COURSE OUTLINE

(1) GENERAL INFORMATION

SCHOOL	SCHOOL OF APPLIED MATHEMATICAL AND PHYSICAL SCIENCES		
DEPARTMENT	SCHOOL OF APPLIED MATHEMATICAL AND PHYSICAL SCIENCES		
LEVEL OF STUDIES	POSTGRADUATE		
MSc PROGRAM	MICROSYSTEMS AND NANODEVICES		
COURSE CODE	**9958**	**SEMESTER**	**2**
COURSE TITLE	ANALOG INTEGRATED CIRCUIT DESIGN		

INDEPENDENT TEACHING ACTIVITIES *In cases where credits are awarded to discrete parts of the course (e.g., Lectures, Laboratory Exercises, etc.), specify them. If credits are awarded as a whole, specify weekly teaching hours and total credits.*	**WEEKLY TEACHING HOURS**	**ECTS**
Lectures – Exercises	2	6
Laboratory	1	
Assignments	0	
(Additional rows may be added if necessary. Detailed descriptions of teaching organization and methods are provided in section (d).)		

COURSE TYPE *general background, specialized background, specialization, skill development*	SPECIALIZATION
PREREQUISITES:	[REQUIRED BACKGROUND KNOWLEDGE]: Electronics I, II, and III. Basic knowledge of Mathematics (differential equations, linear algebra). Full familiarity with signal analysis in the frequency domain, as well as fundamental knowledge of signal processing and automatic control (stability, dynamic systems, etc.). An interest in integrated circuit design.
LANGUAGE OF INSTRUCTION and EXAMINATION:	GREEK
COURSE AVAILABLE TO ERASMUS STUDENTS	YES (offered in English as a reading course).
COURSE WEBSITE (URL)	https://helios.ntua.gr/course/view.php?id=915

(2) LEARNING OUTCOMES

Learning Outcomes

This section describes the learning outcomes of the course, specifying the knowledge, skills, and competencies at the appropriate level that students will acquire upon successful completion of the course.

Refer to Appendix A:

- *Description of the Level of Learning Outcomes for each cycle of studies according to the European Higher Education Area Qualifications Framework*
- *Descriptive Indicators for Levels 6, 7, & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B.*
- *Concise Guide to Writing Learning Outcomes*

Knowledge:

The course is co-taught with the advanced undergraduate course "Analog Microelectronic Circuit Design" of the 8th semester in the School of Electrical and Computer Engineering at NTUA. It offers a detailed presentation of the principles of design and optimization of analog and mixed-signal circuits in CMOS and BiCMOS technologies. The content includes: small- and large-signal models, a systematic methodology for component sizing and biasing, basic circuit structures, operational amplifiers and transconductors, fundamental design techniques, analysis and study of voltage regulator and current-voltage stabilizer circuits. Additionally, it covers low-power circuits for machine learning applications, large-signal behavior issues, principles of switched-capacitor circuits, continuous-time filters, data converters (analog-to-digital), Sigma-Delta converters, and circuit structures for telecommunications circuits and signal processing. The course includes a final design project.

Skills:

Upon successful completion of the course, students will be able to:

- Understand the rationale behind choosing fundamental biasing circuits and make informed design decisions.
- Model and apply basic principles of optimization in the design process.
- Comprehend, analyze, and design fundamental circuits for industrial applications.
- Comprehend, analyze, and design essential circuits for machine learning applications.
- Gain familiarity with tools for the design, analysis, and simulation of analog integrated circuits.
- Understand design specifications and select the appropriate topology for each design challenge.

General Competencies

Considering the general competencies that graduates are expected to acquire (as stated in the Diploma Supplement), which competencies does this course aim to develop?.

Data search, analysis, and synthesis, utilizing necessary technologies *Adaptability to new situations* *Decision-making* *Independent work (primarily through assignments completed at home)* *Teamwork* *Working in an international environment* *Working in an interdisciplinary environment*	*Generation of new research ideas* *Project design and management* *Respect for diversity and multiculturalism* *Respect for the natural environment* *Exhibiting social, professional, and ethical responsibility and sensitivity to gender issues* *Critical and self-critical thinking* *Promotion of free, creative, and inductive thinking*

Competencies:

Upon successful completion of the course, students will develops the ability to:

- Work independently (and, secondarily, collaboratively through assigned group projects).
- Seek out, analyze, and synthesize data and information, utilizing the necessary technologies.
- Gain familiarity with design techniques.
- Become proficient with simulation software.
- Evaluate the structure and functionality of integrated circuits.
- Make design decisions and implement appropriate design choices.

(3) COURSE CONTENT

Introduction to CMOS and BiCMOS technologies, properties of the integrated components, large and small-signal models. Analog IC layout techniques and concepts in Design for Manufacturability (DFM), including Process, Voltage and Temperature (PVT) variation and components' mismatch analysis using local and global corner and Monte-Carlo simulation. Biasing and basic amplification circuits. Operational amplifiers and transconductors, linearization techniques, chopping and switch-capacitor circuits and concepts of gm-C filters. Sample-and-hold circuits, comparators and concepts of D/A and A/D converters. Design of power management circuits including bandgap references, regulators, and charge-pump circuits. Basic concepts in high-frequency models and operation of semiconductor devices. Elements of RF communication systems and transceiver architectures, impedance matching, RF low-noise amplifiers, Phase-Locked Loops (PLL) and their core components including Voltage-controlled oscillators (VCO). Introduction to analog implementation of Machine Learning (ML) algorithms. Design of analog ML classifiers based on Gaussian function and winner-take-all circuits. Co-design of hardware and software for analog intensive machine learning systems. Analog/RF IC design and simulation flow with extensive use of EDA tools (Cadence Virtuoso Studio) – Semester design project.

(4) TEACHING AND LEARNING METHODS - ASSESSMENT

TEACHING METHOD *In person, Distance Learning etc.*	In person
USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) *Use of Information and Communication Technologies (ICT) in Lecturing, Laboratory Training, Communication with Students*	Course Notes, Assignments for Home Study **(**Assignments are provided by the lecturer, and students are required to submit completed work)
ORGANIZATION OF TEACHING *A detailed description of the teaching methods and approaches used in the course, which may include:* *Lectures, Seminars, Laboratory Exercises, Fieldwork, Study and Analysis of Bibliography, Tutorials, Internships, Clinical Exercises, Art Workshops, Interactive Teaching, Educational Visits, Project Development, Report Writing/Assignments, Artistic Creation.* *The student's study hours for each learning activity, as well as hours of independent study, are outlined in accordance with ECTS principles.*	(see table below)

Activity	*Semester Workload*
Lectures	13x3=39 hours
Study	13x4=52 hours
Home Assignments/Exercises	13x4=52 hours
Laboratory	
Completion/Presentation of Project	29 hours
Educational Visits	0
Examinations	3 hours
Total Course Load	[ECTS×13×2,2] 174]

STUDENT ASSESSMENT *Description of the Assessment Process* *Language of Assessment, Assessment Methods, Formative / Summative Assessment Methods, Multiple-choice tests, Short-answer questions, Essay-style questions, Problem-solving exercises, Written assignments, Reports, Oral examinations, Public presentations, Laboratory work, Clinical patient examinations, Artistic interpretations, Other methods, as appropriate* *The assessment criteria are clearly defined and provided to students, ensuring transparency in the evaluation process. These criteria are accessible through the course's online platform where students can review them at any time.*	Language of Assessment: Greek (for Erasmus students: English) Individual design project of an integrated voltage regulator: schematic-level design mandatory, physical design (layout) optional: 60% of the final grade Alternative project: design of integrated circuits implementing an analog classifier: 60% of the final grade Problem sets on: MOS transistor behavior modeling, analysis/synthesis of basic analog microelectronic circuits: 20% of the final grade Oral/Written Examination on the design project and design choices: 20%)

(5) RECOMMENDED BIBLIOGRAPHY

Recommended Bibliography

1) For the MOS Transistor

- *Y. Tsividis, "Mixed Analog-Digital VLSI Devices and Technology," McGraw-Hill, 1995.*
- *Y. Tsividis, "Operation and Modeling of the MOS Transistor," McGraw-Hill, 1987, and second edition 1998.*

2) For SPICE

- *P. T. Tuinenga, "SPICE - A Guide to Circuit Simulation and Analysis Using PSpice," Prentice Hall, 1988.*
- *P. Antognetti and G. Massobrio, "Semiconductor Device Modeling with SPICE," McGraw-Hill, 1988.*

3) For Analog Microelectronic Circuit Design

- *Tony Chan Carusone, David A. Johns, Kenneth W. Martin, "Analog Integrated Circuit Design," 2nd edition (excellent for understanding all basic design stages and options).*
- *P. Grey and R. Meyer, "Analysis and Design of Analog Integrated Circuits," J. Wiley, 3rd edition (very useful for bipolar transistors).*
- *R. Geiger, P. Allen, and W. Strader, "VLSI Design Techniques for Analog and Digital Circuits," McGraw-Hill, 1990.*
- *Gregorian and Temes, "Analog MOS Integrated Circuits," J. Wiley, 1986.*
- *B. Razavi, "Design of Analog CMOS Integrated Circuits," McGraw-Hill, 2000.*
- *D. A. Jones and K. Martin, "Analog Integrated Circuit Design," J. Wiley, 1997.*

4) Analog Layout

- *Alan Hastings, "The Art of Analog Layout," Prentice Hall, 2001.*
- *Dan Clein, "CMOS IC Layout: Concepts, Methodologies and Tools," Newnes, 2000.*