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Design a Low Voltage Energy Harvesting SoC System for Ultra-Low-Power Bio-medical Application

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Abstract: This Paper presents a designing of low voltage energy harvesting SoC system based on Ultra-Low-Power Bio-medical applications. A novel technique (i.e., Genetic Algorithm) has chosen for designing the ultra-low-power circuit with a low voltage energy. This platform harvests ambient vibration energy as its power source, and is capable of self starting, and self-powered operation without the need of a battery. The proposed method consumes very little power, and is especially suitable for the environments, where ambient harvested power is very low. System modeling and analysis of the method will be developed using HSPICE software. The ultimate goal of this research work is to design a low voltage smart electronics circuit of SoC system. To implement our SoC design, the Analog/Digital software from Mentor Graphics will be considered. Experimental results will be presented at our next possible journal publication in future accordingly.

Key words: Wireless Sensor Network, Micro-system, Battery-less, Ubiquitous Devices.

INTRODUCTION

Micro Energy Harvesters are small electromechanical devices, which harvest ambient energy and then convert it into electrical energy, as shown in Table-1 (Murugavel, 2010). Recently, the concepts of Ubiquitous computing, sensing and perception have drawn a lot of attentions in the research community. Computation is embedded into environments to facilitate the interaction among devices and human naturally and causally. One example is Wireless Sensor Network (WSN), which has potential to be used in many areas. The conventional solution for providing the required power to each sensor node is to use electrochemical batteries. However, battery is bulky, costly and difficult to replace regularly in many applications. This poses a big limitation on the development of such systems. In some Ultra Low Power (ULP) applications (e.g., picoradio (Rabaey, 2002) and smart dust (Smart dust, 2004)), which demand low cost, long lifetime, small volume and light weight, eliminating the battery is desirable. Increasing demands for low voltage portable communication products in the consumer marketplace (Borderson, 1991), along with a dramatic increase in DSP applications for those products over the last several years, are the major driving forces behind the development of a high performance, low voltage, and low cost VLSI technology for DSP applications. The key market drivers for those applications include high speed, long battery life, high integration, and low cost (Jun, 1997). To the vision autonomous power controller and low power consumption circuit in future.

2. Description:

A complete WSN node in signal processing and communication area will normally have a power budget of 100 µW. Achieving this requires good application knowledge and well designed energy harvester to enable an optimal balance between power and resolution. The ultimate goal of this research work is to design a micro-power module (i.e., Low voltage circuit) that can be integrated into WSN node. Therefore, in this research work, we will investigate a way to design of low voltage circuit for ULP Bio-medical application that energy harvester to integrate with WSN node. For the most promising concepts, we will build fully integrated demonstrators including micro-power generation, conditioning, storage and management systems.

For some ubiquitous applications, the average power consumption can be down to the level of tens to hundreds of micro watts. In this case, energy harvested from environments can be used as an alternative power source to provide a virtually infinite lifetime (Mateu, 2005; Roundy, 2003). Mechanical energy conversion is

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one of the common sources for these energy harvesting applications. Low level vibrations commonly occur in household or industrial environments. It is estimated that mechanical vibrations inherent in the environment can provide a power density of tens to hundreds of micro watt per cm3, which is sufficient to sustain operations of a sensor node (Arms, 2005). In this work, we focus on the low voltage energy harvesting systems for ULP Bio-medical application. Fig 1 shows the propose block diagram of the micro-system including energy harvesting module.

Table 1: Energy Harvesting Estimates

Energy Source	Harvested Power
Vibration/Motion	
Human	4 μW/cm_2
Industry	100 μW/cm_2
Temperature Difference	
Human	25 μW/cm_2
Industry	1–10 mW/cm_2
Light	
Indoor	10 μW/cm_2
Outdoor	10 mW/cm_2
RF	
GSM	0.1 μW/cm_2
WiFi	0.001 μW/cm_2

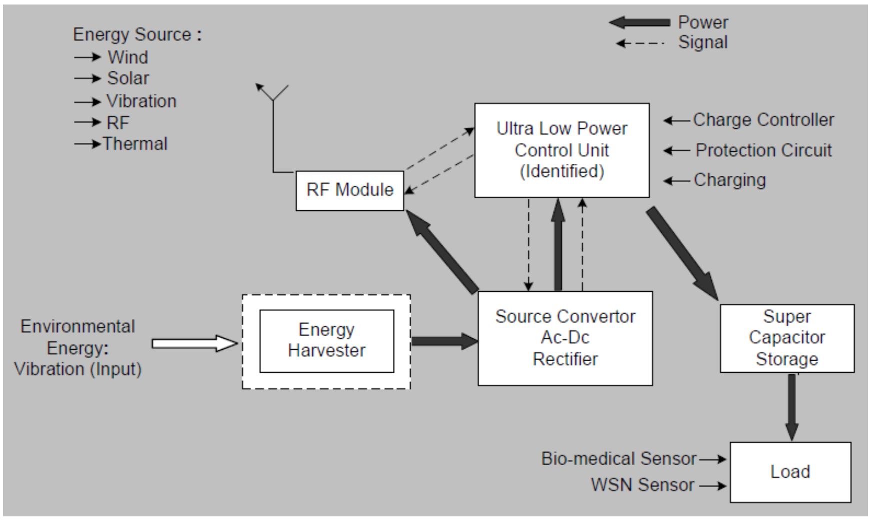

Fig. 1: Propose block diagram of the micro-system including energy harvesting module.

Supplying power to a network of sensor-nodes has traditionally required in expensive wiring installation or routing 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 WSN applications. Energy harvesting technologies are on the verge of new breakthroughs with energy storage, and they are being paired with ULP chipsets as well as plugand-play software. While still in an early phase, energy-harvesting devices, which translate abundant sources of energy such as light, heat and mechanical energy into electrical energy, are rapidly being integrated with wireless sensor technologies. In 2011, there will be 150 million to 200 million wireless sensors being used in factory automation, process and environmental control, security, medicine, and condition-based maintenance, as well as in defense application and intelligence gathering (Ultra-Low Power, 2010). Such wireless sensor systems will require numerous individual devices (nodes/motes) to provide comprehensive monitoring capability; be located in inaccessible places much of the time; and 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. Therefore, there is clearly a need to develop a micro energy source that can last years with little or no maintenance.

3. Objectives:

1. To investigate the micro energy harvester devices, Ultra-Low-Power (ULP) circuit design techniques, and WSN based Bio-medical application from literature survey.
2. To develop, design, and modeling of the identified ULP circuit.
3. To simulate the low voltage-based energy harvesting system for ULP circuit and integrate it within SoC device.
4. To drive a WSN node in Bio-medical applications.

4. Research Methodology:

Firstly, the propose research work on the title "Design a Low Voltage Energy Harvesting SoC System for Ultra-Low-Power Bio-medical Applications" will be performed as SoC level using the following design-flow to experiment our research work, as shown in Fig. 2. To do this research work, we will investigate the literature review on ULP circuit etc. Based on the literature survey among a few past researcher works, as shown in Table-2 the identified ULP circuit will be developed at first and then modeled it as our desire SoC module. The proposed ULP circuit will be simulated using HSPICE software to design a suitable ULP circuit. The designed ULP (i.e., smart electronic circuits) will be also simulated on 90-nm technology. To test the functionality of the smart electronic circuits in signal-levels, we need to perform the circuit functionality in mixed signal of Analog/Digital aspects. To experimental analysis of ULP SoC circuit for Bio-medical application as well as the model will be contrast for Ubiquitous devices.

Table 2: Comparison result on Ultra-Low-Power circuits

Past Researcher`s Works	Voltage in ULP circuits (V)	CMOS Technology in µm/nm	Size of ULP circuit in area mm^2	Operating frequency in MHz	Applications
R.X. Gu and M.I. Elmasry (1993).	2.5	0.8 µm	Not Reported	Not Reported	SRAMs Low Voltage circuits
Jun Ma, Han-Bin Liang *et al*.(1997).	1.8	0.5 µm	Not Reported	Not Reported	DSP Application
Jing-Jou Tang (1999),	1	Not Reported	Not Reported	Not Reported	Gate level circuit design
Alain-Serge Porret *et al*. (2000).	1	0.5µm	Not Reported	916	Not Reported
Thierry Melly *et al*. (2001).	1	0.5 µm	Not Reported	300	Not Reported
Debasis Samanta *et al*. (2002).	1	0.18 µm	Not Reported	Not Reported	Battery operated portable systems.
Huseyin S.Savci *et al.* (2006)	1	0.18 µm	Not Reported	404	MICS transceiver
Edwin Cheng Mu Lim *et al*. (2007).	1	0.18 µm	Not Reported	200	Biomedical Amplifier
Alan Chi Wai Wong *et al*. (2008).	1	0.13 µm	4 × 4	902-928	Biotelemetry
Chang-Tzu Wang *et al*. (2009).	1	21 µm	Not Reported	Not Reported	Rail ESD clamp circuit

5. Conclusion:

This research will provide a detailed technical overview of ULP energy harvesting for WSN, especially recent nano-technology developments and existing barriers. Research will analyzes the markets for ultra-low power energy harvesting of vibration to electricity generation technology covering several primary applications - WSN, building automation wireless, battery-less, low-power switches, automotives, medical uses such as body area networks; precision agriculture; and consumer electronics.

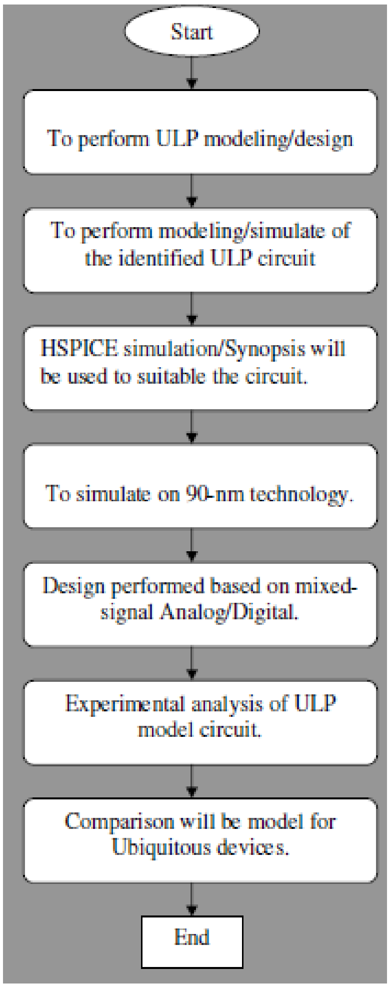

Fig. 2: Design flow.

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