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Doctoral Dissertation
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Toward Fault-Tolerant Applications on Reconfigurable Systems-on-Chip

By

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Abstract

Thanks to their performance, reduced power consumption, and adaptability, Programmable Hardware devices, particularly Reconfigurable Systems-on-Chip, have emerged as a cutting-edge platform for many performance-oriented applications, including embedded ones. However, additional efforts are needed to ensure the correct system functionality for applications where reliability is the main concern. In particular, space exploration requires highly reliable systems that can operate in extreme conditions and environments such as the space radiation environment. Indeed, electronic devices, and especially programmable hardware, are sensitive to radiation-induced faults and errors, necessitating fault tolerance in critical applications.

This dissertation proposes and explores methodologies and techniques to enable accurate fault analysis and reliability evaluation for Hardware-Reconfigurable Systems-on-Chip, with a particular focus on safety-critical systems. It addresses the challenges in analyzing radiation sensitivity in complex systems and applications, such as the need for efficient fault detection and diagnosis strategies and the development of dedicated tools and methodologies.

Methodologies, evaluation flow, and tools for analysis and characterization of radiation-induced faults, such as Single Event Transients and Single Event Upsets, are proposed. They include both physical and electrical simulation approaches and radiation test analysis.

Techniques and methodologies for assessing the reliability of heterogeneous systems-on-chips, which includes both processor systems and accelerators based on reconfigurable hardware paradigms, are also presented. Research efforts cover the sensitivity of different modules against fault models resulting from physical analysis, electrical analysis, and radiation test experiments. Evaluated modules

include soft and hard processors, host-device interfacing systems, and neural network accelerators.

The approaches, methodologies, and results presented in this dissertation aim to enable the development of highly reliable and fault-tolerant systems in a wide range of applications, particularly those requiring operation in extreme environments, such as space exploration. Additionally, the proposed methodologies and techniques can be used to analyze and evaluate the reliability of Reconfigurable Systems-on-Chip. This research wants to provide the necessary means to develop and analyze the reliable and efficient operation of such systems in extreme conditions and open the door for new opportunities for the development of advanced, reliable, and efficient systems based on a comprehensive and detailed analysis of the elements of heterogeneous computational platforms including programmable hardware, providing the methodology as well practical tools for reaching this goal.