1 Introduction

Shielded rooms offer protection against electromagnetic fields. This works two ways, i.e.

- shielding a room against the external electromagnetic environment,
- shielding the environment against electromagnetic interference produced inside a room.

The first case applies to research and development or test installations, computer centers or medical equipment, which will only work properly with adequate protection against RF energy from the outside.

In the second case, e.g. use of spark machining equipment, high-voltage tests or measurement of breakdown field strength, the RF energy that is generated would not only disturb radio and TV reception, it would also impair the working of any electrical equipment close by.

In many instances you have to both protect equipment against sinusoidal stray signals and limit pulsed interference. The latter includes electromagnetic pulses (EMP), a cover term for the effects of lightning (LEMP) and the impact of a nuclear detonation (NEMP).

To prevent interference or surge voltages from penetrating or escaping from a shielded room, all lines passing through the shield need to be fitted with appropriate filters.

2 EMC filters

2.1 Design

Our standard filters come in an RF-tight case for wall mounting and include single or multiple filter circuits depending on the requirement. For higher amperage, the filters are designed as RF-tight cabinets.

Single or current-compensated chokes are used, also depending on the requirement.

Single chokes damp common-mode and differential-mode currents equally well. The large gapping, e.g. through the outer air gap in I core chokes, prevents saturation of the magnetic core by the operating current. A disadvantage, however, is that single chokes for high operating currents are voluminous and costly.

Current-compensated chokes damp for the most part common-mode interference currents, because the magnetic fluxes in the core produced by the operating current and differential-mode current are compensated by the special arrangement of the windings. The advantage here is that the choke remains relatively small in volume even for high operating currents.

2.2 Insertion loss

The insertion loss of filters is determined according to CISPR 17. This specification is stricter than the frequently used MIL-STD-220A, where only an open-circuit measurement is required in the frequency range below 100 kHz.

The loss figures for all EPCOS filters apply for full load in the stated frequency range (refer to section 4.12 for measurement methods).

2.3 Protective measures (grounding)

The high capacitances between the lines and ground require special protective measures. If there are no product-specific requirements, protection with a secondary ground wire (cross section min. 10 mm^2) in accordance with EN 50178 is necessary. For this purpose the filter case have connecting bolts at each end.

Resistors are incorporated in the filter to discharge capacitors after turn-off.

3 EMP protection

The danger to electrical and electronic equipment and systems from electromagnetic pulses is characterized by fields of the order of kilovolts per meter and amps per meter. Where NEMP is concerned, rise and fall times of just a few nanoseconds to a few hundred nanoseconds must be taken into account.

If interference pulses in the nanosecond range are produced on lines by fields of this magnitude, they can be damped by the feed-through capacitors used in the filters or EMP protection units.

Seeing as line systems (power, control and communication lines) exhibit a lowpass response however, they primarily transmit overvoltages in the microsecond range. The short field pulse also stimulates them into natural oscillation, which, depending on the nature and size of the line system, can lie in the frequency range from a few kilohertz to several megahertz. Extra surge protection is needed to reduce these overvoltages.

Ignoring the possibility of a direct lightning strike on the filter or surge protection unit, the connected line is always determinant for the coupling in and transmission of overvoltages. The peak of a surge is thus clearly limited by the withstand voltage of the line carrying the surge pulse and the connector fittings.

In common power systems you cannot expect a figure of more than 20 kV for surge voltage strength. For communication lines it is less. The high-frequency internal resistance is between 10 and 50 Ω. An internal resistance of 10 Ω and a maximum voltage of 20 kV thus produce an unbalanced to ground, sum current of max. 2 kA for a cable. The current per line is correspondingly lower.

3.1 Test conditions

In consideration of what is said above, and which is acknowledged by many official bodies in the absence of appropriate standards, you arrive at the following test conditions:

Surge voltages:

Rate of rise	100 V/µs	Amplitudes in the specifications of the particular filters with EMP protection or EMP protection unit
1 kV/µs	internal resistance R_i = 15 Ω	
10 kV/µs		
1 kV/ns	internal resistance R_i = 50 Ω bzw. 90 Ω	

Surge currents:

Standard wave	8/20 µs
Long wave	10/700 µs

Surge voltage tests serve primarily for testing

- the response of nonlinear protection elements,
- the pulse damping performance of the protection unit as a whole.

Surge current tests (impressed currents) serve for determining the energy carrying capability (absorption or reflection) of the protection units.

Note:

The values for rated surge current listed in the filter specifications were given to illustrate the response of the protection units under extreme load. They cannot be produced by an NEMP.

Those filters with integrated overvoltage protection and the EMP protection units all underwent representative type testing by the Defense Technology Office of the Federal German Army in Munster. The results are available on request.

The basic units of filters with overvoltage protection are the filters for electromagnetic compatibility. The overvoltage protection is housed in an add-on case or in the filter case itself, partly together with extra nonlinear components in the filter configuration.

4 Terms and definitions

4.1 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.

4.2 Nominal voltage V_N

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

IEC 60038 defines the most widely used nominal voltages for public supply networks. 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.

4.3 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. 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).

Short voltage surges are permitted according to EN 133200.

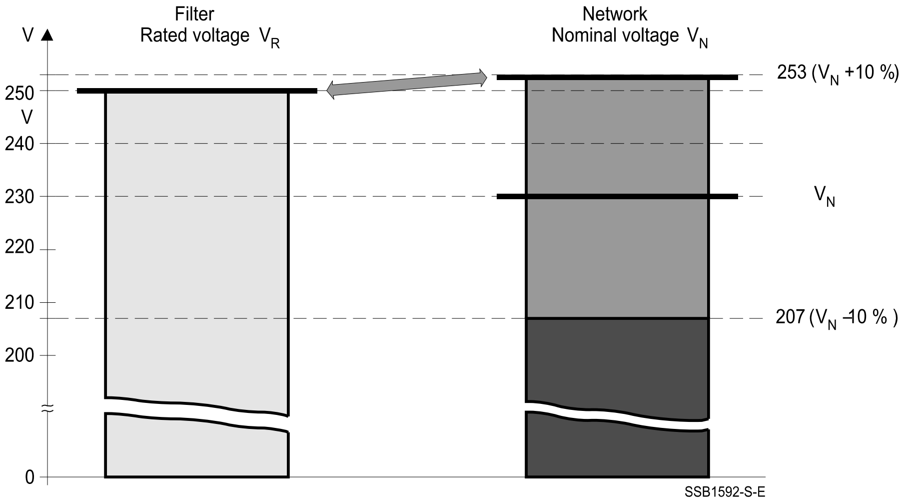

Figure 1
Difference between rated and nominal voltage

4.4 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). This test may be repeated once as an incoming goods inspection or equipment test.

4.5 Voltage drop ΔV

The voltage drop is the difference between the filter input voltage and output voltage produced by applying the rated current to the filter.

4.6 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 should as a rule be reduced in accordance with the derating curves (see also figure 2).

For 2-line filters, the rated current is specified for the simultaneous flow of a current of this value through all the lines. For 4-line filters (e.g. filters with 3 phases and neutral line), the sum of the currents in all 4 lines must not exceed three times the rated current.

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

4.7 Overcurrent I_{over}

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

4.8 Capacitive reactive current $I_{reactive}$

The capacitive reactive current is the current that flows in operation across the capacitors used in a filter. The figures are referred to 230 V nominal voltage for 2-line filters and 400/230 V for 4-line filters and a rated frequency of 50 Hz.

4.9 Power dissipation P_D

The power dissipation in the case of 2-line filters refers to a simultaneous load with the specified rated current. With 4-line filters (filter with 3 phases and neutral line) the sum of all 4 lines must not exceed three times the rated current.

4.10 Current derating I/I_R

The filters are dimensioned for continuous operation at the rated voltage and frequency. They are designed for operation at the full rated current up to specified rated temperature (as a rule 40 °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:

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

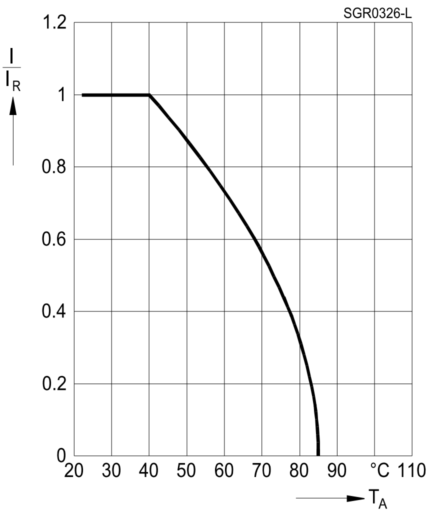

Figure 2
Current handling capability I/I_R as a function of ambient temperature T_A (upper category temperature = 85 °C)

4.11 DC resistance R

The DC resistance is the resistance of a line measured for direct current at an ambient temperature of 20 °C, where the measuring current must be selected substantially lower than the rated current. The data sheets state the maximum value R_{max}.

4.12 Insertion loss

The insertion loss is a criterion for the efficiency of EMC components, as measured by using a standardized test setup (Figure 3).

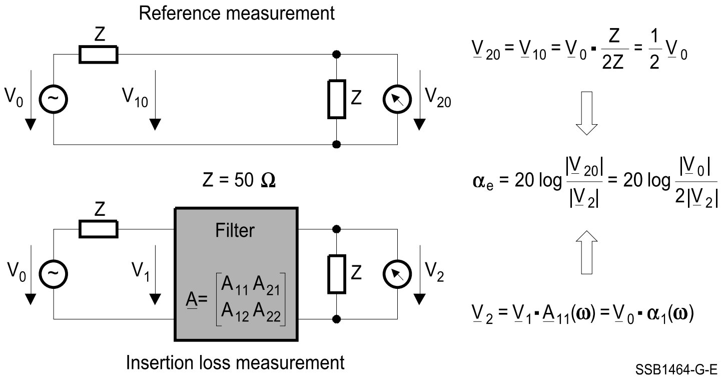

Figure 3
Definition of insertion loss

The input terminals of the filter under test are connected to an RF generator with impedance Z (usually 50 Ω). At the output of the filter, 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.

Insertion loss measuring methods used for EMC filters with 2 lines

a) Differential mode (symmetrical insertion loss measurement)

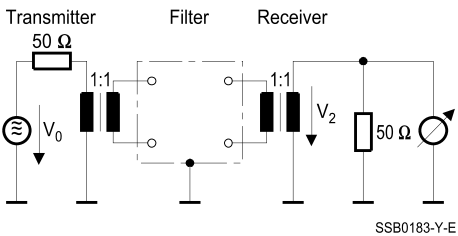

Figure 4
Symmetrical insertion loss measurement to CISPR 17 (1981) Fig. B5

Insertion loss $\alpha_e = 20 \lg \frac{V_0}{2 \cdot V_2}$ [dB] *b) Common mode (asymmetrical measurement), branches connected in parallel*

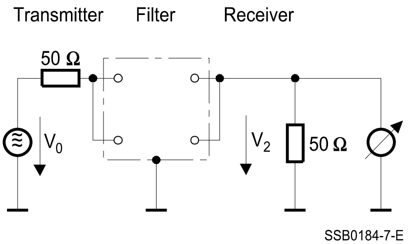

Figure 5
Asymmetrical insertion loss measurement to CISPR 17 (1981) Fig. B6 or MIL-STD 220A

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

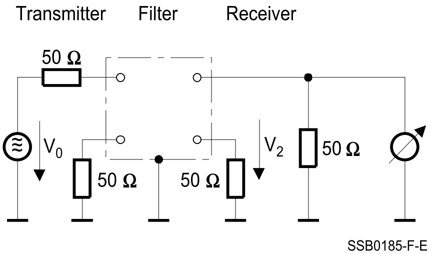

Figure 6
Unsymmetrical insertion loss measurement to CISPR 17 (1981) Fig. B7

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.

4.13 Leakage current I_{leak}

The leakage current I_{leak} is the current that flows to ground or to an external conductive part in a circuit without any failure. For safety hints refer to data book "EMC Filters".

4.14 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. For safety regulations refer to data book "EMC Filters".

4.15 Further general information

Refer to data book "EMC Filters", edition 2001, ordering code EPC:24004-7600.