
Semiconductor Device Modeling With SPICE

Giuseppe Massobrio

Department of Electronics (DIBE)

University of Genova

Genova, Italy

Paolo Antognetti

Department of Electronics (DIBE)

University of Genova

Genova, Italy

Second Edition

McGraw-Hill, Inc.

New York San Francisco Washington, D.C. Auckland Bogotá
Caracas Lisbon London Madrid Mexico City Milan
Montreal New Delhi San Juan Singapore
Sydney Tokyo Toronto

Contents

List of Physical Parameters	ix
Foreword by Robert W. Dutton, Stanford University	xii
Preface	xiii

Chapter 1. PN-Junction Diode and Schottky Diode	1
1.1 DC Current-Voltage Characteristics	1
1.2 Static Model	11
1.3 Large-Signal Model	19
1.4 Small-Signal Model	23
1.5 Schottky Diode and Its Implementation in SPICE2	26
1.6 Temperature and Area Effects on the Diode Model Parameters	28
1.7 SPICE3 Models	31
1.8 HSPICE Models	31
1.9 PSPICE Models	40
References	42
Chapter 2. Bipolar Junction Transistor (BJT)	45
2.1 Transistor Conventions and Symbols	46
2.2 Ebers-Moll Static Model	48
2.3 Ebers-Moll Large-Signal Model	62
2.4 Ebers-Moll Small-Signal Model	70
2.5 Gummel-Poon Static Model	74
2.6 Gummel-Poon Large-Signal Model	96
2.7 Gummel-Poon Small-Signal Model	101
2.8 Temperature and Area Effects on the BJT Model Parameters	105
2.9 Power BJT Model	109
2.10 SPICE3 Models	118
2.11 HSPICE Models	118
2.12 PSPICE Models	128
References	129

Chapter 3. Junction Field-Effect Transistor (JFET)	131
3.1 Static Model	132
3.2 Large-Signal Model and Its Implementation in SPICE2	146
3.3 Small-Signal Model and Its Implementation in SPICE2	148
3.4 Temperature and Area Effects on the JFET Model Parameters	150
3.5 SPICE3 Models	152
3.6 HSPICE Models	152
3.7 PSPICE Models	156
References	158
Chapter 4. Metal-Oxide-Semiconductor Transistor (MOST)	161
4.1 Structure and Operating Regions of the MOST	161
4.2 LEVEL1 Static Model	168
4.3 LEVEL2 Static Model	180
4.4 LEVEL1 and LEVEL2 Large-Signal Model	195
4.5 LEVEL3 Static Model	202
4.6 LEVEL3 Large-Signal Model	210
4.7 Comments on the Three Models	211
4.8 The Effect of Series Resistances	212
4.9 Small-Signal Models	213
4.10 The Effect of Temperature on the MOST Model Parameters	215
4.11 BSIM1 Model	216
4.12 BSIM2 Model	234
4.13 SPICE3 Models	240
4.14 HSPICE Models	242
4.15 PSPICE Models	246
References	247
Chapter 5. BJT Parameter Measurements	251
5.1 Input and Model Parameters	251
5.2 Parameter Measurements	253
References	265
Chapter 6. MOST Parameter Measurements	267
6.1 LEVEL1 Model Parameters	267
6.2 LEVEL2 Model (Long-Channel) Parameters	273
6.3 LEVEL2 Model (Short-Channel) Parameters	279
6.4 LEVEL3 Model Parameters	289
6.5 Measurements of Capacitance	295
6.6 BSIM Model Parameter Extraction	298
References	298

Chapter 7. Noise and Distortion	299
7.1 Noise	299
7.2 Distortion	309
References	324
Chapter 8. The SPICE Program	325
8.1 SPICE2 Capabilities	325
8.2 SPICE2 Structure	333
8.3 Convergence Problems	354
8.4 SPICE2 Operation	357
8.5 Linked-List Specification	361
8.6 SPICE3 Capabilities Versus SPICE2	371
8.7 HSPICE Capabilities Versus SPICE2	371
8.8 PSPICE Capabilities Versus SPICE2	372
References	373
Chapter 9. Metal-Semiconductor Field-Effect Transistor, Ion-Sensitive Field-Effect Transistor, and Semiconductor-Controlled Rectifier	375
9.1 MESFET	376
9.2 ISFET	390
9.3 THYRISTOR	400
References	408
Appendix A. PN Junction	411
A.1 Elements of Semiconductor Physics	411
A.2 Physical Operation of the <i>PN</i> Junction	421
References	444
Appendix B. MOS Junction	445
B.1 MOS Junction	445
References	469
Appendix C. MS Junction	471
C.1 MS Junction	471
References	473
Index	475