

Poster: Multi-source Energy Harvesting for IoT nodes

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Abstract—Power consumption is a primary concern for wireless sensor networks. In order to reduce the use of batteries in the nodes, energy harvesting technologies have been considered. However, most of the existing solutions rely on a single energy source, thus potentially reducing the sensor sustainability. In this paper, we present a circuit that switches between multiple heterogeneous energy sources, and uses a single power conditioning block. A prototype has been developed and validated with an existing wireless sensor. Measurements show that switching between energy sources can efficiently combine two energy sources in order to increase device autonomy and/or quality of service.

I. INTRODUCTION

The primary concern in the deployment of wireless sensor networks is the power consumption of the nodes. In order to increase the Quality of Service (QoS) of nodes, their power consumption can be reduced through the use of duty cycling techniques [1], or through harvesting the energy from the environment. Such systems use an harvesting device to transform available energy (light, vibration, ...) in electric energy, and a power conditioning device to adapt this energy to the node. However, most systems rely on a single energy source, which makes them vulnerable to variations of their environment.

The simultaneous use of multiple energy sources has already been studied. Custom Integrated Circuits (IC) adapted to multiple input sources have been designed [2] [3], but the cost of IC fabrication is prohibitive in many applications. On the other hand, [4] [5] [6] proposed systems which use multiple energy harvesting sources. Each source has its own power conditioning block, which rises the cost and board space of the solution. In this paper, an architecture is proposed which uses only a single power conditioning device.

The rest of the paper is organized as follows. Section II describes the proposed multi-source energy harvesting architecture. A prototype is presented in Section III, along with measurements. Finally, the future developments of our platform are explained in Section IV.

II. MULTIPLE SOURCE SWITCHING SYSTEM

The proposed multi-source energy harvesting system aims for low cost and easy implementation with existing wireless sensor designs. In order to ease industrialization, the system

is developed using Components Off-The-Shelf (COTS). The system, shown in Fig. 1 differentiates from state-of-the-art solutions by using a single power conditioning block shared between multiple energy harvesting sources.

Each source is connected to an energy buffer, used to store the harvested energy. Each energy buffer is connected to the power conditioning block through a switch matrix. Thus, an energy source will charge its energy buffer while its switch is opened, and the power conditioning block will discharge the buffer when the switch is closed. In order to avoid potential damages, the switch must prevent current flow from a source to another. This switch is implemented with a commercial integrated load switch followed by an ideal diode circuit.

The power conditioning block is implemented with a Power Management Integrated Component (PMIC), which includes a voltage converter, a Maximum Power Point Tracking (MPPT) circuit, and a battery charger. A dedicated controller is used to manage the switch matrix. This function is implemented by an ultra low power micro-controller, which enables flexible implementation of multiple switching decision algorithms. However, algorithmic considerations are out of the scope of this paper and a passive algorithm is used based on an individual and periodic turn-off of each switch. Each buffer is therefore connected to PMIC during a given duration T_{SW} .

III. PROTOTYPING AND MEASUREMENTS

A prototype based on this architecture has been developed. The PMIC is a SPV1050 from STMicroelectronics, and the controller is a MSP430FR5969 micro-controller from Texas Instruments. Voltage generators are used to emulate sources.

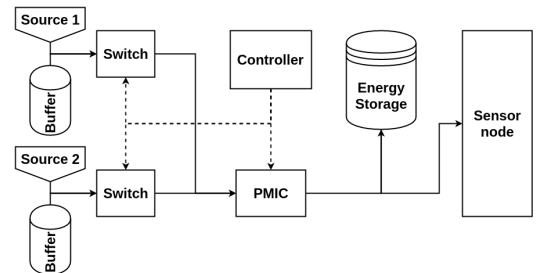


Fig. 1: Multiple source switching system.

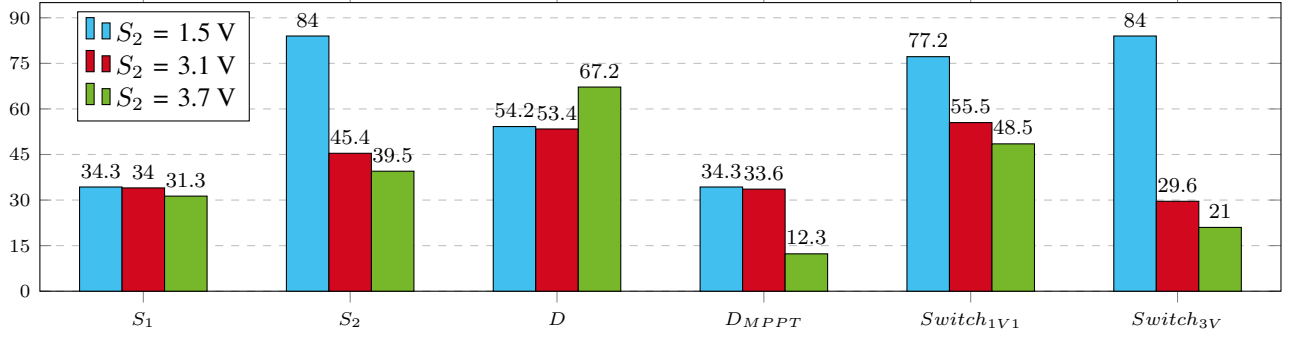


Fig. 2: Average period $\overline{T_{PTX}}$ in s between two LoRa TX depending on situation and S_2 voltage.

The first source is set to 4.2 V, while the second is set between 1.5 V, 3.1 V and 3.7 V. Both sources are limited to 1 mA in order to simulate low power sources. Their energy buffers are respectively set to 4700 μF and 1000 μF .

The SPV1050 implements MPPT using sample and hold: the IC periodically opens its input circuitry for a short time to let the source reach its open voltage V_{OC} of the source. The voltage of the MPP V_{MPP} is then measured as a portion of this voltage (e.g. 70% of V_{OC} for a solar panel) through a voltage divider. This technique can not be applied to the proposed system, as the capacitors used as energy buffers prevent the source from rapidly reaching its V_{OC} . However, it is possible to set an arbitrary voltage V_{REF} on the V_{MPP} pin. The PMIC will then adapt its switching frequency to match its input voltage to V_{REF} .

The proposed system is used to charge a 34.7 mF capacitor array, which powers a LoRaWAN wireless sensor developed by Wi6labs [7]. A simple power manager is implemented: the controller periodically measures the State-of-Charge (SoC) of the energy storage, and sends a signal to the Wi6labs node if it is full. The node wakes up and sends a dummy LoRaWAN packet. The period T_{PTX} is measured for 10 successful transmissions, and the average value $\overline{T_{PTX}}$ is computed. Harvesting energy more efficiently charges the storage faster, and thus lowers $\overline{T_{PTX}}$. The following situations have been evaluated:

- $S_{1/2}$: Source 1/2 only, with MPPT
- D : Sources 1 and 2 connected to a single PMIC through ideal diode circuit, without MPPT
- D_{MPPT} : Source 1 and 2 connected to a single PMIC through ideal diode circuit, with MPPT
- $Switch_{1V1/3V}$: Periodic switch ($T_{SW} = 1\text{ s}$) with PMIC V_{REF} set to 1.1 V or 3.0 V

Measurements results are presented in Fig. 2. The difference between situations D and D_{MPPT} shows the importance of using MPPT circuitry. The proposed solution suffers from this lack of MPPT circuitry. If V_{REF} is set too low, as in situation $Switch_{1V1}$, higher voltage sources operate far from their MPP, and provide less energy. However, setting V_{REF} too high can render low voltage source useless. For example, setting V_{REF} at 3 V makes S_1 , at 4.2 V, operate closer from

its MPP. But if S_2 is smaller than V_{REF} , the PMIC will not draw current from this source, making it useless.

D_{MPPT} is a naive implementation, and is only efficient if the two voltages are close. When the MPPT circuit measures V_{OC} , it will measure the highest voltage in all sources, and set its V_{MPP} accordingly. A lower voltage source will operate far from its MPP, or will not even provide power if its voltage is smaller than the measured V_{MPP} .

IV. CONCLUSION

In this paper, an architecture for multi-source energy harvesting is presented, where several energy sources are multiplexed to a single PMIC through a switch matrix. Functionality of the system has been validated with an industrial existing wireless sensor. Measurements show the possibilities of efficient energy combination, when the sources operate close to their MPP. Future implementations will improve this aspect by adding MPPT circuitry for all sources.

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