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## EE C247B - ME C218 Introduction to MEMS Design Spring 2018

Prof. Clark T.-C. Nguyen

Dept. of Electrical Engineering & Computer Sciences  
University of California at Berkeley  
Berkeley, CA 94720

Lecture Module 2: Benefits of Scaling

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## Lecture Outline

- Reading: Senturia, Chapter 1
- Lecture Topics:
  - ↳ Benefits of Miniaturization
  - ↳ Examples
    - GHz micromechanical resonators
    - Chip-scale atomic clock
    - Micro gas chromatograph

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## Benefits of Size Reduction: MEMS

- Benefits of size reduction clear for IC's in elect. domain
  - ↳ size reduction ⇒ speed, low power, complexity, economy
- MEMS: enables a similar concept, but ...
 

**MEMS extends the benefits of size reduction beyond the electrical domain**

↓

Performance enhancements for application domains beyond those satisfied by electronics in the same general categories

  - Speed → Frequency ↑ , Thermal Time Const. ↓
  - Power Consumption → Actuation Energy ↓ , Heating Power ↓
  - Complexity → Integration Density ↑ , Functionality ↑
  - Economy → Batch Fab. Pot. ↑ (esp. for packaging)
  - Robustness → g-Force Resilience ↑

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## Vibrating RF MEMS

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**Basic Concept: Scaling Guitar Strings**

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**Guitar String**

Vib. Amplitude

Low Q

High Q

110 Hz

Freq.

Vibrating "A" String (110 Hz)

Stiffness

**Freq. Equation:**

$$f_o = \frac{1}{2\pi} \sqrt{\frac{k_r}{m_r}}$$

Freq.

Mass

**$\mu$ Mechanical Resonator**

Metallized Electrode

Anchor

Polysilicon Clamped-Clamped Beam

$h_r$

$W_r$

$L_r$

[Bannon 1996]

**Performance:**

- $L = 40.8 \mu\text{m}$
- $m_r \sim 10^{-13} \text{ kg}$
- $W_r = 8 \mu\text{m}, h_r = 2 \mu\text{m}$
- $d = 1000 \text{ \AA}, V_p = 5 \text{ V}$
- Press. = 70 mTorr

$f_o = 8.5 \text{ MHz}$

$Q_{vac} = 8,000$

$Q_{air} \sim 50$

Transmission (dB)

Frequency [MHz]

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