Safety Application Note ISO 13849

Electromagnetic Interferences (EMI)

For Safety-related Circuits According ISO 13849

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- Specialist in pneumatics
- Specialist in electrical engineering
- Specialist for the programming of control systems and safety switching devices

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Table of Contents

1 General

1.1 Objectives of this Document

- This document provides some basics about electromagnetic environments (interference source, coupling path, and interference sink) to improve the understanding of the requirements for safety circuits according to ISO 13849-1.
- EMC measures are presented that can ensure the immunity of a safety circuit.

1.2 General Notes

- All information in this document must always be evaluated in relation to the specific application to determine whether it applies and is complete.
- The circuits shown are principle circuits, which cannot be complete due to clarity and scope. They are recommendations and do not exclude other possibilities.
- This document describes the minimum required measures for the safety circuit in a machine or system based on IEC 60204-1, Annex H.

1.3 Important Notes

- The EMC-related specifications in the operating instructions of the components used must always be observed. The information contained in this document should be understood as supplementary notes.
- Applications with very strong electromagnetic interference, e.g., electric welding, are not covered by this document. Additional protective measures adapted to the specific application are required here.

2 Basics

2.1 Overview of Electromagnetic Phenomena

Any component, device, or machine that uses electrical energy can be a source of electromagnetic interference. This electromagnetic interference can affect the function and performance of a neighboring component, device, or machine. These interferences can be classified according to the mode of propagation (conducted or radiated) and the amplitude of the electromagnetic interference signal depending on the frequency:

- Low frequency conducted phenomena (e.g., harmonics, voltage dips, and fluctuations);
- Low frequency radiated phenomena (e.g., magnetic fields at mains frequency);
- High frequency conducted phenomena (e.g., fast transients);
- High frequency radiated phenomena (e.g., electromagnetic fields);
- Electrostatic discharges (ESD).

To ensure electromagnetic compatibility (EMC), components, devices, and machines must withstand these phenomena and disturbing effects regardless of their origin.

2.2 General

To achieve electromagnetic compatibility (EMC) for the safety circuit during the operation of a machine or system, EMC measures are necessary from the component manufacturers, machine and system builders, and operators.

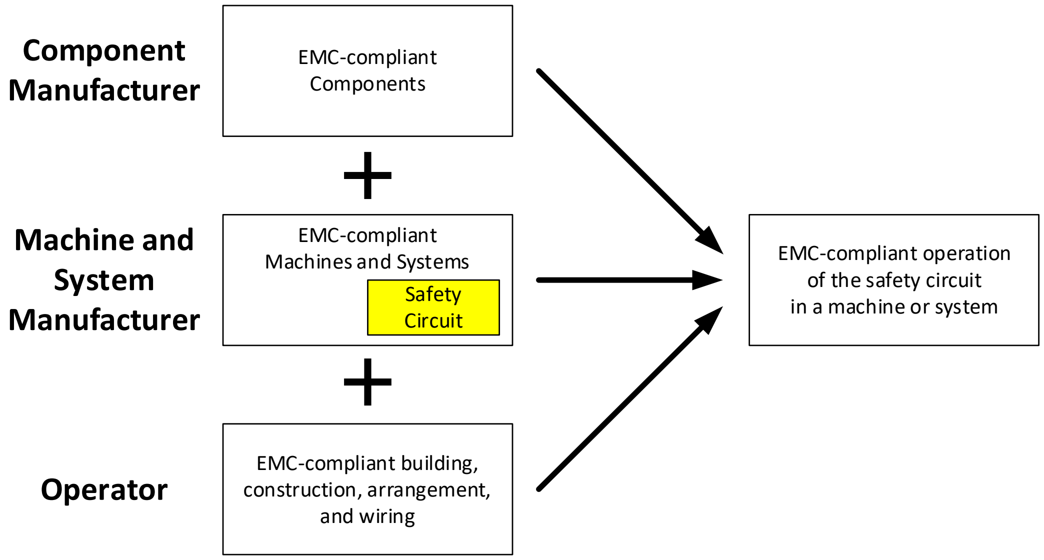


Figure 1 Responsibility Regarding EMC Measures

Each area of responsibility requires EMC measures to achieve sufficient electromagnetic immunity (EMI) for the safety circuit during operation:

- Components should comply with the product-relevant requirements for electromagnetic immunity.
- Machines and systems must be designed, developed, and manufactured so that the system-relevant requirements for electromagnetic immunity are met, and EMC-compliant operation is possible.
- The operator must provide a sufficiently protected building in which the machine or system can be arranged, installed, and connected in an EMC-compliant manner.

2.3 Basics

In an electromagnetic environment, electromagnetic interference can only affect a safety circuit if the following three components are present:

1. Interference source
2. Coupling path
3. Interference sink

The objectives of an EMC-compliant installation are to reduce emissions at the interference source, to interrupt the coupling mechanisms at the coupling path, and to increase immunity at the interference sink.

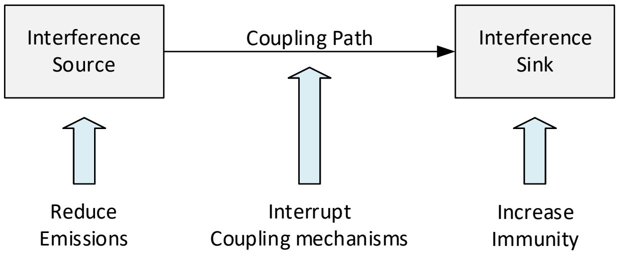


Figure 2 Objectives for the electromagnetic environment

2.3.1 Interference Sources

Interference sources are the causes of electromagnetic disturbances. Their emissions must be eliminated or sufficiently reduced through appropriate measures.

Table 1 Examples of interference sources

Interference Source	Cause of Interference	Effect
Power converters, e.g., servo drive controllers	Circuit	Overvoltage, Compensating currents
Electric motors, e.g., servo motors, stepper motors	Commutator, winding	Electromagnetic field, Magnetic field
Switched inductors, e.g., solenoid valves, contactors, relays	Contacts, coils	Electromagnetic field, Magnetic field
Switching power supplies	Circuit, switching components	Electromagnetic field, Power line disturbance
Spark-generating machines, e.g., electric welding equipment	Contacts, transformer	Electromagnetic field, Power line disturbance, Compensating currents, Magnetic field
Wireless communication, e.g., WLAN, radios	Antenna	Electromagnetic field
Difference in earth or reference potentials	Voltage difference	Compensating currents
High-voltage power line	Current flow, switching of high currents, tripping of fuses	Power line dips, power surges, Electric field, Electromagnetic field

2.3.2 Coupling Paths

The coupling path is the transmission path for interferences from the interference source to the interference sink. There are different coupling mechanisms for this coupling path.

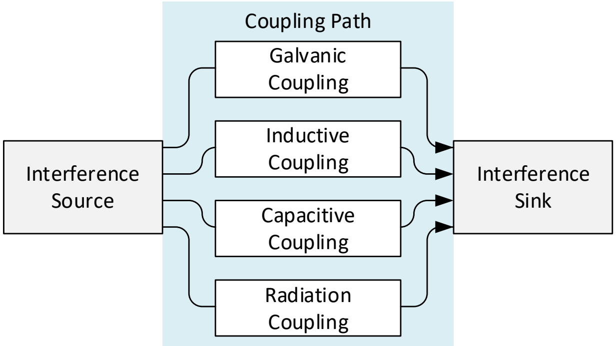


Figure 3 Coupling Mechanisms of the Coupling Path

Table 2 Coupling Mechanisms and Examples of Interference Sources

Coupling Mechanism	**Interference Source**
Galvanic Coupling Occurs whenever two circuits share a conductor, e.g., common ground line.	Examples: Switch-mode power supplies, Starting electric motors, Different potentials of component housings with common power supply.
Capacitive Coupling Occurs between mutually insulated conductors at different potentials.	Examples: Disturbance coupling through parallel-running lines, Static discharge from operating personnel.
Inductive Coupling Occurs between conductor loops where at least one is current carrying. The magnetic field generated by current in one conductor can induce current in another conductor.	Examples: Transformers, electric motors, electric welding devices, Power lines running parallel to signal lines, High-current switched power lines.
Radiation Coupling Occurs when electromagnetic waves hit a conductor. The electromagnetic wave induces currents and voltages.	Examples: Antennas of transmitters, e.g., WLAN, mobile phones, Spark gaps, e.g., collectors of electric motors, electric welding devices.

2.3.3 Interference Sinks

Interference sinks are electrical or electronic devices whose function can be influenced by electromagnetic disturbances.

Table 3 Examples of Disturbance Sinks

Disturbance Sink	Causing Disturbance	Reaction
Microprocessor-controlled devices, e.g., PLCs, safety switching devices, HMI, fieldbus systems, sensors	Impulsive disturbance quantities, e.g., switching operations, electromagnetic fields	Sporadic failure, transmission errors
Analog circuits	Low-frequency disturbance quantities, e.g., potential differences	Superimposition of the signal with the disturbance, e.g., 50 Hz hum on the desired signal

3 Measures to Reduce Electromagnetic Interference

This section contains recommendations for the prevention and reduction of electromagnetic disturbances and is intended to reflect good engineering practice.

Important Notes

- These recommendations do not claim to be exhaustive and should be reviewed and supplemented as needed for the specific application.
- For machines, the relevant legal and normative requirements regarding EMC must be complied with.
- For safety circuits in machines, the application of the following EMC standards may be required:
    - IEC 61000-6-2 – Immunity for industrial environments (up to PL b)
    - IEC 61000-6-7 – Immunity requirements for safety-related systems in industrial locations
    - IEC 61800-3 – EMC requirements including test methods for drive systems and machine tools
    - IEC 61000-1-2 – Procedures for achieving functional safety of electrical systems concerning electromagnetic phenomena

  Additionally, the following standard specifies possible measures to achieve the required immunity:
    - IEC 61204-1 – Electrical equipment of machines – Part 1: General requirements
- If different requirements arise for electrical safety and electromagnetic compatibility, the requirements for electrical safety always take precedence.

3.1 Overvoltage Protection

Requirement IEC 60204-1, H.3.2, a)
Overvoltage is unavoidable in the power supply network and must therefore be taken into account when designing safety circuits. Overvoltage can be caused by lightning strikes, switching operations by the power network operator, short circuits, electrostatic events, etc.
It is recommended to use a protection concept for overvoltage according to IEC 60664-1. IEC 60664-1 defines overvoltage categories for electrical components that are directly connected to the power supply network. The following overvoltage categories exist:

Table 4 Overvoltage categories according to IEC 60664-1

Overvoltage category	Description	Remarks	Examples
IV	Components for use at the installation connection point		Electricity meters, main fuses
III	Components for fixed installation with high availability		Circuit breakers, switches, machines, servo drive controllers
II	Components for connection to a fixed installation		PCs, printers, photocopiers
I	Components with insufficient overvoltage protection for connection to the power supply network	Any occurring overvoltage must be sufficiently limited.	Laptops, PLCs, valve terminals, valves, sensors

The concept of IEC 60664-1 is based on limiting the expected transient overvoltage to a defined level. For this purpose, the user information of the components should specify either the overvoltage category according to IEC 60664-1 or the rated impulse withstand voltage. If this information is not available, it must be assumed that the components are not intended for fixed installation in a power supply network. In such cases, additional measures must be taken.

When selecting components, the following should be considered:

1. Components used in safety circuits should have an overvoltage category of II.
2. If components of overvoltage category I or without any overvoltage category information are used, a Type 3 SPD (Surge Protective Device) must be installed before the safety circuit.
   Instead of an SPD, Type 3, a PELV power supply with overvoltage category II may also be used.

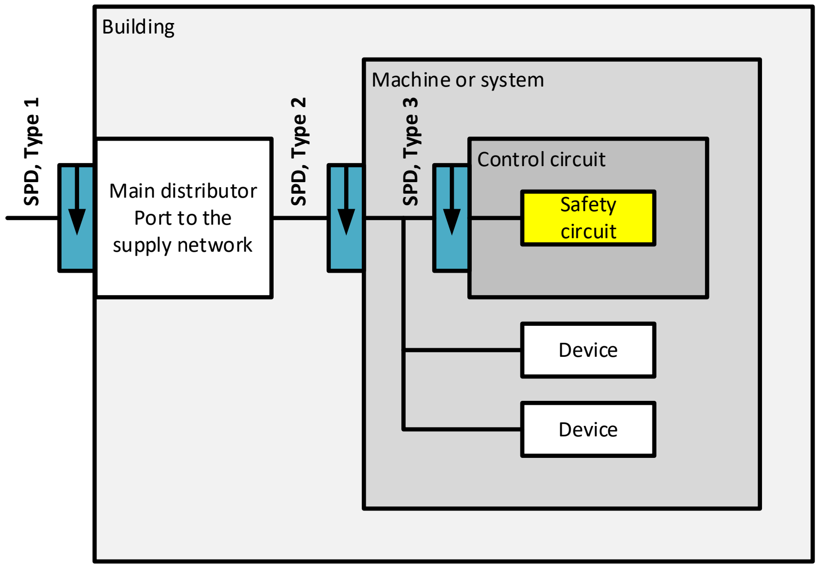


Figure 4 Overvoltage and Transient Protection for Safety Circuits

3.2 Filter

Requirement IEC 60204-1, H.3.2, a)

3.2.1 General

Filters are a supplementary EMC measure to shielding and serve to reduce conducted interference. For this reason, they are inserted into the conducted transmission path between the interference source and the interference sink. They should be installed as close as possible to the interference source.

3.2.2 Solenoid valves, electrically operated holding brakes, electromagnets (inductors)

In principle, all solenoid valves, electrically operated holding brakes, and electromagnets (inductors) are considered inductive sources of interference. When switched off, inductors can generate voltage spikes that are multiples of their own supply voltage, which can damage electronic outputs.
The “suppression of voltage spikes” is also a fundamental safety principle of ISO 13849-2. How this can be implemented is described in the Application Note ➚ “100568 Transient Suppression.”

3.2.3 Servo Drive Controllers and Servo Drives

To comply with the emission limits for servo drive controllers, filters are required for servo drive controllers. These filters serve to filter out the interference generated by the servo drive controller. The necessary filters and measures for servo drive controllers are specified in their user information. It is important that servo drive controllers have an EMC conformity declaration, which confirms compliance with the implementation of EN IEC 61800-3 as a basis.
Festo servo drive controllers have integrated line filters that are sufficient for most applications. When a servo drive controller is used in commercial or residential areas, line inductors may be required to comply with power quality standards according to IEC 61000-3-2. For long motor cables, an external line filter may be necessary.

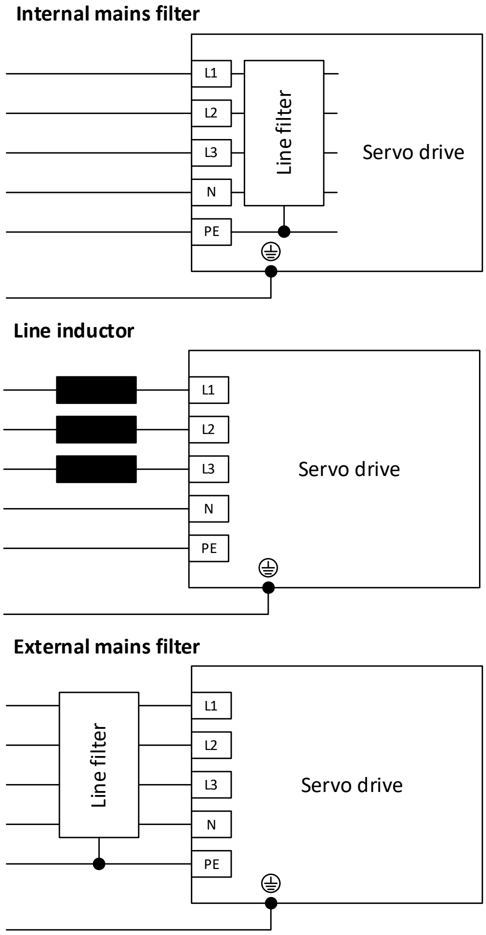


Figure 5 EMC Measures for the Power Supply Connection of Servo Drive Controllers

If sensitive devices are still disturbed, an EMC assessment through measurements is usually necessary. Based on the measurement results, targeted EMC measures and filters can then be dimensioned and installed for the sensitive devices.

Installation Instructions for Filters

1. Filters should be mounted and connected according to the manufacturer’s installation instructions.
2. The installation should be done on a metal plate with a large area and well-conductive contact surface. Painted control cabinet walls, DIN rails, etc., with poor connection to the protective equipotential bonding or limited contact area are not suitable for mounting filters.

Wiring of Filters

1. The supply and output lines of filters should be routed separately.
2. The cables to and from the filters should be routed separately from signal lines.
3. To comply with emission limits, the cables between the filter and the servo drive controller should be kept as short as possible or shielded.

3.3 Protective Equipotential Bonding and Functional Equipotential Bonding

Requirement IEC 60204-1, H.3.2, b), k)

Protective equipotential bonding with the protective conductor is required for electrical safety. It ensures that all non-active and conductive parts are connected to earth. This typically causes dangerous voltages in the event of a fault to be short-circuited, and an overcurrent protection device (fuse) interrupts the electrical power supply. Functional equipotential bonding is not intended for electrical safety. In most cases, it serves to connect sensitive devices to earth or to reduce capacitive and inductive coupling from interference sources.

Devices with high power, such as servo drive controllers, servo motors, and power supplies, can have leakage currents through the protective conductor that may cause interference in other devices. Therefore, the protective conductors of these devices should be consolidated only at a central point within the machine or system.

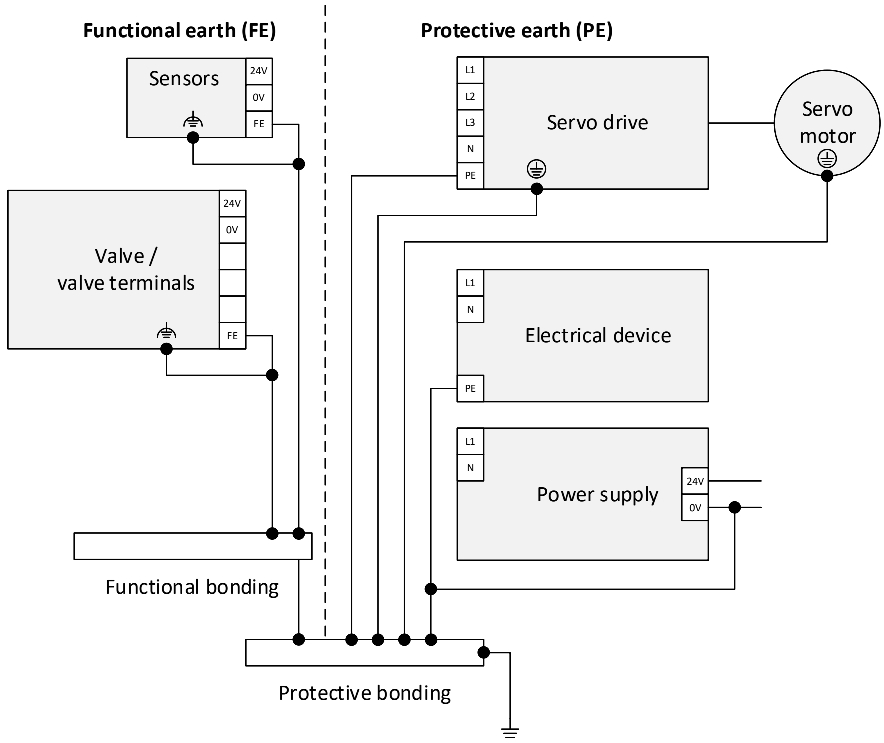


Figure 6 Functional and Protective Equipotential Bonding

Important Notes

- For servo drive controllers, the requirements for protective conductors must always be considered. According to DIN EN 50178, a maximum current of 3.5 mA (AC) or 10 mA (DC) is allowed to flow on protective conductors. Since leakage currents are normally often higher, at least the routing of a second protective conductor in parallel—connected via separate terminals alongside the protective conductor—is required.
- Unused conductors in power cables, for example those intended for controlling a holding brake, must be connected to the protective equipotential bonding at least on one end. Otherwise, dangerous voltages can arise due to capacitive coupling.
- Conductive cable shields must always be connected to the protective equipotential bonding, see ➔ Figure 10.
- Figure 6 shows both functional and protective equipotential bonding. In some cases, a single protective equipotential bonding may be sufficient.

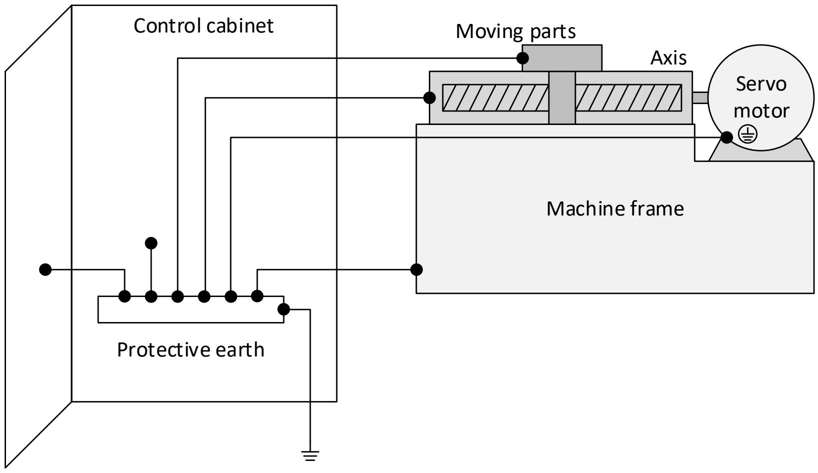


Figure 7 Protective Equipotential Bonding of All Conductive Parts of a Machine

All metallic conductive parts of the machine should be connected to the protective equipotential bonding with low impedance, including the control cabinet and the control cabinet door.

3.4 Cable Routing

3.4.1 Cables

- Unshielded cables of the same circuit must be twisted together, see ➔ Figure 1 and ➔ Section 3.4.2.
- Signal cables and their associated equipotential bonding conductor should be routed with the smallest possible distance between them, see ➔ Figure 8.

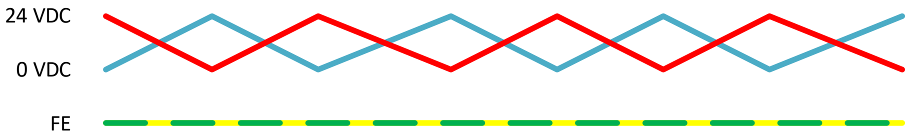


Figure 8 Twisted Cable and Equipotential Bonding Conductor

- Signal cables must never be routed past devices and equipment that can generate strong magnetic fields, such as welding machines, servo motors, and transformers.
- Signal cables should preferably be guided into the control cabinet in a single plane, for example, from below.
- Signal cables should be laid continuously without interruptions.
- Unnecessary cable lengths must be avoided to keep coupling capacitances and inductances as low as possible. Excessively long cables should be shortened.
- The ingress of foreign substances such as oil, cooling lubricants, chips, or dirt into connectors must be prevented.
- Connectors must be securely fastened to the assemblies.

3.4.2 Twisted Cables

Recommendations for the twist rate:

- Use a uniform, tight winding density. The smaller the twists, the smaller the loop area, and thus the lower the induced interference voltage.
- Always twist data, control, or power cables in pairs.
- Typical twist pitches are:
    - Low-frequency signals (analog sensors, control lines):
      10 to 20 twists per meter (twist pitch 50 to 150 mm)

- Digital fieldbuses and fast signals:
  20 to 50 twists per meter (twist pitch 20 to 50 mm)
- Power and supply lines:
  to 10 twists per meter (twist pitch 100 to 200 mm)

The twist pitch depends on the cable type and is usually specified by the cable manufacturer. As a rule of thumb, a short and uniform twist pitch should be used.

Additional Recommendations for Routing:

- Use the shortest possible total cable lengths.
- Employ tight bundling of cables where possible.
- Avoid parallel routing alongside potential interference sources (motor cables, power lines).
- Do not route twisted cables in tight bends to maintain the consistency of the twist pitch.

3.4.3 Power Cables

- Cables carrying current or voltage pulses must always be routed separately from all other cables. This includes, for example, motor cables and power supply lines.
- If separate routing is not possible, shielded cables must be used for the power cables.

3.4.4 Cable Crossings

- Signal cables and power cables may cross each other at right angles.

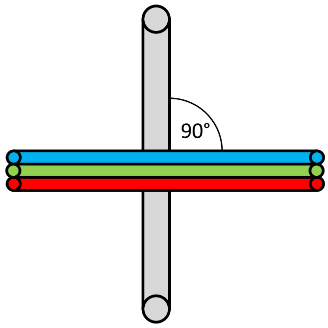


Figure 9 Crossing of Signal and Power Cables

- Close, parallel routing of signal and power cables is not allowed. The minimum distance specified in ➔ Table 5 must be maintained, or other suitable measures must be implemented.

3.4.5 Shielded Cables

Requirement IEC 60204-1, H.3.2, i)

Conductive shields of cables should be connected with low impedance to the protective equipotential bonding. Various methods exist to achieve this:

- The shield is conductively connected to the enclosure via conductive connectors, which in turn are connected to protective earth.
- If a device has only a single connection for individual wires, the shield should be connected over a wide area to protective earth via a bonding bar.
- If current flows through the shield, it may be necessary to use a parallel conductor alongside the shield to reduce the shield current as much as possible.
- When stripping the cable, the shield braid must not be damaged. Shield ends must not be twisted or soldered, as this reduces the effective cross-section. Shield ends must be laid out over a wide area.
- Shielded cables should have a finely stranded braided shield, for example, like NEBM-type cables. Less finely braided shields provide poorer shielding effectiveness. Foil shields have significantly worse shielding performance and are therefore unsuitable.
- Shielded cables should be connected on both ends, over a large area and with good conductivity, to grounded enclosures. This reduces capacitive, inductive, and radiated coupling.

- Cable entries for shielded cables should use cable glands that ensure 360° shield contact and are tested according to IEC 62153-4-10.
- Cable shields should be laid down immediately after passing through the control cabinet entry.
- Separate EMC shield bonding bars should be used for power cables. For signal and data cables, the shield contact points available on devices or inside control cabinets should be used.
- Cable shields should not be interrupted by intermediate terminals.
- Cable shields must be fastened using suitable EMC shield clamps that connect the shield over a large area and with low inductance to the EMC shield bonding bar or available contact points.
- Connectors for shielded data cables, such as fieldbus cables, should only use metallic or metallized connector housings.

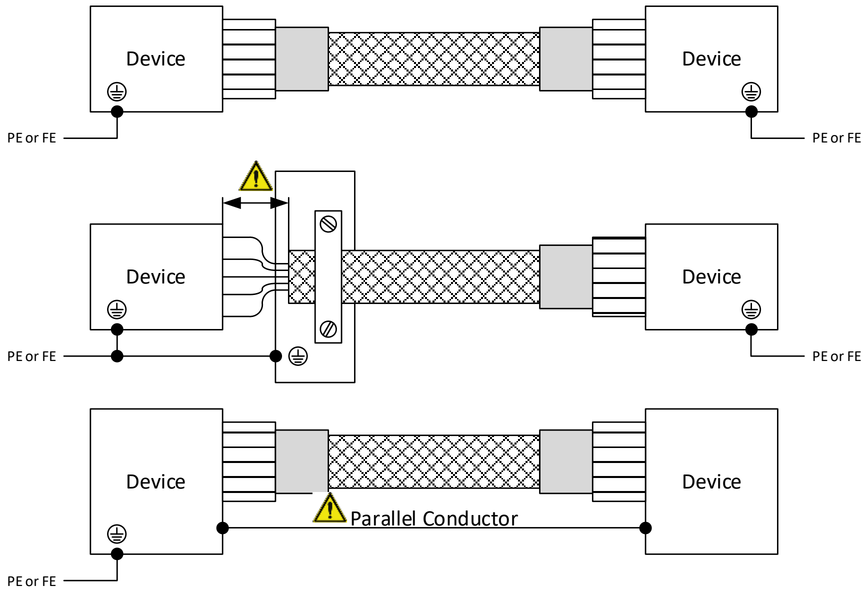


Figure 10 Connection of shield to PE (Protective Earth) or FE (Functional Earth)

Notes

- Free cable ends of shielded cables should be kept as short as possible.
- A parallel conductor for shielding is a measure that does not eliminate the root cause. Efforts should always be made to identify and reduce or eliminate the cause of current flowing through the shield. A good protective equipotential bonding between the machine components can reduce the need for parallel conductors.
- If an interruption in shielded cables is necessary, for example at a terminal point, continuous shielding must be ensured. Free cable ends of shielded cables should be kept as short as possible.

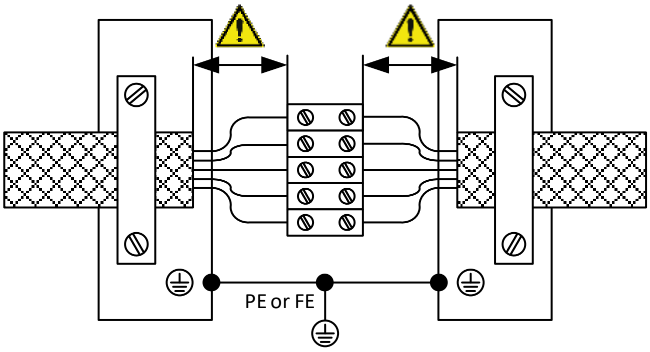


Figure 11 Free cable ends without shielding

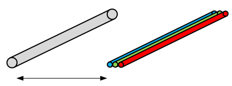
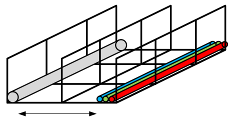
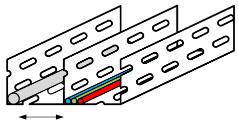
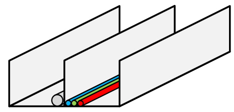
3.4.6 Spare Cables or Unused Conductors

- Never leave spare cables or unused conductors as loose loops in cable ducts. Coiling or long loops increase inductive coupling and radiation.
- Always route cables as straight and loop-free as possible. If bending radii cannot be avoided, use the largest possible radii (> 10 times the cable diameter).
- Shielded spare cables must be contacted all around at the control cabinet, for example, via a cable gland tested according to IEC 62153-4-10. Unused shield ends at the other end must be connected to ground or terminated with a high-frequency capable resistor. Open shields can act like antennas.
- Spare cables should be kept as short as possible (max. 0.5 m in a duct). Longer spare cables should be routed only in separate, shielded sub-ducts to avoid coupling with active cables.
- Attach spare cables close to the enclosure bottom or back panel. Never route them underneath electronic devices.
- Clearly label every spare cable or unused conductor, e.g., “Spare xyz,” length, intended function.
- Document them in the wiring diagram and EMC concept to ensure correct measures during commissioning or retrofitting.
- During retrofits, ensure that fundamental EMC measures (shielding, routing) continue to be observed.

3.4.7 Routing and Spatial Separation

- As a general rule, all cables should be routed as close as possible along metallic enclosure parts, such as control cabinet walls, machine frames, metal rails, etc. Long cable runs through open space can lead to interference coupling.
- Signal cables must be routed separately from power cables with a minimum distance. The recommended minimum distance depends on the routing and the electromagnetic obstacles used. The minimum distances given in ➔ Table 5 apply both horizontally and vertically.
- Loop formation should be avoided by routing cables directly and without loops. Loops increase the coupling area and raise susceptibility to interference.
- If this spatial separation is not possible, shielded cables are generally required.

Table 5 Minimum Distances Between Signal Cables and Power Cables (According to IEC 60204-1, Table H.1)

Without electromagnetic barriers	With electromagnetic barrier made of wire mesh (grid)	With electromagnetic barrier made of perforated sheet	With electromagnetic barrier made of solid sheet metal
			
≥ 200 mm	≥ 150 mm	≥ 100 mm	0 mm
	Wire mesh, Mesch size 50 x 100 mm	Steel sheet, thickness ≥ 1 mm 20% perforation, evenly distributed	Steel sheet, thickness ≥ 1 mm

3.4.8 Cable Ducts

- Cable ducts must form a continuous, conductive metal structure along their entire length.
- Connections must not have insulating layers, must be connected conductively over a large surface area, and must be corrosion-protected.
- A single short slit can reduce shielding effectiveness by a factor of ten at high frequencies.
- Cable ducts must be connected to the protective equipotential bonding with a low-impedance protective conductor.
- Grounding straps should be finely stranded and short (≤ 200 mm) to effectively conduct leakage currents.
- Large-area screw connections to all metal parts conduct low-frequency (LF) and high-frequency (HF) interference currents to the equipotential bonding.
- Closed profiles provide better characteristic impedance than trays with holes or slots. If slots are necessary, they should be arranged parallel to the duct axis. Crosswise slots create local weak points in the shielding.
- Deep profiles reduce the leakage of magnetic fields at the edges.

3.4.9 Recommendations from Device Manufacturers

- The electronic devices used must comply with the requirements of the harmonized standards of the EMC Directive 2014/30/EU. Device manufacturers are therefore obliged to specify the minimum required EMC measures for an application in the installation or operating instructions.
- For this reason, the information provided by the device manufacturer in their user documentation must always be observed and implemented.
- The permissible cable lengths specified by the manufacturer must be adhered to. These cable lengths usually refer to the original cables supplied by the manufacturer.

3.4.10 Protection of Cables

- Cables and connectors must always be protected against mechanical damage, for example by cable ducts, enclosures, or control cabinets.

3.4.11 Energy Chains

- For energy chains, cables suitable for this purpose must be used.

3.5 Construction and Assembly of Control Cabinets

Inside a control cabinet, it is also important to ensure that sources of interference (noise sources) are spatially separated from interference receivers (noise sinks). For this purpose, a zoning concept must be developed for each control cabinet and its surroundings. This means defining EMC zones in which similar types of interference sources or interference receivers are grouped together.
A possible zoning scheme could be defined as follows:

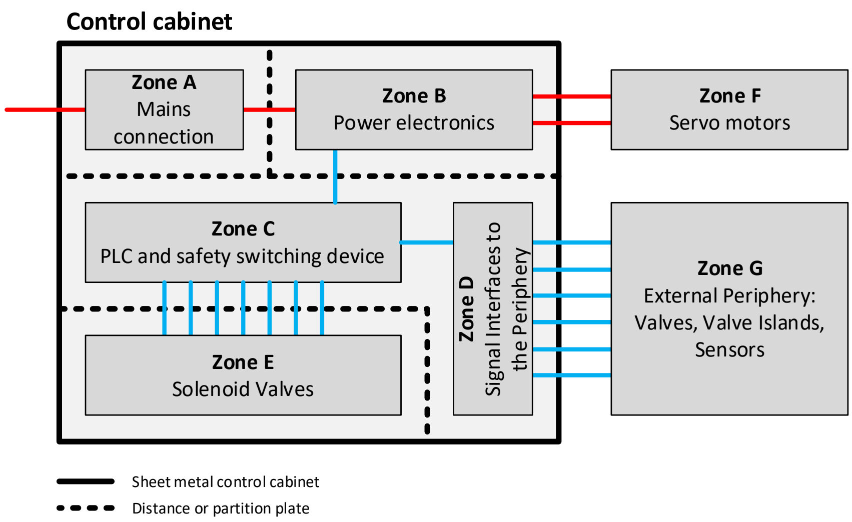


Figure 12 Example of a Zoning Concept for Control Cabinets

Table 6 Example of a Zoning Concept for Control Cabinets

Zones inside control cabinet	**Zones outside control cabinet**
• Zone A: Mains Connection Fuses, switches, contactors, line filters, line chokes • Zone B: Power Electronics Power supplies, servo drive controllers, filters • Zone C: Control, Safety switching device, and Visualization Control system, safety PLC, safety relay • Zone D: Signal Interfaces Digital interfaces, analog interfaces, fieldbuses • Zone E: Solenoid Valves Electrically actuated solenoid valves	• External Zone F: Electric Motors Servo motors, stepper motors • External Zone G: Valves, valve terminals, sensors, external periphery

- Each zone has specific requirements regarding electromagnetic emissions and immunity. These zones must be electromagnetically decoupled either by distance or by a partition plate.
- Components within each zone should have the same EMC environment requirements and the same immunity level.
- Generally, cables within each zone can be routed unshielded; however, the component manufacturers' specifications must always take priority.

- Cables from different zones must be separated and must not be routed together in the same cable ducts. If cables are routed in a common cable duct, additional measures are required—see also ➔ Table 5 and ➔ 3.4.8 Cable Ducts. If no additional measures are possible in the cable duct, shielded cables must be used.

3.5.1 Mechanical Construction of the Control Cabinet

- All metallic parts of the control cabinet, including the cabinet doors, must be electrically well-conductive and connected over a large surface area. The goal is to create a closed Faraday cage.
- The protective equipotential bonding bar and the functional equipotential bonding bar (if used) must be electrically well-conductive and connected over a large surface area to the control cabinet.
- The metallic housings of all devices inside the control cabinet must be well-conductive and connected over a large surface area to the mounting plate or the control cabinet.
- For certain components, a separate connection of the protective conductor to the protective equipotential bonding bar is required, e.g., servo drive controllers.
- All connections must be made permanently. For painted surfaces, the insulating paint layer must be removed or contact washers must be used. For anodized surfaces, contact washers must be used.

3.5.2 Cable Routing in the Control Cabinet

- All power cables must be routed spatially separated from signal and data cables. Power cables include mains cables, DC link cables, connection cables between servo drive controllers and electric motors, and brake resistors. The minimum distance between these cables should be 250 mm, or electromagnetic separation using partition plates is required. These partition plates must be well-conductively connected to the mounting plate.
- Low-interference mains cables, e.g., mains cable from the supply to the line filter, must be routed separately from unfiltered power cables with high interference levels, such as mains cables between line filter and inverter, DC link cables, cables between servo drive controller and brake resistor, and motor cables.
- Signal and data cables and filtered mains cables should only cross unfiltered power cables at right angles to reduce possible interference coupling.
- All cable lengths should be kept as short as possible. Unnecessary cable lengths must be avoided.
- All cables should be routed as close as possible to grounded enclosure parts, such as mounting plates or frames. This reduces both radiated interference and interference coupling.
- Signal and data cables and their associated equipotential bonding conductors should always be routed in parallel and with the smallest possible spacing.
    - If unshielded single conductors are used within a zone, the conductors of the forward and return lines must be twisted together (but not twisted with the equipotential bonding conductor). When using jacketed cables, these are usually twisted.
    - Spare conductors in signal and data cables must be grounded at both ends to provide additional shielding effect.
    - Signal and data cables should enter the control cabinet at only one location, for example, from below.

3.5.3 Cables Outside the Control Cabinet

- All power cables, such as mains cables, DC link cables, connection cables between servo drive controllers and their associated brake resistors, and motor cables, must be routed separately from signal and data cables. The minimum distance between power cables and signal/data cables is 250 mm, or additional measures must be taken, such as shielding.
- For servo drive controllers, the manufacturer's specified cables must be used. Special requirements apply to cables between servo drive controllers and electric motors. The motor cable and the cable to

the motor temperature sensor (PTC) are considered power cables, while the cable to the integrated measurement system is a shielded signal cable.

- Signal cables carrying particularly sensitive setpoint and actual value signals, such as tachometer, encoder, and resolver signals, should be routed continuously with good shielding and shielding contact on both ends.

4 Definitions

- Overvoltage (according to IEC 60664-1, 3.1.11)
  A overvoltage is any voltage having a peak value exceeding the corresponding peak value of maximum steady-state working voltage at normal operating conditions.
- Transient overvoltage (according to IEC 60664-1, 3.1.13)
  A transient overvoltage is a short duration overvoltage of a few milliseconds or less.
- Protective earthing (according to 195-01-11)
  Earthing for purposes of electrical safety.
- Functional earthing (functional grounding) (according to 195-01-13)
  Earthing for purposes other than electrical safety, e.g. as measure for electromagnetic compatibility.
- Protective equipotential bonding (according to 195-01-15)
  Equipotential bonding for the purposes of electrical safety.
- Functional equipotential bonding (according to 195-01-16)
  Equipotential bonding for reasons other than electrical safety
- Impedance to earth (ground) (according to 195-01-17)
  Impedance at a given frequency between a specified point in a system or in an installation or in equipment and reference earth
- Electrical safety (according to 195-01-20)
  Freedom from risk that is not tolerable, and which is caused by electricity
- Earth electrode (ground electrode) (according to 195-02-01)
  Conductive part that is in electric contact with local earth, directly or through an intermediate conductive medium.

5 Used Literature

5.1 Cited Documents from Festo

[100568 Transient Suppression]

5.2 Standards

[1] DIN EN ISO 12100:2011-03 - Safety of machinery - General principles for design - Risk assessment and risk reduction (ISO 12100:2010); German version EN ISO 12100:2010

[2] DIN EN ISO 13849-1:2023-12– Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design (ISO 13849-1:2023); German version EN ISO 13849-1:2023

[3] DIN EN ISO 13849-2:2013-02 – Safety of machinery - Safety-related parts of control systems - Part 2: Validation (ISO 13849-2:2012); German version EN ISO 13849-2:2012

[4] EN 50178:1997-10 - Electronic equipment for use in power installations

[5] DIN EN 60204-1:2019-06 - Safety of machinery - Electrical equipment of machines - Part 1: General requirements (IEC 60204-1:2016, modified); German version EN 60204-1:2018

[6] DIN EN 61000-1-2:2017-07 - Electromagnetic compatibility (EMC) - Part 1-2: General - Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena (IEC 61000-1-2:2016); German version EN 61000-1-2:2016

[7] DIN EN 61000-6-7:2015-12 - Electromagnetic compatibility (EMC) - Part 6-7: Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations (IEC 61000-6-7:2014); German version EN 61000-6-7:2015

[8] DIN EN 61326-3-1:2018-04 - Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) - General industrial applications (IEC 61326-3-1:2017); German version EN 61326-3-1:2017

[9] DIN EN 61508:2011-02 - Functional safety of electrical/electronic/programmable electronic safety-related systems (IEC 61508:2010); German version EN 61508:2010

[10] DIN EN 61511:2019-02 - Functional safety - Safety instrumented systems for the process industry sector - (IEC 61511:2016); German version EN 61511:2017

[11] DIN EN IEC 61800-3:2019-04 - Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods (IEC 61800-3:2017); German version EN IEC 61800-3:2018

[12] DIN EN IEC 62061:2023-02 - Safety of machinery - Functional safety of safety-related control systems (IEC 62061:2021); German version EN IEC 62061:2021

[13] DIN IEC 62153-4-10:2023-08 – Metallic communication cable test methods - Part 4-10: Electromagnetic compatibility (EMC) - Transfer impedance and screening attenuation of feed-throughs and electromagnetic gaskets - Double coaxial test method (IEC 62153-4-10:2015 + AMD1:2020)

[14] IEC 62368-1:2023-05 - Audio/video, information and communication technology equipment - Part 1: Safety requirements

5.3 Legal Regulations

[15] Machinery Directive: Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)

[16] EMC Directive: Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to electromagnetic compatibility (recast)

6 Information about the Document

6.1 General Information

Document Number	**100565**
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6.2 Revision History

Ver.	Date	Ed.	Chapter	Description of Change/Impact
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6.3 Approval/Release of the Document

Role	Signature
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6.4 Period of Validity

Document is valid until 2031-05-06 or until one of the documents used or the required relevant base are changed.

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