

## EMC Standards and Their Application

Without EMC—no market access! Yes, that is the fundamental concept for manufacturers of electrical apparatus and systems to remember. It is therefore necessary to stay current on EMC requirements and standards and to try to understand how each applies to different types of equipment.

Regulations may be mandatory, like U.S. FCC requirements and European EC Directives, or voluntary, like VCCI approval in Japan. In either case, following EMC regulations may impart a market advantage.

Standards are voluntary to use but are recommended as a reference for verification of compliance with regulations. Basic standards describe test procedures, and in some cases test instrumentation and calibration techniques, while more specific product or application standards usually define limits, severity levels, and compliance criteria. This article provides an overview of EMC standards and their use for verifying compliance with regulations.

### Electromagnetic Compatibility—Some Fundamental Concepts

EMC stands for *electromagnetic compatibility* and is defined as the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances to anything in that environment. EMC requirements concern two basic concepts: emissions and immunity or susceptibility.

Electromagnetic disturbance is any phenomenon that may degrade the performance of a device, equipment, or system, or adversely affect living or inert matter.

Electromagnetic interference (EMI) is the degradation of the performance of a device, transmission channel, or system caused by an electromagnetic disturbance. In certain parts of the world, "EMI" is used to characterize emissions. This may lead to confusion when it comes to the characterization of immunity, which is sometimes called EMC!

Electromagnetic disturbances can be conducted or radiated, and the emissions and immunity requirements are referred to in military standards (MIL-STD 461/462) as CE/RE (conducted emission/radiated emission) and CS/RS (conducted susceptibility/radiated susceptibility), respectively.

Disturbances may represent low-frequency (LF) and/or high-frequency (HF) phenomena, as well as broadband and/or narrowband. Broadband disturbances can originate from commutator motors, ignition systems, arc welding equipment, etc.; narrowband from digital electronic circuitry, switched-mode power supplies, and radio communication equipment. Computers have often been reported to cause interference with radio services, including police, aeronautical and broadcast services. On the other hand, radio transmission by a high-frequency carrier, such as a 900 MHz cellular or a 1.8 GHz DCS, can cause problems in computers and all electrical circuits because the carriers are easily picked up by cables and apertures functioning as antennas and are demodulated in electronic circuits by different nonlinear electromagnetic phenomena.

To really understand how electromagnetic disturbances emanate, propagate, and influence electrical systems, one must have a thorough knowledge of electromagnetic field theory and high-frequency phenomena. EMC represents a broad field of technology and may represent a new subject for many manufacturers of electrical products. However, if one follows certain rules of thumb regarding wiring, PCB layout, grounding and shielding, and usage of RFI suppression components, it is not difficult to cope with different EMC standards and regulations.

In industry, it is assumed that electronic control systems can be used in conjunction with interfering switching operations, motor drives, high-frequency ovens, welding equipment, etc. In a car, electronic automatic systems must function when we use our mobile phone or meet other vehicles (with interfering ignition systems). An electronically controlled wheelchair is presumed to function normally even when the person sitting in the chair uses a mobile phone or a portable PC. We demand that life-supporting electromedical apparatus in a hospital function safely even near high-frequency—radiating surgical equipment.

### U.S. Requirements

The general EMC requirements in the U.S. are set by the Federal Communications Commission (FCC), while the Food and Drug Administration (FDA) regulates medical products. Mandatory FCC requirements primarily concern computing devices, defined as any electronic device or system that generates and uses timing pulses at a rate in excess of 9000 cycles per second and uses digital techniques. FCC Part 15 covers radio frequency devices capable of emitting RF energy in the range of 9 kHz—200 GHz. Testing should be done according to ANSI C63.4-1992.

Part 18 covers industrial, scientific, and medical (ISM) equipment (Figure 1), defined as any device that uses radio waves for industrial, scientific, or medical purposes and is not intended for radio communications. While most FCC regulations only concern emissions, FDA also requires immunity for certain life-support equipment. FCC Parts 15 and 18 include regulations as well as technical aspects and limits. FCC Part 68, which governs the technical requirements for registration of telecom terminal equipment, includes lightning surge tests (surge immunity).

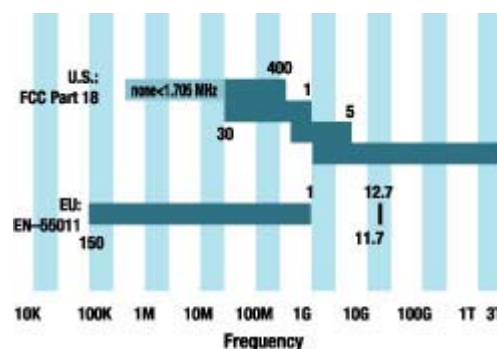


Figure 1. Required frequency range of radiated measurements—ISM.

FCC Part 15 currently has three different procedures for showing conformance:

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- Verification, where the manufacturer or the importer files a test report showing compliance.
- Certification, which requires a review of the application by the FCC, and the use of a unique FCC identification number.
- Declaration of Conformity (DoC), which requires that tests are performed by a test lab accredited by A2LA or NVLAP (other accredited labs may also be accepted).
  
- The following represents an example of the FCC's classification system, where the correct administrative procedure is listed according to product type (Class A refers to nonconsumer products, Class B to consumer products):
  
- Personal computers and peripherals (Class B): Certification or DoC.
- Cpu boards and internal power supplies used with personal computers (Class B): Certification or DoC.
- External switching power supplies (Class A and B): Verification.

The FCC is currently reviewing these procedures with the aim of simplifying them by reducing the number of categories.

**EU Requirements**

The European EMC Directive, 89/336/EEC, sets out the legal requirements on EMC for principally all electric/electronic equipment to be placed or used in the Common Market/ European Economic Area. The European legislation covers emissions as well as immunity.

The EMC requirements are valid for apparatus and systems placed on the market as complete units. Components such as resistors, transistors, or display units are not included. However, components with a direct function to the end-user, like plug-in PC boards, are regarded as equivalent to apparatus and have to follow the same rules (see Table I).

<b>Scope of Regulation— Device Types</b>	<b>FCC</b>	<b>EU EMC</b>
<b>Unintentional Radiators</b>		
Appliances and/or digital circuitry inside	No	Yes
Automotive digital electronics	No	Yes, Auto EMC Directive
Devices with power <6 n W	No	No
Components	No, except cpu boards and power supplies	Yes, if it has a direct function
Electromechanical	No	Yes, except for induction motors

Kits	No, except TV interface device	Yes
Fluorescent lamps, fixtures	No (unless RF ballast)	Yes
Marine digital electronics	No	Yes, Marine Equipment Directive
Medical digital devices	No	Yes, Active Implantable, or Medical Devices Directives
Test equipment	No	Yes
Controls in industrial plants	No	Yes
Battery operated clock <1.705 MHz	No	Yes
Digital devices, PCs, peripherals	Yes	Yes
<b>Intentional Radiators</b>		
Amateur radio transmitters	No, except commercial power amplifiers	No, except EMC for commercial transmitters
Short-range devices	Yes, Part 15	ETS 300, 220, 328, 330, 440, 445, or national rules
High power transmitters	Yes, other FCC Parts	ETSI or national rules

*Table I. Scope of FCC and EU EMC regulations for unintentional and intentional radiators.*

New EEC Directives only set out essential requirements and legal aspects (New Approach). Technical aspects are dealt with in specific standards, the application of which is voluntary. These standards are developed by specific bodies, such as CENELEC or ETSI, and are harmonized to the directives by the action of the European Commission. The EMC Directive itself, however, is based on a presumption principle, which means that a product that meets the requirements of the harmonized standards is also presumed to meet the essential requirements of the EMC Directive.

### **Standardization**

Under the General Agreement on Tariffs and Trade (GATT) and its successor, the World Trade Organization (WTO), member countries are obliged to adopt international standards for national use wherever possible. International standards concerning EMC are primarily developed by the International Electrotechnical Commission (IEC) and the International Special Committee on Radio Interference (CISPR). The new extensive series developed by IEC includes

- IEC 61000-1—Introduction, terms, and conditions.
- IEC 61000-2—Classification of electromagnetic environments.
- IEC 61000-3—Limits and disturbance levels.
- IEC 61000-4—Testing and measurement techniques.
- IEC 61000-5—Installation and mitigation guidelines.
- IEC 61000-6—Generic standards.

Some specific EMC standards have also been published by the International Organization for Standardization (ISO). North American EMC standards are published by the FCC, the American National Standards Institute (ANSI), and the Institute of Electrical and Electronics Engineers (IEEE). Private standards are submitted by Bellcore (for telecom equipment), the Society of Automotive Engineers (SAE) and automotive manufacturers, and the U.S. Department of Defense.

European EN standards concerning EMC are developed by the European Committee for Electrotechnical Standardization (CENELEC).

Regulations and standards concerning telecom and radio transmitting equipment are published by the International Telecommunications Union (ITU) and the European Telecommunications Standards Institute (ETSI).

International and European EMC standards are to a great extent becoming harmonized, due to the fact that many EN standards are based on IEC and/or CISPR standards. There are also similarities between international and U.S. standards, though they are not equivalent. Figure 2 shows some intercompatibility problems between similar emission standards (FCC Part 15 J and CISPR 22 limits, respectively, measured at a distance of 10 m). FCC, however, accepts conformity to CISPR 22: 1985 as an alternative to FCC Part 15 (sections 15.107 and 15.109).

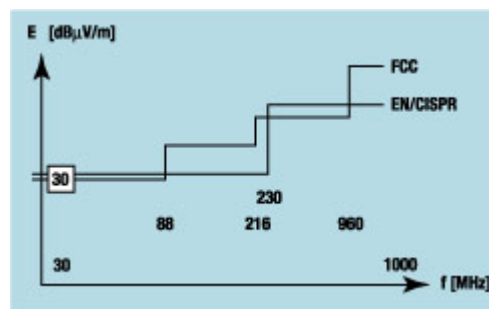


Figure 2. Emission limits compared at a measuring distance of 10 m.

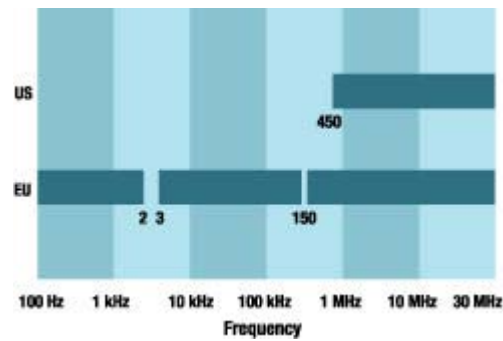


Figure 3. Required frequency range of conducted measurements.

EMC standards are continuously being developed and revised, and the standards "jungle" sometimes seems a bit difficult to get through. It is therefore important to keep track of standards' publication dates, in addition to knowing if a new standard is to be expected in the near future and when an old standard is no longer valid. The following dates are of specific interest in regard to a standard: date of publication (dop) and date of withdrawal (dow) of a conflicting (earlier) standard. Draft standards are sometimes called preliminary, for example prETS or prEN. Temporary EN standards are called ENV.

### Standard Requirements

Standards are principally divided into the following main groups:

#### *Generic/General Standards*

Generic standards refer to the electromagnetic environment in which the apparatus/system is to be used. General standards concern groups of equipment used for general applications in a specific environment, like general telecom equipment and medical and laboratory equipment.

#### *Basic Standards*

Basic standards describe measuring methods and, in some cases, interference levels as well as limits. One of these is the standard series IEC 801-X for process industrial applications, which has been converted into a general series of basic standards, IEC 61000-4-X, which were then translated into European standards as EN 61000-4-X.

#### *Product and Product Family Standards*

These are applicable for specific product types, which are specified within the scope of the standard.

In addition to these standard documents, there are also standards offering guidance on installation techniques, or a code of practice, for example the IEC 61000 series, Part 5 (IEC 61000-5-X).

### EMC Standards Classification

Generic standards have two environmental classes:

1. Residential, commercial, and light industrial environments, including domestic, office, laboratory, and light industrial environments where the apparatus or system is connected to the public mains.
2. Industrial environments, meaning "heavy" industrial environments with separate transformer stations for mains supply, usually with equipment spread over some distance.

This simplified view of the world as one of two categories does not hold true in all cases. There are so-called gray zones such as laboratory or hospital environments where equipment may be connected either to the public mains or to an in-house power net, through a separate transformer station.

CISPR standards concerning emissions, and to some extent corresponding EN standards, have a classification according to the following:

**Class B/CISPR 22**

Information Technology Equipment (ITE) intended primarily for use in domestic environments and may include portable equipment, telecommunications terminal equipment, personal computers, and auxiliary connected equipment.

**Class A/CISPR 22**

ITE, which satisfies Class A but not Class B limits.

The following warning shall be included in the instructions for use: This is a Class A product. In a domestic environment this product may cause radio interference, in which case the user may be required to take adequate measures.

**Class B/CISPR 11**

ISM equipment suitable for use in domestic establishments and in establishments directly connected to a low-voltage power supply network.

**Class A/CISPR 11**

ISM equipment suitable for use in all establishments other than domestic and those directly connected to a low-voltage power supply network.

The emission limits differ 10 dB between Class A and Class B equipment, as well as between the generic emissions standards for the "light" and "heavy" environments, respectively, when referred to the same measuring distance. When recalculated from 10 to 3 meters distance, there is a difference in radiated emissions of 9.5 dB. It should also be noted that the classification of computing devices according to FCC 15, and ISM equipment to FCC 18, is very similar to that of CISPR 22 and CISPR 11 Group 2.

**Which Standards Apply?**

A product standard is one that covers all EMC requirements for a certain product type. In some cases, product standards also cover electrical safety requirements. A product standard takes preference over all other standards. Once it is determined that a product is within the scope of an applicable product family standard concerning emissions and/or immunity, then that standard should be followed. Some examples of family standards include

- CISPR 11/EN 55011 Emission standard for industrial, scientific, and medical (ISM) radio RF equipment (see Figure 3).
- CISPR 12 Emission standard for vehicles, motorboats, and spark-ignited engine-driven devices.
- CISPR 13/EN 55013 Emission standard for broadcasting equipment like radio, television, etc.
- CISPR 14/EN 55014 Emission standard for household apparatus and portable tools.
- CISPR 15/EN 55015 Emission standards for luminaires.
- CISPR 20/EN 55020 Immunity standard for broadcasting equipment, such as radio and television.
- CISPR 22/EN 55022 Emission standard for information technology equipment (ITE).
- CISPR 24/EN 55024 Immunity standard series for ITE.

Newer product family standards also tend to appear as complementary emissions and immunity standards:

- EN 55014-1, EN 55014-2 Emissions and immunity requirements for household apparatus and portable tools.
- EN 55103-1, EN 55103-2 Emissions and immunity requirements for professional audio and video equipment.

Specific types of product family standards transferred into general standards include:

- IEC 555-2/EN 60555-2 LF emissions standard concerning harmonics for household products, etc.
- IEC 555-3/EN 60555-3 LF emissions standard concerning flicker and voltage variations for household products, etc.
- IEC 61000-3-2/EN 61000-3-2 General LF emissions standard concerning harmonics.
- IEC 61000-3-3/EN 61000-3-3 General LF emissions standard concerning flicker and voltage variations.

Today, however, very few pure product standards exist that cover all requirements. Therefore one has to look for an applicable product family standard. An additional complication is that, for the time being, a product can sometimes belong to different product family standards. For example, most household devices must fulfill emissions requirements according to EN 55014-1, as well as EN 60555-2 and EN 60555-3 or EN 61000-3-2 and EN 61000-3-3.

### **Generic/General Standards**

If no product family standard is applicable, one must follow the suitable generic or general standard, which in turn refers to different basic standards. Some of the product family standards are also referred to in other standards, which consequently gives them characteristics of basic standards.

The generic standards include:

- EN 55081-1 Emissions standard for residential, commercial, and light industrial environments.
- EN 55081-2 Emissions standard for industrial environments.
- EN 55082-1 Immunity standard for residential, commercial, and light industrial environments.
- EN 55082-2 Immunity standard for industrial environments.

The IEC is also developing corresponding generic standards, which will be numbered IEC 61000-6-X. A general EMC standard that covers emissions and immunity for medical equipment is EN 60601-1-2, the collateral standard for medical equipment. In addition to this collateral standard, there are a number of product standards covering safety and EMC for specific medical equipment, like EN 60601-2-24, which covers infusion pumps and controllers.

A general EMC standard that covers emissions and immunity for TTE equipment is ETS 300 339 (general standard for radio transmitting equipment). In addition to this standard, there are a number of ETS/prETS standards covering EMC for different telecom and radio transmitting equipment.

As far as the emissions requirements are concerned, the generic standard is more rigorous in regard to light industrial environments than on heavy industry, which as a rule is already rather electromagnetically contaminated. As far as the immunity requirements are concerned, the situation is the opposite. Interference immunity must be harder in heavy industrial environments.

What then is applicable in mixed or special environments? When using the generic standards it is recommended to begin with the most strict requirements, which means that the equipment should be classified according to the "worst" combination, such as EN 50081-1/EN 50082-2. This scenario has sometimes been used for equipment in hospital environments.

### **Basic Immunity Standards**

The IEC standardization committee for industrial processing techniques, TC 65, drafted the first basic standards for immunity to electrical disturbances. This responsibility has been taken over by the committee that works with general EMC standards, TC77 (IEC) and TC 210 (CLC). With this, the publication numbers changed from IEC 801 to IEC 1000/61000 and EN 61000, and thus far the disturbance types that have been dealt with have gone through the following changes:

#### 1. Electrostatic discharges (ESD).

- IEC 801-2, ed. 1.
- IEC 801-2, ed. 2=IEC 61000-4-2=EN 61000-4-2.

2. Radiated, radio frequency electromagnetic fields (RF fields).

- IEC 801-3.
- ENV 50140~IEC 61000-4-3=EN 61000-4-3.

3. Electrical fast transients/burst (EFT).

- IEC 801-4.
- IEC 61000-4-4=EN 61000-4-4.

4. Surges (1, 2  $\mu$ s/50  $\mu$ s).

- ENV 50142~IEC 61000-4-5=EN 61000-4-5.

5. Immunity to conducted disturbances induced by radio frequency fields.

- ENV 50141~IEC 61000-4-6=EN 61000-4-6.

6. Immunity to magnetic fields.

- IEC 61000-4-8, IEC 61000-4-9, and IEC 61000-4-10=EN 61000-4-8, IEC 61000-4-9, and IEC 61000-4-10.

7. Voltage dips, short interruptions, and voltage variations.

- IEC 61000-4-11=EN 61000-4-11.

Because some generic standards and some product standards have been published at the same time as the aforementioned revised standards, we will have to live with references to new, as well as old, basic standard versions for some time.

### Conclusion

EMC regulations will be successively refined. We are going to see a whole series of new standards and amendments during the next few years. In many cases new standards will mean increased testing requirements. And while these testing requirements might not be welcomed by all manufacturers, they will benefit the end-users of electrical equipment.