

the analysis and design of linear circuits

The Analysis and Design of Linear Circuits: A Comprehensive Guide

Introduction:

Are you fascinated by the intricate world of electronics, eager to understand how circuits function, and dreaming of designing your own? This comprehensive guide dives deep into the analysis and design of linear circuits, providing a robust understanding of the fundamental principles and practical techniques. Whether you're a student grappling with circuit theory or an engineer seeking to refine your design skills, this post offers a structured approach, equipping you with the knowledge to tackle even the most complex linear circuit challenges. We'll explore key concepts, analytical methods, and design considerations, making this essential reading for anyone serious about mastering linear circuit analysis and design. Get ready to unlock the secrets behind the seamless flow of electricity!

1. Understanding Fundamental Circuit Components:

Before diving into analysis and design, it's crucial to have a solid grasp of the basic building blocks of linear circuits. This section covers the characteristics and behavior of resistors, capacitors, inductors, and independent and dependent sources. We'll explore their individual properties, including Ohm's Law for resistors, the current-voltage relationships for capacitors and inductors, and the different types of sources (voltage and current). Understanding these components is paramount to effectively analyzing and designing any linear circuit. We will also delve into the importance of circuit symbols and how they aid in visualizing and simplifying complex circuit diagrams.

1. Circuit Analysis Techniques: A Systematic Approach:

This section delves into the core methods used to analyze linear circuits. We'll cover:

Node Voltage Analysis (NVA): A powerful technique that focuses on the voltage at each node (junction) in the circuit. We'll illustrate how to write and

solve the resulting system of equations efficiently, often using matrix methods.

Mesh Current Analysis (MCA): This method utilizes loop currents to analyze the circuit, offering an alternative approach to NVA. We'll discuss how to choose mesh currents strategically and solve the system of equations. Comparisons between NVA and MCA will highlight their strengths and weaknesses in different circuit topologies.

Superposition Theorem: This crucial theorem allows us to analyze circuits with multiple independent sources by considering the effect of each source individually and then summing the results. We will explore its application and limitations.

Thevenin's and Norton's Theorems: These theorems simplify complex circuits by replacing a portion of the circuit with an equivalent simpler model, simplifying analysis and design. We'll learn how to find the equivalent Thevenin and Norton circuits.

Source Transformations: This technique allows us to convert voltage sources to current sources (and vice versa), providing flexibility in circuit analysis.

1. Frequency Response and AC Circuit Analysis:

Linear circuits often operate with time-varying signals, necessitating an understanding of frequency response. This section explores:

Phasors and Impedance: We'll introduce the concept of phasors, a powerful tool for representing sinusoidal signals in the frequency domain. We'll also define impedance, the generalization of resistance to AC circuits, covering the impedance of resistors, capacitors, and inductors.

Bode Plots: These plots graphically represent the magnitude and phase of a circuit's frequency response, providing valuable insights into its behavior at different frequencies. We'll cover how to construct and interpret Bode plots.

Resonance: This phenomenon occurs in circuits containing inductors and capacitors, leading to significant amplification at specific frequencies. We'll explore the conditions for resonance and its implications.

1. Linear Circuit Design Principles:

This section transitions from analysis to design, covering practical aspects of creating circuits to meet specific specifications. We'll discuss:

Filter Design: We'll explore the design of various filters, including low-pass, high-pass, band-pass, and band-stop filters, using different circuit topologies.

Amplifier Design: This covers the design of operational amplifier (op-amp) circuits, such as inverting and non-inverting amplifiers, and explores the concept of gain and bandwidth.

Signal Conditioning Circuits: We will discuss circuits used to modify signals, such as level shifting, summing, and instrumentation amplifiers.

1. Simulation and Troubleshooting:

This section focuses on practical aspects:

SPICE Simulation: We'll introduce SPICE, a widely used circuit simulation software, and discuss its application in verifying designs and identifying potential problems before physical prototyping.

Troubleshooting Techniques: This crucial section will cover practical troubleshooting strategies for identifying and resolving issues in linear circuits, utilizing multimeters and oscilloscopes.

Book Outline: "Mastering Linear Circuits: Analysis and Design"

Introduction: Overview of linear circuits, their applications, and the scope of the book.

Chapter 1: Fundamental Concepts: Basic circuit elements, Ohm's Law, Kirchhoff's Laws, circuit theorems.

Chapter 2: DC Circuit Analysis: Node voltage analysis, mesh current analysis, superposition, Thevenin's and Norton's theorems.

Chapter 3: AC Circuit Analysis: Phasors, impedance, frequency response, Bode plots, resonance.

Chapter 4: Operational Amplifiers: Ideal op-amp model, inverting and non-inverting amplifiers, other op-amp configurations.

Chapter 5: Filter Design: Low-pass, high-pass, band-pass, and band-stop filters.

Chapter 6: Circuit Simulation and Design Tools: Introduction to SPICE and other simulation software.

Chapter 7: Practical Applications and Case Studies: Real-world examples of linear circuit design in various fields.

Conclusion: Summary of key concepts and future trends in linear circuit design.

(Detailed explanation of each point in the outline would expand significantly beyond the 1500-word limit. The above provides a comprehensive framework. Each chapter would contain numerous examples, diagrams, and exercises to reinforce learning.)

FAQs:

1. What is the difference between linear and non-linear circuits? Linear circuits obey the principle of superposition; non-linear circuits do not.
1. Why is circuit analysis important? It allows us to predict the behavior of circuits before building them, saving time and resources.
1. What software is commonly used for circuit simulation? SPICE-based simulators like LTSpice and Multisim are widely used.
1. How do I choose between node voltage and mesh current analysis? The choice depends on the circuit topology; NVA is often preferred for circuits with many nodes and few loops, while MCA is better for circuits with many loops and few nodes.
1. What are the applications of linear circuits? Linear circuits are fundamental in countless applications, including amplifiers, filters, signal processing, and power supplies.
1. What are Bode plots used for? They graphically represent the frequency response of a circuit, showing gain and phase shift at different frequencies.
1. How does resonance affect a circuit's behavior? Resonance causes a sharp increase in the circuit's response at a specific frequency.

1. What are some common troubleshooting techniques for linear circuits?
Using multimeters to measure voltage and current, and oscilloscopes to observe waveforms, are essential.
1. How can I learn more about linear circuit design? Refer to textbooks, online courses, and tutorials. Practice designing and analyzing circuits is crucial.

Related Articles:

1. Understanding Ohm's Law and Kirchhoff's Laws: A foundational explanation of these essential circuit laws.
2. A Beginner's Guide to Operational Amplifiers: An introduction to op-amps and their diverse applications.
3. Designing Low-Pass Filters: A Practical Approach: A step-by-step guide to designing low-pass filters.
4. Mastering AC Circuit Analysis with Phasors: A detailed exploration of AC circuit analysis using phasors.
5. The Power of SPICE Simulation in Circuit Design: A guide to using SPICE for circuit simulation and analysis.
6. Troubleshooting Common Linear Circuit Problems: Practical tips for identifying and resolving issues in linear circuits.
7. Introduction to Network Theorems in Circuit Analysis: An overview of key network theorems, including superposition and Thevenin's theorem.
8. Advanced Filter Design Techniques: Exploring more complex filter designs and their applications.
9. Linear Circuit Applications in Signal Processing: How linear circuits are used in various signal processing applications.

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Roland E. Thomas, Albert J. Rosa, 2004 Basic Circuit Analysis - Circuit Analysis Techniques - Active Circuits - Signal Waveforms - Capacitance and Inductance - First - and Second-order Circuit -

Sinusoidal Steady-State Response - Laplace Transforms - S-Domain Circuit Analysis - Network Functions - Frequency Response - Fourier Series - Analog Filter Design - Mutual Inductance - Power in the Sinusoidal Steady State.

the analysis and design of linear circuits: *The Analysis and Design of Linear Circuits* Roland E. Thomas, Albert J. Rosa, 2006 Now with a stronger emphasis on applications and more problems, this fifth edition gives readers the opportunity to analyze, design, and evaluate linear circuits right from the start. The design examples, problems and applications provided in the book promote the development of creative and design skills.

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the analysis and design of linear circuits: *Analysis and Design of Linear Circuits* Thomas, 1998-01-01

the analysis and design of linear circuits: *The Analysis and Design of Linear Circuits* Roland E. Thomas, Albert J. Rosa, 2001 Learn Linear Circuits by Actually Designing Them! With more examples, problems, applications, and tools, the Third Edition of Thomas and Rosa's *The Analysis and Design of Linear Circuits* presents an effective learn-by-doing approach to linear circuits. The authors not only discuss Laplace transforms, new passive and active elements, time-varying circuits, and fundamental analysis and design concepts, they also provide valuable skill-building exercises and tools. Here's how Thomas and Rosa's learn-by-doing approach works: * Apply concepts to practical problems. Throughout the text, the authors maintain a steady focus circuit design and include a greatly revised set of design examples, exercises, and homework problems. * Master the most modern software tools. The new edition now covers five of today's most widely used programs: Excel (r), Matlab(r), Electronics Workbench(r), and PSpice(r). * Explore real-world applications. The Third Edition now features many new real-world applications that are especially relevant to computer engineering, instrumentation, electronics, and signals. * Build circuits you can use. The text's early coverage of the Ideal Op-Amp will help readers design practical interface circuits, instrumentation systems, and cascade filters. * Evaluate competing designs. Thomas and Rosa show how to evaluate and select the best design from several correct approaches. * Develop circuit analysis and design skills. The text provides many opportunities to apply Laplace and related tools such as pole-zero diagrams, Bode diagrams, and Fourier series. This constant exposure to analysis and design tools will build practical skills.

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Enhanced eText with Abridged Print Companion Roland E. Thomas, Albert J. Rosa, Gregory J. Toussaint, 2019-02-01 While most texts focus on how and why electric circuits work, *The Analysis and Design of Linear Circuits* taps into engineering students' desire to explore, create, and put their learning into practice. Students from across disciplines will gain a practical, in-depth understanding of the fundamental principles underlying so much of modern, everyday technology. Early focus on the analysis, design, and evaluation of electric circuits promotes the development of design intuition by allowing students to test their designs in the context of real-world constraints and practical situations. This updated Ninth Edition features an emphasis on the use of computer software, including Excel, MATLAB, and Multisim, building a real-world problem-solving style that reflects that of practicing engineers. Software skills are integrated with examples and exercises throughout the text, and coverage of circuit design and evaluation, frequency response, mutual inductance, ac power circuits, and other central topics has been revised for clarity and ease of understanding. With an overarching goal of instilling smart judgement surrounding design problems and innovative solutions, this unique text provides inspiration and motivation alongside an essential knowledge base.

the analysis and design of linear circuits: Introduction to Linear Circuit Analysis and Modelling Luis Moura, Izzat Darwazeh, 2005-03-05 Luis Moura and Izzat Darwazeh introduce linear circuit modelling and analysis applied to both electrical and electronic circuits, starting with DC and progressing up to RF, considering noise analysis along the way. Avoiding the tendency of current textbooks to focus either on the basic electrical circuit analysis theory (DC and low frequency AC frequency range), on RF circuit analysis theory, or on noise analysis, the authors combine these subjects into the one volume to provide a comprehensive set of the main techniques for the analysis of electric circuits in these areas. Taking the subject from a modelling angle, this text brings together the most common and traditional circuit analysis techniques (e.g. phasor analysis) with system and signal theory (e.g. the concept of system and transfer function), so students can apply the theory for analysis, as well as modelling of noise, in a broad range of electronic circuits. A highly student-focused text, each chapter contains exercises, worked examples and end of chapter problems, with an additional glossary and bibliography for reference. A balance between concepts and applications is maintained throughout. Luis Moura is a Lecturer in Electronics at the University of Algarve. Izzat Darwazeh is Senior Lecturer in Telecommunications at University College, London, previously at UMIST. - An innovative approach fully integrates the topics of electrical and RF circuits, and noise analysis, with circuit modelling - Highly student-focused, the text includes exercises and worked examples throughout, along with end of chapter problems to put theory into practice

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the analysis and design of linear circuits: Linear Circuit Transfer Functions Christophe P. Basso, 2016-04-27 *Linear Circuit Transfer Functions: An introduction to Fast Analytical Techniques* teaches readers how to determine transfer functions of linear passive and active circuits by applying Fast Analytical Circuits Techniques. Building on their existing knowledge of classical loop/nodal analysis, the book improves and expands their skills to unveil transfer functions in a swift and efficient manner. Starting with simple examples, the author explains step-by-step how expressing circuits time constants in different configurations leads to writing transfer functions in a compact and insightful way. By learning how to organize numerators and denominators in the fastest possible way, readers will speed-up analysis and predict the frequency response of simple to

complex circuits. In some cases, they will be able to derive the final expression by inspection, without writing a line of algebra. Key features: Emphasizes analysis through employing time constant-based methods discussed in other text books but not widely used or explained. Develops current techniques on transfer functions, to fast analytical techniques leading to low-entropy transfer functions immediately exploitable for analysis purposes. Covers calculation techniques pertinent to different fields, electrical, electronics, signal processing etc. Describes how a technique is applied and demonstrates this through real design examples. All Mathcad® files used in examples and problems are freely available for download. An ideal reference for electronics or electrical engineering professionals as well as BSEE and MSEE students, this book will help teach them how to: become skilled in the art of determining transfer function by using less algebra and obtaining results in a more effectual way; gain insight into a circuit's operation by understanding how time constants rule dynamic responses; apply Fast Analytical Techniques to simple and complicated circuits, passive or active and be more efficient at solving problems.

the analysis and design of linear circuits: Linear Circuit Analysis Chi Kong Tse, 1998 Linear Circuit Analysis provides concise and practical treatment of the basics of circuits suitable for undergraduates. Whilst mathematical rigour is not sacrificed, the book is written in an easily-readable style and also covers many topics from a practical, non-mathematical perspective. For those lecturers that wish to explore other teaching methods, the later chapters offer an introduction to the topological method of analysis. The text is ideal for a first course in circuits as the text starts by recapping basics such as Ohm's law before covering the nodal/mesh approach to circuit analysis. As such it equips students with effective analytical skills which will form a solid basis for the rest of their electronic engineering course.

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the analysis and design of linear circuits: Analysis and Synthesis of MOS Translinear Circuits Remco J. Wiegerink, 2012-12-06 This book has its roots in an idea first formulated by Barrie Gilbert in 1975. He showed how bipolar analog circuits can realize nonlinear and computational functions. This extended the analog art from linear to nonlinear applications, hence the name trans linear circuits. Not only did this new principle enable marvellous signal processing functions to be accurately implemented, but also the circuits were simple and practical. The perennial problems of analog IC design, namely temperature sensitivity, processing spread, device nonlinearity and parasitic capacitance were solved to a large extent. Using the trans linear principle in circuit design requires changing your point of view in two ways. First, the grossly nonlinear characteristic of transistors is viewed as an asset rather than as a harmful property. Second, no longer are the signals represented by voltages, but by currents. In fact, the attendant voltage changes are distorted but, as they are very small, they are only of secondary interest. Understanding and analyzing a given trans linear circuit is fairly straightforward. But what about the converse situation: suppose you're given some nonlinear or computational function to implement? How to find a suitable translinear circuit

realization? The general problem of analog circuit synthesis is a difficult one and is receiving much attention nowadays. Some years ago, I had the opportunity to investigate methods for designing bipolar trans linear circuits. It turned out that translinear networks have some unique topological properties. Using these properties it was possible to establish heuristic synthesis procedures.

the analysis and design of linear circuits: *Analysis and Design of Linear Circuits, Lab Manual* Roland E. Thomas, 1994-01-15 Improving upon its widely-acclaimed design coverage, the second edition of this text provides even greater design emphasis, with new open-ended design problems and a focus on evaluating design alternatives. Innovative pedagogy helps readers comprehend the basics; synthesize concepts from multiple chapter topics; design and evaluate circuit stages (or building blocks); and ultimately, design and evaluate complete circuits by integrating the concepts learned throughout the chapters.

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<https://bcs.wiley.com/he-bcs/Books?action=index&bcsId=12533&itemId=1119913020>.

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optimize designs based on real-world constraints. This text is an unbound, three hole punched version.

the analysis and design of linear circuits: Fast Analytical Techniques for Electrical and Electronic Circuits Vatché Vorpérian, 2002-05-23 The only method of circuit analysis known to most engineers and students is nodal or loop analysis. Although this works well for obtaining numerical solutions, it is almost useless for obtaining analytical solutions in all but the simplest cases. In this unusual 2002 book, Vorpérian describes remarkable alternative techniques to solve, almost by inspection, complicated linear circuits in symbolic form and obtain meaningful analytical answers for any transfer function or impedance. Although not intended to replace traditional computer-based methods, these techniques provide engineers with a powerful set of tools for tackling circuit design problems. They also have great value in enhancing students' understanding of circuit operation, making this an ideal course book, and numerous problems and worked examples are included. Originally developed by Professor David Middlebrook and others at Caltech (California Institute of Technology), the techniques described here are now widely taught at institutions and companies around the world.

the analysis and design of linear circuits: Microwave Circuit Design Using Linear and Nonlinear Techniques George D. Vendelin, Anthony M. Pavio, Ulrich L. Rohde, 2005-10-03 The ultimate handbook on microwave circuit design with CAD. Full of tips and insights from seasoned industry veterans, Microwave Circuit Design offers practical, proven advice on improving the design quality of microwave passive and active circuits-while cutting costs and time. Covering all levels of microwave circuit design from the elementary to the very advanced, the book systematically presents computer-aided methods for linear and nonlinear designs used in the design and manufacture of microwave amplifiers, oscillators, and mixers. Using the newest CAD tools, the book shows how to design transistor and diode circuits, and also details CAD's usefulness in microwave integrated circuit (MIC) and monolithic microwave integrated circuit (MMIC) technology. Applications of nonlinear SPICE programs, now available for microwave CAD, are described. State-of-the-art coverage includes microwave transistors (HEMTs, MODFETs, MESFETs, HBTs, and more), high-power amplifier design, oscillator design including feedback topologies, phase noise and examples, and more. The techniques presented are illustrated with several MMIC designs, including a wideband amplifier, a low-noise amplifier, and an MMIC mixer. This unique, one-stop handbook also features a major case study of an actual anticollision radar transceiver, which is compared in detail against CAD predictions; examples of actual circuit designs with photographs of completed circuits; and tables of design formulae.

the analysis and design of linear circuits: Computer Methods for Circuit Analysis and Design Jiri Vlach, Kishore Singhal, 1994 This text is about methods used for the computer simulation of analog systems. It concentrates on electronic applications, but many of the methods are applicable to other engineering problems as well. This revised edition (1st, 1983) encompasses recent theoretical developments and program-writing tips for computer-aided design. About 60% of the text is suitable for a senior-level course in circuit theory. The whole text is suitable for graduate courses or as a reference for scientists and engineers who seek information in the field. Annotation copyright by Book News, Inc., Portland, OR

the analysis and design of linear circuits: Introduction to Electrical Circuit Analysis Ozgur Ergul, 2017-06-26 A concise and original presentation of the fundamentals for 'new to the subject' electrical engineers This book has been written for students on electrical engineering courses who don't necessarily possess prior knowledge of electrical circuits. Based on the author's own teaching experience, it covers the analysis of simple electrical circuits consisting of a few essential components using fundamental and well-known methods and techniques. Although the above content has been included in other circuit analysis books, this one aims at teaching young engineers not only from electrical and electronics engineering, but also from other areas, such as mechanical engineering, aerospace engineering, mining engineering, and chemical engineering, with unique pedagogical features such as a puzzle-like approach and negative-case examples (such

as the unique “When Things Go Wrong...” section at the end of each chapter). Believing that the traditional texts in this area can be overwhelming for beginners, the author approaches his subject by providing numerous examples for the student to solve and practice before learning more complicated components and circuits. These exercises and problems will provide instructors with in-class activities and tutorials, thus establishing this book as the perfect complement to the more traditional texts. All examples and problems contain detailed analysis of various circuits, and are solved using a ‘recipe’ approach, providing a code that motivates students to decode and apply to real-life engineering scenarios. Covers the basic topics of resistors, voltage and current sources, capacitors and inductors, Ohm’s and Kirchhoff’s Laws, nodal and mesh analysis, black-box approach, and Thevenin/Norton equivalent circuits for both DC and AC cases in transient and steady states. Aims to stimulate interest and discussion in the basics, before moving on to more modern circuits with higher-level components. Includes more than 130 solved examples and 120 detailed exercises with supplementary solutions. Accompanying website to provide supplementary materials www.wiley.com/go/ergul4412

the analysis and design of linear circuits: Introductory Circuits Robert Spence, 2008-11-20 Compact but comprehensive, this textbook presents the essential concepts of electronic circuit theory. As well as covering classical linear theory involving resistance, capacitance and inductance it treats practical nonlinear circuits containing components such as operational amplifiers, Zener diodes and exponential diodes. The book’s straightforward approach highlights the similarity between the equations describing direct current (DC), alternating current (AC) and small-signal nonlinear behaviour, thus making the analysis of these circuits easier to comprehend. Introductory Circuits explains: the laws and analysis of DC circuits including those containing controlled sources; AC circuits, focusing on complex currents and voltages, and with extension to frequency domain performance; opamp circuits, including their use in amplifiers and switches; change behaviour within circuits, whether intentional (small-signal performance) or caused by unwanted changes in components. In addition to worked examples within the text a number of problems for student solution are provided at the end of each chapter, ranging in difficulty from the simple to the more challenging. Most solutions for these problems are provided in the book, while others can be found on the accompanying website. Introductory Circuits is designed for first year undergraduate mechanical, biomedical, materials, chemical and civil engineering students who are taking short electrical engineering courses and find other texts on the subject too content-heavy for their needs. With its clear structure and consistent treatment of resistive, reactive and small-signal operation, this volume is also a great supporting text for mainstream electrical engineering students.

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the analysis and design of linear circuits: Mosfet Modeling For Circuit Analysis And Design Carlos Galup-montoro, Marcio Cherem Schneider, 2007-02-27 This is the first book dedicated to the next generation of MOSFET models. Addressed to circuit designers with an in-depth treatment that appeals to device specialists, the book presents a fresh view of compact modeling, having completely abandoned the regional modeling approach. Both an overview of the basic physics theory required to build compact MOSFET models and a unified treatment of inversion-charge and surface-potential models are provided. The needs of digital, analog and RF designers as regards the availability of simple equations for circuit designs are taken into account. Compact expressions for hand analysis or for automatic synthesis, valid in all operating regions, are presented throughout the book. All the main expressions for computer simulation used in the new generation compact models are derived. Since designers in advanced technologies are increasingly concerned with fluctuations, the

modeling of fluctuations is strongly emphasized. A unified approach for both space (matching) and time (noise) fluctuations is introduced.

the analysis and design of linear circuits: Linear Circuit Theory Jiri Vlach, 2016-04-19 This comprehensive textbook covers all subjects on linear circuit theory, with the emphasis on learning the subject without an excessive amount of information. This unique approach stresses knowledge rather than computer use to start and differs from other books by introducing matrix algebra early in the book. The book's 290 problems are meant to b

the analysis and design of linear circuits: Linear Circuit Analysis, Volume I Raymond A. DeCarlo, Pen-Min Lin, 1995-01 The combined three volumes of these texts cover traditional linear circuit analysis topics - both concepts and computation - including the use of available software for problem solution where necessary. This volume discusses topics such as network theorems, and node and loop analysis.

the analysis and design of linear circuits: Basic Engineering Circuit Analysis J. David Irwin, R. Mark Nelms, 2005 Irwin's Basic Engineering Circuit Analysis has built a solid reputation for its highly accessible presentation, clear explanations, and extensive array of helpful learning aids. Now in a new eighth edition, this highly accessible book has been fine-tuned and revised, making it more effective and even easier to use. It covers such topics as resistive circuits, nodal and loop analysis techniques, capacitance and inductance, AC steady-state analysis, polyphase circuits, the Laplace transform, two-port networks, and much more.

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the analysis and design of linear circuits: Linear Network Theory G. I. Atabekov, 2014-05-09 Linear Network Theory presents the problems of linear network analysis and synthesis. This book discusses the theory of linear electrical circuits, which is important for developing the scientific outlook of specialists in radio and electrical engineering. Organized into 13 chapters, this book begins with an overview of circuit theory that operates with electrical quantities, including voltage, charge, and current. This text then examines sinusoidal function as the predominant form of a periodic process in electrical circuits. Other chapters consider the reduction of a series-parallel network to single equivalent impedance, which is one of the main forms of converting circuit diagrams often used in practice. The final chapter deals with the Laplace transformation or operational calculus, which is a combination of methods of mathematical analysis. This book is intended to be suitable for students in the specialized branches of electrical and radio engineering, post-graduates, and engineers extending their theoretical knowledge.

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