Energy Harvesting and Wireless Balancing Power Generation and Consumption

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Wireless, energy harvesting technologies are making waves in building automation and energy conservation controls because they overcome limitations of hardwired solutions and maintenance issues inherent to battery-dependent devices. This article will discuss the science behind wireless, energy harvesting technology and explain how to budget miniscule amounts of energy sufficient for managing building energy usage.

[1]

Buildings account for 40 percent of all energy (electricity and fossil fuel) consumption in the United States and according to the AIA, approximately 50 percent of GHG (greenhouse gas) emissions. By automating control of lighting and HVAC energy management, OEMs can quickly develop solutions that satisfy a historic market demand for energy-saving instruments.

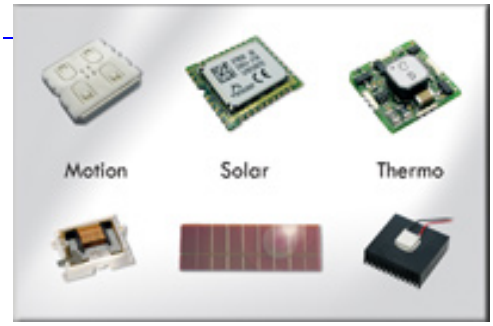
Building Automation Systems (BAS) reduce energy consumption in buildings on average of 40%; however, most buildings in the US do not integrate BAS. Upgrading energy-inefficient buildings with BAS has been hindered by several key factors :

* Existing buildings are expensive to retrofit

* Retrofitting existing buildings with BAS is invasive, often complicated and potentially risky.

Integrators are overcoming these traditional barriers by using batteryless, self-sustaining, wireless sensors and controls. The controls reduce the amount of energy wasted in buildings and bypass many obstacles inherent to hardwired equivalents.

The Industry Responds



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The growing demand for wireless, energy harvesting solutions is spawning new partnerships among key industry vendors. For example, EnOcean and Texas Instruments (TI) are collaborating on innovative wireless solutions for building automation. The companies will jointly create solutions enabling self-powered wireless sensor networks. EnOcean will integrate TI components in its energy-efficient wireless modules.

Energy Harvesting & Wireless

Energy harvesting technology stems from a simple observation - where building sensor data resides, sufficient ambient energy exists to power sensors and radio communications. Harvestable energy sources include: kinetic devices, temperature differentials, light, etc. These rudimentary sources provide enough energy to transmit and receive radio signals between sensors, switches and controls within a building automation system. Instead of batteries, EnOcean-based controls use miniaturized energy converters to supply power to building energy management devices. At the center of energy harvesting and wireless is the EnOcean wireless standard.

Self-powered Wireless Sensors

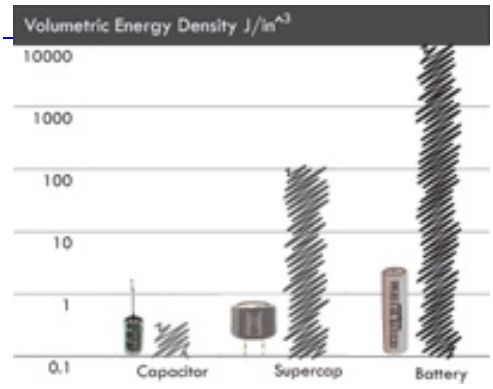
Building Blocks - An energy harvesting wireless sensor is comprised of building blocks, each of which has been optimized specifically for energy harvesting. When factoring the amount of ambient energy available in buildings, continuous operation is only feasible when all of the building blocks are optimized for low power consumption. To power devices within the naturally enforced limits of energy availability, sensors must transmit infrequently, execute procedures within the shortest possible time and be able to switch off all blocks when not required for operation.

Micro Energy Budget & Balance

A wireless, energy harvesting design factors in many variables. The following sections address some of the most important variables to consider. In these

applications, where miniscule amounts of energy are harvested, it is often necessary to store the harvested energy in a reservoir for later use.

Energy Storage



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With almost any energy-harvesting device, it is likely that the source of ambient energy will not always be present. For instance, in the case of solar harvesting, light may not always be available, making energy storage a necessity.

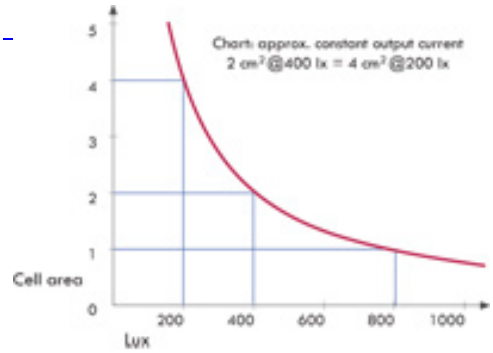
An increasingly popular energy storage reservoir for energy-harvesting applications is the super-capacitor or ultra-capacitor. These electro-chemical capacitors have relatively large volumetric energy density as compared to traditional ceramic, electrolytic or tantalum capacitors, as shown in Figure 3.

Super-capacitors tolerate hundreds, thousands and even millions of charge-discharge cycles, which is two to three orders of magnitude greater than rechargeable batteries. They can also be charged/discharged very quickly. Their volumetric energy density is a couple of orders of magnitude less than typical primary lithium cells (Figure 3). But when combined with an energy harvester, such as a solar cell, they never need replacement. Additionally, they don’t contain toxic chemicals.

Design Considerations

The proper selection and sizing of a super-capacitor for a given application is key. The performance of super-capacitors is affected by time, temperature, voltage, and charge cycling. Consequently, a capacitor whose initial capacitance and ESR barely meet the requirements of the application is not recommended. Capacitance and ESR degrade as time progresses. Thus, designers should determine the minimum voltage and energy requirements of the application and then de-rate the initial capacitance of the super-capacitor.

Solar Energy Harvesting (Indoors)



[4]

One of the most common energy harvesters today is the solar cell. Unfortunately only about 0.1% of the sunlight level is available indoors. That's why amorphous (non-crystalline) silicon cells, with peak sensitivity at 500 nm, are ideally suited for poor light and fluorescent light (FL) conditions.

As a rough estimate, amorphous solar panels (a few cm2) can operate with a current in the range 8.5 uA/cm2 @ 200 lx (FL). This value is extrapolated using a de-rating factor for lower illumination and/or smaller area. That corresponds to 4 uA/cm2 @ 100 lx. A similar extrapolation is shown in the Figure 4.

Care should be taken to ensure that the voltage delivered by the solar cell is above the minimum required by the system (at the lowest expected light level) and that it is below the maximum the system can tolerate (at the highest expected light level).

Generally speaking, designers should define worst-case application requirements and add additional headroom, as necessary.

Thermo-electric Energy Harvesting

An alternative to popular solar panels for applications with limited light is a radio module that can be powered by other external power sources such as a thermo-electric generator. This option is based on a standard Peltier element. Such an energy source, with as little as 2 Kelvin temperature differential, can deliver enough energy to operate low-power EnOcean radio modules. An energy storage device, such as a super-capacitor, provides a reservoir for harvested energy storage and provides the short-term burst current required by the radio module.

Summary

Harvesting ambient energy sources with energy-optimized wireless technologies, offers a wide variety of wireless lighting and HVAC sensors and controls. These devices can be easily installed in almost any building, with minimal invasiveness, to help conserve energy and save costs. Tougher environmental standards and soaring fuel costs demand optimized concepts for the way we use our energy in buildings. That calls for technologies with which such concepts can be speedily and

efficiently implemented – such as energy harvesting and wireless technologies.

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