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A Picowatt Processor

A low-power chip could be used for implantable medical sensors.

By Kate Greene

Before long, sensors may be implanted in our bodies to do things like measure blood-glucose levels in diabetics or retinal pressure in glaucoma patients. But to be practical, they'll have to both be very small--as tiny as a grain of sand--and use long-lasting batteries of similarly small size, a combination not commercially available today.

Now researchers at the University of Michigan have made a processor that takes up just one millimeter square and whose power consumption is so low that emerging thin-film batteries (http://www.technologyreview.com/read_article.aspx?ch=specialsections&sc=batteries&id=17513&a=) of the same size could power it for 10 years or more, says David Blaauw (http://blaauw.eecs.umich.edu/people.php?u=professor) , professor of electrical engineering and computer science at Michigan and one of the lead researchers on the project.

But when this processor, dubbed the Phoenix, is coupled with a battery, the whole package would only be a cubic millimeter in volume. At this scale, Blaauw says, it could be feasible to build the chip into a thick contact lens and use it to monitor pressure in the eye, which would be useful for glaucoma detection. It could also be implanted under the skin to sense glucose levels in subcutaneous fluid. More broadly, this low-power approach to processor design could be used in environmental sensors that monitor pollution, or structural health sensors, for instance.

The processer uses only about 30 picowatts (a picowatt is one-millionth of one-millionth of a watt) of power when idle. When active, the processor consumes only 2.8 picojoules of energy per computing cycle. That amount is about a tenth of the energy used by the most energy-efficient chips on the market, says Jan Rabaey (http://bwrc.eecs.berkeley.edu/People/Faculty/jan/) , a professor of electrical engineering and computer science at the University of California, Berkeley, who was not involved in the research.

The Michigan team's main idea was to design a chip that runs at an extremely low voltage. While microprocessors for personal computers may require two volts of electricity per operation, the Phoenix only needs 500 millivolts, or 75 percent less.

At this voltage, parts of the chip don't operate well, explains Blaauw, so his team redesigned the chip's memory, which is smaller than most processor memory, and its internal clock so that it could operate with minimal electrical input. The chip's clock--the timepiece that synchronizes number-crunching operations--has been reduced to an extremely slow rate of 100 kilohertz, as opposed to the gigahertz rates of personal computers. This approach makes sense for sensors, says Blaauw. "If we wanted to monitor pressure in the eye . . . we only need to take readings every few minutes," he says.

Additionally, the researchers paid close attention to the energy loss that occurs while the chip is in sleep mode, or not collecting or processing data. Transistors in the newest computers are made using a 45-nanometer process in which features on a chip are 45 nanometers in size. While this allows for more transistors on a smaller chip, it also results in electrical leakage, due to the physics of the materials at this scale. Blaauw and his team opted for larger transistors made using a 180-nanometer process, from a previous generation of chips. These transistors are in a "sweet spot," says Blaauw. They are big enough to have minimal leakage and yet small enough for the researchers to fit a large number on a one-millimeter-square chip.

To further minimize leakage, the researchers added special transistors that completely shut off the power supply to the processing transistors when the chip is in standby mode. This is a common approach, says Blaauw, but his team took it to the extreme and dedicated much more of the chip than usual to these "power-gating" transistors. "If a normal [chip] designer would look at this, he'd say, 'You're out of your mind,'" Blaauw says. "But it gives us the power-savings trade-off we need." In sum, the researchers combined a number of already existing tricks and fine-tuned them to achieve the record-breaking low power consumption.

The Michigan team, which is also led by Dennis Sylvester (http://www.eecs.umich.edu/~dennis/) , professor of electrical engineering and computer science, still must add a battery to the Phoenix, and it needs to develop a way for data to be offloaded from the chip for further analysis. Once this is done, the researchers can work on full integration within a biological system, which could take years.

Berkeley's Rabaey, who is writing a book on low-power processors, says that the work is significant. "What has impressed me is that they've driven this to quite extreme numbers," he says. "The energy consumption is extremely low. Nobody else has come even close to this." Rabaey notes that this processor is intended for specialty sensor applications and that it won't show up in a cell phone anytime soon. However, it's an important step toward building implantable medical sensors whose batteries can last for years.

The idea of this low voltage chip is not new, says Rabaey: it's been used successfully in the watch industry for decades. But within the past few years, academic and industry interest in such design has blossomed as engineers are exploring more varied and ubiquitous uses of sensors, devices that require energy-saving tricks in order to be practical.

Upcoming Events

EmTech08 (http://www.technologyreview.com/emtech/08/)
MIT Campus, Cambridge, MA
Tuesday, September 23, 2008 - Thursday, September 25, 2008
http://www.technologyreview.com/emtech/08/
(http://www.technologyreview.com/emtech/08/)

Nano-Net 2008 (http://www.nanonets.org)
Boston, MA
Monday, September 15, 2008 - Thursday, September 18, 2008
http://www.nanonets.org (http://www.nanonets.org)

MIT Professional Institute (http://web.mit.edu/mitpep/pi/courses_topic.html?c1=banner&source=pi+TRevents)
Cambridge, MA
Monday, June 09, 2008 - Monday, August 04, 2008
http://web.mit.edu/mitpep/pi/courses_topic.html?c1=banner&source=pi+TRevents
(http://web.mit.edu/mitpep/pi/courses_topic.html?c1=banner&source=pi+TRevents)

2008 Golden Jubilee Conference (http://gj2008.iitbombay.org/)
New York City, New York
Friday, July 18, 2008 - Sunday, July 20, 2008
http://gj2008.iitbombay.org/ (http://gj2008.iitbombay.org/)

WHIT 4.0 (http://www.whitcongress.com)

Washington, DC

Monday, December 08, 2008 - Wednesday, December 10, 2008

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