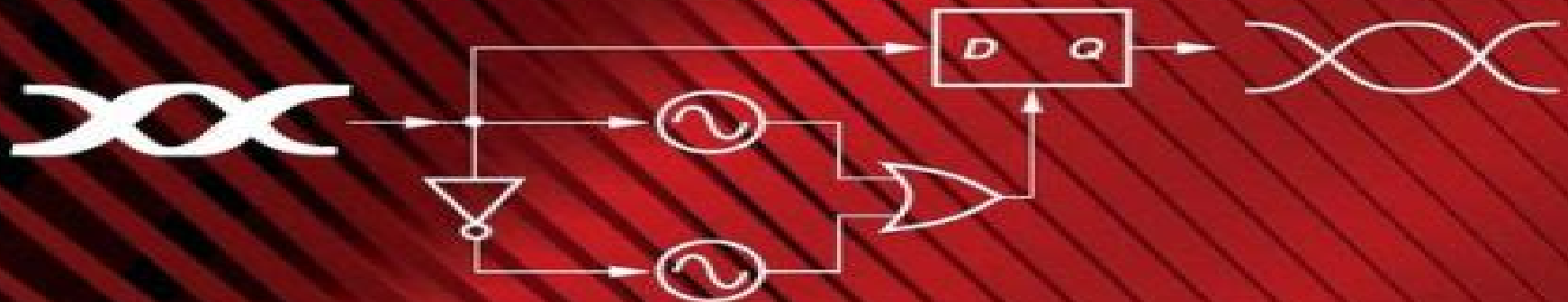


# Design of Integrated Circuits for Optical Communications

Behzad Razavi

*Second Edition*



# Design Of Integrated Circuits For Optical Communications

**Behzad Razavi**



## **Design Of Integrated Circuits For Optical Communications:**

**Design of Integrated Circuits for Optical Communications** Behzad Razavi, 2012-08-21 The only book on integrated circuits for optical communications that fully covers High Speed IOs PLLs CDRs and transceiver design including optical communication The increasing demand for high speed transport of data has revitalized optical communications leading to extensive work on high speed device and circuit design With the proliferation of the Internet and the rise in the speed of microprocessors and memories the transport of data continues to be the bottleneck motivating work on faster communication channels Design of Integrated Circuits for Optical Communications Second Edition deals with the design of high speed integrated circuits for optical communication transceivers Building upon a detailed understanding of optical devices the book describes the analysis and design of critical building blocks such as transimpedance and limiting amplifiers laser drivers phase locked loops oscillators clock and data recovery circuits and multiplexers The Second Edition of this bestselling textbook has been fully updated with A tutorial treatment of broadband circuits for both students and engineers New and unique information dealing with clock and data recovery circuits and multiplexers A chapter dedicated to burst mode optical communications A detailed study of new circuit developments for optical transceivers An examination of recent implementations in CMOS technology This text is ideal for senior graduate students and engineers involved in high speed circuit design for optical communications as well as the more general field of wireline communications **Integrated**

**CMOS Circuits for Optical Communications** Mark Ingels, Michiel Steyaert, 2013-03-09 This work investigates the feasibility of the integration of interface circuits for optical communication systems in a standard unmodified digital CMOS process This paves the way for single chip communication systems where the optical interfaces are integrated on the same die as the required digital circuitry The optical receiver is a key element in the optical communication link In this work a transimpedance amplifier which consists of a voltage amplifier with resistive feedback is used as the first stage Unlike for many other circuits the optimal place of its dominant pole is the input node It is also demonstrated that a high gain of the voltage amplifier is primordial to obtain good performances and that this may be obtained through the use of multiple stages Noise aspects are investigated and the conclusion is drawn that the amplifier's input capacitance can be smaller than the photodiode's capacitance for optimal performance *CMOS Receiver Front-ends for Gigabit Short-Range Optical*

*Communications* Francisco Aznar, Santiago Celma Pueyo, Belén Calvo Lopez, 2012-08-09 This book describes optical receiver solutions integrated in standard CMOS technology attaining high speed short range transmission within cost effective constraints These techniques support short reach applications such as local area networks fiber to the home and multimedia systems in cars and homes The authors show how to implement the optical front end in the same technology as the subsequent digital circuitry leading to integration of the entire receiver system in the same chip The presentation focuses on CMOS receiver design targeting gigabit transmission along a low cost standardized plastic optical fiber up to 50m in length

This book includes a detailed study of CMOS optical receiver design from building blocks to the system level

**Fundamentals of Photonics** Bahaa E. A. Saleh, Malvin Carl Teich, 2020-03-04 Fundamentals of Photonics A complete thoroughly updated full color third edition Fundamentals of Photonics Third Edition is a self contained and up to date introductory level textbook that thoroughly surveys this rapidly expanding area of engineering and applied physics Featuring a blend of theory and applications coverage includes detailed accounts of the primary theories of light including ray optics wave optics electromagnetic optics and photon optics as well as the interaction of light and matter Presented at increasing levels of complexity preliminary sections build toward more advanced topics such as Fourier optics and holography photonic crystal optics guided wave and fiber optics LEDs and lasers acousto optic and electro optic devices nonlinear optical devices ultrafast optics optical interconnects and switches and optical fiber communications The third edition features an entirely new chapter on the optics of metals and plasmonic devices Each chapter contains highlighted equations exercises problems summaries and selected reading lists Examples of real systems are included to emphasize the concepts governing applications of current interest Each of the twenty four chapters of the second edition has been thoroughly updated

*Optoelectronic Integrated Circuit Design and Device Modeling* Jianjun Gao, 2011-09-19 In Optoelectronic Integrated Circuit Design and Device Modeling Professor Jianjun Gao introduces the fundamentals and modeling techniques of optoelectronic devices used in high speed optical transmission systems Gao covers electronic circuit elements such as FET HBT MOSFET as well as design techniques for advanced optical transmitter and receiver front end circuits The book includes an overview of optical communication systems and computer aided optoelectronic IC design before going over the basic concept of laser diodes This is followed by modeling and parameter extraction techniques of lasers and photodiodes Gao covers high speed electronic semiconductor devices optical transmitter design and optical receiver design in the final three chapters Addresses a gap within the rapidly growing area of transmitter and receiver modeling in OEICs Explains diode physics before device modeling helping readers understand their equivalent circuit models Provides comprehensive explanations for E O and O E conversions done with laser and photodiodes Covers an extensive range of devices for high speed applications Accessible for students new to microwaves Presentation slides available for instructor use This book is primarily aimed at practicing engineers researchers and post graduates in the areas of RF microwaves IC design photonics and lasers and solid state devices The book is also a strong supplement for senior undergraduates taking courses in RF and microwaves Lecture materials for instructors available at [www.wiley.com/go/gao](http://www.wiley.com/go/gao)

**Digital and Analog Fiber Optic Communications for CATV and FTTx Applications** Avigdor Brillant, 2008 This book is intended to provide a step by step guide to all design aspects and tradeoffs from theory to application for fiber optics transceiver electronics Presenting a compendium of information in a structured way this book enables the engineer to develop a methodical design approach a deep understanding of specifications parameters and the reasons behind them as well as their effects and consequences on

system performance which are essential for proper component design Further a fundamental understanding of RF digital circuit design and linear and nonlinear phenomena is important in order to achieve the desired performance levels Becoming familiar with solid state devices and passives used to build optical receivers and transmitters is also important so one can effectively overcome design limitations *High-Frequency Integrated Circuits* Sorin Voinigescu,2013-02-28 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

Optical Wireless Communications Roberto Ramirez-Iniguez,Sevia M. Idrus,Ziran Sun,2008-04-03 Over the last three decades interest in Infrared IR technology as a medium to convey information has grown considerably This is reflected by the increasing number of devices such as laptops PDAs and mobile phones that incorporate optical wireless transceivers and also by the increasing number of optical wireless links available for indoor and **Fiber Optics** Abdul Al-Azzawi,2006-12-26 Since the invention of the laser our fascination with the photon has led to one of the most dynamic and rapidly growing fields of technology New advances in fiber optic devices components and materials make it more important than ever to stay current Comprising chapters drawn from the author s highly anticipated book Photonics Principles and Practices Fiber Optics Principles and Practices offers a detailed and focused treatment for anyone in need of authoritative information on this critical area underlying photonics Using a consistent approach the author leads you step by step through each topic Each skillfully crafted chapter first explores the theoretical concepts of each topic and then demonstrates how these principles apply to real world applications by guiding you through experimental cases illuminated with numerous illustrations The book works systematically through fiber optic cables advanced fiber optic cables light attenuation in optical components fiber optic cable types and installations fiber optic connectors passive fiber optic devices wavelength division multiplexing optical amplifiers optical receivers opto mechanical switches and optical fiber communications It also includes important chapters in fiber optic lighting fiber optics testing and laboratory safety Containing several topics presented for the first time in book form Fiber Optics Principles and Practices is simply the most modern detailed and hands on text in the field **High-Speed Optical Receivers with Integrated Photodiode in Nanoscale CMOS** Filip Tavernier,Michiel Steyaert,2011-06-20 This book describes the design of optical receivers that use the most economical integration technology while enabling performance that is typically only found in very expensive devices To achieve this all necessary functionality from light detection to digital output is integrated on a single piece of silicon All building blocks are thoroughly discussed including

photodiodes transimpedance amplifiers equalizers and post amplifiers      *Optik und Photonik* Bahaa E. A. Saleh, Malvin Carl Teich, 2020-04-22 Vollständig bearbeitete Neuauflage des maßgeblichen Grundlagen Lehrbuchs zur Optik und Photonik umfassend bearbeitet und mit einem neuen Kapitel zur Metamaterialoptik erweitert Die Optik ist eines der ältesten und faszinierendsten Teilgebiete der Physik und fest in den Curricula des Physikstudiums verankert Sie beschäftigt sich mit der Ausbreitung von Licht und Phänomenen wie Interferenz Brechung Beugung und optischen Abbildungen Die Photonik umfasst optische Phänomene die primär auf der Wechselwirkung von quantisiertem Licht und Materie beruhen und befasst sich mit dem Verständnis und der Entwicklung optischer Bauteile und Systeme wie etwa Lasern LEDs und photonischen Kristallen In bewährter Weise gibt die vollständig bearbeitete und erweiterte Neuauflage des Saleh Teich eine Einführung in die Grundlagen der Optik und Photonik für Studierende der Physik und verwandter Wissenschaften Ausführliche Erklärungen rund 1000 Abbildungen und die zur quantitativen Durchdringung notwendige Mathematik ermöglichen ein tiefes Verständnis aller Teilgebiete der klassischen und modernen Optik Umfassend und verständlich sämtliche Grundlagen der Optik und Photonik in einem Werk vereint Geschrieben von hervorragenden Didaktikern mit langer Lehrerfahrung optische Phänomene und deren Physik stehen im Vordergrund der notwendige mathematische Apparat wird behutsam entwickelt bearbeitet und erweitert alle Kapitel wurden mit Blick auf noch bessere Verständlichkeit kritisch geprüft und aktualisiert Komplett neu umfangreiches Kapitel zu Metamaterialoptik Optik und Photonik richtet sich an Bachelor und Master Studierende der Physik

Materialwissenschaften und Ingenieurwissenschaften      **Nanodevices for Integrated Circuit Design** Suman Lata Tripathi, Abhishek Kumar, K. Srinivasa Rao, Prasantha R. Mudimela, 2023-11-21 NANODEVICES FOR INTEGRATED CIRCUIT DESIGN Nanodevices are an integral part of many of the technologies that we use every day It is a constantly changing and evolving area with new materials processes and applications coming online almost daily Increasing demand for smart and intelligent devices in human life with better sensing communication and signal processing is increasingly pushing researchers and designers towards future design challenges based upon internet of things IoT applications Several types of research have been done at the level of solid state devices circuits and materials to optimize system performance with low power consumption For suitable IoT based systems there are some key areas such as the design of energy storage devices energy harvesters novel low power high speed devices and circuits Uses of new materials for different purposes such as semiconductors metals and insulators in different parts of devices circuits and energy sources also play a significant role in smart applications of such systems Emerging techniques like machine learning and artificial intelligence are also becoming a part of the latest developments in an electronic device and circuit design This groundbreaking new book will among other things aid developing countries in updating their semiconductor industries in terms of IC design and manufacturing to avoid dependency on other countries Likewise as an introduction to the area for the new hire or student and as a reference for the veteran engineer in the field it will be helpful for more developed countries in their pursuit of better IC design It is a must

have for any engineer scientist or other industry professional working in this area

**High-Speed Devices and Circuits with THz Applications** Jung Han Choi, 2017-09-19 Presenting the cutting edge results of new device developments and circuit implementations High Speed Devices and Circuits with THz Applications covers the recent advancements of nano devices for terahertz THz applications and the latest high speed data rate connectivity technologies from system design to integrated circuit IC design providing relevant standard activities and technical specifications Featuring the contributions of leading experts from industry and academia this pivotal work Discusses THz sensing and imaging devices based on nano devices and materials Describes silicon on insulator SOI multigate nanowire field effect transistors FETs Explains the theory underpinning nanoscale nanowire metal oxide semiconductor field effect transistors MOSFETs simulation methods and their results Explores the physics of the silicon germanium SiGe heterojunction bipolar transistor HBT as well as commercially available SiGe HBT devices and their applications Details aspects of THz IC design using standard silicon Si complementary metal oxide semiconductor CMOS devices including experimental setups for measurements detection methods and more An essential text for the future of high frequency engineering High Speed Devices and Circuits with THz Applications offers valuable insight into emerging technologies and product possibilities that are attractive in terms of mass production and compatibility with current manufacturing facilities

**CMOS Multichannel Single-Chip Receivers for Multi-Gigabit Optical Data Communications** Paul Muller, Yusuf Leblebici, 2007-10-08 The intention of this book is to address a number of timely performance critical issues within the field of short distance optical communications from a circuit designer s perspective It discusses the major trade offs the designer has to deal with in the development of monolithically integrated receivers in CMOS technologies As such it is based on Dr Muller s doctoral dissertation entitled A Standard CMOS Multi Channel Single Chip Receiver for Multi Gigabit Optical Data Communications subm ted to the School of Engineering of the cole Polytechnique F d rale de Lausanne EPFL in May 2006 The dissertation material has been enhanced by the presentation of a number of alternative design approaches and circuit topologies providing exhaustive coverage of the state of the art in optical sho distance receiver circuit design The need for a new processor input output I O interface paradigm is dictated by ongoing te nology scaling and the advent of multi core systems Indeed each new generation of microprocessors and digital signal processors provides higher computing power and data throughput whereas the available bandwidth of the I O interfaces is subject to much slower growth Moving beyond coming serial links to an optical data link paradigm for very short distance board to board and chip chip communications allows for considerable I O interface bandwidth enhancement Fully integrated silicon CMOS receivers are considered to be the technology of choice to lead this solution to economic success because monolithic integration results in lower volume manufacturing cost improved yield and reduced assembly and test expenses

**High-speed Optical Transceivers: Integrated Circuits Designs And Optical Devices Techniques** Yuyu Liu, Huazhong Yang, 2006-03-09 This book explores the unique advantages and large inherent transmission capacity of optical

fiber communication systems The long term and high risk research challenges of optical transceivers are analyzed with a view to sustaining the seemingly insatiable demand for bandwidth A broad coverage of topics relating to the design of high speed optical devices and integrated circuits oriented to low power low cost and small area is discussed Written by specialists with many years of research and engineering experience in the field of optical fiber communication this book is essential for an audience dedicated to the development of integrated electronic systems for optical communication applications It can also be used as a supplementary text for graduate courses on optical transceiver IC design

**Circuits at the Nanoscale** Krzysztof Iniewski, 2018-10-08 Circuits for Emerging Technologies Beyond CMOS New exciting opportunities are abounding in the field of body area networks wireless communications data networking and optical imaging In response to these developments top notch international experts in industry and academia present Circuits at the Nanoscale Communications Imaging and Sensing This volume unique in both its scope and its focus addresses the state of the art in integrated circuit design in the context of emerging systems A must for anyone serious about circuit design for future technologies this book discusses emerging materials that can take system performance beyond standard CMOS These include Silicon on Insulator SOI Silicon Germanium SiGe and Indium Phosphide InP Three dimensional CMOS integration and co integration with Microelectromechanical MEMS technology and radiation sensors are described as well Topics in the book are divided into comprehensive sections on emerging design techniques mixed signal CMOS circuits circuits for communications and circuits for imaging and sensing Dr Krzysztof Iniewski is a director at CMOS Emerging Technologies Inc a consulting company in Vancouver British Columbia His current research interests are in VLSI circuits for medical applications He has published over 100 research papers in international journals and conferences and he holds 18 international patents granted in the United States Canada France Germany and Japan In this volume he has assembled the contributions of over 60 world reknown experts who are at the top of their field in the world of circuit design advancing the bank of knowledge for all who work in this exciting and burgeoning area

Integrated Circuits Peter Shepherd, 1996-11-11 Integrated circuits have revolutionised the world of electronics and the associated areas of computing and communication In past years the tasks of designing manufacturing and testing these types of circuit were restricted to a few specialist engineers However within recent years the proliferation of computer tools and affordable access to IC manufacturing foundries has resulted in a substantial increase in the number of people designing ICs for the first time both in universities and colleges and in industry This book introduces the reader to all aspects of IC design manufacture and testing with a minimum of mathematics but with relevant examples at each stage It examines the overall design strategies the engineering trade offs and the advantages disadvantages and optimum applications of each available technology

*Wavelength Division Multiplexing* Klaus Grobe, Michael Eiselt, 2013-09-12 In this book Optical Wavelength Division Multiplexing WDM is approached from a strictly practical and application oriented point of view Based on the characteristics and constraints of



modern fiber optic components transport systems and fibers the text provides relevant rules of thumb and practical hints for technology selection WDM system and link dimensioning and also for network related aspects such as wavelength assignment and resilience mechanisms Actual 10 40 Gb s WDM systems are considered and a preview of the upcoming 100 Gb s systems and technologies for even higher bit rates is given as well Key features Considers WDM from ULH backbone big picture view down to PON access micro view Includes all major telecom and datacom applications Provides the relevant background for state of the art and next gen systems Offers practical guidelines for system link engineering Analysis and Design of Transimpedance Amplifiers for Optical Receivers Eduard Säckinger, 2017-09-26 An up to date comprehensive guide for advanced electrical engineering students and electrical engineers working in the IC and optical industries This book covers the major transimpedance amplifier TIA topologies and their circuit implementations for optical receivers This includes the shunt feedback TIA common base TIA common gate TIA regulated cascode TIA distributed amplifier TIA nonresistive feedback TIA current mode TIA burst mode TIA and analog receiver TIA The noise transimpedance and other performance parameters of these circuits are analyzed and optimized Topics of interest include post amplifiers differential vs single ended TIAs DC input current control and adaptive transimpedance The book features real world examples of TIA circuits for a variety of receivers direct detection coherent burst mode etc implemented in a broad array of technologies HBT BiCMOS CMOS etc The book begins with an introduction to optical communication systems signals and standards It then moves on to discussions of optical fiber and photodetectors This discussion includes p i n photodetectors avalanche photodetectors APD optically preamplified detectors integrated detectors including detectors for silicon photonics and detectors for phase modulated signals including coherent detectors This is followed by coverage of the optical receiver at the system level the relationship between noise sensitivity optical signal to noise ratio OSNR and bit error rate BER is explained receiver impairments such as intersymbol interference ISI are covered In addition the author presents TIA specifications and illustrates them with example values from recent product data sheets The book also includes Many numerical examples throughout that help make the material more concrete for readers Real world product examples that show the performance of actual IC designs Chapter summaries that highlight the key points Problems and their solutions for readers who want to practice and deepen their understanding of the material Appendices that cover communication signals eye diagrams timing jitter nonlinearity adaptive equalizers decision point control forward error correction FEC and second order low pass transfer functions Analysis and Design of Transimpedance Amplifiers for Optical Receivers belongs on the reference shelves of every electrical engineer working in the IC and optical industries It also can serve as a textbook for upper level undergraduates and graduate students studying integrated circuit design and optical communication *Scientific and Technical Aerospace Reports*, 1995

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