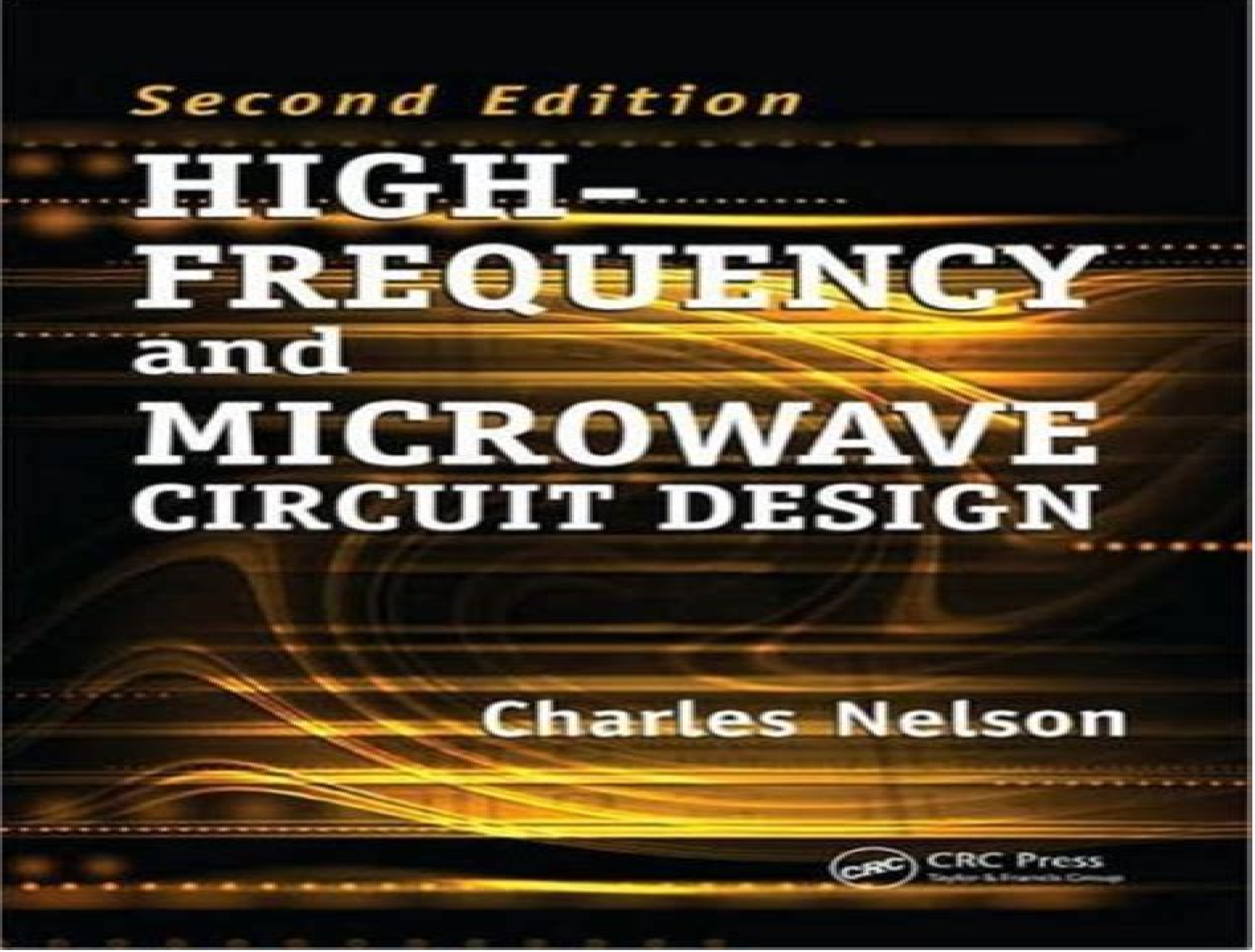

Second Edition

# HIGH-FREQUENCY and MICROWAVE CIRCUIT DESIGN

Charles Nelson

CRC Press
Taylor & Francis Group

# High Frequency And Microwave Circuit Design

**Jia-Sheng Hong**

**High Frequency And Microwave Circuit Design:**

*High Frequency Techniques* Joseph F. White,2016-08-01 This textbook is an introduction to microwave engineering The scope of this book extends from topics for a first course in electrical engineering in which impedances are analyzed using complex numbers through the introduction of transmission lines that are analyzed using the Smith Chart and on to graduate level subjects such as equivalent circuits for obstacles in hollow waveguides analyzed using Green s Functions This book is a virtual encyclopedia of circuit design methods Despite the complexity topics are presented in a conversational manner for ease of comprehension The book is not only an excellent text at the undergraduate and graduate levels but is as well a detailed reference for the practicing engineer Consider how well informed an engineer will be who has become familiar with these topics as treated in High Frequency Techniques in order of presentation Brief history of wireless radio and the Morse code U S Radio Frequency Allocations Introduction to vectors AC analysis and why complex numbers and impedance are used Circuit and antenna reciprocity Decibel measure Maximum power transfer Skin effect Computer simulation and optimization of networks LC matching of one impedance to another Coupled Resonators Uniform transmission lines for propagation VSWR return Loss and mismatch error The Telegrapher Equations derived Phase and Group Velocities The Impedance Transformation Equation for lines derived Fano s and Bode s matching limits The Smith Chart derived Slotted Line impedance measurement Constant Q circles on the Smith Chart Approximating a transmission line with lumped L s and C s ABCD Z Y and Scattering matrix analysis methods for circuits Statistical Design and Yield Analysis of products Electromagnetic Fields Gauss s Law Vector Dot Product Divergence and Curl Static Potential and Gradient Ampere s Law and Vector Curl Maxwell s Equations and their visualization The Laplacian Rectangular cylindrical and spherical coordinates Skin Effect The Wave Equation The Helmholtz Equations Plane Propagating Waves Rayleigh Fading Circular elliptic Polarization Poynting s Theorem EM fields on Transmission Lines Calculating the impedance of coaxial lines Calculating and visualizing the fields in waveguides Propagation constants and waveguide modes The Taylor Series Expansion Fourier Series and Green s Functions Higher order modes and how to suppress them Vector Potential and Retarded Potentials Wire and aperture antennas Radio propagation and path loss Electromagnetic computer simulation of structures Directional couplers The Rat Race Hybrid Even and Odd Mode Analysis applied to the backward wave coupler Network analyzer impedance and transmission measurements Two port Scattering Parameters s matrix The Hybrid Ring coupler The Wilkinson power divider Filter design Butterworth Maximally flat Tchebyscheff responses Filter Q Diplexer Bandpass and Elliptic filters Richard s Transformation Kuroda s Identities Mumford s transmission line stub filters Transistor Amplifier Design gain biasing stability and conjugate matching Noise in systems noise figure of an amplifier cascade Amplifier non linearity and spurious free dynamic range Statistical Design and Yield Analysis High-Frequency and Microwave Circuit Design Charles Nelson,2018-12-14 An integral part of any communications system high frequency and microwave design stimulates major progress in the wireless world and continues to serve as a foundation for the commercial wireless products we use every day The exceptional pace of advancement in developing these systems stipulates that engineers be well versed in multiple areas of electronics engineering With more illustrations examples and worked problems High Frequency and Microwave Circuit Design Second Edition provides engineers with a diverse body of knowledge they can use to meet the needs of this rapidly progressing field The book details the modulation and demodulation of circuits and relates resonant circuits to practical needs The author provides a logical progression of material that moves from medium frequencies to microwave frequencies He introduces rectangular waveguides as high pass devices and explains conditions under which dielectric breakdown may limit the amount of power that may be transmitted in a completely expanded chapter The section on antennas is completely updated to demystify the useful characteristic of antennas and relate their performance to the requirements of digital communication systems Exploring the latest developments in communications engineering this reference outlines a variety of topics using sufficient mathematical derivations and provides an overview of the concepts engineers need to understand current technologies and develop those of the future **Introduction to Microwave Circuits** Robert J. Weber,2001-01-23 Do you want to design a wireless transmitter or receiver for hand held telephones Have you wondered why the printed circuit wires on high frequency circuits don t always run in a straight line This valuable text will answer all of your questions regarding component parasitics and circuit characterization for rf microwave amplifier oscillator and filter circuit design and analysis You will understand why capacitors act as inductors and vice versa and why amplifiers work like oscillators while oscillators for local area networks work more like local area heaters Application of the information in Introduction to Microwave Circuits will reduce design cycle time and costs markedly increasing the probability of first time success in printed circuit or monolithic microwave integrated circuit MMIC design Several approaches are taken into consideration such as the effects of currents on the ground plane bypass and coupling capacitors and nonlinear effects in linear circuits Featured topics include Incorporation of component parasitics in the design cycle Closed form solution to oscillator design Odd mode stability analysis PIN diode analysis for high power switching applications An integrated design example of a 1 25 GHz amplifier oscillator and filter printed circuit is also included which could be useful in printed circuit board designs from tens of megahertz to tens of gigahertz Introduction to Microwave Circuits provides the tools necessary to analyze or synthesize microwave circuits This text is an essential reference for undergraduate students microwave engineers and administrators Also it will assist experienced designers in other fields to meet the current rapid expansion of communication system applications and work effectively in microwave circuit design About the Author Robert J Weber began his prolific career in the Solid State Research Laboratory at the Collins Radio Company later a part of Rockwell International For 25 years he worked on advanced development and applied research in the one to ten gigahertz frequency range and received several distinguished awards for his valuable contributions to the field Dr Weber is involved in ongoing experimental research in integrating microwave circuits with other devices such as MEMS chemical sensors and electro optics Also he teaches microwave circuit design and fiber optics communications at the Department of Electrical and Computer Engineering Iowa State University Dr Weber is an IEEE Fellow Sponsored by IEEE Microwave Theory and Techniques Society **RF and Microwave Circuit Design** Charles E. Free,Colin S. Aitchison,2021-09-14 RF and Microwave Circuit Design Provides up to date coverage of the fundamentals of high frequency microwave technology written by two leading voices in the field RF and Microwave Circuit Design Theory and Applications is an authoritative highly practical introduction to basic RF and microwave circuits With an emphasis on real world examples the text explains how distributed circuits using microstrip and other planar transmission lines can be designed and fabricated for use in modern high frequency passive and active circuits and sub systems The authors provide clear and accurate guidance on each essential aspect of circuit design from the theory of transmission lines to the passive and active circuits that form the basis of modern high frequency circuits and sub systems Assuming a basic grasp of electronic concepts the book is organized around first principles and includes an extensive set of worked examples to guide student readers with no prior grounding in the subject of high frequency microwave technology Throughout the text detailed coverage of practical design using distributed circuits demonstrates the influence of modern fabrication processes Filling a significant gap in literature by addressing RF and microwave circuit design with a central theme of planar distributed circuits this textbook Provides comprehensive discussion of the foundational concepts of RF and microwave transmission lines introduced through an exploration of wave propagation along a typical transmission line Describes fabrication processes for RF and microwave circuits including etched thick film and thin film RF circuits Covers the Smith Chart and its application in circuit design S parameters Mason s non touching loop rule transducer power gain and stability Discusses the influence of noise in high frequency circuits and low noise amplifier design Features an introduction to the design of high frequency planar antennas Contains supporting chapters on fabrication circuit parameters and measurements Includes access to a companion website with PowerPoint slides for instructors as well as supplementary resources Perfect for senior undergraduate students and first year graduate students in electrical engineering courses RF and Microwave Circuit Design Theory and Applications will also earn a place in the libraries of RF and microwave professionals looking for a useful reference to refresh their understanding of fundamental concepts in the field **High Frequency Circuit Design** Ali Behagi,2018-03-20 Unlike the many traditional textbooks written mainly for the classroom teaching the High Frequency Circuit Design book can be taught in a classroom or in a computer lab where students can use a very low cost or no cost software in solving the many examples in the book For example the High Frequency Circuit Design book shows how to use the MATLAB Scripting in solving all the impedance matching examples in the book This book introduces not only a solid understanding of the RF and microwave concepts and components but more importantly it shows how to use the software tools in the analysis and synthesis of these essential components in a design flow as practiced in industry A brief organization of the book is as follows In chapter 1 a thorough analysis of RF and microwave concepts and components are presented In chapter 2 propagation of the plane waves in different media is introduced Popular types of transmission lines such as coaxial microstrip stripline and waveguides are defined and their parameters and performances are discussed Microstrip bias feed and directional couplers are designed In Chapter 3 derivation of RF and microwave network parameters development and use of the network S parameters and the movement of the lumped and distributed elements on the Smith chart are presented In Chapter 4 the subject of resonant circuits and filters are thoroughly discussed and several resonators and filters are designed In Chapter 5 the conditions for maximum power transfer and the equations for matching any two impedances are derived Both analytical and graphical techniques are used to design narrowband and broadband impedance matching networks In Chapter 6 analytic design equations for quarter wave transformer and single stub matching networks are derived Narrowband and broadband distributed matching networks are designed In Chapter 7 single stage amplifiers are designed by utilizing two different impedance matching objectives The first amplifier is designed for maxim gain where the input and the output are conjugately matched the second amplifier is a low noise amplifier where the transistor is selectively mismatched to achieve a specific Noise Figure **High-Frequency Circuit Design and Measurements** P. Yip,2012-12-06 An elective course in the final year BEng progamme in electronic engin eering in the City Polytechnic of Hong Kong was generated in response to the growing need of local industry for graduate engineers capable of designing circuits and performing measurements at high frequencies up to a few gigahertz This book has grown out from the lecture and tutorial materials written specifically for this course This course should in the opinion of the author best be conducted if students can take a final year design project in the same area Examples of projects in areas related to the subject matter of this book which have been completed successfully in the last two years that the course has been run include low noise amplifiers dielectric resonator loaded oscillators and down converters in the 12 GHz as well as the 1 GHz bands mixers varactor tuned and non varactor tuned VCOs low noise and power amplifiers and filters and duplexers in the 1 GHz 800 MHz and 500 MHz bands The book is intended for use in a course of forty lecture hours plus twenty tutorial hours and the prerequisite expected of the readers is a general knowledge of analogue electronic circuits and basic field theory Readers with no prior knowledge in high frequency circuits are recom mended to read the book in the order that it is arranged ______ In_t_ro_d_u_c_tl_ o_n ______ 1 1 Co-simulations of Microwave Circuits and High-Frequency Electromagnetic Fields Mei Song Tong,Xiao Yu Li,2024-07-03 This book aims to provide many advanced application topics for microwave circuits and high frequency electromagnetic EM fields by using advanced design system ADS and high frequency structure simulator HFSS as simulation platforms In particular it contains the latest multidisciplinary co simulation guidance on the design of relevant components and devices Currently the circuit field design and performance analysis and optimization strongly rely on various kinds of robust electronic design automation EDA software RF microwave engineers must grasp two or more types of related simulation design software ADS by Keysight and HFSS by Ansys are the representative for circuit simulations and for field and structural simulations of microwave devices respectively At present these two types of software are widely used in enterprises universities and research institutions The main purpose of this book is to enable readers who are interested in microwave engineering and applied electromagnetics to master the applications of these two tools It also helps readers expand their knowledge boundaries behind those types of software and deepen their understanding of developing interdisciplinary technologies by co simulations The book is divided into three parts The first part introduces the two latest versions of ADS and HFSS and helps readers better understand the basic principles and latest functions better It also advises how to choose appropriate simulation tools for different problems The second part mainly describes co simulations for high frequency EM fields microwave circuits antenna designs EM compatibility EMC and thermal and structural analyses It provides guides and advices on performing co simulations by ADS and HFSS incorporated with other types of software respectively The last part narrates the automation interfaces and script programming methods for co simulations It primarily deals with the Advanced Extension Language AEL Python Data Link PDL and MATLAB interface in ADS For HFSS it discusses VBScript IronPython scripting and Application Programming Interface APIs based on MATLAB Each topic contains practical examples to help readers understand so that they can gain a solid knowledge and skills regarding automated interfaces and scripting methods based on these kinds of software Concisely written in combination with practical examples this book is very suitable as a textbook in introductory courses on microwave circuit and EM simulations and also as a supplementary textbook in many courses on electronics microwave engineering communication engineering and related fields As well it can serve as a reference book for microwave engineers and researchers **RF and Microwave Oscillator Design** Micha Odyniec,2002 This groundbreaking book is the first to present the state of the art in microwave oscillator design with an emphasis on new nonlinear methods A compilation of pioneering work from experts in the field it also provides rigorous theory and historical background Invaluable for professionals at all levels of design expertise this volume helps you to bridge the gap between design practice and new powerful design methods learn all aspects of modern oscillator design and review practical designs and experimental results of fixed frequency high Q low noise oscillators *High Frequency Circuit Design-Second Edition-with 90 Circuit Design Examples* Ali Behagi,2020-12-10 The second edition of the High Frequency Circuit Design is a unique book in the sense that it uses a free software LTspice to construct the schematic diagram and run the circuit simulation to find the circuit response It also uses a low cost software MATLAB to post process the simulated data The high frequency circuit design book introduces not only a solid understanding of the high frequency Concepts and Components such as Network Parameters Transmission Lines Resonant Circuits Filter Design Discrete and Distributed Impedance Matching Circuits Maximum Gain and Low Noise Amplifiers but more importantly it shows how to use design tools to analyze synthesize tune and optimize these essential components in a design flow as practiced in industry The high frequency book is also valuable in that it marries the high frequency circuit design theory with many practical design examples Learning the fundamental theory of the high frequency circuit design with the practical application of low cost software will broaden the student s potential for carrier opportunists **RF and Microwave Circuit Design** Ali A. Behagi,2015-08-05 Microwave Engineering is a vast subject with topics ranging from semiconductor physics to electromagnetic theory This textbook covers the microwave and RF engineering topics from an Electronic Design Automation EDA approach The topics includes RF and microwave concepts and components transmission lines network parameters maximum power transfer requirements lumped and distributed impedance matching and several linear amplifier designs Almost all subject matters covered in the textbook are accompanied by examples that are solved using the latest version of Keysight ADS software University students and practicing engineers will find this book both as a potent learning tool and as a reference guide to quickly setup designs using the ADS software The book thoroughly covers the basics as well as introducing techniques that may not be familiar to some engineers This includes subjects such as the frequent use of the MATLAB Script capability *Micro Electronic Circuit Design for High Performance Applications* Dr. S.Sathya,Dr. Priyanka Veeramosu,Dr. R. Boopathi,Dr. Bindu K V,Mr. Nishant S,2025-01-28 Microelectronic Circuit Design for High Performance Applications is a comprehensive that explores advanced circuit design principles tailored for high speed low power and efficient electronic systems Topics such as semiconductor devices analog and digital circuit design signal integrity and power management the book provides in depth insights into optimizing performance in modern electronic applications It integrates theoretical foundations with practical design methodologies making it valuable for engineers researchers and students involved in cutting edge microelectronics With a focus on emerging technologies the addresses challenges in miniaturization integration and high frequency operation ensuring relevance in contemporary and future electronic design **Microwave Circuit Design Using Linear and Nonlinear Techniques** George D. Vendelin,Anthony M. Pavio,Ulrich L. Rohde,Matthias Rudolph,2021-04-27 Four leaders in the field of microwave circuit design share their newest insights into the latest aspects of the technology The third edition of Microwave Circuit Design Using Linear and Nonlinear Techniques delivers an insightful and complete analysis of microwave circuit design from their intrinsic and circuit properties to circuit design techniques for maximizing performance in communication and radar systems This new edition retains what remains relevant from previous editions of this celebrated book and adds brand new content on CMOS technology GaN SiC frequency range and feedback power amplifiers in the millimeter range region The third edition contains over 200 pages of new material The distinguished engineers academics and authors emphasize the commercial applications in telecommunications and cover all aspects of transistor technology Software tools for design and microwave circuits are included as an accompaniment to the book In addition to information about small and large signal amplifier design and power amplifier design readers will benefit from the book s treatment of a wide variety of topics like An in depth discussion of the foundations of RF and microwave systems including Maxwell s equations applications of the technology analog and digital requirements and elementary definitions A treatment of lumped and distributed elements including a discussion of the parasitic effects on lumped elements Descriptions of active devices including diodes microwave transistors heterojunction bipolar transistors and microwave FET Two port networks including S Parameters from SPICE analysis and the derivation of transducer power gain Perfect for microwave integrated circuit designers the third edition of Microwave Circuit Design Using Linear and Nonlinear Techniques also has a place on the bookshelves of electrical engineering researchers and graduate students It s comprehensive take on all aspects of transistors by world renowned experts in the field places this book at the vanguard of microwave circuit design research Radio Frequency Integrated Circuit Design John W. M. Rogers,Calvin Plett,2010 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 authors 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 **RF/Microwave Circuit Design for Wireless Applications** Ulrich L. Rohde,David P. Newkirk,2004-03-24 A unique state of the art guide to wireless integrated circuit design With wireless technology rapidly exploding there is a growing need for circuit design information specific to wireless applications Presenting a single source guidebook to this dynamic area industry expert Ulrich Rohde and writer David Newkirk provide researchers and engineers with a complete set of modeling design and implementation tools for tackling even the newest IC technologies They emphasize practical design solutions for high performance devices and circuitry incorporating ample examples of novel and clever circuits from high profile companies They also provide excellent appendices containing working models and CAD based applications RF Microwave Circuit Design for Wireless Applications offers Introduction to wireless systems and modulation types A systematic approach that differentiates between designing for battery operated devices and base station design A comprehensive introduction to semiconductor technologies from bipolar transistors to CMOS to GaAs MESFETs Clear guidelines for obtaining the best performance in discrete and integrated amplifier design Detailed analysis of available mixer circuits applicable to the wireless frequency range In depth explanations of oscillator circuits including microwave oscillators and ceramic resonator based oscillators A thorough evaluation of all components of wireless synthesizers **High-Frequency Analog Integrated Circuit Design** Ravender Goyal,1995 Offering comprehensive coverage of state of the art GaAs MESFET technology and design techniques for analog ICs this book features detailed step by step guidance on everything from basic concepts such as biasing network current source current mirrors and differential circuits to more complex designs such as amplifiers mixers oscillators and operational amplifier designs and finally high level functions such as A D and D A converters and their implementation in GaAs technology , **Circuits and Applications Using Silicon Heterostructure Devices** John D. Cressler,2018-10-03 No matter how you slice it semiconductor devices power the communications revolution Skeptical Imagine for a moment that you could flip a switch and instantly remove all the integrated circuits from planet Earth A moment s reflection would convince you that there is not a single field of human endeavor that would not come to a grinding halt be it commerce agriculture education medicine or entertainment Life as we have come to expect it would simply cease to exist Drawn from the comprehensive and well reviewed Silicon Heterostructure Handbook this volume covers SiGe circuit applications in the real world Edited by John D Cressler with contributions from leading experts in the field this book presents a broad overview of the merits of SiGe for emerging communications systems Coverage spans new techniques for improved LNA design RF to millimeter wave IC design SiGe MMICs SiGe Millimeter Wave ICs and wireless building blocks using SiGe HBTs The book provides a glimpse into the future as envisioned by industry leaders Fundamentals of RF and Microwave Circuit Design Ali Behagi,Manou Ghanevati,2017-09-15 RF and microwave circuit design is a fascinating and fulfilling career path It is also an extremely vast subject with topics ranging from semiconductor physics to electromagnetic theory and techniques The Fundamentals of RF and Microwave Circuit Design book covers the subject from a Computer Aided Design CAD standpoint using the low cost or free software such as LTspice AppCAD Smith3 10 and TXLINE Topics discussed in this book include RF and microwave concepts and components transmission lines network parameters and the Smith chart resonant circuits and filter designs power transfer and lumped impedance matching network design distributed impedance matching network design and various amplifier circuits utilizing SPICE simulation software Almost all the subject matters covered in this book are accompanied by practical examples University students will find this book as a potent learning tool and practicing engineers will find it very useful as a reference guide to quickly setup designs using the inexpensive but accurate and powerful software Microstrip Filters for RF / Microwave Applications Jia-Sheng Hong,2011-01-06 The first edition of Microstrip Filters for RF Microwave Applications was published in 2001 Over the years the book has been well received and is used extensively in both academia and industry by microwave researchers and engineers From its inception as a manuscript the book is almost 8 years old While the fundamentals of filter circuits have not changed further innovations in filter realizations and other applications have occurred with changes in the technology and use of new fabrication processes such as the recent advances in RF MEMS and ferroelectric films for tunable filters the use of liquid crystal polymer LCP substrates for multilayer circuits as well as the new filters for dual band multi band and ultra wideband UWB applications Although the microstrip filter remains as the main transmission line medium for these new developments there has been a new trend of using combined planar transmission line structures such as co planar waveguide CPW and slotted ground structures for novel physical implementations beyond the single layer in order to achieve filter miniaturization and better performance Also over the years practitioners have suggested topics that should be added for completeness or deleted in some cases as they were not very useful in practice In view of the above the authors are proposing a revised version of the Microstrip Filters for RF Microwave Applications text and a slightly changed book title of Planar Filters for RF Microwave Applications to reflect the aforementioned trends in the revised book *Wavelets in Electromagnetics and Device Modeling* George W. Pan,2003-04-10 Thema des Buches ist die Elementarwellen Wavelet Theorie Zeit Frequenz Analyse ein Grenzgebiet zwischen Mathematik und Ingenieurwissenschaften viele Anwendungen in der Elektronik darunter Antennentheorie und drahtlose Kommunikation erstes Buch das die Wavelet Theorie auf elektromagnetische Ph nomene und auf die Modellierung von Halbleiterbauelementen anwendet

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