Instructor: Prof. Clark T.-C. Nguyen

*Education: Ph.D., University of California at Berkeley, 1994
* 1995: joined the faculty of the Dept. of EECS at the University of Michigan
* 2006: (came back) joined the faculty of the Dept. of EECS at UC Berkeley
* Research: exactly the topic of this course, with a heavy emphasis on vibrating RF MEMS
* Teaching: (at the UofM) mainly transistor circuit & physics; (UC Berkeley) 140/240A, 143, 243, 245, 247B/ME218
* 2001: founded Discera, the first company to commercialize vibrating RF MEMS technology
* Mid-2002 to 2005: DARPA MEMS program manager
  ▸ ran 10 different MEMS-based programs
  ▸ topics: power generation, chip-scale atomic clock, gas analyzers, nuclear power sources, navigation-grade gyros, on-chip cooling, micro environmental control

Course Overview

* Goals of the course:
  ▸ Accessible to a broad audience (minimal prerequisites)
  ▸ Design emphasis
    ▸ Exposure to the techniques useful in analytical design of structures, transducers, and process flows
  ▸ Perspective on MEMS research and commercialization circa 2018
* Related courses at UC Berkeley:
  ▸ EE 143: Microfabrication Technology
  ▸ EE 147/247A: Introduction to MEMS
  ▸ ME 119: Introduction to MEMS (mainly fabrication)
  ▸ BioEng 121: Introduction to Micro and Nano Biotechnology and BioMEMS
* Assumed background for EE 247B/ME 218:
  ▸ graduate standing in engineering or physical/bio sciences
  ▸ knowledge of microfabrication technology

Course Overview

* The mechanics of the course are summarized in the course handouts, described in lecture today
  ▸ Course Information Sheet
    ▸ Course description
    ▸ Course mechanics
    ▸ Textbooks
    ▸ Grading policy
  ▸ Syllabus
    ▸ Lecture by lecture timeline w/ associated reading sections
    ▸ Midterm Exam: Thursday, March 22
    ▸ Final Exam: Thursday, May 11, 8-11 a.m. (Group 13)
    ▸ Project due date TBD (but near semester’s end)
What Should You Know?

- Basic circuit analysis & design using op amps
- Example: Find the transfer function $v_o(s)/v_i(s)$ of the circuit below.

\[ R_f \quad C_f \quad R_1 \quad v_i \quad v_o \]

Lecture Outline

- Reading: Senturia, Chapter 1
- Lecture Topics:
  - Definitions for MEMS
  - MEMS roadmap
  - Benefits of Miniaturization

MEMS: Micro Electro Mechanical System

- A device constructed using micromachining (MEMS) tech.
- A micro-scale or smaller device/system that operates mainly via a mechanical or electromechanical means
- At least some of the signals flowing through a MEMS device are best described in terms of mechanical variables, e.g., displacement, velocity, acceleration, temperature, flow

Input: voltage, current, acceleration, velocity, light, heat...

MEMS

Output: voltage, current, acceleration, velocity, light, heat, ...

Transducer to Convert Control to a Mechanical Variable (e.g., displacement, velocity, stress, heat, ...)

Control: voltage, current, acceleration, velocity, light, heat, ...

Angle set by mechanical means to control the path of light

[Image of MEMS diagram]
**Other Common Attributes of MEMS**

- Feature sizes measured in microns or less
- Merges computation with sensing and actuation to change the way we perceive and control the physical world
- Planar lithographic technology often used for fabrication
  - can use fab equipment identical to those needed for IC's
  - however, some fabrication steps transcend those of conventional IC processing

**Bulk Micromachining and Bonding**

- Use the wafer itself as the structural material
- Adv: very large aspect ratios, thick structures
- Example: deep etching and wafer bonding

**Surface Micromachining**

- Fabrication steps compatible with planar IC processing

**Single-Chip Ckt/MEMS Integration**

- Completely monolithic, low phase noise, high-Q oscillator
  (effectively, an integrated crystal oscillator)
- To allow the use of >600°C processing temperatures, tungsten (instead of aluminum) is used for metallization