Resonance Tuning for Vibration Energy Scavenging

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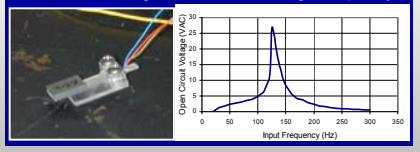
Compressive Axial Preload Expands the Usable Range of Piezoelectric Generators

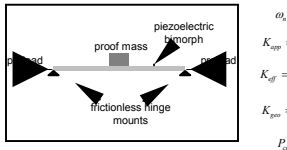
Conventional designs work best at a single frequency...



...but source vibrations vary widely

Vibration Source	Frequency of Peak (Hz)	Peak Acceleration (m/s^2)
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
External windows (size 2ft. x 3ft.) near 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
Haas 3-axis milling machine in operation	83	10-30
Fused deposition modeling machine in operation	200	2.5

Will compres ...ators?



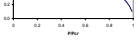
$$\omega_n = \sqrt{\frac{K_{app}}{m}}$$

$$K_{app} = K_{eff} - K_{geo}$$

$$K_{eff} = EI\left(\frac{\pi}{l}\right)^4\left(\frac{l}{2}\right)$$

$$K_{geo} = P\left(\frac{\pi}{l}\right)^2\left(\frac{l}{2}\right)$$

$$P_{cr} = \frac{\pi^2 EI}{l^2}$$



Vision

To develop vibration energy scavenging devices that can be adjusted to generate useful amounts of power from a variety of vibration sources with differing peak frequencies.

By contrast, most vibration energy scavenging devices can only operate effectively using vibrations that precisely match a device's resonance frequency.

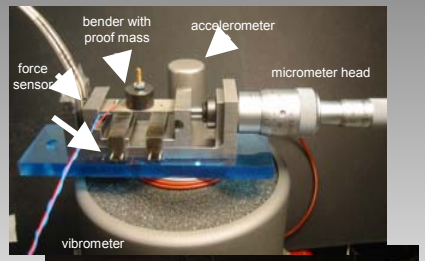
The development of variable-frequency energy scavenging technology is vital to designing a suitable power source for wireless sensor networks and other applications.

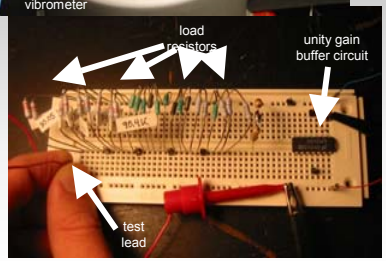
Research Questions

- Can the resonance frequency of a piezoelectric vibration energy scavenger be altered using compressive axial preload?
- How much power is generated by a piezoelectric energy scavenger whose resonance frequency has been thus altered?
- How can a resistive load be used to optimize such a generator's power output?

Methods

- A custom-fabricated steel vise was used to apply compressive preload to a simply-supported piezoelectric bimorph
- Resonance frequency for each level of preload was determined by using a variable-frequency vibration generator
- Optimal power output was determined by varying load resistance

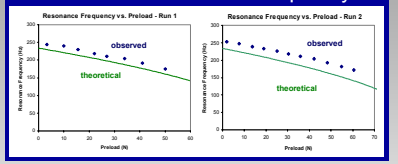




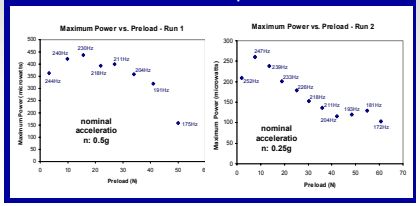
Findings

- Compressive axial preload can reduce resonance frequency up to 30%
- 50-90% of initial power available at frequencies 20% below nominal (no preload) resonance, compared with 2-5% initial power from non-tunable generator

Preload and Resonance Frequency



Preload and Power Output



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