Guest Editorial Selected Papers from the 2021 IEEE International Solid-State Circuits Conference

THE IEEE International Solid-State Circuits Conference (ISSCC) is the flagship conference of the IEEE Solid-State Circuits Society and the foremost global forum for presenting advances in solid-state circuits and systems-on-a-chip. From 2010–2020, the IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS has highlighted selected papers from ISSCC on topics related to biological and healthcare applications. This special section features eight selected papers from ISSCC 2021, held in San Francisco, California, USA from February 16 to February 20, 2021.

This set of papers offers a sample of the rapidly expanding developments in solid-state circuits for health monitoring, therapeutics, diagnostics, and medical research applications. The selection of these papers, whose final decision was based on a thorough peer review process, was coordinated with the IEEE JOURNAL OF SOLID-STATE CIRCUITS (JSSC) to avoid overlap with its ISSCC 2021 special issue, which includes biomedical papers as well. We acknowledge the ISSCC 2021 General Chair, Dr. Kevin Zhang, and the Editor-in-Chief of the IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS, Prof. Guoxing Wang, for their support.

The paper by Lin *et al.* jointly from IMEC, KU Leuven, Holst Centre and Zheihang University presents a low-power, high-dynamic-range (DR), light-to-digital converter (LDC) for wearable chest photoplethysmogram (PPG) applications. The proposed LDC utilizes a novel 2nd-order noise-shaping architecture, directly converting the photocurrent to a digital code. This LDC applies a high-resolution dual-slope quantizer for data conversion, while an auxiliary noise-shaping loop is used to shape the residual quantization noise. A dc compensation loop is also implemented to cancel the PPG signal's dc component, thus further boosting the DR. The prototype is fabricated in 0.18 μm standard CMOS, and experimental results show a power consumption of 28 μW per readout channel while achieving a maximum 134 dB DR. The LDC is also validated with on-body chest PPG measurements.

Fan and her colleagues from Rice University have presented an integrated microheater array with closed-loop temperature regulation that operates based on ferromagnetic resonance of magnetic nanoparticles (MNP), which generate localized heat in response to an external alternating magnetic field in GHz range. They claim that the MNP-based magnetic heating offers superior material specificity and minimal damage to the surrounding environment compared to other competing techniques, such as dielectric or ohmic heating. In their array, each microheater pixel consists of a stacked oscillator and a coil with high magnetic field intensity and an electrothermal feedback loop for precise temperature regulation, eliminating the need for additional RF power amplifiers to achieve a compact pixel area and dc-to-RF energy efficiency of 0.42 mm^2 and 45%, respectively. The 3 mm $\times$ 2 mm integrated microheater array prototype, which houses 12 pixels, is fabricated in the Global Foundries 45-nm CMOS SOI technology, and consumes less than 0.36 W/pixel.

The point-of-care (POC) biomolecular diagnostics capable of rapid analysis have become increasingly more important after the outbreak of the Covid-19 pandemic. So far, sample preparation in a compact form-factor has been a bottleneck in enabling end-to-end POC diagnostics despite the recent advancements in development of sensors for protein and nucleic acid-based assays in chip-scale systems. The paper by Zhu *et al.* from Princeton University presents an electrokinetic microfluidic chip that includes bulk fluid processing via AC-osmotic-based electrokinetic fluid flow as well as cell manipulation, cytometry, and separation for multi-modal cellular and biomolecular sensing, all controlled by a CMOS chip and embedded in a credit card-sized all-in-one biosensing device. The team has incorporated electrode arrays that allow precise control and focusing of cell flow for robust cytometry and subsequent separation as well as an impedance spectroscopy receiver array for cell and label-free protein sensing.

The paper by Lu *et al.* from the National Chiao Tung University presents a fully integrated wireless multimodal sensing chip with voltammetric electrochemical sensing at a scanning rate range of 0.08–400 V/s, temperature monitoring, and biphasic electrical stimulation for monitoring the wound healing progress. The time-based readout circuitry can achieve a 1–20$\times$ scalable resolution through dynamic threshold voltage adjustment. A low-noise analog waveform generator is designed using current reducer techniques to eliminate the large passive components. The chip is fabricated in 0.18 μm CMOS process. The design achieves high linearity over a wide current dynamic range (2 pA–12 μA) while consuming 49 μW at 1.2 V. The current stimulator provides an output current ranging from 8 μA to 1 mA in an impedance range of up to 3 kΩ. The proposed sensing IC is verified for measuring critical biomarkers, including C-reactive protein, uric acid, and temperature.

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The paper by Pochet *et al.* from the University of California, San Diego presents a 2nd-order voltage-controlled oscillator (VCO)-based front-end for direct digitization of biopotentials. This work addresses the nonlinearity of VCO-based ADC architectures with a mismatch-resilient, multiphase quantizer, a gated-inverted-ring oscillator (GIRO), achieving $>$110 dB SFDR. Leveraging the time-domain encoding of the first integrator, the ADC's power is dynamically scaled with the input amplitude enabling up to 35% power savings in the absence of motion artifacts or interference. An auxiliary input impedance booster increases the ADC's input impedance to 50 MΩ across the entire bandwidth. Fabricated in a 65-nm CMOS process, this ADC achieves 92.3 dB SNDR in a 1 kHz bandwidth while consuming 5.8 μW for a 174.7 dB Schreier FoM.

The paper by Moazeni *et al.* from Columbia University and Rice University presents an implantable device for optical neural recording and stimulation over large cortical areas. This device employs lens-less computational imaging and novel packaging to achieve a 250 μm-thick mechanically flexible form factor. The core of this device is an ASIC containing a 160 $\times$ 160 array of time-gated single-photon avalanche photodiodes for low-light intensity imaging and an interspersed array of dual-color flip-chip bonded micro-LEDs. It achieves 60 μm lateral imaging resolution and 0.2 mm^3 volumetric precision for optogenetics over a 5.4 $\times$ 5.4 mm^2 field of view (FoV). The device supports 125-fps frame rate and consumes 40 mW of total power.

The paper by Park *et al.* from KAIST and New York University Abu Dhabi presents a wireless IC that simultaneously delivers power and data over a single inductive link. For data transmission, frequency-shift keying (FSK) is utilized because it supports continuous wireless power transmission without disruption of the carrier amplitude. The link manifests the frequency-splitting characteristic due to a close distance between the coils and provides wide bandwidth for data delivery without degrading the quality factors of link coils. The IC fabricated in a 180-nm BCD process simultaneously achieves up to 115 mW wireless power delivery to the load and 2.5-Mb/s downlink data rate over a single inductive link. The measured overall power efficiency reaches 56.7% and the bit error rate is lower than 10–6 at 2.5 Mb/s. The figure of merit (FoM) for data transmission is enhanced by a factor of 2, and the FoM for power delivery is improved by a factor of 38.7.

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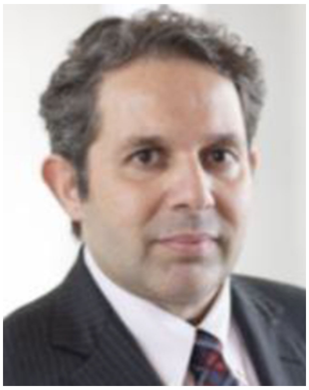

Pedram Mohseni (Senior Member, IEEE) received the B.S. degree from the Sharif University of Technology, Tehran, Iran, in 1996, and the M.S. and Ph.D. degrees from the University of Michigan, Ann Arbor, MI, USA, in 1999 and 2005, respectively, all in electrical engineering. In 2005, he joined Case Western Reserve University, Cleveland, OH, USA, where he is currently the Goodrich Professor of Engineering Innovation and the Inaugural Chair of the Electrical, Computer, and Systems Engineering (ECSE) Department. He also holds a secondary appointment in the Biomedical Engineering Department. He has authored two book chapters and over 130 refereed technical and scientific articles. He holds nine issued and pending patents. His research interests include analog/mixed-signal/RF integrated circuits and microsystems for neural engineering, wireless sensing/actuating systems for brain-machine interfaces, interface circuits for micro-/nano-scale sensors/actuators, and point-of-care diagnostic platforms for personalized health. Dr. Mohseni was a member of the Technical Program Committee (TPC) of the IEEE Radio Frequency Integrated Circuits Symposium from 2012 to 2015, IEEE Custom Integrated Circuits Conference from 2012 to 2019, and IEEE International Solid-State Circuits Conference from 2017 to 2021. He has been a member of the IEEE Solid-State Circuits, Circuits and Systems, and Engineering in Medicine and Biology Societies. He was a member of the Administrative Committee of the IEEE Sensors Council from 2014 to 2017. He was a recipient of several awards, including the National Science Foundation CAREER Award, the Case School of Engineering Research Award, the First-Place Prize of the Medical Device Entrepreneur's Forum at the 58th Annual Conference of the American Society of Artificial Internal Organs, and the ECSE Mihajlo "Mike" Mesarovic Award for Extraordinary Impact. He was the TPC Co-Chair of the IEEE BioCAS Conference in 2017, and the General Co-Chair of the conference in 2018. He has been an Associate Editor and a Guest Editor of several IEEE journals since 2008. He will serve as the Associate Editor-in-Chief of IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS (TBioCAS) starting in 2022.

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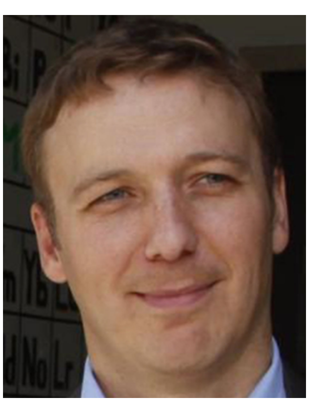

Roman Genov (Senior Member, IEEE) received the B.S. degree in electrical engineering from the Rochester Institute of Technology, NY, USA in 1996, and the M.S.E. and Ph.D. degrees in electrical and computer engineering from Johns Hopkins University, Baltimore, MD, USA in 1998 and 2003, respectively. He is currently a Professor in the Department of Electrical and Computer Engineering at the University of Toronto, Canada, where he is a Member of Electronics Group and Biomedical Engineering Group, and the Director of Intelligent Sensory Microsystems Laboratory. Dr. Genov's research interests are primarily in analog integrated circuits and systems for energy-constrained biological, medical, and consumer sensory applications. Dr. Genov is a co-recipient of Jack Kilby Award for Outstanding Student Paper at IEEE International Solid-State Circuits Conference, Best Paper Award of IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS, Best Paper Award of IEEE Biomedical Circuits and Systems Conference, Best Student Paper Award of IEEE International Symposium on Circuits and Systems, Best Paper Award of IEEE Circuits and Systems Society Sensory Systems Technical Committee, Brian L. Barge Award for Excellence in Microsystems Integration, MEMSCAP Microsystems Design Award, DALSA Corporation Award for Excellence in Microsystems Innovation, and Canadian Institutes of Health Research Next Generation Award. He was a Technical Program co-chair at IEEE Biomedical Circuits and Systems Conference, a member of IEEE International Solid-State Circuits Conference International Program Committee, and a member of IEEE European Solid-State Circuits Conference Technical Program Committee. He was also an Associate Editor of IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS-II: EXPRESS BRIEFS and IEEE SIGNAL PROCESSING LETTERS, as well as a Guest Editor for IEEE JOURNAL OF SOLID-STATE CIRCUITS. Currently he is an Associate Editor of IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS.