INTEGRATED COURSE: BIOELECTRONICS

Electronic Devices Module: it is advised that the student take Physics 1 and 2 before undertaking this course.

Bioelectronics Interface Module: it is advised that the student take Electronic Devices before undertaking this course.

Electronic Devices Module: Specific course training objectives

The course’s objective is to provide the student with information about basic physics and the functioning of simple electronic devices. Using a knowledge of physics as a point of departure, the student will be in a position to understand the physical action of the most important electronic devices (diode and transistor).

Indicator of comprehension skills and knowledge

The course’s goal is to promote, in the student, an understanding of the basic mechanisms for the functioning of electronic devices, with the objective of applying those concepts to the examination of any type of device, based on analog properties of matter.

Indicator of comprehension skills and application of knowledge

The course will provide an adequate number of exercises, with the goal of preparing the student for the application of theoretical knowledge he or she has acquired to practice cases.

Indicator of independent judgment

The course’s intent is to illustrate, for the student, a physics analysis method, the validity of which will be tested through questions and multiple responses that should highlight the student’s acquired autonomy in relation to his or her critical application of acquired knowledge.

Indicator of communication skills

The program’s topics will be fully discussed and the student will be evaluated, at the time of the exam, in terms of his or her ability to orally sustain a discussion relative to the problems covered by the course.

Indicator of independent learning skills

The exam’s structure is, for the most part, methodological: individual devices (those which are most used in the field of microelectronics) are presented as cases that are applications of a more general kind of theory that also could be applied to other cases. The student’s ability to apply the knowledge he or she will acquire will, above all, be evaluated through an oral exam, and also in relation to applicable cases presented during class.

Bioelectronic Interface Module: Course’s specific training objectives

The course’s objective is to provide the student with information on the basics physics involved with the interactions between biological molecules/molecular systems interest, and inorganic microelectronic systems. Using a knowledge of physics and of electronic devices, the student should come to understand the physical behavior of such devices, which are suitable for measuring biological parameters.

Indicator of comprehension skills and knowledge
The course’s goal is to promote, in the student, an understanding of the basic mechanisms involved in interactions of and between biological molecules, above all, from the point of view of the generation of microelectronic devices measurable electric signals. For that reason, biological systems will be presented from the point of view of electronic action (that is to say, as circuit components or objects which are capable of generating an electrical signal).

Indicator of comprehension skills and the ability to apply knowledge

The course will offer students the opportunity to apply the basic knowledge they have acquired through a consideration of some examples of bioelectronic devices.

Indicator of independent judgment

The course’s intent is to illustrate, for the student, a physics analysis, whose validity is general in nature. For that reason, the student should be able to apply his or knowledge to different cases. This skill will be verified through an oral exam.

Indicator of communication skills

The program’s topics will be fully discussed, and the student will be evaluated, at the time of the exam, in terms of his or her ability to orally sustain a discussion relative to the problems covered by the course.

Indicator of independent learning skills

The exam’s structure is, for the most part, methodological: individual devices (those which are most used in the field of microelectronics) are presented as cases that are applications of a more general kind of theory that also could be applied to other cases. The student’s ability to apply the knowledge he or she will acquire will, above all, be evaluated through an oral exam, and also in relation to applicable cases presented during class.

Electronic devices module:

1) Physical properties of semiconductors
   - Brief description of quantum mechanics: energy atom model
   - From the atom to crystals: energy band model, population band, Fermi level, Fermi-Dirac statistics
   - Classification of materials that are basic to conductivity: metals, semiconductors, insulators
   - Intrinsic and extrinsic semiconductors; mobility, laws related to the action of mass
   - Diffusion, Einstein’s Law

2) PN junction:
   - General: structure and distribution of internal electrical fields, equilibrium band diagram, intrinsic tension
   - Solution to the Poisson equation, in abrupt and linear gradient cases
   - C-V characteristics; Equations I-V, in ideal cases
   - Non ideality: influence of the dimensions of the junction’s sides, generation-recombination effects
   - Resistance effects of neutral regions, and regions with a high degree of injection
- Junction breakdown
- Equivalent circuits: small signal concept, linearization of characteristic curves

3) Metallic semiconductor contacts:
- General: structure, equilibrium band diagram, classification of basic energy interfaces
- Schottky contact: definition of barrier height, analysis of internal electrical fields and charge distribution, derivation of tension-current characteristics, C-V characteristics, deviation from ideality
- Classification of interfaces: chemical/physical effects
- Ohmic case, concept of specific Resistance

4) Field effect transistor
- The transistor as an active device: functionality of the transistor, field effect
- MOS structure: analysis of the band diagram, charge distribution, Poisson equation solution, internal distribution of power; Capacity-Tension characteristics
- MOSFET: analysis of physical action, derivation of current equation, C-V characteristics, equivalent circuit model.

5) Diode and transistor circuits
- Simple examples of circuits and circuit solutions.

Bioelectronic interface module:

1) ELECTIVE ELECTRONIC DEVICES COURSES
   The bipolar transistor

2) MICROELECTRONIC TECHNOLOGIES

3) BASIC PROPERTIES OF BIOLOGICAL MOLECULES
   Chemical and physical bonds. Interactions between ions and molecules, in a vacuum and inside of environments

4) Complex molecular systems: membranes, proteins, and nucleic acids

5) The cell

6) Electrical signals in cells: neurons, the power of action, the membrane considered as an electrical system, the power of electrical action as a conduction mechanism for cells
7) Bioelectronic interface: polarizable, non-polarizable, insulator interface

8) Devices based on bioelectronic interfaces: ISFET, CHEMFET

9) Devices based on the optical properties of materials: LAPS

Face-to-face classes and practice exercises, with tutor support.

Written exam/oral exam.


M. Guzzi, “Principi di fisica dei semiconduttori”, Hoepli Editore, Milano

S. M. Sze, “Dispositivi a semiconduttore, comportamento fisico e tecnologia”, Hoepli

R.S. Muller, T.I. Kamins, “Dispositivi elettronici nei circuiti integrati”, Bollati Boringhieri


Addison-Wesley Modular Series on Solid State Devices (sono una serie di volumi in inglese, ciascuno dedicato ad un particolare dispositivo)
