SOFTWARE ENCLOSED
Book not returnable if software
has been removed.
PRENTICE-HALL, INC.

OrCAD PSpice® and Circuit Analysis

FOURTH EDITION

John Keown

Contents

Introduction 1

A Bit of Background 2
Getting Started 3
A Few Helpful Points 4
Here's How It's Done 5
    Creating the Input File 6
    Examining the Output File 7
    Changing the Input File 8
    The Current Directions 9
Further Reading 10

PSpice Overview 11

DC Circuit Analysis 11
AC Circuit Analysis 14
    Probe 17
Transistor Circuit Analysis 20

1
DC Circuit Analysis

An Introductory Example 25
Using SPICE to Investigate the Circuit 26
    Examining the Output File 27
    Another Simple Circuit for Analysis 28
Basic Circuit Laws 30
    Getting More from the Output File 32
    Current Directions 32
Circuit with Two Voltage Sources 33
Thévenin's Theorem and Applications 35
    SPICE and Thévenin's Theorem 36
    Practical Application of Thévenin's Theorem 37
    Circuit for Thévenin Replacement 38
Practical Current Source vs. Practical Voltage Source 41
SPICE Analysis of Circuit with Current Source 42
Norton's Theorem 43
    Using Norton's Theorem 44
    Short-Circuit Current in Missing Element 44
Circuit with Current and Voltage Sources 45
Maximum Power Transfer 46
Dependent Sources in Electric Circuits 47
    Voltage-Dependent Voltage Source 47
    Current-Dependent Voltage Source 50
    Current-Dependent Current Source 51
    Another Current-Dependent Current Source 52
    Voltage-Dependent Current Source 54
    Another Current-Dependent Voltage Source 55
Polynomial-Dependent Sources 56
    Dependent Source as a Function of Two Other Voltages 57
Mesh Analysis and PSpice 59
DC Sweep 61
Using the .PROBE Statement 61
Nodal Analysis and PSpice 63
A Nonplanar Circuit 65
Summary of PSpice Statements Used in This Chapter 66
Dot Commands Used in This Chapter 68
Problems 69

2
AC Circuit Analysis (for Sinusoidal Steady-State Conditions) 75

Series AC Circuit with R and L 75
Series AC Circuit with R and C 77
Parallel Branches in AC Circuit 77
Parallel Branches with Capacitive Branch 78
Maximum Power Transfer in AC Circuit 79
Resonance in Series RLC Circuit 79
Frequency Sweep for Series-Parallel AC Circuit 82
Effect of Changes in Coil Resistance 83
A Parallel-Resonant Circuit 84
    Using the Probe Cursor 85
Finding the Input Impedance of an AC Circuit 86
    Input Impedance of a Two-Branch Network 87
A Phase-Shift Network 89
Locus of Admittances 90
    Admittance Locus for Series RLC 93
Multiple Sources in AC Networks 94
Transformers 96
Frequency Response of Tuned Circuit 97
Three-Phase AC Circuits 98
Power-Factor Improvement 101
Three-Phase Power-Factor Improvement 102
A Three-Phase Rectifier 105
Voltage Regulation in a Three-Phase System 108
A Two-Phase System 109
Summary of New PSpice Statements Used in This Chapter 111
Dot Commands Used in This Chapter 112
.Probe 113
Problems 113

3
Transistor Circuits 119

The Bipolar-Junction Transistor 119
    A Model Suitable for Bias Calculations 119
    Saturation Considerations 121

Biasing Example for a Ge Transistor 121
Small-Signal *h*-Parameter Model of the BJT 123
Common-Emitter Transistor Analysis Using *h*-Parameter Model 123
Common-Collector Transistor Analysis Using *h*-Parameter Model 126
Common-Base Transistor Analysis Using *h*-Parameter Model 127
Other Configurations 128
Using a Circuit Involving Miller's Theorem 128
The Dual of Miller's Theorem 130
CC Circuit with Collector Resistor 133
High-Input-Resistance Amplifier 135
Two-Stage Amplifiers 136
Simplified *h*-Parameter Model 137
The *CE* Amplifier Using the Simplified *h*-Parameter Model 138
Field-Effect Transistor Amplifiers 139
Common-Drain FET with External Drain Resistor 141
Frequency Response of FET Amplifiers 142
High-Frequency Model of the BJT 143
Emitter Follower at High Frequencies 144
DC Sensitivity 147
DC Sensitivity of Biasing Circuit 149
The PSpice Parts Library 150
Sensitivity of Library BJT Circuit 151
Summary of New PSpice Statements Used in This Chapter 152
Dot Commands Used in This Chapter 154
Problems 155

4

Multistage Amplifiers, Frequency Response, and Feedback **161**

Low-Pass Filter 161
Low-Frequency Response of High-Pass *RC* Network 163
Common-Emitter Amplifier with Bypass Capacitor 163
Two-Stage Amplifier at High Frequencies 166
Two-Stage *CE* Amplifier with Voltage-Series Feedback 167
Two-Pole Amplifier Model with Feedback 172
CE Amplifier with Voltage-Shunt Feedback 175
Current-Shunt Feedback Two-Stage *CE* Amplifier 176
Three-Stage *CE* Amplifier Frequency Response 178

Effects of Circuit Modifications 179
Three-Stage Amplifier with Voltage-Shunt Feedback 180
Summary of New PSpice Statements Used in This Chapter 181
Various Forms of Transient Specification 181
The Exponential Source 182
The Pulse Source 183
The *PWL* Source 184
The Frequency-Modulated Source 185
The Sine-Wave Source 186
Problems 188

5
The Operational Amplifier **193**

The Ideal Op Amp 193
Noninverting Ideal Op Amp 195
Op Amp Giving Voltage Difference Output 196
Frequency Response of the Op Amp 197
Using a Subcircuit for the Op Amp 202
Op Amp Differentiator Circuit 203
Op Amp Integrator Circuit 204
Response to Unit Step Function 206
Double Op Amp Circuit 207
Active Filters 210
Second-Order Butterworth Low-Pass Filter 211
Fourth-Order Butterworth Low-Pass Filter 213
Active Resonant Band-Pass Filter 217
Active *RC* Band-Pass Filter 221
Summary of New PSpice Statements Used in This Chapter 222
Problems 223

6
Transients and the Time Domain **227**

Switch Closing in an *RL* Circuit 227
Nonzero Initial Current in the Transient Analysis 228
Resistor and Capacitor in the Transient Analysis 230

A Double-Energy Circuit 232
Overdamped *RLC* Series Circuit 232
The Critically Damped *RLC* Circuit 234
The Underdamped *RLC* Circuit 235
Step Response of an Amplifier 237
Low-Frequency Response of an Amplifier 238
Circuit with Charged Capacitor 240
Switch-Opening Circuit with L and C 242
Circuit with Current Source 244
Bridge Circuit with Initial Current 247
A Ringing Circuit 249
Problems 249

7
Fourier Series and Harmonic Components **253**

Fundamental and Second-Harmonic Frequency 253
Decomposition and Reconstruction of Wave 256
Second-Harmonic Distortion in a Power Amplifier 257
Intermodulation Distortion 259
Adding Sine Waves 263
Adding Fundamental and Second Harmonic 265
Amplitude Modulation 266
Summary of New Dot Command Used in This Chapter 267
Problems 268

8
Stability and Oscillators **271**

The Feedback Loop 271
The Wien-Bridge Oscillator with Initial Help 272
The *LC* Oscillator with Initial Help 274
Measurements with a Test Circuit 276
The Phase-Shift Oscillator 276
The Wien-Bridge Oscillator 279
Another Wien-Bridge Example 282
The Colpitts Oscillator 284
Problems 286

9
An Introduction to PSpice Devices 289

A Half-Wave Rectifier 289
The Built-in Model for a Diode 290
The Filtered Half-Wave Rectifier 292
The Full-Wave Rectifier 295
Full-Wave Rectifier with Filter 295
Simple Diode Clipper 297
A Double-Ended Clipper 298
Variable Load Resistor for Maximum Power 299
Built-in Model for the Bipolar-Junction Transistor 301
Output Characteristics of the Common-Emitter Transistor 302
Input Characteristics of the *CE* Transistor 303
Output Characteristics of the Junction Field-Effect Transistor 305
Other Active Semiconductor Devices 305
The Differential Amplifier 305
    Difference-Mode Gain 305
    Common-Mode Gain 306
    Transfer Characteristics of the Differential Amplifier 306
Logic Gates 309
The 7402 NOR Gate 309
Summary of New PSpice Statements Used in This Chapter 313
New Dot Commands 314
Problems 314

10
The Bipolar-Junction Transistor and Its Model 319

The Bipolar-Junction Transistor 319
    Output Characteristics 319
    Input Characteristics 321
A Common-Emitter BJT Amplifier 321
Biasing Case Study 325
    The AC Analysis 326
CE Amplifier with Unbypassed Emitter Resistor 330
    Finding the Input Resistance 334
Using Our Own Model with the *h* Parameters 334
    The *h*-Parameter Analysis 334

Phase Relations in the *CE* Amplifier 335
The Amplifier without the Emitter Capacitor 336
The Amplifier with the Emitter Capacitor 338
The BJT Flip-Flop 339
The PSpice Analysis 340
The Astable Multivibrator 343
An Emitter-Coupled BJT Multivibrator 344
Problems 349

11
The Field-Effect Transistor **351**

Output Characteristics for the Junction Field-Effect Transistor 351
Input Characteristics for the JFET 352
JFET Biasing Circuit 354
The JFET Amplifier 356
JFET Waveshapes 357
The Power MOSFET 357
The Output Characteristics 357
The Input Characteristics 359
The MOSFET Amplifier 361
The Waveshapes 363
The Gallium Arsenide FET 363
Problems 365

12
Two-Port Networks and Passive Filters **371**

Two-Port Parameters 371
Finding the *y* Parameters 371
Using the *y* Parameters to Solve a Circuit 374
y Parameters of Network with Dependent Source 375
The Open-Circuit Impedance Parameters 377
The *z* Parameters for an AC Circuit 379
Using the *z* Parameters to Solve a Circuit 380
The *ABCD* Parameters 380
The Hybrid Parameters 383

Another Set of Hybrid Parameters 383
Transmission Lines 384
A Long Telephone Line 385
Constant-*k* Filter 387
Stop-Band Behavior of the Constant-*k* Filter 389
Lossless Transmission Line 391
Lossless Line Composed of Several Sections 395
Input Impedance at Points along the Line 397
A Band-Pass Filter 398
Band-Elimination Filter 400
Problems 402

13
Nonlinear Devices **405**

The Nonlinear Resistor 405
The Iron-Core Inductor 406
The *BH* Curve 407
The Iron-Core Transformer 409
Voltage-Controlled Switch for Variable Resistor 411
Current-Controlled Switch 414
Summary of New PSpice Statements Used in This Chapter 416
New Dot Command 416
Problems 416

14
Capture **419**

A DC Series Circuit 420
Creating a Schematic in Capture 420
Analyzing the Circuit 423
Examining the Output File 423
Printing the Results 424
Net Aliases 426
Drawing a Tee Circuit 427
Running the Simulation 428
Dependent Sources in Schematics 429
Voltage-Dependent Voltage Source 431

Current-Dependent Current Source 432
An AC Circuit 436
Producing the AC Sweep 436
Finding More Accurate Trace Values 439
Order of the Nodes 439
Sine-Wave Representation for AC Analysis 440
Plotting Current with Voltages 442
Series Circuit with *R* and *C* 442
Maximum Power to Load Impedance 444
The Probe Voltage and Current Notation 446
Series Resonance 446
Multiple-Source AC Network 448
Sine-Wave Representation of Multisource AC 450
Sine Waves of Currents 452
Transformers 452

15
Transistor Circuits in Capture **455**

Output Characteristics of *Q2N3904* 455
Input Characteristics of *Q2N3904* 458
Common-Emitter Bipolar-Junction Transistor Case Study 459
The AC Analysis 462
The Transient Analysis 462
Modifying the Transistor Parameters 465
Using the *h*-Parameter Model 468
Field-Effect Transistor Characteristics 471
The JFET Amplifier 472
The Transient Analysis (JFET Waveshapes) 478
Frequency Response of BJT 478
Changing the Transistor Characteristics 480

16
Operational Amplifiers in Capture **481**

Noninverting Ideal Op Amp 481
Op Amp for Voltage-Difference Output 483
Frequency Response of the Op Amp 485

Active Filter 486
Active Resonant Band-Pass Filter 489
Part *uA741* 490
Frequency Response of the *uA741* 490
Subroutine-Node Designation 491
The *uA741* as a Level Detector 495
Op Amp Phase Shifter 498
Phase Shift Using an Ideal Op Amp 499

17
Other Topics in Schematics **503**

The Stimulus Editor 503
A Temperature Sweep 506
Changing the Zener-Breakdown Voltage 508
Using the Breakout Zener Diode 511
Noise Analysis 512
Harmonic Content in Output Voltage 516
Using a Variable Parameter 520
Using Device Tolerances 522
Monte Carlo Analysis 524
Worst-Case Analysis 526
Effect of Resistor Tolerance on Worst-Case Analysis 527
Digital Capture 528
The NOR Gate 530
A Half-Adder Circuit 531
A Circuit for Simplification 535
The D Flip-Flop 535

Appendix A **541**

Brief Summary of PSpice Statements

Appendix B **545**

PSpice Devices and Statements

Appendix C 561

Installing the Software, Manuals, and Tutorials

Appendix D 573

PSpice Devices and Model Parameters

Appendix E 579

Sample Standard Device Library

Index 605