EMC

EMC (Electromagnetic Compatibility) is the name given to the ability of electrical and electronic systems to work correctly when they are close together. This is why you are asked to turn off mobiles, etc on aircraft and sometimes in hospitals – you don’t want interference to cause a crash or a pacemaker to malfunction. So any equipment you design needs to be able to operate correctly when near other equipment (survive interference) and also needs to not cause other equipment to malfunction (not generate interference).

This interference can come in many forms and so there are various standards and legal requirements to allow interoperability.

Electromagnetic compatibility itself is defined as:

"the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment."

http://www.iec.ch/emc/explained/environment.htm

Typical sources of interference include, for example, power lines, electronic circuits, electric motors, radio and radar transmitters. Equipment that is disturbed, often called 'victim' equipment by EMC specialists, can include virtually anything that uses or can detect EM energy, such as radio receivers, domestic appliances or electronic circuits of any kind.

One example that I was aware of was that there was a particular street where people were unable to lock or unlock their cars with the remote. Parking a few metres away resolved the problem. The source of this problem? Local interference caused by a wireless burglar alarms battery going flat and causing the transmitter to drift.

Standards bodies

There are many bodies that can generate standards. Here are some common ones:

ISO International Standards Organization
OIML International Organization of Legal Metrology
ETSI European Telecommunications Standards Institute
FCC Federal Communications Commission
BSI British Standards Institute

Making stuff around the world

Taken from guide_to_global_emc_requirements_2007 IEEE

The first task is to identify the countries in which your company’s products are to be sold.
Then you need to determine what EMC compliance requirements (if any) must be met before the products can be marketed in those countries.

Let’s assume that with all of its products, your company always carries out complete EMC testing for the US and EU. Is that enough to allow you to place products everywhere in the world? Unfortunately, it is not. Many countries that require EMC compliance also impose additional hurdles to market entry in terms of deviations to international standards, in-country testing or country presence. Fortunately, there are also simplifying arrangements and agreements that can leverage your EMC testing to cover larger geographical or market areas. They are found under the broad umbrella term MRA (Mutual Recognition Agreements or Arrangements).

**Regulatory compliance procedures**

Countries or regions that regulate product EMC will typically employ one or more of three procedures to determine compliance with national or regional requirements. The particular procedure may depend on product type.

- **Verification** – the product is tested to the applicable EMC standard(s) and brought to market bearing appropriate regulatory marks and/or statements under the vendor’s or importer’s authority (the “responsible party”).

- **Declaration of Conformity** – the vendor or other responsible party declares conformity of the product to the relevant standard(s). Some jurisdictions require accredited testing (US) while others do not. The product may then need to be registered with the regulator (Australia, for example) or not (US for EMC). Regulatory marking and user information are a part of the process.

- **Certification** - the test report from an accredited or recognized laboratory, along with other technical information about the product, is presented to an independent third party for examination against the requirements. If the product complies, it is certified and listed with the regulator. The product may bear the certifier’s mark. Product surveillance may also be a part of the certification process.

It’s not always easy for the regulatory compliance engineer or manager to determine the applicable standards, compliance procedures and contact information for each target country or region. Fortunately, there are simplifying frameworks to lighten the burden.

**Regulatory compliance frameworks**

Mutual Recognition Agreements or Arrangements (MRAs) are multilateral agreements among countries or regions which facilitate market access for signatory members. MRAs can cover the mutual recognition of product testing, certification or both.

However, the existence of an MRA does not imply harmonization of the standards among the participants. For example, the interpretation of appropriate Class A or Class B emission limits in a commercial environment can differ between the US and the EU, as reflected in their respective standards and illustrated below:
Some of the terms common to existing MRAs include:

- Agreement: Binding on participating parties
- Arrangement: Voluntary participation
- CAB: Conformity Assessment Body. A CAB can be either a tester or a certifier or both. In the case of US Telecommunication Certified Bodies (TCBs) and Canadian Certification Bodies, the certifier must also be an accredited test lab. The accreditation criterion for testers is ISO 17025 and for certifiers it is ISO Guide 65.
- Phase I: The MRA partners agree to recognize each other’s test reports
- Phase II: The MRA partners agree to recognize each other’s test reports and certifications (where needed).

One of the better-known MRAs is the agreement between the European Union and the US covering EMC, radio, telecom and several other product sectors. It has become a model for subsequent MRAs.

**EU**

With 27 member states, the population and economy of the EU exceeds that of the US. The EU has simplified the process of access considerably by identifying the “essential requirements” for almost everything that is placed on the market in the EU. The authorities having jurisdiction vary by product type, and each country has a Competent Authority for each product type or directive. For example, the Competent Authority for EMC in the UK is the Department of Trade and Industry (DTI). The specific “essential requirements” for your products will be listed in the directives that apply to your product. In most cases, the directives will be “New Approach” directives for which CE marking signifies compliance and the applicable standards have been published in the *Official Journal of the European Union*.

A good place to start for guidance on directives and standards is [http://www.newapproach.org](http://www.newapproach.org). The CE marking indicates that the equipment bearing the marking complies with all of the applicable “New Approach” directives.

- Most electrical/electronic products must comply with both emission and immunity requirements, according to both the current EMC Directive 89/336/EC and the new EMC Directive replacing it, 2004/108/EC. This includes appliances and many devices exempted from EMI regulation in the US and Canada. In addition, the safety standards for household appliances now require compliance with
limits to the surrounding low-frequency electromagnetic fields according to EN 50366. This is a safety standard, not an EMC standard.

- The “essential requirements” for radio and telecom equipment under the R&TTE Directive 1999/5/EC include electrical safety according to the Low Voltage Directive (but with no lower voltage limit), RF exposure for radio transmitters and EMC according to the EMC Directive. For telecom terminal equipment, there are no more requirements. Radio transmitters must also comply with requirements for efficient use of the spectrum. Both spectrum and EMC standards for radio equipment are published by ETSI, the European Telecommunications Standards Institute.

- Medical devices are approved according to a classification scheme originating with the Medical Device Directive 93/42/EC and used as the prototype for other medical device regulations around the world, including Canada. The basic medical EMC standard is EN 60601-1-2:2001. The EMC requirements are modified by specific standards EN 60601-2-x to define particular test setups or higher or lower limits for particular EMC phenomena. EMC is also a factor for in vitro diagnostic medical devices (Directive 98/79/EC) and active implantable medical devices (Directive 90/385/EEC).

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Note the old EU directive was 2004/108/EC

There is a new one coming into force 2014/30/EU in April 2016. Not sure how if differs at the moment.

**CE Marking**

Fundamentally you are wanting to have a CE mark on your products. The question is how to get that.
First, you need to design your product so that it generates the minimum level of interference, and is protected against interference. There are some common sense things that you should do to achieve this. More complicated products may require specialist advice from EMC houses that can advise on requirements and testing.

Then you need to make sure it conforms to the standards.

You can do most of it yourself unless the directive you are meeting says otherwise. You need to provide evidence that you believe that your device will not cause interference. This is called Self certification. You can then stick a CE mark on the product. However, it is wise to keep checking the rules as they are always changing.

“There is no actual legal requirement for testing to be carried out for the CE mark, but you should be able to demonstrate compliance with the directives if ever required to. In practice, outside of your distributors possibly requiring evidence of conformance for their own protection, the only other likely need to demonstrate compliance is if the health and safety executive, trading standards, etc authorities demanded it and this is actually only likely to happen if a problem has been discovered or occurred. The driving factor for many companies to ensure their products are CE compliant is down to the fact that these authorities can force you to recall your products if it is discovered they are not compliant. They also have the power to fine and even imprison for serious cases.

There are 21+ different directives. Placing a CE mark states that your product complies with all directives that apply to the product.

To give you an idea of the costs involved, to use the BSI to provide CE marking services for a relatively typical electronic product (Low Voltage Directive and EMC compliance) would be likely to cost in the region of £8,000 to £10,000. Bear in mind this just a rough estimate and costs will vary,
sometimes significantly, based on specifics of your product. Of this between £1,000 and £1,500 would typically be the cost to carry out the paperwork side of the work with the remainder being the costs to carry out the lab based testing.

For products that are battery powered the testing requirements are often reduced, especially if the product is targeted at industrial rather than consumer use. A typical battery powered product will not require LVD electrical safety testing, reducing the requirement to just EMC testing for immunity (to interference) and emissions. This can reduce the lab testing cost to around £1500 if the product passes first time and if the products application allows it to be tested to generic industrial standards (EN61000-6-2 for immunity in industrial environments and EN61000-6-4 for emissions in industrial environments) the only paperwork often required in addition to the tests is the CE declaration of conformity. This can also often apply to products that are powered from the mains via a plug top power supply if a power supply is chosen with a valid declaration of conformity to the LVD and EMC directives from the manufacturer. Strictly speaking the product should also be tested connected to the mains supply for electrical safety (LVD), but it is often justifiable to rely on the power supplies LVD compliance and remove this testing requirement.

If your product included wireless communications (e.g. bluetooth, DECT, WiFi etc) then it needs to comply with the Radio and Telecommunications Directive which can add a significant cost. ”

Design Notes

Shielding can be used. The idea is to keep any generated noise in the box, and stop external noise getting in. Similar to a Faraday cage. Its not usually possible to completely seal a box electronically so it is unwise to rely on shielding entirely. RF subsystems quite often have metal boxes around them to shield nearby circuitry.

Quite often you will see ferrite beads or chokes on cables to reduce emissions
However, it is also important to design so that noise is not generated in the first place.

**PCB Design**

Usually a PCB is involved so there are some common techniques that should be used.

1) **Power supply filter.** Power usually comes in in one place and there is at least one regulator. If it is a switching regulator, then there is the risk of high frequency noise. Near this it is usual to have at least two capacitors – One large on (μF) to provide low frequency filtering and a smaller one (nF) to provide higher frequency filtering.

2) **Dividing circuits into blocks.** Quite often there is a digital part of the circuit and an analog part. Keeping these physically separate and powered by separately routed supplies is sensible. These parts can be separately filtered with series inductors as well as capacitor based filters.

3) **Decoupling capacitors.** Noise tends to be high frequency so a capacitor is a good way of providing a low impedance path for it. It is good practice to place a decoupling capacitor very close to each chip used, between VCC and Ground. Any noise on the power supply lines
can then be decoupled to ground before it gets in the chip

4) The power tracks on the PCB should be as low impedance as possible. This is best done by power planes. This gives a low resistance and also allows capacitance coupling between them (extra filtering) and also gives lower inductance than tracks or wires.

5) High speed signals. High speed signals can be high frequency, or can have very fast edges. Fast edges contain harmonics. As a general rule, energy in a digital signal is concentrated below the knee frequency. This is defined as

\[ f_{\text{Knee}} [GHz] = \frac{0.35}{t_{\text{rise}} [ns]} \]

Fig. 4.1 Spectrum of a digital signal with \( f_{\text{Operating}} = 1 \) [MHz] and \( t_r = 0.1 \) [ns]
This leads to the practical point that to avoid distortion (let alone interference) the PCB must be able to carry all these frequencies, not just the operating frequency. PCB traces act as transmission lines at high frequency, and all kinds of things then happen (crosstalk, reflections, radiation).

So as a general rule, high speed signals should be routed with controlled impedance eg microstrip or stripline.

High speed signals require termination at either the driver end or the receiver end. Not both. Without termination, signals will reflect and cause distortion. There is a whole branch of sensor technology called time domain reflectometry that exploits this very fact.

![Graph showing difference termination can make. Termination can be as simple as a resistor to ground (or vcc), of a value equal to the characteristic impedance of the track.](image)

Routing issues. Tight corners are bad for RF. Try and use gentle curved tracks. Minimize the number of vias for high speed signals. A via looks a bit like a change in impedance so can cause reflections. Fast signals (especially differential ones) need to have delay matched routes. This means they are the same length and ideally symmetric. Try to keep high speed signals away from the board edge.

Board material. A common material for boards is called FR4 and this is well characterized now. For example, a microstrip construction in FR4 has a propagation time of about 5.6ps/mm but a stripline in FR4 has about 7ps/mm

![Diagram showing surface microstrip and symmetric stripline.](image)

Guarding. Guarding is an important technique for reducing crosstalk between sensitive tracks.
The victim track (usually a sensitive analog signal track) is protected by the ground track from interference from the aggressive digital track.

The whole thing is a bit of a black art, and nothing makes up for experience. However, common sense can provide many shortcuts!

Please have a look for Getting_EMC_Right_First_Time_Intro.pdf for some more detail. This is a free E-book available online and many of the pictures above have been taken from it.