HUMANITAS UNIVERSITY

MEDTEC SHOOL

Course: Basics of Circuit Theory

Year: 2nd

Period: 1st Semester

Credits: 5

Objectives

Electric circuits (also referred to as electric networks) are ubiquitous in technology and essential to modern engineering, from communication and computer systems aimed at processing and transmitting information, to power systems aimed at delivering electric energy to any kind of equipment. The forefront field of biomedical engineering with its multidisciplinary nature does not represent an exception, since biomedical engineers are expected to understand many specialized circuits which allow operation of sensors, instrumentation, actuators, man-machine interfaces, etc. Circuit theory is the fundamental discipline that pervades all these applications. The goal of circuit theory is to make quantitative predictions on the electrical behavior of circuits, exploiting a rigorous mathematical approach. In this respect, the main objective of this course is introducing students to circuit theory, so to develop applied knowledge of circuit analysis, serving also as a foundation course for future specialistic disciplines.

Lectures and problem sessions will allow students to acquire the following competences:

- **knowledge** of the general subjects of classic circuit theory, that is, the laws, theorems and methods of linear circuits (D1);
- ability to **apply knowledge** to analyze the operation of linear circuits (D2):
    - the solution of resistive circuits
    - the solution of transients in first-order dynamic circuits with dc sources
    - the solution of ac steady-state in dynamic circuits (phasor analysis)
- **understanding** specific subjects related to applicative frameworks (D1):
    - the ideal transformer
    - the ideal operational amplifier and its main circuit configurations
    - the frequency response of basic filters
    - principles of three-phase power-system circuits
    - constitutive law of non-linear devices: diode, MOSFET transistor

Dublin Descriptor D1: Knowledge and understanding
Dublin Descriptor D2: Applying knowledge and understanding.

Prerequisites

- **Mathematics:**
  Essential prerequisites: complex numbers and their algebra, differential calculus for functions of a real variable. Recommended prerequisites: linear differential equations.
- **Fundamentals of Experimental Physics:**
  Work, Energy, Power. Electrostatics. Magnetostatics. Electromagnetic induction.

Contents

1-INTRODUCTION TO CIRCUIT THEORY
Electric quantities in circuits: current, voltage, power and energy. Kirchhoff's Laws of currents and voltages. Tellegen's Theorem and the conservation of energy.

2-LINEAR RESISTIVE CIRCUITS: BASIC CONCEPTS
Constitutive law and properties of linear one-port elements: independent and dependent voltage and current sources, resistor. Series resistors and voltage division. Parallel resistors and current division. Equivalent resistance. Source transformations.

3-NODAL ANALYSIS
Reference node and node voltages. Writing the system of node-voltage equations.

4- LINEAR RESISTIVE CIRCUITS: ADVANCED CONCEPTS
Linearity and the Superposition Theorem. Thevenin's Theorem and Norton's Theorem.

5- TWO-PORT ELEMENTS
Ideal transformer: constitutive law and properties. Ideal Operational Amplifier (OpAmp): constitutive law and properties. Main OpAmp circuit configurations for signal conditioning: Voltage Follower, Inverting Amplifier, Non-Inverting Amplifier, Summing Amplifier, Difference Amplifier, Comparator, Integrator, Differentiator.

6- CIRCUIT DYNAMICS: TRANSIENT AND DC STEADY STATE
Capacitor and Inductor: constitutive law and properties. First-order circuits: transient and dc steady state. Higher-order circuits (hints).

7-SINUSOIDAL AC STEADY STATE AND THE FREQUENCY DOMAIN
7a) Sinusoids and phasors. Impedance and Admittance. Sinusoidal steady-state analysis in the phasors' domain. Power in sinusoidal steady state: average (real/active) power, reactive (imaginary) power, apparent power, power factor, complex power.
7b) Frequency response. Network functions of basic filters.

8- POWER-SYSTEM CIRCUITS
Three-phase circuits for the distribution of electric energy in buildings and hospitals. Protection-earth wire and electric safety (hints).

9- NON-LINEAR CIRCUITS
General definitions about non-linear circuits. Diode: constitutive law, applications. Field-effect transistor (MOSFET): constitutive law, application as small-signal amplifier, application as controlled switch.

Teaching Methods

- Lectures (60 %) to present subjects.
- Problem Sessions (40 %) to develop applied circuit analysis.

Assessment

Written exam composed of

- **Problems** (to verify applied knowledge of circuit analysis)
  Problem #1 (8 points): Resistive circuit (subjects 1, 2, 3, 4)
  Problem #2 (8 points): Transient and dc steady state in a first-order circuit (subject 6)
  Problem #3 (8 points): Circuit in sinusoidal ac steady state (subject 7a)
  (Note: a problem may be composed of a number of elemental exercises/tasks)
- **Questions** (to verify knowledge and understanding)
  Seven questions (7 points) randomly chosen within subjects 5, 7b, 8, 9

Total score: 8+8+8+7=31 points

Texts

Charles Alexander, Matthew Sadiku, *Fundamentals of Electric Circuits*, 7th Ed. (International Student Edition), McGraw Hill, 2021, ISBN: 978-1-260-57079-3