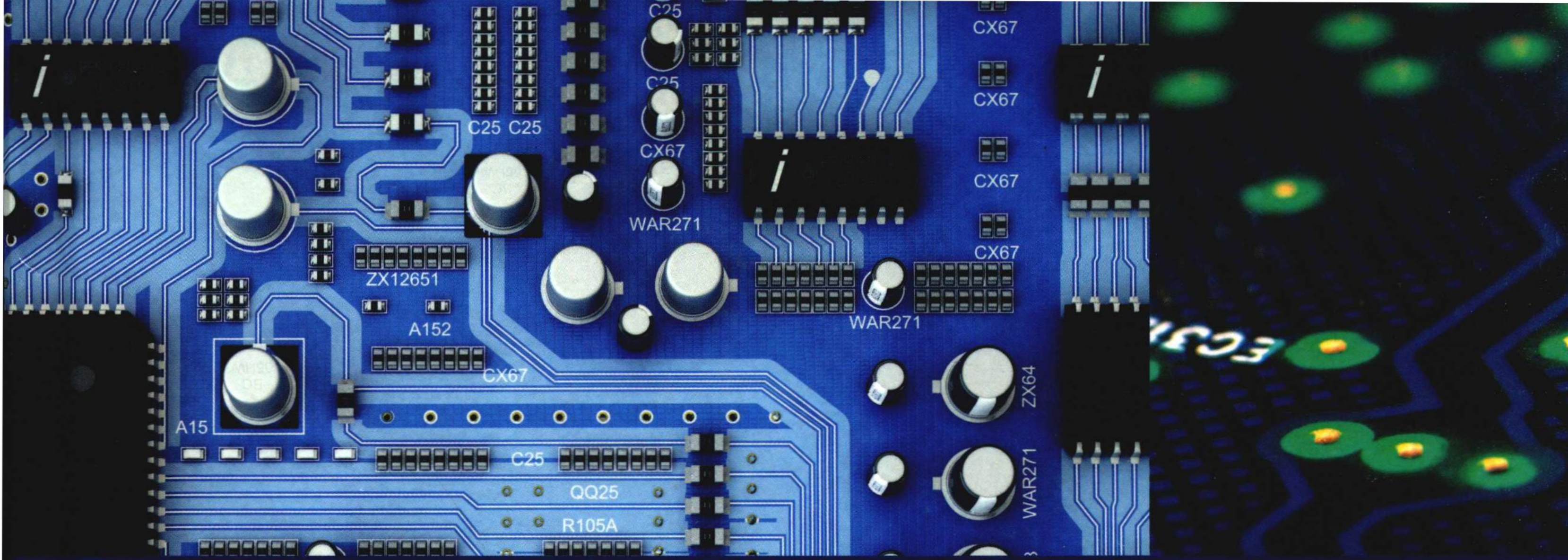
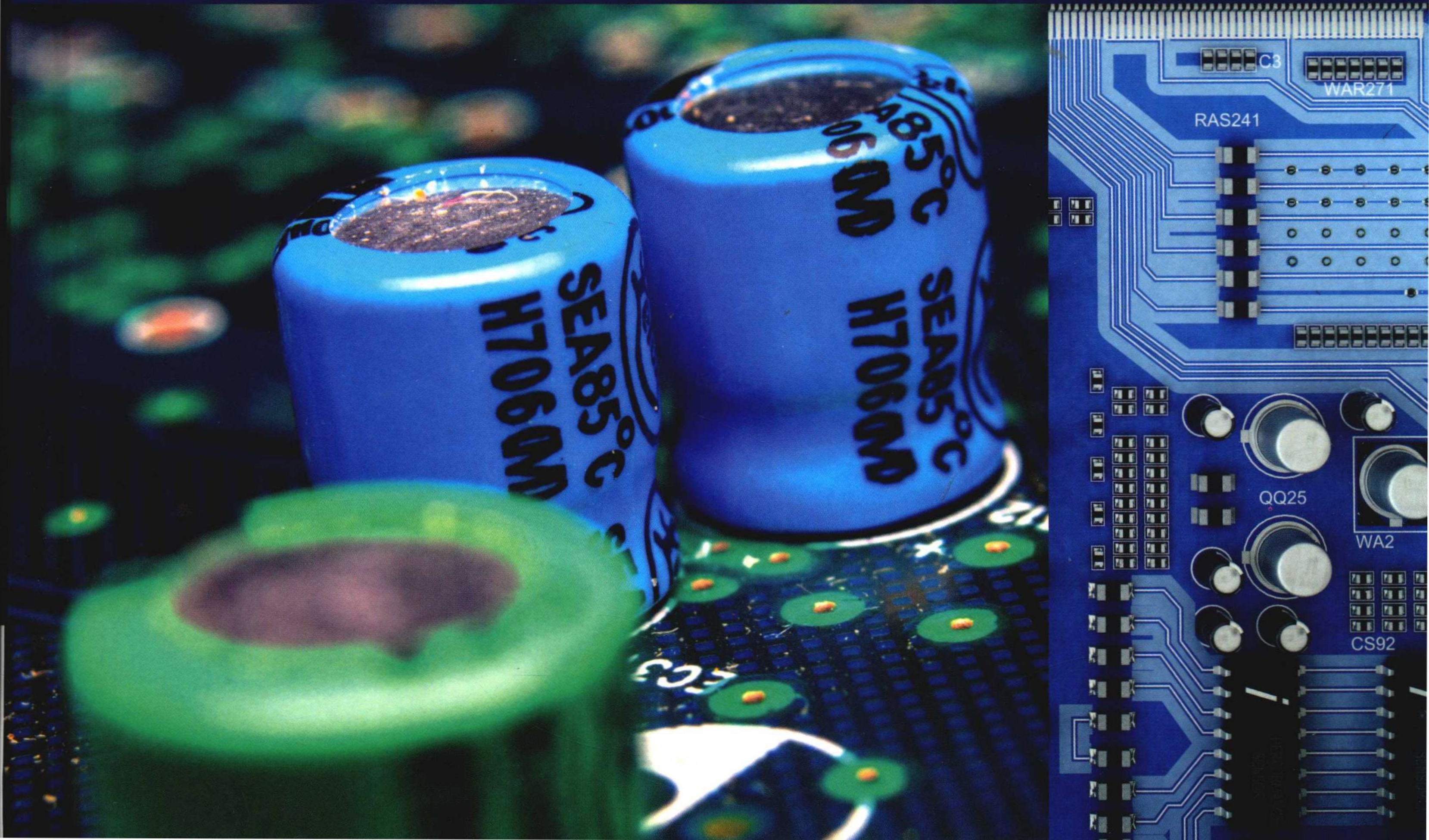
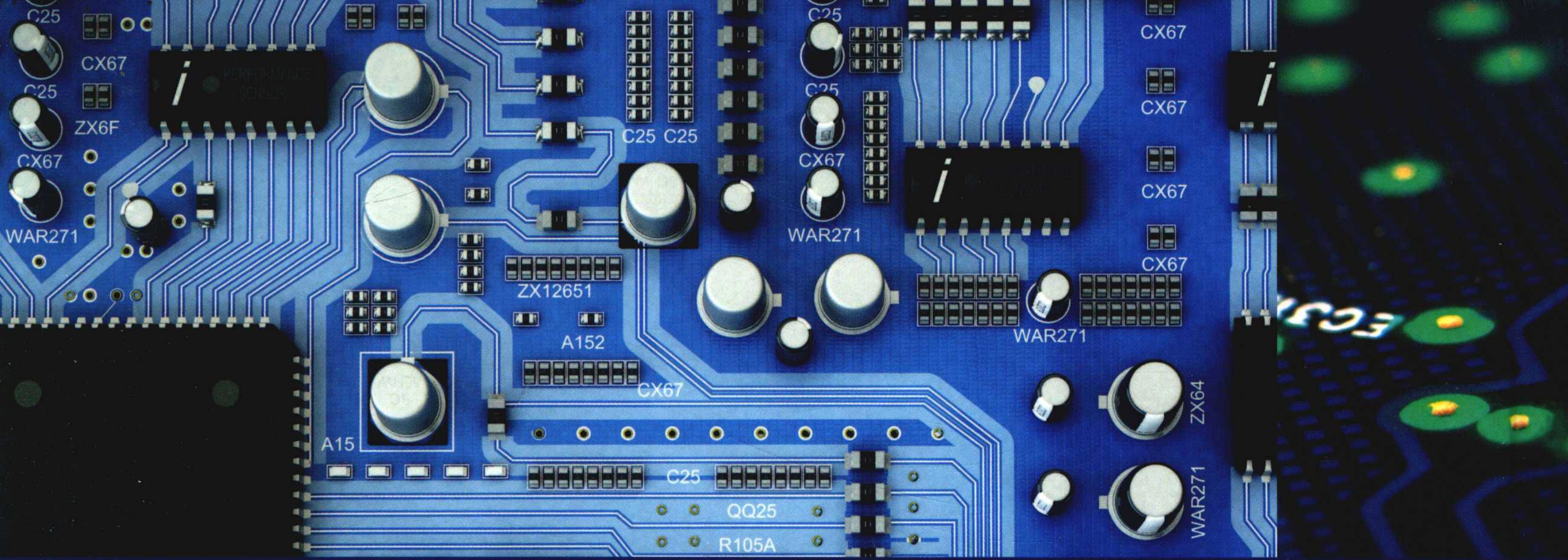


Electric Circuits

JAMES S. KANG





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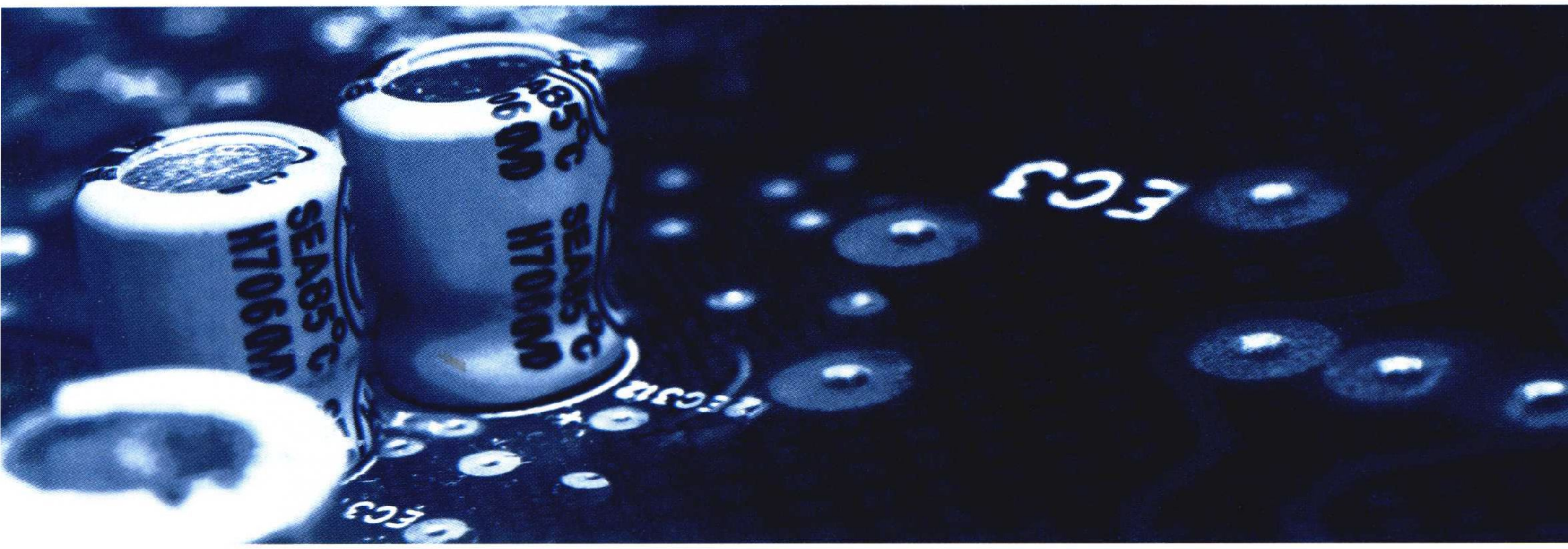

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Preface

This book is intended to be an introductory text on the subject of electric circuits. It provides simple explanations of the basic concepts, followed by simple examples and exercises. When necessary, detailed derivations for the main topics and examples are given to help readers understand the main ideas. MATLAB is a tool that can be used effectively in Electric Circuits courses. In this text, MATLAB is integrated into selected examples to illustrate its use in solving circuit problems. MATLAB can be used to check the answers or solve more complex circuit problems. This text is written for a two-semester sequence or a three-quarters sequence on electric circuits.

Suggested Course Outlines

The following is a list of topics covered in a typical Electric Circuits courses, with suggested course outlines.

ONE-SEMESTER OR -QUARTER COURSE

If Electric Circuits is offered as a one-semester or one-quarter course, Chapters 1 through 12 can be taught without covering, or only lightly covering, sections 1.6, 2.10, 2.11, 3.6, 4.7, 5.6, 5.7, 5.8, 6.7, 7.6, 7.7, 8.8, 8.9, 9.9, 9.10, 10.12, 11.7, 12.5, 12.6, and 12.7.

TWO-SEMESTER OR -QUARTER COURSES

For two-semester Electric Circuit courses, Chapters 1 through 8, which cover dc circuits, op amps, and the responses of first-order and second-order circuits, can be taught in the first semester. Chapters 9 through 20, which cover alternating current (ac) circuits, Laplace transforms, circuit analysis in the *s*-domain, two-port circuits, analog filter design and implementation, Fourier series, and Fourier transform, can then be taught in the second semester.

THREE-QUARTER COURSES

For three-quarter Electric Circuit courses, Chapters 1 through 5, which cover dc circuits and op amps, can be taught in the first quarter; Chapters 6 through 13, which cover the responses of first-order and second-order circuits and ac circuits, can be taught in the second quarter, and Chapters 14 through 20, which cover Laplace transforms, circuit analysis in the *s*-domain, two-port circuits, analog filter design and implementation, Fourier series, and Fourier transform, can be taught in the third quarter.

Depending on the catalog description and the course outlines, instructors can pick and choose the topics covered in the courses that they teach. Several features of this text are listed next.

Features

After a topic is presented, examples and exercises follow. Examples are chosen to expand and elaborate the main concept of the topic. In a step-by-step approach, details are worked out to help students understand the main ideas.

In addition to analyzing RC, RL, and RLC circuits connected in series or parallel in the time domain and the frequency domain, analyses of circuits different from RC, RL, and RLC circuits and connected other than in series and parallel are provided. Also, general input signals that are different from unit step functions are included in the analyses.

In the analog filter design, the specifications of the filter are translated into its transfer function in cascade form. From the transfer function, each section can be designed with appropriate op amp circuits. The normalized component values for each section are found by adopting a simplification method (equal R equal C or unity gain). Then, magnitude scaling and frequency scaling are used to find the final component values. The entire design procedure, from the specifications to the circuit design, is detailed, including the PSpice simulation used to verify the design.

Before the discussion of Fourier series, orthogonal functions and the representation of square integrable functions as a linear combination of a set of orthogonal functions are introduced. The set of orthogonal functions for Fourier series representation consists of cosines and sines. The Fourier coefficients for the square pulse train, triangular pulse train, sawtooth pulse train, and rectified sines and cosines are derived. The Fourier coefficients of any variation of these waveforms can be found by applying the time-shifting property and finding the dc component.

MATLAB can be an effective tool in solving problems in electric circuits. Simple functions such as calculating the equivalent resistance or impedance of parallel connection of resistors, capacitors, and inductors; conversion from Cartesian coordinates to polar coordinates; conversion from polar coordinates to Cartesian coordinates; conversion from the wye configuration to delta configuration; and conversion from delta configuration to wye configuration provide accurate answers in less time. These simple functions can be part of scripts that enable us to find solutions to typical circuit problems.

The complexity of taking the inverse Laplace transforms increases as the order increases. MATLAB can be used to solve equations and to find integrals, transforms, inverse transforms, and transfer functions. The application of MATLAB to circuit analysis is demonstrated throughout the text when appropriate. For example, after finding inverse Laplace transforms by hand using partial fraction expansion, answers from MATLAB are provided as a comparison.

Examples of circuit simulation using OrCAD PSpice and Simulink are given at the end of each chapter. Simulink is a tool that can be used to perform circuit simulations. In Simulink, physical signals can be converted to Simulink signals and vice versa. Simscapes include many blocks that are related to electric circuits. Simulink can be used in computer assignments or laboratory experiments.

The Instructor's Solution Manual for the exercises and end-of-chapter problems is available for instructors. This manual includes MATLAB scripts for selected problems as a check on the accuracy of the solutions by hand.

Overview of Chapters

In **Chapter 1**, definitions of voltage, current, power, and energy are given. Also, independent voltage source and current source are introduced, along with dependent voltage sources and current sources.

In **Chapter 2**, nodes, branches, meshes, and loops are introduced. Ohm's law is explained. Kirchhoff's current law (KCL), Kirchhoff's voltage law (KVL), the voltage divider rule, and the current divider rule are explained with examples.

In **Chapter 3**, nodal analysis and mesh analysis are discussed in depth. The nodal analysis and mesh analysis are used extensively in the rest of the text.

Chapter 4 introduces circuit theorems that are useful in analyzing electric circuits and electronic circuits. The circuit theorems discussed in this chapter are the superposition principle, source transformations, Thévenin's theorem, Norton's theorem, and maximum power transfer.

Chapter 5 introduces op amp circuits. Op amp is a versatile integrated circuit (IC) chip that has wide-ranging applications in circuit design. The concept of the ideal op amp model is explained, along with applications in sum and difference, instrumentation amplifier, and current amplifier. Detailed analysis of inverting configuration and noninverting configuration is provided.

In **Chapter 6**, the energy storage elements called *capacitors* and *inductors* are discussed. The current voltage relation of capacitors and inductors are derived. The energy stored on the capacitors and inductors are presented.

In **Chapter 7**, the transformation of RC and RL circuits to differential equations and solutions of the first-order differential equations to get the responses of the circuits are presented. In the general first-order circuits, the input signal can be dc, ramp signal, exponential signal, or sinusoidal signal.

In **Chapter 8**, the transformation of series RLC and parallel RLC circuits to the second-order differential equations, as well as solving the second-order differential equations to get the responses of the circuits are presented. In the general second-order circuits, the input signal can be dc, ramp signal, exponential signal, or sinusoidal signal.

Chapter 9 introduces sinusoidal signals, phasors, impedances, and admittances. Also, transforming ac circuits to phasor-transformed circuits is presented, along with analyzing phasor transformed circuits using KCL, KVL, equivalent impedances, delta-wye transformation, and wye-delta transformation.

The analysis of phasor-transformed circuits is continued in **Chapter 10** with the introduction of the voltage divider rule, current divider rule, nodal analysis, mesh analysis, superposition principle, source transformation, Thévenin equivalent circuit, Norton equivalent circuit, and transfer function. This analysis is similar to the one for resistive circuits with the use of impedances.

Chapter 11 presents information on ac power. The definitions of instantaneous power, average power, reactive power, complex power, apparent power, and power factor are also given, and power factor correction is explained with examples.

As an extension of ac power, the three-phase system is presented in **Chapter 12**. The connection of balanced sources (wye-connected or delta-connected) to balanced loads (wye-connected or delta connected) are presented, both with and without wire impedances.

Magnetically coupled circuits, which are related to ac power, are discussed in **Chapter 13**. Mutual inductance, induced voltage, dot convention, linear transformers, and ideal transformers are introduced.

The Laplace transform is introduced in **Chapter 14**. The definition of the transform, region of convergence, transform, and inverse transform are explained with examples. Various properties of Laplace transform are also presented with examples.

The discussion on Laplace transform is continued in **Chapter 15**. Electric circuits can be transformed into an s-domain by replacing voltage sources and current sources to the s-domain and replacing capacitors and inductors to impedances. The circuit laws and theorems that apply to resistive circuits also apply to s-domain circuits. The time domain signal can be obtained by taking the inverse Laplace transform of the s-domain representation. The differential equations in the time domain are transformed to algebraic equations in the s-domain. The transfer function in the s-domain is defined as the ratio of the output signal in the s-domain to the input signal in the s-domain. The concept of convolution is introduced with a number of examples. Also, finding the convolution using Laplace transforms are illustrated in the same examples. Plotting the magnitude response and phase response of a circuit or a system using the Bode diagram is introduced.

The first-order and the second-order analog filters that are building blocks for the higher-order filters are presented in **Chapter 16**. The filters can be implemented by interconnecting passive elements consisting of resistors, capacitors, and inductors. Alternatively, filters can be implemented utilizing op amp circuits. Sallen and Key circuits for implementing second-order filters are discussed as well, along with design examples.

The discussion on analog filter design is extended in **Chapter 17**. A filter is designed to meet the specifications of the filter. The transfer function that satisfies the specification is found. From the transfer function, the corner frequency and Q value can be found. Then, the normalized component values and scaled component values are found. PSpice simulations can be used to verify the design.

Orthogonal functions and the representation of signals as a linear combination of a set of orthogonal functions are introduced in **Chapter 18**. If the set of orthogonal functions consists of harmonically related sinusoids or exponential functions, the representation is called the *Fourier series.* Fourier series representation of common signals, including the square pulse train, triangular pulse train, sawtooth waveform, and rectified cosine and sine, are presented in detail, with examples. The derivation and application of the time-shifting property of Fourier coefficients are provided. In addition, the application of the Fourier series representation in solving circuit problems are presented, along with examples.

As the period of a periodic signal is increased to infinity, the signal becomes nonperiodic, the discrete line spectrums become a continuous spectrum, and multiplying the Fourier coefficients by the period produces the Fourier transform, as explained in **Chapter 19**. Important properties of the Fourier transform, including time shifting, frequency shifting, symmetry, modulation, convolution, and multiplication, are introduced, along with interpretation and examples.

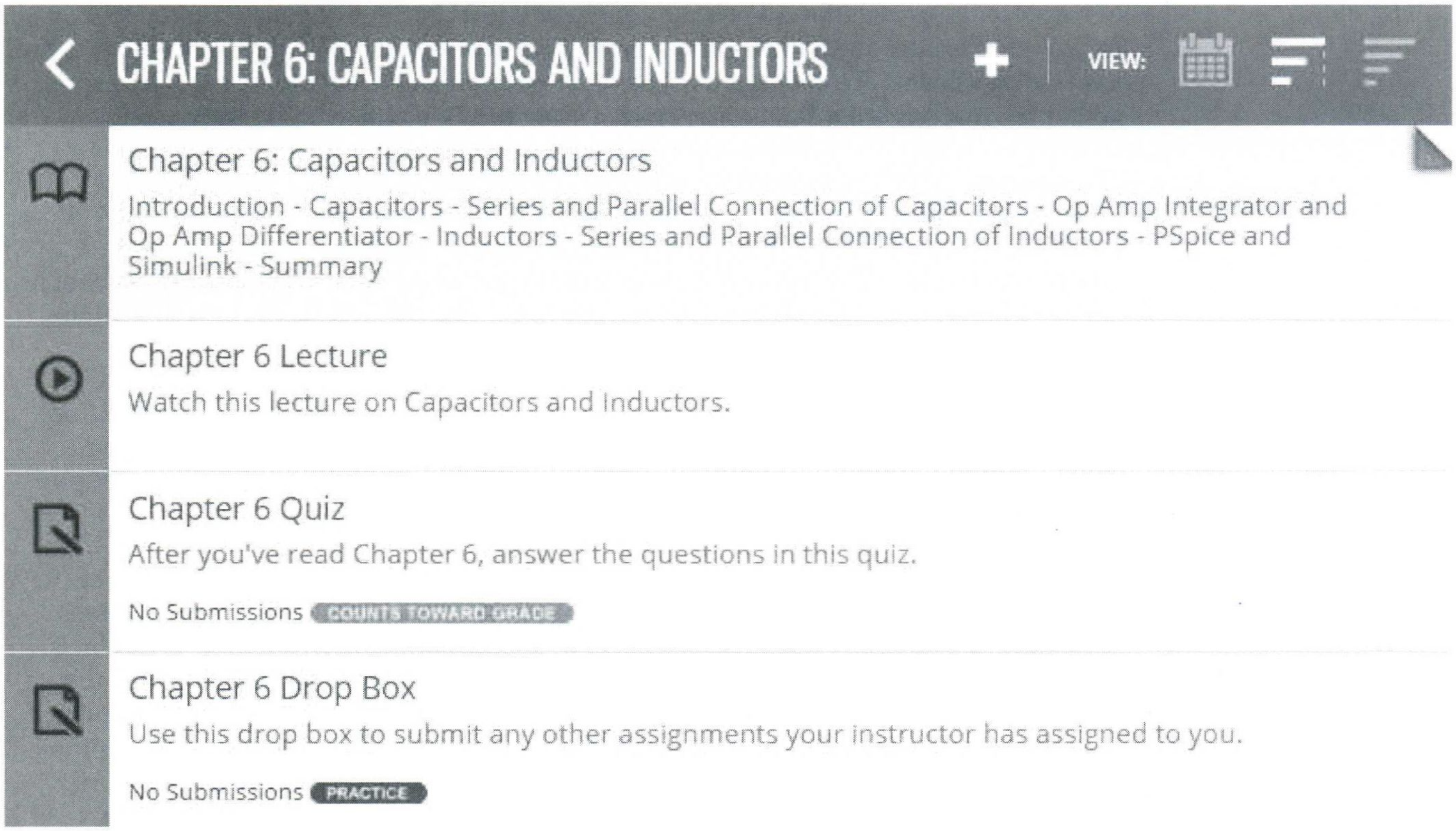
Two-port circuits are defined and analyzed in **Chapter 20**. Depending on which of the parameters are selected as independent variables, there are six different representations for two-port circuits. The coefficients of the representations are called *parameters*. The six parameters ($z, y, h, g, ABCD, b$) for two-port circuits are presented along with examples. The conversion between the parameters and the interconnection of parameters are provided in this chapter.

Instructor Resources

Cengage Learning's secure, password-protected Instructor Resource Center contains helpful resources for instructors who adopt this text. These resources include Lecture Note Microsoft PowerPoint slides, test banks, and an Instructor's Solution Manual, with detailed solutions to all the problems from the text. The Instructor Resource Center can be accessed at https://login.cengage.com.

MindTap Online Course

Electric Circuits is also available through **MindTap**, Cengage Learning's digital course platform. The carefully crafted pedagogy and exercises in this textbook are made even more effective by an interactive, customizable eBook, automatically graded assessments, and a full suite of study tools.



Chapter 6: Capacitors and Inductors

Introduction - Capacitors - Series and Parallel Connection of Capacitors - Op Amp Integrator and Op Amp Differentiator - Inductors - Series and Parallel Connection of Inductors - PSpice and Simulink - Summary

Chapter 6 Lecture

Watch this lecture on Capacitors and Inductors.

Chapter 6 Quiz

After you've read Chapter 6, answer the questions in this quiz.

No Submissions

Chapter 6 Drop Box

Use this drop box to submit any other assignments your instructor has assigned to you.

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- The unique **StudyHub** is a powerful, single-destination studying tool that empowers students to personalize their experience. They can quickly and easily access all notes and highlights marked in the MindTap Reader, locate bookmarked pages, review notes and flashcards shared by their instructor, and create custom study guides.

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