CELL PHONES: ANALOG-DIGITAL COOPERATION

"When a person speaks into a cell phone, a transducer or sensor turns the sound into electrical signals. Those signals are then processed in analog form, converted to digital format, encoded with analog information, transmitted through space, received by another phone, processed by analog means, decoded into digital format, converted back to analog form, conditioned, and finally driven into a speaker, the output of which is again a person's voice.

"And that, of course, is a simplified version."

– Gabriel Rincón-Mora, associate professor, Georgia Tech School of Electrical and Computer Engineering

Photo: Gary Meek

Associate Professor Gabriel Rincón-Mora, left, makes a point to graduate student JinJyh Su about piezoelectric devices.

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"We're taking legacy parts that are the size of a shoebox and putting a single piece of unprotected silicon-germanium in their place," he says.

In the core analog realm, Cressler and his team are investigating the application of silicon-germanium to BiCMOS (SiGe transistors plus CMOS) technology used in very high-performance analog ICs. His team is helping industry researchers understand how to improve the design of these high-end analog circuits and find new applications areas for state-of-the-art analog technologies.

In addition, Cressler is studying the use of SiGe technology to improve data conversion in the very high-speed multi-gigabit range. For years, the problem of converting analog signals into digital code has created a bottleneck because analog-to-digital converters that are extremely fast yet affordable haven't existed. New, faster data converters using SiGe could help redefine communications and radar capabilities.

"In terms of complexity and challenge in the analog design world, very high-speed data converters are at the top," Cressler says.

Energy and Power – Better, Smaller

Gabriel Rincón-Mora, an ECE associate professor, is focusing analog expertise on powering integrated circuits and other microscale devices, and on using energy and power management to maximize a device's operational life.

Energy/power generation and management for mobile devices will become ever more important in coming years, he says, as new, more capable chips nullify the gains made by advances in power conservation.

"We're putting a lot more functionality into a single IC," he says. "So we are ultimately increasing power density while maintaining similar power-source levels."

Rincón-Mora is investigating how to provide power to chip-based mobile sensors using a system composed of a proton exchange-membrane fuel cell and a thin-film lithium ion battery. Working with Paul Kohl, a Regents' professor in the School of Chemical and Biomolecular Engineering, Rincón-Mora and his team are studying how to manage power throughout the whole system – fuel cell, battery and chip – in ways that maximize lifetime and minimize footprint.

Rincón-Mora is also investigating microscale techniques to harvest energy from the surrounding environment. In one project, he is working with Texas Instruments to develop an electrostatic harvesting chip that draws power from the kinetic energy in vibrations. He is also working with Sakis Meliopoulos, another ECE professor, to power wireless microsensors in a power grid by using the field that surrounds an electric cable.

In another project, Rincón-Mora is studying how to scavenge energy from the human body. The aim is to power a biomedical implant called a vestibular prosthesis, a device being co-developed by ECE Assistant Professor Pamela Bhatti to help patients regain their sense of balance. Rincón-Mora plans to power the tiny device through piezoelectric harvesting – generating power from the motion of tiny materials that bend as bodily fluids in the inner ear flow around the implant.

Bhatti is also collaborating with Shreyes Melkote, a professor in the Woodruff School of Mechanical Engineering, to develop an electrode array that would provide better results to patients with a cochlear prosthesis, used to treat total deafness.

Cutting Costs with Analog

Analog expertise is an important asset at the Georgia Tech Research Institute (GTRI), Georgia Tech's nonprofit applied-research arm. Several GTRI laboratories focus on the analog-heavy field of radar and RF technology for military and civilian applications. And GTRI researchers are often tasked with finding ways to replace older analog circuits, in aircraft and elsewhere, that are no longer manufactured.

"We're developing applications as opposed to developing new technologies in analog," says Richard Levin, a GTRI senior research engineer. "We find new ways to apply existing technology so that we can meet the customer's needs."

Levin has been performing analog design that's helping to re-engineer an older circuit board in an Air Force radar-warning receiver. Key components in the all-analog board are no longer made, and obtaining custom replicas promised to be very expensive. Levin is part of a team that has crafted a plug-in replacement board, using mixed-signal technology that combines analog and digital functions.

"Basically, it's a more modern, work-alike circuit made from available parts," says Levin.

Mark Mitchell, a GTRI principal research engineer, reports that his group is working on numerous projects that employ analog-intensive technology to design and develop low-cost phased-array antennas.

"Phased-array antennas have historically been extremely expensive," he says. "That's limited the number of applications where they can be used."

In one program, Mitchell and his colleagues are collaborating with ECE's Cressler to create a single-chip, phased-array module using cutting-edge silicon-germanium technology.

Current phased-array antennas, which use many multi-chip modules, are bulky. Mitchell and Cressler want to pack that functionality into a single silicon-germanium chip.

"You can't get the kind of high-frequency performance we want out of these analog circuits with conventional silicon," Mitchell says. "Only silicon germanium can give us that performance and also cut the cost per element down by a couple of orders of magnitude."

Communicating with the Body

At the Laboratory for Neuroengineering (NeuroLab), the team of Steve DeWeerth, a professor in the Coulter Department of Bio-

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