Subliminal Processor: An Ultra-Low-Energy Microcontroller for Sensor Network Processing

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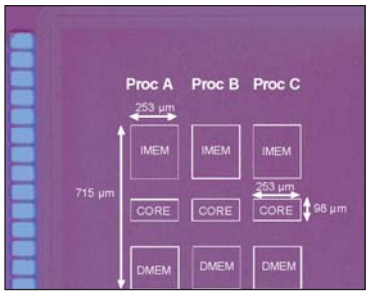
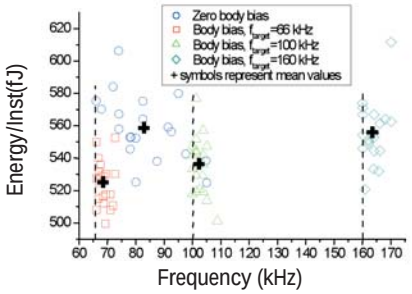
Energy-efficient data processing remains one of the primary targets of WIMS research. Any mobile system, from medical implants to environmental sensors, requires robust digital components with a maximum battery lifetime. With the Subliminal Processor, we have recently made important advances in understanding the limits of energy-efficient digital computing. The Subliminal Processor is a simple 8-bit microcontroller that uses aggressive voltage scaling into the subthreshold regime (i.e., the supply voltage is less than the transistor threshold voltage) to achieve 10–20X energy reductions when compared to operation at nominal voltages. Operation at such low voltages is complicated by high sensitivity to process variations, as well as increased computation times. We have made significant progress in understanding and addressing these problems with two generations of the Subliminal Processor. The first generation was the most energy-efficient processor ever reported, with the CPU (no memories) consuming only 850 fJ/instruction. Recent testing of the second-generation Subliminal Processor, which is operational at supply voltages as low as 150mV, shows that it is even more energy efficient than the first version, with the CPU consuming only 515 fJ/instruction. The second-generation Subliminal Processor was also used to explore techniques for reducing sensitivity to process variations. In particular, we found that tuning of the device body biases can virtually eliminate performance variability in subthreshold circuits and help minimize energy variability. Experimentation with different performance-enhancement techniques also shows that body biasing can be used to achieve circuit-level performance improvements with a negligible energy penalty. For gate-level performance improvements, we find that the use of increased gate lengths (as opposed to the traditional approach of using increased gate widths) is most effective due to reverse short-channel effects. While subthreshold operation has not yet been adopted within commercial applications, our work suggests that careful design will make it a viable and attractive option in the near future. ■



Die photo of three variants of the second-generation Subliminal Processor.



Different body bias configurations minimize energy and performance variability in 20 dies measured at Vdd=300mV.