Designs in Fabrication

Canada's National Design Network®
Prototyping Report:

April 2020 – March 2021

CMC Microsystems and Canada's National Design Network®

Lowering barriers to technology adoption

CMC Microsystems (CMC) is a not-for-profit organization founded in 1984 to enable state-of-the-art design, manufacturing, and testing facilities of advanced technologies.

With headquarters in Montreal and offices across Canada, the organization manages Canada's National Design Network® – a Major Science Initiative in collaboration with over 65 post-secondary institutions to connect 10,000 researchers and 1,000 companies.

CMC Microsystems' fabrication reports describe Canada's National Design Network (CNDN) designs that have progressed to fabrication are published for distribution at:

www.CMC.ca

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For inquiries about this publication: Pat.Botsford@cmc.ca

Introduction

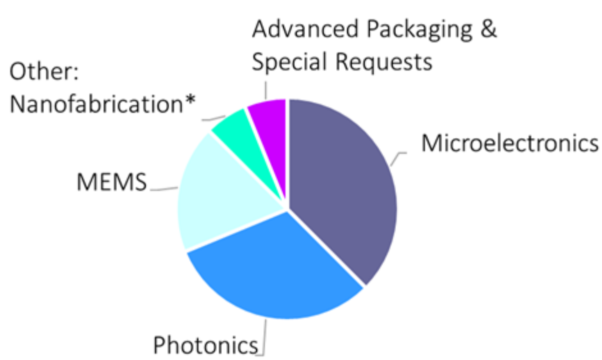
CMC, manager of Canada's National Design Network® (CNDN), delivers key services including industrial-scale multi-project wafer (MPW) manufacturing services, value-added packaging and assembly services and in-house expertise for first-time-right prototypes.

This report describes academic designs that have progressed to fabrication (FAB) for prototype purposes between April 2020 and March 2021. It provides a view into the activities of researchers in Canadian post-secondary institutions – often in the context of applications and solving problems.

FAB Highlights 2020/21: 50 technology runs through partnerships with 8 foundries world-wide

320 Designs Fabricated

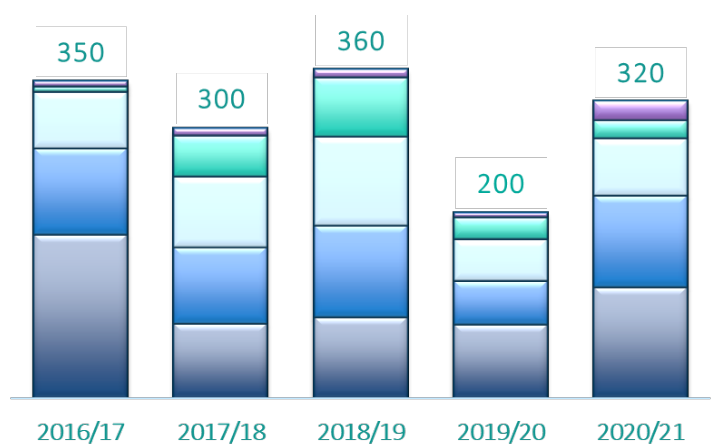
- ✓ **270** fabricated through CMC's global network of industry-scale foundries multi-project wafer (MPW) services.
- ✓ **50** developed through Canada's MNT (micro- nano technologies) network of 40 university-based labs.



*Includes other MNT designs: nanotechnology, micromachining, microfluidics

Figure 1 - Designs Fabricated 2020/21

Five-year highlights: 1530 prototypes



1530 Designs Fabricated
Academics in Canada: 1426 (of 1530)

Figure 2 - Designs Fabricated 2016/17 - 2020/21

950 Photonics Designs Fabricated

CMC's strategic investments give Canada a competitive advantage in photonics!

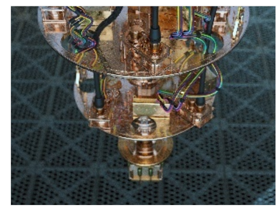
By March 2021, over **950** photonics & optoelectronics designs progressed to fabrication for prototype purposes through CMC (2008/09 through 2020/21), including:

- Over **600** silicon photonics designs (includes fabrication training program projects)
- **120** III-V photonics technology designs

A World-wide Industrial Supply Chain

CMC's strategies focus on a supply chain ecosystem – of more than 100 organizations – that enables world-class industry/academic collaboration, expands support for industrial R&D leading to commercialization of research, and enhances Canadian leadership in manufacturing in photonics and quantum technologies.

Technology Roadmap



In 2020/21, we added strategic focus on **Artificial Intelligence and Machine Learning**, and **Quantum Computing**. New and in development prototyping capabilities include:

Quantum
- CMC joined the IBM Quantum Hub, making IBM's most powerful quantum computer available in Canada for the first time
- With Canadian firm Xanadu Quantum Technologies, we launched the Quantum Sandbox, using the power of Quantum to solve complex problems

Microelectronics
- GlobalFoundries®: FinFET training; 12nm FinFET fabrication

IoT and Edge AI
- RISC-V Cores on CMC GitHub
- Atlas 800 – AI Training/Inference Cluster
- CMC signed a strategic partnership with Canadian AI software company Deeplite, for research and development on next-generation AI-powered solutions

Photonics
- GlobalFoundries®: 45CLO silicon photonics PDK (Jan. 2022)

Micro Electro-Mechanical Systems (MEMS), Nanofabrication, Integration
- Silicon Interposer projects underway
- Electronic Sensor Platform (ESP)

R&D Programs

- **CMC SponsorChip™** is an opportunity for companies to choose a R&D project, such as a chip fabrication technology and CMC takes care of the rest.
  www.CMC.ca/SponsorChip

- **VIE – Virtual Incubator Environment** offers CAD tools access and microelectronics, photonics, and MEMS state-of-the-art processes as well as tools and technical expertise.
  www.CMC.ca/VIE

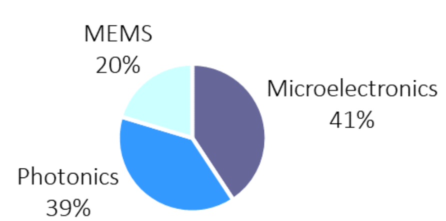


Figure 3: Five-year Industrial & Non-Canadian Academic Designs Fabricated (2016/17-2020-21)

FAB@cmc.ca

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FAB

Looking for Collaborative Opportunities?

For further information we encourage you to contact researchers directly, or contact us:

FAB@cmc.ca

MICROELECTRONICS

CMC has access to a variety of technology nodes across various foundries including Taiwan Semiconductor Manufacturing Company (TSMC), GlobalFoundries®, and STMicroelectronics through global partnerships. This portfolio supports researchers across a variety of growth areas, including Analog, RF, Mixed signal, RF, Digital and Optoelectronics.

Technology: 12nm FinFit CMOS

GF 12LP

All Digital ADC

Applications include: ICT

A fully-synthesizable all-digital ADC with competitive performance to the published state-of-the-art custom analog ADCs.

University of British Columbia
Designer: Avilash Mukherjee Email: avilash@ece.ubc.ca
Professor: Sudip Shekhar Email: sudip@ece.ubc.ca

Technology: 22nm CMOS

GF 22nm CMOS FDX

Study Single Event Effects in 22nm FD-SOI Technology

Applications include: Aerospace, ICT

Fully-depleted SOI (FD-SOI) has become a high-demand technology for the development of commercial and potential space applications due to its high-performance and low power consumption requirement. The effect of energetic particles and the generation of soft errors, which is one of the key factors to be carefully studied in this SOI technology, before it could be used for high reliability applications such as servers, automobile, and space. The objective is to study and evaluate soft error rates in digital circuits implemented in a 22nm FD-SOI test chip and provide guidelines for engineers and researchers in reliability community. The test chip design includes various types of flip flops from standard ones to fault-tolerant ones. It will also include a SRAM block and some ring oscillators. The circuits will be monitored with on-chip testing circuits for soft errors. The obtained results can provide valuable information about sot error rates in this technology and give support for improving the reliability of the integrated circuits.

University of Saskatchewan
Designer: Jaime Cardenas Email: jsc494@mail.usask.ca
Professor: Li Chen Email: li.chen@usask.ca

Noise Shaping Beamformer

Applications include: ICT

The circuit is a demonstration of a 4-antenna noise-shaping beamformer operating over the full 28GHz 5G frequency band. Instead of replicating four identical receivers, this work proposes a design of a multi-port receiver as a one fully interconnected system.

University of Calgary
Designer: Mohammad Radpour Email: mohammad.radpour1@ucalgary.ca
Professor: Leonid Belostotski Email: lbelosto@ucalgary.ca

Technology: 45nm CMOS RF SOI

GF 45nm CMOS RF SOI

60-GHz RF Beamforming Transmitter Using Frequency Multiplier

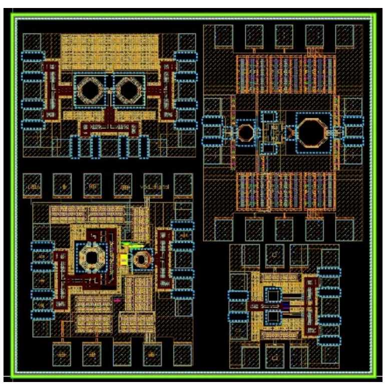
Applications include: ICT

Frequency multipliers are the key enabler for high-frequency signal sources. Traditionally, they were used to multiply the local oscillator (LO) frequency to generate the high-frequency vector modulated signal. However, this technique brings the challenge of implementing the transmitter at such high frequency with acceptable power efficiency. This work focuses on the design of RF beamforming transmitter consisting of a cascade of passive phase shifter, power amplifier, and a frequency doubler which is used as a last stage for frequency up-conversion. This technique allows us to design the whole transmitter at a lower frequency with lower losses and high efficiency.

University of Waterloo
Designer: Mahitab Eladwy Email: meladwy@uwaterloo.ca
Professor: Slim Boumaiza Email: slim.boumaiza@uwaterloo.ca

High-Efficiency Mm-Wave Power Amplifier with Enhanced AM-PM

Applications include: ICT



Several mm-wave frequency bands have been recently allocated in different countries for deployment of 5G high-speed wireless services. These are calling for high performance mm-wave and broadband transmitters that are cable of covering most of the potential bands. This work aims at designing a high-efficiency and high-linearity power amplifiers (PA) that target the frequency band of 37 GHz to 48 GHz.

University of Waterloo
Designer: Mahitab Eladwy Email: meladwy@uwaterloo.ca
Professor: Slim Boumaiza Email: slim.boumaiza@uwaterloo.ca

Technology: 65-nanometer CMOS

TSMC 65nm CMOS

5GS/S 10-bit Hybrid Flash-SAR ADC

Applications include: ICT

Comparator's structure is changed. In the flash part, the references are created using different ratios of the capacitors used in the new structure. Thus, it is a reference less ADC.

University of Alberta
Designer: Behdad Goodarzy Email: goodarzy@ualberta.ca
Professor: Masum Hossain Email: masum@ualberta.ca

60 Gb/s Differential Edge Modulated Signaling

Applications include: ICT

Data will be encoded on a 10 GHz carrier using the rising edge and the falling edge. Amplitude only phase is modulated to encode data – it has higher noise immunity. Main benefits are:

1) Spectrum efficiency.
2) Clock Encoding that allows Burst mode signalling.
3) Super linear energy efficiency with data rates.

The benefit of the approach allows us to achieve 60 Gb/s in 65nm CMOS with only 1.5 p/bit efficiency.

University of Alberta
Designer: Shakib Mahmood Email: shakib1@ualberta.ca
Professor: Masum Hossain Email: masum@ualberta.ca

Advanced CMOS Readout and Signal Processing for Single Photon Avalanche Diode Array Dedicated to High Precision Timing Measurements

Applications include: Defence (Safety, Security), Health/Biomedical

The Groupe de Recherche en Appareillage Médical de Sherbrooke (GRAMS) is working to develop Single Photon Avalanche Diode (SPAD) array integrated in 3D with CMOS electronics to obtain a high-performance photon-to-digital converter. These detectors are used in many applications such as medical imaging (positron emission tomography and computed tomography), particle physics experiments and quantum key distribution. One of the goals of the presented design is to implement a new Phase-Locked Loop (PLL) design in TSMC 65 nm LP that will reduce the timing variations between timestamping circuits. This will ultimately enable us to achieve a 10 ps timing resolution array-wide. Another goal of this revision is to implement new signal processing circuits that will allow our chip to provide significant improvement in Quantum Key Distribution (QKD) and Time-of-Flight Computed Tomography (ToF CT).

For QKD experiments, our detector could enable much smaller and more robust systems. Such systems are the first step to enable the integration of QKD in handheld devices. Another signal processing circuit will enable the use of our sensor in a proof of concept for a ToF CT scanner. This scanner would enable a reduction of the dose of X-rays required to image a patient by a factor 4, thus opening the door to the imaging of children or pregnant women in need.

Université de Sherbrooke
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Burst-Mode Driver for VCSEL-based Links
Applications include: ICT

The tape-out consists of a VCSEL driver which can operate at burst-mode. The project aims to achieve short turn on time and low power consumption when the data transmission is stopped.

Concordia University
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Cryo-LNA for the Dominion Radio Astrophysics Observatory Synthesis Telescope
Applications include: Aerospace

The Dominion Radio Astrophysics Observatory (DRAO) is the National Research Council of Canada (NRC) operated observatory located in Penticton, British Columbia. The DRAO synthesis telescope is an array of seven parabolic dish antennas used for research by many national and international astronomers and astrophysicists. This telescope has led to numerous scientific publications and discoveries however, to continue to push boundaries and continue making discoveries the synthesis telescope needs to be upgraded. Currently, the telescope operates at two narrow frequency bands around 408 MHz and 1420 MHz with a system noise temperature (figure) of approximately 50 K (0.7 dB). The upgrade will require a decreased system noise temperature (increased sensitivity) of less than 25 K (0.36 dB) and a continuous 400-MHz-to-1800-MHz bandwidth. This will be achieved using two receivers one from 400 MHz to 800 MHz and one from 700 MHz to 1800 MHz. The low-noise amplifier fabricated in this project will be used as the front-end of the 700-MHz-to-1800-MHz receiver and will be able to operate at both cryogenic and room temperature allowing for flexibility in the receiver design.

University of Calgary
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Professor: Leonid Belostotski Email: lbelosto@ucalgary.ca

Cryogenic CMOS Device and Circuits for Quantum Computing Electronics
Applications include: ICT

This test chip includes (1) device test structures to study the device behavior under deep cryogenic temperature and (2) digital control network and readout circuits which will be used as control electronics for a scalable silicon qubit array.

University of Waterloo
Designer: Xuesong Chen Email: xuesong.chen@uwaterloo.ca
Professor: Lan Wei Email: l28wei@uwaterloo.ca

Delta-Sigma ADC with Programmable Channel Selection Filter for Acoustic and Ultrasonic Applications
Applications include: Automotive, Defence (Safety, Security), Health/Biomedical, Natural Resource/Energy

This project is to implement a low-frequency low complexity transceiver for acoustic and ultrasonic applications. At the core, an A/D converter and channel selection filter are important building blocks that can be optimized for low battery consumption. The design can be applied for biomedical, acoustic/ultrasonic communication and detection, and ICs for (image) signal processing. In order to meet a required lifetime spanning multiple years, the circuit complexity must be reduced significantly without compromising the link reliability. The goal is to design a low power mixed-signal integrated circuit for power transmitting relay or DSP processing for acoustic and ultrasonic applications.

Dalhousie University
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Professor: Jean-Francois Bousquet Email: jbousquet@dal.ca

Design, Prototyping and Characterization of HW Celerators for Computational Photography, Machine Learning and Video Encryption in Stacked Image Sensors

Applications include: Automotive, Entertainment, Defence (Safety, Security), Health/Biomedical, ICT (3D Imaging, computational photography)

We have successfully demonstrated a new class of so-called coded-exposure cameras that perform advanced types of imaging such as accurate 3D imaging, spectroscopic imaging and wide-dynamic range imaging, all done within a single frame and in challenging visual scenes, such as reflective, scattering and fast-moving scenes. The CMOS image sensor technologies we use to fabricate such image sensors (direct from foundries) are optimized for the analog and photoelectric response of silicon, but not for digital circuits that are needed to process digital information near the pixel array. This limits the design's capability to include on-chip complex and high-performance digital architectures optimized for area, speed, and power. The proposed ASIC will be integrated alongside image sensors to improve and add new functionality to image sensors designed in dedicated technology node.

This request for area allocation is for developing three digital circuits. First circuit will be implementation of a novel machine learning algorithm for object detection. One of the goals is to add dynamic object tracking ability to the camera. It is necessary to have an on-chip object detection system that can locate the position of a moving object in each frame. The second circuit implements on-chip mask generation algorithm that can track the movements of the objects detected by the machine learning circuit. By implementing these two circuits, it is possible to identify the pixels where the desired object is present and control different aspects of these pixels. For example, one can change brightness or the quality of the segment of the frame where specific object is present. The third circuit is used for encrypting the output video. Today, privacy plays a pivotal role in all modern applications and devices. The goal is to add an architecture for increasing the security of the video. This way, raw output from sensor can only be decoded by intended user.

University Of Toronto

Designer: Rahul Gulve	Email: rahul.gulve@mail.utoronto.ca
Professor: Roman Genov	Email: roman@eecg.utoronto.ca

Energy-First Design of LDPC Codes and Decoders (EF-FECtive)

Applications include: ICT

The proposed chip was developed as part of the Energy-First Design of LDPC Codes and Decoders (EF-FECtive) project. It implements a system for decoding LDPC error-correction codes, which have many applications in communications and data storage. The implemented decoder allows decoding a wide variety of LDPC codes, including many codes found in standards such as 5G NR, WiFi, etc. The fabricated chips will be used as references in the design of energy models of LDPC decoders and to confirm the superiority of energy-optimized LDPC codes, thus allowing to advance the state of the art in energy-efficient error-correction codes.

Polytechnique Montréal

Professor: François Leduc-Primeau	Email: francois.leduc-primeau@polymtl.ca

Fine Resolution Sub-ranging DAC Using Optimized Sigma-Delta Bitstreams

Applications include: ICT (Automatic Test Equipment (ATE), pressure sensors, motor speed control)

A high-resolution, DAC is to be implemented. The proposed DAC design is based on sub-ranging and segmentation using optimized Sigma-Delta bit-streams. This design would be very useful in applications where DACs are used for Calibration.

McGill University

Designer: Ahmed Emara	Email: ahmed.emara@mail.mcgill.ca
Professor: Gordon Roberts	Email: gordon.roberts@mcgill.ca

High Dynamic Range, 4-Input, Compact Vector Modulator Network for 5G Beamsteering in Mobile Terminals

Applications include: Automotive, ICT

The design is a compact vector modulator network (VMN) based on a vector-sum phase shifter (VSPS). In order to implement vector modulators at each of the antennas in an array within mobile devices, redundant structures (namely the fixed phase shifters within each VSPS) need to be reused. This design would make beamsteering in 5G devices a possibility since it addresses the issue of limited space. Specific to the IC design being submitted, it will consist of 4 input ports and one output port (which will combine the vector modulated signals of the 4 inputs). The IC will operate at a band centered around 28GHz (a proposed band for 5G mobile communication). The signals on the four inputs can be individually controlled. Furthermore, this design iterates on and improves upon the previously submitted VMN (design) with a focus on improved dynamic range, overall gain and layout.

University of Alberta

Designer: Khaled Al-Amoodi	Email: kalamood@ualberta.ca
Professor: Duncan Elliott	Email: duncan.elliott@ualberta.ca

High-Performance Time-to-Digital Converter for Digital Silicon Photomultipliers Targeting Positron Emission Tomography Applications

Applications include: Health/Biomedical, ICT

Due to Canada's aging population, the number of annual cancer diagnoses has been increasing in recent years. Statistics Canada estimated that an average of 25 Canadians would be diagnosed with cancer every hour of 2019. As such, research on advancing imaging systems for the field of oncology is of great importance, with positron emission tomography (PET) being a primary candidate due to its high sensitivity. Recent developments in photodetectors known as single-photon avalanche diodes (SPADs), have created a paradigm shift pushing research towards digital PET systems. Such systems provide the capabilities of increased imaging sensitivity, lower doses of radio-tracers injected into subjects, lower costs per scan and shorter scan times resulting in a higher patient throughput.

Digital PET can achieve the aforementioned improvements by integrating SPADs along with time-to-digital converters (TDCs) in what are known as digital silicon photomultipliers (dSiPM). TDCs are circuits responsible for timestamping photon arrival times, effectively allowing the systems to achieve a greater timing resolution than their analog counterparts. Improvements in timing resolution provide increased contrast in PET images, thus enabling the earlier detection of cancer which could result in an increased survival rate and decreased medical costs. In this research, our group plans to achieve the following primary research objectives.

- The design of two high-performance TDCs in TSMC 65 nm GP CMOS technology utilizing a novel two-step conversion topology and a single-stage Vernier ring oscillator topology.
- Enable viability for the TDCs within a dSiPM targeting PET imaging applications by maintaining small area and low power consumption.
- Testing of the TDC with an on-chip array of SPADs in a mini-dSiPM prototype.

McMaster University

Designer: Ryan Scott	Email: scottr8@mcmaster.ca
Professor: Jamal Deen	Email: jamal@mcmaster.ca

High-speed and High-sensitivity Imaging Sensor for Positron Emission Tomography Applications

Applications include: Health/Biomedical, ICT

Single photon avalanche diodes (SPADs) fabricated in standard complementary metal-oxide-semiconductor (CMOS) processes become favorable photodetectors in many applications such as biomedical imaging (Raman spectroscopy, fluorescence lifetime imaging microscopy, positron emission tomography (PET), diffuse optical imaging), light detection and ranging and communication. These SPADs can be fabricated at a lower cost and present the potential to be more easily integrated with other signal conditioning and processing circuits such as trans-impedance amplifiers, discriminators, counters and time-to-digital convertors to form a complete detection system on the same chip. In this project, we plan to use the standard CMOS technology (TSMC 65 nm) to design and investigate a novel quench and reset circuit for CMOS SPADs. We also plan to investigate the noise performance with a focus on the random telegraph signal (RTS) noise, for which very limited information is available in decananometer standard CMOS technologies, but which is very important for our biomedical applications. Through the design, optimization, fabrication and measurement of SPADs, we hope to achieve the following primary objectives.

- The design and test of novel SPAD designs in standard CMOS technology with a focus on optimizing performance for PET applications.
- To investigate and design the front-end circuits like quench and reset circuits for SPADs.
- To characterize the performance of the SPADs such as breakdown voltage, temperature coefficient of breakdown voltage, dark noise, afterpulsing, photon detection efficiency and random telegraph signal. With the measurement results, a physical model will be developed and optimized. Such a model can help to simulate and predict the performance of the SPAD before fabrication, allowing for future designs to be optimized further.

McMaster University
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Professor: Jamal Deen Email: jamal@mcmaster.ca

Low-power Display with Energy Saving Features

Applications include: ICT, Other (Nowadays there is a growing trend in the portable electronic market such as smartphones, smartwatches, and head-mounted displays. One important characteristic of these devices is the battery lifetime. Since the display is the most power-hungry block in such devices, it is essential to reduce the power consumption of this block to increase the battery lifetime.

Project Description and Primary Objectives: This test chip will have at least three different components:

1) Updated architecture of Low-power display with dual-driver pixel circuit and its associated drivers and design of low-power display with row driver energy recycling technique.
2) Design of updated architectures for physical unclonable functions (PUFs) and design of a microprocessor capable of symmetric encryption that is secure against side channel analysis; and
3) Designing sequential circuits (static flip-flops) for low-voltage, low-power, and low-energy consumption.

University of Waterloo
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Multi Mode Ultra Wideband Receiver Architecture

Applications include: ICT (Radio Frequency Integrated Circuits)

Different reception methods have been proposed for the Ultra-Wideband (UWB) receivers by the researchers and designers. Each method has its own merits and its own disadvantages. The coherent reception method provides fundamentally better receiver performance in terms of receiver sensitivity compared with a non-coherent receiver, at the cost of power consumption and complexity of the TX/RX synchronization. On the other hand, the non-coherent RX could be realized either by using energy or peak detection that needs a lower level of complexity and amount of power.

École de technologie supérieure
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Professor: Frédéric Nabki Email: frederic.nabki@etsmtl.ca

Multi-Time-Gated SPADs for Biomedical Imaging Applications

Applications include: Health/Biomedical, ICT

The integration of highly-sensitive photodetectors known as single-photon avalanche diodes (SPADs) along with time-to-digital converters (TDCs) provide the possibility of developing high-performance and low-cost sensors known as digital silicon photomultipliers (dSiPMs). In recent years, dSiPMs have demonstrated great uses in biomedical imaging applications such as diffuse optical tomography (DOT), positron emission tomography (PET), fluorescence lifetime imaging microscopy (FLIM), and Raman spectroscopy. Improvements in timing resolution of the photodetection system provide increased signal to noise ratio in these applications. This provides the capability for high-performance biomedical imaging sensors at a low cost when implemented in standard CMOS.

In this work, we plan to use the TSMC 65 nm process to develop a multi-time gated SPAD array to perform DOT measurements on real samples. We plan to perform a comparison of the performance of the multi-time-gated array with a commercial free-running SPAD, in order to assess improvements made to the detector using this topology. In summary, in this design we hope to achieve the following primary objectives:

- The design of a multi-time-gated SPAD array with integrated coarse TDCs
- Full characterization of the SPAD performance
- Performance comparison of the proposed multi-time-gated SPAD array and a commercial SPAD, on the time-of-flight measurement of real samples

McMaster University
Designer: Ryan Scott Email: scottr8@mcmaster.ca
Professor: Jamal Deen Email: jamal@mcmaster.ca

Review, Design, Prototyping, Experimental Characterization, and Comparative Analysis of Digital Architecture in Stacked Image Sensors for Computation

Applications include: Automotive, Defence (Safety, Security), Entertainment, Health/Biomedical, ICT (3D Imaging, Computational Photography)

We have successfully demonstrated a new class of so called coded-exposure cameras that perform advanced types of imaging such as accurate 3D imaging, spectroscopic imaging and wide-dynamic range imaging, all done within a single frame and in challenging visual scenes, such as reflective, scattering and fast-moving scenes. The CMOS image sensor technologies (LF11ISI, XS018) offered by foundries are optimized for the analog and photoelectric response of silicon. It limits the design’s capability to include on-chip complex and high-performance digital architectures optimized for area, speed, and power. The developed ASIC will be integrated alongside image sensors to improve and add new functionality to the image sensors designed in dedicated technology node.

This request for area allocation is for developing a reconfigurable computing architecture for computer vision applications, scene-aware closed-loop computational imaging. The requested area dimensions, 3mm x 4mm, are equal to the dimensions of the image sensor chips. The chip that will be fabricated through this run will be stacked below an image sensor chip that has already been manufactured in 110nm image-sensor technology and successfully tested. As the name suggests, the exposure of individual pixels in CEP camera is controlled by the codes provided to the camera. The proposed design, T6D, will contain reconfigurable accelerators which are optimized for generating such codes at very high rates. In this design we will be developing two main digital blocks:

1) Microprocessor with specialized SIMD extension for computational image processing.
2) Reconfigurable parallel processing architecture.

This proposed system-on-chip solution of the computational image sensor integrated with powerful reconfigurable image-processing hardware allows us to explore and implement new scalable algorithms for HD+ resolution using a compact power-efficient system.

University Of Toronto
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SOC Beamforming IC for K/Ka band Sitcom Applications
Applications include: Automotive

A System-On-Chip 30GHz Transmitter IC with Unit-Circle based Gain/Phase and matching calibration using a on-chip RISC-V based microprocessor.

University of Waterloo

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TSMC 65nm CMOS

SOC Full Duplex Radio (FDR)
Applications include: ICT

Self Interference Cancellation (SIC) Filter for Full Duplex Radio (FDR) application operating at 900 MHz and targeting high self Interference Cancellation.

University of British Columbia

Designer: Hany Abdelraheem	Email: hanyaa@ece.ubc.ca
Professor: Sudip Shekhar	Email: sudip@ece.ubc.ca

SOC - UBC
Applications include: ICT

This design contains a fractional N synthesizer and a VCO-based ADC for a full duplex self interference cancellation (SIC) radio. The synthesizer provides a tunable LO for the SIC clocking circuits, while the low frequency ADC is used for calibration and control of SIC filters.

University of British Columbia

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Professor: Sudip Shekhar	Email: sudip@ece.ubc.ca

Sub 10 ps Timing Precision Photodetector
Applications include: Health/Biomedical

The Groupe de Recherche en Appareillage Médical de Sherbrooke (GRAMS) is working to develop Single Photon Avalanche Diodes (SPAD) array integrated in 3D, using Through Silicon Vias (TSV), with deep sub-micron CMOS electronics to obtain high timing performance photodetectors (< 10 ps FWHM). To achieve this level of performance, we must test multiple front-end electronic variants. This ASIC will pair the front-end electronic variants with 2D CMOS SPAD sensors and will be used in applications such as astrophysics LIDAR. This design has two main objectives:

1) Photodetector designs composed of a SPAD and a quenching circuit.
2) Six design variants (either SPAD or quenching circuit) to evaluate their impacts on timing precision.

Université de Sherbrooke

Designer: Frédéric Nolet	Email: frederic.nolet@usherbrooke.ca
Professor: Jean-François Pratte	Email: jean-francois.pratte@usherbrooke.ca

Ultra-Low Power SAW-Less Voltage-Mode RF Receiver with Reconfigurable Noise and Linearity Performance

Applications include: ICT (wireless communications)

Quantized front-end receiver architecture implemented for dynamic range reconfigurability. Objectives for this front-end receiver are the following:

1) Using quantized architecture allows the design to be scalable and achieves high linearity and low-noise performance when compared with state-of-the-art.
2) Maximizes the use of passive voltage blocks (i.e., mixers and voltage summer) instead of using current-mode blocks to reduce overall power consumption and complexity.
3) Ultra-low power can be achieved using individual DC biasing for all quantized LNAs.

University Of Toronto
Designer: Justin Kim Email: justinyonghui.kim@mail.utoronto.ca
Professor: Antonio Liscidini Email: antonio.liscidini@utoronto.ca

Ultra-wideband Oscilloscope

Applications include: Health/Biomedical

Ultra-wideband Oscilloscope using sub-sampling can be used for restoring the shape of a received UWB signal enabling advanced microwave imaging. This project uses sub-sampling or time expansion technique to produce a clock signal very close to the transmitted signal period using an integer-N frequency synthesizer. For amplifying the received weak signal a novel low noise amplifier covering 2 to 20 GHz is implemented that uses common-gate and common-source configuration simultaneously.

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Ultra-wideband Transceiver System Design

Applications include: Automotive, Health/Biomedical, ICT

In this project, we will design and fabricate an ultra-wideband (UWB) pulse transmitter circuit capable of generating high output voltage UWB pulse under the FCC mask requirements and a receiver circuit that can detect the transmitted/reflected waveform. The proposed UWB transceiver system can be used in wideband radar, low data-rate wireless communication systems, wireless sensor applications and so on. With an ultra-wide bandwidth, the transceiver system can have high resolution when applied as a radar system and high resistance to narrowband interference when used as a communication system. The ability to generate high peak to peak voltage relieves the limitation of the low output swing when implemented in CMOS technology with low supply voltage. In the receiver design, two methods are preferable. The auto-correlation receiver which does not require the frequency synthesizing circuit is compact in size and low in power consumption. While the sub-sampling method can detect the UWB signal preserving more information with larger size and power consumption. The goal for the transceiver design is to implement a system containing an array of UWB transceivers with the feature of high precision imaging and locating.

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Wirelessly-powered Closed-loop Neural Interface Processor
Applications include: Health/Biomedical

Based on the IC developed on 1901CS-ICSTRGMJ, this request for area allocation is for the development of a fully integrated solution combining a low power general purpose microcontoller and next-generation brain state classifier based on the BrainForest architecture.The design implements a system-on-chip that features a closed-loop stimulator along with a built-in machine learning accelerator for the classification of complex temporal patterns in human brain dynamics, with the use of exponentially decaying memories (EDMs). The system is wirelessly powered by employing a custom laid-out on-chip inductor as a power receiver. We propose a design strategy that optimally confines the electric field on the surface of the chip, extending the range of maximum received power available under FDA approved standards. A signal processing analog front-end is comprised by sub-µW voltage & current recording channels, in addition to a biphasic programmable current stimulator. Recent developments have demonstrated the suitability of random classifiers to brain state classification including the winning entry in the widely recognized Kaggle seizure prediction challenge. While random forests are generally computationally complex in terms of on-chip memory requirements, we have identified architectural innovations that could be the missing link to lend their utility to low-power implantable and wearable technology. Such approach also helps to reduce the payload of the data telemetry, also implemented in the system for diagnosis purposes, since already-processed markers can be transmitted instead of entire waveform information. The codesign of the aforementioned blocks in a complete fully wirelessly powered system-on-chip could lead to breakthrough applications in closed-loop neurostimulation implantable devices for the treatment of neurological disorders such as epilepsy and Parkinson's disease.

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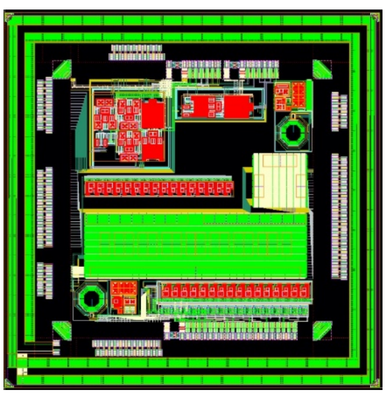
Professor: Roman Genov Email: roman@eecg.utoronto.ca

Wirelessly-powered Closed-loop Neural Interface Processor - Generation II
Applications include: Health/Biomedical



Changes from the (previous) design include:
- new custom hardware for machine-learning acceleration
- rework of connections of processor & BrainForest blocks to SRAM cells

new generation of analog front-end / wireless power/data blocks

This request for area allocation is for the development of the next installment of the design 2001CS-ICSTRCLS. The design implements a system-on-chip that features a closed-loop stimulator along with a built-in machine learning accelerator for the classification of complex temporal patterns in human brain dynamics, with the use of exponentially decaying memories (EDMs). The system is wirelessly powered by employing a custom laid-out on-chip inductor as a power receiver. We propose a design strategy that optimally confines the electric field on the surface of the chip, extending the range of maximum received power available under FDA approved standards. A signal processing analog front-end is comprised by sub-µW voltage & current recording channels, in addition to a biphasic programmable current stimulator. Recent developments have demonstrated the suitability of random classifiers to brain state classification including the winning entry in the widely recognized Kaggle seizure prediction challenge. While random forests are generally computationally complex in terms of on-chip memory requirements, we have identified architectural innovations that could be the missing link to lend their utility to low-power implantable and wearable technology. Such approach also helps to reduce the payload of the data telemetry, also implemented in the system for diagnosis purposes, since already-processed markers can be transmitted instead of entire waveform information. The codesign of the aforementioned blocks in a complete fully wirelessly powered system-on-chip could lead to breakthrough applications in closed-loop neurostimulation implantable devices for the treatment of neurological disorders such as epilepsy and Parkinson's disease.

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Technology: 130-nanometer SiGe BiCMOS

GF 8XP

Millimeter Wave Beamforming IC for Satcom Phased Array

Applications include: ICT

Key building blocks for a millimeter wave beam-forming array for emerging satellite communication.

University of Waterloo
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Technology: 130-nanometer CMOS

TSMC 0.13µm CMOS

A Low-Power Wideband Receiver Front-End for IoT Applications

Applications include: ICT (Internet of Things (IoT))

There is a strong motivation to create a low-noise, wideband, low-power and low-cost receiver front-end that is able to support both local and wide area networks for internet of things (IoT) applications. The proposed design is a current-reuse RF to baseband receiver front-end. It mainly consists of cascoding transimpedance amplifier on LNTA to share DC biasing and using a single supply along with a passive mixer to down-convert an RF signal to an IF signal. In addition, a noise cancelling technique and active inductor enhance the noise performance in order to increase the sensitivity of the receiver and make it suitable for both local and wide area networks. Our design aim is to create a fully integrated receiver RF front-end, which is able to cover a wide frequency range and to support several standards such as NB-IoT and Bluetooth low energy.

École de technologie supérieure
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Bio-Impedance Circuit Design to Measure Vital Signs for COVID-19 Monitoring

Applications include: Health/Biomedical

In this project funded by MITACS, we will develop a CMOS bio-impedance measurement circuit to monitor the respiratory rate (RR) and pulse wave velocity (PWV) in patients who are infected by COVID-19 and even in healthy people. Bio-impedance is the electrical impedance that depends on the various composites of the body. Typically, bio-impedance is used to determine the composition of fat, muscle, and bone in the human body. In this project, we exploit bio-impedance to detect the movement of the pulse wave in an artery for PWV detection and volume change in the abdomen for respiration monitoring. To measure some of the vital signs such as heart rate (HR), blood pressure (BP), respiratory rate (RR) and Pulse Wave Velocity (PWV), it is possible to exploit the bio-impedance. For instance, RR can be monitored by using a BI sensor at the abdomen. The operation principle of RR detection using BI is based on utilizing an AC current which is injected to a local body and the voltage across it is measured. The volume change of the abdomen due to inhalation and exhalation causes impedance variation, generating an amplitude-modulated signal, which can be monitored by the BI technique. BI circuits include a low-power and high-efficiency switched current stimulus (CS), a low-power and high-CMRR instrumentation amplifier (IA), a passive mixer, and a digitally programmable gain amplifier (PGA) with band-pass filter. To measure BI, AC current with frequency of 64 kHz and amplitude of 100 µm Ap-p is injected into the body. These frequencies and amplitudes are chosen under the consideration of human safety. The current stimulus is the most power-consuming block of the BI AFE. The IA is one of the challenging building blocks of the AFE since the nature of the input signal is a weak differential signal in the presence of large common-mode noise. In order to extract the signal under a poor environment, high CMRR and low-noise IA is required.

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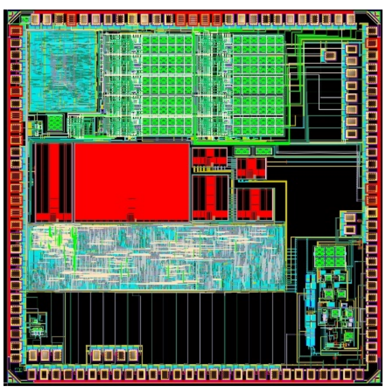
Design and Implementation of An Ultra-small Vital-signs-monitoring Multi-sensing Microsystem for COVID-19 Management

Applications include: Health/Biomedical



This collaborative research project between **Professor Benoit Gosselin** and two major industrial partners in advanced manufacturing and medical technologies aims to design, manufacture and test a tiny, inexpensive and easy-to-use wearable multi-sensing device to continuously monitor patients remotely, and help greatly to manage COVID-19. The envisioned microsensors will achieve an extreme level of miniaturization by combining CMOS custom integrated circuits with ultra-small electronic components available off the shelf (COTS) through an advanced 3D integration strategy that will be developed in collaboration with CMC Microsystems. The miniature multi-sensing device will address the requirements of iMD research, which strives to provide patients with inexpensive multi-sensing monitoring devices of extended battery life to continuously measure temperature, heart rate (HR), blood pressure (BP), oxygen saturation (SPO2) and respiratory rate (RR) remotely. Application-specific integrated circuits (ASICs) and ultra-small COTS will be combined and interconnected together using the advanced system-in-package chip integration that will be developed based on silicon interposers. The power consumption of the whole microsensor will be very low, within a few hundreds of microwatts, in order to extend the battery life.

Université Laval
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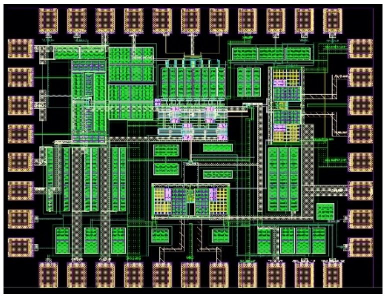
Harmonic Recombination RF Receiver Front-End Using N-Path Filtering for 5G Application

Applications include: ICT (5G application)



Recently, the explosive growth of high data rate connectivity is expected to be fulfilled in part by 5G wireless communication systems that are small in size, low cost and highly reliable. There are two main bands for 5G wireless radios including the mm-wave band and the sub-6 GHz band. The mm-wave frequency band requires more complex radios and is expected to support more specific applications in 5G systems, whereas the sub-6 GHz frequency band is expected to be more prevalent. As such, there is an interest for sub-6 GHz transceivers that leverage new techniques to meet 5G specifications, putting a strain on the RF front-end design.

There is a strong motivation to create a low-noise, wideband, low-power and low-cost receiver front-end that is able to support the sub-6 GHz frequency band. The proposed receiver front-end uses an N-path filter configuration and harmonic recombination at baseband. The RF receiver operates from 0.5 to 6.5 GHz to cover part of the upcoming Wi-Fi band. The amplifiers at baseband are decomposed and reconfigured to select the first and third harmonics of the switching frequency. In addition, the required N-path filter switching clock frequency is reduced by a factor of three by employing the 3rd harmonic, relaxing the LO frequency requirement as well. This allows the proposed receiver to have lower complexity and achieve low power consumption. Our design aim is to create a fully integrated receiver RF front-end, which is able to cover wide frequency range and to support a Sub-6-GHz 5G New Radio.

École de technologie supérieure

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High-resolution CMOS Neural Interface for Synchronized Optogenetics and Electrophysiology (Phase II)

Applications include: Health/Biomedical

In this project funded by NSERC, CIHR and the Weston Brain Foundation, we will develop a complete high-resolution multimodal CMOS brain implant on a chip. This system on a chip will provide both high-resolution multimodal electrophysiological recording and optogenetic photo-stimulation capability within a single chip for studying brain microcircuits of transgenic mice by enabling synchronized optogenetic stimulation and neural activity recording through a closed-loop system. In the phase I we implemented an innovative multichannel analog-to-digital interface prototype for this SOC. This first IC includes a 4-channel low-power and low-dropout LED driver to illuminate light-sensitized neurons in the brain, a 10-channel low-noise and power efficient analog-front-end to collect the evoked bioelectrical activity, 10 in-channel low-power third-order MASH Sigma-Delta modulators for analog-to-digital conversions, a CIC4 decimation filter and a digital controller module to control all building blocks. In phase II (this application), we intend to implement a low-power programmable digital controller to perform closed-loop optogenetics using the IC of the phase I. This controller will efficiently interface the first IC and perform complex neural signal processing to effectively close-the-loop between the neural recording interface and the optical stimulator. This controller will use programmable SRAM (memory compiler already provided by MUSE). It will be programmable in C language and compatible with the MSPGCC compiler. This proposed design represents the next step towards the realization of a complex mixed-signal brain implant on a chip including a microcontroller and all the necessary analog and digital modules to perform closed-loop optogenetics within a single chip. This SOC will be used to study the brain of freely behaving mice through an application paradigm related to the discovery of therapeutics against neurodegenerative diseases of aging.

Université Laval

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Online Spike Sorter

Applications include: Health/Biomedical

A multi-channel neuronal signal processor is designed for brain implants and neural prosthetic applications. It includes VLSI computational modules for data compression, data framing, and spike sorting.

York University
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RRAM-CMOS Platform for Machine Learning Hardware Acceleration

Applications include: ICT

In this project, machine learning hardware is to be designed, and more precisely, a scalable, flexible and innovative strategy for the implementation of the synaptic weight and the associated Multiply and Accumulate operation, one of the most demanding resource for efficient ML hardware will be developed. We will capitalize on an ideal balance between CMOS performance and specific features available with emerging memory devices (i.e., synapses). This project comprises of one chip for inference, and it comprise of CMOS analog and digital circuits like ADC, DAC, TIA, etc. along with RRAM crossbar array. We will implement a massively parallel and dense memory array via multiple passive crossbar interconnection in a system-on-chip strategy. We will show a fully on-chip RRAM based inference accelerator for machine learning applications.

University Of Toronto
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Special Purpose Controller Dedicated to a Visual Prostheses

Applications include: Health/Biomedical

A special-purpose controller is designed for a visual prosthesis being developed in our lab. It includes VLSI computational modules for data framing, and for the generation of stimulation pulses. the chip also includes mixed-signal circuitry for stimulation pulse generation.

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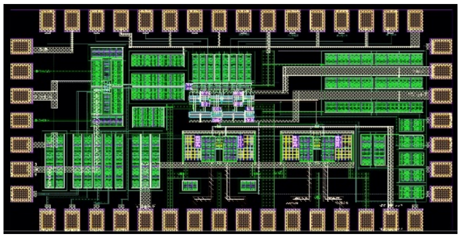
Wide Band Harmonic Rejection Receiver Using a Non-overlapped Clocking Scheme

Applications include: ICT (Wi-Fi in the 6 GHz band)



The unlicensed spectrum in the 2.4 and 5 GHz bands has led to the exponential growth of Wi-Fi. It is expected that Wi-Fi networks will carry almost 52% of global IP traffic by 2022, more than any other wireless technology. Also, the Wi-Fi Alliance has predicted an 800 MHz spectrum shortage by 2020, increasing to 1.12 GHz by 2025. To address this, the FCC has proposed widening the spectrum available for unlicensed usage in the 5.9 - 7.1 GHz band.

Accordingly, wireless systems and devices should be able to efficiently support the higher bands and new standards used in upcoming applications. This puts a strain on the RF front-end specifications, and many wideband transceivers have been proposed for different wireless standards operating in a wide range of frequencies, from MHz up to GHz.

There is a strong motivation to create a low-noise, wideband, low-power and low-cost receiver front-end that is able to support the 5.9 - 7.1 GHz frequency band. The proposed receiver front-end uses harmonic rejection non-overlapped clocking strategy. The proposed harmonic rejection (HR) receiver utilizes a non-overlapped clocking scheme that tunes the duty cycle in a single-path receiver to realize a notch frequency. In this HR receiver, the 1st, the 2nd and 3rd notches are placed at the 1st, 5th and 7th harmonic frequencies, respectively. In the proposed technique, instead of utilizing N-path filtering and harmonic recombination at the baseband to reject the unwanted harmonics, a harmonic rejection non-overlapped clocking scheme with a reset switch during the non-overlapping time is utilized in a single-path topology. The proposed receiver has lower complexity and achieves low power consumption. Our design aim is to create a fully integrated receiver RF front-end, which is able to cover wide frequency range and to support a 5.9 - 7.1 GHz band.

École de technologie supérieure

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Professor: Frédéric Nabki	Email: frederic.nabki@etsmtl.ca

Technology: 180-nanometer CMOS

TSMC 0.18µm CMOS

32-channel Activity-dependent Power-adaptive High-DR Neural Recording SoC with Lossless Data Compression for Energy-efficient Wireless Communication

Applications include: Health/Biomedical

The objective of this design is to build upon earlier foundation work by our group in regard to enablement of long-term ambulatory EEG monitoring using an implantable SoC for neurological diagnosis and real-time EEG monitoring. The proposed design will include multi-channel neural recording SoC with input-adaptive fully dynamic power consumption. This SoC will process the received data in real-time and applies a mixed-signal lossless compression algorithm on the chip to minimize the wireless data transmission throughput. To further maximize the efficiency of the design with respect to power consumption, we intend to include a novel front-end with a fully dynamic (zero-static) power consumption. This design will have significant advantages over conventional EEG monitoring systems which are very limited for long-term monitoring applications due to their high static power consumption and low battery life as well as unnecessarily high data rate which further constrains the usage. Once fully implemented, this design will enable patients to continue their daily activities/routines as their brain's EEG activity being monitored. Prolonged EEG recording has gained wider application in the diagnosis and management of infrequently occurring neurological symptoms and is also utilized in localization of the occurring zone such as epileptic seizures. We intend to validate (in vivo) the fabricated prototypes in collaboration with neurosurgeons and neurologists at Toronto Western Hospital. This project involves the design, simulation and experimental characterization of a long-term implantable EEG monitoring SoC solution and subcomponents such as ultra low-power wireless communications and inductive power reception.

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A CMOS with Dual-phase and Multi-frequency Lock-in-Amplifier for Bioimpedance Measurements

Applications include: ICT (electronics), Health/Biomedical

In this design, we will develop a CMOS integrated impedimetric biosensor for bioimpedance measurement in microbiology applications. Such a system will be a key to establish an effective and rapid method for the capturing and detection of the bacteria. The principle of this technique is based on measuring the small changes in the electrical impedance across the transducers resulted from the current variation in the presence of the metabolite activities of the living microorganisms. This design will provide high-sensitivity fabrication of a fully mixed-signal integrated circuit, fully packaged, and microscale measurement system on a single chip. The proposed design includes a high-sensitivity dual-phase lock-in amplifier (LIA) and automatic phase tuning with a high dynamic reserve capable of extracting the measured electrochemical impedance at small AC currents down to 1 pA and frequency sequences from 1Hz to 10KHz will be designed enabling assessment of bacteria growth and extracting the minimal impedance changes. In this configuration, firstly, a low-noise and high gain transimpedance amplifier (TIA) will amplify and transform the current to voltage. Then, the output voltage of the TIA will be down-converted to a lower frequency signal using a mixer and a local oscillator (LO) at the same frequency of modulated stimulation signal by multiplying to the orthogonal square signals. The resulting signal, which reflects the harmonic content of the LO, is filtered out by a low-pass filter (LPF) to extract the amplitude of the desired signal. The output will be digitized by a highprecision Delta-Sigma (??) over-sampling data converter to improve the SNR. The main advantage of lock-in architecture is the attenuation of low-frequency noise and is easy to implement on-chip.

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A High-frequency Mixed Signals Control System for Buck Converters

Applications include: Aerospace

This project presents a mixed-signal design of the control system used for the buck converters. In this approach, time is used as the processing variable, where voltage-mode and current-mode DC-DC converters are controlled by time-domain circuits, including voltage-controlled oscillators (VCOs), phase detectors, and voltage-controlled delay lines. This eliminates the need for wide bandwidth amplifiers, voltage comparators, and high-resolution ADCs, which results in lower power consumption, higher efficiency, and smaller silicon area. The proposed design aims to enhance the output voltage accuracy and exhibits small area and power consumption. In addition, this mixed signal control system will be working at high frequency to allow minimizing the size of the LC filter in the converter. Moreover, a multi-phase approach is employed to ensure the stability and low noise output.

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Professor: Mohamad Sawan Email: mohamad.sawan@polymtl.ca

A Novel Universal IoT Sensing Node

Applications include: Health/Biomedical

A novel universal IoT readout sensing node is implementation. The chip includes a universal interface that can sense capacitor, resistance, charge, voltage, and current quantities. On Chip two-point calibration is also included to improve performance. The majority of existing sensing node published in literature has a power consumption higher than 10 uW. The implemented circuit is designed to consume lower than 500nW.

Dalhousie University
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Adaptive Power Harvester

Applications include: Agriculture/Agri-Food

Adaptive power harvester.

Carleton University
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ASIC LabPET Scanner with Crystal Identification
Applications include: Health/Biomedical

This project aims to design a prototype of the new Ultra High spatial Resolution (UHR) positron emission tomography (PET) imaging scanner. The UHR scanner is the latest PET imaging scanner being designed at Université de Sherbrooke for brain imaging, based on the LabPET II technology platform developed to achieve high spatial resolution imaging using fully pixelated APD-based detectors and highly integrated parallel front-end processing electronics. This project will improve the LabPET II technology by enabling Depth-of-Interaction (DOI) capability for better and more uniform spatial resolution about 1.25 mm within large Field-of View as for brain scanner.

The ASIC submitted in this run is an upgrade of the previous 64-channel frontend ASIC, with better ESD protection, better stability to prevent oscillation of the analog channel at very high gain, event amplitude extraction with local Analog-to-Digital Converter (ADC) and additional timestamps for DOI, and real-time monitoring of the high voltage biases of the photodetector arrays. The communication protocol in this ASIC is also optimized to used only one LVDS port for data and command output to reduce the number of wires between the between the ASIC and the FPGA that harvest the data. It also allows a bus communication for up to 32 ASICs sharing the same clock and control signals. This run is to experimentally validate all the upgrades done in this design before fabricating the thousands of dies required to fully assemble the UHR scanner.

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ASIC LabPET2.5 Scanner Prototype
Applications include: Health/Biomedical

This project aims to design the 2nd generation of Positron Emission Tomography (PET) scanner at Université de Sherbrooke. The new scanner is based on a pixelized detector based on 1.2 mm x 1.2 mm advanced avalanche photodiode matrix, individually read with the proposed ASIC. The ASIC includes 64 channels. An energy resolution of ~22% and a timing resolution below 3 ns FWHM have been measured. The architecture is based on a Time-over-Threshold (ToT) scheme to extract both the timing and energy information along with a crystal identification capability for depth of interaction measurement. The validation of the design has been done with the previous run. This run is to assemble a full scanner prototype and validate the entire system up to full PET acquisition and image reconstruction.

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Design and Implementation of Capacitance Variation Based Biosensors
Applications include: Environment, Health/Biomedical

The fabricated chip includes three different novel approaches for sensing in biosensors. The proposed approaches, which independently implement different sensing systems, will deliver three different outputs. The proposed approaches contribute a big step towards lab on chip and system on chip, household biosensor for life science bio-marker detection.

University of Windsor
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EM Canary Circuit
Applications include: Aerospace, Automotive

Electromigration failure has been identified as one of the most contentious challenges faced by circuit designers in the next decade. This design will use the piezo-resistive properties of doped Silicon to detect and monitor void growth in buried metal interconnects. The metal interconnects are designed using active (current carrying) reservoir structures and geometry in the metal to accelerate electromigration-void-growth without elevated temperature. The low temperature is key because it allows us to design a metal segment to fail slightly faster without accelerating other failure modes as demonstrated in recent publication. The "canary" test segments can be designed to fail rapidly, or depending on the application, slightly faster than they would otherwise, using the current density and geometry of the active reservoir structure to tune the rate of void growth. The piezo sensors can then monitor the local mechanical stress fields in proximity to the metal interconnect and detect the void growth prognostically BEFORE a failure occurs. A 2x2mm area is needed to fit 64 sensor and test structures. Some of the proposed active reservoir segments will be designed to have near 500 µm of length, following calculations and simulation using the Blech criteria and Korhonen model. The length will guarantee void formation in a reasonable amount of time, with minimal current density during the experiment.

University of Waterloo
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Filtered Setpoint Proportional Control Strategy for Switched Capacitor DC/DC Converter
Applications include: ICT

The conventional proportional control approach inherently suffers from a number of drawbacks, the least of which is the static offset in its response. The conventional approach to solve this problem lies in either: (1) adding an integrator to the loop dynamics, hence modifying it and this might affect the desired transient behavior of the system; or (2) increasing the system gain, would decrease the stability of the system, due to the decreased phase margin.
In this new approach, a modified digital proportional controller is being presented, based on an online bisection algorithm. The new approach focuses on the modification of the setpoint to the system rather than the two prior solutions. The new approach is being designed for a 2:1 switched-capacitor converter as a preliminary test system.

Dalhousie University
Designer: Ahmed Alqallaf Email: sy963238@dal.ca
Professor: Kamal Elsankary Email: km229278@dal.ca

H infinity Time Base PID Controller for Interleaved Switched Capacitor DC/DC Converter
Applications include: ICT

Switched Capacitors (SC) converters have lent themselves to be the solution for partial and complete integration of DC/DC power conversion on-chip. The interest in these converters, even with their inherent losses, has spiked in the recent years due to the advancement achieved in the design of submicron systems. This work proposes new design approach for time based PID controller for four interleaved stages of switched capacitor DC-DC converter. The PID controller is designed using H8 optimization method for structured controllers. Such approach is able mitigate the effect of uncertainties in the system, that could arise in the form of PVT variation. Moreover, this design uses a highly linear resistive based transducer block to replace conventional GM (transconductors) block to drive the oscillators and delay line comprising the TB-PID. Power stage actuation is done via a pulse frequency modulated signal, thus to achieve such actuation a PWM-to-PFM converter is utilized. The interleaving of the power stage is intended to increase efficiency of the system.

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Professor: Kamal Elsankary Email: km229278@dal.ca

Leakage-Compensated Single-Photon-Counting Pixel for a-Se/CMOS X-ray Imagers

Application includes: Health/Biomedical

Offsets produced by leakage current through the amorphous selenium (a-Se) X-ray sensor layer in a-Se/CMOS imagers cause errors in multi-spectral single-photon-counting pixels. These errors reduce the performance of "colour X-ray" systems used in medical diagnostics. To combat this issue, we will implement a new approach to leakage current compensation in single-photon-counting pixels that has minimal impact on pixel dimensions and complexity. Our design will implement a small array of pixels and compensation circuits to fully demonstrate our approach. This work is part of a series of designs related to developing new a-Se/CMOS multi-spectral X-ray imagers.

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Low Power SAR ADC for Voice Signals

Applications include: Health/Biomedical (commercial)

The project is a SAR ADC design for voice signals which uses voice specifications to reduce power consumption.

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Olfactory Sensor on Chip

Applications include: Health/Biomedical

A novel chip designs that is compatible with depositing large numbers of chemically distinct sensing layers to create receptor analogs is developed. To adapt to the diversity of chemically distinct sensing layers, a reconfigurable interface with a large dynamic range is developed to accommodate many sensor types.

Dalhousie University
Professor: Kamal Elsankary Email: km229278@dal.ca

Oscillator-Based Electrochemical Biosensing Array

Applications include: Pharmaceutical (Biopharmaceutical, Chemical), Health/Biomedical

Impedance-based sensing techniques offer rapid, efficient and portable ways of imaging cells, particles and emulsions. Traditional EIS techniques are sensitive to processes occurring within the double layer formed at the interface of the electrode and the surrounding electrolyte. Further, the length of the double layer region is a function of the salt concentration of the solution. Probing beyond the double layer, in solutions containing nearly physiological salt concentrations, requires special techniques. One such technique is to operate sensing circuitry at high frequencies.

We are developing an oscillator-based CMOS sensor array in the 0.18 um process node that is capable of probing both within and outside the double layer. The proposed chip will operate at frequencies up to 200 MHz and will contain a 100x100-pixel array of on-chip 50-um^2 microelectrodes. Each pixel will contain a microelectrode and a current-starved ring oscillator coupled to the electrode to sense changes in the interfacial capacitance. Further, a novel readout architecture will be employed that incorporates a combination of time-division multiplexing (TDM) and frequency-division multiplexing (FDM). This will enable longer measurement times and improved frame rate compared to existing CMOS capacitive biosensor arrays.

University of Waterloo
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Respiratory Signal Extraction Based on Analog Lock-In Amplifier

Applications include: Health/Biomedical

One of the crucial tasks during continuous monitoring of respiratory mechanics using forced oscillation technique (FOT) is to accurately extract the FOT signal. Typically, this process is carried out by a conventional bulky speaker and higher order of FOT signal amplitudes at low FOT frequencies (<10Hz). Followed by a Pneumotach pressure and flow sensing, the resistance (real part) and the reactance (imaginary part) are obtained and further analyzed to extract information about the respiration behavior. Thus, FOT helps to diagnose and monitor various respiratory disorders, e.g., cessations in respiratory rhythm or reductions in breathing amplitude, i.e., sleep apnea.
To miniaturize this system, the FOT frequency need to be increased (to shrink the speaker) and its amplitude needs to be reduced for more patient convenience and ultra-low power (i.e., longer battery life). However, the signal-to-noise ratio (SNR) needs to be at acceptable level for such application which is challenging in the presence of breathing noise floor. Therefore, the proposed design implements a lock-in amplifier (LIA) as an analog front end to extract the known FOT signal even though it is buried under noise floor. In contrast to previous works, this approach is integrated with the ability to work at much higher frequencies which means portable device projection. Beside accuracy, power dissipation is another important factor to be considered when designing bioelectronics. As such, in this system the filtering part will be implemented based on switching capacitor. The LIA figures of merit include power dissipation, SNR, and die area.

Dalhousie University
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Semi Digital Auto Phase Aligned CMOS Optoelectronic Sensor with Ping-pong Auto-zeroed Lock-in Amplifier

Applications include: Health/Biomedical

In this design, we will develop a fully integrated CMOS optoelectronic setup consisting of an optical detector, a front-end circuitry, and a SAR ADC for fiber photometry applications. Such a system will be key to collect Ca+ ionic transfers resulting from brain activity within a freely moving photometry scheme. This system-on-chip (SOC) will provide high-sensitivity fluorescence optical recording along with optogenetic photo-stimulation for enabling optogenetically synchronized fiber photometry in neuroscience experiments. The system is comprised of a photodiode to detect very small fluorescence light power under low illumination. A novel automatic phase tuning lock-in amplifier (LIA) with a high dynamic reserve will extract the very low-input-power fluorescence calcium signals collected by the photodetector through a multimode fiber, which will be inserted into the brain of a freely moving animal to study the intact brain. LIAs can retrieve a signal from a negative input signal-to-noise ratio (SNR) where the desired input signal is buried in a considerable noise power many times higher than the desired input signal power. In an LIA circuit, the input signal is modulated with a carrier of known frequency and then sensed by a dedicated electronic interface. The signal is first amplified and band-pass filtered and then multiplied with a reference signal whose fundamental frequency is equal to that of the input signal. The resulted downconverted signal is filtered out with a narrow band low-pass filter to extract the amplitude and the phase of the desired signal. The designed LIA comprises a novel fully differential ping-pong autozerod trans-impedance amplifier (TIA), a band-pass filter, a variable gain amplifier (VGA), a mixer, a low-pass filter, a comparator, a phase DAC, a delay line, digital circuitry associated with the phase DAC to perform phase tuning in a new and elegant fashion, and a SAR ADC.

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Sensor Integrated Chip

Applications include: Health/Biomedical

Integrated circuit.

Carleton University
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Technology: 350-nanometer CMOS

AMS 0.35µm CMOS (OPTO)

A CMOS Image Sensor for Compressive Time-of-Flight (ToF) 3D Imaging

Applications include: Automotive, ICT (entertainment)

Three-dimensional (3D) sensing cameras have been adopted in various applications and products such as self-driving cars and face recognition sensors on mobile phones. This project focuses on 3D Time-of-Flight (ToF) based CMOS image sensor design for depth sensing. In comparison to the state-of-the-art ToF image sensors which usually have lower spatial resolution than their regular RGB image sensor counterparts, the proposed ToF image sensor design employs compressive sensing (CS) to improve both spatial and temporal resolution. The CS is realized on sensor by introducing exposure-programmable pixels capable of spatial-temporal coded exposure. With a significant reduction in the number of measurements required, through CS-based image reconstruction, the resultant depth map is generated with high resolution and intensity. Such CS-ToF image sensor design paves the way for a low-power and cost-efficient solution for 3D imaging applications with improved accuracy for object detection and tracking.

University of British Columbia
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AMS 0.35µm CMOS (High Voltage)

A Down Converting Level Shifter for BD429 Bus Interface.

Applications include: Aerospace

This design aims to implement a new topology of down converting level shifter. It is a key component in the receiver part of the BD429 data bus interface. The presented level shifter converts the level of the received signal from 5V to 1.8V. For implementing the level shifter, a diode-connected based structure is employed for the down converting part. A voltage controlled current source, and three inverters have been utilized to implement the proposed level shifter. The power supplies of the proposed level shifter in this are 5V and 1.8V as VDDH and VDDL, respectively. The operating frequency of this designed block is 1MHz.

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An Optimized Half-Bridge Based Transmitter for BD429 Data Bus Standard

Applications include: Aerospace

This design aims to implement a level shifter in addition to an optimized half bridge for transmitting data in BD429 data bus standard. The proposed design includes gate driver, optimized level shifter, two power MOSFETs, and optimized dead-time circuit. The data rate and the supply voltage are 1Mbps and 12V, respectively. The new proposed optimized dead-time topology is included to control the power MOSFETs and eliminate the shoot-through effect, in which the two power devices are on. This will decrease the power consumption and enhance the system efficiency. Since the main concept of dead-time part is based on a reconfigurable delay circuit, this transmitter has the capability to be employed for different required delay circuit.

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Design of Critical Blocks for Multi-MHz Gate Driver for DC-DC Converters in Avionic Applications

Applications include: Aerospace

The proposed designs in this works are critical blocks for gate driver, including level shifter, a under-voltage lock-out (UVLO), and a thermal shutdown (TSD) circuits.

- First, a novel level shifter circuit for high-frequency high-voltage (HV) gate-drives. The proposed level shifter is designed based on a capacitive coupler/current mirror/latch (CCL) structure which helps to extend operation voltage of floating supply into negative range, achieve < 1-ns and constant delay, and < 20pJ/transition. Additionally, common mode noise cancellers based on cross current mirror (CCM) and transmission gates (TGs) are also presented to enhance the dV/dt immunity up to 200V/ns.
- Second, low power and compact under voltage lockout (UVLO) and thermal shutdown (TSD) protection circuits using a novel bandgap comparator are designed. The proposed bandgap comparator, which is self-referenced, combines both of a high-accurate bandgap reference and a comparator into one single circuitry. A latch-controlled biasing technique is also presented, with the aims at reducing the static power consumption of the proposed bandgap comparator, thus, UVLO and TSD as low as possible.

École de technologie supérieure
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TSMC 0.35µm CMOS

CMOS-MEMS Sensors and SPM Development

Applications include: ICT (SPM advanced Nano tools such as Atomic Force microscopes (AFM) and Scanning Microwave microscopes (SMM)

a) Sensor Project: 0.35 um CMOS-MEMS actuators will be developed for wearable chemical hazard sensors applications. Additional devices are also included to test a new post-processing process.
b) SPM Project: Designs on this chip include devices with the potential for improved lateral resolution of single-chip CMOS-MEMS scanning probes microscopes (SPMs), manufactured using a novel, high-throughput process. These designs represent improvements over previous designs for this purpose. The designs on this chip represent potential improvements that would allow for enhanced quality and consistency using this new scalable process.

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AMS 0.35µm CMOS

Efficient LED Driver for Digital Displays

Applications include: Entertainment, Environment, ICT, Natural Resource/Energy

A new high-efficiency integrated LED driver will be fabricated in order to substantially improve the performance of digital LED displays.

Queen's University
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Fully Integrated Hall Based Digital Isolator

Applications include: Aerospace

This project aims to implement a System-on-Chip digital isolator using CMOS Hall effect sensor for Aircraft Applications. The design must satisfy certain electrical standards including isolation working voltage of few hundreds of Volts. It includes a coil driver, a CMOS Hall effect sensor, integrated planner coil on metal 4, multiple low noise amplifiers, comparator, and a coil driver. The design trend is using process intermetal SiO2 as an isolation barrier; a coil driver on the high voltage (HV) side drives an integrated spiral coil being formed by metal 4 which is placed on top of the integrated Hall effect sensor on the low voltage (LV) side, to generate signal dependent magnetic field. After sensing the field through Hall sensor, the signal gets amplified, high pass filtered, and a comparator generates the digital output. Minimum isolation level of 800 V, low propagation delay of 10ns, and high common mode transient immunity are expected.

Polytechnique Montréal
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Fully Integrated 10-Bit SAR ADC for System in Package (SiP) Sensor Interfaces (SenInts) in Aerospace Applications

Applications include: Aerospace

The goal of this project is to implement an analog to digital converter (ADC). This 10-Bit ADC is needed to complete the building blocks of system in package (SiP) in several sensor interfaces (SenInts). Four SenInts in VairCRAFT project need 10-Bit ADC block, namely: ANIV, ANOV, PO and BD429. To prevent copying the ADC design in the chip of each SenInt, having an independent ADC chip will save its area in all the SenInt chips. In addition, most of SenInts have HV and LV blocks. Consequently, one of the proposed solutions is to build a SiP of each SenInt based on different chips mainly HV chip, LV chip and the ADC chip. The implemented ADC is a 10-Bit successive approximation analog to digital converter (SAR ADC). The architecture is based on two resistor dividers. The converter operates in free running mode.

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High-Side and Low-Side Versatile Integrated Power Sensor Interface

Applications include: Aerospace

This project aims to build a high-side power sensor interface for driving current to different actuators in avionic applications. This interface is mainly a synchronous DC-DC converter -for stabilizing the variable input voltage supply coming from the plane composed of off-the-shelf passive and power components. An integrated dual-channel gate driver was implemented in the last AMS fabrication run to efficiently drive the DC-DC converter. A wide-bandwidth feedforward voltage-mode feedback is to be implemented in this fabrication run to control the system. The feedback includes a wide-bandwidth operational amplifier, a fast comparator and a tunable ramp generator. The primary objective is to test some innovative ideas in the design of feedback building blocks and evaluate the AMS HV-CMOS technology for integrating the rest of the interface.

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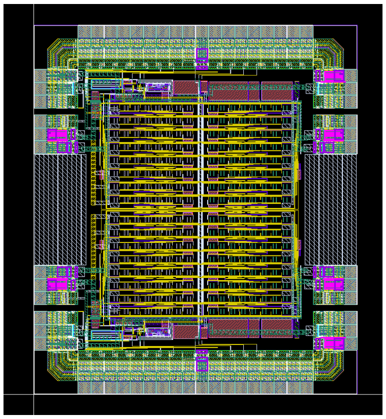
High Throughput Microfluidic-Microelectronic System for Accelerated Drug Development

Applications include: Health/Biomedical



Drug discovery and development is a costly and lengthy endeavor associated with low success rates and high cost. The major obstacle is the conventional preclinical safety evaluation of new drugs, vaccines and therapies with low success rates. There is therefore an urgent need to develop miniaturized innovative in vitro drug screening platforms that precisely measure cell responses to drugs in the microliter scale. In this project, we address this urgent challenge by developing a CMOS capacitive sensor array with a fast response and high dynamic range for higher precision in monitoring a wide variety of cells including immune cells such as neutrophils. The chip includes a large array of interdigitated electrodes on the topmost metal layer. The interface circuit is a novel extended CBCM differential capacitance to current interface together with an on-chip current to frequency converter and a frequency to digital converter. The multiplexing scheme is also novel and allows minimizing the parasitic elements and as a result increased resolution.

York University

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High Voltage Class D Power Amplifier for Versatile Aerospace Systems-on-Chip Integration

Applications include: Aerospace

The goal of this project is to implement a class D power amplifier circuit that provides a configurable output waveform. a Design for the open loop power amplifier is already implemented and the goal of the new design is to design a feedback system that removes the non-linearity of the open loop system, provide a more stable output, resist changes in the power supply and drive multiple loads with multiple values.

Polytechnique Montréal

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High Voltage Fully Integrated Closed Loop Class D Power Amplifier for Aerospace Applications

Applications include: Aerospace

The goal of this project is to implement a fully integrated closed loop class D power amplifier circuit that provides a configurable output waveform. The proposed design generates a staple output DC voltage according to the required voltage level, where the voltage level is controlled through the reference voltage in the feedback part. This generated output is used to drive aircraft's actuators including resolvers, force and pressure sensors, and electro-hydraulic servo valves (EHSV). The proposed class-D power amplifier topology consists of two main parts: feedforward and feedback. The latter removes the non-linearity of the open loop system and allows providing a more stable output. Also, it compensates for changes in the power supply and allows to drive multiple loads with multiple values. The open loop design consists of two subblocks, high side gate driver and low side gate driver operated by a two phase non-overlapping clock that generates the deadtime required to prevent short circuit current in the output stage. Each gate driver consists of two high-voltage level up shifter to convert the low-voltage level to the required voltage levels, two buffer chains, two level down shifters for the feedback circuit, and two power MOSFETs in the output stage.

Polytechnique Montréal

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Wide Dynamic Range Front-end Isolation Amplifier Using Hall Effect Sensor

Applications include: Aerospace

This project aims to implement a programmable gain System-on-Chip amplifier to be used in both current monitoring using shunt resistor as well as differential voltage sensing for Aircraft Applications. The design must satisfy certain electrical standards including isolation working voltage of few hundreds of Volts. It includes a coil driver, a CMOS integrated magnetic field sensitive MOSFET (MAGFET), mid band programmable gain amplifier (PGA), integrated photodiodes, and few logic blocks. The design trend is using process intermetal SiO2 as an isolation barrier; an amplifier on the high voltage (HV) side modulates and drives an integrated spiral coil being formed by metal 2 and 3. Placed on top of the integrated MAGFET on the low voltage (LV) side, these coils generate signal dependent magnetic field. After sensing the field through MAGFET, the signal gets amplified and filtered through a PGA and Anti-Aliasing Filter. Furthermore, clock synchronization between the HV and LV side is performed through an optical synchronizer consisting of an on-chip diver, receiver, and on-board LED. Minimum isolation level of 430 V, offset lower than 0.8 mV, input dynamic range of 0.1-20 V, lower power consumption and small area are expected.

Polytechnique Montréal

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Professor: Mohamad Sawan   Email: mohamad.sawan@polymtl.ca

VCO-based Comparator for Sensor Interface Applications

Applications include: Aerospace

This project aims to implement a versatile Systems-on-Chip integrated sensor interface for Aircraft Applications. This design trend is switching to frequency domain instead of voltage domain and utilize the architectures which involve more digital blocks such as time or frequency domain comparator. A new frequency comparator architecture is presented in this design which consists of two voltage-controlled oscillator (VCO) in the range of MHz, and a phase frequency detector (PFD). The VCO is responsible for receiving the voltage-domain signals and transforming it to a signal with time (frequency)-domain information. In other words, the VCO output represent the input signals to the comparator by their oscillation frequency. A PFD can monitor the difference between the reference frequency and the VCO output and generates two signals to define which input has higher frequency and phase. Furthermore, a pulse generator structure based on the CMOS thyristor-based delay element is used for fault state detection to provide an internally control on the functionality of sensor interface. This structure can provide a stable and constant pulse regardless to its input performance. Since the utilized thyristor-based delay cell is controlled by current instead of voltage, not only we can provide any pulse width in rage of nano to microsecond but also it has high power supply noise rejection and less sensitivity to temperature variation and consumes low power consumption.

Polytechnique Montréal

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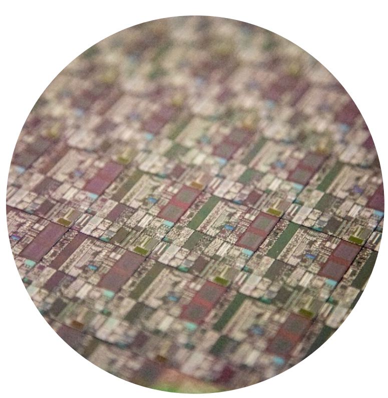

PHOTONICS & OPTOELECTRONICS

CMC and CNDN deliver a program that includes fabrication access to silicon photonics platforms for chip-level monolithic integration, methodologies for scalable integrated photonics design, and graduate-level training in the design, fabrication and testing of photonic integrated circuits. Looking forward, CMC will enable more photonics integration with a strong emphasis on putting more photonic functionality onto each chip, integrating photonics with other technologies including microelectronics, and using both hybrid and monolithic approaches.

Technology: 90nm CMOS-Photonics

GF 9WG

Cov2 Biosensor

Applications include: Health/Biomedical

A COVID-19 biosensor.

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Silicon-Photonic Isolator Replacement

Applications include: ICT

Circuit is the first isolator replacement in SOI process that does not need any process change. It mitigates the parasitic reflections going to the laser source caused by subsequent photonic devices using silicon-photonic and CMOS electronics, not requiring any magneto-optic materials.

University of British Columbia
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Technology: Silicon Photonics – Active & Passive Silicon on Insulator

AMF Silicon Photonics

2-micron-modulation

Applications include: ICT

This project aims to design silicon photonic (SiP) modulators for high-speed application operated at 2µm. As a new window, designing two-micron-operating modulator is critical for optical communication, especially considering this fact that using whole the C and L bands cannot meet the growing demands. Our group has successfully demonstrated SiP Mach-Zehender modulators for high-speed applications on C band. Thus, in this project, we wish to step forward for exploiting new spectrum of mid infrared (MIR). In this regard, we will design a modulator for MIR operational wavelength considering different criteria such as modulation loss, modulation speed, and efficiency. We will include several design variations to measure different conditions.

Université Laval
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Arbitrary Wavefront Generator Based on Orbital Angular Momentum (OAM) Modes

Applications include: ICT

Spatial light modulator (SLM) is widely used in varies free-space scenarios. With the ability to impose spatial varying modulation on a beam of light, SLM adjusts the intensity and the phase of the beam to make it best suits the optical system. The SOI platform provides the flexible tuning on both the amplitude and phase of the light, making it possible to design a circuit that function as an on-chip SLM.

In [1], a 64×64 phase array was demonstrated to generate arbitrary far-field radiation patterns dynamically. In our case, as we're targeting at optical fibre transmission and mode multiplexing, the primary goal is to generate the following mode sets with the same circuit – Linear Polarized (LP) modes, Orbital Angular Momentum (OAM) modes and Cylindrical Vector (CV) modes. Based on our previous work on OAM generator and multiplexer [2][3], a tunable mapping circuit is added so that the generated OAM modes can be converted to LP modes and CV modes by applying proper tuning voltage. Following this design methodology, by expanding the circuit to support higher order modes, an arbitrary wavefront generator can be achieved on SOI.

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Deep Learning, High performance Computing, and RF Signal Processing with Silicon Photonics

Applications include: ICT

We are designing several test systems to implement reconfigurable analog operations using silicon photonic devices. Applications include high efficiency computing, artificial neural networks, and radio frequency communications. We will also continue our development of monolithically integrating electronic components into the IME platform. We propose novel hardware to address fundamental obstacles in traditional computational hardware and signal process. Our primary objectives include:

1) Continued development of photonic Recurrent Neural Network (RNN).
2) Novel design of high-speed photonic weight bank for Artificial Neural Network (ANN) and matric-vector multiplication (MVM) applications
3) Novel design of hybrid Graphen-Si MRR to enable excitable dynamical systems for Spiking Neural Networks (SNN) applications
4) Continued development of generalized microwave photonic linear filter for ultra-wideband RF signal processing applications.

Artificial Intelligent (AI) systems have revolutionized our computational approach to pattern recognition within many applications such as speech and video processing, equalization, and prediction/forecasting. The photonic ANNs we process to develop will enable a significant acceleration in the capabilities of machine learning for high-speed real-time applications. The high-speed photonic weight bank offers a highly efficient matric-vector multiplier for deep learning applications as well as an acceleration to learn speeds of ANNs. Microwave photonics is a technological platform that addresses the shortcomings of traditional RF engineering and enables high-speed processing at extreme dynamic ranges. This technology has the potential to create spectrally efficient reconfigurable wireless networks which can communicate over the entire spectrum without need of band specific hardware.

Queen's University

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Fiber Bragg Grating Modulators

Applications include: ICT

In support of the exponential growth of bandwidth demand, we recently reported several silicon photonic (SiP) travelling wave Mach-Zehnder modulator (TWMZMs) enabling up to 200 Gb/s transmission using pulse amplitude modulation (PAM). The objectives of the proposed designs are to explore the potential of slow-wave modulators, Bragg grating assisted Micro-ring modulators, and Silicon dual-polarization Mach-Zehnder switches. Also, other devices will be studied as a part of the process design kit development (PDK). The circuits being proposed have not been built in a SiP platform and if successful would be extremely valuable to the SiP community. The probability of success is high because we employ known good (i) SiP device designs, and (ii) digital signal processing algorithms.

McGill University

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Four-channel SiP SDM Transmitter

Applications include: ICT

This project aims to demonstrate a four-channel space-division multiplexing (SDM) transmitter using slow-light silicon photonic modulators. The design features a high bandwidth density and a high-power efficiency. We target both short-reach systems in designing PAM modulators and long-haul transmissions in designing IQ modulators. Instead of using conventional Mach-Zehnder modulators (MZMs) and micro-ring modulators (MRMs), we employ a novel concept: MZMs assisted by cascaded Bragg grating resonators (MZM-BGRs). In these modulators, BGRs slow down optical waves in a broad (a few nanometers) optical bandwidth, enhancing phase modulation across a relatively wide operational wavelength range to achieve more stable operation compared to single-resonance-based modulator (e.g., MRM). Our previous work experimentally achieved MZM-BGRs with an ultra-compact footprint and proved their low power consumption, nm-scale operating wavelength range, and high-speed operation [1- 5]. For short-reach applications, we design MZM-BGR with two series lumped electrodes for PAM4 formats without the need for digital-to-analog converters (DAC). We placed four of these modulators in parallel with a careful RF engineering to supress inter-channel crosstalk. We also design IQ modulators based on MZM-BGRs integrated with travelling wave electrodes to generate quadrature amplitude modulation (QAM) signals. These modulators are multiplexed by a mode division multiplexing (MDM) that generate TE0, TE1, TE2, and TE3 modes and coupled to a few-mode elliptical fiber that was designed and fabricated in COPL [11]. In our design, we also explore transmission un-coupled multi-core fiber. Having on-chip MDM enables us to demonstrate a fully integrated SDM transmitter.

Université Laval

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Fully Analog Photonic Brain-inspired Processor

Applications include: Defence (Safety, Security), Health/Biomedical

Brain-inspired machines are typically used to solve highly complex tasks which pose problems to other classical computational approaches. The development of Artificial Intelligence (AI) is directly related to the computational power and speed offered by intelligent devices. Currently, it takes hundreds of CPUs and GPUs, and many weeks to train neural networks in digital hardware. Over the last six years, this compute power has doubled every 3.5 months. Traditional CPUs and GPUs will not be powerful enough to train the neural networks of the near future. Therefore, we use artificial neural networks (ANNs) as brain-inspired machines that allow us to tackle complex problems efficiently.

The primary objective of this chip tape out will be to demonstrate machine learning tasks through matrix operations and the inclusion of an on-chip analog memory (Resistive Random Access Memory and a transistor based Random Access Memory) for the first time. A secondary objective will be to add a 4x4 reconfigurable Mach-Zehnder Interferometers (MZI)-based photonic processor. This step will open the possibility to perform online regression-based training on-chip for some specific neural networks such as Reservoir Computers.

Queens University

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Hybrid Silicon-chalcogenide Components for Non-linear Optics and Kerr Frequency Combs

Applications include: Defence (Safety, Security), Health/Biomedical

The goal of this project is to develop non-linear photonics components based on a novel silicon-chalcogenide hybrid integration scheme. The chalcogenide glass will be deposited in-house as a post-process step to act as an efficient non-linear media while the silicon components will be used for optical functionalities such as chip-wide routing, phase delay, filtering and others. The primary objective of the project is to demonstrate a hybrid, tunable monolithic Kerr frequency comb spanning from the near- to the mid-infrared.

Université Laval

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Integrated Silicon photonic transceiver and stable laser sources for Quantum Key Distribution

Applications include: ICT

We propose to design, implement and characterize a fully integrated silicon photonic Quantum Key Distribution (QKD) transceiver for secure communication applications. This is important because it is the SiP platform which offers the promise of low-cost mass production and the co-integration of control electronics that will be required to optimize real system performance. Recently a group in Singapore demonstrated fully integrated continuous variable QKD system on chip as demonstrated in [1]. Our focus of this project is to first design and characterize the individual components of the QKD transceiver such as single photon detectors, single photon sources and WDM optical filters, and consequently use the developed components to build a fully integrated QKD transceiver with Discrete variable encoding which can achieve high rates of secure key bits for longer QKD links. The design is going to constitute two chips, with each dedicated to the receiver and stable laser sources, respectively.

University of British Columbia

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Professor: Lukas Chrostowski	Email: lukasc@ece.ubc.ca

Integrated Subsystems for CWDM Transceivers and Smart Edge

Applications include: ICT

The design aims to fulfill the optical transceiver subsystems. It includes a SiP transceiver for CWDM systems; and a smartedge subsystem for passive optical network (PON) service overlay. For the SiP transceiver, the design meet 100G-CWDM4 and 400G-CWDM8 MSA standards by providing the complete SiP transceivers. The compactness of the design and power consumption aims at fulfilling more stringent packaging standards such as QSFP-DD, OSFP and/or COBO footprints specifications. The chip supports two input schemes: 1) a main bus for pre-MUXed light and 2) an onboard MUX for discrete sources. The chip also features key components to achieve a standard, cross-platform control technique. The chip also contains a complete tunable DEMUX at the receiver. Finally, the chip contains a complete set of metrology structure aiming at validating and improving wafer-level yield and performances. For the smart-edge with heterogeneous service overlay in PON, the design includes a series of cascade microring modulators, performing two functions: 1) generate the subcarriers for service overlay and 2) overlay the signal. It also includes a mechanism to monitor the working status and to stabilize the thermal-sensitive ring modulators. Two variations of different ring modulators are designed for comparison.

Université Laval

Designer: Xun Guan	Email: xun.guan.1@ulaval.ca
Professor: Leslie Rusch	Email: Leslie.rusch@gel.ulaval.ca

Monolithic Laser Designs based on microcavities and Bragg gratings

Applications include: Automotive, ICT

Light emission is a primary challenge in silicon photonics. With this design we aim to develop a new economic and scalable approach to light sources on silicon using doped and undoped thin films deposited on the silicon chip via post-processing steps. The design focuses on fabricating structures that can potentially be used to design integrated laser cavities on a silicon platform using AMF technology, by post processing deposition of rare earth doped tellurium oxide. Three main structures are used to attempt this, including micro-trench cavities, silicon ring resonators and distributed Bragg reflector cavities.

McMaster University

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Professor: Jonathan Bradley Email: bradljd@mcmaster.ca

Multi-mode Microring Modulators for Spatial Division Multiplexing Application

Applications include: ICT

Our design submission is a Polarization Sensitive Optical Modulator/Demodulator for high-speed spatial division multiplexing (SDM) network. The target modulation bandwidth is 20 GHz for each polarization, which will provide variable data transmission rates of greater than 100 Gbps for full-load work condition. The design not only offers a compact, cost-effective silicon photonic solution for high-speed optical transceivers but also provides the ability to configure the transceiver to adapt to variable transmission formats and bandwidths to maximize spectral efficiency. The main technical challenge of the design is to realize the multi-mode concentric microrings scheme in the modulator circuit which can be configured to pick different polarization at the same resonance from the bus silicon waveguide and then modulate/demodulate this specific signal. This technique will add another freedom beside the wavelength in the conventional Wavelength Division Multiplex (WDM), which potentially can further extend the communication bandwidth by 10 times or an order magnitude. Our modulator consists of at least two concentric microring resonator with different radii. Each microring is made by a rib-slab waveguide with different rib width. To achieve high-speed modulation, we will use depletion-mode pn junctions embedded in the rib waveguide.

University of Alberta

Designer: Yang Ren Email: yr@ualberta.ca

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Optical Neural Network

Applications include: ICT (optical computing)

We propose a photonic neuromorphic circuit using In-Resonator Photoconductive Heaters (IRPH). The IRPH acts as photonic neurons and will be used to demonstrate practical applications in nonlinear optimization, quadratic programming, and deep learning acceleration. The designs include simple circuits for demonstration of the electrical controls, and complex circuits for demonstration of scalability. We propose to demonstrate such system in an integrated, packaged platform using cutting edge photonic wire bonding technology.

University of British Columbia

Designer: Stephen Lin Email: sl0804@ece.ubc.ca

Professor: Lukas Chrostowski Email: lukasc@ece.ubc.ca

Orbital Angular Momentum (OAM) Mode Generator and Multiplexer

Applications include: ICT

This project aims at designing a broadband on-chip orbital angular momentum (OAM) mode generator and multiplexer that can be used in ultra-high-capacity WDM × SDM transmission system. The design follows the same methodology as our previous demonstration [1][2], while several improvements have been made to reduce the insertion loss, increase the purity of the modes and increase the number of supported modes. The design can act as both Mux and Demux, so the performance can be fully characterized in real transmission system. Our goal with this design is to demonstrate a broadband OAM generator and multiplexer that supports 34 modes in both circular polarizations (would be the highest ever demonstrated). Apart from that, we are planning to use 1/3 of the space to gather rich enough datasets from various star coupler designs to build a comprehensive model with predictable performance on SOI platform. Most existing models for star coupler grossly approximate the internal field response, with this comprehensive model, we can further increase the modal purity of our design.

Université Laval

Designer: Daniel Robin	Email: Daniel.robin.1@ulaval.ca
Professor: Wei Shi	Email: wei.shi@gel.ulaval.ca

Segmented Silicon Photonic Modulator for Coherent Optical Transmission

Applications include: ICT (optical communication)

The proposed design is a segmented Mach-Zehender modulator (MZM) for ultra-high-speed modulation beyond 100 Gbaud. It consists of a number of phase shifter segments with a length of 1mm or less that are cascaded in a push-pull structure with distributed RF driving signals. The purpose of this segmented design is to maximize the bandwidth of the MZM with a very low Vp (< 2V) that is compatible to CMOS drivers. As a typical issue in the MZI-based modulator, the power received to each arm is not identical. This asymmetry comes from fabrication imperfections leading to unbalanced couplers and insertion losses over the MZI branches. We solve this issue by designing a tunable power splitter in an MZ interferometer configuration to maximize the extinction ratio, which is critical for coherent transmission where the modulator is biased at the null. Furthermore, several test structures for characterizing the phase shifter will be designed.

Université Laval

Designer: Abdolkhalegh Mohammadi	Email: abdolkhalegh.mohammadi.1@ulaval.ca
Faculty: Wei Shi	Email: wei.shi@gel.ulaval.ca

Silicon Photonics based RF on-chip Antennas Integration with Photodetector and Si-epi Ge Photodetectors at 1550 nm

Applications include: ICT

Project 1: The on-chip unification of photonics and RF wireless components is a profound step in the continuous effort of system designers to extend the advantages of silicon integration to higher frequencies. An antenna integrated into a silicon photonics (SiPh) chip will reduce electrical power loss by averting the frequency dependent off-chip parasitic interconnects between the photodetector and the antenna. In addition, the on-chip antenna will eliminate the need for a matching network to transform the system impedance to 50 O. Therefore, antenna impedance becomes one of the design parameters that further provides design flexibility. In this project, a meander monopole antenna working at 22GHz integrated with Ge photodetector is proposed on the silicon based photonic integrated circuit (PIC). Before this, we had successfully demonstrated the feasibility of RF on-chip antenna on PIC working at 15 GHz. The intended application of this proposed design is short reach high frequency wireless communication between two SiPh.

Project 2: The photodetector (PD) is regarded as the interface between the optical circuit and the electrical circuit. In short-reach applications, the receiver noise is the dominant noise source. A PD with larger responsivity improves the receiver sensitivity and further reduces the required electrical gain of the downstream circuits. In this project, several configurations of Ge photodetectors with vertical cavity have been designed. Without contributing to the devices’ parasitic capacitance, an attempt of increasing the responsivity was made by the inclusion of the Bragg grating reflector at the end of the Si-slab. Thus, a fraction of the light will be sent back to the absorption region which is not absorbed in its first pass. Moreover, to further reduce the optical loss, multi-finger like contacts have been used instead of off-centered continuous contacts. It will enhance the responsivity at a cost of higher resistance.

McGill University

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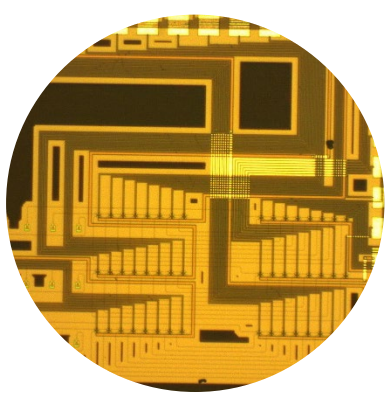
Professor: Odile Liboiron-Ladouceur Email: odile.liboiron-ladouceur@mcgill.ca



Technology: Silicon Photonics Training – Active Silicon on Insulator

Examples of projects using SiEPICfab (Silicon Electronic-Photonic Integrated Circuits Fabrication)

Advanced Micro Foundry (AMF) SOI

- A Broadband Silicon Photonic Sensor Based on RF Spectrum Readout
  University of British Columbia | Designer: Leanne Dias | Professor: Lukas Chrostowski

- Arbitrary Temperature Profiles Using Segmented Micro-Heaters
  Université Laval | Designer: Jonathan Cauchon | Professor: Wei Shi

- Automatic Control Over PN-junction MRR and Extended FSR-MRR Enabling High-Speed Optical Processing
  University of British Columbia | Designer: Mohamed Shemis | Professor: Lukas Chrostowski

- Coherent Radio Over Fiber (RoF) Transceiver with Mode-Division Multiplexing (MDM)
  University of Ottawa | Designer: Ruoshi Xu | Professor: Jianping Yao

- Endless Phase Shifters
  University of British Columbia | Designer: Connor Mosquera | Professor: Lukas Chrostowski

- High Speed PAM-4 SOI Ring Modulator
  McGill University | Designer: Sunami Sajjanam Morrison Professor: Odile Liboiron-Ladouceur

- Hybrid SOI/Fiber Active Mode-lock Comb Laser
  Université Laval | Designer: Jean-Michel Vallée | Professor: Wei Shi

- Integrated Dual-Polarization Mach-Zehnder Switch on Standard SOI Platform
  McGill University | Designer: Jinsong Zhang | Professor: David Plant

- Integrated Tunable PT-symmetric Optoelectronics Oscillator
  University of Ottawa | Designer: Yu Huang | Professor: Jianping Yao

- Micro-Comb Laser in Silicon Photonics
  McGill University | Designer: Rifat Nazneen | Professor: Odile Liboiron-Ladouceur

- On-chip Chirped Spectral Shaper Utilizing a Linearly Chirped Waveguide Bragg Grating
  University of Ottawa | Designer: Peng Li | Professor: Jianping Yao

- Optical Frequency Comb Generation Using Mach-Zehnder Modulators
  Université Laval | Designer: Abdolkhalegh Mohammadi | Professor: Wei Shi

- Proposal for a Micro Ring Modulator Design in Silicon Photonics
  McGill University | Designer: Santiago Bernal | Professor: David Plant

- Segmented Si Modulator
  Université Laval | Designer: Zibo Zheng | Professor: Wei Shi

- Si-Ge lateral p-i-n Photodiode
  McGill University | Designer: Md. Mahadi Masnad | Professor: Odile Liboiron-Ladouceur

- Silicon Mach Zehnder Modulator
  McGill University | Designer: Adam Helmy | Professor: David Plant

- Silicon On-Chip Equalizers
  Université Laval | Designer: Alireza Geravand | Professor: Wei Shi

- Silicon Photonics Broadband Passive Components
  CMC Microsystems | Designer: Luhua Xu | luhua.xu@cmc.ca

- Spatially Modulated Narrowband Bragg Filters
  Carleton University | Designer: Kevan MacKay | Professor: Winnie Ye

- Thermally Tunable Fano Resonator with Double Injection
  University of Ottawa | Designer: Zheng Dai | Professor: Jianping Yao

- WG Under Oxid Etch < 0.4 Ge Enclosure and Via2
  University of British Columbia | Desigenr: Hossan | Professor: Lukas Chrostowski

MEMS

Canada's MEMS community is strong including two MEMS foundries: Teledyne DALSA (Bromont) and Teledyne Micralyne (Edmonton), centres for pilot fabrication, packaging, and system development (INO, C2MI, ACAMP), and several NRC research centres. Additionally, some 40 nanofabrication facilities at universities are used for research and proof-of concept demonstrations of new equipment and processes. CNDN design activity is strong with 387 CMC fabricated MEMS designs over the last 5 years.

Technology: PiezoMUMPs

MEMSCAP PiezoMUMPs

3D MEMS Actuators for Efficient Planar Optical Switching

Applications include: ICT

We request CMC resources to demonstrate novel hybrid MEMS actuators that combine both piezoelectric and electrostatic actuators in the same MEMS device. Our new design uses piezoelectric actuation provided through PiezoMUMPs process to enable out-of-plane actuation of our MEMS platform while using electrostatic actuation for planar XY displacement of the same platform. The planar displacement mechanism through electrostatic actuation was previously designed, fabricated and tested through the PiezoMUMPs process. The results obtained were successfully published in the Journal of Micromachines (Sharma et al. 2019). The MEMS platform demonstrated last year is integrable with optical waveguides and filters such as Bragg gratings and ring resonators on the same chip. However, recent simulation-based analysis and the critical information shared by our industrial partner AEPONYX shows that if silicon nitride-based optics is integrated on the proposed MEMS platform, it causes residual stress in the platform due to silicon nitride thin film and causes out-of-plane bending of the platform.

In this new MEMS design, we aim to provide out-of-plane actuation to the central platform that accommodates waveguides to compensate for any optical misalignment due to the residual stress caused by silicon nitride thin films. This is designed to be done through piezoelectric actuation while electrostatic actuation will be used again for X & Y direction displacement. MEMS device design demonstration through PiezoMUMPs technology gives us the unique opportunity to validate our 3D hybrid MEMS actuator design with the use of both piezoelectric and electrostatic actuation in the same design. Successfully demonstrated MEMS designs can be integrated with silicon nitride-based optics by our industrial partner AEPONYX through their custom fabrication process flow. 3D motion of the MEMS platform in X, Y & Z directions shall further the state-of-the-art translational switching MEMS platform.

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3D Micropositioner for Optical Platforms

Applications include: ICT (optical communication)

In this project, we will propose a novel micro-mechanical structure with 3 degrees-of-freedom as a 3D optical aligner. The proposed structure, which operates based on piezoelectric and electrostatic phenomenons, will be able to move along x-, y-, and z-axis upon applied a relatively low-voltage, i,e., less than 100 V. Furthermore, the structure can eliminate impacts of the optical waveguide stress. Hence, these unique features make the device applicable for integrating in the optical systems to provide perfect alignment between different sectors of the system.

École de technologie supérieure
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A Broadband Bistable Piezoelectric Energy Harvester
Applications include: Environment

This design has to be used as a MEMS piezoelectric energy harvester converting parasitic environmental vibration into useful electrical energy. The proposed structure has an M-shaped geometry with the integration of two proof masses at the links for reducing the operational frequency. It also can benefit from the second mode shape due to the second degree of freedom using the auxiliary beam. Both low-frequency operation and broadband features are tried to be addressed in this design. The model is validated by both analytical modeling and finite element simulation to satisfy expected results.

Memorial University
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A Broadband Low-frequency Piezoelectric Energy Harvester
Applications include: Environment

The design is going to be used as a vibration-based piezoelectric energy harvester, which converts parasitic environmental vibration into the useful electric charges. The proposed structure has an optimized serpentine geometry with the integration of several proof masses at the links for reducing the operational frequency and improving energy conversion efficiency. Thanks to three degrees-of-freedom, the second and the third mode shapes can be located close to each other, providing a wide-band MEMS energy harvester. The model is validated by both analytical modeling and finite element simulation to satisfy expected results.

Memorial University
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An Approach to Validate Electro-thermally Actuated Power MEMS Switches Toward Sustaining High Breakdown Voltage and Power Handling
Applications include: Aerospace

The pathway towards a reliable electro-thermal actuated power MEMS switch using this technology requires a systematic approach to mitigate the effect of joule heating. Here, we implement a chevron (V-shaped) actuator design that incorporates isolation stage and heat sink beams in order to mitigate the elevated temperature across the floating contact.

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An M-Shaped Wideband Piezoelectric Energy Harvester
Applications include: Environment

The design is going to be used as a vibration-based piezoelectric energy harvester, which converts parasitic environmental vibration into the useful electric charges. The proposed structure has an M-shaped geometry with the integration of three proof masses at the links for reducing the operational frequency and improving energy conversion efficiency. Thanks to three degrees-of-freedom, the second and the third mode shapes can be located close to each other, providing a wide-band MEMS energy harvester. The model is validated by both analytical modeling and finite element simulation to satisfy expected results.

Memorial University
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An Optimized Bistable Piezoelectric Energy Harvester

Applications include: Environment, ICT

The design is going to be used as a vibration-based piezoelectric energy harvester, which converts parasitic environmental vibration into the useful electric charges. The proposed structure has an optimized M-shaped geometry with the integration of two proof masses at the links for reducing the operational frequency and improving energy conversion efficiency. Thanks to three degrees-of-freedom, the second and the third mode shapes can be located close to each other, providing a wide-band MEMS energy harvester. The model is validated by both analytical modeling and finite element simulation to satisfy expected results.

Memorial University
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Design and Manufacturing of Temperature Compensated MEMS Resonators for High Q-factor

Applications include: Automotive, Environment, ICT

MEMS resonators are designed with compensated temperature to minimize or cancel off the frequency drift due to the temperature rise. Mainly, for the temperature compensation purpose. Different geometric and mechanical approaches will be applied on the MEMS resonators to compensate the frequency drift which is due to the temperature rise. Using thermal actuators will be the principal idea for this purpose. The designs of IMPTSMK2 are also brought with different frequency ranges and with optimized design.

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Development of Systems for Accelerated Bacteria Collection and Detection (ABCD) Using Electrokinetics

Applications include: Environment, Health/Biomedical

The design is microcantilever biosensors to detect various bioparticles such as E.coli bacteria. The target is to detect them in real-time, point-of-care and very low concentrations. The cantilever will be driven by AC electric potential applied on the piezoelectric material. The resonance frequency shift of the cantilever will be monitored when the bioparticles are deposited on it.

Queen's University
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Frequency-tunable Vibration Energy Harvester Microsystem for Industrial IoT Applications

Applications include: Environment, Entertainment, ICT, Health/Biomedical

The Internet of Things presents many technology opportunities, and it is expected that this market will reach some 400 billion US dollars by 2024 (Yole Développement). Home automation, industry and the environment to name only a few examples will continue to benefit from this new technology. For example, the use of sensors to obtain information on temperature, air and water quality is more and more widespread. However, both its sensors and the wireless communications circuits used to communicate with the Internet requires power. In this context, in recent years, there has been a growing interest in vibration energy harvesters in the industry. Indeed, energy in this form is omnipresent in industrial environments and could therefore be used to power the sensors and the communication systems. However, industrial machines which are an example of energy sources have variable vibration frequencies. This therefore complicates the task of energy harvesters, which must be tunable in order to be able to adapt to the environment to recover vibrational energy at different frequencies and thus maximize efficiency. The objective of this project is to study the possibility of developing frequency tunable piezoelectric energy harvesters for IoT applications in industrial environment. More precisely, energy harvesting will be undertaken using piezoelectric energy harvesting.

Université du Québec à Montréal (UQAM)
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High Performance Breath Mode MEMS Resonator with Self Temperature Compensation

Applications include: Automotive, Environment, Health/Biomedical

Temperature plays an important role in the MEMS resonator performance. The MEMS resonator quality can affect the system that is working with the reference clock which is provided by this resonator. In the last decade, many approaches have been presented to overcome the frequency drift during changing ambient temperature. Many types of researchers use costly and complex techniques to make the frequency steady in different ranges of temperatures. In this design, we are going to use a mechanical approach using Silicon orientation to compensate for the temperature rise. In this design, I designed a temperature sensor to sense the die temperature in order to have a reference and accurate measurement. The novelty of this design is aimed to be the passive approach to compensate for the temperature without using energy and also use different input and output to select the best temperature-compensated design. The devices will be used for timing and sensing applications.

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High Power MEMS Switches for Avionic Application

Applications include: Defence (Safety, Security)

The main objective of this research work is to develop reliable micro-electromechanical systems (MEMS) switches for high power switching applications in avionic systems. In this approach, a DC contact MEMS switch based on chevron (V-shaped) thermal actuation technique is designed in-order to achieve higher isolation and power handling capabilities, lower insertion loss and on-state resistances. This idea will provide the advantage of reaching higher breakdown voltages.

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Improving the Digital Tuning of Cantilevers

Applications include: Automotive, Environment, Natural Resource/Energy

Working toward the improvement of resonators. These designs aim to improve the previously characterized designs. Tuning the resonant frequency of a resonator is also usually impossible after fabrication. The proposed design should allow modification of the resonant frequency in real time. This is achieved using Electrostatically Controlled Clamps. Previous promising results were achieved however, the performance was hindered by the curling of the cantilevers.

École de technologie supérieure
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Integrating MEMS and Terahetrz Signal Processing

Applications include: ICT (communication, signal processing)

Working toward the integration of MEMS devices with Terahertz signal processing to reduce the footprint of future communication technologies. In this design we aim to create a matrix of addressable elements, each element should act as a differentiator for THz signal. For this it should have a displacement of about 1um.

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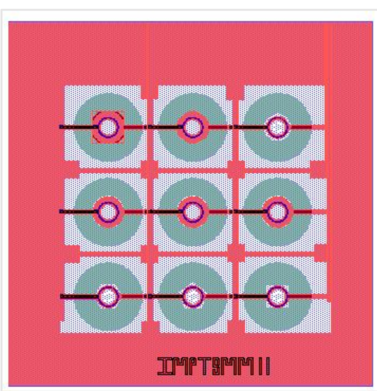
MEMS Micromotor for Optical Swept Filters

Applications include: Health/Biomedical



The designs proposed are related to micro-opto-electro-mechanical systems and more specifically to develop MEMS micromotors for optical micromechanical systems based swept wavelength component. The micromotor is designed to rotate an integrated polygon mirror at very high speeds inside an optical filter for optical coherence tomography (OCT) applications. The basic design consists of stator poles that surround a circular rotor which rotates about a center bearing. The goal is to achieve optimal torque and angular velocity by fine-tuning the parameters of the design such as the number of poles on the rotor and the stator, as well as reducing friction by using a novel geometrical form for the rotor. The current designs are upgraded version of previous fabricated MEMS micromotors with modification in rotor and stator design for higher torque and smaller motor footprints.

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MEMS Positioners for Photonic Integrated Circuits
Applications include: ICT

The proposed waveguide positioner is based on utilizing 3D MEMS actuators to provide dynamic alignment to active components in photonic integrated circuits (PICs). The design consists of a platform supported by flexible beams, to host the positioned waveguide, in addition to actuators responsible of deflecting the platform in various directions to couple the light to the active components or to tune optical filters.

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Micro Linear Displacement Sensor (v3.0)
Applications include: Aerospace, Automotive

This project is continuation of [two designs]. The goal is to optimize a novel type of MEMS displacement sensor that is based on resistive contacts. Gemotric amplification will be used to increase the displacement in different directions. This technique allows a better precision in measurement by reducing the minimal displacement of 2 um imposed by the technology. The Si-Si contact model was previously updated with the first generation of MEMS strain sensor. The MEMS device will be integrated with an embedded system to have complete strain sensor system. Different MEMS structures based on contact resistances will be investigated to find the most suitable for strain sensor applications. A post-processing might be done to coat the structures will metal to reduce the overall contact resistance is required. The design will allow to measure displacement from 2 um to 20 um.

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On-chip MEMS Based Tunable Laser
Applications include: ICT

The project is targeting the realization of a tunable laser, in a low cost and integrated version, with a wide tunability. By circumventing some limitations of tunable diode lasers, it will both leverage and enhance optical networks, in particular for datacenters. In order to achieve this, an efficient (mono-order) diffraction grating is designed to provide a wavelength selection and is associated with a MEMS to provide the mechanical tunability, by displacing an input waveguide which is changing the incidence angle of light on the diffraction grating. This forms an on-chip external cavity to be used as part of the tunable diode laser. Specifically, here, we are designing electrostatic MEMS as comb drive actuators to provide the required displacement of the input waveguide supported by a cantilever beam. In previous designs, it has been seen an unwanted rotation of free-standing part that caused pull-in state. Thus, in this new design we did some modifications on the springs holding mechanism of the movable part.

Concordia University
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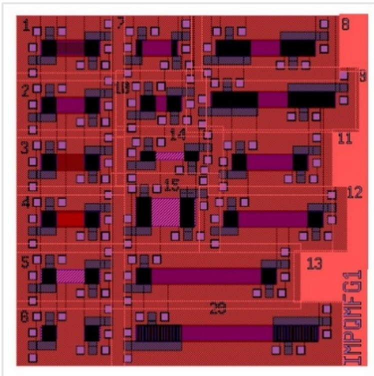
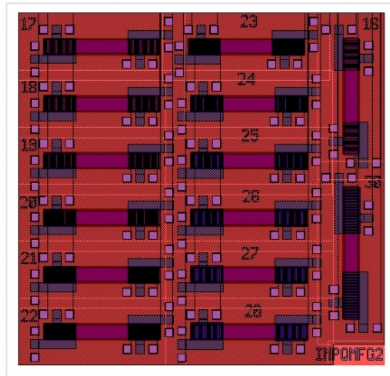
Optimization of Electrode Configuration for Surface-acoustic Wave Microfluidic Sensors
Applications include: Environment, Health/Biomedical

Surface-acoustic wave sensors are a demonstrated means to achieve sensing of chemical or biological species in microfluidic systems. In the context of lab-on-a-chip implementations, power efficiency and signal sensitivity are of utmost importance. This design attempts to investigate the impact of electrode configuration on surface acoustic love-wave transmission power and linearity, with the goal of determining an optimum design.

Université du Québec à Montréal (UQAM)
Professor: Paul-Vahe Cicek Email: cicek.paul-vahe@uqam.ca

Optimization of Surface Composition for Surface-acoustic Wave Microflluidic Sensors
Applications include: Environment, Health/Biomedical

Surface-acoustic wave sensors are a demonstrated means to achieve sensing of chemical or biological species in microfluidic systems. In the context of lab-on-a-chip implementations, power efficiency and signal sensitivity are of utmost importance. This design attempts to investigate the impact of surface composition on surface acoustic love-wave transmission power and linearity, with the goal of determining an optimum design.

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PMUT Resonators for Multiple Sensors Characterization
Applications include: Automotive, Defence (Safety, Security)

Multiple designs of PMUT resonators to be applied as distance, temperature, density and humidity sensors, to be characterized in different conditions and define the best geometry for each kind of sensor. In future work these tests will be applied for the design of real sensors.

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Single Input-Single Output Inertial Gas Sensors
Applications include: ICT, Other

This project is a part of research collaboration between the University of Waterloo and Sapienza University (Rome, Italy).

This project presents a novel multi-beam, multiple resonance, single input-single output MEMS gas sensor. It consists of a U-shaped shuttle mass carrying two microcantilever resonators and excited electrostatically via sidewall electrodes. The device exploits the nonlinear dynamic such as cyclic-fold bifurcation as a detection mechanism.

University of Waterloo
Designer: Ayman Alneamy Email: aalneamy@uwaterloo.ca
Professor: Eihab Abdel-Rahman Email: eihab@uwaterloo.ca

Study of Silicon Orientation Impact on MEMS Resonator
Applications include: Automotive, Environment, ICT

MEMS Resonators are designed with different orientation respect to silicon wafer crystal axes. fundamentally, Silicon is an anisotropic material, with elastic behavior that depends on the orientation of the structure, picking the proper value of E (Young's module) for silicon can resemble to be a daunting task. The crystal orientation of the silicon in a silicon wafer has notable impacts on the microfabrication characteristics of the wafer. By changing the resonator orientation E will change properly, therefore, the TCF1 can change respectively. In a specified direction, the resonator has the minimum drift while sweeping the temperature. In conclusion, the right orientation of the resonator will have a minimum effect on TFC1 of the resonator.

École de technologie supérieure
Designer: Amir Reza Kolahdouz Moghaddam Email: amir-reza.kolahdouz-moghaddam.1@ens.etsmtl.ca
Professor: Frédéric Nabki Email: frederic.nabki@etsmtl.ca

Study of The Effect of Temperature on MEMS Resonator (Lame Mode)
Applications include: Environment, Health/Biomedical, ICT

MEMS Resonators are designed with different orientation respect to silicon wafer crystal axes. fundamentally, Silicon is an anisotropic material, with elastic behavior that depends on the orientation of the structure, picking the proper value of E (Young's module) for silicon can resemble to be a daunting task. The crystal orientation of the silicon in a silicon wafer has notable impacts on the microfabrication characteristics of the wafer. By changing the resonator orientation E will change properly, therefore, the TCF1 can change respectively. In a specified direction, the resonator has the minimum drift while sweeping the temperature. In conclusion, the right orientation of the resonator will have a minimum effect on TFC1 of the resonator.

École de technologie supérieure
Designer: Amir Reza Kolahdouz Moghaddam Email: amir-reza.kolahdouz-moghaddam.1@ens.etsmtl.ca
Professor: Frédéric Nabki Email: frederic.nabki@etsmtl.ca

Study the Effect of Temperature on Silicon and Created a Temperature Compensated Resonator

Areas of application include: Automotive, Environment, Health/Biomedical

Temperature plays an important role in the MEMS resonator performance. The MEMS resonator quality can affect the system that is working with the reference clock which is provided by this resonator. In the last decade, many approaches have been presented to overcome the frequency drift during changing ambient temperature. Many types of research use costly and complex techniques to make the frequency steady in different ranges of temperatures. In this design, we are going to use a mechanical approach using Silicon orientation to compensate for the temperature rise. In this design, I designed a temperature sensor to sense the die temperature in order to have a reference and accurate measurement. The novelty of this design is aimed to be the passive approach to compensate for the temperature without using energy and also use different input and output to select the best temperature-compensated design. The devices will be used for timing and sensing applications.

École de technologie supérieure
Designer: Amir Reza Kolahdouz Moghaddam Email: amir-reza.kolahdouz-moghaddam.1@ens.etsmtl.ca
Professor: Frédéric Nabki Email: frederic.nabki@etsmtl.ca

Technology: PolyMUMPs

MEMSCAP PolyMUMPs

Design of Ultrasonic Transducers with Repulsive-Force Actuation

Applications include: Automotive, Entertainment

The project consists of implementing novel designs of capacitive micro-machined ultrasonic transducers with repulsive-force actuation. The focus of the research is to explore the possibility of fabricating such devices in the standard PolyMUMPs process. The goal of the project is to control the electrodes using electrostatic actuation to achieve a repulsive membrane deflection. This run is considered the first stage of the project as a proof of concept. Several variations of the design will be implemented to investigate the effect of the different structural parameters on the performance of the devices

McGill University
Designer: Roufaida Bensalem Email: rofaida.bensalem@mail.mcgill.ca
Professor: Mourad El-Gamal Email: mourad.el-gamal@mcgill.ca

CMUT Sensors and Arrays

Applications include: Agriculture/Agri-Food

MEMS Gas sensors are fabricated using PolyMUMPs fabrication technique and are coated with designed sensing materials for detection of VOCs in complex environment.

University of Windsor
Professor: Arezoo Emadi Email: arezoo.emadi@uwindsor.ca

CMUT Gas Sensor - Increased Gap

Applications include: Environment

CMUT gas sensor with increased gap height.

University of Windsor
Professor: Arezoo Emadi Email: arezoo.emadi@uwindsor.ca

Gas Sensors

Applications include: Environment

Novel gas sensors have been designed to detect toxic gases in the air. A polymeric sensing material will be used to enhance the sensor sensitivity. New design features were modified and added to the existing design to improve the sensors capacity to carry the detecting polymer and eliminate the stiction. PolyMUMPs fabrication process will be used to validate many experimental to proof the sensor functionality.

University of Waterloo
Designer: Mohamed Arabi Email: msaaarab@uwaterloo.ca
Professor: Eihab Abdel-Rahman Email: eihab@uwaterloo.ca

High Q MEMS Resonator Development
Applications include: ICT

Micro-resonators are widely used in MEMS based accelerometers and gyroscopes as the main sensing element due to their lower size, cost, and power consumption. The resonating mass needs to be keep vibrating during operation. The vibration performance of the micro-resonators depends on a parameter known as quality factor. Quality factor is defined as the ratio between stored energy to dissipated energy. A high-quality factor means it can keep vibrating without pumping further energy. For high precision applications a higher quality factor in range of millions is desired. In this project high Q factor MEMS resonator devices are developed.

University of Windsor
Designer: Ankang Wang Email: wang119f@uwindsor.ca
Professor: Jalal Mohammed Ahamed Email: jahamed@uwindsor.ca

High Q MEMS Resonator for Gyroscopic Applications
Applications include: ICT

Micro-resonators are widely used in MEMS based accelerometers and gyroscopes as the main sensing element due to their lower size, cost, and power consumption. The resonating mass needs to be keep vibrating during operation. The vibration performance of the micro-resonators depends on a parameter known as quality factor. Quality factor is defined as the ratio between stored energy to dissipated energy. A high-quality factor means it can keep vibrating without pumping further energy. For high precision applications a higher quality factor in range of millions is desired. In this project high Q factor MEMS resonator devices are developed.

University of Windsor
Professor: Jalal Mohammed Ahamed Email: jahamed@uwindsor.ca

M3CMUT Ultrasonic Transducer Fabrication
Applications include: Health/Biomedical

Multiple moving membrane capacitive Micromachines ultrasonic transducers (M3CMUT) are fabricated using the three available polysilicon layer in PolyMUMPs process.

University of Windsor
Professor: Arezoo Emadi Email: arezoo.emadi@uwindsor.ca

MEMS Gas Sensors
Applications include: Agriculture/Agri-Food

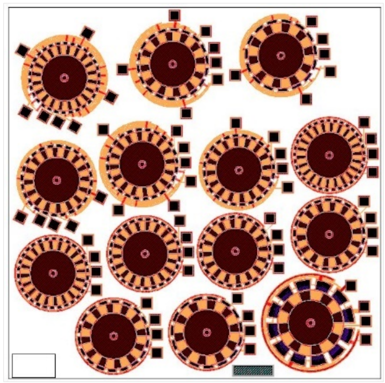
MEMS Gas sensors are fabricated using PolyMUMPs fabrication technique and are coated with designed sensing materials for detection of VOCs in complex environment.

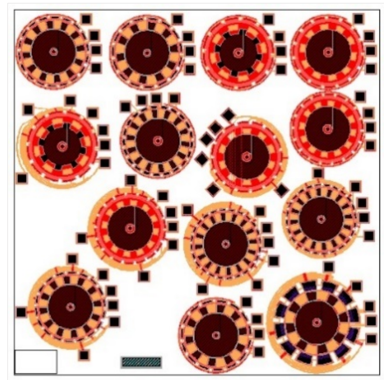
University of Windsor
Professor: Arezoo Emadi Email: arezoo.emadi@uwindsor.ca

MEMS Micromotor for Optical Swept Filters

Applications include: Health/Biomedical

The (two) designs proposed are related to microoptoelectromechanical systems and more specifically to develop MEMS micromotors for optical micromechanical systems based swept wavelength component. The micromotor is designed to rotate an integrated polygon mirror at very high speeds inside an optical filter for optical coherence tomography (OCT) applications. The basic design consists of stator poles that surround a circular rotor which rotates about a center bearing. The goal is to achieve optimal torque and angular velocity by fine-tuning the parameters of the design such as the number of poles on the rotor and the stator, as well as reducing friction by using a novel geometrical form for the rotor. The current designs are upgraded version of previous fabricated MEMS micromotors with modification in rotor and stator design for higher torque and smaller motor footprints.





École de technologie supérieure
Designer: Amit Gour Email: amit.gour.1@ens.etsmtl.ca
Professor: Frédéric Nabki Email: frederic.nabki@etsmtl.ca

MEMS Switches and Sensors

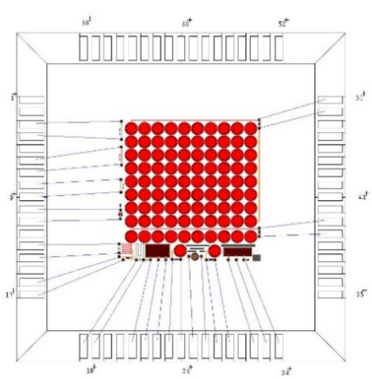
Applications include: Defence (Safety, Security)

MEMS switches and actuators for RF and gas sensing applications.

University of Waterloo
Designer: Edward Jin Email: g9jin@uwaterloo.ca
Professor: Raafat Mansour Email: rrmansour@uwaterloo.ca

MEMS Ultrasonic Transducers for Space Application (with Cornell and NASA)

Applications include: Aerospace



Air Coupled moving membrane transducers for imaging on MARS in collaboration with Cornell/NASA.

University of Manitoba
Designer: Mayank Thacker Email: thacker5@myumanitoba.ca
Professor: Douglas Buchanan Email: douglas.buchanan@umanitoba.ca

Phase Comparator and Mode Shape Suppression in MEMS Resonators
Applications include: Automotive, Environment

Working toward the improvement of resonators and their applications. A design has been prototyped using simulation and real-life measurements in the PiezoMUMPs technology. Switching to PolyMUMPs technology will allow improvement of the performances.

École de technologie supérieure
Designer: Mathieu Gratuze Email: mathieu.gratuze@etsmtl.ca
Professor: Frédéric Nabki Email: frederic.nabki@etsmtl.ca

Superhydrophobic and Oleophobic Surfaces – Synthesis and Applications
Applications include: Aerospace, Automotive

Superhydrophobic and Oleophobic Surfaces. Synthesis and Applications.

University of Windsor
Designer: Zirui Liu Email: liu18w@uwindsor.ca
Professor: Vesselin Stoilov Email: vstoilov@uwindsor.ca

Technology: ESP Electronic Sensor Platform

ESP (3IT)

Biosensing JFET Platform with Printed Graphene Gate and Customizable Functionalization

Applications include: Health/Biomedical

The goal of this research project is to create a novel type of biosensor by combining two complimentary microfabrication techniques. First, a silicon chip containing JFET transistors with an open gate will be fabricated using traditional microfabrication techniques that are highly reliable and give good performance. Second, a graphene layer will be inkjet printed onto the open gate of the transistor. The graphene will act as a sensor transducer to sense gases as well as pH or biological species in solution such as insulin. Graphene has a large surface area and good electrical properties, which makes it the ideal transducer material. The graphene can be functionalized to detect various biological species. Combined with the flexibility of inkjet printing, this will allow different biosensors to be fabricated easily next to each other on the same silicon platform. This compact sensor array will be ideal for lab-on-chip applications and point-of-care diagnostics. The project is based on CMC Microsystems’ Open-Gate Silicon JFET Transistor Technology Platform. The long-term vision is to extend this fabrication platform with the inkjet post-processing so that it can be adapted to any functionalization desired by CMC users.

York University

Designer: Mehraneh Tavakkoli Gilavan	Email: mehitvk@eecs.yorku.ca
Professor: Gerd Grau	Email: grau@eecs.yorku.ca

On-the-Spot Detection and Speciation of Cannabinoids using CMC Open-Gate Silicon JFET Platform

Applications include: Other (cannabis)

This project will aim to integrate cannabinoid sensitive material combinations with the Open-Gate Silicon JFET Platform developed by CMC. We have previously used these materials in combination with organic thin film transistor (OTFT)-based sensor devices with promising result (patent filed). The CMC platform is potentially a more promising architecture for downstream commercialization compared to the previously used OTFT platform. Our preliminary prototypes can detect, quantify and differentiate tetrahydrocannabinol (THC) and cannabidiol (CBD), as well as their acids, the major components of cannabis producing psychoactive and medicinal outcomes, which are of concern to the producer, consumer, and regulator alike. When exposed, to THC and CBD resulting in a change in electronic properties that modifies the electrical response of the OTFT. This response is unique compared to other cannabinoids (e.g., CBG), and other controls (cigarette smoke, e-cigarettes, wood smoke, etc.). We propose that these electronic interactions will similarly modify the response of the JFET devices. Our goal is to translate our sensor materials to this JFET platform and achieve equal or better sensor response as found while using the OTFT platform. Translating our sensor materials to the JFET platform will allow for their more robust use and bring us closer to scalable commercialization. This project will involve 2-3 HQP and will provide a multidisciplinary training opportunity and build on practical microfabrication skills as well as lead to experience working with new sensor platforms. The researchers are working with a startup company (Ekidna Sensing) to commercialize the research into cannabinoid sensors and this project could greatly further that work. Canada is becoming a global leader in the Cannabis industry and the commercialization of this sensor tool will help maintain our competitive advantage.

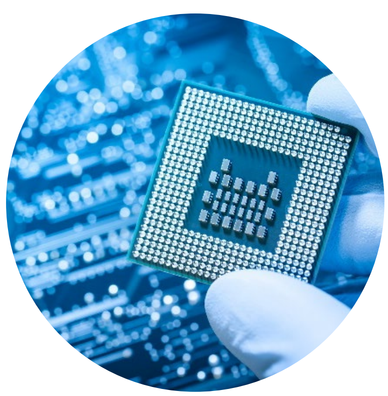
University of Ottawa
Designer: Nicholas Boileau Email: nboil052@uottawa.ca
Professor: Benoit Lessard Email: benoit.lessard@uottawa.ca

Cancer Cell Proliferation Tracking Using JFET platform

Applications include: Health/Biomedical

In this design, an array of JFET sensors are implemented and individually connected to the bonding pads. The electrical fixture is developed using off-chip elements to address each sensor and read the variation of double layer capacitance, dielectric e or charges above the sensors. This device allows us to monitor the effect the cell directly on the chip.

York University
Designer: Abbas Panahi Email: panahimech@gmail.com
Professor: Ebrahim Ghafar-Zadeh Email: egz@cse.yorku.ca



MNT (Micro-Nano Technology) FABRICATION

CMC's MNT Portal - www.cmc.ca/MNT - includes more than **40** MNT facilities located at universities across Canada offering custom fabrication - mask generation, etching, materials deposition, lithography, and characterization. This report describes designs that benefited from CMC's MNT Portal financial assistance.

MNT: MEMS

- Facile fabrication of an ultra low-power electrically gated magnetic field sensor on monolayer graphene
  Application: ICT (nanotechnology, sensors) | MNT: Laboratory of Micro and Nanofabrication (LMN)
  Institut national de la recherche scientifique (INRS)
  Designer: Atiye Pezeshki | E: atiye.pezeshki@inrs.ca
  Professor: Emanuele Orgiu | E: emanuele.orgiu@inrs.ca

- Metal oxide ion-gated transistors for sensing applications
  Application: Environment (Environmental sensors) |
  MNT: Thin Film Physics and Technology Research Center (GCM)
  Polytechnique Montréal

  Professor: Fabio Cicoira | E: fabio.cicoira@polymtl.ca

- Suspended NbSe2 and MoS2 Membranes: optics and electro-mechanical coupled circuits in the quantum regime
  Application: ICT | MNT: NanoFabrication Kingston
  Queen's University
  Designer: Kurt Tyson | E: kurt.henry.tyson@gmail.com
  Professor: Robert Knobel | E: knobel@queensu.ca

- Repulsive force Out-of-Plane comb drive micromirror for application in AGV navigation
  Application: ICT, Other (LIDAR, AGV Navigation, facial/gesture recognition) |
  MNT: Toronto Nanofabrication Centre (TNFC)
  Ryerson University
  Designer: Trevor Tai | E: tstai@ryerson.ca
  Professor: Siyuan He | E: s2he@ryerson.ca

MNT: Microelectronics

- Organic Thin-Film transistors for pressure sensing application
  Application: Health/Biomedical, ICT (organic electronics) | MNT: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Michael Facchini-Rakovich | E: mf4@ualberta.ca
  Professor: Manisha Gupta | E: mgupta1@ualberta.ca

MNT: Microfluidics

- Airborne ascospore detection for the forecasting of Sclerotinia Stem Rot of canola
  Application: Agriculture/Agri-Food, Environment | MNT: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Pedro Duarte | E: duarteri@ualberta.ca
  Professor: Jie Chen | E: jc65@ualberta.ca

- Development of a portable microfluidic platform technology for single-cell capture, detection, and sequencing
  Application: Health/Biomedical | MNT: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Lukas Menze | E: menze@ualberta.ca
  Professor: Jie Chen | E: jc65@ualberta.ca

- Microfluidic device for high-throughput optical dielectrophoresis cytometry characterization of cells
  Application: Pharmaceutical (biopharmaceutical, chemical) | MNT: Nano Systems Fabrication Laboratory
  University of Manitoba
  Designer: Azita Fazelkhah | E: fazelkha@myumanitoba.ca
  Professor: Greg Bridges | E: gregory.bridges@umanitoba.ca

MNT: Micromachining

- Fabrication of PEDOT organic electrochemical transistors by electropolymerization
  Application: Health/Biomedical | MNT: Thin Film Physics and Technology Research Center (GCM)
  Polytechnique Montréal
  Designer: Michel Bilodeau-Calame | E: michel.bilodeau-calame@polymtl.ca
  Professor: Fabio Cicoira | E: fabio.cicoira@polymtl.ca

- Folded ridged half-mode waveguide bandpass and bandstop filters
  Application: Aerospace, Automotive, ICT | MNT: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Thomas Jones | E: trjones@ualberta.ca
  Professor: Douglas Barlage | E: barlage@ualberta.ca

- Silicon micromachined waveguide millimeter-wave switch using photo-induced solid-state plasma
  Application: Aerospace, ICT | MNT: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Thomas Jones | E: trjones@ualberta.ca
  Professor: Douglas Barlage | E: barlage@ualberta.ca

- Electrodeposited PEDOT transistors
  Application: Health/Biomedical | MNT: Thin Film Physics and Technology Research Center (GCM)
  Polytechnique Montréal
  Designer: Jo'Elen Hagler | E: joelen.hagler@polymtl.ca
  Professor: Fabio Cicoira | E: fabio.cicoira@polymtl.ca

- Study of defect migration in metal-oxide for thin-film transistors
  Application: Health/Biomedical (foldable electronics, sensors) |
  MNT: Thin Film Physics and Technology Research Center (GCM)
  Polytechnique Montréal
  Designer: Sanyasi Bobbara | E: 7srb@queensu.ca
  Professor: Fabio Cicoira | E: fabio.cicoira@polymtl.ca

MNT: Nanotechnology

- A design of carbon nanotube field emission X-ray device for improving the uniformity and lifetime
  Application: Health/Biomedical (medical imaging, industrial flaw detection, cancer diagnosis) |
  MNT: Quantum NanoFabrication and Characterization Facility (QNFCF)
  University of Waterloo
  Designer: Jiayu Alexander Liu | E: jiayu.alexander.liu@uwaterloo.ca
  Professor: Tze-Wei (John) Yeow | E: jyeow@uwaterloo.ca

- A pre-clinical evaluation of protein nanoparticles for X-ray triggered drug release
  Application: Health/Biomedical (nanomaterials for drug delivery) | MNT: 4D Labs
  Simon Fraser University
  Designer: Henry Kang | E: hjkang@sfu.ca
  Professor: Byron Gates | E: bgates@sfu.ca

- Carbon Nano Tubes for coulomb explosion
  Application: Health/Biomedical (cancer diagnosis, biomedical imaging (tomosynthesis, computational tomography, etc.)) | MNT: Quantum NanoFabrication and Characterization Facility (QNFCF)
  University of Waterloo
  Designer: Zhemiao Xie | E: z73xie@uwaterloo.ca
  Professor: Tze-Wei (John) Yeow | E: jyeow@uwaterloo.ca

- Development of non-linear optical techniques for assessing the properties of gold nanoparticles and their assemblies
  Application: Health/Biomedical | MNT: 4D Labs
  Simon Fraser University
  Designer: Junko Hashimoto | E: jhashimo@sfu.ca
  Professor: Byron Gates | E: bgates@sfu.ca

- Fabrication of Au-Cu nanostructured alloy films for the plasmonically-assisted CO2 reduction reaction
  Application: Automotive, Defence (Safety, Security), National Resource/Energy | MNT: 4D LABS
  Simon Fraser University
  Designer: Albert Adserias | E: albert_adserias@sfu.ca
  Professor: Gary Leach | E: gary_leach@sfu.ca

- Fabrication of flexible nanogenerators for wearable applications
  Application: Health/Biomedical | MNT: 4D LABS
  Simon Fraser University
  Designer: Amin Abnav | E: amin_abnavi@sfu.ca
  Professor: Michael Adachi | E: mmadachi@sfu.ca

- Fabrication of metal oxide thin-films patterns containing nanoparticles by photochemical metal organic deposition lithography
  Application: ICT, Other (photonic devices as components in light emitters and/or sensors) | MNT: 4D Labs
  Simon Fraser University
  Designer: Rana Faryad Ali | E: kelsey_duncan@sfu.ca
  Professor: Byron Gates | E: bgates@sfu.ca

- Fabrication of plasmonic nano-cavities
  Application: Defence (Safety, Security), ICT (quantum computation) | MNT: 4D LABS
  Simon Fraser University
  Designer: Sasan V. Grayli | E: svosoogh@uwaterloo.ca
  Professor: Gary Leach | E: gary_leach@sfu.ca

- Flexible organic electrolyte gated transistor with low operating voltage and light sensing application
  Application: ICT (organic photo sensing devices) |
  MNT: Thin Film Physics and Technology Research Center (GCM)
  Polytechnique Montréal
  Designer: Mona Azimi | E: mona.azimi@polymtl.ca
  Professor: Fabio Cicoira | E: fabio.cicoira@polymtl.ca

- High frequency bipolar junction transistors-based circuits using 2D materials beyond graphene
  Application: ICT | MNT: 4D LABS
  Simon Fraser University
  Designer: Abdelrahman Askar | E: aaskar@sfu.ca
  Professor: Michael Adachi | E: mmadachi@sfu.ca

- Integrated nano/bio platform for sensitive and high throughput detection of biological analytes (PHASE 3)
  Application: Healthcare/Biomedical | MNT: Thin Film Physics and Technology Research Center (GCM)
  McGill University
  Designer: Mahsa Jalali | E: mahsa.jalali@mail.mcgill.ca
  Professor: Sara Mahshid | E: sara.mahshid@mcgill.ca

- Inversion of singlet and triplet excited states in organic molecules using plasmonic patch antennas
  Application: ICT | MNT: Thin Film Physics and Technology Research Center (GCM)
  Polytechnique Montréal
  Designer: David Myers | E: david-michael.myers@polymtl.ca
  Professor: Stéphane Kéna-Cohen | E: s.kena-cohen@polymtl.ca

- Micro- and nano-structured materials to study protein and cell interactions for improved blood contacting devices
  Application: Health/Biomedical | NanoFabrication Kingston
  Queen's University
  Designer: Kyla Sask | E: kyla.sask@queensu.ca
  Professor: Carlos Escobedo | E: carlos.escobedo@queensu.ca

- Micro- and nano-structured nickel catalysts for the oxygen evolution reaction using a templating technique
  Application: Natural Resources/Energy | MNT: 4D Labs
  Simon Fraser University
  Designer: Alexi Pauls | E: alexi_pauls@sfu.ca
  Professor: Byron Gates | E: bgates@sfu.ca

- Superconducting aluminum air bridges in one liftoff and one EBL step
  Application: ICT | MNT: Quantum NanoFabrication and Characterization Facility (QNFCF)
  University of Waterloo
  Designer: Noah Janzen | E: ncjanzen@uwaterloo.ca
  Professor: Adrian Lupascu | E: alupascu@uwaterloo.ca

- Superconducting aluminum air bridges for wiring flux qubits
  Application: ICT | MNT: Quantum NanoFabrication and Characterization Facility (QNFCF)
  University of Waterloo
  Designer: Michal Kononenko | E: mkononen@uwaterloo.ca
  Professor: Adrian Lupascu | E: alupascu@uwaterloo.ca

- Thin film lithium-ion batteries for careful study of cathode coatings
  Application: Automotive | MNT: 4D Labs
  Simon Fraser University
  Designer: Kelsey Duncan | E: kelsey_duncan@sfu.ca
  Professor: Byron Gates | E: bgates@sfu.ca

- Transistors based on carbon nanotube arrays
  Application: ICT (organic electronics) | MNT: Thin Film Physics and Technology Research Center (GCM)
  Polytechnique Montréal
  Designer: Mona Azimi | E: mona.azimi@polymtl.ca
  Professor: Fabio Cicoira | E: fabio.cicoira@polymtl.ca

MNT: Photonics

- Carbon nanotube distributed Bragg reflector (CNT DBR)
  Application: ICT | MNT: Quantum NanoFabrication and Characterization Facility (QNFCF)
  University of Waterloo
  Designer: HeeBong Yang | E: heebong.yang@uwaterloo.ca
  Professor: Na Young Kim | E: nayoung.kim@uwaterloo.ca

- CMOS compatible Bragg reflection waveguides for second harmonic generation
  Application: ICT, Other (computation / quantum computers) |
  MNT: Quantum NanoFabrication and Characterization Facility (QNFCF)
  University of Toronto
  Designer: Trevor Stirling | E: trevor.stirling@mail.utoronto.ca
  Professor: Amr Helmy | E: a.helmy@utoronto.ca

- Design and fabrication of customized nanoplasmonic nanostructures for biomedical and environmental applications
  Application: Health/Biomedical | MNT: NanoFabrication Kingston
  Queen's University
  Designer: Juan Manuel Gomez Cruz | E: 17jmgc@queensu.ca
  Professor: Carlos Escobedo | E: carlos.escobedo@queensu.ca

- Fabrication of III-V semiconductor waveguides for integrated on-chip nonlinear photonics
  Application: ICT | MNT: Quantum NanoFabrication and Characterization Facility (QNFCF)
  University of Ottawa
  Designer: Kaustubh Vyas | E: kvyas027@uottawa.ca
  Professor: Ksenia Dolgaleva | E: ksenia.dolgaleva@uottawa.ca

- Investigating increased photoluminescence quantum yield in gated monolayer MoS2 devices
  Application: Natural Resources/Energy | MNT: NanoFabrication Kingston
  Queen's University
  Designer: Kurt Tyson | E: kurt.henry.tyson@gmail.com
  Professor: Robert Knobel | E: knobel@queensu.ca

- Nanophotonics using metal nanostructures for biosensing applications
  Application: Health/Biomedical | MNT: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Dipanjan Nandi | E: dipanjan@ualberta.ca
  Professor: Manisha Gupta | E: mgupta1@ualberta.ca

- Photonic crystal based ultra-thin flexible single crystalline solar cells
  Application: Environment | MNT: Toronto Nanofabrication Centre (TNFC)
  University of Toronto
  Designer: Sara Almenabawy | E: sara.almenabawy@mail.utoronto.ca
  Professor: Nazir Kherani | E: nazir.kherani@utoronto.ca

- Solid-state plasmochromic nanodevices
  Application: ICT, Other (integrated photonics) | MNT: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Eric Hopmann | E: hopmann@ualberta.ca
  Professor: Abdulhakem Elezzabi | E: elezzabi@ece.ualberta.ca

- Ultra-efficient flexible silicon solar cell technology
  Application: Natural Resources/Energy | MNT: Toronto Nanofabrication Centre (TNFC)
  University of Toronto
  Designer: Yibo Zhang | E: yibojhhk.zhang@mail.utoronto.ca
  Professor: Nazir Kherani | E: nazir.kherani@utoronto.ca

MNT: Other Technologies

2.5D Assembly

- Microassembly process for wireless retinal implant
  Application: Health/Biomedical | MNT: 3IT.Micro
  Université de Sherbrooke
  Designer: Gabriel Martin-Hardy | E: gabriel.martin-hardy@usherbrooke.ca
  Professor: Réjean Fontaine | E: rejean.fontaine@usherbrooke.ca

Biosensing

- Fabrication and characterization of organic electrochemical transistors (OECTs) based sweat glucose sensors
  Application: Health/Biomedical/Pharmaceutical (biopharmaceutical, chemical) | MNT: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Jiaxin Fan | E: fan1@ualberta.ca
  Professor: Manisha Gupta | E: mgupta1@ualberta.ca

Biosensing

- Fabrication and characterization of organic electrochemical transistors (OECTs) with novel n-type conjugated organic semiconductor
  Application: Health/Biomedical | MNT: NanoFAB (University of Alberta)
  University of Alberta
  Designer: Seongdae Kang | E: seongdae@ualberta.ca
  Professor: Manisha Gupta | E: mgupta1@ualberta.ca

III-V high power electronics

- Techniques for improving the linearity of lattice-matched InAlN/GaN HFETs
  Application: Automotive, Environment, ICT | MNT: McGill Nanotools Microfab
  Concordia University
  Designer: Mehrnegar Aghayan | E: mn.aghayan@gmail.com
  Professor: Pouya Valizadeh | E: pouya@ece.concordia.ca

Appendix A-1 – CNDN by the numbers

Canada's National Design Network is a Canada-wide collaboration between over 65 post-secondary institutions to connect 10,000 academic participants with 1,000 Canadian companies to design, make and test microsystems prototypes.

2020/21 Outcomes

4 030 publications

150 awards

80 patents awarded

430 collaborations with industry

14 new startups

610 trained HQP moved to industry

CMC manages Canada's National Design Network (CNDN).

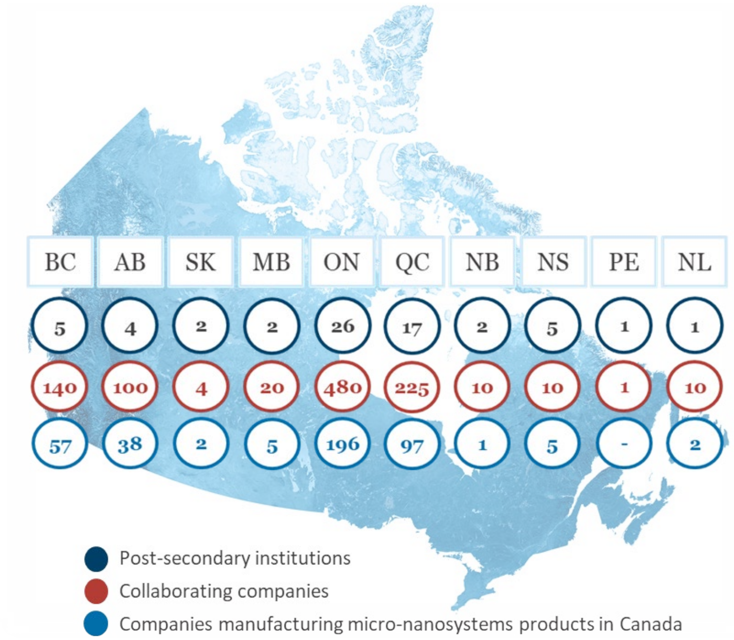


Figure A.1 - CNDN Outcomes 2020/21

Access to leading-edge technologies enables researchers to push the frontiers of science and engineering.

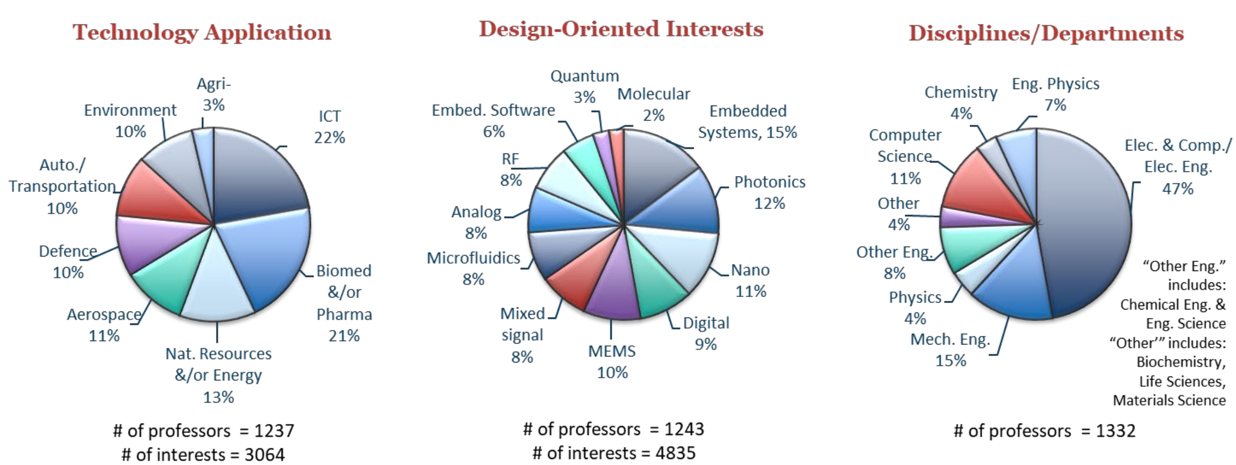
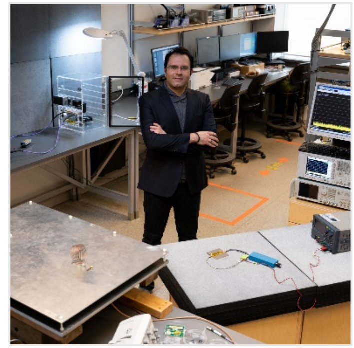


Figure A.2 - CNDN Academic Landscape 2020/21

Appendix A-2 – CNDN success stories

To read CMC Success Stories, including the examples listed below, see www.cmc.ca/SuccessStories

Breaking the ice with microwave sensors



Mohammad Zarifi, University of British Columbia
Although microwave sensors have been used in other applications, the research by Zarifi and his team was the first to show that microwave resonators could be used to detect ice and frost. Subsequent research produced a sensor with enhanced sensitivity and accuracy, capable of detecting ice formation within seconds in real time – a big improvement over existing sensing systems, which require time for ice to accumulate, then melt, in order to detect buildup.

- Published March 2021

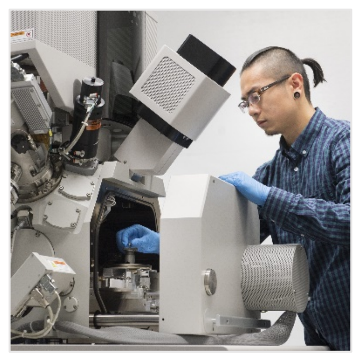
On the road to success

Ebrahim Ghafar-Zadeh, York University
Michael Glogauer, University of Toronto
Amir Sanati Nezhad, University of Calgary

Prof. Ebrahim Ghafar-Zadeh and his team are on the cusp of changing how we test for COVID-19. They are using cutting edge technologies in machine learning and microsystems to develop the simplest, most efficient test possible.

- Published November 2020

A platinum-powered boost for fuel cells

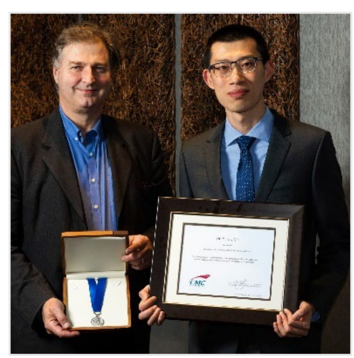


Byron Gates and Michael Paul, Simon Fraser University

Hydrogen fuel cells hold promise for commercially viable, zero-emission electric vehicles. "… we were trying to come up with commercially available materials and scalable processes that could be transferred to industry," explains Dr. Gates, Associate Professor and Canada Research Chair, Tier II in Surface Chemistry, and Head, Centre for Soft Materials in 4D LABS at SFU."

- August 2020

Low-cost sensors yield high-impact technology



Yiheng Qin, McMaster University

Dr. Qin's development of a novel inkjet printing process offers industry a low-cost method for manufacturing highly accurate electrochemical sensors for water monitoring. "Many communities have been under boil water advisories for years. Now I know it's possible to make something simple and useful so that people can know their water is safe to drink."

- March 2020

Appendix B – Technology development for strategic sectors

Strategic Technologies

CMC's strategic direction aims to maximize impact on Canadian research, innovation, and economic growth. Microelectronics, photonics, optoelectronics, micromachining, embedded software, and nano-scale technologies are enabling progress in numerous scientific disciplines. These microsystem technologies contribute to innovative applications in sectors identified by the federal government's Economic Strategy Tables.

Figure B.1 – Technology Development for Strategic Sectors

By enabling access to tools and technologies, the CNDN furthers Canada's leadership in technologies foundational to a thriving digital economy: microelectronics, photonics, quantum computing, Micro Electro-Mechanical Systems (MEMS), nanofabrication, Internet of Things (IoT) and Edge Artificial Intelligence (AI).

Appendix C – Fabrication services for prototypes

Through supplier partnerships, we offer multi-project wafer services and related fabrication products and services for industrial projects and academic R&D.
View our technology selection and FAB schedule online:

www.cmc.ca/FAB

Microelectronics

STMicroelectronics FD SOI 28nm CMOS
TSMC - options:

- 65nm GP CMOS, 65nm LP CMOS, 28nm CMOS, 0.13µm CMOS, 0.18µm CMOS BDC, 0.18µm CMOS, 0.35µm CMOS

AMS 0.35µm CMOS - options:

- Standard, Opto, High Voltage, Post Processing

GlobalFoundries® - ootions:

- 12LP FinFET, 22FDXTM FDSOI 22 nm, 45 nm RFSOI, 90 nm BiCMOS SiGe 9HP, 130 nm BiCMOS SiGe 8XP

Photonics & Optoelectronics

AMF Silicon on Insulator, Passives and Actives
Applied Nanotools (ANT) NanoSOI
GlobalFoundries® - CMOS-photonics options:

- 90WG, 45CLO

Epitaxy - options:
Canadian Photonics Fabrication Centre (NRC-CPFC) III-V Epitaxy on InP Substrates
FBH-Berlin III-V Epitaxy on GaAs Substrates
Landmark III-V Epitaxy on GaAs and InP Substrates

Micro Electro-Mechanical Systems (MEMS)

MEMSCAP PiezoMUMPs
MEMSCAP PolyMUMPs
MEMSCAP - Post-processing for PolyMUMPS
Teledyne DALSA MIDIS™ Platform
Teledyne Micralyne MicraGEM-Si™
Electronic Sensor Platform (ESP)

Micro-Nano Technologies (MNT) Facilities Portal - 40+ facilities located at universities across Canada

- The MNT Award program supports 80% of custom microfabrication costs for projects at open-access facilities in the CNDN by graduate students and post-doctoral fellows at Canadian universities. NSERC Engage/ Alliance grant holders are eligible for an automatic award. Further details: www.cmc.ca/MNT-Portal

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Contact us

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LOWERING BARRIERS TO TECHNOLOGY ADOPTION

CMC helps researchers and industry across Canada's National Design Network® develop innovations in microsystems and nanotechnologies.

CMC MICROSYSTEMS

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