Electromagnetic Compatibility (EMC) 
User’s Guide 
for ELMO Motor Drives 
June 1996
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0. **How to Use the EMC User’s Guide**

This guide addresses two principal issues:
- The meaning of the CE mark and the requirements it imposes;
- How to solve the problems created by the need to meet the requirements imposed by the CE marking process.

Other than the chapters and appendices of an informational nature, principally concerning the CE marking process, the guide is organized around tasks which the user wishes to perform. There is, therefore, no need to read the guide from beginning to end.

The task-oriented chapters five to ten are relatively independent of one another. Once a task is identified, it is sufficient to read only the relevant chapter and the references, if any.

The user who is knowledgeable about the CE EMC directive and the CE marking process, including the draft proposal for a power drive product standard, should read Chapters 1 and 4 and then go to the appropriate task-oriented chapter, beginning with Chapter 5.

The user whose knowledge of the CE EMC directive and the CE marking process is limited should read the first four, informational, chapters before turning to the appropriate task-oriented chapter.

A brief description of the chapters and the appendices follows:

- **Chapter 1** - Introduction
  ELMO product lines and their mechanical construction.

- **Chapter 2** - CE: Its meaning and significance.
  The CE marking process as related to the EMC directive.

- **Chapter 3** - ELMO product lines and the CE mark.
  ELMO product lines as related to the CE marking process and the proposed product standard for power drives.

- **Chapter 4** - EMC environments.
  ELMO’s policy with regard to EMC environments.

- **Chapter 5** - Earthing and grounding.
  Good earthing, grounding, and shielding (cabling) techniques for reducing EMI.

- **Chapter 6** - Installation Considerations.
  Installation of a system containing ELMO power drives.
Chapter 7  - Filtering techniques.
Using filters to reduce EMI.

Chapter 8  - Wiring and cable design.
Proper cabling and connectors for systems containing ELMO power drives.

Chapter 9  - Shielding considerations for racks and cabinets.
Recommendations for bonding the mechanical elements comprising the enclosure.

Chapter 10 - Troubleshooting EMI problems.
Strategies for solving EMI problems.

Appendix A - Common- and differential-mode noise currents.
Common- and differential-mode currents as an EMI source.

Appendix B - Recommended EMI filters.
Selecting a suitable filter for an ELMO power drive.

Appendix C - An example of a declaration of conformity.

Appendix D - ELMO products and their safety requirements.
The CE safety requirements as applied to ELMO products.

Appendix E - ELMO product line and the EMC requirements.
The particular quantitative requirements in accordance with existing generic standards.

Appendix F - ELMO product families. A list of current Elmo product families and their power input requirements.
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1. Introduction.

This guide provides the user of ELMO Motor Drives with general advice and design guidelines to achieve the following goals:

1. Noise-free operation and electromagnetic compatibility (EMC) in a newly developed system;
2. EMC with various electromagnetic environments and with other co-located equipment and systems;

The guide addresses the different configurations of ELMO motor drives available:

- Panel-mount versions;
- Eurocard assembly versions (rack-mount drawer devices);
- Rack-mount modules;
- Cabinet-mounted version (wall-mount enclosed modules).

The panel-mount version is provided with a substantial heat sink containing installation holes. For vertical mounting it can be provided with mounting legs.

The Eurocard assembly is supplied with a 3U or 6U metallic front panel for installation in a 19" drawer for a standard 19" rack-mount.

The rack-mount version is based upon a Eurocard drive assembly, housed in a 19" drawer.

The cabinet-mounted version may be used only for installation in a closed cubicle. At this time, all ELMO products are designed to be used as open-type devices and therefore have to be installed within an electrical enclosure.

In general, recommendations given in this manual should not be considered as compulsory for achievement of electromagnetic compatibility in systems incorporating ELMO motor drives. Since electromagnetic compatibility depends on many environment-specific factors, no standard list of procedures can be given to cover all possible situations. Typically, noise-free drive operation can be achieved by applying just some of the large number of installation and design recommendations given.
2. **CE: Its Meaning and Significance**

One of the major concerns of the European Union (EU) is the free movement of goods among all its member states. Because each member state had its own technical standards, which constituted a barrier to the free movement of goods, it was necessary to "harmonize" the standards of the member states. This "harmonization" was intended to produce a single standard which all member states could accept as their own. Thus, a manufacturer could concentrate his efforts on complying with a single standard and, if successful, be assured that his product could be sold in any member state of the EU. The "harmonization" is achieved in several phases:

1. EU Directives define general objectives but do not go into technical details, which are left to various kinds of standards (European Norms). A product may be required to comply with more than one directive. The relationship between products, directives and standards is illustrated in Fig.2-1:

![Diagram showing the relationship between products, directives, and standards](2-1.jpg)

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Fig. 2-1. The relationship between products, directives, and standards.
2. There are three types of standards (European Norms):
- Basic standards, which define basic phenomenon-related requirements and testing procedures. They do not set quantitative goals or limits to achieve compliance. In a narrow sense, they are concerned with “what” and “how” to test for compliance.
- Generic standards, which build on the Basic standards, specify the requirements for compliance according to particular environments.
- Product and Product Family standards specify the requirements for compliance according to a particular product, or product family. At present, there is an EMC draft proposal of a product standard for electrical motor drives (IEC 1800-3 or FDIS 22G-31).

The relationship of the product to the various types of standards is illustrated in Fig. 2-2.

Fig. 2-2. The relationship of the product to the various types of standards.
The CE mark indicates that the product to which it is affixed complies with all applicable EU Directives. It is affixed by the manufacturer himself, at the end of the manufacturing process, provided, of course, that the requirements of all applicable standards have been met. The CE mark may be affixed on the product itself, on the packaging containing the product, or on the accompanying papers. To justify the use of the CE mark, a manufacturer must do two things:

1. Complete a declaration of his right to use the CE mark, which must be in the manual, or if not, must be delivered with accompanying papers given to the purchaser (for an example of a declaration, see Appendix C.);
2. Make available, in a member state of the EU, a Technical Construction File (TCF). If the manufacturer is not located in a member state, the TCF must be made available by the manufacturer’s official representative in a member state, for a period of at least 10 years following discontinuance of marketing the product.

A TCF must contain all technical information pertaining to the product, such as electrical schematics, mechanical schematics, bills of material, product brochures, and user’s manuals. In addition, the TCF must contain original test results and reports made to show compliance with all applicable standards. Also, the TCF should contain a report of all special measures taken to bring the product into compliance with the standards.

The CE mark is required on all products (apparatus) which are self-contained (“possess an intrinsic function”) as, for example, a computer. Products which are not self-contained (components) also require the CE mark if they “are freely available”, as, for example, a computer monitor which is sold independently. Components not freely available do not require the CE mark, as, for example, a printed circuit board. The distinction between products which do and do not require the CE mark is clarified in Fig. 2-3 on the next page:
Fig. 2-3. CE marking in accordance with the EMC Directive.
3. **ELMO’s Product Line and the CE mark**

ELMO products are available both with and without the CE mark. The requirement of a CE mark derives from two directives:


The EMC directive has been in force from Jan. 1, 1996; the Low Voltage Safety directive will come into force Jan. 1, 1997. At this time (May 1996), CE marking depends only upon the EMC directive, to which the following discussion will be limited. The relation of the ELMO product line to the Low Voltage Safety Directive and its requirements is treated in detail in Appendix D.

The EMC directive sets two requirements for compliance:

- Emission;
- Immunity

These requirements are environment-specific. For the ELMO product line just two environments are relevant:

- Residential, Commercial, and Light Industrial environment (Light Industry, for short);
- Industry environment.

The distinction between the two environments is made on the basis of the power source. An environment is Industrial if power is supplied from a transformer used only by one consumer. An environment is Light Industry if power is supplied from the public mains network (230/400 VAC, 50 HZ) so that a number of consumers share the common power source.

The combination of two requirements and two environments creates four generic standards. The manner in which ELMO has chosen to comply with these standards is described in Chapter 4, EMC Environment. Greater detail concerning the basic standards and the quantitative levels of requirements is given in Appendix E.

Under the existing EMC directive, the need to apply the CE mark to power drive systems is not clearly defined. To clarify this and other issues, a product standard for power drives (IEC 1800) has been submitted for adoption by June 1998. Of the three parts to this standard, only Part 3, relating to EMC, is available as a draft. The proposed product standard is not in conflict with the existing EMC generic standards. Along with the new product standard, a working group, CEMEP, has produced guidelines clearly distinguishing when the CE mark is required on a motor drive and when it is not. These guidelines are based on the approach adopted by the new standard, which makes
applicability to the CE mark depends upon the complexity of the product purchased and upon the customer’s membership in a particular distribution class. In ascending order of complexity, the system may be:

- Basic Drive Module (BDM) - contains control and self-protection circuitry, and a power converter;
- Complete Drive Module (CDM) - contains a BDM and its possible extensions, such as the power feeding section (as an example an isolating transformer) or some auxiliaries (e.g., ventilation);
- Power Drive System (PDS) - contains a CDM, motor, and sensors. If the PDS has its own dedicated transformer, this transformer is considered to be a part of the CDM.

The relation among the three levels of complexity is illustrated in Fig. 3-1:

![Diagram](elmo_motion_control_ltd.03_01.wmf)

Fig. 3-1. Definition of a motion installation.
The distribution class may be:

- Restricted - sales are made only to suppliers, customers, or users, who separately or jointly have technical competence in the EMC requirements of the application of drives;
- Unrestricted - sales are made without regard for the purchaser’s technical competence in the EMC requirements of the application of drives.

The combination of product complexity and method of distribution may be called a “Validity Field” for the application of the CE mark. This is summarized in the following table:

<table>
<thead>
<tr>
<th>VALIDITY FIELD</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Complex component sold “directly to the final consumer”</strong></td>
<td>Placed on the market. Free movement based on compliance with the EMC Directive. CE Declaration of conformity required. CE marking required. The manufacturer of the PDS (or CDM/BDM) is responsible for the EMC behavior of the PDS (or CDM/BDM) under specified conditions. Additional EMC measures outside the item are described in an easy to understand fashion and could actually be implemented by a layman. The resulting EMC behavior is the responsibility of the assembler of the final product, with the understanding that the manufacturer’s recommendations and guidelines are followed.</td>
</tr>
<tr>
<td><strong>Complex component only for professional assemblers.</strong></td>
<td>Intended only for professional assemblers who have a level of technical competence to install correctly. Does not have intrinsic function for the end user. No CE Declaration of conformity, no CE marking. PDS should comply with IEC-22G/21/CDV (IEC1800-3).</td>
</tr>
<tr>
<td><strong>Installation</strong></td>
<td>Not intended to be placed on the market as a single functional unit. Each apparatus or system included is subject to the provisions of the EMC Directive. No CE Declaration of conformity, no CE marking of the installation. The PDSs should comply with IEC-22G/21/CDV (IEC1800-3). Resulting EMC behavior is the responsibility of the installer (e.g. by following an appropriate EMC plan). Essential protection requirements of the EMC Directive, regarding the neighborhood of the installation apply.</td>
</tr>
<tr>
<td><strong>Apparatus/system</strong></td>
<td>Has an intrinsic function for the final user and placed on the market as a single commercial unit. CE Declaration of conformity required (for the apparatus or system) Resulting EMC behavior is the responsibility of the manufacturer of the apparatus or system.</td>
</tr>
</tbody>
</table>

(A) PDS (s) (or CDM/BDM) of the Unrestricted Distribution class in finished item(s)
With one exception, a customer’s membership in the unrestricted distribution class requires that the system or module be provided with the CE Declaration of conformity and the CE mark. The exception is that when one or more PDSs are brought together in or with an apparatus, system, or other components, no CE Declaration and no CE mark is required.

Since ELMO products are sold only to members of the restricted distribution class, they are not required to be CE marked. Nevertheless, future products will be brought to the maximum degree of compliance. In those cases in which full compliance is achieved (the higher-end products), the CE mark will be affixed even though not required.

If the product is supplied without the CE mark, it is on the assumption that the product is to be included in a system (apparatus) which will be tested for compliance by the purchaser. If the system is found to comply with all applicable directives, the purchaser of the non-CE ELMO product will affix the CE mark to his system.

ELMO non-CE-marked products are designed to minimize the purchaser’s difficulties in demonstrating the compliance of the system in which the product is included.

ELMO CE-marked products will be supplied in an enclosure (case). They will, of course, comply with the directives applicable to power drivers, as shown by tests successfully performed in accordance with all applicable standards.
4. **EMC Environment.**

Directive 89/336/EEC (EMC Directive) and Amendment 93/68/EEC specify two sets of requirements for six different environments:
- Residential, Commercial And Light Industry; (Light Industry, for short)
- Industry;
- Traffic /Transportation;
- Utilities;
- Special;
- Information Technologies.

ELMO motor drives are designed to operate in the first two environments: light industry and industry. The difference between these two environments derives from the way in which electrical power is supplied. An industry environment is present when there is an installation with a local power network, which is supplied from a high or medium-voltage transformer dedicated to supplying a manufacturing installation or a plant. The light industry environment is present when the apparatus is connected to the public mains network (230/400VAC, 50Hz). This distinction is important because there are significant differences in EMC requirements.

All equipment and subsystems comprising the system or installation should comply with the EMC requirements for the appropriate environment. EMC requirements are specified for two types of phenomena: Emission and Immunity. The following table specifies generic standards covering emission and immunity aspects of electromagnetic compatibility for both types of environments:

<table>
<thead>
<tr>
<th>Environment</th>
<th>Emission Standards</th>
<th>Immunity Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential, Commercial, Light Industry</td>
<td>EN 50081-1</td>
<td>EN 50081-2</td>
</tr>
<tr>
<td>Industry</td>
<td>EN 50082-1</td>
<td>EN 50082-2</td>
</tr>
</tbody>
</table>

Emission requirements of the light industry environment are more stringent than those of the industry environment. On the other hand, immunity requirements for the industry environment are more demanding than those for the light industry environment. In order to meet EMC requirements in all possible environments, ELMO has chosen to meet the most demanding requirements of each type of environment (emission: EN50081-1, immunity: EN50082-2).

ELMO motor drives are designed to comply with both types of environments on the condition that some of the design guidelines described in this manual are implemented.
5. **Earthing and Grounding.**

ELMO motor drives have to be earthed in one of two ways:

- Direct bonding of the drive housing to the rack metallic structure;
- Earthing by means of low-inductance bonding straps.

If the second option have been selected, flat bonding (as can be seen in Fig 5-1) strap is preferred to the round cable because of its lower inductance (for the same cross-sectional area). Short and wide bonding straps should be used. An attempt should be made to keep the length-to-width ratio below 5:1. Round wire bonds have significant inductance, which limits their effectiveness to audio frequencies. On the other hand, wide bonding straps may provide low-impedance bonding up to several MHz, so that a significant part of the PWM-generated signal spectrum may be covered.

![Fig. 5-1. A Typical Flat Bonding Strap and a Round Cable.](image)

Typical impedance behavior of a round wire/cable (or a PCB track) and flat bonding strap/solid ground plane at different frequencies is presented in Fig. 5-2. As can be seen, flat bonding strap exhibits much less impedance, starting from relatively low frequencies (only a few kHz).
The motor safety ground, also called protective earth (PE), should be a screened cable between the drive and the motor. It should be connected at one end to the motor housing and at the other end to the drive protective earth ground terminal.

A recommended earthing scheme is shown in Fig. 5-3. This figure illustrates earthing arrangements for the most complex configuration, when the following cables are connected to the motor drive:

- 220VAC power cord;
- Motor power cable;
- Motor feedback cable (serving encoders, resolvers or Hall-effect devices);
- RS-232 or RS-485 communication cable to PC or other Controller;
- Floating Control device.

Fig. 5-2. Impedance as a function of frequency for two earthing conductors.
Fig. 5-3. Recommended grounding design for ELMO motor drives
5.1 AC Power cable.

This cable is composed of two parts: between the drive and the EMI Filter and between the EMI filter and the AC power source.

For better EMI filter performance at higher frequencies, a low-inductance safety ground connection between the motor drive and the Power Supply EMI filter is recommended. Usually this is done by direct bonding of the drive and the filter metallic housings to the same rack or cabinet structure.

An additional ground connection between the drive and the filter bodies should be provided for the shielded power cable. This connection need not be low-inductance, and can be implemented as a round wire.

5.2 Motor power cable.

This cable is composed of two parts: the short section between the drive and the EMI filter and the longer section between the EMI filter and the motor. For better EMI filter performance at higher frequencies, a low-inductance safety ground connection should be provided between the motor drive and the EMI filter. Usually this is done by a direct bonding of the drive and the filter metallic housings to the same rack or cabinet structure.

The motor should be earthed to the nearby metallic structure by means of a low-inductance bond. In addition, a safety ground connection between the drive and the EMI filter should be provided for the shielded motor power cable.

AC motor drives may be affected by capacitance between the motor cable wires and the cable screen. This capacitance is charged and discharged, which may cause an overcurrent effect on the motor drive. This effect is significant for long cables (typical capacitance is around 200pF/m). In cases in which the cable capacitance creates an overcurrent, a series choke should be added at the drive output to compensate for the capacitive effect. Since ELMO motor drives are designed for relatively short shielded cable lengths (up to 15 metres) between the drives and the motors, the effect of capacitive loading may usually be neglected, and no special corrective actions are required.

5.3 Motor feedback cable

The electronics of encoders, resolvers or Hall-effect devices should be floating, in order to avoid closing the ground loop. In order to eliminate closing of the ground loop through the shield of the motor signal cable, double shielding of this cable can be used. The shields should be isolated from each other. The end of the inner shield should be terminated at the drive's side, while the end of the outer shield should be terminated at the chassis, at the motor side.
5.4 Motor signal cable

In cases in which the communication cable exceeds 10 meters, the use of RS-485 is recommended. Control devices, like a PC, may be earthed to a metallic structure which has a noise potential different from that of the motor drive. In order to eliminate closing the ground loop through the shield of the communication cable, double shielding of this cable is recommended. The shields should be isolated from each other. The end of the inner shield should be terminated at the drive's side, while the end of the outer shield should be terminated at the chassis, at the controller side.

5.5 Control cable

The control cable connects the motor drive to a switch or relay contacts. The control signal return should be floated at the far (switch) side. For relatively short cables (cable lengths less than 10 meters) and quiet electromagnetic environments, the cable should be implemented as a shielded twisted pair with the shield terminated at both its ends. The metallic box containing the switching device may be isolated from the nearby metallic structure or bonded to it, depending upon the distance between the motor drive and the switches, and also the noisiness of the environment.

Usually, the possible ground loop is not dangerous because of the relatively high immunity of the motor drive control input. In cases of long control cables or noisy environments, double shielding of this cable is recommended. The shields should be isolated from each other. The end of the inner shield should be terminated at the drive's end, while the end of the outer shield should be terminated at the chassis, at the other end.
6. **Installation Considerations.**

In all installations, ELMO motor drives and EMI filters (both on the input power terminals and on the output motor power cable) should be installed on the same metallic ground plane. In most cases, this means installation of the drives and the filters on the same metallic wall of the metallic enclosure. When feasible, the same installation rule is recommended for control devices.

![Diagram showing separation of installation area into power and control areas.](Elmo motion control ltd. 06_01.WMF)

**Fig. 6-1. Separation of installation area into power and control areas.**
Needless to say, all mating surfaces used for bonding the motor drives and EMI filters to metallic structures should be clean of paint, oil or grease and should be moisture-protected. It is recommended that a corrosion-protective finish be applied to all above mentioned mating surfaces.

Installation of the motor drive and motor should take into account electromagnetic pollution emanating from these noisy components and from power interconnection cables. Sensitive components and equipment should be kept at least 25cm apart from the drive modules, DC or AC motors, EMI filters, drive-to-motor cables, relays and contactors.

Resolver and other communication cables should be run between the motor and the drive in a separate screened power cable. For coupling lengths less than 10 meters, this cable should be separated from the motor drive cable by at least 25cm. In cases of long parallel runs, the spacing should be increased proportionally. Parallel runs of both cables should be avoided, when possible. Cross-over of all cables should be done at 90 degrees.

It is recommended that the installation area be divided into the power area, containing all motor drives, and the control area, containing all control devices. Each area should be provided with its own metallic housing. Thus, control devices and drives may be located in separate metallic enclosures within the same metallic rack, as shown in Fig. 6-1.
7. Filtering of Input and Output Power Leads.

Proper filtering of input power leads is absolutely necessary, primarily for compliance with the following technical requirements of the EMC Directive:

- conducted and radiated emission per EN55022, Class B;
- immunity to electrical fast transients on power leads per EN61000-4-4;
- immunity to conducted disturbances induced on power leads per EN61000-4-4.

Conducted emission can be presented as a sum of differential-mode and common-mode current components. Definition of both types of interference currents and explanations of their effect on undesirable electromagnetic radiation are given in Appendix A.

Filters used on the AC power leads to the drives incorporate series inductors (both differential and common-mode types), differential capacitors between phase and neutral leads and common-mode capacitors between each power lead and the chassis. Values of the common-mode capacitors are limited by the permitted leakage current to earth, so that the common-mode rejection at lower frequency ranges depends upon the common-mode inductor.

Filters used on the output leads to the motor can not incorporate a value of a differential capacitance too large because of its loading effect on the PWM signal driver. Large values of the differential capacitor may cause an undesirable activation of the short-circuit protection existing in all ELMO motor drives.

The use of ELMO recommended EMI filters (see Appendix B) is one possible way to comply with applicable EMC requirements. All recommended EMI filters incorporate elements reducing both differential-mode and common-mode noise components. Another way to comply is to use carefully selected EMI filters optimal for each specific application. The use of the proper attenuation curve, supplied by the filter manufacturer or measured by the user, is also discussed in Appendix B.

Several conditions should be satisfied in order to achieve the greatest benefit from the use of EMI filters:

- Good RF bonding should be ensured between the ELMO drive and the recommended filter. This issue was discussed in Chapter 5 of the guide. For best EMI filter performance, in installations within metallic enclosures, the drive and the filter should be bonded to the same metallic part of the enclosure. In cases in which suitable metallic construction is not available, a low-inductive bonding strap or bus bar connection between the drive and the filter should be used.
- Most manufacturers provide earth terminals on both input and output sides of the filter body. Both of these terminals are bonded to the filter housing and should be used for
safety wire connections on both sides of the filter. Fig. 7-1 shows incorrect and correct connections of the safety wires.

- The EMI filter should be located as close as possible to the ELMO motor drive in order to reduce to a minimum the length of wires between the drive and the filter, as shown in Fig. 7-2. It is recommended that the cable length between the drive and the filter be less than 30cm. Shielding of this cable is recommended, with the shield bonded to the chassis at both its ends;
- Maximum separation should be provided between power leads entering and leaving the EMI filters, as shown in Fig. 7-3. These leads should never be run in the same cable bundle.
- For best performance, power leads entering the EMI filter should be routed in such a way that only short lead sections are run inside the metallic enclosure (rack or cabinet). The same recommendation is applicable to motor power cable sections leaving EMI filters to connect with outside motors;
- The length of the motor power cable between the motor drive and the EMI filter should be less than 60cm.

![Incorrect Connections](image1)

![Correct Connections](image2)

Fig. 7-1. Connections of safety wires.
Fig. 7-2. Recommended location of EMI filters inside shielded cabinet.

Fig. 7-3. Layout examples of input and output leads and EMI filters.
Several rules should be followed in order to ensure that the EMI filter installation meets safety requirements:

**Rule 1.**

The drive and the filter should be reliably and permanently earthed to the power mains protective earth terminal. No plug or socket connection of the earthing wire is allowed.

**Rule 2.**

Since all recommended power line filters contain line-to-line and line-to-earth capacitors, bleeding resistors are fitted inside the filters. Filters or wiring should not be touched for at least 10 seconds after the removal of the AC supply voltage.

**Rule 3.**

The EMI filter should be earthed before connecting to the AC power supply in order to bleed relatively high leakage currents through the filter common-mode capacitors to safety ground and to remove hazardous voltage potentials from the filter body.

**Rule 4.**

EMI filters recommended for ELMO motor drives withstand four times their rated current for up to 10 seconds. Fuses or circuit breakers should be chosen accordingly.
8. Wiring and Cable Designs.

8.1 General.

The cable design should comply with both the emission and the immunity requirements of CE directive 89/336. The cable shield should operate as a part of the overall system shield, as illustrated in Fig. 8-1.

Fig. 8-1. Completion of the overall system shield by proper shield design.

It should be stressed here that the overall system shield can be considered completely only when the motor power cable shield is terminated to the chassis at both its ends.

The best shielding effect can be achieved if the shield termination is done around its entire circumference (360 degrees).

This rule can be implemented by using special glands holding the shield, as shown in Fig. 8-2. This technique is recommended at each shielded cable penetration through the wall of the shielded enclosure.
Fig. 8-2. The use of glands for 360 degrees termination of the cable shield.

Another simple but still acceptable technique of shield termination is demonstrated in Fig. 8-3. Here the shield is attached to the wall of the metallic enclosure by means of Ω-type clips.

Fig. 8-3. Termination of the cable screen by means of Ω-type clips.
The use of pig-tail terminations should be avoided, as shown in Fig. 8-4. The relatively large inductance of pig-tails makes a very significant contribution to the overall transfer impedance of the cable shield. Noise penetration into the shielded signal leads due to several centimeters of the pig-tail can be equivalent to several meters of braided shield length.

![Incorrect!](image1)

Fig. 8-4. Illustration of pig-tail connection of the cable shield to be avoided.

Shield termination to the connector pin and its further bond to the metallic housing using a pig-tail is not a recommended practice. Much better shielding can be achieved by 360 degrees shield termination to a conductive backshell, as shown in Fig. 8-5.

![Incorrect!](image2) ![Correct!](image3)

Fig. 8-5. Termination of the cable shields in the case of cables with backshells
The cable shield should be terminated as close as possible to the connector terminals. Incorrect and correct shield terminations are illustrated in Fig. 8-6.

Fig. 8-6. Cable shield termination (long unshielded wires).

8.2 Input Power Cable.

The input power cable is usually unshielded. In order to avoid undesirable noise radiation from this cable, the use of an EMI filter is recommended on input power leads. As described in detail in Chapter 7 of the guide, the EMI filter should be located as close as possible to the drive, in order to reduce the length of the power cable between the EMI filter and the drive. It is important to shield this cable when its length exceeds 15 cm. The shield should be terminated to the chassis at both ends. For the case of lengths shorter than 15 cm, these wires should be twisted. In any case, this cable (or wires) should be run close to the metallic structure.

8.3 Motor Power Cable.

For reduction of undesirable radiation, the cable between the drive and the motor should be shielded. If used, the shield should be bonded to the chassis at both ends. Only braided cable shields will provide reliable shielding. The use of foil shields should be avoided.

If the motor power cable is broken into several sections by the output EMI filter, relay, contactor, and brake resistors, or other device, these devices should be installed within metallic enclosures. In this case, the shield of each section should be terminated at both its ends.
8.4 Feedback and Communication Cables.

Shielded twisted pairs are preferred for feedback and communication cables. For better immunity of these signals, each signal should be run in parallel with its return wire in the same shielded twisted pair. The signal should never be run when separated from its return wire.

RS-485 balanced communication is preferred for its better immunity (see chapter 5 of the guide). In a severe electromagnetic environment, when significant noise potential drop exists between the two ends of the communication link, bonding the cable shield at both its ends to the chassis may result in closing an undesirable ground loop. In these cases, a double shield should be used, so that the inner shield terminates on one end and the outer shield terminates on the other.

In case of a short communication link, the cable shields of all shielded twisted pairs should be terminated at both ends to the chassis.

Hint: Always check for ground potential differences between devices communicating with RS-485 or RS-232, before connecting!
9. **Shielding Considerations for Racks and Cabinets.**

Shielding is a very effective technique for reduction of electromagnetic radiation from racks and cabinets containing motor drives in panel-mounted, Eurocard and Rack-mount versions. The following discontinuities in the cabinet electromagnetic shield may cause severe degradation in its effectiveness:

- doors and covers;
- ventilation apertures;
- openings for penetration of cables.

Doors and covers should be sealed by means of EMI gaskets. Selection of the proper gasket type depends upon the following factors:

- required shielding effectiveness;
- environmental conditions (primarily exposure to moisture and other corrosive factors);
- maintainability requirements.

Electromagnetic field penetration through ventilation openings depends upon the dimensions of the largest opening. The larger the opening, the less is the shielding effectiveness. For purpose of EMI, when safety considerations are not relevant, round holes are more effective than narrow slots. The hole diameter should be less than 1/20 of a wavelength at the greatest interference frequency. Good shielding results are obtained with a hole diameter between 5-8 mm.

When safety considerations are relevant, the regulations stipulating a maximum width of 2.5 mm require the use of a slot for ventilation. A slot of 2.5 x 30 mm may be recommended for adequate EMI shielding, and will also satisfy safety requirements.

Penetration of cables may cause deterioration of the overall cabinet shielding effectiveness and make useless all the efforts to seal other cabinet shielding irregularities. Two techniques may be successfully used to deal with this problem:

- cable shielding and proper shield termination on the walls of the enclosure;
- use of an EMI filter.

It should be remembered that a filter effectiveness at lower frequency ranges (below a few kHz) is very low, so that only a combination of both shielding and filtering can ensure shielding effectiveness over all relevant frequency ranges.
10. Troubleshooting EMI Problems.

The following considerations may be useful when troubleshooting EMI problems, in general, and specifically as encountered in motor drive applications:

- Presence of the three factors: source, propagation path, and target (victim) is necessary for the existence of an EMI problem. Often the problem can be solved by eliminating one of the three factors.

- In most cases there is more than one interference mechanism. Eliminate them one-by-one, applying necessary corrective actions. Never go back in this process, even in cases when some corrective action did not totally solve the problem. Remember that the solution is often complex. In order to save unnecessary corrective actions, go back to some of your corrective actions only after the list of possible mechanisms is exhausted.

- Divide the troubleshooting process into two phases:
  a) Discovering the interference source, path, victim mechanism(s);
  b) Eliminating one of the three factors (source, path or victim) for each interference mechanism.

- It is convenient to segregate all possible EMI interference paths into two categories: conducted and radiated. Remember that in the case of PWM motor-driving signals, both types of interference can be encountered. This is due to a very broad spectrum of PWM interference signal (up to several tens and even hundreds of MHZ). The PWM interference signal contains very high-order harmonics of the switching frequency.

- Conducted interference is primarily due to conducted emission onto the input power leads to the motor drive. The following actions may be useful:
  a) try to feed the drive through an AC isolation transformer or separate AC power source;
  b) try to feed the victim and/or noisy equipment through an EMI filter.

- Interference due to radiated emission may be eliminated or reduced by means of the following corrective actions:
  a) increase the space separation between noisy and victim cables and equipment;
  b) try to route victim and noisy cables so that they cross each other at 90 degrees.
  c) try disconnecting all cables which are not necessary for basic system operation in order to discover possible interference paths;
  d) try to apply an EMI filter to the victim signal leads.
Interference due to crosstalk may be considered as a special case of radiated emission. The following countermeasures may be useful for crosstalk elimination:

a) separate the power cord and the power motor cable from cables with sensitive signals;

b) check the quality of the cable shields and make necessary corrections to the shielding design;

c) try to apply an EMI filter to the victim signal leads.
Appendix A. Common and Differential - Mode Noise Currents.

Consider a two-wire signal cable with currents \( I_1 \) and \( I_2 \), as shown in Fig. A.1.

\[
\begin{align*}
I_1 & \quad \text{Wire #1} \\
I_2 & \quad \text{Wire #2}
\end{align*}
\]

Fig. A-1. Arbitrary currents in two-wire cables.

In general, \( I_1 \) is not exactly equal to \( I_2 \) due to parasitic or other effects. \( I_1 \) and \( I_2 \) can be presented as a linear combination of so called differential and common-mode currents:

\[
I_1 = I_c + I_d \\
I_2 = I_c - I_d.
\]

Common-mode current \( I_c \) and differential-mode current \( I_d \) can be found from the above equations:

\[
\begin{align*}
I_c &= \frac{1}{2} (I_1 + I_2) \\
I_d &= \frac{1}{2} (I_1 - I_2).
\end{align*}
\]

In cases of complete balance between forward and reverse currents, the condition \( I_1 = -I_2 \) is satisfied, so that \( I_c = 0 \).

Common- and differential-mode currents play different roles in the process of electromagnetic radiation from the signal cable. Differential-mode currents in both wires are equal in amplitude and in opposite direction. For this reason, as shown in Fig. A-2, radiation of differential-mode current from wire #1 is nearly compensated by the radiation of the differential-mode current from wire #2.

\[
\begin{align*}
I_d & \quad \text{Wire #1} \\
-I_d & \quad \text{Wire #2}
\end{align*}
\]

Fig. A-2. Field from the differential-mode current in wire #1 is reduced by the field from the differential-mode current in wire #2, especially if twisted.
On the other hand, radiation of the common-mode currents from both wires is added, as can be seen in Fig. A-3.

![Diagram](image)

Fig. A-3. Field from the common-mode current in wire #1 is added to the field from the common-mode current in wire #2 even if twisted.
Appendix B. Recommended EMI Filters for ELMO Motor Drives and Evaluation of Filter Performance.

B.1 Recommended EMI Filters for Elmo Motor Drives.

Currently produced power drives (May 1996) produce more conductive noise than is permitted by most standards. Because of this, it is necessary to connect a line filter to the drives at the point of their connection to the electrical network (mains).

ELMO power drives can be divided into two groups, according to the power source without regard to the motor type (DC or brushless). The two defining power sources are:
1. DC supply;
2. AC supply.

A line filter should be used only in conjunction with an AC supply and should be connected just before the voltage rectification stage. For drives receiving a DC supply, the line filter would have to be connected before the drive and before the power supply which provides the DC voltage.

In the event that a power drive (whether supplied by AC or DC) is fed through a transformer (isolation, step-up, or step-down), the line filter may be connected to the primary or the secondary of the transformer. To achieve minimal current leakage to the ground (medical equipment), the line filter should be connected in series with the secondary, at the cost of a higher current rating for the filter. If ordinary current leakage is allowed, then a lower current rated filter can be connected in series with the primary.

When a number of power drives are driven by one transformer using multiple secondaries, one filter may serve all the drives by connecting the filter in the primary.

Because of the noise generated by currently produced power drives is relatively high, two-stage filters with high attenuation should be used. Despite this recommendation, it is difficult to know with any precision which filter will give the best results. This is because the filter performance depends not just on the filter itself but also upon the quality of the system wiring, the separation of the filters from the drive, and the location of the filters with respect to the output. Additionally, the output impedance of the filter selected should come reasonably close to matching the input impedance of the power drive. For all of these reasons there is no simple procedure for selecting an optimal filter. Unfortunately, the process requires a good deal of a trial and error. Hopefully, the recommendations which follow will reduce the effort required to find a suitable filter for the user’s system.

Although Schaffner filters are recommended, filters of other manufacturers may also be suitable, providing that they have acceptable ratings and performance. An essential
requirement in selecting a suitable filter is its ability to work satisfactorily with a motor driver since such a filter will be called upon to supply very high momentary (peak) currents, as much as twice the rated current, for as long as three seconds. ELMO power drives are capable of meeting these needs, so filters should be chosen accordingly.

In view of the foregoing, the current rating of an input filter working with a power drive in a single phase system should be identical to the current rating of the drive. For example, an IBP12/135 power drive, working at its maximum continuous current of 12A, requires a filter with the same rating of 12A (continuous current). If the current used in the application is less than the rated current of the power drive the rating of the filter may be reduced accordingly.

A Schaffner filter family is composed of filters having essentially the same attenuation curve but with different current ratings. A list of the families recommended for use with ELMO power drives, in decreasing order of attenuation performance, is given below:

- FN 9675
- FN 250
- FN 685
- FN 350
- FN 680

Shaffner filter family FN 2080 (with attenuation performance between FN250 and FN685) may also be used, but then the filter current should use the maximum (peak) current rating of the application and not the nominal (continuous) rating.

When the supply voltage to the power drive is three-phase AC, the current flowing through the line filter is found from the current in the single-phase case, multiplied by 0.58. The recommended Schaffner filter families, again in descending order of attenuation performance, are:

- FN 358
- FN 356
- FN 354

In addition, the type of three-phase connection must be taken into account when choosing a filter. The connection may be a star (the letter Y), with four wires, or delta, with three wires.

In choosing a suitable filter it is important to recognize that the ordering of filters by attenuation performance does not give the same result as ordering the filters by cost. In other words, the filter with the best attenuation performance is not necessarily the most costly. This suggests that both characteristics of a filter must be considered together to
arrive at an optimal result. A more detailed discussion of attenuation curves is presented in the second part of this appendix.

Other Schaffner filter families and the filters of other manufacturers not intended to be used with motor drives may be used, but the user must be prepared to increase the current ratings, in some cases by as much as 80%.
B.2 The Use of Filter Attenuation Curves for Filter Selection.

Most filter manufacturers publish filter attenuation curves, measured in a 50Ω test setup. This test setup accords with the measurement standard MIL-STD-220A. Popularity of the 50Ω measurement environment may be explained by the fact that most test equipment and test cables use a 50Ω standard impedance.

The use of 50Ω filter attenuation curves is very often a frustrating experience. Sometimes the real-world filter performance has nothing in common with the 50Ω attenuation data. The reason for this is that the real-world source and load impedances differ significantly from the standard 50Ω value.

CISPR 17 gives an alternative to the 50Ω measurement method. This alternative approach is called "Approximate Worst Case Method". In this test method, the filter insertion loss is measured with 0.1Ω and 100Ω terminations on the line and load side, respectively. The measurements are then repeated with the terminating impedances reversed.

Experiments have shown that the real-world filter attenuation is closer to results obtained by the 0.1Ω/100Ω method than by the 50Ω/50Ω method. The 0.1Ω/100Ω attenuation is normally slightly less (usually a few dB) than the real-world filter attenuation. Accordingly, 0.1Ω/100Ω attenuation curves should be used when selecting the filter for a specific application.

Another question often asked is which attenuation curve should be used: common-mode or differential-mode. Usually, the differential-mode curve should be used below 1MHz, and the common-mode curve above 1MHz. This suggestion should be taken as a general guideline, and not as an exact prescription.

An often a neglected effect in dealing with attenuation curves is the saturation of filter inductors by load currents. Usually, manufacturers supply unloaded attenuation curves. When the load is significant, degradation in the filter performance is to be expected. It is advisable to select a different filter, if the saturation effect results in attenuation drops of more then 6dB.
Appendix C. An Example of a Declaration of Conformity

An example of a declaration of conformity is given below:

<table>
<thead>
<tr>
<th>Declaration of Conformity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of Council Directive(s) ________________________________</td>
</tr>
<tr>
<td>Standard(s) to which Conformity is Declared _________________________</td>
</tr>
<tr>
<td>Manufacturer’s Name ___________________________________________</td>
</tr>
<tr>
<td>Manufacturer’s Address _________________________________________</td>
</tr>
<tr>
<td>Importer’s Name _______________________________________________</td>
</tr>
<tr>
<td>Importer’s Address _____________________________________________</td>
</tr>
<tr>
<td>Type of Equipment ______________________________________________</td>
</tr>
<tr>
<td>Model No. _____________________________________________________</td>
</tr>
<tr>
<td>Serial No. ________________ Year of Manufacture __________________</td>
</tr>
</tbody>
</table>

We, the undersigned, hereby declare that the equipment specified above conforms to the above Directive(s) and Standard(s).

Place _________________________           __________________________

(Signature)

Date _________________________           __________________________

(Full name)

(Position) – Manufacturer

Place _________________________           __________________________

(Signature)

Date _________________________           __________________________

(Full name)

(Position) – Importer
Appendix D.  Elmo Product Line and Safety Requirements

The safety of an electrical and electronics equipment is defined by directive 73/23/EEC and Amendment 93/68/EEC - Low Voltage Electrical Safety. This directive will come into effect on January 1, 1997.

There is a list of European standards that satisfy this directive. From the list of standards that satisfy the Low-voltage directive, European norm EN 60204-1 was selected as suitable for ELMO’s product line.

This standard is named:

(a generic standard).

However, this standard only sets the requirements; the method of testing for compliance is defined by EN 61010-1.

This standard is named:

EN 61010 - 1, “Safety requirements for electrical equipment for measurement, control and laboratory use. Part 1: General requirements.”
(a basic standard).

For a better understanding of the relation of directives and standards, see Chapter 2.
Appendix E. Elmo Product Line and the EMC Requirements

The Electromagnetic Compatibility (EMC) of electrical and electronics equipment is defined by the EMC directive 89/336/EEC and amendment 92/31/EEC. This directive came into effect on January 1, 1996.

From the list of standards that satisfy the EMC directive, the four European norms selected as suitable for the ELMO product line are:

3. EN 50082-1 - Electromagnetic compatibility-Generic immunity standard, Part 1. Residential, commercial and light industry.
4. EN 50082-1 - Electromagnetic compatibility-Generic immunity standard, Part 2. Industrial environment.

As explained earlier, in Chapter 3, ELMO will use the two standards that are more difficult to meet; EN 50081-1 for emission and EN 50082-2 for immunity.

Testing specifications for the foregoing requirements are provided for each of the standards.

The requirements of EN 50081 - 1 are defined by the following basic standards:

EN 55014 - Limits and methods of measurement of radio interference characteristics of household electrical appliances, power tools, and similar electrical apparatus;
EN 55022 - Limits and methods of measurement of radio interference characteristics of information technology equipment;
EN 60555 - 2 - Harmonics on power lines;
EN 60555 - 3 - Voltage fluctuations on power lines;

The requirements of EN 50081 - 2 are defined by the following basic standards:

EN 55011 - Limits and methods of measurement of radio disturbance characteristics of industrial, scientific and medical (ISM) information technology equipment;
EN 60555 - 2 - Harmonics on power lines;
EN 60555 - 3 - Voltage fluctuations on power lines.
The requirements of EN 50082 - 1 are defined by the following basic standards:

EN 61000-4-2 Electrostatic discharge immunity test;
EN 61000-4-3 Radiated, radio-frequency, electromagnetic field immunity test;
EN 61000-4-4 Electrical fast transient/burst immunity test;
EN 61000-4-5 Surge immunity test;
EN 61000-4-6 Conducted disturbances induced by radio frequency fields immunity test;
EN 61000-4-8 Power frequency magnetic field immunity test;
EN 61000-4-11 Voltage dips, short interruption and voltage variation immunity test.

The requirements of EN 50082 - 2 are defined by the following basic standards:
EN 61000-4-2 Electrostatic discharge immunity test;
EN 61000-4-3 Radiated, radio-frequency, electromagnetic field immunity test;
EN 61000-4-4 Electrical fast transient/burst immunity test;
EN 61000-4-5 Surge immunity test;
EN 61000-4-6 Conducted disturbances induced by radio frequency fields immunity test;
EN 61000-4-8 Power frequency magnetic field immunity test;
EN 61000-4-11 Voltage dips, short interruption and voltage variation immunity test.

Fig. E-1. An example of power drive system (PDS) and various ports in accordance with the generic standards.
The following definitions are used in the standards for the requirements:

Port: Particular interface of the specified apparatus/PDS with external electromagnetic environment (see Fig. E-1.);

Enclosure Port: The physical boundary of the apparatus through which an electromagnetic field may radiate or impinge (see Fig. E-1.);

Power Port: Port which connects the PDS to the power supply which in turn may also feed other equipment (see Fig. E-1.);

Process Measurement and Control Port: Input/Output (I/O) port for conductor or cable which connects the process to the PDS, as defined in Chapter 3 (see Fig. E-1.);

Signal Interface Port: Input/Output (I/O) port for connecting the Basic Drive Module or the Complete Drive Module (CDM) to another part of the PDS (see Fig. E-1.).

The following four tables present the basic standards and the quantitative requirements for the four generic standards:

Emission per EN50081-1

<table>
<thead>
<tr>
<th>Port Type</th>
<th>EN55022 class B ranges of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enclosure Port</td>
<td>30±230MHz limits of 30dB(µV/m) quasi-peak at 10m distance.</td>
</tr>
<tr>
<td>AC Power Ports Input/Output</td>
<td>230±1000 MHz limits of 37dB(µV/m) quasi-peak at 10m distance.</td>
</tr>
<tr>
<td>EN60555 parts 2, 3</td>
<td>EN55022 class B ranges of:</td>
</tr>
<tr>
<td></td>
<td>0.15±0.5MHz limits of 66-56dB(µV) quasi-peak and 56-46dB(µV) average.</td>
</tr>
<tr>
<td></td>
<td>0.5±5MHz limits of 56dB(µV) quasi-peak and 46dB(µV) average.</td>
</tr>
<tr>
<td></td>
<td>5±30MHz limits of 60dB(µV) quasi-peak and 50dB(µV) average.</td>
</tr>
<tr>
<td></td>
<td>EN55014 ranges of: 0.15±30MHz.</td>
</tr>
<tr>
<td>DC Power Ports Input/Output</td>
<td></td>
</tr>
<tr>
<td>Signal Ports Input/Output</td>
<td></td>
</tr>
<tr>
<td>Control Port Input/Output</td>
<td></td>
</tr>
<tr>
<td>Earth Port</td>
<td></td>
</tr>
</tbody>
</table>
## Emission per EN50081-2

<table>
<thead>
<tr>
<th>Port Type</th>
<th>EN50081 ranges of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enclosure Port</td>
<td>• 30÷230MHz limits of 30dB(µV/m) quasi-peak at 30m distance.</td>
</tr>
<tr>
<td></td>
<td>• 230÷1000 MHz limits of 37dB(µV/m) quasi-peak at 30m distance.</td>
</tr>
<tr>
<td>AC Power Ports</td>
<td>EN50081 ranges of:</td>
</tr>
<tr>
<td>Input/Output</td>
<td>• 0.15÷0.5MHz limits of</td>
</tr>
<tr>
<td></td>
<td>• 79dB(µV) quasi-peak and</td>
</tr>
<tr>
<td></td>
<td>• 66dB(µV) average.</td>
</tr>
<tr>
<td></td>
<td>• 0.5÷5MHz limits of</td>
</tr>
<tr>
<td></td>
<td>• 73dB(µV) quasi-peak and</td>
</tr>
<tr>
<td></td>
<td>• 60dB(µV) average.</td>
</tr>
<tr>
<td></td>
<td>• 5÷30MHz limits of</td>
</tr>
<tr>
<td></td>
<td>• 73dB(µV) quasi-peak and</td>
</tr>
<tr>
<td></td>
<td>• 60dB(µV) average.</td>
</tr>
<tr>
<td>DC Power Ports</td>
<td>EN50081 ranges of:</td>
</tr>
<tr>
<td>Input/Output</td>
<td>• Fast transients noise range of 500V (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp according to criterion B.</td>
</tr>
<tr>
<td>Signal Ports</td>
<td>EN50081 ranges of:</td>
</tr>
<tr>
<td>Input/Output</td>
<td>• Fast transients noise range of 500V (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp according to criterion B.</td>
</tr>
<tr>
<td>Control Port</td>
<td>EN50081 ranges of:</td>
</tr>
<tr>
<td>Input/Output</td>
<td>• Fast transients noise range of 500V (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp according to criterion B.</td>
</tr>
<tr>
<td>Earth Port</td>
<td>EN50081 ranges of:</td>
</tr>
<tr>
<td></td>
<td>• AM RF common mode range of 0.15÷80MHz value of: 10V/m (unmodulated, r.m.s.), &amp; 80% of AM at 1KHz. 150Ω Source impedance. according to criterion A.</td>
</tr>
</tbody>
</table>

## Immunity per EN50082-1

<table>
<thead>
<tr>
<th>Port Type</th>
<th>EN61000-4-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enclosure Port</td>
<td>• Electrostatic discharge range of 8KV air discharge according to criterion B.</td>
</tr>
<tr>
<td></td>
<td>• AM RF electromagnetic field range of 27÷500MHz value of 3V/m (unmodulated, r.m.s.) &amp; 80% of AM with 1KHz, according to criterion A.</td>
</tr>
<tr>
<td>AC Power Ports</td>
<td>EN61000-4-4</td>
</tr>
<tr>
<td>Input/Output</td>
<td>• Fast transients noise range of 500V (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp according to criterion B.</td>
</tr>
<tr>
<td>DC Power Ports</td>
<td>EN61000-4-4</td>
</tr>
<tr>
<td>Input/Output</td>
<td>• Fast transients noise range of 500V (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp according to criterion B.</td>
</tr>
<tr>
<td>Signal Ports</td>
<td>EN61000-4-4</td>
</tr>
<tr>
<td>Input/Output</td>
<td>• Fast transients noise range of 500V (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp according to criterion B.</td>
</tr>
<tr>
<td>Control Port</td>
<td>EN61000-4-4</td>
</tr>
<tr>
<td>Input/Output</td>
<td>• Fast transients noise range of 500V (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp according to criterion B.</td>
</tr>
<tr>
<td>Earth Port</td>
<td>EN61000-4-6</td>
</tr>
<tr>
<td></td>
<td>• AM RF common mode range of 0.15÷80MHz value of: 10V/m (unmodulated, r.m.s.), &amp; 80% of AM at 1KHz. 150Ω Source impedance. according to criterion A.</td>
</tr>
<tr>
<td>Port Type</td>
<td>EN Standard</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------</td>
</tr>
</tbody>
</table>
| Enclosure Port| EN 61000-4-2         | • Electrostatic discharge range of 4KV contact discharge, according to criterion B.  
                        • Electrostatic discharge range of 8KV air discharge according to criterion B.  
                        EN 61000-4-3:  
                        • AM RF electromagnetic field range of \(80\div 1000\text{MHz}\) value of 10V/m (unmodulated, r.m.s.), & 80% of AM at 1KHz according to criterion A.  
                        • PM RF electromagnetic field range of 900MHz \(\pm 5\text{MHz}\) value of 10V/m (unmodulated, r.m.s.), & 50% Duty cycle at 200Hz, according to criterion A.  
                        EN 61000-4-8:  
                        • Power-frequency magnetic field range of 50Hz value of 30A/m, according to criterion A.  |
| AC Power Ports Input/Output| EN 61000-4-4       | • Fast transients noise range of 2KV (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp, according to criterion B.  
                        EN 61000-4-6:  
                        • AM RF common mode range of \(0.15\div 80\text{MHz}\) value of 10V/m (unmodulated, rms.), & 80% of AM with 1KHz. 150\(\Omega\) Source impedance, according to criterion A.  |
| DC Power Ports Input/Output| EN 61000-4-4       | • Fast transients noise range of 2KV (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp, according to criterion B.  
                        EN 61000-4-6:  
                        • AM RF common mode range of \(0.15\div 80\text{MHz}\) value of 10V/m (unmodulated, rms.), & 80% of AM with 1KHz. 150\(\Omega\) Source impedance, according to criterion A.  |
| Signal Ports Input/Output| EN 61000-4-4       | • Fast transients noise range of 2KV (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp, according to criterion B.  
                        EN 61000-4-6:  
                        • AM RF common mode range of \(0.15\div 80\text{MHz}\) value of 10V/m (unmodulated, rms.), & 80% of AM with 1KHz. 150\(\Omega\) Source impedance, according to criterion A.  |
| Control Port Input/Output| EN 61000-4-4       | • Fast transients noise range of 2KV (peak) with value of 5/50 Tr/Th ns at a 5kHz repetition frequency with capacitive clamp, according to criterion B.  
                        EN 61000-4-6:  
                        • AM RF common mode range of \(0.15\div 80\text{MHz}\) value of 10V/m (unmodulated, rms.), & 80% of AM with 1KHz. 150\(\Omega\) Source impedance, according to criterion A.  |
| Earth Port    | EN 61000-4-6         | • AM RF common mode range of \(0.15\div 80\text{MHz}\) value of 10V/m (unmodulated, rms.), & 80% of AM with 1KHz. 150\(\Omega\) Source impedance, according to criterion A.  |
## Appendix F. List of Elmo Product Families

### DC brush type motor technology:

<table>
<thead>
<tr>
<th>Family Name</th>
<th>Description</th>
<th>Type of Power</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSA</td>
<td>Miniature servo amplifier with a nominal rating up to 600 Watt continuous power.</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>ISA</td>
<td>Double servo amplifier on single Eurocard with a nominal rating up to 750 Watt each continuous power (on a single Eurocard).</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>ISP</td>
<td>Integrated package, servo amplifier / power supply with a nominal rating up to 1.5kW continuous power (on a single Eurocard).</td>
<td>AC-1φ</td>
<td></td>
</tr>
<tr>
<td>ESA</td>
<td>Modular servo amplifier with a nominal rating up to 4.5 kW continuous power (on a single or a double Eurocard).</td>
<td>DC</td>
<td></td>
</tr>
</tbody>
</table>

### DC brushless type motor technology:

<table>
<thead>
<tr>
<th>Family Name</th>
<th>Description</th>
<th>Type of Power</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBA</td>
<td>Miniature servo amplifier with a nominal rating up to 700 Watt continuous power.</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>NBA</td>
<td>Modular servo amplifier with a nominal rating up to 3 kW continuous power (on a single Eurocard).</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>EBA</td>
<td>High power, modular servo amplifier with a nominal rating up to 8 kW continuous power (on a single or a double Eurocard).</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>IBP</td>
<td>Integrated package, servo amplifier/power supply with a nominal rating up to 8 kW continuous power (on a single or a double Eurocard).</td>
<td>AC-3φ</td>
<td></td>
</tr>
<tr>
<td>DCB</td>
<td>Digital control board with positioning loop.</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>DBA</td>
<td>DCB-card mounted on an EBA-amplifier, with a nominal rating up to 8 kW continuous power.</td>
<td>DC</td>
<td></td>
</tr>
<tr>
<td>DBP</td>
<td>DCB-card mounted on an IBP-amplifier/power supply combination, with a nominal rating up to 8 kW continuous power.</td>
<td>AC-3φ</td>
<td></td>
</tr>
<tr>
<td>PS/S</td>
<td>Unregulated power supplies with or without shunt regulator.</td>
<td>AC-3φ</td>
<td></td>
</tr>
</tbody>
</table>