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## 2EL2530 – Integrated MEMS sensors

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**Instructors:** Jerome Juillard

**Department:** DÉPARTEMENT ÉLECTRONIQUE ET ÉLECTROMAGNÉTISME

**Language of instruction:** ANGLAIS

**Campus:** CAMPUS DE PARIS - SACLAY

**Workload (HEE):** 60

**On-site hours (HPE):** 35,00

**Elective Category :** Engineering Sciences

**Advanced level :** No

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### Description

In many application fields - automotive, medicine, aeronautics and defense, telecommunications or consumer electronics (smartphones, tablets) - the development or integration of miniaturized MEMS (Micro-Electro-Mechanical Systems) sensors is now a prerequisite for the deployment of connected applications. These devices are used as sensors (accelerometers, gyroscopes, pressure sensors, microphones, etc.), actuators (inkjet printers, optical displays) or for energy conversion. They have such advantages in terms of reliability, consumption, metrology, dimensions and cost that they have rapidly become essential (but invisible) elements of our daily lives since the 1990s and will play an increasing role in our future.

This course covers theoretical and practical aspects, from the point of view of modelling (multi-physical/multi-domain modelling, model order reduction), physics (mechanical, electrostatic, fluidic, fundamental metrological limits), technology (micro-manufacturing techniques, integration, packaging), and economics (profitability). It aims at providing a comprehensive overview of the field, which will be of interest to students with a taste for "beautiful physics" and for the design of complex systems, and/or those who wish to understand the large-scale industrialization of integrated devices.

Gap-year internships at major French and international MEMS companies are offered each year.

### Quarter number

SG6

### Prerequisites (in terms of CS courses)

No particular pre-requisite.



## **Syllabus**

Lectures = 15 HPE

L1 - Overview of MEMS (applications: sensors, actuators, transducers, main players)

L2 - Accelerometers and gyroscopes

L3 - Mechanics of MEMS

L4 - Transduction and interface 1

L5 - Transduction and interface 2

L6 - Dissipation

L7 - Fabrication

L8 - Integration and packaging

L9 - MEMS industry

L10 - Economics of MEMS

Labs = 9 HPE

Lab 1-2. Pendular accelerometer - Modeling and simulation with Coventor (3h)

Lab 3-6. Resonant gyroscope - Modeling and simulation with Coventor (6h)

Projects = 9 HPE (examples)

Reverse engineering of a commercial 3-axis accelerometer

Critical study of a 2-axis resonant accelerometer

Electromechanical optimization of a MEMS resonator

Reduced-order modeling of a MEMS energy harvester

Bibliographical study (quartz vs. silicon)

### **Class components (lecture, labs, etc.)**

Lectures (15h), labs (9h), projects (9h)

Lectures and documents in English. Handout available in French.

### **Grading**

Multiple choice test on lectures / labs (50%) Project report (50%).

Skills C1 and C2 assessed through multiple choice exam + project grade (excluding simulation part)

Skill C6 assessed through project grade (simulation part only)

### **Course support, bibliography**

Practical MEMS, V. Kaajakari, Small Gear Publishing, 2009

Inertial MEMS, principles and practice, V. Kempe, Cambridge University Press, 2011

Micro Mechanical Transducers, Pressure sensors, Accelerometers and Gyroscopes, M.-H. Bao, Elsevier, 2000

Micromachined Transducers Sourcebook, G. T. A. Kovacs, McGraw-Hill, 1998



### **Resources**

Coventor MEMS+ software (50 free licences granted by the company)

### **Learning outcomes covered on the course**

Knowing the main types of MEMS sensors / actuators and their applications

Knowing the main fabrication, integration and packaging processes of MEMS devices

Knowing the main physical phenomena involved at the micro-scale (mechanics, transduction, dissipation, noise)

Understanding how MEMS inertial sensors (accelerometers, gyroscopes) work, from physics to electronics and control.

Being able to dimension such a system, and to simulate it using a professional design tool

### **Description of the skills acquired at the end of the course**

C1/C2/C6