Low Power Embedded Systems

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Most people associate computers and computing with either the large-scale supercomputers that hold world records in performance, or the more common desktop computers and terminals that allow users to connect to the Internet. However, for every such computer there are over a hundred *embedded* systems that are invisible. They work behind the scenes because they are hidden within other items that we use. Refrigerators, microwaves, cars, cameras, calculators, mobile phones, televisions, VCRs-the list of appliances that contain simple computers that control their operation is endless. Power consumption is a major issue for battery-operated embedded systems.

My research investigates ultra low power embedded systems. The goal is to reduce the power consumption to the point where the electronics in a device can operate for many years on a single battery. We are using *asynchronous* or *clockless* circuits to implement these systems, because they have some natural low power properties. A conventional digital circuit uses a clock signal for its operation. This global clock controls the flow of information, and is a continuously operating periodic signal that consumes power. A clockless circuit eliminates this signal, and instead only activates when it needs to perform a task. This matches the requirements of embedded systems very well, because they spend most of their time waiting for some activity to occur (e.g. pressing a button on a remote control).

My group developed an embedded microprocessor for use in environmental monitoring applications. This microprocessor is completely asynchronous, and for the applications of interest requires 0.6μW of power. For comparison, common commercially available embedded microprocessors consume between ten and a thousand times as much power depending on how they are used. A reduction in battery requirements directly translates to reduced cost and weight, thereby making the technology more accessible.

The primary application we are considering is the use of such an embedded micro-controller for monitoring applications. For example, suppose we develop a low-cost monitor using such a micro-controller augmented with sensors. A diabetic patient could wear one of these monitors to know when their blood sugar level need to be adjusted. Using a different set of sensors, a large number of monitors could be distributed to monitor air quality, ground water pollution, or safety in a factor (e.g. by monitoring equipment vibrations). These monitors could be used to ensure that soil used by farmers has the appropriate combination of nutrients.

The cost of such systems will end up being dominated by the cost of the sensors and batteries, because the cost of the embedded micro-controller can be made very low (tens of rupees). Whether such systems are deployed will depend on whether the gains from monitoring will outweigh its cost.

Profile. Rajit Manohar received his B.S., M.S. and Ph.D. degrees in Computer Science from the California Institute of Technology. He is current on the faculty at Cornell University, where his group investigates asynchronous VLSI systems. He is the recipient of two best paper awards, an NSF CAREER award, MIT Technology Review magazine's TR35 award, and five teaching awards at Cornell.