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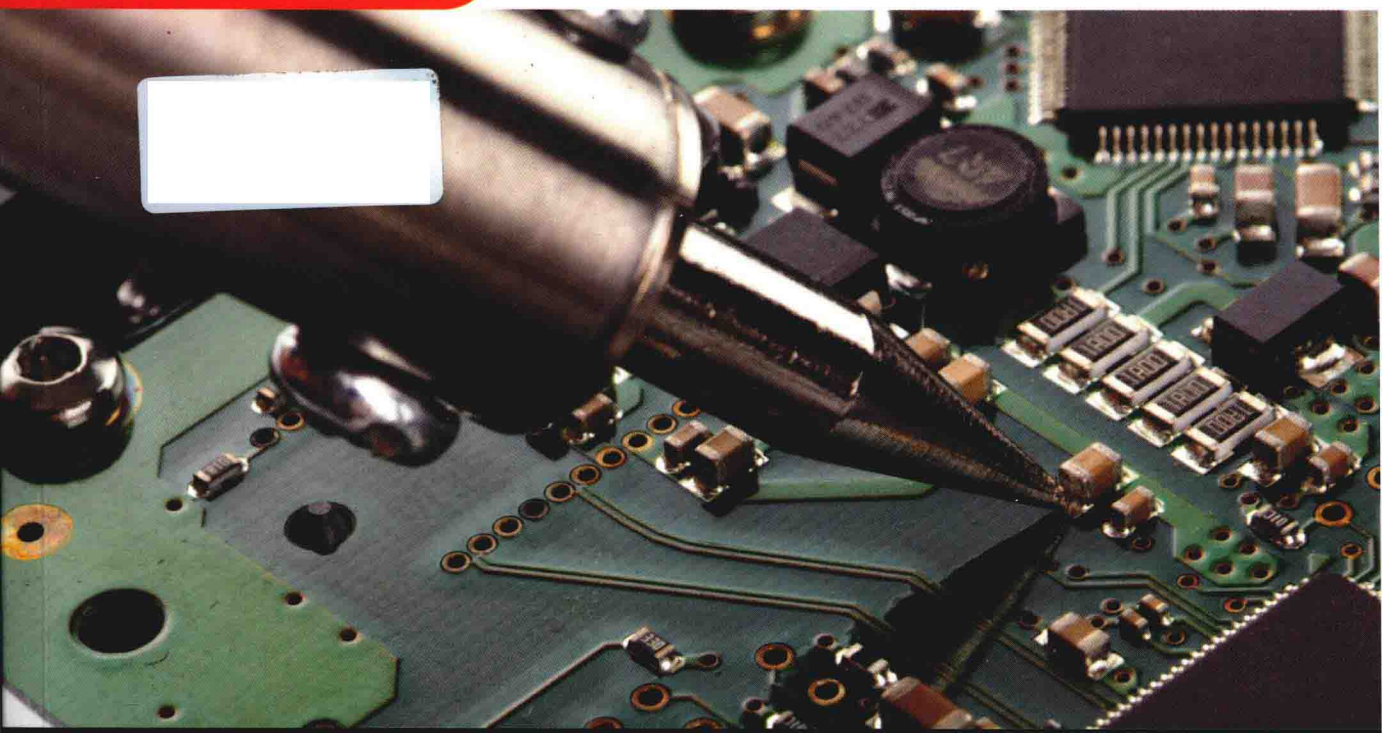

CIRCUITS AND NETWORKS

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A Sudhakar
Shyammohan S Palli

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Circuits and Networks

Analysis and Synthesis

Fifth Edition

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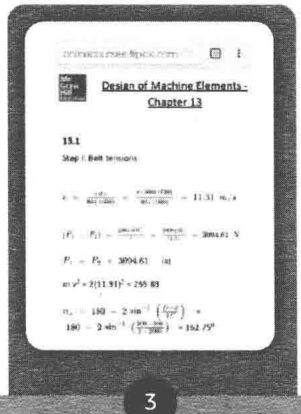

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A Sudhakar is presently working as Principal at RVR & JC College of Engineering, Guntur, Andhra Pradesh. He obtained his BTech (1978–83) from V R Siddartha Engineering College affiliated to Acharya Nagarjuna University, and ME from Jadavpur University, Kolkata (1983–85). Thereafter, he obtained his PhD from Andhra University, Visakhapatnam, in 2002. He has 29 years of teaching and research experience in the field of Electronics and Communication Engineering and has also worked as Associate Professor at AIMST, Malaysia, during 2003–2005. Presently, he is a member of the Planning and Monitoring Board and a Senate Member of Acharya Nagarjuna University. He is a member of various professional societies like IEEE, SEMCEI, ISTE, and Fellow in IETE.

Dr Sudhakar has visited several countries like Malaysia, Singapore, Russia, and Sweden to present papers in international conferences. He has published more than 50 papers in various national and international journals and has co-authored several books, all published by McGraw Hill Education (India). He has completed several projects and is working on various new research and sponsored projects funded by AICTE and UGC, Govt of India. His fields of interest include Circuits, Signals and Systems, and Array Antennas. He received the Prathibha Puraskar from T R Mahesh Charitable Trust, Guntur, for his services in the field of Higher Education, Andhra Pradesh on 19th July, 2014. He has received a Certificate of Excellence for his outstanding services, achievements, and contributions to the field of Electronics and Communication Engineering by the IETE Vijayawada centre on the occasion of "IETE Foundation Day" on 2 November, 2014. Dr A Sudhakar, as Head of the Institution, received the Prestigious Indira Gandhi National Service Scheme Award 2013–14 from the President of India for the NSS Unit of RVR & JC College of Engineering.

Shyammohan S Palli is presently Professor and Head, Department of Electrical and Electronics Engineering, Sir C R Reddy College of Engineering, Eluru, affiliated to Andhra University. Prior to his current assignment, he worked in different capacities, first as Lecturer at Siddaganga Institute of Technology, Tumkur, in the year 1981 and then, he was Lecturer at K L College of Engineering during 1981–87. From 1987–2001, he worked at RVR & JC College of Engineering, Guntur, first as Assistant Professor and then as Professor and Head.

He obtained his BTech in Electrical Engineering from the College of Engineering, Kakinada (JNTU), in 1978. He completed his MTech, specializing in Power Systems in 1980 from the same college. Since then he has been associated with teaching and research and has over 34 years of experience. He has published numerous papers in national and international journals and has authored several books on Networks and Circuits which have found national acclaim. He has also received various sponsored projects funded by AICTE. Presently, he is pursuing PhD in the area of Power System Control at Andhra University. His areas of interest include Control Systems, Power Systems, Operation and Control.

Both the authors also have, to their credit, books specific for regional technical universities, such as for Jawaharlal Nehru Technological University, published by McGrawHill Education (India).

Dedicated to our

Parents

and

Students

Preface

INTRODUCTION TO THE COURSE

This textbook is exclusively designed for electrical engineering students studying a basic level course in circuit analysis offered to undergraduate students of various universities. This edition is prepared with students and instructors in mind. The principal objectives of the book continue to be to provide an introduction to basic concepts for circuit analysis, and to develop a strong foundation that can be used as the basis for further study. To achieve these objectives, emphasis has been placed on basic laws, theorems, and techniques which are used to develop a working knowledge of the methods of analysis, used in further topics of electrical engineering. The mathematical complexity of the book remains at a level well within the grasp of college first-year undergraduate students.

TARGET AUDIENCE

This book is designed for the third semester of EEE/ECE/EI/CSE students of various universities in the country. This book enables the student have a firm grasp on the basic principles of Circuits and Networks: Analysis and Synthesis. It lays emphasis on the basic laws, theorems, and techniques of analysis which helps students develop the ability to design practical circuits that perform the desired operations.

OBJECTIVE OF THE REVISION

The main objective of the revision was to align this extremely popular content with internationally approved learning objectives for the course. Learning Objectives are the heart of every lesson, giving a purpose to learning. They are the foundations for lesson planning so that the students have a sense of purpose to learning and to know what is expected of them.

WHAT'S NEW IN THE FIFTH EDITION

We received a great deal of useful feedback on the fourth edition, and we paid careful attention to it. While attempting to improve the book in all dimensions, our main aim was increasing its usefulness to students and instructors. The revised text and its underlying concepts & principles will be more interesting-to-read, easy-to-understand, and logical-to-follow. Given here is a quick review of the principle newness of the fifth edition over the fourth.

Each of the 19 chapters follows a common structure with a range of learning and assessment tools for instructors and students.

Use of Technology

In bringing out the fifth edition, we have taken advantage of recent technological developments to create a wealth of useful information not present in the physical book. For students using smartphones and tablets, scanning **QR codes** located within the chapters gives them immediate access to more resources.

For interactive quiz with answers,
visit
http://qrcode.flipick.com/index.php/259
OR scan the QR code given here.

The QR code appearing at the last page of each chapter gives students access to additional chapter resources which include Interactive Quizzes.

Learning Tools

❖ Learning Objectives

Each chapter begins with a list of key Learning Objectives that are directly tied to the chapter content. These help in focussed planning for instructors and methodical studying for students. The chapters are now more modularised this will help in systematic concept development.

LEARNING OBJECTIVES

After reading this chapter, the reader should be able to

- **LO 1** Draw the tree, co-tree, twigs and links for a given network
- **LO 2** Describe incidence matrix and its properties; analyse the relationship between KCL and incidence matrix
- **LO 3** Describe the link currents and tie-set matrix
- **LO 4** Describe cut-set and tree branch voltages
- **LO 5** Analyse the network (resistive circuits) using mesh analysis and supermesh analysis and write the mesh equations using inspection method
- **LO 6** Analyse the network (resistive circuits) using nodal analysis and supernode analysis and write the nodal equations using inspection method
- **LO 7** Analyse the network (resistive circuits) using source transformation technique

❖ Arrangement of Pedagogy

The pedagogy is arranged as per levels of difficulty to enable the students to evaluate their learning levels. This assessment of levels of difficulty is derived from Bloom's taxonomy.

Note: ☆☆★ - Level 1 and Level 2 Category
☆★★ - Level 3 and Level 4 Category
★★★ - Level 5 and Level 6 Category

☆☆★ indicates Level 1 and Level 2 i.e., Knowledge and Comprehension based easy-to-solve problems

☆★★ indicates Level 3 and Level 4 i.e., Application and Analysis based medium-difficulty problems

★★★ indicates Level 5 and Level 6 i.e., Synthesis and Evaluation based high-difficulty problems

❖ Definitions and Important Formulae

Features like Definition and Important Formulas are highlighted within the text to draw special attention to important concepts

The average power is expressed in watts. It means the useful power transferred from the source to the load, which is also called true power. If we consider a dc source applied to the network, true power is given by the product of the voltage and the current. In case of sinusoidal voltage applied to the circuit, the product of voltage and current is not the true power or average power. This product is called *apparent power*. The apparent power is expressed in volt amperes, or simply VA.

Apparent power $= V_{eff} I_{eff}$

In Eq. (6.10), the average power depends on the value of cos θ; this is called the *power factor* of the circuit.

$$\therefore \quad \text{Power factor (pf)} = \cos\theta = \frac{P_{av}}{V_{eff}\, I_{eff}}$$

Therefore, power factor is defined as the ratio of average power to the apparent power, whereas apparent power is the product of the effective values of the current and the voltage. ***Power factor*** *is also defined as the factor with which the volt amperes are to be multiplied to get true power in the circuit.*

In the case of sinusoidal sources, the power factor is the cosine of the phase angle between voltage and current

$$pf = \cos\theta$$

As the phase angle between voltage and total current increases, the power factor decreases. The smaller the power factor, the smaller the power dissipation. The power factor varies from 0 to 1. For purely resistive circuits, the phase angle between voltage and current is zero, and hence the power factor is unity. For purely reactive circuits, the phase angle between voltage and current is 90°, and hence the power factor is zero. In an *RC* circuit, the power factor is referred to as *leading* power factor because the current leads the voltage. In an *RL* circuit, the power factor is referred to as lagging power factor because the current lags behind the voltage.

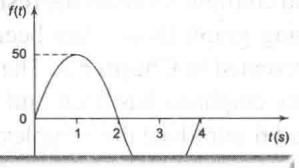
Pedagogy for Student Success

❖ Improved and Expanded In-text Exercises

This is by far the best feature! Exam-friendly pedagogy has been arranged within the text and linked after every Learning Objective. This offers great retention through looping mechanism.

Practice Problems linked to LO 2

☆★★13-2.1 Use step functions to write the expression for the function shown in Fig. Q.1.



★★★13-2.2 Step functions can be used to define a window function. Thus, $u(t-1)-u(t-4)$ defines a window 1 unit high and 3 units wide located on the time axis between 1 and 4. A function $f(t)$ is defined as follows: $f(t) = 0,\ t < 0$

EXAMPLE 2.7

Write the mesh current equations in the circuit shown in Fig. 2.27, and determine the currents.

Solution Assume two mesh currents in the direction as indicated in Fig. 2.28.

The mesh current equations are

$$5I_1 + 2(I_1 - I_2) = 10$$

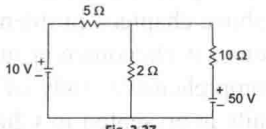


Fig. 2.27

Frequently Asked Questions linked to LO8

☆★★9-8.1 A three-phase motor can be regarded as a balanced Y-load. A three-phase motor draws 5.6 kW when the line voltage is 220 V and the line current is 18.2 A. Determine the power factor of the motor. **[AU Nov./Dec. 2012]**

☆☆★9-8.2 In a three-phase balanced delta system the voltage across R and Y is $400\angle 0°$V. What will be the voltage across Y and B? Assume RYB phase sequence. **[AU April/May 2011]**

☆★★9-8.3 A balanced Δ-connected load has one phase current $I_{BC} = 2\angle -90°$ A. Find the other phase current and the three line currents if the system is an ABC system. If the line voltage is 100 V, what is the load impedance? **[AU April/May 2011]**

☆★★9-8.4 The power consumed in a three-phase, balanced star-connected load is 2 kW at a power factor of 0.8 lagging. The supply voltage is 400 V, 50 Hz. Calculate the resistance and reactance of each phase. **[AU April/May 2011]**

Additional Solved Problems

PROBLEM 9.1

The phase voltage of a star-connected three-phase ac generator is 230 V. Calculate the (a) line voltage, (b) active power output if the line current of the system is 15 A at a power factor of 0.7, and (c) active and reactive components of the phase currents.

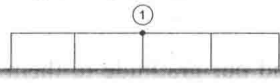
Solution The supply voltage (generator) is always assumed to be balanced

$\therefore\ V_{Ph} = 230$ V; $I_L = I_{Ph} = 15$ A, $\cos\phi = 0.7$, $\sin\phi = 0.71$

PSpice Problems

PROBLEM 5.1

For the parallel circuit shown in Fig. 5.39, find the magnitude of current in each branch and the total current. What is the phase angle between the applied voltage and total current.



Objective-Type Questions

☆☆★9.1 The resultant voltage in a closed balanced delta circuit is given by

(a) three times the phase voltage (b) $\sqrt{3}$ times the phase voltage

(c) zero

☆☆★9.2 Three coils A, B, C, displaced by 120° from each other are mounted on the same axis and rotated in a uniform magnetic field in clockwise direction. If the instantaneous value of emf in coil A is $E_{max}\sin\omega t$, the instantaneous value of emf in B and C coils will be

(a) $E_{max}\sin\left(\omega t - \frac{2\pi}{3}\right)$; $E_{max}\sin\left(\omega t - \frac{4\pi}{3}\right)$

(b) $E_{max}\sin\left(\omega t + \frac{2\pi}{3}\right)$; $E_{max}\sin\left(\omega t + \frac{4\pi}{3}\right)$

❖ Chapter-end Exercises

Pedagogy includes Additional Solved Problems, PSpice Problems, and Objective Type Questions, which is also integrated through QR Codes are featured at the end of the chapter.

ORGANIZATION OF THE BOOK

The basic approach of the previous edition has been retained. All the elements with definitions, basic laws, and configurations of the resistive circuits have been introduced in **Chapter 1**. Analysis of dc resistive circuits using graph theory has been discussed in **Chapter 2**. Network theorems on resistive circuits have been presented in **Chapter 3.** The concept of alternating currents and voltages has been introduced in **Chapter 4**. Due emphasis has been laid on finding out the average and rms values of different waveforms. **Chapters 5 and 6** introduce the complex impedance, and the concept of power and power factor respectively.

The steady-state analysis of ac circuits, including network theorems, has been discussed in **Chapter 7.** In all the above chapters, problems, tutorials, and objective questions on dependant sources have been discussed. Resonance phenomenon in series and parallel circuits, and locus diagrams are presented in **Chapter 8**. A comprehensive study of polyphase systems and power measurement in both balanced and unbalanced circuits is presented in **Chapter 9**. A brief study of coupled circuits, tuned circuits, and magnetic circuits is introduced in **Chapter 10.** The transient behaviour of dc and ac circuits and their responses has been discussed in **Chapter 11.** The Fourier methods of waveform analysis and their applications in circuit analysis have been discussed in **Chapter 12**.

Laplace transforms and their applications are presented in **Chapters 13 and 14.** A brief account of *S*-domain analysis is presented in **Chapter 15**. The parameters of two-port networks and their inter-relations have been discussed in **Chapter 16**. Various types of basic filters, attenuators, and equalizers have been discussed in **Chapter 17.** Elements of realizability and synthesis of one-port *RL*, *RC* networks have been briefly discussed in **Chapter 18**. A chapter on introduction to PSpice has been included as **Chapter 19**. The book also includes brief coverage of active filters and the *j*-operator as appendices.

OLC SUPPLEMENTS

The text is supported by an exhaustive website accessible at
http://highered.mheducation.com/sites/9339219600 with the following supplements:

- **For Instructors**
  - Solutions Manual
  - PowerPoint Lecture Slides
- **For Students**
  - Solutions to Frequently Asked Questions

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Despite the best efforts put in by us and our team, it is possible that some unintentional errors might have eluded us. We shall acknowledge with gratitude if any of these is pointed out. Any suggestions or comments from the readers for improving future editions of the book may please be sent to the publisher's email address.

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