From Digital Processors to Analog Building Blocks:

Enabling New Applications through Ultra-Low Voltage Design

David Blaauw*, Dennis Sylvester, Yoonmyung Lee, InHee Yoonmyung Lee, Suyoung Bang,, Inhee Lee, Yejoong Kim, Gyouho Kim, Hassan Ghead

University of Michigan, Ann Arbor, MI, USA

Blaauw@umich.edu

INVITED PRESENTATION

Abstract

Moore's Law has received much attention over the last decades. However, the lesser known "Bell's law" has potentially had equal impact on the transformation of electronic systems. Bell's law dictates that every decade the size of a complete computing system shrinks in volume by 100x while the number of such devices per person increases. Bell's law has driven the transformation of gigantic mainframes in the 1960s to small handheld devices in the new millenium. It is generally held, that the next class of computing systems on the trajectory of Bell's law are miniature sensing systems that will instrument numerous aspects of our daily lives. In particular, we focus on millimeter sized systems which, being nearly invisible, will open up a host of new application areas in computing such as medical implantable devices for monitoring vital signs and disease, surveillance and entry detection, and environmental monitoring.

The key barrier to achieving this next class of miniature sensing systems is power consumption because the entire system, including processor, memories, radio, timers, input sensor, and power management must operate on a tiny millimeter size battery/energy harvesting unit. Furthermore, performance is not a critical concern in these systems since the vast majority of monitored phenomena change slowly and needs to be sampled only occasionally. Aquired data require only limited processing, which can be performed with kHz clock frequencies or even below. Hence, subthreshold design forms the ideal implementation strategy for these miniature sensor systems since it obtains ultimate energy efficiency at the price of significant performance loss.

In order to meet the power requirements for millimeter sized sensor systems, it is not sufficient to apply subthreshold design to just the digital parts of the system which have been most commonly explored in the literature, such as processors. Since many sensor systems spend the vast majority of their life time in standby mode, the components that remain on during standby or sleep mode can quickly dominate overall energy consumption. These components include timers, power management, voltage references and retentive memories for storing program and measurement data. Hence, subthreshold design must be applied to both the digital and analog design space to fully enable millimeter scale sensor node designs.

In this presentation, we survey recent advances by a number of researchers in apply subthreshold design to key building blocks of a miniature sensor system, including both digital and analog components. We will also examine new application areas for millimeter computing and perform a case study of a millimeter sized pressure sensor for glaucoma and tumor monitoring.