



*Marching Without a Beat*

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For decades, computer processors were typically organized like marching bands: a conductor kept time and band members stepped to the beat. In processors, a clock's pulse determined when all computations and data movement occurred. Today, that paradigm is breaking down, Professor Steven Nowick explained.

Modern processors consist of a handful of smaller processors, or cores. "When you have four separate cores, it is difficult for one clock to keep them in lockstep," Nowick said. The problem will only worsen when future processors have dozens of cores.

Today's transistors also pose problems. As they shrink to a few tens of nanometers, they become much more variable. "Their speeds vary depending on temperature, voltage, and how they are manufactured. Their unpredictability is a major design challenge," Nowick said.

Nowick and colleagues at other institutions have been pursuing an alternative approach: eliminate the clock and let digital components operate at their own speeds. "Let them communicate as conditions require, and make their own decisions with their neighbors about when they need new data and when they will output results," he stated.

"Most digital systems have clocks running at billions of cycles per second. Everything operates in lockstep with that clock. As circuits get larger and more complex, imposing fixed timing on billions of transistors and millions of components is a huge design effort. We think we can solve these problems with asynchronous, or clockless, circuits."

It sounds chaotic, but the Internet works the same way, Nowick said. "People around the world add, update, and remove Web pages individually, without any centralized control mechanism."

In addition to solving timing issues, asynchronous digital systems could provide other advantages. In synchronous chips, even idle components are activated every clock cycle, like band members marching in place. In contrast, the on-demand components in asynchronous systems respond only when necessary. This conserves energy and can prolong battery life in laptops, smartphones, and other portable devices.

Asynchronous processors are potentially easier to design, since new circuits do not have to be synchronized with the entire chip. "It's a Lego-like system, which can be snapped together," Nowick said. Hurdles remain. Engineers need new software tools to design asynchronous circuits, and face subtle issues in designing these circuits correctly.

Nowick is currently working on both challenges, including projects to design a flexible asynchronous interconnection network for future desktop parallel computers, and ultra-low energy signal processors for hearing aids and medical implants.

*B.A., Yale, 1976; M.A., Columbia, 1979; Ph.D. Stanford, 1993*