

# Preface

This book, based on pioneering PhD work at KU Leuven (University of Leuven), Belgium, offers a truly unique combination of techniques and insights in time-domain analog signal processing and radiation hardening by design methodologies.

With the continued and progressive scaling of Complementary metal–oxide–semiconductor (CMOS) chip technologies, a change in paradigm has been established where the conversion of analog to digital signals is shifted to the time domain. Indeed, with the transistor dimensions also the supply voltage becomes lower which tends to limit the dynamic range of classic analog-to-digital converters (ADCs). On the other hand, the improved high-frequency performance in nanometer technologies enables higher resolution in the time domain where the analog information is stored in the time difference between the zero-crossings of an input signal. The ADC is replaced by a time-to-digital converter (TDC).

The need for high-resolution TDCs is numerous as they can be used for all-digital phase-locked loops (ADPLLs), communication circuits, positioning, sensor read-out in instrumentation, time-of-flight measurement, digital oscilloscopes, particle physics, and many more. Different TDC topologies, explained in this book, have been proposed, inspired by the corresponding family of ADCs. Nevertheless, the one family of  $\Delta\Sigma$  ADCs had stayed without TDC counterpart for many years owing to the intrinsic problem of storing and integrating time. Only recently the Holy Grail of higher order noise-shaping  $\Delta\Sigma$  TDCs was unveiled by the authors. The corresponding groundbreaking circuit architectures form the highest motivation of this book.  $\Delta\Sigma$  TDCs are of unprecedented importance since most applications require an extreme temporal resolution down to picoseconds while the analog time input intrinsically varies at a much lower rate (microseconds).

It does not stop here, as the book even takes it one massive leap further. The circuits described in this work have been designed to survive the harshest radiation environments that are found in the most challenging nuclear physics projects in history, namely, the International Thermonuclear Experimental fusion Reactor (ITER) and the Large Hadron Collider (LHC) at CERN. The book discusses all layout-level, circuit-level, and architectural measures needed to design MegaGray (MGy) radiation tolerant integrated circuits (ICs) in nanometer CMOS technologies. This also makes the circuits inherently ultra-robust to process variability, temperature,

and aging effects and paves the way for a larger penetration of advanced integrated electronics in the nuclear and space sector.

This book on radiation tolerant  $\Delta\Sigma$  TDCs is considered indispensable for all engineers, circuit designers, and postgraduate students who are engaged in the design of ADPLLs, TDCs, or other time- or phase-based signal processing circuits. The presented circuits and techniques are essential for all engineers involved in radiation hardened IC design or harsh environment electronics. The book is instructive and informative for all electronic engineers wanting to know more on the design of time-based signal processing circuits or radiation hardening by design.

Enjoy reading!

Heverlee  
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Radiation-Tolerant Delta-Sigma Time-to-Digital  
Converters

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