The School of Informatics, Computing and Engineering (SICE)

INTELLIGENT SYSTEMS ENGINEERING COLLOQUIUM SERIES

Miniature Intelligent Sensing System

Inhee Lee

Inhee Lee received his B.S. and M.S. degrees in electrical and electronic engineering from Yonsei University, Seoul, Korea, in 2006 and 2008, respectively, and a Ph. D. degree in electrical and electronic engineering from the University of Michigan, Ann Arbor, MI, USA, in 2014. He is currently a research scientist at the University of Michigan. Dr. Lee's research is focused on low-power circuit design for miniature intelligent sensing systems. He is developing millimeter-scale or even smaller sensing systems for ecological, biomedical, energy exploration, and Internet-of-things applications. To achieve this goal, he focuses on adaptive energy harvesters, ultra-low-power power management circuits, and energy-efficient sensor interface circuits.

Abstract

Miniature intelligent sensing systems have unique feature sets that include wireless communication, energy harvesting, and a small form-factor, thus enabling non-invasive, secure placement for biomedical, ecological, surveillance, and infrastructure applications, among others. There has been substantial research on the miniaturization of intelligent sensing systems. The size of the bare die is often only 1-2 mm; however, the associated systems are typically much larger than just the die, resulting in centimeter-size systems due to included peripherals such as batteries and casings. This leads to a design challenge for the electronics of miniaturized systems because the maximum physical battery size and battery storage capacity are severely limited. For example, for a system with a millimeter-scale battery to survive for several days (up to a month), the average power consumption must be within the 2-200 nW range. To successfully meet this energy limitation, I was a key contributor to the development of a millimeter-scale intelligent sensing system platform called the Michigan Micro Mote in 2011. To optimize circuit performance, the system is constructed from dies fabricated in different technologies, which are then stacked and wire-bonded together. The stacked structure increases the silicon area per unit volume and also makes it easy to swap layers in and out for flexibility in the system configuration.

In this talk, I will describe this intelligent system platform and show two system examples for ecological and energy exploration applications. The first example is about a system that measures light dose on two different types of snails in Tahiti. In Tahiti, large predator snails (Euglandina rosea) ate up a large number of small prey snail species, most of which became extinct. However, one small snail, Partula hyaline, has endured predation. My partners, biologists, hypothesized that the survival of P. hyaline was due to a difference in light intensities between their habitat and that of the predator snail. We quantitatively confirmed the hypothesis by measuring light dose on the snails using the intelligent sensing systems. The second example is about an intelligent sensing system that measures temperature and pressure in an oil reservoir. In this setting, the temperature exceeds 125oC, and power consumption is significantly increased at high temperature. To achieve a lifetime of several weeks, our team reduced power consumption 63 fold by using 'deep sleep mode' with a battery switch and Flash memory.

In addition, I will introduce one example of a low-power circuit technique that enabled the miniature intelligent sensing system. It is an adaptive energy harvesting circuit that enables the system to overcome the energy limitation. This energy harvester automatically adjusts reconfigurable solar-cell array according to light intensity and battery voltage to extract the maximum power from the solar cells. It achieves 78% harvesting efficiency over a wide range of light intensities and battery voltages, whereas the efficiency of the previous best fully integrated energy harvester is limited to 55%.

WEDNESDAY, MARCH 07, 2018

10:00 AM | LUDDY 1106

SCHOOL OF

INFORMATICS, COMPUTING AND ENGINEERING