the interference source and with good, flat contact to the mounting surface.
- Always equip inductive control elements (contactors, relays, etc.) with suppressors such as varistors, RC elements or damping diodes.

- All connections must be kept as short as possible and as close as possible to the reference potential.
- Avoid spare loops on all connecting cables.
- Cores of signal and data cables that are not used must be grounded at both ends. Free-floating cables act like antennas.
- For unshielded cables, the supply and return conductors must be twisted (twisted pair) in order to dampen symmetrical interferences.
- Lay interference or interference-sensitive cables as far apart as possible (minimum 200 mm).
- If the distance cannot be maintained, additional shielding measures must be taken.
- Cables should be routed as close as possible to grounded housing parts, mounting plates or cabinet frames. This reduces interference radiation, as well as interference couplings.
- Cable crossings of different classes are to be tolerated, parallel laying should be avoided.
- If another routing is not possible, cross the cables at right angles, especially if the signals are sensitive and subject to interference.
- Avoid long cables and interference sources in order to prevent additional coupling points.
- Establish ground connections with the largest possible cross-section to other control cabinets, system components and decentralized devices.



Tab. 5: Notes on cable laying

6.1.2 Motor cable

The outer shield of the motor cable must be connected to the housing on both sides with low impedance. Protective earth and functional earth must not be connected to the same terminal.

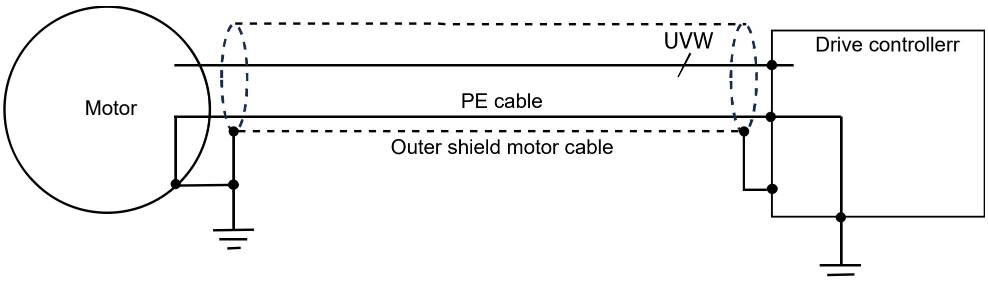


Fig. 12: Motor cable connection

6.1.3 Encoder cable

Instructions:
The outer shields must be connected on both sides.
The inner shields are connected to the GND/0V terminal on one side.

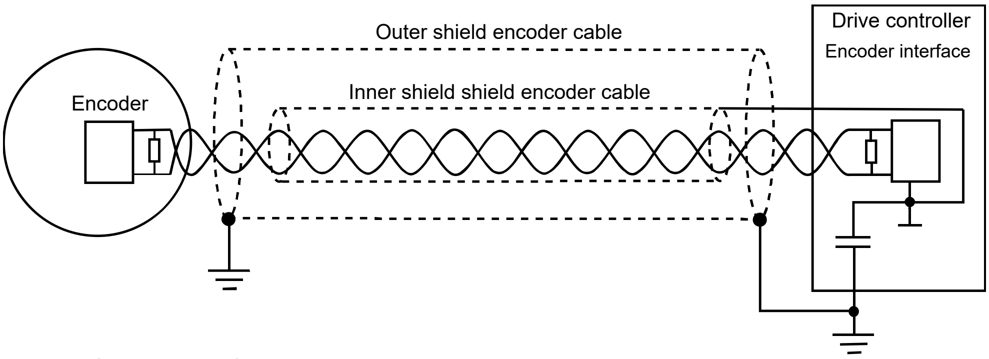


Fig. 13: Connection of encoder cable

Derivation:

- **Outer shield:**

It is coupled capacitively (1) from the motor cable to the motor screen. This creates a current (2) on the outer shield of the motor cable. Part of the return current (2') from the capacitive coupling from UVW to the motor canopy will also flow back via the sensor canopy.

Magnetic coupling of current (2) to the outer shield of the transmitter cable takes place via a transformer (3). If the outer shield of the sensor cable is not connected on both sides, the parasitic transformer (3) also generates a voltage (4) across the sensor cable.
This voltage is coupled capacitively (5) to the sensor signals and causes interference.

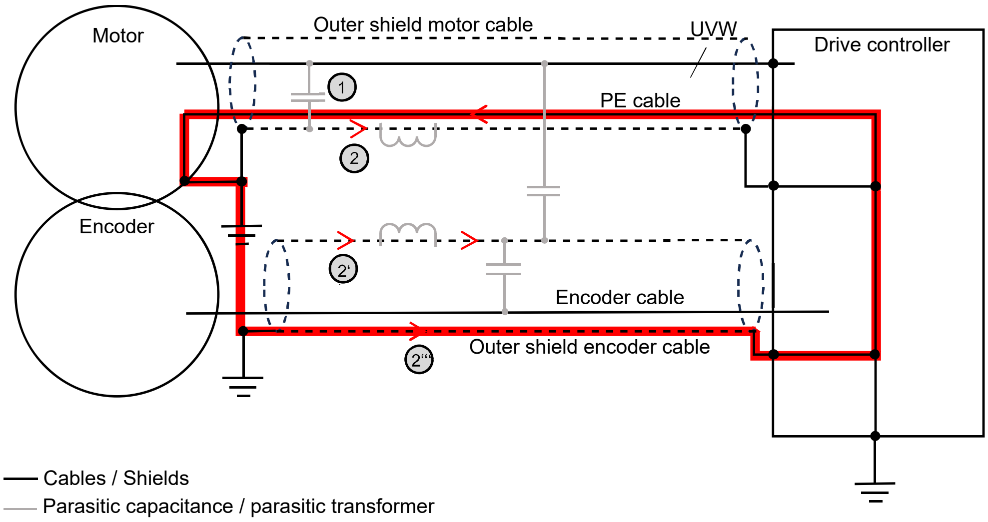


Fig. 14: Motor/encoder cable connection

Due to asymmetry in the structure of the motor cable, an output frequency current (2") is impressed on the PE conductor carried in the motor cable (directed towards the motor), part of which flows back via the outer shield of the sensor cable.

If the sensor cable were to rest on one side of the outer shield, the two currents from (2') and (2") would not flow. The shield is then magnetically ineffective. This results in a common mode being impressed onto the useful signals (via transformer 3). Therefore, apply the outer screen on both sides.

►► Conclusion: Place the outer shield on both sides of the motor and encoder

- **Inner shields:**

Single-side shielding

In audio technology, internal shields are placed on one side, on the transmitter side.

- Disadvantage: If only one side is connected, a symmetrical structure (in terms of characteristic impedance) is not possible => this is not relevant for the useful frequency range.
- A single-side shielding acts as a low-pass filter (which is why it is placed on the transmission side).

Double-side shielding

- Disadvantage: Magnetic coupling (from the outer shield to the inner shield) causes a current I_IS to flow on the inner shield, which in turn couples magnetically (due to cable asymmetry of the twisted signal lines) to the signal lines.

The outer shield is magnetically coupled to the inner screen via the parasitic transformer.

With one-side inner shield grounding, no current is formed on the inner shield, but a voltage is formed that capacitively couples to the signals.

Since the (potential-free) current source (the secondary side of the transformer) **is located in the cable**, a circuit is formed in the cable (see sketch), which cancels itself out over the length of the cable and does not affect the useful signals (regardless of the fact that the inner shield on the converter side is connected to GND).

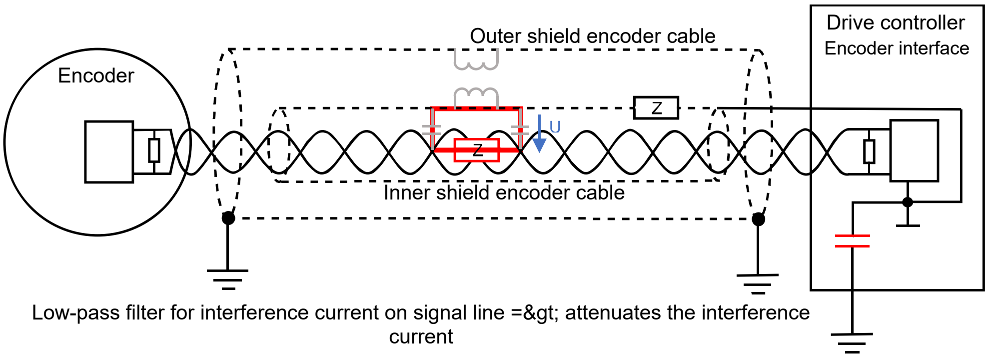


Fig. 15: Connection of encoder cable – shield connected on one side

By connecting the inner shield on the converter side to GND, no voltage swing is generated relative to the signal pair in the event of capacitive coupling from the outside world to the inner shield => see (1)

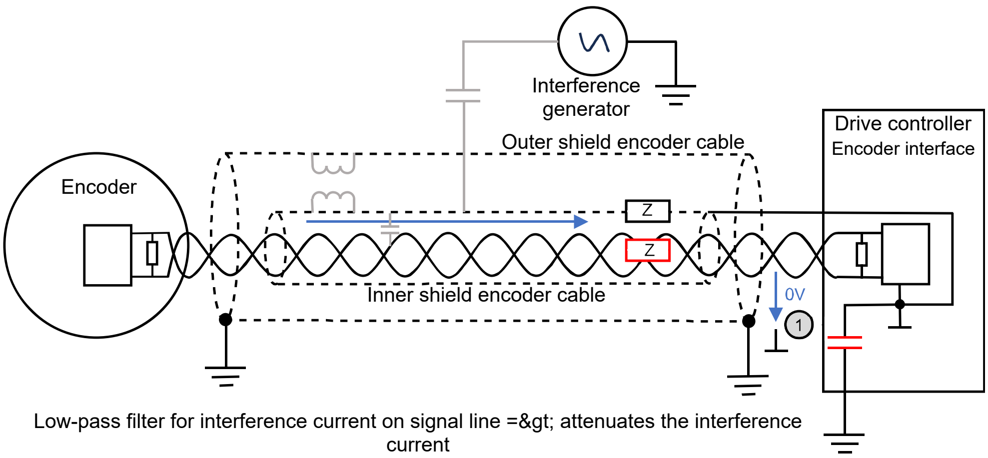


Fig. 16: Connection of encoder cable – shield connected on one side with capacitive coupling

6.1.4 OCT motor cable

Connection

- The outer shield must be applied on both sides.
- The connection must be connected to the PE (e.g. to the shielding plate of the motor terminal) with low impedance.
- The inner shield is applied on both sides.

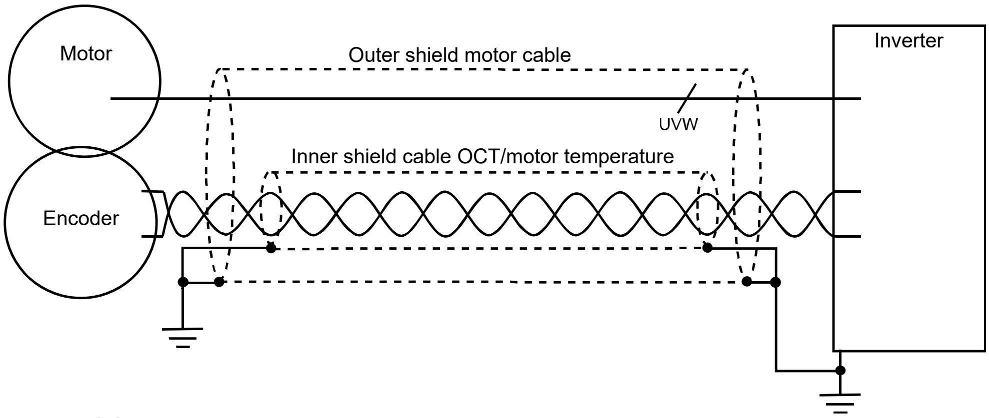


Fig. 17: OCT motor cable

Derivation of inner shield:

Capacitive coupling

If the inner shield were only connected on one side, capacitive coupling would occur from the motor phases to the inner shield and to the data signals. **Since the generator is located outside the cable and the circuit is closed via the converter's intermediate circuit**, a common mode voltage is generated on the signal lines.

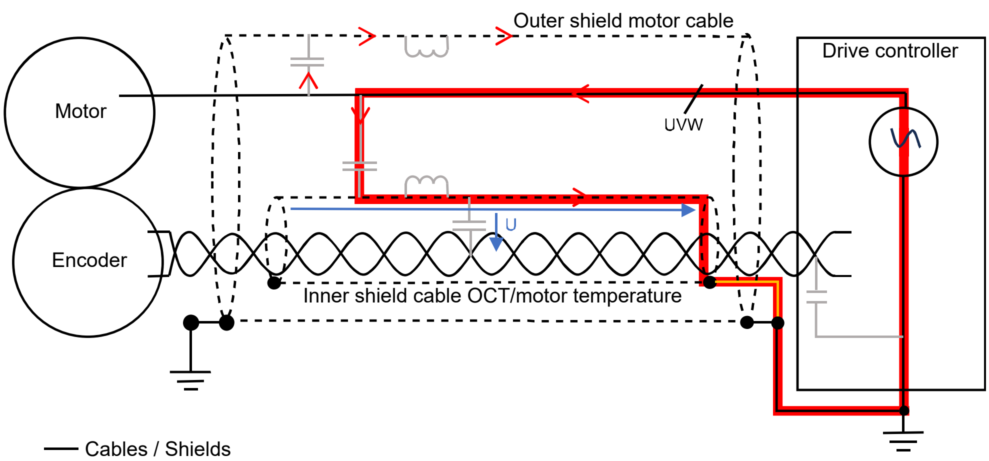


Fig. 18: Connection of OCT motor cable – shield connected on one side

If the inner shield is only connected on one side, a voltage is generated on the inner shield on the open secondary side of the parasitic transformer. This voltage couples in via the parasitic capacitance between the inner shield and the data lines, thereby generating a very high common-mode voltage on the data lines (particularly pronounced in motor cables). This means that a current of significantly more than 10 A can flow through the capacity (1).

If, on the other hand, the inner shield is connected on both sides, a current also flows through the inner shield, but **no** common-mode component is generated via the parasitic coupling between the inner shield and the data lines.

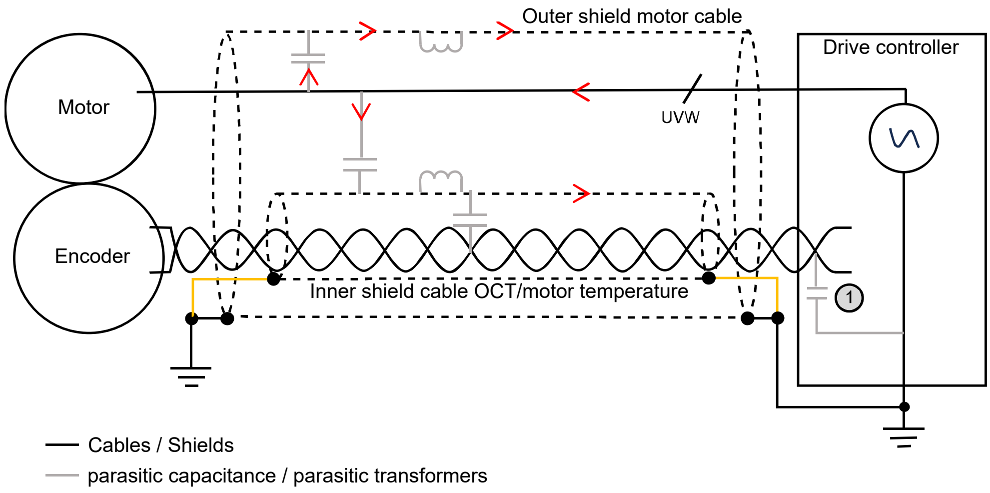


Fig. 19: Anschluss OCT-Motorleitung - Schirm beidseitig aufgelegt

Magnetic coupling
- From UVW to the inner shield (1)
- From the outer shield to the inner shield (2)

The secondary side of the respective transformer is short-circuited by internal shielding on both sides, creating a counter-field that counteracts the magnetic coupling to the signal lines.

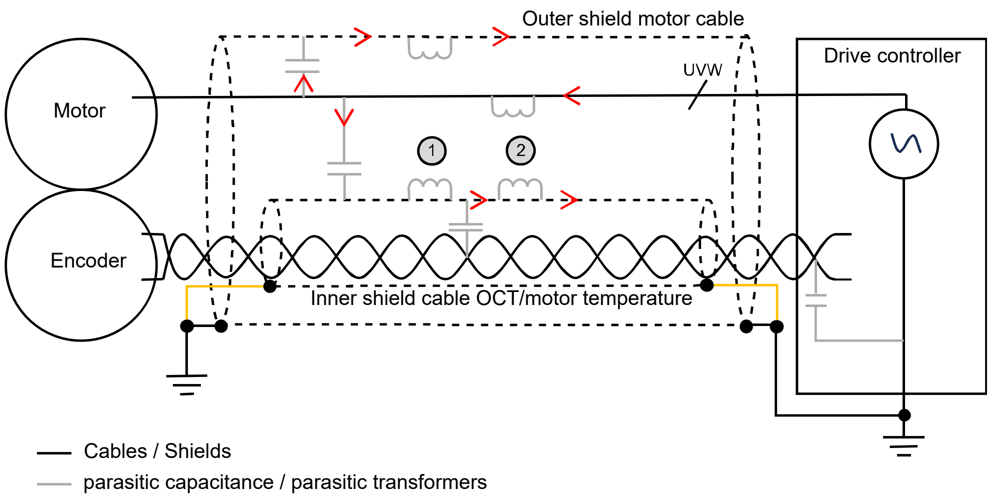


Fig. 20: Connection of OCT motor cable – magnetic coupling

6.1.5 brake cable

The brake cable shield is connected on both sides.

The reasoning/derivation is the same as for the OCT motor cable [▶ 24].

6.1.6 Motor temperature cable

The (inner) shield of the motor temperature cable is applied on both sides.

The reasoning/derivation is the same as for the OCT variant [▸ 24].

6.1.7 Conclusion on signal cables within motor cables

f signals in the motor line (OCT / motor temperature / brake), magnetic coupling must be counteracted . This requires a shield on both sides.

The secondary side of the respective transformer is short-circuited by internal shielding on both sides, creating a counter-field that counteracts the magnetic coupling to the signal lines.

In the case of a separate transmitter line, magnetic coupling is counteracted by the outer shield applied on both sides, and capacitive coupling (from the outside world) is counteracted by the inner shield applied on one side. At the same time, the one-sided application of the inner shield forms a filter against common mode voltages on the signal lines.

6.2 Protective earth

6.2.1 Connection of the protective earth

- The drive controller or the control cabinet wherein the drive controller is installed must be connected to the protective earth at the destination.
- According to EN 61800-5-1, the minimum cross-section of the protective earth conductor must comply with the local safety regulations on protective earth conductors for equipment with high leakage current. Use of a protective earth conductor corresponding to at least half the cross-section of the cables supplying the power terminals.
- An earth connection is available at the drive controller for the connection of the motor protective earth.
- The resistance of the protective earth should be 0.1 Ω or less.

6.2.2 Leakage currents

NOTICE

Malfunctions due to excessive leakage currents

✓ Radio interference filters increase the leakage currents of the devices. When the 3.5 mA threshold is exceeded, one of the following conditions must be met:

a) Protective earth conductor cross-section at least 10 mm² copper

b) Monitoring of the protective earth conductor by a device that independently switches off under fault conditions.

c) Installation of a second protective earth conductor via separate terminals. This must also meet the requirements for protective earth conductors on its own.

6.3 Shield connection

The cable shield is used to extend the housing around the cables.

6.3.1 Connecting the shield connection

- Cable shields must not be used for current conduction.
- A cable shield must not take over the function of an N or PE conductor.
- Always apply cable shields over a large area.
- Do not use unshielded wire connections to extend the cable shield to the earthing point. Pigtails must be avoided. This reduces the shielding effect by up to 90%.

- Apply the cable shield over a large area directly after the cable enters the control cabinet.
- In order to obtain low-resistance HF connections, earthings, shieldings and other metallic connections (e.g. mounting plate, installed devices) over a large area on a bare metallic surface. Use earthing and potential equalization cables with large cross-section (min. 10 mm²) or use thick earthing strips.

6.3.2 Connection variants

For dissipation purposes, the following properties must be observed for a good connection:

- Low impedance / low resistance
- Large cross-section
- Fine wire
- Short cables
- Large area contacted
- 360° if possible
- Metallic conductive components without dirt, varnish, grease or oxide layer

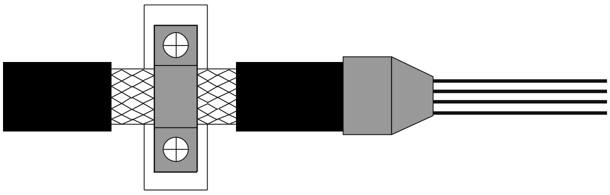


Fig. 21: Shielding with cable clamp

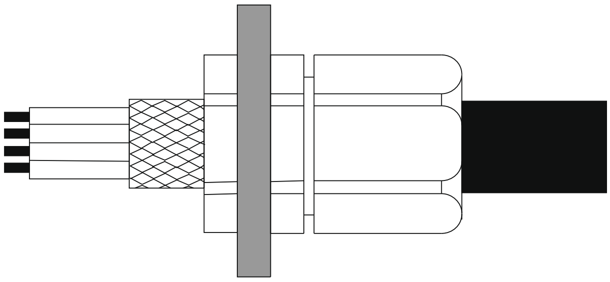


Fig. 22: Shielding with screwed cable gland

A braid that is twisted together at the end or a wire attached to the braid (pig tail) significantly reduces the effectiveness of the shield connection. In principle, this is not recommended..

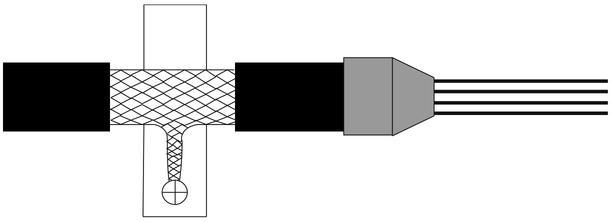


Fig. 23: Shielding with cable shield (pig tails)

6.3.3 Connection on a shield rail

A shield rail must be provided for cable fastening in the control cabinet. This rail must be connected with good conductivity to the mounting plate or to the housing. All shields are placed on this rail.

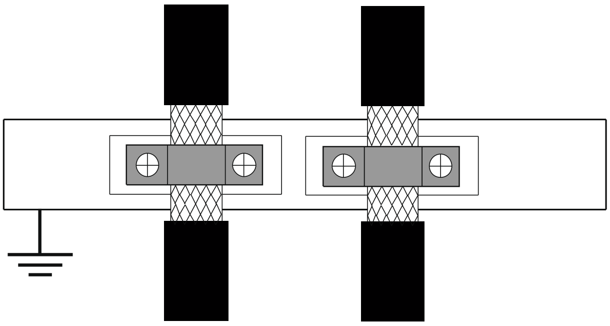


Fig. 24: Connection on a shield rail

6.3.4 Cable length after shielding

If the shielded cable continues after the shield contact, the free cable length should not exceed 10 cm. This also applies to cables inside control cabinets.

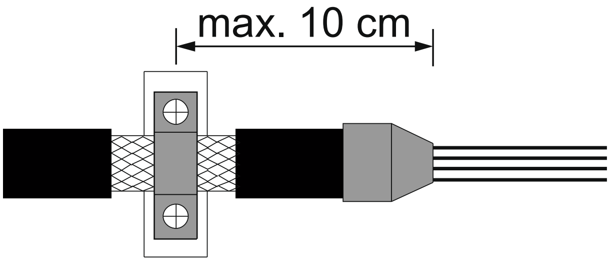


Fig. 25: Cable length after shielding

6.3.5 Equipotential bonding conductor

Cable shields are always applied on both sides. A potential equalization cable (≥ 6 mm²) must be laid parallel to the shielded cable over longer distances and between individual machine components so that any equalizing currents or leakage currents can flow off.

The potential equalization cable should be fine-stranded so that it is effective even with high-frequency interference currents due to its large surface area. In addition, according to IEC 60364-5-54 minimum cross-sections must be observed.

In general:
- Copper 6 mm²
- Aluminium 16 mm²
- Steel 50 mm²
- The earthing system must be connected in a star configuration.
- The PE connection does not replace HF earthing or shielding, but is mandatory for safety reasons.
- If necessary, lightning protection must be provided.
- Atmospheric influences can lead to significant potential shifts.

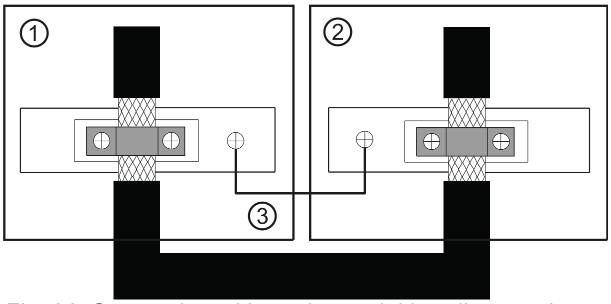


Fig. 26: Connection with equipotential bonding conductor

1 Device A	2 Device B
3 Equipotential bonding conductor	

It is possible to apply the shield capacitively on one side. A multilayer varistor (ZNR) in parallel with the capacitance prevents capacitor breakdown during burst or ESD. A potential equalization cable is not necessary with this measure.

6.4 Functional grounding

CAUTION

Dangerous contact voltages !

✓ Functional earth is not the same as protective earth according to VDE 0100! EMC earth connectors are only used secondarily for protection against dangerous contact voltages.

a) Lay functional earth and protective earth conductor separately from each other ! Test inputs without the motor.

- Welded connections are more suitable than screw connections because no corrosion can occur.
- Select connections as short as possible.
- Metal-powder tapes are preferable to round wires.

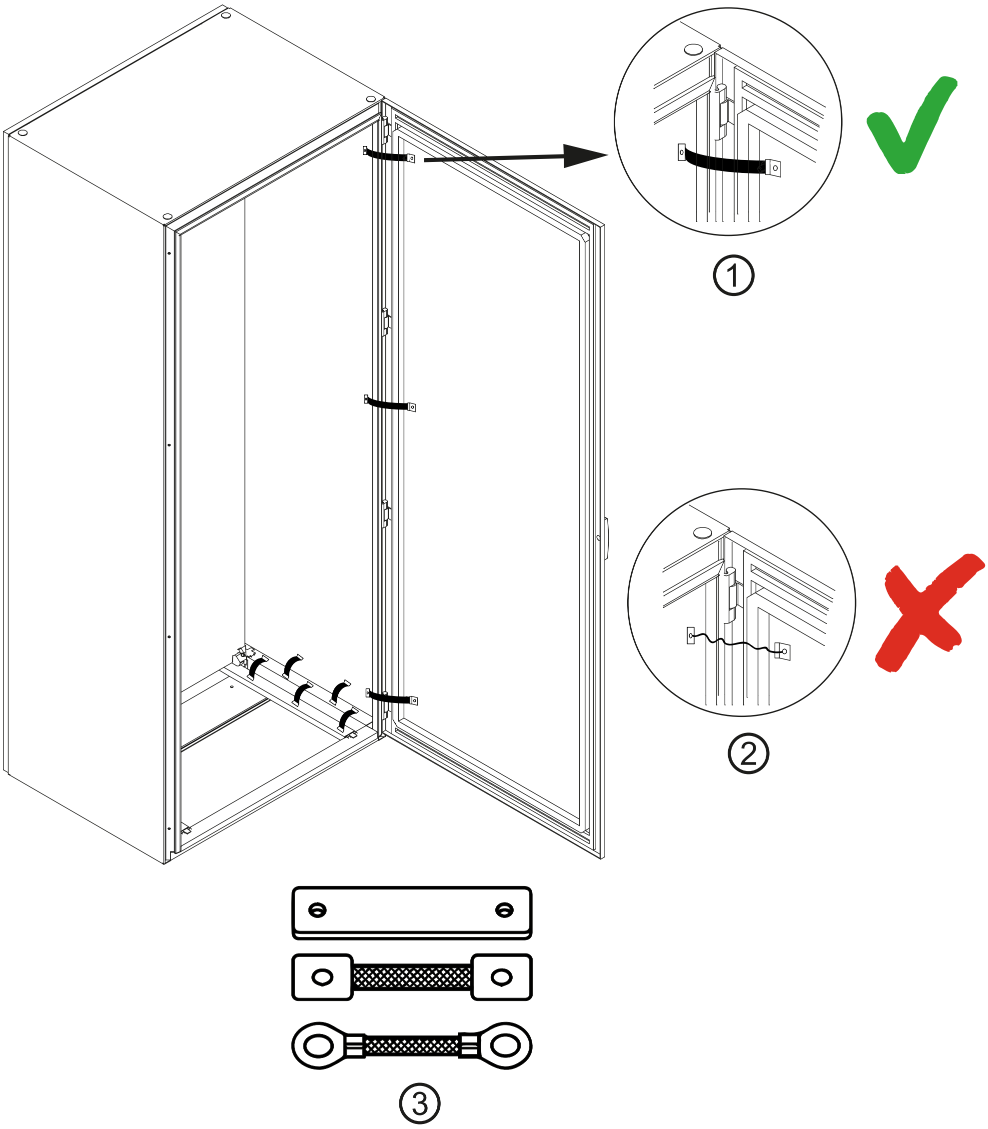


Fig. 27: Functional grounding

1	Correct functional earthing with wide earthing strips
2	Incorrect functional earthing with thin round wires
3	Typical connectors for functional earthing. As large as possible and with a large cross-section.

6.5 Ferrite rings

Drive controllers can cause high-frequency interference on mains and motor cables. The cables, or their shielding, act as antennas. Ferrite rings are used to suppress the common-mode interferences on mains and motor cables and thus reduce the radiated interferences.

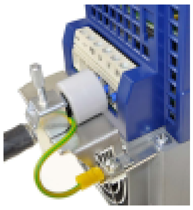
6.5.1 Ferrite ring on the motor cable

NOTICE

Loss of the protective function !

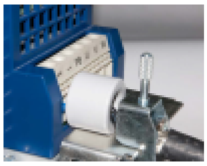
a) Do not lead the PE ptotective earth conductor through the ferrite ring.

- Strip the sheathing of the motor cable.
- Fit the connecting wires with wire end ferrules at the end.

• Slide the ferrite ring over the three motor cables. • Connect the cables to the terminals U, V, W. • Connect PE protective earth conductor to protective conductor terminal. • Place the shielding from the motor cable over a large area on the mounting surface or on the optional shielding plate (as shown in the figure).	 Connection example

Tab. 6: Ferrite ring on the motor cable

6.5.2 Ferrite ring on the DC supply cable

• Strip the sheathing of the DC cable. • Fit the connecting wires with wire end ferrules at the end. • Slide the ferrite ring over the two wires of the DC cable. • Connect the wires to the ++ and - - terminals. • Connect PE protective earth conductor to protective conductor terminal. • Place the shielding from the motor cable over a large area on the mounting surface or on the optional shielding plate (as shown in the figure).	 Connection example

Tab. 7: Ferrite ring on the DC supply cable

A shielded cable provides optimum protection against radiated interferences.

6.5.3 Ferrite ring on the AC supply cable

• Strip the sheathing of the mains cable. • Strip the connecting wires at the end and fit them with wire-end ferrules. • Each wire must cross the ferrite ring three times.	
• Connect the wires to the terminals L1, L2, L3. • Connect PE protective earth conductor to protective conductor terminal.	

Tab. 8: Ferrite ring on the AC supply cable

7 Construction of an EMC-compliant control cabinet

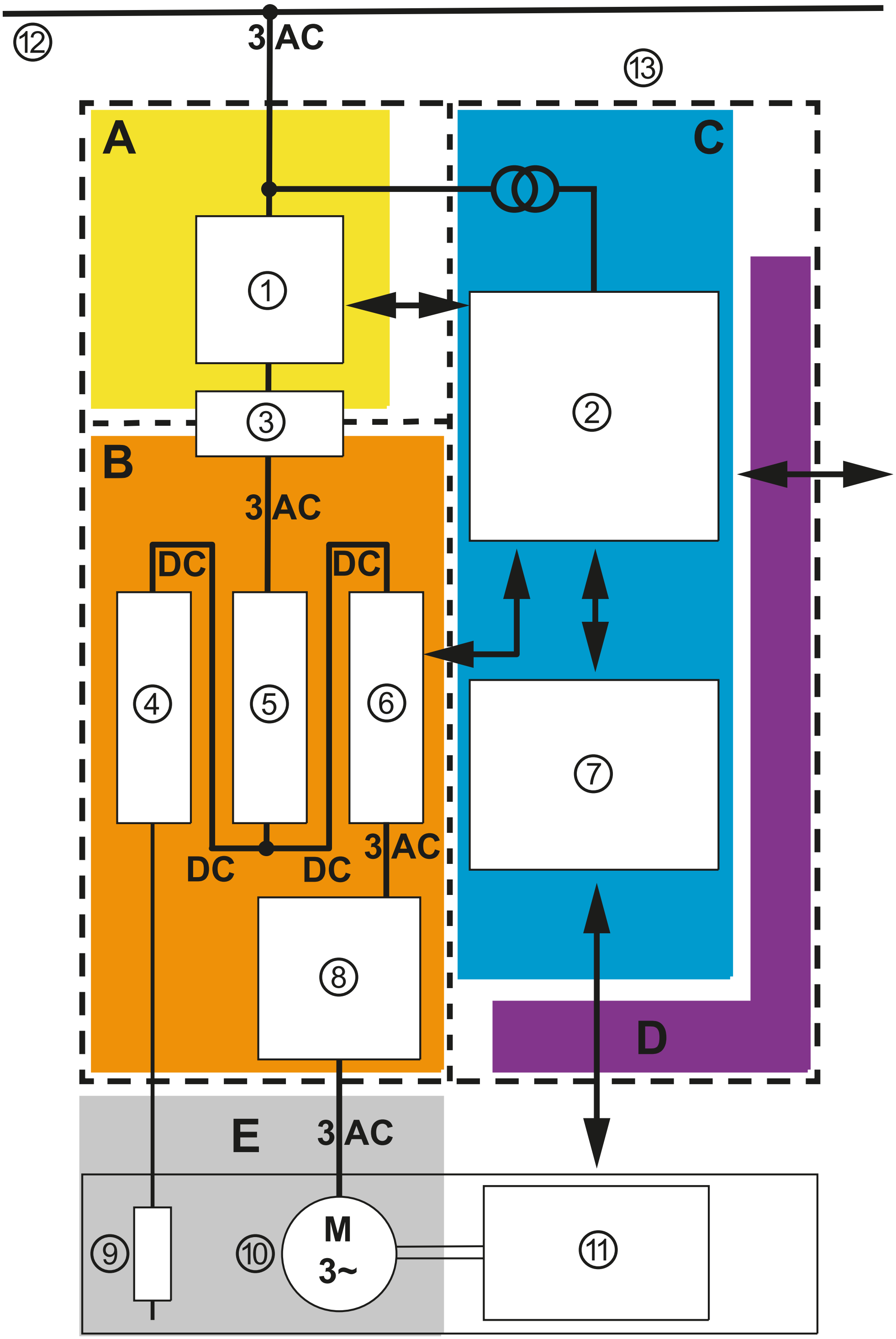


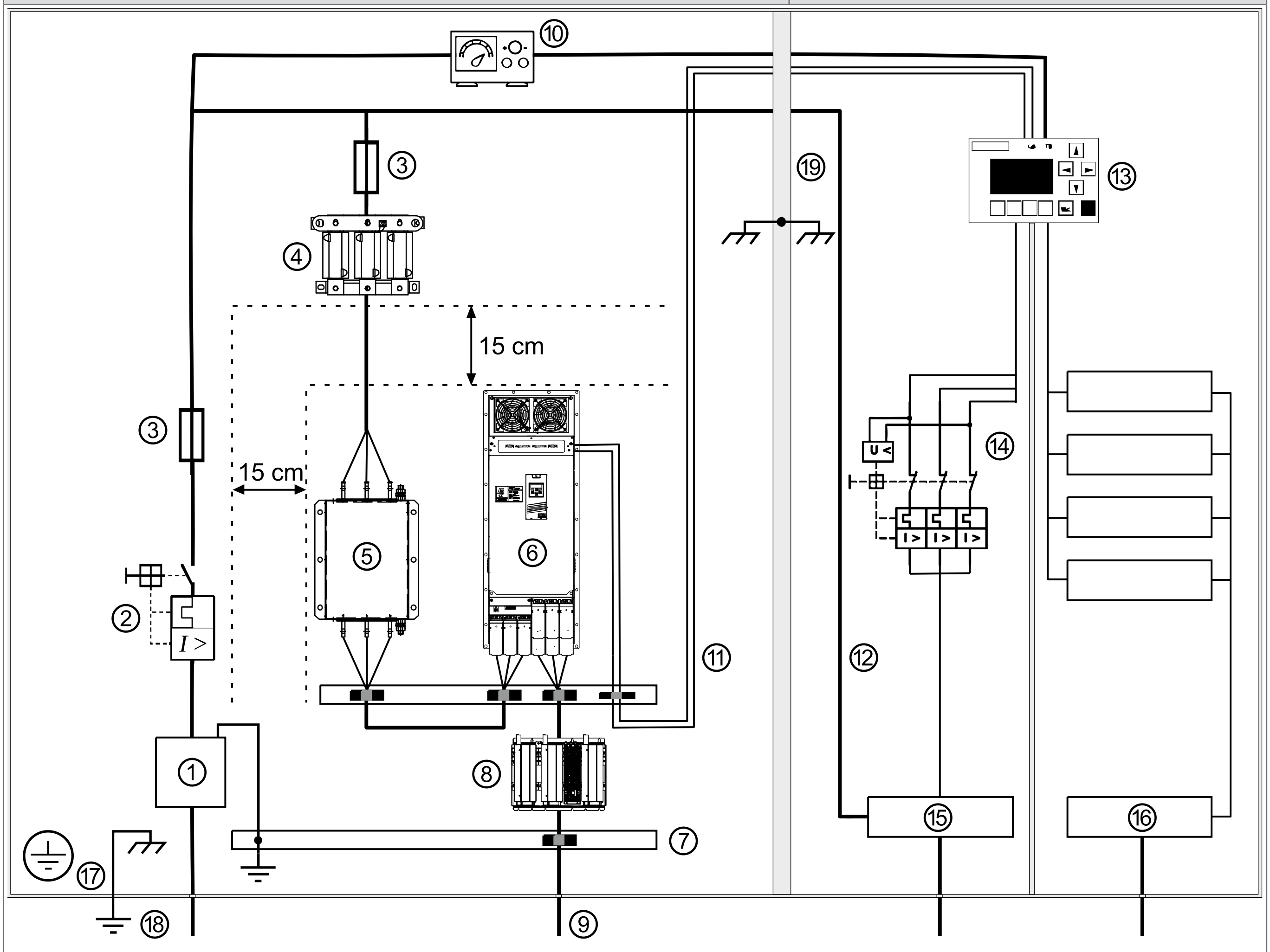
Fig. 28: Exemplary classification of a control cabinet into EMC zones

A	Zone A: Mains connection	B	Zone B: Power electronics
C	Zone C: Control and sensors	D	Zone D: Signal interfaces to the periphery
E	Zone E: Motor cable, braking resistor	1	Mains connection
2	Control	3	Mains filter, mains choke
4	Braking transistor / power unit	5	Rectifier / power unit
6	Inverter / power unit	7	Sensors

8	Motor connection	9	Braking resistor
10	Motor	11	Mechanics
12	Mains	13	Control cabinet

A control cabinet should always be divided into power section and control section. A system should be broadly separated into power section and control section, whether comprising a single enclosure or multiple enclosures. Due to the strong radiation of the power cables, the installation of a shielding wall is recommended. This must be very well connected to the frame or mounting surface (galvanised version or remove paint).

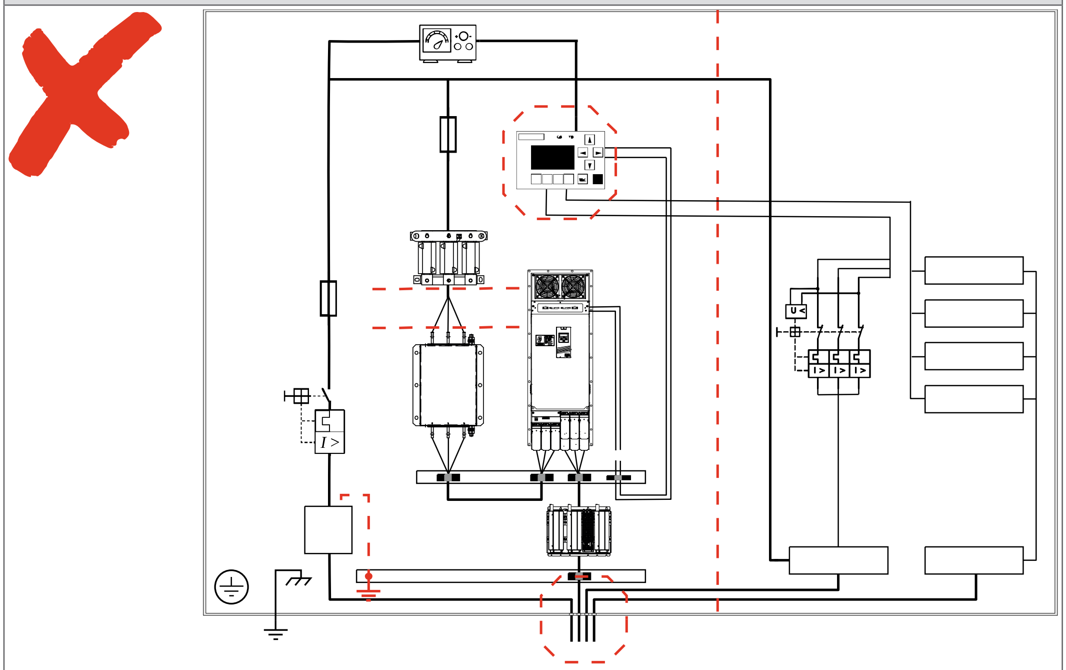
Power section	Control section



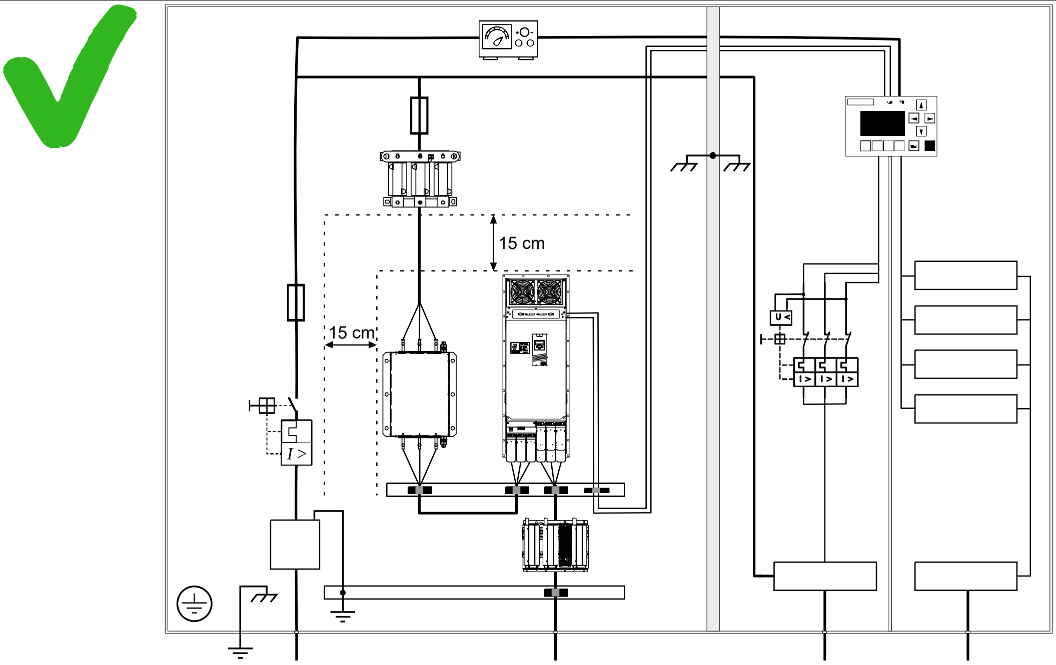
1	Mains input	2	Mains contactor or main switch
3	Mains fuse	4	Mains choke
5	Radio interference filter	6	Drive controller
7	Shield connection with clamps	8	Motor choke / sine-wave filter (option)
9	Motor supply cable	10	Power supply
11	Control cables	12	AC-BUS
13	PLC / PC	14	Contactors / PKZ
15	230V / 400V I/O	16	Logic I/O
17	Mounting plate is common star point (PE)	18	Equipotential bonding with building earth

Tab. 9: Construction of an EMC-compliant control cabinet

7.1 Control cabinet EMC installation

<table>
<tr><th colspan="2">Incorrect installation</th></tr>
<tr><td colspan="2"></td></tr>
<tr><th>Error</th><th>Possible problems</th></tr>
<tr><td>
• No EMC-compatible installation
• Cables are bundled
• No shielding and no functional earthing
• No separation between power and control section
• No metallic partition between power and control section
</td><td>
• Sporadic errors
• Malfunction of measuring equipment
• Malfunction of communication equipment
• Failure or destruction of devices and system parts
• Unsteady control
• Radiation of high-frequency components due to clocked output voltage
• High-frequency interferences are coupled into the mains from the drive controller
• Other electrical devices operated on the mains are disturbed
• High-frequency leakage currents to ground cause interference voltages in adjacent cables
</td></tr>
</table>

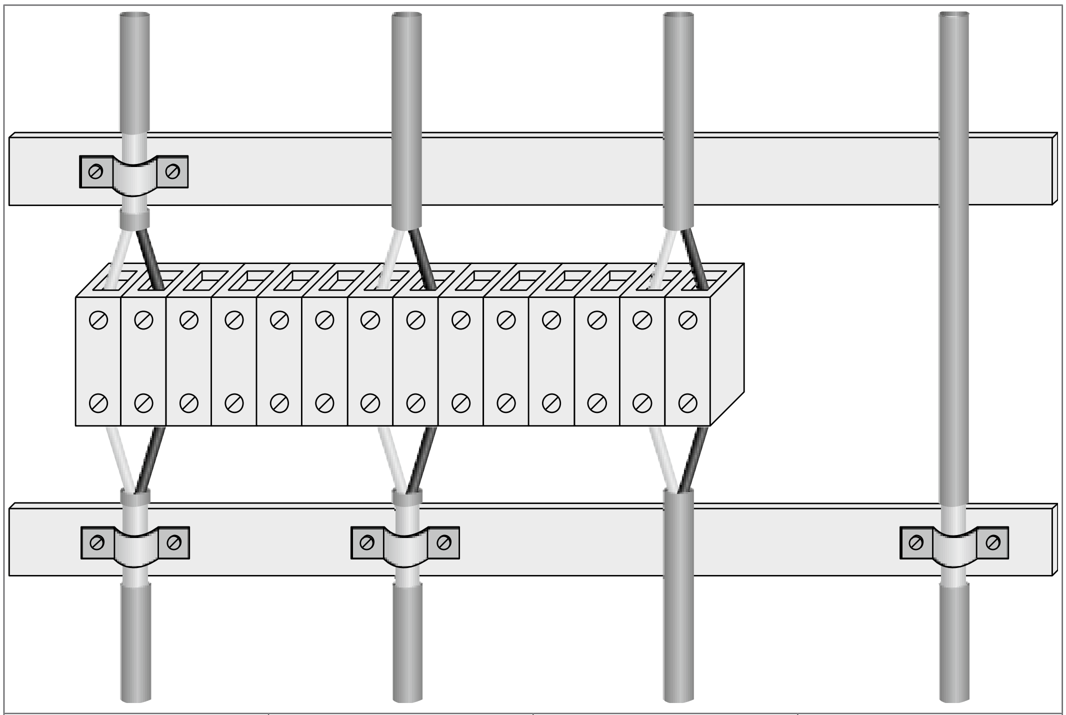
Tab. 10: Incorrect installation

Correct installation

Checklist
• EMC control cabinet planning observed? • Separate control cabinets for power electronics and small signals if possible? • Partition walls contacted all around • Mounting plate EMC-compatible (not painted or anodised)? • Low-impedance earthing bar with mounting plate • Cables of different cable groups spatially separated? • Cables kept short? • Interfering and sensitive cables crossed at right angles? • Are cable shields earthed at the switch cabinet inlet/outlet and on the devices? • Filter properly installed? • Fluorescent tubes placed at a distance from sensitive devices?

Tab. 11: Correct installation

7.2 Control cable connection

To the drive controller



Cable from encoder	Analog cable	Unshielded cable	Data cable

Tab. 12: Control cable connection

- Connect the shield rail flat to the stripped mounting plate and do not use it as strain relief.
- The shield of digital signal cables which are not connected via connection terminals must be connected to the shield buses at the control cabinet entry and in the vicinity of drive controllers in order to reduce the shield impedance.
- If digital signal cables are connected via connection terminals, the shield must be connected flat in front of and behind the terminal.
- If a shield bus is used near the drive controller (max. 20 cm), the shield must not be connected to the drive controller.
- If the shield is earthed with a single conductor, then the interference derivation deteriorates by around 70%.
- The metal clamps available in electronics stores are suitable for the shield connection.
- When using unshielded signal cables, these should always be laid as a twisted pair with forward and return cables.

7.3 Other notes on wiring

For drive controllers with electrolytic capacitors in the DC link, the service life depends on the current load. The use of mains chokes can significantly increase the service life, especially when connecting to "hard" mains or continuous load (S1 operation).

For drives in S1 operation with an average load of > 60% KEB recommends the use of mains chokes with a *Uk* = 4%.

The term "hard" mains can be defined as follows (for guidance):

k = Snet / Sout >> 200

The rated power of the drive converter (*Sout*) is very low compared to the node point power (*Snet*) of the grid. Example:

k = Snet / Sout = 2 MVA (supply transformer) / 6.6 kVA (drive controller) = 330

►Throttle required.

If a mains choke is used, it must usually be mounted on the mains side of the radio interference filter.

8 EMC assessment

Für die Beurteilung der elektromagnetischen Verträglichkeit sind zwei Normen zu beachten.

8.1 EN 55011 (environment standard)

This standard defines the limit values depending on the environment in which the product is operated. A distinction is made between two environments.

First environment describes the non-industrial residential and business environment without its own high or medium voltage distribution transformers.

Second environment defines industrial areas that are not connected to the public low-voltage grid, but they have their own high-voltage or medium-voltage distribution transformers. The limit values are divided into classes A1, A2 and B.

8.2 EN 61800-3 (product standard)

This standard defines the limit values depending on the application area of the product. The limits are divided into categories C1, C2, C3 and C4. Class C4 generally applies only to drive systems with higher voltages (> 1000 V AC) or higher currents (> 400 A). However, class C4 can be valid for the individual device even if it is integrated in complex systems.

The same limit values apply to both standards. However, the standards differ in an extended application in the product standard. The operator decides which of the two standards shall be used, whereby the environment standard is typically used in case of troubleshooting.

The essential connection between the two standards is explained as follows:

Standards			
Category according to *EN 61800-3*	C1	C2	C3
Limit class according to *EN 55011*	B	A1	A2
Operation permissible in			
1. environment (residential environment)	X	X[1]	–
2. environment (industrial environment)	X	X[1]	X[1]
Note required according to *EN 61800-3*	–	[2]	[3]
Distribution channel	Generally available	Limited available	
EMC expertise	No requirements	Installation and start-up by an EMC qualified person	

Tab. 13: Comparison of EN 61800-3 and EN 55011

1. *Use of the device neither as plug-in device nor in mobile devices.*
2. *In a residential environment, the drive system may cause high-frequency interferences that may require interference suppression measures.*
3. *The drive system is not intended for the use in a public low-voltage grid that supplies residential areas.*

8.2.1 Emitted interference requirements

This standard devides emitted interferences into two ranges:

- Low frequency range < 9 kHz

Regarding to compliance with limit values for mains perturbations, the EMC product standard *EN 61800-3/A11* for PDS refers to compliance with the standards *EN 61000-3-2* and *EN 61000-3-12*.

- High frequency range > 9 kHz

The product standard *EN 61800-3/A11* requires compliance with the following emission limits for high-frequency interference emissions for the different categories.

Category	C1	C2	C3	C4
Limit values according to *EN 55011*	Class B	Class A1 and warning notice	Class A2 and warning notice	Class A2 or special EMC planning

Tab. 14: Categories of high-frequency emitted interferences > 9 kHz

Category C1 requires the limit values of class B group 1 according to *EN 55011*.

Category C2 requires the limit values of class A group 1 according to *EN 55011*. Installation by EMC specialist and warning notice: "This is a category C2 product according to *EN 61800-3.* This product may cause radio interference in residential areas. In this case, it may be necessary for the operator to implement appropriate measures."

Category C3 requires the limit values of class A group 2 according to *EN 55011*. However, the limit values are lower than those of class A group 1 and warning notice:

"This type of PDS is not suitable for the connection to a public low-voltage grid that supplies residential buildings. High-frequency interferences are to be expected when connecting to a public low-voltage grid.“

Category C4, the same limits apply as for category C3. If these cannot be met due to high rated values or special technical requirements, the user and manufacturer must agree on special EMC planning.

8.3 Classification of the limit classes

Two classes of devices or equipment are defined in the *EN 55011* standard. Class A and Class B associated with the environment intended for the end use.

8.3.1 Class A

Class A devices are intended for the use in industrial environments.

- Operation in other electromagnetic environments may affect electromagnetic compatibility.

8.3.2 Class B

Class B devices are intended for use in residential, commercial and industrial areas.

Class B requirements:

- Adequate protection for radio and broadcasting services in residential areas.
- Devices that are primarily intended for the use in residential areas must comply with the limit values of class B.

Devices complying with the limit values of class A may not provide adequate protection for residential radio and broadcast services.

8.4 EMC standards

When applying standardization, its hierarchy must be observed. If there is a product standard (Pn), this must be observed. If not, the respective generic standard (Fgn) applies. It contains references to the basic standards (Bn), which describe measuring methods, for example.

EN standard	Type of standard			Title
	Pn	Fgn	Bn	
EN 61800-3	X			Product standard EMC for Power Drive System, includes emission values and immunity requirements for public and industrial network

EN standard	Type of standard			Title
EN 61000-6-1		X		Generic standard Immunity requirement for residential, business and light-industrial environments
EN 61000-6-2		X		Generic standard Immunity requirement for industrial networks
EN 61000-6-3		X		Generic standard for emitted interference in residential, business and light-industrial environments
EN 61000-6-4		X		Generic standard emitted interference for industrial networks

Tab. 15: Hierarchy of EMC standards

9 Revision History

Edition	Version	Remark
2022-11	00	First edition.
2025-08	01	Connection of signal cables within the motor cable. Editorial changes.

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