Power for Wireless H_2 Sensor Network

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Planned Completion = 8/2/2006

Research Goals and Objectives

- To develop a power source for a wireless hydrogen sensor network using a multi-source energy harvester that harvests vibrational energy for operation during ‘dark’ conditions and optical (solar) energy for operation during ‘light’ conditions.
- To design and fabricate a power processor that extracts energy from a photovoltaic and a vibration energy harvester and delivers the energy to a reservoir that supports a self-powered hydrogen sensor network.

Relevance to Current State-of-the-Art

- Current battery technologies have a limited shelflife ~ few years.
- Reclamation of solar radiation is limited to applications with direct exposure.
- Vibrational energy occurs in many structural and mechanical systems.
  - Ambulatory sources [Lakic 1988, Kymissis 1998, Amirtharajah 1998, Antaki 1995, Pelrine 2001].
  - Ground vibrations and vibrating equipment [Roundy 2004, Roundy 2003, Glynne-Jones 2001].
- Goal: Dual-source power harvester to harvest vibrational and solar energy.

Relevance to NASA

- Since a NASA objective is to achieve long (10 year) operating life with minimal maintenance, a wireless system implies both wireless data transmission as well as wireless power generation.

Budget, Schedule and Deliverables

- *Milestones*
- ***1st Quarter***: *Design photovoltaic power processor. Fabricate MEMS piezogenerator.*
- ***2nd Quarter***: *Fabricate and test photovoltaic power processor. Test piezogenerator.*
- ***3rd Quarter***: *Design, fabricate, and test vibration power processor. Package piezogenerator.*
- ***4th Quarter***: *Synthesize multi-input power processor; test photovoltaic and vibration power processors with photovoltaic and piezoelectric generators, sensors, and power transmitters.*

- *Products and Deliverables*
- ***1st Quarter***: *Quarterly report describing circuits and design optimization tools for photovoltaic power processors; schematics and operation waveforms.*
- ***2nd Quarter***: *Photovoltaic power processor prototype and test data; quarterly report*
- ***3rd Quarter***: *Vibration power processor prototype and test data; quarterly report.*
- ***4th Quarter***: *Final report describing updates for previous quarterly reports; circuit synthesis and operation of multi-input power processors; results of integrated system tests; final review meeting.*

	1st Quarter	2st Quarter	3st Quarter	4st Quarter
Expenditures-Nishida	$17,500	$17,500	$17,500	$17,500
Expenditures-Ngo	$17,500	$17,500	$17,500	$17,500

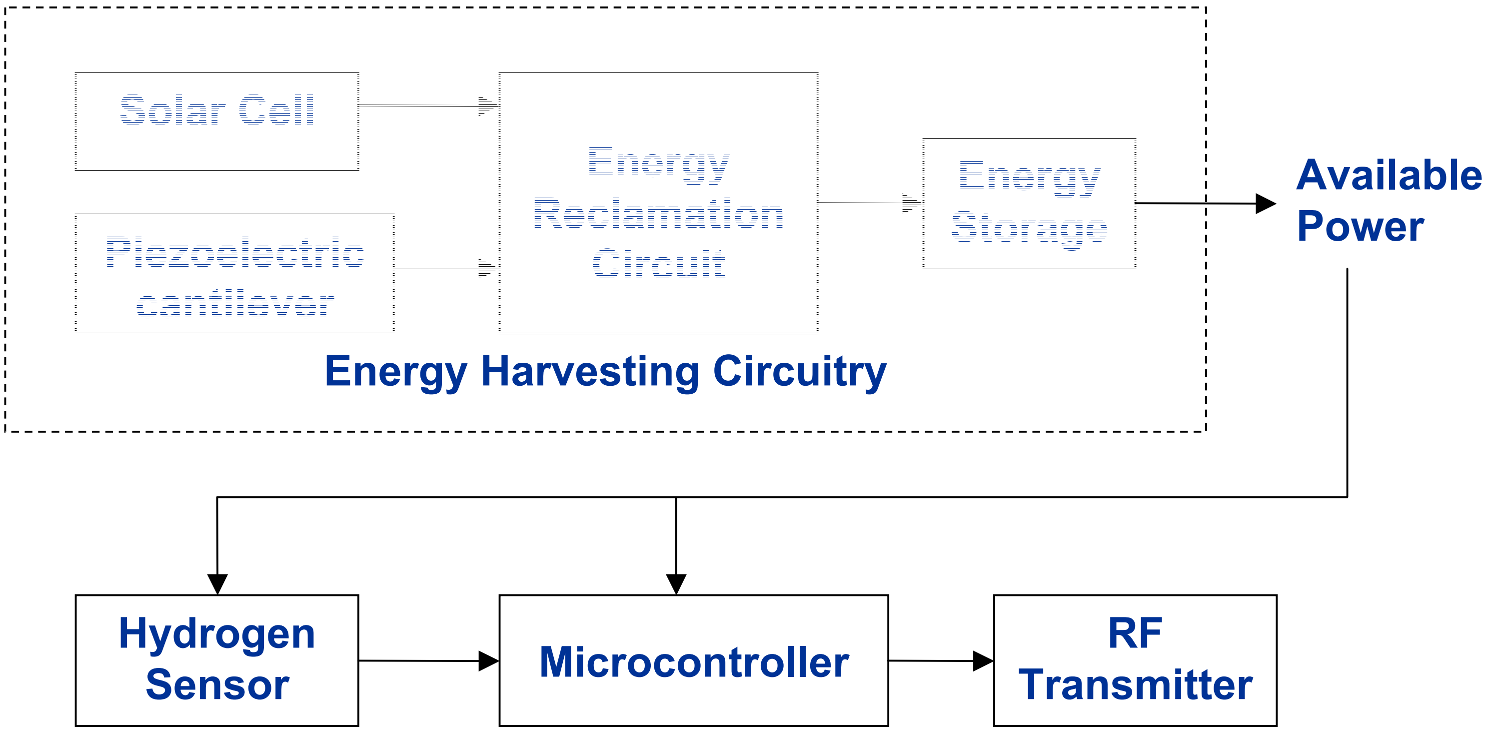
Anticipated Technology End Use

- Multi-energy source power harvester for wireless hydrogen sensor network
- Local ambient energy reclamation to power wireless sensors
  - Condition-based maintenance
  - Structural monitoring
  - Surveillance

Accomplishments and Results

- Power consumption for wireless sensor controller modeled.
- Solar cell power processor designed, fabricated, and tested.
- Vibration piezogenerator power processor designed, fabricated, and tested.
- Electromechanical model formulated for piezoelectric composite beam.
- Scaling theory for micro PZT generators developed and verified using FEM.
- MEMS piezogenerator test structures designed and process flow developed.
- Fabrication of MEMS piezogenerator test structures 70% completed.

System Overview—
Power for Wireless H_2 Sensor Network



Power Budget

Microcontroller & Wireless

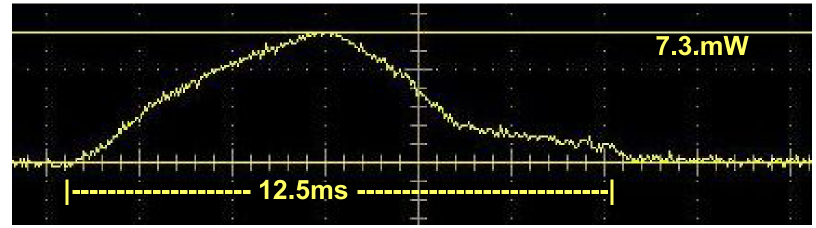
Event	Average Power	Length in Time
Initialization	**3.07 mW**	**12.5ms**
Sense Data	**2.5 uW**	**0.3 ms per bit**
Transmit 1	**261 uW**	**0.5ms per bit**
Transmit 0	**2.5 uW**	**0.5ms per bit**
Remain Idle	**2.5 uW**	**Variable**

- **Includes Power for RF Transmission**
- **Power to transmit a data pattern depends on the data pattern. The long fall time is due to the oscillator not reaching steady state.**

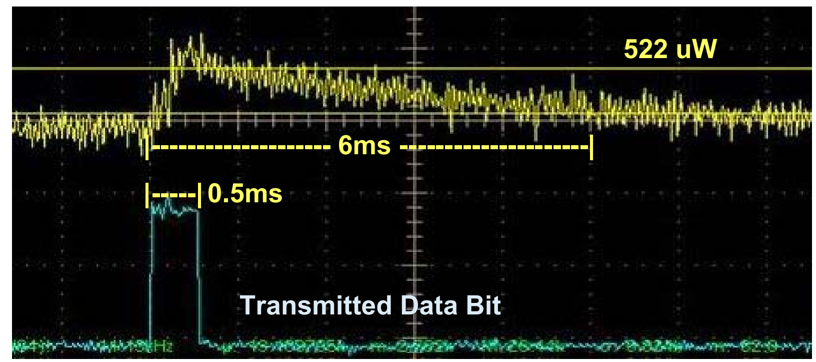
Sensor

Hydrogen Level	Resistance	Average Power
0 ppm	**1563 Ohms**	**84 uW**
500 ppm	**1500 Ohms**	**88.6 uW**

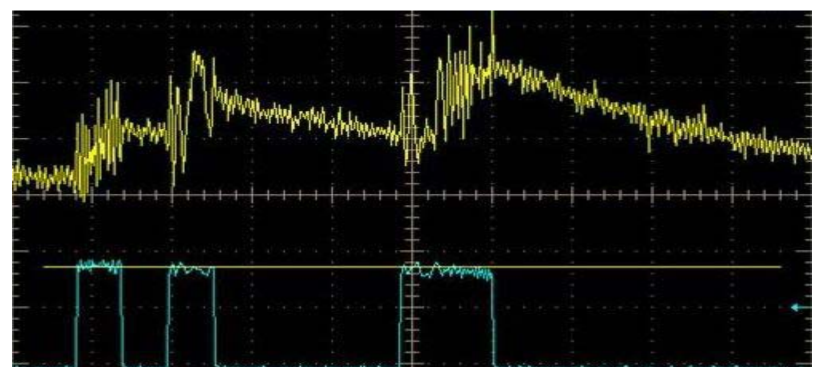
- **Includes Power for Biasing Circuit**



Initialization Power

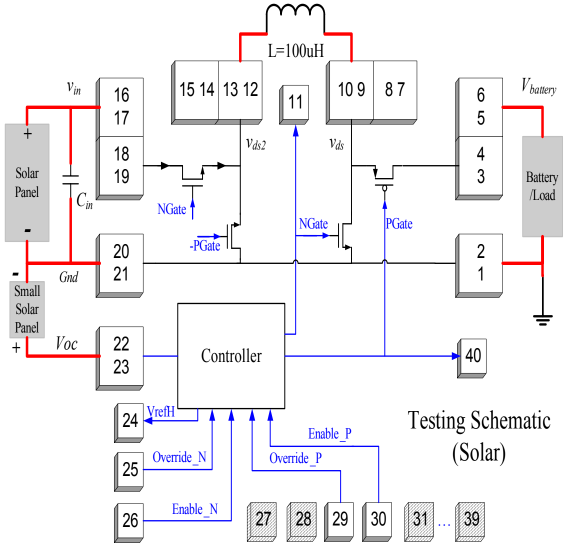


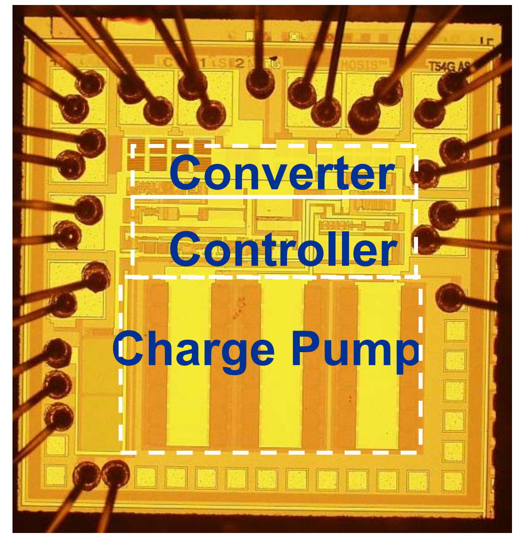
Power to Send 1 bit



Power to Send Data Pattern

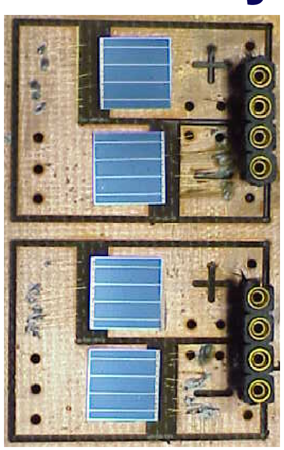
Power Processor IC (Solar): IC & test configuration

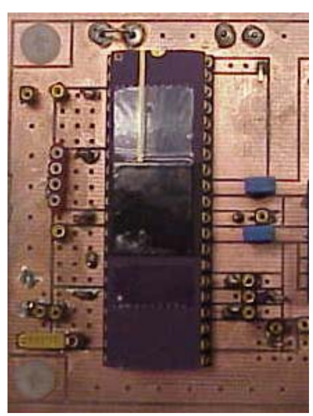




1.5mm

Prototype Test Boards:



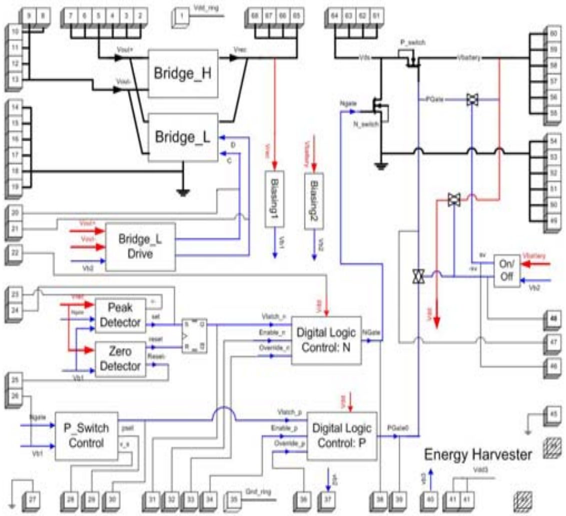


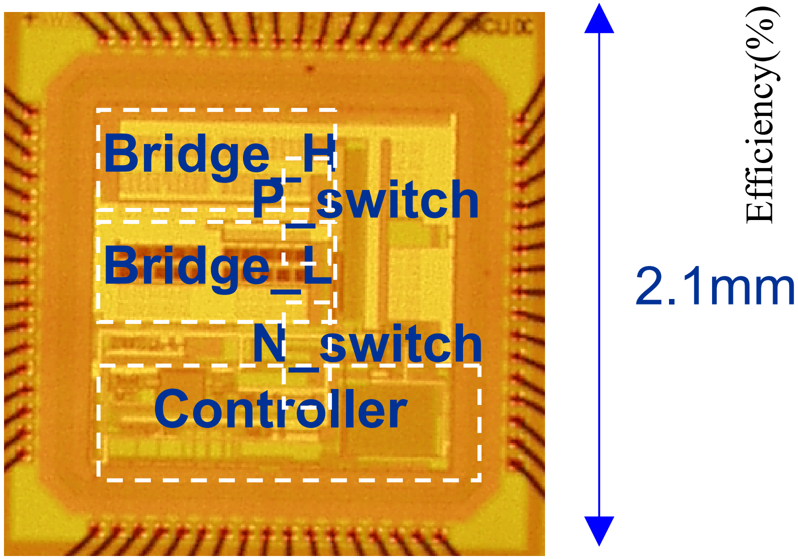
Loads

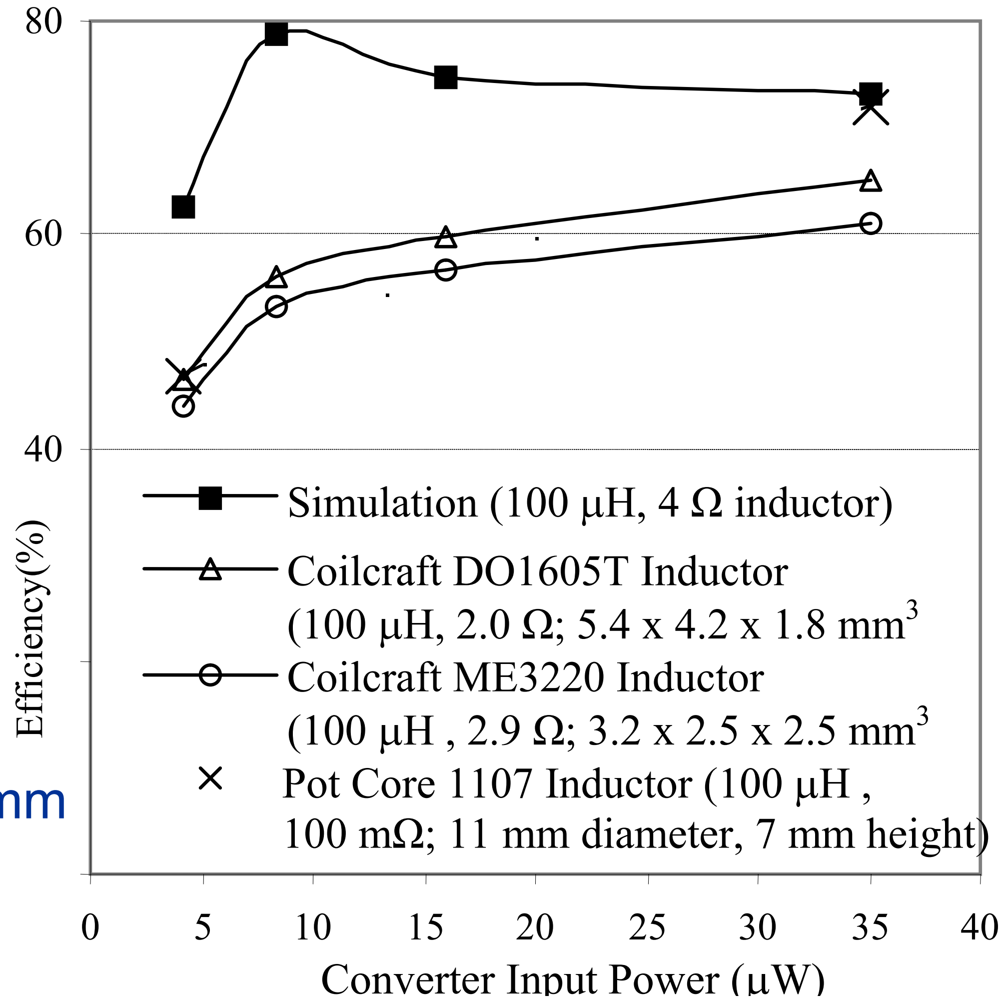
Power processor

- The processor successfully delivered sufficient power for wireless H_2 sensor.

Power Processor IC (Vibration): IC & test configuration

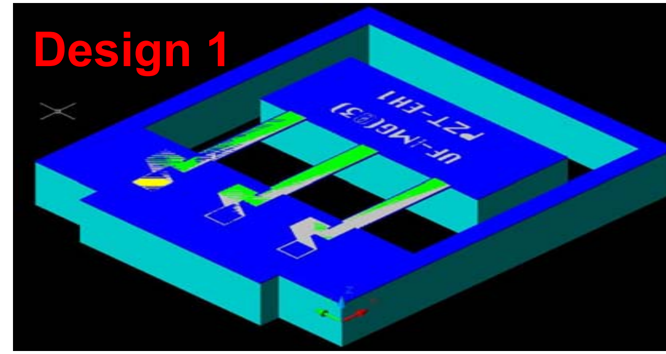




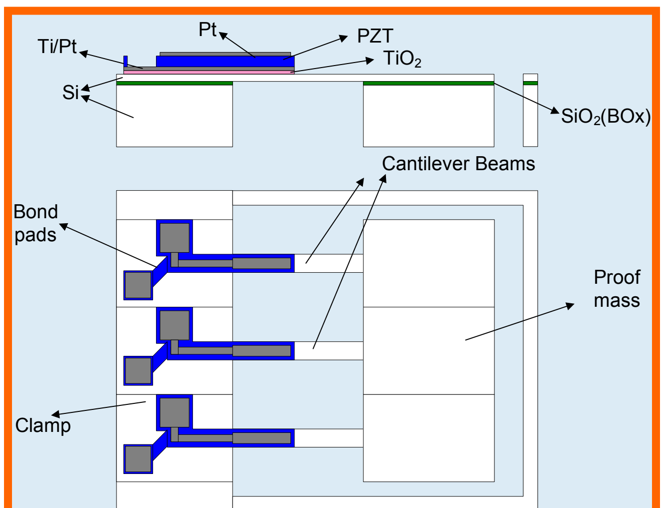


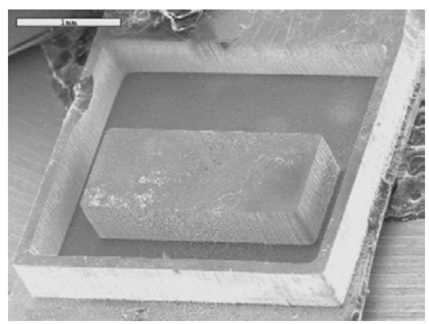
MEMS Piezocantilevers

- Predicted output
  - varies with g's and freq
  - 110 μW/cc (50 μW/gm) for 1g, 100 Hz
- Fabrication 70% complete

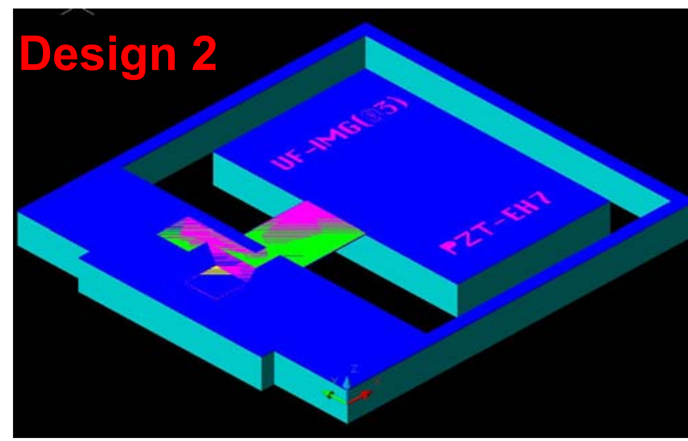


1 mm X 200 µm X 12 µm cantilever beams
1 mm X 800 µm X 500 µm proof mass





Bottom proof mass

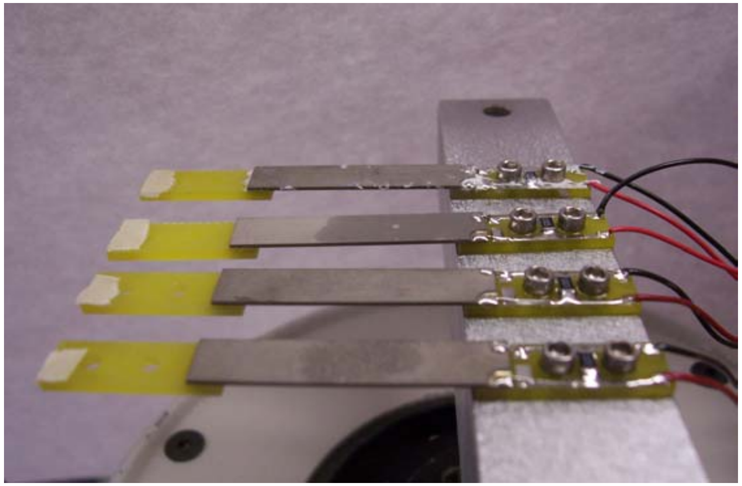


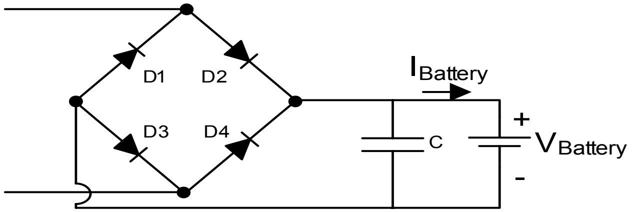
1 mm X 1 mm X 12 µm cantilever beams
2.5 mm X 4 mm X 500 µm proof mass

Mesoscale Piezocantilevers

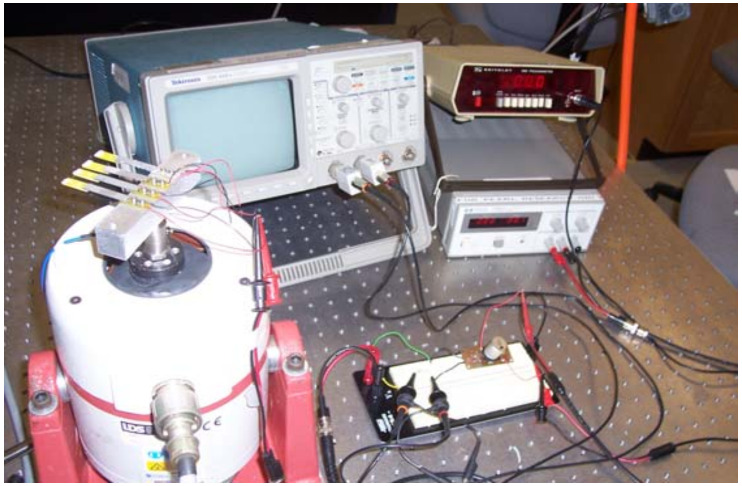
PSI PZT-5A Bimorphs

Length of shim	**1.25 in**
Width of shim	**0.25 in**
Thickness of shim	**4 mil**
Length of PZT	**1.25 in**
Width of PZT	**0.25 in**
Thickness of PZT	**7.5 mil**





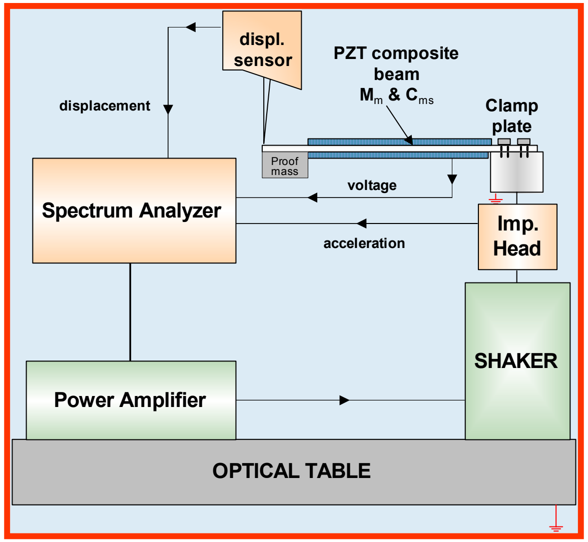
Direct Charging Circuit

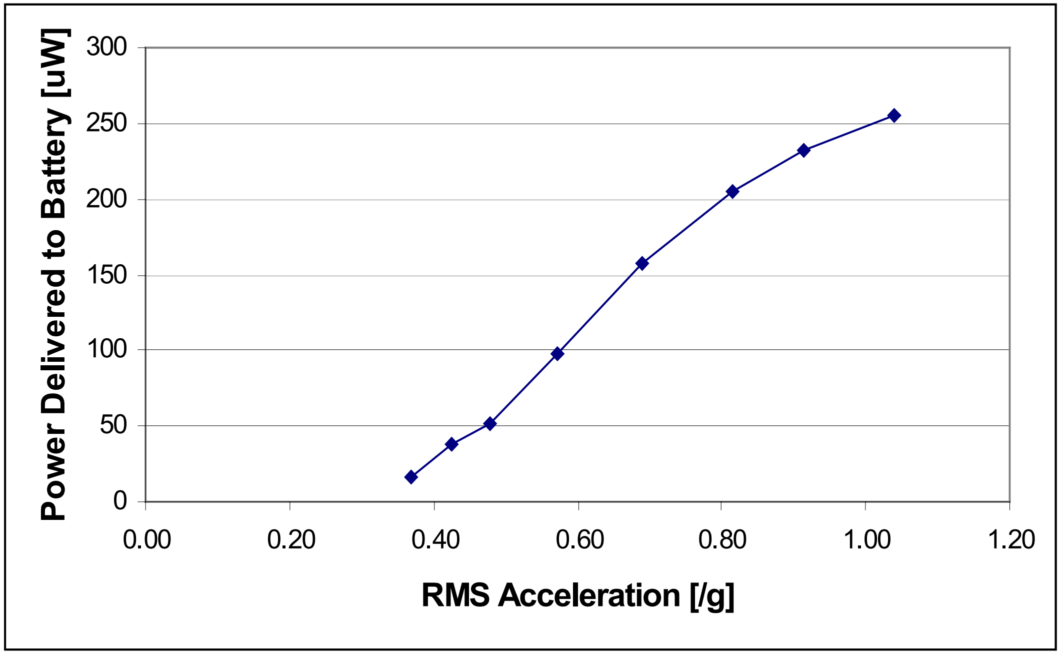


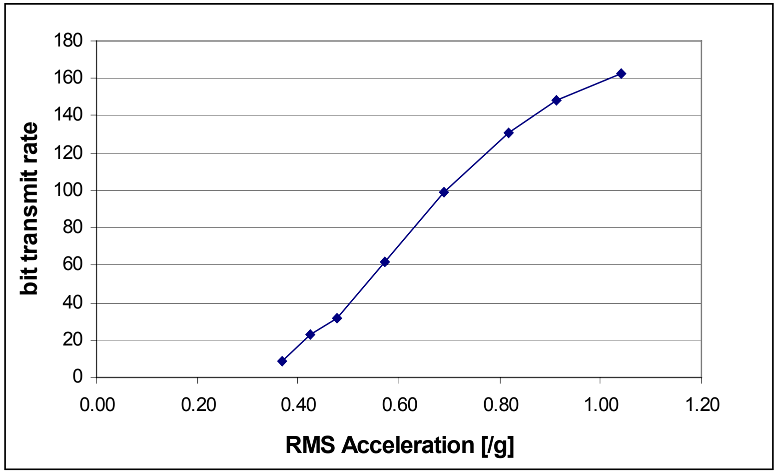
Shaker

Mesoscale Piezocantilevers

- Vibrational energy harvested per mesoscale bimorph piezocantilever
- Sufficient energy to transmit data





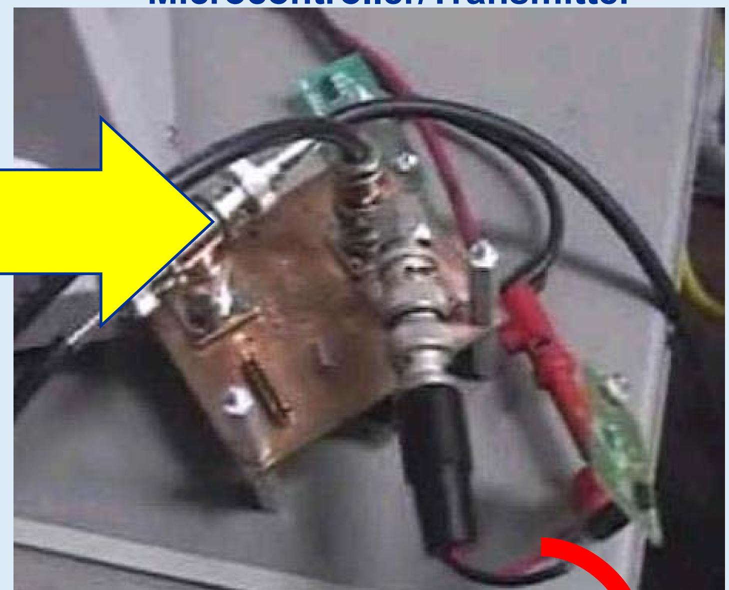


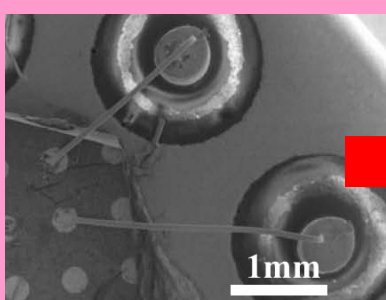
First Prototype Tests—Power for Wireless H_2 Sensor


Vibrational Energy

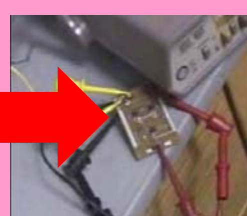
Solar Energy

Microcontroller/Transmitter





ZnO nano-rod



ZnO Interface

WIRELESS

Receiver/DAQ unit

Future Plans

- Continue MEMS piezocantilever device fabrication
- Characterize MEMS piezocantilever
  - Lumped element parameter extraction
    - Comparison with FEM and analytical model
  - Power and voltage measurements
    - Comparison with LEM model
- Demonstrate energy reclamation with power processor
- Develop packaging for multi-power source for wireless hydrogen sensor network

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