Ultra-low power management and voltage regulation

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Abstract – For a massive yet sustainable Internet-of-Things, ultra-low power management and voltage regulation are required to operate the nodes on ambient energy harvesting (EH) while delivering the required supply voltages to the sensing, computing and communication blocks. Latest related results obtained in the electronic circuits and systems (ECS) group include indoor/outdoor solar EH power management units licensed to and industrialized by e-peas semiconductors, RF-harvesting rectifiers, a reconfigurable switched-capacitor converter with a wide load power range in collaboration with ST Microelectronics, a voltage reference with the record 0.2V minimum and an ultra-low-quiescent current linear regulator with most of them included in a 3-mm^2 solar-powered video analysis System-on-Chip (SoC) codenamed SunPixer.

The connection of our daily life's objects to the cloud according to the Internet-of-Things (IoT) vision is about to revolutionize the way we live. To enable this revolution, a massive deployment of sensor nodes is required with predictions announcing up to trillions of these nodes. Such a massive deployment is not environmentally and economically sustainable with current battery-operated technologies. Indeed, to avoid the cost and the ecotoxicity of battery replacement, the IoT nodes need to operate by harvesting the ambient energy present in various forms: solar, thermoelectric, piezoelectric or electromagnetic RF [1].

Commercial energy-harvesting power management units (EH-PMU) fail to meet the demand for autonomous startup (cold start) when the energy storage is empty. A first EH-PMU for micro PV cells based on an inductive boost converter was designed with the specific target to provide robust cold start functionality and maximum-power-point tracking while allowing to supply a wide range of off-the-shelf sensing, computing and communication components. It was licensed to e-peas semiconductors spin-off which successfully prototyped and industrialized it under its AEM product line [2]. A second EH-PMU for micro PV cells was designed based on a single bidirectional multi-gain/multi-mode switched-capacitor converter for direct harvester/load connection and on-chip integration in 65nm CMOS without external inductor [3]. It was integrated within the SunPixer SoC (Fig. 1), which is a 3-mm^2 solar-powered video analysis SoC.

RF electromagnetic energy from wireless communication signals is another interesting energy source in densely populated zones. Front-end interfaces for RF EH-PMU must include an AC/DC converter typically implemented by a rectifier. An optimization method for rectifiers has been developed and validated on the design of a 13.56-MHz rectifiers [4] using UCL-patented ULP diodes on simple Greinacher architecture and with more complex architectures (cross-coupled, differential drive).

From the system supply voltage generated by the EH-PMU, the specific ultra-low-voltage (ULV) load supplies need to be generated and regulated with circuits including:

- the first voltage reference circuit starting at a 0.2-V supply voltage that was successfully prototyped in 65nm CMOS [5],
- an ultra-low-quiescient current linear regulator with a high-dropout (HDO) architecture that was successfully prototyped in 65nm CMOS [6],
- a multi-mode switched-cap DC/DC converter for a wide output power range that was successfully prototyped in 28nm FDSOI CMOS [7] in collaboration with ST Micro (Crolles, France).

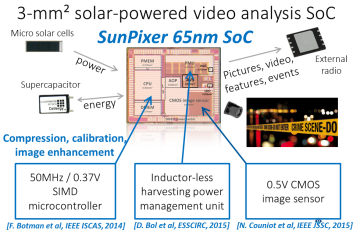

Figure 1: SunPixer SoC in 65nm CMOS.

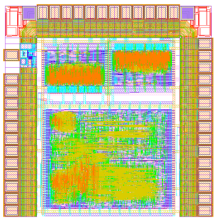

Figure 2: Layout of ADELE LDO regulator in 0.13μm CMOS.

Next research in this field is focused on multi-source EH-PMUs and all-synthesized PMUs using only digital standard cells. A prototype all-synthesized low-dropout (LDO) regulator codenamed ADELE (Fig. 2) was designed. The chip is currently under prototyping.

References

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