IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title: **Low-noise nano scale signal conditioning integrated circuits for portable electro-medical and electro-sensor applications.**

Project Number **IMURA0245** *(will be inserted by The Academy)*

Monash Supervisor(s)	Dr. Jean-Michel Redouté	*Full names and titles*
Monash Primary Contact:	jean-michel.redoute@monash.edu +61399051895	*Email, phone*
IITB Supervisor(s)	Dr. Maryam Shojaei Baghini	*Full names and titles*
IITB Primary Contact:	mshojaei@ee.iitb.ac.in +9122 25767425	*Email, phone*

Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?

(*Feel free to nominate more than one. For more information, see www.iitbmonash.org)*

1. Advanced computational engineering, simulation and manufacture
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research

The research problem

In the context of healthcare, there is a combined research interest striving towards the design of compact personal health monitoring devices and systems. The same synergy is observed in micro systems used for environmental monitoring, where many sensors are kept working in an unsupervised manner. Reducing the power supply level, weight and cost while preserving the main performance specifications are important issues in these devices/systems. The ultimate goal is to integrate such systems on a chip having interfacing modules, a precise signal conditioning circuit, accurate techniques for conversion of physical quantities from one form to another form, one or more data converter(s), storage, a small processor, a wireless transmitter and a synchronizing receiver. These systems interface with the sample or environment or human body in different ways, for example through connection cables, MEMs sensors, active wireless electrodes and so on. The performance of such devices ultimately depends on the clean extraction and amplification of sensor output, sometimes as low as tens of micro volts (like bio-potential signals), from a noisy environment [1-5]. Moreover, the signal conditioning module itself should be very low-noise. Unfortunately, although previous listed precautions are highly recommended, they may not be sufficient to guarantee a faultless operation under all possible circumstances: in many cases, integration of signal conditioning with other processing modules creates other sources of noise on the chip coupled to the main module through the substrate, coupling capacitors between switches and transistors and so on. Other than noise, mismatch between components, variability in supply and process as well as temperature drift, lead to degraded precision which should be taken care of.

So in general, comprehensive portable electro-medical, electro-biosensor and electro-biochemical sensing devices should have two features.

1. They should be low-power, low-noise, highly-precise and take advantage of techniques and technologies for reducing source/effect of different kinds of internal noise and error sources.

2. They should be low-power and immune to external noise sources.

The first objective is the focus of this proposal as explained in the next section.

[1] A. D'Amicob, et al. Low-voltage low-power integrated analog lock-in amplifier for gas sensor applications, Elsevier, Sensors and Actuators B: Chemical, 2009.
[2] L. Turicchia, "Ultra-Low-Power Electronics for Non-Invasive Medical Monitoring", Proceedings of the Custom Integrated Circuits Conference, pp. 85-92, 2009.
[3] Seung Bae Lee, et al., An Inductively Powered Scalable 32-Channel Wireless Neural Recording System-on-a-Chip for Neuroscience Applications, IEEE Trans.on Biomedical Cir. And Sys., December 2010.
[4] J.-M. Redouté, M. Steyaert, "Active load for differential amplifier with high output impedance and reduced supply voltage", IEE Electronics Letters, vol. 44, no. 2, pp. 67-68, January 2008.
[5] "An Ultra Low-Power Current-Mode Integrated CMOS Instrumentation Amplifier for Personal ECG Recorders", M. Shojaei Baghini, S. Nag, R. K. Lal, D. K. Sharma, World Scientific Journal of Circuits, Systems, and Computers*, Dec. 2008.*

Project aims

The aim of this project is to design and optimize low-noise highly-precise integrated circuit topologies for portable medical and sensor applications. Since there are many other high-performance specifications like low power dissipation, linearity, integrity and robustness of such systems, the main challenge will be to trade low-noise and highly precise performance with the other design requirements in an optimal manner. The circuits will be developed on test chips to characterize and test the accomplished accuracy and noise performance.

In general, noise and accuracy performance merits have to trade off with power dissipation. However, portable electro-medical and electro-sensing applications should present a low power operation as well as a low noise to precisely monitor and sense change in the measurement quantity taken from a sensor, sometimes with normalized accuracies up to 50ppm or less. Signal conditioning and conversion of a sensed quantity to another measure play a vital role. Moreover, while designing conversion techniques and the signal conditioning module, the effect of additional sources of noise such as coupled internal switching noise due to digital modules and choppers will be studied and evaluated. This leads to a comprehensive design problem which should be optimized and applied to portable electro-medical and electro-sensor application scenarios. Indeed, while a specific circuit technique helps to reduce effect of one kind of internal noise (say a low-frequency noise), another noise type is increased drastically (say a high-frequency noise with its harmonics). Therefore, the scope of this project is focused on solving such trade-offs using circuit techniques, integrate the designed circuits on test ICs in nano scale MOS processes and apply the acquired circuit knowledge to practical application circuits for biomedical/biosensor applications.

This project will first review and analyse existing topologies and techniques in depth, in order to identify:

- *Trade-offs that different methods impose among the effects of various noise sources (semiconductor device noise, switching noise and interference) and imperfections like mismatches, variability in supply and process as well as temperature drift.*
- *How these trade-offs can be resolved while keeping main merits of the signal conditioning and conversion modules intact for portable biomedical/biosensor applications.*

Consequently, appropriate circuit techniques will be deployed to take care of those trade-offs and achieve the required performance on silicon test chips.