MEMS Vibration Energy Harvesting Applications

We have developed energy harvesters:

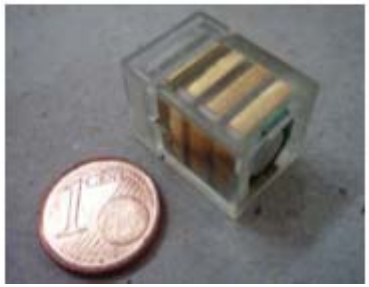
- MEMS fabricated
- Low resonance frequency
- Produced 22 mV_{rms} voltage output from HVAC duct vibration

Lindsay Miller, Dr. Beth Reilly, Romy Fain, Prof. Paul Wright

Wireless sensor nodes

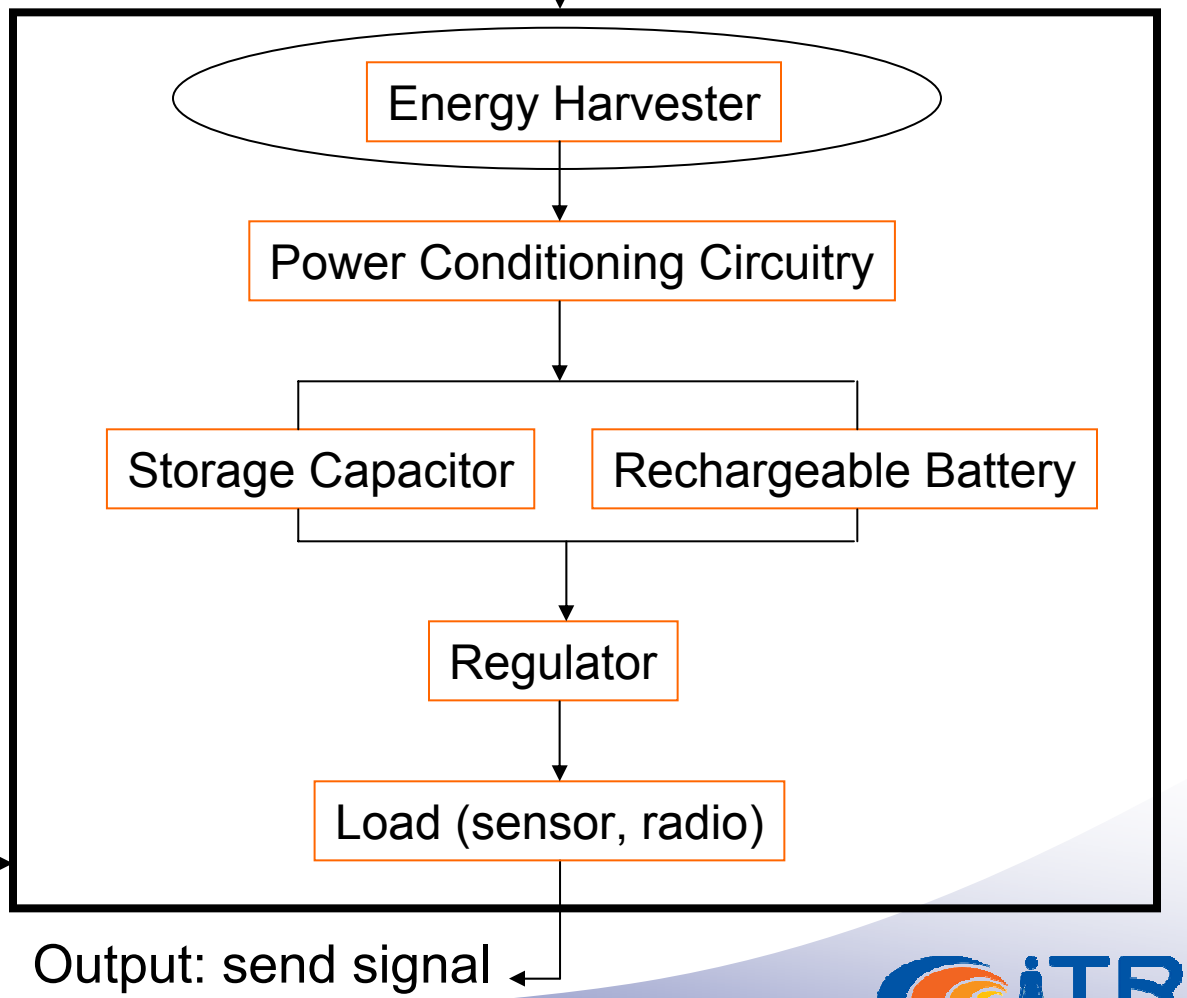
Sensor, Radio, Power Supply

Gen 1: Mica2



Gen 2: UCB pico cube, BWRC

Gen 3:

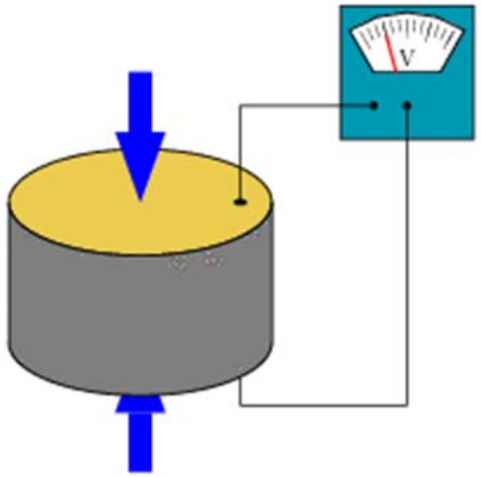


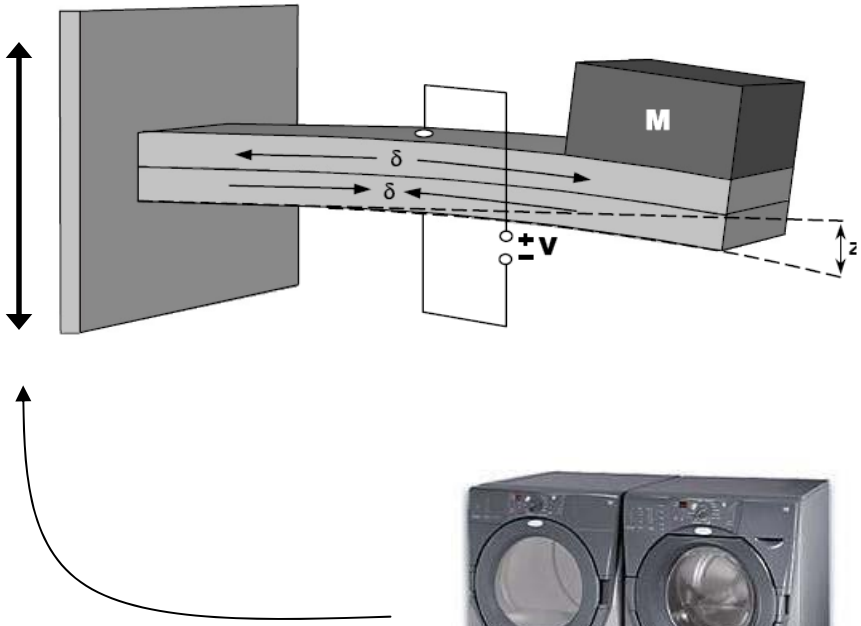
http://berkeley.edu/news/media/releases/2002/08/05_snsor.html - from Intel Research Lab at Berkeley

iTRIS
Center for Information Technology Research in the Interest of Society

Piezoelectrics Background

Piezoelectric materials produce voltage when deformed





Washing machine vibrations:
85 Hz, 0.341 g

Wireless sensor network in building

- Thousands of nodes
- Sensors are low power
- No access to wall power

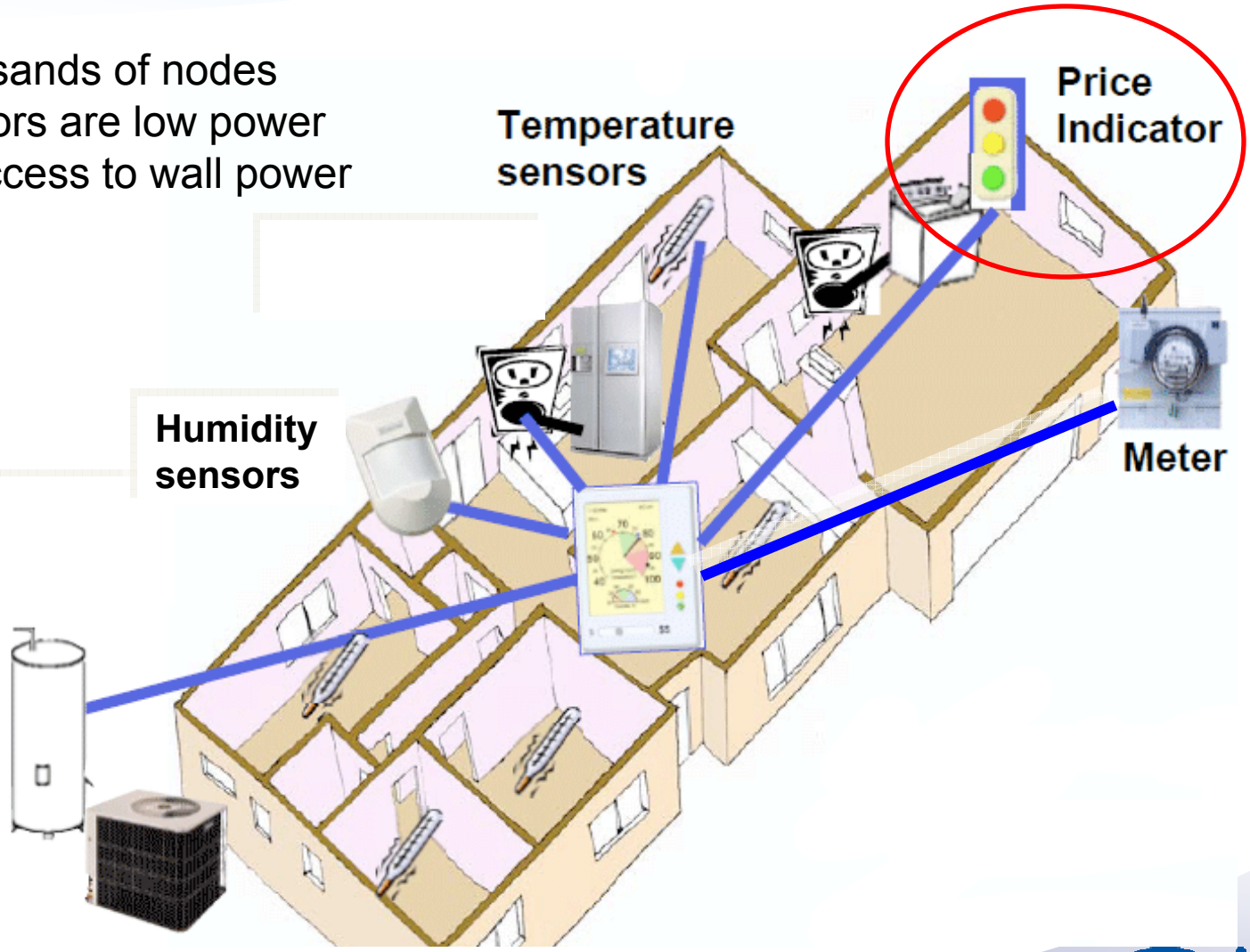
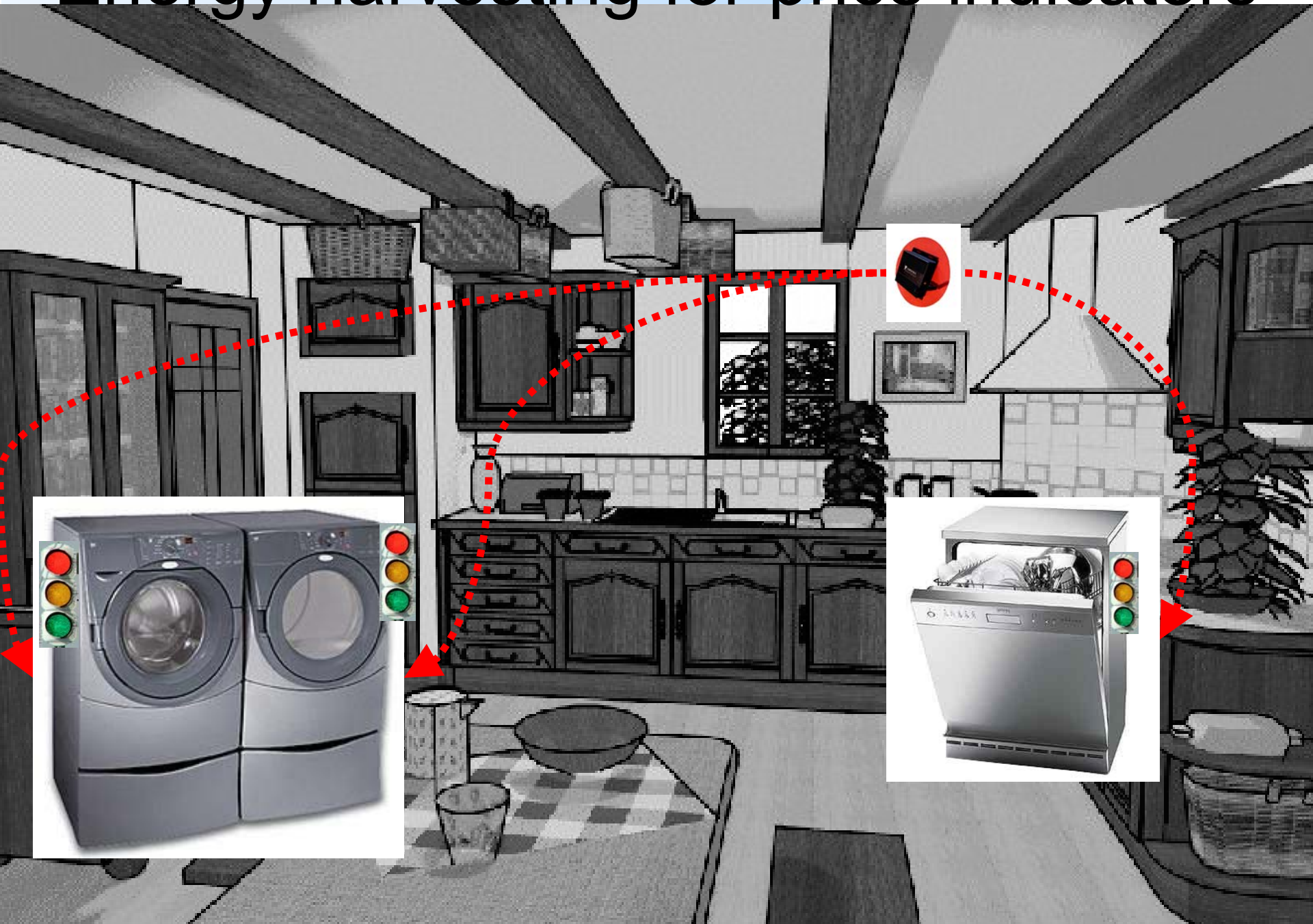


Image: M. Seeman, presentation on Feb 20, 2009

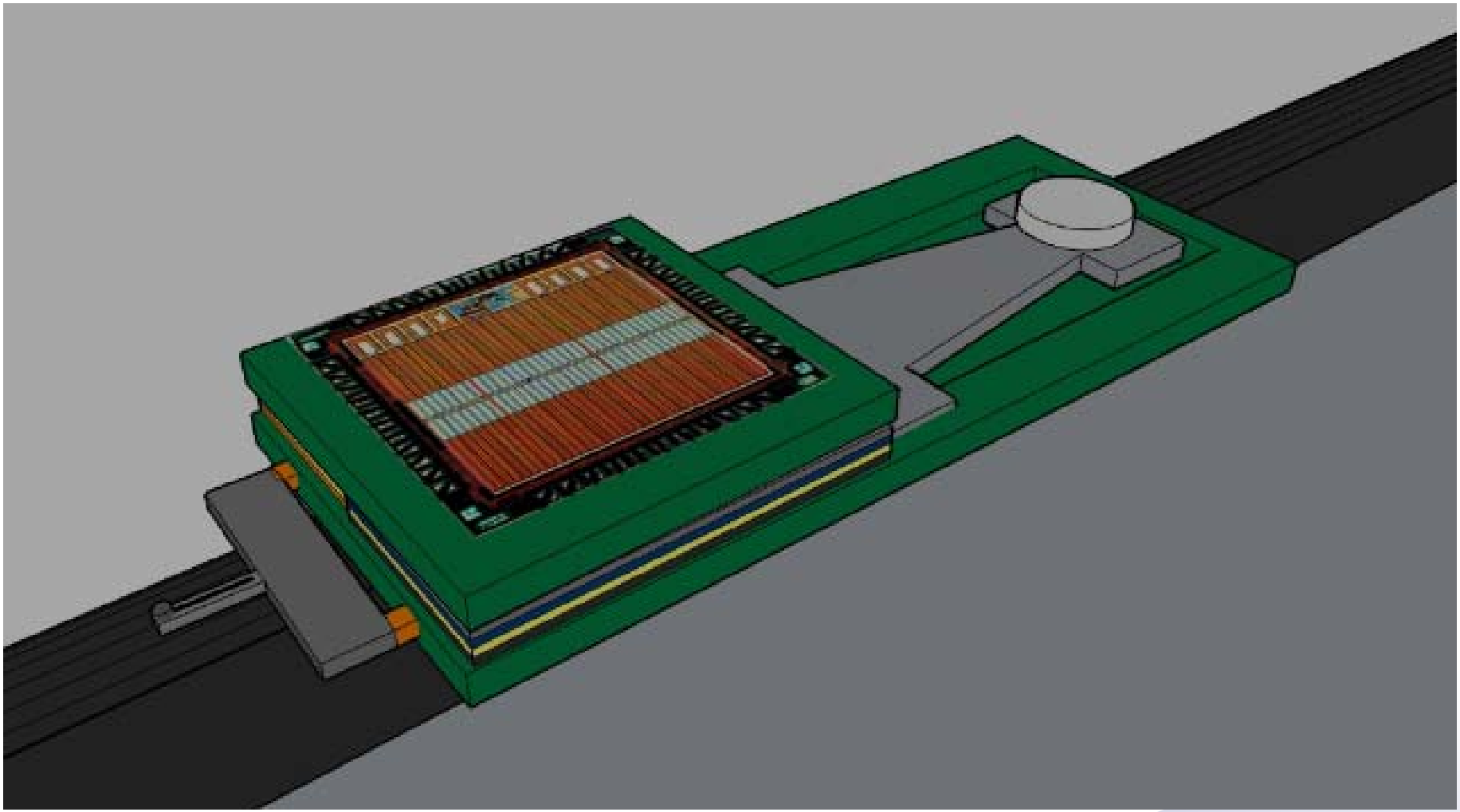
Energy harvesting for price indicators



How much energy is in vibrations?

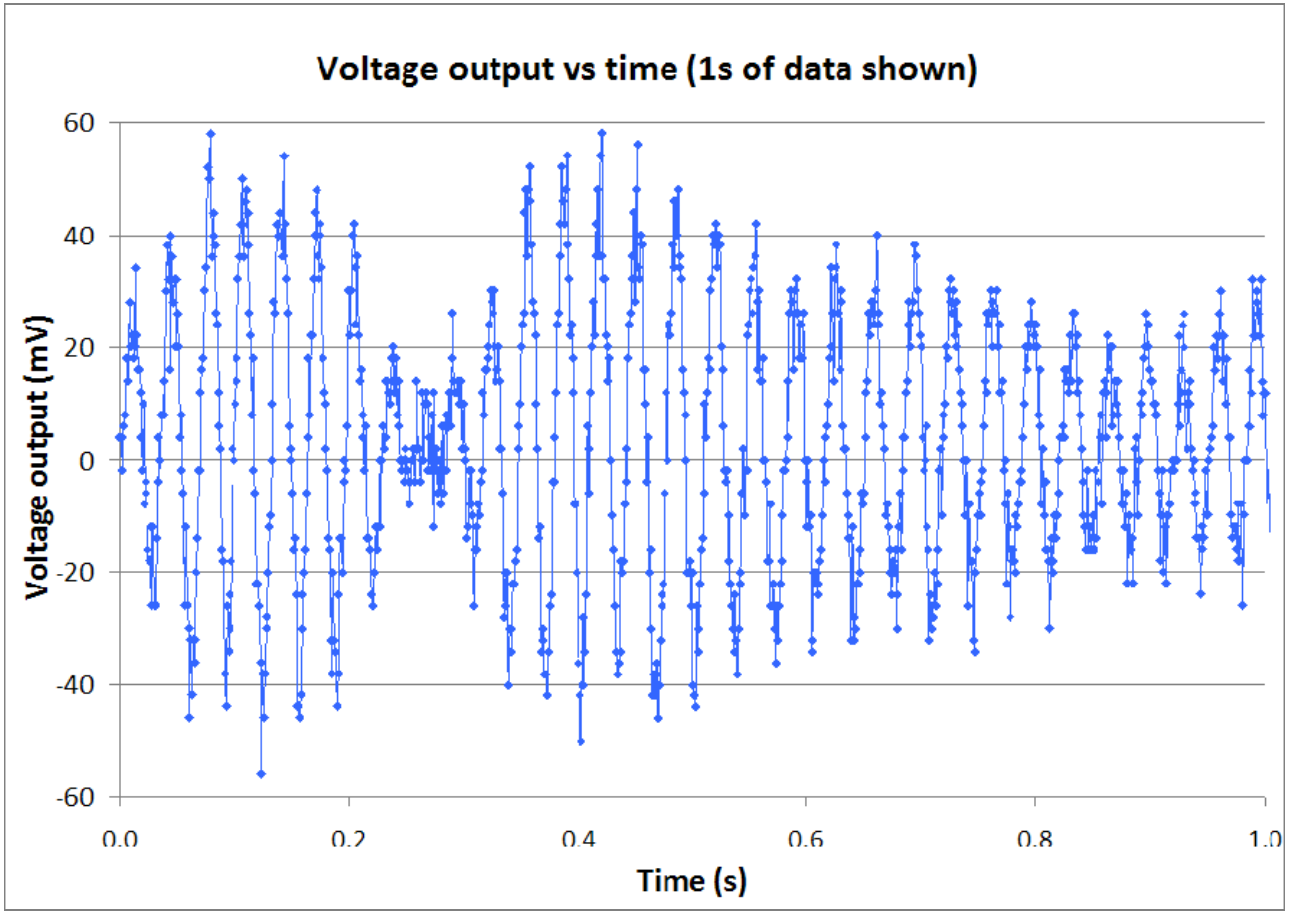
- 200 μW/cm^3 for meso scale device driven by ambient vibrations
- 5 μW/cm^3 goal in order to power radio
- 0.10 μW/cm^3 current MEMS prototype capability when driven by ambient vibrations

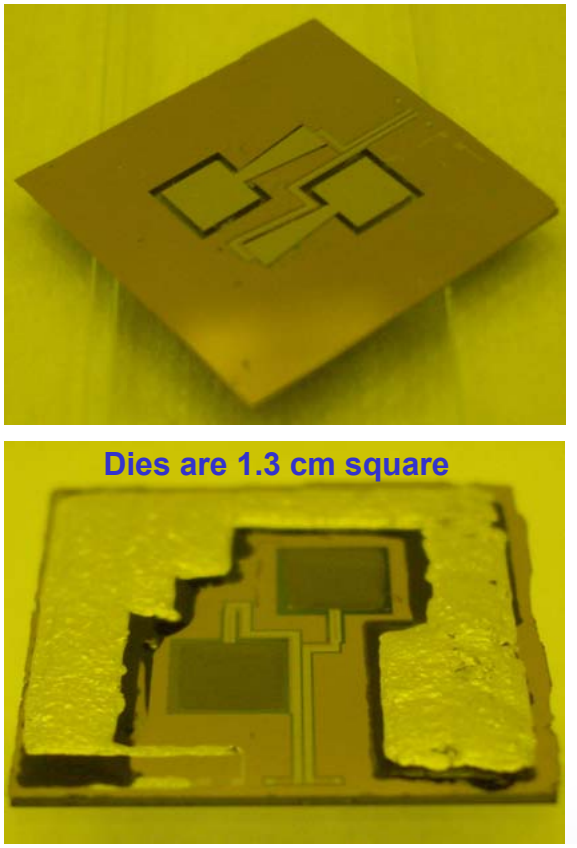
Energy harvesting for current sensor



Vibration harvester preliminary results

Voltage output from beam excited by an HVAC duct





Physical integration of printed capacitor & energy harvester

The beam output signal is ~22 mV_{rms} at ~30 Hz

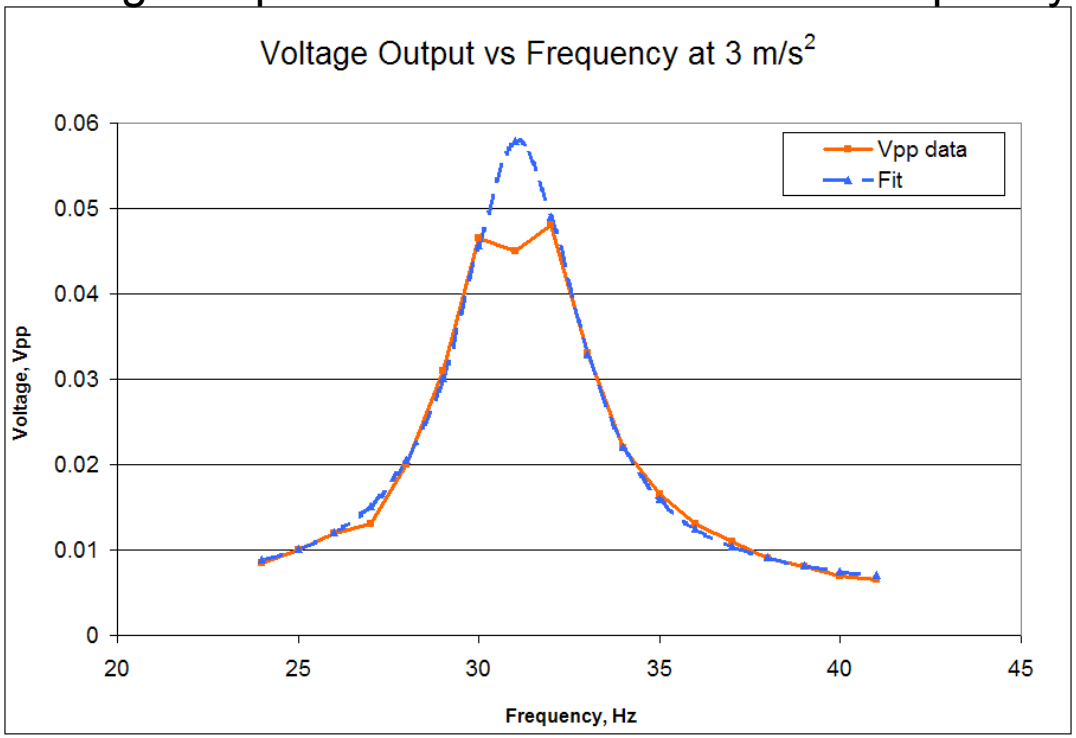
In summary

- We have developed energy harvesters:
  - MEMS fabricated
  - Low resonance frequency
  - Produced 22 mV_{rms} when mounted on HVAC duct
- This harvested energy can be used to
  - Power price indicators on appliances
  - Power current sensors

Thank you. Questions?

Frequency

Voltage output shows 31 Hz resonance frequency



Energy harvesting for industrial sensors

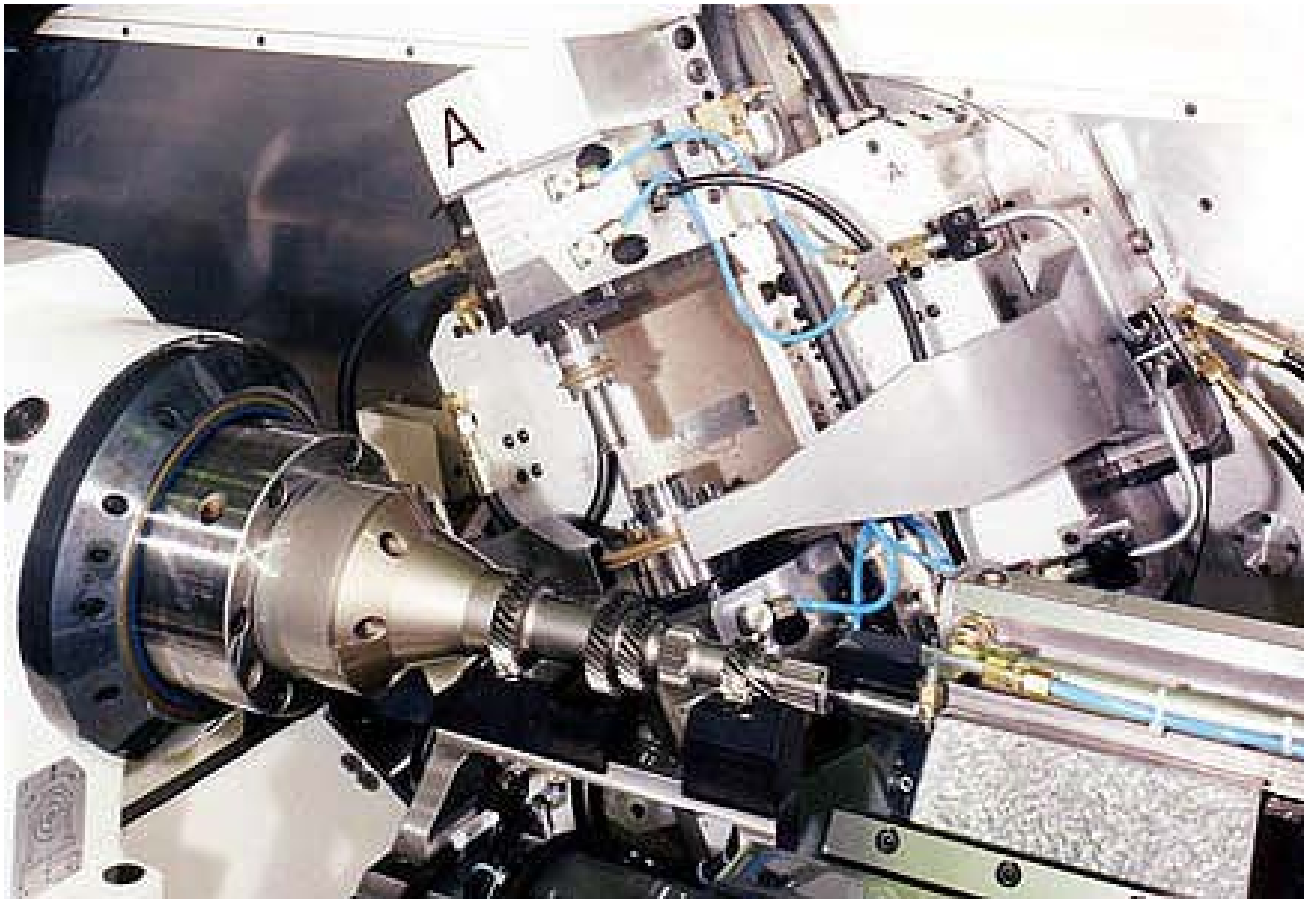
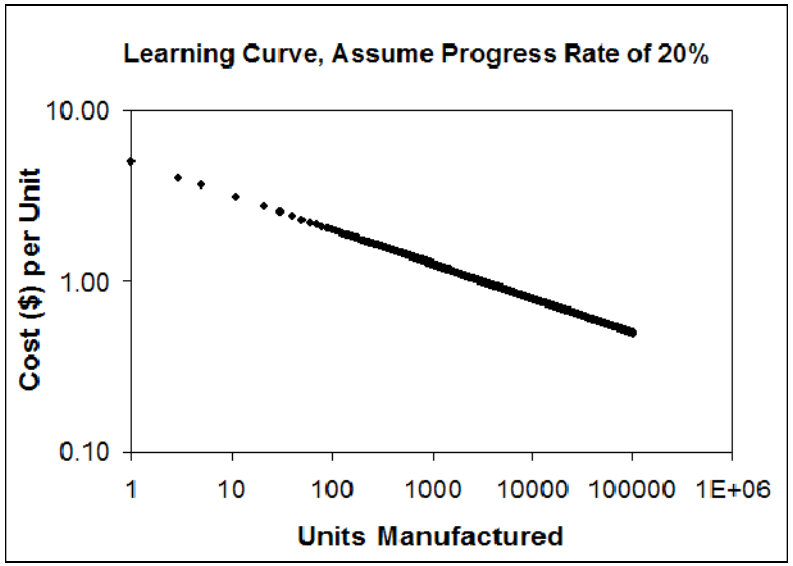


Photo credit: Kapp Technologies external gear profile grinding machine

Vibration Harvester Cost Estimate

- In 1960 1 transistor cost $1
  Now 1 *million* transistors cost $1
- Current cost ~ $5/die (6” wafer)
- Expected cost
  Y =a X^{-b} =($5/part)(1 mil parts)^(-.2)
  Y = < $0.50/die after 1 million made



- Volume potential
  Millions of homes in CA
  ~100 million devices in the US

20% Progress Rates
Solar Photovoltaic Cells
Gas and Wind Turbines
Airframe Manufacture

Yelle, L.E. (1979) "The Learning Curve: Historical Review and Comprehensive Survey", Decision Sciences Vol. 10, pp. 302 – 328.
http://www.ifm.eng.cam.ac.uk/csp/summaries/learningcurve.html and http://www.nrel.gov/docs/fy06osti/39904.pdf