**Universitatea Naţională de Ştiinţă şi Tehnologie Politehnica Bucureşti**
**Facultatea de Electronică, Telecomunicaţii şi**
**Tehnologia Informaţiei**

# COURSE DESCRIPTION

## 1. Program identification information

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| 1.1 Higher education institution | **National University of Science and Technology Politehnica Bucharest** |
| 1.2 Faculty | **Electronics, Telecommunications and Information Technology** |
| 1.3 Department | **Electronic Devices, Circuits and Architectures** |
| 1.4 Domain of studies | Electronic Engineering, Telecommunications and Information Technology |
| 1.5 Cycle of studies | Masters |
| 1.6 Programme of studies | Micro and Nanoelectronics |

## 2. Date despre disciplină

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|---|---|---|---|---|---|---|---|
| 2.1 Course name (ro)<br>(en) | | | | Biosenzori integrați | | | |
| 2.2 Course Lecturer | | | | Prof. Dr. Cristian Ravariu | | | |
| 2.3 Instructor for practical activities | | | | Prof. Dr. Cristian Ravariu | | | |
| 2.4 Year of studies | 1 | 2.5 Semester | 2 | 2.6. Evaluation type | E | 2.7 Course regime | Ob |
| 2.8 Course type | | S | 2.9 Course code | 3 | | 2.10 Tipul de notare | Nota |

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

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|---|---|---|---|---|---|
| 3.1 Number of hours per week | 3 | Out of which: 3.2 course | 1 | 3.3 seminary/laboratory | 2 |
| 3.4 Total hours in the curricula | 42 | Out of which: 3.5 course | 14 | 3.6 seminary/laboratory | 28 |
| Distribution of time: | | | | | hours |
| Study according to the manual, course support, bibliography and hand notes<br>Supplemental documentation (library, electronic access resources, in the field, etc)<br>Preparation for practical activities, homework, essays, portfolios, etc. | | | | | 25 |
| Tutoring | | | | | 5 |
| Examinations | | | | | 8 |
| Other activities (if any): | | | | | 20 |

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| 3.7 Total hours of individual study | 58.00 |
| 3.8 Total hours per semester | 100 |
| 3.9 Number of ECTS credit points | 4 |

## 4. Prerequisites (if applicable) (where applicable)

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| 4.1 Curriculum | Completion and/or promotion of the following subjects:<br>Electronic Devices<br>Spice or MCMA models<br>BSAD or Circuits for Sensors course |

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| 4.2 Results of learning | As prerequisites, the results of the general education in physics, electronic sensors and modeling of active electronic devices, simulation programs (in Athena, Atlas environments) |

**5. Necessary conditions for the optimal development of teaching activities** (where applicable)

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| 5.1 Course | The course will be held in a room equipped with video projector and computer, or through any online method agreed by the University, in special situations. |
| 5.2 Seminary/ Laboratory/Project | Completion and/or promotion of the following subjects:<br>The laboratory will take place in a room with specific equipment, which must include: video projector and laptop, or e-learning facilities, such as Moodle or Teams |

**6. General objective** *(Reffering to the teachers' intentions for students and to what the students will be thought during the course. It offers an idea on the position of course in the scientific domain, as well as the role it has for the study programme. The course topics, the justification of including the course in the currcula of the study programme, etc. will be described in a general manner)*

This discipline is studied within the field of electronic sensors and bioelectronics and aims to familiarize students with the main approaches, models and explanatory theories of the field, used in solving practical applications and problems, with relevance for stimulating the learning process in students.

The Integrated Biosensors discipline addresses as a specific topic basic notions of the elements and principles of detection with biological receptors, with transducers from active electronic devices, specific concepts and principles in the field of biosensors, biosensor integration technologies and enzyme transistors, all of which contribute to the transmission/ providing students with an overview on the methodological and procedural benchmarks related to this continuously expanding field.

**7. Competences** *(Proven capacity to use knowledge, aptitudes and personal, social and/or methodological abilities in work or study situations and for personal and proffesional growth. They refflect the empolyers requirements.)*

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| **Specific Competences** | - Knowledge of the structure and properties of nanotechnologies used for the integration of biomaterials as receptor elements for bio-sensors;<br>- The use of software tools for the advanced simulation of both active transducer devices in sensors and specific technological processes;<br>-The acquisition and deepening of some knowledge for training students in the design of active electronic devices for the purpose of bio-detection, including narrow ranges of analyte concentrations in the living world, as well as the simulation-modeling of electrical phenomena that interfere with the living world, applying the theoretical knowledge from Electronic Devices and Spice Models, adding specific knowledge of bio-electronics, including bio-signals. |
| **Transversal (General) Competences** | - The fulfillment of professional tasks with the exact identification of the objectives to be achieved, potential risk factors, available resources, economic-financial aspects, the conditions for their completion, work stages, working time and deadlines for the sphere bio-sensors;<br>- Responsible execution of tasks in a multidisciplinary team, assuming roles on different hierarchical levels for various fields in bio-detection;<br>- Identifying the need for continuous training and the effective use of information sources and communication resources and assisted professional training both in Romanian and in an internationally spoken language. |

**8. Learning outcomes** *(Synthetic descriptions for what a student will be capable of doing or showing at the completion of a course. The learning outcomes reflect the student's acomplishments and to a lesser extent the teachers' intentions. The learning outcomes inform the students of what is expected from them with respect to performance and to obtain the desired grades and ECTS points. They are defined in concise terms, using verbs similar to the examples below and indicate what will be required for evaluation. The learning outcomes will be formulated so that the correlation with the competences defined in section 7 is highlighted.)*

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| **Knowledge** | *The result of knowledge aquisition through learning. The knowledge represents the totality of facts, priciples, theories and practices for a given work or study field. They can be theoretical and/or factual.*<br>Establishing the stages that marked the development of the field of bio-sensors and integration in Electronics: the development of the MOS transistor, the deviation of the integration technology towards ISFET ion detector transistors, then towards Enzyme-FET transistors.<br>· Notions specific to the field of sensors and enzyme receptor elements and active transducers for biosensors: technologies for the integration of enzymatic membranes in solid state on the Silicon wafer.<br>· Notions/processes/phenomena/structures: Electrophoresis as a biodetection technique, Nerst potentials, Currents according to Butler-Volmer models, Electronic biosensors: analytes, receiver blocks, transducers from transistors subject to sub-micron scaling / Technologies for biosensors: immobilization of enzymes on platelets.<br>· Consequences and relationships: Integrated biosensors can no longer be made in biochemistry laboratories, but in the white rooms of microelectronics factories, because today we have the manufacturing technologies<br>for Enzyme-FET in the same technological area as MOS circuits. Biodetection of either electrical signals or active substances from the living world determines interdisciplinary study relationships. |
| **Skills** | *The capacity to apply the knowledge and use the know-how for completing tasks and solving problems. The skills are described as being cognitive (requiring the use of logical, intuitive and creative thinking) or practical (implying manual dexterity and the use of methods, materials, tools and intrumentation).*<br>- Graduates can elaborate relevant information in various contexts of integrated biosensors: Enzyme-FET transistors, Ion Sensitive FET, DNA-FET, but also co-integration technologies.<br>· Graduates use specific principles with reason for the use, application, design, technology of transistors with integrated biomaterials.<br>· Graduates are encouraged to work productively in a team.<br>· The graduates of this course are encouraged to develop a scientific text in the field of biosensors.<br>· Graduates of this course are encouraged to experimentally verify identified solutions.<br>· Graduates of this course are encouraged to solve practical applications in the field of manufacturing electronic biosensors integrated with transistors.<br>· Graduates of this course are stimulated to adequately interpret causal relationships.<br>· Graduates of this course are encouraged to analyze and compare the optimal functions of various types of transducers for an electronic biosensor.<br>· Graduates of this course are encouraged to develop project solution plans, through project-type applications.<br>Graduates of this course are encouraged to formulate experimental conclusions. |

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| **Responsability and autonomy** | *The student's capacity to autonomously and responsably apply their knowledge and skills.*<br>- Graduates of this course are encouraged to select appropriate bibliographic sources and analyze them.<br>· The graduates of this course are encouraged to respect the principles of academic ethics, correctly citing the bibliographic sources used in the semester project.<br>· Graduates of this course are encouraged to demonstrate receptivity to new learning contexts.<br>· Graduates of this course are encouraged to show collaboration with other colleagues and teaching staff in carrying out teaching activities, during each course, through training to answer questions, or through student presentations of projects.<br>· Graduates of this course are encouraged to demonstrate autonomy in organizing the learning situation/context, as each student has to solve their own part of the individual problems in a project.<br>· Graduates of this course are encouraged to promote/contribute through new solutions, related to the specialized field to improve the quality of social life, being trained every year to publish original works at the student session, but also in specialized journals.<br>· Graduates of this course are encouraged to recognize the technological impact of the solutions proposed in the specialized field on the environment.<br>· Analyze and capitalize on business/entrepreneurial development opportunities.<br>Demonstrates management skills in real-life situations. |

**9. Teaching techniques** *(Student centric techniques will be considered. The means for students to participate in defining their own study path, the identification of eventual fallbacks and the remedial measures that will be adopted in those cases will be described.)*

Starting from the analysis of the students' learning characteristics and their specific needs, the teaching process of the Integrated Biosensors subject will explore both expository (lecture, exposition) and conversational-interactive teaching methods, based on learning models through discovery facilitated by the direct and indirect exploration of reality (experiment, demonstration, modelling), but also on action-based methods such as exercise, hands-on activities and problem solving.

In the teaching activity, lectures are used, based on some Power Point presentations, but also different videos that are made available to the students. Each course begins with the recapitulation of the chapters already covered, with an emphasis on the concepts covered in the last course.

Presentations use images and diagrams so that the information presented is easy to understand and assimilate.

The Biodevices and Cellular Nano-electronics discipline covers information and practical activities aimed at supporting students in their learning efforts and the development of optimal collaboration and communication relationships in a climate conducive to learning through discovery.

The practice of active listening and assertive communication skills, as well as feedback construction mechanisms, are considered as ways of regulating behavior in various situations and adapting the pedagogical approach to the students' learning needs.

Teamwork skills will be practiced to solve different learning tasks.

**10. Contents**

| **COURSE** | | |
|---|---|---|
| **Chapter** | **Content** | **No. hours** |
| 1 | Introduction to the design and manufacturing of sensors | 2 |

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|---|---|---|
| 2 | Biodetection and specific problems of receiver-transducer integration | 2 |
| 3 | Models for potentiometric and amperometric biosensors | 2 |
| 4 | Analytes, receivers, transducers | 2 |
| 5 | ISFET bio-transistors and Enzyme-FET | 2 |
| 6 | Biosensor integration technologies | 4 |
| | **Total:** | 14 |

**Bibliography:**

1. Moodle course material website: https://curs.upb.ro/2021/course/view.php?id=9273
2. Cristian RAVARIU, MOSFET with tips and tricks, Politehnica Press Publisher, e-Book 105pp, Bucharest, Romania, March 2023, (in English). ISBN: 978-606-9608-41-8.
3. Florin Babarada, Cristian Ravariu. Technologies of fabrication for micro and biosensors, pp. 1-258, Publisher: Printech Romania, 2004, ISBN 973-718-119-0.
4. Ravariu C, Parvulescu CC, Manea E, Tucureanu V. Optimized Technologies for Cointegration of MOS Transistor and Glucose Oxidase Enzyme on a Si-Wafer. Biosensors. 2021; vol. 11, no. 12, pp.497, Q1-MDPI.
5. Ravariu, C. From Enzymatic Dopamine Biosensors to OECT Biosensors of Dopamine. Biosensors, 2023, 13(8), 806, pp.1-21, https:// doi.org/10.3390/bios13080806, Q1-MDPI.
6. C. Ravariu, E. Manea, F. Babarada, Masks and metallic electrodes compounds for silicon biosensor integration, Journal of Alloys and Compounds, Elsevier, 2017, vol. 697, pp. 72-79, March 2017, Q1-MDPI.
7. Ravariu, C.; Srinivasulu, A.; Mihaiescu, D.E.; Musala, S. Generalized Analytical Model for Enzymatic BioFET Transistors. Biosensors 2022, 12(7), 474, Q1-MDPI.
8. Cristian Ravariu, Cătălin Pârvulescu, Elena Manea, Adrian Dinescu, Raluca Gavrila, Munizer Purica, Vijay Arora, "Manufacturing of a Nothing On Insulator Nano-Structure with two Cr/Au Nanowires Separated by 18 nm Air Gap," Nanotechnology IOP, vol. 31, no. 27, pp.1-9, 2020, Q1-Red zone/2020
9. C. Ravariu, Vacuum nano-triode in Nothing-On-Insulator configuration working in Terahertz domain, IEEE Journal of the Electron Devices Society, vol. 6, no. 1, 2018, pp. 1115-1123, DOI 10.1109/JEDS.2018.2868465, ISSN: 2168-6734, IF=2.69, Yellow zone /2018.
10. Cristian Ravariu, Ala Bondarciuc. The sensitivity in the IR spectrum of the intact and pathological tissues by laser bio-photometry, Laser in Medical Science, Springer Journal, March 2014, Volume 29, Issue 2, pp 581-588. DOI 10.1007/s10103-013-1358-6, ISSN: 0268-8921, IF=2.003, indexed in: ISI, PubMed/MEDLINE, SCOPUS, INSPEC, Biological Abstracts, BIOSIS, Current Contents/Clinical Medicine. WOS:000333051700024. Red zone / 2013
(Surgery).

**LABORATORY**

| Crt. no. | Content | No. hours |
|---|---|---|
| 1 | Methods of simulating transistor technology in Athena; check along the way | 8 |
| 2 | IS-FET transistor simulation methods in Atlas; check along the way | 8 |
| 3 | Enzyme FET transistor simulation methods; check along the way | 8 |
| 4 | Final check | 4 |
| | **Total:** | 28 |

**Bibliography:**
Moodle website: https://curs.upb.ro/2021/course/view.php?id=9273
. Ravariu C., Manea E., Babarada F., Ursutiu D., Mihaiescu D., Popescu A. "Organic Compounds Integrated on Nanostructured Materials for Biomedical Applications", Chapter 2 at section Biomedical Engineering in the book: Smart Industry & Smart Education . Publishers:
Auer M., Langmann R., Series - Lecture Notes in Networks and Systems, vol 47, Jan 2019, pp 489-497, DOI:10.1007/978-3-319-95678-7_55, Publisher Name - Springer, 2367-3370 .
. Cristian Ravariu, Vijay Arora, Modeling of Enzyme-FET Biosensor Based on Experimental Glucose-Oxidase Receptor, ID 1236, 43rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 30 - November 5, 2021.
. Cristian Ravariu, Dan E. Mihaiescu, Daniela Istrati, Elena Manea, Catalin Parvulescu, Application of the Nonlinear Electrical Conduction Theorem to Emphasize the Optimized Biosensor Sensitivity, The 11th IEEE International Symposium on Advanced Topics In Electrical
Engineering, Bucharest, Romania, March 28-30 2019, pp. 94:1-4.
. The database of the Elsevier Journal Q1 - Biosensors and Bioelectronics, the Open Access Database of the Red Zone MDPI Journal - Biosensors and the Database of the IEEE Electron Devices Society EDS Journals, where C. Ravariu is Chairman for Romania at EDS-Romania.

**11. Evaluation**

| Activity type | 11.1 Evaluation criteria | 11.2 Evaluation methods | 11.3 Percentage of final grade |
|---|---|---|---|
| 11.4 Course | - knowledge of fundamental theoretical notions | written exam in the session | 20% |
| | knowing how to apply the theory to specific problems | written exam in the session | 20% |
| | - verifying the acquisition of theoretical knowledge during the semester | homework during the semester | 20% |
| 11.5 Seminary/laboratory/project | - knowledge of the operating principles of ISFET and EnFET transistors | During the performance of the works in weeks 1-11 | 20% |
| | - oral defenses of semester papers | Weeks 12-14 | 20% |
| 11.6 Passing conditions | | | |
| Obtaining 50% of the total score.<br>Knowing the differences and distinctive characteristics of ISFET - EnFET transistors.<br>Acquiring technology simulation techniques for an integrated BioFET. | | | |

**12. Corroborate the content of the course with the expectations of representatives of employers and representative professional associations in the field of the program, as well as with the current state of knowledge in the scientific field approached and practices in higher education institutions in the European Higher Education Area (EHEA)**

Integrated biosensors, in the current context of the creation of new sensors, for multiple and simultaneous recording of medical analyses, in complementarity with medical electronics and nano-bio-technologies and microelectronics, have become a constant component of the topics of some top international journals, the area Q1-Q2 red - yellow, IEEE-Elsevier-Springer-MDPI, such as Biosensors and Bioelectronics, Biosensors, Lab-On-Chip, and many international conferences (including CAS, ESSDERC, but also the traditional

BIOMED, EMB). Some of the companies and institutions that have interacted over the years with the course holder and implicitly polished the Integrated Biosensors discipline are: MERK, Meckrosistem, Spectrum SRL, Seletron SRL, Tehno-Industrial SRL, IMT, Inst. Paulescu, ICPE-CA, Inst. Cantacuzino, LAAS-Toulouse France, Fac.

of Bioengineering Patras Greece, UEFISCDI, Romanian Academy. More and more in recent years, the industry has an important demand for qualified engineers in interdisciplinary fields, such as that of sensors and especially of integrated biosensors, because the applications are multiple - from remote patient monitoring, but also biosensors for cars , aircraft, equipment.

The course curriculum responds concretely to these current development and evolution requirements, subscribed to the European and world economy, of services in the field of electronic and telecommunications engineering. "Consumer" applications, personalized technologies and applications of biosensors, integration of enzyme testers on Silicon substrate, the medical field, in vitro or in vivo biosensors for the analysis of biological environments, including human or veterinary origin, but also top fields such as micro-nanoprocessing in Si.

Thus, graduates are allowed a quick job after graduation, the course being perfectly framed in the policy of the National Polytechnic University of Science and Technology in Bucharest, both from the point of view of content and structure, as well as from the point of view of the skills and international openness offered the students.

| Date | Course lecturer | Instructor(s) for practical activities |
|---|---|---|
| 21.09.2026 | Prof. Dr. Cristian Ravariu | Prof. Dr. Cristian Ravariu |

| Date of department approval | Head of department |
|---|---|
| 22.09.2026 | Prof. Dr. Claudius Dan |

| Date of approval in the Faculty Council | Dean |
|---|---|
| 22.09.2026 | Prof. Dr. Mihnea Udrea |