MEMS Vibration Energy Harvesting Applications

We have developed energy harvesters:

- MEMS fabricated
- Low resonance frequency
- Produced $22 \text{ mV}_{\text{rms}}$ voltage output from HVAC duct vibration

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Wireless sensor nodes
Sensor, Radio, Power Supply

Input: vibrations

Energy Harvester

Power Conditioning Circuitry

Storage Capacitor  Rechargeable Battery

Regulator

Load (sensor, radio)

Output: send signal

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
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
Energy harvesting for price indicators
How much energy is in vibrations?

- 200 μW/cm³ for meso scale device driven by ambient vibrations
- 5 μW/cm³ goal in order to power radio
- 0.10 μW/cm³ 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

The beam output signal is $\sim 22 \text{ mV}_{\text{rms}}$ at $\sim 30 \text{ Hz}$
In summary

• We have developed energy harvesters:
  – MEMS fabricated
  – Low resonance frequency
  – Produced $22 \text{ mV}_{\text{rms}}$ 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
Vibration Harvester Cost Estimate

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

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