Digital Integrated Circuits and Systems

Academic and Research Staff
Professor Anantha Chandrakasan

Graduate Students
Denis Daly, Patrick Mercier, Manish Bhardwaj

Administrative Staff
Margaret Flaherty

1. Energy Efficient Ultra-wideband Radios

Sponsors
DARPA, NSERC

Project Staff
Denis Daly, Patrick Mercier, Manish Bhardwaj, and Professor Anantha Chandrakasan

For decades, scientists and engineers have been fascinated by cybernetic organisms, or cyborgs, that fuse artificial and natural systems. Cyborgs enable the harnessing of biological systems that have been honed by evolutionary forces over millennia to achieve astounding feats. Male moths can detect a single pheromone molecule, a sensitivity of roughly 10^{-21} grams. Thus, cyborgs can perform tasks at scales and efficiencies that would ordinarily seem incomprehensible. Semiconductor technology is central to realizing this vision because it offers powerful processing and communication capabilities as well as low weight, small size, and deterministic control. An emerging cyborg application is moth flight control, where electronics and MEMS devices are placed on and within a moth to control flight direction. To receive commands on the moth, a lightweight, low-power and low-volume receiver is required. Figure 1 presents an overview of the moth flight control system being developed in collaboration with other scientists and researchers at MIT, the University of Washington, and the University of Arizona.

A critical component of the hybrid-insect system is the wireless communication link, which provides flight control commands to the moth. Pulsed ultra-wideband (UWB) wireless signaling is employed as UWB radios can achieve highly integrated, energy-efficient operation in nanometer CMOS processes [1]-[3]. Power, weight and volume are all highly constrained, necessitating a highly integrated solution with minimal off-chip components. Data is transmitted by PPM modulation in one of three 500-MHz channels in the 3-to-5-GHz band. Figure 2 presents a block-diagram of the wireless receiver system-on-chip. The non-coherent receiver amplifies, squares, and integrates received pulses to measure the amount of energy received in a given time period. A differential, inverter based front end is employed to reduce current consumption while allowing for a single 1V core power supply. The highly duty cycled RX requires 0.5-to-1.4nJ/bit and achieves a sensitivity of -76dBm at a data rate of 16 Mb/s (10^{-3} BER). The moth stimulator generates a multi-channel, digital, pulse-width modulated signal to control flight direction. The radio has been integrated on a miniature, 1g PCB; and preliminary flight control in a wind tunnel has been demonstrated.

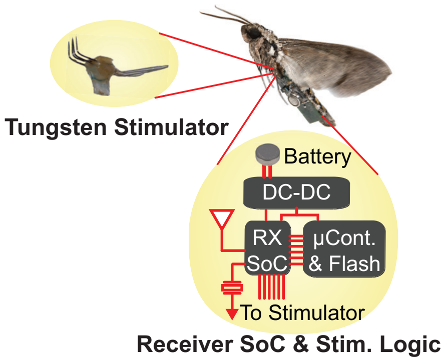

Figure 1: Overview of hybrid-insect flight control system.

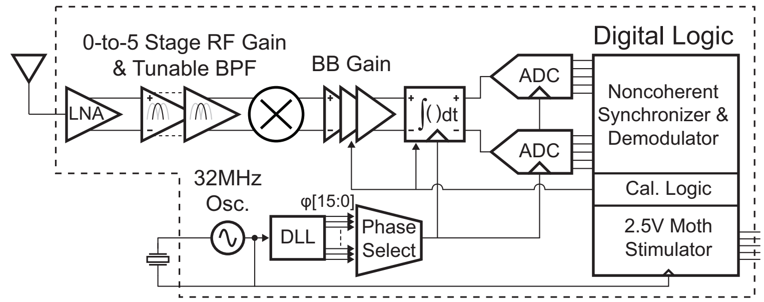

Figure 2: Block diagram of the wireless receiver SoC.

References:

[1] F.S. Lee and A.P. Chandrakasan, "A 2.5nJ/b 0.65V 3-to-5GHz Sub-banded UWB Receiver in 90nm CMOS," in *Proc. IEEE International Solid-State Circuits Conference (ISSCC)*, Feb. 2007, pp. 116-117.

[2] D.D. Wentzloff and A.P. Chandrakasan, "A 47pJ/pulse 3.1-to-5GHz All-digital UWB Transmitter in 90nm CMOS," in Proc. *IEEE International Solid-State Circuits Conference (ISSCC)*, Feb. 2007, pp. 118-119.

[3] L. Stoica, A. Rabbachin, H. Repo, S. Tiuraniemi, and I. Oppermann, "An ultra-wideband system architecture for tag-based wireless sensor networks," *IEEE Transactions on Vehicular Technology*, vol. 54, pp. 1632-1645, Sep. 2005.

Publications:

[1] P. P. Mercier, M. Bhardwaj, D. C. Daly, A. P. Chandrakasan, "A 0.55V 16Mb/s 1.6mW Non-Coherent IR-UWB Digital Baseband with ±1ns Synchronization Accuracy," *IEEE International Solid-State Circuits Conference (ISSCC),* pp. 252-253, Feb. 2009.

[2] D. C. Daly, P. P. Mercier, M. Bhardwaj, A. L. Stone, J. Voldman, R. B. Levine, J. G. Hildebrand, A. P. Chandrakasan, "A Pulsed UWB Receiver SoC for Insect Motion Control," *IEEE International Solid-State Circuits Conference (ISSCC),* pp. 200-201, Feb. 2009.