ARC '16

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http://dx.doi.org/10.5339/qfarc.2016.ICTPP2683

Vibration Energy Harvesting in Wireless Sensor Networks (WSNs) for Structural Health Monitoring (SHM)

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Harvesting of vibration energy from the ambient environment, such as vibrations experienced by bridges due to vehicle movements, wind, earthquakes, has become an essential area of study by many scientists aiming to design new systems which can improve self-powered network sensors in wireless sensor networks (WSN), thus providing a more efficient system that does not require the human involvement.

One of the essential components of WSN systems is the sensor node. It is used to continuously send/receive information to monitor a certain behavior targeted by the application; for example, to monitor bridge infrastructure's health. Sometimes, sensors are programmed and adjusted to send useful data for monitoring 24 hours a day, seven days a week. This configuration harms the sensors' batteries and shortens their lives, since sending/receiving data consumes power and leads to the reduction of the batteries' voltage levels. Due to this fact, energy harvesting is critical to maintaining long-term batteries that can recharge themselves from the available ambient harvested energy and eliminate the need for human involvement in replacing or recharging them in their specified locations in the network.

Recent structural health monitoring systems (SHM), in civil infrastructure environments, have focused heavily on the use of wireless sensor networks (WSNs) due to their efficient use of wireless sensor nodes. Such nodes can be fixed onto any part of the infrastructure, such as bridges, to collect data remotely for monitoring and further processing. However, the drawback of using such sensor networks relies mainly on the finite life-time of their batteries. Due to this problem, the concept of harvesting energy from the ambient environment became more important. Ensuring efficient battery usage would have a great benefit in maximizing overall systems functionality time and ensures efficient use of natural energy resources like solar, wind and vibration energies.

Cite this article as: Ismail L, Elorfali S, Elfouly T. (2016). Vibration Energy Harvesting in Wireless Sensor Networks (WSNs) for Structural Health Monitoring (SHM). Qatar Foundation Annual Research Conference Proceedings 2016: ICTPP2683 http://dx.doi.org/10.5339/qfarc.2016.ICTPP2683.

This work aims to study the feasibility of using a piezoelectric vibration energy harvester to extend overall battery life using a single, external, super-capacitor component which is serving as a storage unit for the harvested energy. The methodology followed in this work states the general direction of the flow of energy in a sensor node which can be summarized into the following:

1- Piezoelectric Vibration Energy Harvester: This module was used to convert mechanical energy of the vibrations from the ambient environment to electrical energy.

2- Energy Harvesting Circuit: This circuit is responsible for the power conditioning, enabling the circuit to output energy to the sensors under certain threshold criteria.

3- Energy Storage: This the super-capacitor served to store harvested energy.

4- Energy Management Scheme: The scheme proposed by this work under the energy requirements and constraints of the sensor nodes in order to conserve batteries voltage level to extend sensors' batteries lives.

5- Wireless Sensors Nodes: Each sensor node type has specific energy requirements that must be recognized so that it can be adequately powered and turned on using the harvested energy.

The main contribution of this work is a proposal of an energy management scheme which ensures that the harvested energy being provided to the harvester circuit must be greater than the energy output that is going to be consumed by the sensor. This proposed scheme has proved the feasibility of using impact vibrations for efficient energy harvesting and subsequently increase the battery life time needed to turn on the wireless sensor nodes.

Furthermore, as a future direction of work, to increase the amount of harvested energy, hybrid power sources can be explored by combining more than one energy source from the ambient environment, such as solar and vibration energy.