Advanced MicroSystems and Circuits Research Group AMSaC Michigan State

Newsletter

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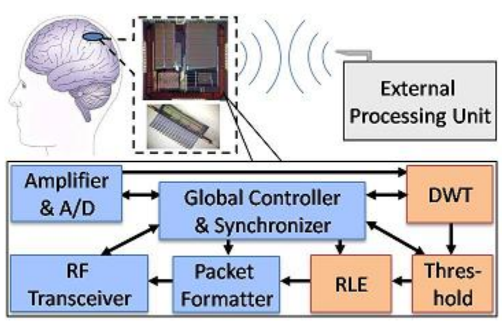
Recent News

Fall 2009	AMSaC lab presents two papers at the ***IEEE BioCAS Conf***, Nov 2009, in Beijing China
Fall 2009	Welcome new AMSaC members: *Yuning Yang, Haitao Li*
Fall 2009	Dr. Mason received funding from the ***NIH Grand Opportunities*** program to study nanoparticle toxicity
Spring 2009	AMSaC lab presents three papers at the ***IEEE ISCAS Conf***, May 2009, in Taipei Taiwan
Fall 2008	AMSaC lab presents two papers at the ***IEEE Sensors Conf***, October 2008, in Italy
Fall 2008	Dr. Mason received funding under the **DARPA Real Nose** program to develop biochemical sensor arrays
Fall 2008	Welcome new AMSaC members: *Lin Li, Xiaoyi Mu, Waqar Qureshi, James Jang, Faisal Abu-Nimeh*
Summer 2008	Congratulations to ***2008 graduates from the AMSaC lab***: *Chao Yang* (Ph.D.)
Summer 2008	Dr. Mason and colleagues receive ***NIH R01 grant*** to develop wireless neural sensor interfaces
Summer 2008	Dr. Mason delivered a week-long workshop on teaching VLSI for the Indo-US Engineering Faculty Institutes
Fall 2007	Dr. Mason and colleagues receive an ***NSF grant*** to build protein-based biosensor array microsystems.

Recent Research Highlights

A Neural Signal Processor for Wireless Implants

Awais M. Kamboh (PhD student) and Yuning Yang (PhD Student)



Block diagram of the neural data compression engine (orange blocks) and its position within an implantable neural recording system.

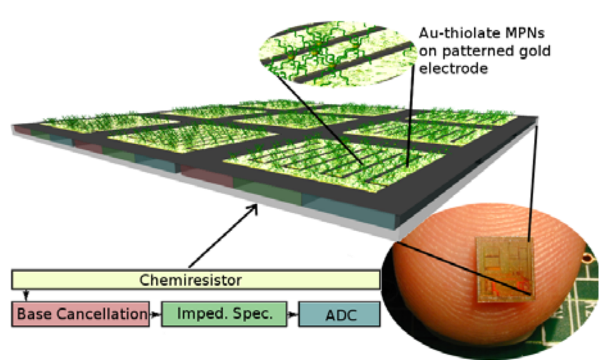
Brain machine interfaces have been recognized as a powerful tool in helping patients with neural disorders. Wireless transmission of potentially hundreds of signals to extracranial processing units must address three major limitations: bandwidth, implant area, and power consumption. For example, without compression, a 32 channel system with a sampling rate of 25KHz per channel and 10 bits of data precision generates data at 8Mbps. Current state-of-the-art wireless transceivers for biomedical applications are not capable of providing the required data bandwidth, necessitating signal compression before transmission. The hardware required for signal compression within the implant must be, firstly, area efficient, to enable minimally invasive surgical procedures, and secondly, power efficient, to avoid any temperature-induced damage to surrounding tissues. High energy efficiency is also required to enable longer periods of operation with little available power.

We are developing a system that enables very high data compression of neural recording while maintaining high signal fidelity. The compression engine employs lossy as well as lossless compressions using Discrete Wavelet Transform (DWT), programmable thresholds, and Run Length Encoding (RLE) hardware blocks to pseudo-simultaneously processes data from multiple channels. Operation of the overall implanted system can be programmed to maximize the tradeoff between application demands and the required spike reconstruction quality. For a prototype 32-channel design, a typical compressor setting results in a data rate of less than 370Kbps, providing a compression of more than 20 times relative to 8Mbps for unprocessed data. The DWT block has been designed, fabricated and tested to work with excellent match between simulated and experimental results. In 0.5µm CMOS, the DWT block requires only 3.84mm^2 of area to process 32 channels of data at 4 levels of decomposition in real time at 25KHz sampling frequency per channel, while consuming only 3mW of power. The overall compression engine is designed to fit within 5.75mm^2. The small size and low power consumption of the system makes it highly suitable for implantable high-density microelectrode array devices.

On-Chip Instrumentation for High Sensitivity Chemiresistor Arrays

Daniel Rairigh (PhD student) and Xiaoyi Mu (MS Student)

Chemiresistors (CR) coated with Au-thiolate monolayer protected nanoparticles (MPN) exhibit a highly sensitive resistance change in response to absorbed vapors and provide extremely low detection limits. In practical applications, resolution is limited by the precision of measurement circuits and noise sources in the transducer and electronics. Theoretical, the capacitive response of a CR can be used to improve sensitivity, but this parameter has not been adequately explored due in large part to the absence of appropriate instrumentation circuits. The aim of this project is to develop a microelectronic instrumentation circuit that will elucidate, with high resolution, both the resistive and capacitive response of a CR within a platform suitable for monolithic integration of a gas sensor array microsystem.



Chemiresistors (CR) coated with Au-thiolate monolayer protected nanoparticles (MPN) form highly sensitive gas sensor arrays when combined with on-chip, low noise instrumentation capable of canceling baseline/drift values and extracting full impedance spectra response.

The primary challenges for high resolution CR instrumentation circuitry include 1) presence of significant variance (between elements) and drift (over time) in baseline resistance, 2) sensor response is a very small fraction (~1ppm) of the baseline value, and 3) measurement of both resistive and capacitive responses is desirable to maximize sensitivity and accuracy. To address these challenges, a new impedance spectroscopy (IS) based readout circuit for CR sensor arrays has been developed. The CMOS analog circuit provides a combination of rapid, self-calibrated baseline cancellation to focus A/D dynamic range and improve resolution. After baseline cancellation, IS measurement is applied to extract real and imaginary impedance components as a function of excitation frequency to reveal both resistive and capacitive response simultaneously. The compact, low noise instrumentation circuit is suitable of on-chip sensor array integration to eliminate wiring noise and maximize measurement resolution in a single-chip gas analysis system.

Recent Publications

Journal Papers

1. C. Yang, S. R. Jadhav, R. M. Worden, A. J. Mason, "Compact Low-Power Impedance-to-Digital Converter for Sensor Array Microsystems," *IEEE J. Solid State Circuits*, vol. 44 (10), pp. 2844-2855, Oct. 2009.
2. D. Rairigh, G. Warnell, C. Xu, E. T. Zellers, A. J. Mason, "CMOS Baseline Tracking and Cancellation Instrumentation for Nanopartical-Coated Chemiresistors," *IEEE Trans. Biomedical Circ. Systems,* vol. 3 (5), pp. 267-276, Oct. 2009.
3. C. Yang and A. Mason, "Fully Integrated 7-Order Frequency Range Quadrature Sinusoid Signal Generator," *IEEE Trans. Instrumentation Measurement*, vol. 58 (10), pp. 3481-3489, Oct. 2009.
4. L. Yu, Y. Huang, X. Jin, A. J. Mason, X. Zeng, "Ionic Liquid Thin Layer EQCM Explosives Sensor," *Sensors and Actuators B: Chemical,* vol. 140, no. 2, pp. 363-370, July 2009.
5. C. Yang, Y. Huang, B. L. Hassler, R. M. Worden, A. J. Mason, "Amperometric Electrochemical Microsystem for a Miniaturized Protein Biosensor Array," *IEEE Trans. Biomedical Circ. Systems*, vol. 3, no. 3, pp. 160-168, June 2009.
6. X. Jin, Y. Huang, A. Mason, and X. Zeng, "Multichannel Monolithic Quartz Crystal Microbalance Gas Sensor Array," *Analytical Chemistry*, vol. 81, no. 2, pp. 595-603, January 2009.
7. A. M. Kamboh, A. Mason, K. G. Oweiss, "Analysis of Lifting and B-Spline DWT Implementations for Implantable Neuroprosthetics," *Journal of Signal Processing Systems*, vol. 52, no. 3, pp. 249-261, Sep. 2008.
8. C. Yang and A. Mason, "Process/Temperature Variation Tolerant Precision Signal Strength Indicator," *IEEE Tran. Circuits and Systems I*, vol. 55 (3), pp. 722-729, April 2008.
9. N. Trombly, A. Mason, "Post-CMOS electrode formation and isolation for on-chip temperature-controlled electrochemical sensors," *IET Electronics Letters*, vol. 44, no. 1, p. 29-30, Jan. 2008.
10. A. Mason, A. V. Chavan, K. D. Wise, "A Mixed-Voltage Sensor Readout Circuit with On-Chip Calibration and Built-In Self-Test," *IEEE Sensors J*, vol. 7, no. 9, pp. 1225-1232, September 2007.
11. A. Kamboh, M. Raetz, K. Oweiss, A. Mason "Area-Power Efficient VLSI Implementation of Multichannel DWT for Data Compression in Implantable Neuroprosthetics," *IEEE Trans. Biomedical Circ. Systems*, vol. 1, no. 2, pp. 128-135, June 2007.
12. K. Oweiss, A. Mason, Y. Suhail, A. Kamboh, K. Thomson, "A Scalable Wavelet Transform VLSI Architecture for Real-Time Signal Processing in High-Density Intra-Cortical Implants," *IEEE Trans. Circuits and Systems I*, vol. 54, no. 6, pp. 1266-1278, June 2007.
13. J. Zhang, J. Zhou and A. Mason, "Highly Adaptive Transducer Interface Circuit for Multi-Parameter Microsystems," *IEEE Trans. Circ. Sys. I,* vol. 54, no. 1, pp. 167-178, Jan. 2007.

Conference Papers

1. X. Liu, D. Rairigh, A. Mason, "A Fully Integrated Multi-channel Impedance Extraction Circuit for Biosensor Arrays," *IEEE Int. Symp. Circuits and Systems*, Paris France, May 2010.
2. A. Kamboh, Y. Yang, K. Oweiss, A. J. Mason, "Design of a Configurable Neural Data Compression System for Intra-Cortical Implants," *IEEE Int. Symp. Circuits and Systems*, Paris France, May 2010.
3. Y. Huang and A. J. Mason, "A Redox-Enzyme-Based Electrochemical Biosensor with a CMOS Integrated Bipotentiostat," IEEE BioCAS Conf., Beijing China, Nov. 2009.
4. X. Liu, L. Li, A. J. Mason, "Thermal Control Microsystem for Protein Characterization and Sensing," IEEE BioCAS Conf., Beijing China, Nov. 2009.
5. Awais M. Kamboh, Karim G. Oweiss and Andrew J. Mason, "Resource Constrained VLSI Architecture for Implantable Neural Data Compression Systems," *IEEE Int. Conf. Circuits Systems*, pp. 1481-1484, May 2009.
6. X. Liu, D. Rairigh, C. Yang, A. J. Mason, "Impedance-to-Digital Converter for Sensor Array Microsystems," *IEEE Int. Conf. Circuits Systems*, pp. 353-356, May 2009.
7. D. Rairigh, X. Liu, C. Yang and A. J. Mason, "Sinusoid Signal Generator for On-chip Impedance Spectroscopy," *IEEE Int. Conf. Circuits Systems*, pp. 1961-1964, May 2009.
8. F. T. Abu-Nimeh, A. Kamboh, M. Aghagolzadeh, U.-M. Jow, A. Mason, M. Ghovanloo, K. Oweiss, "A Highly Modular, Wireless, Implantable Interface to the Cortex," *IEEE/EMBS Conf. Neural Engineering,* Antalya Turkey, pp. 375-378, April 2009.
9. D. Rairigh, G. Warnell, A. J. Mason, C. Xu, M. P. Rowe, E. T. Zellers, E. Covington, C. Kurdak, "Nanoparticle Coated Chemiresistor with CMOS Baseline Tracking and Cancellation," *IEEE Int. Conf. on Sensors*, pp. 196-199, October 2008.
10. C. Yang and A. J. Mason, "Membrane Protein Biosensor with Multi-Channel CMOS Impedance Extractor and Digitizer," *IEEE Int. Conf. on Sensors*, pp. 642-645, October 2008.
11. D. Rairigh, A. Mason, M. P. Rowe, E. T. Zellers, "Baseline Resistance Cancellation Circuit for High Resolution Thiolate-Monolayer-Protected Gold Nanoparticle Vapor Sensor Arrays", *IEEE Int. Symposium on Circ. and Systems (ISCAS)*, pp. 2002-2005, May 2008.
12. C. Yang, D. Rairigh and A. Mason, "Fully Integrated Impedance Spectroscopy for Biochemical Sensor Arrays," *IEEE Biomedical Circuits and Systems Conference*, Montreal Canada, pp. 21-24, November 2007.
13. D. Rairigh and A. Mason, "Compact Impedance Spectroscopy for High Density Sensor Arrays," *IEEJ Int. Analog VLSI Workshop*, Bunratty Ireland, November 2007.
14. A. Mason, Y. Huang, C. Yang, J. Zhang, "Amperometric Readout and Electrode Array Chip for Bioelectrochemical Sensors," *IEEE Int. Symposium on Circ. and Systems (ISCAS)*, pp. 3562-3565, May 2007.