SYLLABUS

1. Data about the program of study

1.1 Institution	Technical University of Cluj-Napoca
1.2 Faculty	Faculty of 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 / Engineer
1.7 Form of education	Full time
1.8 Subject code	53.10

2. Data about the subject

2.1 Subject name	High-Frequency Analog Circuits						
2.2 Subject area	Theoretical area Methodological area Analytic area						
2.3 Course responsible	Assoc. Prof. Marius Neag, PhD Eng. - Marius.Neag@bel.utcluj.ro						
2.4 Teacher in charge with seminar / laboratory / project	Assoc. Prof. Marius Neag, PhD Eng. - Marius.Neag@bel.utcluj.ro Assist. Prof. Raul Oneț, PhD Eng. - Raul.Onet@bel.utcluj.ro						
2.5 Year of study	IV	2.6 Semester	2	2.7 Assessment	V	2.8 Subject category	DS/DOP

3. Estimated total time

3.1 Number of hours per week	4	of which: 3.2 course	2	3.3 project / laboratory	2
3.4 To Total hours in the curriculum	56	of which: 3.5 course	28	3.6 project / laboratory	28

Distribution of time	hours
Manual, lecture material and notes, bibliography	4
Supplementary study in the library, online specialized platforms and in the field	2
Preparation for seminars / laboratories, homework, reports, portfolios and essays	10
Tutoring	2
Exams and tests	4
Other activities:	

3.7 Total hours of individual study	22
3.8 Total hours per semester	78
3.9 Number of credit points	3

4. Pre-requisites (where appropriate)

4.1 curriculum	Fundamental Electronic Circuits, Analog Integrated Circuits, Systems with Analog Integrated Circuits
4.2 competence	Good understanding of the operation and modelling of electronic devices such as diodes, BJT and MOS transistors. Good understanding of Operational Amplifiers and transconductors: internal structure, limitations and parameters, linear and non-linear applications 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 the course	Amphitheatre, Cluj-Napoca
5.2. for the seminars / laboratories / projects	Tutorial room, Cluj-Napoca

6. Specific competences

Professional competences	C2. Applying the basic methods for signal acquisition and processing • C2.3 Use of simulation environments for signal analysis and processing • C2.4 Use of the specific method and tools for signal analysis C3. Application of the basic knowledge, concepts and methods regarding the architecture of computer systems, microprocessors, microcontrollers, languages and programming techniques • C3.5 Projects involving hardware (processors) and software (programming) components C4. Design and use of low complexity hardware and software • C4.1 To define the concepts, principles and methods used in the fields of computer programming, high-level and specific languages, CAD techniques for making electronic modules, microcontrollers, computer systems architecture, programmable electronic systems, graphics, reconfigurable hardware architectures • C4.5 Design of dedicated equipment in the fields of applied electronics, which use: microcontrollers, programmable circuits or computing systems with simple architecture, including related programs C6. To solve technological problems, specific to applied electronics • C6.1 Defining the principles and methods underlying the manufacture, adjustment, testing and troubleshooting of the appliances and equipment in the fields of applied electronics
Cross competences	

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

7.1 General objective	Acquire skills required to organize and complete design projects: understand top requirements and convert them into block-level specifications; analyse comparatively possible implementation solutions and identify design trade-offs, generate models able to reflect limitations/non-idealities inherent to circuit implementations; propose circuit implementations and verify their operations through simulations
7.2 Specific objectives	1. Acquire and assimilate the basic theoretical knowledge necessary to analyse, model, design and verify high-frequency analog circuits and systems 2. Acquire skills and abilities necessary to analyse, model, design and verify high-frequency analog circuits

	3. Acquire the knowledge and skills necessary for systematic analysis and design of systems implemented with high-frequency analog circuits 4. Develop the skills and abilities necessary to design, implement and make use of testbenches for functional verification and characterization of high-frequency analog circuits and systems

8. Contents

8.1 Lecture (syllabus)	Teaching methods	Notes
1. Overview: objectives, content, methodology. Specific features of analog circuits for high-frequency and low-voltage/low-power applications. High-frequency models for main devices: BJ- and MOS-transistors, capacitors, inductors. Methods for sizing MOS transistors based on mathematical analysis and numerical simulations.	Presentation, heuristic conversation, exemplification, problem presentation, teaching exercise, case study, formative evaluation	Use of PowerPoint presentation, projector, blackboard
2. Analog building blocks implemented with BJ- and MOS-transistors: main function and principle of operation, circuit implementations for high-frequency and low-voltage & power applications, frequency characteristics		
3. Analysis of main topologies for low-voltage & low-power, single-ended OAs implemented in BiCMOS and CMOS technologies; frequency compensation methods		
4. Systematic design of BiCMOS and CMOS single-ended OAs		
5. Linear transconductors (Gm cells) with wide linear range for high-frequency applications: classical topologies and circuit implementations; methodologies for systematic analysis and design.		
6. Fully-differential OAs and linear transconductors; circuits for controlling the common-mode level at their differential outputs		
7. High-frequency controlled-gain amplifiers implemented with OAs and linear transconductors: topologies, circuit implement-tations, methodologies for systematic analysis and design.		
8. High-frequency, high-order continuous-time filters : main types, topologies and synthesis methods; implementation of 1st and 2nd order sections by using the AO-R, Gm-C and Gm-C-OA techniques		
9. Noise in analog circuits: main types of electrical noise, noise models for passive and active devices; noise analysis of analog circuits		
10. Frequency synthesizers based on PLL circuits: principle of operation and main parameters of Integer-N and Frac-N synthesizers; system-level analysis, examples of circuit implementation for main functional blocks		
11. Examples of circuit implementation for the main functional blocks within a PLL-based frequency synthesizer: voltage-controlled oscillators, high-frequency dividers, phase and frequency detectors, charge-pumps		
12. Integrated radio receivers: principle of operation, architectures, main parameters, introduction in system-level analysis		

13. Examples of circuit implementation for the main blocks within the signal path of radio receivers: low-noise amplifiers, frequency mixers, band- and low-pass filters, controlled -gain amplifiers		

Bibliography
1. M. Neag, Sisteme cu Circuite Integrate Analogice, Mediamira, 2008
2. B.Razavi, RF Microelectronics, Prentice Hall, 1998, (2011), ISBN: 0138875715
3. T. H. Lee -The Design of CMOS Radio-Frequency Integrated Circuits, Cambridge University Press, Second Edition, 2003
4. P. R. Gray, R. G. Meyer, Analysis and Design of Analog Integrated Circuits, John Wiley and Sons, 2003. 2009
5. D. Johns, K. Martin - Analog Integrated Circuit Design, John Wiley & Sons, 1997

On – line references, posted on the course site: http://www.bel.utcluj.ro/ci/rom/caif/index.html
6. M. Neag - High-Frequency Analog Circuits and Systems – lecture notes and presentations,
7. M. Neag, R. Onet - High-Frequency Analog Circuits and Systems – support material for lab classes.
8. M. Neag, R. Onet - High-Frequency Analog Circuits and Systems – support material for individual design projects.

8.2.1 Laboratory	Teaching methods	Notes
1. Frequency characteristics of analog building blocks implemented with BJT and MOS-transistors; methods for increasing the maximum frequency of operation	Didactic and experimental proof, didactic exercise, team work	Use of laboratory instrumentation, experimental boards, computers, white/magnetic board
2. Systematic design of BiCMOS and CMOS single-ended OAs with the following topologies: Miller, telescopic, folded cascode, feed-forward		
3. Systematic design of BiCMOS and CMOS single-ended and fully-differential transconductors for high-frequency applications		
4. Analysis, design and characterisation of controlled-gain amplifiers implemented with OAs and GM cells		
5. Analysis, design and characterisation of continuous-time filters based on first- and second-order sections implemented by using the AO-RC, Gm-C and Gm-C-OA techniques		
6. System-level analysis and characterisation of an Integer-N frequency synthesizer		
7. System-level analysis and characterisation of a Zero-IF FM radio receiver		

8.2.2 Project	Teaching methods	Notes
1. Project thematic and design requirements. Project plan. Design methodology and technical documentation	Circuit analysis and design exercises; analysis of design options considering design trade-offs; examples of systematically	Use of PowerPoint presentation, projector, blackboard, circuit simulators
2. System-level analysis of a Zero-IF radio receiver: function and parameters of main blocks within the signal path of radio receivers, especially the low-noise and controlled-gain amplifiers and the band- and low-pass filters		
3. Design of the channel filter for the Zero-IF radio receiver: topology options for OA-RC and Gm-C implementations; sizing		

strategies; functional schematic, with OA and Gm represented by parameterized models	sizing a circuit in order to achieve set requirements	
4. Design of the programmable-gain amplifier for the Zero-IF radio receiver: options for OA- and Gm-based implementations; sizing strategies; functional schematic for the PGA, with non-idealities inherent to actual circuit implementation represented by parameterized models		
5. Transistor-level design of the required OAs and Gm cells		
6. Complete design and verification of the channel filter and the PGA as stand-alone blocks		
7. Optimisation of the channel filter + PGA ensemble; final verification and characterisation. Completion of technical documentation.		
Bibliography 1. M. Neag, Sisteme cu Circuite Integrate Analogice, Mediamira, 2008. On – line references, posted on the course site: http://www.bel.utcluj.ro/ci/rom/caif/index.html 2. M. Neag, R. Onet – Design Guide for High-Frequency Amplifiers and Filters. Support material for individual design projects		

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 the expectations of the professional organizations and the employers in the field, where the students carry out the internship stages and/or occupy a job (in the field of analog integrated circuits), and the expectations of the national organization for quality assurance (ARACIS).

10. Evaluation

Activity type	10.1 Assessment criteria	10.2 Assessment methods	10.3 Weight in the final grade
10.4 Course	The level of acquired theoretical knowledge and developed skills for analysis of high-frequency circuit and systems	- Two written tests (theory and problems)	E, max 10 pts. 70%
10.5 Project/ Laboratory	The level of acquired knowledge and abilities for design of high-frequency circuit and systems	- Continuous formative evaluation: multiple-choice tests during lab classes - Homework (problem solving) evaluated periodically - Individual design project (common thematic but individual-lized requirements and design conditions	- L, max. 10 pct 10% - P, max. 10 pct 20%
10.6 Minimum standard of performance			
Qualitative level *Mimimum level of knowledge*			

Principle of operation, typical circuit implementations, main parameters including frequency characteristics of nalog building blocks implemented with BJT and MOS-transistors
Principle of operation, typical circuit implementations and main limitations of OAs and linear transconductors (Gm cells) for low-voltage & power and high-frequency applications
Principle of operation, typical circuit implementations and main parameters of high-frequency amplifiers and continuous-time filters based on OAs and Gm-cells
Principle of operation and main system-level features of PLL-based frequency synthesizers.
Principle of operation and main system-level features of radio receivers.

Mimimum level of competence
Employ standard methods for mathematical analysis of common circuit implementations of high-frequency OAs and linear transconductors and their applications mentioned above
Design and implement testbenches for, and run SPICE-based simulations on, the circuits mentioned above in order to analyze their operation and derive their main parameters and limitations
Employ standard laboratory equipment (power supplies, oscilloscope, function generator, multimeter) for experimental analysis and verification/characterization of analog systems) to perform experiments for validation and characterization of analog circuits and systems;

Quantitative level
- ✓ Active attendance of a majority of lectures
- ✓ Attendance of, and active involvement in, all laboratory classes, resulting in fulfilment of all lab assignments + fully completed homework:
- ✓ Attendance of, and active involvement in, all project classes, resulting in meeting at least the minimum requirements: complete schematics; stable OP and circuit function realized; main parameters (such as gain, bandwidth, attenuation) within 20% of required values
- ✓ Obtain at least 5 points (out of 10) at each written test and at least a mark of 5 (out of 10) for the laboratory and homework assignments and at least a mark of 5 (out of 10) for the project
- ✓ The final mark results from the following formulae: 0.7*E + 0.1*L+ 0.2*P

Date of filling in:	Responsible	Title Surname NAME	Signature
29.09.2019	Course	Assoc. Prof. Marius Neag, PhD Eng.	
	Applications	Assist. Prof. Raul Oneț, PhD Eng.	

Date of approval in the Department of Bases of Electronics ________________________	Head of Department Prof. Sorin HINTEA, PhD Eng.
Date of approval in the Council of Faculty of Electronics, Telecommunications and Information Technology ________________________	Dean Prof. Gabriel OLTEAN, PhD Eng.