TECHNICAL INFORMATION

Background knowledge on EMC

Safety laser scanners, safety camera sensors

SICK
Sensor Intelligence.

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Legal information

Original document

This document is an original document of SICK AG.

Contents

1 About this document

1.1 Purpose of this document

Overview

This document provides information on a suitable electrical connection of safety laser scanners and safety camera sensors from SICK in order to achieve a high level of electromagnetic compatibility (EMC) and a high level of robustness against electrostatic discharge (ESD).

The document deals primarily with safety laser scanners. The basic principles, however, apply equally to safety camera sensors.

The systems in which safety laser scanners and safety camera sensors are used are becoming increasingly complex. Data transfer between devices and systems is increasing. At the same time, safety laser scanners and safety camera sensors are increasingly being used in mobile platforms. It is therefore becoming increasingly important to prevent electromagnetic interference.

Safety components switch all safety outputs to the OFF state in the event of errors in order to rule out potentially dangerous situations. For example, faulty data transmission must lead to a shutdown for safety-related devices, even if it can be tolerated for non-safety-related devices.

Limits of this document

This document deals exclusively with electromagnetic compatibility. Legal requirements and the operating instructions of the devices must also be observed.

The measures described are recommendations only. Depending on the specific circumstances, it is possible in individual cases that the recommendations will not be suitable for a specific application.

Electromagnetic interference depends on the environment in which the product is used. Therefore, despite the measures recommended here, interference caused by other external influences from the environment may occur.

SICK does not guarantee that the measures described will prevent electromagnetic interference (EMI). In particular, SICK excludes any liability for damages arising in connection with the measures described. If necessary, you can obtain further support from your SICK branch office.

1.2 Scope

Product

This document applies to safety laser scanners and safety camera sensors from SICK.

Document identification

Document part number:
- This document: 8027032
- Available language versions of this document: 8027030

You can find the current version of all documents at www.sick.com.

1.3 Target audiences for this document

This document is intended for professionals who plan the electrical integration of safety laser scanners or safety camera sensors from SICK or who eliminate electromagnetic interference.

1.4 Symbols and document conventions

References to sources are given as numbers in square brackets. The sources can be found in the appendix, see "Annex", page 29.

2 EMC: Basics

2.1 Basics of equipotential bonding and reference potential

Overview

For the correct electrical connection of SICK safety laser scanners, it is important to distinguish between equipotential bonding (functional earth FE and protection earth PE) and reference potential (0 V).

Equipotential bonding (earthing)

Equipotential bonding (also: earthing) can be divided into protective equipotential bonding PE (also: protection earth) and functional equipotential bonding FE (also: functional earth). [1)]

Protective equipotential bonding PE

Protective equipotential bonding (also: protection earth) is used to protect persons from electric shock in the event of a fault when indirectly contact the device. [2)] The marking is made using the color combination green-yellow and the letters PE (English: Protective Earth). In some countries, different identifiers are also permitted, e.g., “ground” or “GND”.

Functional equipotential bonding FE

Functional equipotential bonding (also: functional earth) is used with safety extra-low voltage and has a purely functional task. The functional equipotential bonding is intended to reduce electromagnetic influences and thus ensure fault-free operation. The marking is made using the letters FE (English: Functional Earth).

As a rule, functional equipotential bonding FE is established through a connection with the protective conductor system. In some cases, however, this is not sufficient and separate conductors must be laid. An FE connection must never be used as a protective equipotential bonding.

Reference potential 0 V

The reference potential of a circuit is also called ground (GND). The reference potential for SICK safety laser scanners is 0 V. For devices of protection class II, the reference potential is galvanically isolated from the functional earth. SICK safety laser scanners of protection class III feature capacitive coupling, a connection via TVS diodes (Transient Voltage Suppressor) and a connection via varistors.

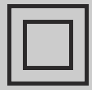
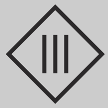
2.2 Protection against electric shock

Protection classes [3)]

Categorization in different protection classes indicates the means by which single-fault safety is achieved.

	**Protection class I** All devices with simple insulation (basic insulation) and a protective conduction connection are in protection class I. The protective conductor must be connected to a terminal marked with the earthing symbol or PE and be green-yellow.

1) Cf [3], section 8.
2) Indirect contact means that a conductive part which is not normally live (e.g., a metal housing) is nevertheless live due to a fault and can be touched by a person.
3) Cf. [1].

	**Protection class II** Equipment in protection class II has increased insulation or double insulation and is not connected to the protective conductor. This protective measure is also known as protective insulation. There shall be no connection of a protective conductor.
	**Protection Class III** Equipment in protection class III operates with a safety extra-low voltage and, therefore, does not require any explicit protection.

Safety extra-low voltage SELV/PELV [4]

AC voltages up to 50 volts rms (V_{rms}) and DC voltages up to 120 volts are permissible as protective extra-low voltage, or more correctly: safety extra-low voltage. Above a limit of 75 volts DC, the requirements of the Low Voltage Directive must also be observed.

When used in normally dry rooms, protection against direct contact (basic protection) can be dispensed with if the rms value of the AC voltage does not exceed 25 volts or the harmonic-free DC voltage does not exceed 60 volts. A harmonic-free state exists when the DC voltage is superimposed with a sinusoidal AC voltage component of no more than 10% effective.

The safety extra-low voltage circuit shall be safely separated from other circuits (adequate air and creepage distances, insulation, connection of circuits to the protective conductor, etc.).

A safety extra-low voltage shall not be generated from the mains using autotransformers, voltage dividers, or series resistors.

Two safety extra-low voltages are distinguished:

- SELV (safety extra-low voltage)
- PELV (protective extra-low voltage)

		ELV (AC < 50 V_{rms}, DC < 120 V)	
		SELV	**PELV**
Type of isolation	**Power sources**	Power sources with safe isolation, e.g., a safety transformer or equivalent power sources	
	Circuits	• Circuits with safe isolation from other non-SELV or non-PELV circuits • Circuits with basic insulation between SELV and PELV circuits	
Relation to earth or a protective conductor	**Circuits**	Unearthed circuits	Earthed or unearthed circuits
	Housing	Housings cannot be intentionally earthed and also not connected to a protective conductor.	Housings can be intentionally earthed or connected to a protective conductor.

4) Cf. [1].

		ELV (AC < 50 V_{rms} , DC < 120 V)	
		SELV	**PELV**
Additional measures	Nominal voltage: • AC > 25 V or • DC > 60 V or • Equipment in water	Basic protection by means of insulation or casings in accordance with standards	
	Nominal voltage in normal dry environment: • AC ≤ 25 V or • DC ≤ 60 V	No additional measures required	Basic protection by means of: • Insulation or sheathing conforming to standards or • Body and active parts connected to main earthing rail

2.3 The EMC influence model

In the EMC influence model, there is an interference source and an interference sink. The interference source influences the interference sink via the coupling path. The coupling path describes the interference coupling between the electronic systems.

Table 1: EMC influence model with examples for interference source and interference sink

Interference source		Coupling path		Interference sink
• Frequency inverters, drives • Motors • Electronic contactors • High and discontinuous currents • Static discharge due to contact or moving machine parts • Thunderstorm • Wireless transmission systems (radio, telephone, WLAN) • Overvoltage		• Capacitive coupling (due to the effect of the electric field) • Inductive coupling (due to the effect of the magnetic field) • Galvanic coupling (via common impedances) • Radiated coupling [5].		• Sensors • Electronic devices • Radio receiver (TV, radio) • Entertainment electronics • Analog signal processing • Information systems • Any conductors, wires • Medical equipment

2.4 Measures to reduce electromagnetic interference (EMI)

In general, only electrical equipment that complies with the requirements of the relevant product laws may be used. These usually refer to EMC standards and requirements for the respective field of application, e.g., industrial.

Some relevant measures to reduce electromagnetic interference are described in this document. Further measures are described in [3] (Appendix H.3.2).

5) Based on [2], p. 76

3 Shielding

Electromagnetic shielding can be introduced into the coupling path at both the interference source and the interference sink. As a result, only part of the electromagnetic interference reaches the interference sink. A shield therefore serves as an interference suppressor. The classic definition of a shield for field-coupled interference is: “An electromagnetic shield is an interference suppression device which serves to weaken electromagnetic fields within or outside a certain range”. [6)]

3.1 Applying a shield

Electromagnetic interference depends on the environment in which the product is used.

Experience shows that the shielding should be applied on both sides. Deviations are only permitted in exceptional and justified cases. Especially when using motors or other inductive consumers, one-sided support of the shielding is not sufficient because it does not act against inductive interferers.

Recommendation:

- Always connect the shielding to FE or PE on both sides and over a large area.

3.2 Mechanical implementation of the support

Overview

By applying the shielding over a large area, it is ensured that the connection is designed to be as low-impedance as possible. A twisted shield or soldered connections should be avoided, as this greatly reduces the effective cross-sectional area of the entire shield and increases the resistance. This greatly reduces the effect and may even lead to additional coupling.

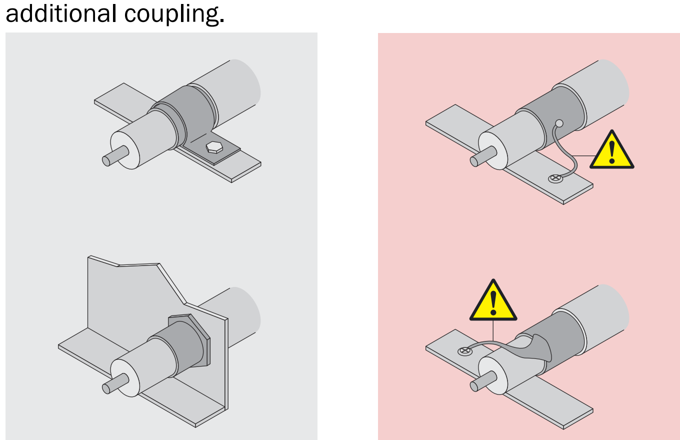


Figure 1: Connecting the shield correctly [7)]

Left	Correct: Shield is short and fully tethered
Right	Incorrect: So-called pigtails

Position of the support

To prevent interference currents from the shielding reaching the inside of the control cabinet, the shielding must be connected to FE or PE where the cable enters the control cabinet.

6) [4], p. 5f.
7) Cf. [1].

In addition, the shielding should be continued to the connection point and reapplied there. As a result, the shielding is incorporated as close as possible to the respective connection point of the line without interruption. The unshielded area of the line is reduced to a minimum.

Recommended components are presented below.

Cable gland at the control cabinet inlet

For metallic feedthroughs, such as when entering a metallic control cabinet, EMC-compliant cable glands with continuation of the shielding braid are the best choice. This ensures that the shielding is applied over a large area without damage and that the cable is additionally protected against mechanical stress. This solution offers the best possible EMC protection and should be preferred.

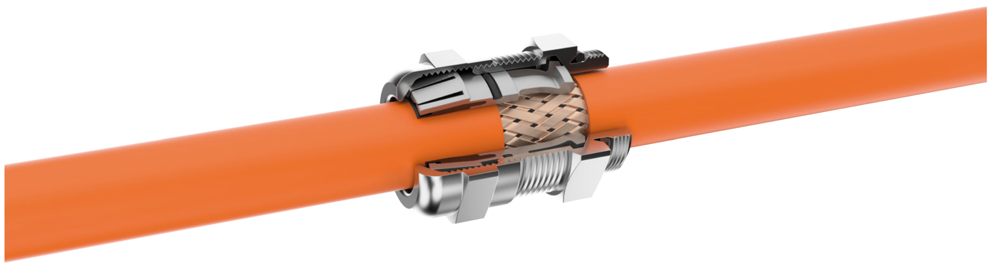


Figure 2: Cable gland with continuation of the shielding braid [8].

Supporting the shielding directly in front of the connection point

Using a shield clamp, the shield can be connected at the right place directly in front of the connection point. A busbar holder snaps onto the top-hat rail and allows the shielding to be placed close to the connection, even for components with higher connection points. Due to the suitable height, the unshielded area in front of the device input and thus the coupling of interferences are minimal.

Figure 3: Shield clamp [9].

Figure 4: Busbar support for high connection point [9].

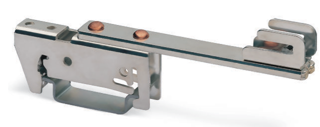


Figure 5: Busbar support for low connection point [9].

Complementary information

If the shielding is not already applied at the entry to the control cabinet, there is a risk that interference currents will be conducted into the sensitive areas of a control cabinet. In the control cabinet, such a shielding must be treated like other cables with high interference potential, laid accordingly, and provided with a filter via suitable measures.

8) [5]
9) [6]

3.3 Recommended data lines

To prevent electromagnetic interference and ensure reliable data transmission, data lines must be shielded. Cables with double shielding are recommended, see figure 6, page 12. The shield coverage should be at least 65%. Braided shields or combinations of braided shields and foil shields provide the best protection against interferers encountered in industry. Pure foil shields are not recommended.

Potential sources of interference can be further reduced by using shielded voltage supply cables.

In addition to the data cable, the plug connectors must also be designed to meet EMC requirements. Recommended are, for example, EMC-compliant M12 Ethernet connectors (see figure 7, page 12), which should be preferred to simple RJ45 connectors in demanding environments.

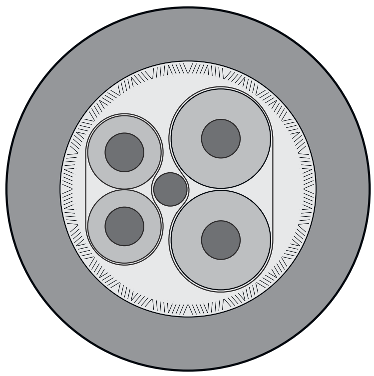


Figure 6: Recommended cable structure using the example of a CAN/DeviceNet cable [10].

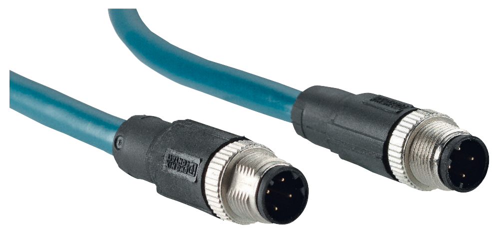


Figure 7: M12 Ethernet cable

3.4 Examples of EMC-compliant wiring and shielding

Figure 8: Large-area connection of the shielding to ground busbars

10) Based on [7], p. 37

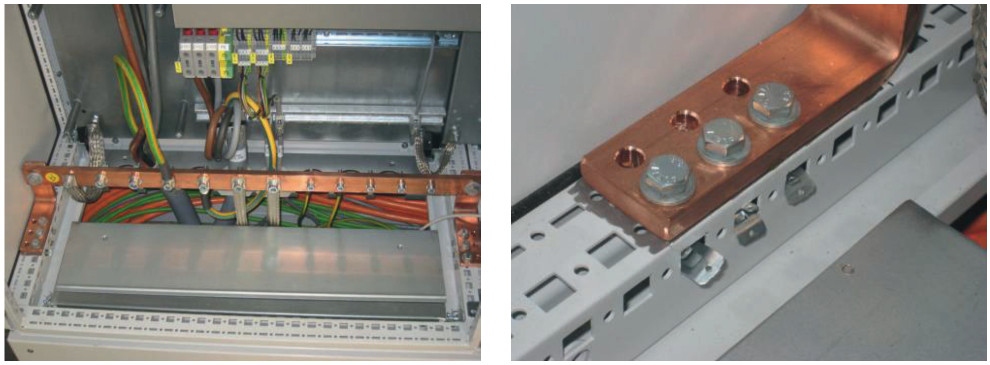


Figure 9: Low-impedance connection due to large design and well-conducting surfaces (coating may have to be removed)

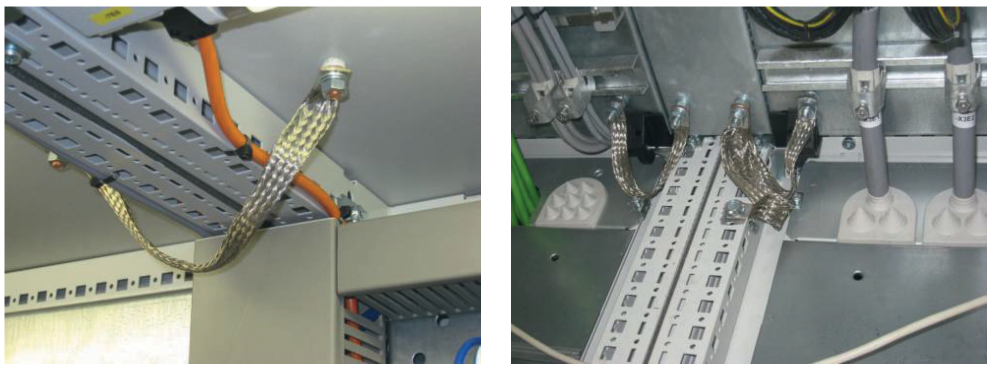


Figure 10: Connection of the metallic parts of the control cabinet to earthing straps

4 Further interference suppression measures

The following subsections contain, among other things, excerpts from [9] and give an overview of general interference suppression measures.

4.1 Mains filter

To prevent high-frequency interference (e.g., from converters) from entering the AC power distribution system despite shielding, mains filters should be used at the input.

For the filter to work properly, it must be mounted directly at the entry to the control cabinet. The unfiltered area of the AC line within the control cabinet is thus reduced to a minimum.

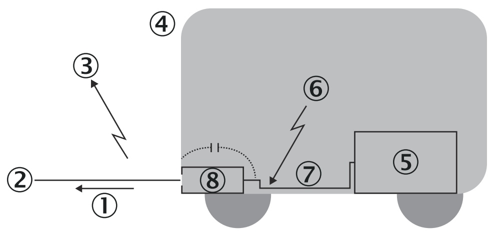


Figure 11: System with properly installed mains filter [11].

① Cable-bound fault
② Cable to the input filter (e.g., supply voltage)
③ Radiation
④ Housing/chassis
⑤ Switched-mode power supply unit and electronics
⑥ Field coupling
⑦ Cable routing close to housing/chassis
⑧ Filter

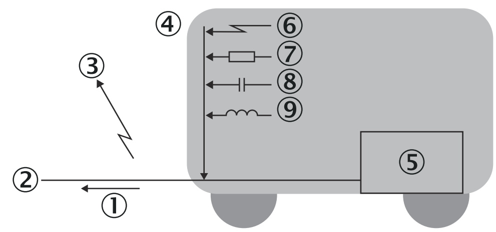


Figure 12: System without mains filter [12]

① Cable-bound fault
② Unfiltered supply voltage cable
③ Radiation
④ Housing/chassis
⑤ Switched-mode power supply unit and electronics
⑥ Field coupling
⑦ Galvanic coupling (e.g., power supply unit noise)
⑧ Capacitive coupling
⑨ Inductive coupling

4.2 Functional earth FE of the system [13]

All system components should be connected to the same ground potential.

Important aspects when connecting the functional earth:

- Welded joints are more suitable than bolted joints.
- Ground straps (earthing straps) are more suitable than round wires.
- Ground straps should be dimensioned as large-area, fine-stranded and with as large a cross-section as possible.
- The contact points must be free of grease, uninsulated and unpainted.
- Fan washers or toothed lock washers must be used for bolted connections.

11) Based on [8]
12) Based on [8].
13) Cf. [9].

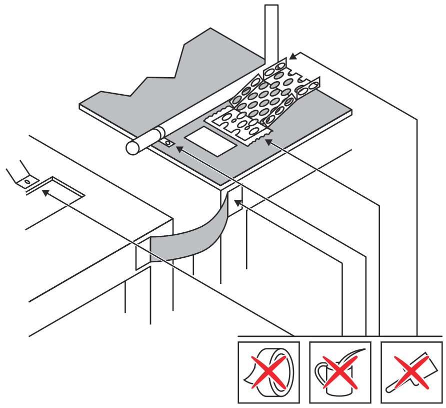


Figure 13: Mechanical connection of the functional earth: non-insulated, grease-free, unpainted [14)]

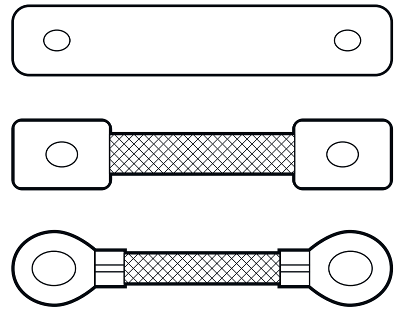


Figure 14: Typical connectors for equipotential bonding: large area, large cross-section [14)]

4.3 Cable routing [15)]

The cable routing makes a significant contribution to the EMC of a system.

Cables are divided into four groups:

- Group I:
  Very sensitive to interference (analog signals, measurement cables)
- Group II:
  Interference-sensitive (digital signals, sensor cables, 24 V DC switching signals, communication signals, e.g., fieldbuses)
- Group III:
  Source of interference (control cables for inductive loads, unswitched power cables, motor brakes, contactors)
- Group IV:
  Strong source of interference (output cables of frequency converters, supply cables)

Appropriate measures must be taken to separate the groups.

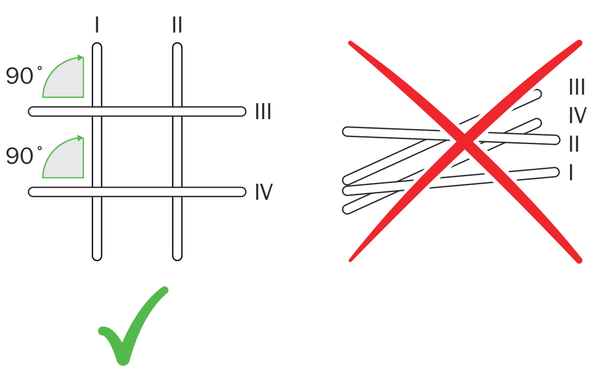


Figure 15: Group I and II cables must be crossed at right angles with Group III and IV cables [14)]

14) Based on [9].
15) Cf. [9].

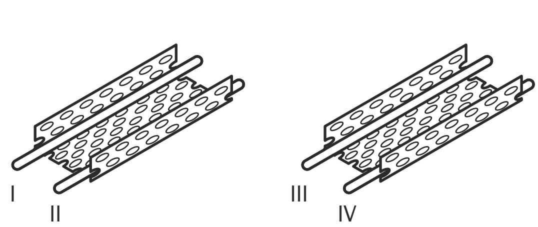


Figure 16: Optimal: Cables laid in different cable ducts [14]

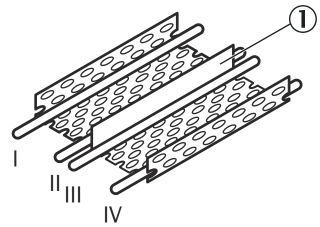


Figure 17: Alternative: Cables separated by a metallic separator ① [14]

The cable routing shown also applies when using energy chains and drag chains.

4.4 Cable trays

For metal cable trays, closed shapes are more suitable than open shapes.

With U-shaped cable trays, the shielding effect is greatest in the edge areas. Cable trays with high side walls are therefore more suitable. The cables should be well below the top edge of the side wall.

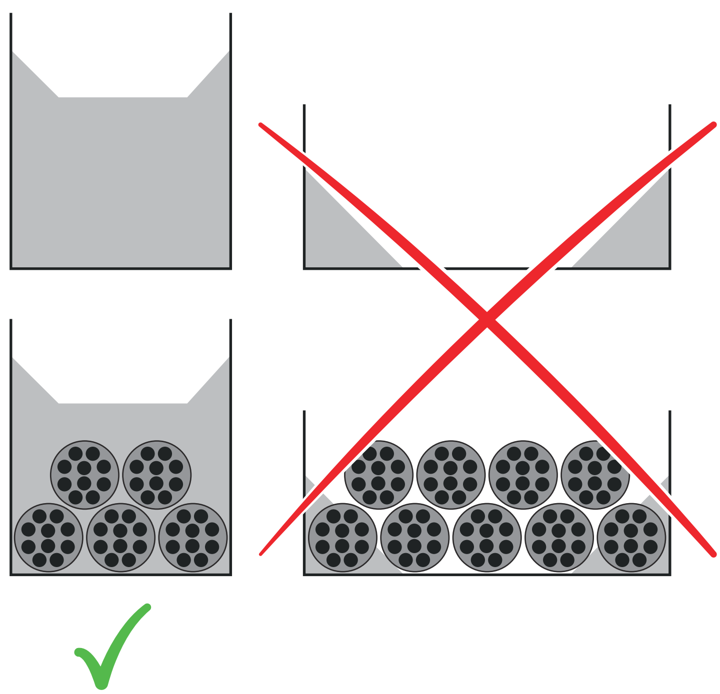


Figure 18: Shielding effect for cable trays [15]

14) Based on [9].
15) Based on [3].

5 Ground loops with PELV by connecting 0 V with FE/PE

EMC problems are often caused in PELV circuits (see "Protection against electric shock", page 7) due to 0 V and FE/PE being connected at several points in a system. This can create a so-called ground loop, via which interference can be coupled-in. Under certain circumstances, currents can even flow back from the power section of a system via signal lines and then influence the signals in an impermissible manner.

To prevent this, 0 V and FE/PE should not be connected. The protection of the extra-low voltage is then ensured by SELV (see "Protection against electric shock", page 7) is ensured. This applies to both basic protection against direct contact and fault protection against indirect contact.

If 0 V and FE/PE need to nevertheless be connected, this connection should only be made at the global neutral point.

If more than one 0 V and FE/PE connection exists, e.g., additionally at a controller in the same circuit, then interference signals can enter the circuit of the safety laser scanner via a galvanic connection.

0 V and FE/PE can also be connected within an electrical component. SICK safety laser scanners have no such internal connection. Display or HMI components, for example, often have such internal connections however.

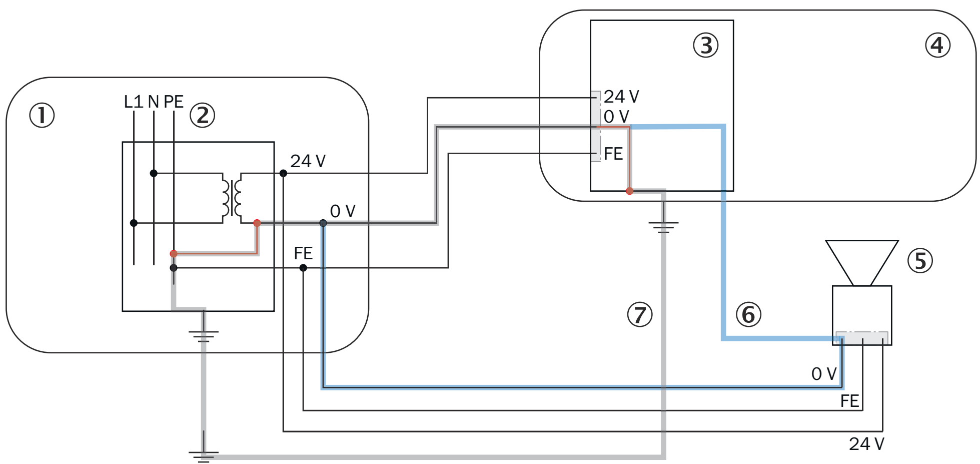


Figure 19: Ground loop by connecting 0 V with FE/PE

① Control cabinet 1
② Power supply unit
③ Control systems
④ Control cabinet 2
⑤ Safety laser scanners
⑥ Galvanic connection, e.g., I/Os
⑦ Ground loop

Ground loops are particularly problematic with I/O devices because additional galvanic connections to the safety laser scanner are created and disturbances in the circuit can flow via the safety laser scanner (see figure 19, page 17, blue path). If the voltage supply and the galvanic connections (e.g., I/O connections) are spatially separated, the negative effect is amplified because the ground loop is increased.

Ethernet signals are galvanically isolated by a transformer or via capacitors. For the safety laser scanners from SICK, the separation is achieved by means of transformers. The described behavior cannot therefore occur with an Ethernet connection. The shielding of the Ethernet line must however be connected with low impedance to the housing of the safety laser scanner, which is at FE potential. For M12 cables, this connection is usually ensured via the thread.

6 FE connections of the safety laser scanners

Overview

The FE connections of the SICK safety laser scanners differ depending on the variant.

Since EMC interference is always application specific, EMC problems may occur even if shielding and FE connection are carried out according to this document.

To avoid ground loops, 0 V and PE should not be connected in the control cabinet of the system.

PE connection

Safety laser scanners from SICK have protection class II or protection class III. They therefore do not have a PE connection (protection earth). For EMC reasons, however, a connection to the functional earth FE is required.

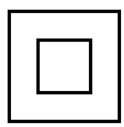


Figure 20: Protection class II

Safety laser scanner with protection class II

- S300 Medium Range (2 m maximum protective field range)
- S3000 Standard
- S3000 Advanced
- S3000 Professional
- S3000 Remote
- S3000 Anti Collision
- S3000 Cold Store

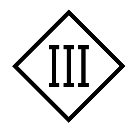


Figure 21: Protection Class III

Safety laser scanner with protection class III

- S300 Mini
- S300 Long Range (3 m maximum protective field range)
- S3000 PROFINET IO
- S3000 PROFINET IO OF
- microScan3
- outdoorScan3
- nanoScan3

In demanding environments, safety laser scanners with protection class III are usually more suitable.

Complementary information

For safe and reliable crimp connections, professional crimping tools should be used.

The following recommendations for connecting the functional earth (FE) are based on empirical values that have led to improvements in electromagnetic compatibility in real applications.

6.1 microScan3

FE connections of the microScan3 variants

The functional earth should be connected via at least one of the FE terminals.

microScan3 Core I/O

- Pin 8 on the M12 plug connector of the connecting cable
- Thread on the M12 plug connector of the connecting cable
- M5 threaded holes on the rear or side of the housing

microScan3 Core I/O AIDA

- Alternative FE connection
- Pin 5 on M12 plug connector
- Thread on the M12 plug connector of the connecting cable
- M5 threaded holes on the rear or side of the housing

microScan3 Pro I/O, microScan3 – EFI-pro, microScan3 – EtherNet/IP™, microScan3 – EtherCAT®, microScan3 – PROFINET (M12)

- Alternative FE connection
- Pin 4 on the M12 plug connector of the voltage supply (XD1)
- Thread on the M12 plug connector of the voltage supply (XD1)
- M5 threaded holes on the rear or side of the housing

microScan3 – PROFINET (RJ45, SCRJ)

- Alternative FE connection
- Pin 5 on the M12 plug connector of the voltage supply (XD1)
- Thread on the M12 plug connector of the voltage supply (XD1)
- M5 threaded holes on the rear or side of the housing

Notes on connecting the functional earth

When using the alternative FE connection, a low-impedance FE connection with an adequate conductor cross-section can be ensured. Especially for longer connecting cables, the alternative FE connection is highly recommended. The cross-section of the connection should be at least 4 mm^2 depending on the conductor length and routing. In regard to the conductor cross-section: the larger the better.

Older system plugs (older than approx. September 2019) and some variants (e.g., microScan3 Core I/O) may not have an alternative FE connector (see figure 22, page 20). In this case, one of the unpainted side or rear M5 threaded holes on the housing (see figure 23, page 21) can be used.

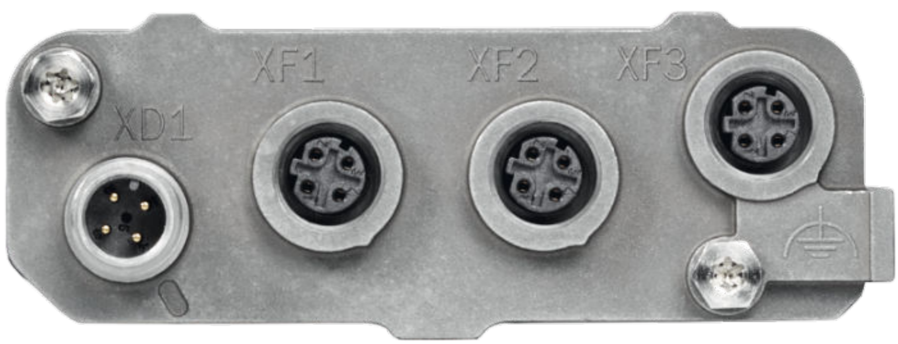


Figure 22: Alternative FE connection on system plugs manufactured on or after 09/2020

Figure 23: Further FE connection option

0 V and FE/PE

If 0 V (secondary side of the DC power supply unit) is connected to PE in the control cabinet of a system, all potentials must be referenced to exactly this neutral point (see figure 24, page 21).

0 V must be disconnected from FE at the safety laser scanner. Internally in the safety laser scanner, this is ensured by the internal protective circuitry. Two separate cables must be routed to the neutral point.

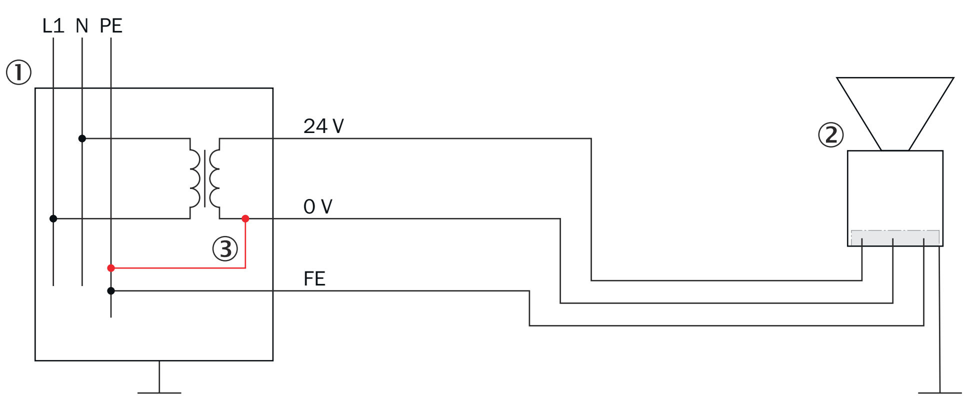


Figure 24: Earthing method for a microScan3/outdoorScan3

① Power supply unit

② Safety laser scanners

③ Connection between 0 V and FE/PE: not recommended

Shielded cables

When using shielded cables, the shielding should be applied on both sides. Deviations are only permitted in exceptional and justified cases. Especially when using motors or other inductive consumers, one-sided support of the shielding is not sufficient because it does not act against inductive interferers.

The shielding of a data cable (for devices with a network connection) is not a sufficient FE connection to the safety laser scanner. An additional FE connection must be established. Data cables must always be shielded and connected to FE/PE at both ends. The shielding of the cable is connected to the FE connection of the safety laser scanner through the thread (for M12 variants) or housing (for RJ45 variants). Since the functional earth is better and more extensive on the M12 thread, devices with M12 connectors are more suitable for EMC-critical applications than devices with RJ45 connectors. An FE/PE connection must also be ensured at the other end of the cable, e.g., at the switch.

6.2 outdoorScan3

FE connections of the outdoorScan3 variants

The functional earth should be connected via at least one of the FE terminals.

outdoorScan3 Core I/O

- Pin 8 on the M12 plug connector of the connecting cable
- Thread on the M12 plug connector of the connecting cable
- M5 threaded holes on the rear or side of the housing

outdoorScan3 – EtherNet/IP™

- Pin 4 on the M12 plug connector of the voltage supply (XD1)
- Thread on the M12 plug connector of the voltage supply (XD1)
- M5 threaded holes on the rear or side of the housing

Notes on connecting the functional earth

In EMC-critical applications, a low-impedance FE connection should be established via one of the unpainted side or rear M5 threaded holes on the housing (see figure 23, page 21). The cross-section of the connection should be at least 4 mm² depending on the conductor length and routing. In regard to the conductor cross-section: the larger the better.

0 V and FE/PE

If 0 V (secondary side of the DC power supply unit) is connected to PE in the control cabinet of a system, all potentials must be referenced to exactly this neutral point (see figure 24, page 21).

0 V must be disconnected from FE at the safety laser scanner. Internally in the safety laser scanner, this is ensured by the internal protective circuitry. Two separate cables must be routed to the neutral point.

Shielded cables

When using shielded cables, the shielding should be applied on both sides. Deviations are only permitted in exceptional and justified cases. Especially when using motors or other inductive consumers, one-sided support of the shielding is not sufficient because it does not act against inductive interferers.

The shielding of a data cable (for devices with a network connection) is not a sufficient FE connection to the safety laser scanner. An additional FE connection must be established. Data cables must always be shielded and connected to FE/PE at both ends. The shielding of the cable is connected to the FE connection of the safety laser scanner through the thread of the M12 connector. An FE/PE connection must also be ensured at the other end of the cable, e.g., at the switch.

6.3 nanoScan3

FE connections of the nanoScan3 variants

The functional earth should be connected via at least one of the FE terminals.

nanoScan3 Core I/O

- Pin 8 on the M12 plug connector of the connecting cable
- Thread on the M12 plug connector of the connecting cable
- M5 threaded holes on the housing

nanoScan3 Pro I/O

- System plug with plug connector: Thread on the M12 plug connector of the connecting cable
- System plug with flying leads: Shielding of connecting cable
- M5 threaded holes on the housing

Notes on connecting the functional earth

Since the nanoScan3 Pro I/O does not have an FE pin, each outgoing cable must be shielded and the shield in the control cabinet must be connected to FE/PE to ensure a continuous FE connection.

In EMC-critical applications, an additional, low-impedance FE connection should be made via one of the unpainted, M5 threaded holes on the side of the housing (similar to the microScan3, see figure 23, page 21). The cross-section of the connection should be at least 4 mm^2 depending on the conductor length and routing. In regard to the conductor cross-section: the larger the better.

Shielded cables

When using shielded cables, the shielding should be applied on both sides. Deviations are only permitted in exceptional and justified cases. Especially when using motors or other inductive consumers, one-sided support of the shielding is not sufficient because it does not act against inductive interferers.

The shielding of a data cable (for devices with a network connection) is not a sufficient FE connection to the safety laser scanner. An additional FE connection must be established. Data cables must always be shielded and connected to FE/PE at both ends. The shielding of the cable is connected to the FE connection of the safety laser scanner through the thread of the M12 connector. An FE/PE connection must also be ensured at the other end of the cable, e.g., at the switch.

6.4 S3000

To achieve the specified EMC safety, the functional earth (FE) must be connected (e.g., at the central ground neutral point of the vehicle or system).

The S3000 does not have a separate FE connection. Certain unpainted areas of the housing can be used to connect the functional earth (see figure 25, page 24).

Figure 25: Possible method of connecting the functional earth

Shielded cables on the S3000

The quality of the shield is essentially dependent on the quality of the connection of the shield. In order to achieve a large-area shield connection on the S3000, the EMC-proof M12/M20 cable glands, which are available as accessories, must be used.

Install EMC-proof cable gland

1. Strip the wire.
2. Expose the shielding braid (see figure 26, page 24).
3. Guide the cable through the coupling nut and the terminal insert.
4. Place the braided shield over the terminal insert (at least 2 mm above the O-ring) (see figure 27, page 24).
5. Push the terminal insert into the housing and tighten the coupling nut (see figure 28, page 24).
6. Mounting the cable gland on the system plug.

Figure 26: Mounting the cable gland on the S3000: Shielding braid

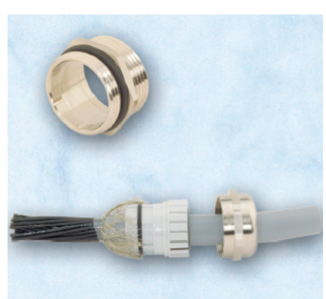


Figure 27: Mounting the cable gland on the S3000: Coupling nut and terminal insert

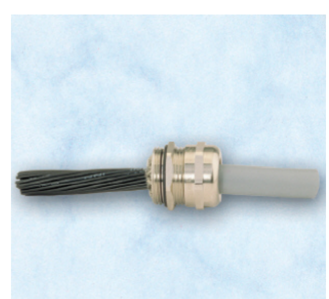


Figure 28: Mounting the cable gland on the S3000: Assembled cable gland

6.5 S300

To achieve the specified EMC safety, the functional earth (FE) must be connected (e.g., at the central ground neutral point of the vehicle or system).

The S300 has an FE connection (FE pin) on the system plug. On the pre-assembled system plugs, the functional earth has the wire color green.

6.6 S300 Mini

S300 Mini Standard

The functional earth must be connected via both connection options:

- Pin 8 on the M12 plug connector of the connecting cable
- Thread on the M12 plug connector of the connecting cable

S300 Mini Remote

On the S300 Mini Remote, the functional earth is connected via the thread on the M12 plug connector. A shielded connecting cable must therefore be used. Only the connecting cables that are explicitly specified in the operating instructions are permitted.

6.7 Using open cable ends

If wires are connected to the safety laser scanner that are not connected outside the device and are therefore "open", an antenna effect can occur.

Measures to avoid the antenna effect at open cable ends:

- ▶ Connect the inputs of the safety laser scanner to 0 V (not to FE).
- ▶ Do not connect the outputs of the safety laser scanner.

7 Earthing method for mobile platforms

The earthing method for a mobile platform depends on the type of voltage supply. The following recommendations must therefore be reviewed on a case-by-case basis and adapted or supplemented as necessary.

Isolated design for mobile platforms:

- Chassis = FE = shielding
  Connection of all FE potentials at a neutral point of the chassis. Shared FE cables should be avoided at all costs. This applies to all components.
- Connection of all 0 V terminals to the 0 V terminal of the respective voltage supply. The 24 V supply circuit for the safety laser scanner and controller should be separate from the supply circuit for motors and other consumers.
  Solution: galvanically isolated DC/DC converter.
- Isolate 0 V and the chassis from each other. If necessary, use a filter (Load Dump Protector) on the voltage supply. It is also possible to use a SELV power supply unit, which creates the separation.

In addition, all metallic chassis parts must be connected in an EMC- and ESD-compliant manner (see figure 29, page 26). If this is not the case, chassis parts can interfere with the vehicle electronics via capacitive coupling (see "The EMC influence model", page 9) (see figure 30, page 26).

An EMC- and ESD-compliant connection can be made, for example, using earthing straps, welded connections, or paint-free threaded connections with serrated or toothed lock washers.

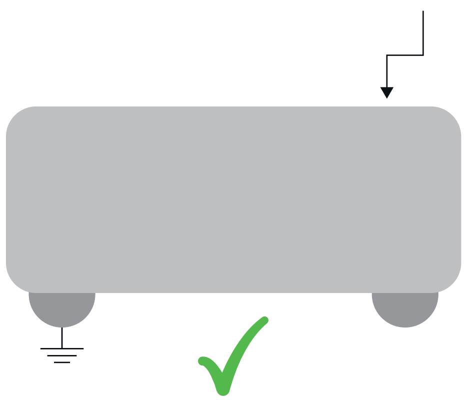


Figure 29: Optimal: The chassis shields and dissipates

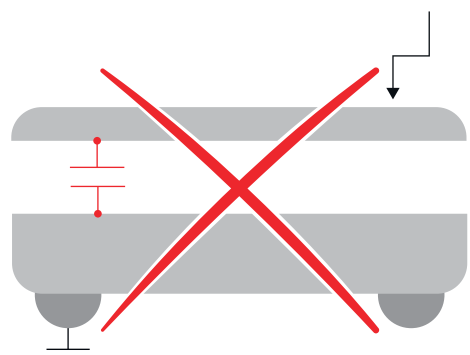


Figure 30: Problem: Capacitive coupling due to mutually insulated chassis parts

7.1 Example earthing method

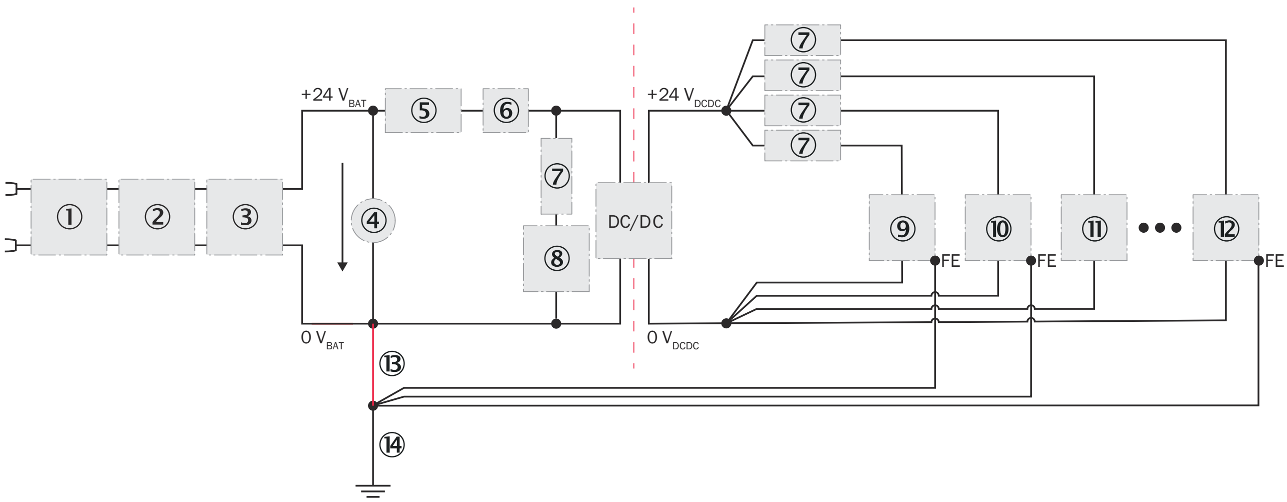


Figure 31: Earthing method for a mobile platform

① Reverse polarity protection
② Charging regulator
③ Circuit protection
④ Rechargeable battery
⑤ Main fuse
⑥ Main switch
⑦ Fuse
⑧ Motor
⑨ Control systems
⑩ Network switch
⑪ Sensor without FE connection
⑫ Sensor with FE connection
⑬ Grounding strap (not recommended)
⑭ Chassis, wheel drive with ESD equipment

The EMC-sensitive components (to the right of the red dashed line) are galvanically isolated from the possible sources of interference (to the left of the red dashed line). Each FE potential is individually connected to the FE neutral point on the chassis. Each 0 V potential is connected to the 0 V neutral point of the voltage supply (DC/DC converter).

Optionally, 0 V_{BAT} and chassis can be connected via a ground strap (red in the figure). This is not recommended, however. If the ground strap results in improved behavior, this may be an indication of potential carryover.

A connection between chassis and 0 V_{DCDC} (as used in automotive engineering) is not recommended. Such a connection can cause EMC problems due to the different components.

7.2 Electrostatic discharge

In [10], electrostatic discharge is defined as a "rapid transfer of charge between bodies with different electrostatic potentials".

Charging occurs, for example, through contact and separation of materials, or can be caused by an electric field (induction). [16)]

16) Cf [10].

In order to achieve protection against electrostatic discharge (ESD) on mobile platforms, ESD equipment in the wheel/tire or a so-called anti-static strips can be used. These measures are primarily aimed at preventing charging and subsequent abrupt discharge with high electrical currents.

To avoid problematic, rapid discharges, the equipotential bonding connection to the antistatic floor is best made with high impedance and a continuous connection. ESD equipment in the wheel/tire is best suited for this purpose.

If, on the other hand, anti-static strips are used, a problematic rapid discharge can occur if the vehicle moves from a poorly conducting surface to a well conducting surface.

The FE neutral point of the mobile platform electronics should be placed close to the ESD equipment.

SICK sensors contain ESD protection measures. If the devices are installed correctly, electrostatic charging of the sensors cannot occur.

8 Annex

8.1 Checklists

If EMC-related problems occur despite the measures described, a sound analysis of the application must be carried out.

For a mobile platform, the following questions can help uncover problems. Parts of the checklists are also suitable for stationary applications.

8.1.1 Ground connection, equipotential bonding

Are FE and 0 V isolated from each other at all components (DC/DC converter, power supply unit, etc.)? ☐ Yes: No further measures required. ☐ No: see "Earthing method for mobile platforms", page 26

Is a metallic control cabinet being used?
☐ Yes: Is the housing of the control cabinet connected to FE and the chassis?
    ☐ Yes: No further measures required.
    ☐ No: see "Earthing method for mobile platforms", page 26
☐ No: Metal control cabinets are recommended.

Are there other control cabinets present?
☐ Yes: Is the housing of the control cabinet connected to FE and the chassis?
    ☐ Yes: No further measures required.
    ☐ No: see "Earthing method for mobile platforms", page 26
☐ No: No further measures required.

Is the ESD equipment in the wheel drive functional? ☐ Yes: No further measures required. ☐ No: Clean or replace wheels.
Are all metal parts of the chassis conductively connected with low impedance? ☐ Yes: No further measures required. ☐ No: see "Earthing method for mobile platforms", page 26

8.1.2 Voltage supply

Is an galvanic isolated DC/DC converter being used? ☐ Yes: No further measures required. ☐ No: see "Ground loops with PELV by connecting 0 V with FE/PE", page 17
Is there a connection between 0 V and FE at the voltage supply? ☐ Yes: see "Ground loops with PELV by connecting 0 V with FE/PE", page 17 ☐ No: No further measures required.
Are there any other voltage supplies? ☐ Yes: see "Ground loops with PELV by connecting 0 V with FE/PE", page 17 ☐ No: No further measures required.
Is the supply voltage within the specified range (V_{Bat_min} … V_{Batt_max}, charging voltage)? ☐ Yes: No further measures required. ☐ No: Safeguard the supply voltage.
Is the supply voltage equipped with additional interference suppression filters? ☐ Yes: No further measures required. ☐ No: see "Mains filter", page 14
Are there any disturbances to the supply voltage (ripple/noise measurement)? ☐ Yes: Further analyze the supply voltage ☐ No: No further measures required.
Are there any disturbances in the supply voltage (ripple/noise/drop measurement)? ______________________________ The response can serve as a basis for further action, if necessary.

8.1.3 Drive motor

What type of motor is installed? (AC/DC, synchronous/asynchronous, brushless/brush motor, stepper motor) ______________________________ The response can serve as a basis for further action, if necessary.
What is the current consumption of the motor under full load, e.g., with fully loaded vehicle, max. trailer load, ramp angle, etc.? ______________________________ The response can serve as a basis for further action, if necessary.
What is the current consumption of the motor when the vehicle is empty? ______________________________ The response can serve as a basis for further action, if necessary.
What is the current consumption of the motor at standstill? ______________________________ The response can serve as a basis for further action, if necessary.
Are the supply and network cables in a common cable duct? ☐ Yes: see "Measures to reduce electromagnetic interference (EMI)", page 9, see "Cable routing ", page 15 ☐ No: No further measures required.
Do the network cables have M12 plug connectors? ☐ Yes: No further measures required. ☐ No: see "Recommended data lines", page 12
Is the shielding of the network cables connected to FE on both sides? ☐ Yes: No further measures required. ☐ No: see "Applying a shield", page 10
Is the motor grounded according to the manufacturer's specifications? ☐ Yes: No further measures required. ☐ No: Check the manufacturer's specifications.
Is motor interference suppressed, e.g., using a second DC/DC converter? ☐ Yes: No further measures required. ☐ No: Ensure interference suppression.
Are regenerative braking systems being used? ______________________________ The response can serve as a basis for further action, if necessary.
Can the operating current of the motor flow through the chassis? ______________________________ The response can serve as a basis for further action, if necessary.
Are the manufacturer's specifications for shielding the inverter and motor cable being observed? ______________________________ The response can serve as a basis for further action, if necessary.

8.1.4 Steering drive

What type of motor is installed? (AC/DC, synchronous/asynchronous, brushless/brush motor, stepper motor) ______________________________ The response can serve as a basis for further action, if necessary.
What is the current consumption of the motor under full load? ______________________________ The response can serve as a basis for further action, if necessary.
What is the current consumption of the motor at standstill? ______________________________ The response can serve as a basis for further action, if necessary.

Are the supply and network cables in a common cable duct? ☐ Yes: see "Measures to reduce electromagnetic interference (EMI)", page 9, see "Cable routing ", page 15 ☐ No: No further measures required.
Do the network cables have M12 plug connectors? ☐ Yes: No further measures required. ☐ No: see "Recommended data lines", page 12
Is the shielding of the network cables connected to FE on both sides? ☐ Yes: No further measures required. ☐ No: see "Applying a shield", page 10
Is the motor grounded according to the manufacturer's specifications? ☐ Yes: No further measures required. ☐ No: Check the manufacturer's specifications.
Is motor interference suppressed, e.g., using a second DC/DC converter? ☐ Yes: No further measures required. ☐ No: Ensure interference suppression.

8.1.5 Other drives

Are there other drives or cable with a high current consumption? ☐ Yes: see "Drive motor", page 30, see "Steering drive", page 30 ☐ No: No further measures required.

8.1.6 Cables

Are the cables described in the SICK operating instructions being used? ☐ Yes: No further measures required. ☐ No: see "Recommended data lines", page 12
Have the power and signal cables been spatially separated? ☐ Yes: No further measures required. ☐ No: see "Measures to reduce electromagnetic interference (EMI)", page 9

8.1.7 Shielding

Are the cables connected to the safety laser scanner using M12 plug connectors? ☐ Yes: No further measures required. ☐ No: see "Recommended data lines", page 12
Is the shielding at the other end of the cable connected via an M12 plug connector or in some other way over a large area? ☐ Yes: No further measures required. ☐ No: see "Mechanical implementation of the support", page 10, see "Recommended data lines", page 12
Are there extensions or connectors in the cables? ☐ Yes: Avoid extensions and connectors in the cables if possible. ☐ No: No further measures required.
Are there any measures against ESD and for shielding RF fields (emission and spurious radiation) via the chassis present? ☐ Yes: No further measures required. ☐ No: Implement appropriate measures if necessary.
Do currents flow across the shielding? (AC/DC/frequency spectrum) ____________________________ The response can serve as a basis for further action, if necessary.

8.1.8 Data transmission

What interfaces and frequencies are being used (e.g., WLAN 2.4 GHz or 5 GHz, BT or BTLE, analog or digital private mobile radio , etc.)? ________________________________ The response can serve as a basis for further action, if necessary.
At what power and frequency does the transmitter transmit? ________________________________ The response can serve as a basis for further action, if necessary.
Are there other radio interfaces? ________________________________ The response can serve as a basis for further action, if necessary.
Are repeaters used? If so, which ones? ________________________________ The response can serve as a basis for further action, if necessary.
Where in the surroundings are repeaters mounted? Is there a correlation with error frequency? ________________________________ The response can serve as a basis for further action, if necessary.
Are damaged telegrams captured using network logging? ☐ Yes: What are the absolute error rates? ________________________________ The response can serve as a basis for further action, if necessary. Are there any temporal clusters? ________________________________ The response can serve as a basis for further action, if necessary. ☐ No: Enable network logging.

8.1.9 Network

Is the sequence specified in the circuit diagram being observed? ☐ Yes: No further measures required. ☐ No: Change the sequence to match the circuit diagram.
Is the shielding on both sides correctly implemented for all Ethernet connections? ☐ Yes: No further measures required. ☐ No: Check the shield support.
Is the network load within a reasonable range for the interface? (TCP/IP ≈ 30%) ☐ Yes: No further measures required. ☐ No: Check utilization.
Where are different network segments connected? ________________________________ The response can serve as a basis for further action, if necessary.

8.2 Useful standards

Standard	Title, topic
EN 1175	Safety of industrial trucks - Electrical/electronic requirements
EN 12895	Industrial trucks - Electromagnetic compatibility
ISO 13766-1	Earth-moving and building construction machinery - Electromagnetic compatibility (EMC) of machines with internal electrical power supply Part 1: General EMC requirements under typical EMC ambient conditions
ISO 13766-2	Earth-moving and building construction machinery - Electromagnetic compatibility (EMC) of machines with internal electrical power supply Part 2: Additional EMC requirements for functional safety
IEC 60204-1	Safety of machinery - Electrical equipment of machines Part 1: General requirements
IEC 61000-6-2	Electromagnetic compatibility Part 6-2: General standards - Immunity for industrial environments
IEC 61000-6-3	Electromagnetic compatibility Part 6-3: Generic standards - Emission standard for equipment in residential environments
IEC 61340-5-1	Electrostatics Part 5-1: Protection of electronic devices from electrostatic phenomena - General requirements
IEC 61496-1	Safety of machinery - Electro-sensitive protective equipment Part 1: General requirements and tests

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Part 5-1: Protection of electronic devices from electrostatic phenomena - General requirements

9 List of figures

10 List of tables

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