Microelectronic Systems

at the

Department of Informatics, University of Oslo

Professor Oddvar Søråsen

October, 2006
University of Oslo

Faculty of Theology
Faculty of Law
Faculty of Arts
Faculty of Medicine
Faculty of Dentistry
Faculty of Social Sciences
Faculty of Education
Faculty of Mathematics and Natural Science
Institute of Theoretical Astrophysics
Department of Informatics
Department of Physics
Department of Geophysics
School of Geography
Department of Pharmacy
Department of Mathematics
Department of Chemistry
Department of Biochemistry
Department of Biology

UoO: 30,000 students, 4,600 employees
Department of Informatics

www.ifi.uio.no

The CS department at UoO
**Key figures**

- 800 Bachelor students
- 550 Master students
- 135 PhD students
- 1800-2000 course students
- 110 courses + seminars
- 6 study programs (3+2)
- 5 years structured Master program directed towards a profession
- International Master
- Participator in “cross discipline” informatics education (faculties of art, soc.sciences, education, law)
- 200 employees (incl PhD-students)
- 13 research groups
- >50 partners in industry and government
- Projects funded by the Norwegian Research Council
- Increasing number of EU projects
- Innovation through UoO centre (Birkeland Innovation)
Main research directions

- Software Technology
  - Object orientation: SIMULA
- Distributed Systems
- Information Systems
- Microelectronic Systems
- Computational Science
  - Splines

Professors O.J. Dahl and Kristen Nygaard:
von Neumann medal, Turing award
Commanders of St. Olaf Order

Splines for geometri and radiance rendering
40% of activities towards medicine/health

Texture analysis in cancer research

Health Information System Program (developing countries)

Self-adapting systems (interactive arm prosthesis)
Participating in the Norwegian Centre of Excellence: Mathematics for Applications
Microelectronic Systems (MES)

→ One of the main research directions at the department
Strategic location of the research field

- Programming
- Signal processing
- MEMS
- Physics

Mikroelektronic Systems
MES research groups

- 6 faculty
  - Dag T. Wisland
  - Yngvar Berg
  - Oddvar Søråsen
  - Bassen Lande
  - Mats Høvin
  - Jim Tørresen

- 2 engineers
  - Håvard Kolle Riis
  - Hans K. Otnes Berge

- 5 part time faculty
  - Sigbjørn Næss (Nera)
  - Alf Olsen (Mikron)
  - Tor Fjeldly (UNIK)
  - Joar M. Østby (SINTEF)
  - Jørgen Norendal (FINT)

- 9 PhD students
  - Shaomeng Li
  - Johannes Lomsdalen
  - Rene Jensen
  - Henning Gundersen
  - Omid Mirmotahari
  - Kyrre Glette
  - Jens Petter Abrahamsen
  - Håkon A. Hjortland
  - Jørgen A. Michaelsen

- 3 Researchers
  - Philipp Häfliger
  - Snorre Aunet
  - Lena Mariann Garder

- EU project: Caviar
- NFR project: Biol
The National Organ for Quality in Education

- The prize winner 2006: Microelectronic Systems
  - Close follow-up of students
  - Extensive use of laboratory work
  - Compulsory tasks/ problems to be solved
  - Tutors
  - Students participate in the development of the education
  - Streamlined curriculum
Microelectronic Systems

- Developing systems based on integrated electronics
  - VLSI, ASIC

- From embedded systems to transistor modeling

- Two main directions
  - A. Robotics and Intelligent Systems
  - B. Nanoelectronics
A. Robotics and Intelligent Systems

- Design of digital systems at a high level of abstraction
  - Interface towards software and algorithms
  - Embedded systems
  - Reconfigurable hardware and self-adapting systems
    - Implementation in FPGAs – Field Programmable Gate Arrays
    - Evolutionary algorithms for designing hardware
  - Machine learning
B. Nanoelectronics

- Full-custom design of analog, digital and mixed-mode circuits
  - Requiring a thorough insight in the technology!

  - Micro effect circuits
  - Data conversion circuits
  - Bio-inspired microelectronics
  - Ultra Wideband Radio
  - RF MEMS – co-integration of MEMS and CMOS
Micro effect circuits

- Investigating methods for reducing power consumption
  - Varios transistor structures
  - Decreased supply voltage
  - Multiple Valued Logic
  - Threshold logic
  - Integrated redundancy
Data conversion circuits

- Effective methods and circuits for data conversion
  - DAC, ADC
  - Delta-Sigma methods
  - Interface to MEMS sensors

Integrated pressure sensor
Bio-inspired microelectronics

- "Neuromorph engineering"
  - Cochlea implant
  - New ways of coding signal for transmission (pulse coding)
Ultra Wideband radio

- Wireless shorthold communication
  - Impuls radio
  - Radar for medical detection
RF MEMS

- Integrated filters and resonators with high Q-factors
- Co-integration of MEMS and CMOS

3D model of H-filter, O.P Arhaug
MEMS a new activity at MES

- **National initiative** to establish micro and nano technology in Norway
  - Norwegian Research Counsel
  - **MiNaLab** in neighbouring building (SINTEF and UiO)
    - on sabbatical leave 03/04

- MEMS a **new degree of freedom** to implement integrated systems
  - microelectronics can use micromechanical components
  - MEMS structures would need an electronic framework

- Suitable **competence** at MES
  - modeling, analysis, implementation of VLSI from transistors to complex systems
Selecting a focus

- MEMS is a broad field
  - focusing on RF MEMS

- ”RF MEMS refers to the design and fabrication of dedicated MEMS for RF (integrated) circuits”
  1a) The components operate by micromechanics and/or
  1b) The components are fabricated by micromachining

- 2) The components are used in RF systems

- A new course established, 2005: INF5490 RF MEMS
Why RF MEMS?

- Challenging, promising and exciting field!
- Close connection to circuit technique

- An increasing number of applications of MEMS in RF
- Large market: wireless communication
  - telecommunication, mobile phones
  - distributed intelligence (observation, activation)
  - environmental surveillance

- IFI/MES strategic activity → Wireless Sensor Nets
Appealing advantages given by RF MEMS

- Circuit and system miniaturization
  - monolithic integration with IC or by packaging!
- Lower cost
  - batch processing
- Lower power dissipation
- Higher performance
  - increased selectivity
  - higher Q-factor
  - reduced loss
  - better isolation
  - low distortion
  - increased bandwidth
Basic RF MEMS components

- Switches
- Variable capacitors
- Inductors
- Phase shifters

- Resonators
- Micromechanical filters

- focusing on real vibrating structures
  - Can be used to implement
    - oscillators
    - filters
    - mixer with filter
Master project (finished)

- Micromechanical filter by resonating beams
  - H structures

- Master student Ole-Petter Arhaug
- Modeling
  - analytical, FEM
- Simulations with CoventorWare, Cadence
- Design according to a specific process: QinetiQ
  - QinetiQ INTEGRAM processes, a part of Europractice

Meshed 3D model for FEM analysis

O-P Arhaug
Filter operation: 2 identical resonators

In phase

Out of phase
CoventorWare simulations for 6 resonating modes (O-P Arhaug)
Harmonic response for given dampings

(a) 0.1
(b) 0.001

O-P Arhaug
On-going project

- Integrated MEMS/CMOS oscillator
  - based on a resonating cantilever beam

- Master student Jan Erik Ramstad (Bachelor HiVe)
- MEMS resonator with CMOS feedback amplifier
- To be used as a "resonant detector"
  - a mechanical resonating structure where physical measurement parameters modify the resonant frequency
  - e.g. sensing acceleration

- Investigate possibilities for monolithic integration
  - post CMOS micromachining
Microstructures made from conventional CMOS followed by two maskless post-CMOS process steps

- Potential Applications
  - Inertial sensors, RF MEMS, infrared sensors, flow and force sensors, ... with on-chip detection and conditioning

Using RF MEMS

- Todays RF systems need **off-chip components** to obtain required performance
  - matching networks, filters, resonators etc.

- RF MEMS components can be used as
  - A) **Replacement** for discrete passive components
  - B) **New** integrated **functionality**
    - new system architectures
    - reconfigurable RF ICs by using switches
On-going project

- RF transceiver for a Wireless Sensor Node
  - Medical application
    - Brain pressure sensor
  - Built-in intelligence
  - Robust
  - Low-power

- Design and demonstration of critical RF MEMS parts
- Interfacing and implementation issues
Personal research goals

- 1) Designing RF MEMS and investigating how to use high performance micromechanical replacement parts in RF systems instead of today's bulky and power consuming off-chip components

- 2) Investigating effective methods for integration of the MEMS with microelectronic subsystems, preferably as a monolithic Si chip (SoC)

- Critical technology and realistic implementations of **Wireless Sensor Nodes**