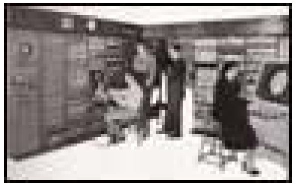
Networking Testbed, Supported by Energy Scavenging

Paul Wright and students

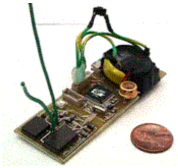
Networking Testbed, supported by Energy Scavenging

Operating system (TinyOS) allows ad hoc networking (Culler)

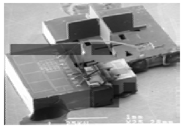


MVS - 60's

DOS / Windows - 80's



TinyOS - 2002



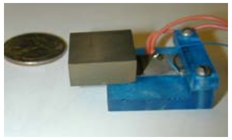
TinyOS - 2004

Energy source for supporting the nodes (Wright)

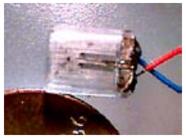
Traditional Batteries

Solar

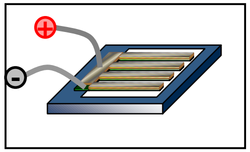
Vibration 2002

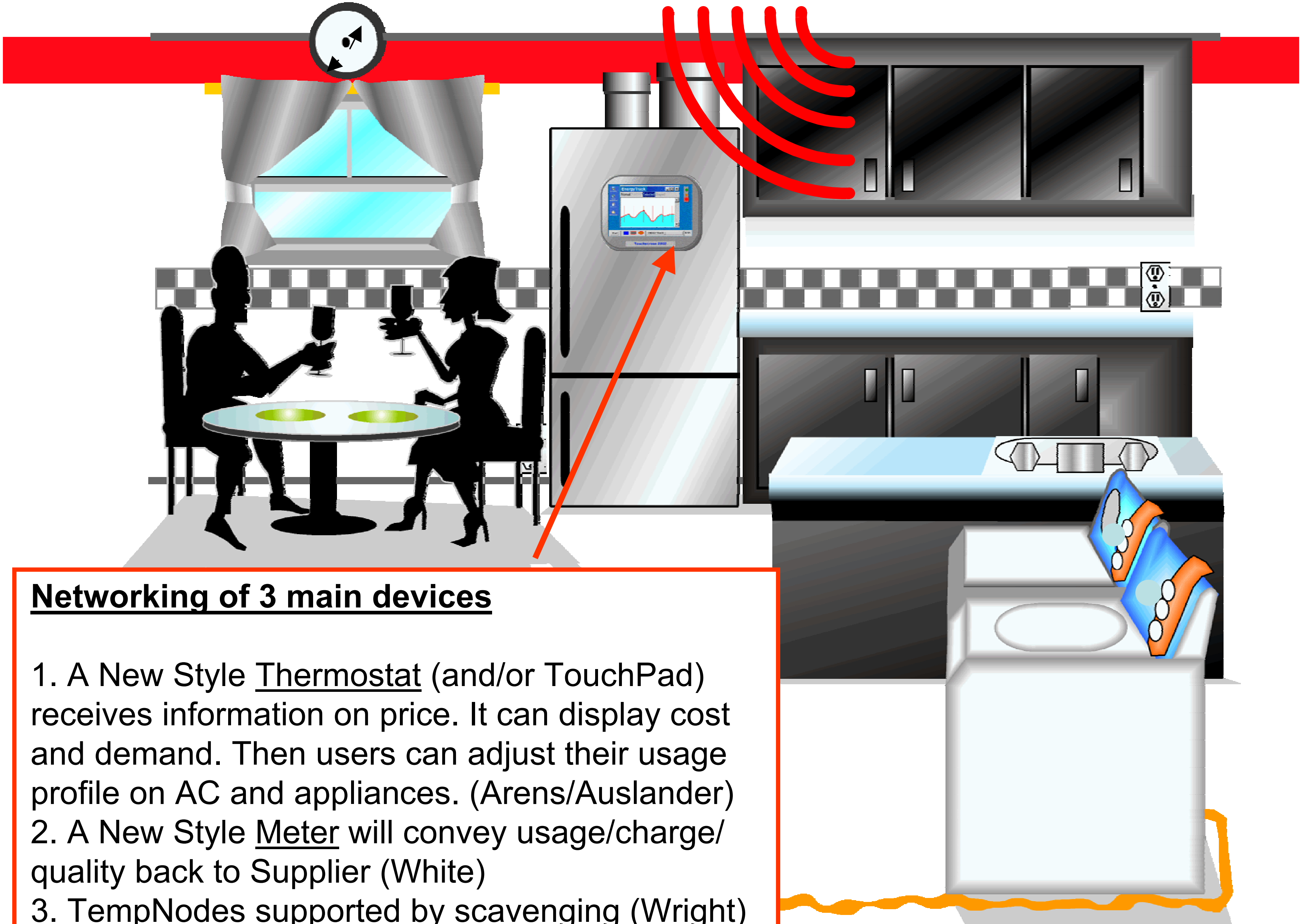


Vibration 2003



Vibration 2004



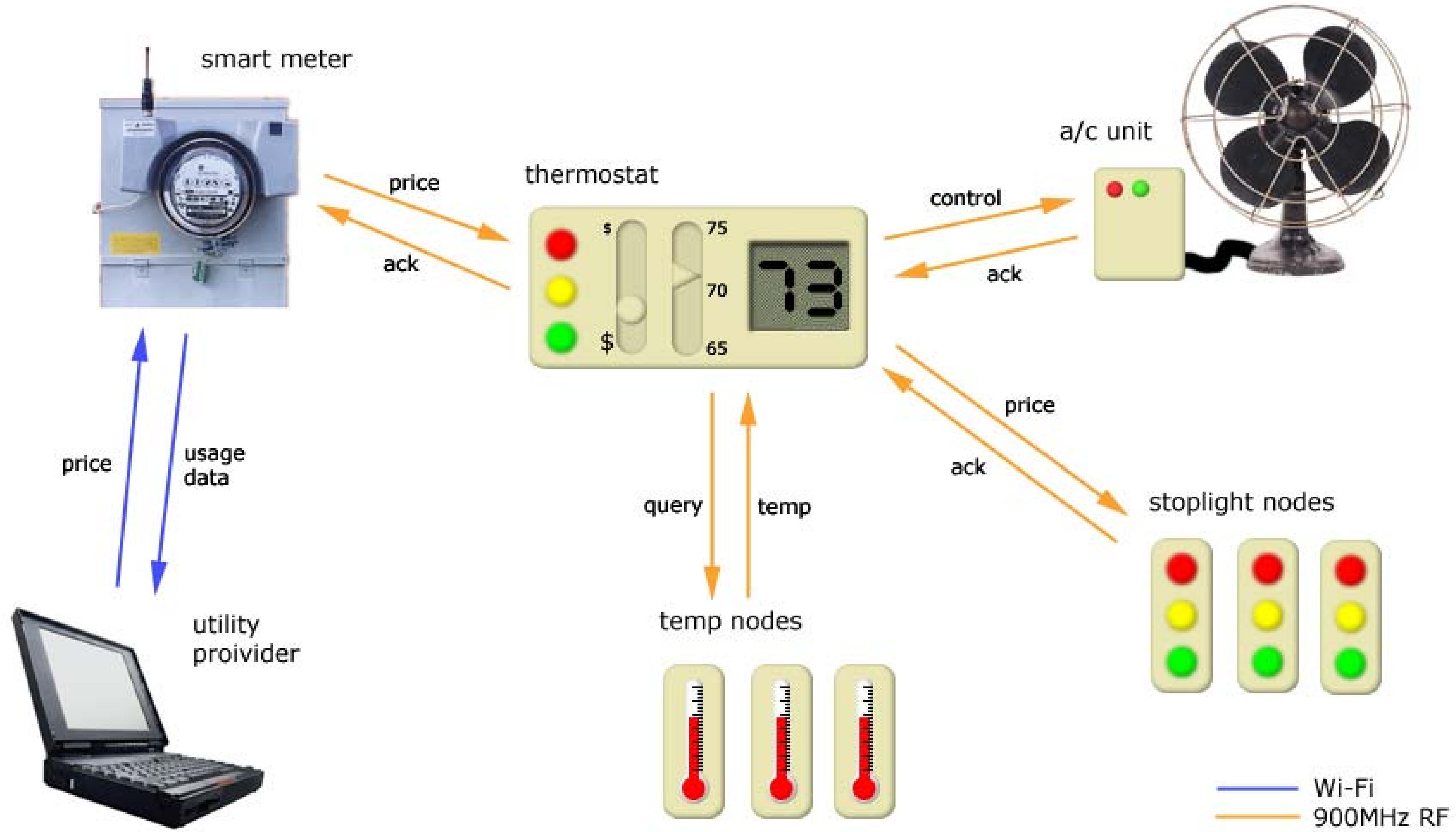


Networking of 3 main devices

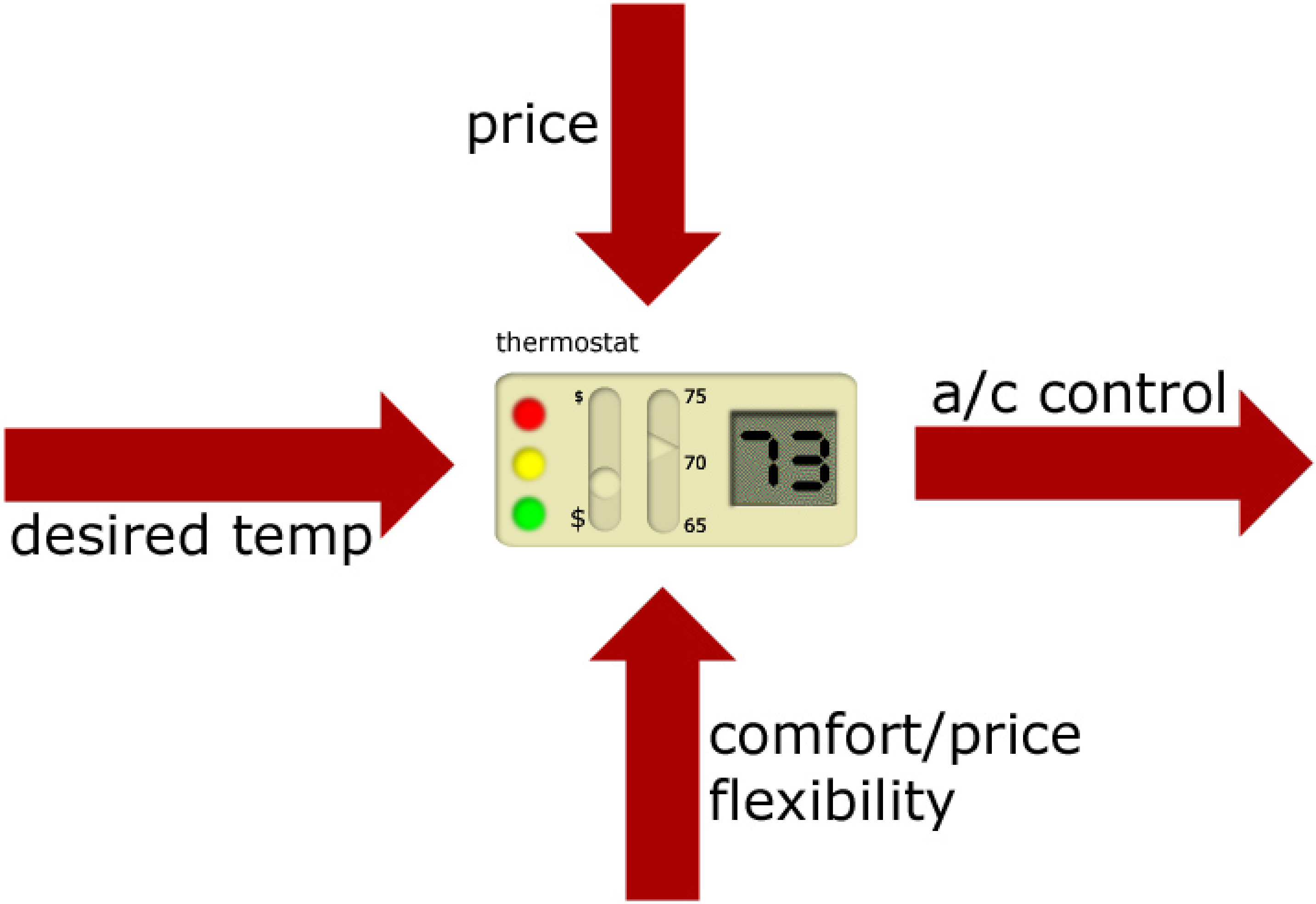
1. A New Style Thermostat (and/or TouchPad) receives information on price. It can display cost and demand. Then users can adjust their usage profile on AC and appliances. (Arens/Auslander)
2. A New Style Meter will convey usage/charge/ quality back to Supplier (White)
3. TempNodes supported by scavenging (Wright)
4. Wireless systems (Rabaey/Culler)

"Network communication testbed"

Dan Hooks, Nate Ota, Will Watts, Andrew Redfern

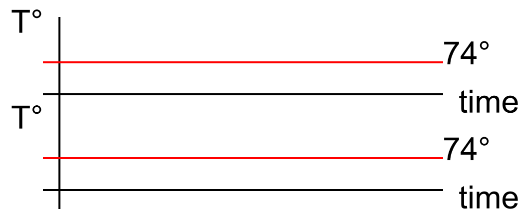
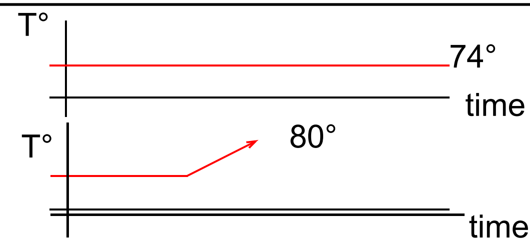
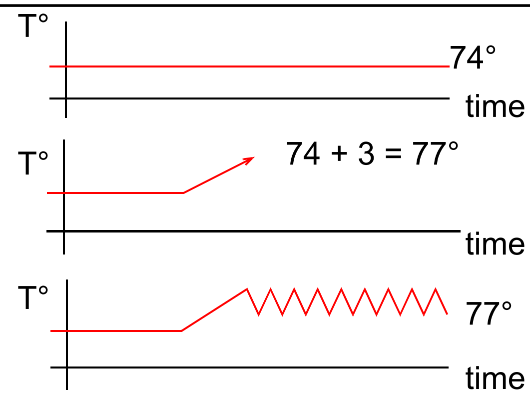


Control logic



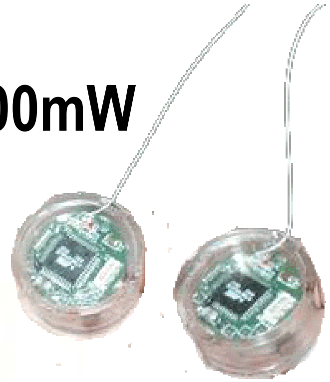
Pause: A light-hearted view of DR @ 74ºC

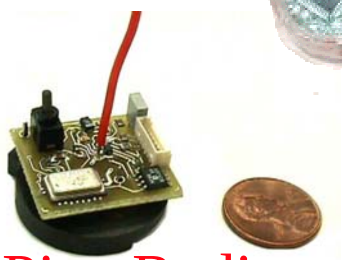
Personal Choices	Two Cost Levels	Fan (or AC)	Averaged Room Temperature, T_{AVE}
Mr. Rich – Donald Trump Mr. Grad Student – Nate Ota Mr. Middle Class – Paul Wright	20 ¢ /kwhr $1.00 /kwhr	On Off	$\Sigma\ (T_1 \text{ to } T_5)\ /5 = T_{AV}$

1. Donald @ 20¢ = Fan on = 2. Donald @ $1.00 = Fan on =		"Mr. Cool" (@74 or less)
3. Nate @ 20¢ = Fan on = 4. Nate @ $1.00 = Fan off =		"Mr. Sweaty" (@>>>80)
		"Mr. OK" (@77)

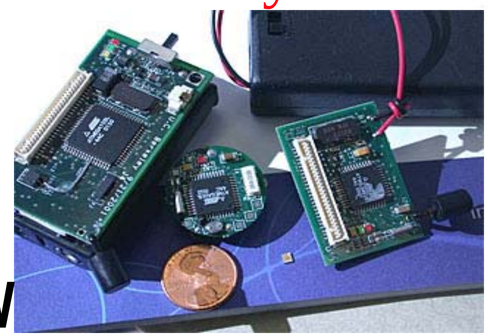
Three enabling technologies for such a testbed

2 - 5cm^3 ~100mW



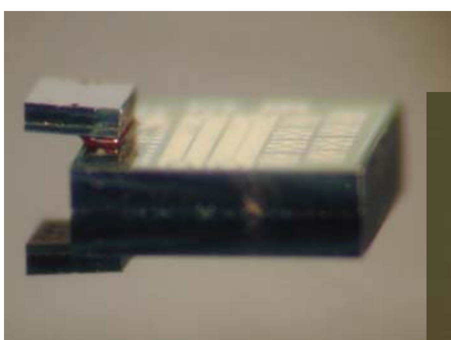


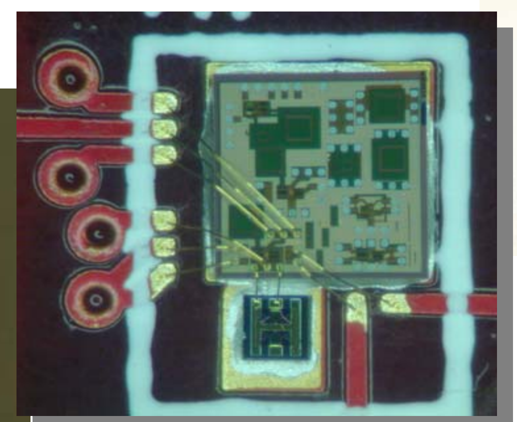
1. Tiny OS

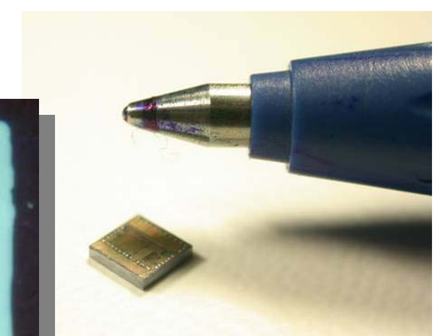


2. Pico Radio

1cm^3 or less and 10-50μW





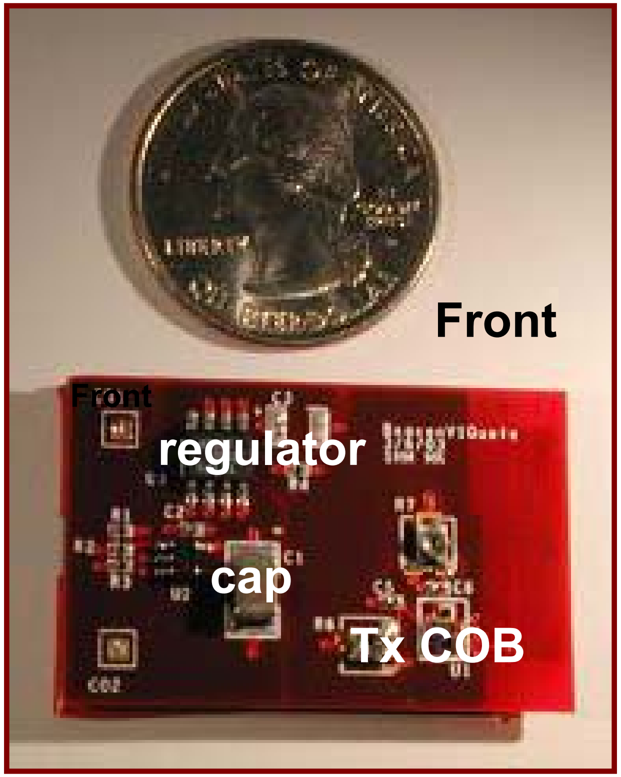


Source: Jan Rabaey

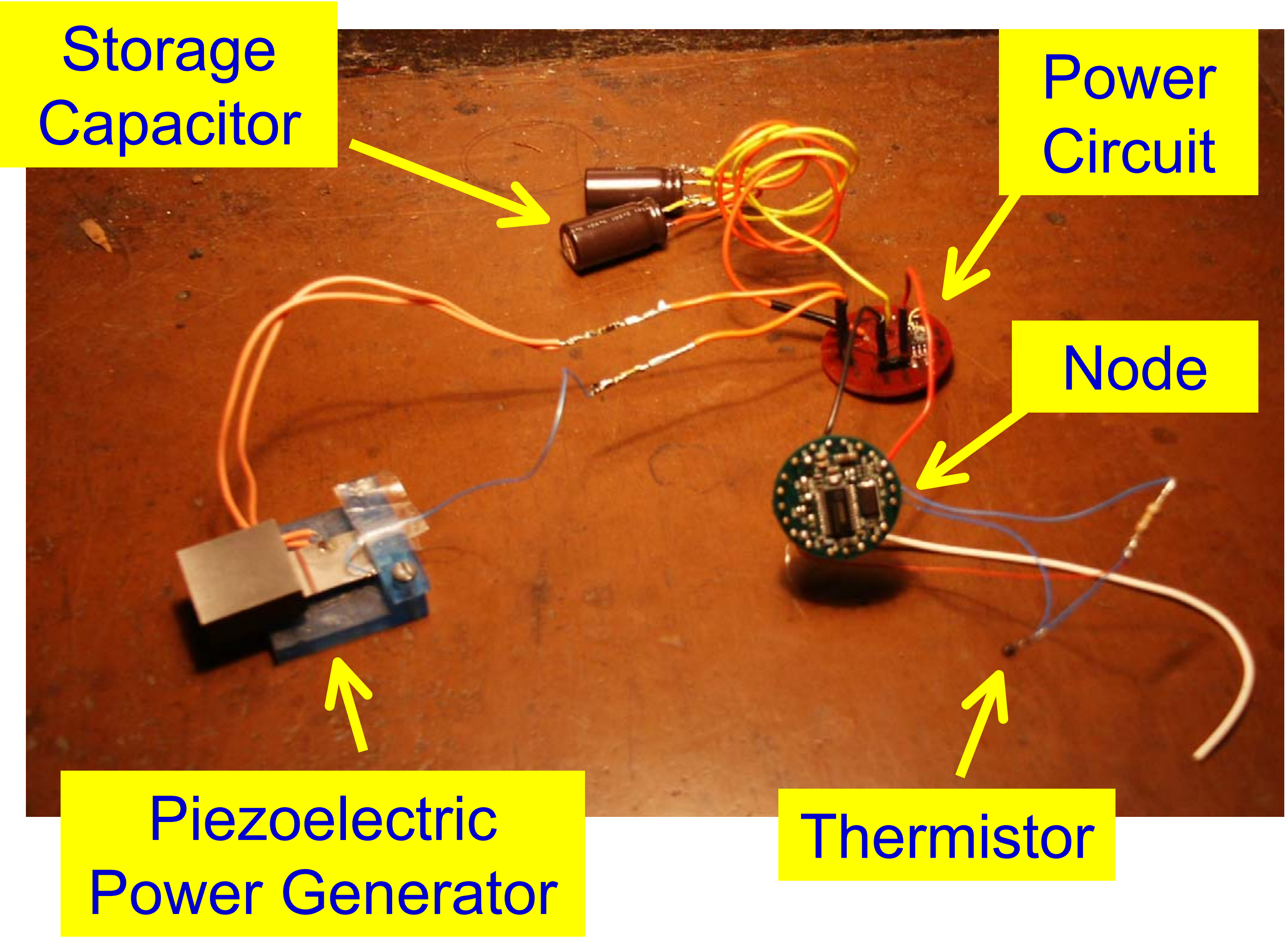
3. Energy Scavenging Methods for the Nodes in the Testbed

Goals:

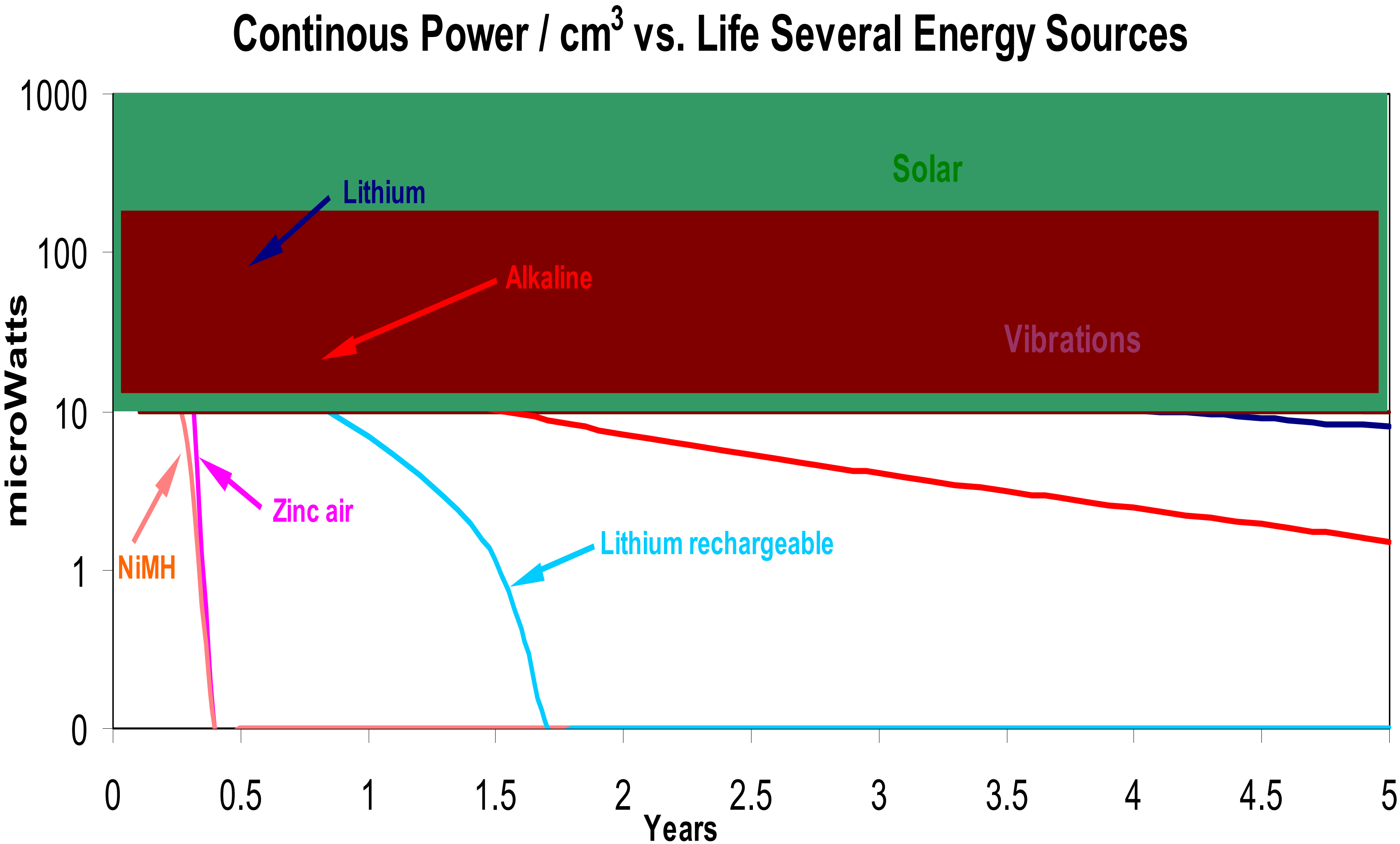
- 3a) Solar & 3b) Vibrational energy scavenging
- Push integration limits - limited by dimensions of solar cell



3b) Wireless Sensor Network (WSN) platforms Powered by Energy Scavenging

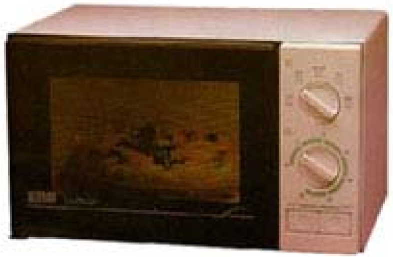


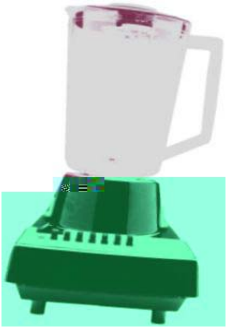
Battery, Solar, and Vibrational Energy



Common Sources of Vibrations

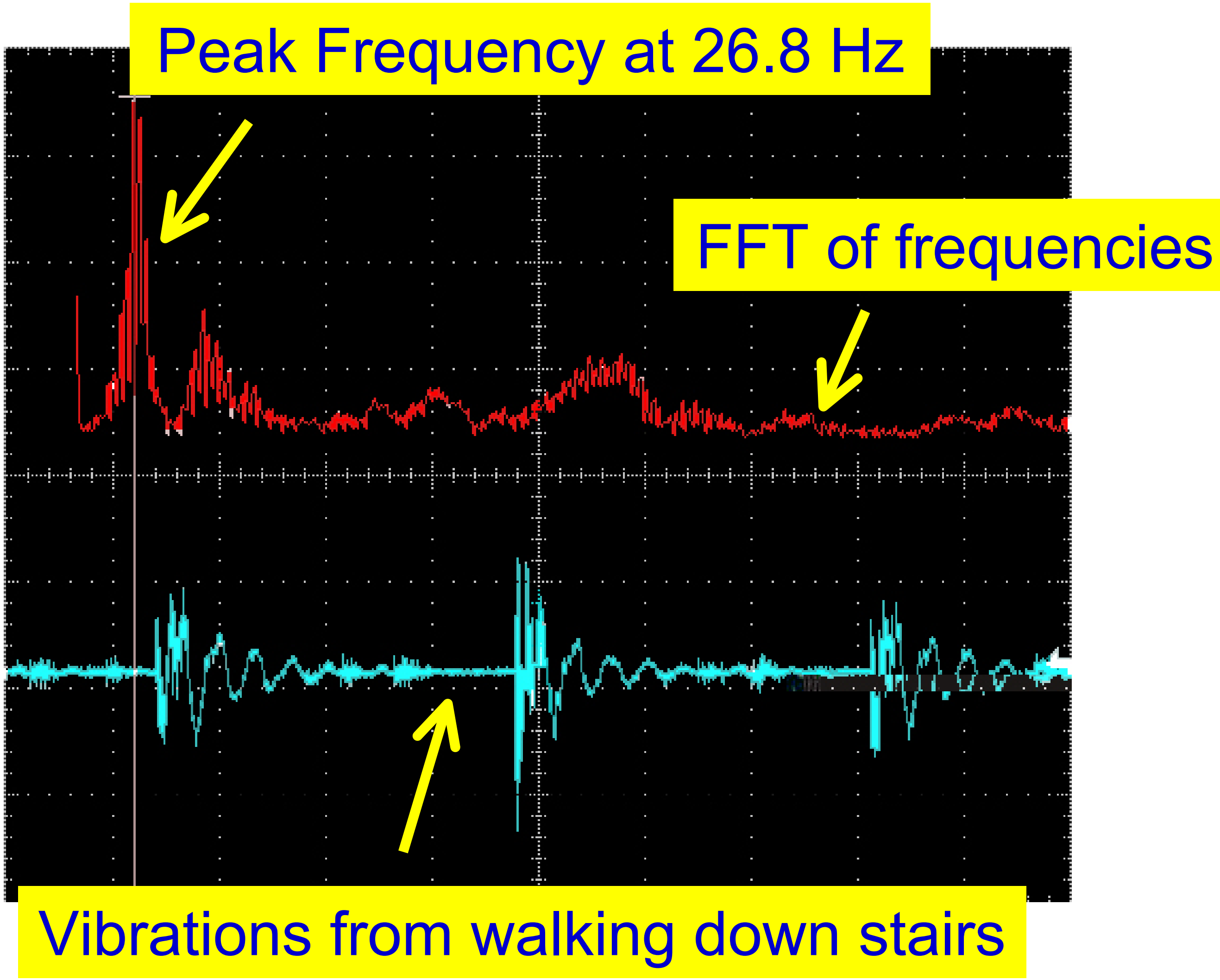
Vibration Source	Frequency of Peak (Hz)	Peak Acceleration (m/s²)
Kitchen Blender Casing	121	6.4
Clothes Dryer	121	3.5
Door Frame (just after door closes)	125	3
Small Microwave Oven	121	2.25
HVAC Vents in Office Building	60	0.2-1.5
Wooden Deck with People Walking	385	1.3
Bread Maker	121	1.03
External Windows (size 2ftx3ft) next to a Busy Street	100	0.7
Notebook Computer while CD is Being Read	75	0.6
Washing Machine	109	0.5
Second Story of Wood Frame Office Building	100	0.2
Refrigerator	240	0.1



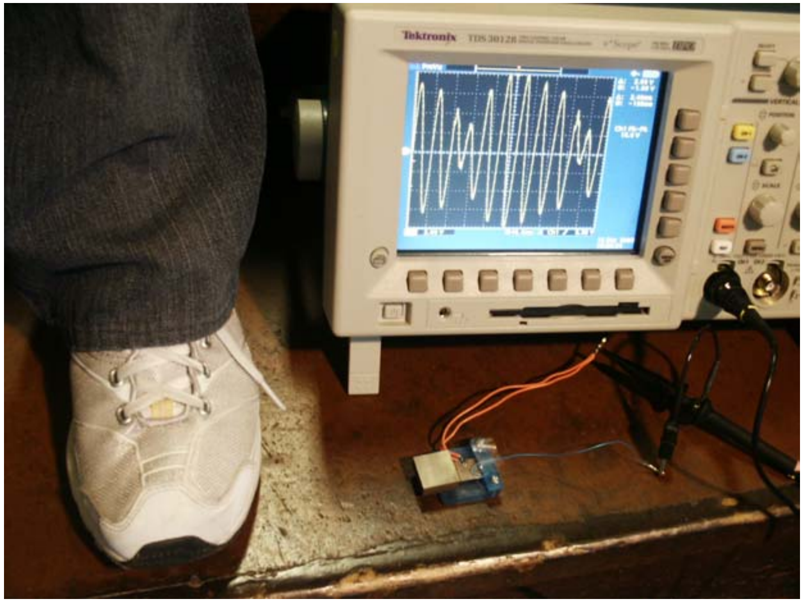


Wooden Stairs

Power generator must match peak frequency of vibration source for max power output



Bender Design



40V peak–to-peak output from bender when someone walks down the stairs

Characteristics

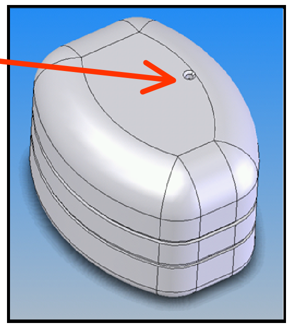
- Piezoelectric: PZT
- Tungsten Alloy Mass: 52 g
- Beam Dimensions:

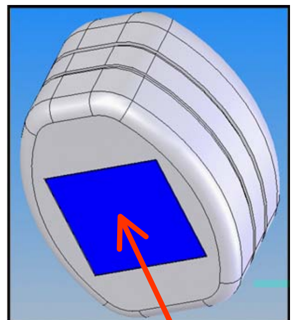
  1.25” x 0.5” x 0.02”

Behavior

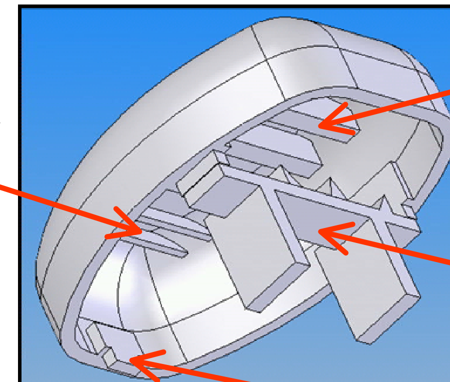
- Resonant Frequency: 26.8 Hz
- Power Output: 450 μW

FDM Packaging

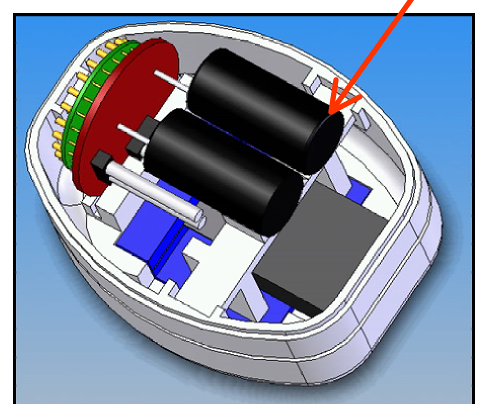




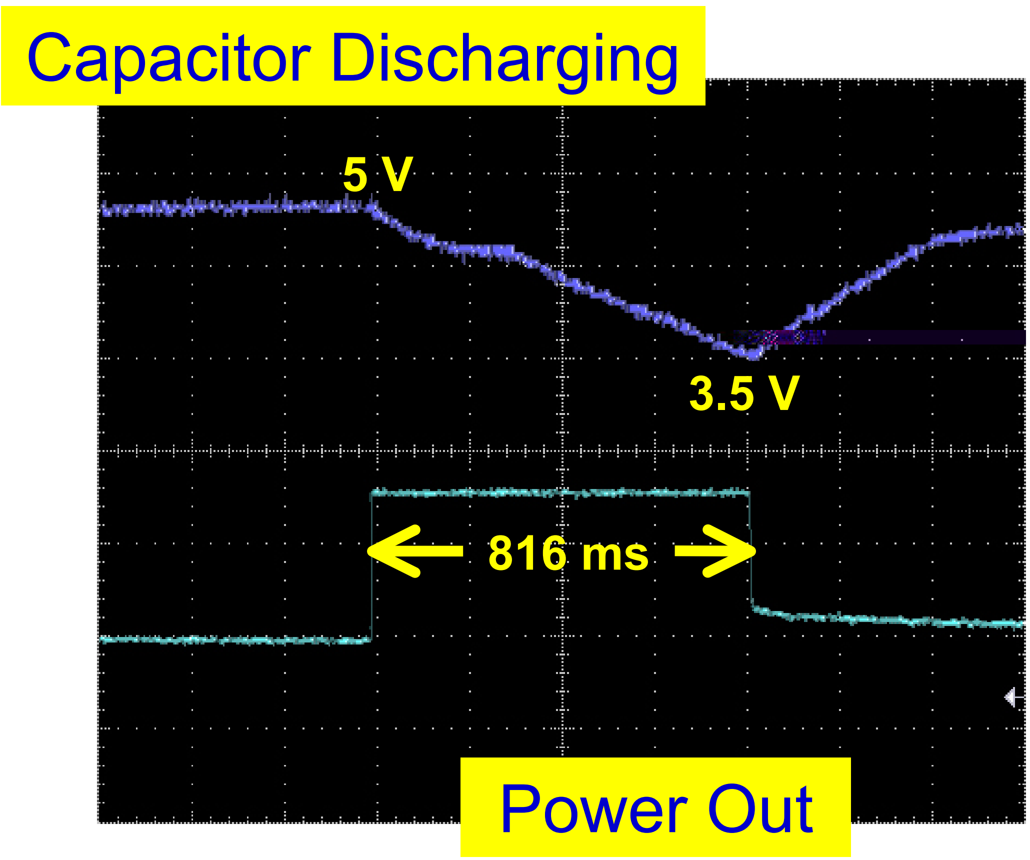
Upper Case

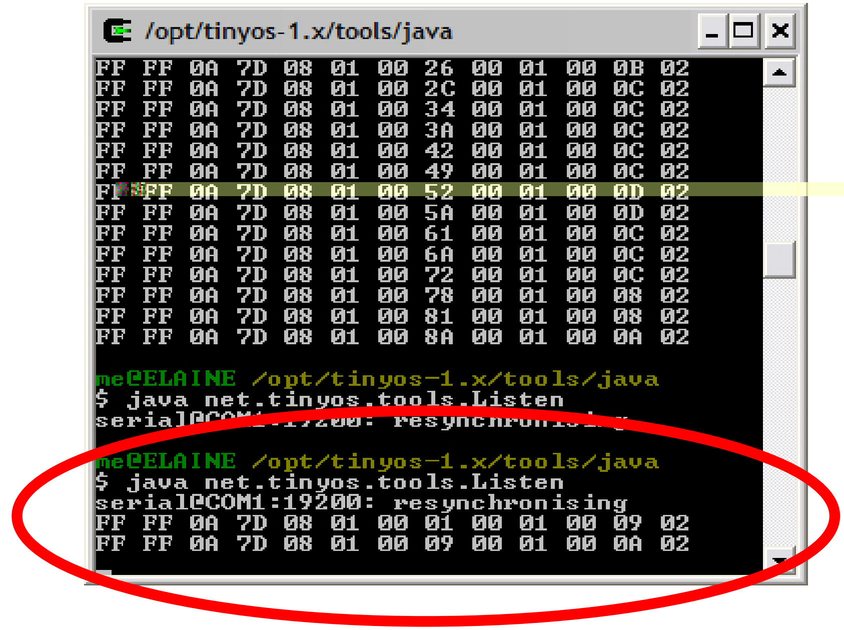


Lower Case



Proof of Concept

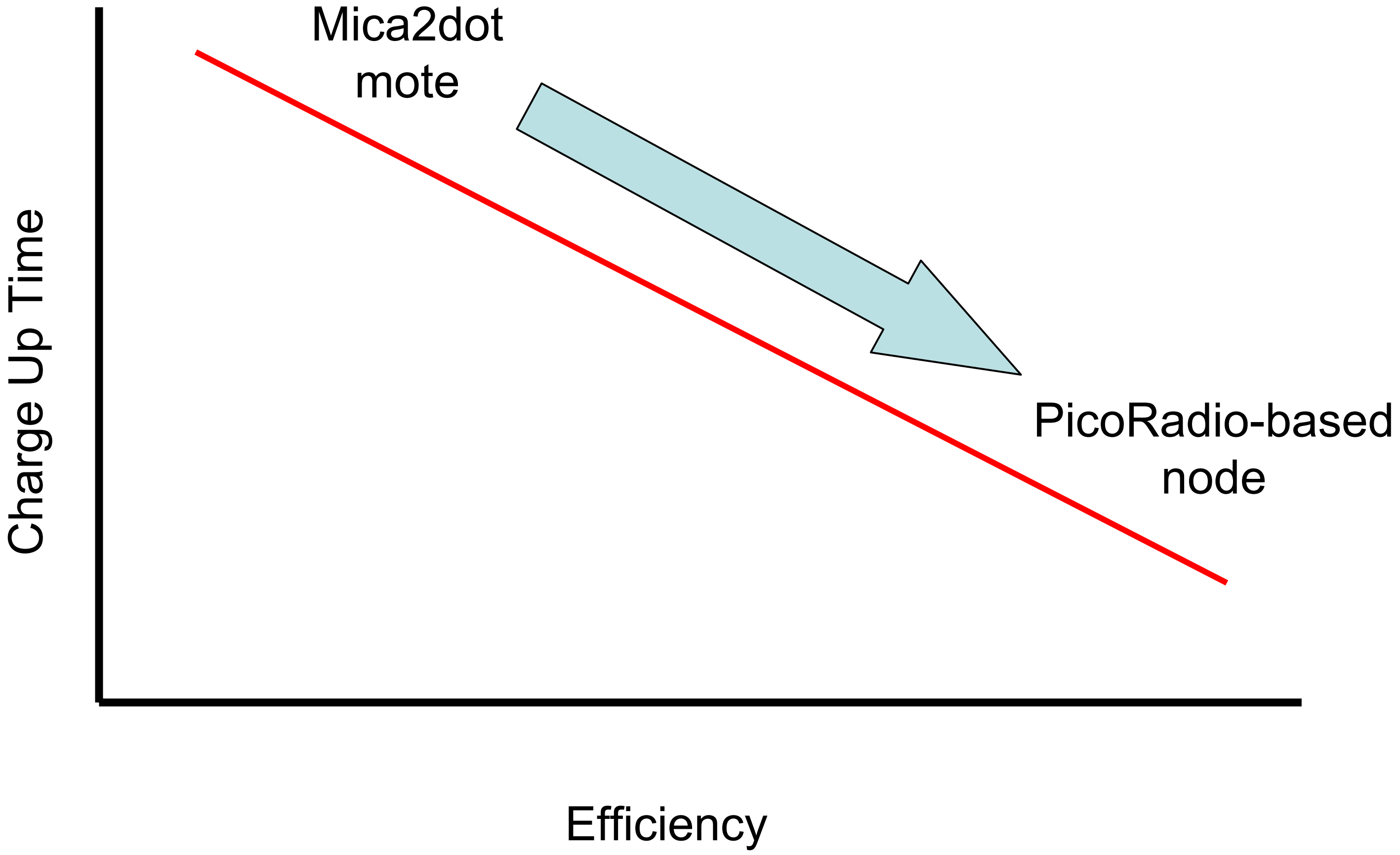




Results

- 3.28 V for 816 ms
- 2 temperature readings transmitted

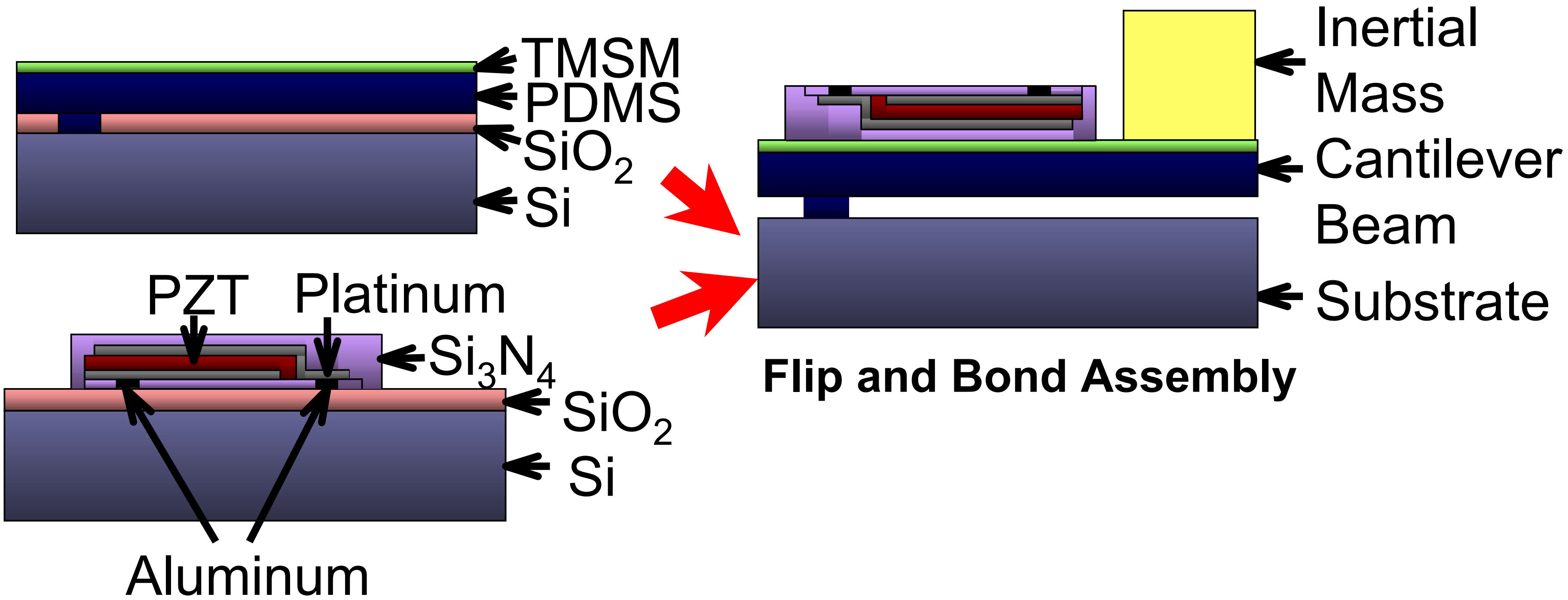
Next Steps



Mica2dot
mote
PicoRadio-based
node
Charge Up Time
Efficiency

Next Steps

Design a variable resonant frequency MEMS bender which adapts to vibration sources with different peak frequencies.



Flip and Bond Assembly

“Network testbed & energy scavenging”

End/Summary/Questions/See Demo