



Inductors

Electromagnetic compatibility (EMC)
General, Services

Date: October 2008

Electromagnetic compatibility (EMC)

General

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).

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 has since been incorporated at national level by the EU member states in the form of various EMC laws and regulations. The most important changes include:

- New definitions of terms (“equipment”, “apparatus”, “fixed installation”)
- Regulations for fixed installations
- Abolition of the “competent body”
- Conformity assessment may also be made without harmonized standards
- 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 or services to an impermissible extent.

1.1 Basic information on EMC

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

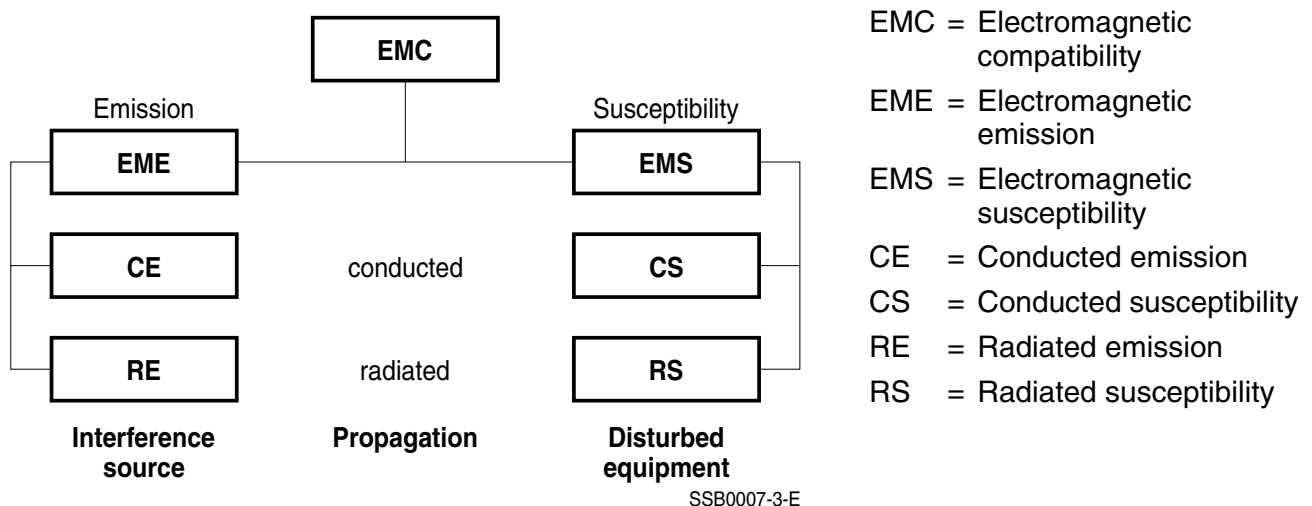


Figure 1 EMC terms

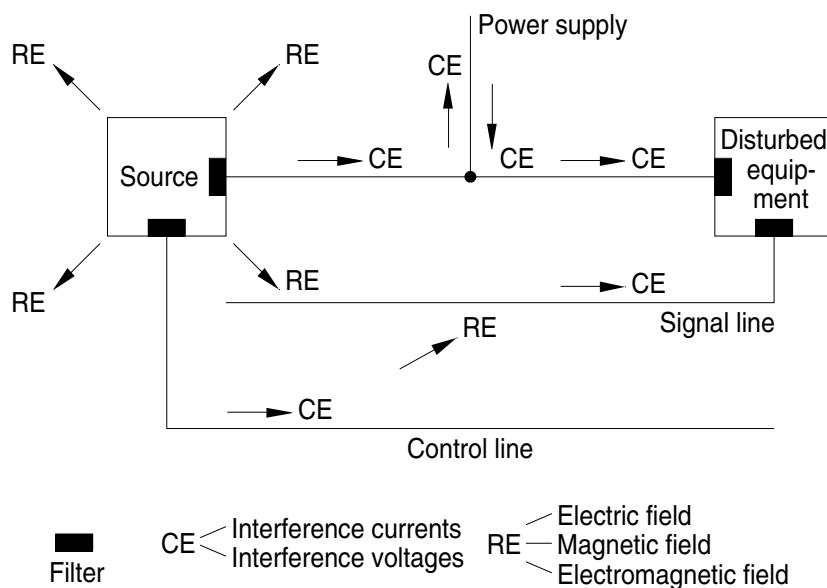
Electromagnetic compatibility (EMC)

General

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.



SSB1685-G-E

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.

1.2 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 micro-processor 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.

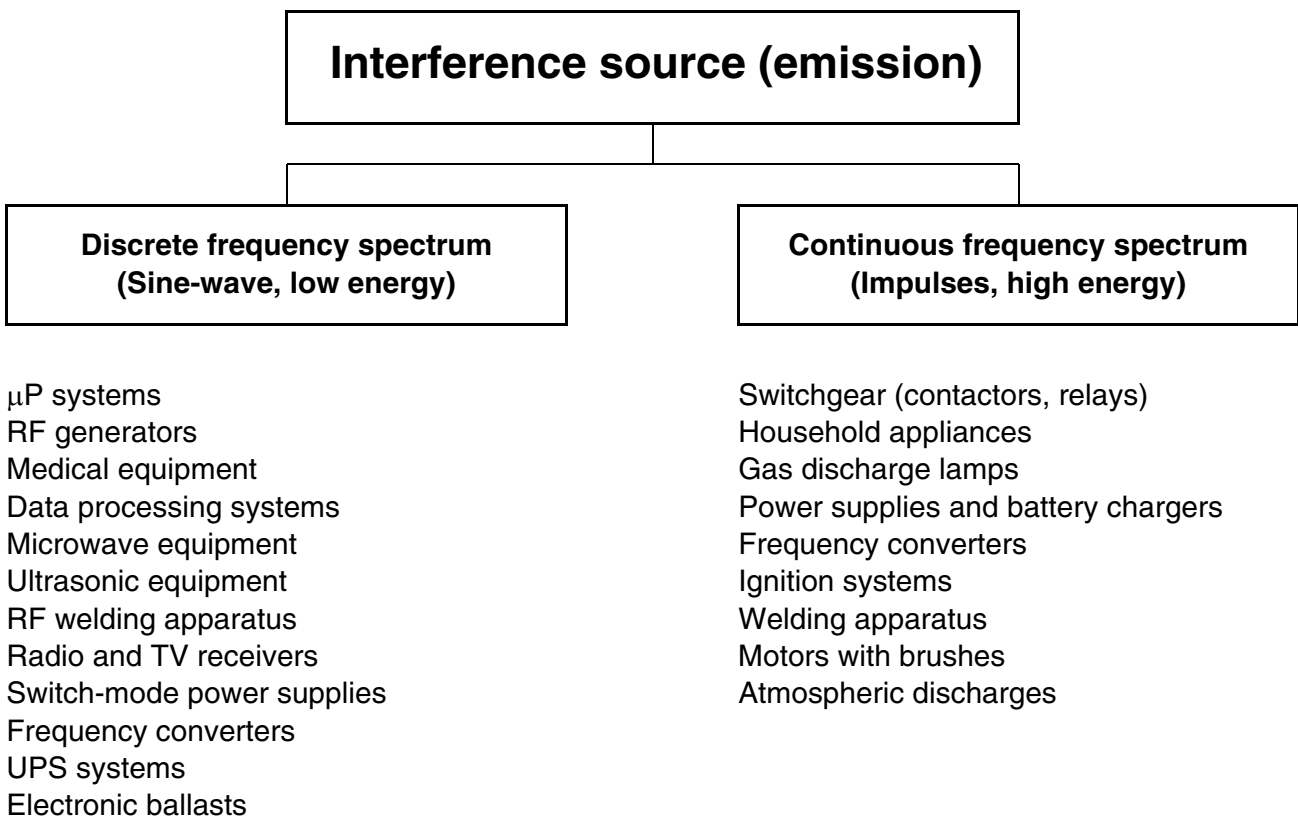


Figure 3 Interference sources

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.

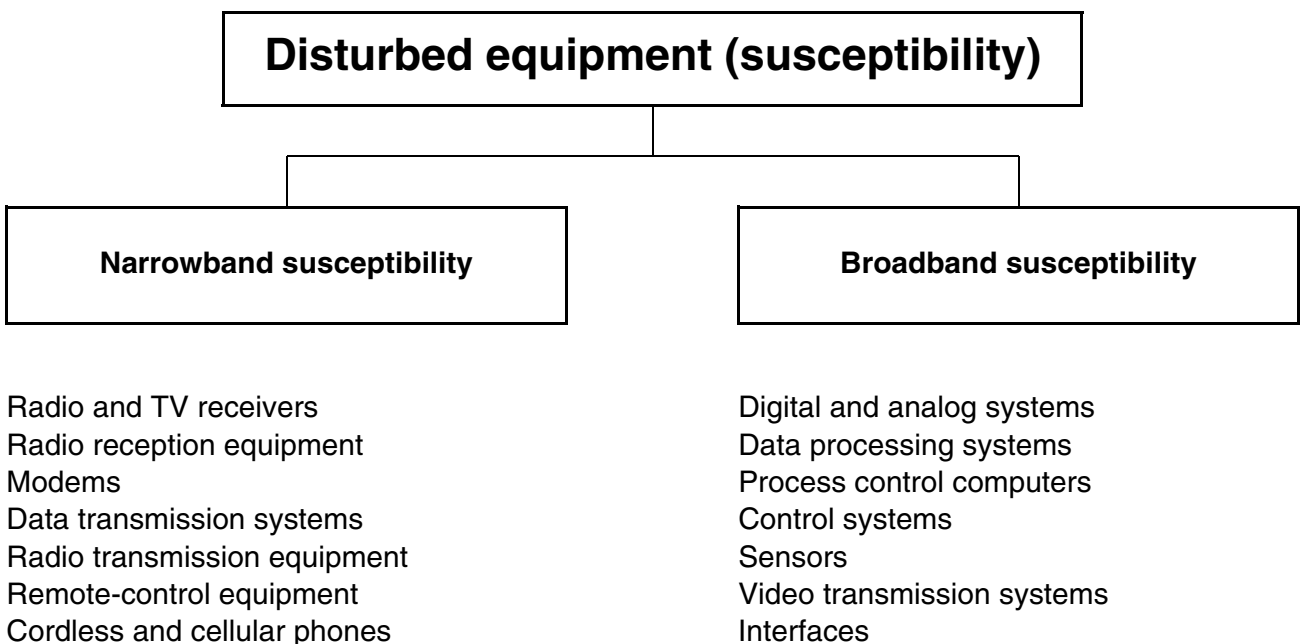


Figure 4 Disturbed equipment

1.3 Propagation of electromagnetic interference and EMC measurement techniques

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 5).

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.

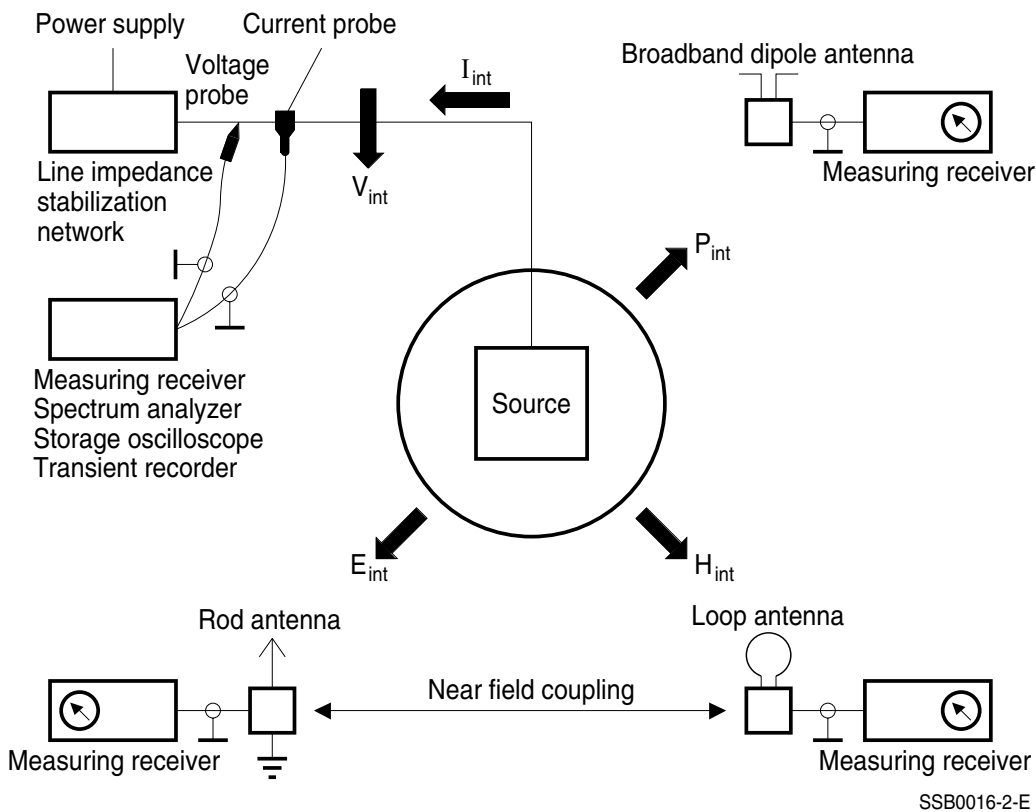


Figure 5 Propagation of electromagnetic interferences and EMC measurement methods

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

Electromagnetic compatibility (EMC)

General

1.4 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 and test methods.

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

EMC standards	Germany	Europe	International
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Generic standards

define the EMC environment in which a device is to operate according to its intended use.

Emission		Germany	Europe	International
	residential	DIN EN 61000-6-3	EN 61000-6-3	IEC 61000-6-3
	industrial	DIN EN 61000-6-4	EN 61000-6-4	IEC 61000-6-4
Immunity		Germany	Europe	International
	residential	DIN EN 61000-6-1	EN 61000-6-1	IEC 61000-6-1
	industrial	DIN EN 61000-6-2	EN 61000-6-2	IEC 61000-6-2

Basic standards

describe physical phenomena and measurement methods.

Measuring equipment		Germany	Europe	International
		DIN EN 55016-1-x	EN 55016-1-x	CISPR 16-1-x
Measuring methods		Germany	Europe	International
	emission	DIN EN 55016-2-x	EN 55016-2-x	CISPR 16-2-x
	immunity	DIN EN 61000-4-1	EN 61000-4-1	IEC 61000-4-1
Harmonics		Germany	Europe	International
		DIN EN 61000-3-2	EN 61000-3-2	IEC 61000-3-2
	Flicker	DIN EN 61000-3-3	EN 61000-3-3	IEC 61000-3-3
Immunity phenomena		Germany	Europe	International
e.g.	ESD	DIN EN 61000-4-2	EN 61000-4-2	IEC 61000-4-2
	EM fields	DIN EN 61000-4-3	EN 61000-4-3	IEC 61000-4-3
	Burst	DIN EN 61000-4-4	EN 61000-4-4	IEC 61000-4-4
	Surge	DIN EN 61000-4-5	EN 61000-4-5	IEC 61000-4-5
	Induced RF fields	DIN EN 61000-4-6	EN 61000-4-6	IEC 61000-4-6
	Magnetic fields	DIN EN 61000-4-8	EN 61000-4-8	IEC 61000-4-8
	Voltage dips	DIN EN 61000-4-11	EN 61000-4-11	IEC 61000-4-11

Electromagnetic compatibility (EMC)

General

EMC standards	Germany	Europe	International
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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 61547
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
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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 μ s (open-circuit voltage) 8/20 μ s (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 2000 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).

Electromagnetic compatibility (EMC)

General

Standard	Test characteristics	Phenomena
Electrostatic discharge (ESD)		
EN 61000-4-2 IEC 61000-4-2	Up 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

1.5 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).

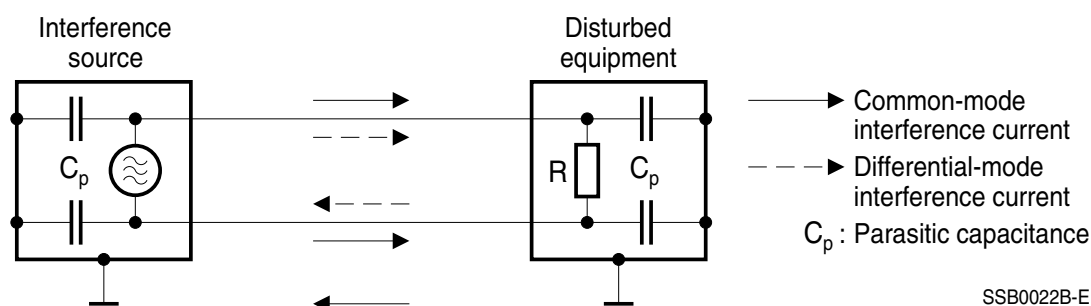


Figure 6 Common-mode and differential-mode interferences

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.

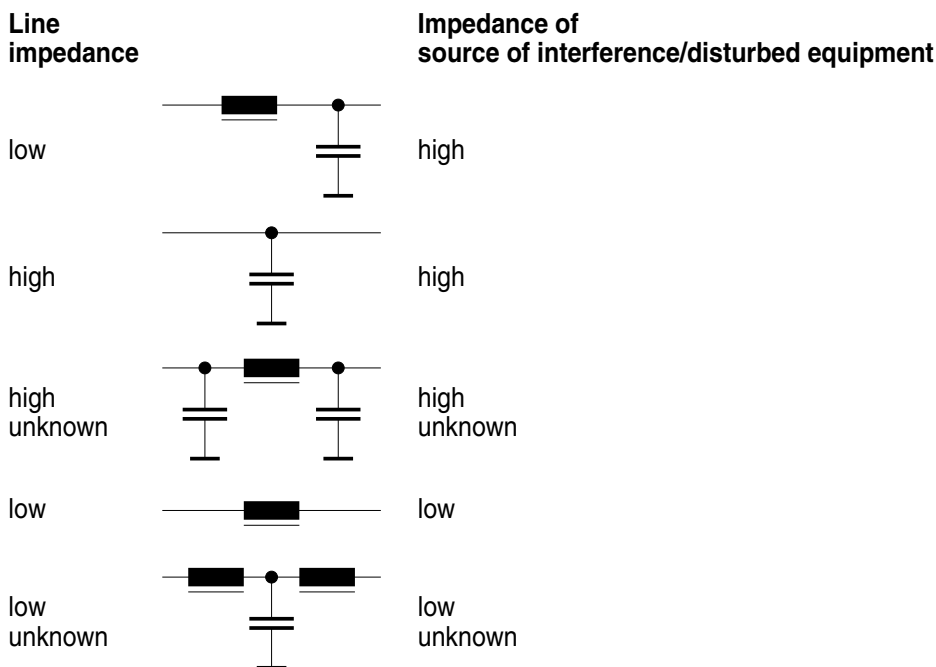
1.6 Filter circuits and line impedance

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 or 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 7.

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 chapter “EMC services”).



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Figure 7 Filter circuits and impedance relationships

2 Selection criteria for EMC components

To comply with currently valid regulations, a frequency range of 150 kHz (9 kHz) to 1000 MHz and even up to 186 Hz has to be taken into consideration in order to ensure electromagnetic compatibility; in addition, however, further aspects such as low-frequency phenomena must be considered. EMC filters must thus have good RF characteristics and are usually 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.

3 Arrangement of EMC components

When designing filter circuits using individual components, observe the following basic rules:

- The components should be arranged along the lines (see example in figure 8) to avoid capacitive and inductive coupling between components and between filter inputs and outputs.
- As insertion loss of a filter circuit in the MHz range is mainly determined by the capacitors connected to ground, the connecting leads of these capacitors should be as inductance-free as possible, i.e. short (resp. broad).
- Filter circuits which are to be installed in devices with limited space must be shielded.

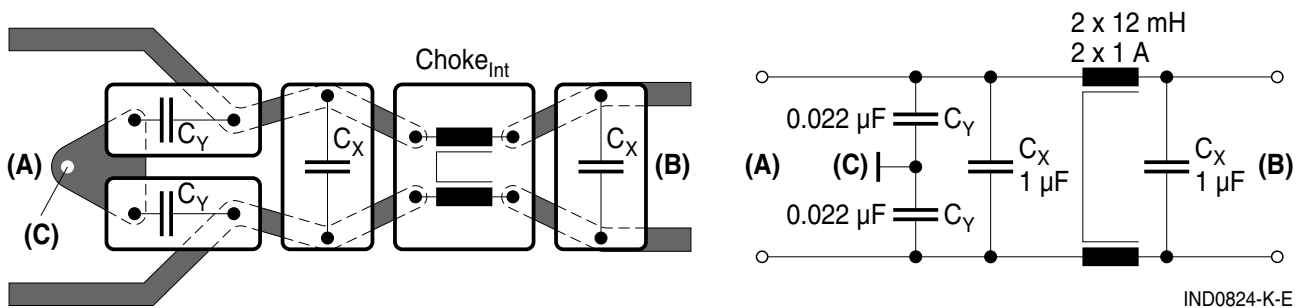


Figure 8 Correct arrangement of filter components, e.g. on a PC board

When using off-the-shelf filters, observe the following rules:

- Ensure a proper electrically conductive connection between the filter case and/or filter ground and the metallic case of the interference source or disturbed equipment, and
- provide sufficient RF decoupling between the lines at the filter input (line causing the interference) and the filter output (filtered line), if necessary by using shielding partitions.

4 Services

To support our customers with their EMC problems and to perform basic investigations on the application of EMC components, we operate a comprehensively equipped EMC laboratory in Regensburg (see section 6). Its facilities are used to prepare EMC solutions for equipment, plants and machines which are optimized in terms of applications and costs, thus assuring compliance.

Furthermore, we cultivate partnerships with other EMC testing laboratories, so that customers can obtain competent advice and support in their vicinity (www.epcos.com/testhouse).

5 Simulation at EPCOS

The circuit simulations performed during the development process are based on the SPICE program.

If a particular problem can be solved more quickly by simulation than by a laboratory set-up, initial data about the simulation object must be acquired. The accuracy of the ambient parameters as well as determination of the permissible tolerance of the results are particularly important in this case.

5.1 Simulation environment

The filters are modeled on the basis of real simulations of their components by means of suitable resistor, choke or capacitor models. If the accuracy is insufficient, side-effects are matched to and integrated with the measured reality by extending the simulation models.

At EPCOS, the following tasks are increasingly being solved with the aid of simulation.

- Speeding up development programs:
highly focused procedures are possible; fewer trials are required
- Cost reduction:
use of components can be optimized; more compact designs are possible
- Investigation and elimination of undesired side-effects:
complex test configurations are avoided
- Simulation of the EMC components in their environment as a decision-making aid:
helping customers to select components for new developments; smaller number of different component samples
- Statistical evaluation with failure investigation for series manufacture:
fewer rejects; improvement of quality

5.2 Simulation level at EPCOS

When a component is modeled at EPCOS, it is based on high quality measurements on the one hand. On the other hand accurate equivalent circuit diagrams for filters and chokes are continuously improved. Together this results in models with increasing accuracy as best benefit for the customer.

Very high expenditures are required to provide our customers with component data to our usual high quality. In order to extend our know-how and experience in the field of simulation, we are very interested in working together in the sectors of simulation and modeling both with our customers and with external partners.

We can currently generate reliable models in the sector of small-signal analysis of chokes and filters. Although we do perform time domain simulations and improve our knowledge in the area of nonlinear, 3D-field and EMC simulation.

6 EMC laboratory

6.1 Qualification

The EMC laboratory Regensburg has been accredited as a test laboratory since October 1994. It was initially accredited according to the guidelines of the German Accreditation Committee (DAR) to DIN EN 45001, as was the first re-accreditation in 1999. It was then converted in 2002 to the new quality standard for laboratories DIN EN ISO/IEC 17025, on which the 2003 re-accreditation was also based. This accreditation assures the consistent independence, impartiality and integrity of the measurement and test results. The laboratory's many years of experience in the entire sector of EMC (first anechoic chamber in Europe 1963) and active cooperation in national and international EMC standardization committees represent an outstanding basis for satisfying customer requirements.

Comprehensive equipment is available in the laboratory (e.g. measuring equipment, test generators, anechoic chamber) for nearly all kind of conducted and radiated EMC tests. The test record which is compiled after successful conclusion of tests is recognized as a proof of conformity with the current EMC standards and regulations, which is a prerequisite for applying the CE mark to a device.

Our own development and production of EMC components ensure that all required interference suppression circuits can be implemented within a short period. A comprehensive stock of capacitors, chokes, filters and accessories is directly available on site.

Of course all devices, equipment and information entrusted to us by different customers will be treated with absolute discretion.

6.2 Services offered

EPCOS' EMC laboratory in Regensburg can assist electrical equipment manufacturers from the design stage right up to the market launch by providing the following services:

- Advisory and training services accompanying the development phase:
 - EMC testing of working development models
 - Recommendation of EMC protection measures such as shielding, grounding, earthing
EMC components (capacitors, chokes and filters)
customer-specific solutions
organisation measures
- EMC testing of prototypes:
 - EMC testing of equipment produced by manufacturing methods (preliminary or pilot series, prototypes)
 - recommendations for EMC measures, as above
- Fields of applications:
 - Industrial electronics
 - Automation and drives
 - Automotive
 - Consumer
 - Lighting

Electromagnetic compatibility (EMC)

Services

- EMC tests to enable a declaration of conformity to be made for the CE mark:
 - test report only lists results, no recommendations or suggestions
 - EMC laboratory is accredited by DAR (DATech)
- EMC tests on site, if useful because:
 - equipment power supply > 200 A on 440/250V power line
 - equipment cannot be transported or transport too expensive
 - EMC environment permits on-site testing

6.3 Solving problems by on-site measurements

In addition to the services offered by the EMC laboratory, EPCOS also offers to work directly together with the manufacturer of the equipment or installation. Our engineers have broad-based know-how in the entire field of EMC as well as extensive experience in the application of EMC components. Optimized and cost-effective results are achieved quickly thanks to the close cooperation between EPCOS and the equipment manufacturers.

- **Help in localizing interference sources**
- **Samples for interference suppression tests are provided; material is available for trial use**
- **Rapid implementation of optimized cost-effective solutions by experienced specialists**
- **Customer-specific components can be developed more quickly**
- **Recommendations for EMC measures such as shielding, grounding, EMC components and EMC filters**
- **Close cooperation between customer and EMC engineers**
- **Reduced development times thanks to problem simulation**

A wide selection of portable equipment is available so that the measurements and services listed above may also be performed

directly at the customer's premises.

6.4 Installations

The laboratory is equipped with an anechoic chamber with a 10-meter test section, three test units for conducted emission measurement in shielded cabins, and a remote-controlled 4.8 m turntable which can be loaded up to 4 tons.

Electromagnetic compatibility (EMC)

Services

6.5 Equipment

Measurement and test equipment for conducted EMC phenomena:

Emission		Immunity	
Measurement receivers	10 kHz to 30 MHz	Signal generators	10 kHz to 230 MHz
Network simulators	Up to 350 A, 690 V	Power amplifiers	25 W to 250 W
Oscilloscopes		Pulse generators	ESD EN 61000-4-2
Probes			Burst EN 61000-4-4
Clip-on probes			Surge EN 61000-4-5
Harmonics test unit	3 × 16 A	Coupling networks	
		Capacitive coupling clamp	
Flicker test unit	3 × 16 A	Inductive coupling clamp	

Measurement and test equipment for radiated EMC phenomena

Emission		Immunity	
Measurement receivers	10 kHz to 26 GHz	Signal generators	10 kHz to 4 GHz
Antennas	10 kHz to 18 GHz	Power amplifiers	25 W to 250 W
Absorbing clamps	30 MHz to 1000 MHz	Antennas	
		Directional couplers	
		Supplementary absorbers	

Selection of tests performed in the EMC laboratory:

- **Conducted emission test under rated load**
- **Radiated emission measurements with 10 m test distance**
- **Radiated immunity test up to 20 V/m below 1 GHz and up to 10 V/m from 1 GHz to 4 GHz**
- **Harmonic current in low-voltage power supply systems up to 16 A**
- **Flicker**
- **Tests at voltage dips, fluctuations and short-time interruptions**
- **Burst**
- **Surge**
- **ESD**

Figure 8 Selection of tests performed at the EMC laboratory in Regensburg

Electromagnetic compatibility (EMC)

Services

A range of auxiliary equipment is already available on the premises to simplify the tests as far as possible for our customers while still performing measurements under real conditions. These include:

- Load installations for converter test up to 90 kW
- Power supply up to 100 A
- Exhaust gas suction
- Transformers for performing measurements at various rated voltages (up to 690 V)
- Water supply for devices under test.

The laboratory is located on the ground floor. Large gates allow access for bulky or heavy installations at ground level.

Whether we perform investigations during the development process or final EMC tests – the maintenance of a high quality level is a high priority for us. Regular calibration and internal inspections of our test equipment goes without saying. However, we place just as much importance on the experience and training of our staff. The documentation of the investigations/tests may be made available in either German or English as desired.

All equipment and information which is entrusted to us by our various customers is naturally treated with absolute discretion. We can also conclude a non-disclosure agreement with you if desired.

6.6 EMC laboratory, site plan

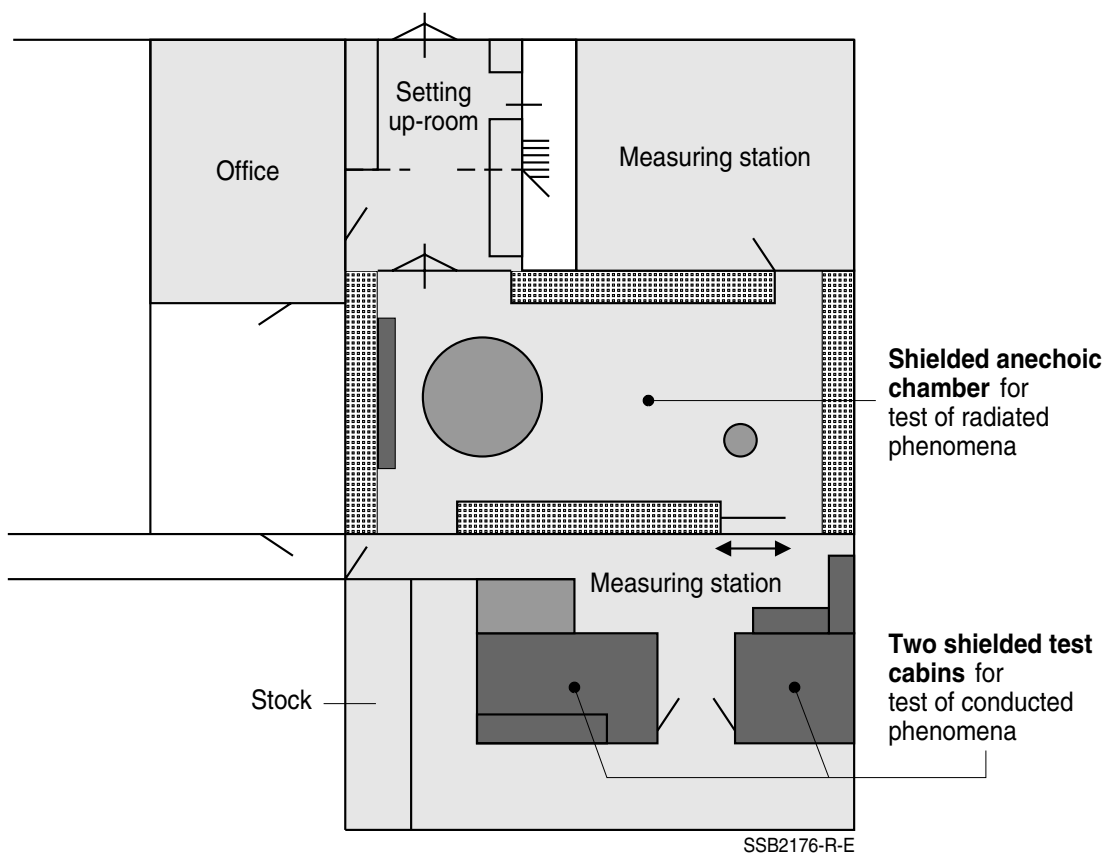


Figure 9 Site plan of EMC laboratory, Regensburg

For further information, refer to our brochure “EMC laboratory Regensburg”, edition 08.06, available in pdf format only under www.epcos.com/publications.

6.7 Accreditation document

Deutsche Akkreditierungsstelle Technik (DATEch) e.V.
Unterzeichner der Multilateralen Abkommen von EA und ILAC zur
gegenseitigen Anerkennung

vertreten im

Deutschen AkkreditierungsRat



Akkreditierung

Die **Deutsche Akkreditierungsstelle Technik (DATEch) e.V.** bestätigt hiermit, dass das
Prüflaboratorium

EPCOS AG
Wernerwerkstraße 2
D-93049 Regensburg

die Kompetenz nach DIN EN ISO/IEC 17025 besitzt, Prüfungen in den Bereichen

Elektromagnetische Verträglichkeit (EMV)

nach den in der Anlage aufgeführten Normen und Spezifikationen auszuführen.

Die Akkreditierung ist gültig bis: **05.10.2009**

Die Anlage ist Bestandteil der Urkunde und besteht aus **10** Seiten.

DAR-Registriernummer: **DAT-P-101/99-01**

Frankfurt/Main, 06.10.2004



i.V. Dipl.-Ing.(FH) R. Egner
Leiter der Akkreditierungsstelle

Mitglied im EA, ILAC, IAF

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Figure 10 Certificate of the Regensburg EMC laboratory

6.8 Partnerships with other EMC testing laboratories

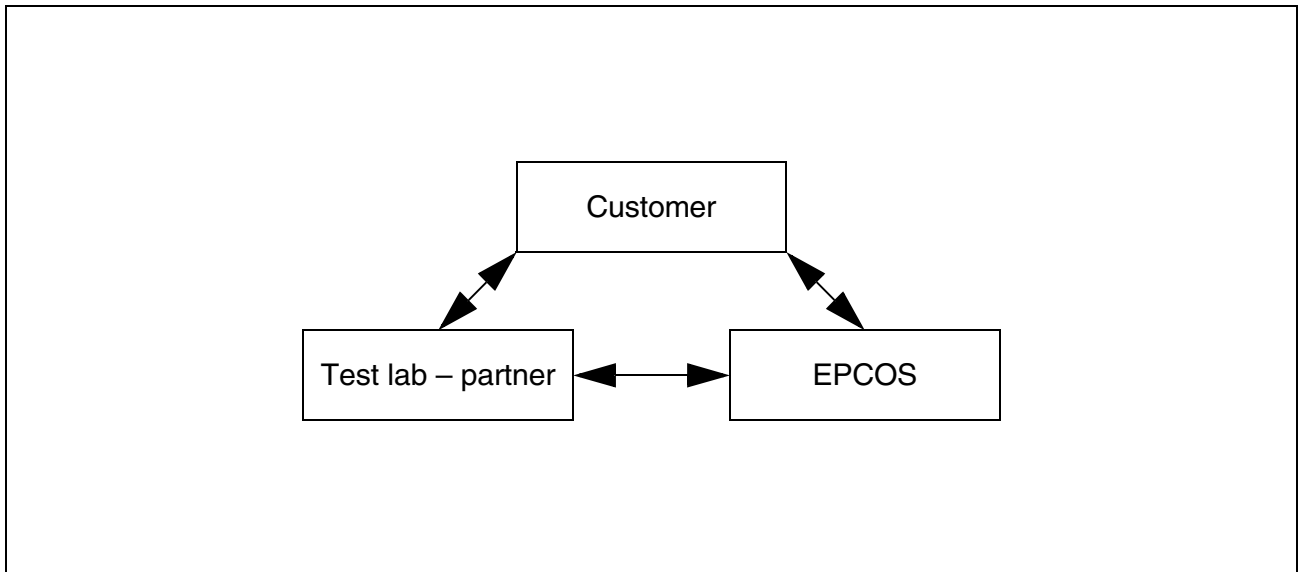
Close co-operation with our customers is indispensable, particularly in the field of EMC, if economically sound and technically optimized solutions are to be found. In order to ensure this, we have developed a concept based on partnerships with EMC testing laboratories. This enables competent EMC advice and problem-solving to be carried out in the vicinity of our customers, parallel to their on-going development work.

This concept encompasses:

- **Faster design-in.**
The selected EMC testing laboratories have a stock of samples of our EMC components. This facilitates interference suppression measurements and enables EMC solutions to be found more quickly.
- **We are closer to our customers.**
The fact that our partner testing laboratories are highly competent and are located close to our customers is an ideal way of facilitating EMC support for on-going development work.
- **Competent EMC advice.**
A regular flow of information, support and mutual EMC training measures and seminars ensure constant high quality.

Upon request, EPCOS can also provide material and personal assistance.

Concept for partnerships with EMC testing laboratories:



Our contract partners

You will find the up-to-date list of our contract partners in the internet under: www.epcos.com/testhouse.