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Circuit Design for Improved Capture of Ambient Energy over a Wide Frequency Range by Piezoelectric Energy Harvesting Devices

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Friday, November 21 - 9:00am - 9:45am

EECT Energy

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Need: Piezoelectric energy harvesting devices, along with their supporting circuitry, have been proposed and developed, at least in prototype, to capture ambient vibrational energy from a wide variety of sources. This energy, when converted from mechanical form into electrical form by piezoelectric devices, can be used to power structural health monitoring circuitry (for bridges, dams, etc.). Electrical power from this type of source is very useful when the use and replacement of batteries, or the use of wired power is either impractical or prohibitive in cost. This presentation will focus on an application, structural health monitoring, because of the perceived need to monitor changes in structural parameters of widely dispersed and remote civil infrastructure. The core of the presentation will be a design to adjust the resonant frequency of the piezoelectric device to the relatively wide range of frequencies that are present in the ambient energy from the vibrating structure. The need for such an adjustment arises from the fact that energy transfer and conversion, from the mechanical energy of vibration to the electrical energy needed to power the monitor circuitry, is optimum when the frequencies of the mechanical and electrical system are matched over a narrow frequency range.

Overview: Energy harvesting from vibration sources, such as roadways and bridge structures, is dependent on tuning the harvesting circuitry to match the characteristic frequencies found in the ambient mechanical structures. There are a wide range of such frequencies, depending on such factors as mass and dimensions of the structure, or the amount and volume of the traffic or other loads on the structure. Piezoelectric energy harvesters, which are in the class of devices called "kinetic energy harvesters," will generate maximum power when the resonant frequency of the generator is matched to the ambient vibration frequencies. By definition, a high-Q resonant device will match frequencies from the mechanical vibrating system only over a narrow range of frequencies, thus yielding very limited frequency bandwidths over which energy can be efficiently harvested. Since many piezoelectric and other vibration energy harvesters utilize cantilever beams as the conversion element, and since the resonant frequency can be shown to be partly dependent on the length of the cantilever, then one of the proposed designs is to adaptively alter the frequency of the piezoelectric element by changing this length in response to the changes in the ambient. Furthermore, it has been established that the mass of the cantilever beam in the piezoelectric unit also affects the frequency, so that adaptively changing the mass loading on the beam can change the frequency. By these two means, this presentation will strive to show that adaptive frequency adjustment can enhance the efficiency of piezoelectric energy harvesters.

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Major Points:

- Need to use energy harvesting to power remote structural health monitoring circuitry.
- Need to match ambient vibrational frequencies to resonant frequency of energy harvesting devices.
- Altering physical characteristics of harvesting devices to adaptively change resonant frequency to match ambient frequencies.
- Comparison of effects of adaptive frequency adjustment on energy conversion efficiency.

Summary: Attendees will understand the physical principles animating the most recent energy harvesting strategies for remote structural health monitoring, and the will also understand how the electronic circuitry and piezoelectric devices work together to perform this monitoring function.