Linear networks analysis and synthesis

Academic Year: (2024 / 2025) **Review date: 20-01-2025**

Department assigned to the subject: Signal and Communications Theory Department

Coordinating teacher: LLORENTE ROMANO, SERGIO

Type: Compulsory ECTS Credits : 6.0

Year : 2 Semester : 2

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Linear Algebra (1º)
Systems and Circuits (1º)
Linear Systems (2º)
Math Extension (2º)
Electronic Components and Circuits (2º)

LEARNING OUTCOMES

CB1: Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2: Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CG3: Knowledge of basic and technological subject areas which enable acquisition of new methods and technologies, as well as endowing the technical engineer with the versatility necessary to adapt to any new situation.
CG13: Understanding and command of basic concepts of linear systems and related functions and transformers. Electrical circuit theory, electronic circuits, physical principles of semiconductors and logic families, electronic and photonic devices, materials technology and their application in resolving problems characteristic of engineering.
ECRT9: Ability to analyze and design combinational and sequential circuits, synchronous and asynchronous circuits, and use of microprocessors and integrated circuits.
ETEGISC4: Ability to select circuits, radiofrequency, microwave, radio broadcasting, radio link and radio determination subsystems and systems.
RA1: Knowledge and Understanding. Knowledge and understanding of the general fundamentals of engineering, scientific and mathematical principles, as well as those of their branch or specialty, including some knowledge at the forefront of their field.
RA2: Analysis. Graduates will be able to solve engineering problems through an analysis process, identifying the problem, recognising specifications, establishing different methods of resolution, selecting the most appropriate one and implementing it correctly. They must be able to use various methods and recognize the importance of social constraints, human health, safety, the environment, as well as commercial constraints.
RA4: Research. Graduates will be able to use appropriate methods to carry out detailed research and studies of technical aspects, commensurate with their level of knowledge. The research involves bibliographic searches, design and execution of experiments, interpretation of data, selection of the best proposal and computer simulation. May require consultation of databases, standards and security procedures.
RA5: Applications. Graduates will have the ability to apply their knowledge and understanding to solve problems, conduct research, and design engineering devices or processes. These skills include knowledge, use and limitations of materials, computer models, process engineering, equipment, practical work, technical literature and information sources. They must be aware of all the implications of engineering practice: ethical, environmental, commercial and industrial.

OBJECTIVES

1. Transversal/Generic objectives:

- Solving mathematical analysis and synthesis problems.
- Apply scientific and technical knowledge to practical situations.
- Solve problems stated mathematically.
- Integrate theoretical knowledge into the solution of problems.

2. Specific learning cognitive objectives

- Deciding and stating the advantages of using mesh or node analysis for a particular network.
- Identifying matrices of mesh and node methods and tell whether they belong to reciprocal systems.
- Naming and identifying the different types of system functions/transfer functions for stable causal linear networks and the relationships between responses in the Laplace, real frequency and time domains.
- Describing part of a network as a two-port.
- Name the different types and manifestations of power in a network with two-ports.
- Stating the maximal power transfer theorems for generators and loads with and without an interposing two-port.
- State the concept of conjugate matching.
- Relating natural and logarithmic power units.
- Stating the conditions for a network to be reciprocal and/or symmetrical
- Describing the filter synthesis process.
- Graphing the analog filter prescription functions in modulus and attenuation.
- Stating the difficulties in synthesizing an ideal low-pass transfer function.
- Stating Approximation Theory for the design of low-pass LC analog filters.
- Mathematically describing frequency transforms for high-pass, band-pass and suppressed-band filters.
- State the advantages of working in normalized frequency, impedance, resistance, inductance and capacitance.
- Deferentially characterizing, with respect to the analog version, the transfer function in the Z domain of digital filters both for infinite and finite impulse responses (IIR & FIR)
- Stating a discrete-time domain response from a difference equation.
- Sketching direct architectures for digital filters.

* Procedural/instrumental objectives:

- Stating and solving analysis equations for linear networks with mesh and node methods both in stationary sinusoidal and in stationary and transient regimes with the unilateral Laplace transform.
- Same with two-ports included in them.
- Describing two-ports by their impedance, admittance, power transfer and image parameters.
- Specifying and synthesizing passive low-, high-, bandpass and suppressed band analog filters using the Butterworth and Chebychev approximations.
- Specifying and synthesizing said filters in the digital case resorting to analog synthesis.
- Simulating analog filters digitally.

DESCRIPTION OF CONTENTS: PROGRAMME

Unit 1: Systematic Linear Network analysis in stationary sinusoidal regimes with mesh and nodal analysis.

1.1. Description of RLC components in SSR.
1.2. Using systematic methods for linear network analysis
    1.2.1. Mesh analysis
    1.2.2. Nodal analysis
1.3. Networks with mutual inductance and transformers
1.4. Real, reactive, and apparent powers. Complex conjugate matching.

Unit 2: Linear Network analysis using the unilateral Laplace transform.

2.1. The unilateral Laplace transform
2.2. The generalization of analysis theorems to the Laplace domain. Use in network analysis: free, driven, stationary and transient regimes.
2.3. Transfer functions. Frequency response. Phase and amplitude response.

Unit 3: Two-port network analysis.

3.1. Two-port description: [z], [y] and [F] parameters.
3.2. Two-port interconnection.
3.3. Image parameters.
3.4. Loaded two-ports. Insertion and transmission losses. Matched two-ports. Conjugate matching. Logarithmic measurement units: Nepers and decibels.

Unit 4: An introduction to the synthesis of passive, analog filters.

4.1. Filtering. Phase and group delay. Phase equalization. Filter types. Filter specification.
4.2. Filter characterization functions.
4.3. Low-pass filter approximation theory. Parameter normalization. Frequency transformations.
4.4. Butterworth and Chebychev filter synthesis: low-pass, high-pass, band-pass and suppressed band.

Unit 5: An introduction to the synthesis of digital filters.

5.1. A comparison with analog filters.
5.2. Z domain transfer functions with infinite and finite impulse responses. Difference equations. Direct architectures. Stability.
5.2. FIR filter synthesis from analog synthesis.
5.3. Analog filter simulation with digital filters.

LEARNING ACTIVITIES AND METHODOLOGY

Three different teaching/learning activities will be used: theoretical lectures, problem-solving sessions and lab sessions.

ECTS credits include in all cases an allotment for personal work and team problem-solving work.

THEORETICAL LECTURES (2,48 ECTS)
Theoretical lectures will include the use of blackboard and slide material to illustrate main concepts in subject. The explanation of theoretical concepts will be complemented with exercises and problem solution sketches. These lectures will require personal initiative and research plus theoretical study: he/she might be asked to develop particular concepts or apply them to specific problem instances either individually or in the group.

PROBLEM SOLVING-SESSIONS AND PROBLEM-SOLVING ASSIGNMENTS (2,64 ECTS)
For problem-solving sessions, students will be given problem statements in advance. Problem solving will include common review of solutions and instructor-led correction. These should help ground knowledge and develop the ability to analyze and transmit information relevant to problem-solving. The common review is expected to improve opinion exchange between instructors and students.

The last minutes of these classes could be spent taking a short assessment test on the content seen during the week.

LABORATORY TESTS (0.86 ECTS)
It is intended to carry out two "software" laboratory in computer classroom where the student can simulate the circuits that have been analyzed or designed in the theoretical sessions. With these simulations, students can evaluate the success of the analysis and design techniques learned in class.

Individual tutoring sessions are intended to involve specific, clearly defined aspects. Appointments will be managed through the learning management system being used during the course. If required, collective tutoring sessions will be held to provide feedback to the group about the solution and assessment results.

ASSESSMENT SYSTEM

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

The evaluation of the subject will be carried out by means of the weighted sum of the continuous evaluation grade (obtained from the marks obtained in the laboratories and the evaluation tests carried out in the last minutes of the problem classes) and the final evaluation test.

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

A minimum grade/score of 4.0 will be needed in the final test.

The final evaluation test will comprise both theoretical questions and problems resembling those of the problem-solving sessions, about all the units in the subject.

BASIC BIBLIOGRAPHY

- Alan V Oppenheim, R. W. Schafer J. R. Buck Discrete-time signal processing., Prentice Hall, 1999

- Anant Agarwal Foundations of Analog and Digital Electronic Circuits, Elsevier, 2005

- C. K. Tse Linear circuit analysis, Addison-Wesley, 1998

- J.W. Nilsson Electric Circuits, Prentice Hall, 2008

- L. E. García Castillo, A. García Lampérez, S. Llorente Romano, M. Salazar Palma Problemas de Análisis y Diseño de Circuitos, Copy Red, S.A., 2016

- R. A. DeCarlo Linear Circuit Analysis, Oxford University Press, 2001

- Santiago Cogollos Borrás Fundamentos de la teoría de filtros, Universitat Politécnica de Valéncia, 2016

ADDITIONAL BIBLIOGRAPHY

- P. R. Adby Ellis Horwood Series: Electrical and Electronic Engineering, Applied Circuit Theory. Matrix and Computer Methods, John Wiley & Sons, 1990

- R. Decarlo, P. M. Lin Circuit Analysis, vol. 2 Prentice-Hall, 1995.

- A. Papoulis Circuits and Systems: A Modern Approach, Rinehart & Winston, 1980.

- F. J. Taylor Principles of Signal and Systems, McGraw-Hill, 1994.

- G. C. Temes, J. W. Lapatra Introduction to Circuit Synthesis and Design, McGraw-Hill, 1977

- S. Karni Applied Circuit Analysis, John Wiley & Sons, 1988..

- W. M. Siebert Circuits, Signals and Systems, MIT Press, 1985.