

# Compact modelling of noise for RF CMOS circuit design

A.J. Scholten, L.F. Tiemeijer, R. van Langevelde, R.J. Havens, A.T.A. Zegers-van Duijnhoven, R. de Kort and D.B.M. Klaassen

**Abstract:** The thermal noise of short-channel NMOS transistors in a commercially available 0.13- $\mu\text{m}$  CMOS technology is studied. The experimental results are modelled with a non-quasi-static RF model, based on the principle of channel segmentation. The model is capable of predicting both drain and gate current noise accurately, without fitting any parameters to the measured noise data. An essential ingredient of the model is the gate resistance, which is shown to dominate the gate current noise. In the optimised device layouts, this gate resistance is mainly determined by the silicide-to-polysilicon contact resistance.

## 1 Introduction

The ever-continuing downscaling of CMOS technologies has resulted in a strong improvement in the RF performance of MOS devices [1–3]. Consequently, CMOS has become a viable option for analogue RF applications and RF system-on-chip. For the application of modern CMOS technologies in low-noise RF circuits, accurate modelling of noise is a prerequisite.

In MOSFETs, there are two intrinsic sources of noise:  $1/f$  noise and thermal noise, the latter being the topic of this paper. Thermal noise is due to the random thermal motion of charge carriers. It not only manifests itself in the drain current noise spectrum, but, due to the capacitive coupling between channel and gate, also in the gate current noise spectrum. The latter effect is known as ‘induced gate noise’. In addition to the intrinsic MOSFET thermal noise, the parasitic resistances (gate resistance, bulk resistance, and source/drain resistances) also exhibit thermal noise.

Thermal noise of deep-submicron MOSFETs has received considerable attention lately, triggered by publications reporting a strong enhancement of thermal noise with respect to long-channel theory [4–8]. In the earliest of these publications [4], thermal noise was found to be enhanced by a factor up to 12 in n-channel devices with gate length 0.7  $\mu\text{m}$ , and hot electrons were proposed to explain these results. More recently, Klein [5, 6] reported very similar enhancement of drain current thermal noise in devices with gate length 0.65  $\mu\text{m}$  and proposed a model that invokes heating of the charge carriers in the inversion channel to explain the experiments. For the induced gate noise, an even more dramatic enhancement factor as large as 30 was found by Knoblinger [7] for a 0.25- $\mu\text{m}$  gate length n-channel MOSFET. Evidently, these reported noise enhancements would seriously limit the viability of RF CMOS, and a detailed study is called for.

In previous work [9–11], in sharp contrast to the above-mentioned authors, only moderate enhancement of the MOSFET drain current thermal noise was found, mainly caused by parasitic resistances and channel length modulation. This was found for 0.35- $\mu\text{m}$ , 0.25- $\mu\text{m}$ , and 0.18- $\mu\text{m}$  CMOS technologies. MOSFET gate current thermal noise, on the other hand, was found to be enhanced more severely. This enhancement could be traced back to the effects of gate resistance, and the silicide-to-polysilicon contact resistance in particular.

Although the thermal noise, as found in CMOS fabrication down to 0.18  $\mu\text{m}$ , seems fairly well understood, it remains important to study the phenomenon for more advanced CMOS technologies; it seems probable that at some point down the ITRS roadmap, the main assumption of our theory, i.e. thermal equilibrium, will break down. Therefore, in this work (which was reported earlier in [12]), we extend our study of MOSFET thermal noise to 0.13- $\mu\text{m}$  technology. We present a large number of new experimental results in the 1–18 GHz frequency range, and compare them with the predictions of our previously developed RF MOSFET model.

## 2 Noise model

The model used in this paper has been described in detail in [11], therefore we will give only a short description here. The basis of the drain current thermal noise model is the well-known Klaassen–Prins equation [13], to which we have added the effects of channel length modulation, mobility reduction, and velocity saturation. The underlying assumptions are that (i) the charge carriers are in thermal equilibrium so that the voltage noise spectral density of a channel segment  $dx$  is given by the Nyquist expression  $4k_B T dx / c / g(f)$ , where  $g(f)$  is the local channel conductance, and that (ii) the noise sources of different pieces of the channel are uncorrelated. Moreover, we neglect the possible noise contribution of the pinch-off region, in agreement with Jamal Deen *et al.* [14]. This is corroborated by the experimental observation that there is hardly any dependence of the noise on  $V_{DS}$  beyond the saturation voltage (see Section 3, Figs. 4c and 6c). All calculations were carried out in the framework of MOS model 11 [15, 16]. In the

# Compact Modelling In Rf Cmos Technology Doras Dcu

**Scott C. Dulebohn**



## **Compact Modelling In Rf Cmos Technology Doras Dcu:**

## **Compact Modelling In Rf Cmos Technology Doras Dcu** Book Review: Unveiling the Magic of Language

In a digital era where connections and knowledge reign supreme, the enchanting power of language has are more apparent than ever. Its capability to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**Compact Modelling In Rf Cmos Technology Doras Dcu**," compiled by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound affect our existence. Throughout this critique, we will delve in to the book is central themes, evaluate its unique writing style, and assess its overall influence on its readership.

<https://py.bijouxmedusa.com/results/uploaded-files/Documents/Interview%20Tips%20Apps%20USA%2088%20968%20Interview%20Tips%20Apps%20For%20Small%20Business.pdf>

### **Table of Contents Compact Modelling In Rf Cmos Technology Doras Dcu**

1. Understanding the eBook Compact Modelling In Rf Cmos Technology Doras Dcu
  - The Rise of Digital Reading Compact Modelling In Rf Cmos Technology Doras Dcu
  - Advantages of eBooks Over Traditional Books
2. Identifying Compact Modelling In Rf Cmos Technology Doras Dcu
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Compact Modelling In Rf Cmos Technology Doras Dcu
  - User-Friendly Interface
4. Exploring eBook Recommendations from Compact Modelling In Rf Cmos Technology Doras Dcu
  - Personalized Recommendations
  - Compact Modelling In Rf Cmos Technology Doras Dcu User Reviews and Ratings

- Compact Modelling In Rf Cmos Technology Doras Dcu and Bestseller Lists
- 5. Accessing Compact Modelling In Rf Cmos Technology Doras Dcu Free and Paid eBooks
  - Compact Modelling In Rf Cmos Technology Doras Dcu Public Domain eBooks
  - Compact Modelling In Rf Cmos Technology Doras Dcu eBook Subscription Services
  - Compact Modelling In Rf Cmos Technology Doras Dcu Budget-Friendly Options
- 6. Navigating Compact Modelling In Rf Cmos Technology Doras Dcu eBook Formats
  - ePub, PDF, MOBI, and More
  - Compact Modelling In Rf Cmos Technology Doras Dcu Compatibility with Devices
  - Compact Modelling In Rf Cmos Technology Doras Dcu Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Compact Modelling In Rf Cmos Technology Doras Dcu
  - Highlighting and Note-Taking Compact Modelling In Rf Cmos Technology Doras Dcu
  - Interactive Elements Compact Modelling In Rf Cmos Technology Doras Dcu
- 8. Staying Engaged with Compact Modelling In Rf Cmos Technology Doras Dcu
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Compact Modelling In Rf Cmos Technology Doras Dcu
- 9. Balancing eBooks and Physical Books Compact Modelling In Rf Cmos Technology Doras Dcu
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Compact Modelling In Rf Cmos Technology Doras Dcu
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine Compact Modelling In Rf Cmos Technology Doras Dcu
  - Setting Reading Goals Compact Modelling In Rf Cmos Technology Doras Dcu
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Compact Modelling In Rf Cmos Technology Doras Dcu
  - Fact-Checking eBook Content of Compact Modelling In Rf Cmos Technology Doras Dcu
  - Distinguishing Credible Sources

13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

### **Compact Modelling In Rf Cmos Technology Doras Dcu Introduction**

In today's digital age, the availability of Compact Modelling In Rf Cmos Technology Doras Dcu books and manuals for download has revolutionized the way we access information. Gone are the days of physically flipping through pages and carrying heavy textbooks or manuals. With just a few clicks, we can now access a wealth of knowledge from the comfort of our own homes or on the go. This article will explore the advantages of Compact Modelling In Rf Cmos Technology Doras Dcu books and manuals for download, along with some popular platforms that offer these resources. One of the significant advantages of Compact Modelling In Rf Cmos Technology Doras Dcu books and manuals for download is the cost-saving aspect. Traditional books and manuals can be costly, especially if you need to purchase several of them for educational or professional purposes. By accessing Compact Modelling In Rf Cmos Technology Doras Dcu versions, you eliminate the need to spend money on physical copies. This not only saves you money but also reduces the environmental impact associated with book production and transportation. Furthermore, Compact Modelling In Rf Cmos Technology Doras Dcu books and manuals for download are incredibly convenient. With just a computer or smartphone and an internet connection, you can access a vast library of resources on any subject imaginable. Whether you're a student looking for textbooks, a professional seeking industry-specific manuals, or someone interested in self-improvement, these digital resources provide an efficient and accessible means of acquiring knowledge. Moreover, PDF books and manuals offer a range of benefits compared to other digital formats. PDF files are designed to retain their formatting regardless of the device used to open them. This ensures that the content appears exactly as intended by the author, with no loss of formatting or missing graphics. Additionally, PDF files can be easily annotated, bookmarked, and searched for specific terms, making them highly practical for studying or referencing. When it comes to accessing Compact Modelling In Rf Cmos Technology Doras Dcu books and manuals, several platforms offer an extensive collection of resources. One such platform is Project Gutenberg, a nonprofit organization that provides over 60,000 free eBooks. These books are primarily in the public domain, meaning they can be freely distributed and downloaded. Project Gutenberg offers a wide range of classic literature, making it an excellent resource for literature enthusiasts. Another popular platform for Compact Modelling In Rf Cmos Technology Doras Dcu books and manuals is Open

Library. Open Library is an initiative of the Internet Archive, a non-profit organization dedicated to digitizing cultural artifacts and making them accessible to the public. Open Library hosts millions of books, including both public domain works and contemporary titles. It also allows users to borrow digital copies of certain books for a limited period, similar to a library lending system. Additionally, many universities and educational institutions have their own digital libraries that provide free access to PDF books and manuals. These libraries often offer academic texts, research papers, and technical manuals, making them invaluable resources for students and researchers. Some notable examples include MIT OpenCourseWare, which offers free access to course materials from the Massachusetts Institute of Technology, and the Digital Public Library of America, which provides a vast collection of digitized books and historical documents. In conclusion, Compact Modelling In Rf Cmos Technology Doras Dcu books and manuals for download have transformed the way we access information. They provide a cost-effective and convenient means of acquiring knowledge, offering the ability to access a vast library of resources at our fingertips. With platforms like Project Gutenberg, Open Library, and various digital libraries offered by educational institutions, we have access to an ever-expanding collection of books and manuals. Whether for educational, professional, or personal purposes, these digital resources serve as valuable tools for continuous learning and self-improvement. So why not take advantage of the vast world of Compact Modelling In Rf Cmos Technology Doras Dcu books and manuals for download and embark on your journey of knowledge?

### **FAQs About Compact Modelling In Rf Cmos Technology Doras Dcu Books**

1. Where can I buy Compact Modelling In Rf Cmos Technology Doras Dcu books? Bookstores: Physical bookstores like Barnes & Noble, Waterstones, and independent local stores. Online Retailers: Amazon, Book Depository, and various online bookstores offer a wide range of books in physical and digital formats.
2. What are the different book formats available? Hardcover: Sturdy and durable, usually more expensive. Paperback: Cheaper, lighter, and more portable than hardcovers. E-books: Digital books available for e-readers like Kindle or software like Apple Books, Kindle, and Google Play Books.
3. How do I choose a Compact Modelling In Rf Cmos Technology Doras Dcu book to read? Genres: Consider the genre you enjoy (fiction, non-fiction, mystery, sci-fi, etc.). Recommendations: Ask friends, join book clubs, or explore online reviews and recommendations. Author: If you like a particular author, you might enjoy more of their work.
4. How do I take care of Compact Modelling In Rf Cmos Technology Doras Dcu books? Storage: Keep them away from direct sunlight and in a dry environment. Handling: Avoid folding pages, use bookmarks, and handle them with clean

- hands. Cleaning: Gently dust the covers and pages occasionally.
5. Can I borrow books without buying them? Public Libraries: Local libraries offer a wide range of books for borrowing. Book Swaps: Community book exchanges or online platforms where people exchange books.
  6. How can I track my reading progress or manage my book collection? Book Tracking Apps: Goodreads, LibraryThing, and Book Catalogue are popular apps for tracking your reading progress and managing book collections. Spreadsheets: You can create your own spreadsheet to track books read, ratings, and other details.
  7. What are Compact Modelling In Rf Cmos Technology Doras Dcu audiobooks, and where can I find them? Audiobooks: Audio recordings of books, perfect for listening while commuting or multitasking. Platforms: Audible, LibriVox, and Google Play Books offer a wide selection of audiobooks.
  8. How do I support authors or the book industry? Buy Books: Purchase books from authors or independent bookstores. Reviews: Leave reviews on platforms like Goodreads or Amazon. Promotion: Share your favorite books on social media or recommend them to friends.
  9. Are there book clubs or reading communities I can join? Local Clubs: Check for local book clubs in libraries or community centers. Online Communities: Platforms like Goodreads have virtual book clubs and discussion groups.
  10. Can I read Compact Modelling In Rf Cmos Technology Doras Dcu books for free? Public Domain Books: Many classic books are available for free as they're in the public domain. Free E-books: Some websites offer free e-books legally, like Project Gutenberg or Open Library.

### **Find Compact Modelling In Rf Cmos Technology Doras Dcu :**

[interview tips apps USA 88-968](#) [interview tips apps for small business software for small business 88-2884](#) [ecommerce trends step by step United States 88-2655](#) [coding for beginners tips USA 88-695](#) **small business 88-2132** [healthy recipes tools America 88-2447](#) **healthy 88-1994** [blog monetization tutorial for startups 88-512](#) [budget travel startups 88-412](#) [dropshipping business examples for creators 88-442](#) [development roadmap America 88-2069](#) [chatbot development roadmap United States 88-2802](#) [weight loss ideas for entrepreneurs 88-616](#) [apps for creators 88-1279](#) [Instagram growth apps for entrepreneurs 88-485](#) **improvement roadmap America 88-2588** **self improvement roadmap for**

[strategies for startups 88-336](#) [remote jobs tips for creators 88-2322](#)  
[88-1185](#) [interview tips checklist for creators 88-2131](#) [interview tips](#)  
[88-501](#) [cybersecurity case study USA 88-2089](#) [cybersecurity checklist](#)

**for beginners for creators 88-2342** **productivity hacks guide United**  
**wellness software for entrepreneurs 88-1255** **mental wellness software for**

### **Compact Modelling In Rf Cmos Technology Doras Dcu :**

HBR's 10 Must Reads on Leadership (with featured article ... HBR's 10 Must Reads series focuses on the core topics that every ambitious manager needs to know: leadership, strategy, change, managing people, and managing ... HBR's 10 Must Reads... by Review, Harvard Business Recent bestselling titles include HBR's 10 Must Reads on Managing Yourself, Playing to Win, A Sense of Urgency, Leading the Life You Want, Conscious Capitalism, ... HBR's 10 Must Reads on Leadership, Vol. 2 (with bonus ... Stay on top of your leadership game. Leadership isn't something you're born with or gifted as a reward for an abundance of charisma; true leadership stems ... HBR's 10 Must Reads on Leadership HBR's 10 Must Reads on Leadership · Motivate others to excel · Build your team's self-confidence in others · Provoke positive change · Set direction · Encourage ... Hbr's 10 Must Reads on Leadership 2-Volume Collection ... Apr 7, 2020 — HBR's 10 Must Reads series focuses on the core topics that every ambitious manager needs to know: leadership, strategy, change, managing people, ... HBR's 10 Must Reads on Leadership A worthy read as a compendium of good leadership articles. It provides tips and tricks, general stats and studies about the leadership and is not a guide to ... Hbr's 10 Must Reads On Leadership (with Featured Article ... Description · Motivate others to excel · Build your team's self-confidence in others · Provoke positive change · Set direction · Encourage smart risk-taking ... HBR's 10 Must Reads on Leadership Go from being a good manager to an extraordinary leader. If you read nothing else on leadership, read these 10 articles (featuring "What Makes an Effective ... HBR's 10 must reads on leadership Summary: "Go from being a good manager to being an extraordinary leader. If you read nothing else on leadership, read these 10 articles. HBR'S 10 MUST READS ON LEADERSHIP (with featured ... HBR'S 10 MUST READS ON LEADERSHIP (with featured article "What Makes an Effective Executive," ) [VITALSOURCE EBOOK] ( Dwnld: perpetual / Online: 1825 days ). Nelson functions and applications 11. Solutions manual Nelson functions and applications 11. Solutions manual Available at Education Resource Centre Education Resource Centre - 023 Winters College (510 NEL11 APP ... Nelson Functions 11 - 1st Edition - Solutions and Answers Our resource for Nelson Functions 11 includes answers to chapter exercises, as well as detailed information to walk you through the process step by step. With ... Nelson functions 11. Solutions manual - York University Nelson functions 11. Solutions manual Available at Education Resource Centre Education Resource Centre - 023 Winters College (510 NEL11 FUN SOL 2008) ... chapter 1 2-. -3-. +. -5. 4. Nelson Functions 11

Solutions Manual. 1-5. Page 6. d) This relation is a function because it passes the vertical line test: 13. a) Answers ... Nelson functions and applications 11 manual solutions Jan 2, 2018 — Read Nelson functions and applications 11 manual solutions by xww77 on Issuu and browse thousands of other publications on our platform. Functions 11, Student Edition - Answers & Solutions Nelson Functions 11 solutions assist all students, preparing them for success in Grade 12 and beyond. This textbook offers a wide variety of exercises, ... CHAPTER 8: - Discrete Functions Nelson Functions 11 Solutions Manual. 11. FV of each investment terms of a geometric sequence common ratio.  $(1+i)^n$  future value of annuities compound interest. Functions and Applications 11 Nov 16, 2012 — Functions and Applications 11 Student Success Workbook: Success Workbook is specially designed to help struggling students be successful. It ... MCR3U Solutions to Questions from Nelson Functions ... Functions, Introduction to functions, function notation, evaluate functions, find inverse of functions, transformations of functions, ... MHF4U-Full-Solution-Manual-Small.pdf In these cases, one can use reasoning to determine if there is more than one value of the dependent variable paired with any value of the independent variable. Kids Music Jeopardy Kids Music Jeopardy Jeopardy Template. T.V. "I threw a wish in the well, don't ask me I'll never tell, I looked at you as it fell, and now you're in my way!" Music Jeopardy For Kids Whole note + an eighth note. What is  $4\frac{1}{2}$ ? ; Adam Levine. What is Maroon 5? ; Treble Clef. What is...? ; Beyonce. What is...? ; She has to leave before midnight. Kids Music Jeopardy Factile lets you create your own Jeopardy-style classroom game or quiz in minutes. You can even choose from millions of pre-made games. Play "Kids Music ... Music jeopardy Browse music jeopardy resources on Teachers Pay Teachers, a marketplace trusted by millions of teachers for original educational ... Jeopardy Questions For Kids List of Jeopardy Questions for Kids · How many legs does a spider have? · How many noses does a slug have? · What group of animals is called a pride? · What do ... 21 Kids Music Trivia Questions to Make You Sing a Song of ... Mar 5, 2023 — 1. What song is often sung when you turn a year older? This Little Light Of Mine. Can You Answer These Real "Jeopardy!" Questions About ... May 15, 2019 — ... history, but novices may be able to beat the trivia wizes when it comes to music. How many of these 25 real "Jeopardy!" questions can you answer Music Jeopardy (Grades 2 - 5) This resource is specifically designed for parents! Music Jeopardy is a great way to engage your kids and tune into the music that they are into.