ABB DRIVES

Grounding and cabling of drive systems

Reference manual

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Reference manual

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Introduction to the manual

Contents of this chapter

This chapter gives a description of the manual.

Applicability

This manual is applicable for low voltage AC and DC drive systems. The drive system in this manual consists of the supply transformer, input power cable of the drive, the variable speed drive (frequency converter), motor cable and motor.

Target audience

This manual is intended for people who are involved in variable speed drive system installations and assembly.

Purpose of this manual

The purpose of this manual is tell you the grounding and cabling principles of variable speed drive systems. The guidelines help you to fulfill the personnel safety, electromagnetic compatibility (EMC) and reliability requirements of the installation.

Limitation of liability

The installation must always be designed and made according to applicable local laws and regulations. ABB does not assume any liability whatsoever for any installation which breaches the local laws and/or other regulations. Furthermore, if the recommendations given by ABB are not followed, the drive may experience problems that the warranty does not cover.

North America

Installations must be compliant with NFPA 70 (NEC)[1)] and/or Canadian Electrical Code (CE) along with state and local codes for your location and application.

[1)] National Fire Protection Association 70 (National Electric Code).

Related documents

Refer to the drive hardware manuals for specific instructions of each drive type.

Literature references on EMC

IEC 61000-5-2:1997. Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling

Technical guide No. 3. EMC compliant installation and configuration for a power drive system (3AFE61348280 [English])

Literature and standards on bearing currents

High Frequency Bearing Currents in Low Voltage Asynchronous Motors 3GZF500930-8.

A New Reason for Bearing Current Damage in Variable Speed AC Drives by J. Ollila, T. Hammar, J. Iisakkala, H. Tuusa. EPE 97. The European Conference on Power Electronics and Applications 8–10 September 1997 Trondheim, Norway. Pages 2.539 to 2.542.

On the Bearing Currents in Medium Power Variable Speed AC Drives by J. Ollila, T. Hammar, J. Iisakkala, H. Tuusa. Proceedings of the IEEE IEDMC in Milwaukee, May 1997.

Evaluation of Motor Power Cables for PWM AC Drives by John M. Bentley, Patric J. Link. IEEE Transactions on Industry Applications, 1997, Volume 33, pages 342–358.

Minimizing Electric Bearing Currents in Adjustable Speed Drive Systems by Patric J. Link. IEEE IAS Pulp & Paper Conference Portland, ME, USA June 1998.

IEC 61000-5-2:1997. Installation and mitigation guidelines – Earthing and cabling

IEC 60034-17:2002 Rotating electrical machines, Cage induction motors when fed from converters – Application guide

IEC 60034-25:2022. Rotating electrical machines – Guide for the design and performance of cage induction motors specifically designed for converter supply

Laakerivirta ja sen minimoiminen säädettyjen vaihtovirtakäyttöjen moottoreissa by Ilkka Erkkilä. Automaatio 1999 14.–16.9. Helsinki.

GAMBICA/REMA Technical Report No. 2 – Motor Shaft Voltages and Bearing Currents under PWM Inverter Operation. 2006.

GAMBICA/REMA Technical Guide Variable Speed Drives & Motors Installation Guidelines for Power Drive Systems 2012.

Technical guide No. 5. Bearing currents in modern AC drive systems (3AFE64230247 [English])

Standard references on cabling

EN 50174-2:2018. Information technology – Cabling installation – Part 2: Installation planning and practices inside buildings

IEC 60364-4-44:2007. Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances

Terms and abbreviations

Term/ Abbreviation	Description
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
FE	Functional earth (ground)
PE	Protective earth (ground)

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Basics

Contents of this chapter

This chapter tells about grounding structures that are needed for interference-free operation of variable speed drive systems and basics of protecting motor bearings.

Objectives of grounding

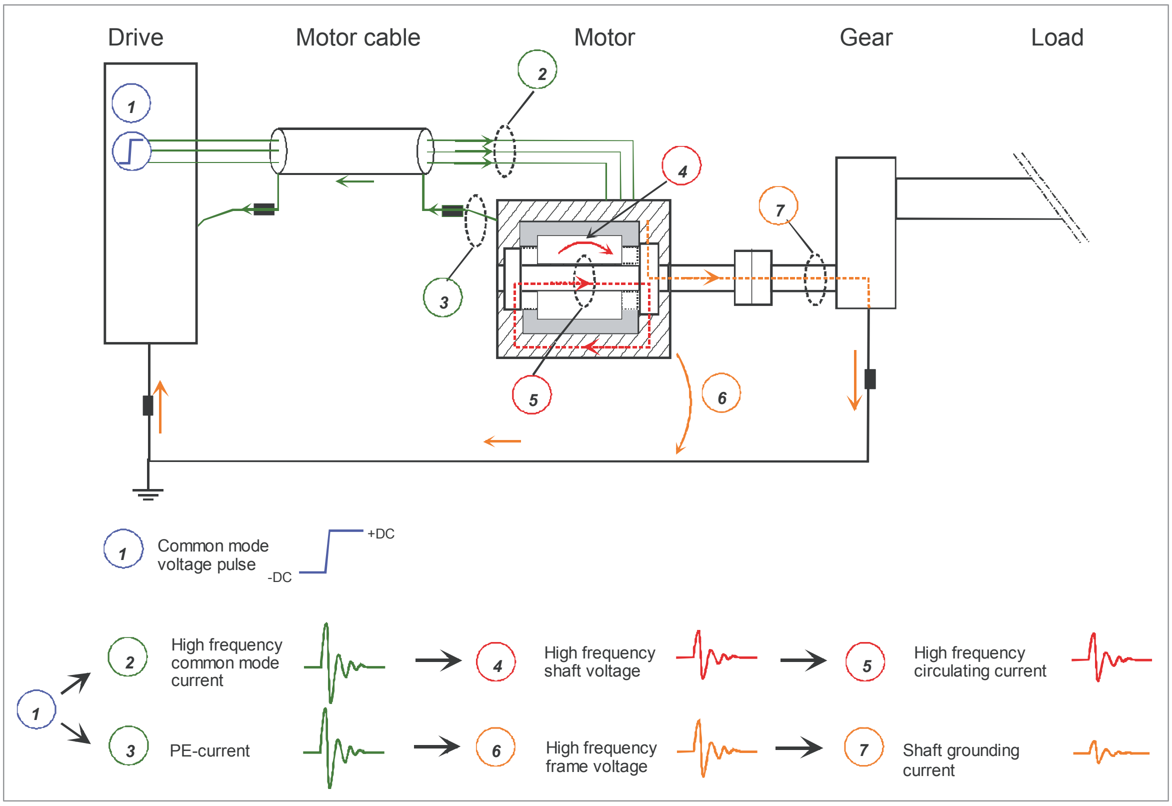
Traditional grounding is based on electrical safety. It ensures personnel safety in all circumstances and limits material damages due to electrical faults. For interference-free operation and reliability of the drive system, more profound methods are needed: highfrequency grounding and equipotential ground planes on building floor, equipment enclosure and circuit board levels.

Attenuating motor shaft and frame voltages

Correct cabling and grounding strongly attenuates motor shaft and frame voltages that can cause high-frequency bearing currents and lead to premature bearing replacements.

Bearing currents

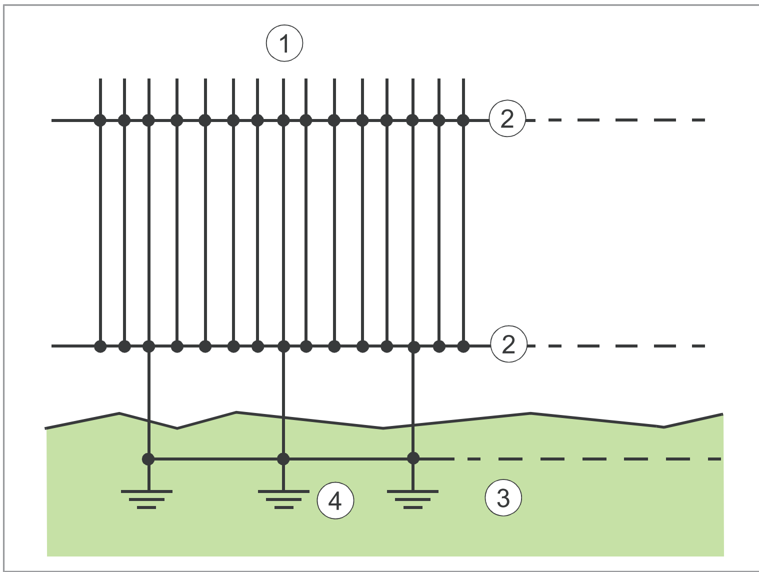
This drawing shows schematically two types of bearing currents: high-frequency circulating current (5) and shaft grounding current (7).



Grounding structure

A well structured grounding begins with ground electrodes which are connected to each other reliably to form a network. In addition, interference-free operation of electronics requires equipotential areas (ground planes or a mesh) on all structural levels where building floors, equipment enclosures and circuit boards are connected. The conductors that connect the electrical equipment to the network need to be short to minimize the grounding impedance.

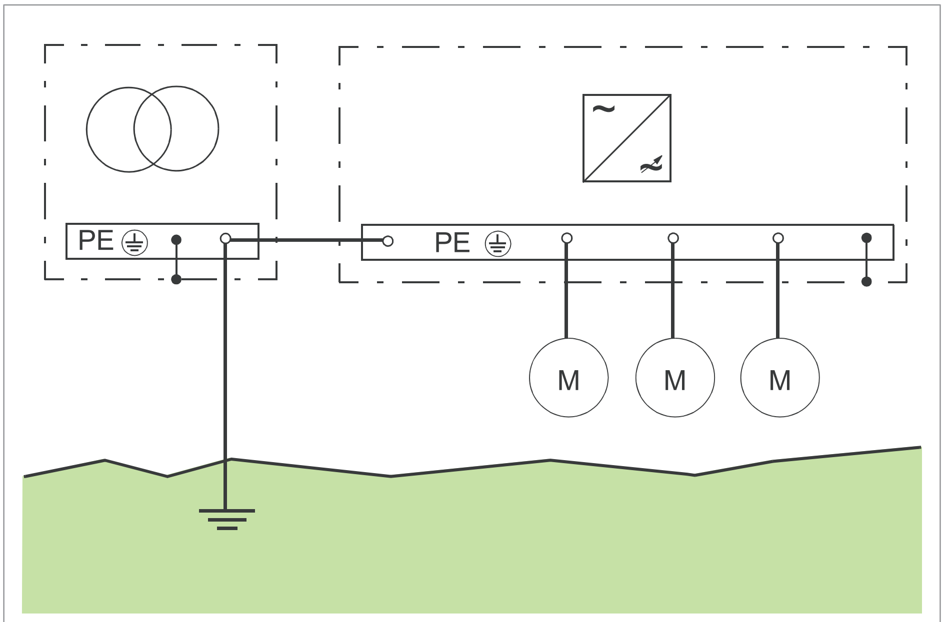
This diagram shows the configuration of ground electrodes and the grounding network that ABB recommends.



1	Power and communications ground
2	Equipotential bonding
3	Soil
4	Multiple bonded ground electrodes

Buildings without ground planes

In many old buildings, well structured ground planes are missing. In thise systems, connect the drive cabinet PE busbar to the factory ground only at one point as shown below.



PE (protective ground) versus FE (functional ground)

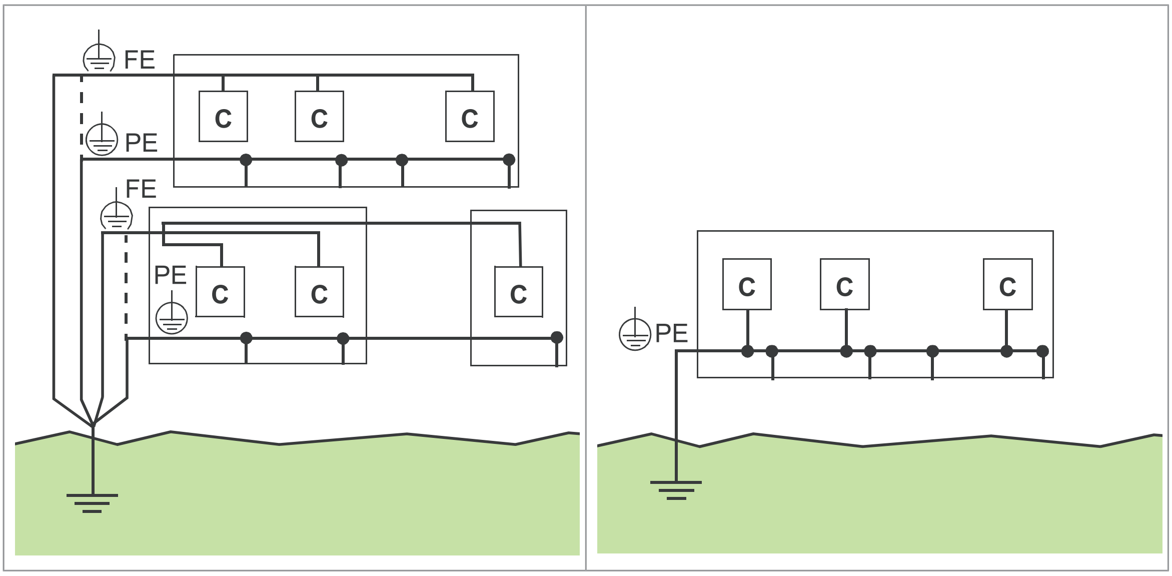
Today's ABB policy is to use uniform, equipotential PE grounding in drive systems. The principle is extended to all structural levels of installations in large buildings which contain electrical equipment. Example levels are floor, equipment cubicle and circuit board levels.

It is not possible to keep all levels of a large system at the same high-frequency potential, but uniform PE grounding at each level ensures electromagnetic compatibility.

In previous ABB products and electronic equipment of other manufacturers and in end user installations, other installation philosophies, for example, systems with PE and FE (former TE) are also used.

The FE system of co-operating equipment can be either general or partial (only part of the equipment uses FE ground). If the PE and FE grounds are connected together at one point only, the PE/FE structure resembles a one-ground-level uniform PE system and may need an effective local high-frequency ground.

The diagrams below show an PE and FE system and an uniform PE system. C denotes control electronics.



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Cabling of drive systems

Contents of this chapter

This chapter gives examples of correct cabling and grounding principles of variable speed drive systems.

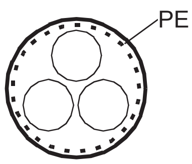
Selecting the power cables

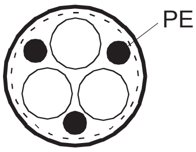
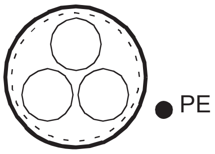
Obey the instructions of this chapter when you select drive system cables with a local vendor.

Select the cables case-by-case in accordance with the local regulations concerning short-circuit protection, operating voltage, permissible touch voltage appearing under fault conditions and current-carrying capacity of the cable. In addition, select a cable type which supports the EMC protection and reliability of the drive system.

Preferred power cable types

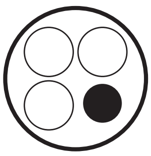
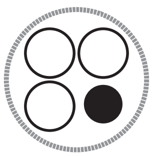
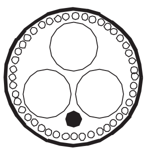
This section shows the preferred cable types. Make sure that the selected cable type also complies with local/state/country electrical codes.

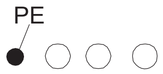
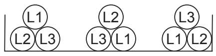
Cable type	Use as input power cabling	Use as motor cabling and as brake resistor cabling
 Symmetrical shielded (or armored) cable with three phase conductors and concentric PE conductor as shield (or armor)	Yes	Yes

Cable type	Use as input power cabling	Use as motor cabling and as brake resistor cabling
 Symmetrical shielded (or armored) cable with three phase conductors and symmetrically constructed PE conductor and a shield (or armor)	Yes	Yes
 Symmetrical shielded (or armored) cable with three phase conductors and a shield (or armor), and separate PE conductor/cable [1)]	Yes	Yes

1) A separate PE conductor is required if the conductivity of the shield (or armor) is not sufficient for the PE use.

Alternate power cable types

Cable type	Use as input power cabling	Use as motor cabling and as brake resistor cabling
 Four-conductor cable in plastic jacket (three phase conductors and PE)	Yes with phase conductor smaller than 10 mm² (8 AWG) Cu.	Yes with phase conductor smaller than 10 mm² (8 AWG) Cu, or motors up to 30 kW (40 hp). **Note:** Shielded or armored cable, or cabling in metal conduit is always recommended to minimize radio frequency interference.
 Four-conductor armored cable (three phase conductors and PE)	Yes	Yes with phase conductor smaller than 10 mm² (8 AWG) Cu, or motors up to 30 kW (40 hp)
 Shielded (Al/Cu shield or armor) [1)] four-conductor cable (three phase conductors and a PE)	Yes	Yes with motors up to 100 kW (135 hp). A potential equalization between the frames of motor and driven equipment is required.

Cable type	Use as input power cabling	Use as motor cabling and as brake resistor cabling
 A single-core cable system: three phase conductors and PE conductor on cable tray  Preferable cable arrangement to avoid voltage or current unbalance between the phases	Yes **WARNING!** If you use unshielded single-core cables in an IT network, make sure that the non-conductive outer sheath (jacket) of the cables have good contact with a properly grounded conductive surface. For example, install the cables on a properly grounded cable tray. Otherwise voltage may become present on the non-conductive outer sheath of the cables, and there is even a risk of an electric shock.	No

[1] Armor may act as an EMC shield, as long as it provides the same performance as a concentric EMC shield of a shielded cable. To be effective at high frequencies, the shield conductivity must be at least 1/10 of the phase conductor conductivity. The effectiveness of the shield can be evaluated based on the shield inductance, which must be low and only slightly dependent on frequency. The requirements are easily met with a copper or aluminum shield/armor. The cross-section of a steel shield must be ample and the shield helix must have a low gradient. A galvanized steel shield has a better high-frequency conductivity than a non-galvanized steel shield.

Not allowed power cable types

Cable type	Use as input power cabling	Use as motor cabling and as brake resistor cabling
 Symmetrical shielded cable with individual shields for each phase conductor	No	No

Required conductivity of the protective conductor

This section gives general requirements for grounding the drive. When you plan the grounding of the drive, obey all the applicable national and local regulations.

The conductivity of the protective earth conductor(s) must be sufficient.

Unless local wiring regulations state otherwise, the cross-sectional area of the protective earth conductor must agree with the conditions that require automatic disconnection of the supply required in 411.3.2 of IEC 60364-4-41:2005 and be capable of withstanding the prospective fault current during the disconnection time of the protective device. The cross-sectional area of the protective earth conductor must be selected from the table below or calculated according to 543.1 of IEC 60364-5-54.

The table shows the minimum cross-sectional area of the protective earth conductor related to the phase conductor size according to IEC/UL 61800-5-1 when the phase conductor(s) and the protective earth conductor are made of the same metal. If they are different metals, the cross-sectional area of the protective earth conductor must be determined in a manner which produces a conductance equivalent to that which results from the application of this table.

Cross-sectional area of the phase conductors S (mm²)	**Minimum cross-sectional area of the corresponding protective earth conductor S_p (mm²)**
S ≤ 16	S [1]
16 < S ≤ 35	16
35 < S	S/2

1) For the minimum conductor size in IEC installations, refer to Additional grounding requirements – IEC.

If the protective earth conductor is not part of the input power cable or input power cable enclosure, the minimum permitted cross-sectional area is:

- 2.5 mm² if the conductor is mechanically protected,
  or
- 4 mm² if the conductor is not mechanically protected. If the equipment is cord-connected, the protective earth conductor must be the last conductor to be interrupted if there is a failure in the strain relief mechanism.

Additional grounding requirements – IEC

This section gives grounding requirements according to standard IEC/EN 61800-5-1.

Because the normal touch current of the drive is more than 3.5 mA AC or 10 mA DC:

- the minimum size of the protective earth conductor must comply with the local safety regulations for high protective earth conductor current equipment, and
- you must use one of these connection methods:
  1. a fixed connection and:
     - a protective earth conductor with a minimum cross-sectional area of 10 mm² Cu or 16 mm² Al (as an alternative when aluminum cables are permitted),
       or
     - a second protective earth conductor of the same cross-sectional area as the original protective earth conductor,
       or
     - a device that automatically disconnects the supply if the protective earth conductor is damaged.
  2. a connection with an industrial connector according to IEC 60309 and a minimum protective earth conductor cross-section of 2.5 mm² as part of a multi-conductor power cable. Sufficient strain relief must be provided.

If the protective earth conductor is routed through a plug and socket, or similar means of disconnection, it must not be possible to disconnect it unless power is simultaneously removed.

Note: You can use power cable shields as grounding conductors only when their conductivity is sufficient.

Additional grounding requirements – UL (NEC)

This section gives grounding requirements according to standard UL 61800-5-1.

The protective earth conductor must be sized as specified in Article 250.122 and table 250.122 of the National Electric Code, ANSI/NFPA 70.

For cord-connected equipment, it must not be possible to disconnect the protective earth conductor before power is removed.

Calculating the cross-sectional area

According to IEC 60364-5-54, the equation below determines the minimum allowed crosssectional area of the protective conductor for disconnection times that are not more than 5 seconds:

$$S = \frac{\sqrt{I^2 t}}{k}$$

where

S	Cross-sectional area of the protective conductor (mm^2)
I	rms value of the prospective fault current which can flow through the protective device in a fault of negligible impedance (A)
t	Operating time of the protective device for automatic disconnection (s)
k	Factor which depends on the material of the protective conductor

Factor k

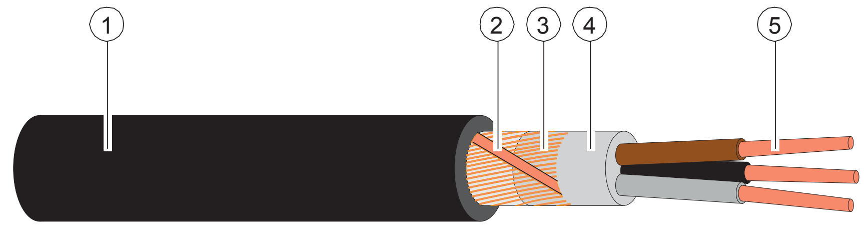
This table shows the values of factor k for for insulated protective conductors not incorporated in cables and not with other cables.

Conductor insulation	**Material of conductor**		
	Copper	**Aluminium**	**Steel**
	Values for k		
70°C PVC	143	95	52
90°C XLPE	176	116	64
85°C rubber	166	110	60
Note: The initial temperature of conductor is assumed to be 30 °C.			

Sufficient shield conductivity to suppress emissions

If the cable shield is used as the sole protective earth (PE) conductor, make sure that its conductivity agrees with the PE conductor requirements.

To effectively suppress radiated and conducted radio-frequency emissions, the cable shield conductivity must be at least 1/10 of the phase conductor conductivity. The requirements are easily met with a copper or aluminum shield. The minimum requirement of the motor cable shield of the drive is shown below. It consists of a concentric layer of copper wires with an open helix of copper tape or copper wire. The better and tighter the shield, the lower the emission level and bearing currents.



1	Insulation jacket
2	Helix of copper tape or copper wire
3	Copper wire shield
4	Inner insulation
5	Cable core

Connecting the drive to the supply power network

This section gives recommendations for the drive supply transformer and input cabling. Switches or input cable protection fuses are not drawn to the drawings. The drawings only show how to connect the cables.

Transformer

ABB recommends a transformer which is dedicated to variable-speed drives and has a static screening between the primary and secondary.

Grounded secondary (TN and TN-S systems)

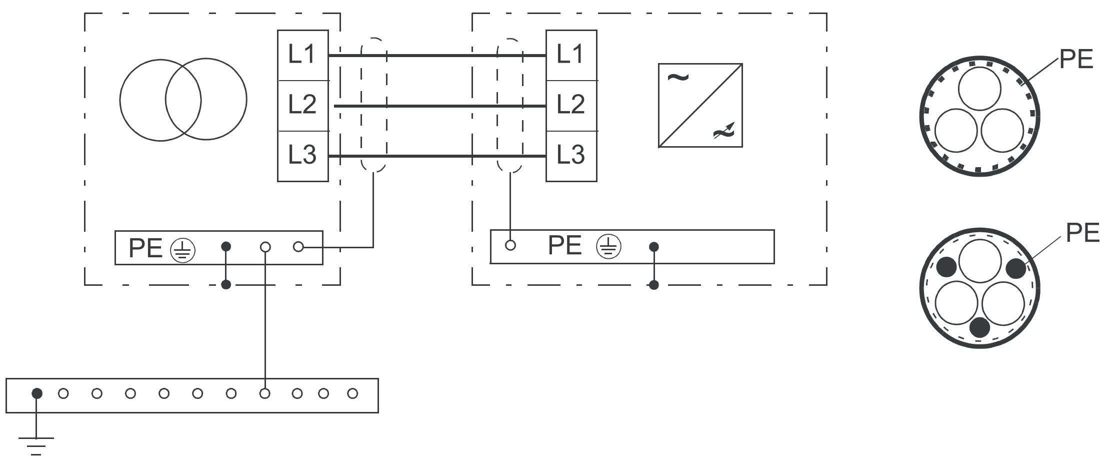
ABB drives can be equipped with EMC filters which reduce disturbances.

Ungrounded secondary (IT systems)

All drive EMC filters and ground-to-phase varistors are not suitable for use in IT (ungrounded) or corner-grounded and mid-point grounded delta systems. Disconnect these filters before you connect the drive to the supply network. For instructions, refer to the drive hardware manual.

Connection diagram of a shielded cable

Connect the shield to PE at both ends as shown below.

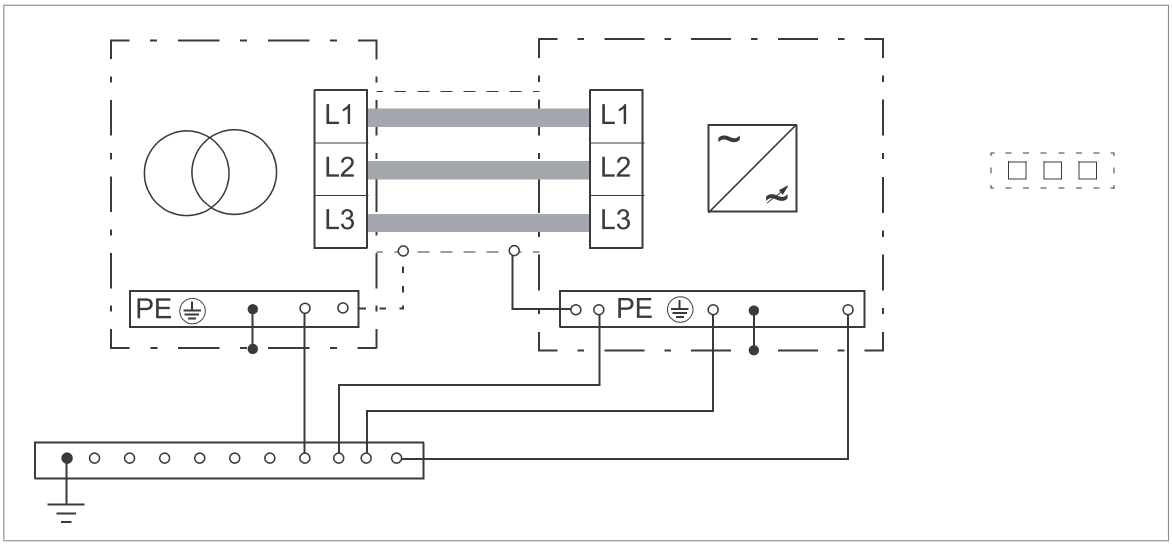


Input connection in high-power supply systems

High-current (> 300 A) variable speed drives can be supplied through a busbar or cable bus system.

Busbar system

Connect the metal conduit (shield) of the busbar system to the PE busbar at either one or both ends.

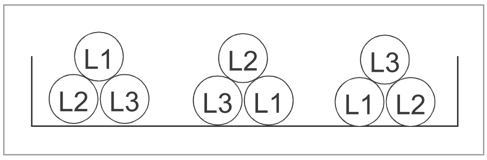


Cable bus system (parallel single-core cables)

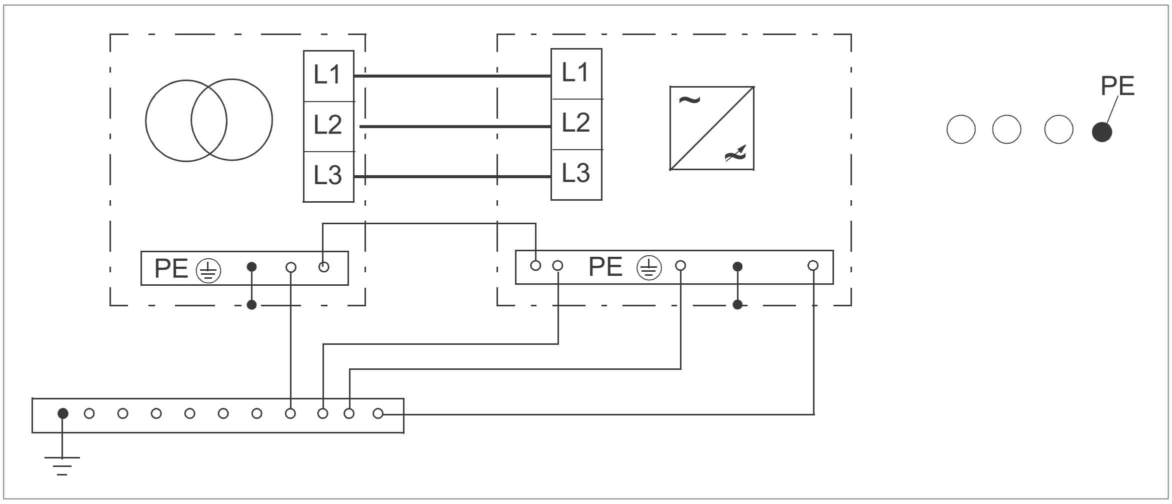
A cable bus system consists of parallel single-core cables for phase conductors. Compared to a corresponding busbar system, the cable bus system has

- better cooling due to separate conductors -> less conductor material is needed
- lower reactance -> longer distances are allowed.

Arrange the cables as shown below to get an as equal current distribution as possible.

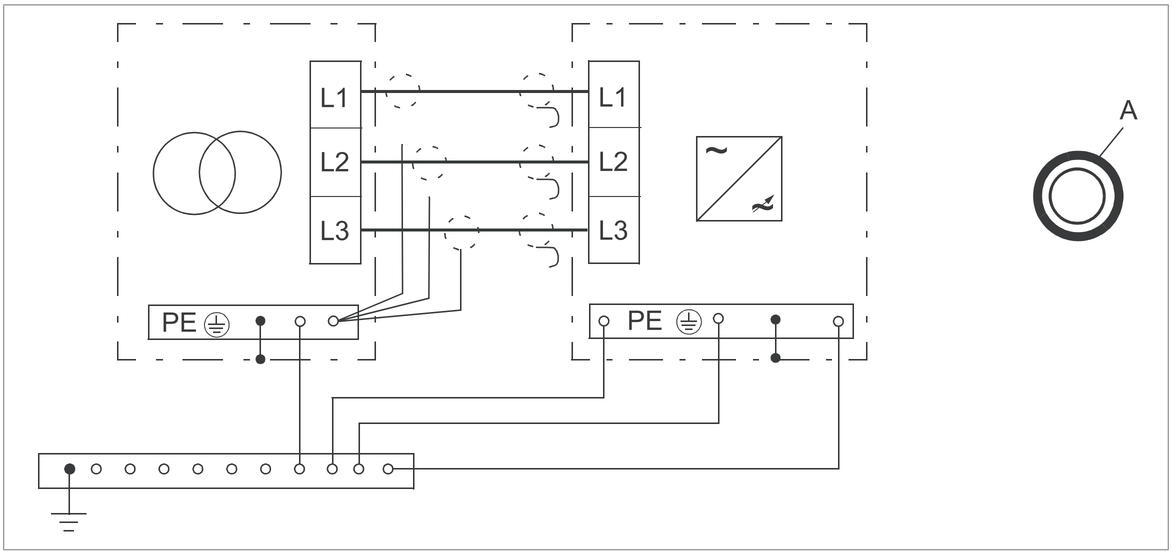


Connect single-core cables without concentric protective shield (armor) as shown below.



WARNING!
Do not use unshielded single core cables for drives with IGBT supply unit on IT (ungrounded) networks. A dangerous voltage can become present on the non-conductive outer sheath of the cable. This can cause injury or death.

In single-core cables which have a concentric protective shield (armor, A below), the phase current induces voltage to the cable shield. If the shields are connected to each other at both ends of the cable, current will flow in the cable shield. It is necessary to prevent this current for personnel safety. Therefore, connect the cable shield to the PE busbar at the transformer side only and insulate the shield at the drive side.



Connecting the drive to the motor

Decreasing bearing current risk

The bearing current risk depends on voltages which have an effect across the motor bearings. Three basic types of voltages can be measured in AC drive applications: shaft end-to-end voltage, shaft voltage to ground or motor frame voltage to ground.

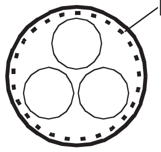
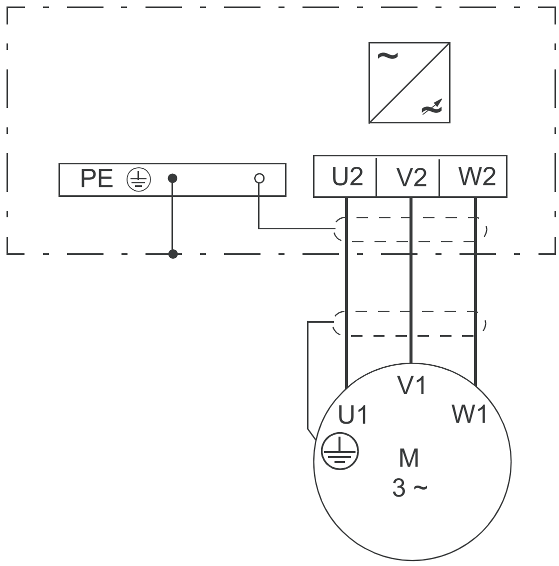
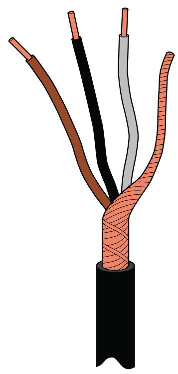
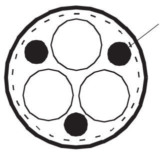
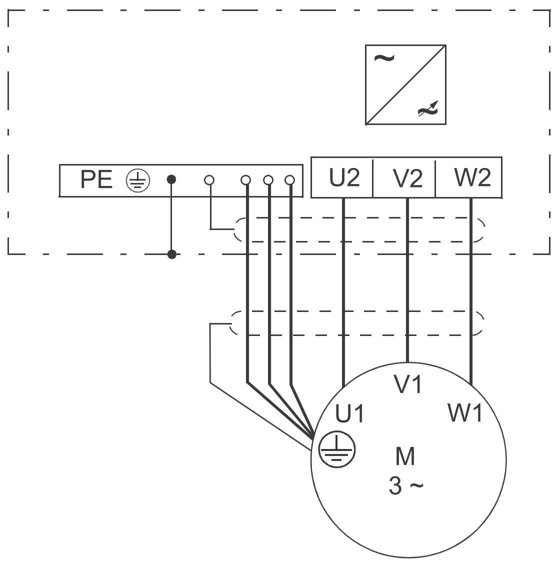
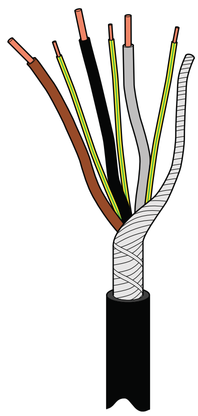
Incorrect motor cabling strongly increases these voltages in medium and high power motors. As a result, the lifetime of the motor, gearbox and driven machine bearings decreases. On the other hand, correct cabling and 360° grounding of the cable shield at both ends effectively decrease these voltages. Symmetrical, shielded cables decrease the motor frame voltage. The effect is more significant at high motor currents.

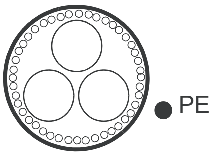
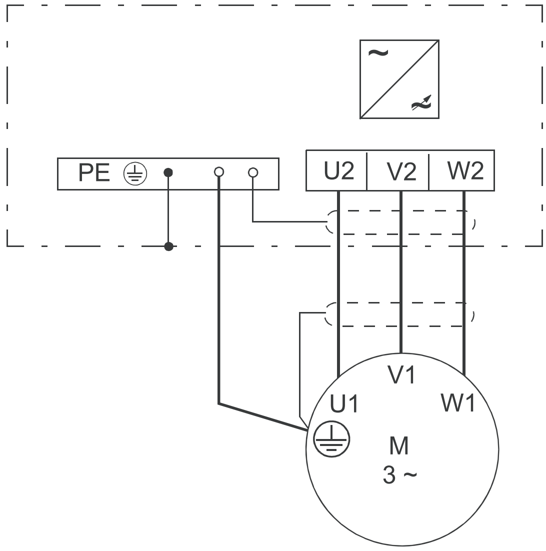
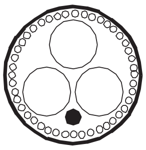
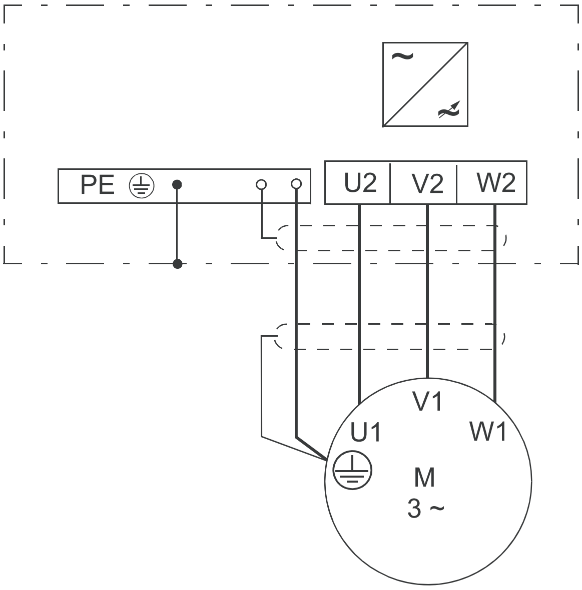
General instructions

Keep the length of the unshielded part of the motor cable as short as possible on the drive side and at the motor junction box. For special instructions, refer to the drive and motor product manuals.

Bond cable trays well electrically to each other and to the grounding electrodes. Aluminium tray systems improve local equalization of potential.

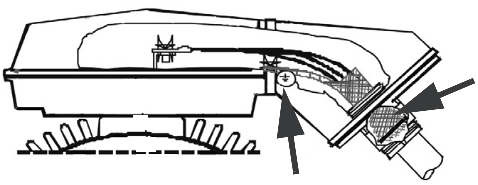
Diagrams of recommended connections

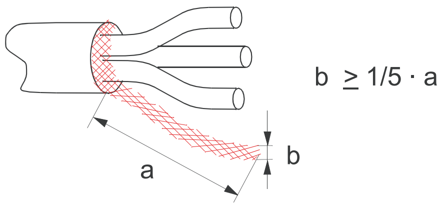
Concentric Cu shield 	 
Concentric Al/Cu shield 	 

Fe armor 	
Al/Cu shield Limited use (up to 100 kW motors, requires potential equalization, see page 25) 	

Grounding the motor cable shield at the motor end

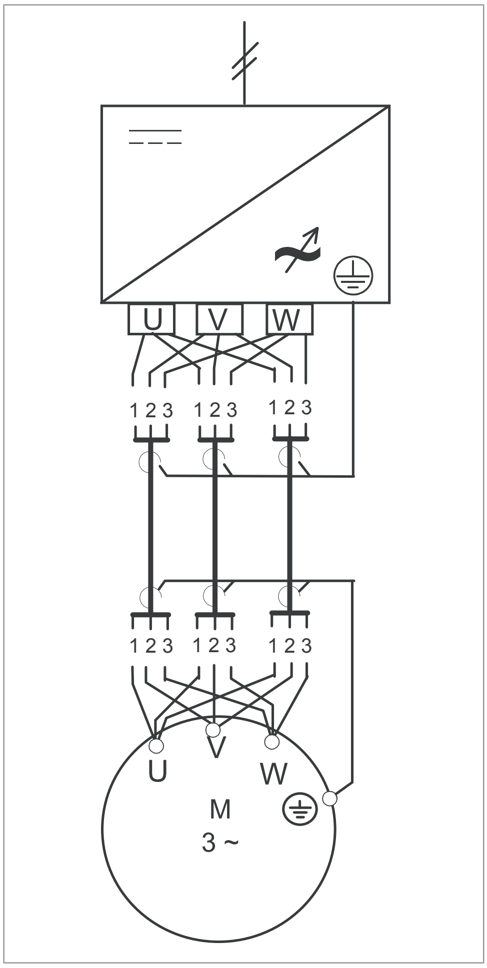
Always ground the motor cable shield at the motor end. For minimum radio frequency interference, ground the motor cable shield 360° at the lead-through of the motor terminal box, or ground the flattened twisted shield (width > 1/5 · length).





Motor cabling of high-power drives

Always connect the cables to high-power drive systems symmetrically as shown below.

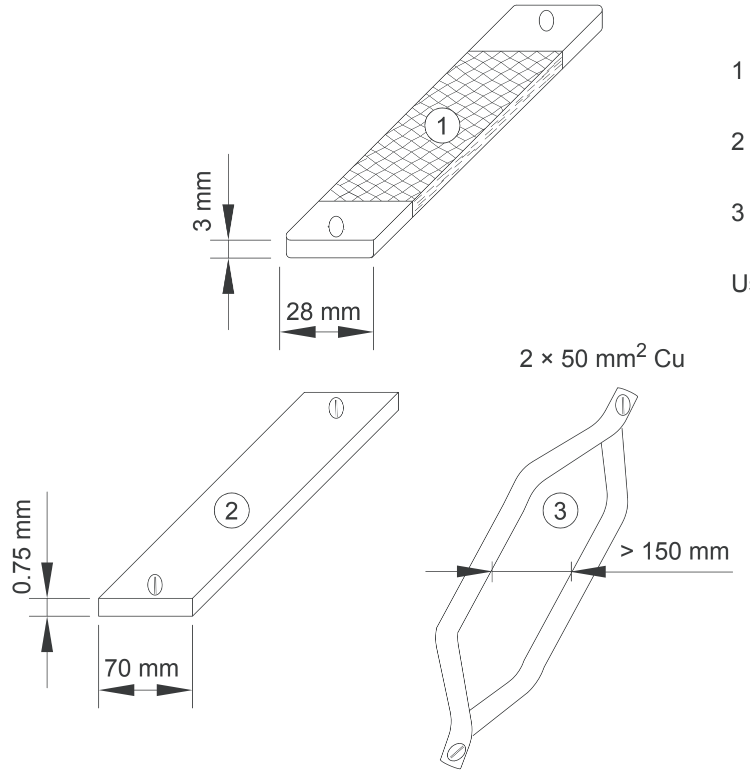


Potential equalization between the motor and driven equipment

With motors from 100 kW upwards, a potential equalization connection between the motor frame and the machinery is sometimes needed due to the grounding conditions of the driven machinery. Potential equalization is typically needed in applications such as pumps (grounded by water) and gearboxes with central lubrication (grounded by oil pipes). As low inductance is the objective, a copper plate or strip with a cross-section of at least 70 mm × 0.75 mm is required between the motor frame and the gearbox/pump frame. Alternatively, at least two separate 50 mm^2 cables can be used. The distance between the cables must be at least 150 mm.

Potential equalization has no electrical safety function. The purpose of it is purely to equalize the potentials. When the motor and the gearbox are mounted on a common steel fundament, no potential equalization is needed.

Install the potential equalization through the shortest possible route. If protection from dirt is needed, use a plastic tube, not a metal conduit.



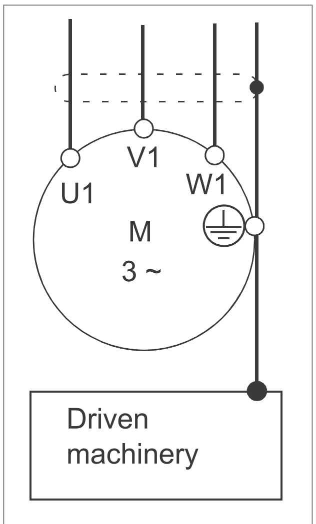
1 Flat braid. Diameter of hole for cable lug 13 mm.

2 Busbar. Connection hole diameter 13 mm.

3 Cables. Diameter of hole for cable lug 13 mm.

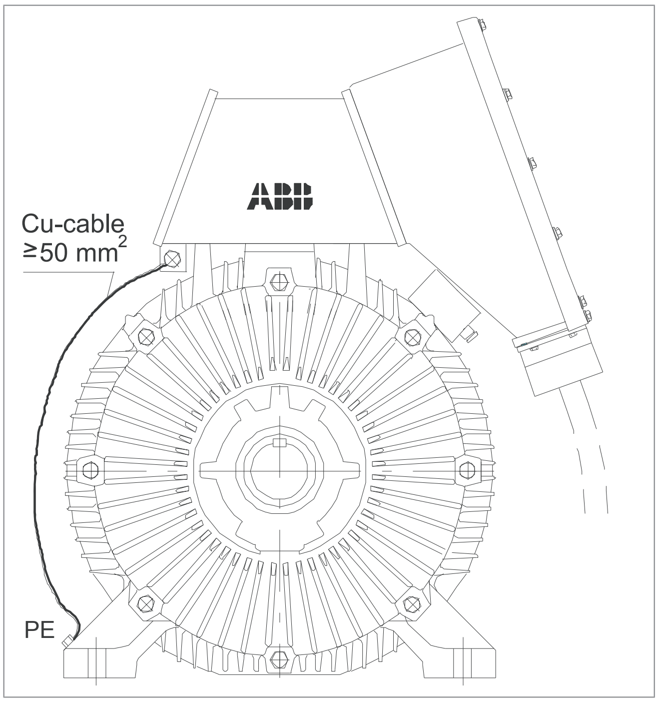
Use M12 screws with washer.

Connection diagram

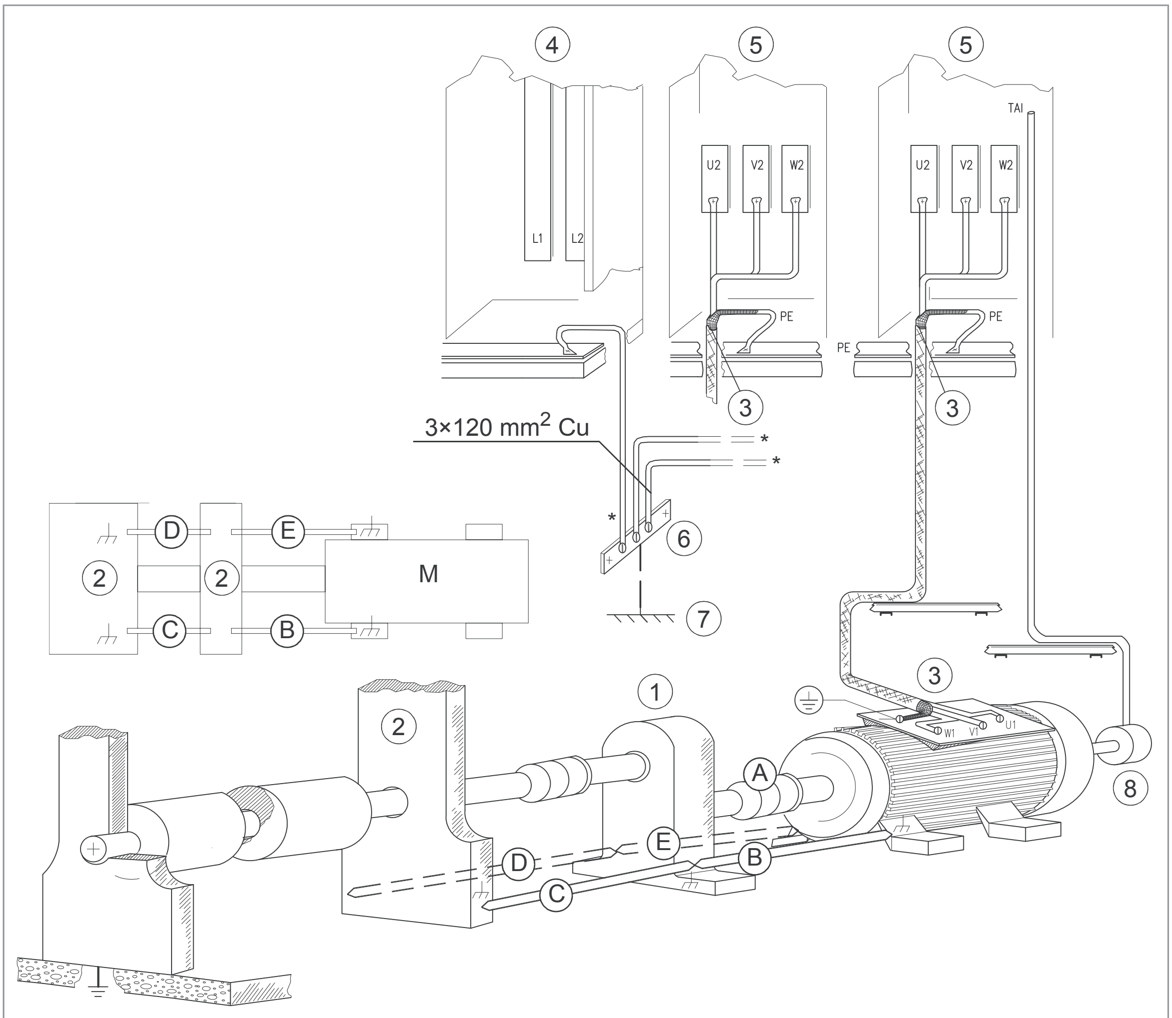


Potential equalization of the motor frame and the terminal box

The motor manufacturer connects the motor terminal box to the PE terminal of the motor frame with a copper cable if the potential equalization between the terminal box and the motor frame is needed. Typically, this is done in ATEX approved AC motors.



Example drive system cabling with potential equalization



A	Electrically conducting shaft		
B	Bonding for pump and fan motors with 100 kW ≤ P_n < 350 kW or IEC 315 ≤ frame size < IEC 400 and for other motors with P_n ≥ 350 kW or frame size ≥ IEC 400. The shaft can go from the motor to the gear box, pump, supporting intermediate bearing or to the fixed machine frame.		
C	Optional bonding	4	Incoming cubicle of the drive
D	Bonding for motors bigger than 1500 kW	5	Inverter module cubicle of the drive
E	Bonding for motors bigger than 1500 kW	6	Main grounding bus
1	Fixed machine frame, pump or gear box	7	Earth electrode
2	Machine frame	8	Pulse encoder
3	360° grounding	-	-

* Both ends and the middle of the PE busbar of the drive should be conneced to the main grounding bus in the electrical equipment room.

Instructions for bondings B, C, D and E

- Make short direct (metal-to-metal) connections.
- Use only non-metallic electrical tube.
- Protect the wiring junctions against corrosion with durable paint or protective compaound.

See section Potential equalization of the motor frame and the terminal box (page 27).

Potential equalization is not required when

- motor shaft is non-conductive or there is an insulating coupling
- motor and gear box are mounted on a common steel plate
- motor is flange-mounted directly on the machine frame.

Motor cable connections to be avoided

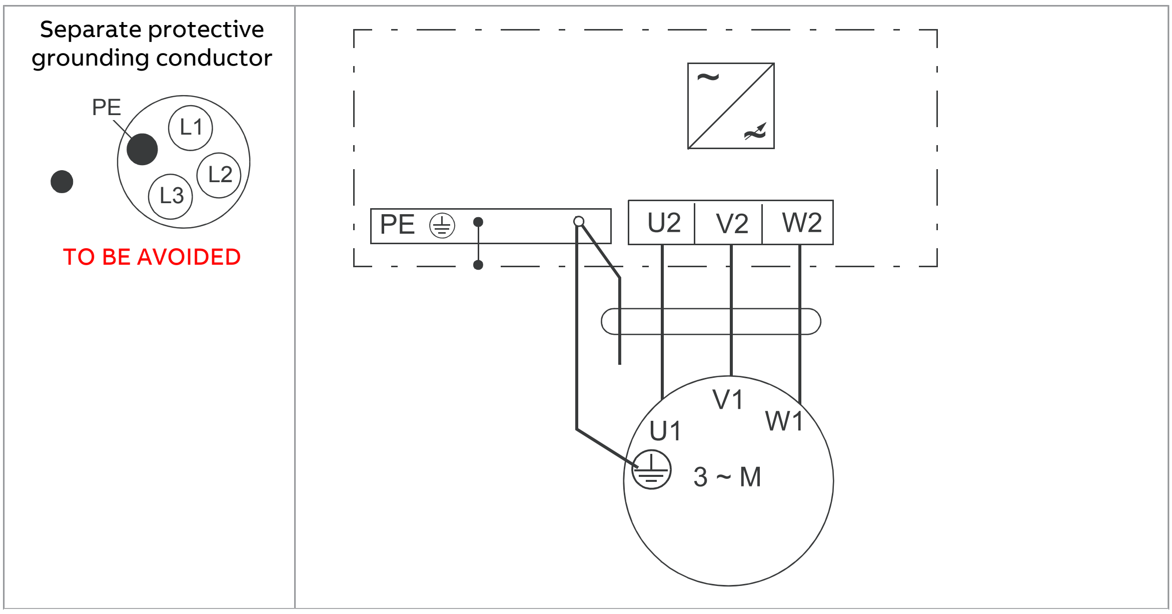
If other than the recommended cable types are used, the following rules are mostly useful. Complying with them does, however, not exclude effects of improper cabling and can void warranty.

Asymmetrical four-core cables

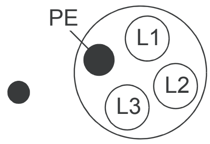
If you have a cable where the phase conductors are not at an equal distance from the ground conductor,

- do not use the ground conductor as the protective conductor
- connect the ground conductor to the PE terminal only at the drive end and isolate it at the motor end. However, if the cable has a fine-pitch interlaced steel plate armor the conductivity of which is at least 10% of the conductivity of the phase conductor, connect the armor to the PE terminal at the drive and motor ends.
- use a separate protective conductor with a cross-sectional area of at least the value given in section Required conductivity of the protective conductor (page 17).
- put the power cable and the protective conductor at least 300 mm apart (not on the same cable tray) in order to prevent inductive disturbance currents in the protective conductor. **If this lay-out can violates the regulations, use other cable types.**
- make the potential equalization connection between the motor frame and the machinery as described under Potential equalization between the motor and driven equipment (page 25).

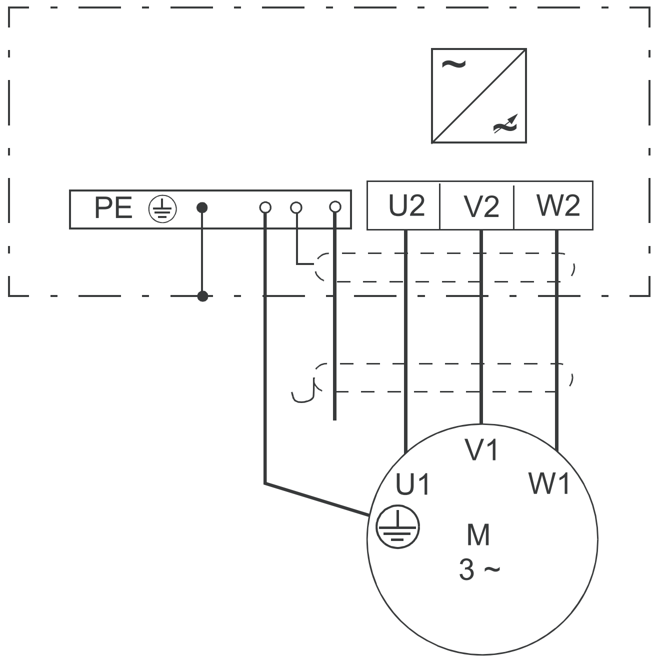
Connection diagrams



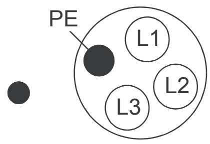
Separate protective grounding conductor, tape Fe armor (armor conductivity < 10% of the phase conductor conductivity)



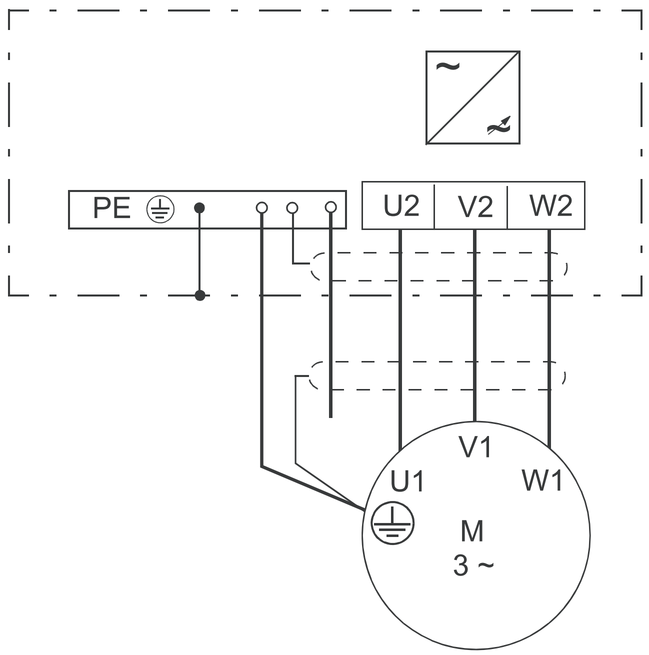
TO BE AVOIDED



Separate protective grounding conductor, tape Fe armor (armor conductivity > 10% of the phase conductor conductivity)

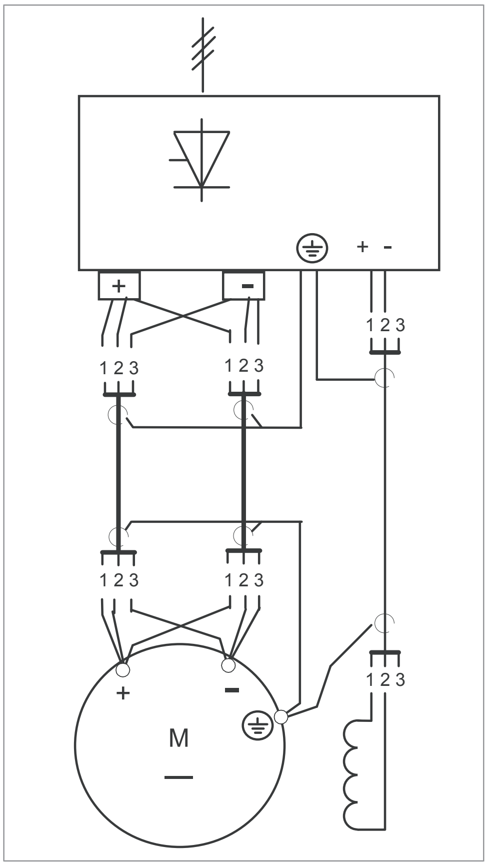


TO BE AVOIDED



DC drives

Obey the same basic cabling guidelines what we give for AC drive systems. The most economical power cable for DC systems has an even number of conductors. You can also use a shielded three-core cable. Use the 2+1 / 1+2 principle (see the figure below) when you install three-core cables in large drive systems, where several power cables are needed. This way the power is shared evenly between the cables.



The excitation cable is a heavy source of interference because of the abrupt commutation. Therefore, always use shielded excitation cables.

Do not use single-core cables for DC drives.

Motors with stator serial winding must have a grounding brush on the shaft to avoid bearing problems.

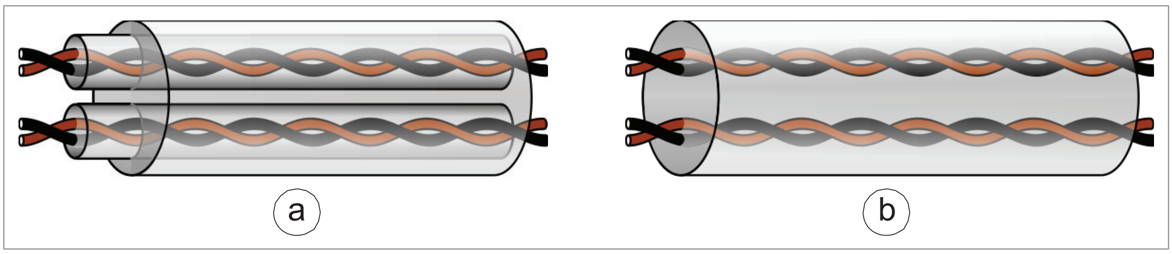
Selecting and connecting control cables

It is very important to use correct cable types to get the EMC compatibility. A wrong cable type can cause severe interference problems. Shielded control cables decrease disturbances. Twisted pair cables decrease disturbances caused by inductive coupling.

Only use shielded control cables. Keep any signal wire pairs twisted as close to the terminals as possible.

Use a double-shielded twisted pair cable for analog signals. ABB recommends this type of cable also for the pulse encoder signals. Use one individually shielded pair for each signal. Do not use common return for different analog signals.

A double-shielded cable (a) is the best alternative for low-voltage digital signals, but single-shielded (b) twisted pair cable is also acceptable.



Signals in separate cables

Run analog and digital signals in separate, shielded cables. Do not mix 24 V DC and 115/230 V AC signals in the same cable.

Signals that can be run in the same cable

If their voltage does not exceed 48 V, relay-controlled signals can be run in the same cables as digital input signals. The relay-controlled signals should be run as twisted pairs.

Relay cable

The cable type with braided metallic shield (for example ÖLFLEX by LAPPKABEL, Germany) has been tested and approved by ABB.

Serial communication (eg, fieldbus)

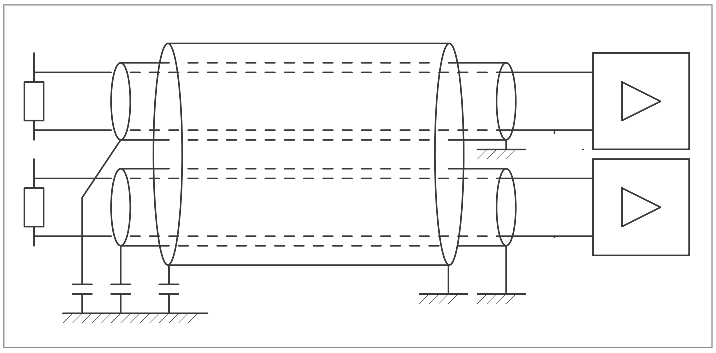
See the fieldbus adapter module user’s manuals.

Connecting the cable shield

Description

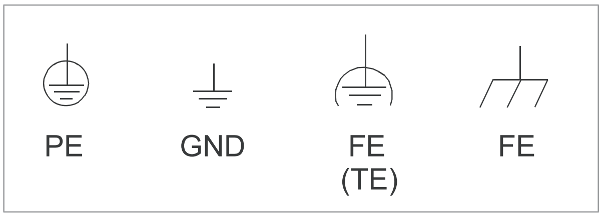
A signal cable shield left unconnected (ungrounded) at both ends does not suppress disturbances. Grounding a signal cable shield at one end only suppresses the electromagnetic field and inductive disturbances enough in most cases.

Grounding a signal cable shield at both ends improves disturbance suppression above a certain frequency, but forms also a loop where low-frequency current flows if the ends of the cable shield are at different potentials. Therefore, if high-frequency grounding is needed, the other end of the shield should be grounded via a capacitor. In some equipment the capacitor is incorporated.



Instructions

Ground the outer shields of all control cables 360° at a grounding clamp at the drive cable entry. Also, connect the pair cable shields and grounding wires to a grounding terminal at the drive side. The grounding terminal can be a special clamp, screw or terminal block marked with PE, FE, GND or one of the following symbols:



Leave the other ends of the control cable shields unconnected or ground them indirectly via a high-frequency capacitor with a few nanofarads, for example, 3.3 nF / 630 V. You can also ground the shield directly at both ends if the ends are in the same ground plane with no significant voltage drop between the ends.

Cabling and insulation of pulse encoders

Always use a double-shielded cable for the pulse encoder signals.

Ground the cable shields only at the pulse encoder interface module if the pulse encoder is not isolated from the motor and earth. However, if the encoder is isolated from the motor and earth, connect the cable shields to the encoder housing also.

For more information, refer to the user's manual of the pulse encoder interface module and the pulse encoder manual.

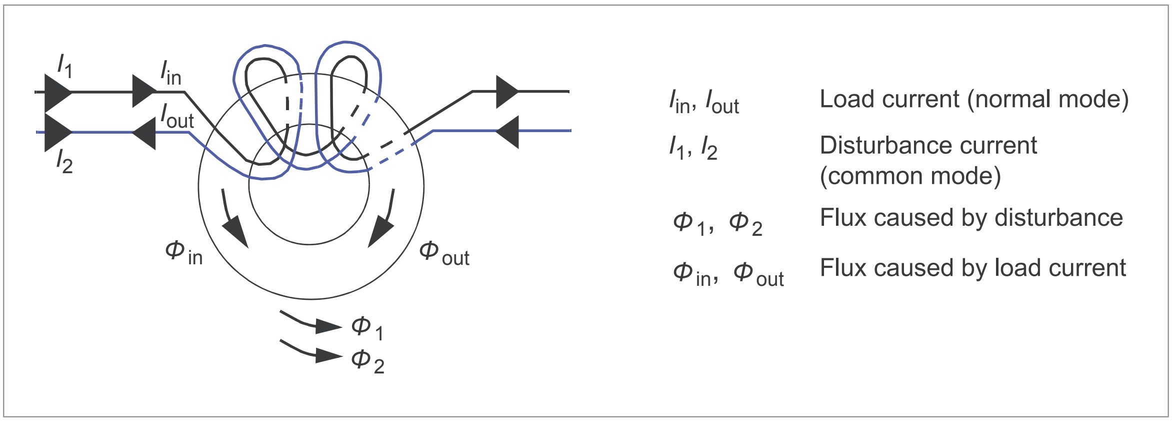
Galvanic isolation

ABB recommends galvanic isolation of control signals especially at long distances. Galvanic isolation improves the interference immunity. It prevents interference caused by common impedance coupling (ground loop) and suppresses inductive coupling interference. Isolate and amplify weak signals at the source end only. Otherwise, the signals can also be isolated at the receiving end.

Common mode inductors

In applications of high emission level such as trains, trams and moving machines, common mode inductors can be used in signal cables to avoid interfacing problems between different systems.

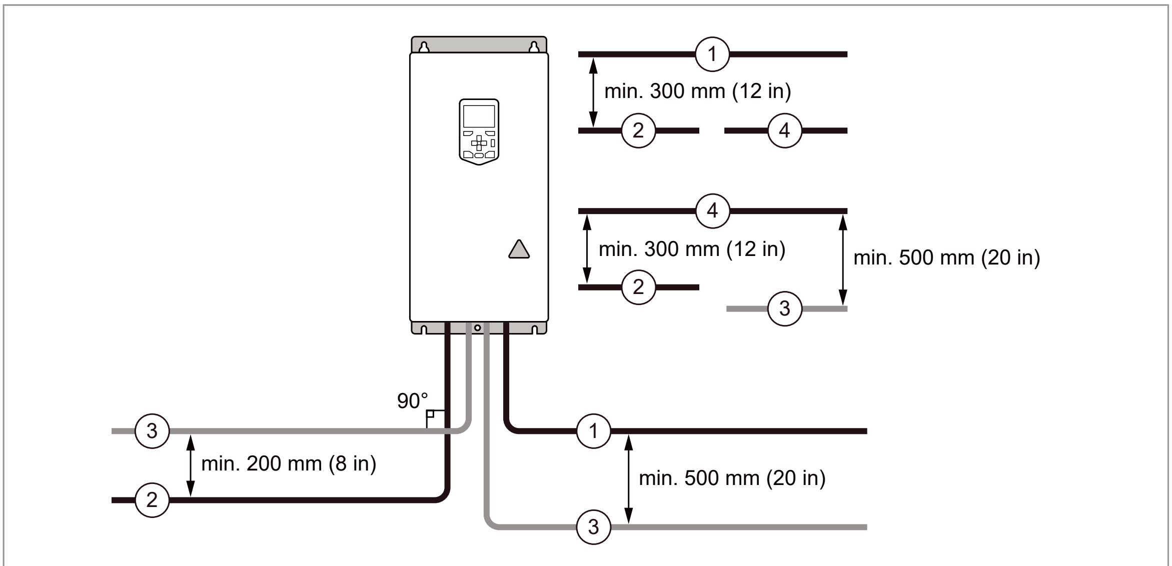
Wrap the signal conductors through the common mode inductor ferrite core as shown in the figure below. The ferrite core increases inductance of conductors and their mutual inductance so that common mode disturbance signals above a certain frequency are suppressed. An ideal common mode inductor does not suppress differential mode signals.



Routing the cables

- Route the motor cable away from other cables. Motor cables of several drives can be run in parallel installed next to each other.
- Install the motor cable, input power cable and control cables on separate trays.
- Avoid long parallel runs of motor cables with other cables.
- Where control cables must cross power cables, make sure that they are arranged at an angle as near to 90 degrees as possible.
- Do not run extra cables through the drive.
- Make sure that the cable trays have good electrical bonding to each other and to the grounding electrodes. Aluminum tray systems can be used to improve local equalizing of potential.

The following figure illustrates the cable routing guidelines with an example drive.



1	Motor cable
2	Input power cable
3	Control cable
4	Brake resistor or chopper cable (if any)

4

Interference coupling

Contents of this chapter

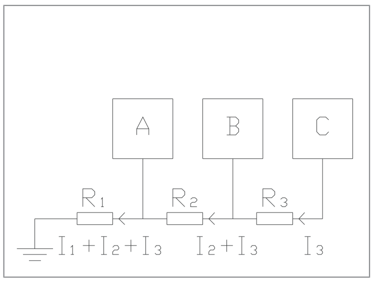
This chapter tells principally about different ways of interference coupling. It also gives guidelines on how to decrease the coupling.

Common impedance coupling

Common impedance coupling is possible if interference source circuits have a common current path (see the figure below), for example, in the grounding or power supply circuit. Current changes in the interfering circuit cause potential changes across the common impedance:

$$u = R \cdot i - L \frac{di}{dt}$$

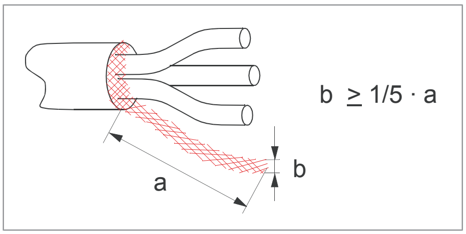
where u denotes the voltage and i the current. The voltage across an inductor is equal to the product of its inductance and the time rate of change of the current through it.



How to decrease coupling via a ground loop

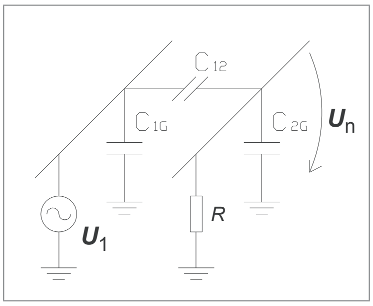
- Use one-point grounding to prevent low-frequency coupling.
- Keep the inductance as low as possible to decrease high-frequency coupling. To get lowest impedance, the relation between the length and width of a grounding

conductor (twisted shield) should be less than five. In practice, this is possible only with multipoint grounding.



Capacitive coupling

Capacitive disturbance is coupled by a changing electric field. The coupling is possible in circuits which have stray capacitance with each other.



Interference voltage (U_n) is proportional to frequency (f), voltage level of the interfering conductor (U_1) and stray capacitance between the conductors (C_{12}):

$$U_n = j2\pi f \cdot U_1 \cdot C_{12} \cdot R.$$

How to decrease capacitive coupling

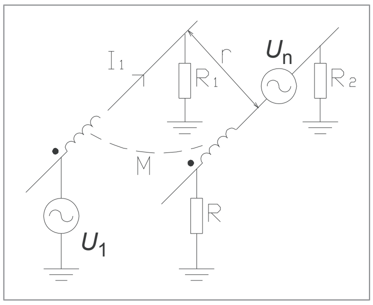
- Decrease stray capacitances between circuits.
- Decrease the impedance level of the victim circuit.
- Limit the frequency level of the interfering circuit.
- Limit the voltage level of the interfering circuit.

How to decrease stray capacitance

- Use metal casings for devices.
- Use shielded conductors.
- Increase the distance between conductors.
- Use a ground plane between conductors.

Inductive coupling

Inductive disturbance is coupled through magnetic field. Current in the interfering circuit generates a magnetic flux around its conductor. When a changing magnetic flux goes through a closed loop, a changing voltage is induced to the victim circuit and, as a result, an interference current flow in the closed loop.



Interference voltage (U_n) is proportional to the frequency (f) and current (I_1) of the interfering conductor and to the mutual inductance of the circuits (M_{12}). Mutual inductance is proportional to the area of the loop perpendicular to the magnetic field lines (A cos θ) devided by the distance between the conductors (r):

$$U_n = j2\pi f \cdot M_{12} \cdot I_1$$

$$M_{12} = \mu \frac{A \cos \theta}{2\pi r}$$

How to decrease inductive coupling between circuits

- Decrease mutual inductance between the circuits.
- Filter the high-frequency content of the interfering circuit.
- Decrease the current of the interfering circuit.

How to decrease mutual inductance

- Use twisted pairs as signal cables.
- Increase the distance between conductors.
- Decrease the loop area by galvanic isolation.
- Avoid parallel conductors and coils.

How to get extra disturbance suppression

- Shield the victim conductor with a material that has high permeability. Highpermeability material "short-circuits" magnetic circuits, so that most of the flux flows through this material.
- Use a metal enclosure or shield to decrease high-frequency disturbance.
- Use high-conductive metal shield materials such as aluminium and copper.

Electromagnetic coupling

Electromagnetic energy can propagate in free space as waves. Every conductor which carries a changing current is a potential transmitter antenna of electromagnetic waves. All conductors can also operate as receiver antennas. In addition, every conductor, whether it is a part of an active circuit or not, shapes the electromagnetic fields and potentially amplifies the antenna operation. Sometimes, a solid insulator can behave in the same way. The efficiency of the antenna increases at high frequencies (above

10 MHz) when the antenna dimensions exceed about 1/100 of the wave length. The dimensions and operation frequencies of normal digital electronics fall into this range.

Also, a part of the climatic interference, for example, lightning at a long distance, lies at frequencies from 10 to 100 MHz. A stroke of lightning close to an electronic equipment easily stops the normal function of the equipment and can damage it. The coupling decreases as the distance increases.

How to protect against electromagnetic waves

- Use ground planes or mesh structures as local ground.
- Use shielded cables.
- Use metal enclosures for equipment. Leaky doors are problematic.
- Make only small openings in enclosures.
- Prevent unintentional antenna structures.
- Ground systematically at short (< 1/10 wavelength) intervals.
- Leave the other ends of the control cable shields unconnected or ground them indirectly via a high-frequency capacitor with a few nanofarads, eg, 3.3 nF / 630 V.

These procedures decrease the electromagnetic coupling at both the source and the victim side.

Further information

Product and service inquiries

Address any inquiries about the product to your local ABB representative, quoting the type designation and serial number of the unit in question. A listing of ABB sales, support and service contacts can be found by navigating to www.abb.com/contact-centers.

Product training

For information on ABB product training, navigate to new.abb.com/service/training.

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