EMC filters

General

Date: January 2006

1 EMC basics

1.1 Legal background

Electromagnetic compatibility (EMC) has become an essential property of electronic equipment. In view of the importance of this topic, the European legislator issued the EMC Directive as early as 1996 (89/336/EEC): it has since been incorporated at national level by the EU member states in the form of various EMC laws and regulations.

The EU's new EMC Directive (2004/108/EC of December 15, 2004) contains several significant innovations compared to the version in force since 1996. It will become binding on all equipment put on the market after the elapse of the transitional period in July 2009. The most important changes include:

- Regulations for fixed installations
- Abolition of the "competent body"
- Conformity assessment may also be made without harmonized standards
- New definitions of terms (”equipment", "apparatus", " fixed installation")
- New requirements on mandatory information, traceability
- Improved market surveillance

The definition of "apparatus“ has now become clearer, so that its scope of validity now covers only apparatus that the end user can use directly. Basic components such as capacitors, inductors and filters are definitively excluded.

The "essential requirements" must be observed by all apparatus offered on the market within the EU. This ensures that all apparatus operate without interferences in its electromagnetic environment without affecting other equipment to an impermissible extent.

1.2 Directives and CE marking

Manufacturers must declare that their apparatus conform to the protection objectives of the EMC Directive by attaching the CE conformity mark to all apparatus and packaging. This implies that they assume responsibility vis-à-vis the legislators for observing the relevant emission limits and interference immunity requirements.

The interference immunity requirements in particular are becoming increasingly important for the operators of apparatus, installations and systems, as their correct functioning can be ensured only if sufficient EMC measures are taken. However, the need for constant functionality also implies high availability of installations and systems and thus represents a significant performance figure for the cost-effective operation of the equipment.

It should be noted that the CE conformity mark not only asserts electromechanical compatibility but also confirms the observance of all the EU Directives applying to the product concerned. The most important general directives apart from the EMC Directive include the Low-Voltage Directive and the Machinery Directive.

Some of these directives also include EMC requirements. Examples are the R&TTE Directive (for radio and telecommunications terminal equipment) and the Medical Products Directive. The EMC Directive does not apply to those products which are covered by these directives.

The manufacturer is responsible for taking the necessary steps to ensure that all applicable directives are observed.

1.3 EMC standards

Dedicated product standards or product family standards are available for many kinds of equipment (see Section 1.9). All equipment not covered by these EMC standards are assessed on the basis of the generic standards. Special rules apply to larger and more complex installations which are assembled on site and are not freely available commercially (see Chapter "Application notes").

1.4 Basic information on EMC

The term EMC covers both electromagnetic emission and electromagnetic susceptibility (Figure 1).

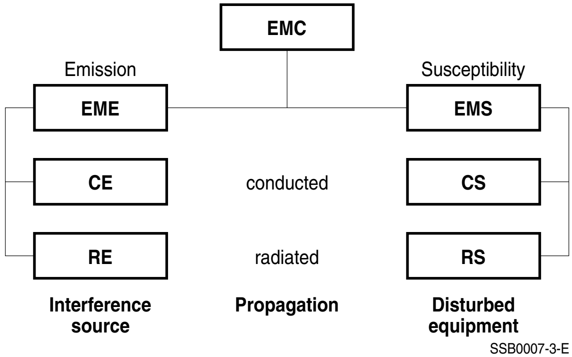


Figure 1 EMC terms

EMC = Electromagnetic compatibility
EME = Electromagnetic emission
EMS = Electromagnetic susceptibility
CE = Conducted emission
CS = Conducted susceptibility
RE = Radiated emission
RS = Radiated susceptibility

An interference source may generate conducted or radiated electromagnetic energy, i.e. conducted emission (CE) or radiated emission (RE). This also applies to the electromagnetic susceptibility of disturbed equipment.

In order to work out cost-efficient solutions, all phenomena must be considered, and not just one aspect such as conducted emission.

EMC components are used to reduce conducted electromagnetic interferences to the limits defined in an EMC plan or below the limits specified in the EMC standards (Figure 2). These components may be installed either in the source or in the disturbed equipment.

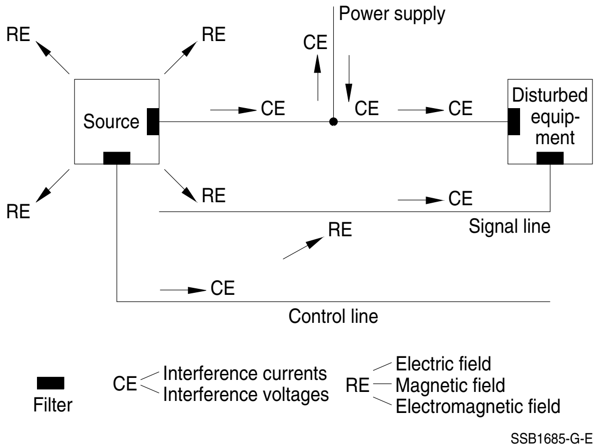


Figure 2 Susceptibility model and filtering

EPCOS offers EMC components with a wide range of rated voltages and currents for power lines as well as for signal and control lines.

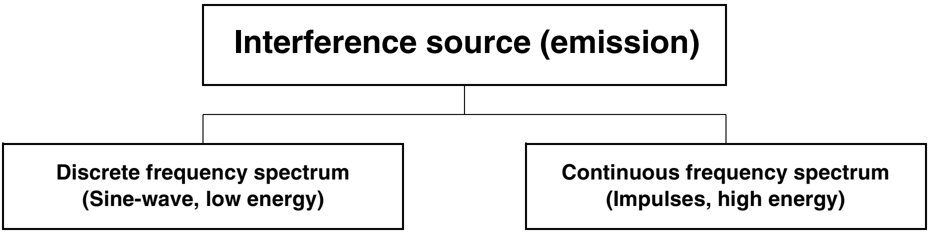
1.5 Interference sources and disturbed equipment

Interference source

An **interference source** is an electrical equipment which emits electromagnetic interferences. We can differentiate between two main groups of interference sources corresponding to the type of frequency spectrum emitted (Figure 3).

Interference sources with discrete frequency spectra (e.g. high-frequency generators and microprocessor systems) emit narrowband interferences.

Switchgear and electric motors in household appliances, however, spread their interference energy over broad frequency bands and are considered to belong to the group of interference sources having a continuous frequency spectrum.



Discrete frequency spectrum	Continuous frequency spectrum
µP systems	Switchgear (contactors, relays)
RF generators	Household appliances
Medical equipment	Gas discharge lamps
Data processing systems	Power supplies and battery chargers
Microwave equipment	Frequency converters
Ultrasonic equipment	Ignition systems
RF welding apparatus	Welding apparatus
Radio and TV receivers	Motors with brushes
Switch-mode power supplies	Atmospheric discharges
Frequency converters	
UPS systems	
Electronic ballasts	

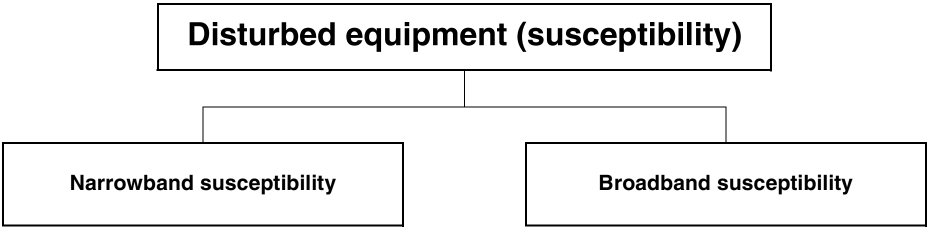
Figure 3 Interference sources

Disturbed equipment

Electrical equipment or systems subject to interferences and which can be adversely affected by it are termed **disturbed equipment**.

In the same way as interference sources, disturbed equipment can also be categorized corresponding to frequency characteristics. A distinction can be made between narrowband and broadband susceptibility (Figure 4).

Narrowband systems include radio and TV sets, for example, whereas data processing systems are generally characterized as broadband systems.



Narrowband susceptibility	Broadband susceptibility
Radio and TV receivers	Digital and analog systems
Radio reception equipment	Data processing systems
Modems	Process control computers
Data transmission systems	Control systems
Radio transmission equipment	Sensors
Remote-control equipment	Video transmission systems
Cordless and cellular phones	Interfaces

Figure 4 Disturbed equipment

1.6 Propagation of interferences

Interference voltages and currents can be grouped into common-mode interferences, differential-mode interferences and unsymmetrical interferences:

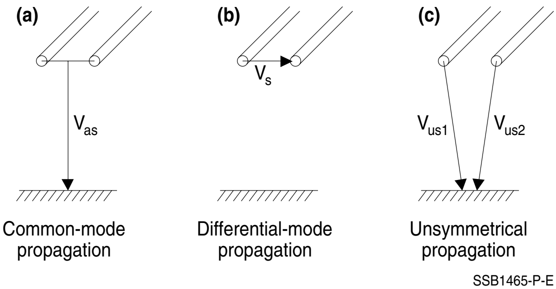


Figure 5 Propagation modes

- **5 (a)**
  Common-mode interferences (asymmetrical interferences):
  – occurs between all lines in a cable and reference potential;
  – occurs mainly at high frequencies (approximately 1 MHz upwards).
- **5 (b)**
  Differential-mode interferences (symmetrical interferences):
  – occurs between two lines (L-L, L-N);
  – occurs mainly at low frequencies (up to several hundred kHz).
- **5 (c)**
  Unsymmetrical interferences:
  – This term is used to describe interferences between one line and the reference potential.

1.7 Characteristics of interferences

In order to be able to choose the correct EMC measures, we need to know the characteristics of the interferences, how they are propagated and the coupling mechanisms. In principle, the interferences can also be classified according to their propagation mode (Figure 6). At low frequencies, it can be assumed that the interferences only spreads along conductive structures, at high frequencies virtually only by means of electromagnetic radiation. In the MHz frequency range, the term coupling is generally used to describe the mechanism.

Analogously, conducted interferences at frequencies of up to several hundred kHz is mainly differential-mode *(symmetrical)*, at higher frequencies, it is common-mode *(asymmetrical)*. This is because the coupling factor and the effects of parasitic capacitance and inductance between the conductors increase with frequency.

X capacitors and single chokes offer effective differential-mode insertion loss. Common-mode interferences can be reduced by current-compensated chokes and Y capacitors. However, this requires a well-designed EMC-compliant grounding and wiring system.

The categorization of types of interference and suppression measures and their relation to the frequency ranges is reflected in the frequency limits for interference voltage and interference field strength measurements.

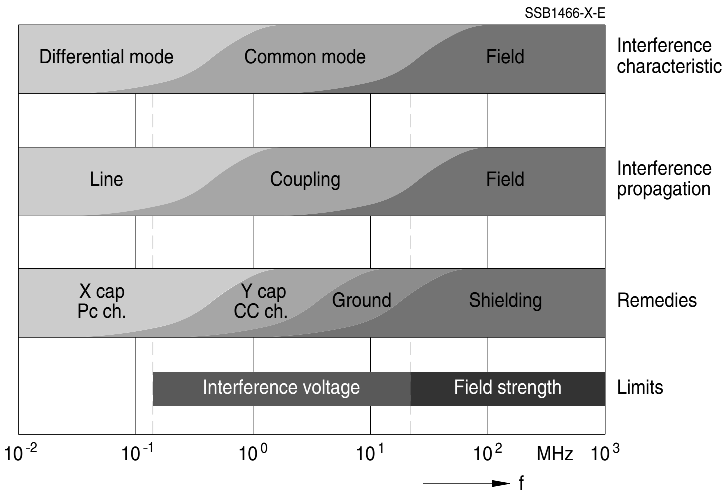


Figure 6 Frequency range overview
Pc ch. = Iron powder core chokes, but also all single chokes
X cap = X capacitors
Cc ch. = Current-compensated chokes
Y cap = Y capacitors

1.8 EMC measurement methods

As previously mentioned, an interference source causes both conducted and radiated electromagnetic interferences.

Propagation along lines can be detected by measuring the interference current and the interference voltage (Figure 7).

The effect of interference fields on their immediate vicinity is assessed by measuring the magnetic and electric fields. This kind of propagation is also frequently termed electric or magnetic coupling (near field).

In higher frequency ranges, characterized by the fact that equipment dimensions are in the order of magnitude of the wavelength under consideration, the interference energy is mainly radiated directly (far field). Conducted and radiated propagation must also be taken into consideration when testing the susceptibility of disturbed equipment.

Interference sources, such as sine-wave generators as well as pulse generators with a wide variety of pulse shapes are used for such tests.

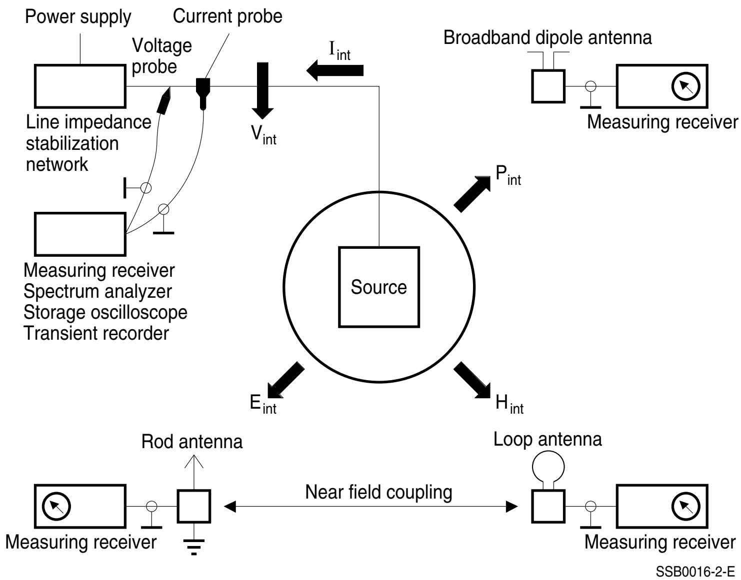


Figure 7 Propagation of electromagnetic interferences and EMC measurement methods

H_{int} = Magnetic interference fields
E_{int} = Electrical interference fields
P_{int} = Electromagnetic interference fields (radiated emission)
I_{int} = Interference current
V_{int} = Interference voltage

1.9 EMC standards

New, harmonized European standards have been issued in conjunction with the EU's EMC Directive or national EMC legislation. These specify measurement methods and limits or test levels for both the emissions and immunity of electrical equipment, installations and systems.

The subdivision of the European standards into various categories (see following table) makes it easier to find the rules that apply to the respective equipment. The *generic standards* always apply to all equipment for which there is no specific *product family standard* or *dedicated product standard*. The *basic standards* contain information on interference phenomena and general measuring methods.

The following standards and regulations form the framework of the conformity tests:

EMC standards	Germany	Europe	International
Generic standards define the EMC environment in which a device is to operate according to its intended use.			
Emissionresidential industrial	DIN EN 61000-6-3 DIN EN 61000-6-4	EN 61000-6-3 EN 61000-6-4	IEC 61000-6-3 IEC 61000-6-4
Immunityresidential industrial	DIN EN 61000-6-1 DIN EN 61000-6-2	EN 61000-6-1 EN 61000-6-2	IEC 61000-6-1 IEC 61000-6-2
Basic standards describe physical phenomena and measurement methods.			
Measuring equipment	DIN EN 55016-1-x	EN 55016-1-x	CISPR 16-1-x
Measuring methodsemission immunity	DIN EN 55016-2-x DIN EN 61000-4-1	EN 55016-2-x EN 61000-4-1	CISPR 16-2-x IEC 61000-4-1
Harmonics Flicker	DIN EN 61000-3-2 DIN EN 61000-3-3	EN 61000-3-2 EN 61000-3-3	IEC 61000-3-2 IEC 61000-3-3
Immunity parameters e.g. ESD EM fields Burst Surge Induced RF fields Magnetic fields Voltage dips	 DIN EN 61000-4-2 DIN EN 61000-4-3 DIN EN 61000-4-4 DIN EN 61000-4-5 DIN EN 61000-4-6 DIN EN 61000-4-8 DIN EN 61000-4-11	 EN 61000-4-2 EN 61000-4-3 EN 61000-4-4 EN 61000-4-5 EN 61000-4-6 EN 61000-4-8 EN 61000-4-11	 IEC 61000-4-2 IEC 61000-4-3 IEC 61000-4-4 IEC 61000-4-5 IEC 61000-4-6 IEC 61000-4-8 IEC 61000-4-11

EMC standards		Germany	Europe	International
Product family standards define limit values for emission and immunity.				
ISM equipment	emission immunity	DIN EN 55011 1)	EN 55011 1)	CISPR 11 1)
Household appliances	emission immunity	DIN EN 55014-1 DIN EN 55014-2	EN 55014-1 EN 55014-2	CISPR 14-1 CISPR 14-2
Lighting	emission immunity	DIN EN 55015 DIN EN 61547	EN 55015 EN 61547	CISPR 15 IEC 1547
Radio and TV equipment	emission immunity	DIN EN 55013 DIN EN 55020	EN 55013 EN 55020	CISPR 13 CISPR 20
High-voltage systems	emission	DIN VDE 0873	—	CISPR 18
ITE equipment[3]	emission immunity	DIN EN 55022 DIN EN 55024	EN 55022 EN 55024	CISPR 22 CISPR 24
Vehicles	emission immunity	DIN EN 55025 —	EN 55025[2] 2)	CISPR 25 ISO 11451 ISO 11452

The following table shows the most important standards concerning immunity.

Standard	Test characteristics	Phenomena
Conducted interferences		
EN 61000-4-4 IEC 61000-4-4	5/50 ns (single impulse) 2.5 kHz, 5 kHz or 100 kHz burst	Burst Cause: switching processes
EN 61000-4-5 IEC 61000-4-5	1.2/50 µs (open-circuit voltage) 8/20 µs (short-circuit current)	Surge (high-energy transients) Cause: lightning strikes mains supply, switching processes
EN 61000-4-6 IEC 61000-4-6	1; 3; 10 V 150 kHz to 80 MHz (230 MHz)	High-frequency coupling Narrow-band interferences
Radiated interferences		
EN 61000-4-3 IEC 61000-4-3	3; 10 V/m 80 to 1000 MHz	High-frequency interference fields
EN 61000-4-8 IEC 61000-4-8	up to 100 A/m 50 Hz	Magnetic interference fields with power-engineering frequency

1) Is governed by the safety and quality standards of the product families.
2) The EU Automotive Directive (95/54/EC) also covers limits and immunity requirements.
3) Some equipment is covered by the R & TTE Directive (Radio- and Telecommunications Terminals).

Standard	Test characteristics	Phenomena
Electrostatic discharge (ESD)		
EN 61000-4-2 IEC 61000-4-2	to 15 kV	Electrostatic discharge
Instability of the supply voltage		
EN 61000-4-11 IEC 61000-4-11	e.g. 40 % V_N for 1 … 50 periods 0 % V_N for 0,5 periods	Voltage dips Short-term interruptions
EN 61000-4-11 IEC 61000-4-11	e.g. 40 % V_N or 0 % V_N (2 s reduction, 1 s reduced voltage, 2 s increase)	Voltage variations

1.10 Propagation of conducted interferences

In order to be able to select suitable EMC components, the way in which conducted interferences are propagated needs to be known.

A floating interference source primarily emits differential-mode interferences which are propagated along the connected lines. The interference current will flow towards the disturbed equipment on one line and away from it on the other line, just as the mains current does.

Differential-mode interferences occur mainly at low frequencies (up to several hundred kHz).

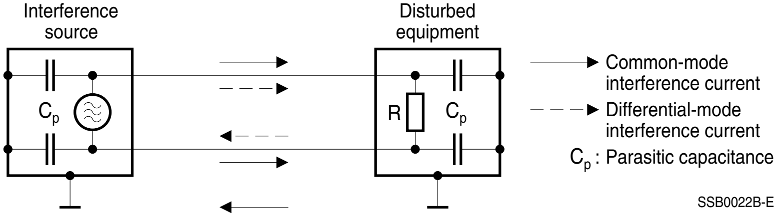


Figure 8 Common-mode and differential-mode interferences

However, parasitic capacitances in interference sources and disturbed equipment or intended ground connections, also lead to an interference current in the ground circuit. This common-mode interference current flows towards the disturbed equipment through both the connecting lines and returns to the interference source through ground. Since the parasitic capacitances will tend towards representing a short-circuit with increasing frequencies and the coupling effects the connecting cables and the equipment itself will increase correspondingly, common-mode interferences become dominant above some MHz.

In Europe, the term of an “unsymmetrical interference” is used to describe the interference voltage between one line and a reference potential. It consists of symmetrical and asymmetrical parts.

EPCOS specifies characteristic values of insertion loss for the individual filter types in order to facilitate the selection of suitable EMC filters.

1.11 Filter circuits and line impedance

EMC filters are virtually always designed as reflecting lowpass filters, i.e. they reach their highest insertion loss when they are – on the one hand – mismatched to the impedance of the interference source and disturbed equipment and – on the other hand – mismatched to the impedance of the line. Possible filter circuits for various impedance conditions are shown in Figure 9.

It is, therefore, necessary to find out the impedances so that optimum filter circuit designs as well as economical solutions can be implemented.

The impedances of the power networks under consideration are usually known from calculations and extensive measurements, whereas the impedances of interference sources or disturbed equipment are, in most cases, not or only inadequately known.

For this reason, it is impossible to design the most suitable filter solution without EMC tests. In this context, we offer our customers the competent consulting of our skilled staff, both on-site and in our EMC laboratory in Regensburg (see also “EMC services”, Section 7, “EMC laboratory”).

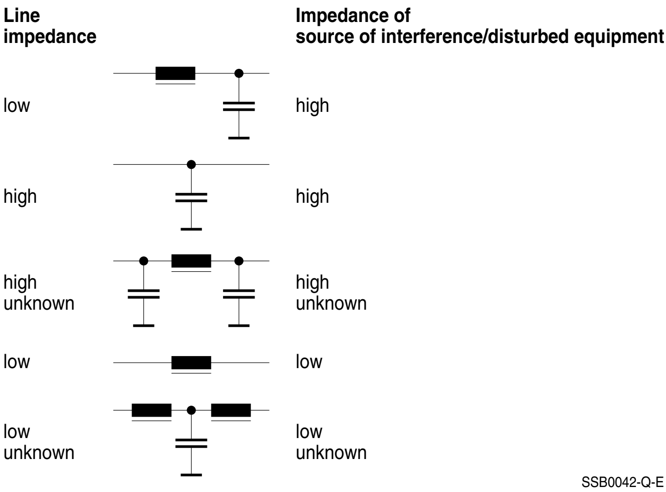


Figure 9 Filter circuits and impedance relationships

2 Selection criteria for EMC filters

To comply with currently valid regulations, a frequency range of 150 kHz to 1000 MHz has to be taken into consideration, in most cases, in order to ensure electromagnetic compatibility; in addition, however, further aspects such as low-frequency phenomena should be considered.

EMC filters must thus have good RF characteristics and are ususally required to be effective over a broad frequency range.

- For individual components (inductors, capacitors) the RF characteristics are specified by stating the impedance as a function of frequency.
- The insertion loss is used as a criterion for selecting EMC filters (see Section 3.1.17).

If the device under test (DUT) is terminated on both sides with an ohmic impedance of 50 Ω, for example, the result of the measurement is referred to as being the 50-Ω insertion loss.

Depending on the particular application intended, priorities for consideration of the three possible kinds of insertion loss

- common-mode (asymmetrical)
- differential-mode (symmetrical) or
- unsymmetrical

must be decided upon.

The measuring method for 50-Ω insertion loss has been adapted from the field of communications engineering and is also specified in the relevant national and international standards.

Although it permits a comparison of different filters, it provides only little information on the efficiency in practical applications.

The reason is – as already mentioned in the previous section – that neither the interference source or disturbed equipment nor the connected power line system will have an ohmic impedance of 50 Ω at frequencies below 1 MHz.

Likewise, the attenuation of interference pulses cannot simply be determined on the basis of the insertion loss curve. In this case, it is also necessary to take the non-linear response of the EMC chokes in the filters into consideration.

We can quote filter-specific values on request if you send us the pulse shapes in question.

3 Terms and definitions

3.1 Electrical characteristics

3.1.1 Rated voltage V_R

The rated voltage V_R is either the maximum RMS operating voltage at the rated frequency or the highest DC operating voltage which may be continuously applied to the filter at temperatures between the lower category temperature T_{min} and the upper category temperature T_{max}. Filters which are rated for a frequency of 50/60 Hz may also be operated at DC voltages.

3.1.2 Nominal voltage V_N

The nominal voltage V_N is the voltage which designates a network or electrical equipment and to which specific operating characteristics are referred.

IEC 60038 defines the most widely used nominal voltages for public supply networks (e.g. 230/400 V, 277/480 V, 400/690 V). It is recommended that the voltage at the transfer points should not deviate from the nominal voltage by more than ±10% under normal network conditions.

3.1.3 Difference between rated and nominal voltage

For filters, the rated voltage is defined as a reference parameter. It specifies the maximum voltage at which the filter can be continuously operated (see Section 3.1.1). This voltage must never be exceeded, as otherwise damage may occur.

Only small deviations are tolerated, such as may occur when a filter with a rated voltage of 250 V is operated at in a network with a nominal voltage of 230 V (230 V +10% = 253 V). This relationship is shown in Figure 10.

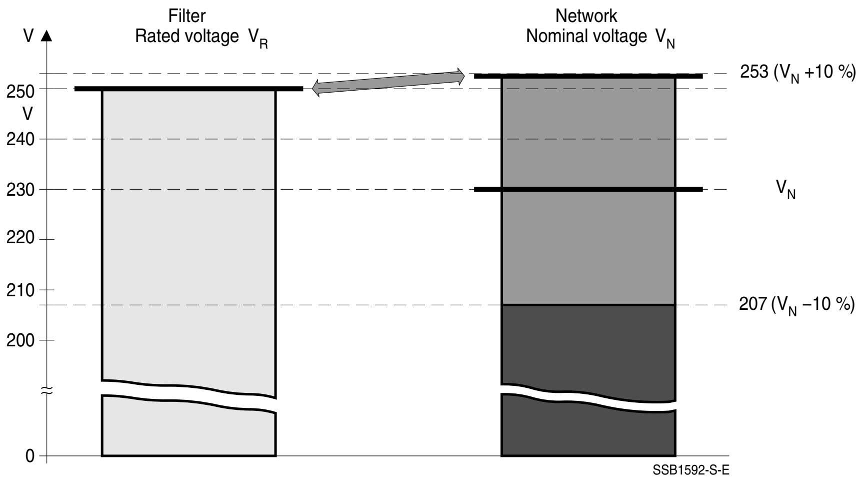


Figure 10 Difference between rated and nominal voltage

When EMC filters and other EMC components are selected, care shall be taken to ensure that the maximum line voltage in each case, e.g. V_N +10%, is not exceeded. Short voltage surges are permitted according to EN 133200.

3.1.4 Network types

The filters are approved for various network types (e.g. TN, TT, IT networks). They are described in Section 7 “Power distribution systems”.

3.1.5 Test voltage V_{test}

The test voltage V_{test} is the AC or DC voltage which may be applied to the filter for the specified test duration at the final inspection (100% test). If necessary, we recommend a single repetition of the test at a maximum of 80% of the specified voltage. The rate of voltage rise or fall must then not exceed 500 V/s. The time shall be measured as soon as 90% of the test voltage permissible for the repeat test has been reached. During the test, no dielectric breakdown may occur (the insulation would no longer limit the current flow). Healing effects of the capacitors are permissible.

3.1.6 Rated current I_R

The rated current I_R is the maximum AC or DC current at which the filter can be continuously operated under nominal conditions.

Above the rated temperature T_R, the operating current shall as a rule be reduced in accordance with the derating curves (see Section 10).

For 2 and 3-line filters, the rated current is specified for the simultaneous flow of a current of this value though all the lines. For 4-line filters (e.g. filters with three phase lines and one neutral line), the sum current of the neutral line is assumed to be close to zero.

Higher thermal loads may occur during AC operation due to non-sinusoidal waveforms. These must be taken into account where necessary.

The temperature rise of the EMC filters at rated current and temperature is tested with a connection via test cross-sections as specified in UL 508:Aug 22, 2000 "Industrial Control Equipment", Table 43.2, Table 43.3 (broadly similar to EN 60947:1999).

3.1.7 Overload capability

The rated current may be exceeded for a short time. Details of permissible currents and load durations are specified in the various data sheets.

3.1.8 Pulse handling capability

Saturation effects (e.g in the ferrite cores used) may occur when high-energy pulses are applied to the components and these may lead to impaired interference suppression. The maximum permissible voltage-time integral area is used to characterize the pulse handling capability of chokes and filters. For standard components a range from 1 to 10 mVs can be assumed. More specific data can be obtained upon request.

3.1.9 Current derating I/I_R

At ambient temperatures above the rated temperature stated in the data sheet, the operating current of chokes and filters must be reduced according to the derating curve (see Section 10).

3.1.10 Rated inductance L_R

The rated inductance L_R is the inductance which has been used to designate the choke, as measured at the frequency f_L.

3.1.11 Stray inductance L_{stray}

The stray inductance L_{stray} (also termed leakage inductance) is the inductance measured through both coils when a current-compensated choke is short-circuited at one end. This affects differential-mode interferences.

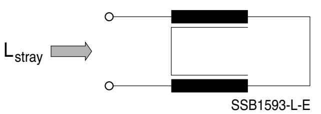


Figure 11 Stray inductance

3.1.12 Inductance decrease $\Delta L/L_0$

The inductance decrease $\Delta L/L_0$ is the drop in inductance at a given current relative to the initial inductance L_0 measured at zero current. The data sheets specify this as a percentage. This decrease is caused by the magnetization of the core material, which is a function of the field strength, as induced by the operating current. Generally the decrease is less than 10%.

3.1.13 DC resistance R_{typ}, R_{min}, R_{max}

The DC resistance is the resistance of a line as measured using direct current at a temperature of 20 °C, whereby the measuring current must be kept well below the rated current.

R_{typ} typical value
R_{min} minimum value
R_{max} maximum value

3.1.14 Winding capacitance, parasitic capacitance C_p

Parasitic capacitances C_p, which impair the RF characteristics of the filters, are related to the filter geometry. These capacitances may affect the lines mutually (differential-mode) as well as the line-to-ground circuit (common-mode). The design of all EMC filters supplied by EPCOS minimizes the parasitic effects. Due to this, our filters have excellent interference suppression characteristics right up to high frequencies.

3.1.15 Quality factor Q

The quality factor Q is the quotient of the imaginary part of the impedance divided by the real part, measured at frequency f_Q.

3.1.16 Measuring frequencies f_Q, f_L

f_Q is the frequency for which the quality factor Q of a choke is specified.
f_L is the frequency at which the inductance of a choke is measured.

3.1.17 Insertion loss

The insertion loss is a measure for the efficiency of EMC components, as measured by using a standardized test setup (Figure 12).

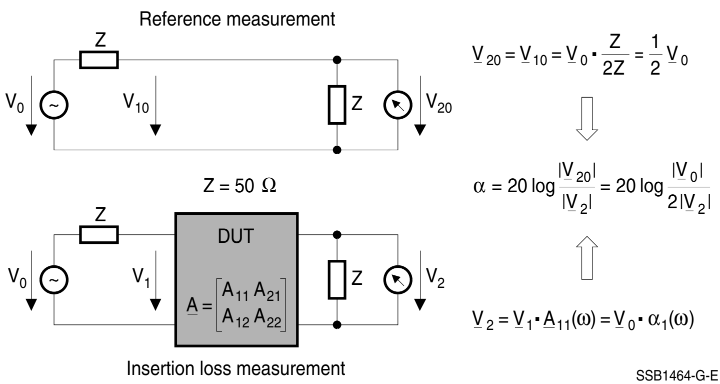


Figure 12 Definition of insertion loss

The input terminals of the device (circuit) are connected to an RF generator with impedance Z (usually 50 Ω) . At the output of the component, the voltage is measured using an RF voltmeter having the same impedance Z. The insertion loss is then calculated from the quotient of half the open-circuit generator voltage V_0 and the filter output voltage V_2.

Test setups for insertion loss measurement used for EMC filters

a) Differential mode (symmetrical insertion loss measurement)

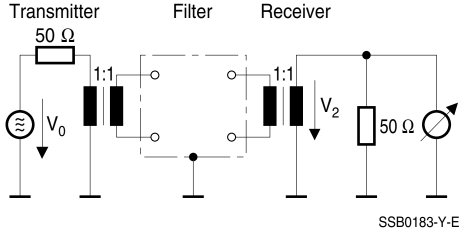


Figure 13 Symmetrical insertion loss measurement to CISPR 17 (1981) Fig. B5

Insertion loss $\alpha = 20 \lg \frac{V_0}{2 \cdot V_2} [\mathrm{dB}]$

b) Common mode (asymmetrical measurement, branches connected in parallel)

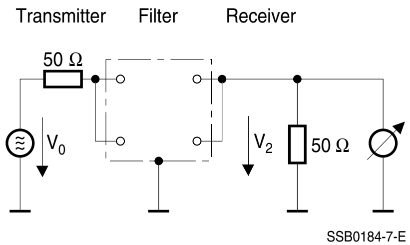


Figure 14 Asymmetrical measurement to CISPR 17 (1981) Fig. B6

Common-mode measurement with lines connected in parallel is widely used in the United States. Some diagrams in this data book show the results of this measurement in addition to those obtained according to a) and c).

c) Unsymmetrical measurement, adjacent branch terminated

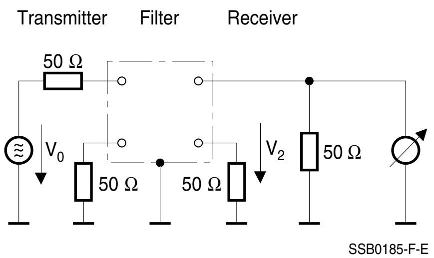


Figure 15 Unsymmetrical measurement to CISPR 17 (1981) Fig. B7

The termination of the adjacent line with a defined resistance value has not yet been standardized. As far as this data book contains insertion loss characteristics determined by other measuring arrangements, the deviations are indicated where the relevant diagrams are shown.

3.1.18 Leakage current

A detailed description of the leakage current together with measurement circuits and safety hints may be found in Section 8, “Leakage current”.

3.1.19 Discharge resistor

Discharge resistors are meant to ensure that the energy stored in the capacitors is reduced to low levels within a short period, so that the voltage at the equipment terminals drops to below permissible maximum values (see also Section 6, “Safety regulations”).

3.2 Mechanical properties

3.2.1 Potting (economy potting, complete potting)

We distinguish between economy potting and complete potting.

Economy potting is used to fix the various parts of the filter in the case. This is an economical technique which allows a single resin-casting procedure to be used. Many EMC filters from EPCOS are thus produced by this method.

Complete potting is required only if the heat dissipation of economy potting is inadequate or in the case of special customer requirements.

3.2.2 Types of winding

EMC filters from EPCOS use chokes with outstanding technical properties. All chokes have exactly reproducible and optimized RF characteristics and are matched to the relevant application (e.g. saturation characteristic with respect to pulses). Both for this reason and because of their design, the filters have reproducible properties (such as insertion loss).

Chokes with different types of winding are used depending on the respective technical requirements. The different types of winding lead to different choke characteristics, especially at high frequencies.

Single-layer winding:

In comparison to all other types of winding, this type of winding leads to the lowest possible capacitances and thus the highest resonance frequencies.

Multi-layer winding:

In comparison to all other types of winding, this type leads to the highest capacitances and thus the lowest resonance frequencies.

Random winding:

This method of winding a coil does not permit the final position of a turn to be predetermined exactly. The cross-section of this type of winding clearly shows a disorderly, “random” arrangement of the turns. This leads to the parasitic capacitances being only minimally greater than those achieved by single-layer winding, and the resonance frequencies are comparable to those achieved by single-layer winding.

RF characteristics of various types of winding

Figure 16 shows impedance as a function of frequency for two chokes of equal inductance. One of the chokes has a 2-layer winding and the other is randomly wound. The choke with random windings has a considerably higher first resonance frequency. The secondary resonances are very much higher than 10 MHz. The impedance at frequencies above the first resonance frequency is approximately five times higher. This leads to better interference suppression at high frequencies.

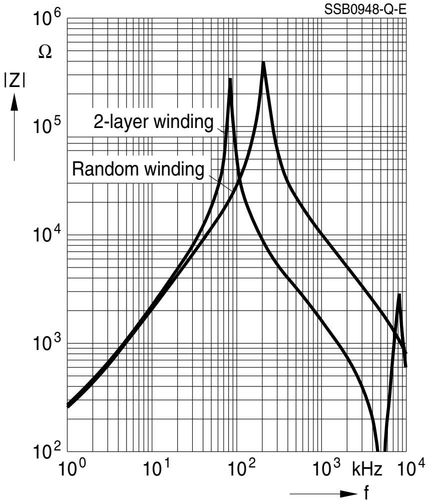


Figure 16 Impedance |Z| versus frequency f
comparison between 2-layer winding and random winding

The RF characteristics of all chokes supplied by EPCOS are reproducible, as the winding processes which we have developed for single-layer, multi-layer and random winding ensure that the characteristics of the inductors produced display very little variation.

The reproducibility of electrical characteristics of chokes is mainly determined by the production technique used. At EPCOS, coils are wound mainly by automatic machines (either fully or semi-automated). This permits even complicated winding patterns to be produced in large production runs with very little variation in product characteristics.

3.2.3 Recommended tightening torques for screw connections

Screw mounting

Most EPCOS EMC filters have metallic housings. The screw mounting is used for mechanical fixing and at the same time sets up the large-area connection to the reference ground via the housing contact (see also Section "Mounting instructions“). A distinction must be made between the functions of mechanical mounting, ground connection and PE connection for protection against shock.

For standard screw connections for the filter mounting, we refer to the state of the art, as the tightening torques depend on the rated size, length, strength category, corrosion protection and lubricant. In case of frontal self-clinching nuts, especially for EMC-compliant mounting, it should be noted that additional fixing is required for filter weights exceeding 10 kg. The installer must always check the strength of the connection with respect to stresses (such as vibrations and shock).

Unless otherwise specified in the data sheets, we recommend the tightening torques listened in the following tables.

Recommended tightening torques for self-clinching nuts:

Rated dimension of self-clinching nut	Torque in Nm (tolerance specifications for setting values)
M 4	1.5 (1.43 … 1.58)
M 5	3.0 (2.85 … 3.15)
M 6	5.1 (4.90 … 5.40)
M 8	12.6 (12.00 … 13.20)

Screw connections via threaded bolts

Tightening torques for feedthrough components are specified separately in the introduction to the Chapter on "1-line filters – feedthrough components".

For current-carrying and PE terminals contacted via threaded bolts, we recommend the following tightening torques:

Rated dimension of threaded bolts	Torque in Nm (tolerance specifications for setting values)
M 4	1.2 (1.10 … 1.30)
M 5	2.0 (1.90 … 2.10)
M 6	3.0 (2.85 … 3.15)
M 8	6.0 (5.70 … 6.30)
M10	10.0 (9.00 … 11.00)
M12	15.5 (14.00 … 17.00)

Screw connections of busbars

For EMC filters with rated currents >100 A, copper bars may be used as contact elements. We recommend the following materials for busbar screw connections.

Part	Recommendation
Busbar	Copper
Screw	Strength category 8.8 or higher to ISO 898 T1, corrosion protection tZn (hot-dip galvanized)
Nut	Strength category 8 or higher to ISO 898 T2, corrosion protection tZn (hot-dip galvanized)
Spring element on the screw and nut side	Conical spring washer to DIN 6796 T2, corrosion protected
Lubricant	MoS_2-based

In order to ensure the required surface pressure, we recommend the following tightening torques:

Rated dimension of threaded bolts	Torque in Nm
M8	15
M10	30
M12	60

3.3 Climatic characteristics

3.3.1 Upper and lower category temperature T_{max} und T_{min}

The upper category temperature T_{max} and the lower category temperature T_{min} are defined as the highest and the lowest permissible ambient temperature, respectively, at which the filter can be operated continuously.

3.3.2 Rated temperature T_R

The rated temperature T_R is defined as the highest ambient temperature at which the filter may be operated at rated current.

3.3.3 Reference temperature for measurements

According to IEC 60068-1, Section 5.1, a temperature of 20 °C is specified as the reference temperature for all electrical measurements, unless the data sheets specifically define other values.

3.3.4 Climatic category

The usability of components in various climates is defined by the climatic category according to IEC 60068-1, Annex A. It is made up of three parameters delimited by slashes.

These parameters represent the stress temperatures for the tests with cold and dry heat and the duration in days of the stress with steady-state damp heat.

Example: 40/085/21

– 40 °C
+ 85 °C
21 days

<u>1st parameter:</u>

Absolute value of the lower category temperature T_{min} as a test temperature for test Aa (cold) to IEC 60068-2-1

<u>2nd parameter:</u>

Absolute value of the upper category temperature T_{max} as a test temperature for test Ba (dry heat) to IEC 60068-2-2
test duration: 16 h

<u>3rd parameter:</u>

Stress duration in days.
Test Cab (damp heat, steady-state) to IEC 60068-2-7
at (93 ±3) % relative humidity (r.h.) and 40 °C ambient temperature

Our filters are also subjected to the following type tests:

- Rapid temperature cycling to EN 133200
  Temperature change in air (test Na).
  Severity of the test, e.g.:
  T_A = –25 °C, T_B = 100 °C, 5 cycles
  Dwell time: 1 h
- Temperature increase to EN 133200
  Determination of the filter temperature with a rated current at the maximum permissible ambient temperature (rated temperature).

We also examine compliance with respect to other environmental influences at the customer's request.

These include:

- Saline vapor test to IEC 60068-2-11
  NaCl solution 5%
  Test duration 96 h
- Noxious gas test to IEC 60068-2-60, method 4
  "4K climate": 0,01 ppm H2S; 0,01 ppm Cl2; 0,2 ppm SO2; 0,2 ppm NO2; 25 °C/75% r.h.
- Damp heat, cyclic to IEC 60068-2-30
  between 25 °C/97% r.h. and 55 °C/ 96% r.h., 24 h per cycle

Specialized test laboratories are available for testing the climatic effects.

3.3.5 Transport and storage temperature

EPCOS EMC filters should ideally be stored at temperatures in the range from –25 to +55 °C as specified for class 1K4 by IEC 60721-3-1: 1997. Please contact our specialists if you face tougher requirements such as air humidity or condensation so that the package can be adapted to its required purpose.

3.4 Terms relating to legislation and directives

The EU Directives and the national laws derived from them make use of important terms, some of which differ from their meaning in everyday language. For this reason, the most important terms from EMC Directive 2004/108/EC of December 15, 2004 as well as from the “Blue Guide” (”Guide to the Implementation of Directives based on the New Approach and the Global Approach”) of the EU are summarized here. Further terms and explanations can be found in the relevant EU Directives or in the “Blue Guide”.

3.4.1 Equipment (EMC Directive)

The term ”equipment” means any apparatus or fixed installation.

3.4.2 Apparatus (EMC Directive)

The term “apparatus” means any finished appliance or combination thereof made commercially available as a single functional unit, intended for the end user and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance.

The following are also deemed to be an apparatus in the sense of the EMC Directive:

a) “Components” or “subassemblies” included for incorporation into an apparatus by the end user, which are liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance;

b) “Mobile installations”, defined as a combination of apparatus and, where applicable, other devices, intended to be moved and operated in a range of locations.

3.4.3 Fixed installation (EMC Directive)

“Fixed installation“ means a particular combination of several types of apparatus and, where applicable, other devices which are assembled, installed and intended to be used permanently at a predefined location.

3.4.4 Manufacturer (Blue Guide)

A manufacturer in the meaning of the New Approach is the person who is responsible for designing and manufacturing a product with a view to placing it on the Community market on his own behalf.

The manufacturer has an obligation to ensure that a product intended to be placed on the Community market is designed and manufactured, and its conformity assessed, to the essential requirements in accordance with the provisions of the applicable New Approach directives.

The manufacturer may use finished products, ready-made parts or components, or may subcontract these tasks. However, he must always retain the overall control and have the necessary competence to take responsibility for the product.

A person who produces new equipment from already manufactured end-products or significantly changes, reconstructs or adapts equipment with respect to its electromagnetic compatibility, also counts as a manufacturer.

3.4.5 Placing on the market and taking into service (Blue Guide)

Placing on the market is the initial action of making a product available for the first time on the Community market with a view to distribution or use in the Community. Making available can be either for payment or free of charge.

Putting into service takes place at the moment of first use within the Community by the end user. However, the need to ensure, within the framework of market surveillance, that the products are in compliance with the provisions of the directives when put into service, is limited.

A product must comply with the applicable New Approach directives when it is placed on the Community market for the first time and put into service.

Placing on the market then refers to a single item of equipment to which this Directive applies, irrespective of the time and place of its manufacture, and irrespective of whether it was manufactured as an individual unit or in series. Placing on the market excludes setting up and displaying the product at exhibitions and trade fairs.

4 Safety approval marks

Now that the various national standards in Europe have been superseded, filters are only tested to the current European standard EN 133200[1] for filters. After approval has been assigned by an authorized test center, the filters are automatically approved in the other member states of the EU with no further testing. The filter then bears the safety approval mark issued by the authorizing center. Our filters are approved by VDE and thus bear the ENEC mark with identification number 10 of the VDE Certification Institute.

Many of our filters bear the UL or CSA approval mark for use in the North American market. A filter additionally tested for the Canadian market by US certification authority UL bears the cUL approval mark or the combined cULus test mark.

The safety approval marks granted for filters are listed in the data sheets.

At the test organizations, our filters are listed under the following file numbers:

Certification institute	File number	Standard
VDE	40405-4730-*	EN 133200[1]
UL	E70122	UL 1283
CSA	LR54258	CSA C22.2 No.8

Europe:

ENEC 10

North America:

UL	CSA	cUL	cULus
USA	Canada	Canada	USA/Canada

1) In future EN 60939-2 (identical with IEC 60939-2:2000-02)

5 CE conformity mark

5.1 What is the CE mark?

The CE mark is a conformity mark valid within the European Economic Area (as formulated in various directives). It declares the conformity of a product to the directives applicable within the single European market.

In the first instance, it must be made clear what the CE mark is not:

- The CE mark is **not an approval mark**
- The CE mark is **not a certification mark**
- The CE mark is **not a safety mark**
- The CE mark is **not issued** by a third independent body.

With a number of exceptions, the CE mark is attached to the product by the manufacturer at his own responsibility after conformity with the protection objectives stipulated by the EC Directives has been determined.

In line with the new approach, the EC Directives contain only the general definition of the protection objectives to be observed. The main objective is to avoid jeopardizing the safety of people and animals or the maintenance of physical assets (Low-Voltage Directive, Article 2).

5.2 No CE mark for components

Purchasers of electronic components have repeatedly called for the introduction of a CE mark. It is erroneously assumed that the use of CE-marked individual parts offers the assurance that CE-compliant equipment will be manufactured so that verification of equipment conformity can be either completely avoided or at least significantly simplified. The wish to “do nothing wrong” also leads to a call for CE-marked components at times.

This attitude overlooks the fact that despite all due care and efforts, the component manufacturer cannot ensure compliance with the required protection objectives of the directives even in the case of components certified by a third party (EMC capacitors, inductors and filters). The tests permit only the safety of the components under standardized test conditions to be assessed, which in the nature of things can only cover part of the stresses occurring in practice. They can never reveal faults in the design of an item of equipment or in its production phase.

This situation inevitably results in the manufacturer’s responsibility for an item of equipment directly usable by the end user. He alone can assess its conformity, test it and ultimately confirm it. This means that any marking of individual components is not relevant to the declaration of conformity of the end product.

The free availability of parts by everyone from wholesale and retail sources is often given as a criterion for marking. This is certainly correct for many freely available products, as these may be used directly by the buyer (= end user), for instance domestic appliances, electrical tools, extension parts for equipment such as graphics cards or hard disks for PCs.

However, this argument does not apply to electronic components, as the buyer cannot use them directly. They are used either as spares for repairs or for constructing new equipment (by hobbyists or amateur radio operators). In any case, however, there is no need to take any action as regards safety in the sense of these directives as long as the components are not further processed. These activities are unequivocally designated in the EU Directives as manufacturing, i.e. a private person acting as a hobbyist or repair technician is regarded in this sense as a manufacturer and must consequently test the resulting (new or modified) products to ensure their conformity.

5.3 Conclusions

All the arguments presented here, above all the “spirit of the law” which reflects the intentions of the founders of the CE marking and of the directives, support the conviction of the components industry that it is impermissible to apply CE marks to the following components:

- passive components (such as capacitors, inductors, resistors, filters) and
- semiconductors (such as diodes, transistors, triacs, GTOs, IGBTs, integrated circuits and microprocessors).

6 Safety regulations

Our consistent goal in manufacturing our components is to satisfy the highest safety standards. As a result of the diverse applications of our customers, however, certain requirements are mutually exclusive. Thus some applications require high insulation resistance (e.g. insulation monitoring), whereas others require residual voltages to be kept within permissible limits.

6.1 Protection from residual voltages

⚠ IEC 60204 and/or EN 50178 stipulate that all active parts must be discharged to a voltage of less than 60 V (or 50 µC) within a period of 5 s. If these stipulations cannot be observed as a result of the mode of operation, the danger zone must be marked in a clearly visible way. This shall be done by attaching a suitable text as well as graphical symbols, such as “Hazardous Voltage” (417-IEC-5036) or “Warning” (7000-ISO-0434). In the case of exposed conductors, a discharge time of 1 s shall be observed or protection grades IP2X or IPXXB (IEC 60529) shall be assured.

The safety requirements “Ensuring protection by limiting the discharge energy” stipulated in the Annex to EN 50178 must also be observed. The limit value of 50 µC lies below the threshold of ventricular flutter.

For active parts which are liable to being touched, the values specified in EN 501178, Annex A.5.2.8.2 table A1 determined by the capacitor voltage V_C and the capacitance C shall be applied (see table below). Calculations and/or measurements must be performed to check these values.

Values of capacitance and load voltage liable to touching (pain threshold):

Capacitor voltage V_C	Capacitance C nF	Capacitor voltage V_C	Capacitance C nF
70	42400	500	18
78	10000	700	12
80	3800	1000	8
90	1200	2000	4
100	580	5000	1.6
150	170	10000	0.8
200	91	20000	0.4
250	61	40000	0.2
300	41	60000	0.133
400	28		

These requirements are as a rule observed because the EMC filters are in most cases connected to the installation and thus to other low-impedance loads.

The manufacturer of the installation or equipment is obliged to check the conditions of the application and to take appropriate action where necessary.

6.2 Discharge resistors

⚠ The EMC filters manufactured by EPCOS are supplied with internal high-ohmic discharge resistors (unless otherwise requested by the customers). Although this measure alone does not as a rule satisfy the stipulations of all the relevant standards, regulations and specifications, it does discharge the capacitance within a certain period of time.

Filters which are not permanently connected (e.g. when the test voltage is applied to the filter at the incoming goods inspection) must be discharged after the voltage has been turned off. Circuit variants with a star configuration of the X capacitors and connection of Y capacitors from a virtual star point are also used to reduce the leakage currents. In this case, discharge may produce internal charge shifts between the capacitors, i.e. a voltage > 60 V may exist between the phase and the case or PE. To avoid this problem, a low-ohmic connection should be set up immediately after the discharge starting at the case or PE terminal to the live terminals of the filter. The relevant safety specifications must be observed.

In customer-specific filters, discharge resistors may also be incorporated between the phase and the case if required. If the voltages and currents exceed rating class 3[1)], special discharge resistors are used which satisfy the requirements of the KU values[2)] for safety-relevant components. The required KU value of 6 (DIN VDE 0800-1) is then achieved for the overall system. However, high insulation resistance can no longer be ensured in this case.

1) The rating class is a range of currents and voltages from which the same physiological values can be expected in a contact circuit (DIN VDE 0800-1).
2) The KU value (symbol KU) is a classification parameter of safety-referred failure types designed to ensure protection against hazardous body currents and excessive heating (DIN VDE 0800-1).

6.3 EMC capacitors

For operation at AC line voltages, EMC filters from EPCOS contain EMC capacitors to EN 132400. These capacitors are subdivided into two classes (class X and class Y).

Class X is designed for applications where capacitor failure would not lead to the danger of electrical shock (typically capacitors between the phases). Class X is subdivided into subclasses X1, X2 and X3 according to the peak pulse voltage in operation.

Class	Dielectric strength	Peak pulse voltage in operation	Application	Pulse test
X1	4.3 V_R	2.5 kV < $V_s \leq$ 4.0 kV	Use for high peak voltages	4.0 kV[1)]
X2	4.3 V_R	$V_s \leq$ 2.5 kV	General purpose	2.5 kV[1)]
X3	4.3 V_R	$V_s \leq$ 1.2 kV	General purpose	none

For applications in which capacitor failure could result in a dangerous electrical shock, capacitors of class Y are used (typically located between phase and case). Depending on the type of bridged insulation used, the range of rated voltages and the peak value of the voltage, a subdivision is made into subclasses Y1, Y2, Y3 and Y4.

Class	Type of bridged insulation	Dielectric strength	Pulse test	Rated voltage range
Y1	Double or reinforced insulation	4.0 kV AC	8.0 kV	$V_R \leq$ 500 V
Y2	Basic or supplementary insulation	1.5 kV AC	5.0 kV	150 V < $V_R \leq$ 300 V
Y3	Basic or supplementary insulation	1.5 kV AC	none	150 V < $V_R \leq$ 250 V
Y4	Basic or supplementary insulation	0.9 kV AC	2.5 kV	V_R < 150 V

1) For $C_R \leq 1$ µF, see also EN 132400.

6.4 Installing and removing EMC filters

⚠ We recommend that the rules generally applicable for the operation of electrical equipment be observed when installing and removing our EMC filters. This includes establishing and securing a no-voltage condition while observing the five safety rules described in EN 50110-1.

The following steps should be performed in the specified sequence, unless important reasons make it necessary to diverge from it:

- Clear all connections
- Secure against turn-on
- Check no-voltage condition
- Ground and short-circuit[1)]
- Cover or safeguard adjacent live parts.

1) The grounding and short-circuit steps may be obviated in small and low-voltage installations unless there is a risk that the installation may be made live (e.g. second input etc.).

7 Power distribution systems (network types)

IEC 60364-4-41 describes various distribution systems for setting up power installations with nominal voltages up to 1 kV.

The distribution systems released for our filters from the data book range are specified in the selector guide.

⚠ The operating conditions must be carefully checked, especially with the use of filters in distribution systems diverging from the specified type of power network! This includes testing the line-to-line voltages and the line-to-ground voltages at possible operating conditions such as faultless operation, earth faults as well as single and multi-phase overcurrent switch. For example, for the error cases of one or two-pole tripping of the overcurrent protective device from surge currents, care should be taken to maintain the permissible line-to-line voltages and line-to-ground voltages. In cases of doubt, please contact the EPCOS technical staff, who will advise you on your specific filter application.

7.1 Designation of the distribution systems

T N (- C - S)

Supply

I: insulated
T: grounded

Installation (body)

N: connected to PE
T: directly grounded

-S: A part of the system is also designed with separate N and PE lines

N and PE

-C: connected
-S: separated

7.2 Grounded phase conductor

In systems in which one phase is grounded, the rated voltage of the filters is reduced to typically $1/\sqrt{3}$ times the specified rated voltage.

Deviations should be approved after a check has been made with our development department for EMC filters.

7.3 TN system

In TN systems, one point is directly grounded. The bodies of the electrical installation are connected to this point via PE. A distinction is made between three subsystems:

- TN-S system
- TN-C system
- TN-C-S system

In the TN-S system, a separated PE is used in the entire system.

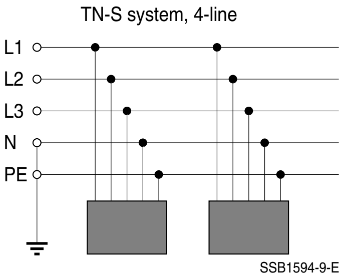


Figure 17 Separated neutral and PE in the entire system; grounded star point

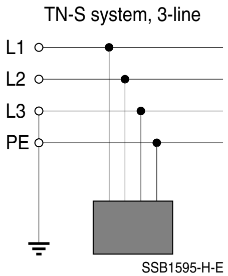


Figure 18 Separated (grounded) phase and PE in the entire system; grounded phase

In the TN-C system, the functions of the neutral and PE are combined in a single line for the entire system.
In the TN-C-S system, these functions are split up in a part of the system.

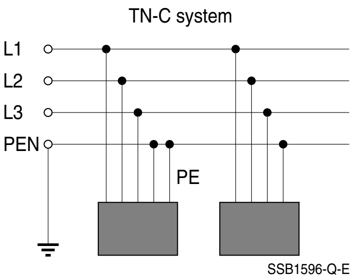


Figure 19 Neutral and PE in the entire system (combined)

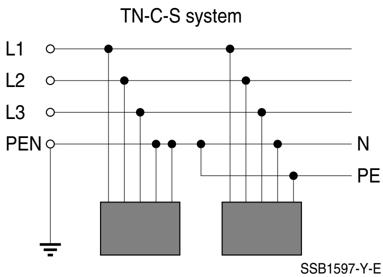


Figure 20 Neutral and PE in a part of the system (combined)

7.4 TT system

In the TT system, one point is directly grounded. The bodies of the electrical installation are connected to ground points which are electrically separate from the ground points used to ground the system.

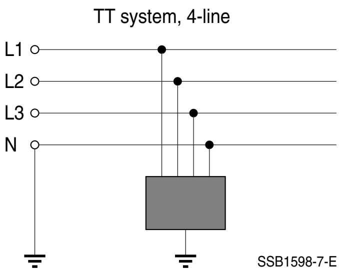


Figure 21 Grounded star point

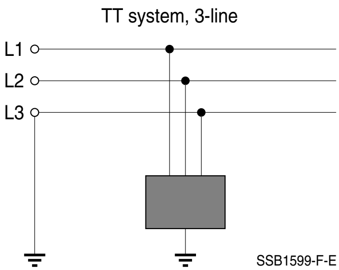


Figure 22 Grounded phase

7.5 IT system

In the IT system, either all active parts are separated from ground or one point is connected to ground via a high impedance (R_{is}). The bodies can be grounded singly or jointly as well as together with the system ground.

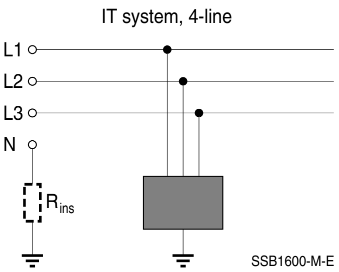


Figure 23 High-impedance grounded star point

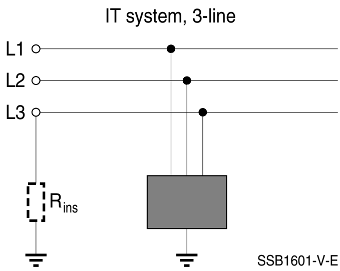


Figure 24 High-impedance grounded phase

The system may be separated from ground; the neutral line may but need not be distributed.

7.6 Special features in IT systems

⚠ In the IT system, a phase line may be continuously short-circuited to ground (conditions and duration as detailed in the equipment specification) in order to complete a running process (for instance a newspaper printing machine). This short circuit is described as the **"first fault case"**.

When EMC filters are used, two possible problems may then occur:

If the first fault case occurs between the feed (line side) and the filter, one of the X capacitors in the filter is connected to ground and thus in parallel to the Y capacitor caused by the external short circuit (see Figure 26). The shift of the star point leads to an increase of the voltage across the remaining X capacitors and the combined X/Y capacitor. The capacitors may then be overloaded if the filter is not rated for this stress.

Our filters approved for IT systems are designed for this first fault case.

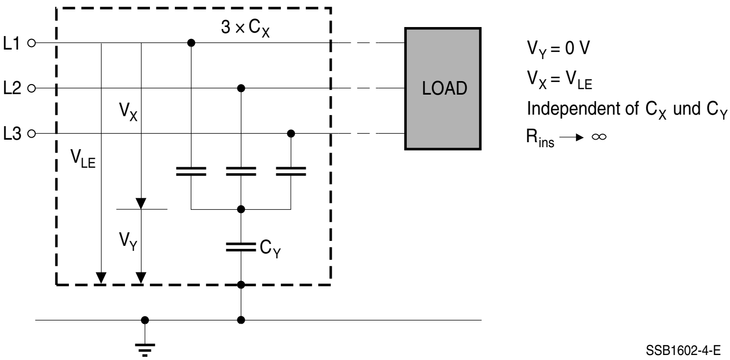


Figure 25 Regular operation

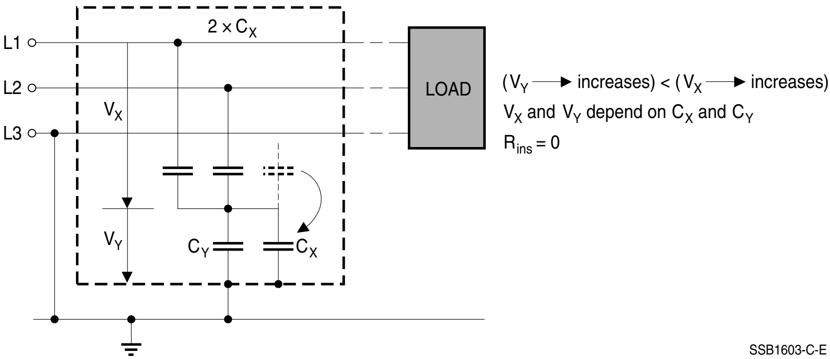


Figure 26 First fault case (one line shorted to ground)

However, if the first fault case occurs between the converter and the motor, the output voltage is shorted directly to ground and thus to the Y capacitors of the filter (see Figure 27). As a result of the high dv/dt of the converter output (several kV/µs), which also exists in no-fault operation, the current through the Y and X capacitors can become very high and consequently damage the filter. Damage may also occur with regenerative converters in the event of an earth fault on the converter input side.

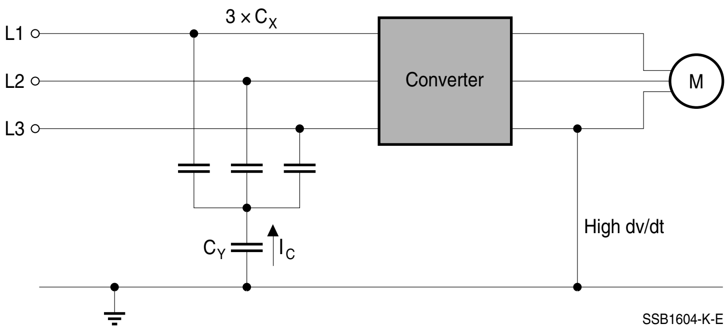


Figure 27 First fault case between converter and motor

Our filters are not designed to handle this or other fault cases. However, if all the boundary conditions are known, some filters can be approved for certain cases by the EPCOS filter development department.

7.7 IT system suitability of filters

⚠ The filters of the B84143B*S024 series can be used in IT systems as long as the operating conditions specified in the data book are observed.

These filters continue to be operable in an IT system
– in the event that one phase on the line side shorts to ground (with the exception of regenerative converters),
– at a specified operating voltage (see rated voltage in the data sheet as well as the marking on the filter) and
– usual power-line quality (see EN 50160).

To obtain information about the functional reliability of the filters in a particular IT application, the possible boundary conditions of operation and the fault cases must either be known exactly or else specified by the user. As the requirements of an IT system differ greatly depending on the application (e.g. short circuit at the converter output), we cannot make any statements which are generally and broadly applicable. However, we will be pleased to support and advise our customers in the event of any special requirements.

Also, we can only assess the risks involved in the use of filters and equipment if we know the boundary conditions.

Power distribution systems (network types)

Only a single high-ohmic connection is permissible in an IT system. An effective EMC filter already sets up this permissible connection to ground due to its Y capacitors (see also EN 61800-3, Annex D.2).

Our IT system filters can handle the line-side short circuit of one phase to ground. All other faults can result in damage to the installation and the filter.

The following factors are relevant for the approval or development of filters designed for special application conditions:

– specifications of the dv/dt value between lines as well as between lines and ground,
– the duration, frequency and combination of the fault cases, and
– the type of installation.

The leakage currents from the filters can trigger an earth-fault monitoring even in the absence of a fault.

8 Leakage current

8.1 General definition

“Leakage current (in an installation): the current which flows to ground or to an external conducting part in a faultless circuit.“

This definition continues to be found in the German standards DIN VDE 0100-200 (terms) and annex. Unfortunately the terms leakage current, touch current and protective-earth current are no longer defined in the standards.

In general, leakage current is the generic term for the following types of current:

– Touch current I_T (electric current passing through a human body that touches one or several parts permitting contact to take place); it is subdivided among its main effects of perception, reaction, let-go and burn.
– Protective earth current I_{PE} (current flowing to protective earth during correct operation).
– Insulation sub-current I_{IT} (current flowing via the insulation).

Except for the introduction, EN 60950-1 and the associated measuring procedure EN 60990 cover only the contact and protective-earth currents.

8.2 Definition of filter leakage current

The following definition applies to all specifications in the data book:

The filter leakage current I_{leak} is the current which flows via the protective earth terminal of the filter to the PE (grounding) point of the installation (as a rule through the EMC capacitors connected to ground). The specified filter leakage current refers exclusively to the filter and differs from the leakage current of the equipment or installation.

In the data sheets, the filter leakage current is known in brief as the “leakage current I_{leak}”. It is specified as a typical value at the rated voltage for standard power systems. It does not represent a maximum value which takes into account all possible cases such as line voltage tolerances, voltage asymmetry, harmonics and maximum component tolerances.

8.3 Measurement circuits for the filter leakage current I_{leak}

Please note that the filter leakage current I_{leak} is added to the leakage currents of the other loads (e.g. parasitic capacitances of cables, motor windings etc.) present in the equipment or installation! The following measurement circuits are based on those published in the standards. During measurement of the filter leakage current I_{leak}, **no** loads are connected to the filter output.

The filter leakage current I_{leak} is measured with an amperemeter P1. This should preferably be a low-resistance multimeter covering the mA range.

8.3.1 Measurement circuit for a 2-line filter

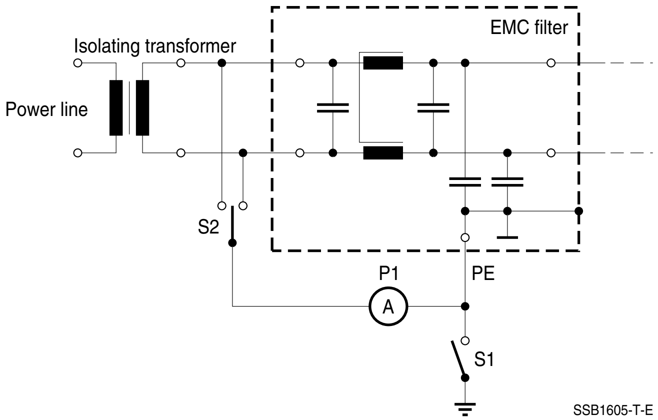


Figure 28 Measurement circuit for a 2-line filter

For the duration of the measurement, switch S1 is opened (open protective earth circuit to PE). The highest value of the filter leakage current I_{leak} is specified which results from measurements made in positions 1 and 2 of switch S2.

8.3.2 Measurement circuit for a 3-line filter

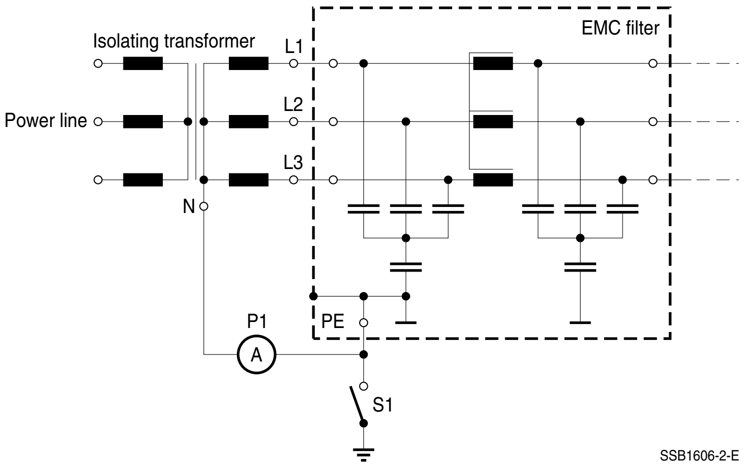


Figure 29 Measurement circuit for a 3-line filter

For the duration of the measurement, switch S1 is opened (open protective earth circuit to PE).

8.3.3 Measurement circuit for a 4-line filter

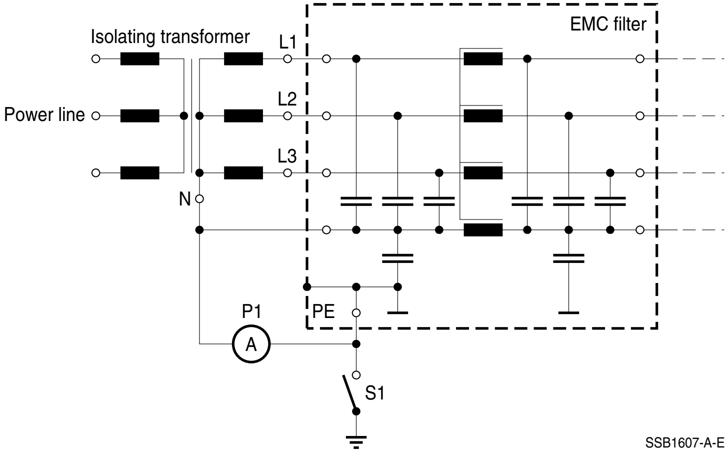


Figure 30 Measurement circuit for a 4-line filter

For the duration of the measurement, switch S1 is opened (open protective earth circuit to PE).

8.3.4 Measurement circuit for a 2-line filter in an IT network

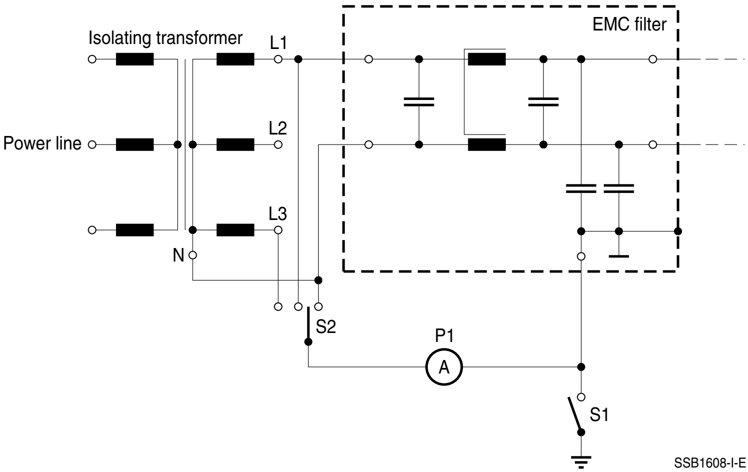


Figure 31 Measurement circuit for a 2-line filter in an IT network

For the duration of the measurement, switch S1 is opened (open protective earth circuit to PE). The highest value of the filter leakage current I_{leak} is specified which results from measurements made in positions 1, 2 and 3 of switch S2.

8.3.5 Measurement circuit for a 3-line filter in an IT network

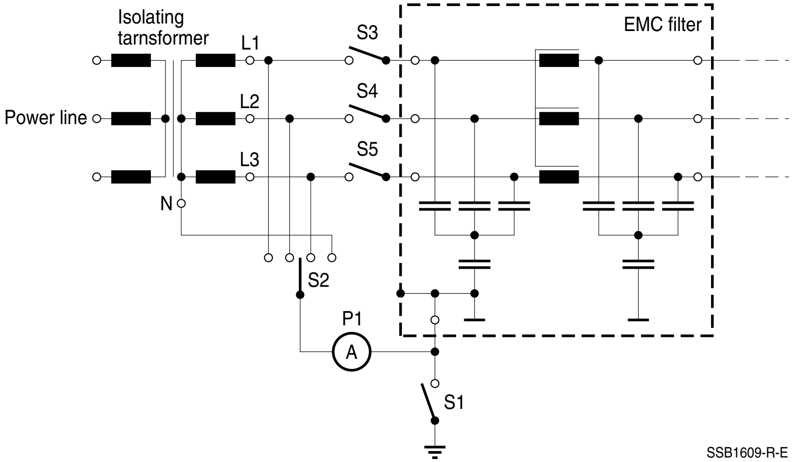


Figure 32 Measurement circuit for a 3-line filter in an IT network

For the duration of the measurement, switch S1 is opened (open protective earth circuit to PE). The highest value of the filter leakage current I_{leak} is specified which results from measurements made in positions 1 to 4 of switch S2 together with the 8 possible combinations resulting from switch positions S3 to S5 (a total of 32 combinations).

8.3.6 Measurement circuit for a 4-line filter in an IT network

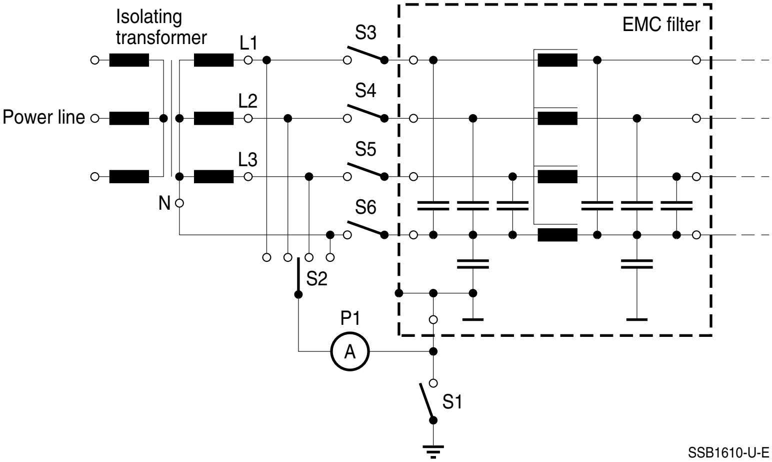


Figure 33 Measurement circuit for a 4-line filter in an IT network

For the duration of the measurement, switch S1 is opened (open protective earth circuit to PE). The highest value of the filter leakage current I_{leak} is specified which results from measurements made in positions 1 to 4 of switch S2 together with the eight possible combinations resulting from switch positions S3 to S6 (a total of 64 combinations).

8.4 Safety notes on leakage currents

⚠ It should be noted that the maximum leakage current of the entire electric equipment or installation is limited for safety reasons. The limits applicable to your application shall be obtained from the relevant specifications, regulations and standards.

As a rule, the following principles apply. However, differing requirements may also exist as a result of certain equipment specifications and may in some cases vary between countries. Be sure to find out the specific requirements for your application. We will be pleased to support you with professional advice in this matter.

- Before putting the installation into operation, first of all connect the filter case to protective earth.
- The protective earth connection shall be set up as specified in DIN VDE 0100-540.
- For leakage currents I_L[1)] ≥10 mA, a fixed connection must be set up between protective earth and the load network. This connection may not be set up via plug connectors. The protective measure against excessive touch current must have a KU value of 6[2)].

  KU = 6 with respect to interruptions is achieved for stationary cable connection ≥10 mm^2 where the type of connection and laying correspond to the requirements for PEN conductors as specified in DIN VDE 0100-540.
- For stationary equipment of protection class I (via industrial connectors or a fixed connection) and a leakage current I_L[1)] <10 mA, a KU value of 4.5[2)] shall be attained for the protective earth connection.

  A value of KU = 4.5 with respect to interruptions is attained:
  – with a permanently connected protective earth circuit ≥1.5 mm^2
  – for a protective earth contact ≥2.5 mm^2 connected via plugs for industrial installations (IEC 60309-2, EN 60309-2).
- If earth leakage circuit breakers are used, the leakage current of the entire equipment or installation must not exceed half the rated trigger current of the protection device.

8.5 Leakage current limits

For touch currents, the limits for perception and reaction are usually of major importance, as the values for let-go and burn are as a rule higher. When measuring protective-earth currents, care should be taken to assure a low impedance of the measuring equipment as well as non-arithmetical summation of the protective-earth currents of the various components in the ramified grounding system.

Two examples will now be shown from standards containing leakage current limits. In all cases, the standards and specifications relevant to the application must be observed. Thus, standards for medical equipment often contain lower limit levels.

1) I_L = Leakage current – let-go
2) The KU value (symbol KU) is a classification parameter of safety-referred failure types designed to ensure protection against hazardous body currents and excessive heating (DIN VDE 0800-1, 800-8, 800-9).

8.5.1 Electrical equipment for domestic use and similar purposes to EN 60335-1

Protection class		Equipment type; connection type	(Leakage current[1]) Touch current perception and reaction
Class	Explanation		
0	Equipment with basic insulation without a protective earth	–	0.5 mA
0I	Equipment with basic insulation without a protective earth, but with a PE terminal	–	0.5 mA
I	Equipment with a protective earth	Moveable appliances	0.75 mA
		Stationary motor-operated appliances	3.5 mA
		Stationary heating appliances	0.75 mA or 0.75 mA/kW rated current, max. 5 mA
II	Equipment with double or reinforced insulation without a protective earth	–	0.25 mA
III	Equipment with safety extra low voltage (SELV)	–	0.5 mA

8.5.2 Requirements for equipment and installations with a rated frequency of 50 or 60 Hz to EN 61140

Current-using equipment	Operating current of equipment	Maximum protective current
With connectors ≤ 32 A	≤ 4 A	2 mA
	7 A but ≤ 10 A	0.5 mA per A of the rated current
	10 A	5 mA
With connectors > 32 A or permanently connected or fixed (with no special measures for the protective earth)	≤ 7 A	3.5 mA
	> 7 A but ≤ 20 A	0.5 mA per A of the rated current
	20 A	10 mA
Permanently connected with protective earth ≥ 10 mm^2 Cu (or 16 mm^2 Al) or connection of two protective earths via separate clamp points with standard cross-section	–	≤ 5% of the rated current of the external conductor

1) To EN 60990 Fig. 4: Measuring circuit for touch current, evaluated for perception and reaction.

8.6 Notes on handling the topic of leakage current in accordance with practice

Users of EMC filters in applications often need to know how to evaluate the filter leakage current specified in the data sheets. At the beginning of Section 8, the term leakage current (I_{leak}) was described for EPCOS EMC filters. As the standards for EMC filters contain no definition or mandatory procedural notes for the specification of the leakage current, this definition depends on the respective manufacturer. A simulation of the leakage currents under the specific application conditions (voltage asymmetry, harmonics, voltage level) may be performed upon request.

Low leakage-current filter circuits are used in many EPCOS filters as far as technically feasible and meaningful. These circuits represent a technically optimized solution for the user, e.g. in a three-phase current TN-S system, the leakage current is close to zero (only insulation currents) for the same phase-ground voltages and exactly identical capacitance values. In practice, of course, the capacitors have a capacitance tolerance. However, EPCOS uses EMI suppression capacitors from leading manufacturers whose technologies have minimized the scatter width of the capacitance tolerance. According to the definition of the features in public power utilities (EN 50160) the voltage difference between phases and neutral does not exceed 6% for 95% of the time (2% unbalance of the positive-sequence system).

The magnitude of a filter's leakage current depends not only on the circuit and the nominal capacitance values, but also on the unbalance and the harmonic content in the power network at the measurement time as well as on the capacitance tolerance and its distribution in the circuit. So the measured value applies only to this measured filter at the particular measuring time. These currents through the Y-capacitors depend not only on the properties of the filter but also on the environment, i.e. the equipment, installations or systems. In converter applications in particular, the low-frequency leakage-current component loses significance compared with the asymmetrical current caused by the switched output voltage.

Although the leakage current was defined for a fault-free circuit (see Section 8.1), its magnitude is also a criterion for the danger to human beings existing in the event of interruption of a protective earth connection when live parts are touched. Depending on the magnitude of the leakage current as measured in a defined manner, certain measures such as suitably designed protective earths of higher reliability are therefore required. See also the previous Section 8.4 “Safety notes on leakage currents“.

The following example shows measured data from 3 EMC filters from various production series of the B84143B0050R110 type in an industrial TN-S power system 400V/230V 50 Hz and in a synthetic power system (free of harmonics).

System supply and time of measurement	Measurement of 3 filters from different production lots[1]				Data book
	Touch current to EN 60990			Difference current[2]	Filter leakage current I_{leak} as per data sheet
	Unweighted	Perception and reaction	Let-go		
	mA	mA	mA	mA	mA
Industrial system time 1	2.14 … 2.22	1.82 … 1.86	1.56 … 1.58	12.05 … 12.50	< 14
Industrial system time 2	2.14 … 2.18	1.76 … 1.82	1.44 … 1.50	11.82 … 12.27	
Industrial system time 3	2.06 … 2.10	1.72 … 1.76	1.40 … 1.44	11.36	
Synthetic power system	0.22 … 0.28	0.20 … 0.27	0.20 … 0.27	0.30 … 0.41	

The example shows that the tolerance of the filter values from three production lots is very low, which is highly indicative of the quality of the EPCOS EMC filters. Due to the harmonic components in the industrial power system, differences to the synthetic power system of almost a power of ten were recorded. The values of the difference current (measurement by summation current transformer are closest to the leakage current specified in the data book, as they have similar definitions.

⚠ **The data-book specification of the filter leakage current are intended for user information only. The specific application must be tested on the basis of applicable standards for observance of the limits in conjunction with all parts of the system! For permanently connected equipment with protective earth currents >10 mA, a fixed protective earth with at least 10 mm² Cu (or 16 mm² Al) or two protective earth wires each with a standard cross-section connected to separate clamp points are required.**

1) Measurement by test laboratory.
2) Vector sum of the momentary values of the currents flowing at the power-side filter input through all active conductors (L1, L2, L3); evaluated as a function of frequency (measured with a leakage current meter 5SZ9 300 from Siemens).

9 Voltage derating for EMC filters

9.1 General

EMC filters are designed to operate at the rated voltage and frequency specified in the data sheet. This assumes that the line voltage is almost sinusoidal and its harmonics lie within the limits permitted by the power utilities.

Voltage derating may be required to deal with any higher voltages which may occur in operation at frequencies exceeding the rated frequency. These may be caused by low-frequency supply-current reactions or overvoltages resulting from system resonances, such as those originating from the switching frequency of a converter in the power line.

9.2 Theoretical relationships

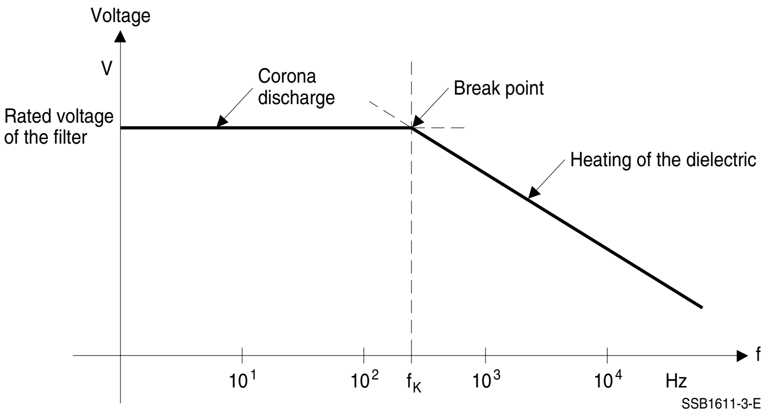


Figure 34 Theoretical relationships of voltage derating in filters

The maximum permissible voltage at the filter depends particularly on two limiting phenomena:

- The horizontal line in the range up to f_K represents the limiting effect due to the corona discharge.
- Above f_K, the permissible voltage declines with frequency and the curve represents the maximum permissible voltage for each singular frequency. If the voltage lies exactly on the curve, the maximum permissible inherent heating of 10 K is attained.

In practice, the filter is subjected to several frequencies (e.g. harmonics of the switching frequency). In order to calculate the total heating effect and thus to determine whether the filter is still being operated in the permissible range, all voltage amplitudes at the various frequencies shall be calculated as described below.

9.3 Calculating the permissible stress

The entire additional heating of the dielectric must not exceed 10 K.

The additional heating for a particular frequency point is calculated by the following formula:

$$\Delta T_n = \frac{10 \cdot (V_{Mn})^2}{(V_{Gn})^2}[K]$$ Formula 1

V_{Mn} = Value measured at a frequency f_n
V_{Gn} = Limit value for a frequency f_n
ΔT_n = Calculated heating of the dielectric for a frequency f_n
f_n = Chosen frequency

This should be calculated for all values $f_n \geq f_K$ which actually occur and should then be summed.

$$\Delta T_{ges} = \sum_{\nu=1}^{m} \Delta T_\nu = \sum_{\nu=1}^{m} \frac{10 \cdot (V_{M\nu})^2}{(V_{G\nu})^2}[K] \leq 10[K]$$ Formula 2

$V_{M\nu}$ = Value measured at a frequency f_ν
$V_{G\nu}$ = Limit value for a frequency f_ν
ΔT_{ges} = Calculated heating of the dielectric for all frequencies
f_ν = Frequency (with index ν 1 … m)

9.4 Estimating the actual stress

The actual stress on a filter by higher-frequency voltages can be determined by using the procedure described above to calculate the temperature increase on the basis of the measured voltages.

The RMS value of the voltage at the line side of the filter must initially be measured at all actually occurring frequencies (higher than f_K). This can be done most simply with a network analyzer which can display the values directly at the individual frequencies, or by measuring the time function and then performing a Fourier transform.

This measurement shall be performed for all line/line and line/PE combinations and converted to the temperature increase for all these cases. The limit values are read off from the relevant diagram (Chapter 9.7) at the corresponding frequency and used in the formula together with the measured value. All temperature values are subsequently summed for each case. If this sum is below 10 K, there is no danger. If it is higher, appropriate measures must be taken to reduce the voltage to permissible values.

Important point:

The voltages must always be measured with the filters connected under rated operating conditions. Any equipment in the vicinity must also be taken into account. Measurements without filters can at best serve as a rough guide. Thus parameters such as the resonances resulting from the circuitry (compensation capacitors, series chokes, transformers, cables) can be changed considerably by the incorporation of a filter.

9.5 Example of permissible stress

A filter of type B84143B*S021 may be stressed with an rms line-line voltage of 760 V AC (rated voltage 690 V AC +10%) and maximum permissible harmonics up to the 25th order according to EN 50160.

9.5.1 Line/line stress

For this example, the maximum permissible values of the harmonics specified by DIN EN 50160 are used, i.e. this represents a kind of worst-case condition for low-voltage networks.

n	V_{Mn} (V)	Frequency (Hz)	ΔT (K)
2	8.8	100	0.0040
3	21.9	150	0.0270
4	4.4	200	0.0013
5	26.3	250	0.0582
7	21.9	350	0.0538
9	6.6	450	0.0065
11	15.4	550	0.0470
13	13.2	650	0.0433
17	8.8	850	0.0325
15, 21	2.2	750. 1050	0.0043
19, 23, 25	6.6	950 … 1250	0.0844
6, 8, 10 … 24	2.2	300 … 1200	0.0172
Total 2 … 25			**0.3795**

There is a temperature increase of around 0.4 K caused by all maximum permissible harmonics (EN 50160) calculated by formula 2 came to around 0.4 K (10 K is permissible). It should be noted that the total value of the harmonic content must not exceed the 8% specified by the standard. The above example yields a THD (Total Harmonic Distortion) of over 11% with all maximum values.

The example shows that EMC filters from EPCOS are securely dimensioned and ensure sufficient distance to the permissible limit values under normal conditions of use and under typical interference aspects.

It should be noted that every component, even if it is dimensioned with a high safety margin, has physical limits which may be reached in cases such as large higher-frequency voltages or resonances.

9.6 Example of impermissible stress

Use of a filter with a rated voltage of 440/250 V at a converter.

During operation, a converter with a non-optimal design (resonances) generates various impermissible higher-frequency voltages.

9.6.1 Line/ground stress

n	V_{Mn} (V)	Frequency (Hz)	ΔT (K)
1	7.34	2350	0.11
2	18.92	2400	0.77
3	29.31	2450	2.03
4	8.13	2500	0.16
5	14.32	4600	0.93
6	56.89	4650	15.98
7	65.33	4700	22.05
8	3.45	4750	0.07
Total			**42.10**

For example, point 6 from the table yields a V_{Gn} value of **45 V** when transferred to the derating diagram (Figure 36) for 440/250 V.

The calculation with formula 2 yields a temperature increase of **15.98 K** specifically for this frequency.

The summed values (ΔT) come to **42 K**.

9.6.2 Line/line stress

n	V_{Mn} (V)	Frequency (Hz)	ΔT (K)
1	5.23	2350	0.11
2	21.47	2400	2.00
3	27.32	2450	3.24
4	13.39	2500	0.81
5	9.73	4600	0.87
6	73.12	4650	55.64
7	64.83	4700	46.70
8	23.73	4750	6.70
Total			**116.06**

In this case, point 7 from the table yields a V_{Gn} value of **30 V** when transferred to the derating diagram (Figure 36) for 440/250 V.

The calculation by formula 2 yields a temperature increase of **46.7 K** specifically for this frequency.

The summed values (ΔT) come to **116 K**.

9.7 General data on voltage derating

The derating curves shown below are typical for many filters and should be regarded as an orientation aid for the various filter groups (2, 3 and 4-line filters). The values for particular filters may deviate from these figures. This is because the voltage handling capability at higher frequencies depends on several parameters:

- The voltage derating of the capacitors used.
- The configuration of the capacitors in the filter
  e.g. several capacitors in series, in a star circuit, or in a delta circuit.
- The rated voltage of the filter (line/line and line/PE).

If the inherent heating of the capacitors calculated with the formulas given above comes close to the limits of the permissible values, you should request exact data for the filter in question.

9.7.1 2-line filters

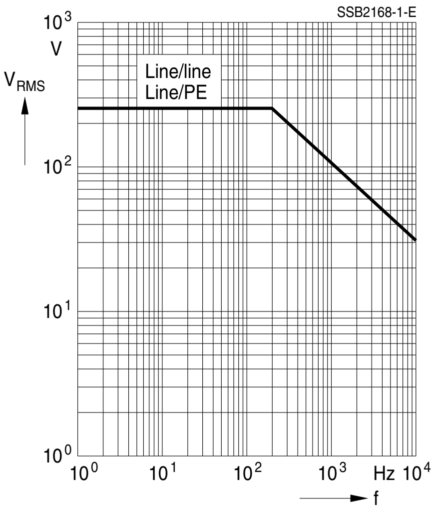


Figure 35 Derating curves for 2-line filters at 250 V.

9.7.2 3 and 4-line filters

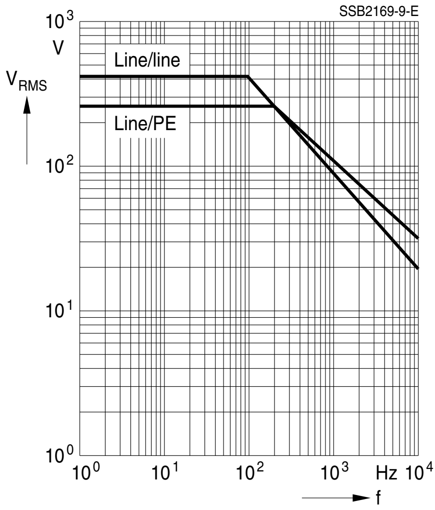


Figure 36 Derating curves for 3 and 4-line filters at 440/250 V

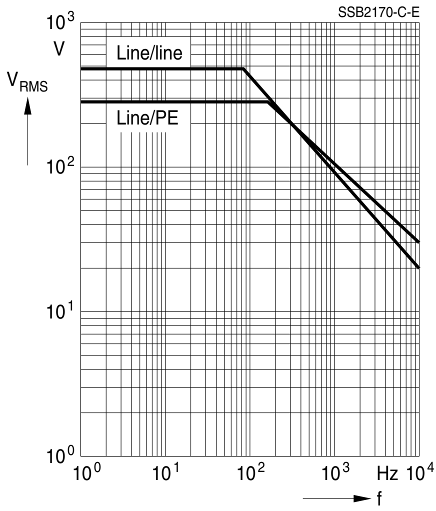


Figure 37 Derating curves for 3 and 4-line filters at 480/275 V

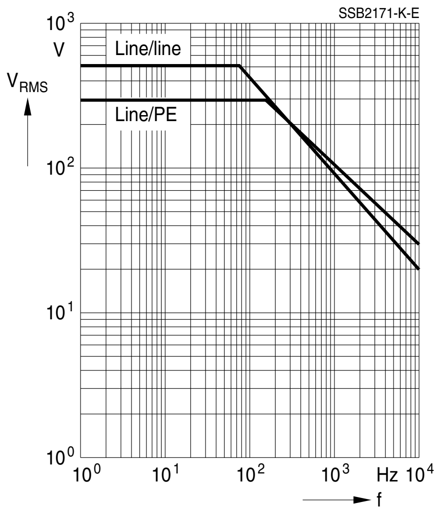


Figure 38 Derating curves for 3 and 4-line filters at 500/290 V

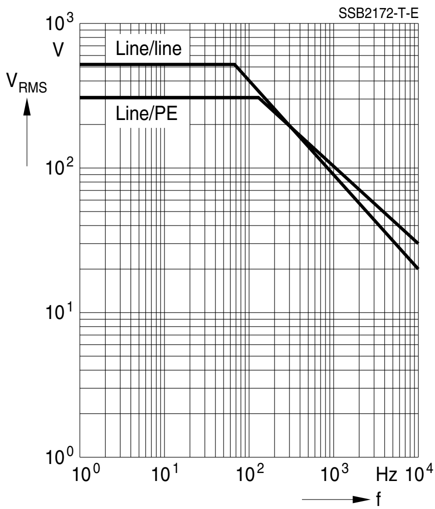


Figure 39 Derating curves for 3 and 4-line filters at 520/300 V

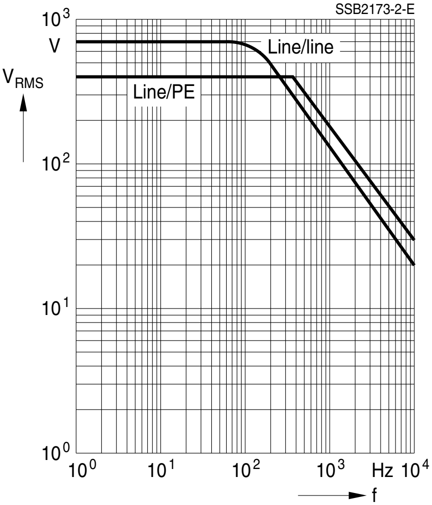


Figure 40 Derating curves for 3 and 4-line filters at 690/400 V

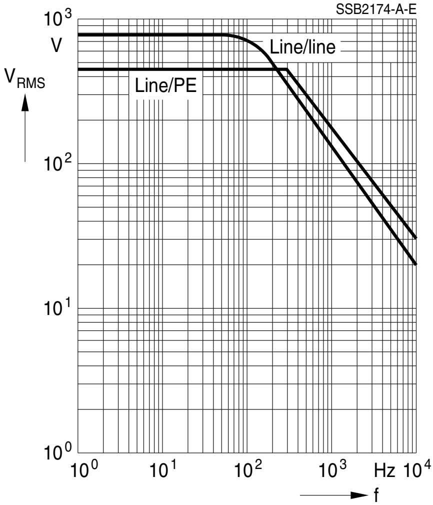


Figure 41 Derating curves for 3 and 4-line filters at 760/440 V

9.8 Hazards caused by overloading the filters

⚠ Experience has shown that as a rule low-voltage power networks contain no critical higher-frequency voltages. Capacitor overload and any associated hazards can therefore be excluded. The maximum permissible values for the 2nd to 25th harmonics of the line frequency specified in the EN 50160 standard can be seen as a kind of worst case.

- However, care should be taken to ensure that no circuits capable of generating resonances occur, for instance as a result of uncoordinated compensation capacitors, transformers, capacitive components of the filters or cables.
- Special care must be taken when using frequency converters to ensure that possible resonant frequencies do not coincide with the switching frequency of the converter or its harmonics.
- If the permissible limits for the higher-frequency voltages at the filter are exceeded, the filter may be damaged or destroyed.

An impermissible overload leads to strong heating of the dielectrics in the capacitors, which can result in arc-overs and short circuits. Such short circuits can as a rule carry very high follow-currents which are fed by the energy stored in the filter capacitors or directly from the connected power supply. These current sources have an extremely low impedance in both cases, thus producing high follow currents (several kA).

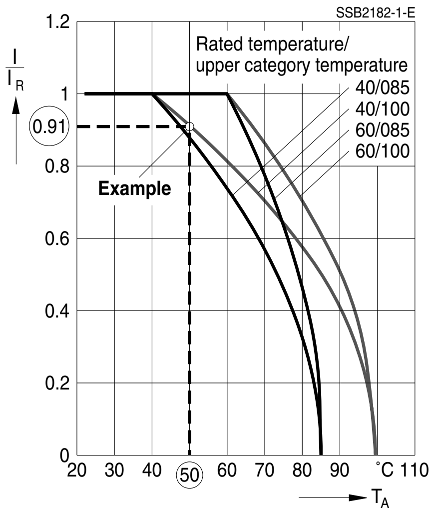
The follow-currents generated by the power supply are not turned off until the fuse is triggered. However, this is never an effective protection for the filter and the capacitors which it contains.

Depending on the ambient conditions (e.g. mounting in equipment or a switch cabinet) and the design of the filter, subsequent damage may also occur in the filter itself and in the environment.

10 Current derating

10.1 Current derating at ambient temperatures exeeding the rated temperature

⚠ EMC filters from EPCOS are dimensioned for continuous operation at the rated voltage and frequency. They are designed for operation at the full rated current up to the specified rated temperature (as a rule 40 °C or 60 °C). When they are operated at ambient temperatures T_A which exceed this temperature, the maximum permissible continuous operating current is obtained by multiplying the rated current by the corresponding derating factor (Figure 42). Non-observance of current derating may lead to overheating and consequently represent a fire hazard.



Formula 3

$$I_{max(T_A)} = I_R \cdot \left(\frac{I}{I_R}\right)$$

Figure 42 Current handling capability I/I_R as a function of ambient temperature T_A

The following curves apply for the specified conditions:

Curve	Rated temperature T_R	Upper category temperature T_{max} 1)
40/085	40 °C	85 °C
40/100	40 °C	100 °C
60/085	60 °C	85 °C
60/100	60 °C	100 °C

1) Second parameter of climatic category (e.g. 25/**085**/21; 25/**100**/21) see chapter 3.3.1 and 3.3.4.

Example:

Given the following:

– Filter B84143B0320S020 (I_R = 320 A)
– Switch cabinet with a maximum internal temperature of 50 °C
– Maximum continuous rms current at the converter input of 280 A

Solution:

From the data sheet of the filter B84143B0320S020:

– Rated current 320 A at a
– rated temperature of 40 °C
– Upper category temperature 100 °C (climatic category 25/100/21)

From the current derating curves:

– Select the relevant curve 40/100
– Read off the associated current handling capability $I/I_R = 0.91$ at an ambient temperature of 50 °C
– 320 A × 0.91 = 291 A (maximum permissible continuous current at 50 °C)
– **291 A > 280 A**

This result shows that in this particular example the filter may be used with a maximum continuous current of 280 A and is thus correctly dimensioned.

10.2 Current derating of 4-line filter with neutral line loading

For 4-line filters (3 phase lines + 1 neutral line), the specification of the rated current refers to 3-phase loading with a sum current of the neutral line close to zero. Significant loading of the total line is to be expected specifically in applications with clocked power supplies such as computers, electronic ballasts etc. In the least favorable case, it can exceed the magnitude of the phase currents. The 4-line filter shall then be dimensioned for a rated current greater than the expected operating current. When the current of the neutral line has the same value as the phase line, the result is a derating factor of $I/I_R = 0.85$.

Example:

Given the following:

– $I_{L1} = I_{L2} = I_{L3} = I_N = 36$ A
– Selected filter, e.g. B84144A0050R000 where $I_R = 50$ A

I_{Lx} = current through line L1 … L3
I_N = current through neutral line

Solution:

Permissible loading 3-phase + N line:

$$I = 0.85 \cdot I_R = 0.85 \cdot 50\text{ A} = 42\text{ A}$$

11 Mechanical tests

Depending on the application and the mounting position, the various vibration, shock or bump tests must be satisfied.

11.1 Passive filters for suppressing electromagnetic interferences

The sectional specification EN 133200 and EN 60068-2-* (IEC 60068-2-*) stipulate the following test conditions:

a) Vibration (test Fc to EN 60068-2-6; IEC 60068-2-6)

Vibration stress shall be applied with a gliding frequency. The preferred severity levels are shown below:

0.75 mm displacement or 98 m/s^2.

The lower amplitude applies in one of the following frequency ranges:

10 Hz to 55 Hz,
10 Hz to 500 Hz,
10 Hz to 2000 Hz.

The preferred duration is 6 h, i.e. 2 h for each axis of vibration.

The detail specification must define both the severity level and the mode of attachment.

b) Shocks (test Ea to EN 60068-2-27; IEC 60068-2-27)

The mode of attachment and the severity level must be defined in the detail specification. The following severity levels are preferred:

Pulse form: half-sinusoidal

Peak value of acceleration m/s^2 (g)	Associated pulse duration ms
49 (5)	30
294 (30)	18
490 (50)	11
981 (100)	6

c) Continuous shocks (test Eb to EN 60068-2-29; IEC 60068-2-29)

The mode of attachment and the severity level must be defined in the detail specifications. Preference should be given to the following severity levels:

Total number of shocks: 1000 or 4000

Acceleration m/s^2 (g)	Associated pulse duration ms
390 (40)	6
98 (10)	16

The values specified above can be met only with filters which are fully potted and as a rule also small (<1 kg).

11.2 Filters for converters or non-potted filters

Because these tend to be highly complex, mechanically resonant filters the general specifications according to EN 60068-2-* (IEC 60068-2-*) do apply. However, very much less rigorous severity levels are applied than in EN 133200. (In some cases, the measured response spectrum showed resonance increases up to a factor of seven.)

a) Vibration — Test Fc to EN 60068-2-6 (IEC 60068-2-6):
packaged or unpackaged
as a rule 2 *g*, max.
Frequency range 10 … 500 Hz.

b) Shocks — Test Ea to EN 60068-2-27 (IEC 60068-2-27):

Acceleration	5 g max.
Pulse duration	30 ms
Six directions	18 shocks altogether

In special cases, the following additional tests are performed:

c) Drop — Test to EN 60068-2-31:
Unpackaged 100 mm height,
1 × around each base edge.

d) Topple — Test to EN 60068-2-31:
1 × around each base edge

e) Free fall — Test to EN 60068-2-32:
Unpackaged 100 mm,
Transport packaged 500 mm,
2 × onto the base area.

11.3 Mounting power and telecommunications line filters in special protective rooms

In Germany, the conditions laid down by the German Federal Ministry for Regional Planning, Building and Urban Development apply in this case. The most important parameters are known as rule classes.

A shock safety class is defined by the shock polygon (V_{max}, a_{max}, s_{max}, r_{max}). The parameters of the safety class simultaneously define the minimum values of the shock test parameters and the parameters used to calculate the stability and deformation verification.

The parameter combinations listed in the following table are defined as rule classes for protected rooms.

Rule class	Main parameters		Secondary parameters	
	V_{max}	a_{max}	s_{max}	r_{max}
Rk 0.63/ 6.3	0.63 m/s	6.3 g	= 10 cm	= 1.5 g / ms
Rk 1.0 /10	1.0 m/s	10 g	= 16 cm	= 2.5 g / ms
Rk 1.6 /16	1.6 m/s	16 g	= 25 cm	= 4.0 g / ms
Rk 2.5 /25	2.5 m/s	25 g	= 40 cm	= 6.3 g / ms
Rk 4.0 /40	4.0 m/s	40 g	= 63 cm	= 10 g / ms

A value of Rk 1.6/16 is usually selected for attaching the filters to ceilings and walls.

11.4 Military applications

In Germany, military applications are largely subject to the requirements of the Federal Office for Defense Technology and Procurement (BWB). The test center must have the approval of this authority in order to conduct the tests.

The tests are defined by the BWB depending on the mounting position. The layout and presentation of the test report are specified.

Extract from the requirements for the shake test:

S_0 (mm)	a_0 m/s^2	f 1/s
0.63	4	2 … 31.5
1.0	6.3	2 … 40
1.6	10	2 … 50
2.5	16	2 … 63

Shock safety classes A to C, as well as set-up ranges I … III are defined for the shock tests. The shock pattern may be triangular, rectangular or sinusoidal. In some cases, military specifications (e.g. MIL 810) are applied. Bump tests are also included.

12 Identification of EMC filters

EMC filters from EPCOS usually bear the following markings:

- Manufacturer's name or logo
- Ordering code
- Approval marks
- Rated voltage; rated frequency
- Rated current; rated temperature
- Climatic category
- Date of manufacture (coded)

General: CYCWD

Example:

05102 => 05 = Calendar year 2005
10 = Calendar week 10
2 = 2nd day of the week = Tuesday

= 8th March 2005

SIFI series, feedthrough filters and capacitors: MM.YY

Example:

03.05 => 03 = Month of March
05 = Calendar year 2005

= March 2005

Different markings may be used at the customer's request.