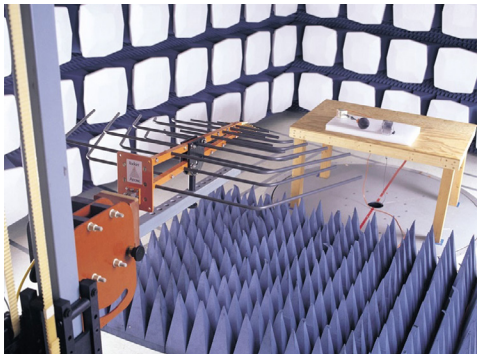
EMC Standards Overview



Electromagnetic Compatibility (EMC) can be defined as the ability of electronics and electrical equipment to operate in their intended environments without suffering unacceptable performance degradation or unintentionally causing performance degradation in other equipment operating in the same shared environment.
Performance degrading threats can be naturally occurring or man-made and can be categorized into 4 types of tests: Radiated Immunity (1), Radiated Emissions, Conducted Immunity, and Conducted Emissions. The tests for EMC are defined in various standards and adopted by numerous organizations. It is imperative that products meet the requirements set forth in these standards, because, among basic interoperability, public safety also relies on the products to perform as intended.

With such a vast array of differing electrical and electronic systems available on the market, all with their own specific needs in terms of EMC, it should be no surprise that there are a sizable number of EMC test standards available. Unfortunately, keeping track of and knowing which standards to apply can be a difficult task in and of itself. Below is an overview of some of the more common standards used across the industry.

(1) The terms Immunity and susceptibility may be used interchangeably throughout this application note. The term 'susceptibility' is used more commonly in military and aviation standards, whereas commercial standards will typically use the term 'immunity'.

1.0 Major International Standards Organizations

To maintain the many standards relating to EMC testing, several organizations, both domestic and foreign, serve as governing bodies for distinct categories of standards.

1.2 International Electrotechnical Commission (IEC)

The IEC is an international organization which prepares and publishes international standards for all electrical, electronic, and related technologies (1). Included in these standards are three categories specific to EMC:

- Basic Standards
  - Basic EMC standards give general rules for achieving EMC. These standards serve as a reference, including definitions of terminology, descriptions of the electromagnetic disturbance under question, measurement and testing techniques, suggested limits that must be adhered to, as well as providing guidelines on installation and mitigation. Therefore, they cannot be applied to a specific product or system. An example of a basic standard is IEC 61000-4-2 which describes the test and measurement techniques for performing the Electrostatic Discharge (ESD) test.
- Generic Standards
  - Generic standards pertain to a specific operating environment for which no specific EMC standards yet exist. They include EMC requirements and test procedures that are applicable to all products that would need to operate in the described environment. For example, IEC 61000-6-2 describes the required immunity tests for equipment to be installed in an industrial environment.
- Product Family Standards
  - Product family standards apply to specific products, or product families, and define test procedures that apply EMC limits for products that are within the scope of that family. For example, IEC 61326-1 is the product family standard for electrical equipment for measurement, control, and laboratory use.

Prior to publishing the standards, the IEC forms and oversees committees which are responsible for developing EMC standards. These standards are either adopted in whole or harmonized with national standards by various governing bodies throughout the world. The two major committees are the International Special Committee on Radio Interference (French title acronym is CISPR) and Technical Committee 77 (TC 77).

CISPR's principal task is at the higher end of the frequency range, from 9 kHz - 400 GHz, preparing standards that offer protection of radio reception from interference sources generated by electrical appliances of all types, the electrical grid system, industrial, scientific, and medical (ISM) RF, broadcasting receivers (sound and TV) and, increasingly, IT equipment (ITE) (2). CISPR typically develops Product Standards for both immunity and emissions.

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The other major committee, TC 77, primarily develops Basic and Generic EMC publications with a focus on immunity EMC requirements and environments, though TC 77 also produces product-family standards covering low-frequency emissions and product immunity standards. TC 77 is broken into three subcommittees:

- SC 77A focuses on low-frequency (up to and including 9 kHz) phenomena
- SC 77B focuses on high-frequency continuous and transient phenomena (greater than 9 kHz), including electrostatic discharge (ESD)
- SC 77C focuses on high-power transients such as those resulting from High-altitude Electromagnetic Pulses (HEMP)

Examples of common IEC and CISPR standards are given in Tables 1 and 2, respectively.

Table 1: Common IEC Standards

Document Number	Subject
IEC 61000-1-X	General Requirements (Basic Concepts, Functional Safety, and Measurement Uncertainty)
IEC 61000-2-X	Environments (Description, Classification, and Compatibility levels)
IEC 61000-3-X	Limits (Emissions and Immunity)
IEC 61000-4-X	Testing and Measurement Techniques
IEC 61000-5-X	Installation and Mitigation Guidelines
IEC 61000-6-X	Generic Standards (Generic Emissions and Immunity Requirements in Various Environments)
IEC 60601-X-X	Medical electrical equipment, Part 1-2: General requirements for basic safety and essential performance, Collateral Standard: Electromagnetic disturbances, Requirements and tests
IEC 61326-X-X	Electrical Equipment for Measurement, Control and Laboratory Use, EMC requirements

Table 2: Common CISPR Standards

Document Number	Subject
CISPR 11	Industrial, scientific and medical (ISM) equipment, Radio-frequency disturbance characteristics, Limits and methods of measurement
CISPR 12	Vehicles, boats, and internal combustion engines, Radio disturbance characteristics, Limits and methods of measurement for the protection of off-board receivers
CISPR 14-1	Electromagnetic compatibility, Requirements for household appliances, electric tools, and similar apparatus, Part 1: Emission
CISPR 14-2	Electromagnetic compatibility, Requirements for household appliances, electric tools, and similar apparatus, Part 2: Immunity
CISPR 15	Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment
CISPR 16-1	Specification for radio disturbance and immunity measuring apparatus and methods, Consists of six parts which specify the voltage, current and field measuring apparatus, and test sites.
CISPR 16-2	Specification for radio disturbance and immunity measuring apparatus and methods, Consists of five parts specifying the methods for measuring high-frequency EMC phenomena
CISPR 16-3	Specification for radio disturbance and immunity measuring apparatus and methods, This is an IEC Technical Report containing specific reports and information on the history of CISPR
CISPR 16-4	Specification for radio disturbance and immunity measuring apparatus and methods, Consists of five parts containing information regarding uncertainties, statistics and limit modeling
CISPR 25	Vehicles, boats, and internal combustion engines – Radio disturbance characteristics, Limits and methods of measurement for the protection of on-board receivers
CISPR 32	Electromagnetic compatibility of multimedia equipment, Emission requirements
CISPR 35	Electromagnetic compatibility of multimedia equipment, Immunity requirements

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1.3 International Organization for Standardization (ISO)

A sister organization to the IEC, ISO also is an international organization which develops and publishes international standards. Like the IEC, the ISO develops standards for a multitude of applications, which include EMC. Where the IEC focuses solely on electrotechnical standardization, ISO goes further by not limiting themselves to one industry. ISO standards can be found in nearly any discipline throughout the world, including (but not limited to) sustainable development, food, water, cars, climate change, etc. Although EMC is only a small part of ISO's domain standards are widely used and relied-upon in the international automotive industry.

1.4 International Telecommunication Union (ITU)

Another sister organization to the IEC (as well as the ISO), the ITU develops technical standards which focus on telecommunication networks and technology, thus allowing these products to interact without interfering with each other. This effort goes together with EMC as limiting emissions from electronic products will prevent interference of the aforementioned networks and technology. Again, the ITU maintains close connection with IEC and ISO to ensure commonality.

2.0 Major European Standards Organizations

European Committee for Electrotechnical Standardization (CENELEC)

Within the European Union, CENELEC is responsible for electrotechnical standardization. CENELEC develops voluntary standards, but primarily adopts (in part or entirely) international standards, often IEC and CISPR standards, as European norm (EN). This is done by publishing the standard in the Official Journal of the European Union and Directive 2014/30/EU. The main objective of Directive 2014/30/EU is to regulate the compatibility of equipment regarding EMC (4). Once these standards are published, applicable products are required, by law, to comply. The standards are also given an 'EN' number once published. For example, many of the published CISPR documents are renamed 'EN 550XX' where 'XX' is the CISPR document number (CISPR 11 becomes EN 55011, CISPR 12 becomes EN 55012, etc.). Finally, by showing compliance to all the applicable standards per Directive 2014/30/EU, a product can apply for and receive a CE mark, thus making it easier for businesses to sell their goods to customers throughout the European Single Market.

European Telecommunications Standards Institute (ETSI)

ETSI produces globally applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies (5). As with the ITU, ETSI's goal is to allow the interaction of ICT equipment without any unwanted interference. Typically, ETSI EMC standards can be recognized by having a document number with this format: ES 300 XXX.

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3.0 Major North American Standards Organizations

United States of America Department of Defense (DoD)

Within the DoD lies the Defense Standardization Program (DSP). The DSP is responsible for developing a large variety of standards, specifications, handbooks, and other documents for a wide range of applications. In terms of EMC, the two most common military standards are MIL-STD-461 and MIL-STD-464. Both documents describe a comprehensive array of immunity and emissions test methods and requirements (see Table 3 for the current list of MIL-STD-461 (Revision G) tests). The main difference between the two is that MIL-STD-461 is intended for controlling and demonstrating EMC on assemblies and subsystems and MIL-STD-464 focuses on total integrated systems.

Despite the intended application being for military use, both documents are free and available to the public. In fact, many countries around the world have adopted MIL-STD-461 and MIL-STD-464 for use in testing their military products for EMC.

Table 3: Required MIL-STD-461 Tests

Requirement	Description
CE101	Conducted Emissions, Audio Frequency Currents, Power Leads
CE102	Conducted Emissions, Radio Frequency Potentials, Power Leads
CE106	Conducted Emissions, Antenna Terminal
CS101	Conducted Susceptibility, Power Leads
CS103	Conducted Susceptibility, Antenna Port, Intermodulation
CS104	Conducted Susceptibility, Antenna Port, Rejection or Undesired Signals
CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation
CS109	Conducted Susceptibility, Structure Current
CS114	Conducted Susceptibility, Bulk Cable Injection
CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads
CS117	Conducted Susceptibility, Lightning Induced Transients, Cables and Power Leads
CS118	Conducted Susceptibility, Personnel Borne Electrostatic Discharge
RE101	Radiated Emissions, Magnetic Field
RE102	Radiated Emissions, Electric Field
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs
RS101	Radiated Susceptibility, Magnetic Field
RS103	Radiated Susceptibility, Electric Field
RS105	Radiated Susceptibility, Transient Electromagnetic Field

(2) Although previous revisions of MIL-STD-461 call out different frequency ranges, have different titles, etc, these have been removed to reflect the test method titles in the current revision of MIL-STD-461 (Revision G).

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Federal Communications Commission (FCC)

The FCC regulates interstate and international communications by radio, television, wire, satellite, and cable in all 50 states, the District of Columbia and U.S. territories. An independent U.S. government agency overseen by Congress, the commission is the United States' primary authority for communications law, regulation, and technological innovation (6). For purposes of EMC, the FCC can be considered analogous to the ITU and ETSI in that these organizations (FCC included) concern themselves with communication interference from ICT products and thus require these products to undergo emissions testing. The methods and limits of this testing are given in Code of Federal Regulations (CFR) Title 47 Part 15 which is free and available to the public. Depending on the type of device being tested, there are four methods of equipment authorization. These include:

- Verification
- Declaration of Conformity (DoC)
- Certification through the FCC
- Certification through Telecommunications Certification Body (TCB)

Details on what type of authorization is required for a certain device type and the necessary steps to achieve authorization can be found online through the Office of Engineering and Technology (OET).

American National Standards Institute (ANSI)

ANSI is an American organization that publishes standards for a wide range of applications over a wide range of product types. For EMC, ANSI has developed its own independent standards, as well as adopted international standards for recognition in the United States. ANSI is also deeply involved in accrediting programs that assess conformance to standards, including various ISO systems. ANSI is the US input to IEC and oversees the US National Committee and Technical Advisory Groups. An example of the breadth of ANSI's involvement in accreditation is in Normalized Site Attenuation (NSA), found in ANSI C63.4.
This is a measure of the attenuation of signals propagated over a site and compared with the theoretical attenuation of these signals over an ideal site. Many of the world's EMC standards reference ANSI's NSA method for determining the quality of the chamber intended to be used for EMC testing.

4.0 Lifecycle of EMC Standards

Technology, products, test methods and requirements are constantly evolving, so to keep up, EMC standards must adapt and adhere to these changes. As can be expected, with so many different standards and standards organizations in the world there are varying lifecycle procedures and durations associated with these different standards. However, most follow the same general process. For the sake of brevity, we will provide an overview of the lifecycle of an IEC publication (7).

- The first stage in developing a new IEC publication is known as the Preliminary Stage. This stage is used when all the details needed to fully realize a new publication have not yet been collected. This stage also applies to work items that have no target date. Depending on the subject of the work item, this stage can have a long duration.
- Once all the preliminary development for a standard is complete, the next step in producing a new IEC publication is to create a New Work Item Proposal (NP). This is known as the Proposal Stage. By submitting an NP to the IEC, the requestor is alerting the IEC that there is a need for a new standard, an update to an existing standard or a technical specification. If the NP is approved, the document moves to the Preparatory Stage.
- In the Preparatory Stage, a Working Draft (WD) of the new or updated publication is prepared. Once the WD is complete, it moves to the Committee Stage.
- In the Committee Stage, the document is submitted as a Committee Draft (CD) to the National Committees for comment and will be available for 12 months. Here, comments from the various committees are returned to the document originator and compiled.
- Next, the document moves to the Enquiry Stage where a Committee Draft for Vote (CDV) is submitted to the National Committees. This is the final opportunity for technical comment. If the document receives a majority vote, a revised version of the document, with incorporated comments, will be submitted for Final Draft International Standard (FDIS) processing. Note that if a CDV is approved unanimously, the document moves straight to publication.
- In the Approval stage, the FDIS (with incorporated comments) is circulated for vote. If it receives a majority positive vote, the FDIS is published.

While there is not necessarily a defined lifecycle duration from standard to standard, once a standard is approved, a stability date is assigned. Typically, this stability date is at least 5 years.

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5.0 What Version of the Standard Should I Use?

With so many standards constantly evolving and changing, it is imperative to know which version of the required standards you should be testing to. Two general rules of thumb can be stated. If military testing is required, ensure that you test to the exact revision stated in the contract. Often times, military contracts will require products to be tested to outdated versions of military standards, so, unless there is a clause within the contract or there is customer permission in place to test to a standard other than what is listed in the contract, test to exactly what the contract dictates.

On the other hand, if a product is required to be tested to commercial standards (IEC, EN, FCC, etc.), two things need to be taken into account. If the product is being tested to a product family standard, then the product must be tested to the individual test standard versions listed in the product family standard. Otherwise, always test to the latest version of the standard(s) in question. This is required by Directive 2004/108/EC, as well as other organizations such as the FCC. Because of this, it is important to be cognizant of the latest standards immediately prior to any test that is to be performed. Additionally, when new versions of standards are released, an evaluation must be done to determine whether a product tested to the previous standards meets the updated requirements. If the product does not meet the new requirements, a redesign is required, and then a retest will need to be performed in a timely fashion to show compliance of the new design. Some organizations, such as the FCC, will sanction fines for products that are non-compliant to the current standard.

11. Major Product Segments and Their Standards

- Automotive
  - ISO, Soceity of Automotive Engineers (SAE) and CISPR
  - Many auto manufacturers have developed their own standards
- Aviation
  - RTCS DO-160, EUROCAE/ED-14G
- Military
  - MIL-STD-461, MIL-STD-464, DEF STAN
- Medical
  - IEC 60601
  - US FDA and EU Directive
- Instrumentation, Scientific, Medical (ISM)
  - IEC, CISPR and FCC Standards
- Multimedia
  - Information Technology - FCC, CISP 22 (emissions) & 24 (immunity)
  - Audio Video - FCC, CISPR 13 (emissions) & 20 (immunity)
  - Combined - FCC, CISPR 32 (emissions) & 35 (immunity

Conclusion

Keeping up with the latest applicable EMC standards for your product can feel like a daunting task, however, knowing how to categorize and where you want to market your product is half of the battle. In many cases, simply knowing these two elements will lead you to the requirement specifications. Knowing the requirements is only the first step, though, so it is up to you to create a design that will allow the product to meet those requirements.

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