SYLLABUS

1. Data about the program of study

1.1	Institution	The Technical University of Cluj-Napoca
1.2	Faculty	Electronics, Telecommunications, and Information Technology
1.3	Department	Bases of Electronics
1.4	Field of study	Electronic Engineering, Telecommunications and Information Technologies
1.5	Cycle of study	Bachelor of Science
1.6	Program of study/Qualification	Applied Electronics/Telecommunications Technologies and Systems
1.7	Form of education	Full time
1.8	Subject code	30.00

2. Data about the subject

2.1	Subject name					Systems with Analog Integrated Circuits					
2.2	Subject area					Integrated Circuits					
2.3	Course responsible/lecturer					Assoc. Prof. Marius Neag, PhD - Marius.Neag@bel.utcluj.ro					
2.4	Teachers in charge of applications					Lecturer Raul Onet, PhD - Raul.Onet@bel.utcluj.ro					
2.5	Year of study	III	2.6	Semester	1	2.7	Assessment	Exam	2.8	Subject category	DID/DOB

3. Estimated total time

3.1 Hours per week	5	of which 3.2 lecture	2	3.3 project / laboratory	3
3.4 Total hours in curricula	70	of which 3.5 lecture	28	3.6 project / laboratory	42

Time allocation	ore
Individual study based on textbooks, lecture material and notes, bibliography	15
Supplementary study in the library, online and in the field	5
Preparation for seminars/laboratory works, homework, reports, portfolios, essays	28
Tutoring	2
Exams and tests	5
Other activities	-

3.7 Total hours of individual study	55
3.8 Total hours per semester	125
Number of credit points	5

4. Pre-requisites (where appropriate)

4.1 Curriculum	Fundamental Electronic Circuits, Analog Integrated Circuits
4.2 Competence	Good understanding of the operation and modeling of electronic devices such as diodes, BJT and MOS transistors. Good understanding of, and ability to use for circuit analysis, the operation and parameters of main analog building blocks: amplifying stages with one- and two-

	transistors, the differential pair, current mirrors, voltage references; general purpose OAs Working knowledge of circuit theory and signal theory Working knowledge of CAD tools employed in the analysis and design of analog circuits

5. Requirements (where appropriate)

5.1 For lecture	Amphitheatre, Cluj-Napoca
5.2 For applications Project / Laboratory	Laboratories with standard electronic equipment, Cluj-Napoca

6. Specific competences

Professional competences	After completing this course, the students should know: - Key features specific to the analysis and design of circuits and systems implemented with analog integrated circuits (ICs); methodologies for analyzing and sizing such circuits - Principle of operation, usual circuit implementations, main non-idealities and the related parameters of general-purpose voltage-mode Operational Amplifiers (OAs), current-feedback OAs (CFB-OA), and linear transconductors (Gm cells) - Main points regarding noise in electrical circuits and noise analysis of OA-based circuits - Typical architectures and circuit implementations, as well as methods for analysing and designing commonly-used linear and nonlinear applications with OAs and Gm-cells: voltage references and linear voltage regulators, precision and instrument amplifiers, filters, precision rectifiers, peak detectors, signal comparators and generators; multipliers/dividers, frequency- to-voltage converters - Principle of operation and main parameters of frequency synthesizers based on Phase Locked Loop (PLL) circuits;
	After completing this course, the students will be able to: - Understand and use datasheet information, as well as simulation and measurement results related to the circuits mentioned above - Analyze and design commonly used linear and nonlinear circuits based on OAs and Gm-cells o voltage references and linear voltage regulators o precision amplifiers, amplifier with variable/programmable gain and instrument amplifiers o continuous-time filters implemented with 1st- and 2nd- order sections o precision rectifiers, peak detectors, sample&hold amplifiers o signal comparators, signal generators and harmonic oscillators, voltage -to-frequency converters o multipliers/dividers, - Analyze applications based on, and design circuits with, Application-Specific Integrated Circuits (ASIC) that implement the circuit functions mentioned above - Analyze effects of electric noise in linear circuits based on OAs and Gm-cells. - Design and implement testbenches for functional verification and characterization of analog circuits and systems listed above through SPICE-based simulations, as well as through measurements - Analyze the architecture and performance of frequency synthesizers based on PLLs, and employ such circuits in larger systems
	By completing the discipline, the students will acquire practical skills such as: - Employ standard CAD tools that include SPICE-based simulators for the analysis, design and verification/characterization of analog circuits and systems - Employ standard lab instrumentation (power supplies, oscilloscope, function generator, multi-meter) for the experimental analysis and verification/characterization of analog systems; - Design and build test setups for the experimental validation and characterization of analog circuits and systems; - Performing methodically circuit simulations and laboratory experiments in order to obtain valid data on the devices-under-test, then process and analyse those data

Transversal competences	- Know and be able to use methodologies for the analysis and design of systems with Integrated Circuits: understand top requirements and convert them into block-level specifications; analyze comparatively possible implementation solutions and identify design trade-offs, generate models able to reflect limitations/non-idealities inherent to ICs - Effective use of various sources of information and computer-aided education, including on-line lectures and tutorials, databases, etc.

7. Discipline objectives (as results from the key competences gained)

7.1 General objectives	Develop students' competencies regarding the analysis, design, verification and characterization of a wide range of analog systems implemented with OAs, Gm-cells and application-specific integrated circuits (ASICs).
7.2 Specific objectives	1. Understand the operation and main limitations of general-purpose and specialized OAs and Gm-cells and be able to estimate the effects those limitations have on circuits implemented with OAs and Gm-cells 2. Understand the operation of, and be able to assess the circuit function and main parameters of a wide range of analog systems based on OAs and Gm-cells 3. Understand the operation and main features resulted from datasheet information of application-specific integrated circuits (ASICs); develop skills and abilities required for analyzing circuits based on ASICs, use them properly and develop new applications with them. 4. Acquire the knowledge and skills necessary for systematic analysis and design of systems implemented with OAs, Gm-cells and ASICs 5. Develop the skills and abilities necessary to design, implement and make use of testbenches for functional verification and characterization of analog systems based on OAs, Gm-cells and ASICs

8. Contents

8.1. Lecture (syllabus)	Teaching methods	Notes
Overview: objectives, content, methodology. General-purpose voltage-voltage operational amplifier (OA): principle of operation, limitations associated with DC operation and corresponding parameters; effects on basic circuits implemented with OAs. Methods for minimizing/compensating the effects of DC non-idealities	Presentation, heuristic conversation, exemplification, problem presentation, teaching exercise, case study, formative evaluation	Use of PowerPoint presentation, projector, blackboard
General-purpose voltage-voltage operational amplifier (OA): limitations associated with small- and large-signal operation; the corresponding parameters and models; effects on basic circuits implemented with OAs.		
Noise in analog circuits: types of electrical noise, modeling and analysis methods. Noise models for passive and active devices.		
Current-Mode active devices - the Current-Feedback Operational Amplifier (CFB-OA) and the linear transconductor (Gm cell): operation; internal structure; modeling; parameters; main applications; comparison with traditional OA.		
Voltage references and linear voltage regulators: function and features; key parameters; main ideas for circuit implementation		
Continuous-time filters: main types, topologies and synthesis methods; implementation of 1st and 2nd order sections by using voltage- and current-mode active devices, particularly the AO-RC and Gm-C techniques		
Controlled-gain amplifiers implemented with voltage- and current-mode active devices		
Precision and instrumentation amplifiers: function & features, parameters; classical implementation solutions in voltage- and current mode.		
Circuits with non-linear transfer characteristics: precision rectifiers; peak detectors; sample-and-hold amplifiers.		
Harmonic Oscillators		
Integrated voltage comparators: structure and applications. Internal structures; main limitations and corresponding parameters. Circuit implementation of: summing and differential comparators; window comparators; Schmitt triggers.		

Signal generators based on bi-stable circuits and on harmonic oscillators: main features and implementation techniques. Examples of OA-based harmonic oscillators, triangular & rectangular – wave and saw-tooth wave generators.		
Analog Multipliers and dividers - main features and implementation techniques; examples of, and applications with, integrated analog multipliers.		
Frequency synthesizers based on PLL circuits: principle of operation, main parameters, examples of circuit implementation for the Voltage-Controlled Oscillator		

Bibliography

1. P. R. Gray, R. G. Meyer, *Analysis and Design of Analog Integrated Circuits,* John Wiley and Sons, 2003. 2009
2. S. Franco – Design with Operational Amplifiers and Analog Integrated Circuits, McGraw-Hill, 1998, 2001, 2014
3. W. Jung (Ed.) - Op Amp Applications Handbook, Springer, 2005
4. D. Johns, K. Martin - Analog Integrated Circuit Design, John Wiley & Sons, 1997
5. B. Razavi - *Design of CMOS Analog Integrated Circuits*, McGraw-Hill, 2001
6. W. Sansen – Analog *Design Essentials*, Springer, 2006
7. M. Neag, *Sisteme cu Circuite Integrate Analogice*, Mediamira, 2008
8. M. Neag, C. Pleșa, M. Purcar, Circuite integrate pentru managementul puterii proiectate cu simulatoare electro-termice, Editura UTPress Cluj-Napoca, 2022, ISBN 978-606-737-574-9
9. M. Neag, I. Kovacs, Integer-N Frequency Synthesizers - An IC Designer's Guide, Editura UTPress Cluj-Napoca, 2022, ISBN 978-606-737-573-2

On – line references

1. M. Neag, Systems with Analog IC – lecture notes and presentations, posted on the course site: http://www.bel.utcluj.ro/ci/eng/saic/index.html

8.2.1 Applications – laboratory classes		Teaching methods	Notes
1	Introduction: presentation of lab equipment and organization. Basic techniques for laboratory characterization of analog circuits and systems	Didactic and experimental proof, didactic exercise, team work	Use of laboratory instrumentation, experimental boards, computers, blackboard
2	Limitations and parameters of general-purpose OAs: DC and large-signal operation		
3	Noise in analog circuits: noise analysis and methods for reducing noise impact on OA-based circuits.		
4	Effects of OA limitations on OA-based linear circuits; methods for reducing the impact on the overall circuit performance		
5	Linear transconductors: parameters and applications.		
6	Voltage references and linear voltage regulators		
7	Continuous-time filters based on first- and second-order sections implemented by using the AO-RC and Gm-C techniques		
8	Precision and Controlled-gain amplifiers.		
9	Instrumentation Amplifiers.		
10	Precision half- and full-wave rectifiers; peak detectors; sample & hold		
11	Voltage comparators implemented with general-purpose OAs and with integrated comparators		
12	Signal generators based on bi-stable circuits and on harmonic oscillators.		
13	Analog Multipliers and applications		
14	Voltage-to-frequency converters for frequency synthesizers based on PLL circuits.		
8.2.2 Applications – Project		Teaching methods	Notes

1	Project definition and design requirements. Role and main parameters of the functional blocks within an analog Front-End for sensors. Project plan. Design methodology, deliverables, technical documentation	Didactic and experimental proof, didactic exercise, computers, blackboard	Use of laboratory instrumentation, experimental boards, computers, blackboard, written and oral test for progress assessment
2	Main limitations of general-purpose OAs and corresponding parameters. Effects of OA nonidealities on voltage-voltage and current-voltage amplifiers implemented with OAs		
3	Methods for minimizing and compensating for OA nonidealities in OA-based linear circuits		
4	Controlled-gain amplifiers implemented with OAs: systematic analysis and sizing methodologies		
5	Design examples for OA-based controlled-gain amplifiers		
6	Instrumentation Amplifiers implemented with OAs and specialized ICs: systematic analysis and sizing methodologies		
7	Design examples for Instrumentation Amplifiers implemented with OAs and specialized ICs		
8	Continuous-time filters implemented with OAs: systematic analysis and sizing methodologies		
9	Design examples for continuous-time filters implemented with OAs.		
10	Precision rectifiers and peak detectors implemented with OAs: systematic analysis and sizing methodologies		
11	Design examples for precision rectifiers and peak detectors implemented with OAs.		
12	Verification and optimization of the entire Analog Front-End		
13	Characterization of the entire AFE; technical documentation		
14	Project completion and evaluation		

Bibliography

1. M. Neag, A. Fazakas, Circuite Integrate Analogice, Casa Cărţii de Ştiinţă, 1999
2. L. Festila, N. Pop, S. Hintea, M. Neag - Circuite integrate analogice. Culegere de probleme, Lito UTCN,
3. T. Danila, N. Cupcea – Amplificatoare Operaționale – Aplicații, probleme rezolvate, Teora, 1994
4. S. Franco – Analog Circuit Design: Discrete & Integrated, McGraw-Hill, 2014
5. W. Jung (Ed.) - Op Amp Applications Handbook, Springer, 2005
6. R. Coughlin, F. Driscoll – Operational Amplifiers and Linear Integrated Circuits, Pretice Hall, 2001

On – line references

1. M. Neag, R. Onet - Systems with Analog IC – Design Guide, material posted on course's site

9. Bridging course contents with the expectations of the representatives of the community, professional associations and employers in the field

The discipline content and the acquired skills are in agreement with those set up by similar courses organized by top universities in Romania and abroad; also, they meet the requirements set by professional organizations and government agencies in this field, as well as the expectations of companies involved in the design, implementation and testing & characterization of systems with analog integrated circuits, such as the potential employers where students carry out practical placements and internships.

10. Evaluations

Activity type	10.1 Assessment criteria	10.2 Assessment methods	10.3 Weight in the final grade
10.4 Lecture	The level of acquired theoretical knowledge and skills in analysis and design of analog integrated circuits	- Summative evaluation exam (theory and problems): Oral and/or written Face-to-face and/or on-line	- E, max 10 pts. 70%
10.5 Applications (lab and project)	The level of acquired practical abilities and design of functional blocks with analog ICs	- Continuous formative evaluation through written or oral tests during project classes and - Individual design project (common thematic but individualized requirements and design conditions (P) - Homework (problem solving) and evaluation of lab reports (L)	- P, max. 10 pts. 30% -L , pass/fail
10.6 Minimum standard of performance			
• Active attendance of all lectures, whether on-site or on-line; skipping a lecture should be compensated by supplemental individual study of teaching materials, with verifiable results • Attendance of, and active involvement in, all laboratory classes, resulting in fulfillment of all lab assignments + homework fully and accurately completed • Obtain an average mark of 5 (out of 10) for each test taken during project classes • Attendance of, and active involvement in, all project classes, resulting in meeting at least the minimum requirements: complete schematics; stable OP, circuit function realized; main parameters (such as gain, bandwidth, attenuation) within 20% of required values • Get at least 5 points (out of 10) at the exam • If all requirements described above are met, the final mark is computed by using the formula: Mark = 0.7 * E + 0.3 * P			

Date of filling in:	**Responsible**	**Title Surname NAME**	**Signature**
11.06.2023	Course	Assoc. Prof. Marius Neag, PhD Eng.	
	Applications	Lecturer Raul Oneț, PhD Eng.	

Data avizării în Consiliul Departamentului Bazele Electronicii 11.07.2023 ___________	Director Departament Bazele Electronicii Prof.dr.ing. Sorin Hintea
Data aprobării în Consiliul Facultății de Electronică, Telecomunicaţii şi Tehnologia Informaţiei 12.07.2023 _________	Decan Prof.dr.ing. Ovidiu Pop