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[1.]Adina POP-VĂDEAN, [2.]Paul Petrică POP, [3.]Tihomir LATINOVIC, [4.]Cristian BÂRZ

HARVESTING ENERGY-ULTRA LOW POWER DEVICE

[1-2.]Technical University - Cluj-Napoca, Department Mechatronics & Machine Dynamics, Cluj-Napoca, ROMANIA
[3.]University of Banja Luka, Faculty of Mechanical Engineering, Banja Luka, BOSNIA & HERZEGOVINA
[4.]Technical University of Cluj Napoca, Center University of North from Baia-Mare, Department of Electrical Engineering Electronics & Computers, Baia Mare, ROMANIA

Abstract: Energy harvesting is rapidly expanding into new applications. The idea of micro-scale energy harvesting, and collecting miniscule amounts of ambient energy to power electronic systems, was still visionary and limited to research proposals and laboratory experiments. Ultra-low-power technology is enabling a wide range of new applications that harvest ambient energy in very small amounts and need little or no maintenance-self-sustaining devices that are capable of perpetual or nearly perpetual operation. An increasing number of systems are appearing that take advantage of light, vibrations and other forms of previously wasted environmental energy for applications where providing line power or maintaining batteries is inconvenient. The following article will discuss several technical challenges and show how ultra-low power technology is playing a key role in overcoming them.

Keywords: energy harvesting, ultra-low, power, ultra-low power, technology, ultra-low power technology

INTRODUCTION - What is Energy Harvesting?

Energy harvesting is a process by which ambient energy is captured and converted into electricity for small autonomous devices making them self-sufficient or process where energy is derived from external sources, captured and stored for use in electronic systems.

Sources as lighting, temperature differentials, vibrations, and radio waves (RF energy) can be re-used to operate low-power electronic devices.

Energy harvesting has gained a lot of interest within the electronics design community over recent years. It is through this process that small quantities of energy can be captured, collected and then utilized by items of electronic equipment, allowing simple tasks to be accomplished without the need for incorporating a conventional power source in the system design. In order to do this effectively, however, the system needs to operate with the highest possible levels of efficiency, both in terms of the constituent parts that are specified and the way the system is laid out. New systems, which are now appearing in industrial and consumer electronics, also promise great changes.

Applications that are now utilizing energy harvesting (or scavenging) include building automation systems, remote monitor/data acquisition devices and wireless sensor networks. As harvesting does not rely on conventional forms of power source it has two key ecological benefits. Firstly it does not result in any depletion of fossil fuel reserves and secondly it does not add to pollution levels (as there are no resultant carbon emissions, nor disposable batteries).

Figure 1. Energy harvesting ways

In addition to dispensing with the need for wiring or cabling and the convenience thereby derived, the real advantage of this sort of implementation for

OEMs and system integrators is that, once it is in place, it effectively has no day-to-day running costs, as there aren't utility bills or costly call out trips to replace batteries, etc.

Where is it useful?

- Where line power is unavailable or costly;
- Where batteries are costly or difficult to replace;
- Where energy is needed only when ambient energy is present.

HOW EXTRACT THE REQUIRED ENERGY?

The harvesting of energy from the environment can be done in a variety of ways (depending on which proves most suitable for the specific application setting), with power levels normally in the region of 10μW to 400μW being generated. Among the mechanisms used are temperature difference, kinetics (normally through vibrational movement), solar power, the piezo-electric effect, the pyro-electric effect, and electro-magnetic. However, with the possible exception of solar energy, the perception that energy harvesting is 'free' energy is not totally accurate. Sources based on vibration or thermal gradients make use of considerable energy waste from the system. As a result repair and maintenance costs do need to be factored in.

Collecting Energy examples:

Music Club

- A dance club in Rotterdam creates energy to power the LED lighting each visitor creates 20W of power by dancing on the flexible floor

Pedestrian Walk

- Use of piezoelectric materials to harvest electrical energy from pedestrians walking over it

Footbridge

- Piezoelectric materials can harvest energy from vibrations, such as the slight movement of a footbridge as pedestrians walk across it.

WHERE TO FIND "FREE ENERGY"?

Typical energy harvester output power

- RF: 0.1μW/cm²
- Vibration: 1mW/cm²
- Thermal: 10mW/cm²
- Photovoltaic: 100mW/cm²

Typical energy harvester voltages

- RF: 0.01mV
- Vibration: 0.1-0.4 V
- Thermal: 0.02 - 1.0 V
- Photovoltaic: 0.5 / 0.7 Vtyp/per_cell

Power consumption

Battery powered Applications in:

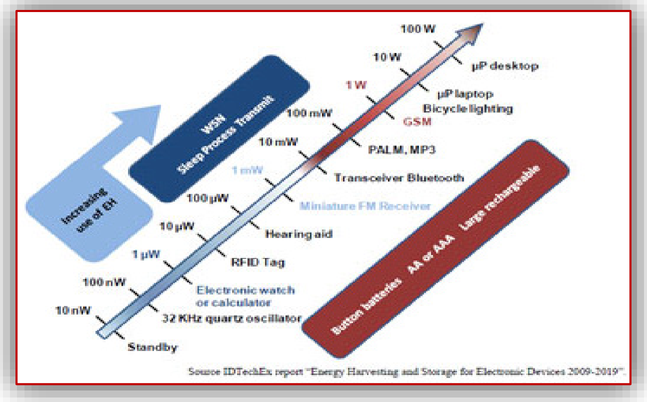
- Body Area Networks : 3μW = 1.8V * 1.7μA

TYPICAL APPLICATIONS

Energy Harvesting applications are potentially everywhere .Applications that are now utilizing energy harvesting (or scavenging) include building automation systems, remote monitor/data acquisition devices and wireless sensor networks.

As harvesting does not rely on conventional forms of power source it has two key ecological benefits. Firstly it does not result in any depletion of fossil fuel reserves and secondly it does not add to pollution levels (as there are no resultant carbon emissions, nor disposable batteries).

In addition to dispensing with the need for wiring or cabling and the convenience thereby derived, the real advantage of this sort of implementation for OEMs and system integrators is that, once it is in place, it effectively has no day-to-day running costs, as there aren't utility bills or costly call out trips to replace batteries, etc.



Source IDTechEx report "Energy Harvesting and Storage for Electronic Devices 2009-2019".

Figure 2. The power Range scale of real world applications

The power that is generated through the harvesting process can be used in many ways, for example:

- Switches (building automation) - Here the mechanical force applied to move the switch ON or OFF is enough to generate a few milli Joules (mJ) worth of energy to run a wireless transmitter. This sends an RF signal that actuates a door latch or a light. As no wiring is needed there are both logistical and aesthetical upshots to this approach.
- Temperature sensors (building automation) - The temperature difference between the ambient air and a heater can provide the power needed to send temperature data back to regulation system wirelessly.
- Air conditioning (building automation) - The vibration of the air-conditioning duct can be employed to create an electrical signal via electromagnetic induction. The air conditioning can be controlled through this signal.
- Remote monitoring (industrial/environmental) - This could be in the form of an unmanned weather station, a gas sensing system in a chemical plant, a Tsunami warning system. A solar cell or a small wind turbine can provide the energy required.

- Medical implants (healthcare) - Such as blood glucose monitors, where heat or body movement allow a low power wireless transceiver placed on the patient's skin to feedback data to a hub without the need for inclusion of a battery (thereby improving the patient's comfort and reducing the inconvenience experienced
- Watches (consumer) - Where the use of either solar or kinetic energy can be used to run a battery-less timepiece.
- Tyre pressure monitoring, using surface acoustic wave (SAW) sensing technology, it is possible to circumvent the issues arising from mounting the battery and complicated electronics needed to support temperature/pressure sensors on each of the vehicle's wheels, thereby reducing bill-of-materials costs and the engineering resource needed.
- Portable consumer electronics Calculators, toys, piezo gas lighters, electronic car keys, electronic apparel etc
- Industrial Mainly buildings, machinery, engines, non-meshed wireless sensors and actuators
- Wristwatches, laptops, e-books,
- Military and aerospace excluding WSN

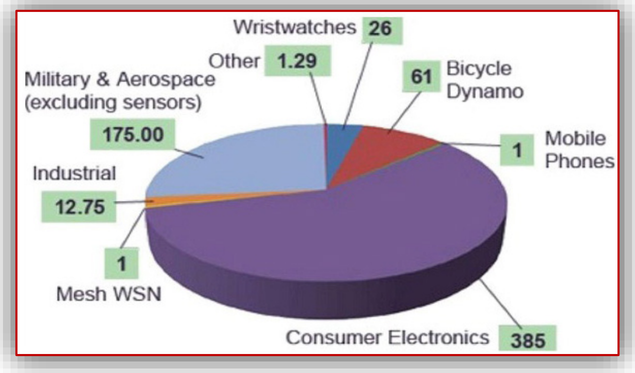


Figure 3. Applications that are now utilizing energy harvesting

MARKET ACCEPTANCE OF ENERGY HARVESTING DEVICES

Market acceptance of energy harvesting devices is very application-dependant

This is based on several parameters:

- Size & weight,
- Amount of power generated versus amount of power needed by the system,
- Cost: Ease of access to grid & ease of access to the module or system to power,
- Number of devices to power,
- Critical mission of the module or system to power,
- Required device lifetime: Projected lifetime for the energy harvesting device compared to the system parts lifetime,
- A major factor to be taken into account is if there is enough power harvested for a particular application from a particular environment, and if the scavenged power needs to be stored.

MARKET DEMAND

Growth in the 2-digit range will increase the market volume by 4 within the next 5 years after 2015.

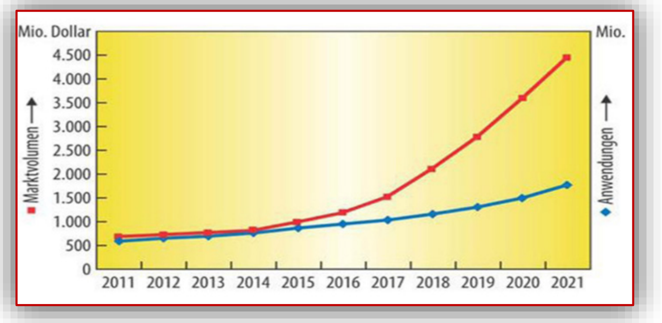


Figure 4. Market acceptance of energy harvesting devices

CONSIDERATIONS ABOUT ENERGY STORAGE METHOD

With only μWs of power to play with, it is clearly vital that everything possible is done to utilize it to the fullest. Engineers need to work hard so they can avoid wastage. This involves both hardware and software considerations and can be done through implementation of highly efficient component parts, as well as ensuring full design optimization.

It is imperative that the electronic system consists of low voltage circuitry made with smart power management. Energy storage may also need to be considered, as the sporadic nature of these systems' operation means that in many cases there is no direct relationship between the time when energy is harvested and the time when it is subsequently utilized.

The storage method used must be low voltage, with a high charge current capability, moderate discharge capability and possibly no self-discharge capability at all. The digital IC at the heart of the system must be able to offer more than adequate processor performance to carry out the system's tasks while simultaneous being able to support low voltage operation, so that the power budget is not exceeded. Furthermore this IC must be cost-effective enough that its implementation does not impact too greatly on the overall expense associated with the system - otherwise the system will have too high a price tag to justify deployment in many of the energy harvesting applications already discussed.

RECENT APPLICATION

Together Canova Tech and ON Semiconductor have developed a fully flexible design platform that enables original equipment manufacturers (OEMs) to test and validate their Energy Harvesting Cell concepts or applications utilizing Canova Tech's ETA

Platform harvester module which features ON Semiconductor's LC87F7932B ultra low power, fully programmable micro controller. This approach combines an ultra-low power microcontroller with an efficient, ready to customize and predefined IC integrating critical and must-have blocks like the harvesting interface and power management functions, sensor and actuator interface.

Based on the LC87F7932 ultra-low power microcontroller unit (MCU) from ON Semiconductor, and Canova Tech ETA Platform , this new development kit gives engineers an industry-proven development kit that can be customized (hardware and Software) in order to suit specific application requirements and thus augment the system's power/performance characteristics.

The ETA platform is fully configurable and it can be interfaced and matched with most of the common energy harvesters in the market, handling DC and AC inputs larger than 0.9V or, with the use of an external transformer, larger than tens of a millivolt. The collected energy can be transferred / stored in various storage elements such as chemical batteries, capacitors and super capacitors. Through it the system can manage the accumulated energy efficiently, regardless of erratic delivery patterns, so that it can implement power saving strategies, like the use of the embedded ultra-low power configurable analog front end, in which the acquisition and conditioning of signals from the system's sensors can be carried out without the supervision of the external MCU.

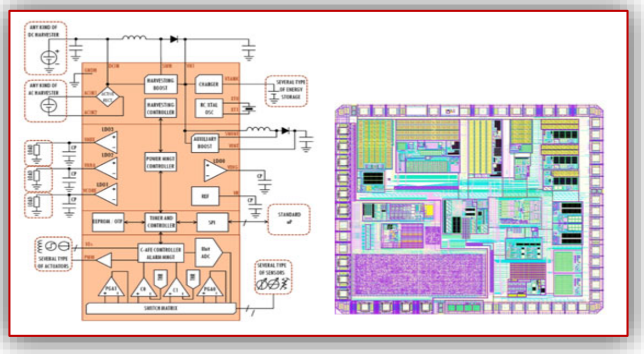


Figure 5. Block Diagram and layout of the Eta Platform

The LC87F7932B MCU is an 8-bit device based on CMOS technology. It has a central processing unit (CPU) running at a 250ns (minimum) bus cycle time. The IC integrates 32 kBytes of on-board programmable Flash memory, 2048 Bytes RAM, an on-chip debugger, an LCD controller/driver, a 16-bit timer/counter and a real time clock. Its 12-bit, 7-channel low power analog-to-digital (ADC) converter transforms the acquired signal after conditioning has been completed by the front end. This digital signal can then be transferred wirelessly or stored for extraction at a later stage depending on the application.

CONCLUSION

There are a number of major obstacles and challenges involved in the design of energy harvesting systems. Engineers need to boost processing performance as much as possible, while keeping overall power budget to a minimum and not accruing heavy expenditure in what can prove to extremely cost-sensitive applications. Every effort must be made to employ the best optimized components and to ensure that the development process is totally streamlined. By employing the development platform detailed in this article, based on an ultra-low power MCU architecture and a configurable and customizable device, engineers can overcome these obstacles and thus realize more effective implementations. This study provides an overview of ultra-low power energy harvesting application, especially recent technology developments and existing barriers.

Note

This paper is based on the paper presented at The International Conference on Social and Technological Development – STED 2015, organized by the University for Business Engineering and Management, in Banja Luka, BOSNIA & HERZEGOVINA (1st and 2nd of October, 2015), referred here as[8].

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University POLITEHNICA Timisoara,
Faculty of Engineering Hunedoara,
5, Revolutiei, 331128, Hunedoara, ROMANIA
http://acta.fih.upt.ro