**Research Areas (cont.)**

**Sensing Systems**

MICL faculty and students are working to distribute wireless sensing technologies widely accessible, e.g., to medical personnel for better treatment of patients due to improved wireless sensing devices for monitoring behavioral on their personal behavior on the safety of buildings and bridges; and to all who want to understand the impact of personal behavior on their health and the environment. Progress toward this goal depends on a wide range of enabling technologies. For example, inexpensive, long-lived, compact, energy-efficient computing; sensor network protocols; low-power sensors (faculty in the Center for Wireless Integrated Systems, WIS, wismserc.org); and compact and novel low-power sensors (faculty in the Center for Wireless Integrated Microsystems, WIMs, wismserc.org).

**Application Areas**

**Health**

Biomedical circuits research in MICL addresses technical innovations in implantable devices and cellular assays to advance health and quality of life, particularly in chronic disease monitoring and treatment of associated disorders. Representative projects include cell fully implantable and wireless 3D neural recording arrays and disposables in in vitro bio-assay monitoring. Ultra low power circuits are a key component of most implantable biomedical devices and pose significant challenges in power, size, and communication distance. MICL researchers have developed micropower RF circuits to enable continuous monitoring of biosignals such as intracranial pressure and intra-arterial pressure flow.

**Energy**

MICL researchers are addressing energy at various levels of computing, from data centers (through near-threshold computing) to sensor networks (by developing miniaturized on-chip sensors to monitor and optimize energy usage) and in between (by translating energy usage and subjective constraints to user satisfaction). For example, Prof. Heath Hofmann’s group is investigating the development of power electronic circuits and associated research is energy harvesting approaches, particularly vibrational harvesting schemes. MICL faculty are working with application researchers on developing low-power circuits for interfacing biosignals and monitoring environmental changes in a disposable platform integrating heterogeneous devices and circuits in 3-D arrays. Current prototyping brokers MOSIS, CMP, and TAPO (for defense-related research), as well as directly with industrial partners. State-of-the-art processes down to 32nm CMOS are available as of late 2010, and 22nm CMOS processes are being developed for commercial fabrication.

**Environment**

Environmental monitoring devices will play an increasing role in conserving natural resources and in urban settings. For example, Prof. Euisik Yoon’s group has developed microfabricated devices to detect and monitor quality of water, air, and soil. Environmental monitoring devices will encompass a variety of sensors and circuits to convert this harvested energy to usable power for integrated circuits and wireless transceivers.

**Power**

MICL researchers are exploring the development of low-power circuits for interfacing biosignals and monitoring environmental changes in a disposable platform integrating heterogeneous devices and circuits in 3-D arrays. Current prototyping brokers MOSIS, CMP, and TAPO (for defense-related research), as well as directly with industrial partners. State-of-the-art processes down to 32nm CMOS are available as of late 2010, and 22nm CMOS processes are being developed for commercial fabrication.

**Security**

Security issues are pervasive in both computing and everyday life. MICL research touches on many of these aspects, from generating random numbers for key generation to ad secure online interactions, to investigating the consequences of novel sources of randomness in integrated circuits, such as transistor thermal noise. The group is also developing an embedded software platform, which supports secure communications and provides developers of novel algorithms.

**Infrastructure**

Minimized sensor nodes have been proposed for monitoring the numerous elements of civil infrastructure, such as bridges and roads, which is approximately 14,000 in the United States and globally. Low-power circuits, including digital, wireless, and data converters, are critical building blocks of these devices. Monitoring ranges in low-power sensing interfaces and energy-efficient on-sensor signal processing also play a critical role. Prof. Khalil Najafi’s faculty are working together with civil engineers on a number of large-scale projects toward the goal of making our roads and buildings safer.

**Resources**

The MICL has a test lab for characterization of analog and digital integrated circuits featuring 4-core single-threaded processors, 32-bit microprocessors, and single-core processors. The lab has dedicated software to aid secure online interactions, to low-power circuits for interfacing biosignals and monitoring environmental changes in a disposable platform integrating heterogeneous devices and circuits in 3-D arrays. Current prototyping brokers MOSIS, CMP, and TAPO (for defense-related research), as well as directly with industrial partners. State-of-the-art processes down to 32nm CMOS are available as of late 2010, and 22nm CMOS processes are being developed for commercial fabrication.

**Testing Facilities and Equipment**

The lab includes a variety of programmable power supplies and characterization tools and printed circuit board design. A planned second phase will include a conference room to facilitate frequent design reviews, as well as space for industrial partners. The lab includes a variety of programmable power supplies and characterization tools and printed circuit board design. A planned second phase will include a conference room to facilitate frequent design reviews, as well as space for industrial partners.

**Electrical and Computer Engineering – EECS Department**

**Michigan Integrated Circuits Laboratory**

The University of Michigan's Michigan Integrated Circuits Laboratory (MICL) is a center of research and education in the design, development, and application of advanced electronic and microelectronic systems. The laboratory is dedicated to advancing the state of the art in semiconductor technology and its applications, with a focus on developing novel approaches to solving problems in areas such as energy harvesting, wireless communication, and biomedical sensors. The laboratory is home to a diverse group of faculty, researchers, and students who are engaged in a wide range of projects, from designing and fabricating novel integrated circuits to developing new applications for these circuits. The laboratory is located in the Lurie Nanofabrication Facility, which is equipped with state-of-the-art equipment and tools for the design and fabrication of advanced electronic devices.

The laboratory is also home to the Michigan Center for Analog Circuits and Signal Processing (MCAS), which focuses on the development of new techniques for analog signal processing, including novel circuit architectures and algorithms for signal processing applications. The laboratory is also home to the Michigan Center for Biomedical Microsystems (MCBMM), which focuses on the development of novel microsystems for biomedical applications, including microfluidic chips and implantable sensors. The laboratory is also home to the Michigan Center for Secure Computing (MCS), which focuses on the development of new techniques for secure computing, including new approaches to privacy-preserving data analysis and new methods for secure communication and data encryption.

The laboratory is also home to the Michigan Center for Energy Harvesting (MCEH), which focuses on the development of new techniques for energy harvesting, including novel circuit architectures for energy harvesting and new methods for energy-efficient electronic devices. The laboratory is also home to the Michigan Center for Nanoscale and Molecular Systems (MCN), which focuses on the development of new techniques for nanoscale and molecular electronics, including novel circuit architectures for nanoscale devices and new methods for molecular-scale electronics.

The laboratory is also home to the Michigan Center for Nanoscale and Molecular Systems (MCN), which focuses on the development of new techniques for nanoscale and molecular electronics, including novel circuit architectures for nanoscale devices and new methods for molecular-scale electronics. The laboratory is also home to the Michigan Center for Nanoscale and Molecular Systems (MCN), which focuses on the development of new techniques for nanoscale and molecular electronics, including novel circuit architectures for nanoscale devices and new methods for molecular-scale electronics. The laboratory is also home to the Michigan Center for Nanoscale and Molecular Systems (MCN), which focuses on the development of new techniques for nanoscale and molecular electronics, including novel circuit architectures for nanoscale devices and new methods for molecular-scale electronics.
Moore’s Law continues to push semiconductor manufacturing capabilities forward at an exponential pace. Integrated circuits, and systems built using them, are at the heart of advancing micro- and nanoelectronics evolution. Circuit design advances enable research in key areas of societal interest, including health care, the environment, and energy. The Michigan Integrated Circuits Laboratory (MICL) brings together researchers with expertise in a range of circuit and system design issues, with particular emphasis on building pioneering demonstration systems in existing application areas.

MICL faculty in Electrical and Computer Engineering at Michigan are investigating very-large scale integrated (VLSI) digital circuits and analog and mixed-signal circuits, wireless/radio-frequency (RF) circuits, as well as sensing and implantable medical devices, as well as energy harvesting and wireless networks. VLSI, operating systems, wireless implantable, hardware/software specification languages, and computer architecture.

Robert P. Dick
Associate Professor
Embedded systems, computer-aided design, VLSI, operating systems, wireless sensor networks, hardware/software specification languages, and computer architecture.

Heath Hofmann
Associate Professor
Simulation, design, and control of power electronic circuits and electromechanical systems.

Michael P. Flynn
Associate Professor
Analog circuits, analog-to-digital conversion, RF and wireless circuits, high-speed serial transceivers.

Khalil Najafi
Schlumberger Professor of Engineering
Solid-state integrated sensors, micromechatronics, analog and digital integrated circuits.

Marios Papaefthymiou
Professor
Energy-efficient, high-performance computer, low-power digital signal processing, VLSI and computer-aided design, robust computing.

Dennis M. Sylvester
Professor
Low-power integrated circuit design, high-performance VLSI, computer-aided design for VLSI.

David D. Wentzloff
Assistant Professor
RF circuits and systems, ultra-wideband (UWB) communication, highly integrated energy-constrained wireless systems such as implantable devices and sensor networks.

EuiSik Yoon
Professor
Integrated circuits and microsystems, wireless implantable biosensors, BioMEMS and microfluidic devices, solid-state sensors and microactuators.

Zhengya Zhang
Assistant Professor
VLSI architecture, digital systems, implementations of communication and signal processing systems.

Research Areas

Digital Circuits and VLSI

MIGL research on digital integrated circuits and VLSIs spans a wide area from high-performance processors to ultra-low-power sensing systems, from communication devices to medical implants, and from sub-threshold CMOS circuits to emerging technologies. Prof. David Blaauw and Dennis Sylvester’s groups are working on low-power nanometer-scale micromachined microsystems that harvest energy from their surroundings to operate perpetually for applications in medical implants and environmental sensors. Research on near-threshold computing (NTC) was pioneered at Michigan and will allow high-performance, energy-efficient server computing using 3-dimensional integration of processor cores and memory layers. Prof. Marios Papaefthymiou’s group is pursuing energy recovery systems and energy-harvesting circuitry that have demonstrated record energy efficiency at GHz clock frequencies and the first-ever sub-threshold circuits operating above 100 MHz. Prof. Zhengya Zhang’s group is conducting research in computing algorithm and circuits co-design to improve the energy efficiency of communication and signal processing systems by exploiting algorithm characteristics.

This area of research also addresses the growing reliability challenges facing the deep-sub-micron CMOS technology. Prof. Sylvester and Blaauw’s groups are investigating transistor wearout behavior through in situ monitoring and wearout sensors that can allow chips to last longer despite unexplained intrinsic reliability. Prof. Zhang, Blaauw, and Sylvester’s groups are pursuing research in reliable computing architectures based on unreliable devices. Prof. Robert Dick’s group is involved in the power, thermal, and reliability modeling and optimization of integrated circuits.

Wireless/RF

Prof. David Wentzloff’s group focuses on energy-efficient circuits for wireless communication. It has developed all-digital radios that are synthesized from standard digital libraries, leveraging the precise timing of CMOS, and benefiting from automated layout and technology scaling. The group also develops radios that enable wireless networks of vanishingly small sensors. One approach to address the severely limited volume and energy capacity constraints is to eliminate the need for a crystal reference. The group has demonstrated radios that derive an accurate clock reference from the standing wave on a patch antenna, and that harvest a clock reference from the GSM cellular network. It has also developed hardware to measure and characterize wireless channel models in real-time for body sensor networks. These models target cognitive body sensor network radios with communication policies that can adapt to body movements. This enables opportunistic communication, and ultimately results in lower total energy consumption. Prof. Michael Flynn’s group is investigating flexible and adaptable energy-efficient transceivers. New digital dominant techniques that exploit the speed of non-DAM CMOS processes are being researched. As an example, a digital-dominated PLL scheme was demonstrated with 2.4GHz and DS-CDMA modulation. An adaptable receiver can reliably receive 0.9GHz and 2.4GHz band 802.15.4 and WiFi very-high-frequency transceivers are also being investigated.

Faculty Members

David Blaauw
Professor
Low-power and high-performance VLSI design, analysis and optimization.

Marios Papaefthymiou
Professor
Energy-efficient, high-performance computer, low-power digital signal processing, VLSI and computer-aided design, robust computing.

Dennis M. Sylvester
Professor
Low-power integrated circuit design, high-performance VLSI, computer-aided design for VLSI.

David D. Wentzloff
Assistant Professor
RF circuits and systems, ultra-wideband (UWB) communication, highly integrated energy-constrained wireless systems such as implantable devices and sensor networks.

EuiSik Yoon
Professor
Integrated circuits and microsystems, wireless implantable biosensors, BioMEMS and microfluidic devices, solid-state sensors and microactuators.

Zhengya Zhang
Assistant Professor
VLSI architecture, digital systems, implementations of communication and signal processing systems.

Khalil Najafi
Schlumberger Professor of Engineering
Solid-state integrated sensors, micromachatronics, analog and digital integrated circuits.

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