Lecture Outline

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

Benefits of Size Reduction: MEMS

- Benefits of size reduction clear for IC’s in elect. domain
  - Size reduction \(\Rightarrow\) 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 \(\rightarrow\) Frequency \(\uparrow\), Thermal Time Const. \(\downarrow\)
- Power Consumption \(\rightarrow\) Actuation Energy \(\downarrow\), Heating Power \(\downarrow\)
- Complexity \(\rightarrow\) Integration Density \(\uparrow\), Functionality \(\uparrow\)
- Economy \(\rightarrow\) Batch Fab. Pot. \(\uparrow\) (esp. for packaging)
- Robustness \(\rightarrow\) g-Force Resilience \(\uparrow\)
Basic Concept: Scaling Guitar Strings

Guitar String

- Vibrating "A" String (110 Hz)
- High Q
- Low Q
- 110 Hz
- Freq.
- Vib. Amplitude

Mechanical Resonator

- Metallized Electrode
- Anchor
- Polysilicon Clamped-Clamped Beam
- Performance:
  - $f_r = 8.5 MHz$
  - $Q_{vac} = 8,000$
  - $Q_{air} \sim 50$
  - $L_r = 40.8 \mu m$
  - $m_r = 10^{-13} kg$
  - $W_r = 8 \mu m$, $h_r = 2 \mu m$
  - $d = 1000 \AA$, $V_P = 5 V$
  - Press. = 70 mTorr

Freq. Equation:
$$f_r = \frac{1}{2\pi} \sqrt{\frac{k_r}{m_r}}$$

[Bannon 1996]