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Functional Safety requires much more than EMI testing (Part 1)

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Functional Safety requires much more than EMI testing

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This is the first part of a two-part article, published in 'Safety Systems',
the Safety-Critical Club Newsletter, Volume 16, Number 3, May 2007, pp 6-9

1. Introduction

Programmable electronic devices are increasingly used in applications where reliable functionality is necessary to achieve sufficiently low functional safety risks. The main reason for this is their increasing functionality and decreasing cost, both achieved through continual shrinking of the silicon dies used to make integrated circuits (ICs). This increasing use of modern electronic technologies is causing higher levels of electromagnetic interference (EMI) in the environment.

All electronic devices have always suffered from inaccuracy or malfunction, even permanent damage, due to EMI in their operational environments. Silicon die shrinking – and its consequent lower operating voltages – reduces the immunity of ICs to EMI. The result of worsening EMI and reducing immunity is decreasing functional reliability, with potentially serious consequences for functional safety.

EMI is controlled in Europe by the electromagnetic compatibility (EMC) Directive (89/336/EEC replaced by 2004/108/EC on 20th July 2007) – which specifically *does not* address any safety matters. Safety Directives generally deal with EMI issues very poorly, if at all [1] [2]. Since most manufacturers and system integrators only aim to comply with *minimum* regulatory requirements, the effects of EMI on functional safety risks are uncontrolled at present, as shown by Figure 1.

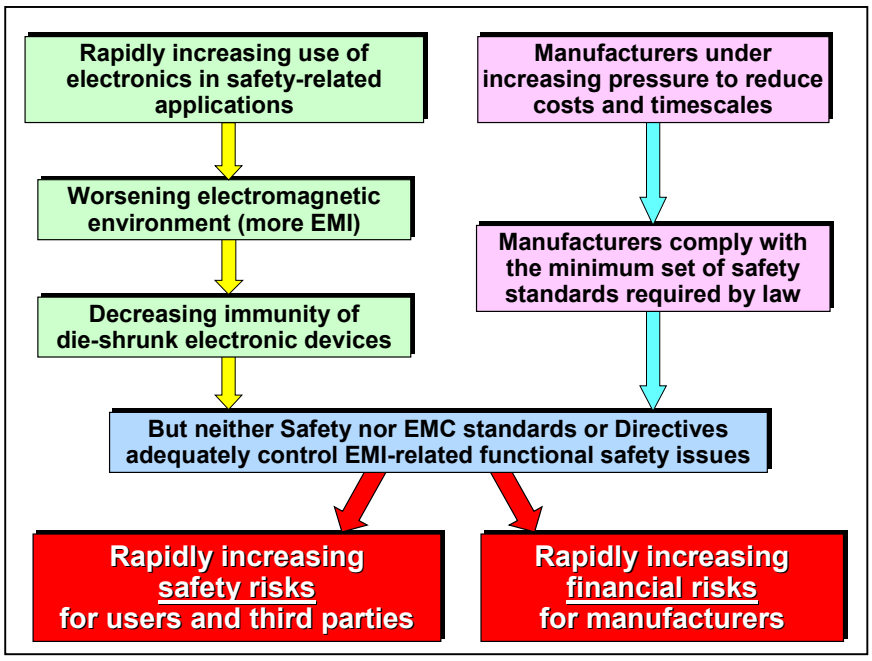

Fig. 1 – Increasing functional safety risks from EMI

The IEE published a guide in 2000 [3] recommending an 'EMI hazards analysis and risk assessment' approach, and since then has run a number of successful training courses on this issue. Only IEC 61000-1-2 [4] employs a similar approach, but it is just a 'Technical Specification' and not (yet) a full IEC standard.

A very few IEC safety standards (and the Automotive EMC Directives) include EMI immunity requirements, but these rely solely on conventional EMI immunity testing, shown below to be incapable of demonstrating that risks are low enough. The EMC standard for medical device safety has recently been amended [5] to state that it is not a safety standard. EMC standards and regulations have developed over decades to in a way that is considered by some to be unequal to modern requirements [6] and is demonstrably unsuitable for safety engineering purposes.

The safety of electrical/electronic equipment is generally verified by…

- Inspecting the design against a number of safety design criteria, well-proven to provide a sufficient level of lifecycle protection, including the effects of the physical environment and foreseeable use/misuse
- Testing samples of the finished design using worst-case combinations of physical environment phenomena, and by simulating each foreseeable fault in turn
- Safety testing of every item manufactured
- Regular safety inspections and tests during the period of use

But conventional immunity testing methods ignore design, and simply test one or two new samples in a benign physical environment. This is quite different from the approach taken for *all other safety issues*, including software (Part 3 of [7]), and is inadequate for a number of reasons, including the following.

2. Shortcomings in conventional EMI immunity tests

2.1 Faults and misuse are not addressed

Equipment must be safe despite (at least) one fault, and despite foreseeable misuse. These can significantly affect equipment's immunity to its everyday EM environment. For example…

- Dry joints or short circuits (e.g. in a filter)
- Incorrect / out-of-tolerance electronic components
- Incorrect, loose or missing fixings associated with shielding or radio-frequency bonding
- Damaged or missing conductive gaskets
- Failure of a surge protection device
- Shielding doors or cover left open
- Installation using incorrect type of cable

Safety tests simulate foreseeable faults and misuse to check safety is maintained, but conventional immunity tests only ever test pristine equipment. This alone shows that conventional immunity testing is inadequate for safety purposes.

2.2 Real EM environments not tested

Standardised immunity tests appear to be primarily designed to be repeatable and use affordable test instrumentation, rather than simulate real-life EM environments. For example: real-life environments include *simultaneous* EMI threats – such as: radiated fields from two or more radio channels; a radiated field plus a fast transient burst on the mains supply or an electrostatic discharge to a keyboard; etc., but conventional tests only apply one EMI threat at a time. [8] shows that equipment that passes conventional immunity tests can readily fail when tested with simultaneous threats, even at lower levels.

The immunity of equipment depends strongly on the waveshapes of transient threats (surges, spikes, etc.), but the waveforms used in conventional transient tests are very simplified.

Modulating an interfering signal at the rate of the electronic processes within equipment can significantly reduce its immunity [9] [10]. EM environments include a huge range of modulations, but conventional immunity tests simply modulate with a 1kHz sinewave (plus 0.5Hz pulse modulation for some medical devices).

The anechoic chambers used for conventional radiated immunity tests are unlike most real-life EM environments, and there are concerns about the uncertainty in the test method itself [11] [12]. Other failures to cover the typical modern EM environment could be listed.

2.3 EMI 'risk assessment ' not done

Conventional immunity tests do not address low-probability EMI threats, even though they could be significant where safety integrity levels (SILs, see [7]) are high [14]. For example, they do not cover the much higher field strengths and/or frequencies caused by the close proximity of cellphones, despite this being a reasonably foreseeable occurrence. Also, they only apply surges of up to ±2kV to equipment mains inputs, even though it is known that ±6kV generally occurs several times each year [13].

For the types of EMI threats that *are* covered, by the conventional tests, the levels are generally based upon the two-sigma point (sigma being the standard deviation) – meaning that 95% of the events should fall below the tested level. But it might be unacceptable for equipment to become unsafe once in every 20 EMI events – especially for high SILs [7].

2.4 Physical environment not considered

Safety is required over the whole lifecycle, but conventional immunity tests never address the effects of the physical environment [15]. Extremes of temperature, supply voltage, shock, vibration, loading, condensation, icing, physical forces, etc. can reduce EMI immunity by degrading filtering, shielding and other EMI suppression measures. For example, [16] reports on tests on an EMI filter that showed that under reasonably foreseeable real-life conditions of ambient temperature and load current, its suppression could degrade by 20dB (i.e. to one-tenth) of that measured during conventional EMI immunity tests.

Ageing also degrades EMI immunity, and can be caused by condensation, liquid spills and spray, mould growth, sand, dust, cleaning (e.g. wire-brushing, solvents) and maintenance – plus wear and tear caused by multiple operations of controls, opening and closing of doors and access panels, temperature cycling, etc. For example, a common ageing problem is corrosion at metal joints, which degrades EMI filtering and shielding.

2.5 Only a representative sample is tested

Even if an example once passed an immunity test, this proves nothing at all about the immunity performance of the equipment actually supplied. The EMC performance of most equipment is vulnerable to variations in components (e.g. semiconductor 'die-shrinks') and supposedly 'small' changes in production (e.g. altered cable routes; modified fixing methods; software 'bug fixes'; substitute components; etc.) - because their manufacturers do not check or control EMI immunity in serial manufacture.

2.6 Emergent behaviour of systems

It can be difficult to test the EMI immunity of some systems, so immunity tests on individual items or sub-assemblies are often considered adequate instead. The following example shows that this can increase safety risks.

Conventional immunity testing permits a DC power supply unit to exhibit any amount of momentary degradation during transient tests, as long as it self-recovers afterwards. In some cases DC outputs collapse to 0V during the transient, but this is considered acceptable behaviour. But where a DC power supply powers a safety-related microprocessor, such a collapse could cause the microprocessor to crash, (hopefully) followed by a reboot. During this upset – and maybe afterwards too – functional safety will be compromised.

Many other simple examples could be given, and more complex interactions are possible. So even where all of the items of equipment comprising a safety system pass their immunity tests, it does not mean that the complete system will be immune enough [14].

3. References

[1] Keith Armstrong, "*New Guidance on EMC-Related Functional Safety*", 2001 IEEE EMC International Symposium, Montreal, Aug. 13-17 2001. Proceedings: ISBN 0-7803-6569-0/01, pp. 774-779.

[2] Keith Armstrong, "*New Guidance on EMC and Safety for Machinery*", 2002 IEEE International EMC Symposium, Minneapolis, Aug. 19-23 2002. Proceedings: ISBN: 0-7803-7264-6, pp. 680-685.

[3] The IET, "Guidance document on EMC and Functional Safety", 2000: http://www.theiet.org/publicaffairs/sectorpanels/emc/index.cfm

[4] IEC/TS 61000-1-2:2001, "*Electromagnetic Compatibility (EMC) – Part 1-2: General – Methodology for the achievement of the functional safety of electrical and electronic equipment with regard to electromagnetic phenomena*."

[5] Amendment 1 to IEC 60601-1-2 Ed2.0 (also Clause 6.2.1.1 in IEC 60601-1-2 Ed3.0)

[6] D A Townsend et al, "*Breaking All the Rules: Challenging the Engineering and Regulatory Precepts of Electromagnetic Compatibility*", 1995 IEEE International Symposium on EMC, Atlanta, ISBN: 0-7803-2573-7, pp 194-199

[7] IEC 61508, "*Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems*", (seven parts).

[8] Michel Mardiguian, "*Combined Effects of Several, Simultaneous, EMI Couplings*", 2000 IEEE International Symposium on EMC, Washington D.C., August 21-25 2000, ISBN 0-7803-5680-2, pp. 181-184.

[9] Wendsche S. and Habiger E., "*Using Reinforcement Learning Methods for Effective EMC Immunity Testing of Computerised Equipment"*, Proc. Int. Symp. Electromagnetic Compatibility (ROMA'96), Rome, Italy, Sept 1996, pp.221-226

[10] Vick R. and Habiger E., "*The dependence of the immunity of digital equipment on the hardware and software structure*", Proc. Int. Symp. Electromagnetic Compatibility, Beijing, China, May 1997, pp 383-386

[11] Jansson, L., and M. Bäckström, "*Directivity of Equipment and its Effect on Testing in Mode-Stirred and Anechoic Chamber*", IEEE Int. Symposium on EMC, Seattle, WA, August 1999

[12] Freyer, G. J., "*Distribution of Responses for Limited Aspect Angle EME Tests of Equipment with Structured Directional Directivity*", The 2003 Reverberation Chamber, Anechoic Chamber and OATS Users Meeting, Austin, TX, April 2003.

[13] EN 50160, "*Voltage characteristics of electricity supplied by public distribution systems*".

[14] Simon J Brown and William A Radasky, "*Functional Safety and EMC*", paper presented at the IEC Advisory Committee on Safety (ACOS) Workshop VII, Frankfurt am Main, Germany March 9/10 2004.

[15] W H Parker, W Tustin and T Masone, "*The Case for Combining EMC and Environmental Testing*", ITEM 2002, pp 54-60.

[16] F Beck and J Sroka, "*EMC Performance of Drive Application Under Real Load Condition*", Schaffner Application Note, 11th March 1999.

This article is based on "*Functional safety requires much more than EMC testing*", Keith Armstrong, EMC-Europe 2004, Eindhoven, The Netherlands, Sep 6-10 2004, ISBN: 90-6144-990-1, pp 348-353.

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