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	**9955**	**SEMESTER**	**2**
COURSE TITLE	MICRO- NANOSENSORS		

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	0.5	
Assignments	0.5	
(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*	SPECIALIZED BACKGROUND (for Specialization Courses) SPECIALIZATION (for Stream or Specialization Compulsory Courses)
PREREQUISITES:	[REQUIRED BACKGROUND KNOWLEDGE]: Technological Processes for Integrated Circuit Fabrication, Basic Electronic Circuits
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=3011

(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:

This course is designed to specialize students in micro/nano sensors used for measuring physical and biochemical parameters. It begins with an introduction to the fundamental characteristics of sensors, including their categorization and the physical principles underlying their operation. The course then covers cutting-edge technology for the fabrication of micro/nano sensors on silicon, integrating these with established silicon-based IC manufacturing processes.

To reinforce these foundational principles and fabrication techniques, specific examples of physical sensors (pressure, acceleration, flow) are examined. This is followed by a detailed study of chemical and biochemical sensors, emphasizing the advantages of incorporating nanomaterials. The course concludes with an overview of the essential electronic circuits for data acquisition and transmission from sensors, bridging the gap between sensor fabrication technology and practical sensor applications.

Skills:

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

- Evaluate a sensor based on its operational characteristics (sensitivity, hysteresis, linearity, etc.).
- Select the most appropriate physical operating principle for designing a micro/nano sensor.
- Integrate the physical operating principle with the fabrication technology for designing a silicon-based micro/nano sensor.
- Incorporate new materials with silicon to enhance sensor development.
- Understand the mechanisms for substance identification in biochemical sensors.
- Design the calibration process for sensors to ensure accuracy and reliability.
- Recommend suitable electronics for sensor signal acquisition to optimize data reading.
- Choose the optimal data transmission method to relay sensor data to a central processing unit for decision-making.

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 develop the ability to:

- Formulate the physicochemical measurement problem to be solved.
- Select the most appropriate physical principle for the operation of the sensor to be developed or utilized.
- Determine the optimal technology for designing and fabricating the sensor.
- Evaluate sensor behavior and performance to assess its effectiveness.
- Integrate the sensor with appropriate electronics for signal acquisition and transmission, creating a complete measurement system.
- Independently analyze internationally published scientific research in the field.
- Organize and present scientific work effectively to an audience.

(3) COURSE CONTENT

- Chapter 1: Sensors and Their Evolution into Integrated Microsystems. This chapter provides a brief overview of the field of microsensors and connects it to the related technology of integrated circuits (ICs).
- Chapter 2: Physical Principles of Sensors. Examines various physical phenomena widely used to convert an input signal into an electrical signal that can be processed by electronic circuits.
- Chapter 3: Fabrication Processes for Microelectronic and Micromechanical Devices – The Nano Dimension. Focuses on the core technological processes for manufacturing microelectromechanical systems (MEMS), with an emphasis on micromechanical processes

rather than electronic device fabrication, as this topic is covered in the "Micro-Nanosystem Fabrication Processes" course.

- Chapter 4: Physical Sensor Devices. Provides examples of sensors used for measuring physical quantities such as pressure, acceleration, temperature, and magnetic field.
- Chapter 5: Chemical/Biological Sensor Devices. Covers examples of sensors designed for the detection of biochemical molecules and the identification of substances.
- Chapter 6: Basic Electronic Circuits. Covers operational amplifiers and basic circuits (inverting, non-inverting, differential, integrator), noise effects, and specialized operational amplifiers (transimpedance, charge amplifier), as well as DC and AC bridges and circuits for measuring resistance and capacitance.
- Chapter 7: Digitalization of Analog Signals. Discusses circuits for converting capacitance to frequency (C/F), voltage to frequency (V/F), and analog-to-digital (A/D) conversion.
- Chapter 8: Basic Types of Sensors Based on Their Response and Readout Circuits. Covers variable resistance sensors, variable voltage sensors, variable current sensors (including photodetectors), and variable capacitance sensors.
- Chapter 9: Sensor Data Management. Introduces platforms and software for sensor data management, data transmission methods including wired transmission (serial communication protocols like RS-232, RS-485, Fieldbus) and wireless transmission (WiFi, Zigbee, Bluetooth).

(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, through Helios platform)
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 workload table below)
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*	**Language of Assessment:** Greek (for Erasmus students: English) **Home Assignments:** 10% of the final grade **Written Examination (problem-solving):** 50% of the final grade **Laboratory**: 10% of the final grade **Completion/Presentation of Project** 30% of the final grade

Activity	*Semester Workload*
Lectures	3x11=33 hours
Study	3x11=33 hours
Home Assignments/Exercises	3x2=6 hours
Laboratory	3x2=6 hours
Completion/Presentation of Project	25x1=25 hours
Educational Visits	0
Examinations	2 hours
Total Course Load	115 hours [ECTS×13×2,2]

the evaluation process. These criteria are accessible through the course's online platform where students can review them at any time.	Explicit mention of these assessment criteria will be available on the Helios platform.

(5) RECOMMENDED BIBLIOGRAPHY

Recommended Bibliography

Julian Gardner 'Microsensors: Principles and Applications' Winfield Hill
Marc Madou 'Fundamentals of microfabrication' CRC Press
Stephen Senturia 'Microsystem Design' Kluwer Academic Publishers
Ramon Pallas-Areny 'Sensors and Signal Conditioning' John Webster

Relevant Scientific Journals

Sensors and Actuators (A and B)
Journal of Microelectromechanical Systems
IEEE Sensors