IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Highly EMI-immune low-noise nano scale integrated circuits for portable electro-medical and electro-sensor applications.**
Project Number	**IMURA0244** *(will be inserted by The Academy)*

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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

The ever increasing integration scale, resulting reduction in power consumption for the same functionality, have initiated a breakthrough in the use of mobile and portable electronic applications. In particular, compact electro-medical applications for personal use allow at-risk patients to continuously monitor one or more specific body function(s) like for instance their heart rate and electrical activity, or glucose level [1]. Because of their portability, these systems introduce a minimal impairment in the patient's daily life: additionally, these appliances allow the recording of continuous measurement data that can be further analysed in detail by health practitioners. Body area networks, connecting several sensors to one centrally worn unit, take these measurements one step further by analysing the obtained results and taking action where necessary (e.g. by alerting the nearest health care centre or by injecting a medicine directly in the patient's bloodstream) [2]. Similarly, portable sensors and associated electronics for environmental monitoring have gained a lot of attention recently. Ideally, portable electro-medical, electro-biosensor and electro-biochemical sensing devices should have a high autonomy, be small in size, lightweight and allow very accurate measurements [3]. Additionally, they should present a high intrinsic robustness against interferences to allow operation in changing electromagnetic environments [4]. Not surprisingly, previously listed specifications yield contradictory requirements, complicating the overall design.

[1] M. Shojaei-Baghini, R. K. Lal and D. K. Sharma, "A Low-Power and Compact Analog CMOS Processing Chip for Portable ECG Recorders", Proceedings of the IEEE Asian Solid-State Circuits Conference, pp. 473-476, 2005.
[2] X. Liu, Y. Zheng, B. Zhao, Y. Wang and M. W. Phyu, "An Ultra Low Power Baseband Transceiver IC for Wireless Body Area Network in 0.18-um CMOS Technology", IEEE Transactions on Very Large Scale Integration Systems, vol. 18, no. 12, 2010.
[3] L. Turicchia, "Ultra-Low-Power Electronics for Non-Invasive Medical Monitoring", Proceedings of the Custom Integrated Circuits Conference, pp. 85-92, 2009.
[4] J-M Redouté and M. Steyaert, "EMC of Analog Integrated Circuits", Springer, 2010.

Project aims

The aim of this project is to design integrated circuit topologies for portable medical and sensor applications, while characterizing and optimizing the trade-offs existing between the various design specifications, like low power consumption, low susceptibility to noise and a higher immunity to external electromagnetic interferences.

As motivated here above, portable electro-medical and electro-sensing applications should present a low power operation as well as a low noise operation: the former increases their overall autonomy and decreases their size, while the latter guarantees that these appliances record and monitor the patient's body functions or sense change in a particular measurement quantity taken from a sensor in a precise and reliable way. Specifically, signal conditioning after detection or sensing should ensure a satisfactory signal to noise ratio. Additionally, keeping the portability of such applications in mind, their electromagnetic compatibility (EMC) behaviour is a key specification resulting from a constantly changing electromagnetic environment since the person may be moving. Generally speaking, the human body connected to the sensors, or in some cases, the relatively long wires connecting the sensors to the electronic handheld unit in some equipment, form antennas on which parasitic signals are induced: the latter are directly injected in the input terminals of the low-noise measuring circuit, where they typically appear as very high common mode signals. Even if no wire is used still capacitive coupling injects noise to the circuit. Circuit techniques can be used to mitigate electromagnetic interferences injected at the input terminals of an integrated instrumentation amplifier, targeted at amplifying the signal that is recorded by a sensor connected to the body: However, these circuit techniques introduce more noise and frequently require more power as well. To summarize, taking into account the low power and low noise requirements, the traditional IC design parameters (like mismatch, common mode rejection, stability, etc.) as well as ascertaining and designing for electromagnetic compatibility, tightens an already very stringent requirement list. On top of all this, as is customary in analogue design, many specification parameters are inter related, and yield conflicting design constraints.

This project will first analyse existing topologies in depth, in order to identify where noise and EMC issues originate, and how these constraints can be resolved using low power novel designs useful for a broad range of applications. These observations will in turn be used to design circuit topologies resolving previously listed constraints.

Expected outcomes

The expected outcomes from this project are threefold:

- *Firstly, circuit topologies for portable electro-medical and electro-sensing applications, presenting a low power operation, a low noise capability and a high immunity against electromagnetic interferences will be studied and designed. Keeping the noise below an acceptable level, while parsimoniously dispensing the power where needed, as well as ensuring an innate immunity to interferences injected on the input pins will characterize balanced and versatile designs. These topologies will be verified with simulations, and test chips will be designed corroborating the theoretical simulations with actual measurements. To that effect, the fabrication of two test chip designs will be targeted during the course of this Ph. D. project.*
- *Secondly, the student participating in this project will be required to publish his or her circuits in highly ranked journals and conferences, in order to disseminate and share with the international academic community the achieved results of this project. Because of the interdisciplinary nature of this research topic, distinct publications read by various scientific communities can be targeted. Moreover, in case suitable inventive ideas come out of this project, joint patents will be applied for.*
- *Thirdly, the achieved findings will be grouped in a particular set of EMI immune design rules, and will be generalized where possible, so as to increase the scope of their applicability. These design guidelines will prove to be very valuable in the design of custom IC's for portable electro-medical and electro-sensing applications with a high immunity to electromagnetic interferences.*