ME237 Jan. 3:0

Mechanics of Microsystems

Instructor

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Teaching Assistant

None allocated as yet
Email: Not applicable

Department: Mechanical Engineering and CeNSE as NE 211

Course Time: Tue., Thu., 8:30 - 10:00 AM

Lecture venue: ME Multimedia Classroom (MMCR)

Detailed Course Page: http://www.mecheng.iisc.ernet.in/~suresh/me237/

Announcements

This course is cross-listed with NE 211. Please check when it is taught as NE 211 by CeNSE and when it is offered as ME 237.

Brief description of the course

Microsystems are integrated systems of small size where the feature sizes are generally of micron dimensions, but sometimes a little larger extending up to millimeters. More important than this "size" qualification, the unique feature of microsystems is the extent to which actuation, sensing, control, manipulation, and computation are integrated in the same system. The notion of integration is also inherent in the way microsystems are manufactured. The same applies to modeling and design. And, that is why special attention is given to the subject we will be studying in this course, by focussing on mechanics.

Microsystems field is more popularly known as MEMS--Microelectromechanical systems. With its early origins in mid-to-late 1960s and accelerated development since late eighties, MEMS field has sufficiently matured now. The "gee-whiz" "show-and-tell" era of "cool" miniaturized devices has almost ended; large and small MEMS industries are seriously competing in the commercial market. Efforts are underway to optimize the performance and cost and to improve the reliability of MEMS. Microfabrication is expensive and time-consuming, which makes it uneconomical to rely upon "build-and-test" approach. Therefore, the issues of simulating them and designing them have become very important. There are now a large number of companies whose mission is developing software for modeling and designing MEMS.

Is modeling and design of MEMS different from that of traditional macro systems? The answer to this is no and yes: "No" because there is almost no new physics or chemistry in most MEMS devices. And therefore, the governing equations are the same as we know them at the macro scale; "Yes" because there are scaling effects that change coefficients in these equations radically and bring about interesting consequences. And then there is integration. How do you simulate and design a device that tightly couples effects of several domains, sometimes all in a single structure? By "domains", we refer here to physical and chemical phenomena such as elastic, electrostatic, thermal, magnetic, dynamics, optical, fluidic, etc. Thus, we often need to solve coupled equation that govern two or more domains simultaneously. Now, think about the system-level issues. How do you design a system that integrates components of several types such as elastic structures, electronic circuits, fluidic elements, optical units, etc., -- all on the same platform? We will discuss these issues in this course. But our focus will be on mechanics.

While our focus is on modeling and design, of necessity, we will also learn about microfabrication and the operating principles of various MEMS devices. So, you get a bird's eye view of the MEMS field as a bonus. And then there is nano... Even before microsystems field matured, nano entered the scene. This course will not delve into this topic but will limit itself to what is popularly known as NEMS--nanoelectromechanical systems. Thermoelastic damping is one topic that goes to the level of nano or sub-micro dimensions. We might consider some other topics, if there is interest and if time permits.

Prerequisites

Engineering mathematics including linear algebra and differential equations; familiarity with finite element analysis is beneficial.

Syllabus

Module 1

Micromechanical suspensions and their multi-axial stiffness calculations

Analysis of stretch, compression, bending, and twisting found in micromechanical elements

Modeling the effects of residual stress and their gradients

Energy issues: strain energy, potential energy, and kinetic energy; energy methods for quick deformation analysis

Mechanical properties of MEMS materials

A detour to finite element analysis; quick theory and a lot of implementation to simulate micromechanical elements

Module 2

Lumped modeling of microsystems

Generalized capacitors, inductors, and resistors; transformers and gyrators

Circuit models of MEMS

Modeling magnetic microactors

Modeling dissipation in MEMS

Module 3

Coupled electromechanics

Electrostatics and capacitance calculations

Modeling coupling between electrostatic and elastic domains

Pull-in analysis

Beam models to study pull-in and beyond pull-in

Dynamics of electromechanical MEMS

Fluid damping in MEMS: Cuette flow

Squeezed-film effects

Modeling electro-thermal microactuators

Modeling piezoresitive elements

Modeling piezoelectric actuators and sensors

Thermoelastic damping

Module 4

Case studies in modeling

Design case-studies

Course outcomes

After taking this course, the students would...

1) become familiar with the field of microelectromechanical systems (MEMS)

2) be able to analyze MEMS components and devices using reduced-order (lumped) models

3) be able to model and simulate multi-physics phenomena found in MEMS and other systems

4) appreciate how to think about a MEMS device at the systems level

5) become comfortable with using MEMS simulation software

6) gain experience in designing MEMS devices

Grading policy

Homeworks will carry 25% of the course grade.

Mid-term will carry 25%.

Project carries 25%.

And, the final examination too carries 25%.

Assignments

The course-work entails attending the lectures, submitting homeworks, taking examinations, and doing a course project. There will be about 10 homework assignments, a mid-term examination, and a final examination. The students are expected to take initiative and read a lot more outside the class to do a substantive course project that starts after the mid-term. By that time, students would have acquired enough background to start a project on a topic/problem of their choice.

Resources

Conference Proceedings

Transducers

This conference is held in the odd years (93, 95, 97, 99, 2001, and so on;) and is attended by MEMS researchers around the world.

Hilton-Head Solid-State Sensors and Actuators

This is held in even years (92, 94, 96, 98, 2000, â€¦) in Hilton Head Island, SC. It is mostly attended by MEMS researchers in USA and is a relatively small, but well-organized conference.

MEMS

This is held every year and is attended by researchers around the world. This is also a small conference.

ASME Winter Annual Meetings

The annual ASME Winter Annual Meeting (officially called International Mechanical Engineering Congress and Exposition) has a number of symposia on MEMS related topics.

MSM (Microsystem Modeling and Simulation)

This is a relatively new conference held in 1998 for the first time and focuses on modeling and design of microsyatems at large.

SPIE Conferences

The conference held by SPIE, the International Society for Optical Engineering, has several symposia that focus on some aspects of MEMS and Smart Structures.

Journals

IEEE/ASME Journal of Microelectromechanical Systems (JMEMS)

Journal of Micromechanics and Microengineering

IEEE Electron Device Letters

Sensors and Actuators A (Physical)

Sensors and Actuators B (Chemical)

Sensors and Actuators C (Materials)

MEMS course web pages at other universities

Massachusetts Institute of Technology taught by Prof. Steve Senturia

University of Washington taught by Prof. Karl Bohringer

University of California, Berkeley taught by Prof. Kris Pister.

University of Maryland taught by Prof. Reza Ghodssi

Columbia University taught by Prof. Vijay Modi and Prof. K. R. Farmer

Oregon Graduate Institue taught by Prof. Milton Scholl

SUNY-Buffalo taught by Prof. David Shaw

University of Pacific taught by Prof. Krysac.

Tel-Aviv University taught by Prof. Dan Haronian.

Visit MEMS Clearing house for a number of links related to MEMS.

Research web pages at other universities and research labs

University of Wisconsin-Madison

Stanford University

Berkeley Sensors and Actuator Center

CalTech

Sandia MEMS group

University of Twente, Netherlands

Columbia University

Tel-Aviv University, Israel

Companies that are engaged in software development for MEMS

Intellisense

Coventor

MEMSCap

ANSYS

Tanner Research

CFD Research

Companies that are developing and marketing MEMS devices

Digital Light Processor at Texas Instruments

Accelerometers and gyroscopes at Analog Devices

Optical cross-connects at Bell Labs Innovations.

Redwood Microsystems

Polychromix with an optimcal MEMS product for telecommunications.

Caliper Technologies the lab-on-a-chip company.

Silicon light machines opto-electronic MEMS products.

Micro sensors: inertial micro-sensors among its main products.

MEMSIC accelerometers and wireless MEMS for markets beyond automotive industry.