Curriculum Master in Smart Electronic Systems - International track - 2022-23

First year – Technical courses

Title	Semi-conductor devices 1 & 2
Goals	This course aims to cover the basics of the semiconductor devices starting with energy band gap physics, carrier doping and transport, leading to the understanding of common semiconductors devices.
Detailed content	• Introduction to semiconductors: concept of energy bands, concept of holes, Fermi level, density of states, effective masses, electron/hole densities. • PN junction physics and general applications: potential barrier, energy bands, drift and diffusion currents, transition and diffusion capacitances, equivalent circuit. • Bipolar transistor: PNP and NPN structures, static characteristic, large and small signal models, hybrid matrix elements, frequency limit, need for HBT. • Metal-semiconductor contacts: Schottky diode and ohmic contact. • Metal-Oxide-contacts: depletion, inversion and accumulation regimes, energy bands, MOS capacitance. • Field Effect Transistor: structures, static characteristic, diffusion capacitance, low and high frequency models. • Transistors for high-speed logic, transistor for high-frequency, transistor for high-power switching, transistor for low noise.
Bibliography	• S. M. SZE, YIMING LI, KWOK K. NG, Physics of Semiconductor Devices, Wiley-Blackwell; 4th edition, 2021. • Robert F. Pierret, Semiconductor Device Fundamentals, Pearson, 2nd edition, 1995.

Title	Sensors and Conditioning Circuits
Goals	This course teaches how to design an analog sensor interface and introduces analog to digital conversion.
Detailed content	The different class of sensors will be presented. AOP amplifier structures will be studied according to the sensor class and their linearity. The noise associated with the AOP will also be discussed. The design of active filters will be detailed by addressing the different approximations (Bessel, Butterworth, Papoulis,...) and low-pass, high-pass, band-pass types. The main principles of analog-to-digital conversion will be explained and applied in a lab. Finally, students will have to make a lux-meter sensitive to 50Hz artificial lighting as part of a mini project.
Bibliography	• Pallas-Areny R., Webster J. G., "Sensors and signal conditioning", Wiley edition • Fraden J., "Handbook of Modern Sensors", Springer edition

Title	Introduction to MEMS and Microelectronic Principles
Goals	The majority of sensors used in connected objects are now manufactured in integrated MEMS (Micro Electro Mechanical Systems) technologies and controlled by dedicated electronics, itself often integrated into the same manufacturing flow. This class will introduce the design and fabrication principles of these components, as well as their fields of application.
Detailed content	• Introduction to Integrated Circuit & MEMS Sensors and actuators (16h) - General introduction - Microfabrication principles - Integrated circuit principles - My first clean room lab • Electromechanical Transducers - Electrostatic Transducers - Other transduction mechanisms At the end of this class, the students will be able to understand the process for manufacturing an integrated component and the associated set of photolithography masks, and will understand the main transduction techniques used in MEMS sensors.
Bibliography	• Nadim Maluf and Kirt Williams, "An Introduction to Microelectromechanical Systems Engineering" Second Edition, Artech House, 2004

Title	Digital Signal Processing
Goals	This course aims to cover the basics of digital signal processing: at the end of the course, you should master the basic tools used in signal processing to analyze, modify or extract information from different types of signals. Note that certain prerequisites are necessary: the continuous and discrete time Fourier transform, the Z-transform, transfer functions and impulse response of discrete systems.
Detailed content	• The Discrete Fourier Transform as a tool for spectral representation of signals • Basic digital filter synthesis and analysis (IIR and FIR) • Properties and analysis of random signals (stationarity, correlation, power spectral density…)
Bibliography	• B. Porat, "Course in Digital Signal Processing", John Wiley & Sons, INC. • D. G. Manolakis, V. K. Ingle, "Applied Digital Signal Processing. Theory and practice", Cambridge University Press.

Title	Introduction to Optoelectronics and Photonics
Goals	The objective of this course is to provide students with a clear knowledge in the structure of semiconductor-based photonics and optoelectronics components, their physics and their structure. Students should be able to design new devices or to understand the technology to be used. The focus will be given on optical waveguides, photodetectors and lasers fundamentals.
Detailed content	• Photodetectors physics – PiN and APD devices • Lasers fundamentals – the Fabry-Perot cavity • Optical propagation – Fibers and Integrated Waveguides for PICs
Bibliography	• M.A. Herman, "Semiconductor Optoelectronics", John Wiley & Sons Editions • G. Lifantes, "Fundamentals of Photonics", Wiley, 2003 • S.Prasad, H.Schumacher, A.Gopinath, "High-speed Electronics and Optoelectronics (Devices and circuits)"

Title	Nanomaterials and Nanosensors
Goals	The objective of this course is to provide a survey of the main nanomaterials and their applications for sensing.
Detailed content	In the first part, we will introduce the fundamental knowledge for nanomaterials (history, definition, type of nanostructure (0D, 1D and 2D), synthesis methods, characterisation methods, and proprieties) and their applications. In the second part, we will focus on nanosensors application in particular. We will provide an overview of the state of the art of nanosensors, main elements for nanosensors, nanosensor fabrication, surface functionalisation and nanosensor applications. Among large nanosensor family, we will focus on semiconductor, carbon nanotubes & graphene-based nanosensors. As sensing process, both optical and electrical methods will be approached.
Bibliography	• Bharat Bhushan, "Springer Handbook of Nanotechnology", 3rd revised and extended edition, 2010 • Dieter Vollath, "Nanomaterials: An Introduction to Synthesis, Properties and Applications", 2nd Edition, Wiley-VCH, 2013 • Larry Nagahara, Nongjian Tao,Thomas Thundat, "Introduction to Nanosensors", Ed: Springer-Verlag New York Inc, 2007 • Kevin C. Honeychurch, "Nanosensors for Chemical and Biological Applications Sensing with Nanotubes, Nanowires and Nanoparticles", Ed. Elsevier, 2014

Title	Hands on Electronic PCB
Goals	The course "Hands on Electronics PCB" targets at providing a practical experience on Printed Circuit Boards to the students. It includes applied courses from a variety of industry players of the domain with a strong project-based approach. The course will browse the materials used for PBC, the mounting technologies and interconnects for a large variety of applications. Students will enable students to fabricate and populate their own PCB and will deal with state-of-the CAD tools and hardware technologies.
Detailed content	The course will cover the following sections: • PCB design rules; • PCB Industrial product: From the idea to the complete realisation; • Project on PCB for Analog-Digital application; • Industrial Design tools from the market: Cadence tools; • PCB materials and interconnects technologies; • Applications to Smart wearables; • PCB and plastronics

Title	General Introduction to IoT
Goals	This course teaches the main IoT standards and to get a good understanding of the PHY layer and budget link possibilities.
Detailed content	This course will lead students to understand the architecture of an IoT network and to identify the different protocols and their applications within the new standards in place. The different layers of the OSI model will be presented, with a focus on the lower ones. The antennas, link budget aspects and link probabilities aspects will be presented. The different possible digital modulations and their relevance to the IoT (data rate aspect, receiver sensitivity...) will be investigated. Spectrum management constraints will be addressed by presenting the different international and national regulatory institutions (ITU, CEPT, ARCEP, ANFR...). IEEE 802 protocols will be introduced, then classical protocols dedicated to IoT like Zigbee or 6LoWPAN will be focused on. This course will also include a series of practical labs on the physical layers of the OSI model (probability of contact, antenna design and experimental measurements of indoor propagation).
Bibliography	• Adryan B., Obermaier D., Fremantle P., “The Technical Foundations of IoT”, Artech House Mobile Communications Series • Raj P., Anupama C. R., “The Internet of Things”, CRC Press • Cirani S., Ferrari G., Picone M., Veltri L., “Internet of Things: architectures, protocols and standards”, Wiley edition

Title	Acquisition and Signal Processing in Biomedical Applications
Goals	The course is based on measuring and processing electrographic signals and is intended to give the knowledge on : How to choose and configure the architecture of an acquisition system in order to preserve useful physiological information Identifying the relevant measurement parameters (duration, frequency range...) Extracting and improving useful physiological information from measured signals
Detailed content	• Introduction to physiological information and action potential • Dimensioning of an acquisition system (sampling frequency, digitization, saving...) • Signal processing to improve measured signals in order to extract physiological markers (filters, wavelets decomposition, statistical characteristics...)
Bibliography	• Wim Van Drongelen, “Signal Processing for Neuroscientists. An introduction to the analysis of physiological signal”, Academic Press, Elsevier • A. Naït-Ali, “Advanced Biosignal Processing”, Springer

Title	Radio-com
Goals	The objectives of this course is to deepen your knowledge on the generic architecture of a digital radio transmitter/receiver and to understand the technology and key parameters for a full transmitter/receiver and for each individual block.
Detailed content	This course covers radio frequency electronics essential in digital radio communication systems (mobile communication, local networks, etc.) and the Internet of Things. The first part of the course entitled "Principles & modelling" will present the methods of design of a digital radio transmitter/receiver. The analog RF part will be approached from the point of view of dimensioning and architecture. The second part of the course, entitled "Designing RF and Microwave Integrated Circuits", will outline the principles and methods of design of linear and non-linear RF and microwave circuits that enter a digital transmission/reception chain. A CAD commercial software will be used to develop and optimise your own RF receiver.
Bibliography	• Tome 1, Geneviève Baudoin & Al, "Radiocommunications numériques" • Tome 2, Martine Villegas & Al, "Radiocommunications numériques"

Title	RF Modules
Goals	The objectives of this course are to understand the RF architecture of RX and TX parts of a node device, to learn how to create an efficient node, and to have a better understanding of indoor radio propagation.
Detailed content	This unit will focus on understanding RF equipment in a Wireless Sensor Network (WSN). First, we will introduce the different basic architectures used in low-power transceivers for IoT and WSN. Then, RF and DC dimensional quantities will be presented for a good understanding of the characteristic parameters of the physical layer used in the technical documentations. Several practical labs will allow the student to familiarise themself with a simple RF module that can be programmed in C language from a µC, with a focus on the consumption, data rate, range and link budget aspects.
Bibliography	• Grace T., "Programming and Interfacing ATMEL's AVRs", Cengage Learning PTR • Saunders S., Aragon-Zavala A., "Antennas and Propagation for Wireless Communication Systems", Wiley edition

Title	Clean Room
Goals	This course is intended to give the knowledge of fundamental semiconductor processing, including micro- fabrication of both integrated electronic circuits as well as MEMS devices. The most conventional technology steps will be detailed. Typical process flows will be discussed as well. The courses will be organized around experimental clean room sessions in which the students in the clean room of ESIEE Paris will achieve classical microelectronic process.
Detailed content	• Fundamentals of semiconductor materials and processing; • Typical process flows of IC and MEMS foundry services. • Keynote advanced Lab session: Fabrication and test of a MicroDevice in clean-room.
Bibliography	• Reza Ghodssi, Pinyen Lin, "MEMS Materials and Processes Handbook", Springer • W. Whyte, "Cleanroom Technology", Wiley

First year – Soft skill courses

Title	Intercultural Management and Communication
Goals	• Intercultural Management: - To introduce students to the main conceptual frameworks used in these fields - To build awareness of their own cultural paradigm - To implement and use the concepts presented in various intercultural and • Organisational contexts - To develop effective strategies of intercultural management - To develop a hands-on, eclectic approach to dealing with intercultural problems • Communication Skills 1: - To improve general presentation skills - To understand the key elements of a professional presentation
Detailed content	• Intercultural Management: - Key concepts – Time, Space & Context - Hofstede's dimensions of culture - Cultural variables from other writers - Multi-cultural teamwork - Managing diverse teams • Communication Skills 1: - Presentation Skills

Title	French Business Culture and Communication
Goals	• French Business Culture: the key or salient features of French culture related to the world of work and business, - To enable students to work more effectively in a French company - To compare the French business environment to others using concepts from Int Cultural Mgt course • Communication Skills 2: Interview skills - To make a CV as impressive as possible - To write an effective cover letter
Detailed content	• FBC - Analysis of French business culture - Cases and role plays related specifically to French business contexts • Communication 2 - Producing a CV and cover letter - Preparation and simulation of a job interview

2nd year – Technical courses

Title	Nanoelectronics
Goals	This course aims foremostly to give competencies in the analysis of semiconductor technologies, from material studies to the design and analysis of advanced semiconductor technologies used in nano-electronics. A clear focus will also be given to the comparison of technologies, from advanced CMOS, low dimension III-V structures, to quantum and low-dimensional technologies that are essential to the domain of micro and nanoelectronics that give routes to further integration in the field of IoT and others.
Detailed content	The course is divided into three main sections: • Semiconductor fundamentals and understanding of low-dimensional structures • Overview of the micro- and nano- technologies and comparisons • The revised European Roadmap in Electronics and Photonics to address the challenges of IoT and cyber-physical systems
Bibliography	• S.M. Sze, "Physics of Semiconductor Devices" • M.A. Herman, "Semiconductor Optoelectronics" • W.D. Callister, D.G. Rethwisch, "Materials Science and Engineering: An Introduction" • Marius Grundmann, "The Physics of Semiconductors"

Title	Communication in Research
Goals	The objective is to learn the basics for good practice in science communication
Detailed content	• How to prepare a scientific presentation • How to write a scientific abstract • How to prepare a scientific poster

Title	Lab on Chip
Goals	This course aims to introduce the concept of lab-on-a-chip (LOC) which is based on the evolution of microelectronic processes towards the integration of processing and analysis functions (biological and/or chemical). Students are trained in LOC design and manufacturing tools. The physical behavior of miniaturized systems is also taught with a focus on microfluidics. Specific Lab Works will occur in clean room for LOC fabrication.
Detailed content	• Lab-on-a-chip Introduction - Application and technology - Microfluidics: scaling laws, flow behavior. • Case study : - Design and fabrication of a LOC for sickle-cell analysis. - Towards an integrated PCR
Bibliography	• J. Castillo-Leon, J. Svendsen, "Lab-on-a-Chip Devices and Micro-Total Analysis Systems", Springer • G. Barbillon, A. Bosseboeuf, K. Chun, R. Ferrigno, O. Français, "Engineering of Micro/Nano Biosystems", Springer

Title	Radio Wave Propagation in Urban Environnement
Goals	The objective of this course is to study the physical mechanisms of the propagation of radio waves in atmosphere, urban and indoor environments. The propagation prediction will be studied according to different contexts of the deployment of the communication systems and following the existing models and their associated parameters. The selection of antennas and frequencies for radio communication will be deepened and the corresponding link budgets will be evaluated. The statistical characteristics of propagating signals will be described and the factors that impede or enhance the radio propagation in different scenarios will be identified.
Detailed content	• Properties of electromagnetic waves • Propagation mechanisms • Communication system and basic models • Atmosphere effects • Fixed radio links • Fading and multipath characterisation • Mobile radio propagation • Indoor radio propagation • Future developments in the wireless communication channel
Bibliography	• Simon R. Saunders and Alejandro Aragón-Zavala, "Antennas and propagation for wireless communication systems," John Wiley & Sons, 2007 • Fernando Pærez Fontæn and Perfecto Mariæo Espiæeira, "Modelling the wireless propagation channel: a simulation approach with Matlab," John Wiley & Sons, 2008 • John S. Seybold, "Introduction to RF propagation," John Wiley & Sons, 2005

Title	Energy Transfer & Harvesting
Goals	Ambient energy recovery has recently emerged as a solution to power autonomous sensors. This is a key point for the success of wireless sensor networks and the Internet of Things (IoT). The objective of this course is to present different techniques used for the production of electrical energy from the sensor environment. Particular attention will be paid to technologies for the recovery of energy from electromagnetic waves and mechanical vibrations using electrostatic/triboelectric and piezoelectric transductions.
Detailed content	• Basics of energy harvesting for small sensors, • Vibration energy harvesting: transduction technics, nonlinear phenomena, behavioral modelisation, • Wireless radio-energy transfer/harvesting: near-field and far-field WPT systems, inductive coupling, rectenna circuits, RF-to-dc conversion mechanism, topologies and arrays, design considerations • Practical labs in the *Sense-city* facility (https://sense-city.ifsttar.fr/en/)
Bibliography	• P. Basset, E. Blokhina, and D. Galayko, "Electrostatic kinetic energy harvesting", Hoboken, NJ: Wiley, 2016 • Nikoletseas, Sotiris, Yuanyuan Yang, and Apostolos Georgiadis, eds. "Wireless power transfer algorithms, technologies and applications in ad hoc communication networks". Springer, 2016

Title	Antennas for Embedded Systems
Goals	This course aims to understand the physics of Maxwell equations and to design a small antenna with professional software
Detailed content	This course applies the results of Maxwell equations to modern aspects in the field of embedded systems. Students will first be introduced to antenna basics (radiation mechanism, radiation pattern, efficiency, impedance) and then gain fundamental knowledge on small antenna design. An important part of practical lab will introduce them to the powerful tools of electromagnetic simulations. First, this will be introduced with Numerical Electromagnetic Code (NEC) to model and better understand simple and canonical small antennas. Then, more sophisticated software as HFSS will be introduced, and students will design and build a four band small antenna fabricated on a PCB for GSM, UMTS and WiFi applications.
Bibliography	• Zhang Z., "Antenna Design For Mobile Devices", Wiley edition • Volakis J. L., C.-C. Chen, K. Fujimoto, "Small Antennas", Mc Graw Hill edition

Title	MEMS Sensors
Goals	The objective of this course is to learn the design, simulation methods and tools for multi-physics components including MEMS devices. Two case studies will be developed, dealing with the design of inertial MEMS.
Detailed content	• Basics of MEMS fabrication • Inertial MEMS - accelerometer - gyroscope • Other MEMS sensors: - for environment, - for energy, - for airborne particle contamination - for healthcare - for biology
Bibliography	• Stephen D. Senturia, "Microsystem Design", Springer ed., 2000

2nd year – Soft skills courses

Title	Corporate Profiling
Goals	• After participating in the first part of the course (12hrs) students should be able to: - Find out basic information about any company, enterprise or organisation - Be able to use basic tools of Business Analysis, such as SWOT, PEST, Ansoff matrix, BCG analysis, Porter's 5 Forces etc. - Use these tools and techniques during their post-graduation job search • Communication Skills 3 - Students should be able to give an effective professional presentation
Detailed content	Students will: • Carry out detailed research of selected businesses • learn the basic tools of Business Analysis • analyse their chosen businesses • present their findings to the group