Researchers propose center to develop future chip-cooling technologies

April 15 2005

Researchers at Purdue University are collaborating with several other universities in proposing a new center to design technologies that will be needed in coming decades to cool advanced computer chips.
"The bottom line is that we've all got to begin working on this problem now, or the computer industry is going to hit a brick wall in about 15 years," said Suresh Garimella, a professor of mechanical engineering at Purdue University. "Future computer chips will generate as much as 10 times more heat than today's computer chips, which means we are going to need new cooling technologies."

Garimella organized a two-day Workshop on Electrothermal Co-Design of Future Electronics, which was held at Purdue in March for experts from industry, government and academia to identify key issues and challenges in coming to terms with future chip-cooling needs.

As computer chips become increasingly more compact, more circuitry will be crammed into a smaller area, producing additional heat. Because excess heat reduces the performance of computer chips and can ultimately destroy the delicate circuits, it will be essential to "co-design" new cooling technologies, Garimella said.

"By 'co-design,' we mean that all of the people involved in designing these chips – the engineers who create the circuits and devices in the processing portion of the chips and the specialists who make the cooling systems – should work together from the beginning," Garimella said. "That way, innovative kinds of cooling devices will be integrated right

into the chip, instead of added on later, which is how it is presently done."

Researchers from eight universities would work to develop prototypes in the proposed Center for Electrothermal Co-Design of Future Electronics, which, if funded, would likely begin operating in June 2006. The universities have submitted a proposal for the center to the National Science Foundation. Garimella is leading efforts to form the center with Sachin Sapatnekar, the Robert and Marjorie Henle Professor in the Department of Electrical and Computer Engineering at the University of Minnesota.

Industry and government experts attending the workshop said one of the center's key roles should be to help corporations explore high-risk concepts – research that could result in truly revolutionary technologies but is too uncertain to justify pursuing from a business point of view.

Alan B. Rohwer, a manager from Raytheon Corp., said the defense industry has a difficult time seeing needs more than five years into the future, so the center could provide an important opportunity for much-needed long-term research and development.

Another important role for such a center, Rohwer said, should be to train students, both at the undergraduate and graduate levels, so university graduates will be ready for the workplace.

The new center would create prototypes that contain circuits and devices that run on less electricity and produce less heat while also using innovative miniature cooling systems. Researchers also would focus on developing software to help engineers design these future chips.

"The way it's currently done is that you have people doing electrical design, then they throw it over to the thermal people, and the cooling

aspects are addressed after the fact," Garimella said. "In the method we propose, the electrical engineers wouldn't design a chip based only on electrical considerations but would talk to a thermal engineer and say, 'I have these possibilities, what would be better from a thermal standpoint?' And the thermal engineer might say, 'This material may be great electrically, but it has very poor heat dissipation properties,' and offer a compromise alternative that satisfies both requirements."

Experts from about 25 companies and federal agencies attended the workshop at Purdue on March 8 and 9. The list of attendees included experts from Intel Corp., IBM, Advanced Micro Devices Inc., General Electric, Hewlett-Packard Development Co., Delphi Electronics and Safety, Sony Corp., Nokia Corp., NASA's Ames Research Center, and the U.S. Defense Advanced Research Projects Agency, or DARPA.

"This was a listening session, essentially, a chance to get down to the nitty-gritty of how to attack this cooling challenge," Garimella said.

Chips in today's computers are cooled primarily with an assembly containing conventional fans and "heat sinks," or metal plates containing fins to dissipate heat.

Current chips generate about 50-100 watts of heat per square centimeter.

"But in the future, say 15 to 20 years from now, the heat generation will likely be much more than that, especially in so-called hot spots, where several kilowatts of heat per square centimeter may be generated over very small regions of the chip," Garimella said. "We want to develop prototypes capable of handling chips that generate more than 2,000 watts per square centimeter at hot spots, which is significantly more heat than is generated by today's chips."

Current integrated circuits, or computer chips, contain about 100 million

transistors each. By around 2010, that number will swell to roughly a billion transistors in a chip.

"The number of transistors per chip has been doubling every 18 months or so, according to a general principle called Moore's law," Sapatnekar said. "From tens of transistors on a chip in the 1960s, we are now in the age where billion-transistor chips will be a reality."

Future computer microprocessors probably will be shaped less like chips and more like cubes – a 3-D structure containing many layers of circuits and devices integrated with tiny cooling devices. The cubes may contain "microchannels" that circulate cooling fluids and solid-state refrigerators half the width of a human hair that work with no moving parts.

"We call this new conceptual chip ICE-cubed, which stands for 3-D integrally cooled electronics," Garimella said.

Researchers also plan to develop a "software platform for ICE-cubed," or "SPICE-cubed," which will be needed to design ICE-cubed chips.

"The software platform will give the broader community a set of design tools and a software toolkit to design future electronics," Garimella said.

The center would strive to develop technologies such as miniature temperature sensors and a "smart power distribution" system that selectively shuts off electricity to portions of a processor that are not needed at a given time. Other possible future innovations to be pursued by the center include a variety of new types of cooling devices, tiny pumps to circulate cooling fluid and methods for harnessing heat produced by chips to generate electricity.

Researchers in the center would use a three-pronged approach. One thrust would focus on "thermally aware devices," or new designs that

don't use as much power, which means they would not produce as much heat as conventional chips. A second thrust would be developing new types of cooling technologies, and the third area would be developing design-automation software to help engineers place the various components in the right locations of the complex, layered ICE-cubed processors.

"Each of these thrusts has leaders from different partner universities in this effort," Garimella said.

The center would be made up of experts from Purdue; the University at Albany, which is part of the State University of New York system; the University of Minnesota; the University of California, Santa Cruz;, the University of California, Santa Barbara; the University of Texas at El Paso; the University of Puerto Rico - Rio Piedras; and Alabama A&M University.

An important function of the center would be to train undergraduate and graduate students, including about 30 doctoral students at a given time, Garimella said.

"Students would be heavily involved in internships at companies, and company employees would spend time in the center in return."

Source: Purdue University