

MEMS Resonators: Fundamentals and Applications

Overview

MEMS resonators and oscillators are being increasingly employed in applications related to timing and frequency control, and as building blocks in micro/nano-fabricated sensors and sensor systems. This course will review the theory, design and applications underlying this emerging field.

The course will begin with an overview of the field and will provide a review of the background in mechanical modelling and fabrication processes including approaches towards wafer-level vacuum packaging. The course will outline the physical mechanisms underlying damping in these systems and discuss analytical and numerical models for damping in resonators. Physical mechanisms underlying non-linear behavior will be discussed and approaches towards constructing discrete resonator and oscillator models incorporating non-linearity reviewed. A review of transduction schemes will be covered including a comprehensive discussion of electrostatic and piezoelectric transduction. Equivalent electrical models, characterization schemes and approaches towards parameter extraction from open-loop measurements will be described. Circuit models for oscillators embedding MEMS resonators will be discussed in depth including a review of oscillator topologies, noise models and approaches to passive and active temperature compensation. Coupled dynamics including aspects related to vibration mode localization and synchronization in coupled non-linear oscillators will be reviewed.

Finally, the course will examine specific applications to timing references, frequency synthesizers, band-pass filters, mixer-filters and sensors. Specific sensor case studies will examine the design of resonant accelerometers, vibratory rate gyroscopes, resonant strain gauges, pressure sensors, IR sensors and gravimetric sensors. The course will also examine aspects related to the design of the front-end and back-end electronics for resonant sensors. Emerging applications in sensing and signal processing will be outlined.

Course participants will learn these topics through lectures and hands-on experiments. Also case studies and assignments will be shared to stimulate research motivation of participants.

Modules	Course dates June 27, 2016 to July 3, 2016 A: MEMS fabrication, B: Resonators, Oscillators, resonant sensors C: Energy harvester, Ultrasound transducer, Exam on July 3, 2016 (for students earning credit).
You Should Attend If...	<ul style="list-style-type: none"> ▪ You are an electronics/ mechanical / MEMS engineer interested in development and novel application of MEMS resonator sensors. ▪ You are industrial professional looking for in-depth knowledge of MEMS resonators ▪ You are a student or faculty from academic institution interested in learning how to research, design, and develop MEMS resonators
Fees	Industry: Rs 20000 per participant, Govt. Research Organizations: Rs 15000 per participant Selected faculty from academic institutions: Rs 10000 per participant Selected students (UG from IIT and PG) from Academic Institutions: Rs 1000 per participant The above fee includes all instructional materials (in CD), laboratory equipment usage charges. The academia participants (students and faculty) will be provided hostel accommodation at extra cost. For other participants limited accommodation in guest house would be provided in payment basis.
How to apply	Step 1: visit http://www.gian.iitkgp.ac.in/GREGN/index and get GIAN registration number Step 2: For participants from Industry and Govt Research organization, cut and paste the following link in your web browser to access payment information and fill the form online: https://docs.google.com/forms/d/1yRjXPXA16dZQdiUzNe8PNsab-tUgpvRS4NuKqyX_UF8/viewform For students and faculty from academia cut and paste the following link in your web browser to fill the application form and after approval email pay registration fees: https://docs.google.com/forms/d/1QG1vZR6xHblrY-7HzeBE4ove5qOSc5l8XvpXo2piWHU/viewform

The Faculty



Ashwin A. Seshia received his BTech in Engineering Physics in 1996 from IIT Bombay, MS and PhD degrees in Electrical Engineering and Computer Sciences from the University of California, Berkeley in 1999 and 2002 respectively, and the MA from the University of Cambridge in 2008. During his time at the University of California,

Berkeley, he was affiliated with the Berkeley Sensor & Actuator Center. He joined the faculty of the Engineering Department at the University of Cambridge in October 2002 where he is presently a Reader in Microsystems Technology and a Fellow of Queens' College. He is a Fellow of the Institute of Physics, a Fellow of the Institution for Engineering and Technology and a senior member of the Institute of Electrical and Electronics Engineers. His research interests are in the domain of microengineered dynamical systems with applications to sensors and sensor systems. Dr Seshia serves on the editorial boards of the IEEE Journal of MicroElectroMechanical Systems, the IEEE Transactions on Nanotechnology and the IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control.



Dr Rudra Pratap is a Professor and the Chairperson of the Centre for Nano Science and Engineering (CeNSE), and an associate faculty of the Department of Mechanical Engineering at the Indian Institute of Science, Bangalore. Dr Rudra Pratap specializes in MEMS and NEMS design. He is currently involved in several MEMS device developments that include MEMS microphones, ultrasound transducers and inertial systems. His research group has carried out extensive studies of energy dissipation in dynamic MEMS devices and developed comprehensive models of damping in such devices. He is keenly interested in MEMS based energy harvesting technologies. Apart from MEMS and NEMS, his research interests include nonlinear dynamics, mechanobiology, and computational mechanics. Dr. Rudra Pratap holds a Ph.D. degree from Cornell University, USA, a Masters degree from the University of Arizona, USA, and a B. Tech. from the Indian Institute of Technology, Kharagpur, India. Prior to joining IISc in 1996, he taught at the Sibley School of Mechanical and Aerospace Engineering, Cornell University, for two and a half years. He was also an 'Invited Professor' at EPFL, Lausanne, Switzerland during 2004-2005. He has been at the Indian Institute of Science, Bangalore, India, since 1996. He is a member of the Vision Group on Nanotechnology of Karnataka State. He has served on the editorial board of various journals. Dr. Pratap has published over 100 papers in journals and conference proceedings and has three books to his credit. He is also the Chairman of i2n Technologies Pvt Ltd, a company that he co-founded in 2010 for making nanotech hardware products. Dr. Pratap is a Fellow of the National Academy of Engineering.



Tarun Kanti Bhattacharyya obtained M.E. and Ph.D. degrees in Electronics and Telecommunication Engineering from Jadavpur University, Kolkata in 1991 and 1996 respectively. He has served as a scientist in areas of thin film technology and micro-electronics in reputed laboratories like Indian Association for Cultivation of Science, Central Glass and Ceramic research Institute, Kolkata and University of Kaiserslautern, Germany. He has been a visiting faculty in University of Washington and University of Michigan. He joined Electronics and Electrical Communication Engineering department, Indian Institute of Technology in the year 2000 and currently he is Professor of Electronics and Electrical Communication Engineering and Advanced Technology Development

Course

Co-ordinator

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Centre. He is also the professor in-charge of the Advanced VLSI Laboratory and the National MEMS Design Centre of IIT Kharagpur. His current research interests include low power RF IC design, MEMS and nano-electronics. He was a recipient of the UNIDO (Vienna) fellowship in 1992 and IBM faculty award 2012. He served as a technical committee member of VLSI Design Conference in 2007 and 2013 as the RFIC track chair for VLSI Design Conference 2013. He is also a technical program committee member of the IEEE SENSORS 2013. He is a member of Indo-Japan collaborative committee on Advanced Micro-Nano Manufacturing Science He has more than 150 publications in esteemed international journals and conferences.



Prasanna S Gandhi received the B.Engg. degree in from the University of Bombay, Mumbai in 1994 and the M.Tech degree from the Indian Institute of Technology, Bombay, Mumbai in 1996, both in mechanical engineering. He received the Ph.D. degree in mechanical engineering from the Rice University, Houston in 2001. Since 2001, he has been faculty member, currently Professor, in the Department of Mechanical Engineering at Indian Institute of Technology, Bombay, Mumbai. His research interests are in the areas of MEMS and Microsystems, Mechatronics, and Nonlinear Dynamical Systems and Control. He has been a recipient of 2006 BOYSCAST fellowship of Govt of India and Prof J.R.Issac fellowship. He has authored over 80 peer reviewed conference and journal papers, along with several patents. He has setup a new laboratory Suman Mashruwala Microengineering Laboratory for research in Micro domain and has successfully completed several research projects sponsored by Govt. and private sector. He has also been a qualified teacher of stress relieving, life enhancing techniques of Art of Living foundation by Sri Sri Ravishankar.

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