e-WiSe Workshop Program

Thursday, November 22th

13.30-13.45: Introduction – M. Bafleur (LAAS-CNRS, France)

Session: Energy in Wireless Sensors 1 - Chair: M. Bafleur (LAAS-CNRS, France)

13.45-14.15: INVITED PAPER: *Development of rechargeable micro batteries based on micro channel structures* – R. Hahn (Fraunhofer IZM, Germany) et al

A technology has been developed for the extreme miniaturization of lithium ion micro batteries using wafer level processing. These batteries will be used as electronic buffer storage in future miniaturized sensor nodes, data loggers, RFID devices and medical applications. The micro batteries can store the energy generated by energy harvesters, which are a prerequisite for energy autarkic wireless sensor nodes and enable the technology for ambient intelligence and the internet of things. Between 2000 and 10000 micro batteries can be fabricated on one 300 mm wafer, being a low cost process. Process optimization of silicon processing was necessary to define cavities for the electrochemical electrodes, current collectors and contacts. The active masses are applied by means of dispensing. Technology development was required to optimize the electrode pastes and electrolyte for application in micro channel structures. Thus a wide variety of state of the art electrode materials can be used and the battery parameters can be tailored according to their application. A novel battery design was tested with anode and cathode fabricated side by side in a planar arrangement. Electrode width and depth as well as electrolyte thickness are the main design parameters to achieve sufficient current capability, which is required for wireless sensor nodes.

14.15-14.35: *Electromagnetic buckled beam oscillator for enhanced vibration energy harvesting* – F. Cottone (ESIEE, France) et al

In this work, a nonlinear vibration energy harvester consisting of a buckled beam and an electromagnetic transducer is proposed. An advantage of this device is that there is no need of permanent magnets to create the bistable potential. Theoretical modeling and experimental investigations on a prototype are presented. The prototype demonstrates a peak power of 2.96 mW at resonance of 52 Hz under 0.32 g of acceleration in the unbuckled configuration, while under bistable regime, it shows a gain up to 115% of power. Besides, both systems show a large bandwidth response compared to resonant cantilever devices.

14.35-14.55: *Energy capture for self-sufficient sensors with optimized photovoltaic cells* - K. Ruhle (University of Freiburg/ Fraunhofer ISE, Germany) et al

The optimization of photovoltaic devices for versatile conditions is necessary to improve the energy capture for indoor applications, such as self-sufficient sensors. However, the design rules of standard outdoor solar cells are not applicable for cells, which are used indoors due to differing conditions from the standard testing conditions (STC). We will discuss the substantial influences on cell efficiencies and their impact on the design of photovoltaic cells with indoor applications. We show that in order to reduce losses due to recombination the influence of impurity recombination outweighs the Auger recombination. Therefore, good quality material and reducing of the doping are favorable. The dopant reducing implies an improvement of J01 and is realizable because Rs has no influence on the efficiency at indoor intensities. The crucial parameter Rsh has to have a value of at least 50 kWcm^2.

14.55-15.15 *High-overtone Bulk Acoustic Resonator (HBAR) as passive sensor: towards microwave wireless interrogation* – JM. Friedt (SENSeOR, France) et al

Increasing the operating frequency of wireless passive sensors is suitable for reducing the global sensor size currently dominated by antenna dimensions, and for improved directivity of the probe electromagnetic signal with either electronic or mechanical beam sweeping by the reader for space domain multiplexing. While surface acoustic wave (SAW) transducers patterned on piezoelectric substrate are one of the standard approaches for passive wireless sensing, their operating frequency is limited by lithography resolution. One alternative approach to increase the operating frequency is to exploit bulk acoustic resonators operating at high overtone – the so-called HBARs. In this paper, the interrogation of such devices is demonstrated either in the time domain (delay line) or frequency domain (resonator), taking advantage of their spectral characteristics, i.e. a comb of modes in the frequency domain, or a comb of time-domain reflections.

15.15-15.30: LIVE DEMOS (AGILENT, SIGFOX) INTRODUCTION

Energy Consumption Measurement and Challenges: New Innovation Dramatically Improves Current Drain Measurement Accuracy - Carlo Canziani (Agilent)

For years, engineers have struggled with measurements that affect the run time of the battery-powered devices. Setups of scopes, DMM's, power supplies, current probes and/or current shunts are complex and they are NOT able to show the details of dynamic current usage. Agilent N6781A Source Measure Unit (SMU) provides breakthrough technology that provides insights into dynamic current characterization that was not available until now. With a single instrument engineers can characterize current from nA to A on a single display. The patented "seamless" ranging technology of Agilent's SMU gives unprecedented accuracy and speed over a range like 28-bits. Now engineers can gain deeper insight into the current drain that directly affects the run time of their product.

Sigfox - On the management of power consumption for M2M/IoT applications - Thomas Nicholls (Sigfox)

Enabling millions of objects to communicate requires a disruptive and energy efficient new connectivity solution. Sigfox is the first cellular network operator dedicated to M2M/IoT solutions. Low throughput on Ultra Narrow-Band allows us to achieve a long-range communication with very low power consumption and at a low cost.

15.30-16.00: COFFEE BREAK/LIVE DEMOS

Session: Energy in Wireless Sensors 2 - Chair: S. Basrour (TIMA-France)

16.00-16.20: *Energy Harvesting for Powering Wireless Sensor Networks on-board Geostationary Broadcasting Satellites* – A. Takacs (LAAS-CNRS, France) et al

This paper addresses the topics of energy harvesting for powering autonomous wireless sensors on board of geostationary broadcasting satellites. The feasibility of energy harvesting by using thermoelectric modules or rectennas is firstly discussed then the design and the implementation of a rectenna is presented. Experimental results in Ka band demonstrate the feasibility of the use of such rectenna in satellite applications.

16.20-16.40: *Datasheet vs. Real World: A Look on Sensor Node Energy Consumption* – A. Sieber (Cottbus, Germany) et al

Energy and run time are mayor concerns in wireless sensor networks. Reliable information about the energy consumption is needed to be able to build a network and tune its application. In this paper we take a look on the energy consumption of the Texas Instruments eZ430-Chronos, an MSP430 based wireless sensor node, and compare it to the manufacturers datasheet. The measurements show how reliable these specifications are and which consequences should be taken.

16.40-17.00: *Scheduling with Quality of Service requirements in Real-Time Energy Harvesting sensors* – M. Abdallah (IRCCyN, France) et al

This paper is concerned with the problem of periodic task scheduling in sensor nodes powered by energy harvesters. We address this issue by proposing two energy-aware scheduling algorithms, respectively called Green-RTO and Green-BWP. They aim to guarantee an acceptable Quality of Service (QoS) measured in terms of deadline success ratio.

17.00-17.20:*Autonomy constraint in microsensor design: from decision making to energy optimization* - V. Dupé (ESTIA, France) et al

This paper exposes our method and simulation tools dedicated to embedded autonomous Microsystems design and optimization. They aim at guiding designers in the choice of the components, materials, technologies and the

microsystem architecture. Moreover, based on a system approach, the developed tools are application dependent. They support the design process, from the specifications to the detailed design and enable designers to optimize the selected architecture.

17.20-17.40: *Case Study of a Wireless Sensor Network for a Building Monitoring Application* - D. Dessales (XLIM–SIC, France) et al

This paper focuses on building monitoring systems that are essentials to identify and improve the building energy performances in an efficient way. The major problem concerns the energy efficiency of the radio communications in order to extend the Wireless Sensor Network lifetime. In this goal, we show why it is important to have a cross-layer approach in the design of such system. More particularly, we show the different levels of optimization and the importance to take into account the physical layer performances in the MAC layer assessment.

20.00: BANQUET DINNER

Friday, November 23rd

Session: Power Management 1 - Chair: P. Basset (ESIEE-France)

8.45-9.15: INVITED PAPER: *A Proof-of-Concept of an Multi-Harvesting Power Source in a Low-Voltage CMOS Technology* – P. Miribel (University of Barcelona, Spain) et al

This paper presents a view of the state of the art in the field of energy harvesting solutions focused on discrete to integrated solutions in the range of low-power generation, from a few microwatts to several nanowatts. A view of commercial solutions to the new trends in new self-powered smart sensors operating without the use of any kind of battery will be presented. A specific solution developed in our laboratory will be used as an example of application.

9.15-9.35: *Design of Controller IC for Asynchronous Conditioning Circuit of an Electrostatic Vibration Energy Harvester* – A. Dudka (LIP6, France) et al

The paper presents a transistor-level design of a power management system for asynchronous electrostatic energy harvester. The designed circuit implements the concept of adaptive behavior of energy harvester, allowing it to operate in an optimal mode in environment where the magnitude of the vibrations may change in time. For the first time, such a system is designed to operate at high voltage (up to 30 V). However, this paper does not concern the design of electromechanical transducer. The IC design has been carried out in 0.35um high-voltage CMOS technology, and has been validated by a coupled VHDL-AMS/SPICE simulation. The control system losses are estimated on the 0.9uW level, whereas the harvested energy is approximately 1.1uW for 14V operation voltage.

9.35-9.55: *Association of Flyback Converters to Harvest Energy from Multiple Hydraulically Connected Biofuel Cells* – N. Degrenne (Ampere, France) et al

Biofuel cells use catalysts (chemical, enzymatic or microbial) to convert chemical energy from organic substrates into electrical energy. This paper investigates energy harvesting from several low-power biofuel cells to power a load under several volts. As biofuel cells can share the same fuel source, isolation is required to aggregate energy towards high voltages (compared to a cell voltage). The proposed converter is based on the well-known flyback topology. The efficiency of the flyback converter is about 60% for an input power of 10mW. The PCB area is 29 cm^2 compared to around 74 cm^2 for a previously built boost converter. The topology of the flyback converter includes a control circuit, which allows a regulation of the input voltage to keep it around the maximum power point (MPP at around 0.3 V). This control circuit is powered internally through an auxiliary sub-circuit.

10.00-10.30: COFFEE BREAK

Session: Power Management 2 - Chair: P. Miribel (University of Barcelona, Spain)

10.30-10.50: *Power Manager with PID controller in Energy Harvesting Wireless Sensor Networks* – TN. Le (IRISA/INRIA, France) et al

System lifetime is the crucial problem of Wireless Sensor Networks (WSNs), and exploiting environmental energy provides a potential solution for this problem. When considering self-powered systems, the Power Manager (PM) plays an important role in energy harvesting WSNs. Instead of minimizing the consumption energy as in the case of

battery powered systems, it makes the harvesting node converge to Energy Neutral Operation (ENO) to achieve a theoretically infinite lifetime and maximize the system performance. In this paper1, a low complexity PM with a Proportional Integral Derivative (PID) controller is introduced. This PM monitors the buffered energy in the storage device and performs adaptation by changing the wake-up period of the wireless node. This shows the interest of our approach since the impractical monitoring harvested energy as well as consumed energy is not required as it is the case in other previously proposed techniques. Experimental results are performed on a real WSN platform with two solar cells in an indoor environment. The PID controller provides a practical strategy for long-term operations of the node in various environmental conditions.

10.50-11.10: *A 60 GHz Transceiver for Low Power Ad Hoc Networks* - C. Loyez (IEMN, France) et al

This paper presents a low power consumption architecture of RF transceiver using impulse radio signals operating at 60 GHz. Both intrinsic features and related technologies of this operating frequency are detailed and the specific topology of this communication and geo-localization system is introduced. The performance of this low power consumption system is validated experimentally. The emitter exhibits an energy efficiency down to 10 pJ/bit and data rates up to 10 Mbps. Geo-localization ability of this 60 GHz system is also experimentally demonstrated with localization accuracy in the range of 40 cm.

11.10-11.30: *Multipurpose use of radiofrequency sources for probing passive wireless sensors and routing digital messages in a wireless sensor network* - G. Goavec-Mérou (FEMTO-ST, France) et al

As the interest for sensor networks is growing, the demand for integrating both measurement algorithm and data transmission pushes to develop adapted electronic platforms to address this challenge. The use of radiofrequency (RF) passive surface acoustic wave sensors probed by radio-modem interfaces commonly found on wireless sensor node platforms is therefore investigated in this work. This approach allows for providing sensors with virtually infinite life expectancy since no local power source is needed on the sensing site. Rather than harvesting energy from the environment, the passive sensor is loaded by an incoming RF source provided by the same RF interface than the one used for digital communication of the gathered data. Implementing such a scheme in an ad hoc wireless sensor network configuration is demonstrated using a novel platform based on the XE1203F radio-modem, which provides the specific interfaces mandatory to such an application. Furthermore, a measurement demonstration locating the sensing element in an oven heated to 550°C emphasizes environmental conditions in which no energy storage or battery would withstand such harsh conditions, while the wireless interrogation between the interrogation unit (reader) and the sensor removes the need for High temperature-compatible connector and electrical cable. Implementing the sensor probing algorithm as well as the radio-modem control interface in the TinyOS executive environment then provides access to all the functionalities of this portable development tool, including multi-hop data routing and dynamic ad-hoc network construction, while complying with a clear software hierarchy ranging from low level drivers accessing the hardware to user applications implemented as tasks.

11.30-11.50: *Implementation and testing of an elastic strain powered wireless sensing system for energy-autonomous applications* – A. Giuliano (Cranfield University, UK) et al

This paper presents implementation and testing of an elastic strain powered wireless sensing system for energy-autonomous applications. The system harvests strain energy from a vibrating structure and convert it into usable electrical energy for powering sensors and a wireless communication node. Typical in-flight vibration frequencies and strain levels on the bottom side of the aircraft wing's root were investigated for testing the performance of the system. Major concerns of the implemented system are the amount of harvested power, in the usable range of milliwatts, and the low power consumption energy-flow management for data sensing and transmitting. Such results arise from the use of flexible piezoelectric macro-fiber composite (MFC) bonded as energy generator to both an aluminum and a composite substrate, and from the integration of a new Energy-Aware Interface (EAI). The harvested power is between 0.5-12 mW under low and non-resonant vibrations of 2.5-10 Hz and 480-1170 μstrain peak-to-peak. The waiting time between two consecutive transmissions was measured around 0.4 s under 1170 μstrain peak-to-peak excitation at 10 Hz. Such achievement shows strong capability to approach self-powered continuous monitoring. The system has potential of being used to harvest strain energy from the vibrations of aircraft in active service for powering an on-board wireless sensor node for Structural Health Monitoring (SHM).

11.50-12.10: WRAP UP AND CLOSING

12.30-14.00: LUNCH