INTRODUCING SW-BASED FAULT HANDLING MECHANISMS TO COPE WITH EMI IN EMBEDDED ELECTRONICS: ARE THEY A GOOD REMEDY?

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Abstract

We summarize hereafter a study [*] *on the effectiveness of two software-based fault-handling mechanisms in terms of detecting conducted electromagnetic interference (EMI) in microprocessors. One of these techniques deals with processor control flow checking. The second one is used to detect errors in code variables. In order to check the effectiveness of such techniques in RF ambient, an IEC 61.000-4-29 Normative-compliant conducted RF-generator was implemented to inject spurious electromagnetic noise into the supply lines of a commercial off-the-shelf (COTS) microcontroller-based system. Experimental results suggest that the considered techniques present a good effectiveness to detect this type of faults, despite the multiple-fault injection nature of EMI in the processor control and data flows, which in most cases results in a complete system functional loss (the system must be reset).*

Introduction

The electromagnetic (EM) environment in which electronic systems have to operate is becoming increasingly hostile while dependence on electronics is widespread and increasing. The need for assurance that application upsets due to the EM environment will not occur is fundamental to acceptance of systems as fit for purpose. In order to solve such problems, design features to impart EM hardness (i.e., Design for Electromagnetic Immunity – DEMI) at the IC-level are beginning to be implemented, but at very high cost in terms of system performance, power consumption, and implementation complexity [1-3].

It is well known that the CMOS technology roadmap leads to the *reduction of supply voltages* (at least for the core part). This fact raises the hope for *less electromagnetic emission* (conducted and radiated). However, this benefit is immediately compensated by a drastically *increased number of simultaneously switching transistors per die*, combined with *faster switching edges due to increasing clock rates* [1]. Thus, *increasing the total RF noise* that can affect embedded functional blocks inside the die itself, as well as affect other dies or ICs placed nearby it. For instance, it is well known that dynamic switching currents in the supply lines on the silicon die are one of the main sources of *radiated electromagnetic emission* which causes the power lines to behave as antennas and to radiate undesired noise. This RF signal induces embedded (more sensitive) functional blocks in the die to suffer from spurious current switching spikes [4]. In addition to affect the functional blocks, these current spikes are conducted in the form of noise outside the IC through the supply and/or data lines and may affect several other components mounted on the application board [5]. Embedded systems

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Most of the solutions found in the literature dealing to minimize EM emissions are design-based propositions [1]. In general, they intend to *reduce the dynamic switching currents* or *optimize distribution of switching currents over time*. As examples, *block decoupling capacitors* and *improved pad-drivers design* contribute to the first, while *clock concepts with intentional non-zero skew* to the second. Note that since I/O signals are important contributors to undesired RF emission in electronic systems, the design of pad drivers as weak as possible could contribute to minimize RF emission. However, note also that this solution leads to a more sensitive IC to noise as well as may expose it to delay faults since transistors become slower with higher temperatures.

Considering the design of ICs with non-zero skew clock signals, this measure effectively reduces electromagnetic emission. However, clock smearing by defining rising and falling edges to occur at different times along with the supply lines plane goes against technology scaling, since a "good" design mandates the implementation of ICs with as perfect as possible synchronized (zero-skew) control signals distributed all over the IC functional blocks. Note also that the zero-skew trend is naturally supported by today's design tools, but if chip designers should take advantage from implementing the clock smearing concept for the sake of reduced RF emission, he/she should perform this clock distribution modification by him/herself, since today's tools do not support directly non-zero clock signal design.

Considering the above discussed, the proposed work deals to impart EM hardness at the software level. This solution can used in conjunction with the IC-level solutions described above, or simply as a standalone alternative solution, which in most cases, (e.g., COTS-based systems) is extremely attractive. As illustrative purpose, some of the rules on which the proposed approach is based on are listed below:

- **Rule #1**: every variable *x* must be duplicated: let *x1* and *x2* be the names of the two copies;
- **Rule #2**: every write operation performed on x must be performed on *x1* and *x2*;
- **Rule #3**: after each read operation on *x*, the two copies *x1* and *x2* must be checked for consistency, and an error detection procedure should be activated if an inconsistency is detected.

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