İskender Haydaroğlu
Thesis Supervisor: Assoc. Prof. Şenol Mutlu

ENERGY HARVESTING WIRELESS OPTICAL MICROSYSTEMS

Abstract

This thesis covers a novel approach to photovoltaic energy harvesting and optical data transmission in the context of millimeter-scaled smart autonomous microsystems through the use of a single light emitting diode (LED) to both efficiently harvest optical energy and transmit data to enable wireless, batteryless operation. A proof of concept design for demonstrating the viability of the use of a LED in the proposed manner, harvesting optical energy and transmitting a fixed device ID optically through the same LED using a transmitter based on a continually running charge pump is presented. Next, a low voltage temperature sensor design is integrated into the existing design, to prove by example that the harvested voltage from the LED is high enough that it requires no voltage boosting to power essential analog blocks such as sub-bandgap references, oscillators, and comparators, as opposed to integrated CMOS photovoltaic harvesting. Finally, an alternative, energy efficient optical transmitter architecture and a new ultra low power, ultra low energy temperature sensor are designed and integrated into a single chip. The scalable, inverter based switched capacitor boosting transmitter uses the trickle current from the LED to charge its capacitors directly with minimized losses in efficiency, transmitting data with 1 nJ/bit to a receiver designed and built in-house for up to 10 cm distance. The temperature sensor consumes less than 3 μW, features digital offset correction and an adaptive fullpartial conversion algorithm to minimize the conversion time, effectively reducing energy per conversion from 0.6 nJ-3 nJ to 0.15 nJ-0.75 nJ. Total power consumption is in the order of 6 μW, harvested by a 0.1 mm^2 LED, making the system viable for millimeter-scaled outdoor solar harvesting applications. All three designs were fabricated in UMC 0.18 μm CMOS process and tested in-house.

PUBLICATIONS

Journals

1. Haydaroglu I., Ozgun M., Mutlu S., “Optically Powered Optical Wireless Transmitter Using a Single Light Emitting Diode”, in IEEE Transactions on Circuits and Systems I: Regular Papers, vol. 64, issue 8, pp. 2003-2012, Aug. 2017. (SCI)
2. Haydaroglu, I., Mutlu, S., "Optical Power Delivery and Data Transmission in a Wireless and Batteryless Microsystem Using a Single Light Emitting Diode," in Journal of Microelectromechanical Systems, vol. 24, no. 1, pp. 155-165, Feb. 2015. (SCI)
3. Mutlu, S., Haydaroglu, I., Sevim, A.O, “Realization of Polymer Charge Pump Circuits Using Polymer Semiconductors”, in Organic Electronics, v.12, issue 2, pp. 312-321, 2011. (SCI)

Conferences

1. Haydaroglu, I., Mutlu, S., "Energy harvesting and data transmitting microsystem using a light emitting diode," Optical MEMS and Nanophotonics (OMN), 2011 International Conference on, Istanbul, 2011, pp. 87-88.
2. Haydaroglu, I., Ozgun, M., Mutlu, S., “Optical Wireless Transmitter with Concurrent Energy Harvesting”, Presentation at the 2016 International Solid State Circuits Conference (ISSCC) Student Research Preview session (Student work in progress), Jan. 31-Feb. 4, San Francisco, CA.

Defense Jury Members

1. Assoc. Prof Şenol Mutlu — Boğaziçi University
2. Prof. Günhan Dündar — Boğaziçi University
3. Asst. Prof. Tamer Özgün — Şehir University
4. Asst. Prof. Ahmet Öncü — Boğaziçi University
5. Asst. Prof. Hakan Doğan — Şehir University

Defense Date: 13.05.2016