

@ A Georgia Tech research team has devised a new electronics technology concept called “system-on-package,” which paves the way for mega-function electronic systems.

Moving Next-Generation Electronics Beyond Moore’s Law

Georgia Tech develops the fundamental concept behind the “Second Law of Electronics” for digital and bio-electronics convergence.

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BELOW: System integration using system-on-package (SOP) technology from Georgia Tech’s Microsystems Packaging Research Center will move electronics beyond the promise of Moore’s Law, which holds that the number of transistors on an integrated circuit doubles every 18 months. From about 50 components per square centimeter in 2004, component density will climb to about a million per square centimeter by 2020. Functional system density will escalate similarly.

Moore’s Law helped create the trillion-dollar worldwide information technology industry through hardware, software, services and applications. But the next trillion-dollar industry will be vastly different; it’s often referred to as the “Digital Convergence Industry,” and it will combine computing, communications, consumer and biomedical applications.

Remember when combining a camera with a cell phone or adding a cell phone to a PDA seemed daring? Such technical tricks relied on Moore’s Law, which holds that the number of transistors on an integrated circuit (IC) doubles every 18 months. In the computing world, having more transistors on a chip means more speed. But in many cases, the ICs affected by Moore’s Law account for just 10 percent of the total system. The other 90 percent of the system is still there, showing up as an array of discrete passive components, packages, connectors and switches interconnected over a printed-circuit board or two. That 90 percent still makes for a bulky system.

Combining today’s advanced nanoscale ICs with the milliscale components that make up 90 percent of typical electronic systems won’t produce the emerging digital convergence the world has been expecting. So, a research team at the Georgia Institute of Technology’s Microsystems

called the First Law — SOP addresses the system integration problem, leading to the “Second Law of Electronics.”

SOP leapfrogs well beyond Moore’s Law. It combines nanoscale ICs with newly developed micro- to nanoscale, thin-film versions of discrete and other components. It embeds both of these components in a new type of package so small that it eventually will transform handhelds into multi- or mega-function systems. SOP products are being developed not just for convergent electronics that combine computing, communication and consumer electronics, but also for systems to detect all manner of substances — toxic and benign — including chemicals in food, the environment and the human body.

This last application will see the convergence of biology, chemistry and digital technology to produce capsules small enough to be introduced into the human body to monitor personal health daily. A capsule could be used, for example, to check vital signs and monitor parameters such as glucose levels, blood pressure and even signs of cancer. The capsule would then wirelessly communicate the information to a physician. Fitted with a reservoir, the capsule also could deliver drugs at programmed intervals to selected places within the body. While some of these concepts are being implemented today, SOP-based bio-electronics can shrink these systems by a factor of 100 or more.

SOP technology represents a radically different approach to electronic and bio-electronic systems. It shrinks bulky circuit boards with their many components and makes them nearly disappear, leading to package-sized systems — hence the name system-on-package. In effect, SOP sets up a new law for system integration. It holds that as the components shrink from milli- to micro- to nanoscale, component density will double every few years, leading to an exponential increase in the number of system functions packaged in a device the size of today’s cell phones.

Packaging Research Center under my direction proposed and demonstrated a new technology called system-on-package (SOP). It addresses the “other” 90 percent of the electronic system and paves the way for what I call “mega-function systems.” In contrast to Moore’s Law, which addresses 10 percent of system integration at the IC- or device-level only —

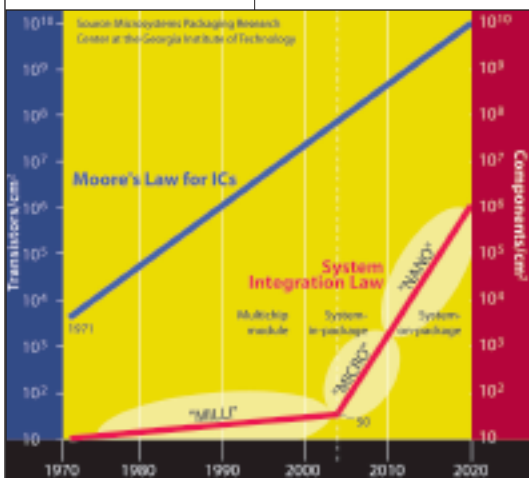


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We began this research in 1993 with a proposal to the U.S. National Science Foundation (NSF) for an Engineering Research Center, which NSF then funded for 11 years. We also have received funding from the Georgia Research Alliance and 167 electronics companies from the United States, Europe and Asia. We have raised about \$200 million to carry out SOP research and educate more than 500 technical leaders. We have also made packaging and systems education at Georgia Tech an academic subject for the first time.

We are not alone anymore in this SOP endeavor. Researchers worldwide are using SOP to combine diverse technologies in new, unusual and cost-effective ways. Everyone is after ultra-compact products built with combinations of digital, analog, radio-frequency (RF), optoelectronic and sensing technologies.

For more than 40 years, circuit designers have counted on the steady increase in transistor density in their pursuit of convergence. For example, engineers at Texas Instruments are building entire signal-processing subsystems with diverse functions on a chip of silicon — a system-on-chip, or SOC, as it's called. The SOP from Georgia Tech offers an alternative way to accomplish the same goal at a lower cost and faster time to market. Unlike SOC, we're not forced to use dissimilar technologies that take time to design and fabricate. We need not compromise speed, cost, time to market or reliability, as in the SOC approach.

Since we began developing the SOP concept in 1993, we have worked with 167 electronics companies from the United States, Japan, Korea and Europe. Included are Advanced Micro Devices, Asahi, Ericsson, Ford, Hitachi, IBM, Intel, Matsushita, Motorola, NEC, Nokia, Samsung, Sony and Texas Instruments. In addition, more than 70 researchers have visited our center to study SOP and its application to their diverse requirements.

So far, at least 50 companies have taken parts of our technology and applied them to their automotive, computer, consumer, military and wireless applications. We also have built a number of test systems that integrate different combinations of analog, digital, RF, optical and sensor components in a single package.

For example, Motorola, which was one of the Packaging Research Center's founding partners, uses parts of SOP technology in two models of its GSM/General Packet

Radio Service quad-band cell phones to gain about a 40 percent reduction in board area. The module contains all the critical cell phone functions: RF processing, base-band signal processing, power management, and audio and memory sections. Not only does the module free up space for new features, it is also the foundation around which new cell phones with different shapes and features can be rapidly designed. The company reports it has shipped more than 20 million SOP-based phones.

At Georgia Tech, we believe the market for multifunctional products and the advantages of designing chips and system packages concurrently are so compelling that companies simply will have to design and fabricate everything together. And as the SOP concept takes off, design-tool and fabrication houses will turn their attention to developing powerful programs for concurrent design and advanced manufacturing, just as they did in the past decade when SOC technology was in its infancy.

@ Read online at: gtresearchnews.gatech.edu/reshor/rh-f06/SOP.html

Parts of this article were excerpted from "Moore's Law Meets Its Match" by Rao Tummala, IEEE Spectrum Magazine, June 2006. It is available on the Web at: www.spectrum.ieee.org/jun06/3649

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PHOTO ILLUSTRATION BY BRIAN CHRISTIE

ABOVE: System-on-package technology developed at Georgia Tech will transform handheld electronic devices into small, multi- or mega-function systems that combine computing, communication and consumer electronics.

LEFT: Professor Rao Tummala is the director of the Georgia Tech Microsystems Packaging Research Center, which developed system-on-package technology that represents the "Second Law of Electronics."

PHOTO BY GARY MEEK

