IITB-Monash Research Academy

An Indian-Australian research partnership

Project Title:	**Highly EMI-immune nano-scale integrated interface circuits for sensing applications**
Project Number	**IMURA0647**

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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
7. Humanities and Social Sciences

The research problem

Recently micro and nano sensors have become an integrated part of many systems in various applications. This trend is going to get strengthened more and more in the future due to massive requirements in different sectors such as personal healthcare, implantable as well as wearable devices, therapeutics, smart environmental monitoring, safety, food industry and mechanized agriculture. Rapid developments in the nanotechnology sector are enhancing this trend. Among various key specifications such as sensitivity and energy autonomy, robustness of such systems against interferences such as electromagnetic interference (EMI) and variable operating conditions are also of great importance. Examples are induced interferences, temperature, humidity and moisture level variations, long term unsupervised use in the field, mechanical and electrical stress, and, exposure to various physical/chemical changes in the proximity of the sensor and sensor-circuit interfacing [1-4]. Severity of each factor changes ccording to the application area and domain from which the information is sensed by the sensor. Robustness and reliable operation of miniaturized sensor systems mainly depend on the two factors: reliability of the nanosensor and robustness of the signal conditioning circuit. Therefore one of the demanding aspects is the design of generic but robust reconfigurable/programmable integrated signal conditioning modules which take advantage of novel yet not complex compensation, nullification and calibration techniques. Limited cases of such techniques and the corresponding *systems are reported in the literature [3-4]. The challenging aspect of such circuit and system-level solutions is the requirement of adaptive compatibility of signal conditioning circuit to unpredictable variations in the sensor behaviour and interference characteristics such as EMI.*

[1] S. Boyapati, D. Das, M. Shojaei-Baghini, J.-M. Redoute, "A Balanced CMOS OpAmp with High EMI Immunity", Proc. of IEEE EMC Europe Conference, pp. 703-708, Gotheborg, Sweden, Sep. 2014.
[2] A. Richelli, J.-M. Redoute, "A Methodological Approach to EMI Resistant Analog Integrated Circuit Design", IEEE Electromagnetic Compatibility Magazine, vol. 4, no. 2, pp. 92-100, 2015.
[3] N. A. Gilda, V. G. Hande, D. K. Sharma, V. Ramgopal Rao and M. Shojaei Baghini, "Low Power, Area Efficient, and Temperature-Variation Tolerant Bidirectional Current Source for Sensor Applications", Elsevier Microelectronics Journal, March 2016.
[4] J.-M. Redoute, M. Steyaert, "An EMI Resisting LIN Driver in 0.35-micron High-Voltage CMOS", IEEE Journal of Solid-State Circuits, vol. 42, no. 7, pp. 1574 - 1582, Jul. 2007.

Project aims

The aim of this project is to design integrated interface circuits for a variety of sensors, which present a high immunity to electromagnetic interference (EMI) and can function in environmentally extreme surroundings (increased reliability).

As electronic sensor and interface circuits become an essential part of almost any miniaturized, implanted or portable electronic application, they need to operate in a variety of environments which may present several challenges. Electromagnetic noise, for instance, is omnipresent and impairs the correct operation of electronic circuits. The effect of electromagnetic noise is further exacerbated by decreasing circuit voltage and power levels, often fuelled by an increased need for an appliance's autonomy and power efficiency. The latter is a particular concern in portable sensor applications which need to efficiently measure and condition small signal levels. Moreover, the proximity of electronic devices and appliances increases the overall amount of electromagnetic pollution. Indeed, because of the portability of several sensor applications, they need to be inherently robust as little is known from the onset about the physical as well as electromagnetic environment they will have to work in. As an example, "electronic nose" type of MEMS/NEMS sensor circuits are used to measure the presence of gases, pollution, air quality and even explosives. These direct environments may occur in harsh surroundings with extreme values in heat, cold, pressure, toxicity and humidity, which makes them best avoided by humans. Designing circuits which can withstand these extreme values while continuing to operate as wanted underpin the challenge behind present proposal.

This project will first analyse existing integrated interface topologies in depth, in order to identify where noise and EMC issues originate and what elements form the weakest links with respect to the reliability, 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 generic circuit topologies resolving previously listed constraints. These circuit design solutions will be applicable to a variety of applications because these follow the same core circuits and techniques for signal sensing and conditioning.

Expected outcomes

The expected outcomes from this project are threefold:

- *Based on the experience, obtained from our first project, we will expand the developed EMI-immune design techniques to the techniques and solutions for current-mode instrumentation amplifiers as well as core signal conditioning circuits such as bridge-base imbalance measurement and oscillator-based measurements. We will first examine the developed designs in our group for EMI susceptibility and then proceed with the required redesigns for the applications aimed for industrial level applications.*
- *We will use two high-voltage foundry runs to develop and test the solutions, mentioned in the previous bullet item, on the CMOS chip. Eventually the solutions will be designed in such a way they can be easily tailored to the domain applications, for example conditioning and driver for micro sensors used in automotive applications and bridge-based interfacing for E-nose applications..*
- *In addition to publications, we aim for filing the developed solutions as patent applications as EMI-immune IPs.*

How will the project address the Goals of the above Themes?

This project proposal is situated in the domain of micro and nanotechnology. It will explore ways to improve the basic limitations arising when designing generic integrated interface circuits sensing and conditioning small signals in electromagnetically harsh and environmentally extreme surroundings. A key factor that will be taken into consideration is the interoperability of the designed solutions so that they are applicable to a variety of circuits and electronic systems.

Some of the goals that will achieved by this project comprise:

- *The design of portable or implantable electronic circuit for ambulatory monitoring. By nature of their portability, these applications should have a high autonomy, while allowing sensitive and continuous measurements to take place in various electromagnetic environments (since they are portable, for instance the patient is on the move and exposed to various unpredictable levels of electromagnetic interferences). The goal of this project is to provide low cost yet effective ways of ensuring a continuous monitoring of particular bodily functions without sacrificing the quality of life. While necessitating less hospital visits, these devices provide health practitioners with a higher amount of monitoring data. As such, portable electro-medical systems benefit society in many ways.*
- *The design of advanced sensors for mechanized and advanced agricultural techniques, evaluating the conditions of climate, rainfall and soil conditions so as to ensure an optimum irrigation and land care. These sensors should be autonomous and not require a frequent battery replacement, meaning that they will need to communicate wirelessly through vast distances and using minimum power levels, hence their robustness to channel interference as well as environmental extremes.*
- *As cars become computers on wheels, they have to become more reliable than our desktop models. From airbags misfiring upon answering a phone call, to engines shutting down when driving on roadways built on high voltage lines and even a truck skidding out of control because of electromagnetic incompatibilities in automotive electronics - a recently published research results states that occasional and untested EMI events that could cause a safety incident only once during a 10-year vehicle life, can still expose drivers to safety risks comparable with those of the world's most dangerous professions. Improving the safety of vehicles and hereby contributing to less traffic casualties by developing vehicular integrated circuits with a high robustness to EMI is an important goal in this project.*
- *The design of a variety of sensor systems for environmental monitoring, such as "electronic nose"-type of sensors for pollution and explosives detection, but also drinking water quality.*

Capabilities and Degrees Required

Candidates should have a MEng or BEng, and have taken CMOS and VLSI design courses. Experience with EDA design tools like Cadence or Tanner is a definite bonus. Candidates should be assertive, problem solvers, passionate about analogue and mixed-signal IC design and willing to work independently.

Potential Collaborators

This proposal is given in collaboration with Dr. Jean-Michel Redout from Monash University.

Please provide a few key words relating to this project to make it easier for the students to apply.

Micro sensors, Nano sesors, EMI Immune Design