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Technology

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Solving the Power Dissipation Challenge

By Nina Morrison

Intel co-founder and multi-billionaire Gordon Moore affected the lives of legions of future gamers and gadget-freaks - many of whom had not yet been born - when he published an article in Electronics Magazine on April 19, 1965. The magazine, which incidentally claims to have invented the word “electronics,” is best known for this 1965 article.

The article in question was called “Cramming More Components onto Integrated Circuits,” and it reads like a prediction for the future by a young man brimming over with more components into miniatures. These microchips are the same size, on a single chip will double every eighteen months. These microchips are the same size, and zap as their predecessors. What was in the early stages of the integrated circuit industry, “power dissipation wasn’t that much of an issue,” Mahmoodi says, “because in early computers the integration density was not that high compared to computers today.” In 1965, the idea that microprocessors would be filled with dozens of computer chips covered from top to bottom with transistors was just an abstraction. However, by 2007, these microchips have become the standard. As computing power increased, so did the associated design problems.

One of the problems that computer designers are faced with is excessive heat. Heat is generated when the switch-like components of information inside a computer chip turns on or off - a process called binary switching, which refers to the way computers do their work. The electrical energy dissipated by the binary switching is transformed into heat energy, which results in a temperature increase. If the temperature increases too much, the computer chip ceases to function properly, and at about 120 degrees Celsius will actually begin to malfunction or even burn.

The smaller “nanoscale” dimensions of all the transistors, jam-packed on so many chips and busily switching on and off, have made it more difficult for engineers to ensure all of these tiny parts are working in order. Overheating and transistor malfunction can wreak havoc on two very important factors: stability and reliability. If a chip gets too hot, it stops its binary switching and starts malfunctioning and even burning.

Mahmoodi creates new designs for integrated circuits in nanoscale technology to compensate for these modern problems. This particular field of specialty did not exist until recently - only in the last few years computer engineers have become so powerful that specially-trained engineers are needed to manage the design problems they pose. Dr. Mahmoodi sees a challenge in the balance between performance and power, and specializes in trying to figure out how to make increasingly powerful machines operate more reliably. As the applications become more and more complicated, the circuitry tends to break down. “This is by no means acceptable,” he said, “and it’s true. A powerful computer that doesn’t work reliably isn’t really a powerful computer at all.”

The increased performance of those chips over the last ten years has sparked a phenomenal boom in technology. The time frame mentioned by Moore in his original article, eighteen months, has become almost a given in the field of electronics. In 1965 Moore was simply writing about his observations and forecasts, but we have come to expect things to improve, or “double,” about every eighteen months. We are perfectly comfortable with replacing our cell phones, PDAs, even our iPods, about every eighteen months — because a better model will most certainly be available.

Dr. Mahmoodi’s interest in digital and integrated circuits formed when he was young. “I used to break them apart, actually,” he says, laughing, “and look inside to see and figure out what is there.”

Mahmoodi became interested in the “power dissipation challenge,” as specialized in the computer engineering industry would refer to it as “find the right balance between power and performance.” His low-power, high-performance digitally integrated circuits designs reduce power and improve speed. A computer’s circuitry needs to “dissipate the least amount of power for the performance that is needed,” Mahmoodi says. One of the approaches he has taken to reduce power...
Moodi’s low-power, high-performance clocking network could be a way to reduce power dissipation without losing speed (performance). In order to recover energy from the clock network, Moodi creates different types of flip-flops, which are electronic circuits that can retain a logical state and also switch back and forth from one state to another. These flip-flops, which serve as bits of memory, use up power as they change states. Moodi proposed four different types of flip-flops that would operate more efficiently and dissipate less power. The proposed flip-flops operate with an unconventional kind of clock network called a nonsinusoidal clocking network — which uses a different kind of waveform to function. The flip-flops, when tested, used up about 46% less power than regular flip-flops.

In addition to the interest from organizations such as DARPA (Defense Advanced Research Projects Agency), which is the research and development branch of the Department of Defense, are also interested. NASA’s space missions also “suffer from limited battery life times for their electronics, so they also have great interest in low-power design,” Moodi says.

In addition to the interest from organizations such as DARPA and NASA, the work that Moodi is involved in helps generate advanced cell phone features like voice-recognition programs, camera and video capabilities, document readers and email and Internet functions.

Video games have also been well-served by the trend towards smaller, faster, more powerful circuitry design. Gamers who once played a ridiculous-looking amusement called Pong, which consisted of two bars moving a ball across the screen, might find the “graphically intensive video games” (as Moodi describes them) of today nearly unrecognizable. The games that are currently on the market are extremely sophisticated applications that feature animation, sound effects, and the occasional celebrity cameo.

Mahmoodi describes them) of today nearly unrecognizable. The games that are currently on the market are extremely sophisticated applications that feature animation, sound effects, and the occasional celebrity cameo. These sophisticated applications “demand more performance from the chips that are running these applications. They need to be able to deliver reasonable speed to the customer. Those chips need to run faster — that’s the demand for performance,” Mahmoodi says. So while Mahmoodi has no interest in Tommy Vercetti’s rise to power, he is interested in designing chips that offer higher speed and greater performance. He sees a challenge there. “There is a trade-off between power dissipation and performance,” he says. “If you do something to boost the performance, typically it results in power dissipation increase. If you want (it) to run faster, typically you have to spend more energy. And also, typically if you do something to reduce energy dissipation, the system tends to get slower.”

So, it’s kind of a trade-off. We need the boosted performance in order to navigate Vice City, but without so much power dissipation that the console heats up and crashes half-way through the game. This is what Mahmoodi means when he speaks of “the design challenge.”

Mahmoodi himself does not have much interest in video games or the latest and greatest cell phones. When asked about his favorite application for low-power, high-performance integrated circuit design, he said that his research was focused on high-speed microprocessors, the kinds that are used in laptops and desktops. He enjoys “looking inside these microprocessors” and “applying ideas wherever possible.” His current project involves “new, innovative micro-architectures for high-speed microprocessors.”

Mahmoodi says that he would like “to raise awareness about all the technological innovation that goes behind the consumer electronics that we enjoy in our daily lives.” He wants the public to appreciate the processes that go into the design of such devices, even though he himself is not particularly interested in all of their applications.

“Even though I invented the technology, I personally don’t follow gadgets and I’m not into that market. I’m using fairly low-tech stuff — even though I design very high-tech. My cell phone is very low-tech, compared to what most other people use,” he says, holding an ancient-looking cell phone (definitely more than eighteen months old) thing to reduce energy dissipation, the system tends to get slower.”

It used to be that biologists and computer scientists had little opportunity for collaboration. Today, however, researchers in these fields at San Francisco State University are forging a new path by combining their distinctly different disciplines.