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Ultra Low Power Energy Harvesting for Wireless Switches and Wireless Sensor Networking - Types, Applications, New Developments, Industry Structure and Global Markets

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Abstracts

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Ultra-low power energy harvesters, or micro energy scavengers, are small electromechanical devices which harvest ambient energy and convert it into electricity. Energy scavengers can harvest different types of energies. Solar energy can be harvested with photovoltaic solar cells, thermal energy can be harvested with thermoelectric generators, mechanical energy can be harvested with piezoelectric, electromagnetic or electrostatic converters, and finally, electromagnetic energy can be harvested through RF resonators.

Energy harvesting and power management integrated circuits (ICs) are in a position to enable the commercial rollout of the next generation of low power electronic devices and systems. Low power devices are being deployed for wireless as well as wired systems, such as mesh networks, sensor and control systems, and micro-electromechanical systems (MEMS). Applications include home automation, building automation, industrial process/automated meter reading, medical, military, automotive tire pressure sensors, radio frequency identification (RFID) and others.

Battery maintenance and replacement are often cited as the biggest reason to use energy harvesting. The first markets for these new technologies have been applications where batteries are problematic, such as building and home automation, military and

avionic devices, communications and location devices, and transportation.

Wireless sensor systems are emerging as a key technology for future remote environmental monitoring in both internal and external environments. Ultra-low power energy harvesting is an important emerging area of low power technology that can provide energy to wireless sensor networks, utilizing the vibrations inherent in structures, vehicles and machinery to create power or harvest energy, as well as solar or heat or human motions that can drive sensors and switches, eliminating the need for wires and batteries

Ultra-low power energy harvesting, however, is the only current option where long term, “fit and forget,” autonomous powering of wireless sensor nodes is the vision. Energy harvesting is a natural complement to ultra-low powering, including wireless mesh sensor networks.

STUDY GOAL AND OBJECTIVES

The coming decade will see the rapid emergence of low-cost, intelligent, wireless switches and wireless sensors and their widespread deployment throughout our environment. While wearable systems will operate over communications ranges of less than a meter, building management systems will operate with inter-nodal communications ranges on the order of meters to tens of meters, and remote environmental monitoring systems will require communications systems and associated energy systems that will allow reliable operation over kilometers. Autonomous power should allow wireless sensor nodes to operate in a “deploy and forget” mode. The use of rechargeable battery technology is problematic due to battery lifetime issues related to node power budget, battery self-discharge, number of recharge cycles and long-term environmental impact. Duty cycling of wireless sensor nodes with long “sleep” times minimizes energy usage. A case study of a multi-sensor, wireless building management system operating on the Zigbee protocol demonstrates that, even with a one-minute cycle time for an 864ms “active” mode, the sensor module is already in sleep mode for almost 99% of the time. For a 20-minute cycle time, the energy utilization in sleep mode exceeds the active mode energy by almost a factor of three and thus dominates the module’s energy utilization, thereby providing the ultimate limit to the lifetime of the power system.

The report reviews the various energy harvesting technologies currently available or under development. These include mechanical (electromagnetic, piezoelectric and electrostatic), light (indoor and solar), thermal, electromagnetic flux, and human power.

Each suits only certain application scenarios, and some have yet to produce useful amounts of energy for practical application.

The study identifies and, where possible, describes the main commercial and academic centers of expertise in developing energy harvesting technologies. The emphasis here is on the UK and Europe, although others are identified. Although it is a small sector that is dominated by academics and very small companies, this is an area where Europe leads in practical application as well as technology development. A list of key patents is compiled to show which organizations are claiming related intellectual property in the field.

REASONS FOR DOING THE STUDY

Supplying power to a network of sensor-transmitters has traditionally required expensive wiring installation or routine battery changes. Gathering data from difficult or dangerous-to-reach locations using wired sensors may be impossible and may even compromise the safety of personnel while installing wiring and replacing batteries. A perpetual power source is essential for many wireless sensor network (WSN) applications. Energy harvesting technologies are on the verge of new breakthroughs with energy storage, and they are being paired with ultra-low power chipsets as well as plug-and-play software.

While still in an early phase, energy harvesting devices, which translate abundant sources of energy such as light, heat and mechanical into electrical energy, are rapidly being integrated with wireless sensor technologies. By 2011, there will be 150M to 200M wireless sensors being used in factory automation, process and environmental control, security, medicine, and condition-based maintenance, as well as in defense applications and intelligence gathering. Such wireless sensor systems will:

- require numerous individual devices (known as nodes or motes) to provide comprehensive monitoring capability;
- be located in inaccessible places much of the time;
- have to operate with long intervals between scheduled maintenance. Periodic maintenance, such as replacing batteries, would clearly increase operating costs, and could be inconvenient, at best, if it required interruption of a continuous process.

There is clearly a need to develop an energy source that can last years with little or no maintenance.

With all these developments, iRAP felt the need to conduct thorough technology, industry and market analyses of ultra-low power energy harvesting for WSNs.

CONTRIBUTIONS OF THE STUDY

The growing opportunity for developing “zero power” applications stems from exponential trends in three separate technologies. First, each new generation of wireless sensors, or microcontrollers, can accomplish much more for much less power. Second, wireless networking is evolving radios and protocols that carry increasing amounts of information at decreasing power levels. Finally, the ability to capture and utilize minute amounts of power by various means has expanded dramatically. This harvesting ability has now surpassed the falling power demands for many small systems, opening the door to myriad possibilities.

The report targets two types of ultra-low power energy harvesting devices – wireless switches for building automation and wireless sensor networks. It analyzes the worldwide markets for ultra-low power energy harvesting for these devices using several technologies – electromagnetic, vibration to electricity, heat to electricity, solar to electricity and radio frequency to electricity – and covering six applications – wireless sensor networks (WSNs), building automation (wireless, battery-less, low-power switches in big commercial buildings), automotives (tire pressure monitoring systems, or TPMSs), medical uses such as body area networks (BANs); precision agriculture; and consumer electronics and IT peripherals. Information and projections are for the period from 2009 to 2014.

This iRAP report focuses on market data and analysis of the growing market for energy harvesting and next-generation storage solutions, specifically for wireless switches and wireless sensor networking.

The report provides the most thorough and up-to-date assessment that can be found anywhere on the subject. The study also provides extensive quantification of the many important facets of market developments in the emerging markets of ultra-low power energy harvesting for WSNs. This, in turn, contributes to the determination of what kind of strategic response suppliers may adopt in order to compete in this dynamic market.

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SCOPE AND FORMAT

The market data contained in this report quantify opportunities for ultra-low power energy harvesting for wireless switches and WSNs. In addition to product types, it also covers the many issues concerning the merits and future prospects of ultra-low power energy harvesting for WSNs, including corporate strategies and the means for providing these highly advanced products and service offerings. It also covers, in detail, the economic and technological issues regarded by many as critical to the industry's current state of change.

The report provides separate comprehensive analyses for the U.S., Japan, western Europe, China, Korea, and the rest of the world. Annual forecasts are provided for each region for the period 2009 through 2014. Cost analysis of ultra-low power energy harvesting for WSNs is provided. Global patent activity and market competition and dynamics in the new technology are also targeted in the report. The report profiles 30 companies, including many key and niche players worldwide, as technology providers and raw material suppliers to ultra-low power energy harvesting for WSNs product manufacturers.

TO WHOM THE STUDY CATERS

This study would benefit existing original equipment manufacturing (OEM) companies involved in wireless switches and –the WSN business as suppliers or potential suppliers and clients looking for ultra-low power energy harvesting devices as alternate power solutions to the conventional battery in a fit-and-forget environment.

This study provides a technical overview of ultra-low power energy harvesting for wireless switches and WSNs, especially recent technology developments and existing barriers. Therefore, audiences for this study include marketing executives, business unit managers and other decision makers in the market, as well as those in companies peripheral to this business.

Because the report also analyzes the strategies and prospects of leading firms active in this space, it will be of interest to:

- firms in the spaces who want to understand the next wave of opportunities and how low power energy harvesting will impact them in the future;

advanced materials, components and sub-contract manufacturing companies who need to analyze the potential for selling their products and services into the low power energy harvesting segment;

investment bankers, venture capitalists and private equity investors who need a realistic appraisal of the revenue potential and timeframes associated with low power energy harvesting technologies based on nanostructured materials.

REPORT SUMMARY

Recent developments in energy harvesting and autonomous sensing mean that it is now possible to power wireless sensors solely from energy harvested from the environment. Clearly, this is dependent on sufficient environmental energy such as vibration, heat and light being present. It is also possible to transfer energy wirelessly to nodes by means of effects such as electromagnetic induction (as used in wireless switches). Energy harvesting is a developing technology area, and prominent technologies facilitate the generation of electricity from electromagnetic induction, electricity from light (photo-voltaics), vibration (vibration energy harvesting) or thermal gradients (thermo-electrics). The intermittent nature of many environmental energy sources• means that viable devices must harvest energy from their operating environment when possible, and buffer excess energy in some kind of energy storage system such as thin-film batteries or supercapacitors.

The confluence of multiple technologies (low power micro-controllers and radios, sophisticated power management, better batteries, practical energy harvesting, and robust networking protocols) has enabled these wireless sensor network (WSN) projects to work in real-world situations to solve real-world problems.

Energy harvesting techniques can deliver energy densities of 7.5 mW/cm2 from outdoor solar, 100 µW/cm2 from indoor lighting, 100 µW/cm 2 from vibrational energy and 60 µW/cm2 from thermal energy typically found in building environments. A truly autonomous, “deploy and forget,” battery-less system can be achieved by scaling the energy harvesting system to provide all of the system needs.

Energy harvesting is now commercially viable technology. This is because the necessary lower power electronics and more efficient energy gathering and storage methods are now sufficiently affordable, reliable and longer lived for a huge number of

applications, especially WSN, to be practicable.

Successfully applied energy harvesting makes very real the prospect of small electronics systems, such as wireless sensors that are self-powered, maintenance-free, and virtually unrestricted in their placement. With careful power management and energy efficient design, developers can now effectively address applications that were totally impractical only a few years ago. This is just the beginning, as reducing power needs and increasing harvesting options perpetually broaden the range of possibilities.

The 2009 market was estimated to be about $79.5 million. In spite of the recession, iRAP estimates that the market will reach $1,254 million in 2014, for an average annual growth rate (AAGR) of 73.6%.

Other major findings of this report are:

Electromagnetic energy harvesting kits will have the highest market share. Vibration-to-energy harvesting kits have a much smaller market share. Thermoelectric generators (TEG), photo-voltaic EH, and radio frequency (RF) energy harvesting will have a combined market share of less than 6% in 2009.

Among the five markets, the potential market for energy harvesting based on wireless sensors and switches in buildings alone is in several billion pieces per year with a market share of over 90% in 2009.

Although starting with low numbers in 2009, the markets for energy harvesting (EH) devices and wireless sensors used in multiple applications such as WSNs (industrial machinery, agriculture, structural health monitoring), tire pressure monitoring systems and medical related market such as body area network (BAN) would reach sizable numbers by 2014.

In 2009, the European market share is highest followed by North America, Japan, China, and the rest of the world (ROW).

In 2014, the Europe market share will remain highest, despite a slight share decrease followed by North America. However, China will take over Japan to reach the third place by 2014.

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Contents

MATERIALS USED IN ENERGY HARVESTING

APPLICATIONS

INDUSTRY STRUCTURE

GLOBAL MARKET AND REGIONAL MARKET SHARES

PATENTS AND PATENT ANALYSIS

COMPANY PROFILES

CROSSBOW TECHNOLOGY, INC.
CYMBET™ CORPORATION
ENOCEAN ALLIANCE
EOPLEX TECHNOLOGIES, INC.
ETV CORPORATION PTY LIMITED
FERRO SOLUTIONS, INC.
FUJI CERAMICS
GREENPEAK TECHNOLOGIES NV
HOLST CENTRE
IMEC
INFINITE POWER SOLUTIONS
INTEL CORPORATION
KCF TECHNOLOGIES, INC.
LUMEDYNE TECHNOLOGIES INC.
MICROPELT GMBH
MICROSTRAIN, INC.
MIDE TECHNOLOGY CORPORATION
MILLENNIAL NET, INC.
NEXTREME THERMAL SOLUTIONS, INC.
OMRON MANAGEMENT CENTER OF AMERICA, INC.
PEHA
PERPETUUM
PIEZO SYSTEMS, INC.
PIEZOTAG LTD.
POWERCAST CORPORATION
POWERFILM, INC.
SANYO ELECTRIC CO., LTD.
SCHRADER ELECTRONICS LTD.
SENSOR DYNAMICS AG
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