SPEC+FMCDIO5chTTLa board

“CE” marking report

Revision 0.3

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Revision Table

Revision	Date	Author	Comments
0.1	16/06/2012	Rodrigo Agis, Seven Solutions. http:\\www.sevensols.com	- Initial version - Reviewer: Eduardo Ros, Seven Solutions. - Reviewer: Richard Carrillo, Seven Solutions. - Reviewer Erik Van Der Bij, CERN
0.2	14/07/2012	Rodrigo Agis, Seven Solutions. http:\\www.sevensols.com	- Erik's comments updated - Reviewer: Erik Van Der Bij, CERN - Reviewer: Eduardo Ros, Seven Solutions.
0.3	27/09/2012	Rodrigo Agis, Seven Solutions. http:\\www.sevensols.com	- Erik's comments updated - Reviewer: Erik Van Der Bij, CERN - Reviewer: Eduardo Ros, Seven Solutions.

Table of contents

1. Introduction

In this report we summarize our impressions regarding the CE marking process for SPEC+FMCDIO5chTTLa boards. The report is not too rigorous, it gathers some lessons we learned in the CE marking process. These lessons can be useful for other potential partners who address similar certification tasks.

What is CE Marking and Why is it necessary?

The CE Marking is a mandatory regulatory requirement for the marketing of products in the domestic and non-domestic market in the European Union [1, 2, 3, and 4]. The CE Marking indicates that a product meets allegedly the directives that apply to the equipment in question. A "directive application" or " directive" is a set of restrictive rules that the CEE established by several European standards agencies such as CEN, CENELEC, etc. [3 and 4]. For example, for electrical equipment designed to be used within certain restricted power voltage. Similarly, the CE marking ensures that the manufacturer has taken all reasonable steps to ensure compliance with them in each of the products sold. Therefore, both the manufacturer and the product meet the essential requirements indicated in the related directives.

The CE marking is necessary because it indicates to governmental officials that the product may be legally placed on the market in their country. Also, CE Marking on a product ensures the free movement of the product within the European Free Trade Association (EFTA) & European Union (EU) single market (total 28 countries), and CE Marking on a product permits the withdrawal of the non-conforming products by customs and enforcement/vigilance authorities.

How is the process?

The CE mark is set by the manufacturer at the end of the control phase of production, following the next procedures and assuming full responsibility for the product sold (CEE Council Decision 93/465/EEC, [3, 4]):

Phase 1 - Identify the directive(s)and the harmonized standards applicable to the product.

Phase 2 - Check the specific requirements of your product.

Phase 3 - Check if your product requires a separate conformity assessment by a Notified Body. For example, when you are trying to certificate an electronic medical product.

Phase 4 - Evaluation of the design (of a prototype or a product sample) using the tests and studies that apply (made by an external certified company such as AT4Wireless).

Phase 5 - Develop and maintain technical documentation (two documents: technical construction file and the declaration of conformity).

Phase 6 - Fit the CE marking to your product.

Advisable Phase 7 (non mandatory) - Evaluation of production (all units of the product must continue to comply serving as the sample studied in the evaluation phase of the design in terms of manufacturing procedures), by a quality control of production (also quality assurance), preferably based on the ISO 9000 quality standards.

Available documentation at the end of CE marking process

At the end of the CE marking process you must to have the following documentation [5, 6] available for any European Inspector:

1.- Result of evaluation of the design: Test Certificate and test Report (elaborated and written by an external certified company).

2.- Technical construction file (elaborated by the manufacturer).

3.- Declaration of conformity file (elaborated by the manufacturer).

2. Type of tests required for CE approval

Mainly your product must pass the following electromagnetic compatibility (EMC) set of tests if you want to apply the CE marking:

- **Radiated emissions** (RF radiated to the air by the product which is being tested): The frequency range from 30 to 1000MHz is investigated for radiated emissions in several position configurations (height and rotation) and radiation modes (horizontal and vertical). The electric field generated by the product is measured by an external antenna. This field must not exceed a certain limit (30 or 37dBµV/m depending on the frequency in Class B domestic standards). These are quasi-peak values (as opposed to maxi-peaks) which mean that the electric field considered is averaged over time.
- **Conducted emissions** (electromagnetic energy coupled in the AC power cord and generated by the product which is being tested): The frequency range from 150KHz to 30MHz is investigated measuring the voltage in the mains used to supply the product. This range covers a lower frequency range which is not covered by the test of radiated emissions. This test is not required If the product is powered by direct current (DC) as in the case of the SPEC board which is powered through a PCIe slot.
- **Radiated immunity** (immunity of the product being test to radiated disturbances induced by radiofrequency fields): Electromagnetic radiation generated by an external antenna in the air is directed towards the product being tested. In the case of the non-domestic products, this field is up to 10V/m. The product must work properly while being radiated. This test is not required for FCC.
- **Conducted immunity** (immunity of the product being tested to conducted disturbances induced by radiofrequency fields): The product must be immune to unwanted “noisy” RF voltages and currents carried by its external

cables. These RF signals range from 150KHz to 80MHz (Vol. Peak. 3V RMS, AM modulation 1Khz and 80% in non-domestic CE marking).

- **Electrical Fast Transient** (immunity of the product being tested to fast transients): A specific burst waveform is applied through coupling to the mains connection and through a probe device to signal connections. Choice of ports for the application of the burst depends on the instructions in the product standard being used, but it is generally applied to AC and DC power ports and to signal and control ports that may be connected to cables longer than 3m. This test may shut down the product; however, it passes the test as long as it recovers without user intervention. Therefore, special care should be taken when the product state may get corrupted when the power supply is suddenly interrupted. In fact, in our EMC test process, we had to repair many times the Linux file system because it was corrupted.
- **Electrostatic discharge (ESD)** immunity (immunity of the product being tested to ESD): The product must work properly even if subjected to realistic levels of ESD. Abrupt releases of charge are performed in external conductive parts of the product (from 4KV to 8KV), for example, computer case, PCIe card bracket, external part of connectors… Therefore, the enclosure of the connectors must be properly connected to ground. You must know that the device could be permanently damage when this test is performed. This warning is usually given by the certification company.
- **Magnetic fields immunity test** (immunity of the product being tested to magnetic fields): The product must operate normally, without any special user intervention, when exposed to powerline-frequency magnetic fields, such as from poorly-routed power wiring.

Electromagnetic compatibility (set of tests)	Ranges that will be checked	Comments
Radiated emissions	30 or 37dBµV/m at 30 to 1000 Mhz	radiated field and frequency range
Conducted emissions	150KHz to 30MHz	frequency range coupled in the AC power cord
Radiated immunity	10V/m	radiated field to the product (360º around)
Conducted immunity	150KHz to 80MHz (Vol. Peak. 3V RMS, AM modulation 1Khz and 80%)	Injected in external communications and power cords
Electrical Fast Transient	5 kV, test pulse: 1,2/50 µs	applied through coupling to the mains connection and through a probe device to signal connections
Electrostatic discharge (ESD)	4KV to 8KV	performed in external conductive parts of the product
Magnetic fields immunity test	poorly-routed power wiring	powerline-frequency magnetic fields

Table 1: Electromagnetic compatibility EMI set of tests and ranges that will be checked in a CE marking test.

3. Norms and domestic/non-domestic "industrial" CE marking

Our product has passed the most restrictive requirements of each environment (domestic and non-domestic or "industrial") in each test. The domestic tests are more restrictive than non-domestic on radiated emission, nevertheless, the non-domestic tests are most restrictive on immunity, therefore, the device can be sold for industrial and domestic environments.

A board meant to be used in an industrial environment, may emit more radiation than in an domestic environment. At the same time, a board meant to be used in an industrial environment must be able to accept more radiation too.
Depending on the market an the environments that your product is targeted, it must adopt different norms (see table 2) will be more or less restrictive (medical, domestic, non-domestic or industrial, etc.).
In some cases, such as the CE mark for domestic products and or industrial, the set of tests passed to the product are the same (radiated emission, conduced emission etc.) but with different thresholds that must be supported. Your product can take advantage (if you did a good design) and pass the tests with more restrictive thresholds of each norms. If your device passed a more preventive standard then, it is automatically marked for a less preventive standards. For example: Our device passed the EM radiated Emission Class B (Domestic) then automatically the certification company mark that your device pass EM radiated Emission Class A (non-domestic or industrial) because Class B is more restrictive than Class A standards (this was also the case for EM Immunity).
Therefore our product will be used, and most importantly marketed, in industrial and domestic environments.

Test	Environments	EM threshold
EM Radiated Emission	Domestic	LOW (*)
EM Radiated Emission	Non-domestic (industrial)	HIGH
EM Immunity	Domestic	LOW
EM Immunity	Non-domestic (industrial)	HIGH (*)

Table 2: EM Conceptual table. (*) that's means more restrictive

The following set of norms (see table 3) were supported by our product. Each norm describe methods of measurement and to standardize operating conditions and interpretation of results. These norms are selected and enforced by the certification company because they know that rules apply to each product to be certified.
The text of the norm or standard is not free. In order to buy a norm, you can contact your national member. Our Spanish member is AENOR (you can following this link [7] or mail to info@aenor.es) or you can buy norms/standards from any of Europeans Members (see [8]). The cost of each norm is around 250€ and can be ordered from Member's web page. Of course, you can try browse in internet and find some free rules, but if you really want the latest updates to be consistent with the current law then you must to buy the norms from your national member.

The norms or standards applied
EM Radiated Emission: Class B (Domestic) EN 55022 (2006) / A1 (2007)
EM Immunity (Non-domestic): EN 61000-4-3 (2006) / A1 (2008) / A2 (2010), EN 61000-4-4 (2004) / A1 (2010) / Corr (2010), EN 61000-4-6 (2009), EN61000-4-2 (2009), EN 61000-4-8 (2010).

Table 3: Set of norms or standards applied to our product.

4. Description of a typical test system. What did we do?

During the emission tests the product must be operating normally making use of its different part to assess if any part generates unwanted emissions. During the immunity tests the device must operate properly without failures, thus its state must be monitored. Therefore, we implemented shell scripts which run a set of PTS tests that checked cyclically the hardware of the product (see table 4). The potential operation failures were stored in log files. To achieve this, we modified the "pts.py" program so that it returned different exit status (error levels) depending on the successful completion of the tests. This allowed the scripts to know what log files should be kept (failures) and what files should be deleted (successful executions). (Other ways to do this could be chosen depending on your device. For example, the inspector could check a LED to indicate any failure). Note: the manufacturer of the product decides how to do that and the company will only check what you tell them. It is your responsibility to be more or less rigorous on this functional checking.

The test was running under standard PC (See Illustration 1) with Linux (Debian version) installed in a USB flash drive. We used this drive to reduce the auxiliary hardware and thus minimize the extra EMI that could be emitted. The duration of tests was about 24 hours including the time used to repair the system (we will discuss this later).

SPEC + FMC-DIO-5chTTLa SUMARY TABLE OF USED TESTS
FMC-DIO-5chTTLa: Test number: 00 01 02 03 10 11 (*) New test 10: unattended version of test 05 New test 11: relaxed version of test 08: Reports error if port voltage >3.25V or <2.7V (instead of 3.2V and 2.8V) (**) http://www.ohwr.org/projects/pts/repository/revisions/master/show/test/fmcdio5chttla/doc
SPEC: Test number: 04 06 07 08 09 10 12 (*) http://www.ohwr.org/projects/pts/repository/revisions/master/show/test/spec/doc

Table 4: FMC-DIO-5chTTLa and SPEC software used for EMC tests.

(*) Tests are described in the SPEC and FMC-DIO-5chTTLa documentation in the PTS repository.

(**) “port voltage” is the voltage measured by the FMC-DIO-5chTTLa board internal DAC in each of the five channels of this board. Test08 simultaneously enables the port output and termination resistor and then performs this measurement to check that the termination resistor of each port works correctly, that is, a specific voltage drop is expected in all the ports. During the EMC tests the board operation must be immune to a considerable RF signal injected in any cable longer than 3m, this is the case of the LEMO-00 cables connected to the FMC-DIO-5chTTLa board ports. Therefore, we used a modified version of test08 to check that this signal is not able to alter the port voltage in a quantity enough to represent a wrong logic state (0) when the port output is set to 1. Thus in test11 we have relaxed the voltage-checking conditions a bit since we did not want to check that the termination resistor is working correctly (we already knew

that), we just wanted to check that voltage fluctuations induced by the RF signal are clearly not large enough to alter the logic state of the port outputs.

Illustration 1. Product configuration. Standard PC without hard-disk + SPEC + **FMC-DIO-5chTTLa.**

The first test that the product passed was the radiated emission test (radiated to the air by the product). In this test our system was introduced in an anechoic chamber (in our case a PC+SPEC+FMC-DIO-5chTTLa without any monitor and the software test running). An antenna was used to explore the RF spectrum radiated by the product (see Illustration 2 and 3) in several product positions (360 degrees) (note: the product is mounted on a rotating platform searching for the angle and frequency where the emissions may exceed the allowable limit). The distance between the product and the antenna was 10 meters (this distance is stated by the standard method of measurement).

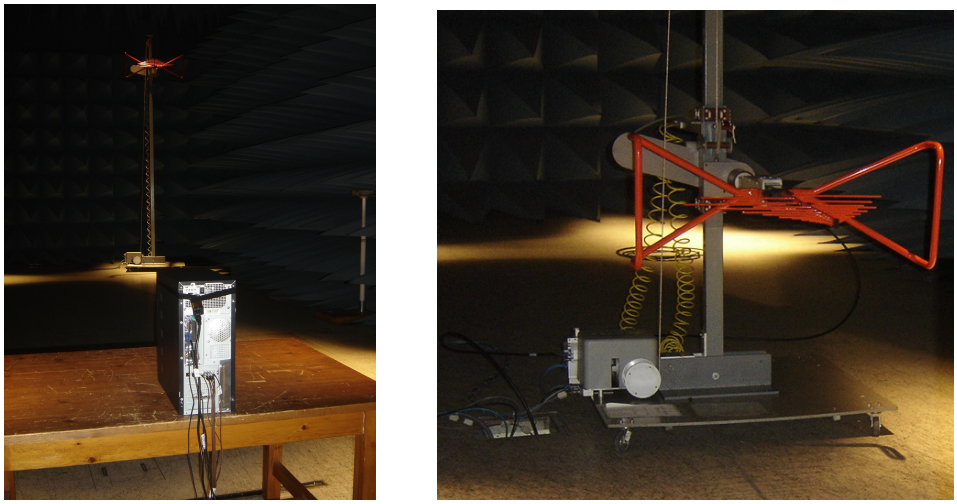

Illustration 2. Radiated emission test. Product in anechoic chamber and image of the antenna.

During the first attempt to pass the radiated emission test, our system (PC+SPEC+FMC-DIO-5chTTLa) passed the requirements (emission levels) for non-domestic environments but failed those for domestic environment. Analyzing the spectrum graph of our system emissions, we located an excessively-high peak at the low frequency part which was radiated through the cord of the power supply (the cord was acting as an antenna). The large peaks of less than 50MHz are usually caused by the power supply (apparently this power supply did not pass the domestic environment requirements). To filter out this signal, since it was not caused by our system, we installed a RFI pre-filter (model FI-2ZFM) in the power supply (you can see a little black box in Illustration 2). Apart from this power supply emission, we found another peak at

192MHz (apparently from the computer hardware) which could be mitigated by means of a proper computer case closing. Finally it passed the test.

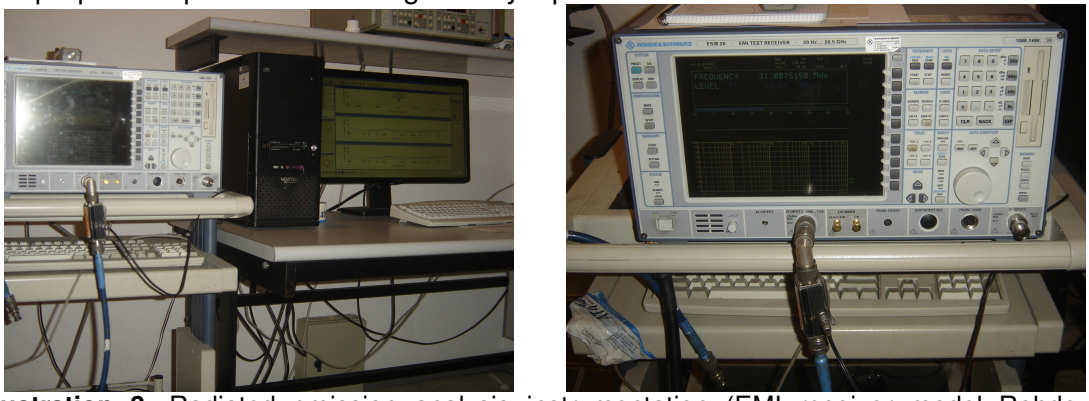

Illustration 3. Radiated emission analysis instrumentation (EMI receiver model Rohde & Schwarz ESIB26).

In the conduced emission test our system was connected to an artificial mains network which is also known as a Line Impedance Stabilization Network (LISN). This artificial mains network is created by a device installed between our system and the real mains. It works as a transducer between the mains port of the product under test and the EMC spectrum analyzer. Again our system failed the test due to disturbances in the mains produced by the PC power supply. We discovered that the power supply was the problem because the disturbances were present in the mains even if all components of our system (main board, cooler, etc.) were disconnected from the power supply. We replaced the original PC power supply with a supposedly high-quality one (NOX URANO 600W), but even using this new power supply we had to install an RFI pre-filter in the power supply. Finally our system passed the test.
Note that since important EMI can be generated by the power supply (even if this is not part of your product), you must take care with the quality of these auxiliary components even if the CE mark can be read on the label. We mean that a lot of components and equipments (for example, PCs, even with high-class power supply, and other components) marked with CE do not pass the CE tests in conditions different to the original ones (which are difficult to know). For example, not all the PC power supplies marked with “CE” pass the EMC tests for domestic environment (maybe they have the “CE” mark because they passed just the non-domestic environment tests). Anyway, since the SPEC board is not supplied directly by the mains network but the PCIe slot, the conducted emission test is not needed and not included in the test report.

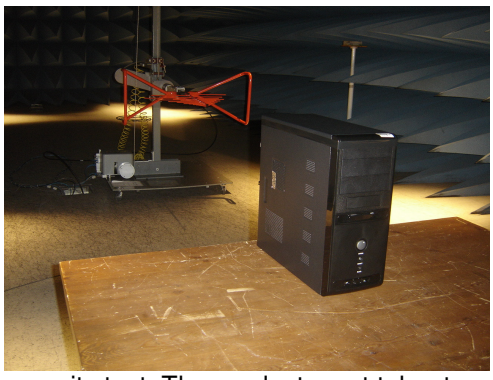

Illustration 4. Radiated Immunity test. The product must tolerate a field of 10V/m in the non-domestic environment test. The product was placed 5m away from the RF source (anechoic material not placed on the floor yet).

Note: If an EMC test is not initially passed, the certificating company can allow you to perform modification of your system in situ so that it can pass the test, but remember

that all changes will be reflected in the final report. In our case since modifications were made on auxiliary components (such as the power supply of the PC), these were not specified in the test report.

In a radiated immunity test, a electromagnetic field of 3V/m for domestic and 10V/m for non-domestic was radiated to the product in different positions (front. back, left and right) (See Illustration 4). The distance between the product and the field generating antenna was 5m (following the corresponding standard). The RF shielding of the product (and PC in which it was installed) passed this test without problems.

5. Things to take special care of (what we learnt)

Every electronic device is different and has its own behaviour regarding electromagnetic emissions, insulation, etc., but the following general recommendations can be applied:

- The certification companies are not usually eager to show/disseminate the "know-how in detail" of the EMC test processes. Obviously, the company gets more money if your system fails some tests and you need to rent the facilities for further trials (longer time). Many tests are made in a certified anechoic chamber (it is a room designed to stop reflections of electromagnetic waves) and the rental cost is high.

- Usually companies ask you if you want to stay present when EMC tests are performed. If you say "yes" you must write a couple of tedious documents regarding personnel security (personal injure) but we recommend going to the company because it is a good opportunity to ask to the assigned engineer and learn about the process.

- The EMC tests can fail if you designed your hardware incorrectly (for example if you designed faulty transmission lines which radiate large amounts of EMI) or installed low-quality parts (such as power supplies or integrated modules with oscillators including DC-DC converters with high levels of EMI). However, when testing PC boards in most cases the problem is external to your product. Even an inadequate computer case can be a trigger for problems. We mean that it is very common to use an external base platform running your custom hardware (for example a PC) which may influence the EMC test result more than the hardware of your own product.

- Be careful with the power supplies connected to the mains. Many of the commercial power supplies are not CE compliant despite they include the "CE" mark (that we guess has been obtained in specific conditions). Especially be carefully with some power supplies of low quality because some products probably passed the EMC test running without any electric-load and, of course, the EMI was minimal during the tests.

- If your power supply is connected to the mains, make sure that it has a good RFI filter adapted to the consumption of your device. Some power supplies have RFI filters but they are usually designed to work under specific consumption conditions.

- Try to pass the EMC tests independently. We mean that if your hardware is powered only by DC, then try to use batteries during the test (at least there will

be no problem with the radiated emissions through the AC cord) and pass the EMC tests for the power source only if you designed it. In other case buy a good power supply with CE marking and internal EMI/RFI filter.

- If the certification company allows it, it is advisable to apply the test to the base platform (PC in which your product will be installed) and afterwards with your product installed to identify EMI sources (that may not be related to your product).

- If an EMC test is not passed, then modifications of your product or platform are allowed so that it can pass the test, but remember that all changes can be reflected in the report (not necessarily if the modifications are made on auxiliary components).

- You must know that your product could be permanently damaged when some immunity tests are conducted (for example, the electrical fast transient/burst immunity test).

6. References

[1] European Commission's Directorate General, http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/electromagnetic-compatibility/index_en.htm

[2] Wellkang Tech Consulting, An international B2B regulatory consulting group, http://www.ce-marking.org/

[3] *CENELEC*: European Committee for Electrotechnical Standardization, http://www.cenelec.eu/.

[4] *CEN*: European Committee for Standardization. http://www.cen.eu

[5] SPEC: http://www.ohwr.org/projects/spec, http://www.ohwr.org/projects/spec/wiki

[6] FMC-DIO-5CHTTLA: http://www.ohwr.org/projects/fmc-dio-5chttla, http://www.ohwr.org/projects/fmc-dio-5chttla/wiki

[7] http://www.aenor.es/aenor/normas/buscadornormas/buscadornormas.asp

[8] http://www.cencenelec.eu/sme/standards/NationalContacts/Pages/default.aspx