



# ESD

**ANALOG CIRCUITS AND DESIGN**

STEVEN H. VOLDMAN



**WILEY**

# Esd Analog Circuits And Design

**Steven H. Voldman**



## **Esd Analog Circuits And Design:**

*ESD* Steven H. Voldman, 2015-01-05 A comprehensive and in depth review of analog circuit layout schematic architecture device power network and ESD design This book will provide a balanced overview of analog circuit design layout analog circuit schematic development architecture of chips and ESD design It will start at an introductory level and will bring the reader right up to the state of the art Two critical design aspects for analog and power integrated circuits are combined The first design aspect covers analog circuit design techniques to achieve the desired circuit performance The second and main aspect presents the additional challenges associated with the design of adequate and effective ESD protection elements and schemes A comprehensive list of practical application examples is used to demonstrate the successful combination of both techniques and any potential design trade offs Chapter One looks at analog design discipline including layout and analog matching and analog layout design practices Chapter Two discusses analog design with circuits examining single transistor amplifiers multi transistor amplifiers active loads and more The third chapter covers analog design layout also MOSFET layout before Chapters Four and Five discuss analog design synthesis The next chapters introduce the reader to analog digital mixed signal design synthesis analog signal pin ESD networks and analog ESD power clamps Chapter Nine the last chapter covers ESD design in analog applications Clearly describes analog design fundamentals circuit fundamentals as well as outlining the various ESD implications Covers a large breadth of subjects and technologies such as CMOS LDMOS BCD SOI and thick body SOI Establishes an ESD analog design discipline that distinguishes itself from the alternative ESD digital design focus Focuses on circuit and circuit design applications Assessable with the artwork and tutorial style of the ESD book series PowerPoint slides are available for university faculty members Even in the world of digital circuits analog and power circuits are two very important but under addressed topics especially from the ESD aspect Dr Voldman s new book will serve as an essential and practical guide to the greater IC community With high practical and academic values this book is a bible for professionals graduate students device and circuit designers for investigating the physics of ESD and for product designs and testing

**ESD Design for Analog Circuits** Vladislav A. Vashchenko, Andrei Shibkov, 2010-07-27 This Book and Simulation Software Bundle Project Dear Reader this book project brings to you a unique study tool for ESD protection solutions used in analog integrated circuit IC design Quick start learning is combined with in depth understanding for the whole spectrum of cross disciplinary knowledge required to excel in the ESD field The chapters cover technical material from elementary semiconductor structure and device levels up to complex analog circuit design examples and case studies The book project provides two different options for learning the material The printed material can be studied as any regular technical textbook At the same time another option adds parallel exercise using the trial version of a complementary commercial simulation tool with prepared simulation examples Combination of the textbook material with numerical simulation experience presents a unique opportunity to gain a level of expertise that is hard to achieve otherwise The book is

bundled with simplified trial version of commercial mixed TM mode simulation software from Angstrom Design Automation. The DECIMM Device Circuit Mixed Mode simulator tool and complementary to the book's simulation examples can be downloaded from [www.analogesd.com](http://www.analogesd.com). The simulation examples prepared by the authors support the specific examples discussed across the book chapters. A key idea behind this project is to provide an opportunity to not only study the book material but also gain a much deeper understanding of the subject by direct experience through practical simulation examples.

**ESD** Steven H. Voldman, 2006-02-03. The scaling of semiconductor devices from sub-micron to nanometer dimensions is driving the need for understanding the design of electrostatic discharge (ESD) circuits and the response of these integrated circuits (IC) to ESD phenomena. *ESD Circuits and Devices* provides a clear insight into the layout and design of circuitry for protection against electrical overstress (EOS) and ESD. With an emphasis on examples, this text explains ESD buffering, ballasting, current distribution, design segmentation, feedback coupling, and decoupling. ESD design methods outlines the fundamental analytical models and experimental results for the ESD design of MOSFETs and diode semiconductor device elements with a focus on CMOS silicon on insulator (SOI) and Silicon Germanium (SiGe) technology. It focuses on the ESD design optimization, integration and synthesis of these elements and concepts into ESD networks as well as applying within the off-chip driver networks and on-chip receivers and highlights state-of-the-art ESD input circuits as well as ESD power clamps networks. Continuing the author's series of books on ESD, this book will be an invaluable reference for the professional semiconductor chip and system ESD engineer. Semiconductor device and process development, quality, reliability, and failure analysis engineers will also find it an essential tool. In addition, both senior undergraduate and graduate students in microelectronics and IC design will find its numerous examples useful.

**The ESD Handbook** Steven H. Voldman, 2021-04-12. A practical and comprehensive reference that explores Electrostatic Discharge (ESD) in semiconductor components and electronic systems. The ESD Handbook offers a comprehensive reference that explores topics relevant to ESD design in semiconductor components and explores ESD in various systems. Electrostatic discharge is a common problem in the semiconductor environment, and this reference fills a gap in the literature by discussing ESD protection. Written by a noted expert on the topic, the text offers a topic-by-topic reference that includes illustrative figures, discussions, and drawings. The handbook covers a wide range of topics, including ESD in manufacturing, garments, wrist straps, and shoes; ESD Testing; ESD device physics; ESD semiconductor process effects; ESD failure mechanisms; ESD circuits in different technologies (CMOS, Bipolar, etc.); ESD circuit types (Pin, Power Pin, to Pin, etc.) and much more. In addition, the text includes a glossary, index, tables, illustrations, and a variety of case studies. Contains a well-organized reference that provides a quick review on a range of ESD topics. Fills the gap in the current literature by providing information from purely scientific and physical aspects to practical applications. Offers information in clear and accessible terms. Written by the accomplished author of the popular ESD book series. Written for technicians, operators, engineers, circuit designers, and failure analysis engineers. *The ESD Handbook*

contains an accessible reference to ESD design and ESD systems      **ESD** Steven H. Voldman, 2014-07-30 A comprehensive and in depth review of analog circuit layout schematic architecture device power network and ESD design This book will provide a balanced overview of analog circuit design layout analog circuit schematic development architecture of chips and ESD design It will start at an introductory level and will bring the reader right up to the state of the art Two critical design aspects for analog and power integrated circuits are combined The first design aspect covers analog circuit design techniques to achieve the desired circuit performance The second and main aspect presents the additional challenges associated with the design of adequate and effective ESD protection elements and schemes A comprehensive list of practical application examples is used to demonstrate the successful combination of both techniques and any potential design trade offs Chapter One looks at analog design discipline including layout and analog matching and analog layout design practices Chapter Two discusses analog design with circuits examining single transistor amplifiers multi transistor amplifiers active loads and more The third chapter covers analog design layout also MOSFET layout before Chapters Four and Five discuss analog design synthesis The next chapters introduce the reader to analog digital mixed signal design synthesis analog signal pin ESD networks and analog ESD power clamps Chapter Nine the last chapter covers ESD design in analog applications Clearly describes analog design fundamentals circuit fundamentals as well as outlining the various ESD implications Covers a large breadth of subjects and technologies such as CMOS LDMOS BCD SOI and thick body SOI Establishes an ESD analog design discipline that distinguishes itself from the alternative ESD digital design focus Focuses on circuit and circuit design applications Assessable with the artwork and tutorial style of the ESD book series PowerPoint slides are available for university faculty members Even in the world of digital circuits analog and power circuits are two very important but under addressed topics especially from the ESD aspect Dr Voldman's new book will serve as an essential and practical guide to the greater IC community With high practical and academic values this book is a bible for professionals graduate students device and circuit designers for investigating the physics of ESD and for product designs and testing      **ESD Basics** Steven H. Voldman, 2012-10-22 Electrostatic discharge ESD continues to impact semiconductor manufacturing semiconductor components and systems as technologies scale from micro to nano electronics This book introduces the fundamentals of ESD electrical overstress EOS electromagnetic interference EMI electromagnetic compatibility EMC and latchup as well as provides a coherent overview of the semiconductor manufacturing environment and the final system assembly It provides an illuminating look into the integration of ESD protection networks followed by examples in specific technologies circuits and chips The text is unique in covering semiconductor chip manufacturing issues ESD semiconductor chip design and system problems confronted today as well as the future of ESD phenomena and nano technology Look inside for extensive coverage on The fundamentals of electrostatics triboelectric charging and how they relate to present day manufacturing environments of micro electronics to nano technology Semiconductor manufacturing handling and auditing processing to avoid ESD

failures ESD EOS EMI EMC and latchup semiconductor component and system level testing to demonstrate product resilience from human body model HBM transmission line pulse TLP charged device model CDM human metal model HMM cable discharge events CDE to system level IEC 61000 4 2 tests ESD on chip design and process manufacturing practices and solutions to improve ESD semiconductor chip solutions also practical off chip ESD protection and system level solutions to provide more robust systems System level concerns in servers laptops disk drives cell phones digital cameras hand held devices automobiles and space applications Examples of ESD design for state of the art technologies including CMOS BiCMOS SOI bipolar technology high voltage CMOS HVCMOS RF CMOS smart power magnetic recording technology micro machines MEMs to nano structures ESD Basics From Semiconductor Manufacturing to Product Use complements the author's series of books on ESD protection For those new to the field it is an essential reference and a useful insight into the issues that confront modern technology as we enter the Nano electronic Era

**System Level ESD Protection** Vladislav Vashchenko, Mirko Scholz, 2014-03-21 This book addresses key aspects of analog integrated circuits and systems design related to system level electrostatic discharge ESD protection It is an invaluable reference for anyone developing systems on chip SoC and systems on package SoP integrated with system level ESD protection The book focuses on both the design of semiconductor integrated circuit IC components with embedded on chip system level protection and IC system co design The readers will be enabled to bring the system level ESD protection solutions to the level of integrated circuits thereby reducing or completely eliminating the need for additional discrete components on the printed circuit board PCB and meeting system level ESD requirements The authors take a systematic approach based on IC system ESD protection co design A detailed description of the available IC level ESD testing methods is provided together with a discussion of the correlation between IC level and system level ESD testing methods The IC level ESD protection design is demonstrated with representative case studies which are analyzed with various numerical simulations and ESD testing The overall methodology for IC system ESD co design is presented as a step by step procedure that involves both ESD testing and numerical simulations

**ESD Testing** Steven H. Voldman, 2016-10-14 With the evolution of semiconductor technology and global diversification of the semiconductor business testing of semiconductor devices to systems for electrostatic discharge ESD and electrical overstress EOS has increased in importance ESD Testing From Components to Systems updates the reader in the new tests test models and techniques in the characterization of semiconductor components for ESD EOS and latchup Key features Provides understanding and knowledge of ESD models and specifications including human body model HBM machine model MM charged device model CDM charged board model CBM cable discharge events CDE human metal model HMM IEC 61000 4 2 and IEC 61000 4 5 Discusses new testing methodologies such as transmission line pulse TLP to very fast transmission line pulse VF TLP and future methods of long pulse TLP to ultra fast TLP UF TLP Describes both conventional testing and new testing techniques for both chip and system level evaluation Addresses EOS testing electromagnetic compatibility EMC

scanning to current reconstruction methods Discusses latchup characterization and testing methodologies for evaluation of semiconductor technology to product testing ESD Testing From Components to Systems is part of the authors series of books on electrostatic discharge ESD protection this book will be an invaluable reference for the professional semiconductor chip and system level ESD and EOS test engineer Semiconductor device and process development circuit designers quality reliability and failure analysis engineers will also find it an essential reference In addition its academic treatment will appeal to both senior and graduate students with interests in semiconductor process device physics semiconductor testing and experimental work

**Edn Designers Guide to Electromagnetic Compatibility** Daryl D Gerke,Bill Kimmel,2002-08-01 In 1996 enforcement of the mandatory European Union EMI EMC electromagnetic interference and compatibility began Before that time many designers were just beginning to worry about EMI problems Now 8 years later the same old EMI problems are still with us and some new ones have emerged as well Anyone selling components or equipment of any sort in Europe and therefore the world for most globally based companies requires compliance with the EMC directive There is no alternative The information in this book enables faster cheaper compliance

**Electrostatic Discharge** Steven Voldman,2019-10-02 As we enter the nanoelectronics era electrostatic discharge ESD phenomena is an important issue for everything from micro electronics to nanostructures This book provides insight into the operation and design of micro gaps and nanogenerators with chapters on low capacitance ESD design in advanced technologies electrical breakdown in micro gaps nanogenerators from ESD and theoretical prediction and optimization of triboelectric nanogenerators The information contained herein will prove useful for for engineers and scientists that have an interest in ESD physics and design

**Electromagnetic Compatibility Engineering** Henry W. Ott,2011-09-20 Praise for Noise Reduction Techniques IN electronic systems Henry Ott has literally written the book on the subject of EMC He not only knows the subject but has the rare ability to communicate that knowledge to others EE Times Electromagnetic Compatibility Engineering is a completely revised expanded and updated version of Henry Ott s popular book Noise Reduction Techniques in Electronic Systems It reflects the most recent developments in the field of electromagnetic compatibility EMC and noise reduction and their practical applications to the design of analog and digital circuits in computer home entertainment medical telecom industrial process control and automotive equipment as well as military and aerospace systems While maintaining and updating the core information such as cabling grounding filtering shielding digital circuit grounding and layout and ESD that made the previous book such a wide success this new book includes additional coverage of Equipment systems grounding Switching power supplies and variable speed motor drives Digital circuit power distribution and decoupling PCB layout and stack up Mixed signal PCB layout RF and transient immunity Power line disturbances Precompliance EMC measurements New appendices on dipole antennae the theory of partial inductance and the ten most common EMC problems The concepts presented are applicable to analog and digital circuits operating from below audio frequencies to those in the GHz range

Throughout the book an emphasis is placed on cost effective EMC designs with the amount and complexity of mathematics kept to the strictest minimum Complemented with over 250 problems with answers Electromagnetic Compatibility Engineering equips readers with the knowledge needed to design electronic equipment that is compatible with the electromagnetic environment and compliant with national and international EMC regulations It is an essential resource for practicing engineers who face EMC and regulatory compliance issues and an ideal textbook for EE courses at the advanced undergraduate and graduate levels

*Digital Systems* Vahid Asadpour, 2018-11-28 This book provides an approach toward the applications and principle theory of digital signal processing in modern intelligent systems biological engineering telecommunication and information technology Assuming the reader already has prior knowledge of signal processing theory this book will be useful for finding novel methods that fit special needs in digital signal processing DSP The combination of signal processing and intelligent systems in hybrid structures rather than serial or parallel processing provide the best mechanism that is a better fit with the comprehensive nature of human This book is a practical reference that places the emphasis on principles and applications of DSP in digital systems It covers a broad area of digital systems and applications of machine learning methods including convolutional neural networks evolutionary algorithms adaptive filters spectral estimation data compression and functional verification The level of the book is ideal for professional DSP users and useful for graduate students who are looking for solutions to their design problems The theoretical principles provide the required base for comprehension of the methods and application of modifications for the special needs of practical projects

Electrical Overstress (EOS) Steven H. Voldman, 2013-08-27 Electrical Overstress EOS continues to impact semiconductor manufacturing semiconductor components and systems as technologies scale from micro to nano electronics This book teaches the fundamentals of electrical overstress and how to minimize and mitigate EOS failures The text provides a clear picture of EOS phenomena EOS origins EOS sources EOS physics EOS failure mechanisms and EOS on chip and system design It provides an illuminating insight into the sources of EOS in manufacturing integration of on chip and system level EOS protection networks followed by examples in specific technologies circuits and chips The book is unique in covering the EOS manufacturing issues from on chip design and electronic design automation to factory level EOS program management in today's modern world Look inside for extensive coverage on Fundamentals of electrical overstress from EOS physics EOS time scales safe operating area SOA to physical models for EOS phenomena EOS sources in today's semiconductor manufacturing environment and EOS program management handling and EOS auditing processing to avoid EOS failures EOS failures in both semiconductor devices circuits and system Discussion of how to distinguish between EOS events and electrostatic discharge ESD events e.g. such as human body model HBM charged device model CDM cable discharge events CDM charged board events CBE to system level IEC 61000 4 2 test events EOS protection on chip design practices and how they differ from ESD protection networks and solutions Discussion of EOS system level concerns in printed circuit boards

PCB and manufacturing equipment Examples of EOS issues in state of the art digital analog and power technologies including CMOS LDMOS and BCD EOS design rule checking DRC LVS and ERC electronic design automation EDA and how it is distinct from ESD EDA systems EOS testing and qualification techniques and Practical off chip ESD protection and system level solutions to provide more robust systems Electrical Overstress EOS Devices Circuits and Systems is a continuation of the author s series of books on ESD protection It is an essential reference and a useful insight into the issues that confront modern technology as we enter the nano electronic era      Testing for EMC Compliance Mark I. Montrose, Edward M. Nakauchi, 2004-07-26 The Keep It Simple KISS philosophy is the primary focus of this book It is written in very simple language with minimal math as a compilation of helpful EMI troubleshooting hints Its light hearted tone is at odds with the extreme seriousness of most engineering reference works that become boring after a few pages This text tells engineers what to do and how to do it Only a basic knowledge of math electronics and a basic understanding of EMI EMC are necessary to understand the concepts and circuits described Once EMC troubleshooting is demystified readers learn there are quick and simple techniques to solve complicated problems a key aspect of this book Simple and inexpensive methods to resolve EMI issues are discussed to help generate unique ideas and methods for developing additional diagnostic tools and measurement procedures An appendix on how to build probes is included It can be a fun activity even humorous at times with bizarre techniques i e the sticky finger probe      **Op Amp Applications Handbook** Walt Jung, 2005 A complete and up to date op amp reference for electronics engineers from the most famous op amp guru      Electrostatic Discharge Protection Juin J. Liou, 2017-12-19 Electrostatic discharge ESD is one of the most prevalent threats to electronic components In an ESD event a finite amount of charge is transferred from one object i e human body to another i e microchip This process can result in a very high current passing through the microchip within a very short period of time Thus more than 35 percent of single event chip damages can be attributed to ESD events and designing ESD structures to protect integrated circuits against the ESD stresses is a high priority in the semiconductor industry Electrostatic Discharge Protection Advances and Applications delivers timely coverage of component and system level ESD protection for semiconductor devices and integrated circuits Bringing together contributions from internationally respected researchers and engineers with expertise in ESD design optimization modeling simulation and characterization this book bridges the gap between theory and practice to offer valuable insight into the state of the art of ESD protection Amply illustrated with tables figures and case studies the text Instills a deeper understanding of ESD events and ESD protection design principles Examines vital processes including Si CMOS Si BCD Si SOI and GaN technologies Addresses important aspects pertinent to the modeling and simulation of ESD protection solutions Electrostatic Discharge Protection Advances and Applications provides a single source for cutting edge information vital to the research and development of effective robust ESD protection solutions for semiconductor devices and integrated circuits      **Silicon Germanium** Raminderpal Singh, Modest M. Oprysko, David Harame, 2004-03-01 An excellent

introduction to the SiGe BiCMOS technology from the underlying device physics to current applications Ron Wilson EETimes

SiGe technology has demonstrated the ability to provide excellent high performance characteristics with very low noise at high power gain and with excellent linearity This book is a comprehensive review of the technology and of the design methods that go with it Alberto Sangiovanni Vincentelli Professor University of California Berkeley Cofounder Chief Technology Officer Member of Board Cadence Design Systems Inc Filled with in depth insights and expert advice Silicon Germanium covers all the key aspects of this technology and its applications Beginning with a brief introduction to and historical perspective of IBM s SiGe technology this comprehensive guide quickly moves on to Detail many of IBM s SiGe technology development programs Explore IBM s approach to device modeling and characterization including predictive TCAD modeling Discuss IBM s design automation and signal integrity knowledge and implementation methodologies Illustrate design applications in a variety of IBM s SiGe technologies Highlight details of highly integrated SiGe BiCMOS system on chip SOC design Written for RF analog and mixed signal designers CAD designers semiconductor students and foundry process engineers worldwide Silicon Germanium provides detailed insight into the modeling and design automation requirements for leading edge RF analog and mixed signal products and illustrates in depth applications that can be implemented using IBM s advanced SiGe process technologies and design kits This volume provides an excellent introduction to the SiGe BiCMOS technology from the underlying device physics to current applications But just as important is the window the text provides into the infrastructure the process development device modeling and tool development Ron Wilson Silicon Engineering Editor EETimes This book chronicles the development of SiGe in detail provides an in depth look at the modeling and design automation requirements for making advanced applications using SiGe possible and illustrates such applications as implemented using IBM s process technologies and design methods John Kelly Senior Vice President and Group Executive Technology Group IBM *EDN, Electrical Design News* ,2000 On-Chip ESD Protection for Integrated Circuits Albert Z.H. Wang,2006-01-03 This comprehensive and insightful book discusses ESD protection circuit design problems from an IC designer s perspective On Chip ESD Protection for Integrated Circuits An IC Design Perspective provides both fundamental and advanced materials needed by a circuit designer for designing ESD protection circuits including Testing models and standards adopted by U S Department of Defense EIA JEDEC ESD Association Automotive Electronics Council International Electrotechnical Commission etc ESD failure analysis protection devices and protection of sub circuits Whole chip ESD protection and ESD to circuit interactions Advanced low parasitic compact ESD protection structures for RF and mixed signal IC s Mixed mode ESD simulation design methodologies for design prediction ESD to circuit interactions and more Many real world ESD protection circuit design examples are provided The book can be used as a reference book for working IC designers and as a textbook for students in the IC design field **Proceedings** ,2001

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## **Esd Analog Circuits And Design Introduction**

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