Politehnica University of Bucharest
Faculty of Electronics, Telecommunications and Information Technology

COURSE DESCRIPTION

1. Program identification information

1.1 Higher education institution	University POLITEHNICA of Bucharest
1.2 Faculty	Faculty of Electronics, Telecommunications and Information Technology
1.3 Department	Department of Devices, Circuits and Electronic Architectures
1.4 Domain of studies	Electronic Engineering, Telecommunications and Informational Technologies
1.5 Cycle of studies	License
1.6 Program of studies/Qualification	Technologies and Systems of Telecommunications (TSTeng)

2. Course identification information

2.1 Name of the course				Analog Integrated Circuits			
2.2 Lecturer				Prof.dr.ing. Cosmin Radu Popa			
2.3 Instructor for practical activities				As.dr.ing. Marius Enachescu			
2.4 Year of studies	III	2.5 Semester	5	2.6 Evaluation type	Exam	2.7 Course choice type	Mandatory

3. Total estimated time (hours per semester for academic activities)

3.1 Number of hours per week, out of which	5	3.2 course	3	3.3 practical activities	2
3.4 Total hours in the curricula, out of which	70	3.5 course	42	3.6 practical activities	28
Distribution of time					hours
Study according to the manual, course support, bibliography and hand notes					45
Supplemental documentation (library, electronic access resources, in the field, etc)					5
Preparation for practical activities, homeworks, essays, portfolios, etc.					5
Tutoring					0
Examinations					5
Other activities					0

3.7 Total hours of individual study	60
3.9 Total hours per semester	130
3. 10 Number of ECTS credit points	5

4. Prerequisites (if applicable)

4.1 curricular	Electronic devices, Fundamental electronic circuits
4.2 competence-based	General knowledge of electronic devices and circuits

5. Requisites (if applicable)

5.1 for running the course	No restrictions
5.2 for running of the applications	Compulsory presence at laboratory classes, according to current PUB regulations.

6. Specific competences

Professional competences	Using the fundamental elements regarding devices, circuits and electronic instrumentation. The application, in typical situations, of the basic methods of acquisition and signal processing.
Transversal competences	-

7. Course objectives (as implied by the grid of specific competences)

7.1 General objective of the course	Analysis, design, applications and performances' optimization of MOS and bipolar analog integrated circuits. Behavior and analysis of various electronic configurations common to many types of analog integrated circuits as: current sources, voltage and current references, small-signal amplifiers, differential amplifiers, output stages, protection circuitry. Presentation of the most widely used internal structures of analog integrated circuits, with a special emphasis on the basic configuration of operational amplifiers. Discussion of the various nonideal characteristics of operational amplifiers. Analysis of circuits' frequency response and study of the stability of feedbacked circuits. Analysis of linear and nonlinear analog computational structures.
7.2 Specific objectives	Practical applications of the material from the course, such as analysis and design of the various subcircuits common in analog integrated circuits, including differential amplifiers, current sources, internal structures of operational amplifiers, various linear and nonlinear applications of operational amplifiers. Hand calculations and simulations for validating the most important aspects of the analog circuits operation.

8. Content

8.1 Lectures	Teaching techniques	Remarks
Chapter I. Introduction. Modeling bipolar and MOS devices; analysis of second-order effects.	Analog integrated circuits course studies fundamental blocks of electronic circuits, analyzed and designed for their implementation in integrated technolgies. This particularity of an integrate realization of	2 hours

Chapter II. Linear and nonlinear applications with operational amplifiers. Parameters of operational amplifiers and their errors comparing with ideal circuits. Elementary comparator and comparator with histerezis.	analog circuits fundamentaly changes the design principles, as well as the specific architectures of each circuit class, comparing with the circuit implementations using discrete components. In this sense, it appears additional information that must be analyzed, related to the matching of devices parameters and to the the specific errors and limitations associated with the implementation in a particular technology, correlated with the additional difficulties imposed by the continuous reducing of integrated devices dimensions. Chapter I represents a recap and a synthesis of fundamentals for modeling bipolar and MOS devices, studied in previous disciplines. Linear and nonlinear applications from Chapter II (inverting and non-inverting amplifiers, adding and subtracting amplifiers, rectifiers or circuits for implementing logarithmic and exponential functiuon) use ideal operational amplifiers. The exclusive availability in practice of real operational amplifiers introduces a multitude of errors, in comparison with the operation using ideal circuits. It results the necessity of continuing the course, for analyzing the internal structures of operational amplifiers. In consequence, it is very important to study the constitutive blocks of operational amplifiers, such as current sources (Chapter III), elementary amplifier stages and differential amplifiers (Chapter IV) and output stages (Chapter V). Using all the previous informations, in Chapter VI is analyzed internal architectures of operational amplifiers and are qualitatively and quatitatively evaluated the errors from ideality and also the practical limitations of real circuits, comparing with ideal circuits, analyzed in Chapter II. Starting from the concrete architectures of operational amplifiers studied in Chapter VI, they are re-analyzed the applications with operational amplifiers (presented in Chapter II) and they are evaluated the effects of parameters of real	8 hours
Chapter III. Current sources and voltage sources. Cascode and self-biased current sources. Current and voltage references. Techniques for realizing the correction of temperature characteristic of voltage references. Methods for improving the power supply rejection for analyzed circuits.		7 hours
Chapter IV. Elementary amplifier stages. Study of differential amplifiers - large signal analysis and small signal analysis; determination of the common-mode input voltage range and the rail-to-rail operation. Study of differential amplifiers having an independent-biased current source as load, of differential amplifiers with a current mirror as load, as well as of cascode differential amplifiers. Evaluation and improvement of CMRR and SVRR; particularities depending on the type of the output (simple or differential). Determination of miasmatches effect on the operation of differential amplifiers.		8 hours
Chapter V. Output stages: operation classes, architectures, operation, characterization		2 hours

<table>
<tr><td>Chapter VI.
Internal structures of operational amplifiers.
Cascode and folded cascode operational amplifiers.
Evaluation of nonidealities of operational amplifiers and methods for improving of their performances.
Rail-to-rail operation of operational amplifiers</td><td rowspan="3">operational amplifiers on the circuits operation. They are proposed methods for improving the performances of operational amplifiers, with a direct impact on maximizing the performances of analyzed applications from Chapter II. Chapter VII studies the circuits frequency response, presenting concrete methods for evaluating analog circuits stability, while Chapter VIII presents elementary information related to linear and nonlinear analog computational structures.
The teaching method is based on the utilization of video projections, the course including a multitude of simulations of analyzed circuits, useful for a good understanding of the discipline and for a concrete evaluation of the limitations of the studied circuits.
Course information are represented by course notes and presentations, available on Moodle and on the following site: http://wiki.dcae.pub.ro/index.php/Cosmin_Popa.</td><td>8 hours</td></tr>
<tr><td>Chapter VII.
Frequency response of circuits and stability of circuits</td><td>5 hours</td></tr>
<tr><td>Chapter VIII.
Linear and nonlinear analog computational structures</td><td>2 hours</td></tr>
<tr><td colspan="3">References
- P. R. Gray, P.J. Hurst, S.H. Lewis, R.G. Meyer, Analysis and Design of Analog Integrated Circuits, John Wiley & Sons Publishing House, 2003;
- P.R. Gray, R.G. Meyer, Analog integrated circuits. Analysis and design, Tehnica Publishing House, 1997;
- A. M. Manolescu, Analog Integrated Circuits, Foton International Publishing House, 1999;
- course slides, available on Moodle.</td></tr>
<tr><td>8.2 Seminary</td><td>Teaching techniques</td><td>Remarks</td></tr>
<tr><td>Linear applications with operational amplifiers</td><td rowspan="6">Teaching is based on the explanations of the teacher and the on a direct involvement of students in solving problems. Presentations from the seminar lectures and problems are available in printed form (see the References). Theoretical knowledge form the seminar will represent the basis for laboratory.</td><td>2 hours</td></tr>
<tr><td>Nonlinear applications with operational amplifiers</td><td>2 hours</td></tr>
<tr><td>Recap on on fundamental electronic circuits.
Parameters of operational amplifiers</td><td>2 hours</td></tr>
<tr><td>Current sources.
Voltage references</td><td>2 hours</td></tr>
<tr><td>Differential amplifiers.
Output stages</td><td>2 hours</td></tr>
<tr><td>Internal structures of operational amplifiers</td><td>2 hours</td></tr>
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Frequency response and the analysis of circuits stability. Test for evaluation of the seminar activity		2 hours
8.3 Laboratory	Teaching techniques	Remarks
Presentation of LT Spice simulation program	The teaching method is based on the recap of theoretical knowledge necessary for understanding of the analyzed circuits' operation, on the realization of measurements and simulations, as well as on the processing of experimental data.	2 hours
Experimental study of elementary circuits with operational amplifiers		2 hours
Simulation of operation of elementary circuits with operational amplifiers		2 hours
Evaluation using simulations of operational amplifiers parameters. Experimental study of operational amplifiers parameters and characteristics		2 hours
Simulation of current sources operation. Simulation of voltage references operation		2 hours
Simulation of differential amplifiers operation		2 hours
Laboratory final test		2 hours
References - Anca Manolescu, Anton Manolescu, Cosmin Popa, *Analysis and design of VLSI CMOS analog integrated circuits*, Printech Publishing House, 2006; - Anca Manolescu, Anton Manolescu, Cosmin Popa, *Analog integrated circuits*, University Politehnica of Bucharest Publishing House, 2005; - Cosmin Popa, *Analog integrated circuits. Laboratory guidebook*, Printech Publishing House, 2014.		

9. Bridging the course content with the expectations of the epistemic community representatives, professional associations and employers representatives for the domain of the program

Analysis and design of analog integrated circuits is an area of great interest, there is an important demand for engineers in the design of analog integrated circuits. Studied and designed analog structures present a multitude of practical applications in most areas of electronics, as well as in areas that indirectly uses electronics. The course curricula specifically responds to current trends and technological evoloution. The course and its related applications provide students knowledge and skills that enable quick employment after graduation in a reputed company in the field.

10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Weight in the final mark
10.4 Lectures	- knowledge about theoretical fundamentals - knowledge of modality of solving problems specific to analog integrated circuits	Partial exam Final exam	20% 40 %
10.5 Practical applications (seminary + laboratory)	- knowledge of theoretical fundamentals and of their modalities of using them for solving specific problems and applications of analog integrated circuits	Evaluation of activity from the seminar	20 %
		Evaluation of the laboratory work	20 %
10.6 Minimal performance standard			
- understanding of the operation of linear and nonlinear applications of operational amplifiers; - analysis of differential amplifier and current sources' operation; - the study of internal structures of operational amplifiers; - frequency response analysis for elementary circuits. The requirement for passing the discipline is to obtain at least 50 % from the maximum number of points for each part of the discipline evaluation, as follows: - at least 10p from a maximum of 20p for passing the seminar activities; - at least 10p from a maximum of 20p for passing the laboratory activities; - at least 10p from a maximum of 20p for passing the partial exam; - at least 20p from a maximum of 40p for passing the final exam.			

Date	Lecturer	Instructor for practical activities
05.09.2017	Prof.dr.ing. Cosmin Popa`	As.ing. Marius Enachescu

Date of department approval

25.09.2017

Director of Department,

Prof.dr.ing. Claudius DAN