

Tunable Active Inductors for Next- Generation Wireless and Biomedical Systems

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Preface

The relentless drive toward miniaturization, energy efficiency, and functional reconfigurability in modern electronics has catalyzed a profound convergence between radio-frequency (RF) integrated circuit design and digital health. At the heart of this transformation lies a deceptively simple yet powerful building block: the active inductor, a synthetic inductive element implemented using transistors, capacitors, and feedback networks in standard CMOS technology. Unlike its passive spiral counterpart, burdened by large silicon footprint, fixed post-fabrication values, and modest quality factors, the active inductor offers electronic tunability, compact integration, and seamless compatibility with advanced semiconductor processes. It is this unique combination of attributes that has positioned active inductors not merely as circuit-level curiosities, but as enablers of next-generation wireless and biomedical systems.

This edited book is structured around two complementary and deeply interconnected themes that reflect the dual nature of modern microelectronics: circuit innovation and system-level impact.

Part I delves into the theoretical foundations, architectural evolution, and performance frontiers of active inductors in CMOS. Beginning with the seminal gyrator-C topology, the narrative traces decades of refinement, from early feedback-resistance and cascode enhancements to recent breakthroughs in differential floating inductors with negative-resistance compensation. These chapters' detail how modern designs achieve unprecedented quality factors (exceeding 2500 in some cases), wide inductance tuning ranges (from a few nanohenries to over 400 nH), and robustness against process–voltage–temperature variations, all while operating in deeply scaled CMOS nodes. The discussion extends beyond the inductor itself to its role in reconfigurable RF front-ends: tunable bandpass filters, low-noise amplifiers, voltage-controlled oscillators, and impedance-matching networks that form the backbone of 5G/6G and multi-standard transceivers.

Yet, the true measure of a technology lies not in its intrinsic performance, but in its capacity to solve real-world problems. This insight forms the natural bridge to **Part II**, where the focus shifts from silicon to society, from circuit parameters to patient outcomes. Here, the book explores how RF innovations empower a new generation of connected healthcare systems. Far from being confined to traditional RF circuits, active inductors, and the reconfigurable front-ends they enable, open the door to an entirely new application domain: intelligent, implantable, and battery-free medical electronics.

They become enablers of RFID-enabled biosensors for cardiovascular monitoring, smart prostheses, and implantable diagnostics. They facilitate energy-autonomous medical devices through RF energy harvesting and wireless power transfer, eliminating the need for battery replacement in chronic-care implants. They support programmable hardware platforms, from ultra-low-power MCUs in wearable patches to FPGAs in real-time neural interfaces, that process bio signals at the edge. And critically, they operate within a framework of security, privacy, and regulatory compliance, where cybersecurity is not an afterthought but a life-critical requirement.

Together, these two parts illustrate a powerful synergy: the active inductor is no longer just a passive replacement, it is a gateway to intelligent, adaptive, and patient-centered technologies. From the physics of synthetic inductance to the ethics of data privacy, this book spans the full spectrum of challenges and opportunities at the intersection of microelectronics, communications, and digital health.

We hope this work not only documents the state of the art but also inspires the next generation of engineers and clinicians to co-design systems that are not only technically brilliant but also humanely impactful.

Hatem GARRAB

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