

## Design Of Cmos Radio Frequency Integrated Circuits

Advances in Analog and RF IC Design for Wireless Communication Systems gives technical introductions to the latest and most significant topics in the area of circuit design of analog/RF ICs for wireless communication systems, emphasizing wireless infrastructure rather than handsets. The book ranges from very high performance circuits for complex wireless infrastructure systems to selected highly integrated systems for handsets and mobile devices. Coverage includes power amplifiers, low-noise amplifiers, modulators, analog-to-digital converters (ADCs) and digital-to-analog converters (DACs), and even single-chip radios. This book offers a quick grasp of emerging research topics in RF integrated circuit design and their potential applications, with brief introductions to key topics followed by references to specialist papers for further reading. All of the chapters, compiled by editors well known in their field, have been authored by renowned experts in the subject. Each includes a complete introduction, followed by the relevant most significant and recent results on the topic at hand. This book gives researchers in industry and universities a quick grasp of the most important developments in analog and RF integrated circuit design. Emerging research topics in RF IC design and its potential application Case studies and practical implementation examples Covers fundamental building blocks of a cellular base station system and satellite infrastructure Insights from the experts on the design and the technology trade-offs, the challenges and open questions they often face References to specialist papers for further reading Essential reading for experts in the field of RF circuit design and engineers needing a good reference. This book provides complete design procedures for multiple-pole Butterworth, Chebyshev, and Bessel filters. It also covers capacitors, inductors, and other components with their behavior at RF frequencies discussed in detail. Provides complete design procedures for multiple-pole Butterworth, Chebyshev, and Bessel filters Covers capacitors, inductors, and other components with their behavior at RF frequencies discussed in detail This modern, pedagogic textbook from leading author Behzad Razavi provides a comprehensive and rigorous introduction to CMOS PLL design, featuring intuitive presentation of theoretical concepts, extensive circuit simulations, over 200 worked examples, and 250 end-of-chapter problems. The perfect text for senior undergraduate and graduate students. This book presents the design of ultra-wideband (UWB) impulse-based transmitter and receiver frontends, operating within the 3.1-10.6 GHz frequency band, using CMOS radio-frequency integrated-circuits (RFICs). CMOS RFICs are small, cheap, low power devices, better suited for direct integration with digital ICs as compared to those using III-V compound semiconductor devices. CMOS RFICs are thus very attractive for RF systems and, in fact, the principal choice for commercial wireless markets. The book comprises seven chapters. The first chapter gives an introduction to UWB technology and outlines its suitability for high resolution sensing and high-rate, short-range ad-hoc networking and communications. The second chapter provides the basics of CMOS RFICs needed for the design of the UWB RFIC transmitter and receiver presented in this book. It includes the design fundamentals, lumped and distributed elements for RFIC, layout, post-layout simulation, and measurement. The third chapter discusses the basics of UWB systems including UWB advantages and applications, signals, basic modulations, transmitter and receiver frontends, and antennas. The fourth chapter addresses the design of UWB transmitters including an overview of basic components, design of pulse generator, BPSK modulator design, and design of a UWB tunable transmitter. Chapter 5 presents the design of UWB receivers including the design of UWB low-noise amplifiers, correlators, and a UWB 1 receiver. Chapter 6 covers the design of a UWB uniplanar antenna. Finally, a summary and conclusion is given in Chapter 7.

The Design of CMOS Radio-Frequency Integrated Circuits Cambridge University Press

Top-down approach to practical, tool-independent, digital circuit design, reflecting how circuits are designed.

The work establishes the design flow for the optimization of linear CMOS power amplifiers from the first steps of the design to the final IC implementation and tests. The authors also focuses on design guidelines of the inductor's geometrical characteristics for power applications and covers their measurement and characterization. Additionally, a model is proposed which would facilitate designs in terms of transistor sizing, required inductor quality factors or minimum supply voltage. The model considers limitations that CMOS processes can impose on implementation. The book also provides different techniques and architectures that allow for optimization.

The striking feature of this book is its coverage of the upper GHz domain. However, the latest technologies, applications and broad range of circuits are discussed. Design examples are provided including cookbook-like optimization strategies. This state-of-the-art book is valuable for researchers as well as for engineers in industry. Furthermore, the book serves as fruitful basis for lectures in the area of IC design.

Modern wireless communications hardware is underpinned by RF and microwave design techniques. This insightful book contains a wealth of circuit layouts, design tips, and practical measurement techniques for building and testing practical gigahertz systems. The book covers everything you need to know to design, build, and test a high-frequency circuit.

Microstrip components are discussed, including tricks for extracting good performance from cheap materials. Connectors and cables are also described, as are discrete passive components, antennas, low-noise amplifiers, oscillators, and frequency synthesizers. Practical measurement techniques are presented in detail, including the use of network analyzers, sampling oscilloscopes, spectrum analyzers, and noise figure meters. Throughout the focus is practical, and many worked examples and design projects are included. There is also a CD-ROM that contains a variety of design and analysis programs. The book is packed with indispensable information for students taking courses on RF or microwave circuits and for practising engineers.

This is a rigorous tutorial on radio frequency and microwave power amplifier design, teaching the circuit design techniques that form the microelectronic backbones of modern wireless communications systems. Suitable for self-study, corporate training, or Senior/Graduate classroom use, the book combines analytical calculations and computer-aided design techniques to arm electronic engineers with every possible method to improve their designs and shorten their design time cycles.

This book provides in-depth coverage of transformer-based design techniques that enable CMOS oscillators and frequency dividers to achieve state-of-the-art performance. Design, optimization, and measured performance of oscillators and frequency dividers for different applications are discussed in detail, focusing on not only ultra-low supply voltage but also ultra-wide frequency tuning range and locking range. This book will be an invaluable reference for

anyone working or interested in CMOS radio-frequency or mm-Wave integrated circuits and systems.

CMOS technology has now reached a state of evolution, in terms of both frequency and noise, where it is becoming a serious contender for radio frequency (RF) applications in the GHz range. Cutoff frequencies of about 50 GHz have been reported for 0.18  $\mu\text{m}$  CMOS technology, and are expected to reach about 100 GHz when the feature size shrinks to 100 nm within a few years. This translates into CMOS circuit operating frequencies well into the GHz range, which covers the frequency range of many of today's popular wireless products, such as cell phones, GPS (Global Positioning System) and Bluetooth. Of course, the great interest in RF CMOS comes from the obvious advantages of CMOS technology in terms of production cost, high-level integration, and the ability to combine digital, analog and RF circuits on the same chip. This book discusses many of the challenges facing the CMOS RF circuit designer in terms of device modeling and characterization, which are crucial issues in circuit simulation and design.

This book enables readers to design effective ESD protection solutions for all mainstream RF fabrication processes (GaAs pHEMT, SiGe HBT, CMOS). The new techniques introduced by the authors have much higher protection levels and much lower parasitic effects than those of existing ESD protection devices. The authors describe in detail the ESD phenomenon, as well as ESD protection fundamentals, standards, test equipment, and basic design strategies. Readers will benefit from realistic case studies of ESD protection for RFICs and will learn to increase significantly modern RFICs' ESD safety level, while maximizing RF performance.

Presenting an expanded and thoroughly revised new edition of Tom Lee's acclaimed guide to the design of gigahertz RF integrated circuits. A new chapter on the principles of wireless systems provides a bridge between system and circuit issues. The chapters on low-noise amplifiers, oscillators and phase noise have been significantly expanded. The chapter on architectures now contains several examples of complete chip designs, including a GPS receiver and a wireless LAN transceiver, that bring together the theoretical and practical elements involved in producing a prototype chip. Every section has been revised and updated with the latest findings in the field and the book is packed with physical insights and design tips, and includes a historical overview that sets the whole field in context. With hundreds of circuit diagrams and homework problems this is an ideal textbook for students taking courses on RF design and a valuable reference for practising engineers.

If you're looking for an in-depth and up-to-date understanding bipolar transistor RFIC design, this practical resource is a smart choice. Unlike most books on the market that focus on GaAs MESFET or silicon CMOS process technology, this unique volume is dedicated exclusively to RFIC designs based on bipolar technology. Until now, critical GaAs HBT and SiGe HBT process technologies have been largely neglected in reference books. This book fills this gap, offering you a detailed treatment of this

increasingly important topic. You discover a wide range of circuit topologies that are optimized for maximum performance with bipolar devices. From discussions of key applications (Bluetooth, UWB, GPS, WiMax) and architectures... to in-depth coverage of fabrication technologies and amplifier design... to a look at performance tradeoffs and production costs, this book arms you with complete design know-how for your challenging work in the field.

Equips students with essential industry-relevant knowledge through in-depth explanations, practical applications, examples, and exercises.

An expanded and revised new edition of Tom Lee's acclaimed guide to the design of gigahertz RF integrated circuits.

A frequency synthesizer is one of the most critical building blocks in any wireless transceiver system. Its design is getting more and more challenging as the demand for low-voltage low-power high-frequency wireless systems continuously grows. As the supply voltage is decreased, many existing design techniques are no longer applicable. This book provides the reader with architectures and design techniques to enable CMOS frequency synthesizers to operate at low supply voltage at high frequency with good phase noise and low power consumption. In addition to updating the reader on many of these techniques in depth, this book will also introduce useful guidelines and step-by-step procedure on behaviour simulations of frequency synthesizers. Finally, three successfully demonstrated CMOS synthesizer prototypes with detailed design consideration and description will be elaborated to illustrate potential applications of the architectures and design techniques described. For engineers, managers and researchers working in radio-frequency integrated-circuit design for wireless applications.

This book describes the design of CMOS circuits for ultra-low power consumption including analog, radio frequency (RF), and digital signal processing circuits (DSP). The book addresses issues from circuit and system design to production design, and applies the ultra-low power circuits described to systems for digital hearing aids and capsule endoscope devices. Provides a valuable introduction to ultra-low power circuit design, aimed at practicing design engineers; Describes all key building blocks of ultra-low power circuits, from a systems perspective; Applies circuits and systems described to real product examples such as hearing aids and capsule endoscopes.

Praise for CMOS: Circuit Design, Layout, and Simulation Revised Second Edition from the Technical Reviewers "A refreshing industrial flavor. Design concepts are presented as they are needed for 'just-in-time' learning. Simulating and designing circuits using SPICE is emphasized with literally hundreds of examples. Very few textbooks contain as much detail as this one. Highly recommended!" --Paul M. Furth, New Mexico State University "This book builds a solid knowledge of CMOS circuit design from the ground up. With coverage of process integration, layout, analog and digital models, noise mechanisms, memory circuits, references, amplifiers, PLLs/DLLs, dynamic circuits, and data converters, the text is an excellent reference for both experienced and novice designers alike." --Tyler J. Gomm, Design Engineer, Micron Technology, Inc. "The Second Edition builds upon the success of the first with new chapters that cover additional material such as oversampled converters and non-volatile memories. This is becoming the de facto standard textbook to have on every analog and mixed-signal designer's bookshelf." --Joe Walsh,

Design Engineer, AMI Semiconductor CMOS circuits from design to implementation CMOS: Circuit Design, Layout, and Simulation, Revised Second Edition covers the practical design of both analog and digital integrated circuits, offering a vital, contemporary view of a wide range of analog/digital circuit blocks, the BSIM model, data converter architectures, and much more. This edition takes a two-path approach to the topics: design techniques are developed for both long- and short-channel CMOS technologies and then compared. The results are multidimensional explanations that allow readers to gain deep insight into the design process. Features include: Updated materials to reflect CMOS technology's movement into nanometer sizes Discussions on phase- and delay-locked loops, mixed-signal circuits, data converters, and circuit noise More than 1,000 figures, 200 examples, and over 500 end-of-chapter problems In-depth coverage of both analog and digital circuit-level design techniques Real-world process parameters and design rules The book's Web site, CMOSedu.com, provides: solutions to the book's problems; additional homework problems without solutions; SPICE simulation examples using HSPICE, LTspice, and WinSpice; layout tools and examples for actually fabricating a chip; and videos to aid learning

This book, first published in 2004, is an expanded and revised edition of Tom Lee's acclaimed RFIC text.

A transistor-level, design-intensive overview of high speed and high frequency monolithic integrated circuits for wireless and broadband systems from 2 GHz to 200 GHz, this comprehensive text covers high-speed, RF, mm-wave, and optical fibre circuits using nanoscale CMOS, SiGe BiCMOS, and III-V technologies. Step-by-step design methodologies, end-of chapter problems, and practical simulation and design projects are provided, making this an ideal resource for senior undergraduate and graduate courses in circuit design. With an emphasis on device-circuit topology interaction and optimization, it gives circuit designers and students alike an in-depth understanding of device structures and process limitations affecting circuit performance.

The purpose of this book is to provide a complete working knowledge of the Complementary Metal-Oxide Semiconductor (CMOS) analog and mixed-signal circuit design, which can be applied for System on Chip (SOC) or Application-Specific Standard Product (ASSP) development. It begins with an introduction to the CMOS analog and mixed-signal circuit design with further coverage of basic devices, such as the Metal-Oxide Semiconductor Field-Effect Transistor (MOSFET) with both long- and short-channel operations, photo devices, fitting ratio, etc. Seven chapters focus on the CMOS analog and mixed-signal circuit design of amplifiers, low power amplifiers, voltage regulator-reference, data converters, dynamic analog circuits, color and image sensors, and peripheral (oscillators and Input/Output [I/O]) circuits, and Integrated Circuit (IC) layout and packaging. Features: Provides practical knowledge of CMOS analog and mixed-signal circuit design Includes recent research in CMOS color and image sensor technology Discusses sub-blocks of typical analog and mixed-signal IC products Illustrates several design examples of analog circuits together with layout Describes integrating based CMOS color circuit

This book focuses on high performance radio frequency integrated circuits (RF IC) design in CMOS. 1. Development of radio frequency ICs Wireless communications has been advancing rapidly in the past two decades. Many high performance systems have been developed, such as cellular systems (AMPS, GSM, TDMA, CDMA, W-CDMA, etc. ), GPS system (global po- tioning



system) and WLAN (wireless local area network) systems. The rapid growth of VLSI technology in both digital circuits and analog circuits provides benefits for wireless communication systems. Twenty years ago not many people could imagine millions of transistors in a single chip or a complete radio for size of a penny. Now not only complete radios have been put in a single chip, but also more and more functions have been realized by a single chip and at a much lower price. A radio transmits and receives electro-magnetic signals through the air. The signals are usually transmitted on high frequency carriers. For example, a typical voice signal requires only 30 Kilohertz bandwidth. When it is transmitted by a FM radio station, it is often carried by a frequency in the range of tens of megahertz to hundreds of megahertz. Usually a radio is categorized by its carrier frequency, such as 900 MHz radio or 5 GHz radio. In general, the higher the carrier frequency, the better the directivity, but the more difficult the radio design. This newly revised and expanded edition of the 2003 Artech House classic, *Radio Frequency Integrated Circuit Design*, serves as an up-to-date, practical reference for complete RFIC know-how. The second edition includes numerous updates, including greater coverage of CMOS PA design, RFIC design with on-chip components, and more worked examples with simulation results. By emphasizing working designs, this book practically transports you into the author's own RFIC lab so you can fully understand the function of each design detailed in this book. Among the RFIC designs examined are RF integrated LC-based filters, VCO automatic amplitude control loops, and fully integrated transformer-based circuits, as well as image reject mixers and power amplifiers. If you are new to RFIC design, you can benefit from the introduction to basic theory so you can quickly come up to speed on how RFICs perform and work together in a communications device. A thorough examination of RFIC technology guides you in knowing when RFICs are the right choice for designing a communication device. This leading-edge resource is packed with over 1,000 equations and more than 435 illustrations that support key topics."

Presenting an expanded and thoroughly revised edition of Tom Lee's acclaimed guide to the design of gigahertz RF integrated circuits. A new chapter on the principles of wireless systems provides a bridge between system and circuit issues. The chapters on low-noise amplifiers, oscillators and phase noise have been significantly expanded. The chapter on architectures now contains several examples of complete chip designs, including a GPS receiver and a wireless LAN transceiver, that bring together the theoretical and practical elements involved in producing a prototype chip. Every section has been revised and updated with findings in the field and the book is packed with physical insights and design tips, and includes a historical overview that sets the whole field in context. With hundreds of circuit diagrams and homework problems this is an ideal textbook for students taking courses on RF design and a valuable reference for practising engineers.

This book describes the state-of-the-art in RF, analog, and mixed-signal circuit design for Software Defined Radio (SDR). It synthesizes for analog/RF circuit designers the most important general design approaches to take advantage of the most recent CMOS technology, which can integrate millions of transistors, as well as several real examples from the most recent research results.

Radio-Frequency Integrated-Circuit Engineering addresses the theory, analysis and design of passive and active RFIC's using Si-

based CMOS and Bi-CMOS technologies, and other non-silicon based technologies. The materials covered are self-contained and presented in such detail that allows readers with only undergraduate electrical engineering knowledge in EM, RF, and circuits to understand and design RFICs. Organized into sixteen chapters, blending analog and microwave engineering, Radio-Frequency Integrated-Circuit Engineering emphasizes the microwave engineering approach for RFICs. • Provides essential knowledge in EM and microwave engineering, passive and active RFICs, RFIC analysis and design techniques, and RF systems vital for RFIC students and engineers • Blends analog and microwave engineering approaches for RFIC design at high frequencies • Includes problems at the end of each chapter

This book explains the application of recent advances in computational intelligence – algorithms, design methodologies, and synthesis techniques – to the design of integrated circuits and systems. It highlights new biasing and sizing approaches and optimization techniques and their application to the design of high-performance digital, VLSI, radio-frequency, and mixed-signal circuits and systems. This first of two related volumes addresses the design of analog and mixed-signal (AMS) and radio-frequency (RF) circuits, with 17 chapters grouped into parts on analog and mixed-signal applications, and radio-frequency design. It will be of interest to practitioners and researchers in computer science and electronics engineering engaged with the design of electronic circuits.

With the proliferation of wireless networks, there is a need for more compact, low-cost, power efficient transmitters that are capable of supporting the various communication standards, including Bluetooth, WLAN, GSM/EDGE, WCDMA and 4G of 3GPP cellular. This book describes a novel idea of RF digital-to-analog converters (RFDAC) and demonstrates how they can realize all-digital, fully-integrated RF transmitters that support all the current multi-mode and multi-band communication standards. With this book the reader will: Understand the challenges of realizing a universal CMOS RF transmitter Recognize the design issues and the advantages and disadvantages related to analog and digital transmitter architectures Master designing an RF transmitter from system level modeling techniques down to circuit designs and their related layout know-hows Grasp digital polar and I/Q calibration techniques as well as the digital predistortion approaches Learn how to generate appropriate digital I/Q baseband signals in order to apply them to the test chip and measure the RF-DAC performance. Highlights the benefits and implementation challenges of software-defined transmitters using CMOS technology Includes various types of analog and digital RF transmitter architectures for wireless applications Presents an all-digital polar RFDAC transmitter architecture and describes in detail its implementation Presents a new all-digital I/Q RFDAC transmitter architecture and its implementation Provides comprehensive design techniques from system level to circuit level Introduces several digital predistortion techniques which can be used in RF transmitters Describes the entire flow of system modeling, circuit simulation, layout techniques and the measurement process Advances in electronics have pushed mankind to create devices, ranging from - credible gadgets to medical equipment to spacecraft instruments. More than that, modern society is getting used to—if not dependent on—the comfort, solutions, and astonishing amount of information brought by these devices. One field that has continuously benefited from those advances is the radio frequency integrated circuit (RFIC) design, which in its turn has promoted countless benefits to the mankind as a payback. Wireless communications is one prominent example of what the advances in electronics have enabled and their consequences to our daily life. How could anyone back in the eighties think of the possibilities opened by the wireless local area networks (WLANs) that can be found today in a host of places, such as public libraries, coffee shops, trains, to name just a few? How can a youngster, who lives this true WLAN experience nowadays, imagine a world

without it? This book deals with the design of linear CMOS RF Power Amplifiers (PAs). The RF PA is a very important part of the RF transceiver, the device that enables wireless communications. Two important aspects that are key to keep the advances in RF PA design at an accelerated pace are treated: efficiency enhancement and frequency-tunable capability. For this purpose, the design of two different integrated circuits realized in a 0.11  $\mu\text{m}$  technology is presented, each one addressing a different aspect. With respect to efficiency enhancement, the design of a dynamic supply RF power amplifier is treated, making up the material of Chaps. 2 to 4.

Improving the performance of existing technologies has always been a focal practice in the development of computational systems. However, as circuitry is becoming more complex, conventional techniques are becoming outdated and new research methodologies are being implemented by designers. Performance Optimization Techniques in Analog, Mix-Signal, and Radio-Frequency Circuit Design features recent advances in the engineering of integrated systems with prominence placed on methods for maximizing the functionality of these systems. This book emphasizes prospective trends in the field and is an essential reference source for researchers, practitioners, engineers, and technology designers interested in emerging research and techniques in the performance optimization of different circuit designs.

This book provides the most comprehensive and in-depth coverage of the latest circuit design developments in RF CMOS technology. It is a practical and cutting-edge guide, packed with proven circuit techniques and innovative design methodologies for solving challenging problems associated with RF integrated circuits and systems. This invaluable resource features a collection of the finest design practices that may soon drive the system-on-chip revolution. Using this book's state-of-the-art design techniques, one can apply existing technologies in novel ways and to create new circuit designs for the future.

Summarizes the schemes and technologies in RF circuit design, describes the basic parameters of an RF system and the fundamentals of RF system design, and presents an introduction of the individual RF circuit block design. Forming the backbone of today's mobile and satellite communications networks, radio frequency (RF) components and circuits are incorporated into everything that transmits or receives a radio wave, such as mobile phones, radio, WiFi, and walkie talkies. RF Circuit Design, Second Edition immerses practicing and aspiring industry professionals in the complex world of RF design. Completely restructured and reorganized with new content, end-of-chapter exercises, illustrations, and an appendix, the book presents integral information in three complete sections: Part One explains the different methodologies between RF and digital circuit design and covers voltage and power transportation, impedance matching in narrow-band case and wide-band case, gain of a raw device, measurement, and grounding. It also goes over equipotentiality and current coupling on ground surface, as well as layout and packaging, manufacturability of product design, and radio frequency integrated circuit (RFIC). Part Two includes content on the main parameters and system analysis in RF circuit design, the fundamentals of differential pair and common-mode rejection ratio (CMRR), Balun, and system-on-a-chip (SOC). Part Three covers low-noise amplifier (LNA), power amplifier (PA), voltage-controlled oscillator (VCO), mixers, and tunable filters. RF Circuit Design, Second Edition is an ideal book for engineers and managers who work in RF circuit design and for courses in electrical or electronic engineering.

The Acclaimed RF Microelectronics Best-Seller, Expanded and Updated for the Newest Architectures, Circuits, and Devices Wireless communication has become almost as ubiquitous as electricity, but RF design continues to challenge engineers and researchers. In the 15 years since the first edition of this classic text, the demand for higher performance has led to an explosive growth of RF design techniques. In RF Microelectronics, Second Edition, Behzad Razavi systematically teaches the fundamentals as well as the state-of-the-art developments in the analysis and design of RF circuits and transceivers. Razavi has written the second edition to reflect today's RF microelectronics, covering



key topics in far greater detail. At nearly three times the length of the first edition, the second edition is an indispensable tome for both students and practicing engineers. With his lucid prose, Razavi now Offers a stronger tutorial focus along with hundreds of examples and problems Teaches design as well as analysis with the aid of step-by-step design procedures and a chapter dedicated to the design of a dual-band WiFi transceiver Describes new design paradigms and analysis techniques for circuits such as low-noise amplifiers, mixers, oscillators, and frequency dividers This edition's extensive coverage includes brand new chapters on mixers, passive devices, integer-N synthesizers, and fractional-N synthesizers. Razavi's teachings culminate in a new chapter that begins with WiFi's radio specifications and, step by step, designs the transceiver at the transistor level. Coverage includes Core RF principles, including noise and nonlinearity, with ties to analog design, microwave theory, and communication systems An intuitive treatment of modulation theory and wireless standards from the standpoint of the RF IC designer Transceiver architectures such as heterodyne, sliding-IF, directconversion, image-reject, and low-IF topologies. Low-noise amplifiers, including cascode common-gate and commonsource topologies, noise-cancelling schemes, and reactance-cancelling configurations Passive and active mixers, including their gain and noise analysis and new mixer topologies Voltage-controlled oscillators, phase noise mechanisms, and various VCO topologies dealing with noise-power-tuning trade-offs All-new coverage of passive devices, such as integrated inductors, MOS varactors, and transformers A chapter on the analysis and design of phase-locked loops with emphasis on low phase noise and low spur levels Two chapters on integer-N and fractional-N synthesizers, including the design of frequency dividers Power amplifier principles and circuit topologies along with transmitter architectures, such as polar modulation and outphasing

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