Lecture 1: Introduction

- Acronyms for the technology:
  - MEMS (Microelectromechanical Systems) in US
  - MST (Microsystems Technology) in Europe

- Definitions of MEMS
  - Miniaturization (most would agree..)
  - A toolbox of techniques and processes (Micromachining)
    - Many “borrowed” from IC industry
  - Specialized, not generic physical application (e.g., Bio-MEMS)
  - A way of merging the functions of sensing and actuation
    with communication and computation at microscale
    - Components → Subsystems → Microsystems

Introduction

- MEMS advantages
  - Miniaturization
  - Multiple components
  - Microelectronics
  - Low Cost

- Example: Accelerometer for airbag system
  - Less than $10, 10 Billions sold by Sept, 2002

Micromechanical sensor surrounded by on-chip excitation, self-test, and signal-conditioning circuitry

Analog Devices’ ADXL-50 accelerometer
Miniaturization

- Suitable for portable applications
  - Small
  - Light-weight
- Better performance in many (but not all!) applications
  - Lighter structures
    - Higher mechanical bandwidths
    - Shock-resistant structures
  - Low thermal mass
    - Fast thermal actuator and sensor
- Smaller means more devices and complexity can fit into the same space at the same cost

Micromachined Transducers

- Transducers convert one energy domain into another form:
  - Thermal, Mechanical, Magnetic, Electrical, Chemical, Radiant
  - Actuators: energy -> mechanical motion
    - Micro-actuators are not widely used because of limited output power, mostly for moving themselves (e.g., micro-mirrors, read/write head servo)
  - Sensors: energy -> electrical signal
    - Microsensor packaging and testing account for ¾ of total cost
Emerging Applications and Market*

- Market dominated by a few devices (e.g., accelerometer, pressure sensor, and inkjet head), no "killer app"
- 1.6 MEMS devices per person as of now. 5 devices per person by 2004 (MEMS Industry Group 2002)

Micro Probe Array

- Micromachined probe array as the platform for nano-scale applications

* Pictures from Calvin Quate, Stanford Univ.
To MEMS or not to MEMS?

- Must meet required specifications and pricing
- SCALING vs. PERFORMANCE (e.g., Uncooled IR imager)
- A good MEMS solution enables
  - A new function (e.g., Medical applications)
  - Cost reduction (e.g., Auto industry)
- Technology success is evaluated by economic success, which must be enabled by “Batch Fabrication”
  - To dilute overall cost of cleanroom maintenance, packaging, etc

High-level Design Issues

- Evaluation of competition
- Manufacturing consideration
- Market projection
- Technological capabilities
- Creative designer
- Modeling and Analysis
**Modeling Levels**

- **System**
  - Block diagram and lumped-parameter Models (solving of ODE's)
- **Device**
  - Analytic macro-model
- **Physical**
  - Numerical simulation of PDE's
- **Process**
  - Technology CAD

**Standards for MEMS?**

- Lack of dominant MEMS standards as the Complementary Metal oxide semiconductor (CMOS) technology for IC industry
  - Contributed by diverse applications with specific needs
  - Resulting in difficulties for developing CAD tools for MEMS design as for IC
    - Technology file
    - Design rules
    - Micromechanical device models
MEMS Information Resources

- **Journals**
  - IEEE/ASME J. of Microelectromechanical Systems, 1992-.
  - Sensors and Actuators: A. Physical, Elsevier Science, Lausanne, Switzerland, 1980-.
  - Sensors and Materials, Japan, 1989-.

- **Conferences**
  - Int’l Conf. on Solid-State Sensors and Actuators (Transducers): odd years in US, Asia, or Europe, 1981-.
  - Solid-State Sensor and Actuator Workshop: Hilton Head Is., SC, June, even years, 1984-.
  - MicroElectroMechanical Systems Workshop, Feb., yearly, 1987-.
  - Int’l Conf. on Modeling and Simulation of Microsystems, 1998-.
  - SPIE Symposium on Micromachining and microfabrication, Nov., yearly, 1995-.
  - Also, IMECE, MRS, IEDM, ISSCC