The Electromagnetic Compatibility of Integrated Circuits—Past, Present, and Future

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***Abstract*—Throughout the decades of continuous advances in semiconductor technology, from the discrete devices of the late 1950s to today's billon-transistor system-on-chip, there have always been concerns about the ability of components to operate safely in an increasingly disruptive electromagnetic environment. This paper provides a nonexhaustive review of the research work conducted in the field of electromagnetic compatibility (EMC) at the IC level over the past 40 years. It also brings together a collection of information and trends in IC technology, in order to build a tentative roadmap for the EMC of ICs until the year 2020, with a focus on measurement methods and modeling approaches.**

***Index Terms*—Emission, history, ICs, modeling, roadmap, standards, susceptibility.**

I. Introduction

ELECTROMAGNETIC compatibility (EMC) research focusing on ICs is not just a recent topic. Early electrical simulators, forerunners of the well-known SPICE simulation tools, were originally designed for simulating the susceptibility of electronic devices to radio frequency interference (RFI). This paper is a modest attempt to review the key developments that have marked the history of research in IC immunity and emissions.

In the past ten years, concerns about EMC have risen in importance as low emissions and high immunity to interference have emerged as key differentiators in overall IC performance. Advances in process integration, higher switching speeds, and more complex circuits tend to increase the amount of parasitic emissions generated by ICs. Reduced supply voltages and an increased number of interfaces tend to decrease the immunity to RFI. EMC has become one of the major causes of IC redesign, mainly due to inadequate design methods and lack of expertise in parasitic noise reduction and immunity improvement. Specific workshops [1] and dedicated sessions at major conferences have enhanced dialogue and exchanges within the IC-EMC community. With the International Electrotechnical Commission (IEC) international standardization committee, applicable standards have emerged both for IC emission and susceptibility characterization [2], and are discussed in Section IV-C. A collaborative book dedicated to the field of EMC at IC level has also been published [3].

The idea of a historical review and roadmap following advances in the EMC of ICs emerged from the authors during EMC Compo 2005 in Munich, Germany. The target was to publish in 2009 an anniversary paper to acknowledge the 30th anniversary of the special issue devoted to the effects of RFI on ICs [4], which appeared in 1979.

An overview of topics that have enjoyed particular scientific interest over the past decades and hold potential for future developments is given in this paper, which comprises four parts. Section II concerns the early work on EMC at the component level and a selection of publications prior to 1996. In Section III, a set of references covering the period 1996–2009 is given. The prospective part of the paper starts with Section IV, which concerns the global trends in the semiconductor technology and the evolution of key parameters that have a direct impact on EMC. The last section gives prospective scenarios for the evolution of parasitic emission and immunity of ICs, as well as roadmaps focusing on standard measurement methods and EMC models.

II. Early Studies on the EMC of ICs

We list here a selection of papers that illustrate advances in the understanding of IC performance in terms of parasitic emission and susceptibility to RFI. This nonexhaustive selection is given in chronological order. The earliest EMC investigations, which primarily concerned the protection of components exposed to a harsh environment, are detailed in Section II-A. During the 1990s, concerns grew over the safety implications of parasitic emissions from components embedded in automotive and aeronautic systems. At the same time, the power and frequency range of transmitters were increasing, creating a more severe and uncontrollable electromagnetic (EM) environment. A selection of important publications related to this evolution is given in Section II-B.

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