2EL2530 – Integrated MEMS sensors

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

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