

Analysis and Design of Elementary MOS Amplifier Stages

The Modular Series of Microelectronic
Device & Circuit Design

Boris Murmann
Stanford University

Roger T. Howe and Charles G. Sodini
Series Editors

ISBN-10: 1-934891-17-1
ISBN-13: 978-1-934891-17-9

Publisher: Tom Robbins
Development Manager: Gretchen Edelson
Project Manager: Catherine Peacock

Library of Congress Control Number: 2012937889

©2013 National Technology and Science Press.

All rights reserved. Neither this book, nor any portion of it, may be copied or reproduced in any form or by any means without written permission of the publisher.

NTS Press respects the intellectual property of others, and we ask our readers to do the same. This book is protected by copyright and other intellectual property laws. Where the software referred to in this book may be used to reproduce software or other materials belonging to others, you should use such software only to reproduce materials that you may reproduce in accordance with the terms of any applicable license or other legal restriction.

MATLAB is a registered trademark of The MathWorks, Inc., 3 Apple Hill Road, Natick, MA

LabVIEW, Multisim and National Instruments are trademarks of National Instruments.

All other trademarks or product names are the property of their respective owners.

Additional Disclaimers:

The reader assumes all risk of use of this book and of all information, theories, and programs contained or described in it. This book may contain technical inaccuracies, typographical errors, other errors and omissions, and out-of-date information. Neither the author nor the publisher assumes any responsibility or liability for any errors or omissions of any kind, to update any information, or for any infringement of any patent or other intellectual property right.

Neither the author nor the publisher makes any warranties of any kind, including without limitation any warranty as to the sufficiency of the book or of any information, theories, or programs contained or described in it, and any warranty that use of any information, theories, or programs contained or described in the book will not infringe any patent or other intellectual property right. **THIS BOOK IS PROVIDED "AS IS." ALL WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY AND ALL IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS, ARE DISCLAIMED.**

No right or license is granted by publisher or author under any patent or other intellectual property right, expressly, or by implication or estoppel.

IN NO EVENT SHALL THE PUBLISHER OR THE AUTHOR BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, COVER, ECONOMIC, OR CONSEQUENTIAL DAMAGES ARISING OUT OF THIS BOOK OR ANY INFORMATION, THEORIES, OR PROGRAMS CONTAINED OR DESCRIBED IN IT, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, AND EVEN IF CAUSED OR CONTRIBUTED TO BY THE NEGLIGENCE OF THE PUBLISHER, THE AUTHOR, OR OTHERS. Applicable law may not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.



Contents

Preface vii

Chapter 1: Introduction 1

- Chapter Objectives 1
- 1-1 Mixed-Signal Integrated Circuits 2
- 1-2 Managing Complexity 4
- 1-3 Two-Port Abstraction for Amplifiers 5
- 1-4 Integrated Circuit Design versus Printed Circuit Board Design 14
- 1-5 Prerequisites and Advanced Material 15
- 1-6 Notation 15
- Summary 15
- References 16
- Problems 16

Chapter 2: Transfer Characteristic of the Common-Source Voltage Amplifier 18

- Chapter Objectives 18
- 2-1 First-Order MOSFET Model 19
- 2-2 Building a Common-Source Voltage Amplifier 26
- 2-3 Channel Length Modulation 41

- 2-4 Two-Port Model for the Common-Source Voltage Amplifier 47
 - Summary 48
 - References 48
 - Problems 48

Chapter 3: Frequency Response of the Common-Source Voltage Amplifier 52

- Chapter Objectives 52
- 3-1 Review of Frequency Domain Analysis 53
- 3-2 Frequency Response of the Common-Source Voltage Amplifier — First-Pass Analysis 58
- 3-3 Frequency Response of the Common-Source Voltage Amplifier— Second-Pass Analysis 63
- 3-4 Open-Circuit Time Constant Analysis 73
- 3-5 High-Frequency Two-Port Model for the Common-Source Voltage Amplifier 79
 - Summary 79
 - References 80
 - Problems 80

Chapter 4: The Common-Gate and Common-Drain Stages 84

- Chapter Objectives 84
- 4-1 Overview of Stage Configurations 84
- 4-2 Bulk Connection Scenarios and Required Model Extensions 85
- 4-3 Analysis of the Common-Gate Stage 90
- 4-4 Analysis of the Common-Drain Stage 98
- 4-5 Application Examples of Common-Gate and Common-Drain Stages 106
 - Summary 108
 - References 109
 - Problems 109

Chapter 5: Biasing Circuits 113

- Chapter Objectives 113
- 5-1 Overview 113
- 5-2 Introduction to Process Variation and Device Mismatch 114
- 5-3 Current Mirrors 117
- 5-4 Current References 132
- 5-5 Voltage Biasing Considerations 134
- Summary 138
- References 139
- Problems 139

Chapter 6: Multistage Amplifiers 143

- Chapter Objectives 143
- 6-1 Low-Frequency Analysis 143
- 6-2 High-Frequency Analysis 147
- 6-3 Design of a Three-Stage Transresistance Amplifier 155
- Summary 163
- References 163
- Problems 163

Index 171

