Energy-Efficient Integrated Biomedical Circuits and Systems for Unobtrusive Neural Recording and Wireless Body-Area Networks

Chul Kim, PhD
Department of Bioengineering, UC San Diego

***Abstract**:* Despite tremendous progress over the years, current brain-machine interface (BMI) systems are relatively bulky, highly invasive, and limited in their effectiveness except for highly constrained tasks such as moving a cursor on a computer screen. To improve performance of current BMI systems, it is necessary to dramatically increase spatial resolution and coverage across the brain without constraining the mobility of the subject. This calls for innovative approaches to high-density integrated neural recording and stimulation using non-invasive or minimally invasive microelectrode and custom silicon integrated circuits at extreme energy and area efficiency.

In this talk, I will present energy-efficient fully integrated miniaturized implants for electrocortical recording and stimulation, and unobtrusive body-area networks systems for subcutaneous power delivery and data communication, as fundamental building blocks to next generation BMI. First I describe a fully wireless, encapsulated neural interface and acquisition chip (ENIAC) in 180nm silicon-on-insulator (SOI) complementary metal-oxide-semiconductor (CMOS) technology for 16-channel neural recording and stimulation including integrated 4x4 electrode array, coil antenna, and wireless power transfer and data telemetry without any external components, completely contained in less than 3mm^3 volume suitable for minimally invasive surgical insertion on the cortical surface. A novel fully integrated wireless power receiver design with an RF-decoupled H-tree signal distribution network delivers 1mW power over 1 cm distance while mitigating RF interference in the sensitive analog front-end and acquisition circuits for recording of electrocorticography (ECoG) signals transmitted through the skull. Second I highlight a 1mm^2 16-channel neural recording and acquisition system-on-chip in 65nm CMOS offering 92 dB input dynamic range and <1μVrms input-referred noise covering DC-500Hz signal bandwidth at 0.8μW power consumption per channel, offering a record 2.6 power efficiency factor (PEF). Validation with *in vivo* recordings in frontal cortex of marmoset primates reveals infra-slow (<0.1 Hz) local-field potentials (LFP) indicative of subject arousal during a visual attention task alternating with periods of rest and feeding. I will further present advances in cognitive radio baseband transceivers for ultra-low power RF wireless non-line-of-sight body-area network communication with spectral tuning and spatial selectivity across 48MHz signal bandwidth at 1.2mW power. These technology advances combine to support further developments towards modular wireless, minimally invasive, whole-brain electrocortical recording at near-cellular resolution.

***Biography**:* Chul Kim received the B.S. degree in electrical engineering from Kyungpook National University, Daegu, South Korea in 2007, the M.S. degree in electrical engineering from the Korea Advanced Institute of Science and Technology, Daejeon, South Korea, in 2009, and most recently in 2017 the Ph.D. degree in bioengineering, UC San Diego, La Jolla, CA, where he currently is a postdoctoral fellow.

During 2009–2012, he was with SK HYNIX, Icheon, South Korea, where he designed power management circuitry for dynamic random-access memory. Dr. Kim was Gold Prize recipient in the 16th Human-Tech Thesis Prize Contest from Samsung Electronics, Suwon, South Korea, in 2010, and received a Best Presentation Award at 2015 Bioengineering Day, UC San Diego. His research interests include micropower design and biomedical applications of integrated circuits and systems for unobtrusive brain–machine interfaces and wireless body-area networks.