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Title: Hybrid Energy Sources for Embedded Sensor Nodes

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Hybrid Energy Sources for Embedded Sensor Nodes

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Abstract

- In this paper, we present a series of hybrid energy configurations that are designed to provide a robust power source for embedded sensing hardware. The proper management of energy resources is a critical component in the design of any deployed sensing network. For systems that are installed in remote or inaccessible locations, or those with an operational lifespan that exceeds traditional battery technologies, energy harvesting is an attractive alternative. Unfortunately, the dependence on a single energy source (i.e. solar) can cause potential problems when environmental conditions preclude the system from operating at peak performance. In this paper we consider the use of a hybrid energy source that extracts energy from multiple sources and uses this collective energy to power sensing hardware. The sources considered in this work include: solar, vibration, thermal gradients, and RF energy capture. Methods of increasing the efficiency, energy storage medium, target applications and the integrated use of energy harvesting sources with wireless energy transmission will be discussed.

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Presentation Outline

- Motivation
- Capabilities of the Embedded Sensor Node
  - Modes of operation
  - Power options
- Energy Harvesting
- Energy Transmission
- Hybrid Powering
- Conclusions

Motivation

- There has been a recent shift toward wireless sensing systems
  - Reduced infrastructure costs over wired systems
  - Can retrofit existing civil, industrial or aerospace systems
- Consideration must be given to several design factors
  - Sensing capability – active v. passive
  - Hardware and software robustness
  - Power consumption / powering options
- Systems must be commercially viable
  - Can the sensor node be built with COTS components and survive long-term deployment?

Powering Embedded Hardware

- Power demands **will** become a major design criteria for long term deployments
  - Currently we are investigating energy harvesting techniques to supplement onboard power sources
- Several sources are available on rotor blades
  - Solar, thermal, kinetic, electromagnetic, etc.
- To provide a robust power source, the harvesting system may need to extract energy from multiple sources

Evolution of the Wireless Impedance Device

- The first generation WID1 was a breadboard prototype capable of monitoring 1 PZT sensor (Mascarenas / Overly)
  - This evolved into a packaged PCB form with the WID1.5
- The WID2 integrated a set of multiplexers, increasing the number of sensors / node to 7, and provides more triggering options (Overly)
- The WID3 builds upon the WID2, providing more stable wireless communication, networking capabilities, and an integrated power conditioning circuit (Taylor)

-
- options
ments
e
e
e
through data
line
Current Draw
Extremely low
Seconds, minutes, days, weeks, months
<15µA
Extremely low
- capacitor
rvesting and
board power

- [illegible]

WID3 – Power Conditioning Module

- The power conditioning module on the WID3 controls how voltage is released to the MCU

1. Allows the system to charge to 3.5V
2. Releases this energy to the WID3
3. Allows continual operation until voltages drop below 2.7V
4. Disconnects power and maintains a 2.7V precharge

Energy Harvesting – LADSS Research Project

- In the summer 2009, students expanded on previous work to develop a hybrid energy harvester to power the sensor node.
- The goal was to develop an energy harvesting system that used could use energy from multiple sources
  - TEG
  - Solar
  - Vibration

Combined Harvester

- TEG Module + PZT Beam
  - Coupled each system using two ALD EH300A energy harvesting circuits
  - TEG module was effective until voltages exceeded 1.2V
- Successfully powered the WID3 sensor node
  - Programmed to measure one sensor and store data

PZT Energy Harvester

- PSI-5A4E (PZT) piezoceramics from Piezo Systems, Inc.
  - Each patch measuring 3.6 cm x 3.6 cm x 0.27 mm
  - Mounted in a bimorph configuration
- Cantilevered spring steel substrate (3.8cm x 86.5cm x 0.5mm)
- Two aluminum blocks, (2.5 cm)³, reduced natural frequencies

PZT Energy Harvester

- Harvester was characterized with a 0-1000 Hz chirp
- First three natural frequencies: 11.8, 119.5, and 775 Hz
- Harvester was excited at its second resonance, 119.5 Hz
- PZT output passed through a full-bridge rectifier
- Rectifier output charged a 0.1F capacitor bank

PZT Energy Harvester

- The Harvester required 70 minutes to reach 3.5 V
- WID3 power draw visible in discharge profile
  - (1) Take measurement, (2) Store data, (3) Confirm storage
- Following voltage drop to 2.7V, recharging begins

Duty Cycle Limitations

- Energy harvesting is a viable means of powering an embedded sensor node for long-term deployment
- Total energy levels are low; for most SHM applications, low duty cycles are acceptable
- On-demand measurements may not be possible without a local power source

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Wireless Energy Transmission – Supplemental Energy

- Energy can be brought to the sensor node at critical times
- RF energy is collected by an antenna connected to the WID3
- This can supplement traditional energy harvesting methods
  - Allows off-schedule measurements
  - Can be used to power multiple nodes

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RF Energy Transmission Experiments

- The sensor node was powered by an RF energy delivery system
  - The rectenna array was composed of 32 rectifying antennas
  - The Charging time to 3.5V was approximately 30 seconds
  - The sensor node maintained a 2.7V pre-charge between cycles

RF Energy as Power for On-Demand Measurements

- At any point in the charge cycle, RF energy can be utilized to quickly provide sufficient energy for multiple measurements
- Following the on-demand measurement, the node can return to its previously scheduled measurement cycle

Summary

- The WID provides a compact, power efficient module that can accept power from numerous sources
  - Traditional batteries, energy harvesters, energy transmission
- Electromechanical and thermoelectric energy harvesters can successfully generate enough energy to operate the WID
  - Provides periodic measurements at low duty cycles
- Radio Frequency (RF) power delivery can sustain continuous on-demand measurements
- The utility of a combined harvester and RF power system has been demonstrated for adding on-demand capability to scheduled measurements