



Electric Circuits Fundamentals

Sergio Franco, *San Francisco State University*

Oxford University Press, 1995

ISBN: 0-19-513613-6

Detailed Table of Contents

FOREWORD, by Adel S. Sedra

PREFACE: Pedagogy and Approach, Content, Course Options, Supplements, Acknowledgments

CONTENTS

1 BASIC CONCEPTS

- 1.1 **Units and Notation**: SI Units, Unit Prefixes, Consistent Sets of Units, Signal Notation
 - 1.2 **Electric Quantities**: Charge, Potential Energy, Voltage, Relation between Electric Field and Potential, Current, Power, Active and Passive Sign Convention
 - 1.3 **Electric Signals**: DC Signals, Time-Varying Signals, The Step Function, The Pulse, Periodic Signals, Ac Signals, Analog and Digital Signals, Average Value of a Signal, Full-Cycle and Half-Cycle Averages
 - 1.4 **Electric Circuits**: Circuit Analysis and Synthesis, Branches, Nodes, Reference Node, Loops and Meshes, Series and Parallel Connections
 - 1.5 **Kirchhoff's Laws**: Kirchhoff's Current Law (KCL), Kirchhoff's Voltage Law (KVL), Power Conservation
 - 1.6 **Circuit Elements**: i - v Characteristic, v - i Characteristic Straight Line Characteristic
 - 1.7 **Sources**: Voltage Sources, Current Sources, A Hydraulic Analogy, Dependent Sources, Voltage Sources in Series, Current Sources in Parallel
- Summary*
Problems

2 RESISTIVE CIRCUITS

- 2.1 **Resistance**: Ohm's Law, i - v Characteristic, Conductance, Power Dissipation, Conduction, Practical Resistors and Potentiometers
 - 2.2 **Series/Parallel Resistance Combinations**: Resistances in Series, Resistances in Parallel, Series/Parallel Resistance Reductions, The Proportionality Analysis Procedure
 - 2.3 **Voltage and Current Dividers**: The Voltage Divider, Gain, The Current Divider, Applying Dividers to Circuit Analysis
 - 2.4 **Resistive Bridges and Ladders**: The Resistive Bridge, Resistive Ladders, R - $2R$ Ladders
 - 2.5 **Practical Sources and Loading**: Practical Voltage Source Model, Practical Current Source Model, The Loading Effect, Operating Limits
 - 2.6 **Instrumentation and Measurement**: Voltage and Current Measurements, Loading, Multi-meters, DC and AC Multimeter Measurements, Oscilloscopes
- Summary*
Problems

3 CIRCUIT ANALYSIS TECHNIQUES

- 3.1 **Circuit Solution by Inspection**: Resistive Ladder Design, DC Biasing
- 3.2 **Nodal Analysis**: The Node Method, Checking, Supernodes
- 3.3 **Loop Analysis**: The Loop Method, Checking, Supermeshes
- 3.4 **Linearity and Superposition**: The Superposition Principle, Concluding Observation
- 3.5 **Source Transformations**: Analysis Techniques Comparison

- 3.6 Circuit Analysis Using SPICE:** SPICE, An Illustrative Example, Resistors, Independent DC Sources, Scale Factors, Automatic DC Analysis, The .OP Statement, Dummy Voltage Sources, The .DC and .PRINT DC Statements, Concluding Remarks

Summary

Problems

4 CIRCUIT THEOREMS AND POWER CALCULATIONS

- 4.1 One-Ports:** i - v Characteristics of Linear One-ports, Finding R_{eq} : Method 1, Finding R_{eq} : Method 2, Remark

- 4.2 Circuit Theorems:** Thevenin's Theorem, Norton's Theorem, Thevenin and Norton Comparison, Concluding Remarks

- 4.3 Nonlinear Circuit Elements:** Iterative Solutions, Graphical Analysis

- 4.4 Power Calculations:** Average Power, RMS Values, AC Multimeters, Maximum Power Transfer, Efficiency

- 4.5 Circuit Analysis Using SPICE:** Finding Thevenin/Norton Equivalentents with SPICE, Nonlinear Resistors

Summary

Problems

5 TRANSFORMERS AND AMPLIFIERS

- 5.1 Dependent Sources:** Resistance Transformation, Transistor Modeling

- 5.2 Circuit Analysis with Dependent Sources:** Nodal and Loop Analysis, Thevenin and Norton Equivalentents, Concluding Remarks

- 5.3 The Transformer:** Circuit Model of the Ideal Transformer, Power Transmission, Resistance Transformation, Practical Transformers

- 5.4 Amplifiers:** Voltage Amplifier Model, Current Amplifier Model, Transresistance and Transconductance Amps, Power Gain

- 5.5 Circuit Analysis Using SPICE:** Voltage-Controlled Sources, Current-Controlled Sources, The Ideal Transformer

Summary

Problems

6 OPERATIONAL AMPLIFIERS

- 6.1 The Operational Amplifier:** Op Amp Model, Op Amp Terminology, The Ideal Op Amp

- 6.2 Basic Op Amp Configurations:** The Noninverting Amplifier, The Voltage Follower, The Inverting Amplifier

- 6.3 Ideal Op Amp Circuit Analysis:** The Op Amp Rule, An Illustrative Example, The Inverting and Noninverting Amps Revisited, Gain Polarity Control, Negative Resistance Converter

- 6.4 Summing and Difference Amplifiers:** The Summing Amplifier, The Difference Amplifier, The Instrumentation Amplifier

- 6.5 Transresistance, Transconductance, and Current Amplifiers:** Transresistance Amplifiers, Transconductance Amplifiers, Current Amplifiers

- 6.6 Op Amp Circuit Analysis Using SPICE:** Transfer Characteristic, Subcircuits

Summary

Problems

7 ENERGY STORAGE ELEMENTS

- 7.1 Capacitance:** Linear Capacitances, i - v Characteristic, Uniform Charge/Discharge, Time Diagrams, v - i Characteristic, Capacitive Energy, A Water Tank Analogy, Capacitances in Parallel, Capacitances in Series, Practical Capacitors

- 7.2 Inductance:** v - i Characteristic, i - v Characteristic, The Principle of Duality, Inductive Energy, Inductances in Series and in Parallel, Practical Inductors, Comparison of the Basic Elements

- 7.3 Natural Response of RC and RL Circuits:** First-Order Differential Equations, The Source-Free or Natural Response, The Time Constant τ , Decay Times, The s Plane

- 7.4 Responses to DC and AC Forcing Functions:** General Solution to the Differential Equation, Response to a DC Forcing Function, The Transient and DC Steady-State Components, Response to an AC Forcing Function, The Transient and AC Steady-State Components, Concluding Observations

Summary

Problems

8 TRANSIENT RESPONSE OF FIRST-ORDER CIRCUITS

- 8.1 Basic RC And RL Circuits:** The Continuity Conditions, DC Steady-State Behavior, The R - C Circuit, The C - R Circuit, RL Circuits
- 8.2 Transients in First-Order Networks:** Capacitive Examples, Inductive Examples
- 8.3 Step, Pulse, and Pulse-Train Responses:** Step Response of R - C and L - R Circuits, Pulse Response of R - C and L - R Circuits, Pulse-Train Response of R - C and L - R Circuits, Step Response of C - R and R - L Circuits, Pulse-Train Response of C - R and R - L Circuits
- 8.4 First-Order Op Amp Circuits:** The Differentiator, The Integrator, The Noninverting Integrator, Creating Divergent Responses, The Root Locus
- 8.5 Transient Analysis Using SPICE:** Energy-storage Elements, The .TRAN and .PLOT TRAN Statements, The Graphics Post-processor, The PULSE Function

Summary

Problems

9 TRANSIENT RESPONSE OF SECOND-ORDER CIRCUITS

- 9.1 Natural Response of Second-Order Circuits:** The Characteristic Equation, Varying the Damping Ratio, Overdamped Response, Underdamped Response, Critically-Damped Response, Undamped Response, The Root Locus, Concluding Remarks
- 9.2 Transient Response of Second-Order Circuits**
- 9.3 Step Response of Second-Order Circuits:** Overdamped Response, Critically Damped Response, Underdamped Response, Overshoot, Settling Time
- 9.4 Second-Order Op Amp Circuits:** A Second-Order Passive Inductorless Circuit, A Second-Order Active Inductorless Circuit, Creating Roots in the Right Half of the s Plane, The Root Locus
- 9.5 Transient Analysis Using SPICE**

Summary

Problems

10 AC RESPONSE

- 10.1 Sinusoids and Phasors:** General Expression for an AC Signal, Phase Difference, Phasors
- 10.2 AC Response of the Basic Elements:** AC Response of the Resistance, AC Response of the Capacitance, AC Response of the Inductance, Limiting Cases
- 10.3 AC Response of First-Order Circuits:** The C - R Circuit, The High-Pass Function, The L - R Circuit, The Low-Pass Function, Relation between the Transient and AC Response, Concluding Remarks
- 10.4 AC Response of Second-Order Circuits:** The Series RLC Circuit, The Band-Pass Function, The Parallel RLC Circuit, Relation between the Transient and Ac Response

Summary

Problems

11 AC CIRCUIT ANALYSIS

- 11.1 Phasor Algebra:** Magnitude Scaling, Polarity Inversion, The j Operator, Differentiation, Integration, The Complex Plane, Rectangular Coordinates, Polar Coordinates, Addition and Subtraction, Graphical Addition and Subtraction, Useful Approximations, Exponential Form, Multiplication and Division, Complex Conjugate, Using Phasors to Solve Differential Equations
- 11.2 AC Impedance:** Generalized Ohm's Law, Impedance and Admittance, Limiting Cases for the Element Impedances, Series/Parallel Combinations, Ac Resistance and Reactance, AC Conductance and Susceptance, RC , RL , and LC Pairs
- 11.3 Frequency-Domain Analysis:** AC Dividers, The Proportionality Analysis Procedure, Nodal and Loop Analysis, Finding the Equivalent Impedance of an AC Port, Thevenin and Norton Equivalents, Concluding Remarks
- 11.4 First-Order Op Amp AC Circuit:** Integrators, the Differentiator, Low-Pass Circuit with Gain, High-Pass Circuit with Gain, Capacitance Multiplication, Inductance Simulation, Concluding Remarks
- 11.5 AC Analysis Using SPICE:** Independent Ac Sources, The .AC Statement, The .PRINT AC and .PLOT AC Statements

Summary

Problems

12 AC POWER AND THREE-PHASE SYSTEMS

- 12.1 **AC Power:** The Power Factor, Power and Impedance, Maximum Power Transfer
- 12.2 **Complex Power:** Real and Reactive Power, Power Factor Correction, Complex Power, Ac Power Measurements
- 12.3 **Three-Phase Systems:** Three-Phase Sources, Three-Phase Loads, Δ -Y and Y Δ Transformations
- 12.4 **Y-Y and Y- Δ Systems:** The Y-Y System, The Y- Δ System
- 12.5 **Power in Three-Phase Systems:** Instantaneous Power, Complex, Real, and Reactive Power, Power Measurements in Three-Phase Systems
- 12.6 **SPICE Analysis of Three-Phase Systems**
 - Summary*
 - Problems*

13 AC RESONANCE

- 13.1 **Series Resonance:** Frequency Response, Phasor Diagrams, Resonance Voltage Rise, Energy at Resonance
- 13.2 **Parallel Resonance:** Practical Resonant Circuits
- 13.3 **Resonant Op Amp Circuits:** A Passive Inductorless Band-Pass Circuit, An Active Inductorless Band-Pass Circuit
- 13.4 **Scaling:** Magnitude Scaling, Frequency Scaling, Magnitude and Frequency Scaling
 - Summary*
 - Problems*

14 NETWORK FUNCTIONS

- 14.1 **Complex Frequency:** Complex Exponential Signals, An Illustrative Example, Generalized Impedance and Admittance, s -Domain Circuit Analysis
- 14.2 **Network Functions:** Zeros and Poles, Physical Interpretation of Zeros and Poles, Procedure for Finding Network Functions
- 14.3 **The Natural Response Using $H(s)$:** Critical Frequencies of Source-Free Circuits, Concluding Remarks
- 14.4 **The Complete Response Using $H(s)$:** The DC Steady-state Response, The AC Steady-State Response, The Complete Response, The Complete Response of RC and RL Circuits, DC Passing and AC Blocking, DC Blocking and AC Passing
- 14.5 **The Frequency Response Using $H(s)$:** Semi-logarithmic Scales, Decibels, An Illustrative Example
- 14.6 **Network Function Building Blocks:** Frequency-Invariant Functions, Functions with a Root at the Origin, Functions with a Real Negative Root, Functions with a Complex Root Pair, Multiple Roots
- 14.7 **Piecewise-Linear Bode Plots:** Plotting Magnitude Directly
- 14.8 **Circuit Responses Using SPICE:** The Sinusoidal Function, Bode Plots Using SPICE
 - Summary*
 - Problems*

15 TWO-PORT NETWORKS AND COUPLED COILS

- 15.1 **Two-Port Parameters:** The T and p Networks, Parameter Conversion, Reciprocal Two-Ports, Non-Existence of Parameters
- 15.2 **the z , y , a , and h Parameters:** The z Parameters, Models of z Parameters, The y Parameters, Models of y Parameters, The a Parameters, The h Parameters, Models of h Parameters
- 15.3 **Two-Port Interconnections:** Series-Connected Two-Ports, Parallel-Connected Two-Ports, Cascade-Connected Two-Ports
- 15.4 **Magnetically Coupled Coils:** Mutual Inductance, The Dot Convention, Dot Marking, Energy in Coupled Coils, The Coefficient of Coupling, Coupled Coil Measurements
- 15.5 **Transformers:** The Linear Transformer, Reflected Impedance, The Ideal Transformer
- 15.6 **SPICE Analysis of Two-Ports and Coupled Coils:** Two-Ports, Magnetically Coupled Coils
 - Summary*
 - Problems*

16 THE LAPLACE TRANSFORM

- 16.1 **The Step and Impulse Functions:** The Physical Significance of $u(t)$ and $\delta(t)$, Practical Considerations, Scaling, Time-Shifting, The Sifting Property
- 16.2 **The Laplace Transform:** Transform Pairs, Convergence

- 16.3 **Operational Transforms:** Linearity, Differentiation, Integration, Time Shifting, Frequency Shifting, Scaling, Convolution, Periodic Functions, Initial and Final Values
- 16.4 **The Inverse Laplace Transform:** Real and Distinct Poles, Complex Conjugate Poles, Repeated Real Poles, Repeated Complex Pole Pairs, Improper Rational Functions
- 16.5 **Application to Differential Equations:** The Forced and Natural Response Components, the Network Function $H(s)$
- 16.6 **Application to Circuit Analysis:** Circuit Element Models, Circuit Analysis Using Laplace Transforms
- 16.7 **Convolution:** Graphical Convolution, Numerical Convolution
Summary
Problems

17 FOURIER ANALYSIS TECHNIQUES

- 17.1 **The Fourier Series:** The Fourier Coefficients, The Power of a Periodic Signal, Mean Square Error
- 17.2 **The Effect of Shifting and Symmetry:** Shifting, Even and Odd Functions, Half-Wave Symmetry, Effect of Discontinuities
- 17.3 **Frequency Spectra and Filtering:** Frequency Spectra, Steady-State Response to a Periodic Signal, Input-Output Spectra, Filters
- 17.4 **The Exponential Fourier Series:** Power, Frequency Spectra
- 17.5 **The Fourier Transform:** Fourier Transform Pairs, Energy Density Spectrum
- 17.6 **Properties of the Fourier Transform:** Fourier Transform Properties, Operational Transforms, Relation to the Laplace Transform
- 17.7 **Fourier Transform Applications:** Comparing the Fourier and Laplace Approaches
- 17.8 **Fourier Techniques Using SPICE:** Fourier Synthesis, Fourier Analysis, Piecewise-Linear Waveforms
Summary
Problems

Appendix 2A: Standard Resistance Values

Appendix 3A: Solution of Simultaneous Linear Algebraic Equations: Gaussian Elimination, Cramer's Rule

Appendix 9A: Euler's Formula and the Undamped Response

Appendix 11A: Summary of Complex Algebra

Answers to Odd-Numbered Problems

Index